PROPOSED BROWSE TO NWS PROJECT

DRAFT EIS/ERD

EPA Assessment No. 2191
EPBC 2018/8319
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Woodside

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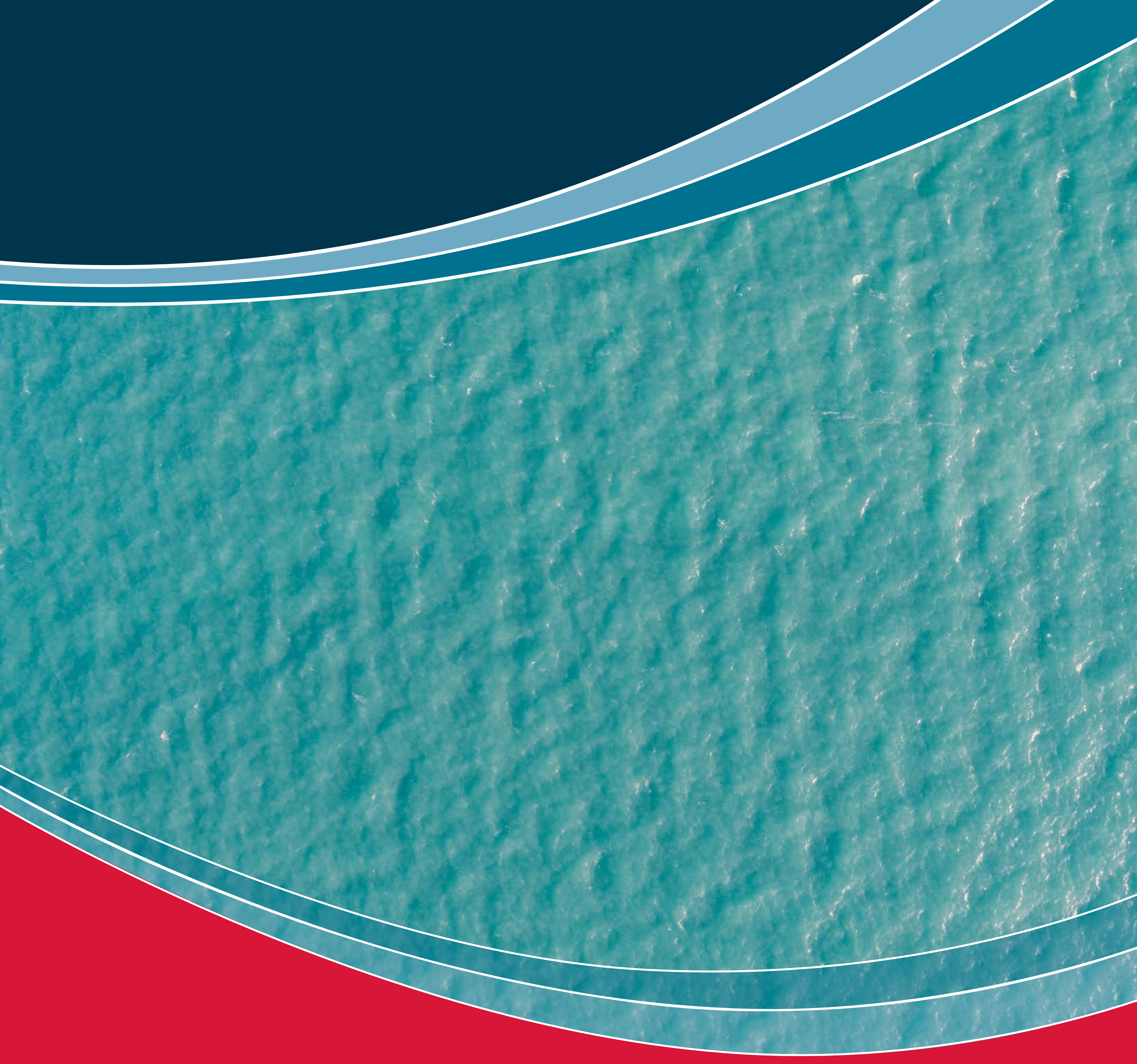
CHAPTER 1

EXECUTIVE SUMMARY



1. EXECUTIVE SUMMARY

1.1 Introduction

The Browse hydrocarbon resource is located in the Brecknock, Calliance, and Torosa reservoirs, approximately 425 km north of Broome and approximately 290 km off the Kimberley coastline of Western Australia (WA). These three fields will be collectively referred to as the Browse hydrocarbon resources. Hydrocarbon resources contained in these reservoirs are predominately gas, with a best estimate of contingent resources (100%) of 13.9 trillion cubic feet (tcf) of dry gas, and approximately 390 million barrels of condensate (Woodside estimate).

Woodside Energy Ltd (Woodside) is Operator for and on behalf of the Browse Joint Venture. The participants in the Browse Joint Venture are:

- Woodside Browse Pty Ltd
- Shell Australia Pty Ltd (Shell)
- BP Developments Australia Pty Ltd (BP)
- Japan Australia LNG (MIMI Browse) Pty Ltd (MIMI)
- PetroChina International Investment (Australia) Pty Ltd (PetroChina).

The Browse Joint Venture proposes to develop the Browse hydrocarbon resources using two 1100 million standard cubic feet per day (MMscfd) (annual daily export average) Floating Production Storage and Offloading (FPSO) facilities. The FPSO facilities will be supplied by a subsea production system and will transport gas to existing North West Shelf (NWS) Project infrastructure via a pipeline which will tie in near the existing North Rankin Complex (NRC) in Commonwealth waters (Note: The NRC is owned by the North West Shelf Joint Venture).

Construction is expected to commence in 2021–2022, with operations expected for up to 44 years.

The proposed Browse to NWS Project was referred to the DoEE under the EPBC Act in October 2018. On the 22 February 2019, the DoEE determined that the proposed Browse to NWS Project is a controlled action and would be assessed at an EIS level of assessment. The decision notice identified these Matters of National Environmental Significance (MNES) as being relevant to the proposed Browse to NWS Project:

- National heritage values of a National Heritage Place
- Listed threatened species and communities
- Listed migratory species
- The Commonwealth marine area, the protected matter being the environment generally.

The WA State waters component of the proposed Browse to NWS Project was referred to the EPA under the EP Act in October 2018. On 22 January 2019, the EPA determined that the proposed Browse to NWS Project requires assessment under Section 29 of the EP Act and set a Public Environmental Review (PER) level of assessment. The determination identified these EPA Environmental Factors as being relevant for the proposed Browse to NWS Project within State waters:

- Benthic Communities and Habitats
- Marine Environmental Quality
- Marine Fauna
- Air Quality.

This draft Environmental Impact Statement (EIS)/ Environmental Review Document (ERD) provides Commonwealth and State regulators with the information required to assess the proposal against the requirements of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the *WA Environmental Protection Act 1986* (EP Act). In addition, this draft EIS/ERD will be used to inform and obtain feedback from stakeholders about the proposed Browse to NWS Project and to demonstrate that impacts from planned activities and risks associated with unplanned activities can be managed to an acceptable level.

Preparation of this draft EIS/ERD has been undertaken in consultation with the Commonwealth Department of the Environment and Energy (DoEE), the WA Environmental Protection Authority (EPA) and other stakeholders. The National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) has been engaged by the DoEE to support the assessment. This EIS/ERD conforms with the EIS Guidelines/Environmental Scoping Document (EISG/ ESD) approved by the DoEE on 5 July 2019 and the EPA on 4 July 2019 (**Chapter 10, Appendix A**). The EISG/ESD was made publicly available on the 8 July 2019.

1.2 Proponent

The proponent for the proposed Browse to NWS Project is Woodside as Operator for and on behalf of the Browse Joint Venture participants.

Woodside is Australia's largest independent oil and gas company with a global portfolio and is recognised for its world-class capabilities as an explorer, a developer, a producer and a supplier of energy.

Woodside is Australia's most experienced liquefied natural gas (LNG) operator, operating 6% of global LNG supply. Woodside operates assets in Australia including the landmark North West Shelf (NWS) Project, which has been operating since 1984 and the Pluto LNG Plant, which commenced production in 2012. Woodside's operated assets are renowned for their safety, reliability and efficiency.

Woodside continues to expand capabilities in marketing, trading and shipping LNG and has enduring relationships that span more than 25 years, with foundation customers throughout the Asia–Pacific region. As a low-cost energy supplier with a sustainable business model, Woodside is pursuing opportunities to deliver affordable energy to the world's growing markets.

Woodside recognises that long-term meaningful relationships with communities are fundamental to maintaining a social licence to operate and works to build mutually beneficial relationships. Woodside is characterised by strong safety and environmental performance in all locations where active and is committed to upholding values of integrity, respect, working sustainably, discipline, excellence and working together.

1.3 Objectives of the proposed Browse to NWS Project

The objectives of the proposed Browse to NWS Project are to:

- optimise the production and recovery of hydrocarbons from the Brecknock, Calliance and Torosa reservoirs
- provide an acceptable return on investment.

In doing so, the proposed Browse to NWS Project will:

- minimise its environmental footprint
- provide a clean and reliable energy source to global markets
- manage environmental, health, security and safety issues in accordance with recognised industry standards and Woodside's requirements
- maximise socio-economic benefits.

1.4 Development Alternatives

The Browse Joint Venture has conducted multiple 'Concept Select' phases for the commercialisation of the Browse hydrocarbon resources. The following four potential broad development themes have been considered since 2004:

- piping Browse gas to the Kimberley for processing onshore (James Price Point (JPP) development concept)
- piping Browse gas to the Burrup Peninsula for processing onshore
- piping Browse gas to Darwin for processing onshore
- floating LNG (FLNG), where processing would take place on a floating facility.

The Browse Joint Venture has previously progressed two development concepts through to front end engineering design (FEED), the James Price Point (JPP) development concept and the FLNG development concept. The outcome of both of these processes was that each concept did not meet Woodside's commercial requirements for a positive Final Investment Decision (FID).

A concept selection and optimisation process was undertaken to incorporate the key insights and opportunities identified in the previous phases and generate a shortlist of concepts. In September 2018, the Browse Joint Venture unanimously decided to proceed with the Browse to NWS Development concept as the option most likely to achieve earliest commercialisation of the Browse resources. A major factor in this decision was the opportunity to minimise environmental impact by developing the Browse hydrocarbon resources using an existing onshore facility.

1.5 Description of the proposed Browse to NWS Project

The proposed Browse to NWS Project will comprise subsea infrastructure and two floating production storage offtake (FPSO) facilities, connected to existing NWS Project infrastructure via the ~900 km Browse Trunkline (BTL).

The key characteristics of the proposed Browse to NWS Project are presented in **Table 1-1** and described below:

- Hydrocarbon extraction will require up to 54 wells with associated subsea infrastructure, including manifolds and flowlines.
- Extracted hydrocarbons will be transferred via subsea infrastructure, including wellheads, manifolds and flowlines, up to the FPSO facilities, which are located in Commonwealth waters.
- Condensate stabilisation and storage will occur on the FPSO facilities prior to offtake to condensate tankers for delivery to market.
- Gas processing will also occur on the FPSO facilities prior to export via the inter-field spur line and BTL to existing NWS Project infrastructure.

The BTL will tie into the existing second trunkline (2TL) near NRC. The NWS Joint Venture (NWSJV) is pursuing approvals for the NWS Project Extension Proposal; the long-term processing of third party gas and fluids and NWSJV field resources using NWS Project infrastructure until around 2070 (EPBC 2018/8335 and EPA 2186). Transmission of the gas from the tie in point and onshore processing of the gas would be undertaken by the NWSJV using existing NWS Project infrastructure.

Activities in State waters will comprise a limited subset of infrastructure and activities. This will include developing up to an estimated 24 wells and associated subsea infrastructure, targeting the hydrocarbon resources of the Torosa reservoir.

A detailed description of the proposed Browse to NWS Project infrastructure is provided in **Section 3.6**. The proposed Browse Development Area and the notional field layout is shown in **Figure 1-1**. The proposed Browse trunkline (BLT) and inter-field spur line routes are shown in **Figure 1-2**.

Table 1-1 Key Characteristics of the proposed Browse to NWS Project

Component	State Proposal Area*	Overall Development (State Proposal Area and Commonwealth water)*
Well count (up to)	24[1]	54[1] (including 19 wells at Calliance, 29 wells at Torosa and 6 wells at Brecknock)
Subsea infrastructure	Wellheads, manifolds, flowlines and umbilicals	Wellheads, manifolds, flowlines, umbilicals, risers, anchors and moorings
Surface facilities	None	Two ~1100 MMscf/d export (annual daily average**) FPSO facilities
Browse Trunkline (BTL)	None	~900 km 42" diameter trunkline with adequate capacity for export of 2,150 MMscf/d
Inter-field spur line	None	~85 km 34" diameter spur line with adequate capacity for export of up to 1,100 MMscf/d (annual daily average).

* *Subject to detailed design and refinement*

** *Annual daily average export is defined as the daily export rate, averaged over an annual period*

Activities associated with the proposed Browse to NWS Project include:

- piling for mooring the FPSO facilities, securing the export riser bases and potentially for mooring the mobile offshore drilling units (MODUs). Suction piling is the most likely option for pile installation, however, depending on the seabed substrate, alternate piling methods such as drilling and cementing or impact piling may be selected.
- development drilling and completions for the development of up to 54 production wells
- installation and commissioning of the subsea umbilicals, risers and flowlines (SURF)
- installation and commissioning of the BTL and inter-field spur line
- installation, hook up and commissioning of the FPSO facilities
- operations including hydrocarbon extraction, gas processing and export and condensate offloading
- Inspection, Maintenance and Repair (IMR) activities to ensure the integrity of the infrastructure and identify any problems before they present a risk of loss of containment
- decommissioning
- support activities including logistics support, project vessels and helicopters.

A detailed description of the activities associated with the proposed Browse to NWS Project is provided in **Section 3.7**.

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[1] *note that the estimated maximum number of expected wells has increased from the Referral estimate of 49 (and 21 in the State Proposal Area), due to additional design considerations including reservoir understanding, which have since taken place.*

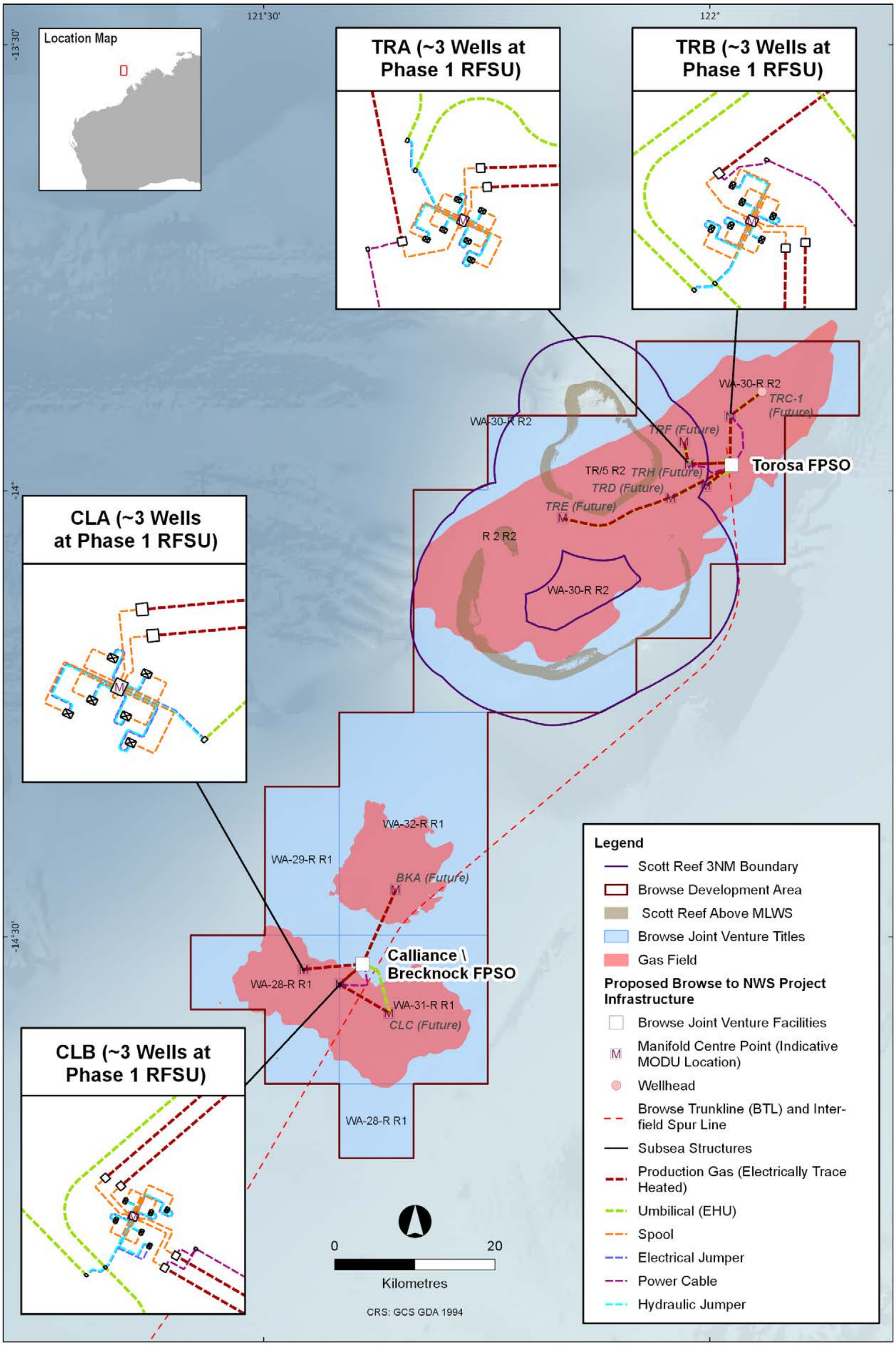

Figure 1-1 Proposed Browse Development Area and Notional Field Layout

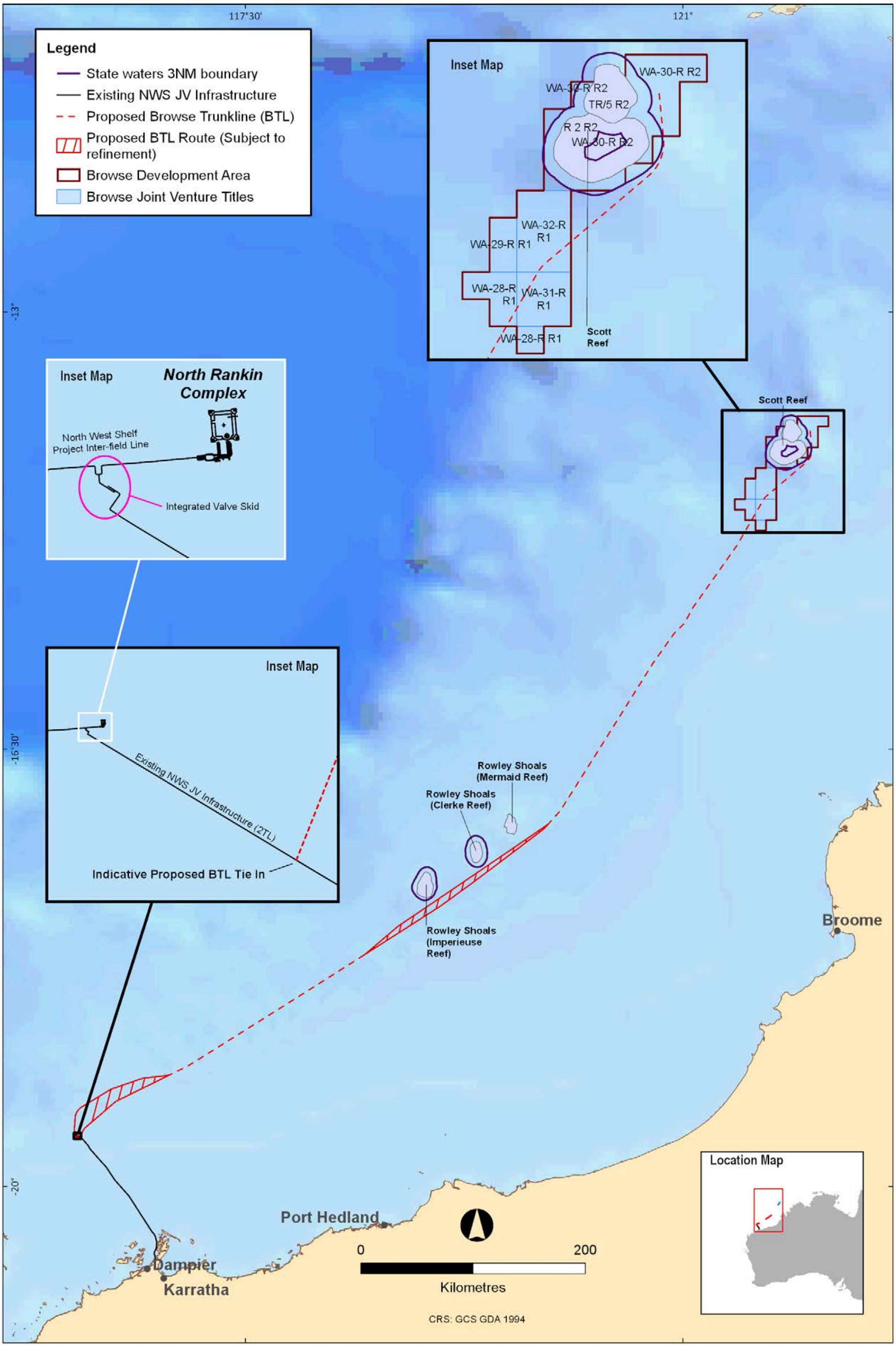

Figure 1-2 Proposed Browse Trunkline (BTL) Route

1.6 Stakeholder Consultation

Woodside has engaged extensively with stakeholders in the past about previous development concepts. Specific engagement concerning the proposed Browse to NWS Project has also been undertaken with a broad range of stakeholders. Since 2004, Woodside has undertaken extensive stakeholder engagement activities in regard to the development of the Browse resources. These stakeholders have included decision-making authorities, other relevant government agencies and authorities (Local, State and Commonwealth), the local community, local Aboriginal groups, academics, research authorities and environmental non-government organisations. Specific engagements were undertaken with Aboriginal stakeholders in relation to any potential impacts to national heritage values, including Aboriginal heritage values. Participants were provided with a detailed overview of the environmental assessment and approval processes. There were opportunities for questions to be asked, responses to be provided and for any outstanding concerns to be understood.

Stakeholder consultations concerning the proposed Browse to NWS Project have provided an overview of the possible business, employment and training opportunities that may be generated in both the Kimberley and Pilbara. Broome stakeholders, in the main, reinforced the need for continued development in the Kimberley to generate economic activity and flow on opportunities for local stakeholders. Stakeholders also raised issues of national heritage (with a focus on rock art) and expressed an interest in understanding mitigation measures relevant to cultural heritage. GHG emissions from petroleum developments was identified as a stakeholder issue during stakeholder engagement (**Chapter 4**).

This draft EIS/ERD has been released for public review, offering stakeholders an opportunity to provide formal input into the environmental impact assessment. In addition to activities undertaken to support the development of the draft EIS/ERD, Woodside, as part of its standard operating practices, will continue to engage with stakeholders throughout all phases of the proposed Browse to NWS Project. This includes ongoing engagement to inform stakeholders about:

- key milestones and activities
- onshore supply chain and logistics support locations
- ongoing social investment in relevant communities.

1.7 Environmental Assessment and Management

1.7.1 Overview

An environmental impact and risk assessment was undertaken in accordance with Woodside's Impact Assessment Procedure, Environment Impact Assessment Guideline and Risk Management Procedure. These documents set out the broad principles and high-level steps for assessing environmental impacts and risks across the lifecycle of Woodside's activities.

Within this process, a distinction is made between an 'impact' and a 'risk' as follows:

- **Environmental Impact:** An expected change to the environment, whether adverse or beneficial, wholly or partially resulting from the planned routine and non-routine project activities (e.g. routine liquid discharges).
- **Environmental Risk:** An unplanned event or incident which impacts the achievement of the stated environmental objectives.

The assessment of impacts and risk was undertaken through a systematic process consistent with Woodside's Impact Assessment Procedure and Environment Impact Assessment Guideline. Each activity (either planned or unplanned) was considered with respect to its potential to affect an environmental receptor. The assessment was informed by a range of environmental studies that included the review of existing data and the modelling of discharges and emissions. Inherent controls, such as design features, legislative requirements, industry good practice and applicable Woodside corporate standards were considered when identifying the credible impact and risk scenarios.

For the purpose of the impact and risk assessment, achievement of the environmental objectives (outlined in **Section 1.7**) and overall acceptability (i.e. whether an environment impact or risk is acceptable) includes consideration of the impact significance level plus the risk rating and likelihood (for unplanned events and incidents).

The assessment of acceptability also considers the:

- principles of Ecologically Sustainable Development (ESD) as defined in Section 3A of the EPBC Act
- Matters of National Environment Significance (MNES) - Significant Impact Guidelines
- WA EPA Environmental Factors and Objectives
- other aspect or receptor requirements including State, Federal and international standards, laws, policies and guidelines, including Conservation management and Recovery plans and conservation advice for EPBC Act listed threatened and/or migratory species. Relevant guidelines, standards or plans are outlined each impact assessment section
- external considerations such as stakeholder feedback
- internal Woodside requirements.

The following sections provide a synopsis of the predicted impacts and potential risks to receptors from the proposed Browse to NWS Project.

1.7.2 Physical Marine Environment

Marine sediment quality (medium value (open waters))

Table 1-2 Marine sediment quality assessment

Receptor	Sediment Quality
Local environment context	Sediments in the Project Area are typical of an undisturbed tropical offshore environment, with low concentrations of metals and nutrients and no hydrocarbons detected from marine sediment quality seabed sampling (refer to **Section 5.2.10**).
Receptor sensitivity	**Medium value (open waters)** Ambient sediment quality is typical of the surrounding environment, with low sensitivity to change and no features of conservation value.
Environmental objective	**Objective 1:** To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **Objective 2:** To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.
Assessment and Conclusion	
Impacts to sediment from the proposed Browse to NWS Project are expected to primarily result from drilling discharges (e.g. cementing, drill cuttings and drilling fluids) and seabed disturbance as a result of the installation of subsea infrastructure. Discharges from construction activities and during operations will be managed to ensure no change to sediment quality within the Scott Reef shallow water benthic habitats (<75 m water depth), therefore impacts to sediment will be confined to deepwater habitat. The overall impact significance level of impacts on sediment quality has been assessed as Minor (D) (based on the assessment of impacts resulting from drilling discharges). As per the criteria outlined in **Section 6.2.3.4**, it is considered that the environmental objectives for this receptor will be achieved and this impact is assessed as **Acceptable**.	

Water quality (medium value (open waters))

Table 1-3 Water quality assessment

Receptor	Water Quality
Local environment context	Water quality in the Project Area near the location of the proposed subsea infrastructure and facilities is typical of an undisturbed tropical offshore environment. Much of the surface waters in this area is nutrient-poor, influenced by the Indonesian Throughflow, with low levels of primary productivity (**Section 5.2.9**).
Receptor sensitivity	**Medium value (open water)** Ambient water quality is typical of an open water environment, with low sensitivity to change.
Environmental objective	**Objective 3:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.

Receptor	Water Quality
Assessment and Conclusion	
Impacts to water quality are predicted to primarily arise from the discharge of produced formation water (PW) (Section 6.3.12) and cooling water (Section 6.3.13) from the FPSO facilities during the operations phase, as these discharges are will occur for the field life. Less significant impacts are predicted as a result of short-term or temporary discharges (i.e. discharge of drill cuttings and fluids during development drilling, subsea control fluids, hydrotest fluids, treated sewage and sullage, treated utility water and putrescible waste). As described in Chapter 6, operational discharges (PW and cooling water from the FPSO facilities) will be managed to meet the defined threshold values (i.e. 99% species protection or no effect concentrations) at the edge of the mixing zone and at the State waters 3 nm boundary 95% of the time, based on dispersion modelling results. As such, no impacts from operational discharges to water quality within the Scott Reef shallow water benthic habitats (<75 m) are predicted. As per the management approach for PW, baseline and periodic monitoring in the receiving environment will be undertaken to detect changes to water quality as a result of FPSO facility PW discharge. As such, the overall significance level for impacts on water quality has been assessed as Minor (D) (based on the assessment of impacts resulting from PW and cooling water discharges from the FPSO facilities). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.	

Air quality (medium value (open waters))

Table 1-4: Air quality assessment

Receptor	Air Quality
Local environment context	Given the distance from any significant anthropogenic emissions sources, air quality within the Project Area is expected to be high (Section 5.2.6).
Receptor sensitivity	**Medium value (open water)** Ambient air quality is typical of an open water environment, with low sensitivity to change.
Environmental objective	**Objective 4:** To not result in a substantial change in air quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.
Assessment and Conclusion	
Impacts to local air quality resulting from atmospheric emissions associated with the offshore activities are predicted to be negligible (Section 6.3.5). This analysis excludes greenhouse gas (GHG) emissions which are addressed below and in Chapter 7. As such, the overall impact significance level of impacts on air quality has been assessed as Slight (E). As per the criteria outlined in Section 6.2.3.4, this impact is assessed as **Acceptable**. Potential impacts associated with atmospheric emissions resulting from the onshore processing of the Browse gas by the NWS JV on the national heritage values of the listed National Heritage Place on the Dampier Archipelago (including aboriginal heritage values) are assessed in the ERD associated with the North West Shelf Project Extension Proposal (EPA 2186, EPBC 2018/8335). GHG emissions, including estimated contributions of NWS scope 1 emissions attributable to the proposed processing of Browse feed gas by the NWS JV and scope 1 and 3 emissions from the proposed Browse to NWS Project to global GHG emissions, are addressed in Chapter 7. This assessment considered the Principles of ESD, MNES Significant Impact Guidelines and the WA EPA Environmental Objectives; as well as GHG specific requirements such as the Paris Agreement, Australia's Nationally Determined Contributions and the Safeguard Mechanism (SGM). The assessment concluded that in consideration of these requirements the proposed Browse to NWS Project is **Acceptable**.	

Ambient light (medium value (open waters))

Table 1-5: Ambient light assessment

Receptor	Ambient light
Local environment context	The Project Area is located approximately 260 km from the shore where there are no existing significant sources of artificial light. The proposed BTL route is also distant from sources of light emissions, except where the proposed BTL route ties in near the existing NRC facilities (Section 5.2.7).
Receptor sensitivity	**Medium value (open water)** Ambient light is typical of an open water environment, with low sensitivity to change.
Environmental objective	**Objective 5:** To not result in a substantial change in ambient light or ambient noise which may adversely impact on biodiversity, ecological integrity, social amenity or human health.
Assessment and Conclusion	
Impacts to ambient light levels resulting from light emissions associated with the proposed Browse to NWS Project, including the FPSO facilities, vessels and MODUs, are predicted to be slight (Section 6.3.3). As such, the overall impact significance level of impacts on ambient light has been assessed as Slight (E). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.	

Ambient noise (medium value (open waters))

Table 1-6: Ambient noise assessment

Receptor	Ambient noise
Local environment context	**Atmospheric noise** The existing anthropogenic noise environment within the vicinity of the Project Area is expected to be primarily associated with commercial shipping activities, as well as occasional petroleum exploration activities. Similar sources of anthropogenic underwater ambient noise may be expected along the proposed BTL route. **Underwater noise** Underwater noise in the Project Area is characterised by occasional general vessel traffic, seismic surveys, suspected illegal blast fishing at Scott Reef and marine fauna. Underwater noise from marine fauna recorded at the Browse Development Area included calls from humpback whales, minke and dwarf minke whales, pygmy blue whales, Bryde's whales, as well as calls from unidentified whales and fish chorus (Section 5.2.8).
Receptor sensitivity	**Medium value (open water)** Ambient noise is typical of an open water environment, with low sensitivity to change.
Environmental objective	**Objective 5:** To not result in a substantial change in ambient light or ambient noise which may adversely impact on biodiversity, ecological integrity, social amenity or human health.
Assessment and Conclusion	
Atmospheric (Section 6.3.7) and underwater (Section 6.3.8) noise emissions are predicted to occur during all phases of the proposed Browse to NWS Project. Impacts of these noise emissions on ambient atmospheric noise levels are expected to be Negligible (F). Impacts from underwater noise are expected to be Slight (E). Sensitive receptors to underwater noise are generally different to the receptors for atmospheric noise, and primary sources of atmospheric noise at the Browse Development Area (helicopters, piling, flaring) will be intermittent. As such, the overall impact significance level of impacts on ambient noise has been assessed as Slight (E). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.	

1.7.3 Ecological Receptors

Plankton communities (medium value (open waters))

Table 1-7: Plankton communities assessment

Receptor	Plankton Communities
Local environment context	Plankton communities have a naturally variable distribution in both space and time in oceanic waters, noting that the NWMR is typically characterised by low planktonic productivity. Estimates of the phytoplankton biomass (measured as chlorophyll a) close to Scott Reef are approximately twice that of open waters (sampled at distances greater than 50 km to the south-west of South Scott Reef). The open water location sampled is likely to be representative of the general outer shelf open water environment and so is representative of the oceanic waters of the Project Area (Section 5.3.1.1)
Receptor sensitivity	**Medium value (open water)** Plankton populations are typical of an open water environment, with low sensitivity to change due to high turnover/recovery and no species of high importance or quality.
Environmental objective	**Objective 7**: To not have a substantial adverse effect on a population of plankton, including its lifecycle and spatial distribution.
Assessment and Conclusion	
Slight impacts to plankton communities may result from multiple but separated discharge streams, including PW (Section 6.3.12) and cooling water (Section 6.3.13) discharges from the FPSO facilities during operations. Less significant impacts, expected to have no lasting effect on plankton populations, may occur during construction, commissioning and operations as a result of discharges including hydrotest fluid, vessel cooling water, treated utility water and putrescible waste; as well as underwater noise emissions. No significant increase in toxicity is predicted as a result of potential comingling of the PW and cooling water plumes after discharge. There will be minor impact to water quality and the nature of open water plankton populations are widespread and have a high turnover. As such, the overall impact significance level of impacts on plankton has been assessed as Slight (E) (based on the assessment of impacts resulting from PW and cooling water discharges from the FPSO facilities). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.	

Table 1-9: Shallow water benthic communities and habitats (<75 m water depth) (high value habitat)

Receptor	Shallow water benthic communities and habitats
Local environment context	Shallow water benthic communities and habitats in the Project Area include those at Scott Reef. In addition, the proposed BTL route passes at a distance of a few kilometres from the Rowley Shoals shallow water benthic communities and habitats. Important species within these habitats include corals, seagrass and macroalgae.
Receptor sensitivity	**High value habitat** Species of high importance with high sensitivity to change.
Environmental objective	**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results. **Objective 8:** To not result in the establishment of a known or potential invasive marine species (IMS) in the Scott Reef system. **Objective 9:** To avoid direct (i.e. physical footprint) disturbance to Scott Reef shallow water benthic habitat (<75 m bathymetry). **Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry).

Receptor	**Shallow water benthic communities and habitats**
Assessment and Conclusion	
As detailed in **Chapter 6**, no infrastructure is planned to be placed on or near any shallow water benthic habitats (e.g. Scott Reef and the Rowley Shoals). In addition, discharges during construction, commissioning and operations will be managed to avoid impact to these shallow water benthic habitats. This will include a commitment to manage operational discharges (PW and cooling water from the FPSO facilities) to meet the defined threshold values (i.e. 99% species protection or lowest no effect concentration) at the edge of the mixing zone and at the State waters 3 nm boundary, 95% of the time; and a commitment to manage drilling discharges (in particular bottom-hole well section discharges) at drill centre locations in the State Proposal Area (i.e. TRA, TRD, TRE and TRF) in such a manner to avoid impacts to Scott Reef shallow water benthic communities and habitats (<75 m water depth). These management objectives are supported by a range of both feasible and industry proven management measures.	

Deepwater benthic communities and habitats (>75 m water depth) (medium value habitat)

Table 1-8: Deepwater benthic communities and habitats assessment

Receptor	**Deepwater benthic communities and habitats**
Local environment context	The benthic communities inhabiting the predominantly soft, fine sediments of the deepwater benthic habitats are characterised by infauna such as polychaetes and sparsely distributed sessile and mobile epifauna. The density of benthic fauna is typically lower in deep-sea sediments (greater than 200 m) than in shallower coastal sediment habitats, but the diversity of communities may be similar. As confirmed by deepwater surveys (**Section 5.3.1.2**).
Receptor sensitivity	**Medium value** No species of high importance.
Environmental objective	**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.
Assessment and Conclusion	
Minor impacts to the deepwater benthic habitats and communities are predicted within the Project Area as a result of the localised physical footprint of the installed subsea infrastructure, BTL and inter-field spur line (including seabed preparation and installation activities) (**Section 6.3.1**). In addition, discharges during construction, commissioning and operations (including the drilling discharges, subsea control fluids and hydrotest fluids) may impact these deepwater benthic habitats and communities. Impacts to deepwater benthic habitats and communities within the Project Area as a result of the installation of the subsea infrastructure and drilling discharges (**Section 6.3.15**) are not expected to be significant as they will be restricted to areas largely composed of soft sediment habitat and sparse benthic biota and the physical footprint represents a small fraction of the widespread and representative deepwater benthic habitat type within the region. Further, there are no predicted lasting impacts to these deepwater benthic habitats from other discharges related to the proposed Browse to NWS Project. As such, the overall impact significance level of impacts on deepwater benthic habitats has been assessed as Minor (D) (based on the assessment of impacts resulting from seabed disturbance (Minor (D)) and drilling discharges (Slight (S)). As per the criteria outlined in **Section 6.2.3.4**, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.	

Fauna (high value species)

Seabirds and migratory shorebirds

Table 1-9: Seabirds and migratory shorebirds assessment

Receptor	Seabirds and migratory shorebirds
Local environment context	As the only emergent land mass within the immediate vicinity of the Browse Development Area, Scott Reef serves to provide nesting and/or roosting for seabirds, albeit in small numbers in comparison to other breeding and roosting sites in the region. This includes the little tern, which has a resting BIA at Scott Reef, associated with Sandy Islet. In addition, due to the large geographical range of seabirds, most species occurring within the wider NWMR have the potential to occur and transit through the Project Area. The islands of the Rowley Shoals (which the proposed BTL route passes at a distance of a few kilometres) are known to support a wide range of seabird species, including WA's second largest breeding colony of red-tailed tropicbird. The Rowley Shoals have also been identified as BIAs for the white-tailed tropicbird. Migratory shorebirds are occasionally observed in very low numbers at Scott Reef. Sandy Islet may be used as a staging site during the migrations between the Northern Hemisphere and Australia. Given its small size, however, Sandy Islet is unlikely to support large numbers of migratory shorebirds. Due to the large geographical ranges of migratory shorebirds, many of the species known to occur within the wider NWMR have the potential to transit through the Project Area, which overlaps with the migratory shorebird corridor. Shorebird presence in the Project Area is expected to be transitory and seasonal (Section 5.3.2.3).
Receptor sensitivity	**High value species** MNES species known to be present.
Environmental objective	**Objective 11:** To not have a substantial adverse effect on a population of seabirds or migratory shorebirds, or the spatial distribution of the population. **Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species.
Assessment and Conclusion	
Some slight behavioural modifications to seabird and migratory shorebird behaviour may be observable as a result of atmospheric noise from helicopters and flaring and light emissions from vessels, MODUs and the FPSO facilities. As such, the overall impact significance level of impacts on seabirds and migratory shorebirds have been assessed as Minor (D) (based on the assessment of impacts resulting from light emissions (Minor (D)) and atmospheric noise (Slight (S)). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objectives for this receptor will be achieved and this impact is assessed as **Acceptable**.	

Fish

Table 1-10: Fish assessment

Receptor	Fish
Local environment context	Fish assemblages within the Browse Development Area occupy a diverse range of habitats and are typical of the fish communities and species representative of the Timor Province. These fish assemblages include: + shallow-water, site-attached coral reef fish communities with characteristically high diversity and abundance + open water pelagic fish + deep water, demersal fish communities (Section 5.3.2.8). EPBC Act listed fish species that may occur within the Project Area include the whale shark, shortfin mako, longfin mako, green sawfish and largetooth sawfish. The whale shark foraging BIA extends north along the northern WA coastline (predominately inshore of the Project Area) from Ningaloo almost to the Northern Territory (NT) border (Section 5.3.2.2). Based on studies undertaken of the whale shark's migratory behaviours, this species may occur within the Project Area, albeit in low numbers (Section 5.3.2.7).
Receptor sensitivity	**High value species** MNES species known to be present.
Environmental objective	**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population.
Assessment and Conclusion	
Slight impacts with no lasting effect may occur to fish as a result of discharges during construction, commissioning and operations, including hydrotest fluid, cooling water, PW, treated utility water, sewage and sullage and putrescible waste. Slight impacts with no lasting effect may also occur as a result of underwater noise emissions during construction (e.g. piling, VSP, MODU on DP) and operations (e.g. subsea infrastructure operations, routine FPSO operations, use of DP). However, no lasting effect on fish is expected to occur from these aspects. As such, the overall impact significance level of impacts on fish has been assessed as Slight (E). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objectives for this receptor will be achieved and this impact is assessed as **Acceptable**.	

Marine mammals

Table 1-11: Marine mammal assessment

Receptor	Marine mammals
Local environment context	The PMST identified 27 marine mammal species as potentially occurring within the Project Area. Of these, the pygmy blue whale (endangered and migratory), humpback whale, sei whale, fin whale (vulnerable and migratory) and Bryde's whale (migratory) are considered most likely to occur (albeit representing a low percentage of each species populations) within the Project Area and/or interact with the proposed Browse to NWS Project (**Section 5.3.2.4**). There are BIAs for migration and breeding and calving for the humpback whale along the WA coast and within the NWMR, but there are no known BIAs within the Project Area. A migratory BIA for the pygmy blue whale extends for most of the length of the NWMR within offshore waters and encompasses Scott Reef. The Conservation Plan for Blue Whales (Commonwealth of Australia, 2015) also documents a possible foraging area which encompasses the majority of Scott Reef and its surrounds. It is expected pygmy blue whales will occur within the Browse Development Area, albeit in low numbers, and it is acknowledged that pygmy blue whales have been recorded in the channel between North and South Scott Reef; and that they may forage opportunistically in and around Scott Reef (given it is a possible foraging BIA). Other marine mammal species identified as likely to occur in the Project Area (such as the sei whale, fin whale and Bryde's whales) are expected to be limited to infrequent transient individuals (**Section 5.3.2.4.3**).
Receptor sensitivity	**High value species** MNES species known to be present.
Environmental objective	**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 15:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population.
Assessment and Conclusion	
The primary source of potential impacts to marine mammals such as pygmy blue whales is from underwater noise emissions during construction (e.g. piling, VSP, MODU on DP) and operations (e.g. subsea infrastructure operations, routine FPSO operations, use of DP) (**Section 6.3.8**). No lasting effect on marine mammals is predicted as a result of other aspects, including marine discharges. As described in **Section 6.3.8**, modelling has indicated that while no injury or mortality to marine mammals is predicted to occur, there is potential for some degree of behavioural modification as a result of underwater noise emissions associated with the proposed Browse to NWS Project. These impacts have been demonstrably minimised such that only localised behavioural modification of marine mammals within the vicinity of the noise source may occur (i.e. less than 2% of the pygmy blue whale possible foraging area). Given that relatively low numbers of transient marine mammals are expected to seasonally occur within the Project Area, only slight behavioural modifications are expected to occur, with no long-term effects at a species population level. These impacts are not considered to be significant, based on the MNES significant impact criteria for listed endangered species (**Table 6-5**), and are not inconsistent with the recovery objectives within the Conservation Management Plan for the Blue Whale (2015-2025) (Commonwealth of Australia, 2015). As such, the overall impact significance level of impacts on marine mammals has been assessed as Minor (D) based on the assessment of impacts resulting from underwater noise emissions. As per the criteria outlined in **Section 6.2.3.4**, it is considered that the environmental objectives for this receptor will be achieved and this impact is assessed as **Acceptable**.	

Marine reptiles

Table 1-12: Marine reptile assessment

Receptor	Marine reptiles
Local environment context	The PMST identified six species of marine turtle species as potentially occurring within the Project Area; green turtle, hawksbill turtle, flatback turtle (vulnerable and migratory) and the leatherback turtle, loggerhead turtle, olive ridley turtle (endangered and migratory). The marine turtles documented to be present in the Browse Development Area include the vulnerable green turtle and loggerhead turtle. These species are described in **Section 5.3.2.5**. The Recovery Plan for Marine Turtles identifies Habitat Critical to the Survival of a Species and this has been identified for the Scott Reef – Browse Island green turtle genetic stock within the Project Area (**Section 5.3.2.5.1**). Habitat Critical for Survival is the nesting habitat of Sandy Islet and a 20 km internesting buffer at Scott Reef (Commonwealth of Australia, 2017). There are also nesting and internesting BIAs at Scott Reef (associated with nesting at Sandy Islet) for both the green turtle and hawksbill turtle (**Section 5.3.2.5.2**).
Receptor sensitivity	**High value species** MNES species known to be present.
Environmental objective	**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.
Assessment and Conclusion	
The primary sources of potential impacts to marine turtles are artificial light emissions from the MODU and FPSO facilities operating at Torosa; and underwater noise emissions resulting from potential pile driving activities, drilling and the MODU DP. Chemical discharges are noted as a threat to marine turtles in the Recovery Plan for Marine Turtles in Australia 2017-2027' (Commonwealth of Australia, 2017), however, marine discharges from the proposed Browse to NWS Project are not predicted to result in any lasting effect on marine turtles. As described in **Chapter 6**, impacts from these aspects on marine turtles are not predicted to be significant and it is considered that they can be managed to an acceptable level through the implementation of mitigation measures. As described in **Chapter 6**, light and noise emissions are not expected to significantly impact the breeding cycle of marine turtles at Sandy Islet, Scott Reef (predominately green turtles) given the temporary nature of pile driving activities and the MODU's presence at a single location not impacting Sandy Islet. Potential impacts may also occur to sea snakes as a result of marine discharges and underwater noise emissions resulting from the proposed Browse to NWS Project. As described in **Chapter 6**, impacts to water quality are not expected to be significant and impacts to sea snakes from noise emissions are expected to be limited to slight behavioural/avoidance behaviour. As such, the overall impact significance level of impacts on marine reptiles has been assessed as Minor (D) based on the assessment of impacts resulting from underwater noise emissions (Minor (D)) and light emissions (Minor (D)). As per the criteria outlined in **Section 6.2.3.4**, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.	

Key Ecological Features (KEF) (medium value)

Table 1-13: KEF Features assessment

Receptor	KEF Features
Local environment context	The Browse Development Area overlaps with the Continental slope demersal fish communities and Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEFs. The proposed BTL route traverses the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF and the Ancient coastline at 125 m depth contour KEF (Section 5.3.3.1).
Receptor sensitivity	**Medium value** Designated sensitive Area. Values protected by legislation.
Environmental objective	**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a KEF.
Assessment and Conclusion	

Seabed disturbance and marine discharges will occur within these KEFs, however, no lasting effect is predicted to occur to the conservation values of these KEFs. The Project will be the first permanent infrastructure installed in the following KEFs:

- Seringapatam Reef and Reef and Commonwealth waters in the Scott Reef Complex KEF
- Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF.

Existing anthropogenic impacts for these KEFs include climate change related impacts, physical habitat modification (shipping anchorage, offshore construction and fishing practices (Commonwealth of Australia, 2012). The Continental Slope Demersal Fish Communities and Ancient Coastline at 125 m depth contour KEFs contain other existing oil and gas infrastructure (pipelines and the North Rankin Complex).

The values of the Continental slope demersal fish communities KEF, the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF and the Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEF are primarily related to high productivity and aggregations of marine life.

As described earlier, no lasting impacts to plankton or fish are expected to occur. As such, no impacts to the values of these KEFS (high productivity and aggregations of marine life) are expected. Likewise, seabed disturbance is unlikely to significantly impact productivity or marine life aggregation.

Similarly, impacts to the Ancient coastline at 125 m depth contour KEF may occur where the proposed BTL crosses this KEF near the NRC tie-in point, as a result of the permanent installation of the BTL and temporary vessel-based marine discharges during construction and IMR activities. The values of the Ancient coastline at 125 m depth contour KEF relate primarily to its unique seafloor geology, which are unlikely to be impacted by marine discharges associated with the proposed Browse to NWS Project.

As such, the overall impact significance level of impacts on KEFs has been assessed as Negligible (F). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor) will be achieved and this impact is assessed as **Acceptable**.

Australian Marine Parks (medium value (multiple use zones))

Table 1-14: AMP Features assessment

Receptor	AMP Features
Local environment context	The proposed BTL route traverses the Multiple Use Zones (IV) of the ArgoRowley Terrace and Kimberley Marine Parks. It should also be noted that the proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park National Park Zone. Rationale for the route selection of the BTL is provided in Chapter 3.
Receptor sensitivity	**Medium value (multiple use zones)** Designated sensitive area. Values protected by legislation.
Environmental objective	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.
Assessment and Conclusion	
Impacts to AMPs will occur as a result of the permanent installation of the proposed BTL and temporarily due to vessel-based marine discharges of cooling water, putrescible waste and sewage and sullage during construction and IMR activities. Threatening processes for the Kimberley Marine Park and Argo-Rowley Terrace Marine Park are similar to those described above for the affected KEFs. The impact of seabed disturbance on the Multiple Use Zone of the two AMPs has been minimised, as far as practicable, through a route selection process (Chapter 3). Impacts have been assessed as negligible as the area traversed by the proposed BTL represents a small proportion of the total area of the AMPs and is of medium receptor sensitivity. The activities are considered to be consistent with the objective of the Multiple Use Zone (VI) to provide for ecologically sustainable use (including construction and operation of pipelines) and the conservation of ecosystems, habitats and native species. As described in Chapter 6, given their temporary and transient nature, the impact of the vessel-based marine discharges is not expected to result in any lasting effect on the values of the two AMPs traversed (i.e. the Kimberley Marine Park and Argo-Rowley Terrace Marine Park). As such, the overall impact significance level of impacts on AMPs has been assessed as Negligible (F). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.	

State marine parks and nature reserves (high value)

Table 1-15: State marine parks and nature reserves assessment

Receptor	State marine parks and nature reserves
Local environment context	There are no State marine parks within the Project Area, however, the BTL route passes approximately 3 km from the Rowley Shoals Marine Park (Section 5.3.3.2). The Scott Reef Nature Reserve which was designated in 1993 and encompasses South Scott Reef (including Sandy Islet) down to the low mean water mark (Atlas of Marine Protection, 2019). This Nature Reserve protects the physical and ecological features of Scott Reef which are described throughout Chapter 5, including important nesting habitat (Habitat Critical for Survival of a Species) for the green turtle.
Receptor sensitivity	**High value** Designated sensitive area. Values protected by legislation.
Environmental objective	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.

Receptor	State marine parks and nature reserves
Assessment and Conclusion	
Given the distance of the proposed activities from State Marine Parks (the Rowley Shoals Marine Park is located approximately 3 km from the proposed BTL route at its closest point), no impacts to State Marine Parks as a result of the proposed activities are predicted. Slight impacts are predicted to occur to the Scott Reef Nature Reserve as a result of potential seabed subsidence, however, the reef growth rates are expected to match or exceed any sea level reduction. As such, the overall impact significance level of impacts on State marine parks and nature reserves has been assessed as Minor (D) (based on the assessment of impacts resulting from subsea subsidence). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.	

Other protected places (high value)

Table 1-16: Other protected places assessment

Receptor	Other protected places
Local environment context	There are no National Heritage Sites within the Project Area. The closest National Heritage Sites are the Dampier Archipelago (including the Burrup Peninsula) and the Ningaloo Coast (Section 5.4.3.2). There are no World Heritage Sites within the Project Area (Section 5.4.3.3). Commonwealth Heritage Places located within or within the vicinity of the Project Area include Scott Reef and Surrounds – Commonwealth Area, and Mermaid Reef – Rowley Shoals (Section 5.4.3.1).
Receptor sensitivity	**High value** Designated sensitive area. Values protected by legislation.
Environmental objective	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place. **Objective 19:** To not have a substantial adverse impact on heritage values.
Assessment and Conclusion	
As described above, project activities will be managed to avoid impacts occurring to shallow water habitats (<75 m depth) which includes Scott Reef and Surrounds. Likewise, no impacts are predicted to occur to the Mermaid Reef – Rowley Shoals Commonwealth Heritage Place. As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.	

1.7.4 Socio-Economic Receptors

State and Commonwealth managed fisheries (high value user)

Table 1-17: State and Commonwealth managed fisheries assessment

Receptor	State and Commonwealth managed fisheries
Local environment context	State managed commercial fisheries in close proximity to the Project Area include Northern Demersal Scalefish, Mackerel, WA North Coast Shark, Onslow Prawn, Abalone, South West Coast Salmon, Pilbara Fish Trawl, Specimen Shell, Marine Aquarium Fish, West Coast Deep Sea Crustacean and Pearl Oyster Managed Fisheries. The Commonwealth managed fisheries located within the vicinity of the Project Area include the North West Slope Trawl Fishery, the Western Tuna and Billfish Fishery, the Southern Bluefin Tuna Fishery and the Skipjack Tuna Fishery (Western Skipjack Tuna Fishery). In 1974 the Australia-Indonesia Memorandum of Understanding regarding the Operations of Indonesian Traditional Fishermen in Areas of the Australian Fishing Zone and Continental Shelf – 1974 (MoU 74) was signed by the Governments of Australia and Indonesia, allowing allowed Indonesian fishers to continue to fish in designated areas using traditional methods only (Sections 5.4.2.1 and 5.4.2.2).
Receptor sensitivity	**High value marine user** Key fishing area, with high importance to stakeholders.
Environmental objective	**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.
Assessment and Conclusion	
The total seabed area restricted from trawling activities (due to snag risk) in the region as a result of anthropogenic seabed infrastructure is a relatively small proportion of the available fishery managed zones. As described above, no lasting effect on fish are expected to occur as a result of the proposed activities, with the impact significance level of impacts on fish assessed as Slight (E). Further, slight impacts (disturbance to other users) are predicted to occur to managed fisheries as a result of the physical presence of infrastructure (exclusion from a very small portion of potential fishing grounds) associated with the proposed Browse to NWS Project. Given no lasting impact to target fish species is predicted and the exclusion from some fishing grounds as a result of the physical presence of infrastructure. As such, the overall impact significance level of impacts on State and Commonwealth fisheries has been assessed as Minor (D) (based on the assessment of impacts of disturbance to other users from the physical presence of infrastructure). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.	

Tourism and Recreation/Scientific Studies (high value user)

Table 1-18: Tourism and Recreation/Scientific studies assessment

Receptor	Tourism and Recreation/ Scientific studies
Local environment context	Recreation and tourism activities in the NWMR occur predominantly in WA State waters adjacent to coastal population centres (e.g. Broome), with a peak in activity during the winter months (dry season) (Section 5.4.2.6). Only one to two recreational fishing charter operators run trips to Scott Reef. The location has the potential to provide significant opportunities for pelagic sport fishing; however, given the distance from Broome and closest landfall and associated costs, only a limited number of charter operators are prepared to take recreational fishers out to Scott Reef. Those companies that do visit Scott Reef tend to make the trip only four to five times per year, spending around five days at the reef each time. Fishing is mainly focused on the south, west and north extremities of Scott Reef, generally only going into the South Scott Reef lagoon for snorkelling and for layover at night.
Receptor sensitivity	**High value users** Project area has low to medium level of utilisation by stakeholders.

Receptor	Tourism and Recreation/ Scientific studies
Environmental objective	**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.
Assessment and Conclusion	
No lasting effect is predicted to occur to the tourism, recreation or scientific studies values in the Project Area (and in particular Scott Reef). As such, the overall impact significance level of impacts on tourism, recreation and scientific studies has been assessed as Slight (E). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.	

Shipping (medium to high value user)

Table 1-19: Shipping assessment

Receptor	Shipping
Local environment context	Shipping activity in and around the Browse Development Area is sparse, with the main commercial shipping routes located approximately 50 to 100 km west, intersecting the proposed BTL route at various locations, depending on the port. The main shipping activity in the NWMR relates to transits to and from Broome and transportation of goods between Australian and international ports. Major ports are adjacent to the Roebuck, Montebello and Dampier Commonwealth marine reserves (Section 5.4.2.4).
Receptor sensitivity	**Medium/high value users** Busy shipping area is located outside of Project Area, but shipping traffic still likely to be high.
Environmental objective	**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.
Assessment and Conclusion	
Impacts to shipping will be limited to slight temporary impacts during construction of the proposed BTL and infrequent IMR activities. The overall impact significance level of impacts on shipping has been assessed as Minor (D). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.	

Industry (low value user)

Table 1-20: Industry assessment

Receptor	Industry
Local environment context	The NWMR supports a number of industries including petroleum exploration and production, as well as minerals extraction. There are seven sedimentary petroleum basins in the NWMR: the Northern and Southern Carnarvon basins, Perth, Browse, Roebuck, Offshore Canning and Bonaparte basins. Of these, the Northern Carnarvon, Browse and Bonaparte basins hold large quantities of gas and comprise most of Australia's reserves of natural gas (Section 5.4.2.5).
Receptor sensitivity	**Low value** The Project Area is not of extensive use by other Industry.
Environmental objective	**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.
Assessment and Conclusion	
Displacement of, or interference with, other oil and gas activities is not expected within the Browse Development Area. However, activities associated with the proposed BTL, such as BTL installation, may result in short term interference, particularly at the NWS infrastructure tie in location (5-10 km away from NRC). This short term interference will be no greater extent than is necessary. As such, the overall impact significance level of impacts on industry has been assessed as Negligible (F). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.	

Settlements (medium value users)

Table 1-21: Settlements assessment

Receptor	Settlements
Local environment context	The proposed Browse to NWS Project presents potential social benefits and impacts to communities within WA and particularly Broome and the Dampier Peninsula, with Broome being the potential primary supply chain and logistics support location (Section 5.4.4).
Receptor sensitivity	**Medium value users** Regionally important, low sensitivity to change.
Environmental objective	**Objective 22:** To protect social surroundings from significant harm.
Assessment and Conclusion	
Atmospheric noise emissions from helicopters (transiting from logistic locations and the Project Area) are not predicted to have any lasting effect on settlements. Atmospheric noise emissions from helicopters are the only aspect predicted to result in potential impacts to settlements. As such, the overall impact significance level of impacts on settlements has been assessed as Negligible (F). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.	

Aboriginal and indigenous heritage (high value users)

Table 1-22: Aboriginal and indigenous heritage assessment

Receptor	Aboriginal and indigenous heritage
Local environment context	No known sites of Aboriginal Heritage significance are located within the Development Area, according to the WA Department of Aboriginal Affairs' Aboriginal Sites Inquiry System. The existence of any unknown Aboriginal sites or artefacts of significance within the Browse Development Area, or the wider NWMR, is considered highly unlikely due to the site's remote location offshore (Section 5.4.3.1).
Receptor sensitivity	**High value users** Browse Development Area is of high importance to stakeholders.
Environmental objective	**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.
Assessment and Conclusion	
No impact to aboriginal heritage within the Project Area is expected to occur as a result of the proposed Browse to NWS Project. Slight impacts to traditional Indonesian fisher utilising the MOU 74 area may occur as a result of the physical presence of infrastructure. As such, the overall impact significance level of impacts on settlements has been assessed as Minor (D) (based on the assessment of impacts of disturbance to other users from the physical presence of infrastructure on Indonesian fishers). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**. It is noted that potential impacts associated with atmospheric emissions resulting from the onshore processing of the Browse gas by the NWS JV on the national heritage values of the listed National Heritage Place on the Dampier Archipelago (including aboriginal heritage values) are addressed in the North West Shelf Project Extension ERD (EPA 2186, EPBC 2018/8335).	

Maritime archaeology

Table 1-23: Maritime archaeology assessment

Receptor	Maritime archaeology
Local environment context	The Australian National Shipwreck Database and the WA Maritime Museum Shipwreck Database list one protected historic wreck within the Browse Development Area. The historic shipwreck of the Yarra is located at South Scott Reef (Section 5.4.3.2).
Receptor sensitivity	**High value** Maritime archaeology protected by legislation exists within the Browse Development Area.
Environmental objective	**Objective 19:** To not have a substantial adverse impact on heritage values.
Assessment and Conclusion	
No impacts to the marine archaeology within the Project Area (i.e. shipwrecks at Scott Reef) are predicted. As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.	

1.7.5 Overall Assessment of Risks from Unplanned Events or Incidents

Environmental risks from unplanned events or incidents may have significant consequences to multiple high value receptors on a regional scale. However, it is important to note that with the implementation of industry good practice mitigation and management measures by Woodside, a highly experienced operator, as well as significant legislative requirements and regulatory oversight, the likelihood of a significant risk event occurring and resulting in significant impacts is highly unlikely to remote.

Chapter 6 provides an assessment of the risk events identified during the impact and risk assessment. The following risks were identified as having a low risk rating due to the likelihood of the risk event occurring, along with the subsequent consequence:

- accidental dropped objects from vessels, the MODU or the FPSO facilities impacting benthic habitats – Section 6.3.1
- damage to unidentified maritime archaeology (ship or plane wrecks) during the placement of subsea infrastructure or the BTL and inter-field spur line Section 6.3.1
- unplanned release of treated sewage and sullage above regulatory limits – Section 6.3.9
- unplanned release of treated utility water above regulatory limits – Section 6.3.10
- unplanned release of PW at significantly elevated discharge concentrations that would lead to water quality impacts within the State waters 3 nm boundary – Section 6.3.12
- unplanned release of cooling water at significantly elevated discharge concentrations that would lead to water quality impacts within the State waters 3 nm boundary – Section 6.3.13
- unplanned discharge of hazardous and non-hazardous inorganic waste – Section 6.3.14
- dispersal of drill cuttings and fluids being greater than predicted, resulting in impacts to high value shallow water habitats at Scott Reef beyond those predicted – Section 6.3.15
- unplanned discharge of subsea control fluid at a volume significantly greater than predicted – Section 6.3.16
- unplanned vessel interactions with marine turtles and fish (whale sharks) – Section 6.3.18

Environmental risks that were ranked as moderate or high included the following:

- the risk posed by the potential higher utilisation of the Browse Development Area by pygmy blue whales and subsequent increased impact of underwater noise (moderate risk) – Section 6.3.8
- the unplanned vessel interactions with marine mammals (moderate risk) – Section 6.3.18
- the introduction and establishment of IMS at Scott Reef (moderate risk) – Section 6.3.19
- unplanned hydrocarbon releases (moderate to high risk) – Section 6.3.21.

It should be noted that the moderate and high-risk rating for these risks was driven by the significance of the potential consequences to high value receptors, on a regional scale. The likelihood of these risks occurring and resulting in subsequent impacts is considered highly unlikely to remote.

The planned mitigation and management actions for each of these risk events are described in Chapter 6. Given that the likelihood of any of these risk events occurring is considered unlikely to remote, the planned mitigation and management measures, and in consideration of the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for each receptor (Table 6-7) potentially impacted by these risk events will be achieved and, as such, these risks are assessed as **Acceptable**.

1.8 Greenhouse Gases

GHG emissions are those that absorb infrared radiation in the atmosphere and release this energy as heat, consequently increasing global temperatures. This increase in temperature is projected to have an adverse effect on natural ecosystems as a result of reductions in the bioclimatic range within which a given species or ecological community exists.

GHG Emission Estimates

Forecast GHG emissions for the proposed Browse to NWS Project have been estimated, based on:

- the current level of concept definition and assumptions regarding commercial arrangements
- anticipated controls and inputs associated with the nature of the feed gas
- the scale, efficiency, interaction and complexity of the extraction, processing, production and compression of the product stream.

Woodside has identified energy efficiency and emissions reductions measures that have been incorporated into the design of the proposed Browse to NWS Project. These include measures such as waste heat recovery units, active heating for hydrate management, the use of batteries and the use of nitrogen to purge the flare stack. These measures represent an approximately 1 MT CO_2-e/annum emissions reduction.

Upstream emissions from the proposed Browse to NWS Project (i.e. Scope 1 emissions (i.e. emissions directly from the proposed Browse to NWS Project) are estimated to be 163 CO_2-e MT over 44 years, resulting primarily from reservoir gas venting, fuel combustion and intermittent flaring.

Based on current Safeguard Mechanism (SGM) requirements, it is anticipated that reservoir CO_2 emissions will contribute to the proposed Browse to NWS Project exceeding any facility baseline by approximately 50Mt CO_2-e, which would need to be offset in accordance with the rules of the SGM.

Global GHG emissions will continue to have a potentially significant effect on receptors. However, indirect, climate change induced impacts to sensitive environmental receptors resulting directly from the proposed Browse to NWS Project are difficult to predict and likely immeasurable. However, it is possible to estimate the contribution to global emissions. As a standalone project, taking into account all planned emissions reduction and offsetting measures, it is estimated that Scope 1 and Scope 3 emissions from the proposed Browse to NWS Project could contribute in the range of 0.06% to 0.15% global GHG emissions, depending on the Nationally Determined Contributions (NDC) scenario considered. Given these estimates, it is not considered credible that as a standalone project, GHG emissions from the proposed Browse to NWS Project will significantly impact sensitive environmental receptors.

It should also be noted that the provision of clean and reliable energy is paramount to the lifting of worldwide living standards. As a clean and reliable energy source, gas is expected to play a key role in the future energy mix (as a partner to intermittent renewables). Gas has the potential to contribute significantly to the reduction in global GHG emissions by displacing higher carbon intensive power generation (e.g. coal burning).

Overall, in the context of Australia's international commitments and National and State legislation and policy, it is considered that given the proposed mitigation of emissions, the offsetting measures proposed and the importance of gas as a clean and reliable source of energy in the current and future energy mix, GHG emissions from the proposed Browse to NWS Project are acceptable.

The proposed Browse to NWS Project has proposed a GHG Abatement Plan to continuously review mechanisms to mitigate and manage GHG emissions and compliance with SGM baseline requirements through Australian carbon credit units to offset anticipated excess emissions over baseline.

1.9 Environmental Management and Monitoring

Within the Woodside Management System (WMS), the overall direction for environmental management is set through the corporate Health Safety, Environment and Quality Policy. This policy states Woodside's commitment to minimising adverse effects on the environment from its activities and to improving environmental performance. It sets out the principles for achieving the objectives for the environment and how these are to be applied. The policy is applied to all Woodside's activities, and all employees, contractors and Joint Venture partners engaging in activities under Woodside operational control.

As part of the development of this draft EIS/ERD, management and mitigation measures have been identified and will be implemented to reduce the level of impact and risk to an acceptable level in consideration of the EPBC Act, EP Act and other relevant legislation and regulations. In accordance with Woodside's risk management standards and for the purpose of the draft EIS/ERD, where a risk has been assessed as low, this risk is deemed acceptable and no further management is required. Where the risk level is moderate or higher, additional management and mitigation measures to prevent or mitigate the risk to an acceptable level are considered and implemented if the cost and HSE risks are not grossly disproportionate to the environmental benefit gained.

The central management and monitoring commitments include, but not limited to the following:

- Key outcomes:
  - No infrastructure will be placed on Scott Reef shallow water benthic communities and habitats (<75 m bathymetry).
  - A Maximum Level of Ecological Protection is proposed for Scott Reef shallow water benthic communities and habitats (<75 m bathymetry)
  - PW and cooling water discharges from the FPSO will be managed in Commonwealth waters to ensure the defined threshold values (e.g. 99% species protection or no effect concentrations) are met at the State waters 3 nm boundary, 95% of the time based on dispersion modelling results.
  - Drilling discharges (in particular, bottom-hole section discharges) at drill centre locations in the State Proposal Area (i.e. TRA, TRD, TRE and TRF) will be managed using industry proven techniques to avoid potential impacts to Scott Reef shallow water benthic communities and habitats (<75 m bathymetry).
  - Based on current SGM requirements, it is anticipated that reservoir CO_2 emissions will contribute to the proposed Browse to NWS Project exceeding any facility baseline by approximately 50 Mt CO_2-e over field life, which would need to be offset in accordance with the rules of the SGM.
- Key management strategies:
  - Underwater noise monitoring of a RFSU operational well will be undertaken to inform an adaptive management approach for noise management for the TRD and TRE wells if required.
  - FPSO PW will be treated prior to being discharged overboard using a tertiary treatment system, such as a Macro Porous Polymer Extraction (MPPE) system which is considered industry best practice.
  - Project vessels will not travel at speeds greater than 12 knots with the State Proposal Area, or 6 knots in the Scott Reef channel.
  - Fast Crew Transfer Vessels (FCTVs) will operate under an approved FCTV Management Strategy (to be detailed in subsequent Environment Plans as required) which will describe the appropriate additional control measures to manage vessel strike risk for the FCTV. Subject to the potential for technological innovation and additional engineering controls as discussed in Chapter 6, FCTVs will not travel at speeds greater than 30 knots (reduced from ~50 knots) in sensitive areas (e.g. the humpback whale migration corridor) at sensitive times.
  - Project vessels and MODUs will be subject to a risk assessment process to assess the likelihood of introducing IMS when transiting to the Project Area. Based on the outcomes of risk assessment, management measures commensurate with the risk (such as the treatment of internal systems, IMS inspections or cleaning) will be implemented.
  - Internationally sourced Project vessels and MODUs required within 3 nm of Scott Reef (State Proposal Area) for longer than 48 hours will be inspected by an experienced IMS expert/marine scientist for IMS; and cleaned where required[2].
  - Project vessels will not use heavy fuel oil or intermediate fuel oil.
- Assurance:
  - Light monitoring will occur during drilling and completion of a well at TRE drill centre to verify modelling predictions.
  - Periodic and ‘for cause’ toxicity testing and characterisation of the physical and chemical composition of the FPSO PW stream prior to discharge will be undertaken.
  - During steady state FPSO operations, PW modelling and infield verification will be completed to verify the modelling predictions.
  - Baseline and periodic water and sediment quality monitoring at a gradient away from the FPSO facility in the receiving environment will be undertaken to detect changes as a result of FPSO PW discharge.
  - During steady state FPSO operations, cooling water modelling and infield verification will be completed to verify the modelling predictions.
  - Verification monitoring for seabed subsidence will be undertaken.
  - IMS surveillance program will be undertaken at Scott Reef, consisting of a baseline survey prior to the commencement of activities in the State Proposal Area, and periodic surveys over the life of the proposed Browse to NWS Project.

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[2] *Subject to confirmation, vessel/rig may be permitted re-entry within Scott Reef State waters (3 nm) without re-inspection provided its movements outside Scott Reef State waters at stationary or at slow speeds (less than three knots) in waters less than 50 metres deep do not exceed a period totalling greater than seven accumulative days prior to returning to Scott Reef State waters (3 nm).*

- Verifying science:
  - The Scott Reef long term monitoring program will continue to monitor the functionality and status of the reef system, throughout the full lifecycle of the proposed Browse to NWS Project.
  - The existing pygmy blue whale data will be updated by targeted monitoring programs to verify impact predictions and inform adaptive management approaches at relevant times throughout the proposed Browse to NWS Project life cycle.
  - The existing turtle data will be updated by targeted monitoring programs to verify impact predictions at relevant times throughout the proposed Browse to NWS Project life cycle.

It should be noted that further environmental review and the implementation of additional controls will be undertaken in subsequent phases of the project, such as during the preparation of Environment Plans for activities under the scope of the draft EIS/ERD. While the overarching environmental objectives will be carried through to the Environment Plans, controls and corresponding performance criteria will be detailed in the Environment Plans and implemented to reduce risks to As Low As Reasonably Practicable (ALARP). During construction, contractors will also be required to prepare environmental management plans for Woodside approval that detail how the project requirements will be met in relation to their specific activity.

1.10 Record of environmental management

Woodside, as operator for and on behalf of the BJV, believes excellence in environmental performance is essential to our business success worldwide and is compatible with balancing the economic, social and environmental needs of sustainable development.

Woodside employs a structured approach to the management of the environment via the formal and documented WMS. Through policies, processes, procedures and standards the WMS requires that impacts from Woodside's operations are either avoided or kept to ALARP. It also drives continuous improvement in the company's environmental performance.

Woodside's commitment to responsible environmental management was recognised by the Australian Petroleum Production and Exploration Association (APPEA) as the recipient of the Environment Excellence Award in 2009, 2012, 2015, 2016, 2017 and 2019. Woodside was recognised in 2009 for appraisal activities at Scott Reef, including environmental research undertaken at Scott Reef in association with the Maxima 3D marine seismic survey and the Gigas 2D Pilot Ocean Bottom Cable marine seismic survey. This recognition was for Woodside's approach to undertaking activities in a highly sensitive environmental setting. The 2012 and 2017 APPEA Environment Awards recognised Woodside's partnerships with AIMS and Western Australian Museum (WAM). These long-term relationships have contributed shared scientific knowledge to academic, government, industry and the broader community's understanding of biodiversity and ecological function in WA's tropical marine ecosystems.

1.11 Conclusion

This draft EIS/ERD has been prepared by Woodside, as Operator for and on behalf of the Browse Joint Venture participants, to meet the requirements of the EPBC Act, EP Act, Woodside standards and the EISG/ESD in relation to the proposed Browse to NWS Project.

This draft EIS/ERD presents the predicted impacts from planned activities and the environmental risks associated with unplanned events and incidents. The acceptability of the impacts and risks were assessed using the Principles of ESD, the EPBC Act Significant Impacts Guidelines, the WA EPA Environmental Objectives, the North-west Marine Parks Network Management Plan (Director of National Parks, 2018), specific species conservation and recovery plans, internal and external context, as well as other requirements. The conclusion of this assessment was that the impacts and risks presented by each aspect are **Acceptable** (refer to Chapter 9).

The Browse Joint Venture has considered the outcomes of the impact and risk assessment process and developed a range of mitigation and management measures to be implemented throughout the life cycle of the proposed Browse to NWS Project.

In summary, taking into account the unique values of Scott Reef and surrounds, the principles of ESD, the objectives of the EPBC Act and EP Act, and other relevant requirements, the Browse Joint Venture has concluded that the predicted impacts from planned activities and the potential risks from unplanned events and incidents have been reduced to an **Acceptable** level. The Browse Joint Venture considers that the proposed Browse to NWS Project can be implemented in a manner that will result in significant socio-economic benefits, while limiting environmental impacts and risks so that they are consistent with relevant regulations, policies, plans, principles and guidance.

1.12 Acronyms used

Acronym	Definition
2TL	Second Trunkline
µg	Microgram
µm	Micrometre
AASM	Airgun Array Source Model
ACCUs	Australian Carbon Credit Units
AFMA	Australian Fisheries Management Authority
AFZ	Australian Fishing Zone
AGRU	Acid Gas Removal Unit
AIMS	Australian Institute of Marine Science
AIS	Automatic Identification System
ALARP	As Low As Reasonably Practicable
AMOSC	Australian Marine Oil Spill Centre
AMSA	Australian Maritime Safety Authority
AMP	Australian Marine Park
ANN	Artificial Neutral Network
ANZECC/ ARMCANZ	Australian and New Zealand Environment and Conservation Council
APPEA	Australian Petroleum Production and Exploration Association
ARC	Australian Research Council
As	Arsenic
AS/ISO	International Standards Organisation and Standards Australia
AUSREP	Australian Ship Reporting System
BC Act	*Biodiversity Conservation Act 2016* (WA); replaced the *Wildlife Conservation Act 1950* (WA) and *the Sandalwood Act 1929* (WA) on 1 January 2019
BCCI	Broome Chamber of Commerce and Industry
BIA	Biological Important Area
BJV	Browse Joint Venture
BOD	Basis of Design
BoD	Biological Oxygen Demand
BoM	Bureau of Meteorology
BOP	Blow-out Preventer
BPP	Benthic Primary Producer
BPPH	Benthic Primary Producer Habitat
BRUVS	Baited Remote Underwater Video Stations
BTEX	Benzene, toluene, ethylbenzene and xylene
BWA	Brecknock
BTL	Browse Trunkline

Acronym	Definition
$CaCO_3$	Calcium Carbonate
CAMBA	China–Australia Migratory Bird Agreement
CCS	Carbon Capture and Storage
CER	Clean Energy Regulator
CGSS	CO_2 Geological Storage Solutions Pty Ltd
CH_4	Methane
CHL	Commonwealth Heritage List
CITES	International Convention on International Trade in Endangered Species of Wild Fauna and Flora
CLC	International Convention on Civil Liability for Oil Pollution Damage
CME	Chamber of Minerals and Energy of Western Australia
CMP	Cetacean Management Plan
CO_2	Carbon dioxide
Co	Cobalt
COLREGS	The Convention on International Regulations for Preventing Collisions at Sea 1972
CP	Cathodic Protection
Cr	Chromium
CRA	Corrosion Resistant Alloy
CRG	Community Reference Group
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSG	Coal-seam Gas
Cth	Commonwealth of Australia
Cu	Copper
Cwlth	Commonwealth
DAS	Distributed Acoustic Sensing
DAWR	Department of Agriculture and Water Resources
DBCA	Department of Biodiversity, Conservation and Attraction
DFAT	Department of Foreign Affairs and Trade
DMIRS	Western Australian Department of Mines, Industry Regulation and Safety
DoEE	Department of the Environment and Energy
DO	Dissolved Oxygen
DOF	Department of Fisheries
DoIIS	Department of Industry, Innovation and Science
DP	Dynamically Positioned

Acronym	Definition
DPIRD	Department of Primary Industries and Regional Development
E	Environment
EAG	Environmental Assessment Guideline
EAAF	East Asian-Australasian Flyway
EEZ	Exclusive Economic Zone
e.g.	For example
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EISG	EIS Guidelines
EISG/ESD	EIS Guidelines/ Environmental Scoping Document
EMBA	Environment that May be Affected
ENSO	El Niño Southern Oscillation
EP	Environmental Plan
EP Act	*Environmental Protection Act 1986 (WA)*
EPA	Environmental Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
EPP	Environmental Protection Policy
EPOs	Environmental Performance Objectives
EQC	Environmental Quality Criteria
EQMP	Environmental Quality Management Plan
EQOs	Environmental Quality Objectives
ERD	Environmental Review Document
ERF	Emissions Reduction Fund
ERP	Emergency Response Plan
ESD	Ecological Sustainable Development
EVs	Environmental Values
FARA	Friends of Australian Rock Art
FEED	Front-end Engineering and Design
KEF	Key Ecological Feature
FCTVs	Fast Crew Transfer Vessels
FEWD	Formation Evaluation While Drilling
FID	Final Investigation Decision
FLET	Flowline End Termination
FLNG	Floating Liquefied Natural Gas
FPSO	Floating Production Storage and Offloading
FRMA	*Fish Resources Management Act 1994*
FWRAM	Full Waveform Range-dependent Acoustic Model
GHG	Greenhouse Gas
GLNG	Gladstone LNG
GWP	Global Warming Potential

Acronym	Definition
H2S	Hydrogen Sulphide
Ha	Hectare
HFO	Heavy Fuel Oil
HF	High-frequency
HFCs/CFCs	Hydrochlorofluorocarbons/ chlorofluorocarbons
HFO	Heavy Fuel Oil
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
ICAO	International Civil Aviation Organization
IEA	International Energy Agency
IFC	International Finance Corporation
IFL	Interfield Line
IFO	Intermediate Fuel Oil
IGAB	Intergovernmental Agreement on Biosecurity
IMCRA	Integrated Coastal and Marine Regionalisation of Australia
IMO	International Maritime Organization
IMOS	Australian Integrated Marine Observing System
IMR	Inspection, Maintenance and Repair
IMS	Invasive Marine Species
IMSMP	IMS Management Plan
IOGP	Oil and Gas Producers
IPCC	Intergovernmental Panel on Climate Change
IPRP	Independent peer review panel
ISPOCET	Integration, Sustainability, Political, Organisational, Commercial, Economic and Technical
ITF	Indonesian Throughflow
IUCN	International Union for the Conservation of Nature
JAMBA	Japan–Australia Migratory Bird Agreement
JANSF	Joint Authority Northern Shark Fisher
JASMINE	JASCO Animal Simulation Model Including Noise Exposure
JPP	James Price Point
KBSB	King Bay Supply Base
KEF	Key Ecological Feature
KGP	Karratha Gas Plant
Km	Kilometre
L	Litre
LAT	Lowest Astronomical Tide
LEPs	Levels of Ecological Protection

Acronym	Definition
LF	Low-Frequency
LNG	Liquefied Natural gas
LoR	Limit of Reporting
LWIV	Light Well Intervention Vessel
m	Meters
MAC	Murujuga Aboriginal Corporation
MAFMF	Marine Aquarium Fish Managed Fishery
MARPOL	The International Convention for the Prevention of Pollution From Ships, 1973 as modified by the Protocol of 1978
MARS	MARine Sediment
MEAP	Marine Expert Advisory Panel
MEE	Maritime Environmental Emergencies
MEG	Mono Ethylene Glycol
MDO	Marine Diesel Oil
mg	Milligrams
mm	Millimeters
MMscfd	Million standard cubic feet per day
MNES	Matters of National Environmental Significance
MODIS	Moderate Resolution Imaging Spectrometer
MODU	Mobile Offshore Drilling Unit
MONM-BELLHOP	Marine Operations Noise Model
MoU	Memorandum of Understanding
MP	Marine Park
MPA	Marine Protected Area
MPPE	Macro Porous Polymer Extraction
MRU	Mercury Removal Unit
MSL	Mean Sea Level
MSS	Marine Seismic Survey
$MtCO_2$-e	Million tonnes of Carbon Dioxide-equivalent
MTMP	Marine Turtle Management Plan
MUDMAP	Three-dimensional discharge and plume behaviour model
MUWG	Marine Users Working Group
N2O	Nitrous oxide
NAC	Ngarluma Aboriginal Corporation
NaCl	Sodium Chloride
NDCs	Nationally Determined Contributions
NDSF	Northern Demersal Scalefish Managed Fishery
NEBRA	National Environmental Biosecurity Response Agreement

Acronym	Definition
NGER Act	*National Greenhouse and Energy Reporting Act 2007* (Cth)
NGERS	National Greenhouse & Energy Reporting Scheme
NGO	Non Government Organisation
NH_4	Ammonium
Ni	Nickel
NIMS	Non-indigenous Marine Species
nm	Nautical Miles
NMFS	National Marine Fisheries Service
NO_x	Nitrogen Oxides
NO_2	Nitrite
NO_3	Nitrate
NOEC	No Observable Effect Concentration
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NOPTA	National Offshore Petroleum Titles Administrator
NORMs	Naturally Occurring Radioactive Materials
NRC	North Rankin Complex
NSW	New South Wales
NT	Northern Territory
NTU	Turbidity
NWSTF	North West Slope Trawl Fishery
NRSMPA	National Representative System of Marine Protected Areas
NWBF	Non-water Based Fluids
NWMR	North-west Marine Region
NWS	North West Shelf
NWS Project	The North West Shelf Project
NWSJV	North West Shelf Joint Venture
NYFL	Ngarluma Yindjibarndi Foundation Ltd
OBC	Ocean Bottom Cable
OBS	Ocean Bottom Seismographs
OIM	Offshore Installation Manager
OPEP	Oil Pollution Emergency Plan
OPGGS (E) Regulations	Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009
OPGGS Act	*Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cth)
OSCP	Oil Spill Contingency Plan
OSMP	Oil Spill Management Plan
OSMPs	Operational and Scientific Monitoring Programs
OSV	Offshore Support Vessel

Acronym	Definition
PAH	Polycyclic Aromatic Hydrocarbons
Pb	Lead
PER	Public Environmental Review
PDSM	Pile Driving Source Model
PFTIMF	Pilbara Fish Trawl Interim Managed Fishery
PFW	Produced Formation Water
pH	Potential of hydrogen (measure of acidity)
PK	Zero-to-Peak sound pressure level
PLET	Pipeline End Terminal
PLONAR	Pose little or no risk to the environment
PMST	Protected Matters Search Tool
PPT	Parts per thousand
PSD	Particle Size Distribution
PSL Act	*Petroleum (Submerged Lands) Act 1982* (WA)
PTS	Permanent Threshold Shift
PW	Produced Water
RDA	Rank Abundance Distribution
RFSU	Ready for Start Up
ROKAMBA	Republic of Korea–Australia Migratory Bird Agreement
ROV	Remotely Operated Underwater Vehicle
SA	South Australia
SCSSVs	Surface Controlled Subsurface Safety Valves
S.E.	Standard Error
SEIFA	Socio-Economic Indexes for Areas
SEL	Sound Exposure Level
SDS	Sustainable Development Scenario
SDUs	Subsea Distribution Units
SGM	Safeguard Mechanism
SIA	Social Impact Assessment
SMPEP	Ship-board Marine Pollution Emergency Plan
SO_x	Sulphur Dioxide
SOPEP	Ship-Board Oil Pollution Emergency Plan
SRRP	Scott Reef Research Project
SPRAT	Species Profile and Threats Database
SPL	Sound Pressure Level
SURF	Subsea Umbilicals, Risers and Flowlines
TEC	Threatened Ecological Communities
TCF	Trillion Cubic Feet
TN	Total Nitrogen

Acronym	Definition
TOC	Total Organic Carbon
TP	Total Phosphorus
TPH	Total Petroleum Hydrocarbons
TRE	Western drill centre
TRD	Eastern drill centre
TS	Torosa South
TSS	Total Suspended Solids or Temporary Threshold Shift
TTS	Temporary Threshold Shift
UKOOA	United Kingdom Offshore Operators Association
UM3	Updated Merge Flow Model
UNCLOS	United Nations Convention on the Law of the Sea
UNESCO	The United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
US EPA	United States Environmental Protection Agency
UV	Ultraviolet
VHF	Very-high Frequency
VMS	Vessel Monitoring System
VOC	Volatile organic compound
VSP	Vertical Seismic Profiling
VSTACK	Wavenumber integration model
WA	Western Australia
WA DOF	WA Department of Fisheries
WAF	Water Accommodated Fractions
WAFIC	Western Australian Fishing Industry Council
WAM	Western Australian Museum
WAMSI	Western Australian Marine Science Institution
WANCSF	Western Australian North Coast Shark Fishery
WBCSD	World Business Council for Sustainable Development
WBF	Water Based Fluid
WEL	Woodside Energy Ltd
WEO	World Energy Outlook
WET	Whole Effluent Toxicity
WMS	Woodside Management System
WRI	World Resources Institute
WSTF	Western Skipjack Tuna Fishery
Zn	Zinc

1.13 EIS Guideline (EISG) / ESD Checklist

1.13.1 ESD Checklist

Refer to Chapter 10, Appendix B.

1.13.2 EISG Checklist

Table 1-1 EISG Scoping Checklist

Required Work	Section
Invitation to make a submission	
The draft EIS/ERD will include an invitation to make a submission including: 1. details on how and when public submissions will be addressed in the assessment and decision-making process 2. how submissions can be made 3. what form submissions should take 4. when submissions should be made.	Chapter 1 (Executive Summary)
Executive Summary	
An executive summary that outlines the key findings of the EIS/ERD will be provided. The executive summary will briefly: 1. state the background and the need for the Proposed Action and State waters proposal 2. discuss alternatives to the Proposed Action, State waters proposal and the reasons for selecting the preferred option and rejecting alternatives 3. summarise the installation, operational and decommissioning activities associated with putting the Proposed Action and State waters proposal into practice 4. state the proposed schedule for key activities and the expected duration of the Proposed Action and State waters proposal 5. provide an overview of the existing regional and local environments, summarising the features of the physical, biological, social and economic environment relating to the Proposed Action, State waters proposal and associated activities with each 6. describe the expected, likely and potential impacts of the Proposed Action and State waters proposal on the environment during the installation, operational and decommissioning phases 7. summarise the environmental protection measures and safeguards, monitoring and decommissioning procedures to be implemented for the Proposed Action and State waters proposal 8. provide an outline of the environmental record of Woodside.	Chapter 1 (Executive Summary)

Required Work	Section
General Information	
The EIS/ERD should provide the background of the proposed Browse to NWS Project including: 1. the title of the action 2. the full name and postal address of the designated proponent 3. a clear outline of the objective of the action 4. the location of the action 5. the background to the development of the action 6. how the action relates to any other actions (of which the proponent should reasonably be aware) that have been, or are being, taken or that have been approved in the region affected by the action 7. the current status of the action 8. the consequences of not proceeding with the action 9. a brief explanation of the scope, structure and legislative basis of the EIS/ERD 10. the specific EPBC Act MNES and WA EPA Environmental factors affected by the action 11. a description of government planning policies and statutory controls which will influence the proposed Browse to NWS Project. All applicable jurisdictions and areas of responsible authorities within the area will be listed and shown on maps at appropriate scales.	Chapter 2 (General Information)
Description of the Action	
All installation, operational, IMR and decommissioning components of the action will be described in sufficient detail to understand the Proposed Action and State waters proposal and assist in determining the associated potential environmental impacts. This will include the location (including coordinates) of all works to be undertaken, structures to be built or elements of the action that may have relevant impacts (on MNES and/or WA EPA Environmental Factors) and other social or economic impacts. In addition, proposed safeguards and mitigation measures to deal with relevant impacts of the action will be included.	Chapter 3 (Proposed Browse to NWS Project)
The description of the action will also include details on how the works are to be undertaken (including all stages of development and their timing) and design parameters for those aspects of the structures or elements of the action, including how the operation is to be managed, that may have relevant impacts and other social or economic impacts.	General location figures – Chapter 2 (General Information)
The description will include the use of aerial photographs, maps, figures and diagrams, where appropriate. A general location map will be provided that illustrates the existing and proposed infrastructure and will include the location of known potential future expansions or new developments in the vicinity. Reference will be made to detailed technical information in appendices where relevant.	
The description will also include any other requirements for approval or conditions that apply, or that Woodside reasonably believes are likely to apply, to the Proposed Action or State waters proposal.	

Required Work	Section
Feasible Alternatives	
Any feasible alternatives to the action to the extent reasonably practicable, including: 1. if relevant, the alternative of taking no action and/or part of the Proposed Action and State waters proposal 2. a comparative description of the adverse and beneficial impacts of each alternative on MNES and WA Environmental Factors 3. sufficient detail to make clear why any alternative is preferred to another and if approval is being sought for feasible alternatives as part of this assessment process. Short, medium and long-term advantages and disadvantages of the options will be discussed.	**Chapter 3**, **Section 3.8** (Development Alternatives) **Chapter 2**, **Section 2.8** (Development Justification)
Social and Economic Matters	
For the purpose of the assessment under the EPBC Act, information will be provided on the broader social and economic impacts (positive or negative) of the Proposed Action. Any information provided for this purpose will be in a separately identified section or appendix of the EIS/ERD. Such information provided may address: 1. the broader economic benefits of the Proposed Action going ahead versus alternatives 2. any effects on employment that may occur beyond the immediate scope of the Proposed Action (including versus alternatives). Any methodology used to calculate indirect effects associated with employment will be provided information on the amount of domestic and/or overseas investment for capital infrastructure (including versus alternatives) 3. any other social or economic issues that may relate directly or indirectly.	**Chapter 3**, **Section 3.9** (Social and Economic Matters)
Stakeholder Engagement	
The EIS/ERD will provide details of any consultation in relation to the Proposed Action and State waters proposal including: 1. consultation that has already taken place 2. documented response or results of the consultation that has taken place 3. any further proposed consultation. Woodside will consult with relevant stakeholders in relation to the proposed Browse to NWS Project. These stakeholders include decision-making authorities, other relevant government agencies and authorities (local, state, and Commonwealth), the local community, local indigenous groups, academics, research authorities and environmental non-government organisations. The EIS/ERD will describe the consultation method adopted, existing stakeholder forums and skills and techniques used to ensure effective communication of the nature and detail of proposed Browse to NWS Project. This will include the means used to identify concerns and to gauge and progress mitigation strategies. The assessment documentation must provide details of the potential indirect impacts of the proposed action on the (Indigenous rock art) values of the Dampier Archipelago (including the Burrup Peninsula) National Heritage Place, and the extent to which these values may potentially be impacted by the proposed action following any planned mitigations.	**Chapter 4** (Stakeholder Engagement)

Required Work	Section
Description of the Environment	
The EIS/ERD will include a detailed description of the environment within the Project Area and the surrounding areas (including State waters) that may be affected by the Proposed Action. The environment that may be affected (EMBA) by the proposed Browse to NWS Project, which is the largest spatial extent where unplanned events could have an environmental consequence on the surrounding environment will be described. The spatial areas of the defined EMBA and Project Area will be used to identify and describe all environmental values, including environmental and socio-economic, that are relevant to the project. The relevant receptors (based on the preliminary impact and risk assessment) and their relationship with the MNES categories and the WA EPA.	Chapter 5 (Existing Environment)
This EIS/ERD chapter will describe the following elements of the environment within the Project Area: + Physical environment including + Climate and atmospheric characteristics + Oceanographic conditions, bathymetric and geotechnical information + Marine water and marine sediment characteristics	Chapter 5, Section 5.2 (Physical Environment)
+ Ecological environment including + An overall evaluation of the flora and fauna communities identified with reference to: + habitat values in a local, regional and national context + presence of endemic species + regional representation; conservation and biodiversity values + economic and cultural values of species + unique habitats.	Section 5.3 (Ecological Marine Environment)
+ Particular attention will be given to the conservation values within Scott Reef and surrounds	Chapter 5, Section 5.3.1 Ecological Communities
A broader description of the biodiversity and biogeography of the receiving environment, including the identification of sensitive environments along with key ecological relationships and interdependencies (e.g. coral spawning, fish spawning aggregations, flora and fauna relationships).	Chapter 5, Section 5.3.2 (Fauna)
A description of listed threatened species and ecological communities (EPBC Act sections 18 & 18A), listed migratory species (EPBC Act sections 20 & 20A) and protected species under the Biodiversity Conservation Act 2016 that are likely to be present in the vicinity of the proposed Browse to NWS Project. Descriptions will include the predicted temporal and spatial variability in occurrence within the Project Area, known habitat utilisation or requirements and relevant identified threats to their survival. Details of the scope, timing and scientifically robust methodology for studies or surveys used to provide information on the listed species/communities/habitats at the site (and in areas that may be impacted by the project) will also be included. Species to be addressed in the EIS/ERD include, but are not be limited to the following. Additional EPBC Act listed threatened and listed migratory species will be considered following completion of the relevant modelling studies to be undertaken to determine the species that may be affected (refer to Chapter 10, Appendix C for list of species).	Chapter 10, Appendix C (PMST Search's)

Required Work	Section
A description of the marine environment (EPBC Act sections 23 & 24A and EP Act) relevant to the action, including, but not limited to, habitat, species and values of listed Western Australian and Commonwealth Heritage places, Key Ecological Features (identified in the relevant Marine Bioregional Plan) and Western Australian and Commonwealth Marine Parks including: + distance from the Proposed Action + reserve characteristics + status + IUCN category + Conservation value + relevant management strategies	Chapter 5 (Existing Environment) Chapter 5, Section 5.4.3.1 (Commonwealth Heritage Places) Chapter 5, Section 5.3.3.1 (Key Ecological Features) Chapter 5, Section 5.3.3.2 (Australian Marine Parks)
Appropriate resources will be reviewed and cited throughout, including all relevant government issued conservation advice and recovery plans, and recent ecological studies where available (e.g. AIMS North West Shoals to Shore Research Program). The extent of existing disturbance to flora and fauna, and the incidence of introduced pest species will be discussed.	Throughout Chapter 5 (Existing Environment)
Socio-economic environment including: + A description of all existing uses and users of the Project Area including discussion of scientific research, tourism, commercial, traditional and recreational fishing, military areas and shipping routes (where relevant). + A description of government planning policies and statutory controls which will influence the project, surrounding areas of future, planned and current use. All applicable jurisdictions and areas of responsible authorities within the area will be listed and shown on maps at appropriate scales. + Any places with known or anticipated heritage, social or cultural values, such that they have been recognised with listing or recording under relevant State or Commonwealth legislation or are anticipated to be listed under such legislation - a description of any historic shipwrecks within the area pursuant to the Commonwealth Underwater Cultural Heritage Act 2018 (which will replace the Historic Shipwrecks Act 1976 on 01 July 2019) and State Maritime Archaeology Act 1973, including locations.	Chapter 5, Section 5.4 (Socio-Economic Environment) Chapter 2, Section 2.11 (Policy, Legal and Administrative Framework) Chapter 5, Section 5.4.3 (Places of Heritage Value)
Studies Workplan	
Marine sediments: + Literature review of Woodside information and publicly available information. + Implementation of a marine environmental survey of the BTL corridor including sampling and characterisation of marine sediments.	Chapter 5, Section 5.2.10 (Sediments) Chapter 10, Appendix D.1 (BTL Route Survey)
Marine Water Quality: + Literature review of Woodside information and publicly available information. + Implementation of a marine environmental survey of the BTL corridor including sampling and characterisation of marine water quality.	Chapter 5, Section 5.2.9 (Water Quality) Chapter 10, Appendix D.1 (BTL Route Survey)
Air quality: + Literature review of Woodside information and publicly available information.	Chapter 5, Section 5.2.6 (Air Quality)
Ambient light: + Literature review of Woodside information and publicly available information.	Chapter 5, Section 5.2.7 (Ambient Light)
Ambient noise: + Literature review of Woodside information and publicly available information.	Chapter 5, Section 5.2.8 (Ambient Underwater Noise)

Required Work	Section
Plankton Communities: + Literature review of Woodside information and publicly available information.	Chapter 5, Section 5.3.1 (Ecological Communities)
Epifauna and Infauna: + Literature review of Woodside information and publicly available information. + Implementation of a marine environmental survey of the BTL corridor including characterisation of infauna and epifauna assemblages.	Chapter 5, Section 5.3.1.2 (Benthic Habitats and Communities) Chapter 10, Appendix D.1 (BTL Route Survey) (BTL Route Survey)
Coral: + Literature review of Woodside information and publicly available information. + Preparation of habitat maps with demonstrated ground truthing for areas where proposed infrastructure will be installed on the seabed within the Browse Development Area. + Implementation of a marine environmental survey of the BTL corridor including benthic habitat characterisation (noting that due to water depths, it is considered highly unlikely that hard coral communities will occur along the BTL corridor).	Chapter 5, Section 5.3.1.3 (Benthic Primary Producers) Chapter 5, Figure 5-22 (Scott Reef Habitat Map) Chapter 10, Appendix D.1 (BTL Route Survey)
Seagrass: + Literature review of Woodside information and publicly available information. + Preparation of habitat maps with demonstrated ground truthing for areas where proposed infrastructure will be installed on the seabed within the Browse Development Area. + Implementation of a marine environmental survey of the BTL corridor including benthic habitat characterisation (noting that due to water depths, it is considered highly unlikely that seagrass will occur along the BTL corridor).	Chapter 5, Section 5.3.1.3 (Benthic Primary Producers) Chapter 5, Figure 5-22 (Scott Reef Habitat Map) Chapter 10, Appendix D.1 (BTL Route Survey)
Macroalgae: + Literature review of Woodside information and publicly available information. + Preparation of habitat maps with demonstrated ground truthing for areas where proposed infrastructure will be installed on the seabed within the Browse Development Area. + Implementation of a marine environmental survey of the BTL corridor including benthic habitat characterisation (noting that due to water depths, it is considered highly unlikely that macroalgae will occur along the BTL corridor).	Chapter 5, Section 5.3.1.3 (Benthic Primary Producers) Chapter 5, Figure 5-22 (Scott Reef Habitat Map) Chapter 10, Appendix D.1 (BTL Route Survey)
Seabirds and migratory shorebirds: + Literature review of Woodside information and publicly available information including a review of applicable State and Commonwealth guidance and conservation plans. + Protected Matters Search and SPRAT profile review of relevant species.	Chapter 5, Section 5.3.2.1 (EPBC Listed Species) Chapter 5, Section 5.3.2.3 (Seabirds and Migratory Shorebirds) Chapter 10, Appendix C (PMST Search's)

Required Work	Section
Fish: + Literature review of Woodside information and publicly available information including a review of applicable State and Commonwealth guidance and conservation plans. + Protected Matters Search and SPRAT profile review of relevant species. + Implementation of a marine environmental survey of the BTL corridor including the opportunist recording of marine megafauna.	Chapter 5, Section 5.3.2.1 (EPBC Listed Species) Chapter 5, Section 5.3.2.7 (Fish) Chapter 10, Appendix C (PMST Search's) Chapter 10, Appendix D.1 (BTL Route Survey)
Marine Mammals: + Literature review of Woodside information, including the recently completed study on the current state of knowledge for blue whales, and publicly available information including a review of applicable State and Commonwealth guidance and conservation plans. + Protected Matters Search and SPRAT profile review of relevant species. No further marine mammal specific surveys are considered necessary to inform the impact assessment. However, the implementation of a marine environmental survey of the BTL corridor will include the opportunist recording of marine mega fauna.	Chapter 5, Section 5.3.2.1 (EPBC Listed Species) Chapter 5, Section 5.3.2.4 (Marine Mammals) Chapter 10, Appendix C (PMST Search's) Chapter 10, Appendix D.1 (BTL Route Survey)
Marine reptiles (turtles): + Literature review of Woodside information and publicly available information including a review of applicable State and Commonwealth guidance and conservation plans. + Protected Matters Search and SPRAT profile review of relevant species. + No further marine reptile specific surveys are considered necessary to inform the impact assessment. However, the implementation of a marine environmental survey of the BTL corridor will include the opportunist recording of marine mega fauna.	Chapter 5, Section 5.3.2.1 (EPBC Listed Species) Chapter 5, Section 5.3.2.5 (Marine Turtles) Chapter 10, Appendix C (PMST Search's) Chapter 10, Appendix D.1 (BTL Route Survey)
Marine reptiles (Sea snakes): + Literature review of Woodside information and publicly available information including a review of applicable State and Commonwealth guidance and conservation plans. + Protected Matters Search and SPRAT profile review of relevant species. + No further marine reptile specific surveys are considered necessary to inform the impact assessment. However, the implementation of a marine environmental survey of the BTL corridor will include the opportunist recording of marine mega fauna and sea snakes.	Chapter 5, Section 5.3.2.1 (EPBC Listed Species) Chapter 5, Section 5.3.2.6 (Sea Snakes) Chapter 10, Appendix C (PMST Search's) Chapter 10, Appendix D.1 (BTL Route Survey)
Key Ecological Features (KEFs): + Literature review of Woodside information and publicly available information. + Implementation of a marine environmental survey of the BTL corridor including the benthic habitat survey, sediment sampling and water quality sampling within each intersected KEF.	Chapter 5, Section 5.3.3.1 (Key Ecological Features) Chapter 10, Appendix D.1 (BTL Route Survey)
Australian marine parks: + Literature review of Woodside information and publicly available information. + Implementation of a marine environmental survey of the BTL corridor including the benthic habitat survey, sediment sampling and water quality sampling within each intersected Australian marine park.	Chapter 5, Section 5.3.3.2 (Australian Marine Parks) Chapter 10, Appendix D.1 (BTL Route Survey)

Required Work	Section
State marine parks and reserves: + Literature review of Woodside information and publicly available information.	Chapter 5, Section 5.3.3.2 (State Marine Parks and Reserves)
Commonwealth managed fisheries: + Literature review of Woodside information and publicly available information. + Ongoing stakeholder consultation.	Chapter 5, Section 5.4.2.1 Commonwealth Managed Fisheries) Chapter 4 (Stakeholder Consultation)
State managed Fisheries: + Literature review of Woodside information and publicly available information. + Ongoing stakeholder consultation.	Chapter 5, Section 5.4.2.2 (State Managed Fisheries) Chapter 4 (Stakeholder Consultation)
Tourism and recreation: + Literature review of Woodside information and publicly available information. + Ongoing stakeholder consultation.	Chapter 5, Section 5.4.2.6 (Tourism) Chapter 4 (Stakeholder Consultation)
Shipping: + Literature review of Woodside information and publicly available information. + Ongoing stakeholder consultation.	Chapter 5, Section 5.4.2.4 (Shipping) Chapter 4 (Stakeholder Consultation)
Industry: + Literature review of Woodside information and publicly available information. + Ongoing stakeholder consultation.	Chapter 5, Section 5.4.2.5 (Industry) Chapter 4 (Stakeholder Consultation)
Indigenous Heritage: + Literature review of Woodside information and publicly available information. + The assessment documentation must provide details of any potential indirect impacts of the proposed action on the (Indigenous rock art) values of the Dampier Archipelago (including the Burrup Peninsula) National Heritage Place, and the extent to which these values may be impacted by the proposed action following any planned mitigations.	Chapter 5, Section 5.4.3.1 (Indigenous Heritage) Chapter 5, Section 5.4.3.2 (National Heritage Places)
Maritime Archaeology: + Literature review of Woodside information and publicly available information.	Chapter 5, Section 5.4.3.2 (Marine Archaeology)

Required Work	Section
Impact and Risk Assessment Requirements	
This section will include: + Description of all relevant potential impacts and risks of the action. + A detailed assessment of the nature and extent of the potential short term and long term relevant impacts, including on MNES and WA EPA Environmental Factors including the natural Heritage values of 'Scott Reef and surrounds'. + A statement whether any relevant potential impacts are likely to be unknown, unpredictable or irreversible. + Analysis of the significance of the relevant potential impacts and risks. + Any technical data, any sources of authority, and other information used or needed to make a detailed assessment of the relevant potential impacts. Reliability of forecasts and predictions, confidence limits and margins of error will be indicated as appropriate.	Throughout Chapter 6 (Impact and Risk Assessment)
General impacts The following encompasses a list of general impact considerations: + Discuss the effects of the overall action on the functioning of the marine environment, including effects to the marine environment surrounding the proposed development. + Identify the source of potential impacts, e.g. ship-movements, artificial lighting, noise. + Discuss potential impacts which may arise through the transportation, storage and use of dangerous goods (if any), fuels and chemicals, such as accidental spills. + Consider the application of a waste management hierarchy (e.g. reduce, reuse, recycle, tread, dispose) and potential impacts caused by the need for waste disposal and management of emissions, refuse, effluent and hazardous waste (if any) in discussing potential impacts, consider how the interaction of extreme environmental events and any related safety response may impact on the environment. + Consider potential impacts throughout the life of the proposed Browse to NWS Project – from construction, commissioning, IMR activities and operations through to decommissioning.	Throughout Chapter 6 (Impact and Risk Assessment)
Physical and biodiversity impacts The following encompasses a list of physical and biodiversity impact considerations:	
+ Consider potential impacts to the sea floor through anchoring and direct placement, sediment disturbance, as well as any impacts of removal. The zone of likely seabed disturbance will be identified.	Chapter 6, Section 6.3.1 (Seabed Disturbance)
+ Consider potential impacts to fauna and flora species, including rare, threatened, or otherwise valuable flora and fauna, communities (particularly listed threatened species and communities, listed marine species including whales and other cetaceans and listed migratory species). In assessing impacts, consideration will be given to factors such as population composition and density including changes to communities, breeding success, habitat, or disturbances to migration or migratory patterns and other wildlife movements. + Consider potential impacts to the recovery of species where a species recovery plan is in place including factors called up in the requirements of the relevant recovery plans. + Consider potential impacts, if any, on and habitat, conservation areas, biological important areas, key ecological features and protected areas (including Australian Marine Parks), and in particular Scott Reef and surrounds.	Throughout Chapter 6 (Impact and Risk Assessment)
+ Consider potential impacts arising from the introduction and/or spread of exotic pest species.	Chapter 6, Section 6.3.19 (Unplanned Introduction of IMS)

Required Work	Section
Impacts of emissions to air and water The following encompasses a list of emissions to air and water impact considerations: + Discuss the potential impact of solid, liquid and gaseous emissions and waste produced by the operation, including greenhouse gas emissions. + Refer to the NWS Extension assessment being progressed by the NWS JV under the EP Act (Assessment number 2186) and EPBC Act (EPBC 2018/8335) in relation to potential impacts resulting from the processing of Browse gas by a third party on the Burrup Peninsula. + Include a discussion on the eventual fate of the waste. + Provide a full evaluation of PW, CW and hydrotest discharges including anticipated composition of discharge, modelling of the mixing zones and discussion on the potential impacts of discharge, including the spatial and temporal impacts of discharged PW and hydrotest fluid on marine fauna and key benthic ecological receptors (e.g. corals, seagrass, magroalgae), which may provide habitat and food resources for listed threatened species (e.g. marine turtles). + Consider the potential impacts of water clarity, salinity and temperature changes with specific reference to stratification of the water column. + Discuss potential impacts related to the discharge of sewage, sullage and other production related discharges. + Discuss impacts of potential spillage of hydrocarbons related to construction, production, storage and shipping. Modelling of spills will take into account seasonal variations throughout the year. Modelling will also take into account proximity to sensitive marine areas, in particular Scott Reef and surrounds. The evaluation of the potential impacts of oil spills is to be carried out using a thorough risk-assessment methodology.	Throughout Chapter 6 (Impact and Risk Assessment)
Socio-economic and cultural impacts Discussion of the potential socio-economic and cultural impacts of the proposed Browse to NWS Project as required. This will include a description and discussion of potential impacts (both positive and negative): + Caused by any short, medium and long-term changes, interruption, alteration or curtailment of activities and uses of the area due to the Proposed Action, including changes affecting traditional uses, recreational uses, conservation and tourism. + On sites of historical or cultural significance. + On existing industry and commerce • to employees in terms of workplace health and safety • on shipping and any potential traffic hazards. + On visual and aesthetic values, impacts to tourism and access for conservation purposes. + To historic shipwrecks in the area, including potential impacts on, as yet, unknown shipwrecks or those in unsurveyed areas.	Throughout Chapter 6 (Impact and Risk Assessment)
Cumulative impacts will also be identified and addressed. Cumulative impacts from the proposed Browse to NWS Project may occur in two ways: + Aspect-based – Cumulative or combination effects from concurrent and/or sequential activities associated with the proposed Browse to NWS project, and other activities/projects resulting in the same aspects as those identified for the proposed Browse to NWS Project. + Receptor-based – Cumulative or combination effects on a receptor, both from multiple aspects of the proposed Browse to NWS Project and similar/multiple aspects resulting from other activities/projects.	Throughout Chapter 6 (Impact and Risk Assessment) Chapter 9 (Overall Conclusions)

Required Work	Section
Underwater noise emissions: + Literature review of Woodside owned and publicly available information including a review of applicable State and Commonwealth guidance and conservation plans. + Implementation of a subsea piling acoustic modelling study to generate predictions of the ensonified area and ranges to acoustic thresholds and estimate acoustic exposure to pygmy blue whales and green turtles. + Implementation of acoustic modelling study for MODU DP activities to generate predictions of the ensonified area and ranges to acoustic thresholds and estimate acoustic exposure to pygmy blue whales and green turtles.	Chapter 6, Section 6.3.8 (Underwater Noise)
Light emissions: + Literature review of Woodside owned and publicly available information including a review of applicable State and Commonwealth guidance and conservation plans. + Use of previous modelling to inform impact assessment.	Chapter 6, Section 6.3.3 (Light Emissions)
Physical presence of infrastructure during construction: + Literature review of Woodside owned and publicly available. + Information to inform impact assessment including the calculation of predicted seabed disturbance.	Chapter 6, Section 6.3.1 (Seabed Disturbance) Chapter 6, Section 6.3.2 (Disturbance to Other Users)
Gaseous emissions – air emissions: + Literature review of Woodside owned and publicly available information to inform impact assessment. + The assessment documentation must provide details of any potential indirect impacts of the proposed action on the (Indigenous rock art) values of the Dampier Archipelago (including the Burrup Peninsula) National Heritage Place, and the extent to which these values may be impacted by the proposed action following any planned mitigations.	Chapter 6, Section 6.3.5 (Atmospheric Emissions: Offshore Activities) Chapter 6, Section 6.3.6 (Atmospheric Emissions: Third Party Processing of Browse Gas)
Treated sewage: + Literature review of Woodside owned and publicly available information to inform impact assessment.	Chapter 6, Section 6.3.9 (Marine Discharges: Sewage and Sullage)
Treated PW and NORMs: + Literature review of Woodside owned and publicly available information to inform impact assessment. + Implementation of a PW Dispersion Modelling study to predict the fate and transport of PW discharges from the FPSO In order to determine the number of dilutions achieved from the FPSO facilities, which is required to determine an appropriate mixing zone, outside which no impacts to the receiving environment are predicted. The PW Dispersion Modelling will also be used to inform predictions of the extent, severity and persistence of environmental impacts within the defined mixing zones.	Chapter 6, Section 6.3.12 (Marine discharges: Produced Water)
Treated utility water – drain discharges: + Literature review of Woodside owned and publicly available information to inform impact assessment.	Chapter 6, Section 6.3.10 (Marine discharges: Treated Utility Water, Chemical and Deck Drainage Discharges)
Treated utility water – desalination brine: + Literature review of Woodside owned and publicly available information to inform impact assessment.	Chapter 6, Section 6.3.10 (Marine discharges: Treated Utility Water, Chemical and Deck Drainage Discharges)

Required Work	Section
Cooling Water: + Literature review of Woodside owned and publicly available information to inform impact assessment. + Implementation of a Cooling Water Dispersion Modelling study to predict the fate and transport of cooling water discharges from the FPSO in order to determine the mixing zone, outside which no impacts to the receiving environment are predicted. The Cooling Water Dispersion Modelling will also be used to inform predictions of the extent, severity and persistence of environmental impacts within the defined mixing zones	Chapter 6, Section 6.3.13 (Marine discharges: Cooling Water)
Putrescible organic waste, Inorganic non-hazardous Waste, Hazardous waste - chemicals, radioactive and medical waste: + Literature review of Woodside owned and publicly available information to inform impact assessment.	Chapter 6, Section 6.3.11 (Marine Discharges: Putrescible Waste)
Drill cuttings and fluids on sensitive receptors: + Literature review of Woodside owned and publicly available information to inform impact assessment. + Use of previous modelling to inform impact assessment.	Chapter 6, Section 6.3.15 (Drilling or Completions Discharges)
Subsea control fluid: + Literature review of Woodside owned and publicly available information to inform impact assessment.	Chapter 6, Section 6.3.16 (Marine Discharges: Subsea Control Fluid)
Hydrotest fluid: + Literature review of Woodside owned and publicly available information to inform impact assessment. + Implementation of a Hydrotest Dispersion Modelling Study to predict the fate and transport of hydrotest discharges from the BTL in order to determine the number of dilutions achieved, which is required to determine an appropriate mixing zone, outside which no impacts to the receiving environment are predicted. The Hydrotest Dispersion Modelling will also be used to inform predictions of the extent, severity and persistence of environmental impacts within the defined mixing zones.	Chapter 6, Section 6.3.17 (Marine Discharges: Hydrotest Fluid)
Atmospheric Noise: + Literature review of Woodside owned and publicly available information to inform impact assessment.	Chapter 6, Section 6.3 7 (Atmospheric Noise)
IMS: + Literature review of Woodside owned and publicly available information to inform impact assessment.	Chapter 6, Section 6.3.19 (Physical Presences (unplanned): Invasive Marine Species)
Seabed subsidence: + Literature review of Woodside owned and publicly available information to inform impact assessment.	Chapter 6, Section 6.3.20 (Production Activities: Seabed Subsidence)
Hydrocarbon spill: + Literature review of Woodside owned and publicly available information to inform impact assessment. + Implementation of a Hydrocarbon Spill Modelling study to describe the dispersion and degradation characteristics of a range of hydrocarbon spill scenarios.	Chapter 6, Section 6.3.21 (Unplanned Hydrocarbon Releases)

Required Work	Section
Greenhouse Gases	
This chapter will summarise: 1. Receptors in the environment in the Australian jurisdiction that are sensitive to an increase in greenhouse gas (GHG) content in the atmosphere - the focus should be on the most sensitive receptors, and receptors that may be sensitive to elevated GHG levels in the local airshed. 2. Trends in the condition of the receptors identified at point 1. 3. The (direct and indirect, or Scope I–III) GHG emissions from the Proposed Action (sources and volumes). 4. How the (total of direct plus indirect) GHG emissions from the Proposed Action could impact the receptors identified at point 1. 5. Mitigation and any offset measures proposed to reduce: GHG emissions from the Proposed Action; and their impacts (see also point 2 in Appendix A) - this section will include a discussion of the steps taken at the: company, Burrup Hub vision and this individual project level, to reduce GHG emissions. 6. How the Scope I GHG emissions from the Proposed Action will be estimated. 7. How the Scope II and III GHG emissions from the Proposed Action will be estimated the extent to which the direct and indirect GHG emissions from the Proposed Action will affect the trends in the condition of the receptors identified at point 1. 8. Relevant Australian and international legislation and policy in relation to the management of climate change. Note: Without limiting what is required, the EIS/ERD must (a) identify those components of the environment in the Australian jurisdiction that are most likely to be impacted by climate change/most vulnerable to the impacts of climate and assess in detail the likely flow-on consequences of such an increase in atmospheric, air and water temperatures to those components of the environment; and (b) for all other components of the environment in the Australian jurisdiction, assess the likely impacts of climate change at a higher level (for instance, a more general discussion and/or impacts on types of ecosystems, heritage places, terrestrial habitat, marine habitat, migratory species).	**Chapter 7** (Greenhouse Gases)
Environmental Mitigation, Management and Monitoring	
Overview of Woodside's HSE Management System Standard + Health, Safety, Environment and Quality (HSEQ) Policy + Standards + Environmental Objective + Processes for implementing, checking and acting on relevant environmental management measures as the Project is developed.	**Chapter 8** (Environmental Mitigation, Management and Monitoring)

Required Work	Section
Environmental Monitoring	
Woodside will continue a long-term environmental monitoring program at Scott Reef, including water quality and coral health monitoring, that will be implemented prior to development at Torosa; with the results of this program used to demonstrate no long-term negative effects to Scott Reef resulting from the proposed Browse to NWS Project. The draft EIS/ERD will describe the objectives and scope of this long-term monitoring. Where identified as required, additional planned monitoring will be described including the objective and scope of specific monitoring plans. These plans would subsequently be developed prior the commencement of the relevant activity and would take into consideration relevant guidance such as the Revised Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2018 (ANZG(2018)).	Chapter 8 (Environmental Mitigation, Management and Monitoring)
Environmental Offsets	
In the event that impacts cannot be avoided or mitigated, the draft EIS/ERD will provide detail of the approach to be applied to offsetting impacts. It should be noted that offsets for GHG emissions are addressed separately in Section 3.9. This approach will include a commitment to develop an offsets plan that would provide details of offsets proposed to compensate for residual impacts on EPBC listed species, including the following: + The type of offsets proposed. + The extent to which the proposed offset actions correlate to, and adequately compensate for, the impacts to EPBC listed species. + For proposed land-based offsets, the suitability of the location of proposed offset sites, including the current land tenure and method of securing and managing the offset for the life of the impact. + For non-land-based offsets, details of the proposed offset and how it will compensate for the proposal's residual significant impacts. + The conservation gains to be achieved by the offset (for example, positive management strategies that improve the site, or how the future loss, degradation or damage of the protected matter will be averted or mitigated) The time it will take to achieve the proposed conservation gains. + The level of certainty that the proposed offset will be successful. + The EIS/ERD will explain how the proposed approach to applying offsets (if any) meet the principles of the Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy (2012).	Chapter 8 (Environmental Mitigation, Management and Monitoring)
Overall Conclusion	
An overall conclusion as to the environmental acceptability of the Proposed Action and State waters proposal will be provided, including discussion on compliance with the principles of Ecological Sustainable Development and the objects and requirements of the EPBC Act and EP Act. This will include a qualitative assessment of the cumulative impacts on each key receptor and assess impacts on a more holistic, whole-ecosystem level, considering the potential cumulative impacts of the proposed project, and any existing and future concurrent activities, on the existing environment. Reasons justifying undertaking the Proposed Action and State waters proposal in a manner proposed will be outlined. The conclusion will highlight measures proposed or required by way of mitigating or managing any unavoidable impacts on the environment. Measures proposed by way of offset and the change in residual impacts following the offset will be restated here.	Chapter 9 (Overall Conclusions)

Required Work	Section
Environmental record of person(s) undertaking the Proposed Action	
+ Details of any proceedings under Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of natural resources against: + the person proposing to take the action; and + for an action for which a person has applied for a permit, the person making the application. + details of the Woodside's HSEQ policy and planning framework.	Chapter 8, Section 8.3 (Environmental record of person(s) undertaking the Proposed Action)
Information Sources	
For information given in a draft EIS/ERD, the draft must state: + the source of the information + how recent the information is + how the reliability of the information was tested + what uncertainties (if any) are in the information.	Chapter 2, Section 2.10.6 (Information Sources)
References	
All reference cited within the draft EIS/ERD will be listed. This will be accurate and concise and include the addresses of an internet pages used as source data.	References are provided for each Chapter

CHAPTER 2

GENERAL INFORMATION

2. GENERAL INFORMATION

2.1 Introduction

The Browse hydrocarbon resource is located in the Brecknock, Calliance and Torosa reservoirs, approximately 425 km north of Broome and approximately 290 km off the Kimberley coastline of Western Australia (WA). Hydrocarbon resources contained in these reservoirs are predominately gas, with contingent resources of 13.9 trillion cubic feet (tcf) of dry gas, and approximately 390 million barrels of condensate (Woodside estimate).

The Browse Joint Venture (BJV) holds seven petroleum retention leases under the Commonwealth Offshore Petroleum and Greenhouse Gas Storage Act 2006 (OPGGS Act), the WA Petroleum (Submerged Lands) Act 1982 (PSL Act) and the Petroleum and Geothermal Energy Resources Act 1967 (WA). Five of the leases (WA-28-R, WA-29-R, WA-30-R, WA-31-R and WA-32-R) are in Commonwealth waters. Two leases (TR/5 and R2) are within WA's jurisdiction (State).

Woodside Energy Ltd (Woodside) is Operator for and on behalf of the BJV. The participants in the BJV are:

- Woodside Browse Pty Ltd
- Shell Australia Pty Ltd (Shell)
- BP Developments Australia Pty Ltd (BP)
- Japan Australia LNG (MIMI Browse) Pty Ltd (MIMI)
- PetroChina International Investment (Australia) Pty Ltd (PetroChina).

The BJV proposes to develop the Brecknock, Calliance and Torosa fields (collectively known as the Browse hydrocarbon resources) using two 1100 million standard cubic feet per day (MMscfd) (annual daily export average) Floating Production Storage and Offloading (FPSO) facilities. The FPSO facilities will be supplied by a subsea production system and will transport gas to existing North West Shelf (NWS) Project infrastructure via a pipeline which will tie-in near the existing North Rankin Complex (NRC) in Commonwealth waters (Note: The NRC is owned by the North West Shelf Joint Venture (NWSJV)). A single continuous pipeline extends from the Torosa FPSO, connecting in the Calliance/Brecknock FPSO and will tie in to existing NWS Project infrastructure. For ease of understanding it is hereafter described as two sections, a ~85 km section from the Torosa FPSO to the Calliance/Brecknock FPSO called the inter-field spur line and a ~900 km section from the Calliance/Brecknock FPSO towards NRC called the Browse Trunkline (BTL).

Construction is expected to commence ~2021–2022, with operations expected for up to 44 years.

Preparation of this draft Environmental Impact Statement (EIS)/Environmental Review Document (ERD) (draft EIS/ERD) has been undertaken in consultation with the Commonwealth Department of the Environment and Energy (DoEE), the WA Environmental Protection Authority (EPA) and other stakeholders. The National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) has been engaged by the DoEE to undertake the assessment of the marine based controlling provisions. This draft EIS/ERD conforms with the EIS Guidelines/Environmental Scoping Document (EISG/ESD) approved by the DoEE on 5 July 2019 and the EPA on 4 July 2019 (**Chapter 10, Appendix A**). The EISG/ESD was made publicly available on the 8 July 2019.

2.2 Title

The title of the Commonwealth Proposed Action/State Proposal (Proposed Action/State Proposal) is the 'proposed Browse to NWS Project'.

2.3 Proponent

The proponent for the proposed Browse to NWS Project is Woodside for, and on behalf of, the BJV participants.

Woodside was the pioneer of the LNG industry in Australia and is now the largest Australian natural gas producer. With a global portfolio, they are recognised for their world-class capabilities as an integrated upstream supplier of energy.

Woodside's mission is to deliver superior shareholder returns by realising the vision of becoming a global leader in upstream oil and gas.

Woodside's assets are renowned for their safety, reliability and efficiency, and Woodside is Australia's most experienced liquefied natural gas (LNG) operator, operating 6% of global LNG supply. Woodside's producing assets in Australia include the North West Shelf (NWS) Project, which has been operating since 1984. In 2012, production from the Pluto LNG Plant commenced.

Woodside continues to expand their capabilities in marketing, trading and shipping LNG and have enduring relationships that span more than 25 years, with foundation customers throughout the Asia–Pacific region. As a low-cost energy supplier with a sustainable business model, Woodside is pursuing opportunities to deliver affordable energy to the world's growing markets.

Woodside recognises that long-term, meaningful relationships with communities are fundamental to maintaining a social licence to operate and work to build mutually beneficial relationships. Woodside is characterised by strong safety and environmental performance in all locations where active, and is committed to upholding values of integrity, respect, working sustainably, discipline, excellence and working together.

Woodside, as the proponent of the proposed Browse to NWS Project, can be contacted on:

Email:	feedback@woodside.com.au
Phone:	1800 422 977
Street address:	Environment Manager Proposed Browse to North West Shelf Project Mia Yellagonga, 11 Mount Street, Perth WA, 6000.
Postal address:	Environment Manager Browse to North West Shelf Project GPO Box D188, Perth, WA, 6840.

2.4 Objectives of the proposed Browse to NWS Project

The objectives of the proposed Browse to NWS Project are to:

- optimise the production and recovery of hydrocarbons from the Brecknock, Calliance and Torosa reservoirs
- provide an acceptable return on investment.

In doing so, the proposed Browse to NWS Project will:

- minimise its environmental footprint
- manage environmental, health, security and safety issues in accordance with recognised industry standards and Woodside's requirements
- maximise socioeconomic benefits.

2.5 Project Overview

The proposed Browse to NWS Project aims to commercialise the Browse hydrocarbon resources in these stages:

- development drilling of the Brecknock, Calliance and Torosa reservoirs
- installing and commissioning subsea infrastructure
- installing and commissioning the proposed BTL and inter-field spur line
- installation, hook-up and commissioning of the FPSO facilities
- operating the FPSO facilities, including: gas processing and compression; gas export via the inter-field spur line and proposed BTL; and stabilisation, storage and export of condensate
- decommissioning reservoir infrastructure at the end of reservoir life (~44 years).

The proposed Browse to NWS Project will comprise subsea infrastructure and two FPSO facilities connected to existing NWS Project infrastructure via the ~900 km proposed BTL. The reference case is for 12 wells (although additional may be required) for Phase 1 Ready for Start Up (RFSU) of the two FPSO facilities and up to 54 wells[1] are anticipated over field life. Activities in State waters will comprise a limited subset of infrastructure and activities and include developing up to an estimated 24 wells and associated subsea infrastructure targeting the hydrocarbon resources of the Torosa reservoir. Extracted hydrocarbons will be transferred via subsea infrastructure, including wellheads, manifolds and flowlines, up to the FPSO facilities, which are located in Commonwealth waters.

The Project Area will comprise:

- The proposed Browse Development Area (in which the Brecknock, Calliance and Torosa fields, the FPSO facilities; and the subsea production systems, including wells, will be located). The proposed Browse Development Area is in the order of ~2897 km^2 in area. Note that the physical footprint in the Browse Development Area is only a small subset of the total area. This is further described in **Section 6.3.1.2**, **Table 6-9**.
- The proposed BTL and inter-field spur line Development Area will run ~900 km south-west from the Calliance/Brecknock FPSO facility to the tie-in point with the NWS Project infrastructure near NRC, and include an approximately ~85 km inter-field spur line connecting the Torosa FPSO to the Calliance/Brecknock FPSO. The proposed BTL and inter-field spur line Development Area will be in the order of ~2760 km^2 in area (excluding overlap with proposed Browse Development Area) and will be entirely within Commonwealth waters. The physical footprint in the pipeline corridor is only a small subset of the total area, as set out in **Section 6.3.1.2**, **Table 6-9**, and the route remains subject to refinement. Note the proposed BTL and inter-field spur line Development Area will not be closer than 2 km to Mermaid Marine Park National Park Zone (IUCN II) or the Rowley Shoals Marine Park or enter the State Proposal Area (see below).
- The State Proposal Area which comprises all areas within the Browse Development Area above the low water line (based on mean low water springs) and all waters within 3 nm of the low water line. The State Proposal Area is in the order of ~1,220 km^2 in area.

The total size of the Project Area will be in the order of ~5657 km^2. The total estimated direct and potential indirect disturbance area is estimated at 13.44 km^2 and 34.84 km^2 (including 25% contingency) respectively in **Section 6.3.1.2, Table 6-9** and State ERD **Section 8.3.4.2**.

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[1] *Note that the estimated maximum number of expected wells has increased from the proposed Browse to NWS Project Referrals estimate of 49, due to improved understanding of the reservoir.*

The proposed Browse Development Area and the notional field layout is shown in **Figure 2-1**. The proposed BTL and inter field spur line routes are shown in **Figure 2-2**.

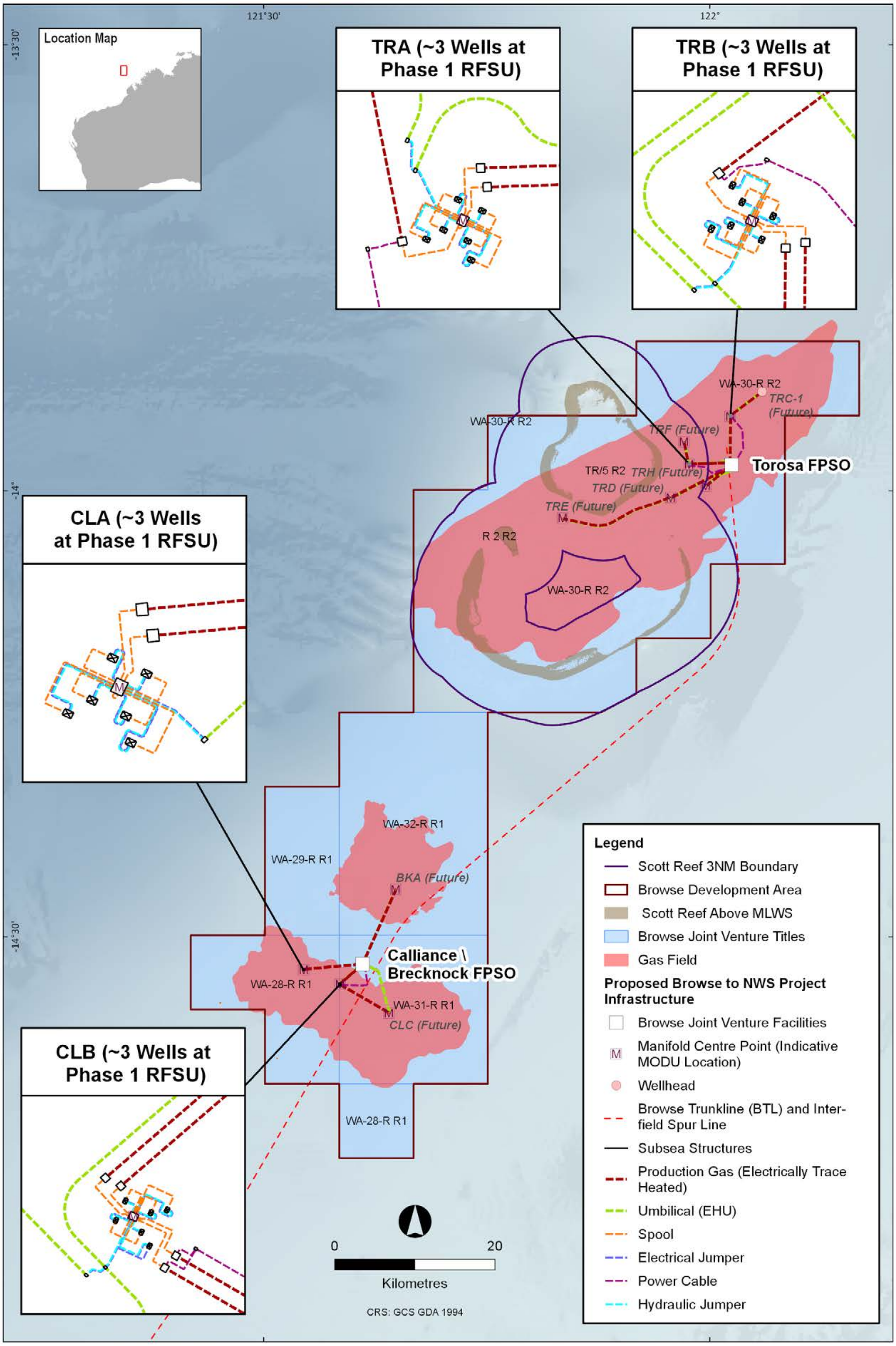

Figure 2-1 Proposed Browse Development Area and Notional Field Layout

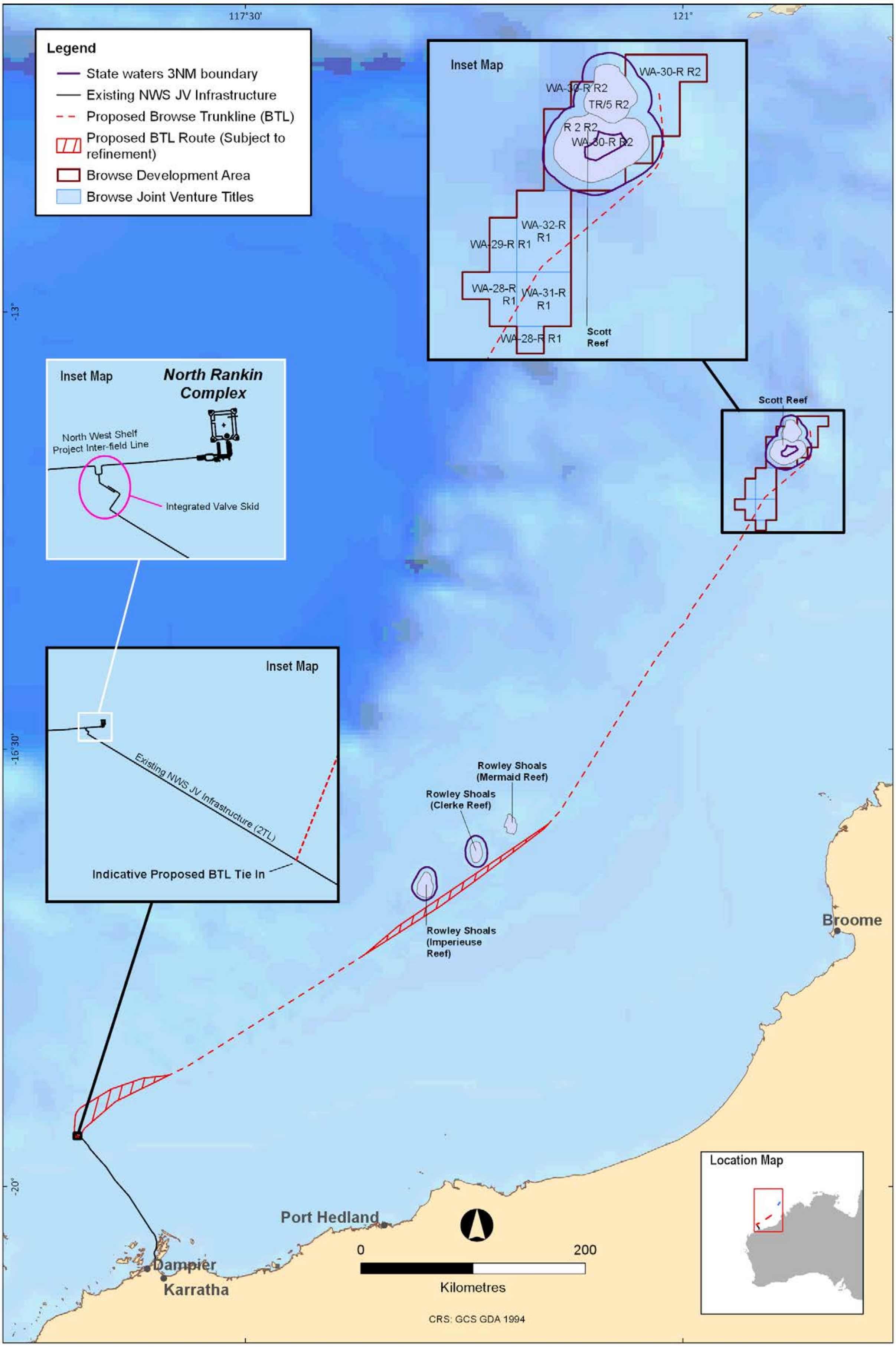

Figure 2-2 Proposed Browse Trunkline (BTL) Route

2.6 Current Status of Proposed Action/State Proposal

Information provided in this draft EIS/ERD is based on current knowledge of the proposed Browse to NWS Project.

The BJV participants expect that environmental aspects and associated potential impacts described in this draft EIS/ERD will remain unchanged as the proposed Browse to NWS Project progresses. However, any changes to the proposed Browse to NWS Project concept and associated activities will continue to be monitored as the proposed development matures.

2.7 Relationship with Other Proposed Actions/State Proposals

2.7.1 Previous Development Options for the Browse Resources

The BJV selected the James Price Point (JPP) development concept in 2010 and progressed both State and Commonwealth environmental approvals:

- upstream: Commonwealth EPBC 2008/4111
- downstream: referral and request that the proposal be declared a derived proposal under WA Ministerial Statement 917.

In April 2013, Woodside announced that the JPP development concept did not meet the company's commercial requirements for a positive Final Investment Decision (FID).

Following the JPP development concept decision, Woodside reviewed the concepts. Based on advances made in the Floating LNG (FLNG) technology and business confidence, the BJV selected FLNG technology as the development concept to progress the commercialisation of the Browse resource.

In November 2013, the FLNG development concept was referred under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (EPBC 2013/7079). The portion of the development concept that lies in State waters (the Torosa Subsea Development) was also referred to the EPA under the WA *Environmental Protection Act 1986* (EP Act) in December 2014. The FLNG development concept received approval under the EPBC Act in August 2015. In February 2015, the EPA decided that the Torosa Subsea Development did not require assessment under the EP Act. In March 2016, following completion of FEED work, the BJV considered the prevailing economic and market environment and decided not to progress with the FLNG development concept at that time.

2.7.2 Resource Appraisal and Feasibility Studies

Woodside will be required to progress a range of resource appraisal activities and feasibility studies to support the commercialisation of the Browse gas reservoirs associated with the proposed Browse to NWS Project. These activities may include seismic surveys, drilling of appraisal wells, and environment, geophysical and geotechnical surveys. All these activities will be short-term and small in scale and not directly related to developing facilities for the recovery of hydrocarbons from the Browse reservoirs for processing and export. These activities do not form part of the scope of the proposed Browse to NWS Project and will be subject to separate environmental approvals as required.

2.7.3 Other Woodside Exploration Activities

Woodside is active in a range of other petroleum exploration retention leases in WA. Exploration and any future appraisal activities in retention leases outside those relevant to the Proposed Action/State Proposal are not related to the proposed Browse to NWS Project.

2.7.4 Other Developments in the Browse Basin

Several other petroleum activities in the Browse Basin are currently being conducted or proposed by other petroleum operators, including:

- Operation of the Ichthys LNG Development by INPEX (105 km to the north east of the Browse Development Area).
- Operation of the Prelude FLNG Project by Shell (140 km to the north east of the Browse Development Area).
- Development of the Crux Project by Shell (170 km to the north east of the Browse Development Area).
- Exploration and appraisal of the greater Poseidon area by ConocoPhillips and Karoon Gas (historic activity 37 km north east of, and existing permits adjacent to, the Browse Development Area.
- Exploration drilling of the Bratwurst area by Shell (300 km to the north east of the Browse Development Area).

No interaction is expected between these activities and the proposed Browse to NWS Project.

2.8 Development Justification

2.8.1 Development of the Browse Resources

The three Browse reservoirs, Brecknock, Calliance and Torosa, are estimated to contain ~13.9 tcf of dry gas and 390 million barrels of condensate. For the proposed

Browse to NWS Project, this translates into supplying ~44 years of cleaner energy to global markets. LNG is less emissions intensive than all other fossil fuels and can contribute directly to the global reduction of greenhouse gas emissions when it is used to replace more emissions intensive fuels such as coal. The increased use of LNG also has several environmental benefits, such as:

- reduced emissions of particulates and sulfur dioxide
- significantly lower demand for water for cooling requirements.

The BJV participants are committed to working with the WA and Commonwealth Governments, local communities and other relevant stakeholders to realise opportunities from the development of the Browse hydrocarbon resources across all phases of the development. The proposed Browse to NWS Project has the potential to make a significant contribution to the national and state economies and provide long-term, sustainable local content and employment opportunities.

The proposed Browse to NWS Project will require onshore infrastructure and logistics support throughout all its phases to ensure efficient and safe installation and operation of the facilities. Both the onshore support infrastructure and offshore facilities will contribute to employment and business opportunities in WA. In accordance with the *Australian Jobs Act 2013* (Cth), Woodside has an approved Australian Industry Participation Plan.

The proposed Browse to NWS Project is a mega-project expected to deliver significant benefits during its ~44-year operations (refer to **Section 3.8.3**).

These environmental, social and economic benefits will not be realised or will be significantly delayed if the proposed Browse to NWS Project does not proceed at this time.

2.8.2 Browse to North West Shelf Concept

Significant screening work was done when assessing a development proposal for the Browse resources. Five development concepts were assessed: Browse to JPP; Browse to NWS; Browse to Darwin; Offshore LNG; and FLNG. These concepts were compared using safety and technical risk, time to commercialisation, environmental sensitivity, socioeconomic factors, heritage input and economic factors.

After extensively assessing a range of alternative developments, the proposed Browse to NWS Project was considered the most likely commercially viable option to develop the resources, while meeting selection criteria related to the environmental, social and economic evaluation.

2.9 Assessment Process

2.9.1 Environmental Referrals

The proposed Browse to NWS Project was referred to the DoEE under the EPBC Act in October 2018. On the 22 February 2019, the DoEE determined that the proposed Browse to NWS Project is a controlled action and would be assessed at an EIS level of assessment. The decision notice identified these Matters of National Environmental Significance (MNES) as being relevant to the proposed Browse to NWS Project:

- National heritage values of a National Heritage Place
- Listed threatened species and communities
- Listed migratory species
- The Commonwealth marine area, the protected matter being the environment generally.

The WA State waters component of the proposed Browse to NWS Project was referred to the EPA under the EP Act in October 2018. On 22 January 2019, the EPA determined that the proposed Browse to NWS Project requires assessment under Section 29 of the EP Act and set a Public Environmental Review (PER) level of assessment. The determination identified these EPA Environmental Factors as being relevant for the proposed Browse to NWS Project within State waters:

- Benthic Communities and Habitats
- Marine Environmental Quality
- Marine Fauna
- Air Quality.

2.9.2 Assessment Process

The assessment of the proposed Browse to NWS Project under the EPBC Act and EP Act is being undertaken as a coordinated assessment between the DoEE and EPA.

This approach includes:

- simultaneous referrals of the proposed Browse to NWS Project under the EPBC Act and EP Act (completed October 2018)
- development of EIS Guidelines (EISG) (under the EPBC Act) and an ESD (under the EP Act), which describe the requirements for a draft EIS/ERD (completed as single document (EISG/ESD) July 2019)
- development of a single draft EIS/ERD document, to be issued to DoEE and EPA for comment on adequacy and approval, before release for public comment
- preparation of a single final EIS/ERD document, which will be submitted to the DoEE and EPA for assessment and publication
- decisions on the acceptability of the proposed Browse to NWS Project.

2.10 This Document

2.10.1 EIS Guidelines and Environmental Scoping Document

An EISG/ESD has been developed by Woodside in consultation with DoEE and WA EPA to:

- address the assessment requirements of the DoEE under the EPBC Act
- address the assessment requirements specified in the EP Act (Part C of the EISG/ESD).

In general, the EISG/ESD describes the required content of the draft EIS/ERD and set the scope of studies required to allow assessment and decision on the appropriateness of the proposed Browse to NWS Project.

The EISG/ESD is provided in **Chapter 10, Appendix A**.

2.10.2 Purpose of Draft EIS/ERD

This draft EIS/ERD provides Commonwealth and State regulators with the information required to assess the proposal against the requirements of the EPBC Act and EP Act.

In addition, this draft EIS/ERD will be used to inform and obtain feedback from stakeholders about the proposed Browse to NWS Project and demonstrate that impacts from planned activities, and risks associated with unplanned activities, can be managed to an acceptable level.

The aims of this draft EIS/ERD and the subsequent public review process are:

- To provide a source of information from which interested individuals and groups may gain an understanding of the proposed Browse to NWS Project, the need for the proposed Browse to NWS Project, the alternatives, the environment it could potentially affect, the impacts that may occur and the measures proposed to be taken to avoid or minimise these impacts.
- To provide a forum for public consultation and informed comment on the proposed Browse to NWS Project.
- To provide a framework in which decision-makers can consider the environmental aspects of the proposed Browse to NWS Project, including biophysical, cultural, social, heritage, economic, technical and other factors.

This draft EIS/ERD:

- Describes the components of the proposed Browse to NWS Project and the activities to be undertaken.
- Places the proposed Browse to NWS Project in the context of the local and regional physical, ecological and socioeconomic environment.
- Identifies and assesses potential impacts to the physical, ecological and socioeconomic environment.
- Defines management and mitigation measures proposed to reduce potential adverse impacts to the environment to an acceptable level.
- Demonstrates that Woodside has a comprehensive management structure and system to implement, maintain and monitor the commitments detailed in this draft EIS/ERD.

2.10.3 Scope of Draft EIS/ERD

The scope of this draft EIS/ERD document is limited to construction and operation of the upstream component of the proposed Browse to NWS Project, including:

- Development drilling, completion and well unload activities (drilling and completion) of the Brecknock, Calliance and Torosa reservoirs.
- Installing and commissioning subsea infrastructure, including anchors and mooring lines, umbilicals, flowlines, flexible risers and manifolds.
- Installing and commissioning the proposed BTL and inter-field spur line, including tie-in to existing NWS Project infrastructure near NRC.
- Installation, hook-up and commissioning of the FPSO facilities.
- Operating the subsea infrastructure, including wells/wellheads, umbilicals, flowlines, risers and manifolds; including inspection, maintenance and repair activities.
- Operating the FPSO facilities, including condensate stabilisation, storage and offtake, gas processing (carbon dioxide [CO_2] and water removal and gas compression) and export.
- Transmitting gas from the FPSO facilities to the NWS Project infrastructure tie-in point.
- Decommissioning subsea infrastructure (including well plug and abandonment), BTL, inter-field spur line and FPSO facilities at the end of reservoir field life (~44 years).

Existing NWS Project infrastructure will be used to transport and process gas from the tie-in point near NRC. This infrastructure is the subject of different joint venture arrangements and is outside the scope of this draft EIS/ERD.

The proposed Browse to NWS Project will involve vessel and helicopter movements that support the offshore facilities; however, new onshore infrastructure is not required to proceed. Potential supply chain and logistics support locations include:

- Broome Logistics Hub
- Karratha/Dampier Supply Facility
- Exmouth.

As the locations for supply chain and logistics support infrastructure are not yet determined, vessel and helicopter movements from a range of potential locations to the proposed Browse to NWS Project are being considered.
Existing infrastructure and related services will be used.

2.10.4 Scope of Assessments

This draft EIS/ERD document has been prepared to provide a comprehensive impact and risk assessment of the proposed Browse to NWS Project across all relevant jurisdictions. It should be noted, however, that the scope of the regulator assessments being undertaken under the EPBC Act and State EP Act differ according to the jurisdiction.

The scope of the EPBC Act assessment undertaken by the DoEE includes all activities (refer to **Section 2.10.3**) and related impacts and risks to the matters relating to each controlling provision (refer to **Section 2.9**).

The scope of the EPA's assessment under the EP Act is proposed Browse to NWS Project infrastructure and related activities within State waters and related impacts and risks to the relevant EPA Environmental Factors (refer to **Section 2.9**).

2.10.5 Structure and Content of Draft EIS/ERD

Table 2-1 summarises this draft EIS/ERD structure and provides an overview of the content of each chapter.

Table 2-1 Overview of draft EIS/ERD Structure and Contents

Chapter	Content	Description
1	Executive Summary	+ Outlines the key findings of the draft EIS/ERD.
2	General Information	+ Provides the background of the proposed Browse to NWS Project.
3	Description of Proposed Action/State Proposal	+ All installation, commissioning, operational and decommissioning components of the Proposed Action/State Proposal described in sufficient detail to understand the proposed Browse to NWS Project in both State and Commonwealth waters and help determine the associated potential direct and indirect environmental impacts and risks. + The location (including coordinates) of all works to be undertaken, structures to be built, or elements of the Proposed Action/State Proposal that may have relevant impacts (on MNES and/or EPA Environmental Factors) and other social or economic impacts. + Proposed safeguards and mitigation measures to deal with relevant impacts of the Proposed Action/State Proposal. + Details on how the works are to be undertaken (including all stages of development and their timing) and design parameters for those aspects of the structures or elements of the Proposed Action/State Proposal that may have relevant environmental impacts and other social or economic impacts. + Aerial photographs, maps, figures and diagrams, where appropriate. + Reference to detailed technical information in appendices, where relevant. + Any feasible alternatives to the Proposed Action/State Proposal. + Information on the broader social and economic impacts (positive or negative) of the Proposed Action/State Proposal.
4	Stakeholder Engagement	+ Details of any consultation in relation to the proposed Browse to NWS Project including completed consultation, planned consultation and documented responses or results of consultation.
5	Description of the Environment	+ Detailed description of the physical, ecological and socioeconomic environment of the Project Area and the surrounding areas (including State waters) that may be affected by the proposed Browse to NWS Project.

Chapter	Content	Description
6	Impacts and Risks	+ Description of the impact and risk assessment process. + Description of all relevant potential impacts of the Proposed Action/State Proposal. + Analysis of the significance of the relevant potential impacts and risks. + Any technical data, any sources of authority and other information used or needed to make a detailed assessment of the relevant potential impacts. + Reliability of forecasts and predictions, confidence limits and margins of error. + Proposed mitigation and management measures. + Environmental objectives and performance criteria.
7	Greenhouse Gases (GHG)	+ Summarise the receptors in the environment in the Australian jurisdictions that are sensitive to an increase in GHG content in the atmosphere focusing on the most sensitive receptors and receptors that may be sensitive to elevated GHG levels in the local airshed. + Trends in the condition of the receptors identified. + The method for predicting and the predicted (direct and indirect, or Scope I–III) GHG emissions and how they could impact the identified receptors. + Mitigation and any offset measures proposed. + The extent to which the direct and indirect GHG emissions will affect the trends in the condition of the identified receptors. + relevant Australian and international legislation and policy in relation to the management of climate change.
8	Environmental Mitigation, Management and Monitoring	+ Outline the environmental management framework applicable to the proposed Browse to NWS Project including internal, external and regulatory reporting requirements.
9	Overall Conclusion	+ Overall conclusions as to the environmental acceptability of the Proposed Action/State Proposal, including discussion on compliance with the principles of ecological sustainable development and the objects and requirements of the EPBC Act and EP Act. + Reasons justifying undertaking the proposed Browse to NWS Project in the manner proposed. + Highlight measures proposed or required to mitigate or manage any unavoidable impacts on the environment. + Measures proposed to offset environmental impacts and the change in residual impacts following the offset. + Details of any proceedings under Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of natural resources. + Details of the source of the information, how recent the information was, how the reliability of the information was tested and the uncertainties (if any) in the information.
10	Appendices	+ Key technical reports prepared in support of the draft EIS/ERD.

2.10.6 Information sources

This draft EIS/ERD has been prepared using information sourced from an extensive selection of background studies, scientific papers, text books, government websites and published and unpublished technical reports. All information used has undergone technical or scientific reviews, with many being published in peer reviewed journals. This draft EIS/ERD contains the most current relevant information available and notes any uncertainties in data.

2.11 Policy, Legal and Administrative Framework

2.11.1 Overview

This Section summarises the legislation, standards and guidelines that apply to the proposed Browse to NWS Project, including:

- Commonwealth policy, legislation, regulations and technical guidance
- WA policy, legislation, regulations and technical guidance
- international policies, guidelines, standards and technical guidance
- international conventions and protocols to which Australia is a signatory.

2.11.2 Commonwealth Policy Framework

Australian Offshore Petroleum Development Policy

The Australian Offshore Petroleum Development Policy encourages petroleum exploration in Australia's offshore areas and is administered by the Commonwealth Government. Commonwealth and State Government agencies issue titles to the private sector to facilitate exploration and development of petroleum reserves within Australia and its territorial waters. The titleholders have an obligation to undertake exploration and/or development of their titles. They also have an obligation to certify the nature and the extent of the reserves. Following the discovery of a petroleum resource, the titleholder may apply for a licence to produce the resource and to construct pipelines and other infrastructure.

The regulatory framework for offshore petroleum development is principally provided by the OPGGS Act and associated regulations.

Australia's Oceans Policy

Australia's Oceans Policy, introduced in 1998, is a framework for integrated and ecosystem-based planning and management for Australia's marine jurisdictions. The policy promotes ecologically sustainable development of Australia's ocean resources and encourages internationally competitive marine industries, while ensuring the protection of marine biological diversity. The policy also promotes integrated planning and management. The policy's aims are:

- exercising and protecting Australia's rights over its marine jurisdictions
- meeting its obligations under the United Nations Convention on the Law of the Sea 1982 (UNCLOS)
- understanding and protecting the marine environment.

The core of Australia's Oceans Policy is the development of Marine Bioregional Plans, which are based on large marine ecosystems, are binding on all Commonwealth Government agencies and are relevant to the environmental impact assessment processes.

Marine Bioregional Plans

The Marine Bioregional Plans aim to strengthen the operation of the EPBC Act to help ensure that the marine environment remains healthy and resilient. Four Marine Bioregional Plans have been developed—South-west, North-west, North and Temperate East. The proposed Browse to NWS Project lies in the North-west Marine Region (Commonwealth of Australia, 2008). These plans:

- provide information on conservation values and the current and emerging pressures within each region
- describe conservation priorities and measures for the region
- provide a source of information for government and industry to improve the way the marine environment is managed and protected
- support strategic, consistent and informed decision-making under Commonwealth environment legislation in relation to Commonwealth marine areas
- support efficient administration of the EPBC Act to promote the ecologically sustainable use of the marine environment and its resources
- provide a framework for strategic intervention and investment by government to meet policy objectives and statutory responsibilities
- improve the understanding of Australian oceans by providing a consolidated picture of the biophysical characteristics and the diversity of marine life (Commonwealth of Australia, 2008).

Emissions Reduction Fund

The Commonwealth Government is implementing a Direct Action Plan, which is designed to efficiently and effectively source low-cost emissions reductions to meet Australia's target of a 26-28% reduction in GHG emissions on 2005 levels by 2030 (Commonwealth of Australia, 2015). A key component of the Direct Action Plan is the Emissions Reduction Fund, which provides incentives for abatement activities across the Australian economy and will complement the Carbon Farming Initiative.

EPBC Act Policy Statement 2.1 – Interaction Between Offshore Seismic Exploration and Whales

This policy aims to minimise the likelihood of injury or hearing impairment of whales, based on current scientific understanding, by providing:

- practical standards to minimise the risk of acoustic injury to whales near seismic survey operations
- a framework that minimises the risk of biological consequences from acoustic disturbance from seismic survey sources to whales in biologically important habitat areas or during critical behaviours
- guidance to both proponents of seismic surveys and operators conducting seismic surveys about their legal responsibilities under the EPBC Act.

Although seismic activities are outside the scope of this draft EIS/ERD, this policy will be adopted for activities/aspects of the proposed Browse to NWS Project that generate underwater noise similar to levels generated by seismic surveys

Australian Ballast Water Management Requirements 2017

On 1 July 2001, Australia introduced mandatory ballast water management requirements to reduce the risk of introducing harmful aquatic organisms into Australia's marine environment through ship's ballast water. These requirements are consistent with International Maritime Organization (IMO) Guidelines for minimising the translocation of harmful aquatic species in ships' ballast water. Version 7 of the requirements were released in July 2017 and included updates to reflect the *Biosecurity (Ballast Water and Other Measures) Amendment Act 2017* (Cth) and the Biosecurity (Ballast Water & Sediment) Determination 2017 (Commonwealth of Australia, 2017).

Any ballast water that has been exchanged at sea by an approved method is deemed to be acceptable for discharge in Australian ports/waters.

National Biofouling Management Guidance for the Petroleum Production and Exploration Industry 2009

This guidance document aims to help operators in the petroleum production and exploration industry minimise the amount of biofouling accumulating on vessels, infrastructure and submersible equipment and thus minimise the risk of spreading marine pests around the Australian coastline.

Revised Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2018

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000) were superseded by revised guidelines in 2018 and released as an online resource available at http://www.waterquality.gov.au/anz-guidelines. These guidelines are intended to provide government, industry, consultants and community groups with a comprehensive set of tools to assess and manage ambient water quality in a wide range of water resource types and according to designated environmental values. The guidelines are the recommended limits to acceptable change in water quality that will continue to protect the associated environmental values.

2.11.3 Commonwealth Legislation

Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act is the Commonwealth Government's primary environmental legislation and is the principal statute for the protection and management of MNES. Together with the WA EP Act, the EPBC Act forms the legislative basis for this draft EIS/ERD.

Under the EPBC Act, any action that is likely to have a significant impact on MNES must not be taken without the approval of the Minister for the Environment. Actions with the potential to impact MNES trigger the Commonwealth environmental assessment and approval process.

Offshore Petroleum and Greenhouse Gas Storage Act 2006

The OPGGS Act provides a framework for all offshore petroleum exploration, production, recovery and GHG storage activities in Commonwealth waters. The Act is supported by regulations and directions that cover safety, diving, petroleum resource management and environmental management. Several assessments are required under the OPGGS Act from the Designated Regulatory Authority to construct, operate and decommission a petroleum or GHG storage facility.

The related OPGGS (Environment) Regulations 2009 (OPGGS (E) Regulations) ensure that any petroleum activity is consistent with environmentally sustainable development principles and is carried out in such a way that the environmental impacts and risks of the activity are reduced to As Low As Reasonably Practicable (ALARP) and are of an acceptable level (Government of Australia, 2014).

NOPSEMA is the regulator of environmental management requirements under the OPGGS Act and associated regulations, including the OPGGS (E) Regulations. NOPSEMA's specific environmental management functions in Commonwealth waters involve:

- developing and implementing effective monitoring and enforcement strategies to ensure compliance under environmental management law
- investigating accidents, occurrences and circumstances with regard to deficiencies in environmental management
- monitoring environmental incidents and reporting investigations to the responsible Commonwealth Minister and State and Northern Territory Minister
- assessing Environment Plans (EPs), including associated Oil Pollution Emergency Plans (OPEPs)
- providing advice to people on matters relating to environmental management related to petroleum activities

- providing information, assessments, analysis, reports, advice and recommendations to the Commonwealth Minister on petroleum and GHG storage activities
- maintaining a record of titleholders
- providing contracts for related services on a cost-recovery basis for State/Territory governments and foreign governments.

Assessments required under the OPGGS Act and associated regulations include:

- Environment Plan assessment and acceptance
- Oil Pollution Emergency Plan (OPEP) assessment and acceptance
- Safety Case assessment and acceptance
- petroleum production licences
- pipeline licences in Commonwealth waters
- infrastructure licences (if a facility needs be located outside a proponent's production licence)
- petroleum safety zones.

Under the OPGGS (E) Regulations, the titleholder of a petroleum or GHG storage activity must not carry out that activity unless an accepted EP is in force for the activity. The Environment Plan must describe the activity, the receiving environment, environmental aspects and assess potential impacts. In addition, an Environment Plan must contain appropriate risk-based environmental performance outcomes and standards, an implementation strategy. It must also provide criteria for determining whether the outcomes and standards are met.

In addition, under the OPGGS (E) Regulations, an OPEP is required as part of the Environment Plan's implementation strategy. The OPEP must be accepted by NOPSEMA before any drilling, construction, or production activities can commence within a retention lease.

For the proposed Browse to NWS Project, activities in Commonwealth waters requiring an accepted Environment Plan and OPEP may include (but are not limited to): development drilling; installation, hook-up and commissioning of subsea infrastructure and the FPSO facilities; installing and commissioning the BTL and inter-field spur line; operations and maintenance; and decommissioning. Environment Plans for all relevant activities will be submitted to NOPSEMA for approval before activities commence.

Other Commonwealth Legislation

The proposed Browse to NWS Project is subject to further Commonwealth legislative requirements in addition to the EPBC Act and OPGGS Act. These include, but are not limited to the:

- *Australian Heritage Council Act 2003*
- *Australian Jobs Act 2013*
- *Biosecurity Act 2015*
- *Civil Aviation Act 1988*
- *Environment Protection (Sea Dumping) Act 1981*
- *Hazardous Waste (Regulation of Exports and Imports) Act 1989*
- *National Greenhouse and Energy Reporting Act 2007 (NGER Act).*
- *National Radioactive Waste Management Act 2012*
- *Navigation Act 2012*
- *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*
- *Protection of the Sea (Harmful Anti-fouling Substances) Act 2006*
- *Submarine Cables and Pipelines Protection Act 1963*
- *Underwater Cultural Heritage Act 2018.*

2.11.4 Western Australian State Policy Framework

State Environmental Policies

Section 17(3)(d) of the EP Act allows the EPA to develop policy proposals (State Environmental Policies) that must be followed in WA.

Environmental Protection Policies

Part III of the EP Act allows for the EPA to draft Environmental Protection Policies (EPPs) for consideration and approval by the Minister for Environment. Once approved by the Minister, EPPs are tabled in Parliament and have the force of law. There are currently no EPPs in force that are relevant to the proposed Browse to NWS Project.

Environmental Offsets Policy

The WA Environmental Offsets Policy 2011 is an overarching framework for implementing environmental offsets in WA. The policy *"seeks to ensure environmental offsets are applied in specified circumstances in a transparent manner to engender certainty and predictability, while acknowledging that there are some environmental values that are not readily replaceable"* (EPA, 2014).

GHG Emissions Policy for Major Projects

The Western Australia Government released a GHG Emissions Policy for Major Projects on 28 August 2019. The Policy includes an aspirational target of net zero greenhouse gas emissions by 2050. The Minister for Environment will consider how the Policy relates to major proposals assessed under Part IV of the EP Act (Government of Western Australia, 2019).

Aquatic Biosecurity Policy

The Department of Primary Industries and Regional Development's (DPIRD) Aquatic Biosecurity Policy *"applies to aquatic pests and diseases that impact on the environment, the economy and social amenity, to ensure their management in a manner consistent with* *relevant International, National and State obligations and legislation including the Intergovernmental Agreement on Biosecurity (IGAB) and the National Environmental Biosecurity Response Agreement (NEBRA)."* (DPIRD, 2017). The IGAB is an agreement between the Commonwealth government and all State and Territory Governments (except Tasmania) that defines the roles and responsibilities of the governments and priority areas with respect to minimising the impact of pests and diseases on Australia (DAWR, 2018).

2.11.5 Western Australian State Legislation

Environmental Protection Act 1986

The EP Act is the principal statute pertinent to environmental protection in WA. It provides for the prevention, control and abatement of environmental pollution and for the conservation, preservation, protection, enhancement and management of the environment.

The EPA has statutory obligations under the EP Act to conduct environmental impact assessments, initiate measures to protect the environment from environmental harm and pollution and to advise the WA Minister for Environment on environmental matters.

Biodiversity Conservation Act 2016

The *Biodiversity Conservation Act 2016* (BC Act) replaced both the *Wildlife Conservation Act 1950* and the *Sandalwood Act 1929* on 1 January 2019. The objectives of the BC Act are to conserve and protect biodiversity and biodiversity components in the State and to promote the ecologically sustainable use of biodiversity components in the State.

Petroleum (Submerged Lands) Act 1982

The PSL Act provides the regulatory framework for the exploration and production of petroleum resources adjacent to the WA coast. The Petroleum (Submerged Lands) (Environment) Regulations 2012 are based on the Commonwealth OPGGS (E) Regulations and have the objective of ensuring petroleum or geothermal energy activities are carried out in a manner consistent with the principles of ecologically sustainable development. The WA Department of Mines, Industry Regulation and Safety (DMIRS) is the regulator of environmental management requirements under the PSL Act and associated regulations. The Petroleum (Submerged Lands) (Environment) Regulations 2012 require an Environment Plan be in force for any petroleum activity undertaken in WA State waters. For the proposed Browse to NWS Project, these activities may include (but are not limited to): development drilling; installing and commissioning subsea infrastructure; operating and maintaining subsea infrastructure; and decommissioning. These Environment Plans will be submitted for approval by the DMIRS before the activity commences.

Other State Legislation

- *Biosecurity and Agriculture Management Act 2007*
- *Conservation and Land Management Act 1984*
- *Fish Resources Management Act 1994 (This Act will be replaced by the Aquatic Resources Management Act 2016, however there is no confirmed timeframe for this transition)*
- *Heritage Act 2018*
- *Land Administration Act 1997*
- *Maritime Archaeology Act 1973*
- *Petroleum and Geothermal Energy Resources Act 1967*
- *Pollution of Waters by Oil and Noxious Substances Act 1987.*

2.11.6 Western Australian State Technical Guidance

The EPA has developed a series of guidance statements for assessing environmental impacts in accordance with Part IV of the EP Act. These guidance statements help project proponents and the public understand the requirements for protecting the environment under the EP Act. The guidance statements referred to in preparing the EP Act referral include:

- Instructions for the referral of a Proposal to the Environmental Protection Authority under Section 38 of the Environmental Protection Act 1986 (EPA, 2018)
- Environmental Impact Assessment (EIA) (Part IV, Divisions I and II) Administrative Procedures (EPA, 2016a)
- Statement of Environmental Principles, Factors and Objectives (EPA, 2016b)
- Environmental Factor Guideline – Benthic Communities and Habitats (EPA, 2016c)
- Technical Guidance – Protection of Benthic Communities and Habitats (EPA, 2016c)
- Environmental Factor Guideline – Marine Environmental Quality (EPA, 2016d)
- Technical Guidance – Protecting the Quality of Western Australia's Marine Environment (EPA, 2016e)
- Environmental Factor Guideline – Marine Fauna (EPA, 2016b)
- Environmental Assessment Guidelines: Environmental Assessment Guideline for Protecting Marine Turtles from Light Impacts (EAG 5) (EPA, 2010)
- Environmental Factor Guideline – Air Quality (EPA, 2016f)
- Environmental Factor Guideline – Greenhouse Gas Emissions (EPA, 2019).

2.11.7 International Agreements

Australia is a signatory to several international conventions and agreements relevant to environmental protection. Those that may apply to the proposed Browse to NWS Project include:

- International Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal 1989 (Basel Convention)
- Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and Their Environment (commonly referred to as the China–Australia Migratory Bird Agreement [CAMBA])
- International Convention on the Conservation of Migratory Species of Wild Animals 1979 (Bonn Convention)
- International Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)
- Convention on the International Maritime Organization 1948
- International Convention for the Prevention of Pollution from Ships, 1973/1978 (commonly known as MARPOL 73/78)
- International Convention on Civil Liability for Oil Pollution Damage, 1969 and 1992 (CLC 69; CLC 92)
- Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds and Birds in Danger of Extinction and Their Environment (commonly referred to as the Japan–Australia Migratory Bird Agreement [JAMBA])
- Kyoto Protocol 1997
- Montreal Protocol on Substances that Deplete the Ozone Layer 1987
- Protocol to International Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter, 7 November 1996 (previously known as the London Dumping Convention)
- Agreement between the Government of Australia and the Government of the Republic of Korea on the Protection of Migratory Birds (commonly referred to as the Republic Of Korea–Australia Migratory Bird Agreement [ROKAMBA])
- The Convention on International Regulations for Preventing Collisions at Sea 1972 (COLREGS)
- United Nations Convention on the Law of the Sea 1982 (UNCLOS)
- United Nations Framework Convention on Climate Change 1992
- Australia–Indonesia Memorandum of Understanding – 1974 (MoU 74)
- Revised Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2018
- The Stockholm Convention on Persistent Organic Pollutants 2004
- Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade.

CHAPTER 3

DESCRIPTION OF PROPOSED ACTION/ STATE PROPOSAL

3. DESCRIPTION OF PROPOSED ACTION/STATE PROPOSAL

3.1 Proposed Browse to NWS Project Overview

The proposed Browse to NWS Project comprises two FPSO facilities and subsea infrastructure, to be located approximately 290 km north-west of mainland Australia and approximately 425 km north of Broome, Western Australia; connected to existing NWS Project infrastructure by the approximately 900 km BTL.

Hydrocarbon extraction will require up to 54 wells and associated subsea infrastructure including manifolds and flowlines. Condensate stabilisation and storage will occur on the FPSO facilities prior to offtake to condensate tankers for delivery to market. Gas processing will also occur on the FPSO facilities prior to export via the inter-field spur line and BTL to existing NWS Project infrastructure.

The BTL will tie into the existing second trunkline (2TL) near NRC. The NWS JV is pursuing approvals of the NWS Project Extension Proposal for the long-term processing of third party gas and fluids and NWS JV field resources through the NWS Project infrastructure until around 2070 (EPBC 2018/8335 and EPA 2186). Transmission of the gas from the tie in point and onshore gas processing is proposed to be undertaken using NWS Project infrastructure, subject to finalisation of commercial arrangements and regulatory requirements.

The key characteristics of the proposed Browse to NWS Project are presented in **Table 3-1**. The Browse Development Area notional field layout is shown in **Figure 2-1**. The BTL and inter-field spur line route are shown in **Figure 2-2**.

Table 3-1 Key Characteristics of the Proposed Browse to NWS Project

Component	State Proposal Area*	Overall Development (State Proposal Area and Commonwealth water)*
Well count (up to)	24[1]	54[1] (including 19 wells at Calliance, 29 wells at Torosa and 6 wells at Brecknock).
Subsea infrastructure	Wellheads, manifolds, flowlines and umbilicals	Wellheads, manifolds, flowlines, umbilicals, risers, anchors and moorings.
Surface facilities	None	Two ~1100 MMscf/d export (annual daily average**) FPSO facilities.
Browse Trunkline (BTL)	None	~900 km 42” diameter trunkline with adequate capacity for export of 2,150 MMscf/d.
Inter-field spur line	None	~85 km 34” diameter spur line with adequate capacity for export of up to 1,100 MMscf/d (annual daily average).

* *Subject to detailed design and refinement*

** *Annual daily average export is defined as the daily export rate, averaged over an annual period*

3.2 Development within State Proposal Area

Activities in the State Proposal Area will be a limited subset of the proposed Browse to NWS Project, including the development of up to an estimated 24 wells targeting the hydrocarbon resources of the Torosa reservoir. Extracted hydrocarbons will be transferred via subsea infrastructure, including wellheads, manifolds and flowlines, up to the Torosa FPSO facility, located in Commonwealth water.

The highest intensity of activities within the State Proposal Area will be likely to occur during the drilling and completion activities, installation activities and future decommissioning phases. During these periods, a mobile offshore drilling unit (MODU) and approximately ten vessel may be present in the State Proposal Area.

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[1] *note that the estimated maximum number of expected wells has increased from the Referral estimate of 49 (and 21 in the State Proposal Area), due to additional design considerations including reservoir understanding, which have since taken place.*

As all infrastructure within the State Proposal Area is subsea, operation of the wells will be controlled remotely via the FPSO facilities that will be located in Commonwealth water. Outside of drilling and completion and installation periods, surface activities in the State Proposal Area will comprise inspection, maintenance and repair activities involving one or two vessels, later phase well construction and decommissioning (including well plug and abandonment).

3.3 Development within Commonwealth water

Within Commonwealth water, activities will include the development of an estimated 30 wells targeting the hydrocarbon resources of the Torosa, Brecknock and Calliance reservoirs. Extracted hydrocarbons will be transferred via subsea infrastructure, including wellheads, manifolds and flowlines, up to the two FPSO facilities.

As is the case with the State Proposal Area, the highest intensity of activities in Commonwealth water will be likely to occur during the drilling and completion activities, installation activities and future decommissioning phases; during which time, a mobile offshore drilling unit (MODU) and approximately twenty vessels may be present. This accounts for activities in the Browse Development Area, BTL installation and support vessel transit through Commonwealth water.

During normal operations, processing of the gas and condensate will occur on the two FPSO facilities within Commonwealth water, as will the storage and offtake of condensate and the export of the dry gas via the BTL and inter-field spur line. Support activities in Commonwealth water will include inspection, maintenance and repair (IMR) activities involving one or two vessels, regular personnel and supplies transfers via vessel and helicopters, later phase drilling and decommissioning (including well plug and abandonment).

3.4 Appraisal Activities

On-site appraisal activities for the Browse reservoirs have occurred since the first discovery in 1971. Early wells were drilled within the southern lagoon of Scott Reef, accompanied by 2D seismic surveys conducted throughout the 1970s, 80s and 90s. As emerging LNG markets began to increase the viability of developing the Browse reservoirs in the early 2000s, resource appraisal activities increased. Since 2004, additional 2D and 3D seismic surveys have been undertaken at each of the three reservoirs, as follows:

+ In 2007, the Maxima 3D Marine Seismic Survey (MSS) was undertaken to collect 3D seismic data from the Torosa gas reservoir.
+ In 2008, the Gigas 2D ocean bottom cable (OBC) MSS was conducted at North Scott Reef to test the suitability of the OBC technique for seismic data acquisition and to provide additional 2D seismic data over part of the Torosa gas reservoir.
+ In July 2011, the Tridacna 3D OBC MSS was undertaken at Scott Reef as part of an ongoing programme to better understand the southern portion of the Torosa gas reservoir.
+ In 2012, the Rosebud 3D MSS was undertaken between the two areas previously surveyed during the Maxima and Tridacna 3D MSS to obtain seismic data to map subsurface geology and complement information collected during the two previous MSS conducted in the area.

Appraisal wells have been successfully drilled at each reservoir. This has included three wells at Calliance, three at Brecknock and eight at Torosa (17 wells have been drilled in total, including initial exploration wells). This includes the Torosa-6 well, drilled on the edge of South Reef, and the Torosa-5 well, drilled near the eastern entrance to the channel between North Scott Reef and South Scott Reef.

Going forward, a range of resource appraisal activities and feasibility studies are proposed to support the consideration of potential development of the Browse hydrocarbon resources. The proposed activities may include seismic surveys, drilling of appraisal wells (nominally two wells) and geophysical, geotechnical and environment surveys. These will all be short-term and small scale in nature and are not directly related to the development of facilities for the recovery of hydrocarbons from the reservoirs. These activities will not form part of the scope of the proposed Browse to NWS Project EIS/ERD. These activities will be subject to separate environmental approvals, as required.

3.5 Proposed Browse to NWS Project Schedule

Subject to all necessary joint venture and regulatory approvals being obtained and appropriate commercial arrangements being finalised, the indicative timeframes for the proposed Browse to NWS Project are:

+ commencement of construction and drilling and completion activities from approximately 2021-2022, followed by installation and commissioning activities
+ RFSU and commencement of operations occurring in the mid-2020s
+ operations continuing for up to 44 years.

Following operations, decommissioning activities will be carried out.

3.6 Project Infrastructure

The proposed Browse to NWS Project comprises key infrastructure components such as wells, subsea infrastructure, FPSOs and subsea pipelines (BTL and inter-field spur line). The BTL and inter-field spur line route are shown in **Figure 2-2**.

3.6.1 Production Wells

It is anticipated that the proposed Browse to NWS Project will require drilling and completion of up to 54 production wells at the Brecknock, Calliance and Torosa reservoirs over the life of the Development (refer to **Table 3-1**). Up to 24 of the wells will be located in the State Proposal Area, the other wells will be located in Commonwealth water.

The 54 production wellheads are anticipated to be located within approximately 500 m of the drill centres, which are shown in the Browse Development Area notional field layout (**Figure 2-1**). The indicative locations for the drill centres are provided in **Table 3-2**.

A wellhead will be installed at the top of each well. The wellhead will hold the production well casing and enable installation of the christmas tree, complete with well control facilities. Christmas trees are steel structures with various valves and are used to:

- control production, whereby hydraulically controlled valves on the christmas trees are used to control flow rates and provide a well shut-off mechanism
- manage chemical injection.

Surface controlled subsurface safety valves (SCSSVs) will be installed in the wells.

To optimise the layout of the subsea infrastructure, production wells will be arranged around drill centres (a cluster of wells around a central manifold) with up to seven drill centres located at Torosa, three at Calliance and one at Brecknock reservoir. The number and location of these wells and drill centres will depend on reservoir target areas, seabed bathymetry and features to optimise reservoir recovery.

Table 3-2 Indicative Drill Centre Locations

Field	Drill Centre	Drill Centre Coordinates	Jurisdiction
Torosa	TRA	389 521 E, 8 455 338 N	State
Torosa	TRB	394 478 E, 8 461 330 N	Commonwealth
Torosa	TRC	398 330 E, 8 464 422 N	Commonwealth
Torosa	TRD	387 315 E, 8 451 207 N	State
Torosa	TRE	374 207 E, 8 448 595 N	State
Torosa	TRF	388 865 E, 8 458 144 N	State
Torosa	TRH	391 540 E, 8 452 679 N	Commonwealth
Calliance	CLA	343 189 E, 8 392 356 N	Commonwealth
Calliance	CLB	347 600 E, 8 390 575 N	Commonwealth
Calliance	CLC	353 539 E, 8 387 015 N	Commonwealth
Brecknock	BKA	354 250 E, 8 402 400 N	Commonwealth

3.6.2 Subsea Infrastructure

The wells at each drill centre will be connected to manifolds by well jumpers (specially-designed pieces of pipe used to transport production fluid between components of the subsea infrastructure) to allow reservoir fluids to be carried from the wells to the manifolds. The manifolds will connect the wells to corrosion resistant alloy (CRA) clad (or lined) flowlines that will be routed back to the FPSOs. Connection between the flowlines and the FPSO facilities will be achieved using flexible risers through a Flowline End Termination (FLET) or riser base manifold.

To prevent hydrate formation in the subsea system, the flowlines and import risers will be actively heated. Mono-ethylene Glycol (MEG) will also be required to prevent hydrate formation in the components of the subsea that are not actively heated – the use of which has been minimised by the use of active heating technology. There will be no continuous injection of MEG during operations due to the adoption of active heating technology.

An example of subsea infrastructure for illustrative purposes is provided in **Figure 3-1**. Each of the subsea infrastructure types described above will be located in both State and Commonwealth water, except for the flexible risers, mooring turrets and permanent FPSO mooring anchors, which will only be located in Commonwealth water.

Subsea infrastructure will be powered, monitored and controlled from the FPSO facilities using a network of electro-hydraulic control umbilicals and subsea distribution units (SDUs). Each drill centre will be serviced by an electro-hydraulic umbilical, which will follow a similar alignment as the infield flowlines. Some umbilicals may be integrated within the production flowline bundle. Umbilicals will also be tied back to the FPSO facilities using a system of flexible risers.

Other subsea infrastructure will include the piles and mooring lines for the FPSO mooring and, potentially, piles for permanent moorings for the MODU/Light Well Intervention Vessel (LWIV). An estimated 18 mooring piles per FPSO will be installed, with each connected to a FPSO facility by a mooring line.

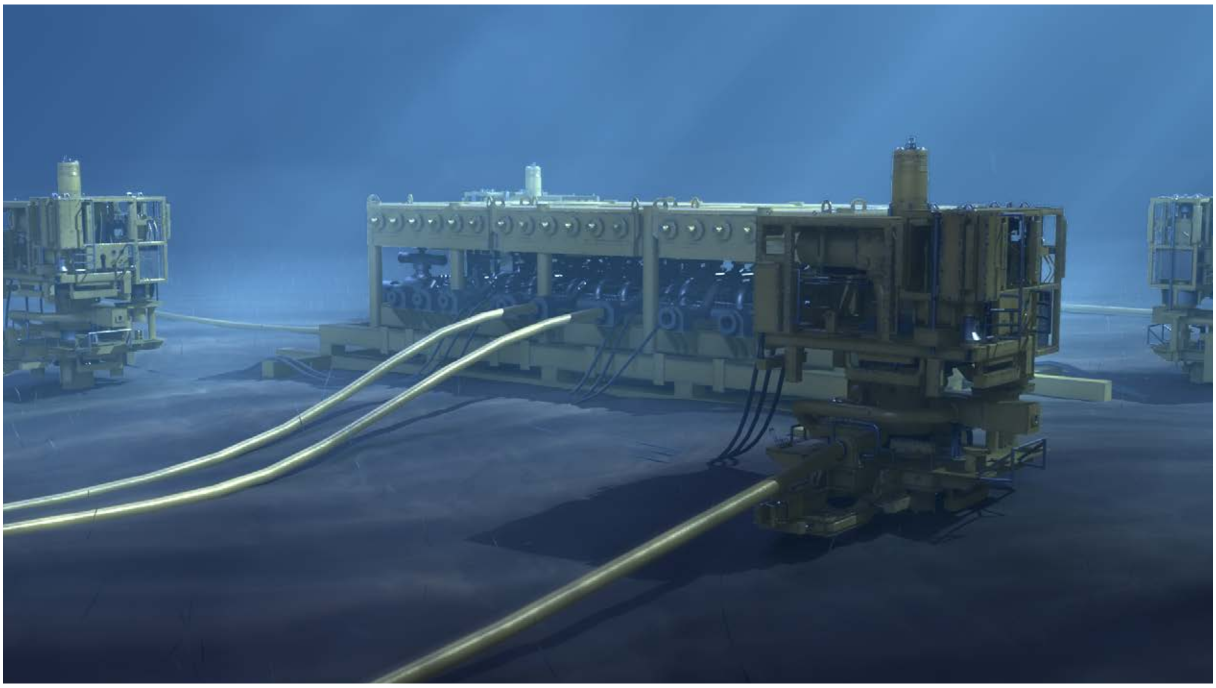

Figure 3-1 Indicative Layout of Subsea Infrastructure

3.6.3 FPSO Facilities

The proposed Browse to NWS Project will include two FPSO facilities, each with a maximum export capacity of approximately 1,100 MMscf/d (annual daily average). Each FPSO will be located within Commonwealth water at the Torosa and Calliance/Brecknock fields.

The key features of each FPSO are:

- ship-shaped hull (in the order of 350 m x 66 m x 35 m (length-width-depth) with approximately 1,000,000 barrels' effective condensate storage)
- double side and single bottom hull
- permanently moored on station via a turret mooring system
- facilities including:
    - reservoir fluid inlet
    - reservoir fluid processing equipment including:
        - depletion compression (post RFSU)
        - water treatment and overboard disposal
        - condensate stabilisation and compartmentalised storage
        - acid gas removal
        - mercury removal
        - hydrocarbon and water dew pointing
        - export gas compression
    - utilities such as cooling water, desalination and power generation
    - accommodation for up to 60 people during routine operations and 180 people during major maintenance activities, including supporting services such as sewage treatment and putrescible food maceration
- tandem condensate offloading.

Each FPSO will be moored via a turret mooring system and will be designed to remain permanently on station during reservoir life, including during severe weather events. However, the FPSOs can be disconnected if required (e.g. for refurbishment). As the FPSOs will weathervane around the turret, they will be equipped with two thrusters at the stern of the vessel to control the heading of the facility for operational reasons (ie during offtake activities or during particular metocean conditions).

An indicative schematic of the FPSO facilities is shown in **Figure 3-2** (not to scale).

Figure 3-2 Indicative FPSO Facilities (schematic not to scale)

3.6.4 BTL and Inter-Field Spur Line

Gas will be exported from the FPSO facilities via the BTL, a 42” carbon steel trunkline that will run approximately 900 km south-west from the Calliance/Brecknock FPSO facility to the tie-in point with the NWS Project infrastructure near NRC. The BTL will have adequate capacity for export of 2,150 MMscf/d (annual daily average).

An 85 km 34” carbon steel inter-field spur line will connect the Torosa FPSO facility to the BTL near the Calliance/Brecknock FPSO. The inter-field spur line will have a capacity of 1,100 MMscf/d (annual daily average)

The entire length of the BTL and inter-field spur line will be located in Commonwealth water.

3.7 Development Activities

3.7.1 Piling

Piling will be required for mooring the FPSO facilities, securing the export riser bases and potentially for MODU mooring. Data from the surveys undertaken by Woodside in 2014 has been analysed and demonstrates that suction piling for FPSO moorings is likely to be feasible. Therefore, suction piling is the most likely option for pile installation.

Suction piles are installed by gently lowering the pile onto the seabed and using gravity to lower the pile into the soft substrate. Installation is completed by pumping out the entrapped water inside the pile, with the resulting differential pressure driving the pile into the seabed.

Should alternate piling methods be selected, options will include drilling and cementing (for MODU only) or driven piling, which involves the application of force to drive the pile into the seabed. The greatest underwater noise impact is associated with driven piling. While piling methodology is subject to detailed engineering, it is expected that the hammer size used for FPSO piling will range from a 600Kj light hammer to a 1,200Kj high energy hammer.

For more information please refer to **Section 6.3.8**.

3.7.2 Development Drilling and Completions

3.7.2.1 Drilling

The proposed Browse to NWS Project requires the drilling of up to 54 production wells (24 within the State Proposal Area). It is anticipated that the drilling and completion activities will be completed in multiple phases. The first phase will be drilling and completion of wells to achieve RFSU, with subsequent phases of drilling and completion of additional wells undertaken over the life of the development to optimise reservoir recovery. It is anticipated that in the order of 12 wells will be required at RFSU.

Production wells will typically be drilled to depths of between 3,500 and 4,500 m vertical depth beneath sea level to intersect the reservoirs. In order to reach the optimum location in the reservoir, the well may be drilled at inclination (up to horizontally), to maximise recovery of reservoir fluids. These horizontal sections of wells will typically radiate outwards from each well centre, although this will be influenced by geological conditions, reservoir targets and proximity to other well centres.

It is anticipated that a MODU will be used to drill and complete the wells. The MODU may be either conventionally moored or dynamically positioned (DP). A DP MODU may require the placement of transponders on the seabed as part of the positioning system. A moored MODU is anticipated to require the use of anchors, suction piles, drilled and cemented piles or driven piles. Up to 12 piles per drill centre would be required. A 500 m petroleum safety zone will be established around the MODU.

Figure 3-3 shows an example of a MODU. The MODU to be utilised during development drilling and completion will be fitted with typical solids control equipment which may include, but will not be limited to, shale shakers, cuttings dryers and centrifuges to separate the remaining fluid from the cuttings.

Figure 3-3 Mobile Offshore Drilling Unit (MODU)

Typically, the drilling process will start with the drilling of the largest size hole and a smaller diameter conductor will be cemented inside this hole. Next, a smaller diameter hole section will be drilled, and a surface and intermediate casing will be run in and cemented. Casings provide structural support for the hole walls, isolate geological formations and allow pressure management that may be experienced during drilling. Additional casing/liner sizes may be required to manage drilling risk. Drilling will then be paused far above the hydrocarbon reservoir. Cementing may involve a discharge of excess cement at the seabed.

A blow-out preventer (BOP) and riser system will then be installed. With the BOP in place, a hole will then be drilled into the top of the reservoir and a liner cemented over this hole section. The final hole section will then be drilled through the reservoir as required based on reservoir targets.

Formation Evaluation While Drilling (FEWD), or wireline logging activities, may be undertaken. This may include logging activities containing radioactive sources. Vertical Seismic Profiling (VSP) or other well-based acoustic imaging techniques may be conducted to generate a high-resolution seismic image of the geology in the well's immediate vicinity. This uses a small airgun array, typically comprising a system airguns with a total volume of 750 inch^3 of compressed nitrogen. During VSP operations, downhole receivers are positioned in a section of the wellbore (station) and the airgun array is typically discharged into the water at given distances from the well. The generated sound pulses are reflected through the seabed and are recorded by the receivers to generate an image of the subsurface. This process is repeated as required for different stations in the wellbore.

Drilling fluids will be used to lubricate the drill string, resist any pressure from the wellstream and return cuttings to the surface. They will be formulated according to the well design, the expected reservoir geological conditions and the surrounding formations. Drilling fluids are comprised of a base fluid, weighting agents and chemical additives used to give the fluid the exact properties required to minimise environmental impact and make the drilling as efficient and safe as possible. The selection of fluid types will not be finalised until the detailed design phase when well design is confirmed.

The top-hole sections of the well will be drilled using seawater with bentonite and then bentonite and guar gum sweeps. The bottom-hole sections will be drilled with either water based fluids (WBF) or non-water based fluids (NWBF).

Drilling production wells will generate drilling discharges composed of drill cuttings and drilling fluids that will be discharged to the marine environment typically at the seabed (>300 m water depth) for the top-hole well sections and subsequently at or near the sea surface for the bottom-hole well sections.

A summary of the drill cuttings and fluid volumes expected to be discharged are presented in Table 3-3 below:

Table 3-3 Indicative cuttings volumes and fluid type for a typical Browse well.

Indicative well section diameter	Indicative Drill Length (m)	Indicative Cuttings Volume (m³)	Indicative Fluids Volume (m³)	Indicative Fluid Type
42”	100	89 m^3	427	Seawater with bentonite sweeps
26”	440	151 m^3	1327	Seawater with bentonite sweeps
16”	2970	385 m^3	965	Weighted Gel (Bentonite) WBF
12 ¼	2799	213 m^3	925	WBF or NWBF
9 ⅞	243	12 m^3	790	WBF or NWBF
Total per well	**6,552 m**	**850 m^3**	**4,435 m^3**	

Given the potential sensitivities of Scott Reef shallow water benthic communities and habitats to sedimentation from drilling discharges, Woodside has committed to managing the drilling discharges at drill centre locations in the State Proposal Area (i.e. TRA, TRD, TRE and TRF) in such a manner that no potential impacts to Scott Reef shallow water benthic communities and habitats (<75 m water depth) will occur. For more information on discharge of drill cuttings and fluids, please refer Section 6.3.15.

Well annular fluids refer to the fluids that remain in the wellbore, or annular spaces between the casing. It may consist of weighted drilling fluid and cement-contaminated mud, seawater, barite, cement polymer, and may include small amounts of hydrocarbon.

If a well is underperforming, or surveillance indicates debris is contained within the well, the contents of the wellbore may be flowed to a MODU. This displaces the well fluids (i.e. suspension/completion fluids). These are discharged overboard, as potential gas content makes it too dangerous to personnel to filter or treat them.

Navigational and operational lighting is required on the MODU at levels that provide a safe working environment for personnel and maritime shipping safety. The MODU is expected to have a number of similar discharges to the FPSO facilities, including cooling water, treated utility water, sewage and putrescible waste. The fuel source for power generation on the MODU will likely be diesel.

3.7.2.2 Completions

Once the well has been drilled it will be completed, which is the process for making the well ready for production. Completions activities may be conducted using a light well intervention vessel (LWIV), MODU or a combination of the two. This process will involve the installation of the lower completions (including well casings, liners), the installation of the wellhead and Christmas tree and the installation of the upper completions (including the production tubing). During this installation process the well will remain isolated, with two independent and verifiable barriers. Typically, the BOP is removed in this sequence and replaced with an alternative barrier. The subsea christmas tree may be installed by a construction vessel on wire.

The well will then be flowed to the MODU or a suitable vessel. This first production is known as unloading and typically lasts approximately 1-2 days per well. Once stable flow is achieved, the produced fluids will be sent to tanks for separation. The produced gas and condensate will be flared, while produced water, making up a small proportion of the drill cuttings and fluids discharge stream, will be treated prior to discharge overboard.

Once unloading activities are completed, the wells will then be isolated until they are connected up to the FPSO facilities. The option to unload wells directly to the FPSOs (once connected) may also be considered in future. It should be noted that the precise sequence of the drilling, completions and unloading activity is dependent on the type of christmas tree installed.

There are a number of drilling and completions unplanned contingencies that may be required if operational or technical issues occur. These contingencies do not represent significant additional risks or impacts but may generate additional volumes of discharges such as drilling cuttings and fluids. These contingencies may include well workover, side-tracks, well suspension and well intervention. These activities, or other intervention activities, may be conducted using a LWIV, a MODU or a combination of the two.

3.7.3 Subsea Umbilicals, Risers and Flowlines (SURF) Installation and Commissioning

3.7.3.1 Site Preparation

Seabed preparation works may be required to position flowlines on a level surface so as to provide stability to the SURF infrastructure. In particular, seabed preparation may be required through the sand wave region at the eastern entrance to the channel between North Scott Reef and South Scott Reef and within the channel itself. Seabed preparation works will most likely be undertaken using ploughing and/or mass flow excavation techniques (mass flow excavation is an activity where water is pumped into the sediment to disturb and displace it). Protection and additional stabilisation methods, such as trenching and rock placement, may also be required to limit potential damage to flowlines and subsea infrastructure.

Pre-lay and post lay survey works (including but not limited to multibeam, side scan, geophysical and geotechnical investigation) may be undertaken during the SURF installation scopes to verify seabed and confirm positioning.

3.7.3.2 Installation

The indicative installation process for subsea infrastructure and the FPSO is described in this section. This process is subject to refinement during detailed engineering.

SURF infrastructure required for start-up (with the exception of the riser) will be installed prior to the arrival of the FPSO facilities, with further infrastructure installed throughout the life of the proposed Browse to NWS Project. SURF infrastructure such as manifolds, flowlines, umbilicals, mooring systems and risers will be transported to site by a combination of installation vessels and cargo barges. Subsea installation of equipment will be performed by specialist DP vessels. These will be equipped with submersible Remotely Operated Vehicles (ROVs), which will aid in the installation, hook-up and commissioning processes.

The manifolds and SDUs will be lowered to the seabed with their position confirmed using acoustic transducers mounted on each manifold. Similar transducers will be mounted on each wellhead to ensure the manifold does not contact the wellheads. Drill centres with multiple wells may require one or more manifolds.

With the manifolds in place, the subsea well jumpers, infield flowlines and umbilicals will be installed on the seabed. Flowlines are expected to be either reel laid or installed as towed bundles. If flowlines are reel laid, the infield flowlines will be installed progressively within a defined corridor using a pipe-lay vessel, whereby each flowline will be lowered to the seabed as the vessel moves forward. The flowlines will be laid directly on the seabed and the umbilicals will be laid alongside the flowlines.

If flowlines are installed as towed bundles, then the bundles will be fabricated onshore at the supply chain location (refer Section 3.7.9.1) and then towed into position at a controlled depth. Each bundle will then be flooded, allowing it to be lowered into place.

For subsea structures, mudmat foundations are currently proposed. Piled foundations for subsea structures are unlikely to be required. If flowlines require anchoring to mitigate flowline walking, piling may be required at one or both ends of the flowlines.

The flexible risers will be installed using a DP installation vessel. Typically, one end of each riser will be pulled up and hung off on the FPSO facility using a winch located on the facility. Each of the flexible risers will be installed filled with MEG or inhibited seawater, inhibited potable water or free flooding. It the risers are installed free flooding, they will be flushed with inhibited seawater following first end hook-up to the FPSO.

To achieve the final riser design configuration, buoyancy modules are generally installed directly onto the riser during the installation. Once each riser has been connected to the FPSO, the subsea end is typically laid to a FLET or riser base manifold. Diverless connectors are likely to be used to connect each riser to the FLET/manifold. The subsea installation of the flexible umbilical risers will typically follow the same methodology as attaching the risers to the FPSO. However, the umbilicals will be connected to SDUs. Flexible risers may require anchor holdback piling.

During the installation process, pieces of project infrastructure may temporarily be stored on the seabed until required. This is known as wet storage, and there is likely to be one wet storage site near each drill centre.

3.7.3.3 Commissioning

Once installation and hook-up of the SURF infrastructure is complete, Flood, Clean, Gauge and hydrotesting (FCGT) may be conducted on the SURF infrastructure to test the integrity (leak testing) of the subsea infrastructure. This will be conducted using hydrotest fluids, whereby the pipeline will be pressurised with fluids and the pressure will be monitored to detect leaks. Hydrotest fluids may consist of various constituents including seawater, biocides, oxygen scavenger, corrosion inhibitors, MEG and fluorescent dye.
The fluids will then be left in place to provide corrosion protection, prior to dewatering in preparation for the introduction of reservoir fluid.

The flowline and riser hydrotest fluid will mostly likely be returned to the FPSO facility and then discharged to sea in Commonwealth waters. However, in certain cases, discharge may occur in deep water at the manifolds or riser base FLETS for rigid flowlines.

For flowlines connected to those production manifolds that are located within 3 nm of Scott Reef, the discharge of flowline hydrotest fluid will occur from the end of the flowline furthest from Scott Reef, where technically feasible. For flowlines which are terminated at both ends within the State Proposal Area (for TRE and TRF manifolds), discharge of flowline hydrotest fluid in the State Proposal Area may be unavoidable. Given that the TRE and TRF manifolds are daisy-chain connected to other manifolds in the State Proposal Area, and are not part of Torosa Phase 1 RFSU equipment, future engineering will consider the viability of alternatives to flowline hydrotest fluid discharge in the State Proposal Area. If discharge within the State Proposal Area is unavoidable, a PLONOR hydrotest fluid will be considered. Minor hydrotest discharges associated with smaller pieces of subsea equipment may also occur in situ.

Hydrotest fluid volumes for a flowline will vary depending on the flowline section to be tested. Volumes are estimated to be up to approximately 950 m^3 of hydrotest fluid for the TRE flow line and up to approximately 250m^3 for TRF flow line. A subsea flowline hydrotest discharge is likely to take less than a day to complete. These discharges will occur once for each piece of infrastructure during pre-commissioning.

3.7.4 Installation of BTL and Inter-field Spur Line

3.7.4.1 Site Preparation

Seabed preparation works may be required to position the BTL on a level surface so as to provide stability. Seabed preparation may be required through the sand wave regions along the BTL route, including in proximity to the Argo-Rowley Terrace Marine Park. Seabed preparation works will most likely be undertaken using ploughing and/or mass flow excavation techniques. The laying of mattresses or rock placements at crossings over existing third party infrastructure to avoid damage may also be required. Wet storage areas may also be required at each end of the pipeline.

Pre-lay and post lay survey works (including but not limited to multibeam, side scan, geophysical and geotechnical investigation) may be undertaken during the BTL installation scopes to verify seabed and confirm positioning.

3.7.4.2 Installation

The BTL and inter-field spur line will be installed via a specialised installation vessel, which will have an established 500m Petroleum safety zone. Sections of pipe will be welded together on the vessel before being laid directly onto the sea floor from the vessel. Typically, these vessels are held in place via DP systems. Sections of pipe may be brought to the specialised installation vessel from the fabrication yard progressively, using other project vessels.

The specialised installation vessel is expected to be the largest project vessel apart from the FPSO facilities, and is expected to have up to approximately 700 people on board at peak times. It is expected to have a number of similar discharges to the FPSO facilities, including cooling water, treated utility water, sewage and putrescible waste. It is expected that during pipelay the specialised installation vessel will move along the BTL and inter-field spur line route at a rate of up to approximately 5km/day, depending on the pipelay vessel and operational conditions such as sea state.

The BTL and inter-field spur line will be connected to the FPSO using riser bases, rigid tie-in spools and flexible risers. The tie-in spools may be flushed to displace the liquid used during the construction and preservation period to the local environment with nitrogen and/or MEG. Hook-up of the equipment on the seabed is typically achieved using ROVs. Export riser bases will be installed. During installation, temporary anchors may be required at each end of the pipeline.

3.7.4.3 Second Trunkline (2TL) Preparation for Browse export gas and BTL Tie-in

The 2TL is owned and operated by North West Shelf Joint Venture (NWS JV). The Browse to NWS Project scope requires preparation of 2TL to enable transportation of Browse export gas. The exact details of this work are yet to be finalised as is the allocation of portions of the work to each joint venture, which remain subject to commercial arrangements and regulatory requirements. The following is a description of the currently anticipated scope.

First, 2TL will be isolated from other NWS JV infrastructure followed by the tie-in of the Browse Trunk Line (BTL) to 2TL. This work requires use of various vessels, including diver support vessels, installation support vessels and ROVs.

After NWS JV stops using 2TL for production and isolates 2TL from the NWS infrastructure upstream of the 2TL, a pig launcher is attached to infrastructure located near NRC. A pig is sent from the launcher down 2TL to the Karratha Gas Plant (KGP). The pig is intended to remove hydrocarbons from 2TL which will be filled with chemically treated seawater. A small volume of the chemically treated seawater will be received at the KGP at the end of the pigging campaign. Receipt of hydrocarbons and fluids at KGP is outside the scope of this draft EIS/ERD.

Following the pigging campaign, a small section of 2TL located approximately 5-10 km downstream from NRC may be cut and removed, a new flange welded to the 2TL and a new valve skid installed. The valve skid may then be connected via a spool, or spools to the Browse Trunkline Pipeline End Terminal (PLET). Prior to commissioning of 2TL, preservation fluid (similar in composition to hydrotest fluid described above) may be discharged from the 2TL at the connection point, likely to be from the valve skid. The 2TL, including the remaining portion of 2TL upstream from the cut at the BTL tie-in to the IVS skid, will remain infrastructure owned by NWS JV.

Additional contingency isolations may be required in order to safely tie in the Pig Launcher and/or isolate NWS JV infrastructure from 2TL. Minor releases of hydrocarbons may be associated with the tie-in of the pig launcher and BTL, or with the installation of contingency isolations.

3.7.4.4 Commissioning

FCGT may be conducted on the BTL and inter-field spur line. If FCGT is required, the lines will first be flooded with treated seawater to fill the lines. Cleaning and gauging of the lines will then be performed by propelling a pig train through the flowline utilising flooded filtered treated seawater. The pipelines will be pigged in a controlled manner to clean the internal surface of the pipeline and to determine if any unacceptable restrictions and/or obstructions exist in the line.

The hydrotest fluids are likely to consist primarily of seawater which is chemically treated at an appropriate concentration (e.g. 600 ppm) with chemicals such as biocides, corrosion inhibitors and oxygen scavenger to prevent corrosion from oxidation and microbial action for the required preservation period and maintain trunkline integrity. In addition, a fluorescein dye will be added to the hydrotest fluid to visually identify leaks during hydrotesting. The combination of hydrotest fluid constituents for the BTL depends on the trunkline material type and the required preservation period.

If required, hydrotesting of the BTL will involve discharge of up to 846,000m^3, which may occur at either the 2TL tie in point near NRC or at the FPSO locations, to sea near the seabed. The project is actively pursuing dry commissioning through the detailed design, as a potential alternative to FCGT.

The export risers may also require integrity testing prior to commissioning. This would be performed with treated seawater, potable water or MEG, with the hydrotest fluid recovered to the FPSO facility for disposal overboard.

For more information on hydrotest discharge, please refer **Section 6.3.17**.

3.7.5 FPSO Facilities Installation and Commissioning

3.7.5.1 Installation

The FPSO facilities will be constructed at an existing fabrication yard overseas and towed to site using ocean going tugs. Installation of the facilities is likely to occur approximately one year apart.

A turret and mooring system (TMS) will be installed to moor each FPSO facility. The mooring lines will be secured to the seabed by anchors. The configuration is expected to comprise three mooring bundles per FPSO facility, with up to six mooring lines per bundle. The anchor piles will typically be 6 m to 10 m in diameter, and up to 50 m in length, with each weighing approximately 450 tonnes.

Once on location, each FPSO facility will be connected to the mooring system. The turret and mooring system will include a non-rotating component to support the mooring lines, risers and umbilicals. This configuration will allow the facility to freely weathervane with prevailing metocean conditions.

Once the FPSO facility is moored, hook-up of the facility to the SURF infrastructure and the BTL (Calliance/Brecknock FPSO) and the inter-field spur line (Torosa FPSO) will be completed.

3.7.5.2 Commissioning

As the FPSO facilities will be constructed at an existing fabrication yard overseas, pre-commissioning of the facilities will be preferentially carried out at the yard and may include inspection, cleaning, testing, drying, inerting and first fill of process chemicals and adsorbents for the gas treatment system.

Commissioning of the overall production system will be conducted from each FPSO facility on location. Commissioning will include testing, adjusting and monitoring of all process and utility systems.

3.7.6 Operations

3.7.6.1 Hydrocarbon Extraction

During operations, hydrocarbons extracted from the reservoirs will flow via the christmas trees and manifolds through the flowlines and risers to the FPSO facilities. The flow rate of hydrocarbons will be controlled by subsea choke valves at the christmas trees. Subsea hydraulic control fluids will be used to operate subsea valves. During operation of the valves, subsea hydraulic control fluids may be discharged to the surrounding environment.

Distributed Acoustic Sensing (DAS) surveys may be conducted over the life of field to assess the developed reservoir's performance. DAS is an emerging technology that is being investigated to help monitor reservoir performance. The data is acquired using a survey or support vessel equipped with an acoustic source array, with a total volume currently anticipated to be approximately 750 cubic inches. The source emits sound energy pulses that are detected by a fibre optic cable installed in the development wells as part of the upper completion.

DAS Surveys are related to the operation and development of facilities for the recovery of hydrocarbons from the reservoirs. These activities form part of the scope of the proposed Browse to NWS Project.

Pressure and saturation changes in the reservoir will be monitored over the life of the Project. Data will be used to inform decisions regarding production rates and water ingress.

Processing

Processing on the FPSO facilities topsides will commence with the feed stream being separated into a gas and a liquid stream (condensate and produced water). The liquid stream will then be further separated, with the produced water sent for treatment to minimise hydrocarbons.

The condensate from the separated liquid stream will be stabilised and sent to compartmentalised condensate storage tanks prior to offloading. Up to 50,000 bbls of condensate will be produced daily per facility. A mercury removal unit (MRU) will be installed in the condensate system to meet condensate specification requirements.

When hydrocarbons are recovered from the reservoir, produced water (PW) will also be generated. which is separated out from the hydrocarbon components during the production process and discharged to the marine environment. This PW may consist of a combination of formation water (water that occurs naturally within the hydrocarbon-bearing geological formations that is drawn into the well during hydrocarbon recovery), and condensed water (water vapour contained in the gaseous phase of the reservoir fluids that condenses out of the gas as the pressure and temperature is reduced when the reservoir fluids are brought up to the surface). Formation water from the Browse reservoirs is expected to be saline, while condensed water is fresh.

The PW stream discharged from the FPSO facilities will be treated using a tertiary treatment system, such as a Macro Porous Polymer Extraction (MPPE) system that meets Woodside and accepted industry standards prior to being discharged overboard, and discharge below the surface (approximately 14 m below MSL). After treatment, PW will then be discharged overboard. PW rates and composition will be dependent on condensed and formation water rates, which will vary over the life of the reservoir. Formation water is actively avoided during reservoir recovery. However, over time water is drawn towards the well and produced. As such, formation water (and therefore PW) is expected to be highest towards the end of the reservoir life. The FPSO PW treatment circuit will be designed for a maximum processing capacity of 5,723 m^3/day on each FPSO.

For the environmental impact and risk assessment of this discharge, refer **Section 6.3.12**.

The gas stream will be sent to a separate MRU prior to being sent to an acid gas removal unit (AGRU) to remove compounds such as reservoir CO_2 and hydrogen sulphide (H_2S). The removed compounds are directed to atmosphere by a vent line. Entrained hydrocarbons and volatile organic compounds in the vent line will typically be incinerated by thermal oxidisers and converted to CO_2. In the event that thermal oxidisers are not available, the methane and volatile organic compounds are vented to atmosphere unincinerated.

Post AGRU, the gas stream then proceeds to gas conditioning, which removes water (dehydration) and removes heavy hydrocarbons (hydrocarbon dew pointing), prior to export compression.

Energy and heat requirements for each FPSO facility, including for the gas compression processes, will be provided by gas turbines (export and depletion compression) or electric motors (flash gas compression). When heat is required in addition to the heat recovered from gas turbines, heat sources such as fired or electric heaters will be used to provide the surplus heat.

Flare stacks will be included on the FPSO facilities for the safe combustion of waste gases. Controlled flaring will be required during start up and planned shutdowns. During commissioning, the flaring may continue until the full system is operational and has reached steady-state operations. In addition, a sequence of planned shutdowns, depressurisations and non-routine (emergency) shutdowns during commissioning would also result in increased emissions from the flare. Once the system is operational, there will be no routine flaring with the exception of pilot gas (fuel gas supplied to keep the flare alight) and compressor seal gas. During normal operations, non-routine flaring may result from equipment failure, shutdowns, production restarts, emergency depressurisation, well remediation and well commissioning. Low pressure waste gases may also be vented or flared, including from the cargo tanks and PW degasser. An overview of the processing of each stream is shown in **Figure 3-4**.

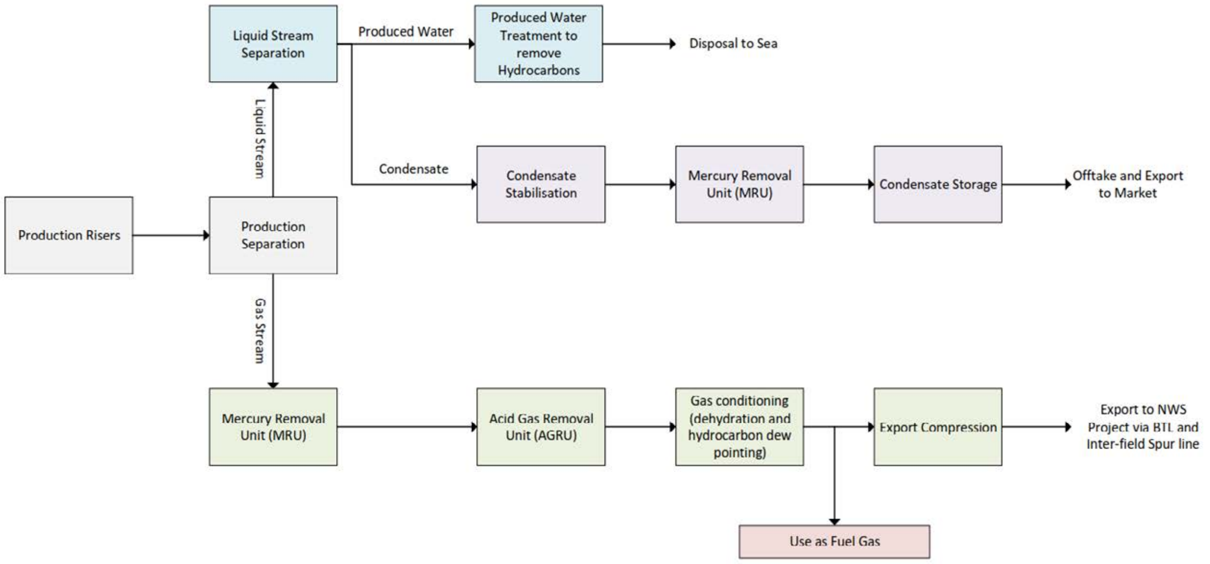

Figure 3-4 Processing Schematic

3.7.6.2 Condensate offload

Condensate will be loaded on to condensate tankers using flexible hoses every two to four weeks (depending on the production rate). Condensate tankers will be positioned astern of the FPSO facility and supported by tugs as required. Condensate offloading is expected to take approximately 24 hours for 650,000 bbls of condensate (plus some time for mooring and unmooring operations). Offloading operations may require the simultaneous operation of FPSO facility thrusters and thrusters on the tugs. During offloading, the main engines of the condensate tankers will not typically be operating. A support vessel may also be present in the vicinity.

3.7.6.3 Gas Export

Transport of the dry gas to the onshore processing facility will be via the inter-field spur line, BTL and 2TL. Processing of the gas onshore is outside the scope of this draft EIS/ERD. Liquids will not be present in the inter-field spur line and BTL.

3.7.6.4 Utilities

The FPSOs have a number of utility systems to support the hydrocarbon processing. These systems include:

- Process and essential cooling water systems
- Fresh and potable demineralised water system
- A utility water, chemical and deck drainage system
- Power generation.

The FPSO facilities will have a cooling water system where seawater will be pumped up to the facility to remove excess heat from machinery systems and the FPSO process, treated with hypochlorite and passed through the heat exchangers prior to discharge overboard. The cooling water system will consist of both a Process Seawater System and an Essential Seawater System. The Process Seawater System services hydrocarbon processing equipment, while the Essential Seawater System primarily services marine systems. It is estimated that the Process Seawater System demand will be in the order of 720,000 m^3/day per FPSO facility, however, some variation in the exact discharge rate may be expected as the project engineering design is finalised. The Essential Seawater System demand will be significantly smaller (expected to be <5% of the Process Seawater System). A hypochlorite system will inject chlorine to protect the seawater cooling system from biofouling. Residual chlorine will be discharged overboard as part of the cooling water discharge stream in the order of 0.2 to 1.0 ppm. Residual chlorine levels will be monitored, and the system routinely maintained so residual chlorine levels at the point of discharge are such that the threshold values (as defined in the environmental impact and risk assessment) are achieved at the Scott Reef 3 nm State waters boundary. For the environmental impact and risk assessment of this discharge, please refer **Section 6.3.13**.

Reverse osmosis units on the FPSO facilities will supply fresh and demineralised water at a total rate of approximately 21.5 m^3/h. This process will generate desalination brine, which consists of water with elevated salinity (typically 20 to 50% higher than the intake seawater) and low concentrations of anti-scale chemicals. Desalination brine will be discharged

to sea with discharge expected to be continuous throughout the life of the proposed Browse to NWS Project. Volumes will vary depending on potable water requirements on each FPSO facility. Discharge of desalination brine from the FPSO facilities will be likely to occur below sea level.
For the environmental impact and risk assessment of this discharge, please refer Section 6.3.10.

The two FPSO facilities will discharge treated utility water, chemical and deck drainage. Treated utility water comprises the discharge from drains and bilges, non-process chemicals (e.g. cleaning chemicals) and fire suppression systems on the FPSO facilities, as well as desalination brine from these same sources during all phases of the proposed Browse to NWS Project. Drainage (bilge water) from within machinery spaces will be captured in a bilge tank for treatment, where oil will be recovered and treated water (less than 15 mg/L oil in water) discharged overboard.
For the environmental impact and risk assessment of this discharge, please refer Section 6.3.10.

Gas turbines will be used for providing power to the facilities and the export gas compressors on the FPSOs. Gas turbines are a key source of air emissions, including greenhouse gases. For the environmental impact and risk assessment of air emissions, please refer Section 6.3.5. For the environmental impact and risk assessment of greenhouse gas emissions, please refer Chapter 7.

Navigational and operational lighting is required on the FPSO facilities at levels that provide a safe working environment for personnel and maritime shipping safety. Typical FPSO lighting is from LED lights, with only a small number of high-pressure sodium floodlights. On average, illumination levels of approximately 200 Lux will be used in outdoor operational areas, with the exception of lighting for navigation and collision prevention. For the environmental impact and risk assessment of light, please refer Section 6.3.3.

3.7.6.5 Accommodation

The routine operational workforce will number up to approximately 60 people onboard each FPSO facility. During peak times only (e.g. hook-up and major shutdown events), additional people may be required and each FPSO facility will have the capacity to accommodate approximately 180 people. Accommodation for these people will be based on the FPSO facilities.

It is not currently anticipated that an accommodation support vessel (ASV) will be required to support commissioning or major maintenance. If an ASV is required to support hook-up and commissioning, it is only likely to be required for a short period (i.e. 6-12 months).

Each FPSO facility will include a Sewage Treatment Plant onboard to process sewage and sullage (grey water generated from domestic processes such as dish washing, laundry and showers). Treated sewage and sullage will be discharged to sea. For environmental impact and risk assessment of this discharge, refer Section 6.3.9.

Food scraps and other putrescible waste will be produced from each FPSO facility (approximately 1-2 kg per person per day), MODU and support vessels during all phases of the proposed Browse to NWS Project.
For environmental impact and risk assessment of this discharge, refer Section 6.3.11.

3.7.7 Inspection, Maintenance and Repair Activities (IMR)

The subsea infrastructure will be designed to require only minor degrees of intervention. Inspection and maintenance will be undertaken to ensure the integrity of the infrastructure and identify any problems before they present a risk of loss of containment. Intervention may be required to repair identified problems. Subsea activities can be broadly categorised into the following groups:

- Inspection - the process of physical verification and assessment of components in order to detect changes to its as-installed state in comparison to previous or baseline inspections. Typical subsea inspection activities may include visual inspection, cathodic protection (CP) surveys, side scan sonar/ multi-beam echo sounding, photogrammetry, process composition testing, corrosion probes, corrosion mitigation checks, metocean and seismic monitoring, cathodic protection testing and non-destructive measurement/testing, which may be supported by ROV or diver.
- Maintenance - required at regular and/or planned intervals to prevent deterioration or failure of equipment, or to maintain performance or reliability before failure or unacceptable deteriorations occurs. Maintenance activities may include cycling of valves, and leak and pressure testing.
- Repair - activities that may be required when a subsea system or component is degraded, damaged or has deteriorated to a level outside of acceptance limits as defined by design codes. Damage sustained may not necessarily pose an immediate threat to continued system integrity but may present an elevated level of risk to safety, health and environment or production reliability. Repair activities may also be associated with response to an emergency scenario.

Where IMR activities requires the subsea infrastructure to be entered, flushing will be performed before disconnecting a subsea component, to maximise hydrocarbon displacement in order to reduce potential residual hydrocarbon or chemical releases to the subsea environment upon disconnection.
The flushing chemicals used for this activity may be

supplied from either the facility or a chemical package via a downline from a support vessel. Flushing will take place at a predetermined rate, volume and/or duration designed to reduce the volume of residual hydrocarbons or chemicals within the component and adjoining structures prior to disconnection. Following disconnection, the residual hydrocarbon or chemical volume and the flushing medium will be released to the subsea environment. Post disconnection, residual hydrocarbons and chemicals may remain in the component due to the limiting factors discussed above. Prior to the component being lifted on board a support vessel; a secondary higher velocity flush may be required to ensure the component meets safety requirements for storage on the support vessel deck. If so, it will typically be flushed to the subsea marine environment with seawater (treated with biocide, oxygen scavenger and surfactant supplied from a chemical package) up to 10 times the volume of the component via a downline from a support vessel.

3.7.8 Decommissioning

At the end of the proposed Browse to NWS Project life, the facilities will be decommissioned in accordance with good oilfield practice and relevant legislation and practice at the time. Decommissioning will occur once the Brecknock, Calliance and Torosa reservoirs have reached the end of their economic life and may occur in stages. It is likely to include well suspension, plugging and abandoning wells.

In the event that additional reservoirs or third-party reservoirs have been tied into the proposed Browse to NWS Project infrastructure, this could increase the development's economic life and thus postpone decommissioning.

As per the OPGGS Act (Section 572(2)), all structures, equipment and other property will be maintained in good condition and repaired, that are: (a) in the title area; and (b) used in connection with the operations authorised by the permit, lease, licence or authority.

The OPGGS Act (Section 572(3)) outlines that a titleholder "must remove from the title area all structures that are, and all equipment and other property that is, neither used nor to be used in connection with the operations: (a) in which the titleholder is or will be engaged; and (b) that are authorised by the permit, lease, licence or authority". However, this obligation is subject to other provisions of the Act and allows titleholders to identify and seek approval for alternative arrangements, which will be demonstrated in activity specific Environment Plans. Subsequently, decommissioning activities may include:

- production wells plugged and abandoned, and all infrastructure removed from the seabed
- removal of manifolds
- removal of umbilicals
- purging and flushing of infield flowlines, BTL and inter-field spur line which may either be left in place or removed
- disconnection of the fibre optic extension cables which may either be left in place or removed
- disconnection from mooring and tow-away of FPSO facilities
- piles and mooring remain at location, within the seabed.

Given the expected life of the project, the decommissioning of the proposed Browse to NWS Project is not likely for many years. Given the possible improvements in technology that may occur between now and the time of decommissioning, it is not possible to fully scope the decommissioning strategy that will be employed at that time. The strategy (which may also include an assessment of alternatives to the complete removal of subsea infrastructure) will be demonstrated through activity-specific Environment Plans developed closer to the time.

3.7.9 Support Activities and Infrastructure

3.7.9.1 Logistics Support

The proposed Browse to NWS Project will require supply chain and logistics support during construction and operations. Requirements for supply chain and logistics support for the proposed Browse to NWS Project may include:

- port access for supply and support vessels to transfer people, equipment, materials and waste to and from the Project Area
- airport access for fixed-wing aircraft and helicopters to transfer people and supplies to and from the Project Area
- search and rescue capabilities
- onshore support for receiving, storing, and distributing materials and equipment.

The proposed Browse to NWS Project is not dependent on the development of new onshore supporting infrastructure to proceed. Supply chain and logistics support locations that have existing services and infrastructure for ongoing regular support over the whole life of the proposed Browse to NWS Project are being considered, with the assessment and selection focused on using supply chain services and infrastructure within WA.

Potential supply chain and logistics support locations in Australia include:

- Broome
- Djarindjin
- Dampier/Karratha
- Exmouth
- Perth.

Facilities in Broome include the Port of Broome, which is the main deep water port servicing the Kimberley region. The port supports livestock export, offshore oil and gas, supply vessels, pearling, fishing charter boats, cruise liners and is the main fuel and container receiving point for the Kimberley. Facilities at the port include an outer berth, two inner berths, fuel and potable water distribution facilities, a laydown area, lighting suitable for night work and a slipway. Other facilities include the Broome International Airport which is located in the centre of the town of Broome and includes a runway for fixed wing operations and a heliport which opened in 2008. A helipad is also available on site with space for four larger helicopters and 10 additional helicopter parking positions are available near the airport.

The King Bay Supply Base is located in the Port of Dampier and is operated by Woodside (Woodside 2014). The facility is suitable for a wide range of vessels varying in size and configuration such as harbour tugs, supply vessels, crew and utility vessels and transportation/heavy lift vessels.

Facilities in Djarindjin include a fixed and rotary wing aviation base which supports existing offshore oil and gas facility crew change operations.

As the proposed Browse to NWS Project will be using existing supply and logistics services and infrastructure which are managed by third parties, such services and infrastructure are not considered further as part of this assessment. The scope of this assessment is limited to vessel and helicopter movements between the Project Area and the potential supply chain and logistics support locations. Any activity at supply chain and logistics support locations is outside the scope of this assessment.

In addition, there may be a requirement to conduct short term, discrete logistical support activities from time to time at various port and airport locations along the coast of WA, Australia and internationally to support activities throughout the life of the proposed Browse to NWS Project. These activities are likely to be consistent with general shipping activities.

3.7.9.2 Project Vessels and Helicopters

The drilling and completion, installation and commissioning phases will be supported by barges, tugs, survey vessels, supply vessels (thereafter referred to as support vessels) and installation and pipelay vessels.

The operations phase will require a small number of vessels in attendance in the vicinity of the FPSO facilities for transporting personnel, stores, consumables, equipment and waste on a routine basis. The supply vessels will travel between the supply chain and logistics support facility (or facilities) and the FPSO facilities, while tugs will travel to the facility to support offloading as required. Vessels will also be required to support IMR activities. Support vessels typically are expected to have between 20 and 100 POB each vessel, although this may increase depending on the type of vessel.

Personnel transfer to offshore facilities from Broome will be either via helicopter or vessel. If helicopters are used, it is anticipated that up to five personnel transfers a week per FPSO facility will be required during normal operations.

Fast crew transfer vessels may be used for crew transfer. These crew transfer vessels are capable of travelling at 50 – 55 knots. It is anticipated that one transfer per day would occur during normal operations, with additional transfers during shut downs and major maintenance.

Vessel requirements during the decommissioning phase are unknown at this stage as decommissioning plans have not been finalised. However, it can be expected that decommissioning may use similar vessels to those engaged for installation activities.

Vessels are expected to have a number of similar discharges to the FPSO facilities, including cooling water, treated utility water, sewage and putrescible waste. The fuel source for power generation on vessels will likely be diesel.

3.7.9.3 Communications

Due to the distance of the Browse Development Area from the mainland, a reliable high-speed communication network will be required between the FPSO facilities and the mainland. The network is likely to be supplied by connection of an extension cable to an existing fibre optic cable.

Installation, including cable lay to the vicinity of the proposed FPSO, has been undertaken by the cable owner and is outside the scope of the draft EIS/ERD. The cable owner has laid the cable and includes a junction box in the vicinity of the proposed FPSO. Extension cable laid from the junction box and connection to the proposed FPSO facilities is within the scope of this draft EIS/ERD and will include connection of the extension cable to the junction box and extension cable lay to the proposed FPSO facilities locations, where it is likely to be connected to the dynamic umbilical riser bases for both the import and export systems. These operations are likely to be undertaken by ROV. The extension cable from the junction box will either be surfaced laid (with natural burial over time) or buried (via ploughing or trenching).

Communications during construction and IMR activities will be via standard offshore communications systems.

3.8 Development Alternatives

3.8.1 Selection of the Browse to NWS Concept

The BJV has conducted multiple 'Concept Select' phases for the commercialisation of the Browse reservoirs. The following four potential broad development themes have been considered since 2004:

- piping Browse gas to the Kimberley for processing onshore (James Price Point (JPP) development concept)
- piping Browse gas to the Burrup Peninsula for processing onshore
- piping Browse gas to Darwin for processing onshore
- floating LNG (FLNG), where processing would take place on a floating facility.

As detailed in **Section 2.7.1**, the BJV has previously progressed two development concepts through to FEED, the James Price Point (JPP) development concept and the FLNG development concept. The outcome of both of these processes was that each concept did not meet Woodside's commercial requirements for a positive FID.

After previous negative investment decisions, the BJV decided to re-assess its approach to developing the Browse resource. It formed an Owners Working Group to reassess and co-create the future of Browse. In total, 39 alternative concepts were identified and assessed, considering current market conditions.

Within the requirements of good oil-field-practice, a number of business drivers were considered in selecting the development concept. The primary drivers were:

- safety
- economic performance
- optimising economic recovery.

In support, the following set of key drivers were used to guide decision making:

- Global competitiveness: decisions should aim to increase value and maintain a globally competitive cost of supply, where decisions should balance the risk and reward.
- Flexibility & robustness: decisions should seek to minimise risk and maintain robustness to wide range of uncertainties, where simple solutions should be favoured over more complex alternatives. Decisions should also minimise any impacts to future operability, availability or maintainability; consider the execution feasibility and not introduce excess risk in construction; and should consider how they may impact the commercial arrangements.
- Stakeholder acceptance: ability to achieve stakeholder alignment, government approvals in the desired timeframe and supported by the BJV as a whole. All HSE risks should be managed to ALARP and seek to apply inherently safe principles.
- Marketability: decisions should not impact the ability to market the Browse products.

An initial qualitative screening of each of 39 options against the following criteria was carried out: Integration, Sustainability, Political, Organisational, Commercial, Economic and Technical (ISPOCET). A concept selection and optimisation process was undertaken to incorporate the key insights and opportunities identified in the previous phase, to generate a shortlist of concepts with the potential to have line of sight to a globally competitive development concept. In July 2017, the BJV unanimously decided to proceed with the Browse to NWS development concept.

3.8.2 Comparison with Previous Browse Concepts

Throughout the approvals process of the previous Browse development concepts, including the JPP and the FLNG concepts (approved under EPBC Act and deemed not assessed under the WA EP Act), various technical studies were undertaken to inform the assessment of the impacts and risks associated with the development concept. Many of the potential environmental impacts associated with offshore drilling and completion, installation and operational activities of the previous development concepts remain unchanged and relevant to the proposed Browse to NWS Project. Similarities between the concepts include the number and locations of wells and subsea tiebacks, which have either reduced or remain broadly unchanged. The notable differences are the addition of the inter-field spur line and the BTL.

Significant work to support previous environmental approvals has been undertaken with respect to understanding, assessing and mitigating potential environmental impacts and risk. Due to the similarities between the Browse to NWS Project and previous concepts, this work has been used to inform the impact and risk assessment, where appropriate. Compared to the approved FLNG development concept, in terms of environmental aspects, the proposed Browse to NWS Project is expected to lead to:

- a reduction in the number of offshore facilities (2 x FPSO vs 3 x FLNG). Only one FPSO will be located at Torosa (compared to 2 x FLNG). Only one FPSO will be located at Calliance/Brecknock (compared to 2 x FLNG)
- a reduction in the number of development wells from 64 over development life to a maximum of 54
- a reduction in shipping near Scott Reef as there will be no LNG offtake
- a reduction in cooling water discharge

- approximately the same amount of condensate storage per FPSO and offtake (slight reduction overall due to 2 x FPSO vs 3 x FLNG)
- increased capacity for PW discharge during later field life
- approximately the same distance between the facilities and Scott Reef
- a reduction in noise sources (fewer offshore facilities, less well drilling, completion and well unload (drilling and completion) activities, no LNG tanker traffic)
- a reduction in mono ethylene glycol (MEG) injection requirements relating to a change from continuous MEG injection to active heating (noting that MEG injection will still be required for start-up and shutdown)
- a change to MEG discharge within the FPSO PW stream as opposed to recovery on a FLNG facility. This will result in higher MEG concentrations discharged but only at flowline or well restarts as opposed to continuous trace MEG concentrations in the PW stream.
- decreased energy consumption (CO_2) for offshore processing as compared to FLNG, based on removal of liquefaction requirements from the proposed offshore development concept, with this decrease partially offset by additional requirement for export compression
- increased seabed disturbance due to installation of the BTL and the inter-field spur line.

Table 3-4 provides a comparative assessment of the impacts and risks to relevant MNES and EPA Environmental factors for the proposed Browse to NWS Project and alternate development concepts.

Table 3-4 Comparative Assessment of Development Alternatives Impacts and Risk to MNES and WA EPA Environmental Factors

	Comparison proposed Browse to NWS Project vs Infield Development with New Onshore Processing Facility	Comparison proposed Browse to NWS Project vs FLNG Development Concept
Project differentiators		
	The proposed Browse to NWS Project has similar subsea infrastructure requirements with a similar number of offshore facilities and a longer gas export pipeline than a new onshore processing development concept such as the JPP Development Concept. The key differentiator is the use of an existing onshore processing facility which removes the requirement for significant onshore development.	The proposed Browse to NWS Project has similar subsea infrastructure requirements with a reduced number of offshore facilities when compared to the FLNG Development Concept. No gas export pipeline or onshore processing facilities would be required for the FLNG Development Concept.
Relevant Matters of National Environmental Significance		
Listed Threatened Species and Ecological Communities Listed Migratory Species	There is likely to be significantly lower impact and risk to listed threatened species, ecological communities and listed migratory species from the Browse to NWS Project, when compared to the development of a new onshore processing facility. This is due to the additional impact and risk to marine and terrestrial flora and fauna and their habitats from the development footprint associated with onshore facilities, dredging, trenching and clearing of native vegetation.	The key differentiator between the proposed Browse to NWS Project and the FLNG Development Concept is the requirement for the BTL and inter-field spur line. The installation of the BTL and inter-field spur line is not expected to result in significant additional impact or risk to listed threatened species and ecological communities or listed migratory species. As such, both concepts are considered to present a similar impact and risk to these MNES.

	Comparison proposed Browse to NWS Project vs Infield Development with New Onshore Processing Facility	**Comparison proposed Browse to NWS Project vs FLNG Development Concept**
The Commonwealth Marine Area	Both the proposed Browse to NWS Project and the onshore development concept would be likely to have broadly similar discharge and emissions to the Commonwealth Marine Environment. While a longer gas export pipeline is required for the proposed Browse to NWS Project, this is not expected to have a significant impact. As such, both concepts are considered to present a similar risk to the Commonwealth Marine Environment.	The proposed Browse to NWS Project is likely to have slightly less discharge and emissions to the Commonwealth Marine Environment than the FLNG Development Concept. While a gas export pipeline would be required for the proposed Browse to NWS Project, this is not expected to have a significant impact. As such, both concepts are considered to present a broadly similar impact and risk to the Commonwealth Marine Environment.
National Heritage Places	The controlling provision 'National Heritage Places' is addressed in North West Shelf Project Extension Proposal (EPBC 2018/8335 and EPA 2186).	No impact to National Heritage Places would be likely to occur as a result of the FLNG Development Concept.
Relevant EPA Environmental Factors		
Benthic Communities and Habitats	There is likely to be significantly lower impact and risk to benthic communities and habitats from the Browse to NWS Project when compared to the development of a new onshore processing facility. This is due to the additional impact and risk to marine and terrestrial flora and fauna and their habitats from the development footprint associated with onshore facilities, dredging, trenching and clearing of native vegetation.	Impacts to benthic communities and habitats in the State Proposal Area are expected to be broadly similar between the proposed Browse to NWS Project and FLNG Development Concept.
Marine Environmental Quality	Both the proposed Browse to NWS Project and the onshore development concept would be likely to have broadly similar discharge and emissions to the State Proposal Area around Scott Reef. However, a new onshore development would be likely to have higher levels of impact and risk within State jurisdiction at the onshore development site due to construction and operational discharges from onshore facilities. As such, impacts and risks to marine environmental quality are considerably less for the proposed Browse to NWS Project than the new onshore development option.	Impacts to marine environmental quality in the State Proposal Area are expected to be broadly similar between the proposed Browse to NWS Project and FLNG Development Concept.

	Comparison proposed Browse to NWS Project vs Infield Development with New Onshore Processing Facility	Comparison proposed Browse to NWS Project vs FLNG Development Concept
Marine Fauna	Both the proposed Browse to NWS Project and the onshore development concept would be likely to have broadly similar impacts and risks to marine fauna within the State Proposal Area around Scott Reef. However, a new onshore development would be likely to have higher levels of impact and risk within the State Proposal Area at the onshore development site due to construction and operational discharges from onshore facilities (including dredging requirements). As such, impacts and risks to marine fauna are considerably less for the proposed Browse to NWS Project than the new onshore development option.	Impacts to marine fauna in the State Proposal Area are expected to be broadly similar between the proposed Browse to NWS Project and FLNG Development Concept.
Air Quality	Impacts to air quality are expected to be significantly less between the proposed Browse to NWS Project and the new onshore development option as a result of significantly less emissions produced during construction.	Impacts to air quality are expected to be broadly similar between the proposed Browse to NWS Project and FLNG Development Concept.

3.8.3 Refinement of the Browse to NWS Concept

3.8.3.1 Development infrastructure location determination

Modifying the location of development infrastructure has the potential to affect operational requirements, which in turn may affect resource recovery and the economic viability of the proposed Browse to NWS Project. In particular for the Torosa reservoir in close proximity to Scott Reef, placement of the proposed project infrastructure has been based on the following considerations:

- All infrastructure must avoid physical footprint disturbance to Scott Reef shallow water benthic communities and habitats (i.e. > 75 m water depth).
- The Torosa reservoir is more extensive and potentially more compartmentalised than the Brecknock and Calliance reservoirs and, therefore, likely to require access (i.e. drilling) from a number of locations to allow optimal recovery of reserves. The number of wells has been optimised to balance environmental objectives, operational requirements and optimal recovery of reserves.
- FPSO facility locations have been selected based on optimised subsea infrastructure layout to reach the proposed drilling locations to access the Torosa reservoir. Unnecessary infrastructure or extended flowline lengths would add significant cost due to increased raw material and installation requirements, unnecessarily increase the environmental impact due to the additional material requirements and seabed disturbance, and present operational challenges (such as assurance of hydrocarbon flow through the flowlines).

3.8.3.2 BTL and inter-field spur line route selection

A comprehensive route selection assessment process was undertaken for the proposed BTL and inter-field spur line, which included a reconnaissance survey aimed at identifying a viable corridor for the BTL and inter-field spur line. Initial screening explored the option of a direct pipeline to shore (i.e. no tie-in into 2TL), however, this was deemed to be unviable due to the prohibitive cost and additional seabed and nearshore/shoreline disturbance.

A key design consideration for the BTL and inter-field spur line route was to minimise risks associated with geohazards, metocean hazards and abrupt bathymetry features such as sand waves and steep slopes. As such, the route has been selected to run at depths of between 280 and 400m, to minimise the requirement for secondary stabilisation (and hence seabed disturbance) before turning towards the mainland and the tie-in point near NRC at a depth of approximately 125m. Within this constraint, the reconnaissance survey was used to identify the proposed route.

It should be noted that, as shown in **Figure 2-2**, the route is subject to refinement, particularly near the Rowley Shoals and the tie-in point near NRC.

Two alternative routes were considered (**Figure 3-5**). The key drivers considered in the route selection process, and an assessment of the proposed route and alternatives are presented in **Table 3-5**. Alternatives considered included:

- Avoiding incursion into the Kimberley Marine Park (Multi Use Zone) by locating the BTL north of the marine park. While potentially technically viable, this alternative would result in significant increased complexity due to water depths greater than 600m and associated risk due to the large changes in water depth that would occur along the route. The increased route length would also result in increased habitat modification as a result of seabed disturbance and a greater requirement for steel (due to the longer pipeline), with associated indirect impacts.
- Avoiding incursion into the Argo-Rowley Terrace Marine Park Multi Use Zone (VI) and increasing separation from Mermaid Marine Park (National Park Zone (II)) and the Rowley Shoals State Marine Park by locating the BTL further south. The reconnaissance survey identified significant sand waves to the south of Rowley Shoals which constrained route selection. Installation of the BTL in this area would require significant seabed preparation. This was not considered preferable due to the additional disturbance to the seabed. By locating the BTL further south this would also result in the BTL being placed in significantly shallower water that would require additional environmental impact of secondary stabilisation. This has also been deemed as unviable due to the additional life of field integrity risks associated with pipeline stability in shallow waters. As such, the proposed BTL route is closer to the Rowley Shoals than initially proposed and will traverse the Multiple Use Zone (VI) of the Argo-Rowley Terrace Marine Park (Commonwealth). However, while the final BTL route has yet to be confirmed, these sand waves may lead to the BTL being located within the KEF of Mermaid Reef and Commonwealth waters surrounding Rowley Shoals (**Figure 5-43**) but outside of the State Rowley Shoals Marine Park and Commonwealth Mermaid Reef Marine Park (National Park Zone (II)) (**Figure 5-44**).

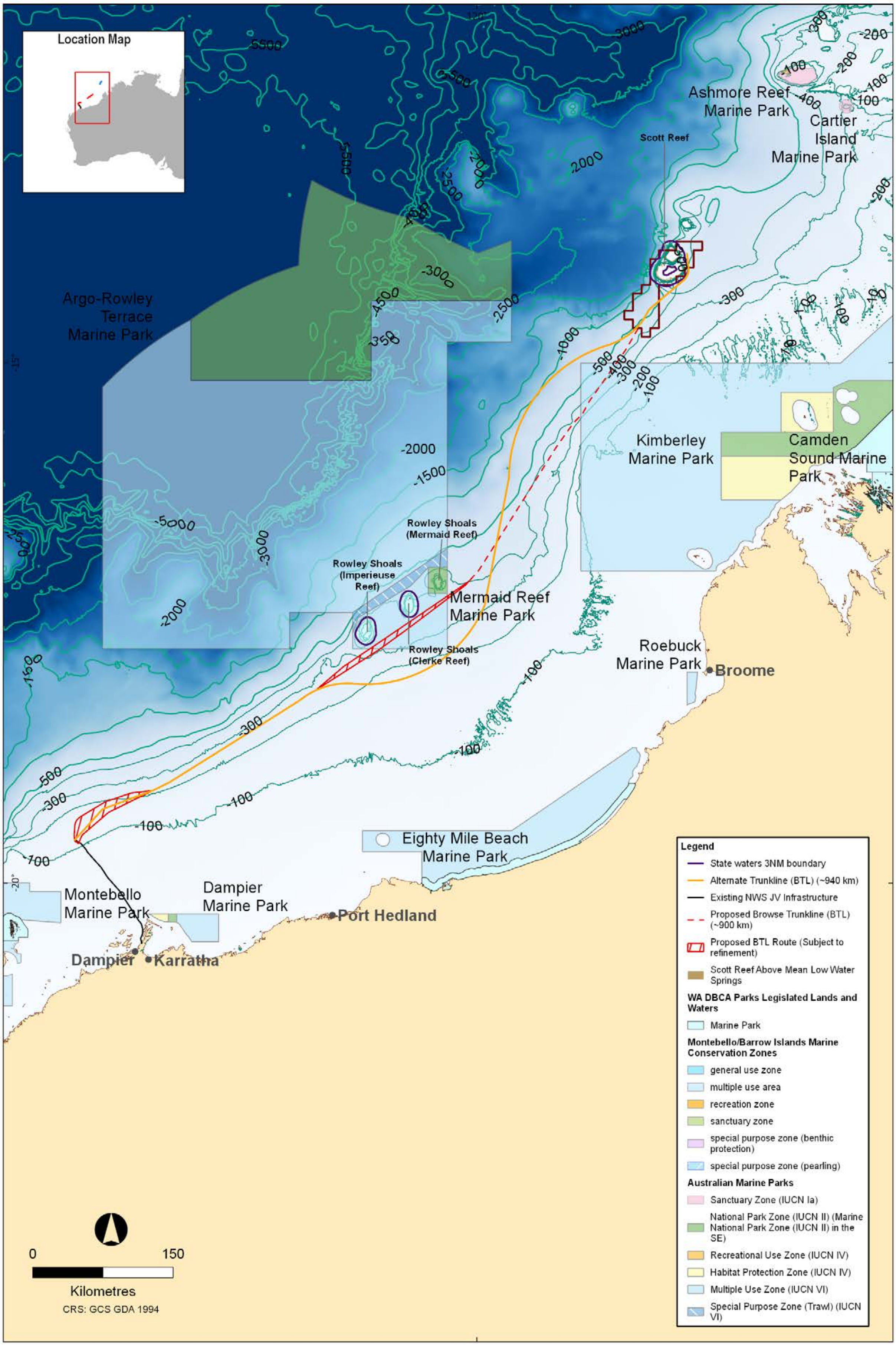

Figure 3-5 Alternative Browse Trunkline Route considered

Table 3-5 BTL and Inter-field Spur Line Route Assessment

Objective	Proposed Route	Alternative 1 – Avoid incursion into Kimberly Marine Park Multi Use Zone	Alternative 2 – Avoid incursion into Argo-Rowley Terrace Marine Park Multi Use Zone/ Increase separation from Mermaid Marine Park National Park Zone & Rowley Shoals State Marine Park
Minimise health and safety risk	The proposed route represents the lowest health and safety risk as it: + presents the most technically simple approach that inherently reduces health and safety risk + reduces the number of start-up laydowns + minimises the structures to be laid on the seabed + minimises the construction period. In addition, the route has been selected to reduce the BTL exposure to high seabed and cyclonic currents, thus reducing the need for installation of secondary stabilisation.	Alternative 1 increases health and safety risk (in comparison to the proposed route) as: + the deviation results in significant depth changes along the route, increasing technical complexity which inherently increases health and safety risk + potentially increases the number of start-up laydowns due to increased route length + it increases the construction period.	Alternative 2 increases health and safety risk (in comparison to the proposed route) as: + the deviation results in a significant increase in complexity due to the requirement for significant seabed preparation (due to the presence of sand waves south of Rowley Shoals) and secondary stabilisation due to the shallow waters where installation would occur. This increase in complexity inherently increases health and safety risk. + The additional complexity will require additional vessels to manage seabed preparation and secondary stabilisation, increasing health and safety exposure. + it increases the construction period.

Objective	Proposed Route	Alternative 1 – Avoid incursion into Kimberly Marine Park Multi Use Zone	Alternative 2 – Avoid incursion into Argo-Rowley Terrace Marine Park Multi Use Zone/ Increase separation from Mermaid Marine Park National Park Zone & Rowley Shoals State Marine Park
Minimise environmental impacts and risks	The proposed route has been selected as it addresses all other criteria while limiting environmental impacts to an acceptable level. Specifically: + The shortest viable route has been selected to minimise the amount of seabed disturbance required. + The route has been selected to reduce the tonnage of steel which minimises the indirect environmental impact associated with production of pipeline. + The route minimises the amount of seabed preparation and secondary stabilisation required. + The route avoids key environmental sensitivities are far as practicable.	Alternative 1 eliminates impacts (primarily seabed disturbance) within the multiple use zone of the Kimberley Marine Park. Alternative 1 also reduces the distance the BTL traverses the Continental Slope Demersal Fish Communities KEF. Alternative 1 results in increased impact to the marine environment as it increases the BTL route length, which results in an increase in habitat modification due to seabed disturbance. An increased requirement for steel also results in indirect environmental impact associated the production of pipeline. Longer construction time results in additional air emissions and increased risk with respect to unplanned incidents and events such as a hydrocarbon spill.	Alternative 2 eliminates impacts (primarily seabed disturbance) within the multiple use zone of the Argo-Rowley Terrace and the Mermaid Reef and Commonwealth water surrounding Rowley Shoals KEF. It also reduces risks to the Mermaid Marine Park national park zone and the State Rowley Shoals Marine Park from unplanned incidents and events. Alternative 2 results in increased impact to the marine environment as it increases the BTL route length which results in more habitat modification due to seabed disturbance. The requirement for additional seabed preparation (due to sand waves) and secondary stabilisation (due to shallow water) further increases impacts on benthic habitats. An increased requirement for steel also results in indirect environmental impact associated the production of pipeline.

Objective	Proposed Route	Alternative 1 – Avoid incursion into Kimberly Marine Park Multi Use Zone	Alternative 2 – Avoid incursion into Argo-Rowley Terrace Marine Park Multi Use Zone/ Increase separation from Mermaid Marine Park National Park Zone & Rowley Shoals State Marine Park
Minimise environmental impacts and risks cont.	The proposed route traverses the: + Continental slope demersal fish communities KEF. + Seringapatam Reef and Commonwealth water in the Scott Reef Complex KEF. + Mermaid Reef and Commonwealth water surrounding Rowley Shoals KEF which may be entered depending on the final selected route. + Ancient coastline at 125 m depth contour KEF. The proposed route also traverses: + Kimberley Marine Parks (multiple use zone). + Argo-Rowley Terrace (multiple use zone). The proposed route passes ~2 km from the Mermaid Reef Marine Park (national park zone). ~3 km from the Rowley Shoals State Marine Park.		Longer construction time results in additional air emissions and increased risk with respect to unplanned incidents and events such as a hydrocarbon spill.
Simplicity	As described above, the selected route presents the most technically simple approach.	Increased technical complexity in relation to significant changes in water depth along the route.	Significantly increased technical complexity in relation to significant changes in water depth along route, and the requirement for increased seabed preparation (due to sand waves) and secondary stabilisation (due to shallow waters).

Objective	Proposed Route	Alternative 1 – Avoid incursion into Kimberly Marine Park Multi Use Zone	Alternative 2 – Avoid incursion into Argo-Rowley Terrace Marine Park Multi Use Zone/ Increase separation from Mermaid Marine Park National Park Zone & Rowley Shoals State Marine Park
Existing infrastructure	The route has been selected to maintain a minimum 250 m separation between the BTL and known existing seabed infrastructure including abandoned exploration wells. Consideration was also given to limiting possible interaction with the Finders Resources indicative reservoir area where practical.	As per proposed route.	As per proposed route.
Stakeholder Acceptance	No significant impacts to stakeholders such as commercial fisheries, shipping, industry or tourism and recreation are expected.	As per proposed route.	As per proposed route.
Cost	The selected route minimises route length, construction timeframe and secondary stabilisation requirements and presents the most cost effective viable option.	Additional route length and technical complexity increase construction cost.	Additional route length, as well as significant seabed preparation (due to sand waves) and secondary stabilisation (due to shallow water) requirements significantly increase construction costs.
Feasibility	Normal practice so no significant feasibility issues anticipated.	Significant depth changes and increase in pipeline length likely to test technical and financial feasibility.	Sand waves south of Rowley Shoals and the requirement to lay BTL in shallow waters significantly increases technical risk and associated cost.

3.8.3.3 Produced water disposal options assessment

Detailed consideration was given to the disposal of PW. Options considered for the proposed Browse to NWS Project were:

- PW disposal overboard to sea
- PW disposal to a reservoir via re-injection
- PW disposal onshore.

PW disposal onshore (via exporting PW on offtake tankers) has been screened out as it is was not deemed a viable life of project solution.

Table 3-6 presents a comparative assessment of the PW disposal options.

Table 3-6 PW Disposal Options Comparison

Objective	PW disposal overboard to sea	PW disposal to a reservoir via re-injection
Minimise health and safety risk	Lowest health and safety risk, inherently safe option.	Requires drilling and completion of two water disposal wells (MODU), associated subsea infrastructure (installation vessel) plus, additional topsides equipment including high pressure re-injection pumps. Increased health and safety risk to personnel associated with additional high pressure re-injection systems and associated flowlines and injection wells.
Minimise environmental impacts and risks	Ongoing impact associated with continuous discharge of PW and associated PW mixing zone.	Removes PW environmental impact (when operating) Minor increase in GHG emissions associated with higher power requirements for re-injection pumps.
Simplicity	Requires PW treatment technologies to meet discharge requirements are well understood.	Complexity introduced with reservoir management requirements requiring incorporation of PW re-injection monitoring as well as operational complexity with the topsides and subsea infrastructure.
Stakeholder Acceptance	Potential stakeholder concerns due to ongoing impact associated with continuous discharge of PW and associated PW mixing zone.	No significant challenges anticipated.
Cost	No incremental increase as treatment facility likely to be required for both options	Cost estimated to be significantly higher
Feasibility	Normal practice so no significant feasibility issues anticipated	Feasible, subject to identification of suitable reservoir target, albeit with increased complexity associated with additional infrastructure installation and operations.

A detailed environmental impact and risk assessment of PW has been conducted (refer Section 6.3.12). This assessment has concluded that no significant environmental impacts are predicted and that the discharge of PW is acceptable. The increased health and safety risks, technical complexity, capital and operating costs associated with PW re-injection into a reservoir, are considered to be grossly disproportionate to the environmental benefit likely to be gained from this approach.

Therefore, it is considered that PW re-injection is not a viable option and PW disposal to sea is the preferred option for the proposed Browse to NWS Project.

3.8.3.4 Selection of hydrate management strategy

Consideration has been given as to the best way to manage hydrate formation in subsea infrastructure. Options considered for the proposed Browse to NWS Project were:

- Continuous MEG injection with MEG regeneration; or
- Active heating of flowlines and risers, with MEG injection of unheated subsea components during shutdowns.

Under continuous MEG injection and regeneration, there would be minimal discharge of MEG in PW, as MEG is essentially a closed loop system. Under an active heating alternative, MEG is inboarded into the FPSO, diluted to meet acceptable levels and then discharged as part of the PW stream.

MEG regeneration is an energy intensive process, and the adoption of active heating of the flowlines and risers is expected to save approximately 0.20 MT CO_2-e per anum compared to the use of MEG regeneration. Given that MEG is considered to be a PLONOR substance, the environmental benefit gained from CO_2-e emissions savings are considered to outweigh the environmental impact of discharging MEG in PW. The hydrate management strategy minimises MEG discharge, as MEG is only required for the components of the subsea infrastructure which do not have active heating and is only expected to be used when the infrastructure is not operating.

3.8.3.5 Geosequestration

Refer to Section 7.7.3.

3.8.3.6 Consideration of CO_2 injection to manage subsidence

Given the location of a portion of the Torosa reservoir under Scott Reef, and the risk of unplanned subsidence from hydrocarbon extraction, consideration has been given to reinjecting the CO_2 component of the reservoir fluid back in to the depleted portion, in the context of technical feasibility and other risks this may introduce.

CO_2 injection into depleted oil or wet gas reservoirs is a proven technology, although this is principally used as a means of maximising the recovery of heavier hydrocarbons through improved sweep efficiency. It is widely applied onshore but more limited in offshore applications. Re-injection of CO_2 is typically undertaken at the end of reservoir life and application throughout field life for dry gas reservoirs is relatively novel. Risks associated with the injection of CO_2 into the production reservoir include substantial production risks and technical integrity risks associated with a reservoir fluid with higher CO_2 content.

Woodside has, therefore, deemed CO_2 re-injection into the gas reservoir to enhance gas recovery or to manage subsidence as not appropriate for the proposed Browse to NWS Project. Consideration of CO_2 re-injection as a means of managing carbon emissions is discussed in Chapter 7.

3.8.3.7 Consideration of seawater injection to manage subsidence

Based on the characteristics of the Torosa reservoir, Woodside anticipates production to be conducted under ‘depletion drive’ conditions, whereby production is enhanced by the expansion of the gas as pressure in the reservoir decreases due to hydrocarbon extraction from the well. Injection of significant volumes of water to replace gas extracted from the reservoir would alter the gas to liquid ratio in the reservoir and affect pressure in the reservoir and production rates.

3.9 Social and Economic Matters

Section 6.4 outlines details of the Social Impact Assessment undertaken for the proposed Browse to NWS Project.

With regards to the possible economic benefits that may flow from the proposed Browse to NWS Project, Woodside commissioned ACIL Allen to prepare an Economic Impact Assessment to consider the potential benefits that may flow from its various activities to the Karratha region, the Shire of Broome and the broader Western Australian and Australian economies.

ACIL Allen utilised its in-house computable general equilibrium model, Tasman Global. ACIL Allen modelled three development scenarios and assessed the economic impact of three scenarios against a modelled baseline scenario. One of the scenarios was ‘Browse and NWS Project Extension’, which modelled the economic impact of proposed upstream and downstream developments associated with Woodside and its joint venture partners’ interests in the Browse Basin. This included development of the Brecknock, Calliance and Torosa fields, associated subsea infrastructure, connection to the NWS Project Infrastructure and logistics through Broome in the Kimberley region.

ACIL Allen concluded that the Browse and NWS Project Extension scenario is expected to result in a significant direct contribution to the Australian economy through capital and operational spending, employment, taxation and royalty payments and exports and is expected to generate:

- capital expenditure of $36 billion in Western Australia between 2019-2063, including $27.3 billion on the proposed Browse project
- peak construction workforce of over 1,800 jobs in 2024 or, on average, 700 jobs per annum between 2019 and 2063
- around 720 operations jobs created or sustained on average during operations, including up to 320 jobs in the Karratha region during operations
- $493 million of annual average operational expenditure in WA, including $15 million of spend per annum for Broome logistics support activities
- almost $63 billion of total taxation and royalty payments.

Further detail, including the assumptions on which the assessment is based, is available on ACIL Allen's website: https://www.acilallen.com.au/insights/future-development.

The proposed Browse to NWS Project is considered to be the development concept most likely to achieve commercialisation of the Browse resources. Partial development of those resources would affect the potential commercial viability of the proposed Browse to NWS Project.

CHAPTER 4

STAKEHOLDER CONSULTATION

4. STAKEHOLDER CONSULTATION

4.1 Overview

Stakeholder consultation and engagement is an integral component of the environmental impact assessment and environmental approvals process. This section describes Woodside's approach, as the Operator of the proposed Browse to NWS Project, to stakeholder consultation broadly and for the proposed Browse to NWS Project specifically.

Woodside's objectives for stakeholder consultation are to:

- improve stakeholder awareness and understanding of the proposed Browse to NWS Project.
- provide stakeholders with opportunities to obtain information about the proposed Browse to NWS Project. This includes the physical, ecological, socio-economic and cultural environment that may be affected, the potential impacts that may occur, and the prevention and mitigation measures proposed to avoid or minimise those impacts.
- collect feedback from stakeholders on their concerns regarding the proposed Browse to NWS Project and, where possible, address stakeholder concerns through further activities or by implementing additional mitigation measures.

Woodside has engaged extensively with stakeholders in the past about previous development concepts, as described in the following sections. Specific engagement concerning the proposed Browse to NWS Project has also been undertaken with identified stakeholders.

4.2 Historical Stakeholder Engagement

Woodside has been engaging with stakeholders about development of the Browse resources since 2004. At first this related to the JPP concept and then the previous FLNG Development concept. A wide variety of stakeholders, including environment and conservation groups, NGOs, Commonwealth, State and Local Government, tourism operators, fishing groups, Aboriginal representatives, local businesses and service providers, and local communities were involved in the process.

Feedback from previous stakeholder engagement was reviewed when engagement activities were planned for the proposed Browse to NWS Project. This feedback was also considered in the preparation of this draft EIS/ERD, as many of the project components were carried over from previous concepts.

4.2.1 James Price Point Development Concept

Stakeholder engagement regarding the development of the Browse resources by means of the JPP concept began in 2004. This informed the draft Upstream EIS, which was published for public review in November 2011 (EPBC Referral 2008/4111).

As part of the stakeholder engagement process for the JPP Concept, Woodside consulted with a wide range of stakeholders and established a number of key groups, including the:

- Community Reference Group (CRG) – workshops to gauge broader, representative community values and views
- Marine Expert Advisory Panel (MEAP) – international marine ecology experts
- Expert Advisory Panel
- Marine Users Working Group (MUWG) – marine based stakeholders from fishing, pearling and marine tourism
- Independent Peer Review Panel (IPRP)
- Perspectives Group (Reconciliation Action Plan commitment).

Key methods of engagement during consultation relating to the JPP Concept included:

- production of the Scott Reef Status Report in 2009
- publishing research in international, peer reviewed journal articles
- presentation of scientific work at national and international conferences
- information sessions aimed at presenting survey data to interested parties
- Browse Development update meetings
- stakeholder information sessions and facilitated workshops
- the opening of a regional Woodside office in 2010.

4.2.2 FLNG Development Concept

The FLNG development concept stakeholder engagement included representatives from Commonwealth, State and local government, businesses and the fishing industry, non-government organisations (NGOs) and the tourism industry. Stakeholders included those with which Woodside had already established a working relationship as part of its ongoing activities in WA and the Browse Basin, as well as those identified through engagements with regulators, government agencies, desktop research and regional contacts. A full list of stakeholders engaged during the FLNG Development Concept stakeholder engagement can be found in the Browse FLNG Development Draft EIS (Woodside Energy Limited, 2014).

Methods used to identify key issues relating specifically to the previous Browse FLNG Development included:

- group and individual face-to-face meetings
- factsheets distributed to stakeholders
- Woodside's website
- Woodside's regional office.

Indigenous Stakeholders
Other than Indigenous Indonesian fishers, no Indigenous stakeholders were identified in relation to the Browse Development Area (**Figure 2-1**) during consultation in relation to either the JPP or FLNG Development Concepts.

There are no known sites of Aboriginal Heritage significance located within the Browse Development Area according to the WA Department of Aboriginal Affairs' Aboriginal Sites Inquiry System.

4.2.3 Key Issues

The following stakeholder issues previously identified during the stakeholder engagement process remained current for the proposed Browse to NWS Project: interaction with protected areas under Commonwealth and State legislation

- interactions with fisheries, including increased traffic resulting in increased risk of collisions
- understanding of physical and ecological characteristics of the Browse Development Area
- aspects of petroleum development with potential for impact on listed species, such as vessel movements, light, GHG and underwater noise emissions
- the potential impact on the amenity value of Scott Reef
- the risk of the introduction and establishment of Invasive Marine Species (IMS) and resulting impact on fisheries
- the risk of a significant hydrocarbon spill and resultant impacts
- the proposed supply chain and economic opportunities for the local community
- cumulative impacts
- decommissioning.

Each of these issues have been considered within this draft EIS/ERD.

4.3 Stakeholder Engagement Specific to the Proposed Browse to NWS Project

The process for stakeholder consultation, as undertaken by Woodside as the Operator of the proposed Browse to NWS Project, included the identification of stakeholders and their relevance to the project.

Table 4-1 shows stakeholders and stakeholder groups involved. They were identified as a result of historical stakeholder engagement, Woodside's ongoing activities, direct engagements with government agencies and regulators and via community engagements and forums.

Table 4-1 Identified stakeholders

Commonwealth Government Agencies	
Department of Industry, Innovation and Science (DoIIS)	National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA)
Department of Environment and Energy (DoEE)	National Offshore Petroleum Titles Administrator (NOPTA)
Australian Industry Participation Authority	Australian Fisheries Management Authority (AFMA)
Department of Agriculture and Water Resources - Biosecurity	Department of Foreign Affairs and Trade (DFAT)
Department of Prime Minister and Cabinet	
WA State/Local Government Agencies	
Environmental Protection Authority	Department of Mines, Industry Regulation and Safety
Department of Jobs, Tourism, Science and Innovation	Department of Transport
Department of Planning, Lands and Heritage	Shire of Broome
Department of Education	Kimberley Ports Authority/Port of Broome
City of Karratha	Kimberley Development Commission
Regional Development Australia	Pilbara Development Commission
Traditional Owner Groups/Aboriginal Stakeholders	
Murujuga Aboriginal Corporation (MAC)	Ngarluma Yindjibarndi Foundation Ltd (NYFL)
Nyamba Buru Yawuru	Kimberley Land Council
Ngarluma Aboriginal Corporation (NAC)	Beagle Bay Community
Djarindjin Community Corporation	Lombadina Community Corporation
Kullarri Regional Communities Indigenous Corporation	Ardyaloon (One Arm Point) Community Corporation
Five language groups with interests in the Burrup Peninsula: Ngarluma, Yindjibarndi, Wong-Goo-Tt-Oo, Yaburara and Mardudhunera	
Business/Tourism/Peak Bodies/Education providers	
Broome Chamber of Commerce and Industry	Broome Future Alliance
Broome International Airport	Kimberley Marine Supply Base
Djarindjin Airport	North West Regional TAFE
Kimberley Marine Tourism Association	Broome Visitor Centre
Local service providers	
Non-Government Organisations	
Australian Conservation Foundation	The Wilderness Society of WA
World Wildlife Fund	Save the Kimberley
Conservation Council of WA	Environs Kimberley
Friends of Australian Rock Art (FARA)	Market Forces
Greenpeace	
Fisheries	
Western Australia Fishing Industries Council (WAFIC)	Australian Fisheries Management Authority (AFMA)
Commonwealth Fisheries Association	
Industry	
Australian Petroleum Production and Exploration Association (APPEA)	Chamber of Minerals and Energy of Western Australia (CME)
Australian Marine Oil Spill Centre (AMOSC)	Various oil and gas operators

Members of State and Federal Parliament including Ministers and Shadow Ministers were identified and engaged. They are not individually listed above.

4.3.1 Voluntary Social Impact Assessment (SIA)

In 2018, Woodside commissioned a voluntary Browse to NWS Project SIA of the proposed Browse to NWS Project to support internal decision-making. The SIA represents a separate process to the broader stakeholder engagement undertaken by Woodside.

The SIA was undertaken during Concept Definition and was finalised in 2019. (Advisian, 2019) The scope of work included the development of community baselines. A summary of the relevant community baseline is presented in **Section 5.4**. Stakeholder consultation was undertaken as part of the SIA process, in November and December 2018 (with 29 stakeholders in Broome) and again in March and April 2019 (with 49 stakeholders in Broome and Dampier Peninsula) to:

- provide details of the proposed Browse to NWS Project
- better understand stakeholder and community perceptions of the potential impacts and benefits of the proposed Browse to NWS Project
- verify baseline data, collect further baseline data against some indicators and identify local values, attitudes and aspirations.

Stakeholder groups consulted included:

- local Chamber of Commerce
- Aboriginal organisations
- local businesses
- local government staff and councillors
- port authorities
- regional development commissions
- residents
- service providers, including air services, community, education, health and tourism.

Stakeholders who were consulted in 2018 and 2019 for the SIA generally expressed optimism about the proposed Browse to NWS Project. It was recognised by stakeholders that the proposed Browse to NWS Project is different to the previous onshore proposal at James Price Point. There was strong support for establishing Broome as a service hub and recognition that a section of community will always oppose any development. A number of stakeholders referred to a downturn in the Broome economy and saw the proposed Browse to NWS Project as an opportunity to reinvigorate Broome.

Overall, stakeholders on the Dampier Peninsula expressed support for the proposed Browse to NWS Project, but there was a desire to see clear benefit for their communities.

Further information regarding the SIA is detailed in **Chapter 6**.

4.3.2 Ongoing Stakeholder Engagement

Woodside has continued to engage with relevant stakeholders in relation to the proposed Browse to NWS Project. These stakeholders have included decision-making authorities, other relevant government agencies and authorities (Local, State and Commonwealth), the local community, local Aboriginal groups, academics, research authorities and environmental NGOs.

Multiple methods of engagement have been used, including via face-to-face meetings, community forums, emails, letters and phone calls.

Table 4-2 shows stakeholder engagement undertaken in relation to the proposed Browse to NWS Project following the Commonwealth and State environmental referrals in October 2018.

Table 4-2 Stakeholder Consultation Activities to Date

Stakeholder	Date	Issues / topics raised *(by who proponent or stakeholder)*	Proponent response / outcome *(response or outcome undertaken (or proposed) by the proponent (referring to relevant environmental factor/s)*
The Shire of Broome, local service providers, the Broome Chamber of Commerce, the Broome Future Alliance, the Kimberley Marine Supply Base, the Broome International Airport Group, the Kimberley Land Council and Nyamba Buru Yawuru	November 2018	**Proponent:** Overview of the proposed Browse to NWS Project and the environmental approvals process.	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project, environmental approvals.
Murujuga Aboriginal Corporation (MAC)	January 2019	**Proponent:** Overview of the proposed Browse to NWS Project and the environmental approvals process.	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project, environmental approvals and cultural heritage management.
Department of Industry, Innovation and Science	January 2019	**Proponent:** Overview of the proposed Browse to NWS Project.	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project.
Department of Transport	February 2019	**Proponent:** Overview of the proposed Browse to NWS Project.	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project.
City of Karratha	February 2019	**Proponent:** Overview of the proposed Browse to NWS Project.	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project.
Karratha Community Liaison Group including representatives from NYFL, City of Karratha, LandCorp, WA Police, Department of Local Government and Communities, Pilbara Ports, Karratha Districts Chamber of Commerce and Industry, Regional Development Australia, Pilbara Development Commission and Dampier Community Association	March 2019	**Proponent:** Overview of the proposed Browse to NWS Project and environmental approvals.	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project and status of environmental approvals, including the timing of the public comment period for the EIS/ERD.
Representatives from Ngarluma, Yindjibarndi, Yaburara/Mardudhunera, Wong-Goo-Tt-Oo	March 2019	**Proponent:** Overview of the proposed Browse to NWS Project and environmental approvals.	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project, environmental approvals and cultural heritage management.

Stakeholder	Date	Issues / topics raised *(by who proponent or stakeholder)*	Proponent response / outcome *(response or outcome undertaken (or proposed) by the proponent (referring to relevant environmental factor/s)*
Representatives from Djarindjin, Djarindjin airport, Lombadina and Ardyaloon (One Arm Point)	March 2019	**Proponent:** Overview of the proposed Browse to NWS Project and environmental approvals. **Stakeholders:** Asked about possible impacts from Browse to NWS Project to marine life.	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project and environmental approvals. Proponent to provide information on marine life sensitivity receptors and proposed environmental objectives.
Murujuga Aboriginal Corporation (MAC)	March 2019	**Proponent:** Overview of the proposed Browse to NWS Project and environmental approvals.	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project, environmental approvals and cultural heritage management.
Environmental Protection Authority	March 2019	**Proponent:** The proposed Browse to NWS Project and environmental approvals.	**Outcome:** Proponent to continue engagement regarding environmental approvals.
Department of Environment and Energy	March 2019	**Proponent:** The proposed Browse to NWS Project.	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project.
Broome Chamber of Commerce (BCCI), various members of BCCI	April 2019	**Proponent:** The proposed Browse to NWS Project.	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project and status of environmental approvals.
Shire of Broome and Councillors	April 2019	**Proponent:** The proposed Browse to NWS Project.	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project and status of environmental approvals.
Broad range of Karratha community stakeholders	May 2019	**Proponent:** The proposed Browse to NWS Project. **Stakeholders:** Expressed interest in local training, employment and contracting opportunities.	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project, the status of environmental approvals and local opportunities.
City of Karratha - councillors	May 2019	**Proponent:** The proposed Browse to NWS Project.	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project, the status of environmental approvals and local opportunities.

Stakeholder	Date	Issues / topics raised *(by who proponent or stakeholder)*	Proponent response / outcome *(response or outcome undertaken (or proposed) by the proponent (referring to relevant environmental factor/s)*
Representatives from MAC	May 2019	**Proponent:** The proposed Browse to NWS Project and environmental approvals.	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project, environmental approvals and cultural heritage management.
Representatives from NYFL	May 2019	**Proponent:** The proposed Browse to NWS Project and environmental approvals.	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project, environmental approvals and cultural heritage management.
Representatives from Ngarluma, Yaburara/Mardudhunera, Wong-Goo-Tt-Oo	June 2019	**Proponent:** The proposed Browse to NWS Project and environmental approvals.	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project, environmental approvals and cultural heritage management.
Environmental Protection Authority	June 2019	**Proponent:** The proposed Browse to NWS Project and environmental approvals.	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project, environmental approvals.
Broome community Engagements: Representatives from the Shire of Broome, North Regional TAFE, Kimberley Marine Supply Base, Broome International Airport, Kimberley Ports Authority, Toll Logistics, Broome Future Alliance, Kimberley, Broome Chamber of Commerce and Industry, Regional Development Australia, Nagula Jarndu (Yawuru Jarndu Aboriginal Corporation), Broome Surf Life Saving, Polly Farmer Foundation, Nyamba Buru Yawuru, Kullarri Regional Communities Indigenous Corporation, WA Police, Buru Energy, Broome Bird Conservatory, Centurion, Save the Children, Kimberley Development Commission, Broome Transit, Department of Education, local service providers, community stakeholders	August 2019	**Proponent:** The proposed Browse to NWS Project. **Stakeholders:** Expressed interest in local training, employment and contracting opportunities and community partnerships.	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project, environmental approvals, cultural heritage management, logistics, training, employment and contracting opportunities and community partnerships and social investment.

Stakeholder	**Date**	**Issues / topics raised** ***(by who proponent or stakeholder)***	**Proponent response / outcome** ***(response or outcome undertaken (or proposed) by the proponent (referring to relevant environmental factor/s)***
Ngarluma Aboriginal Corporation (NAC)	September 2019	**Proponent:** The proposed Browse to NWS Project.	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project, environmental approvals and cultural heritage management.
Murujuga Aboriginal Corporation (MAC)	October 2019	**Proponent:** The proposed Browse to NWS Project, environmental approvals and the approach to Cultural Heritage Management for Browse to NWS Project. **Stakeholder Group:** Interested in understanding the proposed Browse to NWS Project as far as it may affect direct or indirect impacts to rock art.	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project, environmental approvals and cultural heritage management.
Ngarluma Aboriginal Corporation (NAC)	October 2019	**Proponent:** The proposed Browse to NWS Project, environmental approvals and the approach to Cultural Heritage Management for Browse to NWS Project.	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project, environmental approvals and cultural heritage management.
Representatives from Djarindjin, Lombadina and Ardyaloon (One Arm Point) Beagle Bay	October 2019	**Proponent:** Overview of the proposed Browse to NWS Project, status of environmental approvals, presentation provided on marine life sensitivity receptors and proposed environmental objectives (detailed in EIS/ERD).	**Outcome:** Proponent to continue engagement regarding the proposed Browse to NWS Project.
Broome community engagements	November 2019	**Proponent:** The proposed Browse to NWS Project. **Stakeholders:** Expressed interest in local training, employment and contracting opportunities.	**Outcome**: Proponent to continue engagement regarding the proposed Browse to NWS Project, environmental approvals, cultural heritage management, logistics, training, employment and contracting opportunities.

4.3.3 Aboriginal stakeholders

Meetings were held with Aboriginal stakeholders to explore any potential impacts on national or Aboriginal heritage values. Participants were provided with a detailed overview of the environmental assessment and approval processes. There were opportunities for questions to be asked, responses provided and any outstanding concerns to be understood.

Woodside corporate meetings are held on a regular basis with MAC, NYFL and the five language groups who have an interest in the Burrup Peninsula. These meetings provide an opportunity to give updates on the proposed Browse to NWS Project, as well as information about the environmental approvals process and mitigation approach.

The North West Shelf Project Extension ERD details engagement with Aboriginal stakeholders in relation to any potential impacts of the North West Shelf Project Extension Proposal (EPBC 2018/8335) on national and Aboriginal heritage values of the listed National Heritage Places on the Dampier Archipelago. Traditional owners and custodians were included in this consultation. Woodside recognises that it may not always be appropriate for Aboriginal people to disclose information about highly significant matters, and therefore we take seriously any concerns raised in broader terms.

Other than Indigenous Indonesian fishers, no Indigenous stakeholders were identified in relation to the Browse Development Area (Figure 2-1).

4.3.4 Summary of Stakeholder Feedback

Stakeholder consultations concerning the proposed Browse to NWS Project have reinforced understanding of the possible business, employment and training opportunities that may be generated in both the Kimberley and Pilbara, especially for Aboriginal residents.

Broome stakeholders, in the main, reinforced the need for continued development in the Kimberley to generate economic activity and flow on opportunities for local stakeholders. Stakeholders also raised issues of national heritage (with a focus on rock art) and expressed an interest in understanding mitigation measures relevant to cultural heritage.

Broome and Dampier Peninsula stakeholders also placed a high value on the preservation of the natural environment for tourism and cultural reasons.

4.4 Ongoing Stakeholder Engagement

This draft EIS/ERD has been released for public review, which offers stakeholders an opportunity to provide formal input into the environmental impact assessment. In addition to activities undertaken to support the development of the draft EIS/ERD, Woodside, as part of its standard operating practices, will continue to engage with stakeholders throughout all phases of the proposed Browse to NWS Project. This includes ongoing engagement to inform and consult stakeholders about:

- key milestones and activities
- onshore supply chain and logistics support locations
- ongoing social investment in relevant communities.

CHAPTER 5

DESCRIPTION OF THE ENVIRONMENT

5. DESCRIPTION OF THE ENVIRONMENT

5.1 Introduction

This section describes the physical and ecological marine environment of the Project Area, the Environment that May be Affected (EMBA; **Section 5.3.5**) and the broader North-west Marine Region (NWMR), taking into consideration both Commonwealth Matters of National Environmental Significance (MNES) and relevant WA EPA key environmental factors. The socio-economic environment pertaining to the proposed Browse to NWS Project is also outlined in this section.

This section is structured to give a regional overview of each environmental aspect (as defined within the EISG/ESD) within the NWMR, followed by a discussion of the specific areas within the Project Area (as described in **Chapter 2**), including the Browse Development Area (with specific discussion of the environmental aspects at Scott Reef), the proposed BTL route, the inter-field spur line and potential logistics and supply locations along the WA coastline (**Section 5.3.4**). A description of the EMBA in the event of a worst-case credible hydrocarbon spill is also provided in **Section 5.3.5**.

The majority of the proposed Browse to NWS Project environmental footprint (described in **Chapter 2**) has been studied and surveyed as part of the environmental approvals process for the previous development concepts. However, the BJV has commissioned additional studies and surveys to specifically inform the proposed Browse to NWS Project.

The Project Area is located within the NWMR, which is further divided into eight provincial bioregions (**Figure 5-1**). The Browse Development Area is located within the Timor Province bioregion, with the proposed BTL route extending into the Northwest Transition and Northwest Shelf Province bioregions. Further information on the regional setting of the Project Area is provided in **Section 5.2.1**.

The information in this section has been primarily based on publicly available literature, as well as technical studies commissioned by the BJV over a number of years. Key information sources include:

- peer reviewed journals
- industry and government technical reports and data
- DoEE resources and published literature, including but not limited to:
  - An EPBC Act Protected Matters Database search identifying listed Threatened and Migratory species and communities occurring in and within the vicinity of the Project Area (Browse Development Area, the proposed BTL and inter-field spur line route).
  - Species Profile and Threats (SPRAT) Database providing information about species and ecological communities listed under the EPBC Act.
  - EPBC act listed species conservation plans, recovery plans and conservation advices for threatened species and ecological communities as outlined within the EISG/ESD.
- BJV commissioned environmental studies:
  - Scott Reef, a remote oceanic reef system approximately 270 km off the WA coastline, has been the focus of particular survey effort by the BJV over the past two decades. As shown in **Figure 5-2**, the Torosa reservoir underlies both the Commonwealth and State waters of Scott Reef. Scott Reef and its surrounds is identified as Key Ecological Feature (KEF; described in **Section 5.3.3.1**) and is environmentally significant within the NWMR.
  - An environmental survey of the proposed BTL route was completed in 2019 (Advisian, 2019a) and included the collection of water quality, sediment quality and seabed habitat and benthic community information.

5.1.1 Matters of National Environmental Significance (MNES)

As described in **Chapter 3**, the EPBC Act controlling provisions for the proposed Browse to NWS Project include the following:

- National heritage values of a National Heritage place
- Listed Threatened species and Threatened Ecological Communities
- Listed Migratory species
- Commonwealth marine area, the protected matter being the environment generally.

An EPBC Act Protected Matters Database search was undertaken via the Protected Matters Search Tool (PMST) (Department of the Environment and Energy, 2013) for the Project Area (**Chapter 10, Appendix C.1**), which encompasses the Browse Development Area, the proposed BTL and inter-field spur line route. The results of the PMST search with regards to Threatened or Migratory species, Threatened Ecological Communities and the Commonwealth Marine Environment are discussed in **Section 5.3**. The relevant National Heritage

Places are addressed in **Section 5.4.3**. A summary of the MNES relevant to the Project Area is provided in **Table 5-1** below and described within the Section.

Table 5-1 Summary of the Environmental Values Identified by the PMST to be of Relevance for the Project Area

MNES	Number
World Heritage Properties	None
Commonwealth Heritage Places	1
National Heritage Places	None*
Wetlands of International Importance	None
Listed Threatened Ecological Communities	None
Listed Threatened species	20
Listed Migratory species	38
Commonwealth Marine Areas	1
Great Barrier Reef Marine Park	None

* *Note that while no National Heritage Places exist within the defined Project Area, the Dampier Archipelago (including Burrup Penisula National Heritage is located in proximity to the NWS Project infrastructure where Browse gas is proposed to be processed. Information with regards to the national heritage values of this National Heritage Place are detailed in the North West Shelf Project Extension ERD (EPBC 2018/8335))*

5.1.2 WA EPA Environmental Factors

As described in **Chapter 2**, the following WA EPA Environmental Factors were determined as being relevant for the proposed Browse to NWS Project within State waters:

- Benthic Communities and Habitats
- Marine Environmental Quality
- Marine Fauna
- Air Quality.

The existing environment relevant to these factors is described in this Section.

5.2 Physical Marine Environment

This section describes the physical characteristics of the Project Area in the context of the wider NWMR. The oceanographic characteristics of the Project Area and the geomorphic characteristics of the Project Area and nearby receptors are of particular focus.

5.2.1 Regional Setting

The Project Area is located within the NWMR; one of five marine regions established to delineate Australia's Commonwealth waters based primarily on ecosystem characteristics (Commonwealth of Australia, 2012a; **Figure 5-1** below). The NWMR encompasses Commonwealth waters from the border of WA and the Northern Territory (NT), to Kalbarri (Commonwealth of Australia, 2012a). This region includes the North West Shelf (NWS) and Sahul Shelf, several ecologically significant coral reefs, and is characterised by expanses of continental shelf and slope (Commonwealth of Australia, 2012a; Heyward and Radford, 2019).

The NWMR has been further sub-divided into eight provincial bioregions. The Project Area overlaps with the NWMR provinces as follows: The Browse Development Area is located within the Timor Province bioregion (shown in **Figure 5-1**) and includes the inter-field spur line route, and the proposed BTL which extends from the Timor Province bioregion through the North-west Transition bioregion and into the North-west Shelf Province, where it terminates prior to tie in to existing NWS Project infrastructure near North Rankin Complex (NRC).

The physical attributes of the NWMR as they pertain to the proposed Browse to NWS Project are described in this section. A description of the corresponding ecological attributes is subsequently provided in **Section 5.3**.

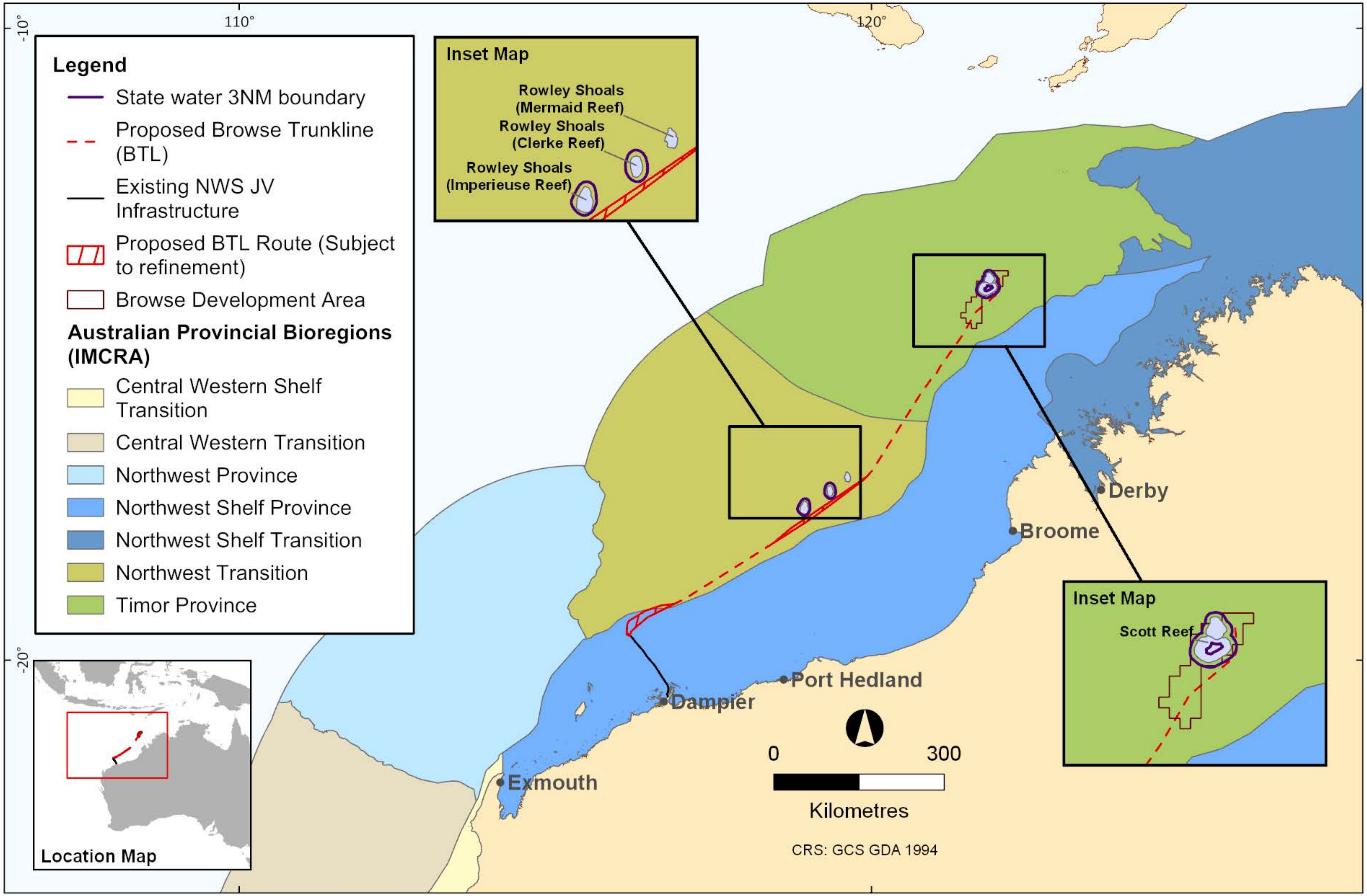

Figure 5-1 Provincial Bioregions of the North-west Marine Region (Commonwealth of Australia, 2006)

5.2.2 Bathymetry and Geomorphic Environment

Regional Overview

The NWMR is characterised by expanses of continental shelf and slope, with complex areas of bathymetry such as plateaux, terraces and major canyons that facilitate upwelling of nutrients and sediment transport (**Figure 5-2**; Commonwealth of Australia, 2012a). The continental shelf in the northern most part of the region (north of Cape Leveque) is described as a 'rimmed ramp', as the waters over the outer margins of the shelf are shallower than the middle portions (Commonwealth of Australia, 2008). This 'ramp' is a unique feature of the Australian continental margin in this region, with the rim at its outer edge being the site of a number of coral reefs including Ashmore, Cartier, Scott and Seringapatam Reefs (Commonwealth of Australia, 2008). More than 40% of the NWMR is less than 200 m deep. The shallow shelf is contrasted by features such as the Cuvier and Argo abyssal plains which reach depths in excess of five kilometres (Commonwealth of Australia, 2012a). This variation in bathymetry and interactions with oceanographic processes provides a diversity of habitat to marine fauna and flora within the NWMR (Commonwealth of Australia, 2012a). A number of bathymetric features within the NWMR are classified as Key Ecological Features (KEFs) by the DoEE due to their importance in supporting biodiversity and/or ecosystem function within the region. These are described in **Section 5.3.3.1**.

Browse Development Area

The Browse Development Area is located in water depths of approximately 400 to 1,000 m, with the greatest water depths occurring on the western side of Scott Reef, an annular reef approximately 17 km long and 16 km wide comprised of two coral reef atolls rising steeply from depths of approximately 400-500 m (**Figure 5-2**). These atolls, referred to as South Scott Reef and North Scott Reef, are separated by a deep channel, as shown in **Figure 5-3**. North Scott Reef features a shallow lagoon approximately 20 m deep with only two small channels linking it to the surrounding ocean. The shallow enclosed waters of the North Reef lagoon contain a range of habitats that are very different to those seen in the deeper, more open lagoon of South Scott Reef (Gilmour et al., 2013[1]). The deep lagoon within South Scott Reef ranges in depth from approximately 20 to 70 m and contains unique habitats, as discussed in **Section 5.3.1.2**.

The Torosa reservoir lies partially under Scott Reef. The bathymetry surrounding Scott Reef reflects the broader deep water environment of the Browse Development Area (described in **Section 5.3**) and has been described as primarily flat and smooth with a seabed gradient of approximately 0.1°, with water depths of between 400 and 500 m (Fugro Survey Pty Ltd, 2006; URS Australia Pty Ltd, 2007a; **Figure 5-4**). There are a number of mounds roughly 4 m wide and reaching 10 m in height located on the seabed in the north-western portion of the reservoir. The origin of these mounds is as yet unknown (Fugro Survey Pty Ltd, 2006). The seabed sediment habitat within the Browse Development Area are largely soft and unconsolidated, as described in **Section 5.2.10**.

Notably, Scott Reef experiences natural subsidence; since the last interglacial period subsidence has become increasingly rapid, in geological terms (0.04 metres per thousand years (m/kyr) (Collins and Testa, 2010; Collins, 2011). Scott Reef also experiences sea level change cycles. Each reef growth phase has kept pace with rising sea levels (Gilmour et al. 2013b); during the Holocene period (last 10,000 years), 14 to 35 m of vertical reef growth has occurred.

The overlying seabed at the Brecknock and Calliance reservoir areas are located at similar depths to the Torosa reservoir (approximately 590 m; **Figure 5-2**) with seabed gradients of 1.4 and 0.6 degrees respectively. Sediments at these locations are unconsolidated and described primarily as soft, silty clay/clayey silt sediments (Fugro Survey Pty Ltd, 2006). There are areas of exposed layers of eroded stiff clay and cemented silt which subsequently comprise more consolidated sediments. 'Mega ripples' or 'sand waves' are featured to the north-north-west of the Brecknock reservoir seabed area at water depths of more than 650 m (Fugro Survey Pty Ltd, 2006). These sand waves are orientated in a north-east to south-west direction with a crest to crest distance between 10 and 30 m. These features are no higher than 1 m from crest to trough (Fugro Survey Pty Ltd, 2006).

Browse Trunkline

As detailed in **Section 5.2.1**, the proposed BTL route extends from the Timor Province bioregion through the south eastern boundary of the North-west Transition bioregion at depths of between 280 and 440 m, before turning east towards the mainland and a tie in point near NRC at a depth of approximately 125 m in the North-west Shelf Province bioregion. The proposed BTL route is largely devoid of geomorphic features; Rankin Bank, Glomar Shoal and the Rowley Shoals, described in **Sections 5.2.3** and **5.3.5.1**, are the only known physical topographic features within the vicinity of the proposed BTL route. A benthic survey was undertaken in March and April 2019 to confirm the environmental characteristics of the seabed along the proposed BTL route (Advisian, 2019a, **Chapter 10, Appendix D.1**). The results of this survey are discussed in **Section 5.3**.

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[1] *Gilmour et al., 2013 available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

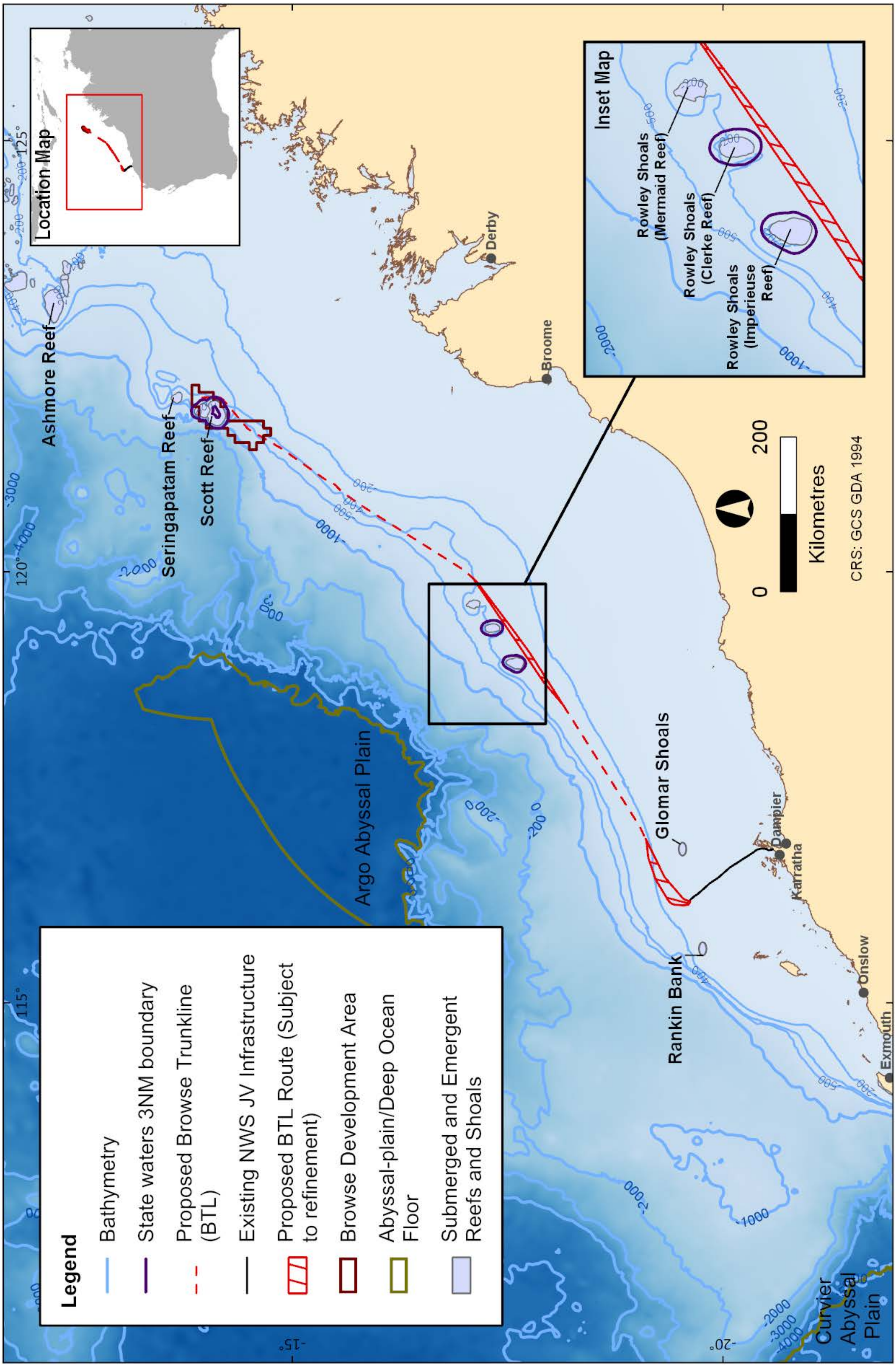


Figure 5-2 Bathymetry of the North-west Marine Region (based on Baker et al., 2008a)

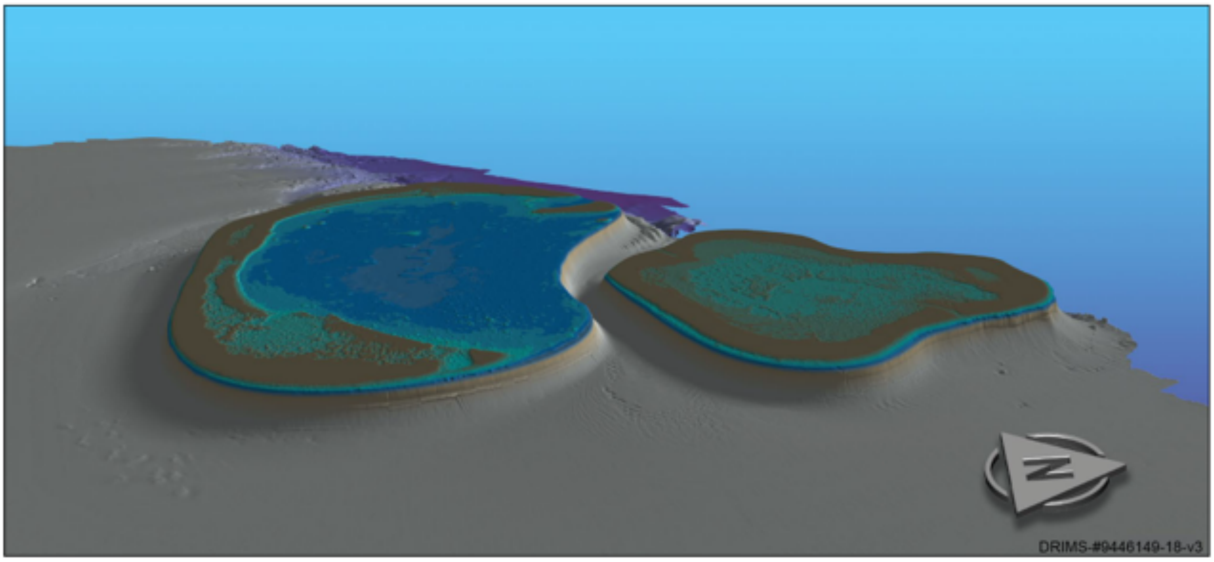


Figure 5-3 Three-dimensional Merged Bathymetric Data for Scott Reef

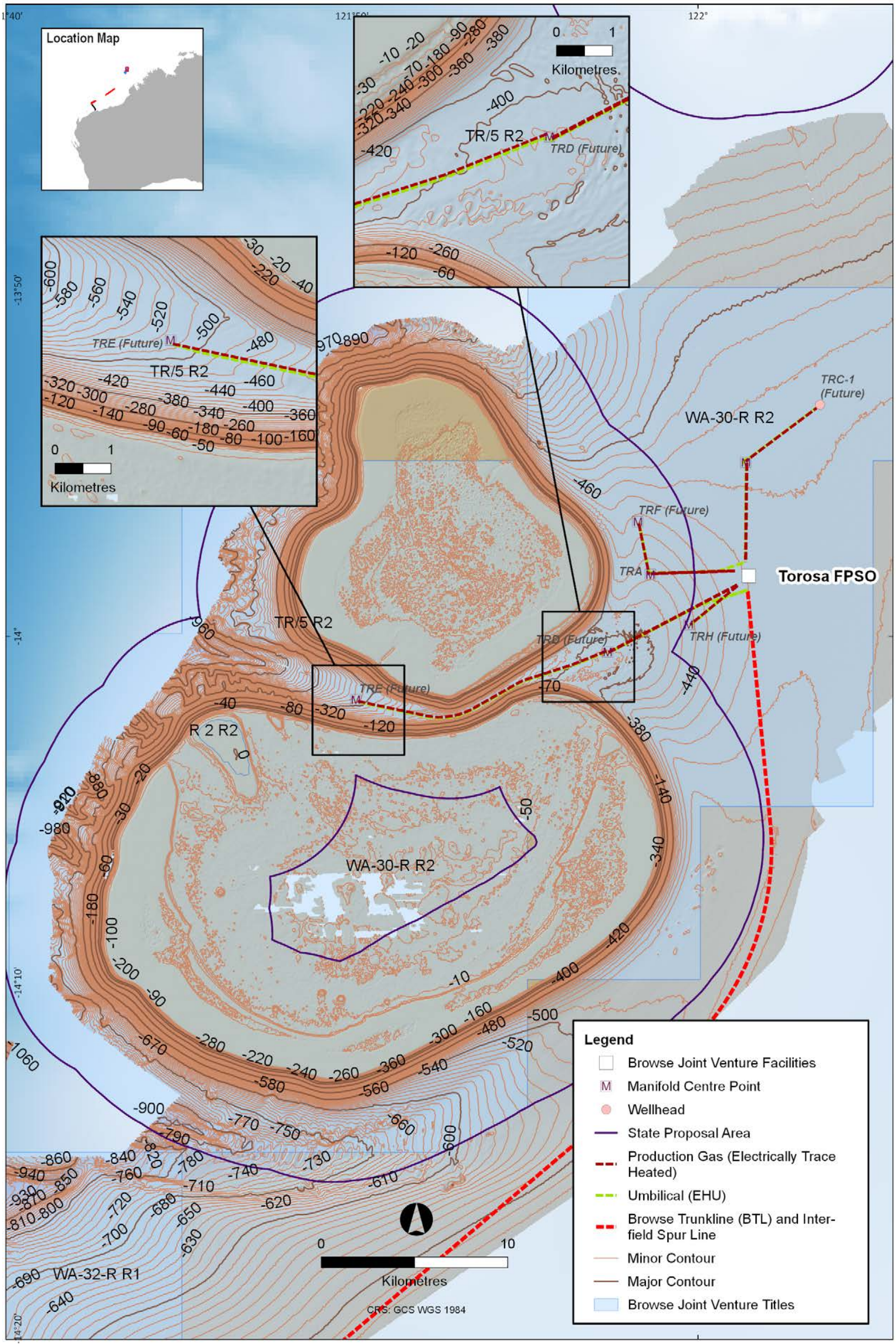


Figure 5-4 Bathymetry of the Scott Reef System

5.2.3 Submerged and Emergent Reefs and Shoals

As described in **Section 5.2.1**, there are a number of submerged and emergent reefs and shoals within the NWMR. Those within the vicinity of the Project Area (shown in **Figure 5-3**) are described briefly in this section. The specific ecological values of these reefs and shoals as relevant to the Project Area are described in subsequent sections.

5.2.3.1 Scott Reef

As described in **Section 5.2.2**, Scott Reef is an emergent reef comprising two coral continental shelf atolls located over a portion of the Torosa reservoir (**Figure 5-2**). Scott Reef is one of the largest emergent reefs within the NWMR. The reef system comprises shallow to deep bathymetry shaped by the coral reef structure and a deepwater channel separates North and South Scott Reef (**Figure 5-3**).

At high tide only a portion of reef system on the north-west edge of South Scott Reef, named Sandy Islet, is visible. The reef is situated in both Commonwealth and State waters and includes the Scott Reef Nature Reserve (described in **Section 5.3.3.3**).

Due to the location of Scott Reef within the Browse Development Area (**Section 5.2.2**; **Figure 5-2**), a number of long-term ecological studies of the reef have been commissioned by the BJV. The key ecological characteristics of Scott Reef as identified by these and other studies are described throughout **Section 5**.

5.2.3.2 Seringapatam Reef

Seringapatam Reef is a continental shelf atoll located approximately 23 km north of the Project Area which forms part of a KEF with Scott Reef; Seringapatam Reef and Commonwealth waters in the Scott Reef Complex (detailed in **Section 5.3.3.1**). Seringapatam Reef is an emergent coral reef, but unlike Scott Reef has no permanent island or islet. The reef is characterised by a combination of physical environmental conditions including clear, warm waters typical of oceanic environments and a large tidal range that provides a high physical energy input to these remote reef marine ecosystems.

5.2.3.3 Rowley Shoals

The Rowley Shoals comprises three distinct reef continental shelf atolls of similar dimension, shape and orientation that are located at the edge of the continental shelf (Baker et al., 2008a; Department of the Environment and Conservation, 2007). The coral atolls are named Mermaid Reef, Clerke Reef and Imperieuse Reef. They are orientated in a north-south orientation and are each approximately 30 to 40 km apart (Baker et al., 2008a). Each atoll covers an area of approximately 80 to 90 km^2 and extends almost vertically from seafloor depths of approximately 400 m (Department of Biodiversity, Conservation and Attractions, 2019). At high tide only the sandy island habitats of Clerke and Imperieuse Reefs remain visible (Commonwealth of Australia, 2000).

The Rowley Shoals are protected by the WA Rowley Shoals Marine Park (Clerke Reef and Imperieuse Reef) and Commonwealth Mermaid Reef Marine Park (Mermaid Reef) (Department of the Environment and Conservation, 2007). Mermaid Reef and Commonwealth Waters Surrounding Rowley Shoals is also a KEF (described in **Section 5.3.3.1**).

The Rowley Shoals marine environment features clear oceanic waters in contrast to the more turbid waters closer to the mainland (Department of the Environment and Conservation, 2007). The Rowley Shoals are located approximately 390 km from the Browse Development Area and the proposed BTL route passes approximately 2 km from the boundary of the Commonwealth Marine Park at Mermaid Reef, 3 km from the boundary of the state marine park at Clerke Reef and 4.5 km from the boundary of the state marine park at Imperieuse Reef. A description of the ecological habitats and communities at the Rowley Shoals is provided in **Section 5.3.5.1**.

5.2.3.4 Rankin Bank

Rankin Bank is a sedimentary formation located on the continental shelf approximately 80 km north-east of the tie in point near NRC. It includes three major banks delineated by the 50 m bathymetric contour with minimum recorded water depths of 18.6 m from the lowest astronomical tide (LAT), 22.5 m (LAT) and 30.5 m (LAT). Rankin Bank is the only large, complex bathymetrical feature on the outer western shelf of the West Pilbara (AIMS, 2014).

5.2.3.5 Glomar Shoal

The Glomar Shoal is an area of the continental shelf elevated above the surrounding seabed. The submerged shoals are located approximately 95 km north of Dampier and 800 km from the Browse Development Area. The shallowest portion of the shoals ranges from 22 m to 28 m (LAT), approximately 65 km east of the tie-in point near NRC. The seabed comprises biogenic carbonate sediments, dominated by gravel and sand (Falkner et al., 2009). On a regional level, the Glomar Shoal is not thought to constitute a specific habitat type, although it is considered unique on a local scale. The Glomar Shoal is a designated KEF (**Section 5.3.3.1**).

5.2.4 Climate and Atmospheric Characteristics

The NMWR experiences a monsoon climate with two distinct seasons; the 'wet' season from December to March which is characterised by high rainfall and cyclonic activity, and the 'dry' season from April to

November which is characterised by dry weather and milder temperatures. This climate is dictated by anticyclones, a sub-tropical ridge of high-pressure cells, and the monsoon trough, a broad tropical low-pressure region. Within the NWMR these two atmospheric pressure systems in turn drive the following key weather patterns:

- South-east trade winds – these are steady north-east to south-east winds occurring from April to September with the intensification of the anticyclone pressure system over southern WA or South Australia (SA). Weather conditions associated with the south-east trade winds are mainly fine conditions with low rainfall across the affected area.
- North-west monsoon – these are north-west to south-west winds that occur from October to March bringing widespread heavy rainfall and cloud.
- Tropical cyclones – there are typically associated with an active monsoon trough (further discussed in **Section 5.2.4.6**).

The description of meteorological conditions in the following sections is based on data recorded at Browse Island, Troughton Island and Koolan Island (approximately 150 km, 430 km and 260 km away respectively from the Browse Development Area) and at Scott Reef (RPS MetOcean, 2007). These locations are shown on **Figure 5-5** below. **Table 5-2** summarises temperature, rainfall, relative humidity and evaporation data for the Browse Development Area.

Table 5-2 Meteorological Data Representative of the Browse Development Area

Month	Mean Monthly Minimum Temperature[1]	Mean Monthly Maximum Temperature[1]	Mean Rainfall[2]	Mean Relative Humidity[1]	Mean Daily Evaporation[3]
Units	°C	°C	mm	%	Mm
January	24.90	31.20	273.40	79.71	7.27
February	24.10	36.40	195.20	84.39	6.69
March	24.80	33.30	131.90	-	6.62
April	26.90	32.90	29.30	74.28	7.21
May	23.40	33.60	40.20	73.28	7.83
June	21.40	29.70	6.20	66.74	7.33
July	23.70	29.30	2.80	65.62	7.46
August	23.90	28.00	0.50	67.01	8.23
September	24.30	30.50	0.30	75.60	8.44
October	23.40	36.30	2.40	74.53	7.88
November	27.50	35.40	11.00	76.28	8.03
December	23.90	35.10	121.50	75.41	8.16
Annual	**21.40**	**36.40**	**811.80 (total)**	**74.33**	**7.60**

1 *Temperature and relative humidity data recorded at Scott Reef between 2006 and 2007 (RPS MetOcean, 2007).*

2 *Rainfall data recorded at Troughton Island between 1956 and 2019 (Bureau of Meteorology, 2019a)*

3 *Evaporation rates recorded at Koolan Island between 1982 and 2007 by (RPS MetOcean, 2008b)*

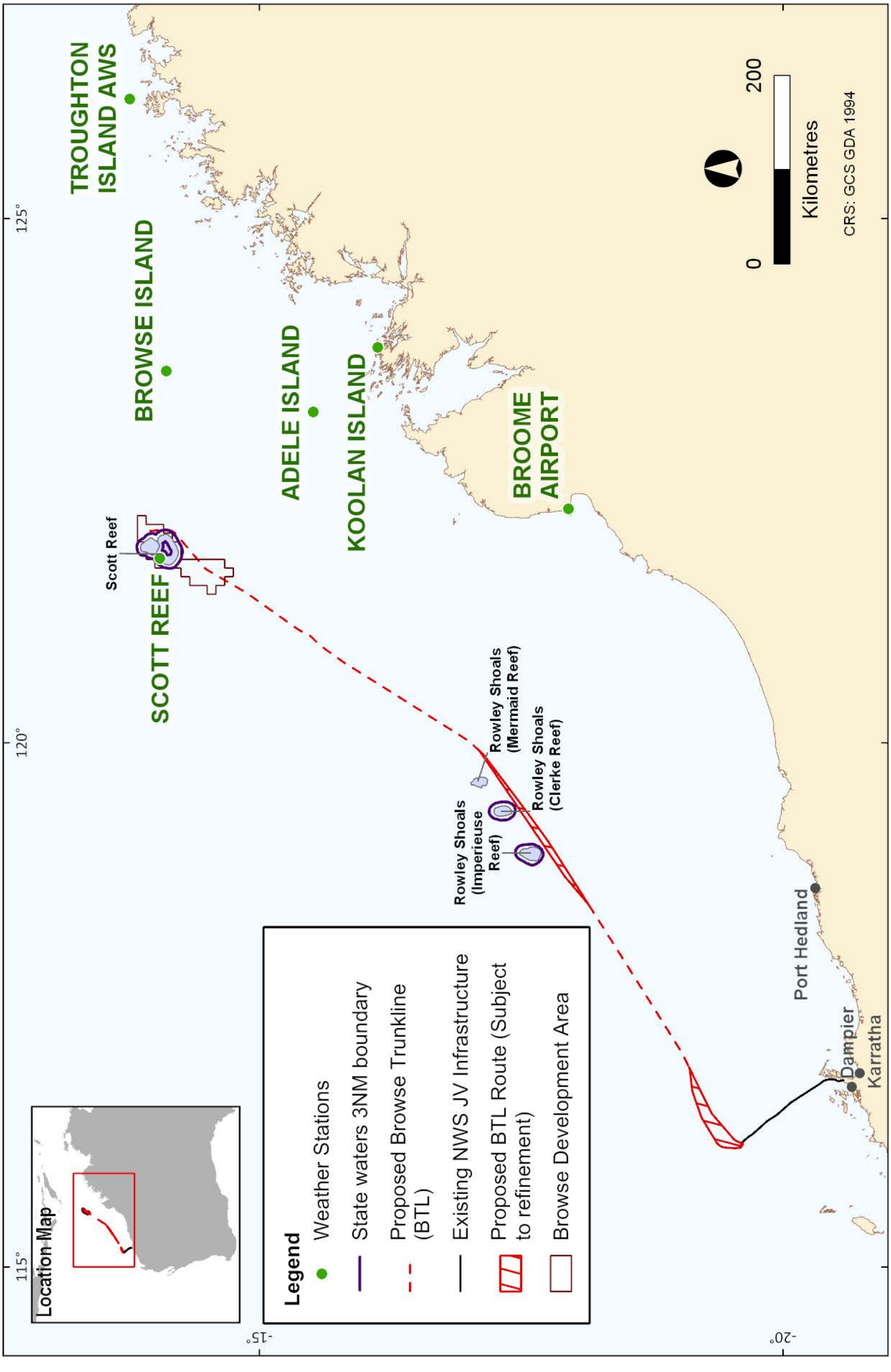


Figure 5-5 Meteorological Data Relevant to the Proposed Browse to NWS Project was Recorded at Browse Island, Troughton Island, Koolan Island and Scott Reef

5.2.4.1 Air Temperature

The mean monthly air temperatures recorded at Browse Island (representative of the NWMR) between 2013 and 2019 ranged from 27.9°C in July and August, to 32.7°C in April (BoM 2019).

Air temperatures recorded at Scott Reef between 2006 and 2007 (indicative of the Browse Development Area) ranged from a minimum of 21.4°C in June and a maximum of 36.4°C in February and (**Table 5-2**; (RPS MetOcean, 2007)).

5.2.4.2 Humidity

The NWMR experiences high relative humidity in summer months, which in turn invites consistent summer monsoons (the wet period), with south-east trade winds bringing lower humidity in winter months (MetOcean Engineers, 2005).

The mean monthly humidity at Scott Reef was found to fluctuate from 78% in summer to 70% in winter, with an annual average of 74% recorded between September 2006 and August 2007. The highest recorded mean monthly humidity was in February (84%), with the lowest being in July (66%) (see **Table 5-2**; (RPS MetOcean, 2007).

5.2.4.3 Rainfall

The NWMR experiences heavy tropical cyclone activity with associated monsoons and thunderstorms, which influences highly variable rainfall with approximately 90% received during summer. Extreme rainfall and thunderstorm events are connected to tropical cyclones or low-pressure systems, which have consequently caused unpredictable and isolated rainfall.

Recorded rainfall data at Troughton Island have been used to provide a representative indication of rainfall within the Browse Development Area. Troughton Island receives an annual average of 812 millimetres (mm) of rain, with approximately 90% (722 mm) of it falling during the summer months (Bureau of Meteorology, 2019a). The month of January has the highest rainfall average (273.4 mm), with September recording the lowest rainfall average (0.3 mm).

5.2.4.4 Evaporation

The closest location to the Browse Development Area where reliable evaporation data have been recorded is Koolan Island (RPS MetOcean, 2008b). Measurements taken between 1982 and 2007 demonstrated a mean annual evaporation rate of approximately 7.6 mm (see **Table 5-2**). Evaporation rates will usually be higher in the early summer months and lower in the winter months, varying between 6 and 9 mm.

5.2.4.5 Winds

High pressure systems in the Project Area will primarily bring east to south-easterly winds in the dry season. Average winds speeds during this season are approximately 16.6 km/hr with maximum wind gusts of 65 km/hr (MetOcean Engineers, 2005). The wet season brings dominate westerly winds with average wind speeds approximately 17 km/hr, and maximum gusts exceeding 100 km/hr (generally associated with tropical cyclones).

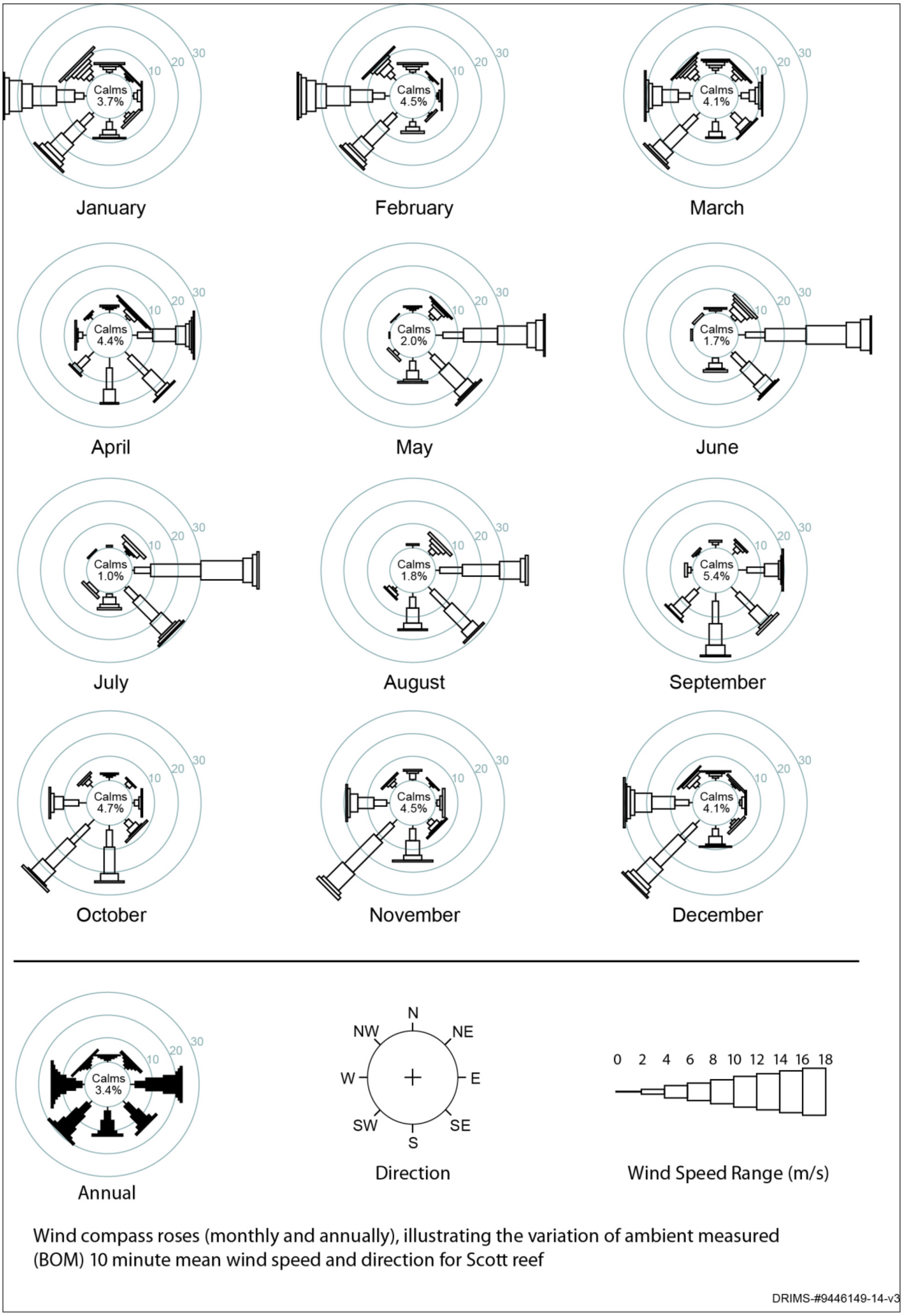
Wind roses which illustrate the variation of mean wind speed and direction throughout the year for Scott Reef are shown in **Figure 5-6** below. Wind direction is primarily west to south-westerly October through to March (approximately the wet season), changing to primarily east to south-easterly April through September (approximately the dry season). Wind speeds reached above 30 km/hr for all months other than March, April and September (MetOcean Engineers, 2005).

5.2.4.6 Tropical Cyclones

The wet season in north-west WA is synonymous with tropical cyclones. Tropical cyclones experienced in WA are low pressure systems that typically form in the warm waters off the north-west coast, with associated wind circulations of at least gale force strength (Bureau of Meteorology, 2019b; 2019c). Tropical cyclones within this region have a preferred direction of movement, typically tracking west-south-west and then south. If a tropical cyclone tracks south of approximately 22° S and/or crosses the Pilbara coastline, it will tend to accelerate in a south-south-east direction (Bureau of Meteorology, 2019b). The path of a tropical cyclone is, however, variable and particularly responsive to the weather patterns at the time (Bureau of Meteorology, 2019b). An average of five cyclones form in this region off the north-west of WA each season (Bureau of Meteorology, 2019b). **Figure 5-7** below shows the tracks of cyclones that have passed within 100 km of the Project Area since 1981.

Tropical cyclones bring torrential rains and damaging winds. Tropical cyclone activity in Australia is regulated by the El Niño Southern Oscillation (ENSO) (see **Section 5.2.4.7** below) with fewer cyclones occurring during El Niño years. The onset of the monsoon season is typically two to six weeks later during El Niño years, often resulting in drought conditions across eastern Australia (Bureau of Meteorology, 2019b).

Across WA, the Pilbara and Kimberley coastlines are the areas that are most likely to be affected by tropical cyclones at the onset of the cyclone season. As the season progresses, the west coast of WA is increasingly likely to be affected (Bureau of Meteorology, 2019b).



Wind compass roses (monthly and annually), illustrating the variation of ambient measured (BOM) 10 minute mean wind speed and direction for Scott reef

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Figure 5-6 Wind Compass Roses (Monthly and Annual) Illustrating the 10 minute Mean Wind Speed and Direction at Scott Reef. Data from the Australian Bureau of Meteorology (BoM) (MetOcean Engineers, 2005)

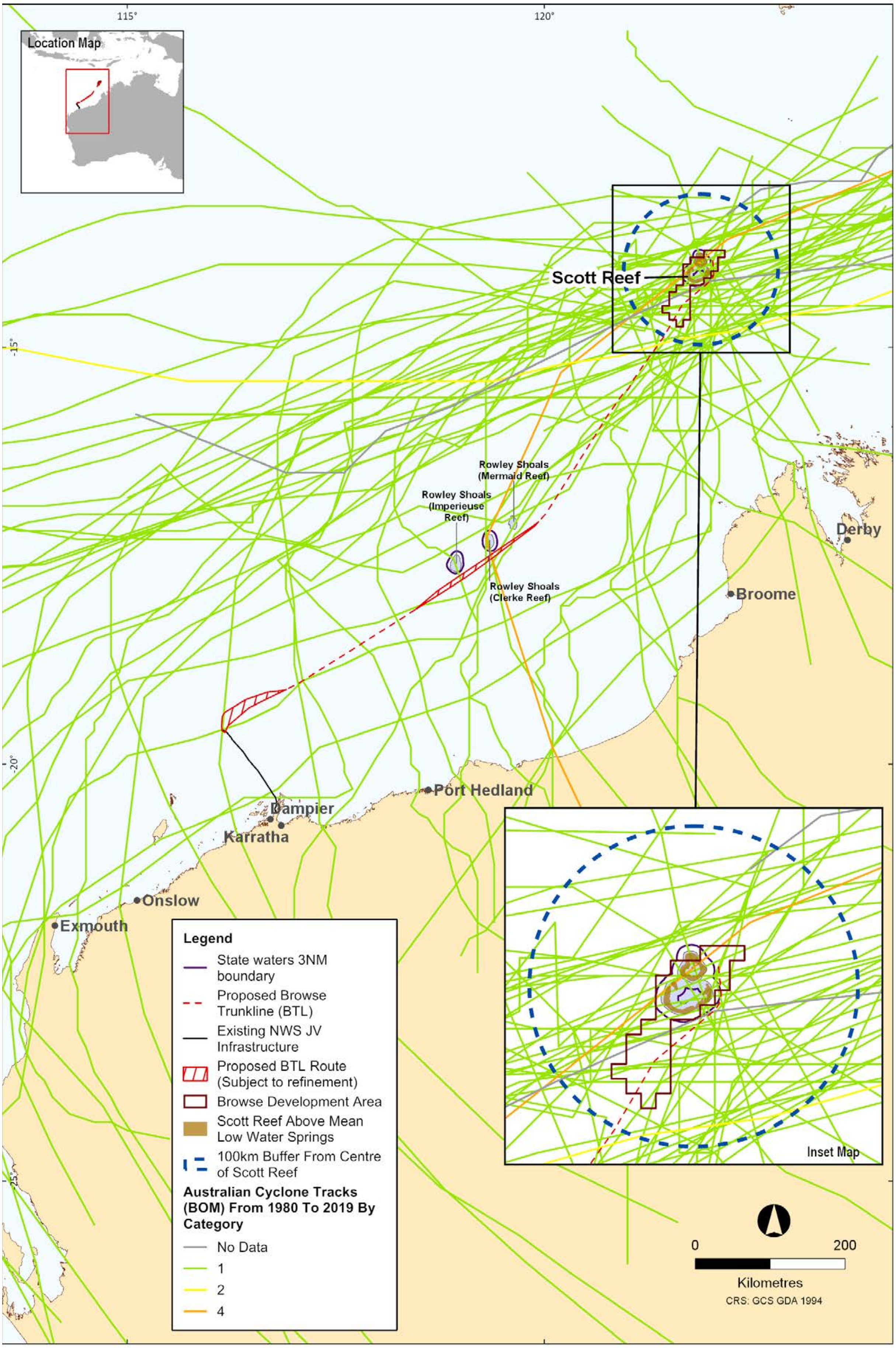

Figure 5-7 Tracks of Cyclones Passing within 100 km of the Project Area between 1981 and 2017 (Bureau of Meteorology, 2019b)

5.2.4.7 El Niño Southern Oscillation (ENSO)

The El Niño Southern Oscillation (ENSO) is the term used to describe the oscillation between the El Niño phase and the La Niña, or opposite, phase (Bureau of Meteorology, 2008). El Niño refers to the extensive warming of the central and eastern tropical Pacific Ocean which leads to a major shift in weather patterns across the Pacific. This generally occurs every three to eight years and is associated with a weaker Walker Circulation and drier conditions in eastern Australia. Conversely, La Niña refers to the cooling of the central and eastern tropical Pacific Ocean due to strengthening equatorial trade winds causing the upwelling of cooler deeper waters. This also results in the accumulation of warmer surface waters in the western Pacific and waters north of Australia.

5.2.5 Oceanographic Environment

The description of the oceanographic environment of the Browse Development Area and wider region in this section is largely informed by long term metocean studies commissioned by the BJV in support of the previous development concepts (RPS MetOcean, 2008b).

5.2.5.1 Wave Climate

The wave climate of the NWMR is primary influenced by the following physical factors:

- Locally generated wind waves, generally from the west during summer westerly monsoon and the east during winter easterly trade winds.
- Swells propagated from storms in the Southern Ocean or the southern portion of the Indian Ocean, typically arriving from the south-west (RPS MetOcean, 2008a).
- Swell directions can vary within the region, depending on wind direction, locations of storms and the influence of local bathymetry.

Maximum and mean swell and seas for the NWMR are generally larger during the dry season than the wet season, due to strong easterly wind-generated seas and winter swells from the Southern and Indian Oceans. Wave heights in the NWMR average 1 to 2 m, with typical periods of 10-12 seconds.

Wave heights close to Scott Reef vary due to local bathymetric and diffraction effects; however, are generally less than 1 m with typical periods ranging from 3 – 15 seconds (RPS MetOcean, 2008a). Monsoonal storms, tropical cyclones and their associated high winds can generate waves heights of up to 21 m (Woodside Energy Limited, 2014).

5.2.5.2 Tsunamis

Tsunamis may be caused by catastrophic earthquakes, landslides, volcanic events, glacier collapse and meteorite impacts (Watts, 2009). The tsunami potential for the NWMR is considered to be moderate (Geoscience Australia, 2012) based on the geology of the region. The NWMR is bordered by an active tectonic plate boundary, known as the Sunda Arc, which is capable of generating tsunamis. This volcanic arc is located to the north-west of Australia, south of Indonesia where the Australian Plate is subducting beneath the Sunda Plate. This poses the greatest tsunami threat to the north-west coast (Burbidge and Cummins, 2007) and a number of tsunami events have occurred in this broad area in recent years.

Watts (2009) conducted modelling of a series of scenarios (e.g. landslides, earthquakes), based on recent or known geological activity, to predict the potential extent of a tsunami in the region of the Browse Development Area. It was found that peak amplitudes and trough amplitudes (wave height) for each scenario are less than 4 m due to the water depth of the NWMR.

According to the modelling study, the greatest wave amplitude that could be experienced at Calliance would be around 2.4 m, as a result of an underwater landslide to the south-west of the Browse Development Area (Watts, 2009). Brecknock and Torosa might each expect maximum wave amplitudes of approximately 2.7 m and 1.7 m respectively, also as a result of underwater landslide scenarios. Modelling results for a number of more likely normal earthquake scenarios resulted in maximum wave amplitudes of up to 0.1 m across the three reservoirs (Watts, 2009).

5.2.5.3 Tides

Regional Overview

Tides within the NWMR are semi-diurnal; two high tides and two low tides occur each day. These tides have a spring/neap cycle of approximately seven days. This refers to the maximum and minimum tidal range experienced, with the neap cycle featuring a lower tidal range than average, and the spring cycle featuring a higher tidal range than average (Commonwealth of Australia, 2008).

Water flow within coastal areas and the inner to mid-shelf are influenced by a combination of tides and winds, whereas water flow over the outer shelf, slope, rise and deeper waters of the NWMR is primarily influenced by the large scale regional circulation described below (Commonwealth of Australia, 2008).

Tidal fronts are known to occur at the separation of vertically mixed waters and stratified areas of the water column. Tidal fronts occurring within the NWMR have been implicated in zones of higher biological productivity. Occurrence of tidal fronts typically coincides with weakening of the Leeuwin Current and fronts appear to be delineated by depth contours (Commonwealth of Australia, 2008).

Internal tides (or barotropic tides) occur at the interface of waters of different densities (i.e. at a thermocline) and are prominent in the NWMR. These tides are characteristically large in scale and frequently occur in ocean basins. Internal tides can rise and fall at contrasting rates to the associated surface tide but are typically semi-diurnal (occurring twice daily). Internal tides may move toward or away from the shore (Commonwealth of Australia, 2008).

Internal tides may generate internal waves (solitons) as they intersect topographical seafloor features such as the shelf break or continental slope (Commonwealth of Australia, 2008). These waves may be tens of kilometres long with crests of up to 75 m (Commonwealth of Australia, 2008). The NWS is a known area of internal wave generation. Both internal tides and internal waves are thought to be more prevalent during summer months due to the increased stratification in the water column. These waves may break on reaching topographic features such as Scott Reef and may result in overall mixing of the water column and increased turbulence at the seabed (Commonwealth of Australia, 2008).

Browse Development Area

Tides within the waters of the Browse Development Area range from +2.30 m to -2.30 m mean sea level (MSL). The highest astronomical tide in the area occurs within Scott Reef (+5.3 m) (MetOcean Engineers, 2005), with the tidal current flow around Scott Reef influenced by the reef and channel bathymetry (i.e. the macro tidal environment), which alters the tidal ranges from the open waters of the broader Browse Development Area. The exposure and immersion of the reef through the tidal cycle also has a major influence on the surface currents at Scott Reef (AIMS, 2006) and within the Browse Development area. The spring tidal range at Scott Reef is approximately 4.5 m (Seafarer Tides, 2011).

5.2.5.4 Currents

Regional Overview

The dominant surface currents in the NWMR are the Indonesian Throughflow (ITF), the South Equatorial Current and the Eastern Gyral Current, as shown in **Figure 5-8** below (Commonwealth of Australia, 2008). The ITF waters occur within the upper surface water layers. Recirculation of these waters occurs through interactions with the surface Eastern Gyral Current and the sub-surface Holloway Current (Commonwealth of Australia, 2008).The ITF and South Equatorial Current flow poleward, bringing warm, low salinity, oligotrophic waters. The ITF is a key link in facilitating the exchange of heat and water between ocean basins on a global level, by transporting water from the Pacific Ocean to the Indian Ocean through Indonesian seas (Commonwealth of Australia, 2008). This passage through Indonesian seas introduces freshwater inputs and run-off caused by high rainfall to the waters which arrive in the NWMR (Commonwealth of Australia, 2008).

Seasonal surface currents within the NWMR include the Holloway Current, which originates north of Darwin and is associated with the North West Monsoon pressure system, and those surface currents further south; the Ningaloo Current, Shark Bay Outflow and Capes Current, also shown in **Figure 5-8** (Commonwealth of Australia, 2008).

Sub-surface currents which dominate the NWMR are the Leeuwin Undercurrent and the West Australian Current (shown in **Figure 5-8**). These sub-surface currents flow against the surface currents listed above and originate from waters in the Subantarctic Mode Water Body (Commonwealth of Australia, 2008). These waters are typified by high oxygen concentrations, cooler temperatures and high salinity (Commonwealth of Australia, 2008).

The ITF and Leeuwin Current are signature currents in waters off the coast of WA and within the NWMR. Notably, the movement of warm waters south by the Leeuwin Current facilitates the occurrence of tropical and sub-tropical species further south than they would otherwise occur. The ITF and Leeuwin currents experience variability between years and seasons, typically associated with variation in atmospheric pressure gradients (Commonwealth of Australia, 2008).

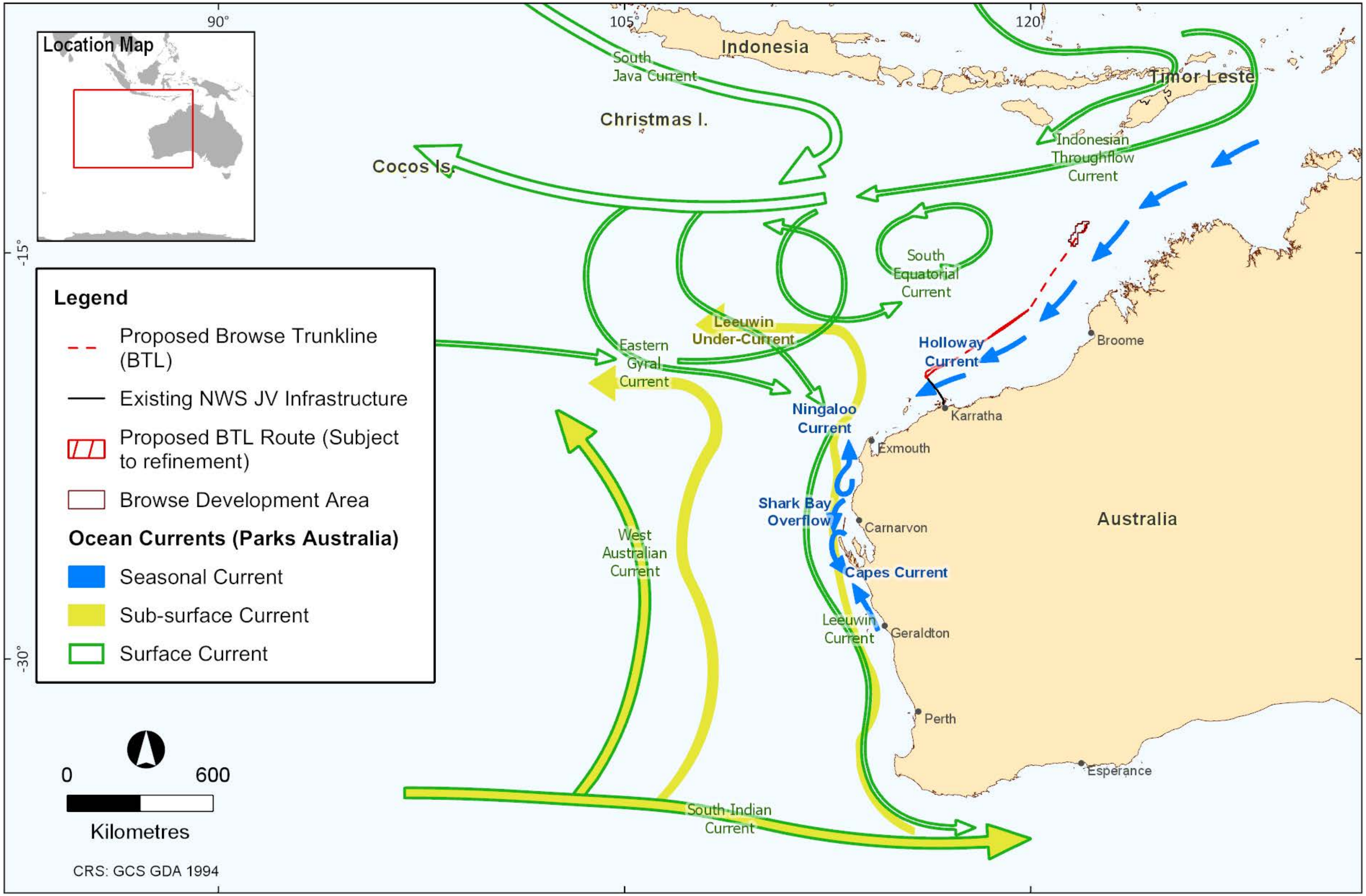

Figure 5-8 Dominant Ocean Currents within the NWMR (Commonwealth of Australia, 2008)

Browse Development Area

The ITF, located to the north of Scott Reef (Figure 5-8), does not directly influence the Browse Development Area, however; eddies that shed off and travel along the shelf-break have been recorded in measurements taken at the Brecknock and Calliance reservoirs with current speeds up to 0.3 to 0.4 m/s (DHI Water & Environment Pty Ltd, 2009[2]).

Scott Reef

The local water flow within the reef system is largely influenced by the macro tidal environment and its interaction with the topography of the reef structure. The spring tidal range is approximately 4.5 m with a semi-diurnal tidal cycle (Seafarer Tides, 2011). Depending on the cycle of the tide, the reef flat may be exposed or immersed and it is this cycle of exposure and inundation that has a major influence on the surface currents and thermodynamics of the reef (AIMS, 2006; Green et al., 2019b). Oceanic currents and the seasonal monsoonal weather conditions impact the layering of the water column so that the surface mixed layer deepens during periods of persistent wind and thins during calm periods (Brinkman et al., 2010).

The Scott Reef system is largely subject to the seasonal and inter-annual variability in temperature and salinity structure exhibited by the regional oceanic waters, with greater variability within the South Scott Reef lagoon caused by local processes such as enhanced vertical mixing due to internal waves, modified horizontal advection, residence times and local evaporation (Brinkman et al., 2010). Circulation is controlled by a south-eastward tidal propagation, with tidal currents flooding from the north-west and receding in a south-easterly direction. Tidal driven flood currents within the channel between North and South Scott Reef propagate towards the east with enhanced velocities. The circulation around and inside Scott Reef is determined by dynamic influences (winds and tides) as well as thermodynamic processes (Green et al., 2019b).

There is no evidence of persistent upwelling or downwelling currents at Scott Reef, but seawater temperature monitoring has recorded some evidence of localised intrusions of cooler water around the western and eastern entrances to the channel between North and South Scott Reef during spring tides (Green et al., 2019b). Such cool water intrusions are primarily semi-diurnal in timing, driven by the strong semi-diurnal periodicity in the prevailing internal wave and tide regime in the channel, combined with horizontal shear due to the strong tidal currents that can entrain water from below the sill depth of the channel up into the lagoon. Logger data suggests that the cool water entering the lagoon originates within the thermocline from depths shallower than 160 m, with no evidence of deeper waters entering the lagoon system (Brinkman et al., 2010).

Browse Trunkline

The proposed BTL route extends into the North West Shelf Transition provincial region which is similarly influenced by the ITF and the recirculation of these surface waters via the South Equatorial current.

5.2.5.5 Salinity

Regional Overview

The ITF brings warm, low salinity water into the region from the tropical western Pacific Ocean and drives upwellings of cold water onto the shelf from the deep Timor Trough to the north. An average salinity of 34.59 PSU was recorded across the NWMR (Brewer et al., 2007).

Browse Development Area

Salinity conditions through the water column were investigated at different locations in the Browse Development Area and around Scott Reef (Brinkman et al., 2009a[3]; Gardline Marine Services Pty Ltd, 2009a[4]). Across the Browse Development Area, oceanic salinity conditions prevail throughout the year with salinity remaining relatively uniform at 34 to 35 PSU. In the absence of major rivers, freshwater runoff from the land does not exert a pronounced influence on salinity conditions in the offshore marine environment of the Browse Development Area. At sampling locations at the Calliance and Brecknock reservoirs a halocline was evident. At these locations, salinity increased (by between 0.1 and 0.5 PSU) from approximately 34.5 PSU at depths of between 50 and 75 m, to 34.7 PSU at about 200 to 250 m water depth (Gardline Marine Services Pty Ltd, 2009).

Scott Reef

Studies have demonstrated a complex and seasonally varied salinity profile around the reef system with evidence for multiple interleaving layers within the mixed layer (<100 m) and in the thermocline to 300 m depth. Salinity within the lagoonal system of Scott Reef is generally horizontally and vertically uniform; however, there are transient episodes of salinity stratification due to local rainfall, evaporation and enhanced vertical mixing with water from the upper thermocline within the channel (Brinkman et al., 2010[5]).

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[2] *DHI Water & Environmental Pty Ltd, 2009 available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

[3] *Brinkman et al., 2009a available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

[4] *Gardline Marine Services Pty Ltd, 2009a available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

[5] *Brinkman et al., 2010 available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

Studies at Scott Reef recorded a mean salinity within South Scott Reef lagoon of 34.4 PSU, with a range of between 33.8 and 34.6 PSU (Brinkman et al., 2009a). Variability in the mean salinity between seasons reflects the water column characteristics of the surface mixed layer in surrounding oceanic water. There is evidence that salinities within South Scott Reef lagoon may at times rise above those of the surrounding waters and is likely to be a consequence of evaporation within the lagoon (**Figure 5-9**, Brinkman et al., 2010). Conversely, heavy rainfall has also been found to reduce surface salinity in the South Scott Reef lagoon to below that of the surrounding oceanic surface water for short periods (one to two days) (Brinkman et al., 2010).

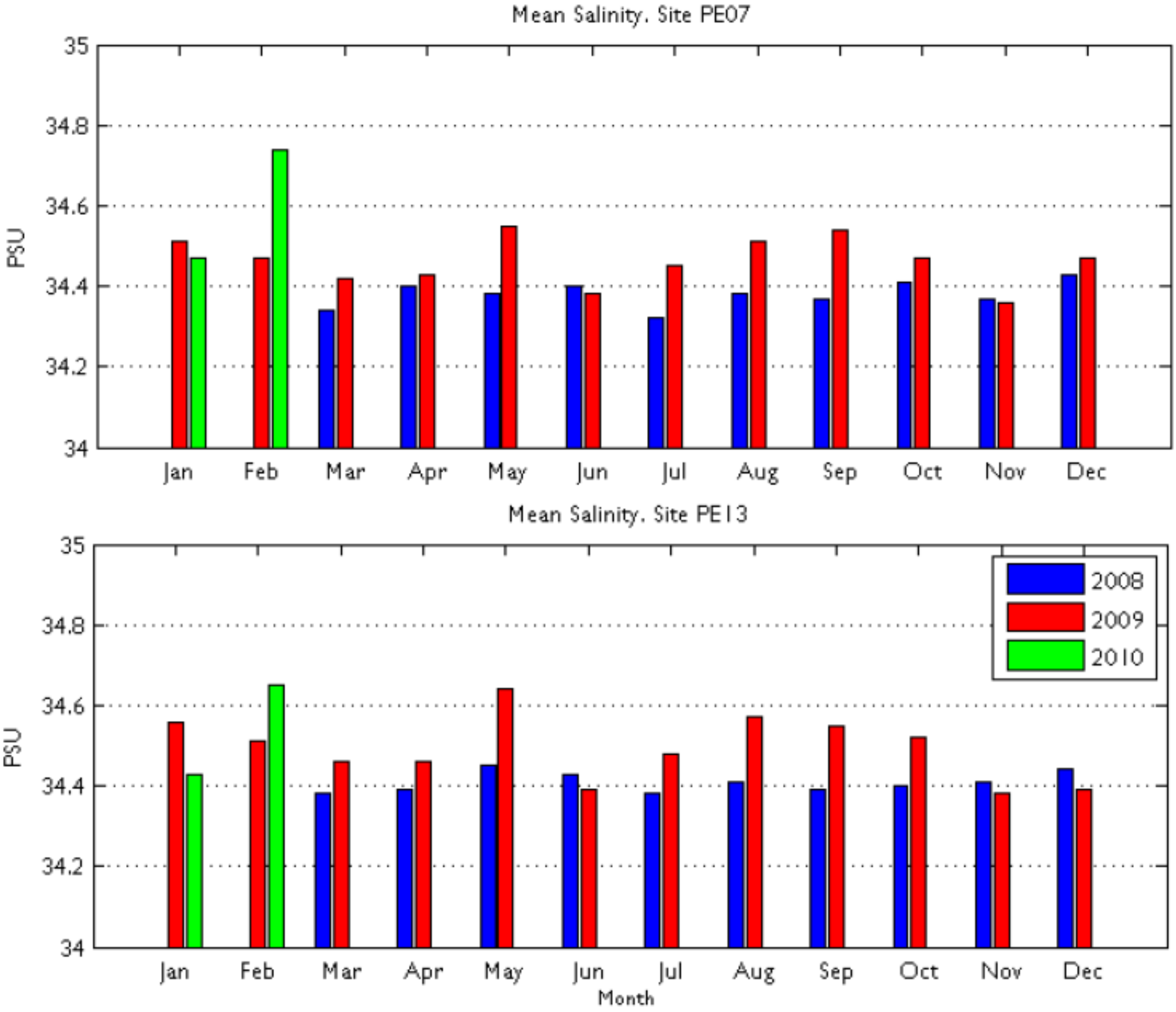

Figure 5-9 Monthly Average Salinity at In-situ Logger Sites Adjacent to the Channel between North and South Scott Reef (Top) and in the Interior of the South Scott Reef Lagoon (Bottom) (Brinkman et al., 2010).

Browse Trunkline

Salinity conditions through the water column were investigated at 20 sampling locations along the proposed BTL route (Advisian, 2019a). At these locations, the salinity ranged between 34.2 to 35.1 PSU and remained between this range across the depth profile.

5.2.5.6 Water Temperatures

Regional Overview

Water temperatures within the NWMR are driven by the ITF which transports warm waters into the region from the Pacific Ocean (Brewer et al., 2007). Water temperatures are subsequently warmest in the northern portion of the NWMR, varying between mean maximum temperatures of 31°C in summer and 27°C in winter (RPS MetOcean, 2008a). The region also experiences a horizontal gradient with waters typically warmer closer to the coast (Woodside Energy Limited, 2009a).

Browse Development Area

The Browse Development Area is situated within the Timor Province. This provincial sub-region is similarly dominated by the warm oligotrophic waters of the ITF and features a particularly pronounced thermocline associated with internal tides (Commonwealth of Australia, 2008).

Surface temperatures in the Browse Development Area vary from around 29°C (31°C maximum) in summer to around 27°C (19°C minimum) in winter (Brinkman et al., 2009a; Gardline Marine Services Pty Ltd, 2009). Sampling undertaken in the 2009 dry season (during June and July) recorded sea surface temperatures between 27°C and 28°C at sampling locations at the Calliance and Brecknock reservoirs (Gardline Marine Services Pty Ltd, 2009).

Scott Reef

Scott Reef is characterised by a well-mixed surface layer (0 m -100 m water depth) of warm water (27ºC - 30ºC), with water temperatures below the mixed surface layer declining to less than 10ºC at 400 m (**Figure 5-10**, Brinkman et al., 2010). Average daily water temperature within the South Scott Reef lagoon between March 2008 and February 2010 ranged from 24.7°C to 30.4°C, with minimum and maximum observed temperatures of 24.4°C and 30.9°C. Water temperature in the lagoon shows strong seasonality with a maximum in April followed by a minimum in late August (Brinkman et al., 2010). Ocean currents and seasonal atmospheric cycles can bring cool water into the lagoon on occasion, as described in **Section 5.2.5.4**.

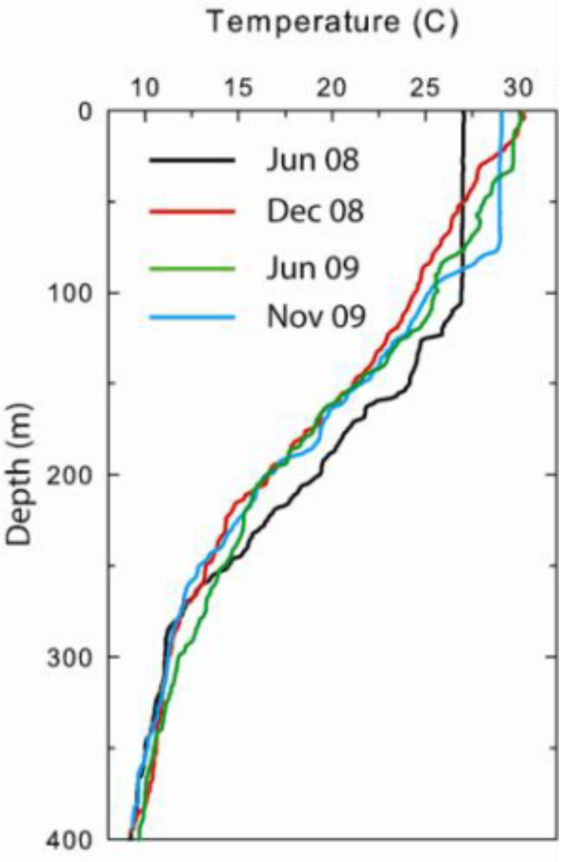

Figure 5-10 Vertical Profile of Water Temperature at an Open Water Site in the Vicinity of Scott Reef (Brinkman et al., 2010)

Browse Trunkline

Water temperature through the water column from seabed to surface at 20 locations along the proposed BTL route was measured in March and April 2019 (Advisian, 2019a). Temperatures ranged from 9.3°C at a depth of greater than 400 m, to 30.7 °C at surface waters, and there was a clear trend of decreasing temperature with increasing depth. Surface water temperatures varied by up to approximately 3°C with no spatial trend (Advisian, 2019a).

A thermocline at approximately 20 to 30 m depth was recorded at the majority of sites along the proposed BTL route and two sites (at the time of survey) with recorded thermoclines at approximately 50 m (Advisian, 2019a).

5.2.5.7 Thermoclines

The transitional layer between the well mixed surface waters (0-100 m) and cooler deeper waters (as described in **Section 5.2.5.4** and **Section 5.2.5.6**) is known as a thermocline (Brinkman et al., 2010). The depth of this thermocline is controlled by the strength of the ITF, which varies seasonally (Brewer et al., 2007). Within the Browse Development Area thermoclines were limited to areas where water depths were greater than 50 m (Gardline Marine Services Pty Ltd, 2009). At 50 to 80 m depth within the water column, temperatures decrease by between 1 to 5°C. In the deeper waters at the Brecknock, Calliance and Torosa reservoirs a further temperature decrease was recorded at 350 m (down to 10°C) and 600 m (down to 7 to 8°C) (Gardline Marine Services Pty Ltd, 2009).

In the cooler winter months, a clearly defined surface mixed layer of almost uniform temperature (approximately 27°C) generally persists as deep as 100 m in the deep waters overlying the gas reservoirs (Brinkman et al., 2009a; Gardline Marine Services Pty Ltd, 2009). The mixed layer, and therefore the depth of the thermocline, varies seasonally whereby deep winter mixing contrasts with summer stratification (Gardline Marine Services Pty Ltd, 2009; RPS MetOcean, 2008b). Water temperatures below 300 m water depth show little seasonal difference (**Figure 5-10**, Brinkman et al., 2010).

5.2.5.8 Nutrient Upwelling

Regional Overview

Much of the surface water in the region is oligotrophic (nutrient poor) water transported from the ITF (Brewer et al., 2007). Consequently, primary productivity is likely to be low, however; oceanographic processes do occur to transport deeper, cooler, nutrient rich water to the surface. These processes include (but are not limited to) internal wave and tide regime, the horizontal shear due to the strong tidal currents and tropical cyclones.

Browse Development Area

Tropical waters such as those within the Browse Development Area are typically nutrient poor, as described above for the wider region, except in the event of local or regional upwelling activity. Upwelling is the movement of denser, cooler, and usually nutrient-rich water from deeper locations towards the ocean surface, replacing the warmer, generally nutrient-depleted surface water. Nutrients introduced into the near surface layer during mixing or upwelling events are likely to initiate a general increase in primary productivity and increased plankton growth (Brinkman et al., 2009b[6]).

Scott Reef

At Scott Reef there is a continual cycle of upwelling with the cooler, nutrient-enriched waters from the channel thermocline (depths shallower than 160 m) moving laterally into the deep lagoon of South Scott Reef with the flooding tide (Brinkman et al., 2010). The majority of the cool water and dissolved nutrients that enter the lagoon are pulled out of the lagoon once more with the ebbing tide. Data collected at Scott Reef, however, shows that a proportion of this intruded water does mix with the lagoon water and remains resident in the lagoon for time scales longer than a tidal cycle (up to five days) (Brinkman et al., 2009b). Green et al. (2019a) also found waters advected into the lagoon during spring tides (from depths of approximately 75 m deep) to be richer in nutrients and chlorophyll a. This results in locally enhanced productivity near the seabed of the lagoon (Brinkman et al., 2009b) and it is proposed that this is the primary mechanism through which allochthonous (imported) nutrients are delivered to the benthic and pelagic communities of the lagoon (Green et al., 2019a).

It is unlikely that water from the deeper (greater than 200 m) portions of the deep channel between North Scott Reef and South Scott Reef are directly upwelled into the South Scott Reef lagoon (Brinkman et al., 2009b). This is because it is energetically more efficient for water to move and mix laterally along constant density surfaces than vertically against the significant density gradients that exist in and around Scott Reef (Brinkman et al., 2009b).

5.2.6 Air Quality

The Browse Development Area is situated approximately 260 km from the WA coastline and is thus remote from urban and/or industrial air pollutants. Air quality at the Browse Development Area is therefore expected to be of high quality.

Air quality along the proposed BTL route is similarly expected to be of high quality. Some industrial air pollutants may occur at the terminating south end of the proposed BTL route due to the presence of existing infrastructure associated with NRC and other petroleum activities within the area (e.g. Angel), however, as NRC is similarly located offshore of WA, air quality is expected to be high.

5.2.7 Ambient Light

As the Browse Development Area is situated approximately 260 km from the WA coastline it is remote from urban and/or industrial light emissions. The proposed BTL route is similarly removed from sources of light emissions, except where the proposed BTL route connects to the existing facilities at NRC.

5.2.8 Ambient Underwater Noise

Noise logger studies undertaken by (McCauley, 2011[7]) in and around Scott Reef (see locations in Figure 512) between 2006 and 2010 detected underwater noise associated with vessel traffic, exploration drilling, seismic surveys (including the Maxima, Endurance, Gigas, Vulcan and Canis seismic surveys), suspected illegal dynamite fishing, and marine fauna. Vessel and seismic noise featured prominently in these recordings and extended for long periods of time. Seismic detections were low frequency (< 50 Hz) inside the southern lagoon of Scott Reef, and were considered a persistent and widespread

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[6] *Brinkman et al., 2009b available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

[7] *McCauley, 2011 available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

contributor to background noise within range of the noise loggers (McCauley, 2011) during this period.

Ambient noise from marine fauna included calls from humpback whales, minke and dwarf minke whales, pygmy blue whales, Bryde's whales, as well as calls from unidentified whales and fish choruses (McCauley, 2011; further discussed in **Section 5.3.2.4**).

The existing anthropogenic noise environment within the vicinity of the Project Area is expected to be primarily associated with commercial shipping activities, as well as occasional petroleum exploration activities. Similar sources of anthropogenic underwater ambient noise may be expected along the proposed BTL route.

5.2.9 Water Quality

Regional Overview

Water quality in the Browse Development Area near the location of the proposed subsea infrastructure and facilities is typical of a pristine tropical offshore environment. Much of the surface water in this area is nutrient poor water transported from the ITF, with low levels of primary productivity (see **Section 5.3.1.1** for additional details on primary productivity within the Project Area).

Browse Development Area

This section describes the water quality in the Browse Development Area primarily based on findings from three surveys (Baker et al., 2008a) with sampling locations shown in **Figure 5-12**. Sampling was undertaken at the surface, mid-water and seabed for the surveys. Results are discussed in the context of the 2018 ANZECC & ARMCANZ guideline values (ANZG, 2018). It is acknowledged that the available data on water quality within the Browse Development Area was recorded 10-12 years ago; however, given the remote location of the Browse Development Area and the lack of any significant anthropogenic inputs within the area, the historical data are an appropriate representation of the current water quality conditions for the purposes of the impact assessment process. In addition, comparison of the historic water quality data with the more recent data collected as part of the BTL environmental survey in 2019 demonstrates the similarities in key water quality characteristics within such deepwater offshore locations. The comparison demonstrated that such waters were characterised by low turbidity, nutrient poor waters, with some naturally occurring metals.

Total suspended solids (TSS)

As part of monitoring events conducted at Scott Reef in 2008 and 2009, AIMS sampled TSS concentrations at various depths in the water column (surface, mid and bottom) adjacent to the reef and with South Scott Reef lagoon. TSS concentrations ranged from 0 mg/L to 2.4 mg/L (Brinkman et al., 2010, 2009b, 2009a, unpublished data), with no significant differences in TSS concentrations between surface, mid-water and deep waters. The low turbidity and associated high water clarity reported is typical of oceanic waters, which allows coral growth at depths of up to 70 m (Brinkman et al., 2009b).

Mean TSS concentrations recorded across the Browse Development Area by Gardline Marine Services Pty Ltd (2009a) were 23 mg L^{-1}, 22 mg L^{-1} and 24 mg L^{-1} for the surface, mid-water column and near seabed respectively (**Table 5-3**). The results showed no marked variation in TSS concentrations between sampling depths.

Table 5-3 Total Suspended Solids sampled within the Browse Development Area in Winter (June to July) 2009 (Gardline Marine Services Pty Ltd, 2009)

Sample station	Top water column (surface) (mg/l)	Middle water column (mg/l)	Bottom water column (near seabed) (mg/l)
Cal-28	47	33	38
Cal-29	15	28	19
Cal-30	22	23	32
Cal-31	6	14	17
Cal-33	30	7	32
Cal-38	30	38	42
Cal-41	25	34	8
Tor-44	30	35	28
Tor-57	25	26	20
Tor-58	30	12	31

Within Scott Reef, lagoon waters were reported to have low levels of turbidity (0.04 to 1.50 NTU), with very limited spatial variability in the deep sections of the lagoon (Brinkman et al., 2010). TSS concentrations measured in the North Reef lagoon were less than 1 mg/L and often close to the limits of detection for this method (Brinkman et al., 2010). Sample sites located on the margins of the reef slopes and in the channel between West Hook and the Sandy Islet show higher variability and higher average turbidity levels than observed within the lagoon system (Brinkman et al., 2010). Within the deeper sites in the lagoon there is little evidence of a sustained increase in turbidity near the seabed as a result of localised resuspension of settled matter (Brinkman et al., 2010). There is no apparent seasonal variation in turbidity across the reef system, with the only seasonal variability noted at a shallow inner reef site in South Scott Reef Lagoon (**Figure 5-11**, Brinkman et al., 2010) , presumably driven by localised wind and wave activity transporting suspended matter across the reef flat. At all other sites, particularly sites in the interior of the lagoon there is little apparent seasonality (**Figure 5-11**, Brinkman et al., 2010).

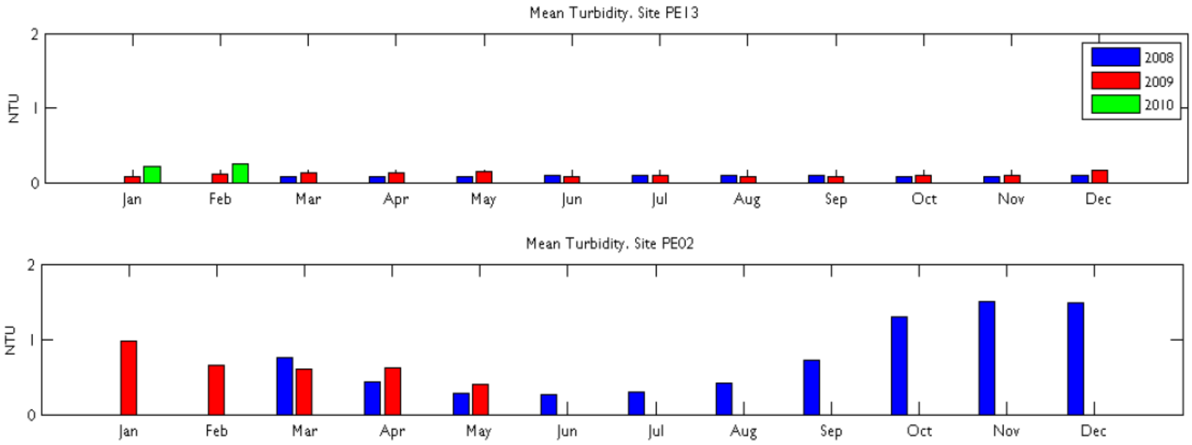


Figure 5-11 Monthly Average Turbidity (NTU) at Observational Sites PE13 (Lagoon) and PE02 (Inner Reef) (Brinkman et al., 2010)

Nutrients

Total nitrogen (TN) concentrations recorded across the Browse Development Area were generally low, with mean recorded concentrations of 1.0 mg/L, 3.0 mg/L and 1.1 mg/L for the surface, mid-water column and near seabed respectively (**Table 5-4**; Gardline Marine Services Pty Ltd, 2009a). Except for a higher concentration of 21.3 mg/L, recorded in mid-water at a sampling station within the Calliance field, the results were generally uniform across all the sampling sites. The reason for this high value was not clear but TN concentrations above and below in the water column had low (less than 1.0 mg/L) TN concentrations. Nitrogen oxides (NO_x) concentrations were consistent at all locations sampled across the Browse Development Area, being lowest (approximately 0.01 mg/L) in surface waters and increasing with depth (see **Table 5-4**). This was also observed for Ammonia (NH_4). where the mean concentration in surface waters was consistently lower than 0.1 mg/L across the Browse Development Area and was generally higher at depth (see **Table 5-4**).

The highest NH_4 concentration (0.09 mg/L) in surface waters across the Browse Development Area was recorded at Calliance. The relatively higher nutrient concentrations recorded at this location could relate to processes driving the seasonal (winter) peak productivity such as vertical uplift described by (Brinkman et al., 2009a; Green et al., 2018) for waters in proximity to Scott Reef.

Nutrient concentrations in terms of TN recorded by Gardline Marine Services Pty Ltd (2009a) for offshore waters were similar to previous findings by URS Australia Pty Ltd, (2007a). At a number of sites located in deep waters adjacent to North Scott Reef and South Scott Reef, URS Australia Pty Ltd, (2007a) reported variable but elevated TN concentrations up to 0.7 mg/L in surface waters. Concentrations of phosphorous were higher (0.25 mg/L) deeper in the water column than in surface waters (0.19 mg/L). With regards to nutrient enrichment, the delivery of biologically available nitrate and phosphate to the water column around Scott Reef is associated with physical processes such as wave-induced upwelling from deeper waters (< 200 m) (Brinkman et al., 2009a; Commonwealth of Australia, 2008). It is possible that similar enrichment processes are present in the waters overlying the Brecknock, Calliance and Torosa reservoirs, which might explain the recorded elevated nutrient concentrations.

Brinkman et al. (2010) observed that the waters around Scott Reef are oligotrophic (low nutrient - low biomass) in character. Sampling demonstrated that concentrations of dissolved inorganic nitrogen (NH_4^+, NO_{2-}, NO_{3-}) and phosphorus (PO_4^{3-}) were very low at all three deep-water reef sites. Within the South Reef lagoon, the upper water column (0 - 30 m) was also characterised by very low nitrate and phosphate concentrations at all times (Brinkman et al., 2010). Nitrate concentrations, in particular, were near or below detection limits (<0.02 $_{\mu}$m). Slightly elevated nitrite concentrations (< 0.2 $_{\mu}$m) were consistently measured in samples collected in the upper thermocline (Brinkman et al., 2010).

Metals

Metal concentrations in offshore waters are released into the water column during physical and chemical weathering of the underlying geology (Geoscience Australia, 2013). Metal concentrations are usually extremely low, as offshore waters are generally undisturbed by human activity (Batley, 1996). With the exception of arsenic (As), copper (Cu), nickel (Ni) and zinc (Zn), the metal concentrations found throughout the Browse Development Area were below the minimum reporting levels (less than 0.005 mg/L) defined in the ANZECC & ARMCANZ guidelines (ANZG, 2018).

Elevated concentrations of Cu (greater than 0.01 mg/L) and Zn (greater than 0.05 mg/L) were recorded at the majority of sampling sites in waters overlying the Brecknock and Calliance reservoirs (see **Table 5-4**; Gardline Marine Services Pty Ltd, 2009a). The highest concentration of Zn was recorded at the Torosa reservoir (0.25 mg/L). Concentrations above the minimum reporting levels for As, Cu, Ni and Zn were recorded at only one sampling site overlying the Torosa reservoir.

Metal analyte levels were below the limit of reporting (LoR) for the Browse Development Area: With concentrations of cobalt (Co), chromium (Cr), Cu, lead (Pb) and Ni at or below 0.001 mg/L (Gardline Marine Services Pty Ltd, 2009), the Brecknock, Calliance and Torosa reservoirs are reflective of the anthropogenically undisturbed waters of the region.

pH

According to the Intergovernmental Panel on Climate Change (IPCC), the mean pH of open ocean surface waters ranges between 7.9 and 8.3 (Intergovernmental Panel on Climate Change, 2007). Although pH can decrease with depth, carbon dioxide (CO_2) present in the atmosphere also reacts with water to give carbonic acid, therefore reducing the pH value in surface waters.

The pH values recorded in the Browse Development Area are somewhat lower than the pH expected for seawater, with surface pH values measured in the Browse Development Area ranging from 7.2 to 7.8 (Gardline Marine Services Pty Ltd, 2009) for all but two sampling locations, which appeared to fall below 7 pH at depths greater than 100 m. This is unlikely for seawater and suggests anomalous data for these two samples.

Chlorophyll a

Gardline Marine Services Pty Ltd (2009a) and Schroeder et al. (2009) reported chlorophyll a concentrations in waters within the Browse Development Area and at Scott Reef of less than 1 mg/m^3. In addition, the vertical distribution and concentrations of chlorophyll a were reported for the waters within, and in proximity to, South Scott Reef lagoon (Brinkman et al., 2009a). The distribution of chlorophyll a displayed a similar pattern of seasonal variability between the open water site and sites closer to Scott Reef. In winter there was a more uniform vertical distribution of chlorophyll a within the mixed layer whereas December (summer) was characterised by a peak in concentration (0.4 to 0.5 micrograms per litre (µg/L)) at water depths from 75 m to 100 m. The concentration of chlorophyll a at stations close to Scott Reef was reported as being twice that recorded for the open water site. Within the South Scott Reef lagoon, the concentration of chlorophyll a was uniformly low (around 0.3 µg/L) through the water column in winter while summer was characterised by a sub-surface peak in concentration (greater than 1.0 µg/L) at around 40 m depth. Schroeder et al., (2009) did also detect area of seasonally high chlorophyll a concentration to the north of Scott Reef. As described in **Section 5.2.5.8**, chlorophyll a within the South Scott Reef lagoon is found to vary with tidal fluctuations due to the advection of waters from the channel between South and North Scott Reef (Green et al., 2019a).

Browse Trunkline

An environmental survey undertaken along the proposed BTL route was used to inform the following description of the water quality along the proposed BTL route (Advisian, 2019a) (**Chapter 10, Appendix D.1**). Nineteen locations were sampled between March and April 2019 along the proposed BTL route with depths ranging from 128 m to 434 m. At each of the locations water quality samples were collected from sub-surface, mid-water and near seabed. The results of the sampling represent a snapshot of the indicative water quality along the proposed pipeline route, with the physico-chemical characteristics consistent along the proposed BTL route and considered representative of the north-west offshore oceanic environment.

Turbidity (NTU)

NTU concentrations ranged from 0 NTU to 2.35 NTU across sampling sites with no significant differences in turbidity concentrations between surface, mid water and deep waters at each location. Turbidity levels varied across the proposed BTL route and did not appear to be influenced by water depth or substrate type.

Nutrients

Nutrient analyses were above the ANZECC & ARMCANZ default trigger values for offshore marine waters at many of the sampling locations at depth (**Table 5-5**; ANZG, 2018). Across the proposed BTL route, total nitrogen (TN) concentrations ranged from <0.05 mg/L to 0.394 mg/L, Ammonia (NH_4) concentrations ranged from 0.007 mg/L to 0.261 mg/L, Nitrite and Nitrate concentrations ranged from 0.002 mg/L to 0.344 mg/L and Total Phosphorus (TP) concentrations ranged from 0.012 mg/L to 0.06 mg/L.

Metals

Water sampling results for trace metals were mostly below the ANZECC & ARMCANZ 99% trigger values at the sampling locations across the proposed BTL route (**Table 5-5**; ANZG, 2018; Advisian, 2019a); copper was found to exceed the 99% trigger value in the surface samples at two locations, although all concentrations were below the 95% trigger value.

pH

The pH ranged between 8.47 (at a depth of approximately 375 m) and 8.97 (at the surface), with a general trend of decreasing pH with depth.

Dissolved Oxygen (DO)

Oxygen saturation (%Sat) ranged from 26% to 79% with a general trend of decreased saturation with depth.

Total Phosphorus (TP)

TP increased with depth at all sample sites, with all surface samples slightly exceeding the trigger level of

0.01 mg/L.

Table 5-4 Mean Nutrient and Dissolved Metal Concentrations (µg/L) Recorded in Water Samples Collected at Sampling Stations in the Browse Development Area in Winter (June to July) 2009 (Gardline Marine Services Pty Ltd, 2009)

	Nutrients[1] (µg/L)				Dissolved Metals[2] (µg/L)								
Analyte	**TN**	**NO_3/NO_2**	**NH_4**	**TP**	**As**	**Cd**	**Cu**	**Cr**	**Co**	**Hg**	**Ni**	**Pb**	**Zn**
99% Trigger Value[3] (µg/L)	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**0.7**	**0.3**	**7.7**	**0.005**	**0.1**	**7**	**2.2**	**7**
LOR (µg/L)	**100.0**	**100.0**	**100.0**	**100.0**	**1.0**	**0.1**	**1.0**	**1.0**	**1.0**	**0.1**	**1.0**	**1.0**	**5.0**
Calliance Reservoir (3 sampling locations at 416 – 584 m maximum water depth)													
Surface	900.0	40.0	<100.0	<50.0	126.0	<1.0	11.0	<10.0	<5.0	<0.1	<10.0	<10.0	67.0
Mid-water	7700.0	140.0	<100.0	<50.0	127.0	<1.0	11.0	<10.0	<5.0	<0.1	<10.0	<10.0	43.0
Seabed	1100.0	230.0	<100.0	<50.0	124.0	<1.0	10.0	<10.0	<5.0	<0.1	<10.0	<10.0	61.0
Brecknock Reservoir (3 sampling locations at 549 – 645 m maximum water depths)													
Surface	900.0	10.0	<100.0	<50.0	66.0	<1.0	11.0	<10.0	<10.0	<0.1	<10.0	<10.0	<50.0
Mid-water	1200.0	240.0	<100.0	<50.0	65.0	<1.0	11.0	<10.0	<10.0	<0.1	<10.0	<10.0	<50.0
Seabed	700.0	340.0	<100.0	<50.0	68.0	<1.0	<1.0	<10.0	<10.0	<0.1	<10.0	<10.0	<50.0
Torosa Reservoir (1 sampling location at 474 m maximum water depth)													
Surface	700.0	30.0	<100.0	<50.0	189.0	<0.5	11.0	<5.0	<5.0	<0.1	<7.0	<5.0	257.0
Mid-water	3100.0	10.0	<100.0	<50.0	190.0	<0.5	12.0	<5.0	<5.0	<0.1	<8.0	<5.0	830.0
Seabed	1400.0	100.0	330.0	<50.0	190.0	<0.5	12.0	<5.0	<5.0	<0.1	<7.0	<5.0	62.0

[1] *Total Nitrogen (TN), Nitrate (NO_3), Nitrite (NO_2), Ammonia (NH_4) and Total Phosphorus (TP).*

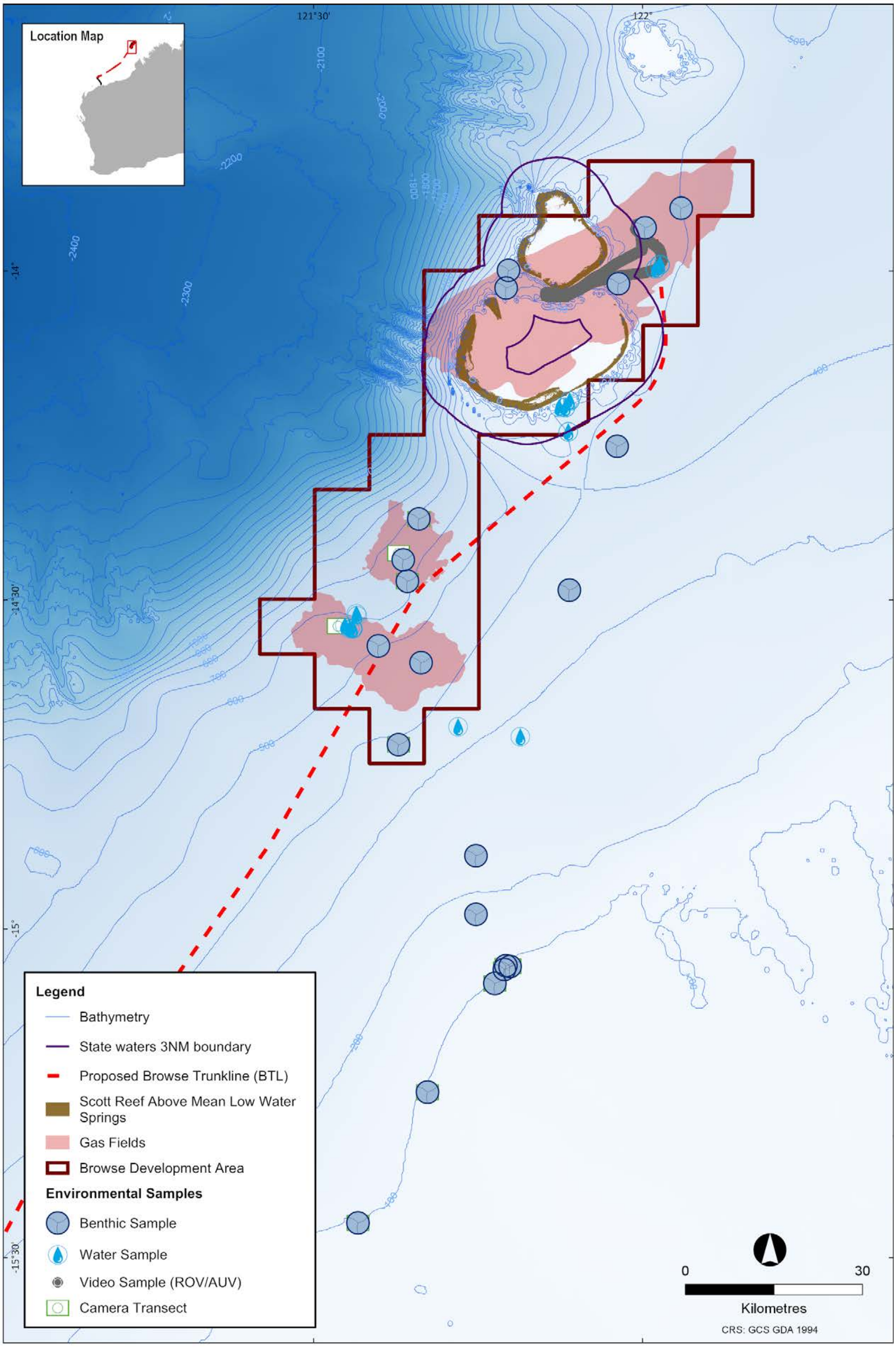


Figure 5-12 Historical Environmental Sampling Locations Relevant to the Project Area, Supported by BJV Surveys

Table 5-5 Nutrient and Dissolved Metal Concentrations (µg/L) Recorded in Water Samples Collected at Sampling Stations in the BTL in March and April (Autumn) 2019 (Advisian, 2019a)

Analyte	Limit of Reporting (LOR)	ANZECC & ARMCANZ (ANZG, 2018) Trigger level for marine water		Range in Values
		99%	95%	
Nutrients				
Total Nitrogen (µg/L)	50.0	N/A	N/A	50.0 – 394.0
Nitrite and Nitrate (µg/L)	2.0	N/A	N/A	2.0 – 344.0
NH4 (µg/L)	5.0	N/A	N/A	7.0 – 261.0
Total Phosphorus (µg/L)	5.0	N/A	N/A	12.0 – 60.0
Metals				
Aluminium (µg/l)	5	27 (pH > 6.5)[1]	55 (pH > 6.5)1	5 - 19
Arsenic (µg/l)	0.5	1 (III)[1] 0.8 (V)[1]	24 (III)[1] 13 (V)[1]	1.4 – 2.1
Barium (µg/l)	1	N/A	N/A	5 - 18
Cadmium (µg/l)	0.2	0.7	5.5	< 0.2
Chromium (µg/l)	0.5	7.7	27	< 0.5 – 1.9
Copper (µg/l)	0.2	0.3	1.3	< 0.2 – 0.7
Cobalt (µg/l)	0.05	0.005	1	< 0.05
Iron (µg/l)	5	N/A	N/A	< 5 – 18
Mercury (µg/L)	0.04	0.1	0.1	< 0.04
Nickel (µg/l)	0.5	7	70	< 0.5
Lead (µg/l)	0.2	2.2	4.4	< 0.2 – 0.5
Tin (µg/l)	5	N/A	N/A	< 5
Vanadium (µg/l)	0.5	50	100	0.8 – 5.8
Zinc (µg/l)	5	7	15	< 5

1 Value provided is for freshwater as no marine water guideline value is available.

5.2.10 Sediments

Background

The distribution and movement of sediments is an important component of marine ecosystems, with sediments having a strong influence on primary production in the water column and on the seabed, as well as on the distribution and evolution of benthic habitats (Margvelashvili et al., 2006). Marine sediments are principally derived from weathering of the adjacent landmass ('terrigenous sediments') or biological processes ('pelagic sediments'). Marine carbonate sediments are formed from the skeletal remains of carbonate-secreting marine organisms and reportedly account for approximately 60% of the sediments in the NWMR (Commonwealth of Australia, 2008).

Regional Overview

Sediments within the NWMR are comprised of bio-clastic (i.e. derived from skeletal fossil fragments), calcareous (i.e. derived from calcium carbonate) and organogenic (i.e. derived from living organisms) sediments (Baker et al., 2008a). These sediments were deposited by relatively slow and uniform sedimentation rates, as the NWMR is an area of winnowing (i.e. transport of sediment via flow of water) as opposed to active deposition.

A variety of processes control the sediment transport mechanisms of the inner shelf, middle shelf, outer shelf/slope and abyssal plain/deep ocean floor of the NWMR; the inner shelf is influenced by the outflow of terrigenous sediments from rivers, whereas sediments of the middle shelf region are predominantly influenced by tidal processes. Sediments of the outer shelf/slope are influenced through a combination of slope processes and large ocean currents.

The sedimentary features of the NWS and, therefore, the Project Area, are shown in Figure 5-13 and Figure 5-14 below. The inner shelf is typified by sand, with localised accumulations of mud and gravel. Silt sized sediments in the inner shelf have been found to contain 30% carbonate and 70% non-carbonate sediments with skeletal fragments of benthic fauna. Terrigenous sediments are typically less common within the inner shelf and are restricted to areas adjacent to rivers. The middle shelf is typified by sand with deposits of coral and gravel. The outer shelf and shelf slope are dominated by fine grained sediments and feature characteristic accumulations of carbonate deposits at the shelf edge. Pteropod and Globicerina Ooze refers to sediments partially derived from particular planktonic marine invertebrates.

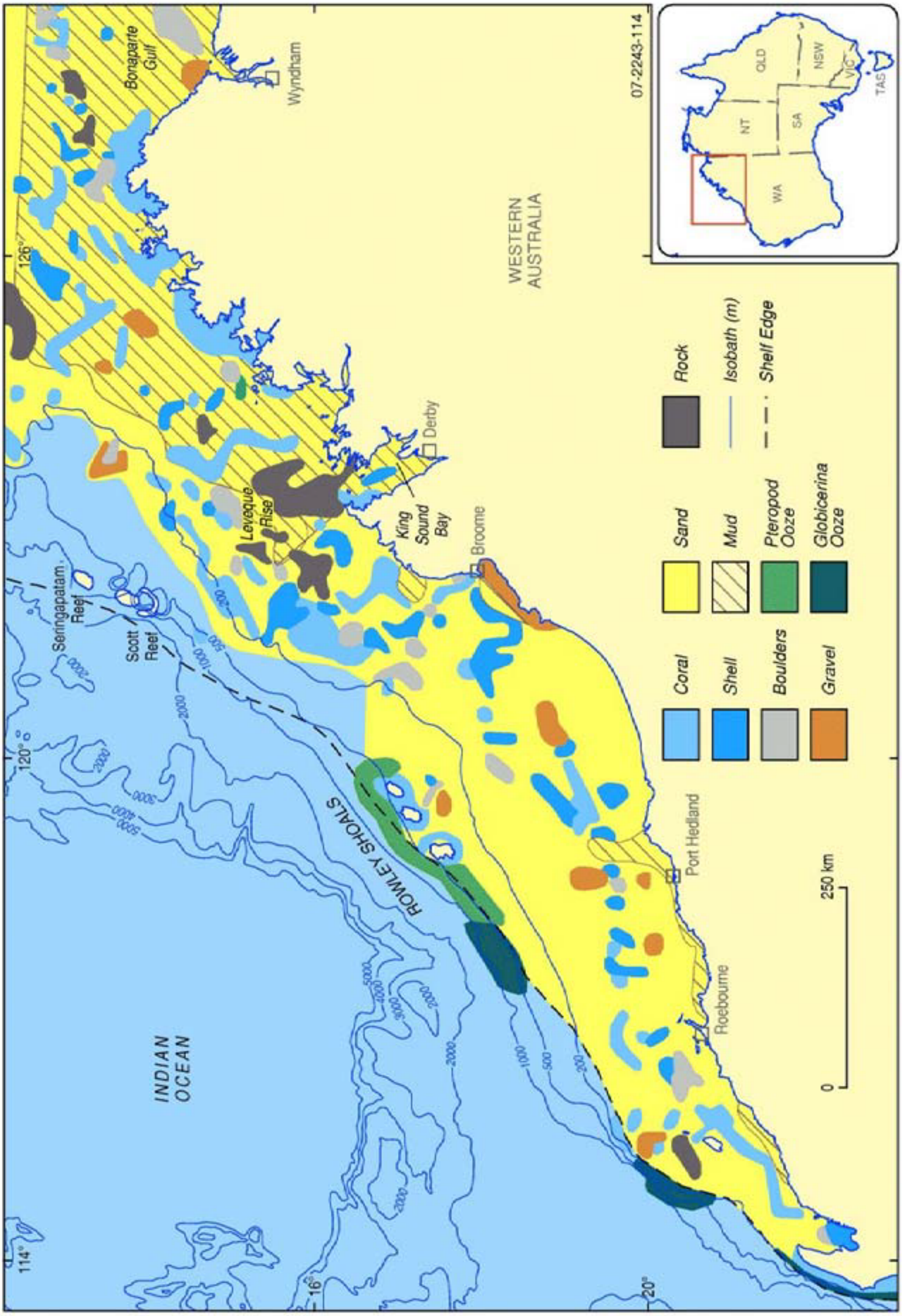


Figure 5-13 Sedimentary Characteristics of the North West Shelf (Baker et al., 2008b)

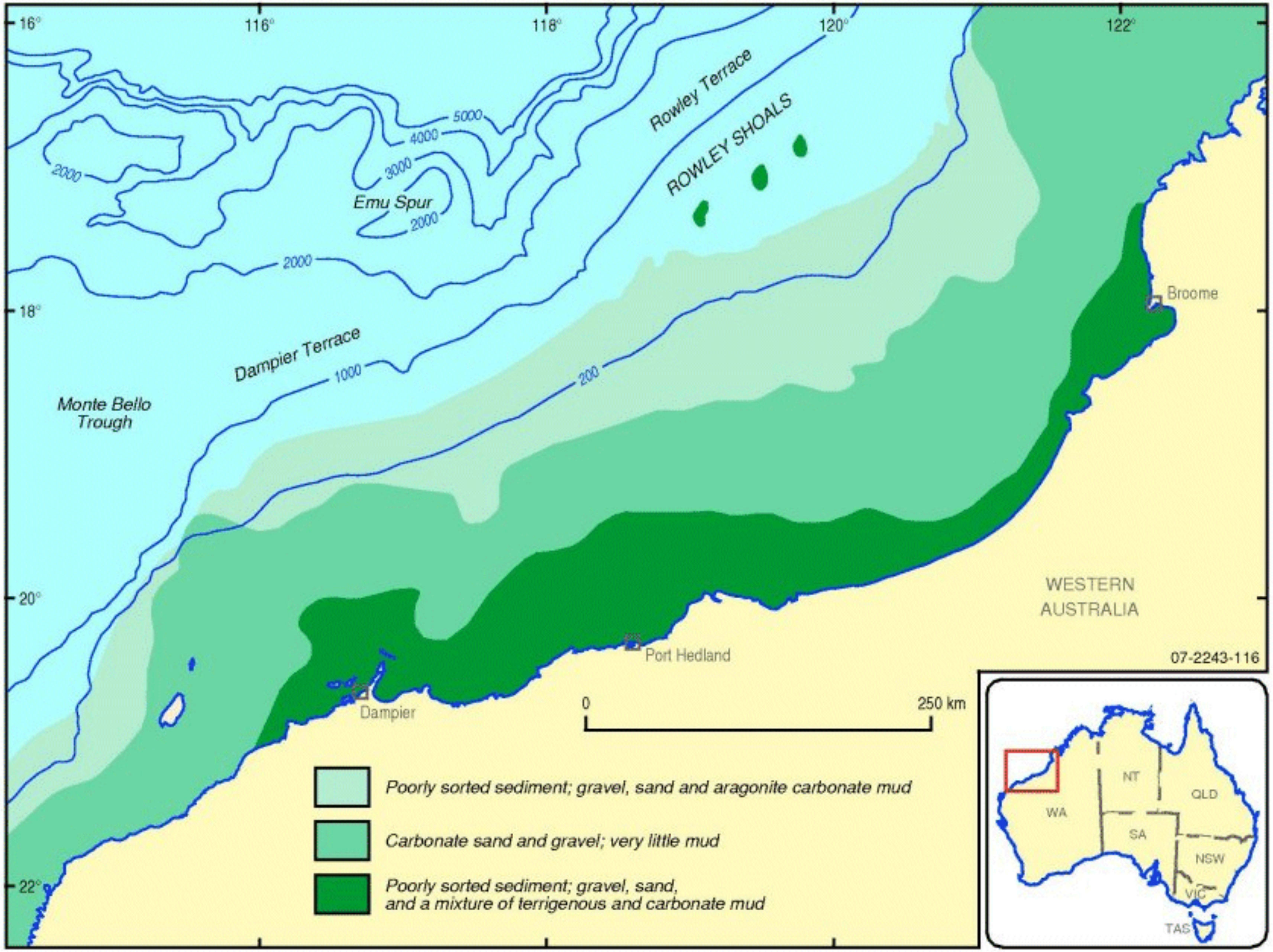


Figure 5-14 Overview of Seabed Sediments of the North West Shelf and Project Area (Baker et al., 2008b)

Browse Development Area

This section describes the sediment characteristics and quality in the Browse Development Area (including Scott Reef) primarily based on findings from three studies (Brinkman et al., 2009a; Gardline Marine Services Pty Ltd, 2009; URS Australia Pty Ltd, 2007a) with sampling locations shown in **Figure 5-12** above. Seabed sediments were also investigated as part of benthic surveys (**Figure 5-15** and **Figure 5-16**) by Gardline Marine Services Pty Ltd (2009a). Results are discussed in the context of the 2013 revision of the ANZECC & ARMCANZ guideline values for sediments (Simpson et al., 2013). It is acknowledged that the available data on sediment quality within the Browse Development Area was recorded between 10 and 12 years ago, however, given the remoteness of the Browse Development Area, the lack of any significant anthropogenic inputs within the area and the general lack of variability in sediment quality parameters (particularly within deep water environments), the historical data are an appropriate representation of the current sediment quality conditions for the purposes of the impact assessment process.

Physical sediment characterisation

Particle size distribution (PSD) analyses showed that sediments in the Browse Development Area were generally classified as muddy sand with variable gravel components (**Table 5-6**; and **Figure 5-15** and **Figure 5-16**). The seabed sediments at the Brecknock, Calliance and Torosa reservoirs were generally soft silt and clay, with areas of sand and stiff, hard and/or cemented material (Fugro Survey Pty Ltd, 2006; Gardline Marine Services Pty Ltd, 2009). The seabed close to the underlying reservoirs is characterised by a shallow (1 to 2°) featureless gradient. However, there is some irregularity associated with a current-eroded valley and sand waves with exposed layers of hard or cemented material amongst the seabed areas overlying and close to the Brecknock, Calliance and Torosa reservoirs.

Seabed surface sediments within the channel separating North and South Scott Reefs are characterised by well-rounded cobble/rubble (coral) and very coarse shell fragments. There are also areas of strongly rippled coarse sands (5 to 15 cm high) and small rubble with generally very little benthos (URS Australia Pty Ltd, 2007a). The paucity of fine sediment is characteristic of the surrounding seabed and is thought to be due to strong scour by tidal currents. PSD analysis (URS Australia Pty Ltd, 2007a) showed a general trend of finer sediment with increasing distance from Scott Reef, although this varied due to variable exposure to the prevailing tidal currents.

Hydrocarbons

No evidence of hydrocarbon contamination in sampled seabed sediments was reported in the Browse Development Area (Gardline Marine Services Pty Ltd, 2009; URS Australia Pty Ltd, 2007a). Gardline Marine Services Pty Ltd (2009a) reported that the concentration of total petroleum hydrocarbons (TPH) in all collected samples across the Browse Development Area was below the limits of detection (Gardline Marine Services Pty Ltd, 2009).

Nutrients

Gardline Marine Services Pty Ltd (2009a) reported TN concentrations ranged from 40 to 1900 micrograms per gram (µg/g) in seabed sediment samples collected within the Browse Development Area. Substantially high concentrations of TN (up to 1900 µg/g) were recorded in sediments collected in seabed sediments overlying or close to the Brecknock and Calliance reservoirs. Total phosphorous levels were variable, but the range (300 to 700 µg/g) was generally consistent throughout the Browse Development Area.

URS Australia Pty Ltd (URS Australia Pty Ltd, 2007b) reported that nutrients in deep-sea seabed sediments collected close to Scott Reef were well within the normal baseline values expected for carbonate-dominated sediments in remote tropical settings.

Metals

Metal concentrations recorded in seabed sediment samples collected across the Browse Development Area were variable (see **Table 5-6**), with no strong correlation between metal concentration and PSD or water depth identified (Gardline Marine Services Pty Ltd, 2009). With the exception of a slight exceedance in Ni concentrations at two locations and Hg concentrations at one location, metal concentrations (As, Cd, Cu, Cr, Co, Hg, Pb and Zn) in collected sediment were below trigger levels reported in the Australian and New Zealand interim sediment quality guidelines (ANZG, 2018).

URS (URS, 2007a) also reported that metal concentrations in seabed sediments collected close to Scott Reef were below these guideline levels, with the highest concentrations observed within the fine sediments close to Scott Reef.

Table 5-6 Physical characteristics of Sediments collected in the Browse Development Area (Gardline Marine Services Pty Ltd, 2009)

Sampling Station	Sampling Depth (m)	Median Particle Size (µm)	Fines %	Sand %	Gravel %	Modified Folk Classification (Folk 1954)
Calliance Reservoir						
Cal-28	416	3	78.03	21.67	0.30	Mud
Cal-29	488	2	93.65	6.15	0.20	Mud
Cal-30	584	3	90.74	9.16	0.10	Mud
Brecknock Reservoir						
Cal-38	549	2	93.61	6.29	0.10	Mud
Cal-31	593	5	87.7	12.1	0.20	Mud
Cal-41	645	30	64.61	34.59	0.80	Mud
Torosa Reservoir						
Tor-53	392	360	0.98	96.42	2.60	Slight gravelly sand Mud
Tor-45	467	30	73.59	25.61	0.80	Mud
Tor-44	474	7	79.16	20.24	0.60	Mud
Tor-55	559	45	58.81	40.79	0.40	Mud
Tor-54	561	60	51.59	48.01	0.40	Mud

Table 5-7 Mean Nutrient, Total Organic Carbon (TOC) and Metal Concentrations Recorded in Sediment Samples Collected at Sampling Stations in the Browse Development Area (Gardline Marine Services Pty Ltd, 2009)

	Calliance Reservoir	Brecknock Reservoir	Torosa Reservoir	
Number of Sampling Stations	**3**	**3**	**5**	
Depth range (m)	**416 - 584**	**549 - 645**	**392 - 561**	**Trigger Value[1]**
Nutrients (µg/g)				
Total Nitrogen	1523	843	366	N/A
Total Phosphorous	603	394	360	N/A
Nitrite and Nitrate	0.34	0.38	0.29	N/A
Organic Content (%)				
TOC	0.75	0.68	0.34	N/A
Metals (µg/g)				
Arsenic	1.16	<1	<1	20
Cadmium	0.30	0.30	0.20	1.5
Copper	14.80	11.8	4.50	65
Chromium	18.70	13.3	5.80	80
Cobalt	5.20	4.40	1.90	N/A
Mercury	0.04	0.04	0.02	0.15
Nickel	19.5	16.2	5.60	21
Lead	3.90	3.30	1.50	50
Zinc	33.80	26.60	12.60	200

[1] *Trigger values correspond with the latest revision of the ANZECC/ARMCANZ Sediment Quality Guidelines (Simpson et al., 2013).*

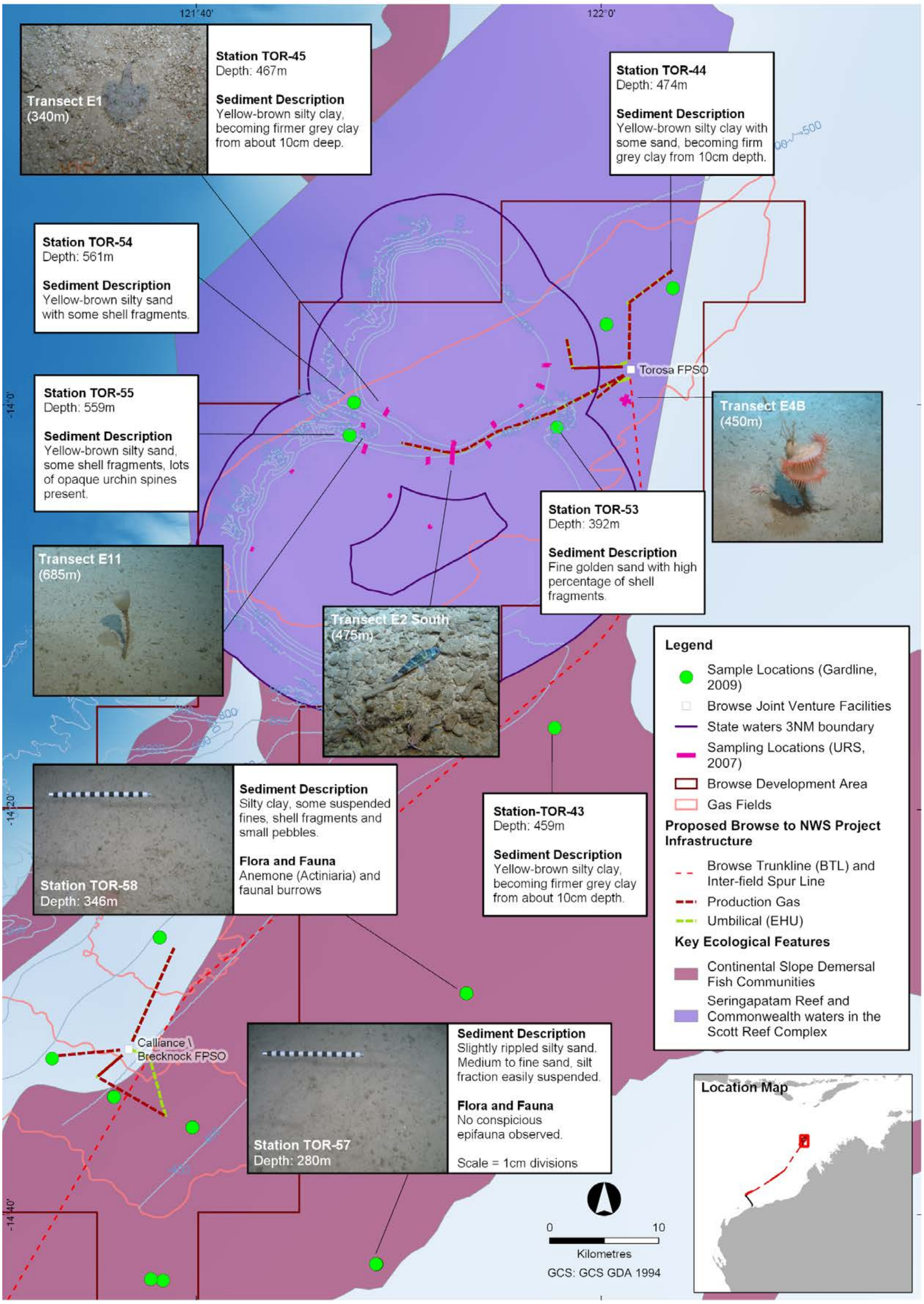
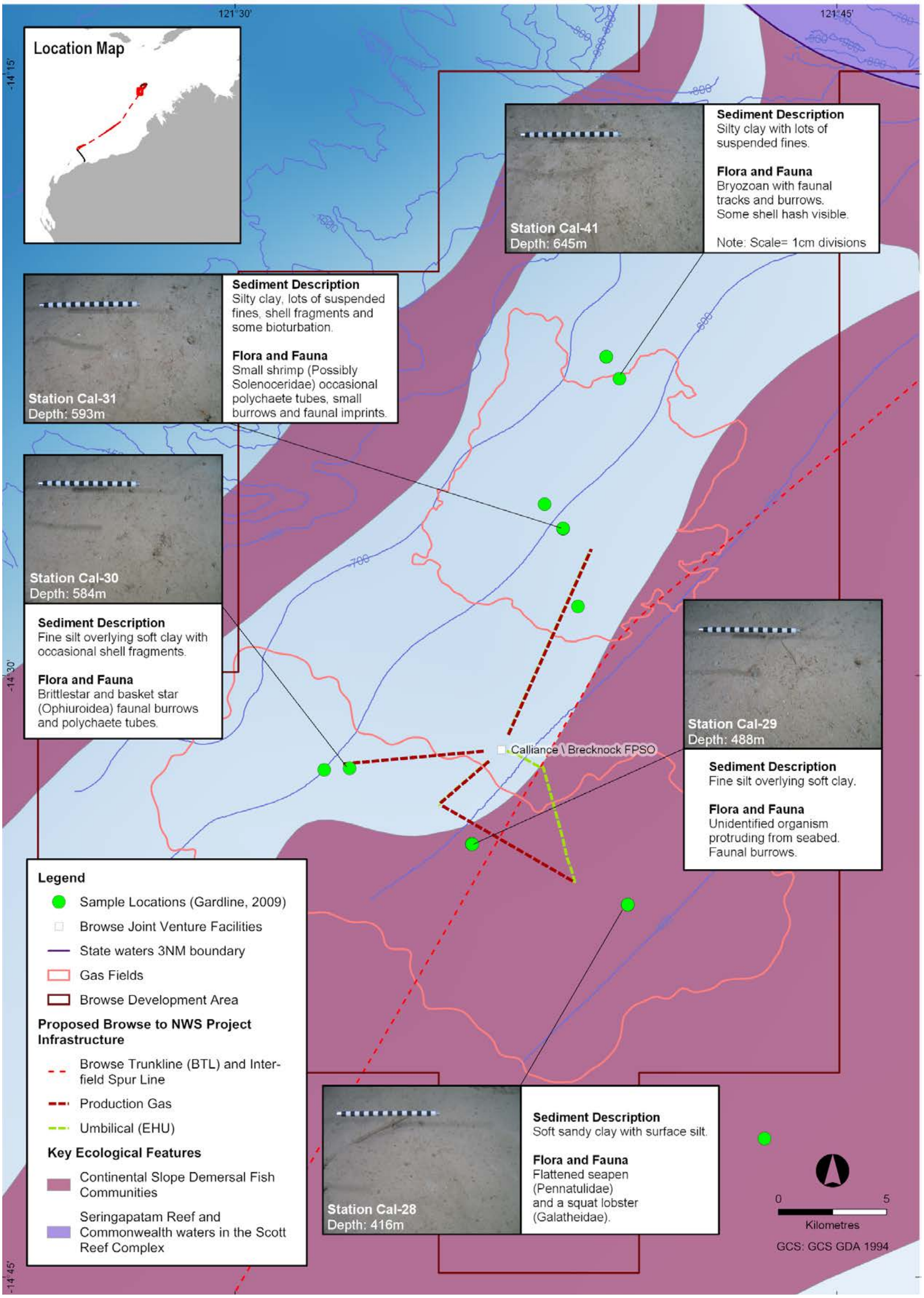


Figure 5-15 Deep Water Benthic Habitat Survey and Sampling Locations of the Torosa Reservoir Area and Surrounds (Gardline Marine Services Pty Ltd, 2009)



Station Cal-41, Depth: 645m

Sediment Description
Silty clay with lots of suspended fines.

Flora and Fauna
Bryozoan with faunal tracks and burrows. Some shell hash visible.

Note: Scale= 1cm divisions

Station Cal-31, Depth: 593m

Sediment Description
Silty clay, lots of suspended fines, shell fragments and some bioturbation.

Flora and Fauna
Small shrimp (Possibly Solenoceridae) occasional polychaete tubes, small burrows and faunal imprints.

Station Cal-30, Depth: 584m

Sediment Description
Fine silt overlying soft clay with occasional shell fragments.

Flora and Fauna
Brittlestar and basket star (Ophiuroidea) faunal burrows and polychaete tubes.

Station Cal-29, Depth: 488m

Sediment Description
Fine silt overlying soft clay.

Flora and Fauna
Unidentified organism protruding from seabed. Faunal burrows.

Station Cal-28, Depth: 416m

Sediment Description
Soft sandy clay with surface silt.

Flora and Fauna
Flattened seapen (Pennatulidae) and a squat lobster (Galatheidae).

Figure 5-16 Deep Water Benthic Habitat Survey and Sampling Locations of the Brecknock and Calliance Reservoir Areas (Gardline Marine Services Pty Ltd, 2009)

Browse Trunkline

The North West Atlas has compiled an interactive map of the MARine Sediment (MARS) database which contains detailed information on seabed sediment characteristics for samples collected within Australia's marine jurisdiction (Australian Government, 2019). **Figure 5-17** indicates that the grain size along the majority of the proposed BTL route is greater than 70% mud. As the proposed BTL route turns and approaches NRC on the NWS the sediment will tend toward less than 10% mud (Australian Government, 2019).

Sediment sampling was undertaken along the proposed BTL route in May and June of 2019 by Advisian (2019a) (**Chapter 10, Appendix D.1**). Samples were collected using a box corer (dimensions 0.5 m x 0.5 m x 0.5 m). Sampling locations are shown in **Figure 5-18**, **Figure 5-19** and **Figure 5-20**. The twenty locations were chosen as representative of the environmental sensitivities along the proposed BTL route. Specifically, three Key Ecological Features (KEFs; discussed in **Section 5.3.3.1**) were the focus of sampling; Ancient Coastline at the 125 m depth contour, Mermaid Reef and commonwealth waters surrounding the Rowley Shoals and Continental Slope Demersal Fisheries.

The results of the sediment sample analyses are shown in **Table 5-8**, **Table 5-9** and **Table 5-10**. Sediments along the proposed BTL route were predominately sands, as well as clays and silts. Samples were analysed for hydrocarbons, Benzene, Toluene, Ethylbenzene and Xylenes (BTEX), metals and nutrients, such as Nitrogen and Phosphorous. There were no exceedances of guideline values for marine sediments (Simpson et al., 2013) except for one instance, sample S-B-06, for which Nickel was 43.1 mg/kg. As the water depth at this sample location (the southernmost end of the Continental Slope Demersal Fisheries) was 434 m and the area is largely free from anthropogenic influences, this is likely to be naturally occurring variation in Nickel. Minimal variation was observed in Nickel concentrations at all other sampling sites Advisian (2019a, **Chapter 10, Appendix D.1**).

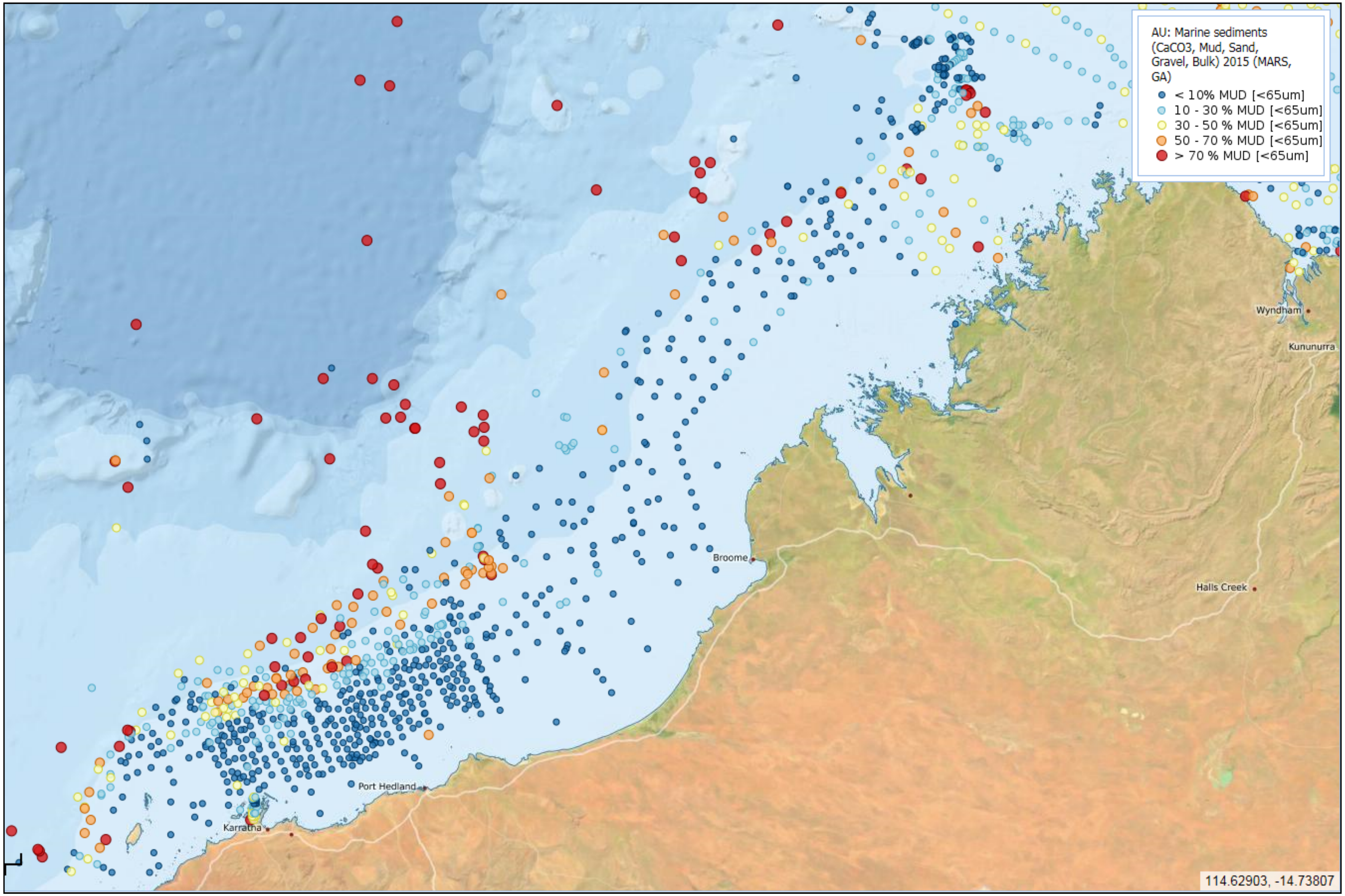
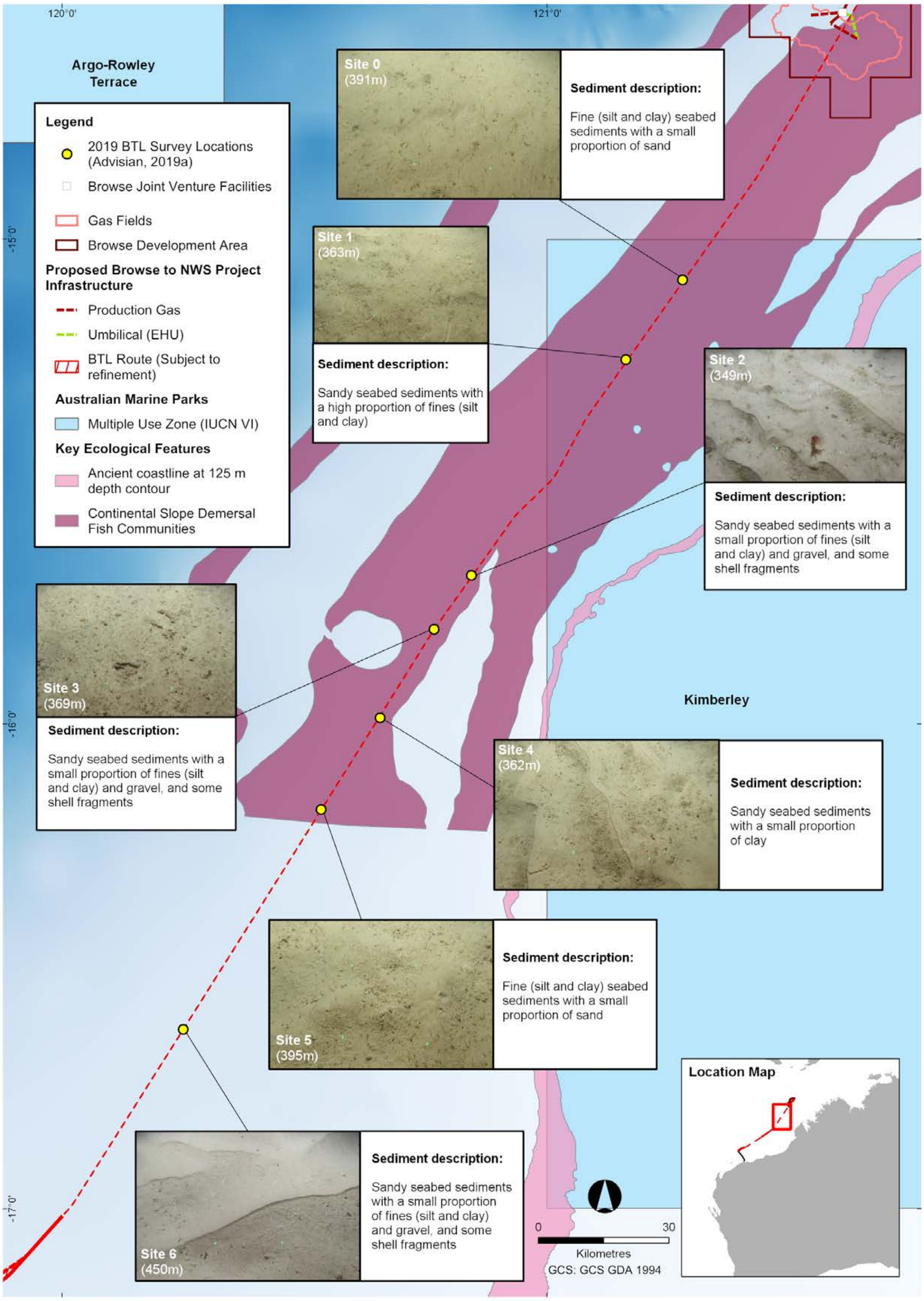


Figure 5-17 Marine Sediment Grain Size for the NWS (Australian Government, 2019) and includes the Browse Development Area and the Proposed BTL Route



Site 0 (391m)

Sediment description: Fine (silt and clay) seabed sediments with a small proportion of sand

Site 1 (363m)

Sediment description: Sandy seabed sediments with a high proportion of fines (silt and clay)

Site 2 (349m)

Sediment description: Sandy seabed sediments with a small proportion of fines (silt and clay) and gravel, and some shell fragments

Site 3 (369m)

Sediment description: Sandy seabed sediments with a small proportion of fines (silt and clay) and gravel, and some shell fragments

Site 4 (362m)

Sediment description: Sandy seabed sediments with a small proportion of clay

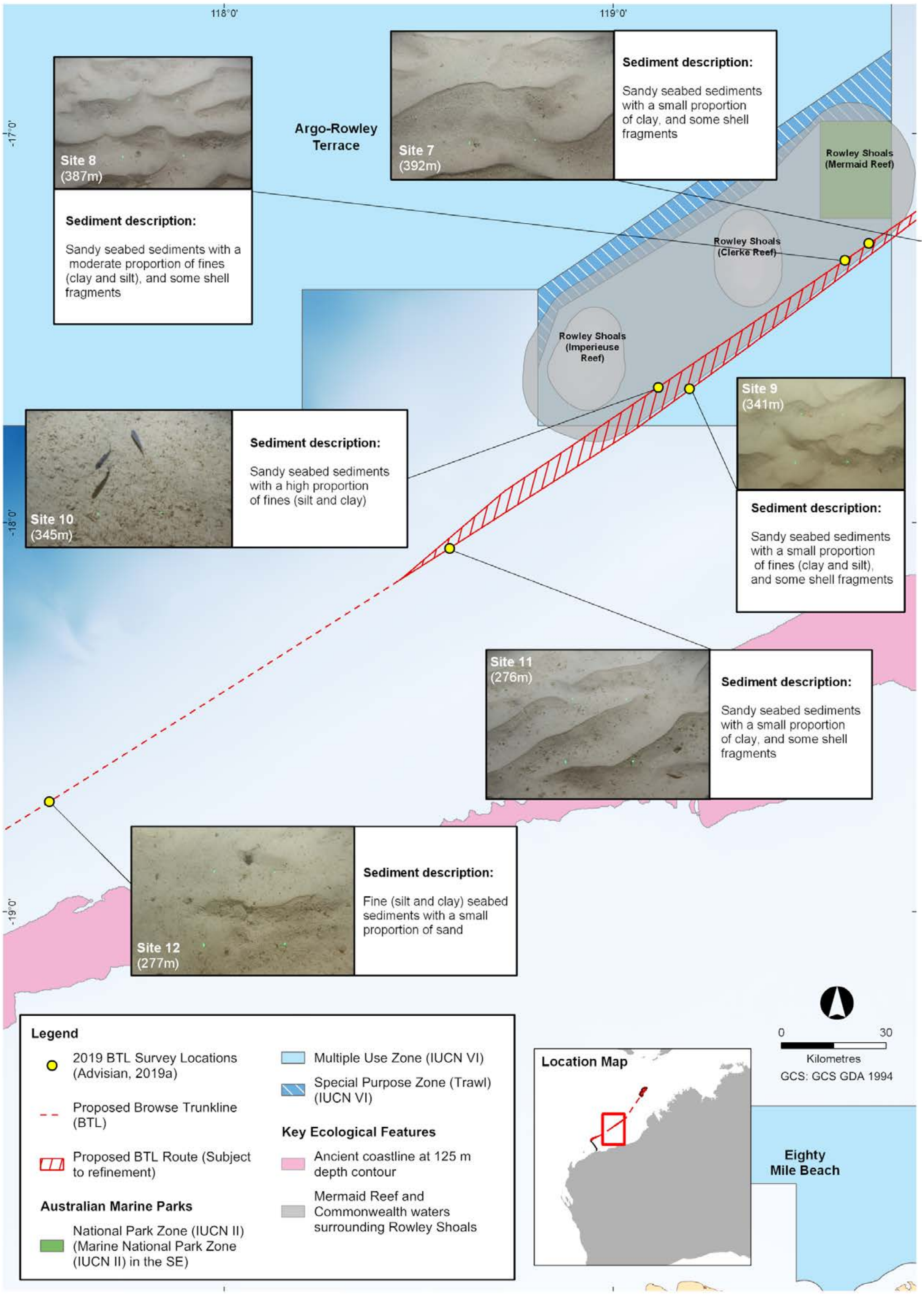
Site 5 (395m)

Sediment description: Fine (silt and clay) seabed sediments with a small proportion of sand

Site 6 (450m)

Sediment description: Sandy seabed sediments with a small proportion of fines (silt and clay) and gravel, and some shell fragments

Figure 5-18 Deep Water Benthic Habitat at Sampling Locations Along the Proposed BTL Route Survey (Advisian 2019a)



Site 7 (392m) – Sediment description:

Sandy seabed sediments with a small proportion of clay, and some shell fragments

Site 8 (387m) – Sediment description:

Sandy seabed sediments with a moderate proportion of fines (clay and silt), and some shell fragments

Site 10 (345m) – Sediment description:

Sandy seabed sediments with a high proportion of fines (silt and clay)

Site 9 (341m) – Sediment description:

Sandy seabed sediments with a small proportion of fines (clay and silt), and some shell fragments

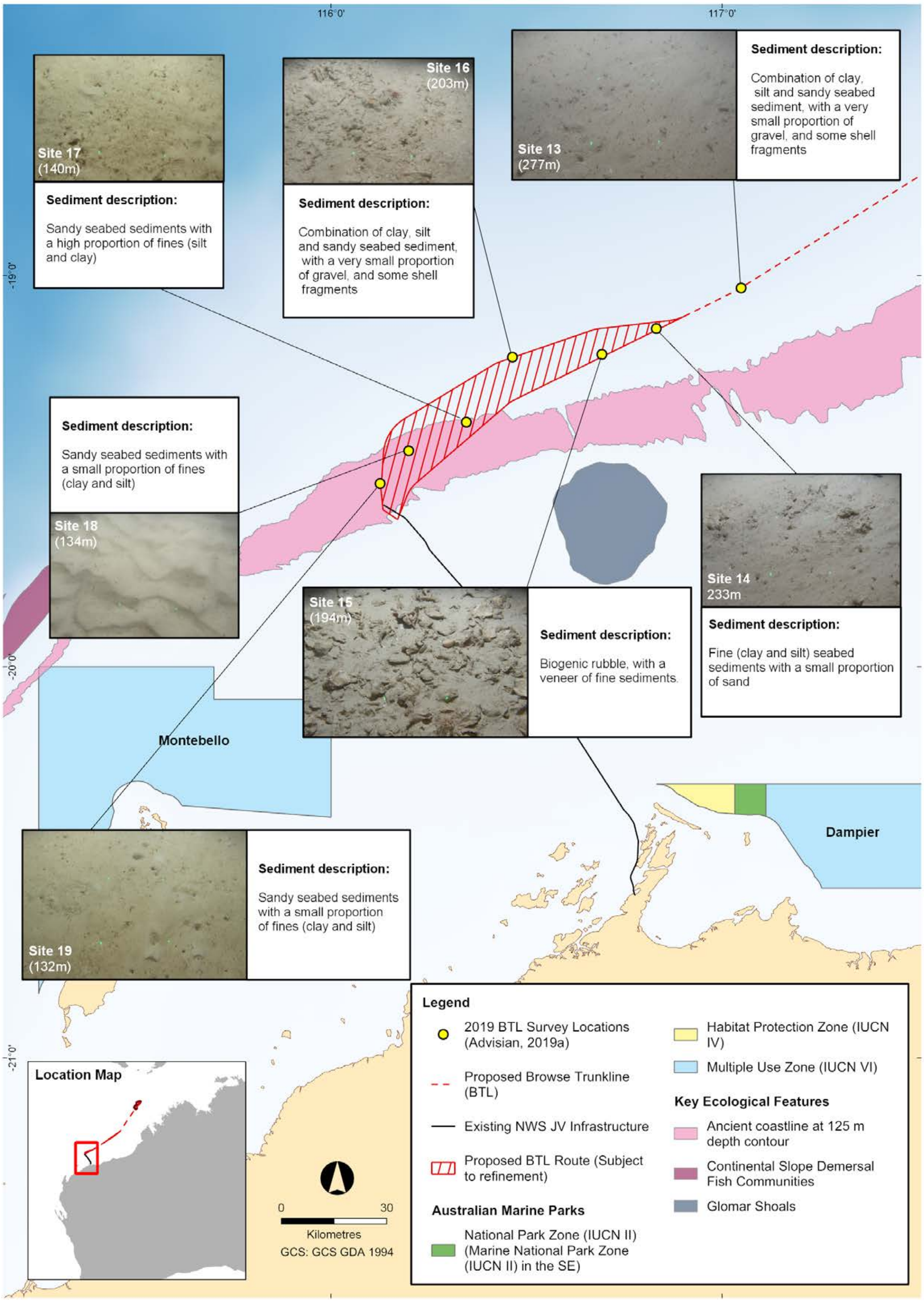
Site 11 (276m) – Sediment description:

Sandy seabed sediments with a small proportion of clay, and some shell fragments

Site 12 (277m) – Sediment description:

Fine (silt and clay) seabed sediments with a small proportion of sand

Figure 5-19 Deep Water Benthic Habitat at Sampling Locations Along the Proposed BTL Route Survey (Advisian 2019a)



Sediment description: Sandy seabed sediments with a high proportion of fines (silt and clay)

Sediment description: Combination of clay, silt and sandy seabed sediment, with a very small proportion of gravel, and some shell fragments

Sediment description: Combination of clay, silt and sandy seabed sediment, with a very small proportion of gravel, and some shell fragments

Sediment description: Sandy seabed sediments with a small proportion of fines (clay and silt)

Sediment description: Biogenic rubble, with a veneer of fine sediments.

Sediment description: Fine (clay and silt) seabed sediments with a small proportion of sand

Sediment description: Sandy seabed sediments with a small proportion of fines (clay and silt)

Legend

- ○ 2019 BTL Survey Locations (Advisian, 2019a)
- – – Proposed Browse Trunkline (BTL)
- — Existing NWS JV Infrastructure
- ▨ Proposed BTL Route (Subject to refinement)

Australian Marine Parks

- 🟩 National Park Zone (IUCN II) (Marine National Park Zone (IUCN II) in the SE)
- 🟨 Habitat Protection Zone (IUCN IV)
- 🟦 Multiple Use Zone (IUCN VI)

Key Ecological Features

- ▨ Ancient coastline at 125 m depth contour
- ▨ Continental Slope Demersal Fish Communities
- ▨ Glomar Shoals

Figure 5-20 Deep Water Benthic Habitat at Sampling Locations Along the Proposed BTL Route Survey (Advisian 2019a)

Table 5-8 Sampling Depth and Sediment Classifications of Sediment Samples Taken Along the proposed BTL route, Based on Particle Size (Advisian, 2019a)

Sample ID	Sampling Depth (m)	% Clay (<2 µm)	% Silt (2- 60 µm)	% Sand (0.06 - 2.00 mm)	% Gravel (> 2 mm)	% Cobbles (>6 cm)
S-B-00	378	38	40	22	<1	<1
S-B-01	349	23	18	59	<1	<1
S-B-02	339	14	5	79	2	<1
S-B-03	356	13	3	81	3	<1
S-B-04	348	11	<1	89	<1	<1
S-B-05	382	31	50	19	<1	<1
S-B-06	434	15	<1	85	<1	<1
S-B-07	377	6	<1	93	1	<1
S-B-08	373	22	7	70	1	<1
S-B-09	328	5	1	94	<1	<1
S-B-10	331	14	22	62	2	<1
S-B-11	267	11	<1	88	1	<1
S-B-12	268	36	49	15	<1	<1
S-B-13	267	36	16	44	4	<1
S-B-14	225	47	30	22	1	<1
S-B-16	197	33	19	45	3	<1
S-B-17	136	16	28	56	<1	<1
S-B-18	131	8	1	90	1	<1
S-B-19	128	10	8	81	1	<1

Table 5-9 Hydrocarbon and BTEX Analysis Results for Sediment Samples taken along the proposed BTL route by (Advisian, 2019a)

Sample ID	Total Petroleum Hydrocarbons (TPH) (mg/kg)		Sum of Polynuclear Aromatic Hydrocarbons (PAH) (µg/kg)	Sum of BTEX (mg/kg)
	C6-C9 Fraction	C10 - C36 Fraction (sum)		
Trigger Value[1]	*N/A*	*280*	*10,000*	*N/A*
LOR	*3*	*3*	*4*	*0.2*
S-B-00	<3	<3	<5	<0.2
S-B-01	<3	<3	<4	<0.2
S-B-02	<3	<3	<4	<0.2
S-B-03	<3	<3	<4	<0.2
S-B-04	<3	<3	<4	<0.2
S-B-05	<3	16	139	<0.2
S-B-06	<3	<3	<5	<0.2
S-B-07	<3	<3	<4	<0.2
S-B-08	<3	<3	<5	<0.2
S-B-09	<3	<3	<5	<0.2
S-B-10	<3	<3	<4	<0.2
S-B-11	<3	18	<5	<0.2
S-B-12	<3	<3	<5	<0.2
S-B-13	<3	<3	<4	<0.2
S-B-14	<3	<3	<4	<0.2
S-B-16	<3	<3	<4	<0.2
S-B-17	<3	<3	<4	<0.2
S-B-18	<3	<3	<4	<0.2
S-B-19	<3	<3	<4	<0.2

[1] *Trigger values correspond with the latest revision of the ANZECC/ARMCANZ Sediment Quality Guidelines (Simpson et al., 2013)*

Table 5-10 Proposed BTL Route Sediment Sample Analysis Results for Nutrients and Metals (Advisian, 2019a)

Analyte	Nutrients					Metals (mg/kg)											
Sample ID	Total Nitrogen (TN) (mg/kg)	Total Phosphorous (TP) (mg/kg)	Total Organic Carbon (TOC) %	Ammonia as N (mg/kg)	Nitrite and Nitrate (mg/kg)	Al	Fe	Cd	Cr	Cu	Pb	Ni	V	Zn	Ba	Sn	Hg
Trigger Value[1]	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*1.5*	*80*	*65*	*50*	*21*	*N/A*	*200*	*N/A*	*N/A*	*0.15*
LOR	*20*	*2*	*0.02*	*1*	*0.1*	*50*	*50*	*0.1*	*1*	*1*	*1*	*1*	*2*	*1*	*0.1*	*0.1*	*0.01*
S-B-00	1450	688	0.77	<1.0	0.1	4620	5290	0.2	15.5	11.2	2.6	14.1	10.6	25.8	43.0	0.3	0.02
S-B-01	1000	613	0.56	<1.0	0.1	2440	2940	0.1	10.0	7.1	1.7	8.8	5.0	15.3	20.2	0.2	0.01
S-B-02	420	763	0.22	<1.0	0.5	930	1290	0.2	7.2	3.1	1.0	4.4	3.0	7.7	10.9	<0.1	<0.01
S-B-03	460	430	0.25	<1.0	0.1	1080	1560	0.1	6.2	3.2	<0.1	4.4	2.7	11.6	12.5	0.1	<0.01
S-B-04	570	550	0.30	<1.0	0.2	1320	2080	0.2	7.7	3.9	1.6	4.7	3.5	9.6	13.5	0.1	<0.01
S-B-05	1510	696	0.82	<1.0	0.2	2800	3340	0.2	12.0	10.3	2.0	11.4	6.4	19.8	42.6	0.2	0.02
S-B-06	580	390	0.3	<1.0	1.1	2220	3660	0.2	6.9	5.7	11.3	43.1	9.8	19.1	28.2	0.2	0.02
S-B-07	350	1180	0.18	<1.0	0.9	1390	2620	0.2	6.5	2.9	2.6	8.9	4.6	14.5	11.2	0.1	0.01
S-B-08	520	1470	0.33	<1.0	1.3	1260	2310	0.2	7.3	3.8	1.8	6.3	4.3	14.6	11.9	0.1	0.01
S-B-09	320	852	0.13	<1.0	0.9	1100	2320	0.2	7.6	2.7	1.2	3.6	2.7	14.1	8.3	0.1	<0.01
S-B-10	550	748	0.22	<1.0	0.1	1130	2420	0.2	7.3	3.7	1.5	5.1	3.2	14.8	12.1	0.1	0.01
S-B-11	430	1770	0.25	<1.0	0.3	1220	2790	0.2	9.4	3.6	2.2	5.0	5.9	14.3	8.2	0.1	<0.01
S-B-12	1300	862	0.66	<1.0	0.1	1740	2030	0.2	12.6	7.8	1.5	9.2	4.8	11.6	17.8	0.2	0.01
S-B-13	620	689	0.29	<1.0	<0.1	770	1460	0.2	8.2	3.3	1.5	4.7	3.0	10.4	11.9	0.1	<0.01
S-B-14	610	862	0.28	<1.0	<0.1	820	2000	0.2	9.4	2.9	<1.0	4.5	3.5	7.6	13.5	0.2	<0.01
S-B-16	520	720	0.44	<1.0	<0.1	600	1160	0.2	8.1	2.3	<1.0	3.7	3.0	15.0	10.3	0.4	0.03
S-B-17	650	715	0.36	<1.0	0.1	1080	1780	0.2	10.0	3.7	1.1	5.4	2.8	7.2	19.6	<0.1	0.01
S-B-18	520	1600	0.32	<1.0	<0.1	1210	2590	0.2	11.3	2.7	1.6	4.9	3.6	8.8	11.0	0.1	<0.01
S-B-19	530	1320	0.36	<1.0	<0.1	1250	2400	0.2	11.3	3.1	1.6	5.5	3.4	9.0	36.2	0.1	0.01

[1] *Trigger values correspond with the latest revision of the ANZECC/ARMCANZ Sediment Quality Guidelines (Simpson et al., 2013).*

[2] *Aluminium (Al),Iron (Fe),Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Nickel (Ni), Vanadium (V), Zinc (Zn), Barium (Ba), Tin (Sn) and Mercury (Hg)*

5.3 Ecological Marine Environment

This section discusses the ecology, biodiversity and biogeography of the Browse Development Area, including Scott Reef, and the proposed BTL route in the context of the wider NWMR. EPBC Act listed Threatened and Migratory species are of particular focus and are summarised in **Section 5.3.2**.

5.3.1 Ecological Communities

The NWMR has a large area of continental shelf and continental slope, with a range of bathymetric features such as canyons, plateaus, terraces, ridges, reefs, banks and shoals. The marine environment in this region is typified by tropical marine ecosystems with diverse habitats of coral reef, soft sediments, canyons and limestone pavement. The NWMR boasts high species diversity and is home to significant populations of internationally threatened species (Director of National Parks, 2018). The key species and habitats which form the ecological communities' representative of the broader NWMR and Project Area are discussed in the following sections.

5.3.1.1 Plankton

Plankton plays an important role as a source of food to many large aquatic organisms. Phytoplankton are the primary producers; single-celled microscopic algae that capture light energy and dissolved nutrients and convert them into biomass that acts as the foundation for all higher consumer levels in the food chain.

Zooplankton, which are the dominant consumers of phytoplankton, provide a source of food for other zooplankton, larger invertebrates, fish, and some megafauna such as EPBC Act listed whale sharks and cetaceans, including humpback and blue whales.

A high degree of temporal and spatial variability is a common feature of plankton populations and is strongly linked to localised and seasonal productivity (Evans et al., 2016). Fluctuations in abundance and distribution occur both vertically and horizontally in response to tidal cycles, seasonal variation (light, water temperature and chemistry, currents and nutrients) and cyclonic events. Phytoplankton populations have very marked seasonal cycles of abundance and zooplankton, which rely on them for food, are subject to similar seasonality. In tropical regions, higher plankton concentrations generally occur during the dry season (Hayes et al., 2005). Plankton are a key indicator for ecosystem health and change as it is abundant, short-lived, not harvested and sensitive to changes in temperature, acidity and nutrients (Richardson et al., 2015).

Plankton distribution and abundance has been measured for over a century in Australia and has been compiled and made publicly available through the Australian Ocean Data Network (NCRIS, 2017). These data were used to nationally assess marine ecosystem health and has indicated that as warm waters extend further south, tropical phytoplankton species (which have a lower productivity) are also moving further south (Thompson et al., 2015).

Phytoplankton

Background

Phytoplankton growth in the marine environment is primarily mediated by the availability of nutrients (particularly nitrogen). Without nutrients, phytoplankton growth is poor even with ample sunlight and warm water. Phytoplankton growth is limited to the sunlit zone of the water column (the photic zone) where adequate photosynthetically available sunlight penetrates (Hallegraeff, 1995). In deep offshore waters that are distant from nutrient introductions from the land, phytoplankton growth is strongly associated with physical processes that move nutrient-rich water from dark deeper water into the upper sunlit photic zone, where the nutrients become available to phytoplankton and are rapidly taken up and used for growth. These 'nutrient upwellings' can occur through numerous mechanisms, mostly driven by winds interacting with currents and continental shelf topography.

Regional Overview

The NWMR has two distinct phytoplankton assemblages; a tropical oceanic community in offshore waters and a tropical shelf community confined to the NWS (Hallegraeff, 1995). The phytoplankton of the shelf waters of the region is predominantly nanoplankton (2 to 20 µm) diatoms (Hayes et al., 2005). Nanoplankton in these waters were reported to contribute between 60 to 97% of phytoplankton abundance, based on chlorophyll measurements (Hallegraeff and Jeffrey, 1984). These nanoplankton had a similar species composition to phytoplankton assemblages in sub-tropical and temperate Australian waters. In contrast, larger-sized (greater than 20 µm) phytoplankton (mainly diatoms and dinoflagellates) were found to be more diverse.

Six years of daily Moderate Resolution Imaging Spectrometer (MODIS)-Aqua satellite datasets from the NWMR (between November 2002 and December 2008) showed that chlorophyll (and thus phytoplankton) levels are low in summer months (December to March) and higher in the winter months (Schroeder et al., 2009). Low chlorophyll levels during summer months may be a result of lower plankton productivity during the wet season or lower nutrient inputs from warm surface waters dominant during summer. However, it is likely that much of the primary production is taking place below the surface, where the MODIS imagery does not penetrate (Schroeder et al., 2009). The winter months are relatively cloud free and surface chlorophyll is high throughout most of the region.

Browse Development Area

Communities of phytoplankton in oligotrophic tropical waters, such as those around Scott Reef, are usually dominated by picoplankton (less than 2 µm; Brinkman et al., 2009a). These are primarily preyed upon by similarly small organisms, such as bacteria, small unicellular flagellates, ciliates and viruses. While much of the productivity of picoplankton is consumed and recycled within this 'microbial loop', consumption and leakage of organic matter from the microbial loop ultimately drives much of the pelagic ecosystem in oligotrophic tropical waters (Brinkman et al., 2009a).

Phytoplankton at Scott Reef and surrounding waters, including the Torosa reservoir, is dominated by picoplankton, particularly the marine cyanobacteria genera *Prochlorococcus* and *Synechococcus* (Brinkman et al., 2009a). Estimates of the phytoplankton biomass (measured as chlorophyll a) close to Scott Reef are approximately twice that of open waters (sampled at distances greater than 50 km to the south-west of South Scott Reef). The open water location sampled is likely to be representative of the general outer shelf pelagic environment and so is representative of the oceanic waters of the Project Area. This difference is considered to most likely reflect the enhanced vertical mixing of nutrients into the surface layer around Scott Reef through interactions between the local hydrodynamics and the local topography (Brinkman et al., 2009a).

Browse Trunkline

The phytoplankton communities along the proposed BTL route are relatively low according to chlorophyll a concentrations which provide an indicator of primary productivity (as shown in **Figure 5-21**; Australian Government, 2018). This is typical for the NWMR where pelagic production is phytoplankton based, with hot spots around oceanic reefs and islands (Brewer et al., 2007).

The North West Atlas has compiled an interactive map of primary productivity hotspots based on satellite data collected between 2002 and 2014 (Australian Government, 2018). Acknowledging the temporal and spatial variation inherent in oceanic primary productivity, the data (shown in **Figure 5-21**) does demonstrate that primary productivity is generally higher along the coast, with hotspots located at some reefs and shoals. The majority of the area encompassed by the proposed BTL route demonstrates a low level of primarily productivity.

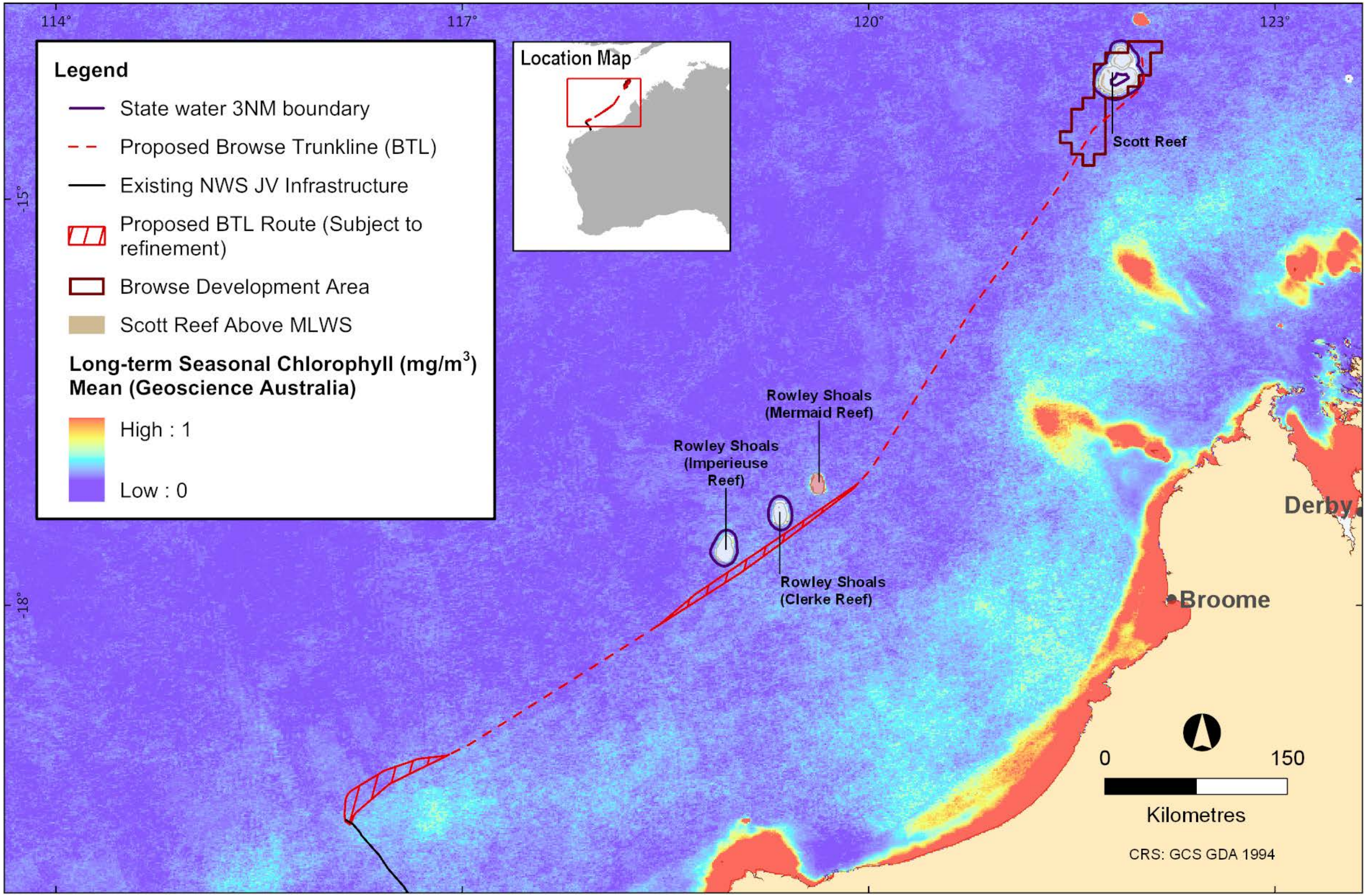


Figure 5-21 Primary Productivity Measured as Chlorophyll a Concentration for NWS (Australian Government, 2018) and includes the Browse Development Area and Proposed BTL Route

Zooplankton

Background

Zooplankton include representatives of all the major invertebrate phyla and include both holoplankton (permanent members of the plankton) and meroplankton (temporary members of the plankton). Meroplankton consist of larval and juvenile stages of animals that adopt a different lifestyle once they mature. Many fish and crustaceans are planktonic in the early stages of their development (Swadling et al., 2008). Zooplankton generally feed on phytoplankton, detritus and other zooplankton, and as a result, are primarily found in surface waters where food resources are most abundant.

Regional Overview

Recent data collected as part of the Australian Integrated Marine Observing System (IMOS) Australian Plankton indicated that Australian offshore waters contain a relatively low levels of zooplankton biomass, with copepods dominate within samples across all stations (Eriksen et al., 2019). Spatial and temporal patterns in the distribution and abundance of macrozooplankton on the NWS are influenced by sporadic climatic and oceanographic events, with large inter-annual changes in assemblages (Wilson et al., 2003). Amphipods, euphausiids, copepods, mysids and cumaceans are among the most common components of the zooplankton in the region (Wilson et al., 2003).

Browse Development Area

Zooplankton surveys have been conducted in the vicinity of the Torosa reservoir, with samples collected at three deepwater locations (two in waters overlying the Torosa reservoir and one to the south-west of Scott Reef). The surveys found that the biomass was similar in both June and December, representative of the dry and wet seasons respectively. The biomass of the mixed layer (less than 100 m) was recorded at concentrations of approximately 9 mg/m^3, which dropped to approximately 2 mg/m^3 in deeper water (greater than 100 m; Brinkman et al., 2009a). The zooplankton samples were dominated by copepods, with an increasing dominance of the family Oncaeidae with depth.

Zooplankton biomass and abundance within the South Scott Reef lagoon tends to be greater in the wet season than in the dry season, and is dominated by calanoid and cyclopoid copepods (Brinkman et al., 2009a). The community composition of the mixed layer at the deepwater sites (outside the reef) resembled that observed in the lagoon, with larvae the most abundant of the non-copepod plankton in both the lagoon and deeper waters. Jaspers et al., (2009) also found that larvaceans comprised a large proportion of the summer plankton in the Indian Ocean, and it is suggested that, in terms of total production, these animals will exceed the contribution by copepods.

Sampling of the deepwater in the channel between North Scott Reef and South Scott Reef suggests that zooplankton is more concentrated in the mixed layer of the channel than at other locations in the area (Brinkman et al., 2009a). The samples were dominated by large copepods; however, at least six species of euphausiids (krill) were collected, albeit in low abundance. Echo sounder surveys using a towed single beam sonar indicated a high density of zooplankton biomass along the channel's southern wall and at the eastern and western ends of the channel (Jenner et al., 2009). Little water column biomass was evident in the centre of channel, probably due to the occurrence of high velocity currents. There was evidence that krill comprised some portion of the zooplankton biomass recorded, however, this was not quantified by Jenner et al., 2009) Brinkman et al. (2010) identified six genera of tropical krill (Euphasiid shrimps) from Scott Reef but their zooplankton sampling at Scott Reef was unable to demonstrate that the channel was a hotspot of krill abundance though mechanisms of potential localised plankton (including krill) aggregations may occur.

The intrusion of cool waters into the South Scott Reef lagoon (as discussed in **Section 5.2.5.8**) brings supplies of 'new' nutrients, primarily in the form of biologically available nitrate and phosphate. This is expected to result in a growth burst of the most rapidly growing phytoplankton, which are usually the diatoms. Many diatoms are large celled and are an available food source to grazing zooplankton such as copepods.

Browse Trunkline

The waters along the proposed BTL route are expected to be typical of the offshore waters surrounding Australia, containing a relatively low zooplankton biomass, particularly in the offshore environment (Eriksen et al., 2019).

5.3.1.2 Benthic Habitats and Communities

Background

This section provides an overview of the deepwater benthic habitat types of the NWMR, and those that have been identified within the Browse Development Area and proposed BTL route. A detailed account of ecological functioning and diversity within a regional context and other information for Benthic Primary Producers (BPPs) (i.e. seagrass, macroalgae and coral) and marine invertebrate fauna (e.g. sponges, crustaceans, and molluscs) is presented in **Section 5.3.1.3** and **Section 5.3.1.4** respectively.

Regional Overview

The NWMR encompasses large seabed areas of deepwater habitats dominated by soft sediments (sandy and muddy substrata with occasional patches of coarser sediments) and sparse benthic biota. In 2007, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) conducted extensive benthic habitat mapping surveys and epifauna (fauna living on the surface of the sediment) sampling in shelf to deep waters (100 to 1000 m) spanning 13 sites between Barrow Island and Ashmore Reef, running downslope across the continental shelf and continental slope of the NWS (Williams et al., 2010). This research represents a highly comprehensive study of an otherwise historically little studied region and forms the basis of our understanding of this offshore area. Survey techniques included the use of epibenthic sleds and beam trawls for epifauna sampling, and camera tows and multi-beam echo sounder for characterising habitats. Within each site, surveys were conducted in a range of water depths (100 m, 200 m and 400 m), as well as in deeper waters (700 m and 1000 m), which correspond to the environment of the Browse Development Area footprint. Biological data from beam trawls were also used to spatially model abundance and diversity across the region based on Rank Abundance Distribution (RDA) methods. The results of this study are discussed below.

Survey sites located on the continental slope (approximately 400 m water depth) predominantly comprised soft muddy sediments. Epifauna at these sites were sparsely distributed and limited to isolated individual biota including sessile crinoids, anemones, glass sponges and sea pens. Occasional non-sessile, mobile fauna, characteristic of the deeper benthic communities were recorded, and, included: echinoderms (urchins, holothurians and sea stars) and decapods (prawns and crabs). Modelling indicated a 1 km long beam trawl across the continental shelf would be expected to yield sparse (less than 20 individuals) and low diversity (less than 10 species) of epibenthic fauna (≥1 cm body size; Williams et al., 2010). Similar benthic biota composition were reported for continental slope seabed habitats at depths of 700 and 1000 m (Williams et al., 2010).

Although soft sediment habitat may appear homogenous and featureless, there is likely to be some marked differences in terms of ecological functioning and faunal composition between the shelf and continental slope seabed habitats of the Browse Development Area. Typically, the spatial and temporal distribution of benthic fauna at any location depends on factors such as sediment characteristics, nature of the underlying substrate, food availability and depth. In particular, the 200 m isobath (inland of the Browse Development Area) is widely believed to represent a key transitional barrier with regards to marine ecology (Brewer et al., 2007; Gage and Tyler, 1992). Notably, beyond the 200 m isobath, the deeper water benthic biota are diverse but less abundant as the benthic communities rely on the settling of organic detritus from the overlying water column as a primary food source (Brewer et al., 2007).

Browse Development Area

Epifauna and infauna (fauna burrowing into the top few centimetres of the seabed) communities inhabiting the predominantly soft sediment benthic habitat in the Browse Development Area were surveyed in 2009 during the dry season (June and July; Gardline Marine Services Pty Ltd, 2009a). The findings of the surveys provide a general description of the benthic assemblages expected to be present in the vicinity of proposed infrastructure (i.e. those on the seabed within the field locations of Calliance, Brecknock and Torosa). Studies have demonstrated that diversity and abundance of deepwater benthic habitats (i.e. >300 m in depth) are largely a factor of seabed and sediment characteristics as well as broadscale oceanic drivers, such as nutrient availability and currents (Dunstan et al., 2012).

Epifaunal Assemblages

Gardline Marine Services Pty Ltd (2009a) conducted remote benthic community imagery surveys at multiple locations across the Browse Development Area and wider region in 2009 (as shown in **Figure 5-15** and **Figure 5-16**). The study found that the deep water seabed areas overlying the Brecknock, Calliance and Torosa reservoirs (400 to 600 m) are comprised of fine sand and silt, with epifauna limited to isolated individuals and sparse benthic biota such as bryozoan colonies, brittlestars, basketstars and sea anemones (**Figure 5-15** and **Figure 5-16**). Furthermore, seabed biodiversity studies of habitat and biological diversity along the Kimberley section of the deep continental shelf undertaken by Williams et al. (2010), reported similar benthic biota for the regional continental slope seabed habitats, demonstrating that these habitats support deepwater benthic biota that are widespread and not unique to the Browse Development Area.

Similarly, Brewer et al., (2007) reported that the seabed areas in the general vicinity of the reservoir areas, which lie on the Ashmore terrace, consisted of muddy substrates supporting epifauna that are likely to be limited to deposit-feeders rather than suspension-feeders such as sponges and soft corals. Further information on deepwater marine biota (invertebrates) is provided in **Section 5.3.1.4**.

Infaunal assemblages

Gardline Marine Services Pty Ltd (2009a) collected infaunal macrobenthos samples (body size of greater than 0.5 mm) from 11 sampling stations in soft sediment benthic habitats across the Calliance, Brecknock and Torosa reservoirs (**Figure 5-15** and **Figure 5-16**).

Two 0.1 square metre (m^2) grabs were collected at each station, from which 614 benthic organisms were recorded from 74 taxa, in 43 families from six phyla (as shown in **Table 5-11**). Infauna were identified to the lowest practicable taxonomic level, usually to

Family or Genus level, but for some groups (Cnidaria, Platyhelminthes and Chordates), to Class or Phylum level. Taxonomy was conducted by experts at Murdoch University.

Overall, the most abundant infauna, accounting for 53.4% of all infaunal assemblages, were the polychaete bristleworms from the phylum Annelida, with representatives from 27 families, dominated by the Spionidae, Syllidae, Eunicidae and Nereididae (shown in **Table 5-12**). Representatives from the sub-phylum Crustacea accounted for 22.5% of benthic infaunal samples, comprising mainly isopods (57%), amphipods (20%), Cumacea (13%), Malacostracea (3%) and crabs and shrimps (Decapoda – > 1%). The remainder were represented by deep-sea aplacophorans (8%), peanut worms (Sipunculidea – 7%, Phascolosomatidea – 1%), brittlestars (Ophiuroidea – > 1%), ribbonworms (Nemertea – 1%), clams (Bivalvia – < 1%), and some unidentified individuals (2%).

The highest infauna abundance was recorded at station CAL-38 located in the seabed area overlying the Brecknock reservoir with 124 individuals/m^2 sampled, while the lowest infauna abundance was recorded at TOR-53 located in the seabed area overlying the Torosa reservoir with 8 individuals/m^2 sampled. Infauna abundance at different areas within the Browse Development Area showed marked variations between sampling stations, which was indicative of a patchy distribution of infauna in seabed sediments (as shown in **Table 5-13**).

Overall, the mean number of recorded taxa per station showed no marked differences between the seabed areas overlying and close to the reservoir areas within the Browse Development Area. Taxa per station, ranged from 12.0 (standard deviation (±) 1.0) taxa per station for seabed areas located overlying the Calliance reservoir to 17.0 (± 5.2) taxa per station for seabed areas located overlying the Brecknock reservoir and 13.2 (±10.8) taxa per station for seabed areas located overlying the Torosa reservoir (**Table 5-13**).

The survey findings subsequently indicated a comparable overall diversity (in terms of taxa richness) of infauna in the Browse Development Area, despite some observed differences in composition and density of individuals (**Table 5-13**). This finding was similar to previously reported comparisons of deep water seabed areas. Gage (1996) reported that the density of benthic fauna will typically be lower in deep-sea sediments (greater than 200 m) as compared to shallower coastal sediments, but the diversity of communities may be similar. Although seemingly homogeneous and providing little structural complexity, deep-sea soft sediments have variability at small spatial scales (e.g. burrows and mounds of biogenic origin). These provide a variety of niches for small deep-sea benthic fauna. Such small-scale features in the deep-sea environment are thought to be stable due to low energy and low sedimentation rates (Gage, 1996).These may be some of the reasons for the patchiness and diversity of deepwater benthic biota within the survey area.

Table 5-11 Mean Taxonomic Richness per Station (± standard deviation) of Benthic Infauna Recorded across the Browse Development Area (Gardline Marine Services Pty Ltd, 2009)

Phylum	**Class**	**Common Name**	**Calliance Reservoir**	**Brecknock Reservoir**	**Torosa Reservoir**	**All Areas**
No. of Sampling Locations			**3**	**3**	**5**	
Sampling Depth Range (m)			**416-584**	**549-645**	**392-561**	
Annelida	Polychaeta	Bristleworms	14	21	31	46
Arthropoda (Sub-phylum: Crustacea)	Malacostraca	Isopods, amphipods, shrimps and crabs	8	10	7	16
Mollusca	Bivalvia	Bivalves	-	2	1	3
	Aplacophora	Aplacophorans	1	1	1	1
Echinodermata	Ophiuroidea	Brittlestars	-	1	1	1
Nemertea	Nemertea	Ribbonworms	1	1	1	1
Sipunculida	Sipunculidea	Peanut worms	1	2	1	2
	Phascolosomatidea	Peanut worms	1	1	1	1
Unidentified	-	-	1	1	2	3
Total			**27**	**40**	**46**	**74**

Table 5-12 Mean abundance per Station (±) (individuals/m³) of Benthic Infauna Recorded across the Browse Development Area (Gardline Marine Services Pty Ltd, 2009)

Phylum	Class	Common Name	Calliance Reservoir	Brecknock Reservoir	Torosa Reservoir
No. of Sampling Locations			**3**	**3**	**5**
Sampling Depth Range (m)			**416-584**	**549-645**	**392-561**
Annelida	Polychaeta	Bristleworms	126.7 (±102.6)	131.7 (±61.7)	148.0 (±101.3)
Arthropoda (Sub-phylum: Crustacea)	Malacostraca	Isopods, amphipods, shrimps and crabs	95.0 (±67.6)	86.7 (±83.3)	20.0 (±25.5)
Mollusca	Bivalvia	Bivalves	15.0 (±16.6)	-	4.0 (±8.9)
	Aplacophora	Aplacophorans	6.7 (±11.5)	53.3 (±92.4)	13.0 (±26.4)
Echinodermata	Ophiuroidea	Brittlestars	-	3.3 (±5.8)	7.0 (±11.0)
Nemertea	-	Ribbonworms	6.7 (±11.5)	5.0 (±8.7)	1.0 (±2.2)
Sipunculida	Sipunculidea	Peanut worms	30.0 (±10.0)	35.0 (±35.4)	7.0 (±11.0)
	Phascolosomatidea	Peanut worms	6.7 (±11.5)	3.3 (±5.8)	3.0 (±6.7)
Unidentified	-	-	6.7 (±11.5)	11.7 (±20.2)	2.0 (±4.5)
Total			**278.3 (±161.5)**	**335 (±247.8)**	**205.0 (±142.5)**

Table 5-13 Mean Taxonomic Richness per Station (± standard deviation) of Benthic Infauna Recorded across the Browse Development Area (Gardline Marine Services Pty Ltd, 2009)

Phylum	Class	Common Name	Calliance Reservoir	Brecknock Reservoir	Torosa Reservoir
No. of Sampling Locations			**3**	**3**	**5**
Sampling Depth Range (m)			**416-584**	**549-645**	**392-561**
Annelida	Polychaeta	Bristleworms	6.0 (±1.7)	8.7 (±3.5)	9.4 (±6.5)
Arthropoda (Sub-phylum: Crustacea)	Malacostraca	Isopods, amphipods, shrimps and crabs	3.7 (±0.6)	4.3 (±3.2)	1.6 (±2.1)
Mollusca	Bivalvia	Bivalves	-	1.0 (±0.0)	0.2 (±0.4)
	Aplacophora	Aplacophorans	0.3 (±0.6)	0.3 (±0.6)	0.4 (±0.5)
Echinodermata	Ophiuroidea	Brittlestars	-	0.3 (±0.6)	0.4 (±0.5)
Nemertea	-	Ribbonworms	0.3 (±0.6)	0.3 (±0.6)	0.2 (±0.4)
Sipunculida	Sipunculidea	Peanut worms	1.0 (±0.0)	1.3 (±0.6)	0.4 (±0.5)
	Phascolosomatidea	Peanut worms	0.3 (±0.6)	0.3 (±0.6)	0.2 (±0.4)
Unidentified	-	-	0.3 (±0.6)	0.3 (±0.6)	0.4 (±0.9)
Total			**12.0 (±1.0)**	**17.0 (±5.2)**	**13.2 (±10.8)**

Scott Reef
The deepwater habitats surrounding the Scott Reef system overlying the Torosa Field generally comprise soft sediment seabed areas with sparse benthic biota, as described for the Browse Development Area in Section 5.3.1.2 and as show in Figure 5-15. The key shallow water benthic habitats and communities of Scott Reef are discussed in detail within Section 5.3.1.3.

Browse Trunkline
The majority of the proposed BTL route traverses the Northwest Transition bioregion along the south eastern boundary at depths of between 280 and 440 m, before turning towards the NWS and a tie in point near NRC at a depth of approximately 125 m. A benthic survey was undertaken in March and April 2019 to confirm the environmental characteristics of the seabed along the proposed BTL route (Advisian, 2019a, Chapter 10, Appendix D.1). The BTL environmental survey demonstrated that the seabed along the trunkline was predominately unconsolidated soft sand (Figure 5-18, Figure 5-19 and Figure 5-20), largely devoid of epibenthic communities, with occasional solitary non-coral benthic invertebrates (e.g. crinoids and anemones) observed.

Samples were collected using a box corer (0.5 x 0.5 x 0.5 m; the same as was used for sediment sampling) and sieved using an Endecott sieve with a 1 mm mesh size, with samples preserved using an ~ 10% borax buffered formalin solution (Advisian, (2019a), Chapter 10, Appendix D.1).

A total of 20 sites were sampled, ranging in depths from 125 to 428 m deep; however, at three sites (site 4, 9 and 11) only shell material was collected (i.e. no soft sediment) most likely due to consolidated substrate at these sites (reference). The results of the survey are summarised in Table 5-14 and Table 5-15. Typically, those sites with higher infauna abundance also had higher taxa richness. The phyla represented were comparable to those found within the Browse Development Area, with Annelida the most taxonomically rich phyla, followed by Arthropoda. Infauna abundance at the sites varied between zero (site 15) and 57 (site 13) Table 5-15.

Table 5-14 Abundance and Richness of Each Infauna Phylum Identified Across all Sites (Advisian, 2019a)

Phylum	Total Infauna Abundance	Total Taxa (Family) Richness
Annelida	142	21
Arthropoda	89	16
Chordata	3	2
Echinodermata	22	4
Mollusca	1	1
Nemertea	1	1
Sipuncula	35	2
Total	293	47

Table 5-15 Infauna Abundance and Taxa Richness for Each Site Sampled, and Site Location within a KEF or Marine Park (Advisian, 2019a)

Site No.	0	1	2	3	4[1]	5	6	7	8	9[1]
Total Abundance	8	14	5	30		3	6	1	8	
Taxa (Family) Richness	3	5	2	9		4	2	1	3	
Depth (m)	376	346	336	351		378	428	377	371	
Marine Park	✓	✓						✓	✓	
KEF	✓	✓	✓	✓		✓		✓	✓	
Site No.	**10**	**11[1]**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Total Abundance	3		22	57	37	0	31	28	15	25
Taxa (Family) Richness	1		8	14	3	0	10	11	4	7
Depth (m)	329		265	261	224	188	196	132	130	125
Marine Park	✓									
KEF	✓							✓	✓	✓

[1] *No soft sediments were collected at these sites*

5.3.1.3 Benthic Primary Producers

Benthic Primary Producers (BPPs) are predominately marine plants (e.g. seagrasses and macroalgae), but also include invertebrates such as scleractinian (reef-building) corals, which acquire a significant proportion of their energy from symbiotic microalgae that live in the coral animal (polyps). Benthic Primary Producer Habitat (BPPH) is defined as “the functional ecological communities that inhabit the seabed within which BPPs are prominent components and areas of seabed that can support these communities” (EPA, 2009a). BPPH plays a major role in marine ecosystem functioning, including acting as a substrate and providing shelter and food for animals, as well as contributing to physical stability of the seabed. The BPPs relevant to the proposed Browse to NWS Project are described below.

Seagrass

Background

Seagrasses are marine flowering plants, the presence of which physically affect the seabed, and can significantly influence ecosystem structure. Seagrass fulfils a number of functions in the marine environment. In addition to transferring energy into food webs, seagrass provides substrates for benthic species, affects water flow and rates of sedimentation, stabilises sediments, acts as sites for larval settlement and influences nutrient dynamics (Butler and Jernakoff, 1999). Seagrass is important as nurseries and habitat for numerous species of fish and invertebrates, and also provides an important food source for grazing animals such as marine turtles and dugongs, with dugongs feeding almost exclusively on seagrass (Lanyon et al., 1989).

Seagrasses require light to grow and survive and typically occur in shallow areas where there is usually abundant light. The maximum depth limit of seagrass is largely controlled by the availability of light, the minimum light requirement being 10 to 20% of surface light (Short et al., 2001). Some species are adapted to growing and surviving in environments where light levels may be reduced, such as turbid shallow coastal waters. Species of the genus Halophila often grow in deeper water than other species, and have been known to survive at around 5% of surface light (Butler and Jernakoff, 1999). Shallow water distribution of seagrasses may also be limited by light levels, as photosynthesis can be inhibited by exposure to high light conditions (Larkum et al., 2006).

Regional Overview

In the NWMR, seagrass habitats are generally found in shallow water environments near the mainland and offshore reefs and shoals. Of the reefs and shoals in the NWMR, Ashmore Reef has been found to have the highest average cover of seagrass (2% cover, or 471 ha of 22,697 ha; Skewes et al., 1999b). However, much of this was very sparse cover and there were only 220 ha of seagrass with a greater than 10% cover (Brown and Skewes, 2005). Seagrass was found to generally occur on the shallow reef flats of Ashmore Reef and was dominated by *Thalassia hemprichii*, which is common on shallow reef flats throughout the Indo-west Pacific. The reefs surrounding Cartier Island were reported to have a seagrass cover of 1.17 ha out of 1086 ha (0.11%) (*T. hemprichii*), and Seringapatam Reef was found to have a seagrass cover of 2.02 ha out of 5,519 ha (0.04%) (*T. hemprichii* and *Halophila ovalis* in approximately equal quantities). Skewes et al. (Skewes et al., 1999b) did not observe any seagrass communities on the reefs surrounding Browse Island and Hibernia Reef.

Browse Development Area

Water depths within the Browse Development Area are generally too deep to provide suitable conditions for seagrass growth other than shallower reef and lagoon habitats in the Scott Reef system. Seagrasses were not recorded at areas surveyed in the deeper waters of the Browse Development Area (**Figure 5-15** and **Figure 5-16**).

Scott Reef

Scott Reef supports five species of seagrass: *Thalassia hemprichii, Thalassodendron ciliatum, Cymodocea rotundata, Halophila ovalis and H. decipiens* (URS Australia Pty Ltd, 2006a). These species occur widely throughout the Indo-Pacific region. *Thalassia hemprichii* is the most abundant seagrass at Scott Reef (Skewes et al., 1999b; URS Australia Pty Ltd, 2006a). Skewes et al. (Skewes et al., 1999b) reported the dominance of *T. hemprichii*, along with less common *H. ovalis* at South Scott Reef, and *T. hemprichii* and *H. ovalis* as co-dominants, with minor *T. ciliatum* at North Scott Reef, all occurring on the reef edge, lagoon edge and shallow lagoon. Seagrasses recorded in less than 15 m depth covered a total of 23 ha out of 10,613 ha (0.22%) at North Scott Reef, and 77 ha out of 14,400 ha (0.54%) at South Scott Reef.

The highly energetic environment and significant tidal exposure of Scott Reef restricts the area of habitats potentially suitable for seagrass establishment to a small proportion of the total area, resulting in only low abundance (Skewes et al., 1999b; URS Australia Pty Ltd, 2006a). The low abundance of seagrass at Scott Reef may also be due to the limited amounts of sand on the reef flat, which may have been stripped in recent years by tropical cyclones. The area of seagrass at Scott Reef is significantly less than recorded for Ashmore Reef.

Surveys in 2006 (URS Australia Pty Ltd, 2006a) rarely encountered species other than *T. hemprichii*. Where observed, *T. ciliatum* and *C. rotundata* both occurred in association with T. hemprichii in high energy, upper reef flat environments. They occurred in small patches with an area of less than 1.0 m^2 and, more commonly, 0.25 to 0.5 m^2. Within these patches, the shoot density and percentage cover were also low (less than 10%).

Halophila ovalis was encountered in mono-specific patches in more sheltered shallow subtidal environments (typically on sand in the lee of small coral bommies) at a depth of approximately 2 to 3 m below MSL, with both patch-size and shoot-density low. *Halophila decipiens* was sparsely distributed in deeper habitats (20 to 40 m) (less than 10% cover).

Skewes et al. (1999b) did not record any seagrass at depths greater than 15 m, and ROV surveys of deepwater outer reef and lagoon habitats (greater than 40 m) at Scott Reef did not report any observations of seagrass (URS, 2007b; 2007a).

Browse Trunkline

Water depths along the proposed BTL route are too deep for the establishment of seagrass communities and the BTL survey confirmed the absence of seagrass communities (Advisian, 2019a).

Relatively sparsely distributed, seagrass communities are present within the Rowley Shoals which are located approximately 2 km at the closest point from the proposed BTL route (Mermaid Reef Marine Park boundary). *Thalassia hemprichii* has been recorded at Mermaid and Clerke Reefs and *Thalassodendron ciliatum* and *Halophila ovalis* have been recorded at Mermaid Reef (Berry, 1986; Walker and Prince, 1987), primarily within the lagoon.

Macroalgae

Background

Macroalgae are important components of coastal ecosystems, occupying a wide range of habitats. Many species are restricted to hard surfaces due to the lack of a root system for anchoring in soft sediment (Diaz-Pulido and McCook, 2008). However, some species such as *Halimeda* and *Caulerpa* spp. are adapted to growth in unconsolidated sediment (WAM, 2009). Macroalgae have minimum light requirements for photosynthesis that vary with species. Some species can occur in waters greater than 200 m deep; however these are limited to small generally crustose, often calcified, algae (Markager and Sand-Jensen, 1992).

In tropical reef environments macroalgae play a major role in reef health. In addition to being primary producers and providing food for reef fish and invertebrates, they serve to consolidate sediments in sandy areas (*Halimeda* spp. and *Caulerpa* spp.), contribute to the content and structure of the sediment (e.g. dead *Halimeda*), and consolidate and contribute to the structure of reef crests (e.g. crustose coralline algae; URS Australia Pty Ltd, 2006a). However, macroalgae compete with corals for space on reefs and may out-compete corals under certain conditions, resulting in a 'phase-shift' to algae-dominated reefs. Such phase-shifts often occur following disturbances that stress or kill corals, or following anthropogenic disturbances such as overfishing or eutrophication (Diaz-Pulido and McCook, 2008).

The abundance, growth and reproduction of many macroalgal species are highly variable in time in particular showing seasonal changes in biomass and reproduction, and changes in response to habitat disturbances.

Regional Overview

A total of 351 species of marine benthic red algae (Huisman, 2018) and 171 species of marine benthic brown and green algae (Huisman, 2015) have been recorded in north-western Australia. Surveys in the Kimberley region by Western Australian Museum (WAM) have identified 72 species of macroalgae in the southern Kimberley (Walker, 1995), and 90 species (not including coralline algae) in the northern Kimberley, most of which are widespread tropical taxa (Walker et al., 1996). A review of the algal flora of Mermaid, Scott and Seringapatam Reefs compared to the wider Indo- Pacific region by WAM (WAM, 2009) found these reefs to represent a small subsection of the Indo-Pacific flora, with almost all species identified elsewhere in north-western Australia or from further north. The Indo-Pacific flora is highly diverse, with some subsets of the region regarded as 'biodiversity hotspots. However, it is acknowledged that much of the region is poorly known and high diversity in some areas may reflect collection efforts (WAM, 2009).

Browse Development Area

The growth of macroalgae in the deep waters of the Browse Development Area is restricted due to light availability and lack of hard substrate to support attachment in the predominantly soft sediment habitats of the area. A benthic habitat survey found no macroalgal beds during 11 drop camera surveys within the Browse Development Area (**Figure 5-15** and **Figure 5-16**).

Scott Reef

A total of 121 species of algae have been reported from Scott Reef, however, there is likely to be a number of smaller, cryptic species that have not yet been recorded (WAM, 2009); (Sinclair Knight Merz Ltd, 2009). Two surveys of macroalgae at Scott Reef in 2006 found general algal cover to be approximately 5 to 10% in shallow and intertidal areas, but it was highly variable with some areas approaching 100% cover (WAM, 2009). Species composition was similar to Seringapatam Reef and Rowley Shoals. The higher energy reef fronts typically supported the encrusting coralline *Hydrolithon onkodes* near the crest. This species is characteristic of this zone in most Indo-Pacific reefs. Other species from reef front habitats were often associated with dark recesses within the vertical walls, including species such as *Peyssonnelia inamoena* and *Corynocystis prostrata*. Species of *Halimeda* were found to be common across reef flats, on reef outcrops and in sandy pools. The turf green alga *Boodlea vanbosseae* was almost always present on outcrops, as was the spongy green Boodlea composita. Other turfs included the red algae *Polysiphonia* spp., *Coelothrix irregularis*, and *Gelidiopsis* spp. In some locations, dense monospecific stands of algae were observed. These were not consistently of one species, but the most common was *Ulva* spp., which was usually associated with shallow, sandy habitats. Other monospecific stands were observed at North Scott Reef (comprised of the red alga *Polysiphonia* spp.) and at several locations in South Scott Reef (dominated by *Coelothrix irregularis*).

An additional survey of deepwater habitats in the Scott Reef lagoons (URS, 2007b) identified areas where *Halimeda* occurred in clumps many metres in diameter and was the dominant component of the community. Such densities of *Halimeda* are not considered unique in the region, with similar densities observed at Mermaid, Scott and Seringapatam Reefs (WAM, 2009). Dense *Halimeda* banks have been reported for the Big Bank Shoals, the Barracouta and Vulcan Shoals in the Timor Sea (Heyward et al., 1997; Heyward et al., 2010). Long-term monitoring (LTM) of Scott Reef benthic communities by AIMS identified an increase in turf and coralline algae from an average of 37% (± 2% Standard Error (S.E.) to 75% (± 2% S.E.) after the mass-bleaching of corals in 1998. This corresponded with a decrease in hard corals, soft corals and sponges by at least a half. The cover of fleshy macroalgae was less than 1% at all locations both before and after the bleaching. Turf and coralline algae remained the dominant benthic group during 2004 (65% ±4% S.E.) with little recovery of the other groups. Increases in coral cover since 2004 have corresponded with decreases in algal cover. However, observations from 2008 found that turf and coralline algal cover was still higher than prior to the bleaching (43% ±2% S.E.; Gilmour et al., 2009a[8], 2008). Through the cycles of impact and recovery between 1994 and 2017, the substrata that has become available following the loss of corals has been colonised by coralline algae and the cover of all other benthic groups (e.g. sponges and macroalgae) remained low (< 5%). The mass bleaching in 1998 and 2016 caused the largest and most uniform reductions in coral cover and subsequent increases in coralline algae (Gilmour et al., 2018).

Browse Trunkline

Water depths along the proposed BTL route are too deep to provide suitable conditions for macroalgae establishment and the BTL survey confirmed the absence of macroalgae (Advisian, 2019a).

Surveys of the marine algal community at the Rowley Shoals which are located approximately 2 km at the closest point from the proposed BTL route (Mermaid Reef Marine Park boundary), found that they were similar to the species found at Scott Reef and Seringapatam where over 100 species of marine algae were recorded (Huisman et al., 2009). The vertical walls in the shallow relatively exposed locations of the Rowley Shoals support the mat-forming green alga Claedophora herpestica. The dark recesses of the vertical walls includes species such as *Peyssonnelia inamoena* and the recently described *Corynocystis prostratra*, both new records for Western Australia (Huisman et al., 2009). Long term monitoring of benthic communities at the Rowley Shoals indicates that the cover of macroalgae is low at all habitats across all reefs but cover has varied across years (Gilmour et al., 2018). During the 2017 survey, coralline algae covered most of the substrata not occupied by hard or soft corals, particularly at the reef (Gilmour et al., 2019, **Chapter 10, Appendix D.2**).

Corals

Background

Corals are made up of colonies of individual polyps, which asexually divide to form new polyps thereby increasing the overall coral colony size (Veron, 2000). Corals belong to two groups; the soft octocorals and the hard scleractinian corals which secrete an external limestone skeleton. Scleractinian corals are important reef builders and under suitable conditions can form geological structures (i.e. reef) over time. Some soft corals (especially those in the family Alcyoniidae) may also contribute to reef-building. Coral reefs form gradually over time and can be many tens of thousands of years old, during which time they respond to changes in sea level and other environmental conditions (Veron, 2000). Corals, particularly at Scott Reef have the ability to inhabit a range of depths depending on substrate and benthic light availability. This adaptability is evident at Scott Reef, where corals inhabit a range of depths, from the intertidal reef flat to the deep parts of the South Scott Reef lagoon. In addition, deepwater corals within the aphotic are known to inhabit deeper areas of the seabed, however, none have been observed within the Browse Development Area.

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[8] *Gilmour et al., 2009a available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

Corals are able to flourish in nutrient poor waters because of their relationship with zooxanthellae alga and this symbiotic relationship is dependent on sunlight. Coral reefs support a range of species by providing shelter, feeding, spawning and nursery areas, resulting in the large and diverse communities for which they are renowned. Species using reef habitat for food and shelter include those with protected status under the EPBC Act such as marine turtles and sea snakes. Individual coral species are not protected under the EPBC Act; however, the ecological and heritage value of coral reefs is recognised in Australian Commonwealth and State waters through the designation of coral reef dominated marine protected areas (MPAs), KEFs and heritage listings.

Regional Overview

Coral reefs and communities of the NWMR include: remote oceanic reefs systems (atolls) such as Scott Reef, Seringapatam etc, fringing reefs around offshore islands such as Browse Island and along coastlines such as the Kimberley Region and submerged shoals on the NWS such as Rankin Bank and Glomar Shoal (Veron and Marsh, 1988).

Browse Development Area

Within the deep waters of the Browse Development Area (i.e. the seabed excluding Scott Reef), no deepwater soft or hard corals were observed during environmental surveys (Gardline Marine Services Pty Ltd, 2009a; Hudson and Fletcher, 2006.

Scott Reef

Overview

Over the past 25 years the coral communities at Scott Reef has been extensively studied creating one of the most comprehensive long-term datasets of tropical coral reef communities globally. Since 1994, AIMS has led the majority of these studies with additional research undertaken by other governmental agencies and commercial organisations. Studies on the reef system have included consideration of the broad range of benthic habitats present, however, the primary focus has been on the coral reef communities dominant within the shallow parts of the reef. A summary of the 2017 long term monitoring survey report, Gilmour et al., 2019 is provided in **Chapter 10, Appendix D.2**.

The scleractinian corals (light dependent), which are found to a maximum depth of 75 m (**Figure 5-22** and **Table 5-16**), are the keystone species of the coral communities within the Scott Reef system which are considered to be of high conservation and ecological value.

This section provides a summary of the historical and status of the coral reef communities at Scott Reef, particularly considering the large-scale perturbations observed over the last 25 years.

Coral habitats

Scott Reef hosts the largest diversity of hard corals within Western Australia (Richards et al., 2014), with fourteen distinct benthic habitat types described and mapped (**Figure 5-22** and **Table 5-16**; Smith et al., 2006). The shallow water habitats occupy 170.5 km^2 at North Scott Reef and 147.1 km^2 at South Scott Reef.

Historical studies recorded 307 species of hard corals from 60 genera and 14 families (Gilmour et al., 2009b[9]; WAM, 2009). During more recent surveys in 2017, 236 species of hard coral from 60 genera were recorded from within the shallow and deepwater coral habitats. Of the species recorded, six were new records for Australia and three were new records for WA (Gilmour et al., 2019a, Chapter 10, Appendix D.2). By comparison, studies of other offshore reefs at Ashmore, Seringapatam and the Rowley Shoals (Mermaid Reefs) recorded 255 species at Ashmore Reef, 159 species at Seringapatam Reef and 211 species of corals at Mermaid Reef (WAM, 2009).

Uniquely, South Scott Reef hosts extensive deep lagoonal coral habitats (30 – 70 m; Gilmour et al. 2013), which are largely protected from the direct influence of major storms by the surrounding horseshoe-shaped emergent reef rim (Heyward and Radford, 2019). Such deepwater mesophotic coral habitats are primarily composed of foliaceous corals, with high coral cover historically observed (Heyward and Radford, 2019), though these habitats suffered some mortality associated with recent bleaching events.

The narrow, deepwater, outer reef slopes, by contrast, are characterised by filter-feeding, ligh independent octocorals (sea fans and whips) and sponges with little presence of hard corals. The deep seabed habitats off the reef slopes are largely characterised by sandy, soft sediments with sparse benthic biota (invertebrate fauna) (e.g. anemones, sea urchins, brittle stars, crinoids and sea pens) (URS Australia Pty Ltd, 2007b) (**Figure 5-22** and **Table 5-16**; Smith et al., 2006).

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[9] *Gilmour et al., 2009b available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

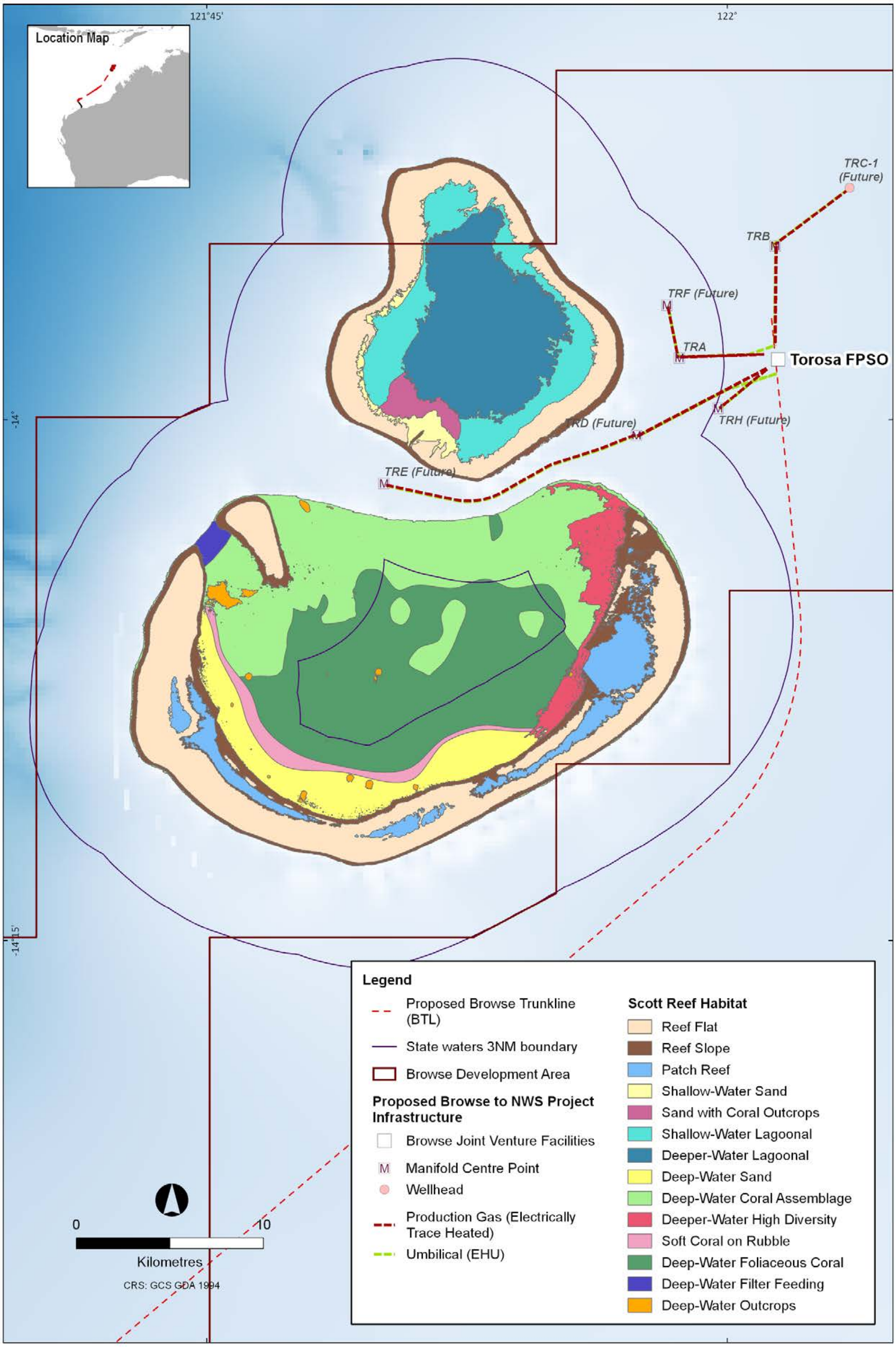

Figure 5-22 Scott Reef Habitat Map (Smith et al., 2006)

Table 5-16 Benthic Habitat Types at Scott Reef

Habitat Type	Description
Reef flat habitat (1 to 4 m depth)	Reef flat habitat is the largest habitat at Scott Reef. Coral cover on the reef flat is low (less than 5%) and patchy comprising stunted corals from the families Faviidae, Poritidae, Acroporidae and Pocilloporidae. In deeper sections, the reef flat is predominantly sand, rubble and dead coral fragments and overall this habitat has little structural complexity. Compared to other Scott Reef habitats, hard coral diversity on the reef flat is reported to be low-to-moderate (20 to 40 species) and supports a low diversity and low abundance of fish and low invertebrate diversity (Smith et al., 2006). Reef flat habitat represents a harsh environment for the survival and growth of corals. The shallow reef flat is periodically tidally exposed at spring low tide and is exposed to the effects of storm damage and bleaching events. The eastern sides of North and South Scott Reef were particularly affected by Cyclone Fay in 2004. While the mass bleaching event in 2016 caused severe bleaching at all shallow water habitats across the entire Scott Reef system, the sites least affected were on the reef flat (Gilmour et al., 2018). In the bioregional context, this habitat is not considered rare with very similar habitats found at other coral reefs in the region (e.g. Rowley Shoals and Ashmore Reef).
Reef slope habitat (4 to 30 m depth)	Reef slope habitat has the highest hard coral diversity of any habitat at Scott Reef, with over 150 hard coral species recorded. Several of the hard-coral species (e.g. *Acropora indonesia*) recorded from this habitat in 2004 surveys were new records for WA. This habitat is structurally highly complex and occurs along the exposed outer edge of North and South Scott Reef and at the inner slope of South Scott Reef and supports very diverse fish groups and high invertebrate diversity (Smith et al., 2006). The mass bleaching event in 2016 resulted in a decrease in hard coral cover from 45% to 10% at reef slope locations across the reef system (Gilmour et al., 2018).
Patch reef habitat (1 to 20 m water depth)	Patch reef habitat occurs along the southern edge of the South Scott Reef lagoon floor. Patch reef habitat comprises large shallow coral outcrops (10 m across), dominated by branching corals, interspersed with areas of sand and staghorn (*Acropora*) corals. Compared to other Scott Reef habitats, this habitat supports moderate hard coral diversity (40 to 70 species) and moderate fish and invertebrate diversity (Smith et al., 2006). Most of the species on the patch reef habitat also occur in reef slope habitat. Like other shallow water habitats, corals in this habitat are were heavily impacted, suffering a high mortality (greater than 75% loss) after the 2016 bleaching event (Gilmour et al., 2018).
Shallow-water sand habitat (3 to 7 m depth)	Shallow-water sand habitat occurs along the western edge of the North Scott Reef lagoon and comprises flat calcareous sand and was observed to be devoid of sessile species including corals, seagrass and sponges. The habitat supports low fish and invertebrate diversity (Smith et al., 2006). Sand eels (Order Creediidae) and a number of sand goby species were common. Given that sandy bottom habitats are common in the region.
Sand with coral outcrops habitat (3 to 8 m depth)	Sand with coral outcrops habitat (3 to 8 m depth) occurs in an area at the south of the North Scott Reef lagoon. This habitat is predominately a sand habitat interspersed with a few small outcrops (1 to 5 m across) on which a variety of corals, mainly acroporids, and sponges attain high cover. This habitat supports a low fish diversity and low to moderate invertebrate diversity (Smith et al., 2006).
Shallow-water lagoonal habitat (3 to 12 m depth)	Shallow-water lagoonal habitat (3 to 12 m depth) spans a large proportion of the North Scott Reef lagoon. This habitat is dominated by corals in the Family Acroporidae, particularly branching and staghorn acroporids. Poritid hard corals and sponges are also well-represented. Hard coral diversity is moderate to high (50 to 90 species) compared to other Scott Reef habitats. The habitat has high structural complexity and supports moderate fish diversity and low to moderate invertebrate diversity. The coral cover and species diversity were dramatically reduced at all lagoon habitats across Scott Reef following the 2016 bleaching event. Acropora species which dominate this zone were most affected, but other genera such as *Stylophora, Hydnophora* and *Pocillipora* also experienced severe declines (Gilmour et al., 2018).
Deeper-water lagoonal habitat (12 to 25 m depth)	Deeper-water lagoonal habitat occurs in the central area of the North Scott Reef lagoon. Although this habitat has high structural complexity, a major feature of this habitat is the high cover of dead acroporid hard corals that have an overgrowth of algae, as a result of the 1998 bleaching event after which little or no coral recovery has occurred. Coral diversity is low (10 to 25 species) compared to other Scott Reef habitats. The habitat is dominated by massive poritid hard corals, algae and encrusting sponges and supports low fish diversity and low to moderate invertebrate diversity (Smith et al., 2006).

Habitat Type	Description
Deepwater sand habitat (25 to 38 m depth)	Deepwater sand habitat covers an area at the southern and western margin of the South Scott Reef lagoon. This habitat is very sheltered with low energy conditions. It comprises fine sediment and is largely devoid of sessile epifauna such as corals or sponges. Fauna observed in this habitat included high densities of sea urchins in some areas. Low density patches of seagrass were also reported (Smith et al., 2006). The habitat was found to support low fish diversity and a very low invertebrate diversity. A benthic infauna survey conducted by (URS, 2007b) found foraminifera to be the most abundant infaunal phylum in this habitat (approximately 2000 individuals/m^3), followed by echinoderms (approximately 1500 individuals/m^3), and annelids (approximately 1000 individuals/m^3). This habitat is not considered a rare habitat in the bioregion, and on a local scale at Scott Reef, is considered to be of low conservation significance.
Deepwater coral assemblage habitat (35 to 55 m depth)	Deepwater coral assemblage habitat is the third largest habitat at Scott Reef. This habitat supports a low to moderate diversity of hard corals (40 to 70 species) with variable cover (5 to 70%) of hard corals growing on rubble. No one coral group dominates with representatives from Acroporidae, Poritidae, Fungiidae and Agariciidae being common. Calcareous alga also dominates some areas. The habitat supports high fish diversity and moderate invertebrate diversity (Smith et al., 2006). The sheltered conditions of this habitat provide an important refuge for deeper water corals, and it is considered a rare habitat in the bioregion.
Deeper water high diversity habitat (30 to 50 m depth)	Deeper water high diversity habitat occurs across an area at the eastern side of the South Scott Reef lagoon. This habitat is structurally complex and contains a diverse benthic community with numerous families of hard corals, sea whips, fans and sponges as well as the calcareous algae *Halimeda*. It also supports high fish and invertebrate diversity (Smith et al., 2006) and is an important area of marine biodiversity in the bioregion.
Soft coral on rubble (30 to 50 m depth)	Soft coral on rubble occurs across a narrow area at the southern edge of South Scott Reef lagoon. This habitat is dominated by the zooxanthellate soft coral *Xenia* found growing on dead foliaceous coral rubble, with occasional hard corals and areas of calcareous algae *Halimeda*. The occurrence of *Xenia* at unusually deep depths for this species is a notable feature of this habitat, which is attributed to adequate light penetration to these depths. Compared to other Scott Reef habitats, hard coral diversity at this habitat is low (less than 25 species). This habitat supports a low to moderate fish diversity and moderate invertebrate diversity (Smith et al., 2006).
Deepwater foliaceous coral habitat (30 to 60 m depth)	Deepwater foliaceous coral habitat is the second largest habitat at Scott Reef (**Figure 5-22**). This sheltered habitat supports low diversity coral communities (20 to 40 species) dominated by thin plated (foliaceous), physically fragile corals mostly from the genera Montipora as well as Pachyseris and Echinopora. Other corals interspersed among the foliaceous corals include *Acropora*, *Leptoseris* and *Porites*. Some of the species present within these deepwater habitats are not found in shallower waters, and at least one species (e.g. *Acropora pichoni*) is a new record for WA. Coral cover at the coral dominated sites ranges from 15 to 40%, but some sites have exceptionally high coral cover at 65%. Surveys conducted during 2016 and 2017 indicate that the deeper communities (45 to 60 m) were relatively unaffected by the elevated temperatures during this time, however, communities at 20 to 30 m appear to have experienced high mortality (Gilmour et al., 2018). Moderate fish and invertebrate diversity was reported (Smith et al., 2006). This habitat is rare and thus important in the bioregion.
Deepwater outcrops habitat (20 to 40 m depth)	Deepwater outcrops habitat occurs on large pinnacles that occur in several relatively small areas in the South Scott Reef lagoon. Hard corals dominate this habitat and occur in moderate diversity (50 to 80 species) compared to other Scott Reef habitats. This habitat is similar to reef slope habitat at a similar depth.
Deepwater filter feeding habitat (>75 m – 500 m)	Deepwater filter feeding habitat occurs on the steep and narrow, deepwater slopes and is dominated by filter-feeders such as azooxanthellate (light independent) sea whips and fans (octocorals) and sponges with low hard coral diversity (less than 20 species) (Smith et al., 2006). This habitat supports low to moderate fish diversity and moderate invertebrate diversity (Smith et al., 2006). These deepwater communities have a very low diversity and were extremely different to those in the shallows. However, this habitat is not uncommon in the bioregion (Smith et al., 2006). The deep seabed habitats off the reef slope are largely characterised by sandy, soft sediments with sparse benthic biota (invertebrate fauna) (e.g. anemones, sea urchins, brittle stars, crinoids and sea pens) (URS Australia Pty Ltd, 2007b).

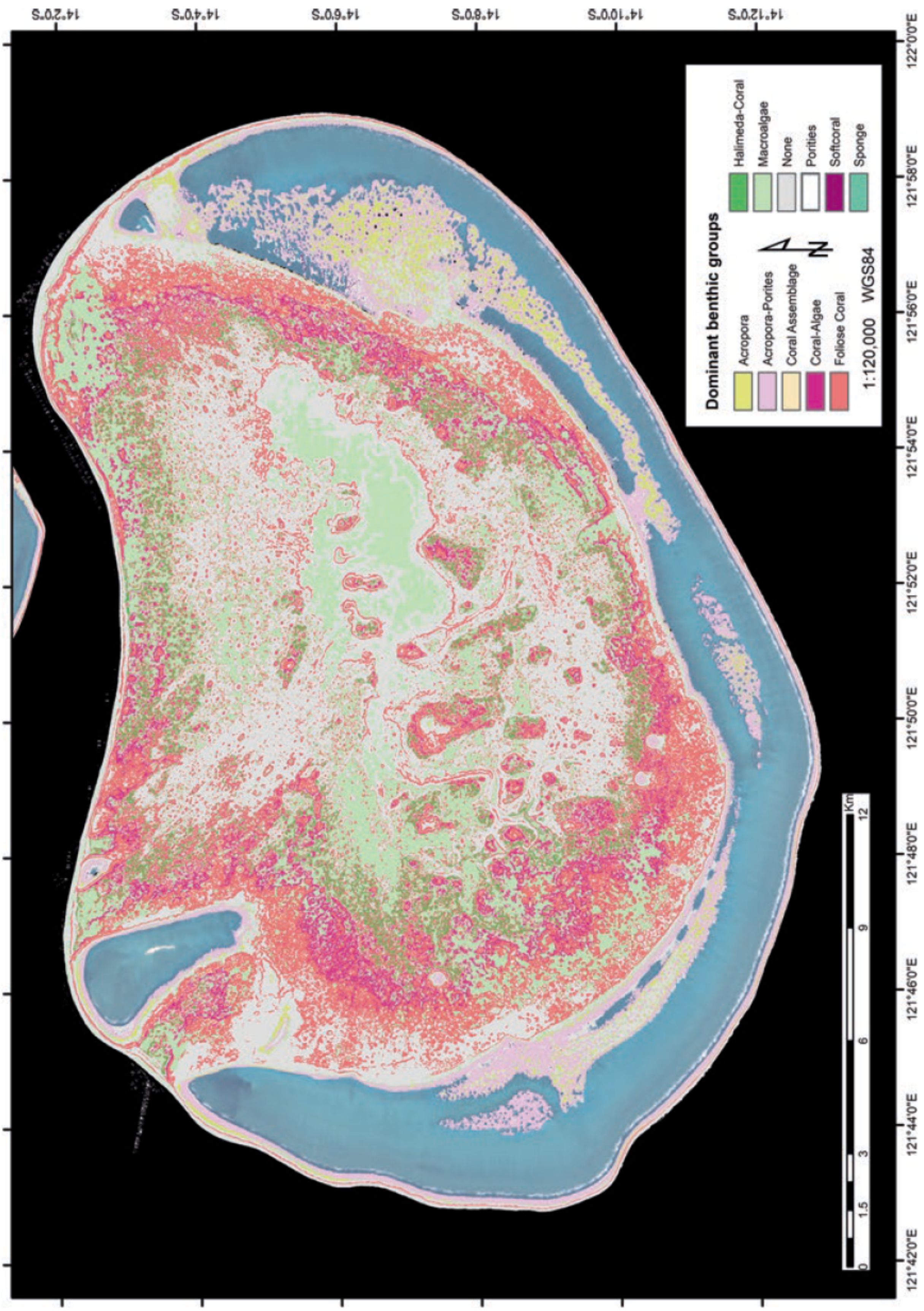

Figure 5-23 South Scott Reef Habitat Model for the Mesophotic Lagoon (Heyward and Radford, 2019)

Studies of the deepwater lagoon at South Scott Reef demonstrate that community composition is markedly different to the shallow water habitats at Scott Reef (**Figure 5-23**). The corymbose and tabulate Acropora corals that dominate the shallow (<20 m) reef slopes at Scott Reef are mostly absent or found in very low numbers at 40 – 60 m in South Scott lagoon. In mesophotic depths, hard corals, calcareous algae, soft corals, sponges, bryozoans, and other invertebrates are the key sessile taxa on the seabed (Heyward and Radford, 2019). During the 2017 survey of the South Scott deep lagoon, coral cover at the coral dominated sites ranges from ~15 to 40%, but some sites have exceptionally high coral cover at ~65%. The communities with high coral cover are dominated by foliose corals (particularly *Montipora, Pachyseris* and *Leptoseris*), massive corals (*Porites*) and encrusting corals (*Montipora*). Some of the sites also have high cover of hispidose (bottlebrush) Acropora species (Gilmour et al., 2018).

Recruitment

Importantly, in the context of recent mortality events, significant work has been undertaken to understand the scale and strength of population connectivity among the geographically isolated coral reefs of the Timor Sea in north-western Australia. Genetic studies of hard coral show that Scott Reef, Rowley Shoals, Dampier and Ningaloo reefs are genetically different, with no connectivity among coral communities evident (Whitaker, 2004; Underwood et al., 2007; Underwood, 2009; Underwood et al., 2009). Hence, these isolated offshore reefs rely on local recruitment for population replenishment (Gilmour et al., 2018).

Studies at Scott Reef have identified that two short and distinct periods of mass spawning occur during spring and autumn, unlike single mass spawning events at most other reefs around Australia (Gilmour et al., 2009a). The dominant coral spawning period at Scott Reef is autumn (March/April), with a secondary, lesser spawning event in spring (October/November). Broadcaster corals spawning occurs for a few nights after a full moon at these times. Based on an extensive field study of 68 species covering autumn 2008, 2009 and 2010 and spring 2008 and 2009, it was found 60% of species only spawned in autumn, 16% only spawned in spring and 25% spawned in both seasons (but mostly in autumn), with little evidence of individual colonies spawning twice or switching between seasons (Gilmour et al., 2010[10]). Approximately 80% of reproductive output by spawning corals occurs in autumn and approximately 20% in spring (Gilmour et al., 2010). Very few corals (e.g. massive Porites spp.) broadcast spawn in other months. Corals at Scott Reef that are brooders are likely to have multiple gametogenic cycles and therefore spawn several times throughout the year (Gilmour et al., 2008[11]; Gilmour et al., 2009a). Approximately 55% of reproductive output of brooding corals occurs from November to May, and 45% at other times of the year. More recently, a study examining spawning patterns between 2007 and 2016 at Scott Reef found that split spawning occurred frequently and predictably and is driven by a disconnect between lunar and seasonal cues. Split spawning in coral populations occurs when gamete maturation and mass spawning are split over two consecutive months to align spawning dates with favourable conditions for reproduction (Foster et al. 2018).

Mass spawning of corals in autumn occurs at times of peak water temperatures, light winds and neap tides, all of which reduce larval dispersal. Most mass-spawned larvae disperse across Scott Reef, over distances of <10 km and probably settle within a week with sites of high cover of spawning corals contributing to the recruitment of corals at other sites. In contrast, most brooded larvae are competent to settle when released, and probably settle less than 1 km from the parent colony (Gilmour et al., 2010). Current flows therefore have a large influence on patterns of coral larvae dispersal, coral recruitment and connectivity within Scott Reef (Gilmour et al., 2011[12]). Furthermore, studies on the dispersion of coral larvae at Scott Reef (Done et al., 2015; Foster and Gilmour, 2018) demonstrates that while there is marked movement of larvae within the reef system itself (for broadcast spawning corals), there is no evidence to suggest that those coral larvae that initially dispersed off the reef return to Scott Reef to settle.

Spatial and temporal patterns in genetic diversity in the brooding hard coral *Seriatopora hystrix* and the broadcast spawning coral *Acropora tenuis* at Scott Reef and Rowley Shoals has been studied for more than a decade (Gilmour et al., 2009a, 2010, 2011 and 2015). Local genetic structure appears to be relatively stable at the Scott Reef system suggesting that neither geographic isolation nor disturbance history has compromised the coral standing stock of genetic diversity at Scott Reef in these species. These results not only highlight the importance of self-recruitment for the maintenance of these geographically isolated populations, but also that occasional longer distance connectivity within the reef system (a few tens of kilometres) can redistribute genetic diversity across the metapopulation and facilitate persistence of local populations across spatially and temporally variable environments (Gilmour et al., 2018).

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[10] *Gilmour et al., 2010 available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

[11] *Gilmour et al., 2008 available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

[12] *Gilmour et al., 2011 available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

Coral Monitoring at Scott Reef

Benthic communities and habitat condition at seven locations along the reef slope (6 m LAT) have been monitored as part of a long-term monitoring program established at Scott Reef. Monitoring at these locations has been undertaken regularly since 1994, with most sites surveyed annually between 1994 and 1999, and then in 2003, 2004, 2005, 2008, 2010, 2012, 2014, 2015, 2016 and 2017. In response to the 2016 mass-bleaching event, additional monitoring sites were established adjacent to the historic reef slope sites in the shallower reef crest habitat (3 m LAT), and at locations within the lagoon at North Scott Reef and Seringapatam Reef (Gilmour et al., 2019, **Chapter 10, Appendix D.2**).

Coral community composition at Scott Reef has been tracked for 25 years and been shown to change in both benthic cover and species richness, as shown in **Figure 5-24** and **Figure 5-25**. This is likely to have been driven by local environmental conditions, natural life histories of coral groups, as well as acute disturbances such as storms, cyclones and bleaching events. The mean cover of hard and soft corals, and turf and coralline algae, has historically varied according to the frequency and severity of sea surface temperature anomalies, storms and cyclones, in addition to an outbreak of coral disease in 2010 (Gilmour et al., 2015).

The most recent monitoring survey conducted in 2017 found that the coral community at Scott Reef has been severely degraded following a sustained thermally induced bleaching in 2016, with the loss of approximately 80% coral cover within the shallow monitoring sites. Within the seven monitoring sites surveyed in 2017, a total of 153 species from 49 genera were recorded (Gilmour et al., 2019, **Chapter 10, Appendix D.2**). To provide context of the recent coral mortality, significant reef wide disturbances observed since 1994 are outlined and further described below:

- a widespread thermal-induced mass bleaching event in 1998 resulted in a 75% decrease in cover of hard and soft corals and sponges in shallow waters (less than 10 m)
- a Category 5 cyclone (Cyclone Fay) in 2004 caused major physical damage to coral communities on the exposed eastern flank of the reef
- a less severe cyclone in 2007 (Cyclone George) caused further localised damage, particularly to very shallow (less than 5 m) exposed coral communities
- a less severe thermally-induced mass bleaching event in 2010 caused selective bleaching varying among locations and coral genera
- moderate coral bleaching in 2011 caused bleaching to approximately 5% of coral colonies
- a monsoonal storm in 2012 caused significant damage to the reef and the coral communities with a decrease in coral cover
- a widespread thermal-induced mass bleaching event in 2016 resulted in a 75% decrease in cover in shallow waters (<20 m depth).

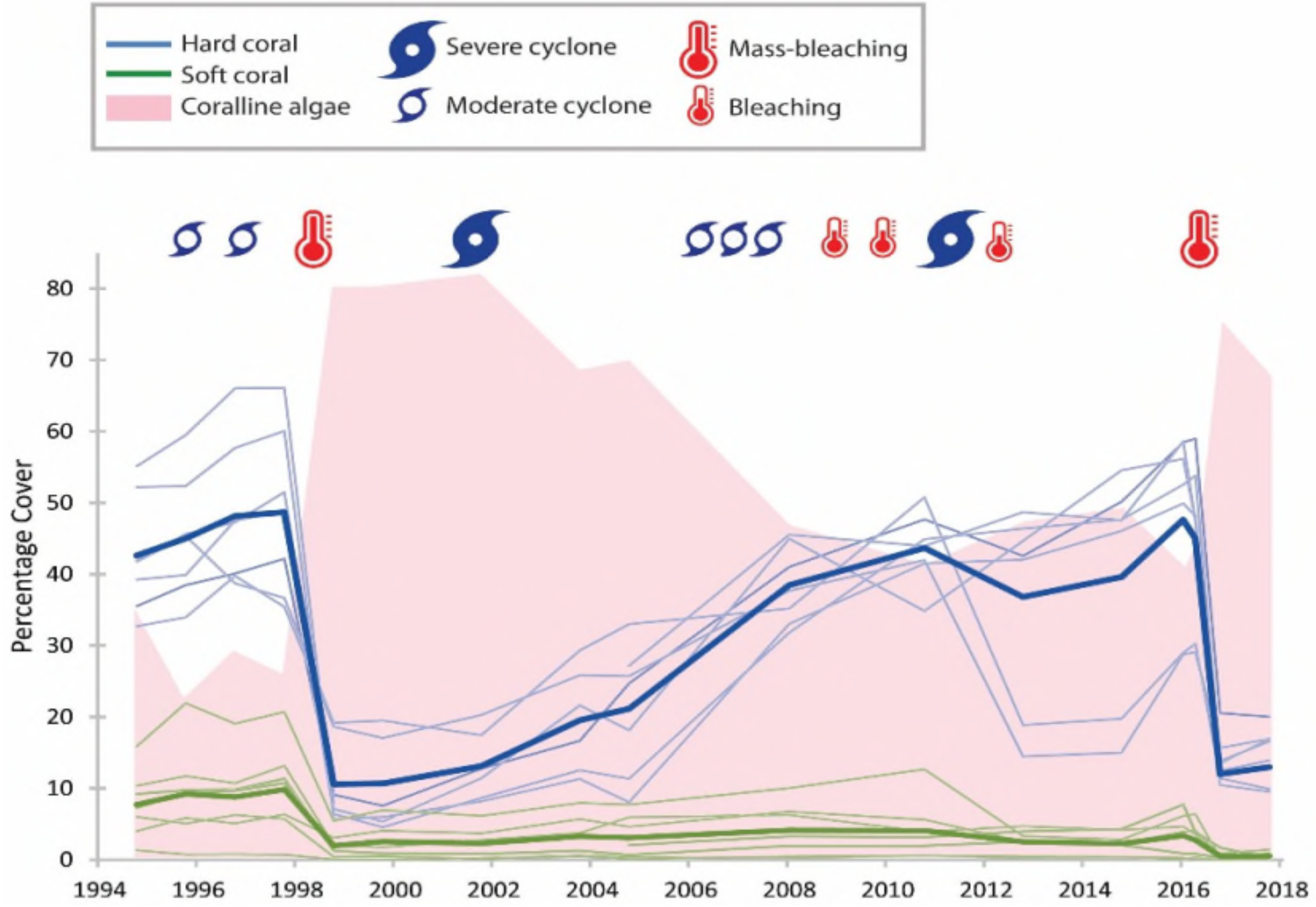

Figure 5-24 Temporal Changes in Coral Cover and Community Structure Across Scott Reef Between 1994 and 2017 (Gilmour et al., 2018)

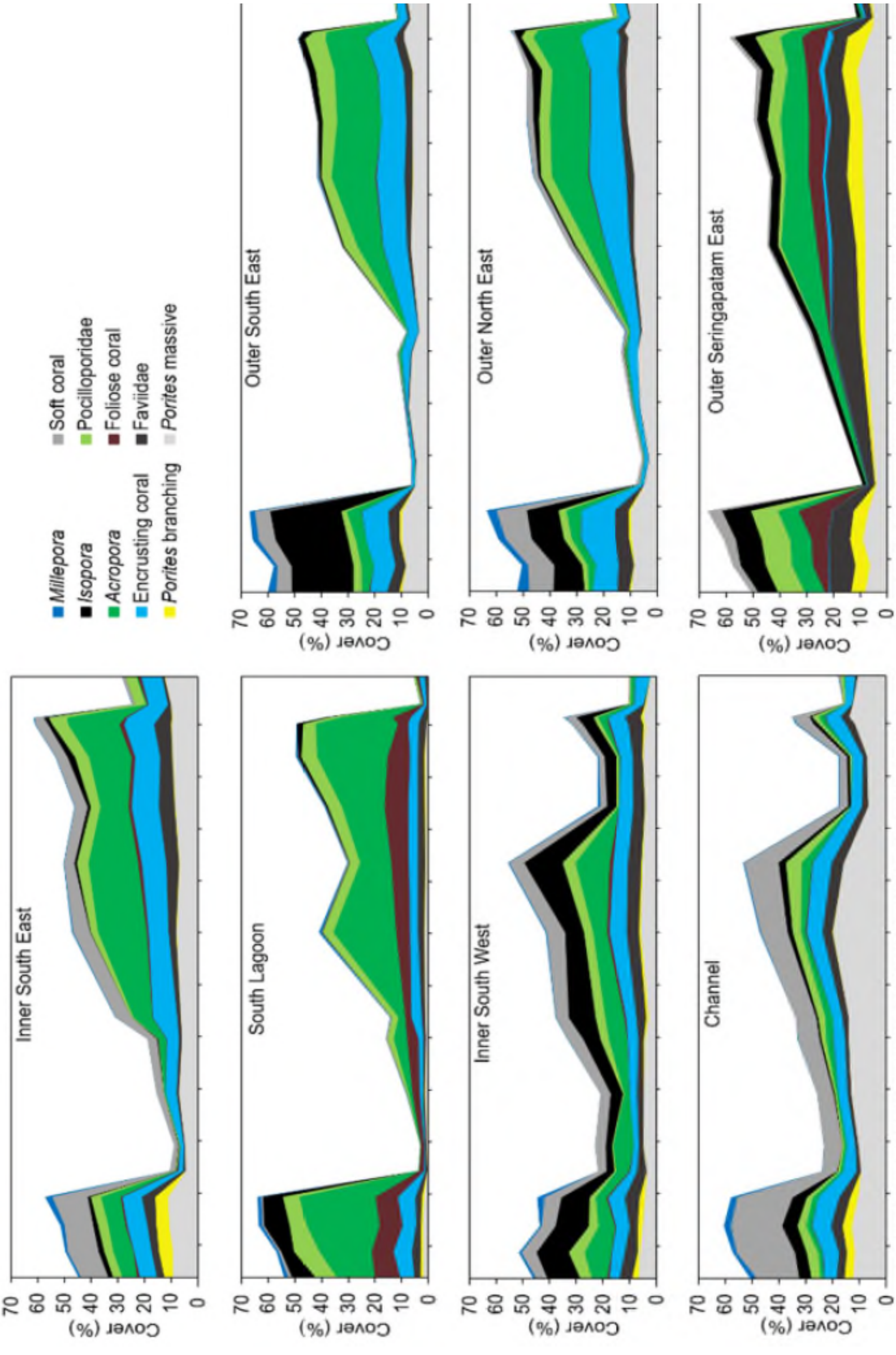

Figure 5-25 Temporal Changes in Community Structure at EAach Long Term Monitoring Location at Scott Reef and Seringapatam Reef from 1994 to 2017 (Gilmour et al., 2018)

Between 1994 and 1997 there were no severe disturbances and coral cover across the reef system was observed to have increased from 53% to 61%. Coral cover was high at all locations (45 to 70%) and most of the remaining substrata was covered by coralline algae (30 to 40%) (Gilmour et al., 2018).

The Indian Ocean wide mass bleaching event in 1998 caused a dramatic decrease from approximately 45% to approximately 10% coral cover within shallow water habitats (< 20 m) across the entire reef system and a relative reduction in cover of approximately 80%. The most notable effect was the loss of coral cover for Isopora, Pocilloporidae, Faviidae and soft corals communities and the comparable increase in crustose coralline algae (Gilmour et al., 2018).

Three years after the 1998 mass-bleaching there had been little change in mean coral cover at locations across the reef system. Coral groups had small variations (< ±2%) in cover since 1998; however, there was little change in the community structure within the locations. The post-bleaching communities were characterised by corals that had previously been abundant and were least susceptible to bleaching, particularly the massive *Porites* and the *Montipora* (Gilmour et al., 2018).

Between 2002 and 2004 the communities commenced a trajectory to their pre-bleaching structure and mean coral cover increased. This recovery, however, was slowed by Cyclone Fay in early 2004. The mean cover of coralline algae had decreased to 68% and coral cover had increased to 23%. This was largely driven by ongoing increases in Montipora, encrusting corals and Porites but also by groups that had been more severely impacted by the mass-bleaching including *Acropora*, *Pocilloporidae*, soft corals and *Isopora* (Gilmour et al., 2018).

A rapid increase in coral cover and return to the pre-bleaching structure commenced in 2004. Between 2004 and 2010 the mean cover of coralline algae had decreased to 40% and coral cover had increased to 45%. Species that had initially been slow to recover were now driving the increase in coral cover. The largest mean increases in cover (approximately 3%) were in *Monitipora, Acropora* and Pocilloporidae. Several local disturbances between 2004 and 2010 caused both increases and decreases in cover of coral groups at all locations. The impacts from three cyclones during 2007/2008 were restricted to the more susceptible corals including *Acropora* and Pocilloporidae at the most exposed locations. Following the cyclones, disease outbreaks and coral bleaching affected the *Acropora* at the inner south-east and particularly south lagoonal communities in 2009/10. The resulting decreases in coral cover were comparable to the rapid increases (10 – 20%) that had occurred from 2004 and 2008 (Gilmour et al., 2018). By 2010, the mean cover of hard corals was higher than that prior to the 1998 mass-bleaching at all but two of the worst affected LTM sites due to recent disturbances. Most communities were characterised by the same coral groups as prior to the mass bleaching and showed similar trajectories of recovery. Branching *Porites* and *Millepora* had been rare prior to 1998 and proved most susceptible to bleaching with little recovery over the 12 years. In contrast, Isopora was common (5 – 30% cover) at most locations before the mass bleaching in 1998 had not recovered by 2010 with mean cover across the reef system returning to only 30% of that before the mass bleaching. Soft corals were less susceptible to bleaching and thus had returned to approximately 40% of their pre-bleaching cover by 2010 (Gilmour et al., 2018).

In 2012, impacts from Cyclone Lua reduced mean cover of hard and soft corals within the reef system the only disturbance to do so since the mass-bleaching in 1998. The impacts from the cyclone were restricted to a few locations with a westerly aspect. Between 2010 and 2012 there were large decreases (28 to 32%) in cover at the channel and inner south-west communities, with all coral groups affected. The cyclone impacts were followed by a rapid increase in cover between 2010 and 2014 (Gilmour et al., 2018).

Between 2012 and the start of 2016 no severe disturbances affected the reef system, allowing a period of recovery. Mean hard coral cover increased between 6 and 15% at all locations across the reef. The mean cover of soft corals had changed little, with only small (<3%) increases and decreases in cover at all locations. By the end of 2015, communities had shifted towards their pre-bleaching structure (Gilmour et al., 2018).The 2016 mass-bleaching event dramatically reduced both coral cover and species diversity across the Scott Reef system, causing severe and widespread bleaching to a depth of 20 m (Gilmour et al., 2018).Most species at all lagoon and reef-slope communities were affected. Biodiversity losses were apparent in shallow (3 – 5 m) and deeper (8 – 10 m) zones; however, the greatest declines occurred amongst species only recorded in the deeper zone (Gilmour et al., 2015). All LTM and additional survey sites demonstrated bleaching impacts, with at least 30% of colonies affected at all sites. Overall, there was a >75% relative reduction in cover at most of the locations across the reef system making it similar in scale and severity to the 1998 mass-bleaching (Gilmour et al., 2018; **Figure 5-25**).

The Future of Coral Communities at Scott Reef

The current state of coral communities at Scott Reef system is symptomatic of other tropical reefs systems impacted by increasingly variable and sustained climatic conditions (Hoegh-Guldberg et al., 2017). Within previously resilient reef systems, the increased frequency and intensity of natural perturbations has limited recovery amongst affected reefs and has created a regime of disturbances with little selectivity, affecting all corals across all shallow water (< 20 m) habitats (Gilmour et al., 2018).

Like all coral reefs globally, Scott Reef coral reef communities are likely to suffer further coral bleaching events. Gilmour et al. (2013) documented the recovery of Scott Reef after the 1998 mass bleaching and long-term monitoring results suggest addressing local pressures, such as pollution and overfishing are important for reef resilience and recovery from disturbances such as mass bleaching. However, the severity and frequency of future coral bleaching events will determine Scott Reef's ability to recover.

Browse Trunkline
Water depths along the proposed BTL route are too deep to provide suitable conditions for light dependent hard corals communities and the BTL survey confirmed the absence of light dependent hard corals (Advisian, 2019a) (**Chapter 10, Appendix D.1**).

Rowley Shoals

The Rowley Shoals, located approximately 2 km at the closest point from the proposed BTL route (Mermaid Reef Marine Park boundary), are considered to be an ecological stepping stone for reef species which originate in Indonesian / Western Pacific waters and are a valuable benchmark for Indo-West Pacific reefs (Department of the Environment and Conservation, 2007). The coral atolls are also thought to be a possible source of recruitment for reefs further south along the WA coast due to their position in the headwaters of the Leeuwin Current (Director of National Parks, 2018; DEC, 2007).

Intertidal and subtidal coral reefs are a dominant component of the benthic marine habitats at the Rowley Shoals (**Figure 5-26**). Long-term studies of the coral communities have identified a total of 43 genera and 184 species of corals, with a small percentage of the genera (eight in total) accounting for more than 80% percent of total hard coral cover (Department of the Environment and Conservation, 2007 and Gilmour et al., 2018) with these corals thought to be regionally significant as many are not found within the inshore tropical waters of northern Australia. In addition, the clear waters of the shoals allows coral communities to exist over a wide range of depths, while the strong wave action on the outer coral slopes and the wide tidal range result in distinct patterns of zonation across the reef (Veron, 1986).

The Rowley Shoals represents the most "natural" example of an oceanic coral reef atoll within the NWMR. Monitoring of the coral communities at the Rowley Shoals has been undertaken regularly since 1994 and provides a rare opportunity for long-term studies of dynamics of coral communities under natural regimes of disturbance (Gilmour et al., 2019, **Chapter 10, Appendix D.2**).

Despite their relative isolation from the mainland, as with many coral reefs globally, Rowley Shoals has experienced regular environmental perturbations over the past 24 years, including periods of elevated water temperatures, and extreme winds and waves generated by cyclones and storms (**Figure 5-27**). Fortunately, these reefs have not suffered any major coral mortality as a result of regional heat stress events since the Indian Ocean wide bleaching event in 1998. Some coral bleaching occurred in 2016 during an extended temperature; however, only minor coral mortality (<10%) was observed across the reefs (Gilmour et al., 2018). During this period, the highest estimates of bleaching were observed within shallow lagoonal habitats, particularly at the Mermaid Reef lagoon sites. Despite the observed coral bleaching, mean hard coral cover at the reefs increased from 45% in 2015 to 47% in 2017.

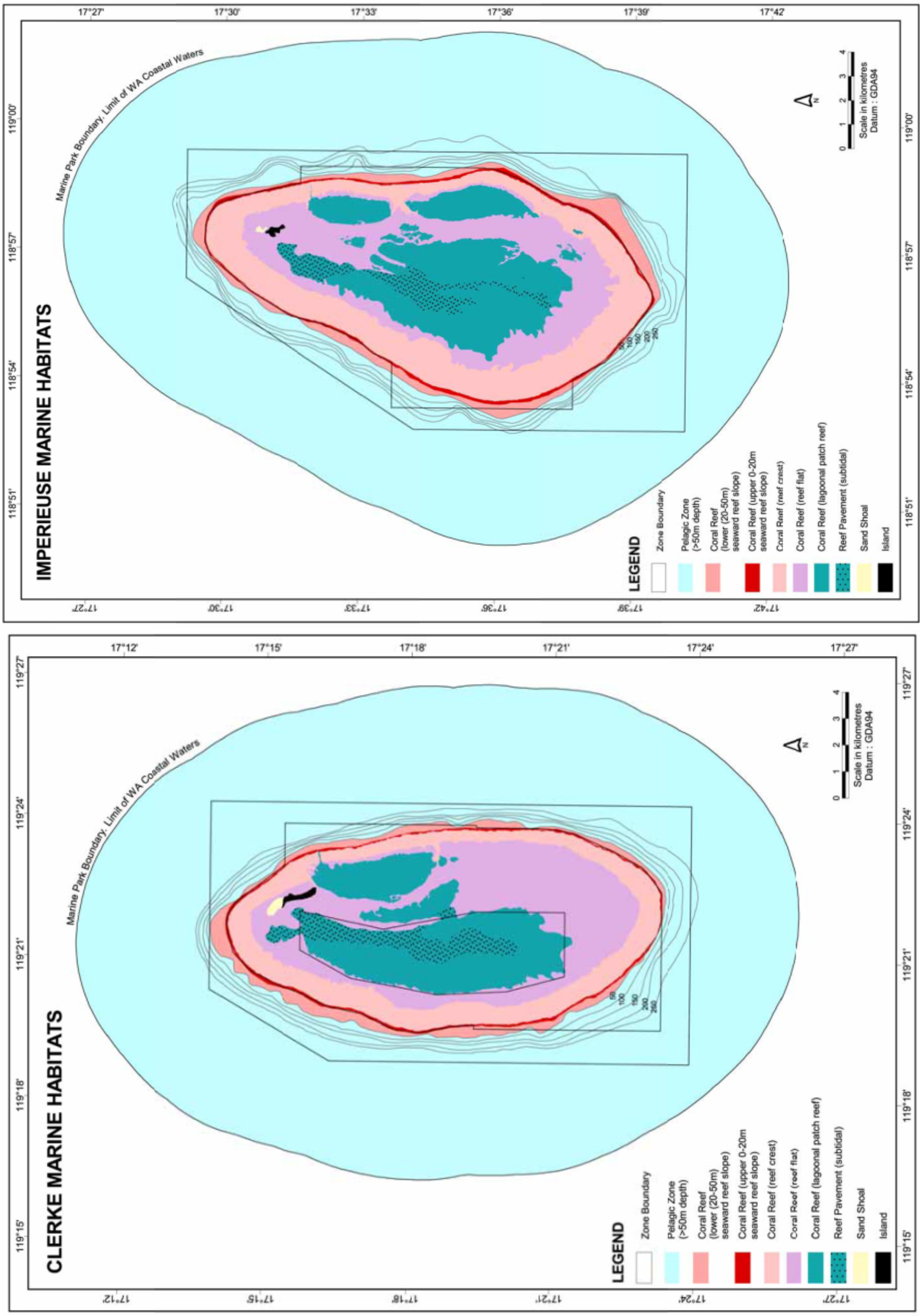

Figure 5-26 Dominant Benthic Marine Habitats at Clerke Reef and Imperieuse Reef (DEC 2007)

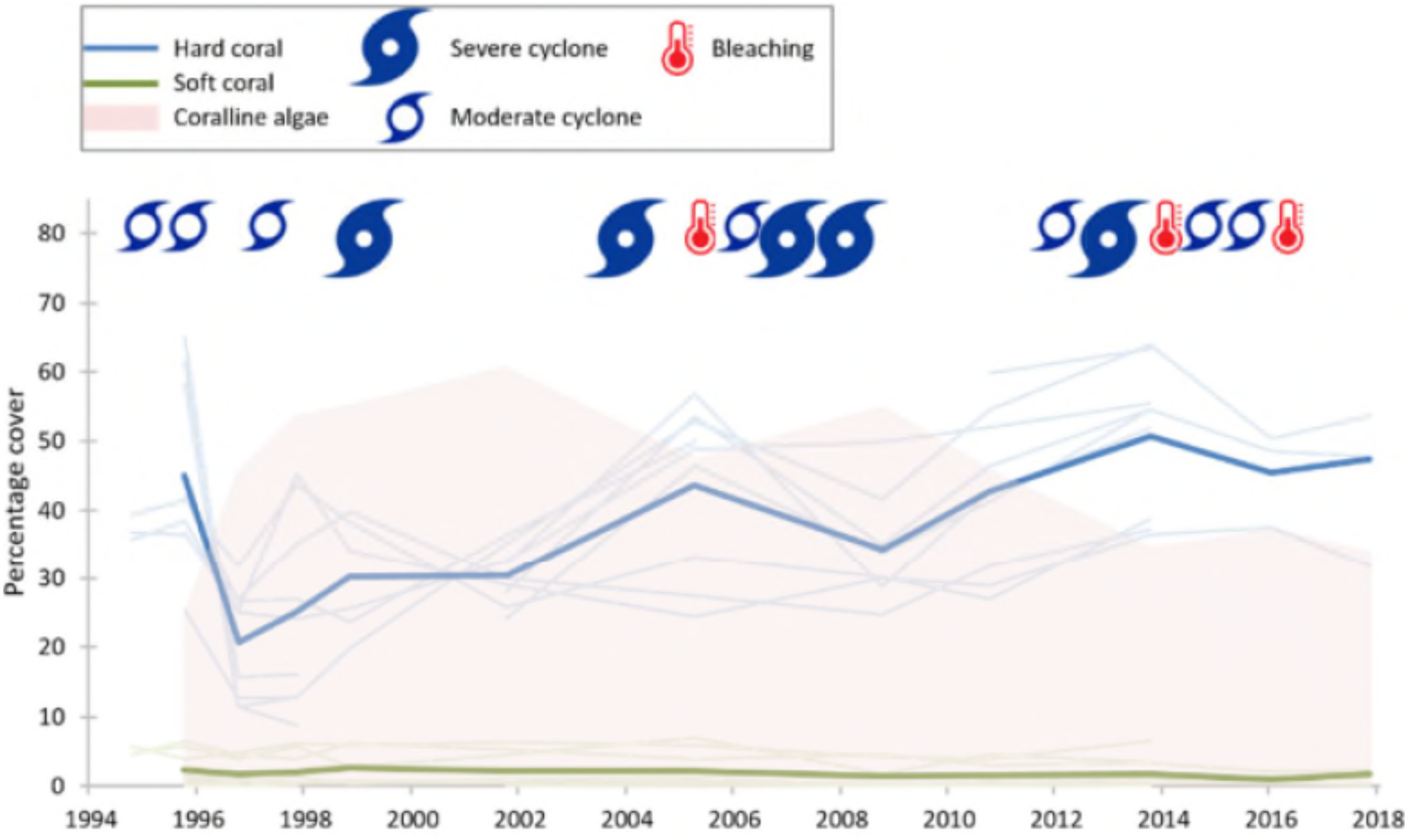

Figure 5-27 Changes in Coral Communities at Rowley Shoals through Periods of Impact and Recovery (Gilmour et al., 2018)

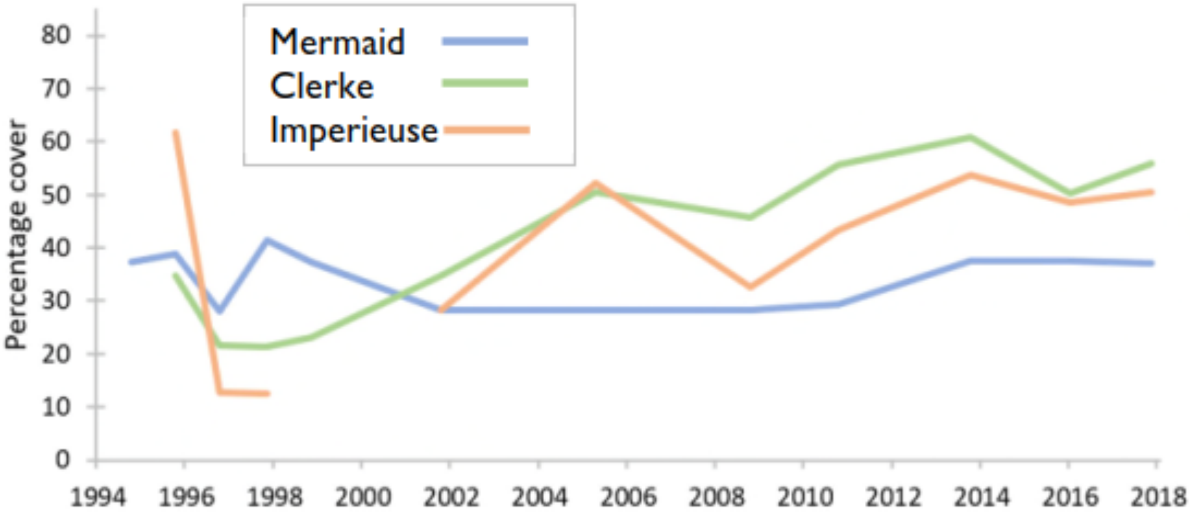

Figure 5-28 Changes in the Mean Coral Cover through Time at Each Reef Location at the Rowley Shoals (Gilmour et al., 2018)

The coral communities at the Rowley Shoals have demonstrated a high capacity for recovery over the last 23 years (Figure 5-28). It is likely that this resilience stems from the high cumulative cover of corals and coralline algae, and the scarcity of other benthic competitors. The recovery of the reef system from severe disturbance also depends critically on their patterns of larval connectivity and the genetic diversity. The Rowley Shoals reef system is genetically isolated, and relies on their surviving stocks and existing genetic diversity with few larvae dispersing more than 35 km from their natal reef patch (Gilmour et al., 2018).

A description of the broader benthic habitats within the Rowley Shoals is provided in Section 5.3.5.1.

5.3.1.4 Benthic Invertebrates

Water depths of the majority of the Project Area (up to 650 m) preclude the establishment of benthic primary producing habitats. Therefore, sparely distributed non-photosynthetic epifaunal and infaunal benthic biota (marine invertebrates) are the primary benthic communities within the Project Area. This section provides an overview of the key sessile and mobile benthic invertebrate taxa known to be present within the Project Area (i.e. the Browse Development Area and the proposed BTL), a broader discussion on benthic habitat and communities of the deep waters of the project area is provided in Section 5.3.1.2.

Sponges

Background

Sponges are ecologically important and often host large numbers of commensal invertebrates and microorganisms (Ponder et al., 2002). Due to their lack of reliance on benthic light availability for photosynthesis, sponges are found in a very broad range of marine environments, from tidal areas to the deep waters of the abyssal plain. Adults are sessile and most attach to any suitable surface, although numerous species bore into rocks or calcareous substrates such as coral reefs or shells. Sponge distribution has been linked to a wide variety of environmental variables including light, water depth, substrate type, water quality and flow regimes and, being sessile filter feeders, sponges thrive in areas where currents are strong (Hooper and Ekins, 2004).

Regional Overview

Sponges frequently form spatially heterogeneous benthic communities in Australian waters (Hooper and Ekins, 2004). Numbers of species from locations in the NWMR are summarised in Table 5-17. Williams et al. (2010) reported on the diversity of sponges (across the North West Shelf based on findings from cross-shelf CSIRO surveys conducted in 2007. The study identified 99 species from 30 families and 61 genera in the region, of which 96 (97%) were uncertain species requiring further taxonomic study. Taxonomic identification of sponge samples with the collections of the Western Australian Museum and the databases of the Atlas of Living Australia determined that species richness varies considerably between locations within the NWMR, with both relatively low diversity communities (less than 25 species e.g. Rowley Shoals and Exmouth Gulf) and exceptionally rich communities (greater than 250 species) with the Dampier - Port Hedland regions. However, this difference in species richness may in part be related to collection effort (Hooper and Ekins 2004) and as documented in Table 5-17 for collection sites across the NWMR.

Table 5-17 Summary of Sponge Fauna Collected from Locations in the NWMR

Region	Number of Localities Sampled	Number of Species	Number of Endemic Species	Number of Genera
Rowley Shoals[1]	23	23	6	20
Ashmore, Cartier and Hibernia Reefs[1]	39	125	32	77
Mermaid Reef[1]	16	59	-	31
Seringapatam Reef[2]	5	41	-	28
Scott Reef South[2]	24	96	-	50
Broome Region[1]	6	81	16	48
Dampier and Port Hedland Regions, NWS[1]	168	344	127	129
Exmouth Gulf[1]	10	20	0	16
Shark Bay[1]	15	57	18	38

1 *Hooper et al. 2002*

2 *WAM 2009*

The highest diversity reported in Williams et al. (2010) was at the outer continental shelf (approximately 100 m depth) with between 8 and 68 species recorded at six sites of which most (approximately greater than 90%) require further taxonomic study. At the shelf edge (200 m), sampling at three sites yielded between 0 and 3 species, all of which were also uncertain species. In samples taken from six sites on the continental slope at 400 m depth and two sites at 700 m depth, no demosponges were recorded. At 1,000 m depth on the continental slope, two sites were sampled. Four demosponge species were found at one of these locations, three of which require further taxonomic study.

Sponge communities on the reefs of the NWMR are broadly dissimilar. This may be a result of restricted connectivity due to the limited dispersal capabilities of some sponge larvae, and a requirement for specialized habitats that are not present at all reefs. A study by WAM found more than half the sponges identified at Mermaid, Seringapatam and Scott Reefs to be unique to a single reef (WAM, 2009). Only 10% of sponges were found at all of the reefs and 33% of species were found at only one location on a reef; a further 14% were only found at two of the locations surveyed.

Browse Development Area

Sponges occur at all depths where hard substrate is available for attachment in the marine environment and may therefore occur anywhere within the Browse Development Area. However, benthic surveys in the deepwater seabed areas overlying the gas reservoirs showed sponges to be sparsely distributed in these areas (Gardline Marine Services Pty Ltd, 2009a; Hudson and Fletcher, 2006; URS, 2007a).

Scott Reef

A study conducted by WAM in 2006 at Scott Reef collected 96 sponge species, with 46 species unique to Scott Reef (WAM, 2009). A ROV inspection of outer-reef habitats of Scott Reef in deep waters recorded abundant sponges communities on the outer reef slope (up to 100 m deep; URS, 2007a). Sponges were common on the lower slope, boulder zone and rampart habitat units of the outer reef habitats. Sponges were not recorded from the channel floor, however, which is heavily scoured by tidal currents. Long-term monitoring of Scott Reef benthic communities by AIMS identified a decrease in sponges after the mass bleaching event at Scott Reef in 1998. By 2008, sponges had recovered with large relative increases in cover at most sites, to a mean cover of 3% (±1% S.E.), compared to less than 1% prior to the bleaching (Gilmour et al., 2008). The surveys carried out at Scott Reef showed that despite having low cover, there is a high level of biodiversity, with 79 of the species identified unique to the reef (Gilmour et al., 2013; WAM, 2009).

Browse Trunkline

Within the deep waters of the proposed BTL route, sparse individual sponges were noted at two sampling locations of the environmental survey (site 13 and site 15, refer to Figure 5-18) within areas of unconsolidated rubble substrate. No extensive epibenthic habitats, including sponges were observed during the survey.

When the long term monitoring sites at the Rowley Shoals which are located approximately 2 km at the closest point from the proposed BTL route (Mermaid Reef Marine Park boundary), were surveyed in 2017, the cover of sponges was low at all habitats across all reefs (Gilmour et al., 2019). A quantitative survey documenting the diversity and abundance of sponges at Mermaid, Scott and Seringapatam Reef identified 60 species at Mermaid Reef. Twenty four species were recorded only at Mermaid Reef and this study found the fauna at Mermaid Reef was distinct from that at Scott Reef, which is likely due to the large numbers of rare species found at each of the reefs (Fromont and Vanderklift, 2009).

Crustaceans

Background

Crustaceans are an extremely diverse taxonomic group and as a result occupy a large range of habitats in the ocean, both benthic (seabed) and pelagic (water column) habitats. Small benthic crustaceans such as amphipods, copepods and isopods form the basis of many ocean food chains. The euphausiids (krill) are an important pelagic food source for fish and marine megafauna such as baleen whales and whale sharks. Krill are highly gregarious and form schools that often exceed densities of 1000 individuals/m^3 (Ponder et al., 2002).

Regional Overview

Crustaceans are generally among the dominant epibenthic and infaunal invertebrates of the soft sediment habitats of the North-west continental shelf, and have strong Indo-west Pacific affinities (Gardline Marine Services Pty Ltd, 2009a; Heyward et al., 1997; Heyward et al., 2001; Andrew Heyward et al., 2001).

Williams et al. (2010) reported on the crustacean diversity (Class: Decapoda) across the NWS adjacent to the Browse Development Area based on findings from surveys in 2007. Overall, 372 species from 60 families and 186 genera were recorded in the region, of which 133 (36%) species require further taxonomic study. Similar decapod crustacean diversity was found at the outer continental shelf (100 m depth) and the continental slope (400 m depth). At the six sites sampled at 100 m depth, between 36 and 84 species were recorded, of which approximately 30 to 45% of species require further taxonomic study. At 400 m depth, between 11 and 96 species were recorded at six sites, of which approximately 8 to 20% require further taxonomic study. At deeper locations on the continental slope, fewer locations were sampled (two each at 700 m and 1000 m water depth). Similar diversity was recorded (19 to 50 species at 700 m depth and 29 to 36 species at 1,000 m water depth). Between about 10 to 30% of these species require further taxonomic study.

Surveys by WAM in the Kimberley region have identified more than 200 species of decapod crustaceans (Davie and Short, 1996; 1995; Hewitt, 1997). Areas with the greatest range of habitat types were found to generally support the greatest diversity of species.

A study of three offshore atolls (Mermaid, Seringapatam and Scott Reef) by WAM in 2006 identified a total of 157 crustacean species (WAM, 2009). This more than doubled the number of species previously recorded from these atolls, and the number of species will increase further with identification of unidentified specimens. Xanthidae (stone crabs – 45 species) was the most diverse family at all reefs, which is typical of Australian coastal waters. Other diverse families included Majidae (spider crabs – 14 species), Diogenidae (hermit crabs – 14 species) and *Portunidae* (swimming crabs – 14 species). There was a high diversity and abundance of galatheids (squat lobsters), particularly at Mermaid Reef. The painted rock lobster, *Panulirus versicolor*, is the only species of rock lobster known from the reefs. Live specimens were recorded only from Scott Reef (North and South Scott Reefs) during the WAM survey and all were juveniles (WAM, 2009). A single carapace of a juvenile was also collected from Mermaid Reef (Rowley Shoals), indicating the species occurs there but possibly in low numbers.

There are a number of commercially important crustacean species in the NWMR, and State managed fisheries include the Onslow, Nickol Bay, Broome and Kimberley prawn fisheries that target banana prawns (*Penaeus merguiensis*), western king prawns (*Penaeus latisulcatus*), brown tiger prawns (*Penaeus esculentus*) and endeavour prawns (*Metapenaeus* spp.; Gaughan and Santoro, 2018). A preliminary harvest strategy has been determined for the Pilbara Developmental Crab Fishery which targets blue swimmer crab (*Portunus pelagicus*; Gaughan and Santoro, 2018). Tropical lobsters (*Panulirus ornatus*), for which there is a small recreational fishery in WA, have been recorded as bycatch in the Pilbara Trawl Fishery (Stephenson and Chidlow, 2003). Further details of fisheries in the region can be found in **Section 5.3.3**.

Browse Development Area

Crustaceans are expected to be among the dominant infaunal and epibenthic invertebrates in the deepwater soft sediment habitats of the Browse Development Area, as observed by a benthic survey of the area in 2009 (**Figure 5-15** and **Figure 5-16**) (Gardline Marine Services Pty Ltd, 2009). Within water depths between 281 m and 646 m, the results of the survey demonstrated that arthropod crustaceans contributed between 0% and 84% of individuals and between 0% and 60% of taxa recorded in infauna samples. There were no distinct patterns of distribution between locations or in relation to environmental variables such as sediment type. Occasional crustaceans were recorded from towed camera surveys of the seabed in the Browse Development Area, such as squat lobsters (Gardline Marine Services Pty Ltd, 2009).

Scott Reef

Crustaceans are abundant at Scott Reef; one hundred and five species were identified by WAM at South Scott Reef and 63 at North Scott Reef from 14 and 10 survey stations respectively, within water depths between 0 m and 20 m LAT (WAM, 2009). A survey by WAM found the proportion of unique crustacean species at South Scott Reef to be 29% and 19% at North Scott Reef (WAM, 2009). Crustaceans were found to be the fifth most abundant phylum recorded in benthic habitat surveys of the deepwater sands in the south-east of South Scott Reef Lagoon (URS, 2007c). Snapping shrimp (Family Alpheidae) were the most abundant crustaceans, with a density of 225 individuals/m^3. Scott Reef has been surveyed for invasive marine species and no invasive crustacean species were identified (Sinclair Knight Merz Ltd, 2009).

Browse Trunkline

Within the deep waters of the BTL, sparse individual crustaceans were noted at eleven of the sampling locations of the environmental survey within areas of soft substrate.

Molluscs

Molluscs occupy a wide range of habitats in the ocean, both benthic and pelagic. None of the mollusc species in the region are protected by the EPBC Act, however, giant clams (tridacnids), which are common on the reefs of the region, are listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Please refer to **Table 5-18**.

Regional Overview

A number of molluscs are commercially exploited in the NWMR. A species of Trochus snail (*Trochus niloticus*) is collected by traditional Indonesian fishers from reefs and shoals in the MoU 74 Box (**Section 5.4.2.3**; Skewes et al., 1999b). Numerous surveys of the reefs in the MoU 74 Box, including Scott Reef, have reported depleted populations of these Trochus snails (Rees et al., 2003; Skewes et al., 1999b; Smith et al., 2001, 2002; URS Australia Pty Ltd, 2006a). There is also a commercial pearl oyster fishery that operates in fishing grounds primarily off Eighty Mile Beach, with smaller catches taken around the Lacepede Islands (north of Broome). The species targeted is the Indo-Pacific silverlipped pearl oyster (*Pinctada maxima*; Gaughan and Santoro, 2018).

Species diversity in nearshore habitats off the mainland is lower than the offshore atolls of Scott Reef and Ashmore Reef where there are lower tidal ranges and clearer, less productive waters (Wells, 1989). Diversity appears to increase with increasing latitude, with greater species numbers on the more southern reefs and island groups closer to the mainland (e.g. Dampier Archipelago) as compared to numbers recorded for the Kimberley (offshore) region. Mollusc fauna found in the Kimberley region are generally widespread throughout the Indo-West Pacific. However, there is a small proportion of the fauna that is endemic to the Kimberley such as the littorinid *Tectarius rusticus* (Wells, 1992).

Surveys of the molluscan fauna of Mermaid, Seringapatam and Scott Reef recorded a total of 339 molluscan species from the three reefs (WAM, 2009). Species numbers were generally similar across the reefs and habitats surveyed. The species of molluscs encountered are mainly of Indo-Pacific origin and the reefs are considered to have a greater biogeographic affinity with the Indonesian Archipelago than the WA mainland (WAM, 2009).

Six species across two genera of giant clams have been reported from the offshore reefs and shoals of the Northwest Marine Region: *Tridacna maxima, T. gigas, T. squamosa, T. derasa, T. crocea* and *Hippopus hippopus*. Recent surveys of Scott and Seringapatam Reefs have found the abundance of giant clams low (except *T. crocea*), probably as a result of environmental pressures (e.g. thermally induced bleaching and cyclonic activity; URS Australia Pty Ltd, 2006a; WAM, 2009).

Browse Development Area

Molluscs are expected to be sparsely distributed and in low abundance in the soft sediment habitats of the Browse Development Area. A benthic infauna survey conducted in the Browse Development Area within depths between 281 m and 646 m, found molluscs to be scarce within seabed samples (**Figure 5-15** and **Figure 5-16**; Gardline Marine Services Pty Ltd, 2009a). Molluscs only contributed 4% of the total number of individuals and 9% of taxa recorded from infauna samples (**Table 5-11** and **Table 5-12**).

Table 5-18 Mollusc Species Recorded from Various Surveys Undertaken within the NWMR

Surveyed Locality	Year	No. of Researchers	Survey Duration (person-days)	Total Species	Source
Mermaid, Scott and Seringapatam Reefs	2006	2	32	339	(WAM, 2009)
Mermaid, Scott and Seringapatam Reefs	1986	2	22	324	(Wells and Slack-Smith, 1986)
Central Kimberley	1996	1	13	292	(Bryce, 1997)
Eastern Kimberley	1995	2	24	265	Wells and Bryce, 1996)
Southern Kimberley	1994	1 – 2	15	232	(Wells and Bryce, 1995)
Dampier Archipelago	1998, 1999	2	52	695	(Slack-Smith and Bryce, 2004)

Scott Reef

At Scott Reef, molluscs were most abundant within the lower intertidal area off Sandy Islet (Wells and Slack-Smith, 1986). This sandy habitat was dominated by cones, terebrids and ceriths, while rocky areas were dominated by thaids and cones. Species of nerites, mitres, cowries and buccinids were also collected in the rocks. Two hundred and twenty-one mollusc species were identified from South Scott Reef (from 14 survey stations) and 183 species from North Scott Reef (from 10 survey stations; WAM, 2009). Species numbers were similar at South and North Scott Reef at the lagoon and outer reef slope habitats surveyed. However, South Scott Reef had a greater number of species at the reef platform habitats surveyed (three reef platform stations surveyed at both North and South Scott Reef). The patchy nature of the platforms is a possible cause for this disparity in species numbers.

A survey of the deepwater sand habitats of the south-east inner reef edge at South Scott Reef found molluscs (bivalves and gastropods) to be among the most abundant phyla recorded over the survey area. A total of 20 families were recorded, with the highest density exhibited by the Tellinidae (bivalves) of 206 individuals/m^3 (URS, 2007c). Deep seabed ROV transects conducted around Scott Reef and in the channel between the reefs did not report any significant numbers of macro-molluscs (URS, 2007a).

Of particular note is the marine snail *Drupella* spp. which feeds on live coral and has caused high coral mortality WA reefs in the past. *Drupella* does occur at Scott Reef, however, no outbreaks have been observed. In addition, Scott Reef has been surveyed for invasive marine species and no invasive mollusc species were identified at that time (Sinclair Knight Merz Ltd, 2009).

Browse Trunkline

No molluscs were observed during the BTL environmental survey (Advisian, 2019a).

Echinoderms

Background

Echinoderms are benthic animals that are largely sedentary but include mobile species ranging from sea urchins, starfish brittle stars and sea cucumbers. Some species bore into soft rock or coral or graze on algae on these substrates and can be important agents of reef erosion. The crown-of-thorns starfish (*Acanthaster planci*), which feeds on live coral, has been the subject of considerable attention due to the damage caused during periodic population explosions in areas such as the Great Barrier Reef. Crown-of thorns starfish have not been reported in significant numbers from the remote oceanic reef systems of the NWMR (i.e. Rowley Shoals, Scott Reef, Ashmore and Cartier Reefs). The largest known population of *A. planci* in WA has previously been recorded in the Dampier Archipelago (Wells et al., 2003).

Regional Overview

A number of sea cucumber species (also known as bêche-de-mer or trepang) are commercially exploited in the NWMR. Sea cucumbers are collected by traditional Indonesian fishers from reefs and shoals in the MoU 74 Box (**Section 5.4.2.3**; Skewes et al., 1999a). Sea cucumbers are widespread on the offshore reefs and shoals throughout the region. However, the common species tend to be of low or no commercial value, while numbers of the high-value species (such as *Holothuria whitmaei, Holothuria fuscogilva* and *Thelenota ananas*) have been severely depleted by Indonesian fishers (Skewes et al., 1999a; URS Australia Pty Ltd, 2006a; WAM, 2009). As the abundance of high-value species has declined, fishing effort has begun to include medium and low-value species (Skewes et al., 1999a). However, despite low abundances in recent surveys, *H. fuscogilva*, and *T. ananas* were still frequently collected by Indonesian fishers at Scott Reef in 2008 (EPA, 2009b).

Limited surveys of the continental shelf in the NWMR have found soft sediment habitats to support low-density communities of echinoderms (Gardline Marine Services Pty Ltd, 2009a; SKM, 2006). Williams et al. (2010) reported on the echinoderm diversity across the NWS adjacent to the Browse Development Area based on findings from surveys in 2007. Overall, 269 species from 75 families and 195 genera were recorded in the region, of which 92 (34%) species require further taxonomic study. The highest diversity of echinoderms was found at the outer continental shelf (100 m depth) with between 18 and 52 species recorded at 6 sites. On the continental slope at 400 m depth, between 2 and 24 echinoderm species were recorded. At both the 100 m and 400 m depths, between approximately 15 and 25% of echinoderm species recorded at sites were uncertain species requiring further taxonomic study. Higher echinoderm diversity was found at 700 m (8 and 50 species at 2 sites) and 1,000 m (29 and 37 species at 2 sites) on the continental slope. At these deepest sites, between approximately 10 and 25% of species require further taxonomic study.

Surveys conducted by WAM in the Kimberley region in the early 1990s found echinoderm diversity to be lower than in areas surveyed further offshore in WA at similar latitudes, such as Rowley Shoals, Scott Reef and Ashmore Reef (Morgan, 1992). Echinoderms were found to be more abundant in the clearer waters west of Cape Leveque than in the more turbid waters of the Kimberley coast. A total of 82 species were identified (8 sea stars, 13 feather stars, 28 brittle stars, 11 sea urchins and 22 sea cucumbers). Forty-eight percent of the echinoderm species recorded have a widespread Indo-west Pacific distribution, about a third have a more restricted Indo-west Pacific distribution, and 11 species (15%) are endemic to northern Australia (predominantly brittle stars and echinoids).

Browse Development Area

Echinoderms are expected to be sparsely distributed and in low abundance in the soft sediment deepwater habitats of the Browse Development Area. Benthic infauna surveys conducted across the Browse Development Area found echinoderms to be scarce, contributing approximately 5% of the total number of individuals and 4% of taxa recorded from infauna samples within depths between 281 m and 646 m (**Figure 5-15** and **Figure 5-16**; **Table 5-11** and **Table 5-12**; Gardline Marine Services Pty Ltd, 2009a). A wide range of echinoderms were recorded from towed camera surveys of the seabed in the Browse Development Area, including sea urchins, sea stars, brittle stars, feather stars, basket stars (Gardline Marine Services Pty Ltd, 2009).

Scott Reef

Echinoderms are widespread across all habitats of Scott Reef; Marsh (1986) recorded a total of 117 echinoderm species from Scott Reef and Seringapatam (21 sea stars, 19 sea urchins, 25 sea cucumbers, 36 brittle stars and 16 feather stars). Recent surveys have recorded fewer species but did not use comparable sampling methods or effort (URS Australia Pty Ltd, 2006a; WAM, 2009).

Deepwater ROV transects conducted around Scott Reef and within the channel between the two reefs found benthic fauna in the areas outside of the channel to be more diverse and slightly more abundant than those encountered within the channel, presumably related to the currents scouring of the channel floor (URS, 2007a). During the survey, echinoderms observed included holothurians, sea urchins and brittle stars. Stones and small pieces of rubble that were occasionally encountered supported crinoids and were inhabited by other species of this Phylum including brittle stars and other benthic biota. Two small species of sea cucumber were encountered but displayed no obvious distribution. Brittle stars and crinoids were observed amongst rubble and rock in the channel, however, organisms in general were few and sparsely distributed.

Browse Trunkline

Within the deep waters of the proposed BTL route, sparsely distributed individual echinoderms were noted from seabed imagery at six of the nineteen sampling locations during the environmental survey (Advisian, 2019a) within areas of soft substrate. The Rowley Shoals also support a diverse assemblage of echinoderms (Bryce and Whisson, 2009; Bryce and Marsh, 2009).

5.3.1.5 Threatened Ecological Communities

Threatened Ecological Communities (TECs) are ecological communities where the natural composition and function of the ecological community have been significantly depleted across its full range, such that they are threatened due to a risk of extinction. Three categories exist for listing TECs under the EPBC Act: critically endangered, endangered and vulnerable. There are no TECs listed within the Project Area, as per **Table 5-1**.

5.3.2 Fauna

5.3.2.1 EPBC Listed Species

Due to the physical characteristics described above in **Section 5.2**, the NWMR is an important region for species listed as Matters of National Environmental Significance (MNES) under Part 13 (Species and Communities) of the EPBC Act, as well as species listed under the WA *Biodiversity Conservation Act 2016* (BC Act).

A PMST search was undertaken on 18 March 2019 for EPBC Act listed species potentially occurring within the Project Area. A 5 km buffer was applied. The PMST (report provided in **Chapter 10, Appendix C.1**) identified 20 listed Threatened species and 38 listed Migratory marine / wetland species as potentially occurring within the Project Area.

The PMST report results were reviewed in the context of existing studies, literature and the SPRAT database (Department of the Environment and Energy, 2019a) in order to assess the likelihood of each listed species occurring in the Project Area and/or interacting with the proposed Browse to NWS Project. The majority of listed species were determined to be transient visitors within the Project Area and/or unlikely to occur in significant numbers; or species whose range or preferred habitat indicated that they are highly unlikely to occur within the Project Area. These species have been documented in **Chapter 10, Appendix C.7**.

Those species assessed as likely to occur within the Project Area and/or likely to interact with the proposed Browse to NWS Project are summarised in **Table 5-19** below. Where applicable, the corresponding species recovery and/or conservation plans, and key threats are also provided in **Table 5-19**. In addition, several species not in the PMST report were identified by the DoEE within the EPBC Referral decision notice and EIS Guidelines and/or relevant literature as potentially occurring within the Project Area or being impacted by the proposed Browse to NWS Project and therefore requiring consideration. These are also listed in **Table 5-19**.

Table 5-19 Listed, Threatened and Migratory Species Identified by the PMST and DoEE and Assessed as Likely to Occur in the Project Area and/or Interact with the Proposed Browse to NWS Project

Species	EPBC Act Listing	IUCN Category	Status under BC Act	Recovery plan / conservation advice	Key threats identified in recovery plan / conservation advice
Birds					
Common noddy[5] *(Anous stolidus)*	Migratory, International Agreement[1]	Least Concern	Migratory	None	Not Applicable
Streaked shearwater[5] *(Calonectris leucomelas)*	Migratory, Marine, International Agreement[1]	Near Threatened	Migratory	None	Not Applicable
Lesser frigatebird[5] *(Fregata ariel)*	Migratory, Marine, International Agreement[1]	Least Concern	Migratory	None	Not Applicable
Little tern[5] *(Sternula albifrons)*	Migratory, Marine, International Agreement[1]	Least Concern	Migratory	None	Not Applicable
Barn swallow[5] *(Hirundo rustica)*	Migratory (Terrestrial), Marine, International Agreement[1]	Least Concern	Migratory	None	Not Applicable
Australian lesser noddy *(Anous tenuirostris melanops)*	Vulnerable, Marine	No listing	Endangered	Conservation Advice *Anous tenuirostris melanops* Australian lesser noddy (Threatened Species Scientific Committee, 2015a)	Habitat degradation / modification
White-tailed tropicbird *(Phaethon lepturus)*	Migratory, International Agreement[1]	Least Concern	Migratory	None	Not Applicable
Abbott's booby *(Papasula abbotti)*	Endangered, Marine	Endangered	No listing	Conservation Advice *Papasula abbotti* Abbott's booby (Threatened Species Scientific Committee, 2015b)	Habitat loss Introduced species
Red-tailed tropicbird[2] *(Phaethon rubricauda)*	Migratory, Marine, International Agreement[1]	Least Concern	Migratory, Priority 4[3]	None	Not Applicable
Crested tern[4] *(Sterna bergii)*	Marine, Migratory, International Agreement[1]	Least Concern	Migratory	None	Not Applicable
Brown Booby[4] *(Sula leucogaster)*	Marine, Migratory, International Agreement[1]	Least Concern	Migratory	None	Not Applicable

Species	EPBC Act Listing	IUCN Category	Status under BC Act	Recovery plan / conservation advice	Key threats identified in recovery plan / conservation advice
Ruddy Turnstone[4] *(Arenaria interpres)*	Marine, Migratory, International Agreement[1]	Least Concern	Migratory	Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a)	Habitat loss / modification Anthropogenic disturbance Climate variability & change
Common sandpiper[5] *(Actitis hypoleucos)*	Migratory (Wetland), Marine, International Agreement[1]	Least Concern	Migratory	Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a)	Habitat loss / modification Anthropogenic disturbance Climate variability & change
Marine Mammals					
Pygmy blue whale[5] *(Balaenoptera musculus brevicauda)*	Endangered, Migratory, Cetacean, International Agreement[1]	Endangered	Endangered	Conservation Management Plan for the Blue Whale: A recovery plan under the *Environment Protection and Biodiversity Conservation Act* 1999 2015-2025 (Commonwealth of Australia, 2015b)	Climate variability and change Noise interference Vessel disturbance
Humpback whale[5] *(Megaptera novaeangliae)*	Vulnerable, Migratory, Cetacean, International Agreement[1]	Least Concern	Conservation Dependent	Conservation Advice for *Megaptera novaeangliae* (humpback whale) (Threatened Species Scientific Committee, 2015c)	Climate and oceanographic variability and change Noise interference Vessel disturbance and strike Habitat degradation including coastal development and port expansion Entanglement

Species	EPBC Act Listing	IUCN Category	Status under BC Act	Recovery plan / conservation advice	Key threats identified in recovery plan / conservation advice
Sei whale[5] *(Balaenoptera borealis)*	Vulnerable Migratory, Cetacean, International Agreement[1]	Endangered	Endangered	Conservation Advice *Balaenoptera borealis* sei whale (Threatened Species Scientific Committee, 2015d)	Climate and oceanographic variability and change Anthropogenic noise and acoustic disturbance Vessel strike Habitat degradation including pollution (increasing port expansion and coastal development)
Fin whale[5] *(Balaenoptera physalus)*	Vulnerable Migratory, Cetacean, International Agreement[1]	Vulnerable	Endangered	Conservation Advice *Balaenoptera physalus* fin whale (Threatened Species Scientific Committee, 2015e)	Climate and oceanographic variability and change Anthropogenic noise and acoustic disturbance Vessel strike Habitat degradation including coastal development, port expansion and aquaculture
Bryde's whale *(Balaenoptera edeni)*	Migratory, Cetacean, International Agreement[1]	Least Concern	No Listing	None	Not Applicable
Spinner dolphin *(Stenella longirostris)*	Cetacean	Least Concern	Priority 4[3]	None	Not Applicable

Species	EPBC Act Listing	IUCN Category	Status under BC Act	Recovery plan / conservation advice	Key threats identified in recovery plan / conservation advice
Marine Reptiles					
Green turtle[5] *(Chelonia mydas)*	Vulnerable, Migratory, Marine	Endangered	Vulnerable	Recovery plan for marine turtles in Australia (Commonwealth of Australia, 2017)	Climate change and variability Marine debris (entanglement and/or ingestion) Chemical and terrestrial discharge (acute and/or chronic) Terrestrial predation Light pollution Habitat modification (infrastructure/coastal development) Vessel disturbance Noise interference (acute and chronic)
Loggerhead turtle[5] *(Caretta caretta)*	Endangered, Migratory, Marine	Vulnerable	Endangered		
Hawksbill turtle[5] *(Eretmochelys imbricata)*	Vulnerable, Migratory, Marine	Critically Endangered	Vulnerable		
Olive ridley turtle[5] *(Lepidochelys olivacea)*	Endangered, Migratory, Marine	Vulnerable	Endangered		
Flatback turtle[5] *(Natator depressus)*	Vulnerable, Migratory, Marine	Data Deficient	Vulnerable		
Leatherback turtle[5] *(Dermochelys coriacea)*	Endangered, Migratory, Marine	Vulnerable	Vulnerable	Recovery plan for marine turtles in Australia (Commonwealth of Australia, 2017) Conservation Advice *Dermochelys coriacea* (Leatherback Turtle) (Department of the Environment and Energy, 2008)	
Olive sea snake *(Aipysurus laevis)*	Marine	Least Concern	N/A	No Conservation Advice or Recovery Plans for these species of sea snake.	N/A
Turtle-headed sea snake *(Emydocephalus annulatus)*	Marine	Least Concern	N/A		
Dusky sea snake *(Aipysurus fuscus)*	Marine	Endangered	N/A		
Duboi's sea snake *(Aipysurus duboissi)*	Marine	N/A	N/A		
Slender-necked sea snake *(Hydrophis coggeri)*	Marine	Least Concern	N/A		
Horned sea snake *(Acalyptophis peronii)*	Marine	Least Concern	N/A		

Species	EPBC Act Listing	IUCN Category	Status under BC Act	Recovery plan / conservation advice	Key threats identified in recovery plan / conservation advice
Fish					
Whale shark[5] *(Rhincodon typus)*	Vulnerable, Migratory, Marine	Endangered	Other specially protected fauna (OS)	Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015f)	Vessel strike Habitat disruption (from mineral exploration, production and transportation)
				Whale shark (*Rhincodon typus*) recovery plan 2005 - 2010 (Department of the Environment and Heritage, 2005) No longer in effect	Habitat degradation / modification Climate and ocean change
Shortfin mako *(Isurus oxyrinchus)*	Migratory, Marine, International Agreement[1]	Endangered	No Listing	None	N/A
Longfin mako *(Isurus paucus)*	Migratory, Marine, International Agreement[1]	Endangered	No Listing	None	N/A
Green sawfish[5] *(Pristis zijsron)*	Vulnerable, International Agreement[1]	Critically Endangered	Vulnerable	Sawfish and River Sharks - Multispecies Recovery Plan (Department of the Environment, 2015) Conservation Advice for Green Sawfish (Department of the Environment, Water, Heritage and the Arts, 2008) Conservation Advice for *Pristis pristis* (largetooth sawfish) (Department of the Environment, 2014)	Habitat degradation / modification
Largetooth sawfish[5] *(Pristis pristis)*	Vulnerable, International Agreement[1]	Critically Endangered	Priority 3 (P3 – Poorly-known species)		

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[1] *Fauna protected under an International Agreement.*

[2] *The red-tailed tropicbird was not identified by the PMST, however, this species is known to occur at the Rowley Shoals (Department of the Environment and Conservation, 2007) and is therefore likely to occur as a vagrant within the Project Area.*

[3] *Priority 4 is defined as 'Rare, Near Threatened and other species in need of monitoring'.*

[4] *These species were not identified by the PMST, however, studies (Smith et al., 2004; Jenner et al., 2009) have identified these species as occurring at Scott Reef.*

[5] *These species were identified by the DoEE as part of the EPBC Referral Decision as likely being impacted by the proposed Browse to NWS Project.*

5.3.2.2 Biologically Important Areas

Biologically Important Areas (BIAs) are spatially delineated areas where aggregations of individuals of a species are known to display biologically important behaviours (Department of the Environment and Energy, 2019b). These behaviours may include breeding, foraging, resting and/or migration. BIAs were developed simultaneously with the Marine Bioregional Plans to inform regulatory and management decisions and are not enforced by legislation (Department of the Environment and Energy, 2019b).

A review of the relevant conservation advices, management and recovery Plans, and the National Conservation Values Atlas (Department of the Environment and Energy, 2019c) identified a number of BIAs which are within or in the vicinity of the Project Area. An assessment of the likelihood of interaction between the proposed Browse to NWS Project and these BIAs was undertaken; the results are summarised in Table 5-20.

Table 5-20 Description of Relevant Species' Biologically Important Areas (BIAs) within the vicinity of the Project Area, and the Likelihood of Interaction between the species / activity and the proposed Browse to NWS Project (Department of the Environment and Energy, 2019c)

Species	EPBC Act Listing	Description	Likelihood of interaction with proposed Browse to NWS Project
Birds			
Lesser frigatebird *(Fregata ariel)*	Migratory, Marine, International Agreement[1]	Breeding/Foraging BIAs: Known breeding and foraging areas along the Kimberley and Pilbara coastlines, including offshore islands such as Ashmore and Long Reefs, Adele, Lacepede and Bedout islands.	Potential interaction with installation and support vessels. Browse Development Area > 65 km from BIA. Proposed BTL route > 60 km from BIA.
Little tern *(Sternula albifrons)*	Migratory, Marine, International Agreement[1]	Resting BIAs: Known resting areas primarily on islands along the Pilbara and Kimberley coasts, including the sandy cays of Ashmore Reef, Rowley Shoals and Scott Reef. Breeding BIAs: Known breeding BIAs along Kimberley, Pilbara and Gascoyne coasts.	Potential interaction with installation and support vessels. Browse Development Area intersects BIA. Proposed BTL route intersects the BIA.
White-tailed tropicbird *(Phaethon lepturus)*	Migratory, International Agreement[1]	Breeding BIA: Known breeding and foraging areas at Rowley Shoals and Ashmore Reef.	Potential interaction with installation and support vessels. Browse Development Area > 90 km from BIA. Proposed BTL route intersects the BIA.
Wedge-tailed shearwater *(Ardenna pacifica)*	Migratory, Marine, International Agreement[1]	Breeding/Foraging BIAs: Known foraging and breeding BIAs exist on the Kimberley and northern Pilbara coasts and islands.	Potential interaction with installation and support vessels. Browse Development Area > 80 km from BIA. Proposed BTL route is approximately 4 km from the BIA.

Species	EPBC Act Listing	Description	Likelihood of interaction with proposed Browse to NWS Project
Cetaceans			
Pygmy blue whale *(Balaenoptera musculus brevicauda)*	Endangered, Migratory, Marine	Migratory BIA: McCauley et al., (2018) describe three migratory stages around Australia for the East Indian Ocean (EIO) Pygmy blue whale population: a 'southbound migratory stage' where whales travel southwards from Indinesian waters down pass WA, mostly from October to December but possibly into January of the following year, a protracted 'southern Australian stage' (January to June) where animals spread across southern waters of the Indian Ocean and south of Australia and a 'northbound migratory stage' (April to August) where animals meander back to Indonesia again. A satellite tagging study (Double et al. (2014) showed tagged whales travelled relatively near to the western Australian coastline (100±1.7 km) throughout March and April until reaching North West Cape. The whales then travelled northwards and offshore (238.0±13.9 km) during May towards Indonesia and by June, whales were travelling through the Savu and Timor Sea. Pygmy blue whales are generally moving along the WA shelf break in deep waters (500-1,000 m) and northbound whales have been detected off Exmouth, the Montebello Islands and Scott Reef between April and August (peaking in June and July). Pygmy blue whales pass south by the latitude of Scott Reef over late October to late December, with the southbound migration of whales off the Montebello Islands and North West Cape from October to the end of January, peaking in late November to early December (McCauley, 2011; see **Section 5.3.2.6.2**). Foraging BIA: the Conservation Management Plan for Blue Whales (Commonwealth of Australia, 2015c) documents a possible foraging area at Scott Reef.	Potential interaction with installation and support vessels. The Browse Development Area and Proposed BTL route are within the pygmy blue whale migratory BIA.
Humpback whale *(Megaptera novaeangliae)*	Vulnerable, Migratory	Migratory BIA: The west coast humpback whale population migrates between summer feeding grounds in the Southern Ocean and tropical breeding and calving grounds off northern WA, as detailed in **Section 5.3.2.6.1**. With reference to the Browse Development Area; a large majority of both north- and southbound humpback whales typically remain landward of the 100 m isobath along the Kimberley coast (including the Dampier Peninsula) and, therefore, primarily inshore of and distant from the Project Area. Humpback whales may occur in the vicinity of Scott Reef at any time during the migration seasons, but observations indicate low numbers and do not represent a significant proportion of the population (see **Section 5.3.2.6.1**).	Potential interaction with installation and support vessels. Browse Development Area is >140 km away from BIA. Proposed BTL route located outside of BIA (approximately 40 km distance at closest point).

Species	EPBC Act Listing	Description	Likelihood of interaction with proposed Browse to NWS Project
Marine Reptiles			
Green turtle *(Chelonia mydas)*	Vulnerable, Migratory, Marine	Nesting/Internesting BIA: Scott Reef is a known nesting area for green turtles, with internesting areas in waters surrounding waters Scott Reef (Commonwealth of Australia, 2017). There are additional green turtle BIAs for nesting, internesting and foraging within the vicinity of the Project Area, including at Ashmore Reef, Cartier Island, Lacepede Islands and / Muiron Islands areas.	Potential interaction with installation and support vessels. The Browse Development Area is located within the BIA.
Loggerhead turtle *(Caretta caretta)*	Endangered, Migratory, Marine	Foraging BIAs: Known foraging area in the western Joseph Bonaparte Depression, James Price Point, De Grey River to Bedout Island. Nesting/Internesting BIAs: Known nesting and internesting at islands surrounding the Dampier Archipelago, Montebello Islands, Lowenthal Island and Ningaloo coast / Muiron Islands areas.	Potential interaction with installation and support vessels. The Browse Development Area is located > 290 km from BIAs for this species. Proposed BTL route is located > 85 km from BIAs for this species.
Hawksbill turtle *(Eretmochelys imbricata)*	Vulnerable, Migratory, Marine	Nesting/Internesting BIA: Scott Reef, specifically Sandy Islet, is known to support some nesting, with internesting areas in surrounding waters (Commonwealth of Australia, 2017). However, as mentioned in **Section 5.3.2.6.2**, only one individual was tagged during surveys by Guinea (2009[13]). Other nesting/internesting and foraging BIAs include Ashmore Reef, and a number of islands and some coastal areas of the Pilbara.	Potential interaction with installation and support vessels. The BIA is located within the Browse Development Area.
Fish			
Whale shark *(Rhincodon typus)*	Vulnerable, Migratory, Marine	Foraging BIA: Known foraging area extending northward from Ningaloo along the 200 m isobath. As discussed in **Section 5.3.2.8**, satellite tracking indicates that whale sharks migrate northward approximately along the 200 m isobath (McKinnon et al., 2002; Meekan and Radford, 2010[14]; Wilson et al., 2006).	Very low likelihood of interaction. The Browse Development Area is located > 20 km from the BIA. Proposed BTL route is located within the BIA.

1 *Fauna protected under an International Agreement.*

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[13] *Guinea, 2009 available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

[14] *Meekan and Radford, 2010 available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

5.3.2.3 Habitat Critical to the Survival of a Species

The EPBC Act Significant Impact Guidelines 1.1 – MNES (Commonwealth of Australia, 2013) define 'habitat critical to the survival of a species' as areas necessary:

- "for activities such as foraging, breeding or dispersal
- for the long-term maintenance of the species (including the maintenance of species essential to the survival of the species)
- to maintain genetic diversity and long-term evolutionary development
- for the reintroduction of populations or recovery of the species."

Such habitat may be, but is not limited to, habitat identified in a recovery plan and/or habitat listed on the Register of Critical Habitat.

Habitat critical to the survival of marine turtles have been identified for each known genetic stock. These locations are listed in the 'Recovery Plan for Marine Turtles in Australia 2017-2027' (Commonwealth of Australia, 2017). Protection of these nesting and internesting habitats is necessary to maintain genetic diversity for each of the six marine turtle species. The nesting and internesting habitat critical for survival for each species of marine turtle relevant to the Project Area are shown in **Figure 5-29**, **Figure 5-30** and **Figure 5-31**, and listed in **Table 5-21**.

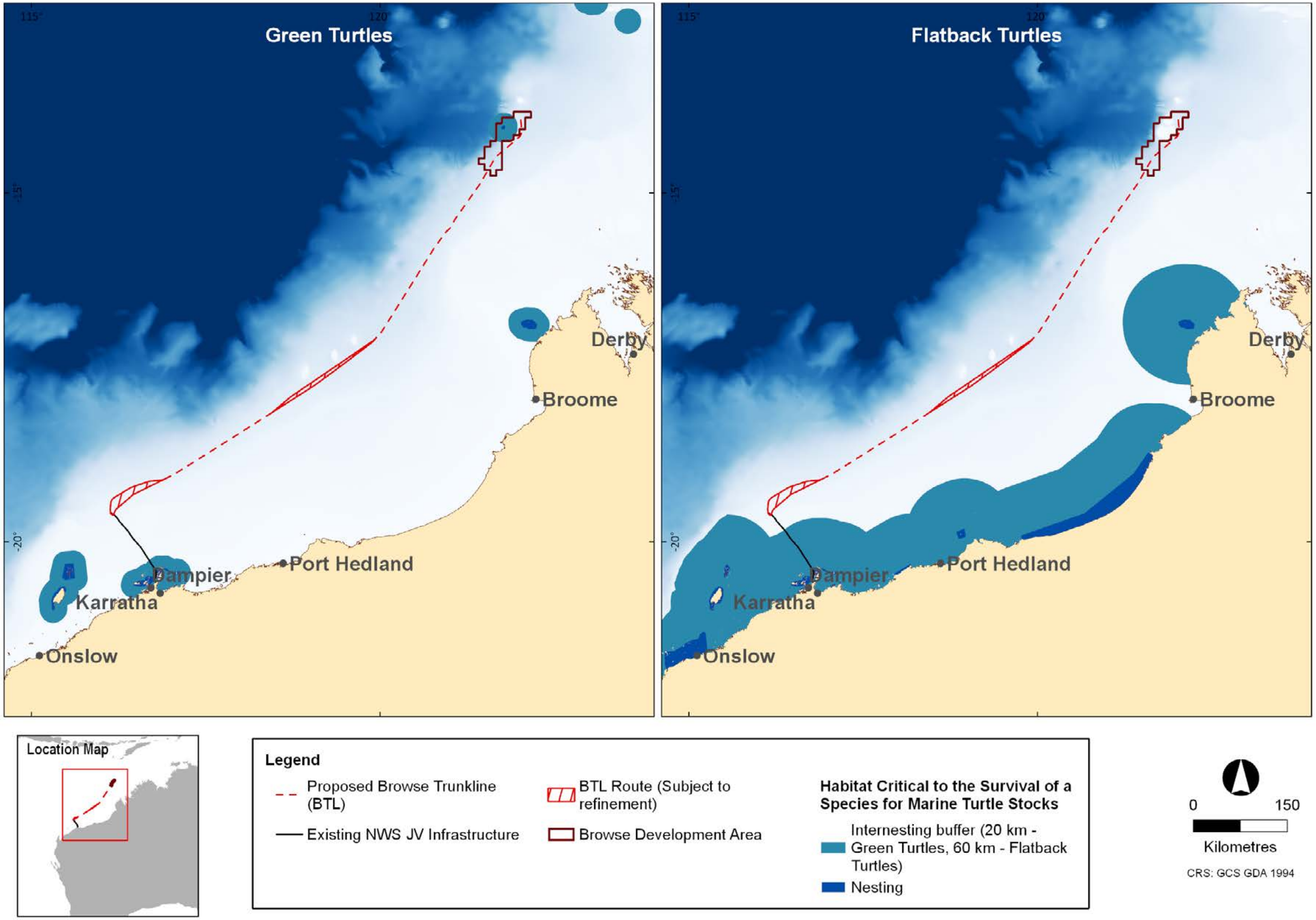

Figure 5-29 Habitat Critical to the Survival of Marine Turtles within the Vicinity of the Project Area for the Green and Flatback Turtles. 'Recovery Plan for Marine Turtles in Australia 2017-2027' (Commonwealth of Australia, 2017)

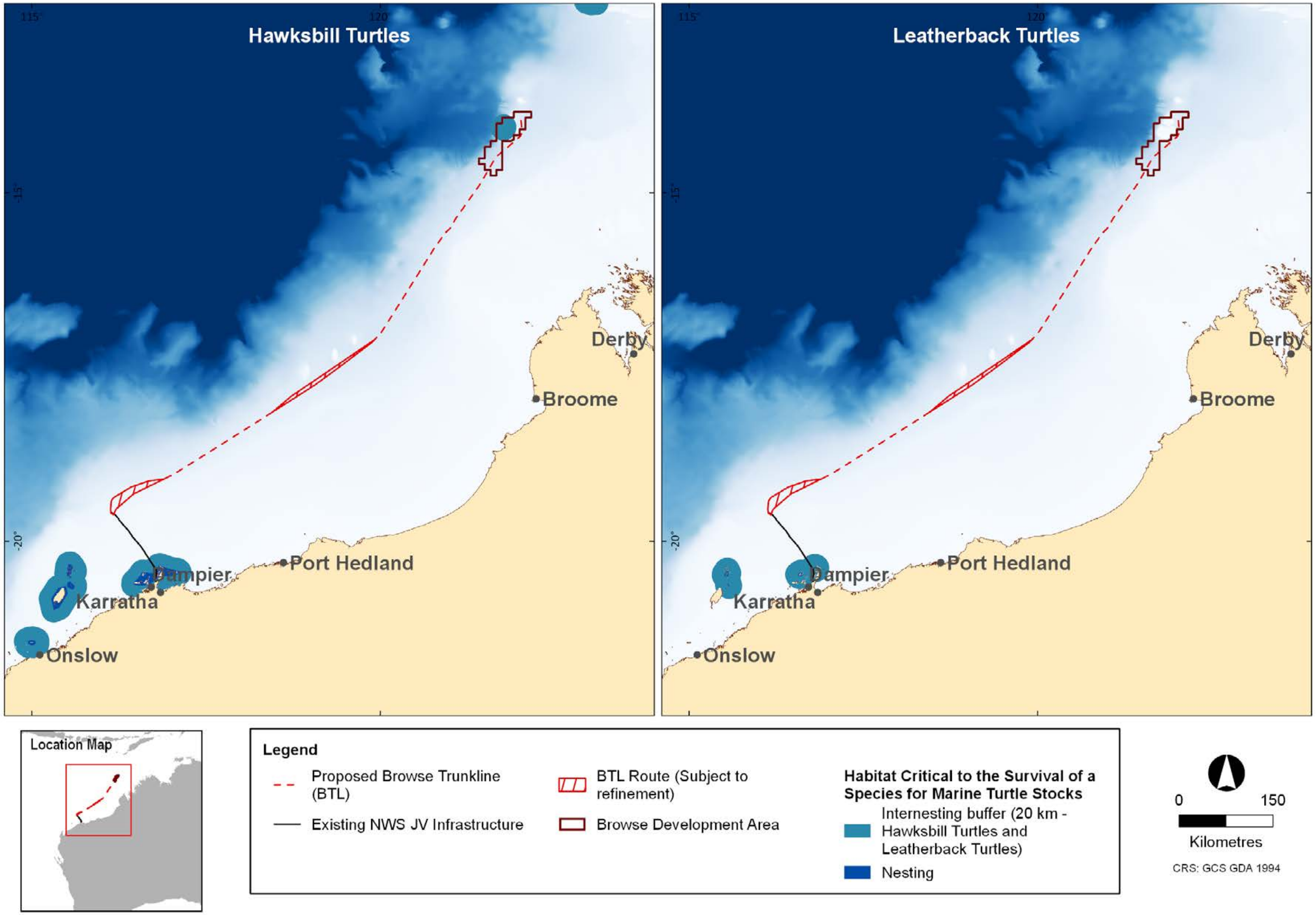

Figure 5-30 Habitat Critical to the Survival of Marine Turtles within the Vicinity of the Project Area for the Hawksbill and Leatherback Turtles. 'Recovery Plan for Marine Turtles in Australia 2017-2027' (Commonwealth of Australia, 2017).

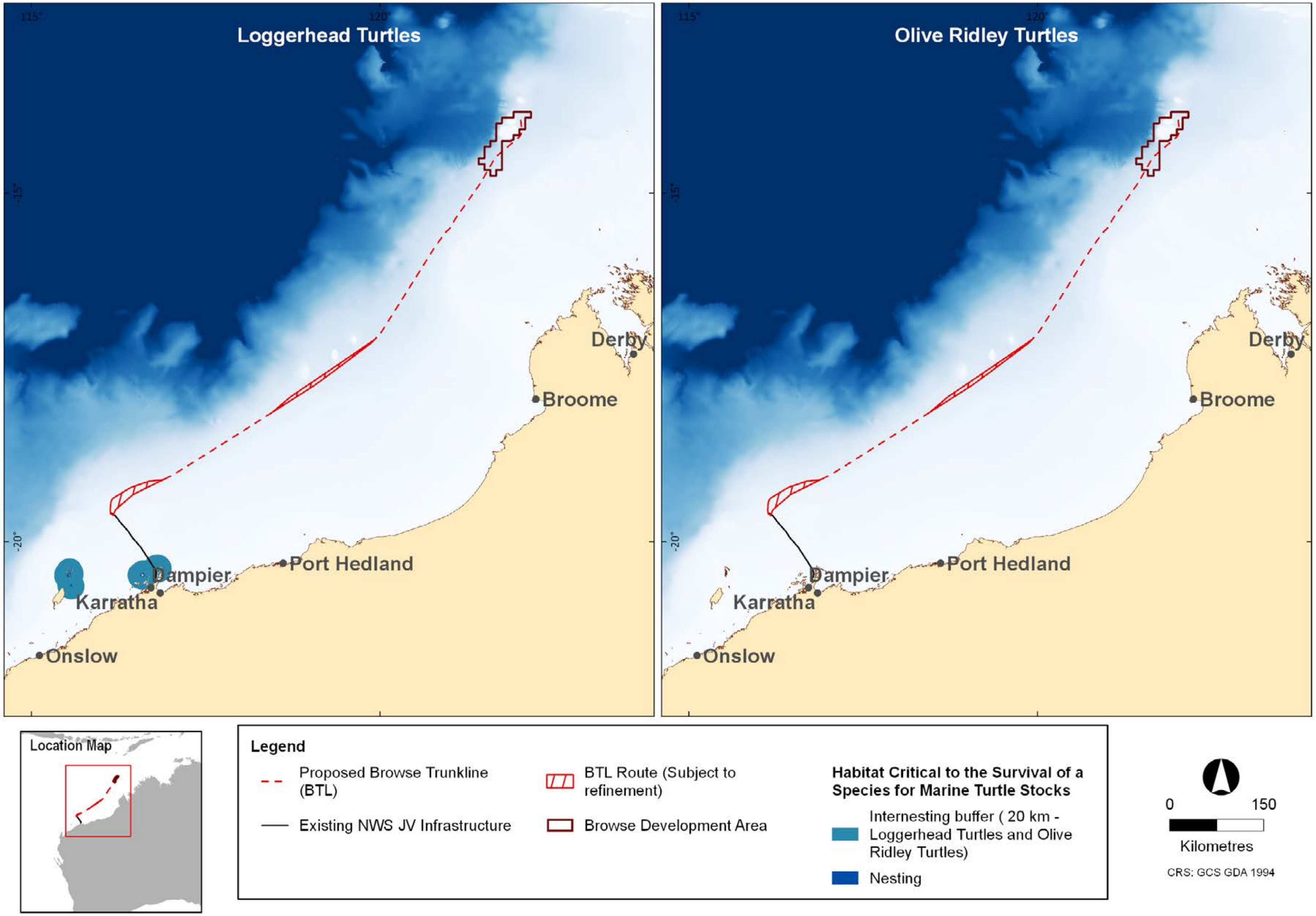

Figure 5-31 Habitat Critical to the Survival of Marine Turtles within the Vicinity of the Project Area for the Loggerhead and Olive Ridley Turtles. 'Recovery Plan for Marine Turtles in Australia 2017-2027' (Commonwealth of Australia, 2017).

Table 5-21 Habitat Critical to the Survival of Marine Turtles Within the Vicinity of the Project Area (Department of the Environment and Energy, 2017)

Genetic Stock	Habitat Critical for Survival for Marine Turtles		Time of Year
	Nesting Location	Internesting Buffer	
Green Turtle			
North West Shelf	Adele Island, Maret Island, Cassini Island, Lacepede Islands, Barrow Island, Montebello Islands (all with sandy beaches), Serrurier Island, Dampier Archipelago, Thevenard Island, Northwest Cape, Ningaloo coast	20 km radius	Nov-Mar
Ashmore Reef	Ashmore Reef and Cartier Island	20 km radius	All year (peak: Dec-Jan)
Scott Reef-Browse Island	Scott Reef (Sandy Islet) and Browse Island	20 km radius	Nov-Mar (peak: Jan-Feb)
Loggerhead Turtle			
Western Australia	Dirk Hartog Island, Muiron Islands, Gnaraloo Bay, Ningaloo coast	20 km radius	Nov-May
Flatback Turtle			
South-west Kimberley	Eighty Mile Beach, Eco Beach, Lacepede Islands	60 km radius	Oct-Mar (Peak: Dec-Jan)
Pilbara	Montebello Islands, Mundabullangana Beach, Barrow Island, Cemetery Beach, Dampier Archipelago (including Delambre Island and Huay Island), coastal islands from Cape Preston to Locker Island	60 km radius	Oct-Mar
Unknown genetic stock Kimberley, Western Australia	Maret Islands, Montilivet Islands, Cassini Island, Coronation Islands (includes Lamarck Island), Napier-Broome Bay Islands (West Governor Island, Sir Graham Moore Island – near Kalumbaru), Champagny, Darcy and Augustus Islands (Camden Sound)	60 km radius	May-July
Hawksbill Turtle			
Western Australia	Dampier Archipelago (including Rosemary Island and Delambre Island), Montebello Islands (including Ah Chong Island, South East Island and Trimouille Island), Lowendal Islands (including Varanus Island, Beacon Island and Bridled Island), Sholl Island	20 km radius	Oct-Feb
Olive Ridley Turtle			
Unknown genetic stock Kimberley, Western Australia	Prior Point, Vulcan Island, Darcy Island, Llangi, Cape Leveque	20 km radius	May-July
Leatherback Turtle			
Australia	Cobourg Peninsula to Cape Arnhem (including Danger Point) and adjacent islands (including Wessel Islands and Elcho Island)	20 km radius	Dec-Jan

5.3.2.4 Seabirds and Migratory Shorebirds

Seabirds include both pelagic and coastal species. They generally forage offshore and may spend extended periods at sea. Seabirds nest in colonies, which can vary in size from a few dozen birds to millions. Outside of the breeding season, individuals may also aggregate in areas of high prey density. Many seabird species undertake annual migrations of thousands of kilometres.

Migratory shorebirds are generally associated with wetland or coastal environments. Shorebirds may use coastal environments for feeding, nesting or migratory stopovers. In coastal environments, shorebirds generally feed during low tide on exposed intertidal mudflats and find areas in which to roost at high tide. Many shorebird species also undergo annual migrations, typically breeding at high latitudes of the northern hemisphere and migrating south for the non-breeding period (Bamford et al., 2008; Commonwealth of Australia, 2015a).

Migratory birds generally travel between sites through 'flyways' of which there are nine globally (Hansen et al., 2016). The East Asian-Australasian Flyway (EAAF) is of most relevance to the Project Area and associated shorebird and seabird species. This flyway extends from north-eastern Asia and western Alaska in the north, to Australia and New Zealand in the south, encompassing 23 countries (Hansen et al., 2016; **Figure 5-32**). There are 37 species of shorebird and seabird which annually migrate to Australia via the EAAF (Hansen et al., 2016).

Many migratory seabirds and shorebirds are protected under the international Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) and through bilateral agreements between Australia and Japan (JAMBA), China (CAMBA) and the Republic of Korea (ROKAMBA). Important migratory bird habitats may also be part of wetlands recognised as internationally significant under the Ramsar Convention (discussed in **Section 5.3.3.4**).

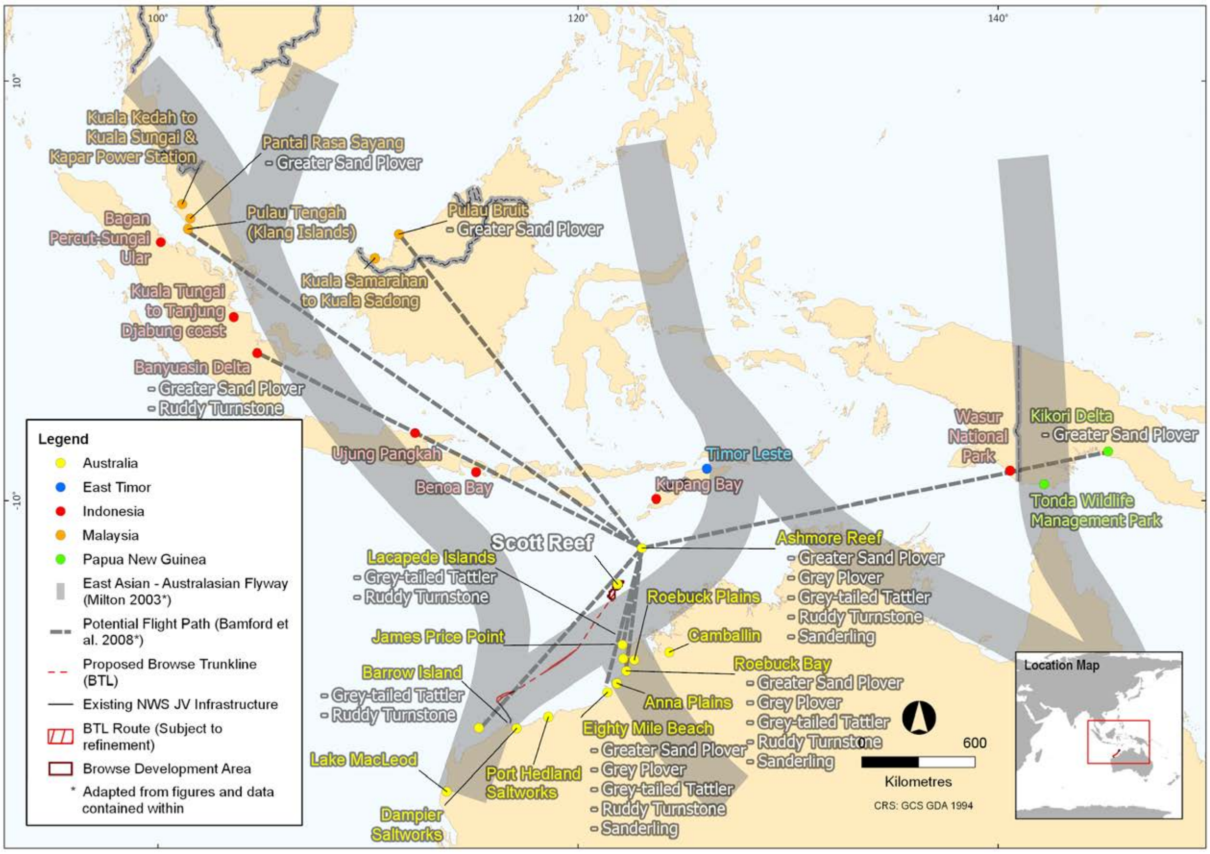

Figure 5-32 Potential Flight Paths of Migratory Shorebirds and Seabirds, Including the East Asian-Australasian Flyway (EAAF), Relevant to the Project Area (adapted from Bamford et al., 2008; Milton, 2003)

5.3.2.4.1 Seabirds

Regional Overview

Seabirds within the NWMR consist of tropical and sub-tropical breeding species and non-breeding migratory species. Dunlop et al. (1988) identified 33 species of seabird during a survey of WA continental shelf and oceanic waters in October 1987. More recent surveys around Ashmore Reef, Seringapatam Reef, Scott Reef and the wider Browse Basin region identified 26 species of seabird, including the brown booby, Abbott's booby, streaked shearwater and lesser frigatebird (Jenner et al., 2009, 2009; Milton, 1999; Smith et al., 2004; WAM, 2009).

A number of offshore islands within the NWMR support breeding colonies of seabirds; the islands at Ashmore Reef are regarded as supporting some of the most important seabird breeding colonies on the NWS. Browse island support a large breeding colony of crested terns, with some evidence of breeding by Eastern Reef Egrets (Clarke, 2010). The Lacepede Islands (approximately 300 km south of Scott Reef) are also an important breeding site for seabirds including the lesser frigatebird, brown booby, bridled tern, roseate tern and common noddy (Commonwealth of Australia, 2008). The Lacepede Islands support some of the largest brown booby colonies in WA. In 1982, 7370 and 10,300 nesting pairs were counted on West Lacepede and Middle Lacepede Islands respectively (Burbidge et al., 1987). During the same survey, 2700 nesting pairs of lesser frigatebirds were counted on West Lacepede Island (no nests were present on Middle Lacepede Island).

Other offshore islands in the NWMR also support breeding populations of seabirds. For example, brown boobies, masked boobies and lesser frigatebirds have been observed to breed on Adele Island and on Bedout Island (Burbidge et al., 1987); the Dampier Archipelago/Cape Preston region is a nesting area for at least 16 species of seabird (Department of Conservation and Land Management, 2005); and the Montebello/Barrow Islands region contains significant breeding colonies for at least 15 species of seabird.

Browse Development Area

Due to the large geographical range of seabirds, there is potential that most species occurring within the wider NWMR may occur transitionally within the Project Area. The PMST Species identified two species of threatened seabird as potentially occurring within the Browse Development Area; the Abbott's booby (Endangered, Marine) and Australian lesser noddy (Vulnerable, Marine). In addition, six other species of listed marine and/or migratory seabird species were identified as having the potential to occur within and/or interact with the proposed Browse to NWS Project. These are described in **Table 5-22** in the following table.

Scott Reef

Scott Reef is the only emergent land mass within the immediate vicinity of the Browse Development Area which may serve to provide nesting and/or roosting for seabirds. Seabirds around Scott Reef are predominately associated with Sandy Islet, a part of South Scott Reef, and occur in small numbers in comparison to other breeding and roosting sites in the region. Smith et al. (2004) recorded little tern (500 individuals), brown booby (6), ruddy turnstone (50), Australian lesser noddy (200) and the common noddy (30) during a survey at Scott Reef in 2003. Seabird surveys conducted at Scott Reef observed greater numbers of birds during spring than winter (Jenner et al., 2009). Seabird species typically roost on Sandy Islet at night and are presumed to forage in nearby and offshore waters during the day. It is not currently known if any of the observed species are permanently resident on Sandy Islet.

Browse Trunkline

The proposed BTL route passes approximately 2 km at its closest point from the Mermaid Marine Park Boundary. The islands of the Rowley Shoals are known to support a wide range of seabird species, including WA's second largest breeding colony of red-railed tropicbird (Department of the Environment and Conservation, 2007).

It is expected that many seabirds may be present within the Project Area whilst transiting, migrating or foraging, however, they are not expected to be present in large numbers.

Table 5-22 Seabird Species Identified by the PMST and/or by Previous Surveys as Potentially Occurring within and/or Interacting with the Proposed Browse to NWS Project

Species	EPBC Act Listing	Description
Common noddy[5] *(Anous stolidus)*	Migratory, International Agreement[1]	Within WA the common noddy typically occurs off the north-west and central coast. This species nests on islands and rocky islets, with a strong nesting preference for rocky and cliff edge habitats. Breeding frequency and migratory patterns for the common noddy appear to vary. There are breeding colonies on at least 50 islands within Australia (31 in Queensland), including Christmas and Cocos Keeling Islands (Department of the Environment and Energy, 2019d). This species has been recorded from surveys within the north-west region of WA, as well as at Scott Reef (Smith et al., 2004), although in low numbers (30 individuals at Scott Reef) and is therefore expected to occur within the Project Area.
Streaked shearwater[5] *(Calonectris leucomelas)*	Migratory, Marine, International Agreement[1]	The streaked shearwater is known to breed along the coast and on offshore islands of north-east Asia and migrates south during winter to Australia. This species is regularly recorded in northern Australia from October to March, despite the species not breeding in Australia (Marchant and Higgins, 1990). The streaked shearwater mostly occurs over pelagic waters; in northern Australia it is usually found in waters more than 18 km from the mainland, while in the Gulf of Carpentaria it mostly occurs in waters more than 100 km from the mainland (Blaber and Milton, 1994; Marchant and Higgins, 1990). Though this species hasn't been noted within the Project Area, it is commonly observed on Ashmore Reef and therefore may be present transiting through the Project Area.
Lesser frigatebird[5] *(Fregata ariel)*	Migratory, Marine, International Agreement[1]	The lesser frigatebird breeds on tropical islands, including North Keeling and Ashmore Reef, within north-west WA. During the non-breeding season some individuals migrate to equatorial waters (Menkhorst et al., 2017). Along the WA coastline the lesser frigatebird is often sighted at and northwards of Eighty Mile Beach (Menkhorst et al., 2017). This species is known to nest on the Lacepede, Adele and Bedout Islands (Burbidge et al., 1987). Due to this species distribution over offshore islands in north-west WA, it is likely that the lesser frigatebird will be present within the Project Area.
Little tern[5] *(Sternula albifrons)*	Migratory, Marine, International Agreement[1]	The little tern is a coastal seabird which usually forages in very shallow water, more often in brackish lagoons and saltmarsh creeks (Birdlife Australia, 2019). The species is widespread in Australia, with breeding sites widely distributed from north western WA, around the northern and eastern Australian coasts to south-eastern Australia. The species is known to breed on barren or sparsely vegetated beaches located on seashores, islands, estuaries and offshore coral reefs. Approximately 500 individuals were recorded at Scott Reef by Smith et al. (2004) and BIAs (known resting areas) for the species have been identified at both Rowley Shoals and Scott Reef, intersecting the proposed BTL route and within Browse Development Area respectively. The little tern is, therefore, expected to occur within the Project Area.
Barn swallow[2,5] *(Hirundo rustica)*	Migratory (Terrestrial), Marine, International Agreement[1]	The barn swallow is a migratory species, however, it is not typically considered a 'seabird' or 'shorebird'. The barn swallow typically occurs in northern Australia on Cocos-keeling Islands, Christmas Island, Ashmore Reef and at some sites along the WA coast within and northward of the Pilbara region (Department of the Environment and Energy, 2019e). The species breeds throughout the northern hemisphere and migrates to northern Australia in the boreal winter months (Department of the Environment and Energy, 2019e). The barn swallow was identified as potentially occurring with the Project Area, as well as other offshore islands and reefs within the vicinity of the Project Area. Based on this species' habitat preferences and distribution it is, however, only expected to occur within the Project Area in low numbers.

Species	EPBC Act Listing	Description
Australian lesser noddy *(Anous tenuirostris melanops)*	Vulnerable, Marine	The Australian lesser noddy is usually only found around its breeding islands in the Houtman Abrolhos Islands and possibly on Ashmore Reef in WA (Storr et al., 1986). This species usually occupies coral-limestone islands that are densely fringed with white mangrove Avicennia marina and occasionally occurs on shingle or sandy beaches (Higgins and Davies, 1996). The Australian lesser noddy may forage well out to sea (Johnston and Storr, 1998; Storr et al., 1986) or in seas close to breeding islands and fringing reefs (Storr et al., 1986) (Whittell, 1942). Approximately 200 individuals were recorded at Scott Reef by (Smith et al., 2004) and this species is expected to occur within the Project Area, albeit in low numbers.
White-tailed tropicbird *(Phaethon lepturus)*	Migratory, International Agreement[1]	The white-tailed tropicbird occupies marine habitats in tropical waters. The species breeds on islands and atolls, where it nests in a variety of habitats including on bare sandy ground. White-tailed tropicbirds are known to breed at Rowley Shoals. The proposed BTL route intersects an identified BIA associated with Rowley Shoals which is a known foraging area for the white-tailed tropicbird (Department of the Environment and Energy, 2019c). Outside of the Rowley Shoals, the white-tailed tropicbird is not expected to occur within the Project Area.
Abbott's booby *(Papasula abbotti)*	Endangered, Marine	The Abbott's booby is a large, long-lived seabird known only to nest at Christmas Island. This species is known to forage over large distances offshore when nesting. Nesting habitat is restricted to heights of greater than 150 m in tall rainforests in the western, central and northern portions of Christmas Island (Commonwealth of Australia et al., 2004) and therefore is not expected to occur within the Project Area.
Red-tailed tropicbird[3] *(Phaethon rubricauda)*	Migratory, Marine, International Agreement[1]	The red-tailed tropicbird breeds on islands and atolls, where it nests in a variety of habitats including on bare sandy ground. Red-tailed tropicbirds are known to breed at the Rowley Shoals. They display similar feeding behaviours as the white-tailed tropicbird (Department of the Environment and Energy, 2019f). Outside of the Rowley Shoals, the red-tailed tropicbird is not expected to occur within the Project Area.
Crested tern[4] *(Sterna bergii)*	Marine, Migratory, International Agreement	Created Terns are relatively common coastal seabird, that is known to nest in dense colonies on coastlines and islands throughout Australia. They often breed in densely packed colonies on small offshore islands and have been noted at Scott Reef (Smith et al., 2004) and are therefore known to be present within the Project Area.
Brown Booby[4] *(Sula leucogaster)*	Marine, Migratory, International Agreement[1]	Within Australia, the Brown Booby is commonly found from Bedout Island in Western Australia, around the coast of the Northern Territory to the Bunker Group of islands in Queensland with occasional reports further south in New South Wales (NSW) and Victoria (Marchant & Higgins 1990). At sea, the Brown Booby flies and feeds individually or in flocks, sometimes in large mixed-species flocks, and often travel in extended skeins (a flock in flight). The species breeds colonially and roosts communally with other Brown Boobies or other species. This species has been previously noted at Scott Reef (Smith et al., 2004) and are therefore known to be present within the Project Area.
Ruddy Turnstone[4] *(Arenaria interpres)*	Marine, Migratory, International Agreement[1]	A small, stocky shorebird, with a short, pointed bill, the Ruddy Turnstone is widespread within Australia during its non-breeding period of the year (Bamford et al., 2008), including from Tasmania in the south to Darwin in the north and many coastal areas in between. It is found in most coastal regions, with occasional records of inland populations (Higgins and Davies, 1996). This species has been noted at the Rowley Shoals and may traverse within the vicinity of Scott Reef on their southern migration (Bamford et al., 2008); however, it not expected in large numbers within the Project Area.

1 Fauna protected under an International Agreement.

2 This species was listed by the DoEE as potentially being impacted by the proposed Browse to NWS Project and, therefore, included in this table; however, it is not expected to occur within the Project Area.

3 The red-tailed tropicbird was not identified by the PMST, however, this species is known to occur at the Rowley Shoals (Department of the Environment and Conservation, 2007) and is therefore likely to occur as a vagrant within the Project Area.

4 These species were not identified by the PMST, however, studies (Smith et al., 2004; Jenner et al., 2009) have identified these species as occurring at Scott Reef.

5 These species were identified by the DoEE as part of the EPBC Referral Decision as likely being impacted by the proposed Browse to NWS Project.

5.3.2.4.2 Migratory Shorebirds

Regional Overview

The annual life cycle of Australia's migratory shorebirds has four approximate phases; breeding (May to August) in the northern hemisphere, southward migration (August to November), non-breeding (December to February) in the southern hemisphere, and northward migration (March to May). Potential flight paths used by migratory shorebirds during their northward and southward migrations are shown in **Figure 5-32**.

Within the NWMR, Ashmore Reef (more than 200 km north of the Browse Development Area) is recognised as an internationally important site for five species of migratory shorebird (ruddy turnstone, grey plover, greater sand plover, sanderling and grey-tailed tattler). The sand flats of Ashmore Reef and neighbouring Cartier Island are recognised as particularly important for feeding migratory shorebirds during non-breeding periods. These sandflats are also an important staging point during the migration between the Northern Hemisphere and Australia.

On the WA mainland, Roebuck Bay and Eighty Mile Beach have been identified as two of the most important areas in the EAAF for migratory shorebirds, with counts of 336,000 individuals on Eighty Mile Beach and 170,900 individuals in Roebuck Bay (Bamford et al., 2008), representing over 30 species. These sites are used more heavily during the southward migration (i.e. the breeding period from May to August) and many birds remain throughout the non-breeding period (December to February; Bamford et al., 2008). Roebuck Bay and Eighty Mile Beach are listed as RAMSAR sites (see **Section 5.3.3.4**) because they are internationally important migration stopover and feeding areas for migratory shorebirds.

Due to the large geographical ranges of migratory shorebirds, many of the species known to occur within the wider NWMR have the potential to pass through the Project Area. The Project Area also overlaps with the migratory shorebird corridor and as such shorebird presence is expected to be transitory and seasonal.

Browse Development Area

As mentioned previously, migratory shorebird species known to occur within the wider NWMR may also occur within the Project area, including the Browse Development Area, due to their large geographical ranges. Within the Browse Development area, migratory shorebirds are most likely to occur at Scott Reef (as the only available land mass) albeit in small numbers, as detailed below.

Scott Reef

Migratory shorebirds are occasionally observed in very low numbers at Scott Reef and Sandy Islet may be used as a staging ground during the migration between the Northern Hemisphere and Australia (Commonwealth of Australia, 2008). However, given its small size, Sandy Islet is unlikely to support large numbers of migratory shorebirds.

Potential flight paths of some species may occur in the vicinity of Scott Reef as migratory shorebirds make their way to key mainland sites (Roebuck Bay and/or Eighty Mile Beach) or islands such as Barrow Island, as shown in **Figure 5-32**.

The following migratory shorebird species were identified by the PMST as potentially occurring within the Project Area and are known to forage or rest at sites along the WA coastline (e.g. Ashmore Reef, Eighty Mile Beach, Roebuck Bay); the red knot, curlew sandpiper, eastern curlew, and sharp-tailed sandpiper (Bennelongia Pty Ltd, 2009; Clarke, 2010; Hale and Butcher, 2009). Additionally, the common sandpiper (described in **Table 5-23** below and listed in **Table 5-19**) was identified by the DoEE as potentially being impacted by the proposed Browse to NWS Project, and is therefore described here for completeness.

These shorebird species are not expected to utilise habitats within the Project Area; however, they are migratory species, with key sites within the vicinity of the Project Area and therefore, may occur within the Project Area when undertaking migrations between these key sites and northern hemisphere breeding sites.

Table 5-23 Shorebird Species Identified by the PMST and/or by previous Surveys as Potentially Occurring within and/or Interacting with the Proposed Browse to NWS Project

Species	EPBC Act Listing	Description
Common sandpiper[1] *(Actitis hypoleucos)*	Migratory (Wetland), Marine	The common sandpiper typically uses narrow and often steep shorelines, in sheltered sites with few other shorebird species. Preferred habitats include mangrove-lined creeks, and areas of mud with outcropping rocks (Menkhorst et al., 2017). The common sandpiper migrates to mid-latitudes in Asia, returning to Australia late July / August (Menkhorst et al., 2017). Due to this species' habitat preferences and migratory behaviour, the common sandpiper is expected to occur in low numbers, if at all, within the Project Area.

[1] *The common sandpiper was not identified as potentially occurring within the Project Area by the PMST, however, this species was identified by the DoEE as potentially being impacted by the proposed Browse to NWS Project and so is listed here for completeness.*

Browse Trunkline

The Rowley Shoals are believed to be important resting and feeding grounds for migratory shorebirds (Commonwealth of Australia, 2008) with large flocks of unidentified waders being recorded at Clerke and Imperieuse Reefs (Department of the Environment and Conservation, 2007). Given the proximity of the proposed BTL route to the Rowley Shoals (approximately 3 km at the closest point to Clerke Reef) and the migratory nature of these species, it is expected that migratory shorebirds may occur in the vicinity of the proposed BTL route.

5.3.2.5 Marine Mammals

Marine mammals have wide distributions that are associated primarily with seasonal feeding and migration patterns that are linked to their reproductive cycles. Twenty-seven cetacean species are known to occur in the NWMR and all are protected under Commonwealth and WA legislation.

The PMST identified 27 cetacean species as potentially occurring within the Project Area. Of these, the pygmy blue whale, humpback whale, sei whale, fin whale, Bryde's whale and spinner dolphin are considered likely to occur within the Project Area and/or interact with the proposed Browse to NWS Project. These species are discussed in this section. Other marine mammals identified by the PMST but not discussed further in this section were determined to be transient visitors within the Project Area or species whose range or habitat indicated that they are highly unlikely to occur within the Project Area. These species have been documented in **Chapter 10, Appendix C.7**, with justification as to why they were not included in this Chapter.

A number of surveys have been undertaken in recent years to establish baseline data for marine mammals, primarily humpback whales and pygmy blue whales, within proximity of the Browse Development Area. These are summarised in **Table 5-24** below.

Table 5-24 Marine Mammal Surveys Undertaken in Recent Years within Proximity of the Project Area

Study	Author	Description
Marine Megafauna Report: Browse Marine Megafauna Study 2009 Humpback Whale Survey Report: Browse MMFS 2009 Marine Megafauna Survey Report: Browse Marine Megafauna Study 2010 Humpback Whale Survey Report: Browse Marine Megafauna Study 2011	RPS 2010a, 2010b, 2011, 2012[15]	*Aerial and Vessel Based Survey* A number of aerial and vessel-based surveys were undertaken over three years by RPS (2009 – 2011) to establish a baseline for the distribution, relative density and abundance of marine megafauna within the Browse LNG Precinct development project area (previous project concept). The surveys were designed to target humpback whales (vulnerable, migratory) and dugongs (migratory). The surveys were conducted between Cape Bossut and Cape Leveque, from the mean high tide mark to approximately the 20 m isobath. Specific areas of focus included a 90 km2 box offshore of James Price Point within the humpback whale migration corridor) and an offshore survey area extending from the mainland out to Scott Reef (RPS Environment and Planning, 2010a).
Humpback Whale Distribution and Abundance in the Nearshore South-West Kimberley during Winter 2008 using Aerial Surveys Nearshore Vessel Surveys in the South-West Kimberley Region During the Humpback Whale Southern Migration, 2008	Jenner & Jenner, 2009a; 2009b	*Aerial and Vessel Based Survey* Surveys were undertaken in the nearshore south-west Kimberley region during winter 2008 to determine the seasonal distribution and abundance of humpback whales in this area.

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[15] RPS 2010a, 2010b, 2011, 2012 available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies

Study	Author	Description
Woodside Kimberley Sea Noise Logger Program, Sept-2006 to June-2009: Whales, Fish and Man-made Noise	McCauley, 2011	***Acoustic Survey – Noise Loggers*** Noise loggers (complemented by observational surveys) were deployed within the Scott Reef lagoon and waters surrounding Scott Reef in 2006 (McCauley, 2011). The noise loggers established a baseline of ambient noise emissions from both environmental and anthropogenic sources within range. Whale songs were detected for pygmy blue whales, humpback whales and Bryde's whales.
Satellite Tracking of Northbound Humpback Whales (*Megaptera novaeangliae*) off Western Australia	Double et al., 2012	***Satellite Tracking*** Twenty-eight humpback whales were tagged off the North West Cape on their northward migration in 2011. Data on the whales' migration over subsequent weeks was collected.
Satellite Tagging of South-bound Female Humpback Whales in the Kimberley Region of Western Australia, Report produced for Woodside Energy Limited	Double et al., 2010	***Satellite Tracking*** Twenty-three humpback whales were tagged between the 24th August to 6th September 2009. The tags were deployed in three regions: Camden Sound (5); Buccaneer Archipelago (6); and Pender Bay (12). Three tags failed to provide any location data, and a further seven failed to provide any location data after the day of deployment. Data from the remaining tags was reported up to 29th September (191 whale-days of location data).
Migratory Movements of Pygmy Blue Whales (*Balaenoptera musculus brevicauda*) Between Australia and Indonesia as Revealed by Satellite Telemetry	Double et al., 2014	***Satellite Tracking*** Eleven pygmy blue whales' northbound migratory movements were tracked over two years off the coast of WA. Three individuals were tagged within the Perth Canyon in 2009 and twelve in 2011, with 11 tags successfully transmitting.
Habitat associations of cetaceans and seabirds in the tropical eastern Indian Ocean	Sutton et al., 2019	***Vessel Based Surveys*** These vessel based surveys were undertaken in the Browse Basin during winter and spring 2008 (refer to Jenner & Jenner, 2009a, 2009b), and reported on to determine the habitat associations of cetaceans and seabirds with sub-marine topography and local oceanic conditions.

5.3.2.5.1 Humpback Whale

Background

The humpback whale, *Megaptera novaengliae*, is listed as Vulnerable, Migratory and Cetacean under the EPBC Act, and Conservation Dependant under the WA *Biodiversity Conservation Act 2016* (BC Act), **Table 5-19**. As identified in **Table 5-19**, this species is considered to potentially occur within the Project Area and/or interact with the proposed Browse to NWS Project.

Humpback whales are baleen (filter feeding) whales weighing up to 40 tonnes and measuring up to 18 m (Threatened Species Scientific Committee, 2015c). The species has a wide global distribution and displays distinct migration pathways between breeding and calving grounds in lower latitudes and feeding grounds in higher latitudes (Department of the Environment and Energy (DoEE), 2019). In Australian waters two genetically distinct populations migrate annually along the West (Group IV) and East coasts (Group V) between May and November (RPS Environment and Planning, 2010a). In WA, the migration pathway extends from Albany to the Kimberley coastline, passing through the NWMR (Threatened Species Scientific Committee, 2015c). The species typically travels in waters less than 200 m deep in coastal areas (Jenner et al., 2001).

Historically, this species has suffered significant population decline due to unsustainable whaling practices (Threatened Species Scientific Committee, 2015c). Since the 1982 moratorium on commercial whaling population numbers have recovered significantly; from approximately 2,000 to 3,000 individuals in 1991, to between 19,200 - 33,850 individuals in 2008 (Bannister and Hedley, 2001; Bejder et al., 2019; Hedley et al., 2009). This is in keeping with results of five aerial surveys undertaken between 2000 and 2008 by Salgado-Kent et al. (2012), which produced a population estimate for the Group IV population of 26,100 individuals (CI 20,152 - 33,272) in 2008. Current population growth for the Group IV population is estimated to be between 9.7 and 13% per annum (Threatened Species Scientific Committee, 2015c). Using the Salago-Kent et al., (2012) estimate in 2008 of 26,100 individuals and an annual population growth rate of 10%, 2019 population estimates could be greater than 75,000 individuals.

Regional Overview

The Group IV population migrates northward from their Antarctic feeding grounds around May each year, reaching the NWMR around early June. The southward migration subsequently starts in mid-September, around the time of breeding and calving (typically August to September) (Threatened Species Scientific Committee, 2015c). Within the NWMR there are key calving areas between Broome and the northern end of Camden Sound, and resting areas in the southern Kimberley region, Exmouth Gulf and Shark Bay (shown in **Figure 5-33**). In particular, high numbers of humpback whales are observed in Camden Sound and Pender Bay from June to September each year (Threatened Species Scientific Committee, 2015c). The WA Lalang-garram / Camden Sound Marine Park provides protection for humpback whales within the calving area via a Special Purpose Zone within the marine park encompassing an area approximately 1,680 km^2 (Department of Parks and Wildlife, 2013). In addition, there are BIAs for migration and breeding and calving for the humpback whale along the WA coast and within the NWMR (shown in **Figure 5-33**; see **Section 5.3.2.2**).

Humpback whales typically occur off the Dampier Peninsula from June to October each year, with peak occurrence in late July to mid-August (RPS, 2012). Surveys undertaken within the NWMR by RPS between July and October 2009 (RPS Environment and Planning, 2010b, 2010a) found humpback whales to be widespread throughout the survey area (described in **Table 5-24**), with the majority of individuals following the WA coastline closely between Broome and Pender Bay (RPS Environment and Planning, 2010a). Sightings were much lower at the Lacepede Islands and Scott Reef compared with coastal areas, with less than 5% of sightings occurring within 8 km of the shoreline. The mean distance of sightings was 27 km offshore and typically between the 10 and 50 m depth contours (RPS Environment and Planning, 2010a). Based on combined data from surveys across three consecutive years (2009 – 2011), 80% of humpback whales were sighted between 8.5 and 45.9 km offshore (RPS Environment and Planning Pty Ltd, 2012).

As mentioned above, in 2008 the Group IV population was estimated to be 26,100 individuals, compared with 20,044 in 2007 and 18,629 in 2006 (Salgado-Kent et al., 2012). A total of 13,115 individuals were estimated to pass along the Dampier Peninsula on their northward migration to Camden Sound in 2009, with similar estimates in 2010 and 2011 (RPS Environment and Planning Pty Ltd, 2012). Based on population estimates by Jenner et al. (2001) this would indicate that almost half of the Group IV population of humpback whales do not travel this far north along the WA coast (RPS Environment and Planning, 2010a). This is in keeping with the results of a tagging study undertaken by Double et al. (2012) in which some tagged individuals turned southward prior to reaching Dampier Peninsula on their northward migration. The southern migration peaks at the end of September, with females with calves the last to leave the breeding grounds (RPS Environment and Planning, 2010b). Exmouth Gulf (approximately 1,130 km away) and Shark Bay (> 1,200 km away) are regular resting locations. Exmouth Gulf in particular serves as a key resting and breeding area on the southward migration (Bejder et al., 2019), providing calm, protected waters (from the predominately south-easterly winds) for mothers to nurse calves prior to the continuation of the southward migration to Antarctic waters.

Browse Development Area

Some surveys have sighted humpback whales as far offshore as Ashmore Reef and the Rowley Shoals (Jenner et al., 2001). More recent studies have indicated that 80% of individuals travel less than 46 km from the coastline within waters less than 50 m deep (RPS Environment and Planning, 2010b; 2012). For instance, whilst a series of aerial surveys around Scott Reef and the offshore Project Area recorded a total of 13 whales (including two calves) at Scott Reef, the majority of humpback whale sightings during these surveys occurred to the north and west of the Lacepede Islands (approximately 300 km south of Scott Reef), with abundance rapidly decreasing with increasing water depth (RPS Environment and Planning, 2010a).

Only a very small percentage (<1%) of the Group IV humpback whale populaion are likely to be present during seasonal migratory periods within the Browse Development Area, which is located approximately 240 km north-west offshore of Camden Sound. There are also no designated migratory or other BIAs overlapping with the Browse Development Area, as described in the following sub-sections

Scott Reef

Noise logger data collected by McCauley (2011; **Figure 5-12**) indicated that humpback whale presence within range of Scott Reef peaked from late June to early October each survey year. Noise loggers were located inside and outside of the Scott Reef lagoon areas and noise detection range for this species were estimated at 50 km. Noise logger data also indicated that individuals were most often located inshore of Scott Reef towards the 200 m contour and that the reef was on the periphery of the area utilised by humpback whales. (McCauley, 2011). As noted above, it has been visually verified that some individuals may occur within the vicinity of Scott Reef; 13 humpback whales (including two calves) were observed at Scott Reef during aerial surveys in 2010 (RPS Environment and Planning, 2010a).

Based on historical observations (Jenner et al., 2001) and studies by RPS (2010b) and McCauley (2011), it is likely that there may be a very small percentage of the Group IV humpback population transiting through or utilising the Browse Development Area and, in particular, within the vicinity of Scott Reef.

Browse Trunkline

The proposed BTL route is located between approximately 125 and 300 km offshore of the WA coastline, does not overlap any humpback whale BIAs and does not traverse the humpback whale migration route or any known areas of aggregation. It is therefore expected that only very small percentage of transient individuals may occur in the area of the proposed BTL route, predominately during migration periods (northward commencing May/June and southward commencing as early as mid-August through September. Humpback whales were sighted during the 2019 Woodside environmental survey of the proposed BTL route with highest sightings and animals recorded in July and August 2019 with a total of 30 sightings and 65 humpback whales.

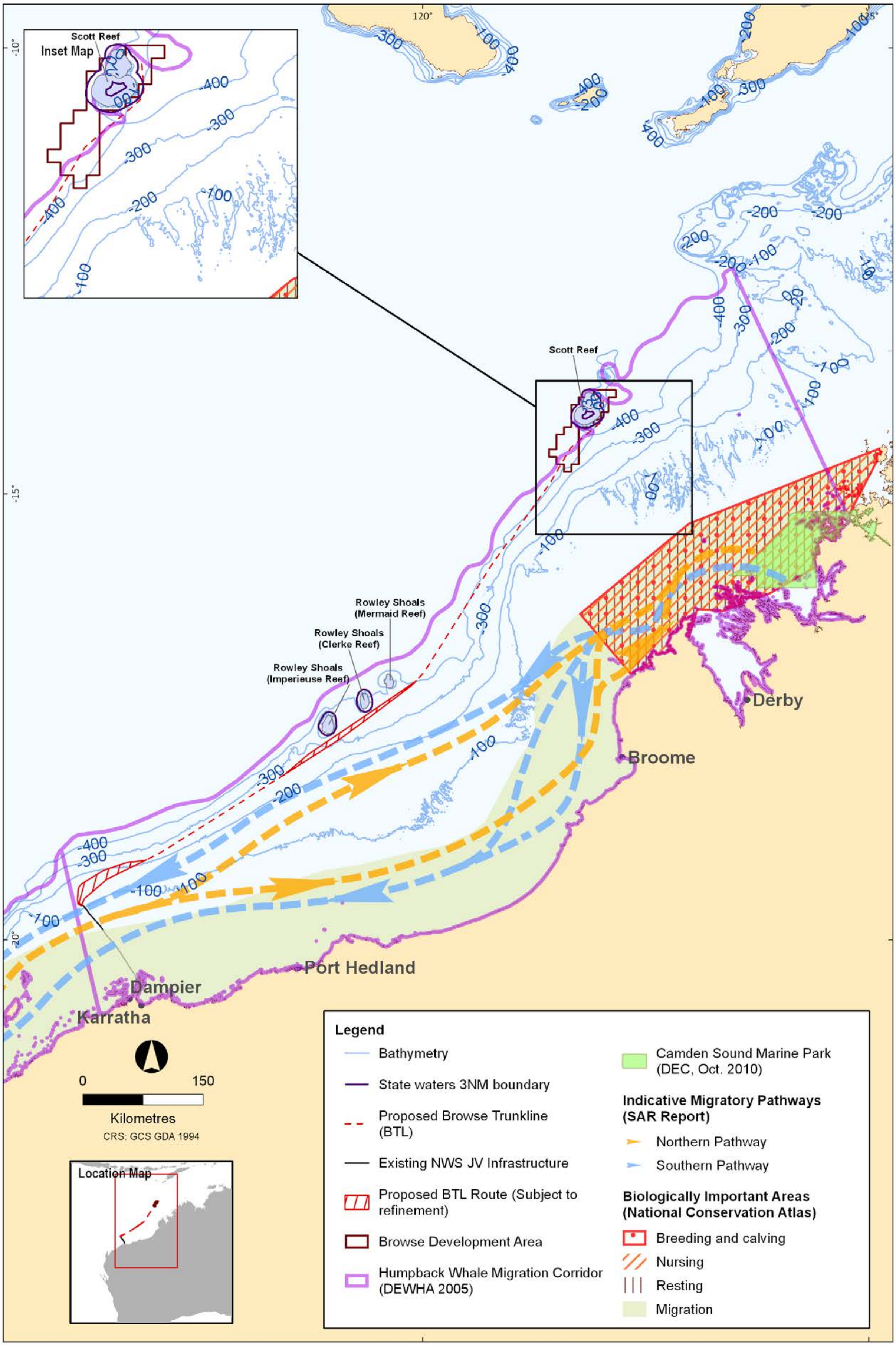


Figure 5-33 Humpback Whale Biologically Important Areas (BIAs) and Indicative Northern and Southern Migratory Corridors (developed from Jenner et al., 2001)

5.3.2.5.2 Blue Whales

Background

Blue whales (*Balaenoptera musculus*) are the largest of the whale species, reaching up to 30 m and weighing an average of 100 to 120 tonnes (Commonwealth of Australia, 2015b; DoEE, 2019b).

Blue whales (*Balaenoptera musculus*) is listed as Endangered, Migratory and Cetacean under the EPBC Act, and Endangered under the WA *Biodiversity Conservation Act 2016* (BC Act, September 2018 list), **Table 5-19**. As identified in **Table 5-19**, this species is considered to potentially occur within the Project Area and/or interact with the proposed Browse to NWS Project.

There are two subspecies of blue whale that occur within Australian waters; the Antarctic blue whale, *B. m. intermedia*, and the pygmy blue whale, *B. m. brevicauda*. These two subspecies are differentiated by morphology, distribution, vocalisation and genetics (Commonwealth of Australia, 2015c); key differences are outlined below. The blue whale is a baleen filter feeder and primarily feeds on krill but alsoopportunistically feeds on fish and squid . Both sub-species have been significantly impacted by historical whaling activities and whaling remains a threat today outside of Australia's jurisdictional waters. A dedicated Conservation Management Plan 2015-2025 for blue whales (Commonwealth of Australia, 2015c) has a recovery objective to minimise anthropogenic threats to allow for their conservation status to improve so that they can be removed from the EPBC Act threatened species list. Threats to this species, as identified in the Conservation Management Plan include climate variability and change, noise interference (anthropogenic sources of underwater noise) and vessel disturbance (Commonwealth of Australia, 2015c). As described below, only the pygmy blue whale is considered likely to occur seasonally within the Project Area.

B. m. intermedia: Antarctic blue whale population

The Antarctic sub-species of blue whale can reach over 30 m in length and weigh up to 180 tonnes (Commonwealth of Australia, 2015c). Antarctic blue whales feed off Antarctica (including off the Australian Antarctic Territory) with limited evidence suggesting that a proportion of this sub-species migrates north into subtropical latitudes of the Pacific and Indian Ocean to breed (Commonwealth of Australia, 2015c); within WA waters this sub-species has been detected off Cape Leeuwin (May to November) and the Perth Canyon (May to October) and off Dampier in June (Balcazar et al., 2017; McCauley et al., 2004; Stafford et al., 2004). This sub-species has also been recorded in waters off the west and north coasts of Tasmania (May to December; Gedamke et al., 2007) and off the east coast of Australia (March to October; Balcazar et al., 2017). Due to the seasonality of these records, it has been suggested that these areas form part of this sub-species' migratory route and/or breeding habitat (Commonwealth of Australia, 2015b); however, breeding grounds for this sub-species are yet to be identified (Blue Planet Marine, 2019). Records of this species at the Perth Canyon and Bass Strait coincide with peaks in productivity and may indicate opportunistic feeding alongside the pygmy blue whale (Balcazar et al., 2017; Tripovich et al., 2015).

Notably, despite these records, the Antarctic blue whale is considered to be uncommon north of 60°S, in contrast to the pygmy blue whale which typically occurs north of 54° (DoEE, 2019g; Blue Planet Marine, 2019). Acoustic studies have detected the Antarctic blue whale in the Australian Antarctic Territory and the Western Antarctic Peninsula year-round, suggesting that at least a portion of the sub-species population does not migrate each season (Commonwealth of Australia, 2015c). Due to the known distribution of this sub-species it is not considered that the Antarctic blue whale will occur within the Project Area.

B. m. brevicauda:

East Indian Ocean pygmy blue whale population

The pygmy blue whale sub-species can reach over 24 m in length but has the same morphological appearance as the Antarctic blue whale sub-species. The East Indian Ocean (EIO) pygmy blue whale population is seasonally distributed from Indonesia (a potential feeding ground) to south west of Australia and east across the Great Australian Bight and Bonney Upwelling to beyond the Bass Strait (Blue Planet Marine, 2019; **Figure 5-34**). This sub-species population is referred to as the East Indian Ocean pygmy blue whale, due to its geographic distribution primarily in the Indian Ocean and south Australian waters. Like other baleen whales, the pygmy blue whale migrates between feeding and breeding grounds each year (Blue Planet Marine, 2019; McCauley et al., 2018). The species typically inhabits deeper offshore waters historically leading to difficulty in determining migration patterns accurately. Migration also seems to be variable, with some individuals appearing as resident to areas of high productivity and others undertaking migrations across long distances (Commonwealth of Australia, 2015c). There are currently insufficient data to accurately estimate population numbers of the pygmy blue whale in Australian waters (Blue Planet Marine, 2019; Commonwealth of Australia, 2015c). McCauley et al. (2018) describe three migratory stages around Australia for the East Indian Ocean (EIO) Pygmy blue whale population: a 'southbound migratory stage' where whales travel southwards from Indonesian waters down pass WA, mostly from October to December but possibly into January of the following year, a protracted 'southern Australian stage' (January to June) where animals spread across southern waters of the Indian Ocean and south of Australia and a 'northbound migratory stage' (April to August) where animals meander back to Indonesia again.

A satellite tagging study (Double et al. (2014) showed tagged whales travelled relatively near to the western Australian coastline (100±1.7 km) throughout March and April until reaching North West Cape. The whales then travelled northwards and offshore (238.0±13.9 km) during May towards Indonesia and by June, whales were travelling through the Savu and Timor Sea.

There are two estimates of the population size of the EIO pygmy blue whale for WA, McCauley and Jenner (2010) calculated the population to be between 662 and 1,559 individuals in 2004 based on passive acoustics (whale callings), and Jenner et al. (2008) based on photographic mark and recapture calculated between 712 and 1,754 individuals but both estimates did not account for animals travelling further west into the Indian Ocean (McCauley et al., 2018). More recent passive acoustic data estimates a 4.3% growth rate that applies to the proportion of EIO pygmy blue whales using the south eastern Austraiian coast and may not reflect the full population but does imply an increasing population (McCauley et al. 2018).

The Perth Canyon (WA), an area of high productivity due to the presence of upwelling and interaction of the Leeuwin Current and Undercurrent, is a key seasonal feeding location for the pygmy blue whale, between November and May (Commonwealth of Australia, 2015c). Other possible feeding grounds off the WA coast include the wider area around the Perth Canyon, and the waters off Exmouth and Scott Reef (Commonwealth of Australia, 2015c). The western Great Australian Bight is also thought to provide foraging grounds, and to act as a transitional feeding area between the Perth Canyon and the Bonney Upwelling. The Bonney Upwelling, located off the coast of Portland, Victoria and adjacent waters, is another known key seasonal feeding ground for this species (Commonwealth of Australia, 2015c). This area supports an abundance of krill and pygmy blue whale aggregations occur in this area from November to May, with a peak observed in February (Blue Planet Marine, 2019; Butler et al., 2002; Commonwealth of Australia, 2015c; Gill et al., 2011). The distribution of the pygmy blue whale at these feeding grounds varies seasonally due to seasonal fluctuations in environmental conditions, which influence upwelling events and prey availability (Commonwealth of Australia, 2015c).

The northward migration from the Perth Canyon to breeding grounds potentially as far as Indonesia is thought to occur between March / April and June, with the southern migration occurring between September and December (Commonwealth of Australia, 2015c). Satellite tracking indicates that at least some individuals of this sub-species aggregating and/or feeding in the Bonney Upwelling migrate westward in the austral winter to the Perth Canyon and potentially further north to Indonesia (Gill et al., 2011; Blue Planet Marine, 2019). Inter-annual variation in migration trends for this population have, however, been noted; McCauley et al. (2018) found a southward migratory pulse along the WA coast between October and December, which extended in some years into January of the following year. Southward migrating individuals were also recorded in close proximity to shore at Geographe Bay (south-west WA, south of the Perth Canyon) between November and December (McCauley et al., 2018).

Tasman-Pacific pygmy blue whale population

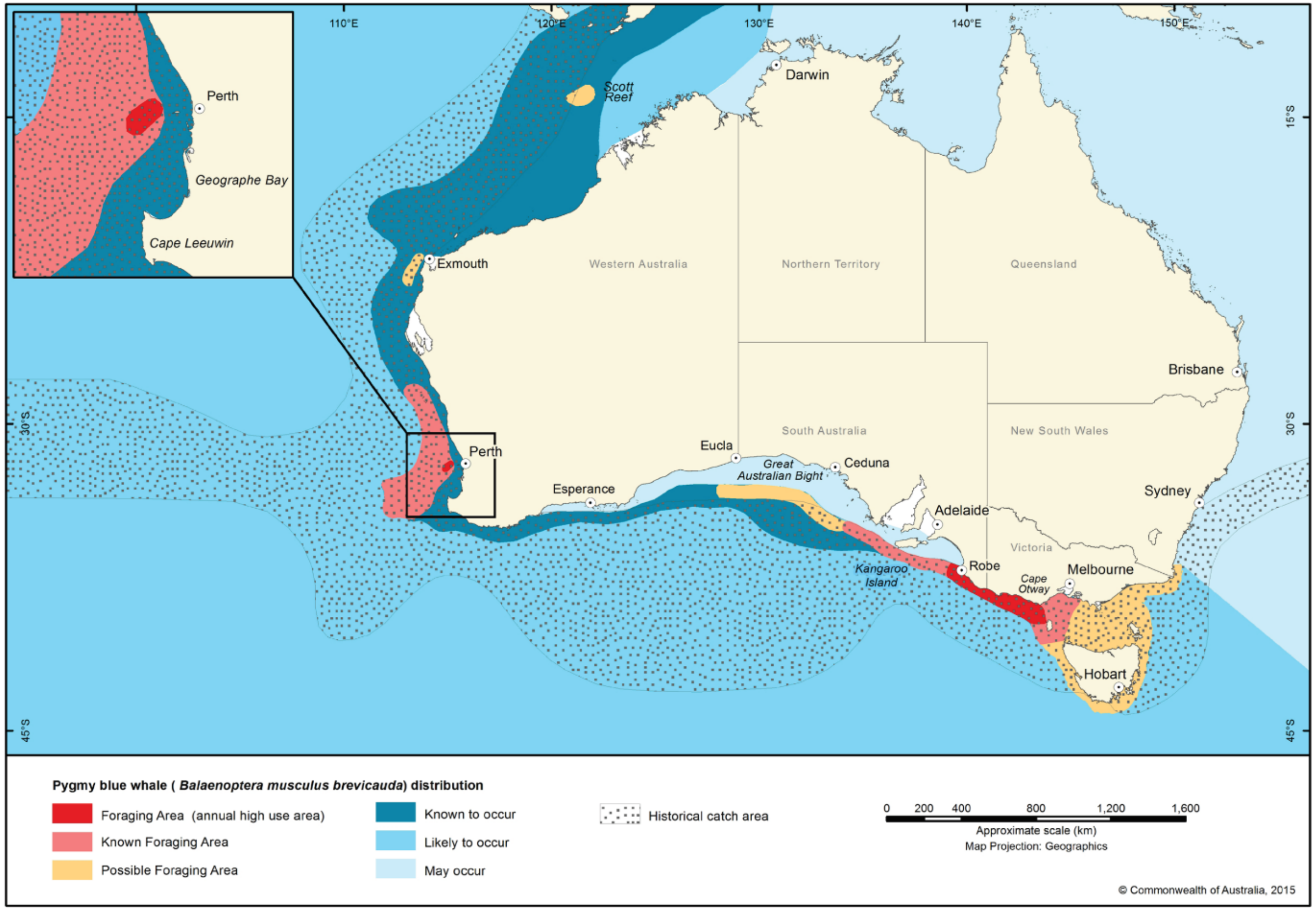
The Tasman-Pacific pygmy blue whale population occurs in waters offshore of eastern Australia in the Tasman Sea and in the Pacific Ocean (Commonwealth of Australia, 2015c). Migratory pathways and habitat use for this species within Australian waters are not known. Acoustic detections for this population can be differentiated from those of the pygmy blue whale population described above and the population has been detected at the Bass Strait (May to June) and along the east coast of Australia (Blue Planet Marine, 2019; Commonwealth of Australia, 2015c; Jolliffe et al., 2019). It is noted that all three populations of blue whales present in Australian waters (i.e. the two pygmy blue whale populations and the Antarctic blue whale population) may overlap in the Bass Strait in south east Australia, whilst maintaining their distinct distributions (Commonwealth of Australia, 2015c).

Regional Overview

Along the west coast of Australia, the Perth Canyon is a seasonally important area for the pygmy blue whale (as shown by both visual and acoustic surveys (McCauley et al. 2000, 2004; Balcazar et al. 2015), with pygmy blue whales arriving from as early as November and numbers increasing to a peak in the following March to May period. The Perth Canyon is an area of high productivity due to the presence of upwelling and interaction of the Leeuwin Current and Undercurrent and is a key feeding location for this sub-species of blue whale (Commonwealth of Australia, 2015c). The number of individual pygmy blue whales present at any one time in this area is highly variable throughout the migratory season and between years. Based on aerial line transect surveys from 2000-2004, an average of 30 (95% CI: 15-58) individuals were present within the peak season (McCauley et al., 2004). The pygmy blue whale is typically present in the Perth Canyon from November to June, with an observed peak between March and May (Commonwealth of Australia, 2015c; Blue Planet Marine, 2019). A recent study by (Jolliffe et al., 2019) using passive acoustic monitoring found vocalisations peaking in the Perth Canyon between February and June (2003 – 2017); coinciding with the northern migration of the pygmy blue whale.

The pygmy blue whale feeds in the Perth Canyon at depths of 200 to 300 m, which overlaps the typical distribution of krill (200 – 500 m water depth (day) to surface (night) (McCauley, 2004, Commonwealth of Australia, 2015c). Other possible feeding grounds off the WA coast include the wider area around the Perth Canyon, and the waters off Exmouth and Scott Reef (Commonwealth of Australia, 2015c). The Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c) documents a possible foraging area for the pygmy blue whale at Scott Reef (**Figure 5-35**).

Similar to other baleen whales species, the pygmy blue whale migrates between feeding and breeding grounds each year. There is a migratory BIA for the pygmy blue whale within WA waters, which extends for most of the length of the NWMR within offshore waters (as detailed in **Section 5.3.2.1.1**) and encompasses Scott Reef. The northward migration from the Perth Canyon to breeding grounds potentially as far as Indonesia is thought to occur between March / April and June, with the southern migration occurring between September and December (Commonwealth of Australia, 2015c). Satellite tracking of pygmy blue whales has indicated lower rates of travel and relatively longer occupancy within the Perth Canyon/Naturaliste Plateau region (Double et al., 2014), possibly indicating a portion of the population does not migrate each season.



Foraging Area (Annual high use area)	Blue whales are regularly observed feeding on a seasonal basis
Known Foraging Area	Known foraging occurs in these areas but is highly variable both between and within seasons
Possible Foraging Area	Evidence for feeding is based on limited direct observations or through indirect evidence, such as occurrence of krill in close proximity of whales, or satellite tagged whales showing circling tracks. Blue whales travel through on a seasonal basis, possibly as part of their migratory route

Known to occur	Blue whales are known to occur based on direct observations, satellite tagged whales or based on acoustic detections
Likely to occur	Blue whales are likely to occur based on occasional observations in the area and nearby areas
May occur	Evidence for the presence of blue whales through strandings or rare observations
Historical catch area	Blue whales were caught during the whaling period based on whaling data

Figure 5-34 Distribution of the Pygmy Blue Whale, B. m. brevicauda, around Australia (Commonwealth of Australia, 2015c)

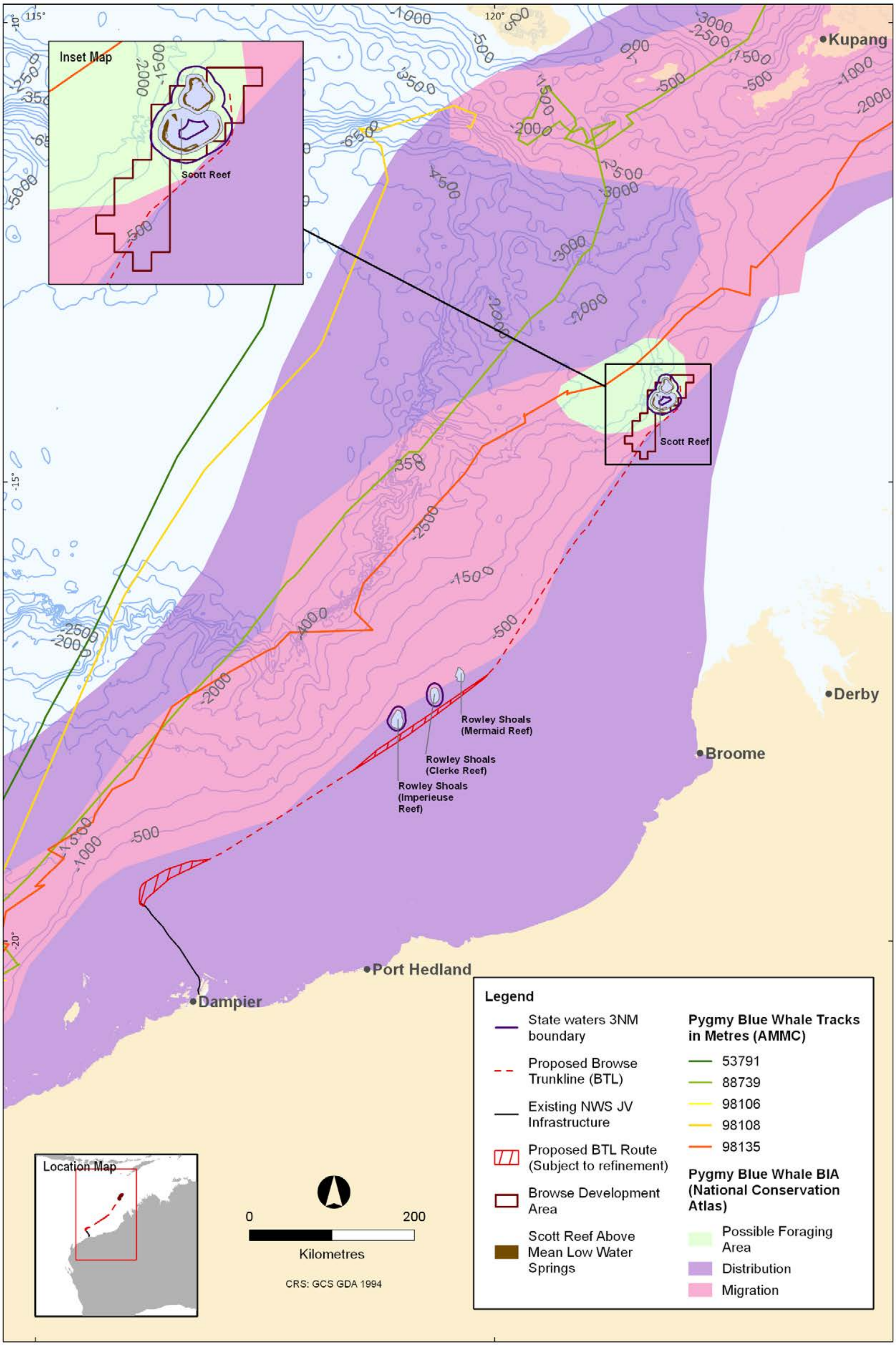


Figure 5-35 Biologically Important Areas (BIAs) (DoEE) and Satellite Tracking Data from Northward Migrating Pygmy Blue Whales undertaken by Double et al. (2014)

Browse Development Area

The northward pygmy blue whale migration has been tracked using satellite tagging of a small number of individuals for the WA population (Double et al., 2014). Tagged individuals were found to migrate north from the Perth Canyon/Naturalist Plateau region (the tagging location) in March/April, with the southern migration from Indonesia occurring from September (Double et al., 2014). Individuals were found to use waters between 40 and 100 km offshore of WA with reduced rates of transit through the Perth Canyon and North West Cape/Ningaloo Reef, which are locations of high productivity where foraging and possible foraging, respectively, occur (C. Jenner and M-N Jenner, unpublished data 2001) and Indonesia. Indonesian waters (specifically the Banda and Mollucca Seas) may subsequently represent a foraging area and/or calving area (Double et al., 2014).

Tagged individuals transited west of the Browse Development Area (and Scott Reef), as shown in **Figure 5-35**. These data indicate the migration corridor may encompass waters further west than the extent of the BIA. Passive acoustic detections of pygmy blue whales during the southbound migration in December 2014 to January 2015, from an array of 14 ocean bottom seismographs (OBS) deployed on the Exmouth Plateau north-west of North West Cape, indicated that the animals tended to travel southward much further away from the WA coast, at distances of up to 400 km from shore, than that expected from data collected on their northbound migration (Gavrilov et al., 2018). There are additional acoustic monitoring surveys that support this (Gavrilov et al., 2011; Gavrilov and McCauley, 2013; McCauley et al., 2004; Salgado Kent et al., 2012; Salgado-Kent et al., 2012; Stafford et al., 2011) and suggest the existence of multiple migratory routes (Double et al., 2014).

Scott Reef

As detailed above, visual and acoustic monitoring has recorded pygmy blue whales passing in and around Scott Reef as well as the broader NWMR (refer to **Table 5-24** for past megafauna surveys and tagging studies and to the desktop review by Blue Planet Marine (2019)). As mentioned previously, the Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c) documents a possible foraging area at Scott Reef that encompasses the majority of Scott Reef, as well as waters to the west (**Figure 5-35**).

Marine megafauna vessel and aerial-based surveys have been conducted at Scott Reef by dedicated marine scientists and trained observers over a period from June 2008 to October 2010 and represent over 700 hours of survey effort (Jenner and Jenner, 2010; RPS Environment and Planning, 2010b; RPS Environment and Planning, 2012; Sutton et al., 2019). Pygmy blue whale sightings were as follows:

+ There were a total of eight sightings of pygmy blue whales at Scott Reef in 2008 (three individuals recorded in winter (June to August); five individuals recorded in spring (October to November). The pygmy blue whales were observed near the eastern and western entrances of the Scott Reef channel with two of the pygmy blue whales followed for a distance of 100 m as they swam through the channel (Sutton et al., 2019).
+ Jenner and Jenner (2010) observed one pygmy blue whale on the first day of aerial surveys over Scott Reef in August 2008; the individual was observed swimming northward <1 km from the western entrance of channel between North and South Scott Reef.

Notably, marine seismic surveys undertaken with dedicated marine fauna observers at Scott Reef in 2007, 2008 and 2011 (representing an estimated 1,534 hours of observation effort) recorded no pygmy blue whale sightings. It is acknowledged that the marine fauna observations are specific to the seismic survey and do not reflect results of dedicated marine fauna survey effort.

Unlike at the Perth Canyon, North West Cape/Ningaloo Reef and the Bonney Upwelling, where foraging is known to occur (C. Jenner and M-N Jenner, unpublished data 2001), pygmy blue whales at Scott Reef have not been directly observed foraging. Double et al. (2014) also did not record satellite tagged individuals transiting through Scott Reef or displaying slowed rates of transit at the same latitudes as this feature. The species has, however, been observed at Scott Reef during periods of elevated plankton biomass (Blue Planet Marine, 2019) indicating feeding may occur in this area. Six genera of tropical krill (Euphasiid shrimps) have been identified from Scott Reef but zooplankton sampling at Scott Reef was unable to demonstrate that the channel was a hotspot of krill abundance that might possibly act as a cue for the attraction of megafauna, though other mechanisms of potential localised plankton (including krill) aggregations may occur (Brinkman et al., 2010). It has been noted that the seasonal presence and distribution of pygmy blue whales at known foraging areas is expected to vary with the seasonal abundance of prey species such as krill (Blue Planet Marine, 2019). If the pygmy blue whale's presence at Scott Reef is associated with foraging, their presence and distribution may subsequently be seasonally dependant on prey availability and distribution.

To estimate occurrence and seasonality of pygmy blue whales passive acoustic monitoring was utilised; noise loggers were positioned within and around Scott Reef between 2006 and 2009 (McCauley 2011). These recorded singing pygmy blue whales passing through the wider Scott Reef region, with a preference for the west of Scott Reef. Two seasonal peaks were detected; during the southbound migration between October to December and possibly into January, and during the northbound migration between mid-April and early August (McCauley, 2011). A number of individuals were detected transiting through the channel between North and South Scott Reef over the three survey years, with a peak occurring between October and January each year (McCauley, 2011). Few–if any–individuals venture far into Scott Reef southern lagoon (McCauley, 2011). Based on the noise logger data, pygmy blue whales within the vicinity of Scott Reef are likely to travel alone or in small groups. Based on density estimates from this study, between 6 and 40% of the individual whales travelling northward part North West Cape go on to pass by Scott Reef (McCauley, 2011).

These studies indicate that pygmy blue whales pass through the Scott Reef area and this area represents a possible foraging area for the species (as outlined in Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c)). However, multiple visual surveys, over multiple years, have failed to observe significant numbers of individuals present or evidence of foraging. While six species of krill are known to be found within the channel at Scott Reef, it is unclear if they are at an abundance or density that would support pygmy blue whale feeding (Brinkman et al., 2010).

Browse Trunkline

The migratory BIA for the pygmy blue whale mostly extends to the west of the proposed BTL route (**Figure 5-35**), however, portions of the proposed BTL route do overlap the migratory BIA. This species may occur in the area of the proposed BTL route. Peak periods of occurrence in this area may be within the migration windows of March / April to June, and September to December.

5.3.2.5.3 Other Marine Mammals

Bryde's Whale

The Bryde's whale, *Balaenoptera edeni*, is the second smallest of the baleen whales and is listed as Migratory and Cetacean under the EPBC Act. This species is the least migratory of its genus and is restricted geographically from the equator to approximately 40°N and S, or the 20° isotherm (Bannister et al., 1996). The Bryde's whale is known to exhibit inshore and offshore forms in other international locations which vary in morphology and migratory behaviours (Bannister et al., 1996). This appears to also be the case within Australian waters (Department of the Environment and Energy, 2019i). The species is subject to whaling in the western North Pacific Ocean, however; as there are no population estimates for the Bryde's whale the impacts of whaling activities or other factors are difficult to determine (Department of the Environment and Energy, 2019i).

The Bryde's whale has been recorded in waters off most Australian States and Territories; however, there are currently no population estimates available for Bryde's whales globally, or in Australian waters (Department of the Environment and Energy, 2019i).Australian inshore stocks of Bryde's whales are thought to be a similar size or smaller than stocks off South Africa (estimated at 582 ± 184 animals: (Best et al., 1984)). McCauley (2011) detected the Bryde's whale using noise loggers deployed in and around Scott Reef from 2006 to 2009, and found this species to be present within the Project Area in low numbers throughout the year. The data indicated that this species was typically present as individuals, with occasional calls from multiple whales. Individuals were recorded moving slowly and called for long periods. Other noise logger data recorded between Exmouth and north of Darwin also has shown no apparent trend / seasonality (McCauley, 2011). Despite the lack of significant data on this species, it is apparent that Bryde's whales are likely to occur along the proposed BTL route and within the Browse Development Area year-round. However, given their known life-history traits and broad distribution it is unlikely that Scott Reef, in particular, represents important habitat for the species.

Sei Whale

The sei whale, *Balaenoptera borealis,* is a moderately large whale reaching up to 21 m in length. The species is listed as Vulnerable and Cetacean under the EPBC Act. Like many large whale species, the sei whale has been subject to historical whaling pressures (Threatened Species Scientific Committee, 2015g). The sei whale is primarily found in deep oceanic waters around much of Australia and exhibits a migration pathway influenced by seasonal feeding and breeding patterns. Sei whales have been infrequently recorded in Australian waters (Bannister et al., 1996). Due primarily to difficulties in distinguishing the sei whale from the blue whale, accurate global population estimates and migration patterns have not been determined for this species. Reliable estimates of the sei whale population size in Australian waters are currently not possible due to a lack of dedicated surveys and their natural characteristics, which mean that they range widely over a very large area that poses accessibility issues for survey counts (Department of the Environment and Energy, 2019j). Similarly, the extent of occurrence and area of occupancy of sei whales in Australian waters cannot be calculated due to the rarity of sighting records (Department of the Environment and Energy, 2019j).

Local distribution patterns and movements of sei whale populations are not well documented, and are not considered to be reliable (Department of the Environment and Energy, 2019j). However, it is well known and documented that sei whales occur throughout the Southern Hemisphere, predominantly offshore, migrating between low-latitude tropical and subtropical regions in the winter and temperate and subpolar latitudes in summer (Leaper et al., 2008; Reilly et al., 2008). They will typically travel in small pods of three to five individuals, with some segregation by age, sex and reproductive status (Department of the Environment and Energy, 2019j). Calving grounds are presumed to exist in low-latitudes with mating and calving potentially occurring during winter months (Threatened Species Scientific Committee, 2015g). However, there are no known mating or calving areas in Australian waters (Parker, 1978).

Due to this species' preference for deep oceanic waters, it is considered unlikely that the sei whale will be present in large numbers within the Project Area. Transient individuals may, however, occur within the Project Area.

Fin Whale

The fin whale, *Balaenoptera physalis*, is listed as Vulnerable and Cetacean under the EPBC Act and is distributed in both the Southern and Northern hemispheres between 20 and 75°. The species is widely distributed within Australian waters (excluding NSW and the NT); however, data indicates this species prefers deeper oceanic waters (Threatened Species Scientific Committee, 2015e). This species is the second largest of the whales (reaching up to 27 m in length) and has been subject to intense historical whaling. It is estimated that the global population suffered a 70% decline in three generations (1929 – 2007) (Threatened Species Scientific Committee, 2015e).

Fin whales regularly occur from polar to tropical waters but are rarely found in inshore waters (Department of the Environment and Energy, 2019k). The fin whale is thought to migrate from higher latitude summer feeding grounds to lower latitude breeding grounds and the species rarely utilises coastal inshore waters. The species has been observed in groups of six to 10 individuals, as well as in pairs and alone (Threatened Species Scientific Committee, 2015e). Accurate distribution patterns are not known within Australian waters and the majority of data are from stranding events (Department of the Environment and Energy, 2019k).

Stranding events and whaling records are the primary source of fin whale distribution data in Australian waters, with stranding events being reported in small numbers in WA (Bannister et al., 1996). One stranding was reported in 1951 near Mandurah, and the other in 1996 at Cottesloe (Chittleborough, 1996). Additionally, fin whales have been recorded vocalising off the Rottnest Trench, Western Australia, between January and April 2000 (McCauley et al., 2000). It is currently not possible to accurately estimate the population size of fin whales in Australian waters predominantly due to the species' behaviour and local ecology, as the proportion of time they spend at the surface varies greatly depending on these factors (Department of the Environment and Energy, 2019k). Therefore, accurate population estimates are difficult to conduct. In addition, natural fluctuations of fin whales in Australian waters are unknown; however, long-range movements do appear to be prey-related (Department of the Environment and Energy, 2019k). Littaye et al. (2004) indicated that fin whales adapt their movements and group size depending on long-term food availability as opposed to short-term environmental conditions.

A recent study by Aulich et al. (2019) used passive acoustic monitoring as a tool to identify the migratory movements of fin whales in Australian waters. On the west coast, the earliest arrival of these animals occurred at Cape Leeuwin in April, and between May and October they migrated along the WA coastline to the Perth Canyon, which likely acts as a way-station for feeding (Aulich et al., 2019). Some whales were found to continue migrating as far north as Dampier (Aulich et al., 2019).

Based on the available information, it is possible that the fin whale may occur within the Project Area, as transient individuals and in low numbers.

Spinner Dolphin

The spinner dolphin, *Stenella longirostris*, is a listed Cetacean under the EPBC Act. Only one of the four subspecies occurs within WA; S. l. longirostris (Department of the Environment and Energy, 2019l). The species is primarily distributed within pelagic zones but has also been observed within a diversity of offshore and coastal habitats. Within WA, this species has been recorded as far south as Bunbury (Department of the Environment and Energy, 2019l). It is possible that, as in international waters, there are oceanic and near-shore populations of this species within Australian waters (Perrin et al., 1991; Wade and Gerrodette, 1993). The spinner dolphin may exhibit some seasonal movement and/or range extensions, however, it is not known to be migratory (Department of the Environment and Energy, 2019l).

Surveys undertaken in 2004 (AIMS, 2004) and in 2008 (Sutton et al., 2018) frequently recorded spinner dolphins near Scott Reef. Aerial surveys undertaken in 2009 (RPS Environment and Planning, 2010b) also recorded spinner dolphins near Scott Reef, predominately in waters between 20 and 100 m in depth. Sightings consisted of individuals as well as groups of up to 100. The species was thought to be present year round with no apparent seasonality in abundance or distribution (RPS Environment and Planning, 2010b). The area of occupancy of spinner dolphins is yet to be calculated, due to the sparsity of sighting records for a large proportion of the range (Department of the Environment and Energy, 2019l).

Globally, spinner dolphins are primarily distributed in pelagic zones; however, they are also a common occurrence over shelf waters and some forms can be found regularly in shallow waters near islands and shallow reefs (Leatherwood and Reeves, 1983; Perrin, 2002). Currently, there are no population estimates available for spinner dolphins globally or within Australian waters; therefore, the proportion of the global population in Australian waters is unknown (Department of the Environment and Energy, 2019l). In addition, there is a lack of surveys relative to the Australian population of spinner dolphins, with offshore distribution primarily reliant on incidental sightings,beach-cast and reported by-catch animals (Department of the Environment and Energy, 2019l).

Due to historic records and the known distribution of this species, it is likely that the spinner dolphin may be present within the Project Area, primarily in the vicinity of Scott Reef, throughout the year; however, it is unlikely that they are reliant on the reef habitats given their population range and distribution.

Other Dolphins

The majority of dolphin species included in the PMST report were determined to be species whose range or preferred habitat indicated that they are highly unlikely to occur within the Project Area, or were transient visitors within the Project Area unlikely to occur in significant numbers. These species have been acknowledged and documented in **Chapter 10, Appendix C.7**.

5.3.2.6 Marine Turtles

Six species of marine turtle occur within Australian waters; the leatherback turtle, loggerhead turtle, olive ridley turtle, green turtle, hawksbill turtle and flatback turtle. All six marine turtle species are known to occur within the NWMR and are protected under the EPBC Act and BC Act.

Marine turtles require both marine and terrestrial habitats to complete their life history stages, as described below. These animals are highly migratory and exhibit strong fidelity to their nesting and breeding locations (Department of the Environment and Energy, 2017). Australia has some of the largest marine turtle nesting rookeries in the Indo-Pacific region. The NWMR supports a number of these rookeries on both coastal beaches and offshore island habitats (Department of the Environment and Energy, 2017). Marine turtle species and their relevance to the Project Area are discussed below, with a particular focus on the green turtle that is known to nest within the Browse Development Area.

Marine Turtle Life Cycle

Female marine turtles lay an average of two to six clutches of eggs in the sand above high tide each nesting season (Commonwealth of Australia, 2017). The nesting period for each species is variable. The period between successive clutches being laid is termed the internesting period and during this time females typically remain close to their nesting location (Commonwealth of Australia, 2017). The number of female marine turtles nesting each season may vary between years, possibly due to prey availability and environmental conditions, and between species. For a clutch to be successful the eggs must have favourable conditions within the nest, including sufficient ventilation, suitable temperature range, high humidity and the nest must not be subject to flooding, erosion or compaction (Commonwealth of Australia, 2017). The incubation period is typically two months but varies across species. Notably, adult turtles do not provide paternal care of eggs or hatchlings/juveniles (Commonwealth of Australia, 2017).

Once hatched, the ‘hatchlings’ emerge from the nest and orient toward the sea using low elevation light (Witherington and Bjorndal, 1991). The hatchlings use additional cues to orient themselves once in the water (Lohmann and Lohmann, 1998, 1992)hatchling green turtles (Chelonia mydas L. to reach deeper waters. Hatchlings are not required to feed for their first few days, instead relying on internalised yolk (Commonwealth of Australia, 2017). There is limited knowledge on the first years of a marine turtles’ life (often referred to as ‘the lost years’) with regards to distribution and foraging ecology; it is thought they drift on ocean currents feeding and sheltering amongst debris and other organisms. Juveniles have a pelagic stage prior to returning to coastal and/or continental shelf waters. At this later stage, juveniles typically have small home ranges in sub-tidal and intertidal coral, rocky reef, seagrass and soft-bottomed habitats (Commonwealth of Australia, 2017). Some green turtles are thought to remain in the open ocean for their juvenile stage and into adulthood. Sexual maturity occurs at between 20 and 50 years. Adult marine turtles undertake migrations from their breeding grounds to breed and nest, showing strong site fidelity (Commonwealth of Australia, 2017). Please refer to **Figure 5-36**.

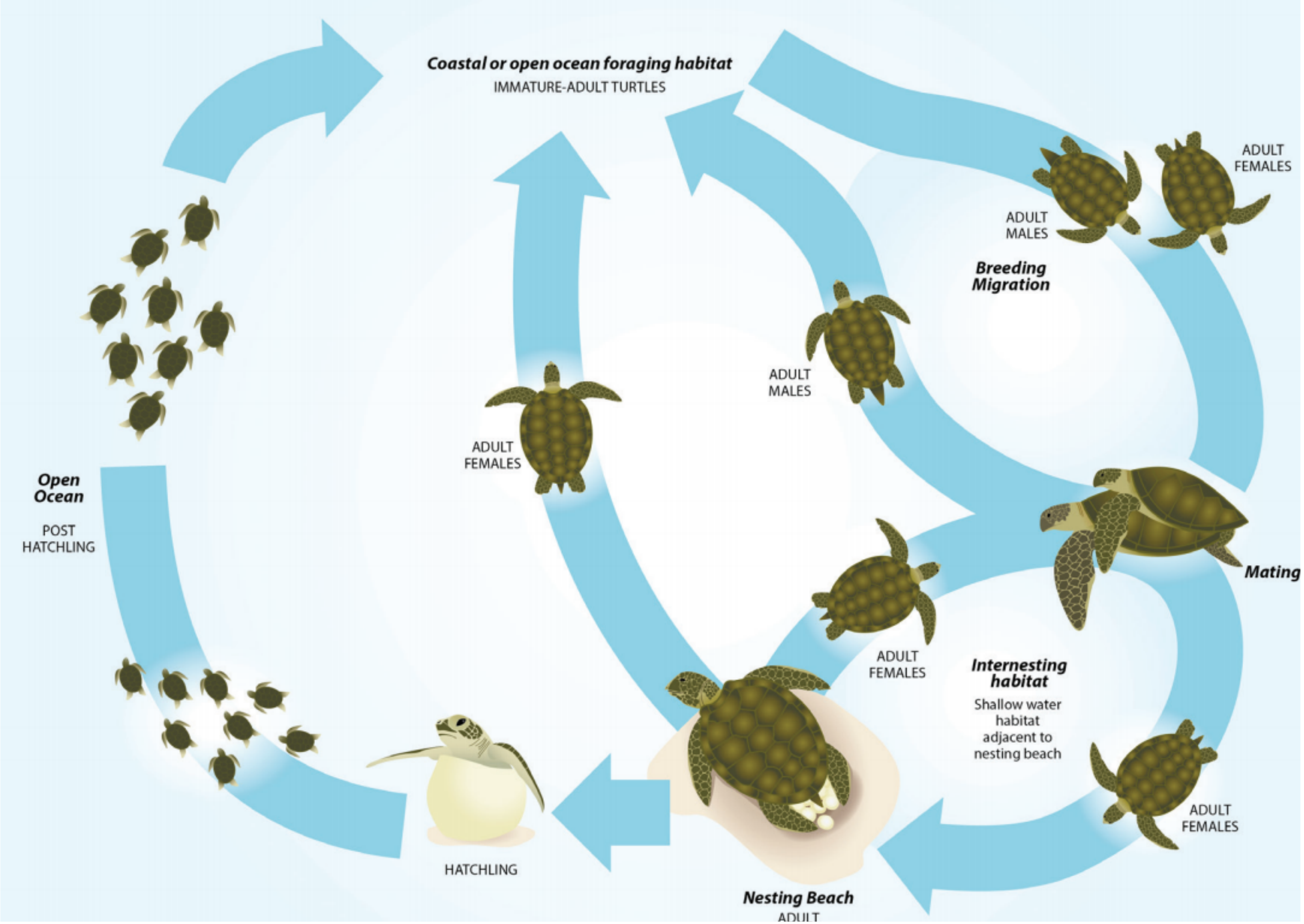


Figure 5-36 Generalised Marine Turtle Life Cycle (Source: Commonwealth of Australia, 2017)

5.3.2.6.1 Green Turtle

Regional Overview

The green turtle is distributed widely across northern Australia with a total of nine genetic stocks identified to date for this species (Commonwealth of Australia, 2017). There are three genetic stocks within the NWMR; the North West Shelf, Ashmore Reef, and Scott Reef-Browse Island genetic stocks. Dispersal of these genetic stocks occurs over a large area in waters north and east of the northern WA coastline (Department of the Environment and Energy, 2017). The North West Shelf genetic stock comprises multiple nesting rookeries within close proximity, whilst the Ashmore Reef and Scott Reef-Browse Island genetic stocks are comparatively genetically isolated with fewer nesting rookeries (Department of the Environment and Energy, 2017).

As discussed in **Section 5.3.2.2**, there are habitat critical areas for the green turtle identified in the 'Recovery Plan for Marine Turtles in Australia 2017-2027' (Commonwealth of Australia, 2017). These areas encompass at least 70% of the nesting area for each genetic stock. The habitat critical areas within the vicinity of the Project Area are shown in **Figure 5-29** and listed in **Table 5-21**.

Key green turtle rookeries within the NWMR include the Lacepede Islands (the largest green turtle rookery in WA) and Ashmore Reef, which both feature nesting and internesting BIAs (**Section 5.3.2.1.1**). High densities of green turtle are known to occur at the Lacepede Islands, which are located approximately 300 km south of Scott Reef. Satellite tracking of green turtles from the Lacepede Islands was undertaken between November 2010 and May 2011 (RPS, 2011). Green turtles successfully tracked in this study were found to travel north from the Lacepede Islands broadly along the WA coast toward Cape Talbot, before taking slightly different paths toward the NT coastline (RPS, 2011) (further detailed in **Section 5.3.4.2**).

Threats to the green turtle as identified by the 'Recovery Plan for Marine Turtles in Australia 2017-2027' (Commonwealth of Australia, 2017) vary between genetic stocks but include the following:

+ climate change and variability
+ marine debris (entanglement and/or ingestion)
+ chemical and terrestrial discharge (acute and/or chronic)
+ terrestrial predation
+ light pollution
+ habitat modification (infrastructure/coastal development)
+ vessel disturbance
+ acute and/or chronic noise interference.

A number of priority actions specifically required to recover each stock have been identified and noted within this recovery plan by the DoEE (Commonwealth of Australia, 2017).

Browse Development Area

Within the Browse Development Area, Sandy Islet (a part of Scott Reef) is a known nesting site for green turtles (specifically the Scott Reef – Browse Island genetic stock). Sandy Islet is habitat critical for survival nesting site and there is a 20 km internesting buffer around Sandy Islet (as described in **Section 5.3.2.2** and **Table 5-21**). Scott Reef also overlaps with nesting and internesting BIAs for green turtles (Department of the Environment and Energy, 2015; **Section 5.3.2.1.1** and **Table 5-20**).

Scott Reef

Sandy Islet is a known green turtle nesting site for the Scott Reef – Browse Island genetic stock. A number of studies supported by the BJV participants have been undertaken to establish a baseline of marine turtle nesting activity (including breeding, nesting and internesting behaviour and movement) of the breeding population at Scott Reef.

Seven surveys conducted during 2006, 2008 and 2009 indicate that the summer months from late November to February are the preferred breeding season for green turtles at Sandy Islet (Guinea, 2009). A total of 435 nesting green turtles were flipper tagged during these surveys; 314 of which were tagged post August 2008 (Guinea, 2009). An indicative estimate of nesting population size for the 2008/2009 season was 779 ± 383 (± se), determined from eight days of survey over the 2008/2009 nesting season. However, as Guinea (2009) highlights, this estimate should be used with caution and may not be a true measure of the nesting population as the assumptions that underpin the estimate are yet to be tested. Another population size estimate using genetic analysis suggests the total effective population size of green turtles at Scott Reef was approximately 2,500 individuals (Dethmers et al., 2006). The 'Recovery Plan for Marine Turtles in Australia 2017-2027' (Commonwealth of Australia, 2017) states a population of between 1,000 and 5,000 individuals utilise Sandy Islet for breeding. While these population estimates are indicative, both Guinea 2009 and 'Recovery Plan for Marine Turtles in Australia 2017-2027' (Commonwealth of Australia, 2017) suggest the Sandy Islet population is smaller than that of the Lacepede Islands and other rookeries in WA. Guinea (2009) also noted that the average remigration interval for green turtles is three to five years and that future monitoring should account for this.

A 2010 study (undertaken during January/February) of nesting green turtles at Sandy Islet utilised onshore monitoring (i.e. flipper tagging, track census, nest success), manta tows (to survey nesting/internesting habitat) and satellite tagging (12 nesting females; **Figure 5-38**) survey techniques (Guinea 2010[16]; 2011[17]). 56 nesting turtles were flipper tagged at Sandy Islet with a nesting population estimate for the 2009/2010 season of 79 ± 25 individuals. This is significantly smaller than the above mentioned 2008/2009 tagging numbers and nesting population estimate. Guinea (2010) have suggested this inter-annual fluctuation in nesting females may be related to fluctuations in food supply in foraging locations.

Eleven of the 12 satellite nesting females tagged for this 2010 study returned to Sandy Islet post tagging to re-nest (Guinea 2010, 2011). These 11 individuals returned between one and four times (i.e. maximum of five nesting events), with an average internesting internal of 10 days (Guinea 2010, 2011). The satellite tagged turtles were found to remain within 3 km of Sandy Islet during the internesting period, except for one individual which travelled into the South Scott Reef Lagoon, 12 km south of Sandy Islet. Satellite tagged individuals were found to spend the majority of their internesting period in dives (83.2% of activity) and a small percentage of the time at the surface (15.2%), with less than 2% of the internesting period spent on Sandy Islet (Guinea, 2010, 2011). Dive duration ranged from 15 to 25 minutes with maximum dive depths ranging from 35 to 45 m within the South Scott Reef lagoon (Guinea 2011). Notably, both juvenile and mature male (9 individuals) green turtles were observed in the internesting habitat around Sandy Islet during the 2010 survey (Guinea 2010).

Pendoley (2005) has also previously undertaken satellite tagging of nesting green turtles at Sandy Islet; four nesting females were tagged during the 2002/2003 and 2003/2004 nesting seasons. In keeping with the Guinea 2010 survey (Guinea 2010, 2011), individuals were not recorded farther than 14 km from Sandy Islet during the internesting period and most stayed within 5 km of Sandy Islet and in water depths of between 5 and 10 m. Furthermore, no tagged turtles swam off Scott Reef into waters deeper than 50 m, or into the channel between North and South Scott Reef (Pendoley 2005).

These satellite tagging studies (Guinea 2010, 2011; Pendoley 2005) are supported by visual census undertaken by Guinea (2009) which identified the southern region of Sandy Islet, in waters over shallow sand (from 7 to 17 m; refer to Area A **Figure 5-37**), as the preferred internesting area for green turtles. In addition, two areas of subtidal sandy substrate located to the southwest of Sandy Islet were also utilised by internesting green turtles during these surveys as smaller aggregation areas (Areas B and C in **Figure 5-37**) (Guinea 2009). The manta tows conducted during the 2010 survey also confirmed this, and indicated that internesting and other adult turtles preferred habitat comprising sandy substrates amongst coral blocks (Guinea 2010).

Green turtles were found to use the entire habitat of Sandy Islet for nesting, with seasonal variation recorded in the specific areas of the islet used for nesting, as well as in the shape of the sand habitat available for nesting at Sandy Islet (Guinea 2010, 2011). Notably, destruction of nests by other individuals attempting to nest was common in the 2006 to 2009 surveys due to the density of nesting turtles at the northern and southern ends of Sandy Islet, and this was a main contributor to nest failure (Guinea 2009). This type of nest failure was not as prevalent in the 2009/2010 season due to a lower density of nesting females (Guinea 2010). Another contributor to the failure of nests between 2006 and 2009 was turtles nesting below the spring high water mark (Guinea, 2009).

The migratory routes and behaviour of green turtles leaving Scott Reef have been assessed and documented from the Guinea (2011) satellite tracking study. Upon leaving Sandy Islet, tagged turtles swum through South Reef lagoon and over the shallow reef flat of the Reef. Once they had left Scott Reef they dispersed toward the WA mainland via two distinct post-nesting migration pathways (shown in Figure 538); travelling east and north toward the Bonaparte Archipelago and then north along the coast to the NT, or travelling south to Cape Leveque and then south along the coast to the De Grey River in the Pilbara region (Guinea, 2011). This eastern post-nesting migration route along the northern coast of Australia was also recorded by Pendoley (2005). Satellite tagged green turtles logged an average migration swimming speed of 2.05 km/hr (1.38 – 2.63 km/hr) (Guinea, 2011), which is similar to swim speed data previously recorded by Pendoley (2005) for green turtles leaving Scott Reef. This satellite tracking also suggests green turtles spent the majority of their migration in dives (> 70% of tracking time; dive depths between 35 and 80 m; Guinea, 2011) and that they migrate quickly from Sandy Islet and Scott Reef after their final nesting season event.

Green Turtle Hatchlings at Sandy Islet

Information on the number of green turtle hatchlings successfully emerging from their nests on Sandy Islet and reaching the ocean during the peak nesting season is very limited, and is complicated by the variation in the estimates of the size of the nesting green turtle population utilising this nesting beach. Hatchling numbers are likely to vary considerably from season to season, given that females can re-nest up to five times in one season, and the variability in the number of nests,

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[16] *Guinea, 2010 available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

[17] *Guinea, 2011 available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

hatching success and emergence success. Based on the mean number of nests per night during three survey periods at Sandy Islet - 26.9 ± 9.32 for December 2008 (Guinea, 2009); 29.1 ± 4.52 for January 2009 (Guinea, 2010) and 3.8 ± 2.52 for January-February 2010 (Guinea, 2011) - the estimated total number of hatchlings to emerge successfully from their nests per night varies from 244 (2010 season) to 2,037 (2009 season). The estimated total number of hatchlings to emerge successfully from their nests per night during survey period in the 2008 season was 1,588.

Browse Trunkline

The proposed BTL route does not traverse known green turtle areas identified as habitat critical to the survival of the species or foraging, nesting or internesting BIAs. At its closest point, the proposed BTL route comes within 4 km of the internesting BIA at Scott Reef. Due to the migratory nature of this species, however, it is possible that individuals may transit the area of the proposed BTL route.

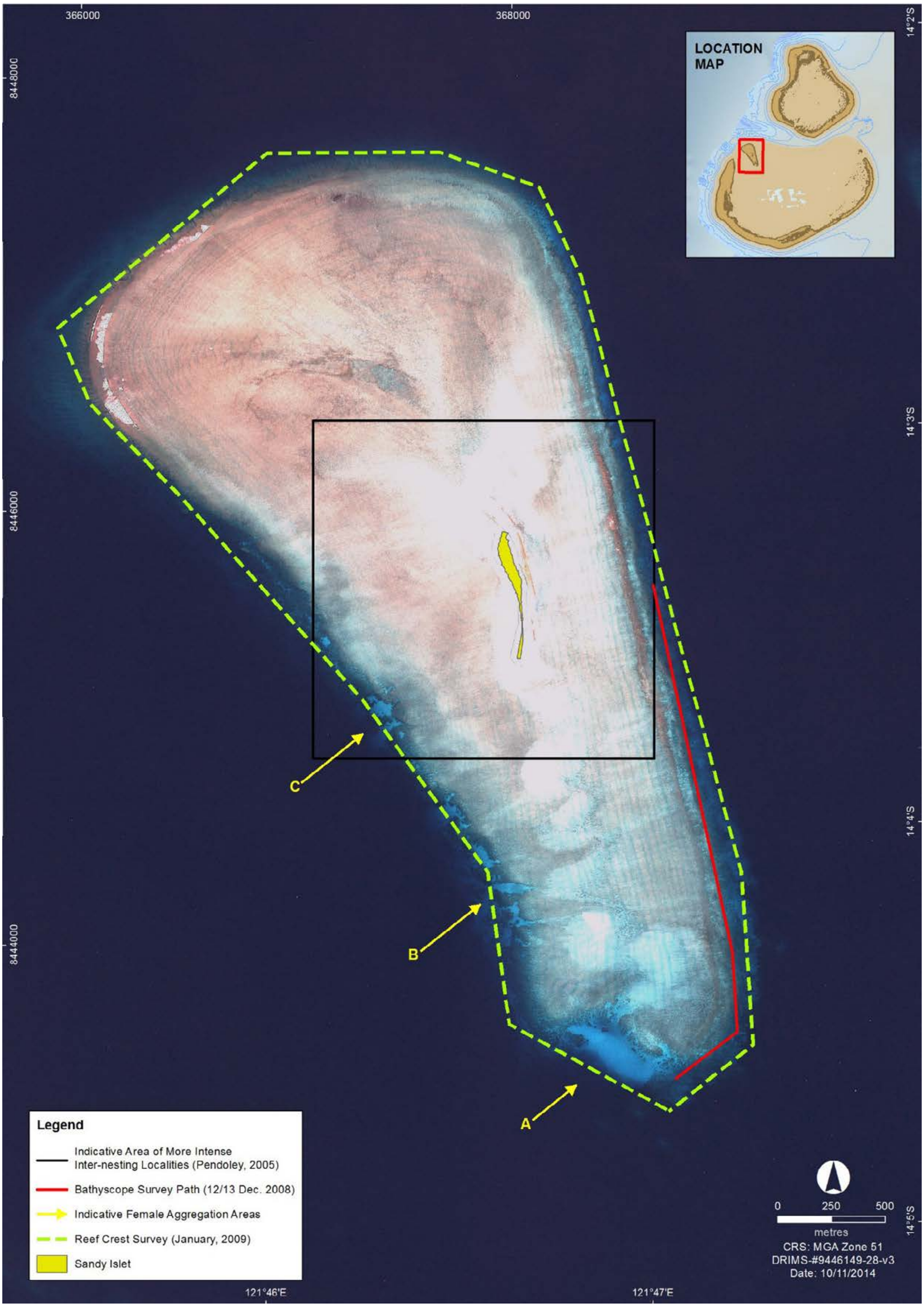

Figure 5-37 Areas of Particular Importance as Known Internesting Areas for Nesting Green Turtles at Sandy Islet, Scott Reef, as Identified by Guinea (2009)

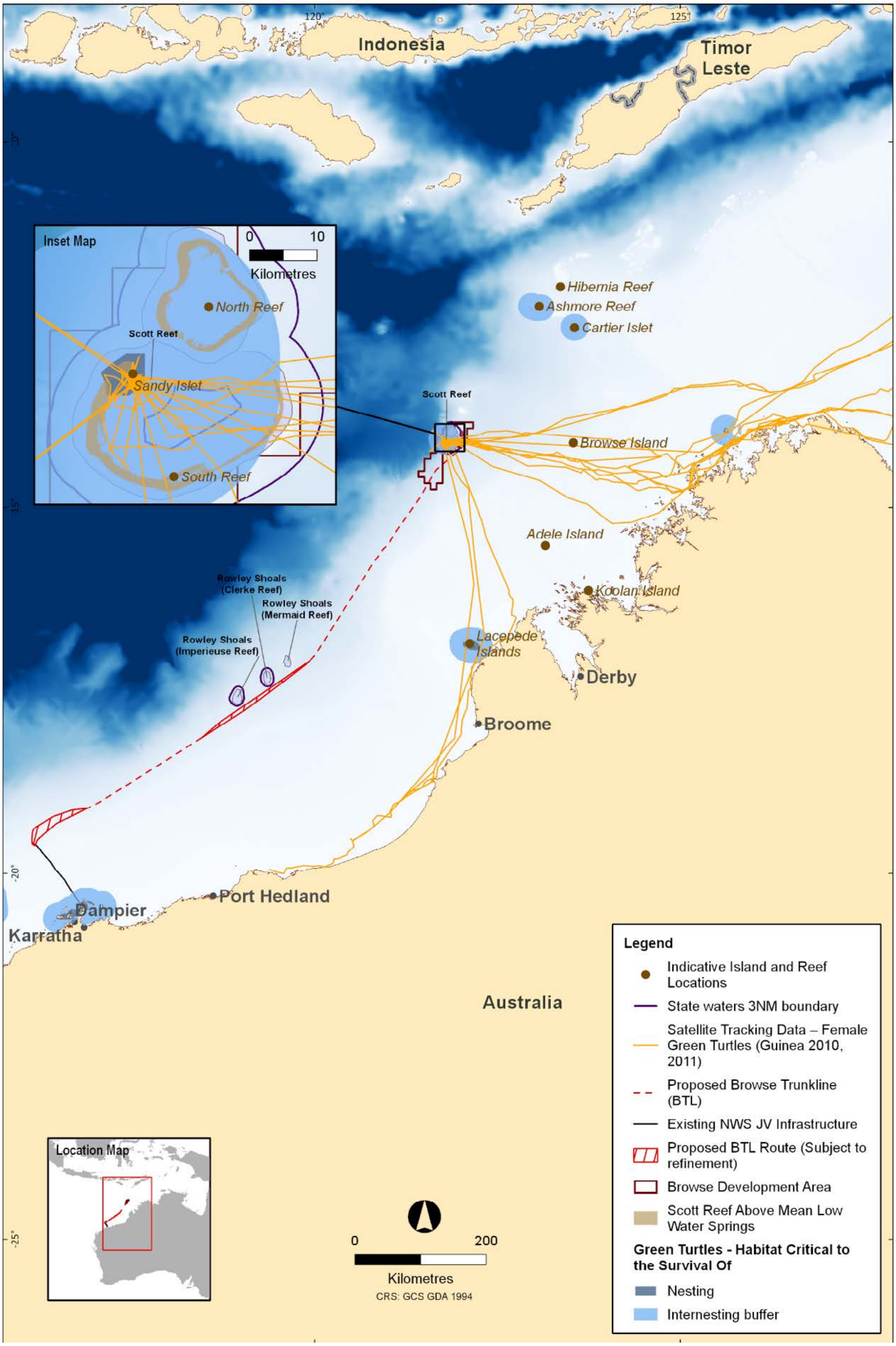

Figure 5-38 Satellite Tracking of 12 Green Turtle Individuals from Sandy Islet, Scott Reef representing post-nesting migration (Guinea, 2011)

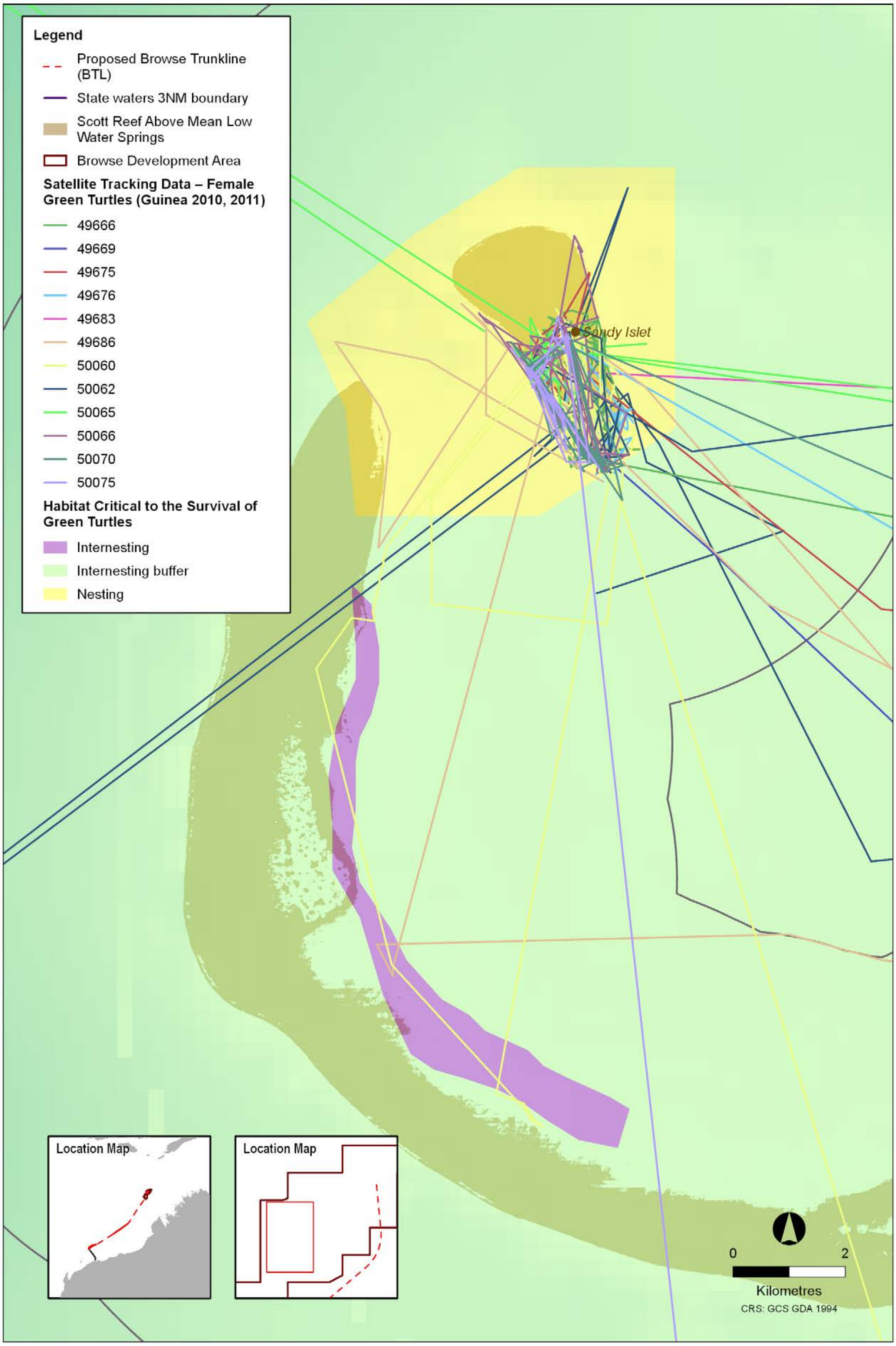

Figure 5-39 Satellite Tracks of 12 Female Green Turtles at Sandy Islet during the Internesting / Nesting Period (Guinea, 2011)

5.3.2.6.2 Other Marine Turtles Species

Owing to their migratory habits, the other five species of marine turtle known to occur within WA each have the potential to occur within the Project Area, however; foraging, nesting or internesting areas, BIAs or areas identified as habitat critical to the survival of a species have not been identified within the Project Area. An overview of these five species of marine turtle is provided in Table 5-25 below.

Table 5-25 Description of Other Species of Marine Turtle Occurring within the North-west Marine Region. 'High' and 'Very High' Risk Threats to those Genetic Stocks Within the Vicinity of the Project Area are also Listed

Common Name	EPBC Act	Description	Threats (Commonwealth of Australia, 2017)
Loggerhead turtle *(Caretta caretta)*	Endangered, Migratory, Marine	Loggerhead turtles have a global distribution and occur throughout eastern, northern and WA (Limpus, 2008). Loggerhead turtles migrate over 2600 km between foraging and nesting areas (Limpus, 2008). In WA, they nest in low numbers on the Muiron Islands and on the beaches of North West Cape (Department of the Environment and Energy, 2017). There has been one reported loggerhead nesting at Ashmore Reef (Department of the Environment and Energy, 2019m).	Climate change and variability Chemical and terrestrial discharge (acute) Fisheries bycatch (domestic)
Olive ridley turtle *(Lepidochelys olivacea)*	Endangered, Migratory, Marine	The olive ridley turtle is the smallest of all marine turtles. They have a global tropical and sub-tropical distribution and are known to forage primarily in soft bottom habitats ranging in depth from six to 35 m (Commonwealth of Australia, 2008). The species also forages in pelagic habitats up to 200 m in depth (Department of the Environment and Energy, 2017). Olive ridley turtles have been recorded nesting in WA only twice, both times in the Kimberley region (RPS, 2010), with most nesting occurring in the NT (Department of the Environment and Energy, 2017).	*No specific threats listed for this genetic stock.*
Leatherback turtle *(Dermochelys coriacea)*	Endangered, Migratory, Marine	The leatherback turtle is the largest of all marine turtles. They are pelagic feeders and spend the majority of their lives in the open ocean in tropical, sub-tropical and temperate waters throughout the world (Limpus, 2009a). Leatherback turtles have been recorded feeding in the coastal waters of all Australian States and Territories. It is thought that they migrate from Australian waters to breed at larger rookeries in neighbouring countries such as Indonesia, Papua New Guinea and Solomon Islands. There are no known foraging sites for this species within WA and no records of Leatherback turtles nesting in WA (Department of the Environment and Energy, 2017).	Climate change and variability Marine debris (ingestion) International take (outside Australia's jurisdiction) Fisheries bycatch (international and domestic)

Common Name	EPBC Act	Description	Threats (Commonwealth of Australia, 2017)
Hawksbill turtle *(Eretmochelys imbricata)*	Vulnerable, Migratory, Marine	Hawksbill turtles are found in tropical, sub-tropical and temperate waters, with nesting mainly confined to tropical beaches (Limpus and Miller, 2008). This species is distributed across northern and eastern Australia and occurs widely within the NWMR. There is one genetic stock recognised currently within WA. This genetic stock is one of the largest populations of hawksbill turtle remaining globally and is the largest in the Indian Ocean (Limpus, 2009b). Key nesting rookeries occur at islands within the Dampier Archipelago and Montebello Islands, with lower density nesting occurring at the Lowendal Islands and Sholl Island (Limpus, 2009b). Peak breeding season occurs from November to May (Department of the Environment and Energy, 2017). A single hawksbill turtle was tagged (2006) and recaptured (2009) on Sandy Islet by Guinea (2009). There are no other records of hawksbill turtles nesting at Scott Reef, although the Recovery Plan recognises that some nesting for this species occurs at Scott Reef and Ashmore Reef (Department of the Environment and Energy, 2017), and Sandy Islet is a nesting BIA for this species, with an internesting BIA in the surrounding waters. Whilst the hawksbill turtle is known to occur within the Rowley Shoals Marine Park, the habitats within the marine park are not thought to be significant for this species (Department of the Environment and Conservation, 2007).	International take (outside Australia's jurisdiction) Climate change and variability Light pollution
Flatback turtle *(Natator depressus)*	Vulnerable, Migratory, Marine	The flatback turtle is found only in the tropical waters of northern Australia, Papua New Guinea and Irian Jaya, and is one of only two species of marine turtle without a global distribution (Limpus, 2007). Nesting is known to only occur in Australia for this species. The NWMR is an important nesting area for flatback turtles, with nesting occurring mainly from October to March (Department of the Environment and Energy, 2017). The major rookeries in WA are on the eastern coast of Barrow Island and at Mundabullangana Station near Cape Thouin on the mainland (greater than 500 km south of Broome) (Limpus, 2007). Nesting also occurs at other locations along the mainland coast and islands of tropical WA, including the Lacepede Islands (Department of the Environment and Energy, 2017; RPS Environment and Planning Pty Ltd, 2010) (see **Section 5.3.4.2**).	Climate change and variability Chemical and terrestrial discharge (acute) Light pollution Habitat modification (infrastructure/coastal development)

5.3.2.7 Sea Snakes

Regional Overview

Sea snakes occur throughout the tropical waters of Australia. There are three genera of sea snake; *Aipysurus* and *Emydocephalus*, which are typically found in coral reef habitats, and *Hydrophis*, which preferentially use inter-reef soft sediment habitats. Sea snakes typically occur in coastal, shallow water habitats (excluding the pelagic yellow-bellied sea snake) as they are air breathing animals (Udyawer et al., 2016). There are 25 species of sea snake known to occur off the WA coast, four of which are endemic to the NWMR; the short-nosed sea snake (EPBC Act; Critically Endangered), leaf-scaled sea snake (Critically Endangered), dusky sea snake (listed Marine) and large-headed sea snake (listed Marine).

Sea snake species in waters off WA have experienced population declines in recent decades. Ashmore and Hibernia Reefs (approximately more than 200 km from the Project Area) have historically been hotspots for sea snake diversity, however, surveys undertaken between 1978 and 2013 indicate significant population decline at these sites. Known threats to sea snakes within the NWMR include trawling and other fishing activities (Udyawer et al., 2016).

Udyawer et al. (2016) undertook a survey of sea snakes in the NWMR between 1999 and 2016, deploying 2290 Baited Remote Underwater Video Stations (BRUVS). Five hundred and eight two sea snakes were recorded, with the highest rates of sea snake sightings recorded in the Northern Oceanic Shoals. The majority of sea snakes were of genus *Aipysurus* followed by *Hydrophis* and *Emydocephalus* (Udyawer et al., 2016). *Aipysurus* species were found to be indicative of high coral cover and sea surface temperatures were found to significantly define species assemblages in non-reef habitats (Udyawer et al., 2016).

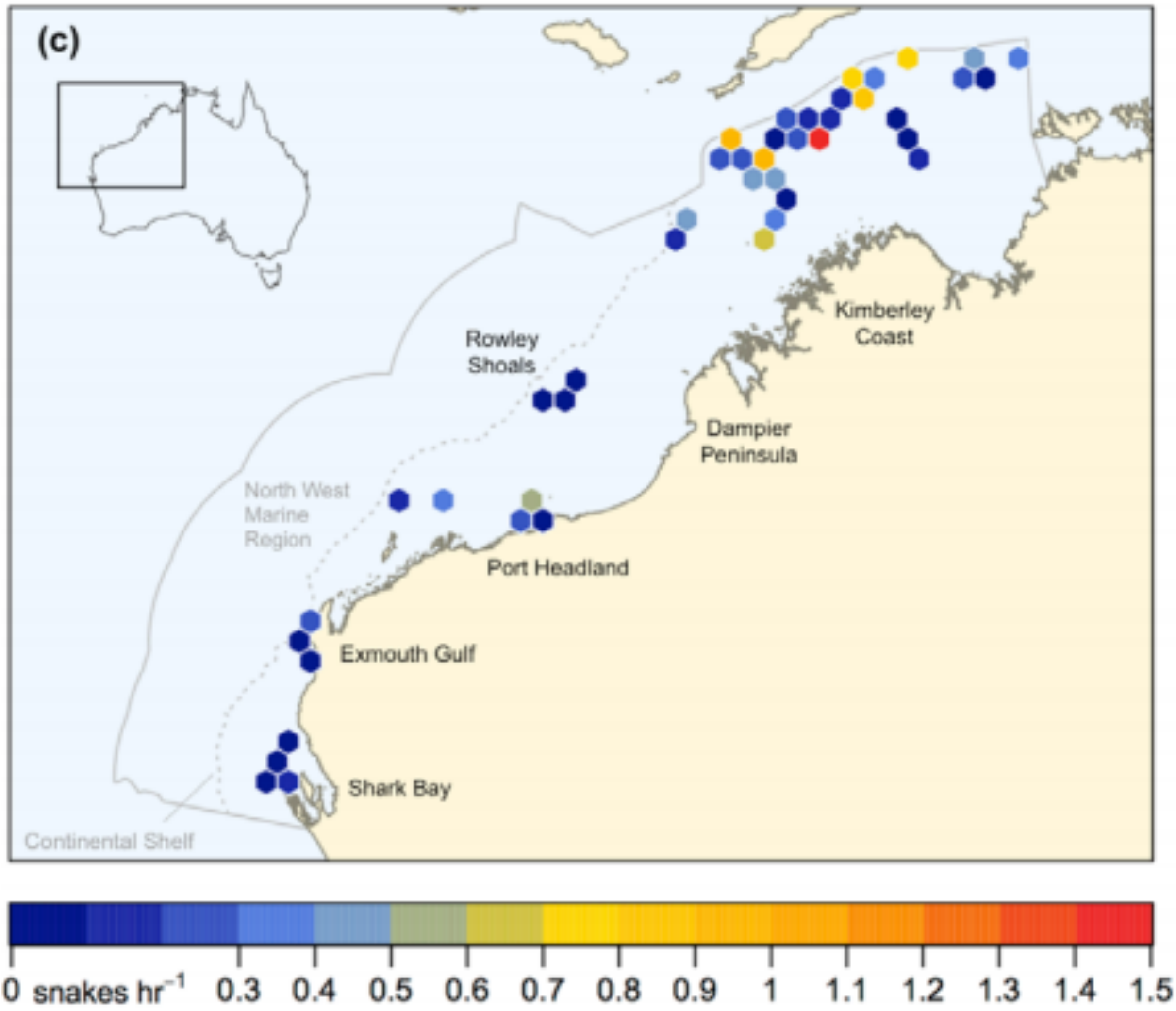

Figure 5-40 Rate of Sea Snake Observations at the 2290 BRUV Locations within the North-west Marine Region (Udyawer et al., 2016)

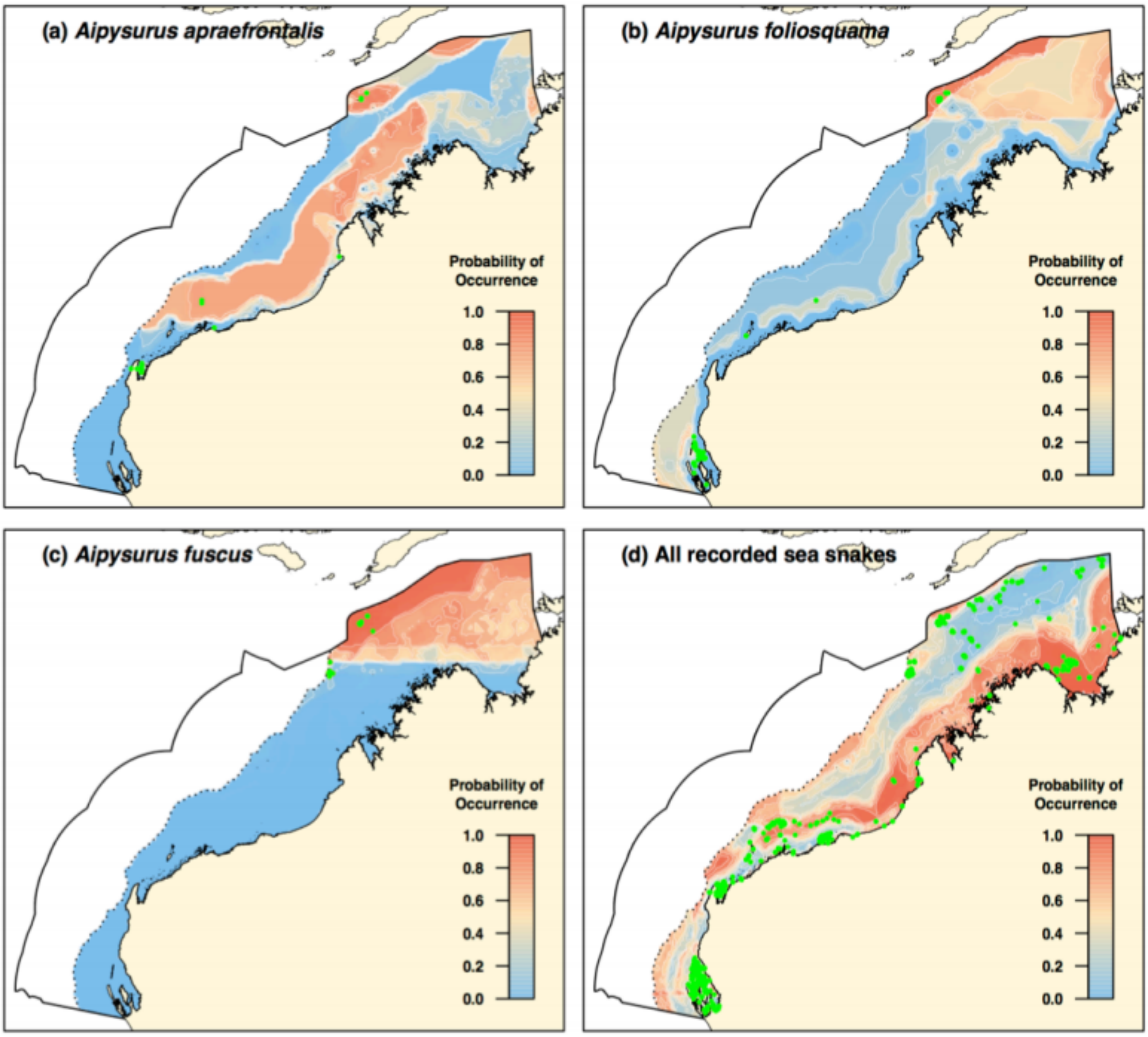

Figure 5-41 Probability of Occurrence Plots for Three Species of Genus Aipysurus based on Environmental Parameters and Data Collected from 2290 BRUVS (Udyawer et al., 2016)

Browse Development Area

The PMST identified the EPBC Act Critically Endangered short-nosed sea snake (*Aipysurus apraefrontalis*) as potentially occurring within the Browse Development Area. Although previously thought to be largely restricted to Ashmore and Hibernia Reefs, this species has not been recorded at these sites since 1998 (Department of the Environment and Energy, 2019n). This species was also not sighted at Scott Reef in the most recent surveys by URS Australia Pty Ltd (2006b, 2007a) undertaken in February, September and November 2006. Sixteen other sea snakes (EPBC Act listed Marine) were also identified by the PMST as potentially occurring within the Project Area.

Scott Reef

Based on data collected by Udyawer et al. (2016) probability of occurrence plots were generated for three species of interest, including the short-nosed sea snake. The data indicates that the short-nosed sea snake is likely to occur within the vicinity of the Project Area, based on available habitats and other environmental parameters (Udyawer et al., 2016). As noted previously, comprehensive surveys of sea snakes at Scott Reef in 2006, however, did not observe the short-nosed sea snake (URS Australia Pty Ltd, 2007a, 2006b). These surveys, however, did identify the olive sea snake, turtle-headed sea snake, dusky sea snake, Duboi's sea snake, slender-necked sea snake and horned sea snake; species which were identified as potentially occurring within the Project Area by the PMST Search. Sea snakes that were recorded were most common in the more complex reef habitats, although no key sites for juveniles or adults were identified at Scott Reef. No seasonal peaks were detected indicating the majority of individuals were likely residential (Udyawer et al., 2016).

Browse Trunkline

The seabed along the proposed BTL route does not feature any shallow or complex marine habitats and, as such, the sea snake species identified by the PMST are not expected to occur in the area of the proposed BTL route other than as isolated individuals. Notably, no sea snakes have been reported from the Rowley Shoals despite the similarity in habitats between Scott and Seringapatam Reefs, which both feature sea snake records, and other shoals in the NWMR which are known to feature sea snakes (Berry, 1986; Long and Holmes, 2008).

Based on this information, it is expected that, within the Browse Development Area, sea snakes will be present in association with the habitats in the shallower waters associated with Scott Reef and not the deeper waters in the vicinity of proposed Browse to NWS Project subsea infrastructure.

5.3.2.8 Fish

Regional Overview

Fish communities occupy a range of habitats from highly diverse coral reefs, where up to 200 species may be present on less than a hectare of coral reef, to deepwater habitats below the euphotic zone (greater than 200 m depth in open ocean), and to the open-water pelagic zone. Fish play an important ecological role and form vital links in many trophic ecosystems where small predators such as herring and sardines feed on plankton and are subsequently preyed upon by larger predators such as sharks, tuna and mackerel.

The NWMR contains a diverse range of fish of tropical Indo-west Pacific affinity (Allen et al. 1988). The region is characterised by the highest level of endemism and species diversity compared with other areas of the Australian continental slope. Last et al. (2005) recorded 1,431 species from the three bioregions encompassing the continental slope, whilst also acknowledging some information gaps.

The NWMR is known for its demersal slope fish assemblages; the continental slope of the Timor Province and the North-west Transition supports more than 418 and 505 species of demersal fish respectively, of which 64 are considered to be endemic. This is the second richest area for demersal fish species across the entire Australian continental slope. Conversely, the broad Southern Province, which covers most of southern Australia, supports 463 species, only 26 possibly being endemic.

Last et al. (2005) described the Timor Province, which includes the Browse Development Area, as the most strongly defined province for demersal slope fish species in the area. The demersal fish species of the Timor Province occupy two distinct demersal community-types (biomes) associated with the upper slope (depths of 225 to 500 m) and the mid-slope (depths of 750 to 1,000 m; Last et al., 2005). The demersal slope fish assemblages of the NWMR have been identified as a KEF (Department of the Environment, Water, Heritage and the Arts (DEWHA), 2008), as described in **Section 5.3.3.1**.

The NWMR also features a diversity of pelagic fishes (those living in the pelagic zone) and bentho-pelagic fishes, including tuna, billfish, bramids, lutjanids, serranids and some sharks (DEWHA, 2007). These species feed on salps and jellyfish, and more often on secondary consumers such as squid and bait fish. Water depth provides an indication of the level of interaction between pelagic and benthic communities within the NWMR; in waters deeper than 1000 m, for instance, the trophic system is pelagically-driven and benthic communities rely on particulates which fall to the seafloor (DEWHA, 2007).

Pelagic fish play an important ecological role within the NWMR; small pelagic fish, such as lantern fish, inhabit a range of marine environments, including inshore and continental shelf waters and form a vital link in and between many of the region's trophic systems, feeding on pelagic phytoplankton and zooplankton and providing a food source for a wide variety of predators including large pelagic fish, sharks, seabirds and marine mammals (Bulman, 2006; Mackie et al., 2007). Large pelagic fish, such as tuna, mackerel, swordfish, sailfish and marlin are found mainly in oceanic waters and occasionally on the continental shelf (Brewer et al., 2007). Both juvenile and adult phases of the large pelagic species are highly mobile and have a wide geographic distribution, although the juveniles more frequently inhabit warmer or coastal waters (DEWHA, 2008).

The NWMR contains 157 chondrichthyan species (subclass Elasmobranchii: sharks, skates and rays and subclass: Holocephali: chimaera), 18 of which are endemic. This includes 94 shark species, many of which are found in other parts of Australia, and which represent approximately 19% of the world's shark species (Heupel and McAuley, 2007). Sharks, skates and rays occupy a broad range of habitats, from shallow to deep water, with some species being pelagic (e.g. bronze or dusky whaler shark – *Carcharhinus obscurus*), and others demersal (e.g. leopard shark – *Stegostoma fasciatum*).

A number of fish species within the NWMR are fished both commercially and recreationally. Commonly fished species are listed in **Table 5-26** below, and those State and Commonwealth Fisheries relevant to the proposed Browse to NWS Project are described in **Section 5.4.2.1**.

Table 5-26 Common Commercial and Recreational Fish Species within the NWMR (Department of Agriculture and Water Resources (DAWR), 2018; Gaughan and Santoro, 2019)

Species Name	Common Name
Carcharhinus limbatus/tilstoni	Blacktip sharks
Carcharhinus plumbeus	Thickskin (sandbar) shark
Carcharhinus obscurus	Bronze whaler shark
Galeocerdo cuvier	Tiger shark
Lutjanus sebae	Red emperor
Lethrinus lentjan	Red spot emperor
Lethrinus nebulosus	Spangled emperor
Lutjanus vitta, L. quinquelineatus, L. carponotatus, L. lutjanus	Flagfish (Spanish flag)
Lutjanus malabaricus	Saddle tail snapper
Lutjanus erythropterus	Crimson snapper
Lethrinus miniatus	Sweetlip emperor
Lethrinus hutchinsi	Blue-spot emperor
Epinephelus species	Estuary rock cod, yellow spotted rock cod and Rankin cod
Plectropomus maculatus	Coral trout
Pristipomoides species	Tropical snappers
Scomberomorus commerson	Spanish mackerel
Scomberomorus semifasciatus	Grey mackerel
Carangidae	Trevally species
Saurida spp.	Lizardfish
Thunnus tonggol	Longtail tuna
Thunnus albacares	Yellowfin tuna
Tetrapturus audax	Striped marlin

Browse Development Area

Fish assemblages within the Browse Development Area occupy a diverse range of habitats and are typical of the fish communities and species representative of the Timor Province. These fish assemblages range from shallow-water, site-attached coral reef communities with characteristically high diversity and abundance to deepwater fish communities of limited knowledge and some of an ephemeral nature. For example, an ROV survey in July 2006 of the Brecknock-2 well site in deep water (571 m) identified several fish species within the vicinity of the well location, including Synaphobranchus eels. It is likely that the well and activities acted as an aggregation attractant. However, in a second survey in September 2006, these deepwater fish species were less abundant (Hudson and Fletcher, 2006).

The PMST identified 30 species of seahorse and pipefish (family Syngathidae, which are teleosts (bony fishes)) which are listed as 'marine' under the EPBC Act. These species are typically associated with seagrasses, mangroves, reefs and sand, or rubble habitats (Commonwealth of Australia, 2012b) and, in particular, the shallow waters of Commonwealth Marine Reserves such as Ashmore and Mermaid Reefs (Commonwealth of Australia, 2012b). Within the Browse Development Area, it is expected that these species are most likely to occur within the vicinity of Scott Reef.

Based on available existing information, including a number of previous field studies and SPRAT profiles, the EPBC Act Listed fish species that are likely to occur within or in close proximity to the Browse Development Area are the fish species listed in **Table 5-27**. This list includes the whale shark (EPBC Act listed Vulnerable) which was also identified by the PMST as potentially occurring within the Project Area.

Table 5-27 Fish Species Identified by the PMST and/or by previous Surveys as Potentially Occurring within and/or Interacting with the proposed Browse to NWS Project

Common Name	EPBC Act	Description
Whale shark *(Rhincodon typus)*	Vulnerable, Migratory, Marine	Whale sharks occur in both tropical and temperate waters (Colman, 1997). There is a general lack of knowledge on many aspects of whale shark biology, including definitive migration patterns. They are normally oceanic and cosmopolitan in their distribution and are known to aggregate in the reef front waters adjacent to the Ningaloo Reef (more than 300 km south of the Project Area; Colman, 1997; Wilson et al., 2006). Aggregations may be between 300 and 500 individuals (Wilson et al., 2006), however, research indicates the Ningaloo population of whale sharks is declining (Bradshaw et al., 2007). The conservation advice for the whale shark (Threatened Species Scientific Committee, 2015f) notes that the NWMR is considered to be important to whale sharks for foraging. Key foraging areas include: + the Ningaloo Marine Park and adjacent commonwealth waters (depths of 60–100 m) in March to July + northward from Ningaloo Marine Park along the 200 m isobath of the northern WA coastline (predominantly inshore of the Project Area) in July to November (Department of Sustainability, Environment, Water, Population and Communities, 2012). A number of satellite tracking studies have been undertaken in recent years of whale sharks in waters west of the Australian coastline (McKinnon et al., 2002; Meekan and Radford, 2010; Wilson et al., 2006). These data indicate that individuals typically migrate north and west from feeding grounds in Ningaloo into the Indian Ocean, and towards Timor Leste or further west towards Sumatra and Java. Satellite tracking has also indicated that some individuals may travel to or within the vicinity of Scott Reef as part of this migration (Meekan and Radford, 2010; Wilson et al., 2006). Long-term residency and movement patterns of whale sharks to assess utilisation of marine protected areas and habitat preferences was presented by Reynolds et al. (2017) using satellite telemetry data from 29 whale sharks tagged at Ningaloo Reef between 2010 and 2015. The analysis confirmed the importance of the Ningaloo marine park for whale sharks year round and that outside the whale shark season there was a southerly shift of animals within the marine park, This study also tracked migratory movement of whale sharks with some individuals having travelled a distance of at least 300 km from Ningaloo Reef before returning, whereas some individuals travelled away from the reef without returning during the study (Reynolds et al., 2017). Individuals typically travelled north and north-east of Ningaloo Reef, however, they also moved north-west and south. One individual travelled as far as 1,567 km to the south coast of Java, Indonesia, before returning to Ningaloo Reef (Reynolds et al., 2017). A review of the literature available for the whale shark by Meekan and Lester (2017) has grouped migration from Ningaloo Reef as either towards the open Indian Ocean, towards the coast of Indonesia, or to the north east into the Timor Sea with the drivers for these movements as yet unknown. Notably, whale shark aggregations at Ningaloo Reef are mainly comprised of juvenile males (Meekan and Lester, 2017). Anecdotal evidence from sightings data collected from the Woodside offshore facilities on the NWS indicate whale sharks are present on the NWS in the months of April, July, August, September and October, corresponding with the Whale shark's seasonal migration to and from Ningaloo Reef. Based on the available information, it is expected that whale sharks may occur within the Project Area, albeit in low numbers.

Common Name	EPBC Act	Description
Shortfin mako *(Isurus oxyrinchus)*	Migratory, Marine, International Agreement[1]	The shortfin mako shark is a large pelagic shark found in tropical and warm-temperate seas in water depths up to 500 m. This species has no habitat associations with the sea floor. The shortfin mako is a wide-ranging oceanic shark widespread in Australian waters (preferring water temperatures above 16°C) (Threatened Species Scientific Committee, 2014) and is likely to occur in the Project Area.
Longfin mako *(Isurus paucus)*	Migratory, Marine, International Agreement[1]	Similar to the shortfin mako, the longfin mako is a widely distributed oceanic tropical shark, but more rarely encountered. It can be differentiated from the shortfin mako by the length and shape of its pectoral fins (Threatened Species Scientific Committee, 2014). In Australian waters, it is found from Geraldton (WA), along northern Australia to Port Stephens (New South Wales) (Last and Stevens, 2009) and is also considered likely to occur in the Project Area.
Green sawfish *(Pristis zijsron)*	Vulnerable, International Agreement[1]	The green sawfish occurs in northern Australian waters, predominately from Broome (WA) to Cairns (Queensland). The species has a shark-like body, flattened head and elongated snout / rostrum studded with rostral teeth (the 'saw'). The green sawfish can grow up to 5 m in length (Department of the Environment, Water, Heritage and the Arts, 2008). The green sawfish typically occurs in shallow waters, including inshore marine waters, river mouths, estuaries and sandy / muddy beaches (Department of the Environment and Energy, 2019o). There are BIAs at Eighty Mile Beach, Roebuck Bay / Broome, Cape Leveque and Camden Sound for foraging, pupping and nursing. The PMST identified the green sawfish as potentially occurring within the vicinity of the proposed BTL route. However, given the habitat preferences and known distribution of this species, it is not expected that the green sawfish will occur within the Project Area.
Largetooth / Freshwater sawfish *(Pristis pristis)*	Vulnerable, International Agreement[1]	The largetooth sawfish is the largest freshwater fish in Australia, weighing up to 600 kg and reaching 6.56 m in length (Department of the Environment, 2014). The species has been recorded in sandy / muddy bottomed river and estuarine habitats. Records vary from 400 km inland out to 100 km offshore. The species undergoes a marked shift in habitat utilisation between early life stages and adult life stages; from riverine and estuarine habitats to marine and estuarine habitats (Department of the Environment, 2014). The largetooth sawfish has BIAs for foraging, nursing and pupping at 80 Mile Beach, Broome / Roebuck Bay and King Sound. Based on this species habitat preferences it is not likely that the largetooth sawfish will occur within the Project Area. The PMST search did not identify this species as potentially occurring within the Project Area.

[1] *Fauna protected under an International Agreement.*

[2] *This species was originally identified as potentially occurring within the Project Area in the Environmental Referral Supporting Document. The Project Area has since been refined and this species were not identified in the updated PMST search. Although raised by the DoEE as potentially being impacted by the proposed Browse to NWS Project, this species is not expected to occur within the Project Area. This species is included here for completeness.*

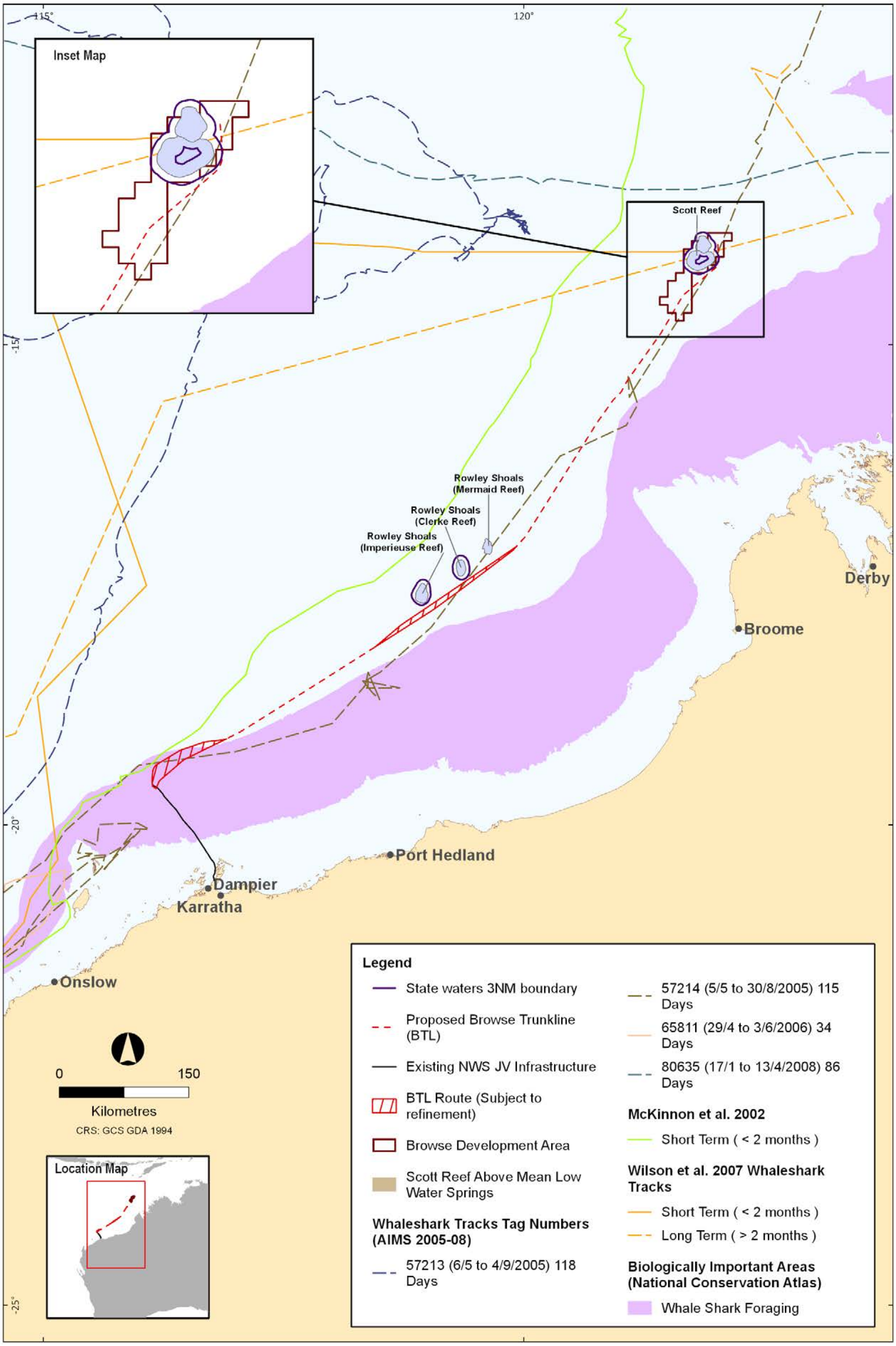

Figure 5-42 Satellite Tracking of Whale Shark Migration Pathways from Exmouth and Ningaloo. Individuals Typically Travelled North and East of the Project Area (McKinnon et al., 2002; Meekan and Radford, 2010; Wilson et al., 2006)

Scott Reef

A survey of shallow water fish communities (0-20 m) was undertaken by WAM at Scott Reef in 2006. At North Scott Reef, approximately 271 fish species were recorded of which 12% were confined to the lagoon, 31% confined to the outer reef, and 57% were found in both habitats (WAM, 2009). Species confined to the outer reef of North Scott Reef were more diverse and numerous. Out of the 325 fish species recorded from South Scott Reef during the same survey, around 11% were confined to the lagoon, 18% to the outer reef and 71% were found in both habitats (WAM, 2009). The overall composition of fish fauna at Scott Reef is generally similar to that of oceanic reefs in the tropical Indo-west Pacific, with a stronger affinity to the islands of eastern Indonesia than to the adjacent Australian mainland.

The species compositions of shallow reef fish assemblages at Scott Reef have been found to differ from those at Rowley Shoals located 300 km to the south. The main species responsible for such differences were the damselfish species *Pomacentrus lepidogenys* and *Chrysiptera rex* that were abundant at the Scott Reef system but absent from the Rowley Shoals. The most abundant species at Scott Reef belong to the family Pomacentridae, with nine of the ten most abundant species being from this family (Cripps et al., 2008).

High shallow-water fish species richness and abundance are recorded for the remote reef systems of the NWMR and species richness was higher at Scott Reef (721 species) than at either Ashmore Reef (568 species) or the Rowley Shoals (569 species; Gilmour et al., 2009b). A new record in Australia of the butterflyfish, *Chaetodon oxycephalus*, was noted for Scott Reef (Heyward et al., 2000). Studies did, however, record slightly more families of fishes at the Rowley Shoals and Ashmore Reef (75 families) than at Scott Reef (69 families; Gilmour et al., 2009b).

A study using BRUVS in water depths of 25 to 63 m at South Scott Reef lagoon recorded 228 demersal and pelagic fish species from 39 families (Cappo et al., 2008). Herbivorous and coral feeding families were widespread, and it is possible that deeper habitats offer refuge from the effects of coral bleaching for some species. Fish assemblages of South Scott Reef lagoon can be further classified according to environmental factors such as water movement, degree of exposure, water depth, habitat type and location within the lagoon.

Studies indicates fish communities at Scott Reef have undergone a significant change in composition through an 18-year period and they are now quite different to those that occurred on the reef prior to a mass coral bleaching event in 1998 (Gilmour et al., 2013). In the years following the 1998 coral bleaching at Scott Reef (described in **Section 5.3.1.3**), fish communities changed significantly as their habitats have been subject to change as a result of the environmental perturbations on the reef. Numbers of fish species reliant on hard coral (e.g. *Chaetodon trifascialis*) for food and/ or shelter were reduced during the initial post-bleaching phase (1998 to 2004) but increased with the recovery of hard corals (2005 to 2008). Conversely, the abundance of species with a dietary preference for algae (e.g. *Plectroglyphidodon lacrymatus*), which increased after the bleaching (1998 – 2004), have since declined (Gilmour et al., 2011, 2009a). Up until the most recent bleaching induced coral mortality at Scott Reef, a decline in herbivore abundance had been observed, with numbers of corallivores fish showing signs of stabilisation (Gilmour et al., 2013).

Abundances of larger, mobile fish species such as Labrids (wrasses) and Lethrinids (emperors), in particular seem to be unrelated to previous disturbances and abundances have increased steadily (approximately 30%; **Figure 5-24**; Gilmour et al., 2009a; 2010). A decrease in shark numbers over the past decade, most likely from overfishing (Gilmour et al., 2011; Meekan et al., 2006), may account for the increase in the large grazers.

The effect of the bleaching event in 1998 was most striking on the obligate associates of live coral, species that used coral either for food or for shelter. The impact of fishing on shark assemblages was investigated using BRUVS at shallow and deep remote oceanic reef systems sites at fished (Scott Reef, Cartier and Ashmore reefs) and unfished reefs (Rowley Shoals; Gilmour et al. 2007; Meekan et al. 2006). It was demonstrated that there were no differences in the species compositions of shark assemblages in the shallow water at all reefs. However, there were differences between fished and unfished reefs in deep water. Although there was evidence of recovery of shark numbers since the cessation of fishing at Ashmore and Cartier reefs, there was no evidence of such recovery at Scott Reef where fishing continues. This was particularly pronounced for species such as the grey reef shark (*Carcharhinus albimarginatus*), tiger shark (*Galeocerdo cuvier*) and the hammerhead sharks (*Sphyrna lewini* and *S. mokarran*).

Browse Trunkline

The seabed along the proposed BTL route does not feature any shallow or complex marine habitats, and as such fish communities along the BTL are representative of the deepwater habitats below the euphotic zone (greater than 200 m depth in open ocean) and the open-water pelagic zones in the NWMR. A PMST search of the proposed BTL route (**Chapter 10, Appendix C.2**) identified the same fish species as potentially occurring along the BTL route as identified for the Browse Development Area (**Table 5-27**). Similarly, to the Browse Development Area, whale sharks, long fin makos and short fin makos are likely to occur along the proposed BTL given their broad ranging distribution. The proposed

BTL route traverses a foraging BIA for whale sharks which extends north along the northern WA coastline (predominately inshore of the Project Area) from Ningaloo almost to the NT border. As described in Table 5-27 green sawfish and largetooth/freshwater sawfish are not expected to occur in the area of the proposed BTL route given the habitat preferences and known distribution of this species.

5.3.3 Regional Conservation Values of Relevance to the proposed Browse to NWS Project

5.3.3.1 Key Ecological Features

KEFs are elements of the Commonwealth marine environment that are considered to be of regional importance for either a region's biodiversity or its ecosystem function and integrity. The Commonwealth marine environment is a matter of national environmental significance (MNES) under the EPBC Act.

The following criteria are used to identify KEFs in Australia (Commonwealth of Australia, 2012a):

- a species, group of species or community with a regionally important ecological role (e.g. a predator, prey that affects a large biomass or number of other marine species)
- a species, group of species or community that is nationally or regionally important for biodiversity
- an area or habitat that is nationally or regionally important for:
  - enhanced or high biological productivity
  - aggregations of marine life
  - biodiversity or endemism
  - a unique seafloor feature with ecological properties of regional significance.

A summary of the KEFs located within the vicinity of the Project Area is provided in Table 5-28 below and shown in Figure 5-43. A detailed in Section 5.3.3.1 a benthic survey was undertaken along the BTL route in March and April 2019 to confirm the environmental characteristics of the seabed along the proposed BTL route (Advisian, 2019a, Chapter 10, Appendix D.1). The BTL environmental survey demonstrated that the seabed within the KEFs along the BTL route is typical of the broader region and largely devoid of epibenthic communities.

Table 5-28 Summary of Key Ecological Features (KEFs) within Proximity of the Project Area (Department of the Environment and Energy, 2019p)

KEF	Description	Distance from Project Area
Continental slope demersal fish communities	*High levels of endemism.* The diversity of demersal fish assemblages on the continental slope in the Timor Province, the North-west Transition and the North-west Province is high compared to elsewhere along the continental slope.	Within the Browse Development Area. The proposed BTL route traverses the KEF for ~ 250 km.
Seringapatam Reef and Commonwealth waters in the Scott Reef Complex	*High productivity and aggregations of marine life.* Seringapatam Reef and the Commonwealth waters in the Scott Reef complex are regionally important as they support diverse aggregations of marine life, high primary productivity and high species richness.	Within the Browse Development Area.
Ancient coastline at 125 m depth contour	*Unique seafloor feature with ecological properties of regional significance.* Parts of the ancient coastline, particularly where it exists as a rocky escarpment, are thought to provide biologically important habitats in areas otherwise dominated by soft sediments.	>40 km from Browse Development Area. The proposed BTL route traverses the KEF for ~ 40 km near the NRC tie-in point.
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	*High productivity and aggregations of marine life.* Mermaid Reef and the Commonwealth waters surrounding the Rowley Shoals are recognised as areas of enhanced productivity and high species richness, facilitated by the breaking of internal waves in the waters surrounding the reefs. This results in the mixing and re-suspension of nutrients from water depths of 500 to 700 m into the photic zone. Migratory pelagic species are present due to the steep changes in slope, such as dolphins, tuna, billfish and sharks.	325 km from the facilities and subsea infrastructure. The proposed BTL route is located within the KEF with the closest distance to boundary of the state marine park being 3 km (Clerke Reef) and ~ 2 km from the boundary of the Commonwealth Marine Park at Mermaid Reef.
Glomar Shoal	*High productivity and aggregations of marine life.* The Glomar Shoal is regionally important for their high biological diversity and high localised productivity. Evidence suggests that the shoals support a high abundance of fish.	>740 km from the facilities and subsea infrastructure. ~25 km from nearest point of the the proposed BTL route.
Canyons linking the Argo Abyssal Plain and Scott Plateau	*High productivity and aggregations of marine life.* The canyons linking the Argo Abyssal Plain and Scott Plateau are important features likely to be associated with aggregations of marine life.	>180 km from the facilities and subsea infrastructure. >180 km from nearest point of the proposed BTL route.
Ashmore Reef and Cartier Island and surrounding Commonwealth waters	*High productivity and aggregations of marine life.* Ashmore Reef and Cartier Island and surrounding Commonwealth waters are regionally important for feeding and breeding aggregations of bird and other marine life. They are all areas of enhanced primary productivity in an otherwise low-nutrient environment. Ashmore Reef also supports the highest number of coral species of any reef off the WA coast.	230 km from the facilities and subsea infrastructure. ~ 210 km from nearest point of the proposed BTL route.

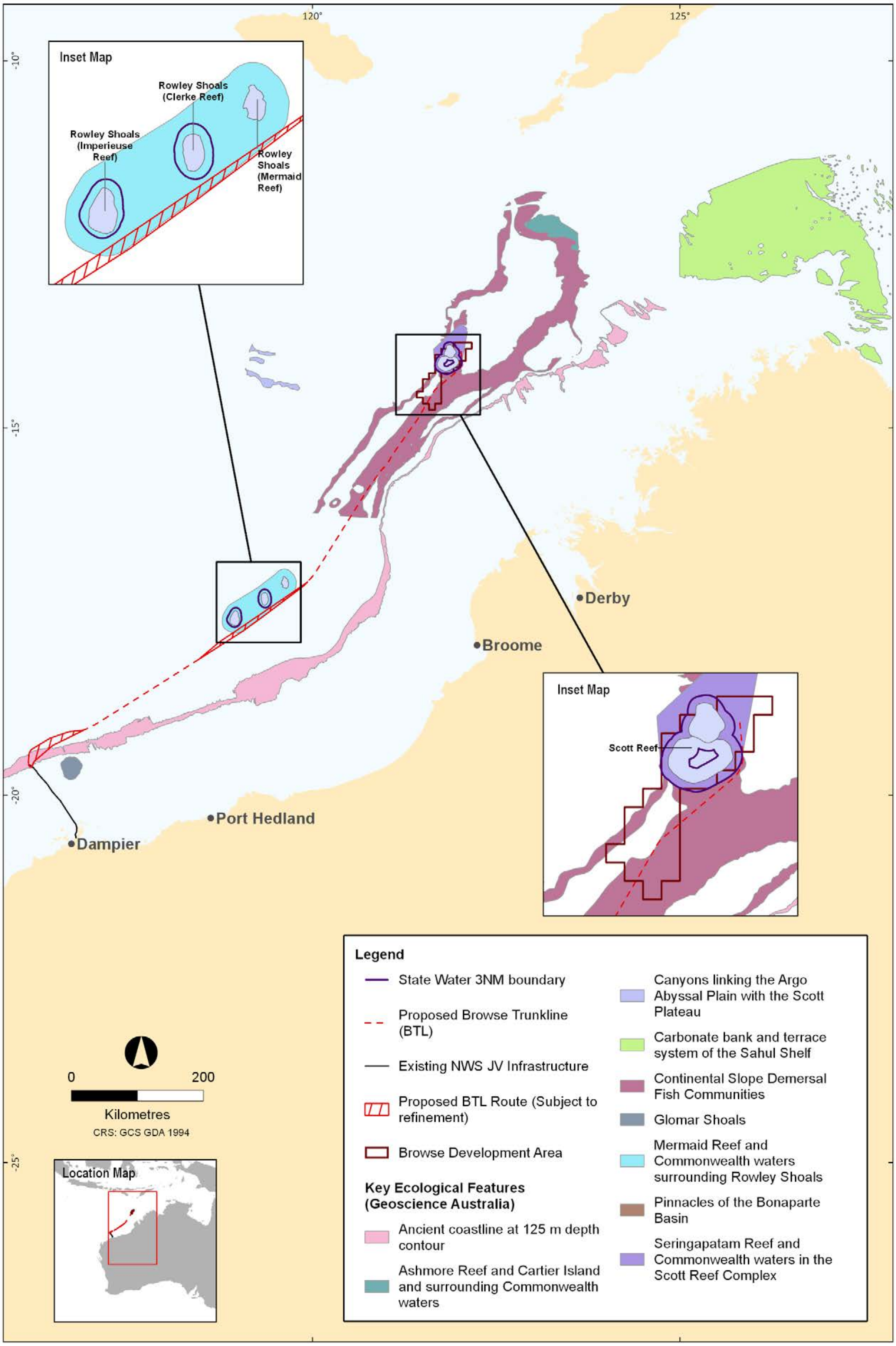

Figure 5-43 Key Ecological Features within the Vicinity of the Project Area (DoEE, 2019m)

5.3.3.2 Australian Marine Parks

A network of marine parks has been designated around Australia as part of a National Representative System of Marine Protected Areas (NRSMPA). There are six marine park networks geographically aligned with the Marine Regions of Australia. The objective of the network is to ensure sustainable use and enjoyment of the natural resources within the parks, whilst maintaining the protection and conservation of their biodiversity and natural, cultural, socio-economic and heritage values (Director of National Parks, 2018).

The proposed BTL route traverses through the multi-use zones (IUCN category VI) of the Kimberley and Argo-Rowley Australian Marine Parks (AMPs; as shown in **Figure 5-44**) which belong to the North-west Marine Parks Network. Additionally, the Project Area is located within the vicinity of several other AMPs within this network. These AMPs and their values are summarised in **Table 5-29** below, with a description of the benthic habitats and communities along the proposed BTL route included in **Section 5.3.1**.

A detailed in **Section 5.3.3.1** a benthic survey was undertaken along the BTL route in March and April 2019 to confirm the environmental characteristics of the seabed along the proposed BTL route (Advisian, 2019a). The BTL environmental survey demonstrated that the seabed within the AMPs along the BTL route is typical of the broader region and largely devoid of epibenthic communities.

Table 5-29 Australian Marine Parks (AMPs) within the Vicinity of the Project Area (Director of National Parks, 2018)

Australian Marine Park	IUCN Category[1]	Description and Values	Distance from Project Area
Kimberley Marine Park (74,469 km^2)	IV – Habitat/ species management area	The Kimberley Marine Park provides protection for the habitats and ecological communities in waters offshore of the Kimberley coastline, ranging in water depth from less than 15 to 800 m.	~ 40 km from the Browse Development Area. The proposed BTL route runs through the Multiple Use Zone (IUCN VI) of the Kimberley Marine Park for approximately 68 km.
		Natural values – natural values of the Kimberley Marine Park include: + ecosystems representative of the northwest shelf province, northwest shelf transition and Timor province (Section 5.2.1) + the KEFs 'Ancient coastline at the 125 m depth contour' and 'Continental slope demersal fish communities' intersect this AMP (see Section 5.3.3.1) + breeding habitat for seabirds (Section 5.3.2.3 and Section 5.3.2.4) + internesting and nesting habitat for marine turtles (Section 5.3.2.2, Section 5.3.2.3 and Section 5.3.2.4) + breeding, calving and foraging habitat for inshore dolphins (Section 5.3.2.5.3) + calving, migratory pathway and nursing habitat for humpback whales (Section 5.3.2.2 and Section 5.3.2.5.1) + migratory pathway for pygmy blue whales (Section 5.3.2.2 and Section 5.3.2.5.2) + foraging habitat for dugongs (Section 5.3.2.5.3) + foraging habitat for whale sharks (Section 5.3.2.2 and Section 5.3.2.8). Of these natural values, those relevant to the project are discussed throughout this Chapter (as per the section references provided).	
		Cultural values – key cultural values that extend into the Kimberley Marine Park and that are recognised by the national heritage listing for the West Kimberley are: + Wanjina Wunggurr Cultural Tradition + log-raft maritime tradition + interactions with Makassan traders + pearl resources. Due to the nature and coastal location of these values, they are not anticipated to be significantly impacted by project activities and have not been described further.	
		Heritage values – there are no international, Commonwealth or National heritage listings relevant to the Kimberley Marine Park.	
		Social and economic values – socio-economic values of this marine park include tourism, recreation, mining and traditional use. Relevant values are described further in Section 5.4.	

Australian Marine Park	IUCN Category[1]	Description and Values	Distance from Project Area
Argo-Rowley Terrace Marine Park (146,003 km^2)	VI – Protected area with sustainable use of natural resources	This AMP provides protection for the ecological communities and habitats of the deeper offshore waters of the region, in water depths ranging from 220 to 6,000 m. This includes protection for many bathymetric features, including aprons and fans, canyons, continental rise, knolls/abyssal hills and the terrace and continental slope. This AMP provides connectivity between the Mermaid Reef Marine Park / WA Rowley Shoals Marine Park and the deeper waters of the NWMR.	~ 125 km from the Browse Development Area. The proposed BTL route runs through the Multiple Use Zone (IUCN VI) of the Argo-Rowley Terrace Marine Park for approximately 97 km.
		Natural values – natural values of the Argo-Rowley Terrace Marine Park include: + ecosystems representative of the northwest transition and Timor province (**Section 5.2.1**) + the KEFs ‘Canyons linking the Argo Abyssal Plain and Scott Plateau’ and ‘Mermaid Reef and Commonwealth waters surrounding the Rowley Shoals’ intersect this AMP (see **Section 5.3.3.1**) + species listed as Threatened, Migratory, Marine or Cetacean under the EPBC Act (**Section 5.3.2**) + BIAs, including resting and breeding habitat for seabirds and a migratory pathway for the pygmy blue whale (**Section 5.3.2.2**). Of these natural values, those relevant to the project are discussed throughout this Chapter (as per the section references provided).	
		Cultural values – as noted in the ‘North-west Marine Park Management Plan’ (Director of National Parks, 2018), limited information regarding the cultural significance of this marine park is currently available.	
		Heritage values – there are no international, Commonwealth or National heritage listings relevant to the Argo-Rowley Terrace Marine Park.	
		Social and economic values – socio-economic values of this MP include fishing and mining. Relevant values to the proposed Browse to NWS Project are described further in **Section 5.4**.	

Australian Marine Park	IUCN Category[1]	Description and Values	Distance from Project Area
Ashmore Reef Marine Park (583 km^2)	Ia – Strict nature reserve	Ashmore Reef (see Section 5.3.3.4) is an emergent oceanic shoal with vegetated islands protected by this AMP. The reef and broader Marine Park is a stepping stone connecting reef systems along the WA coast by facilitating the transport of biological material. This AMP it is a biodiversity hotspot that features high endemism in demersal fish communities. The AMP supports some of the most important seabird breeding colonies on the NWS, and features BIAs for marine turtles, pygmy blue whales and dugongs. Ashmore Reef is also internationally recognised for its high diversity of sea snakes.	~ 230 km north-west of the Browse Development Area.
		Natural values – natural values of the Ashmore Reef Marine Park include: + ecosystems representative of the northwest shelf province, northwest shelf transition and Timor province (Section 5.2.1) + the KEFs 'Ashmore Reef and Cartier Island and surrounding Commonwealth waters' and 'Continental slope demersal fish communities' (see Section 5.3.3.1) + habitats associated with two extensive lagoons, sand flats, shifting sand cays, extensive reef flat and seagrass (Table 5-36) + species listed as Threatened, Migratory or Marine or Cetacean under the EPBC Act (Section 5.3.2.1) + BIAs, including those for seabirds, migratory shorebirds, marine turtles and the pygmy blue whale (Section 5.3.2.2) + features the Ashmore Reef Ramsar Site (Section 5.3.3.4). Of these natural values, those relevant to the project are discussed throughout this Chapter (as per the section references provided).	
		Cultural values – as noted in the 'North-west Marine Park Management Plan' (Director of National Parks, 2018), limited information regarding the cultural significance of this marine park for Indigenous Australians is currently available. The MP does, however, contain Indonesian artefacts and grave sites and the reef is still visited by Indonesian fishers (see Section 5.4.2.3).	
		Heritage values – there are no international or National heritage listings relevant to the Ashmore Reef MP. Ashmore Reef was Commonwealth Heritage listed in 2004.	
		Social and economic values – socio-economic values of this marine park include tourism, recreation and scientific research. Relevant values are described further in Section 5.4.	

Australian Marine Park	IUCN Category[1]	Description and Values	Distance from Project Area
Cartier Island Marine Park (172 km^2)	Ia – Strict nature reserve	This AMP encompasses a diversity of habitats, including Cartier Island (an unvegetated sand island described in Table 5-38), a mature reef flat, Wave Governor Bank (a submerged pinnacle), and two shallow pools. Cartier Island and the broader AMP is a stepping stone connecting reef systems along the WA coast by facilitating the transport of biological material. **Natural values** – natural values of the Ashmore Reef Marine Park include: + ecosystems representative of the Timor province (Section 5.2.1) + the KEFs 'Ashmore Reef and Cartier Island and surrounding Commonwealth waters' and 'Continental slope demersal fish communities' (see Section 5.3.3.1) + high diversity and abundance of hard and soft corals, gorgonians, sponges and encrusting organisms + species listed as Threatened, Migratory or Marine or Cetacean under the EPBC Act (Section 5.3.2.1) + BIAs, including those for seabirds, marine turtles and the whale shark (Section 5.3.2.2). Of these natural values, those relevant to the project are discussed throughout this Chapter (as per the section references provided). **Cultural values** – as noted in the 'North-west Marine Park Management Plan' (Director of National Parks, 2018), limited information regarding the cultural significance of this marine park for Indigenous Australians is currently available. **Heritage values** – there are no international, Commonwealth or National heritage listings relevant to the Cartier Island Marine Park. The Ann Millicent shipwreck is located within this AMP. **Social and economic values** – socio-economic values of this MP include scientific research. Relevant values are described further in Section 5.4.	~ 230 km north-west of the Browse Development Area.

Australian Marine Park	IUCN Category[1]	Description and Values	Distance from Project Area
Mermaid Reef Marine Park (540 km^2)	II – National park	The Mermaid Reef Marine Park features water depths between 15 and 500 m. Mermaid Reef is one of three reefs forming the Rowley Shoals (**Section 5.2.3.3**); the best geological example of shelf atolls in Australia. The AMP is of national and international significance due to its pristine character, coral formations, geomorphic features and diverse marine life. It is a key area for over 200 species of hard corals and 12 classes of soft corals with coral formations in pristine condition.	~ 325 km south-west of the Browse Development Area. ~ 2 km from the proposed BTL route at its closest point.
		Natural values – natural values of the Ashmore Reef Marine Park include: + ecosystems representative of the northwest transition (**Section 5.2.1**) + the KEF 'Mermaid Reef and Commonwealth waters surrounding Rowley Shoals' (see **Section 5.3.3.1**) + species listed as Threatened, Migratory or Marine or Cetacean under the EPBC Act (**Section 5.3.2.1**) + BIAs, including those for seabirds and the pygmy blue whale (**Section 5.3.2.2**) Of these natural values, those relevant to the project are discussed throughout this Chapter (as per the section references provided).	
		Cultural values – as noted in the 'North-west Marine Park Management Plan' (Director of National Parks, 2018), limited information regarding the cultural significance of this marine park for Indigenous Australians is currently available.	
		Heritage values – there are no international or National heritage listings relevant to the Mermaid Reef MP. Mermaid Reef was Commonwealth Heritage listed in 2004 and the 'Lively' shipwreck is located within this MP (**Section 5.4.3**)	
		Social and economic values – socio-economic values of this MP include scientific research. Relevant values are described further in **Section 5.4**.	

Australian Marine Park	IUCN Category[1]	Description and Values	Distance from Project Area
Dampier Marine Park (1,252 km²)	VI – Protected area with sustainable use of natural resources	The Dampier Marine Park is a shallow marine park ranging in water depths from 15 to 70 m. It encompasses several submerged reefs and shoals. The reserve provides a high level of protection for offshore shelf habitats adjacent to the Dampier Archipelago.	~ 800 km south-west of the Browse Development Area. ~ 105 km south-east of proposed BTL route at its closest point.
		Natural values – natural values of the Ashmore Reef Marine Park include: + ecosystems representative of the northwest shelf province (Section 5.2.1) + species listed as Threatened, Migratory or Marine or Cetacean under the EPBC Act (Section 5.3.2.1) + BIAs, including those for seabirds, marine turtles and the humpback whale (Section 5.3.2.2). Of these natural values, those relevant to the project are discussed throughout this Chapter (as per the section references provided).	
		Cultural values – no specific Indigenous Australian cultural values were noted in the 'North-west Marine Park Management Plan' (Director of National Parks, 2018), although the Ngarluma, Yindjibarndi, Yaburara and Mardudhunera people were identified as having responsibility for sea country within the marine park.	
		Heritage values – there are no international, Commonwealth or National heritage listings relevant to the Dampier Marine Park.	
		Social and economic values – socio-economic values of this MP include port activities commercial fishing and recreation. Relevant values are described further in Section 5.4.	
Montebello Marine Park (3,413 km²)	VI – Protected area with sustainable use of natural resources	The Montebello Marine Park is located offshore of Barrow Island in water depths of 15 to 150 m. The MP provides connectivity between the nearby Barrow Island and Montebello Islands MPs (Section 5.3.5.2) and deeper shelf and slope waters.	~ 860 km south-west of the Browse Development Area. ~ 62 km south-east of proposed BTL route at its closest point.
		Natural values – natural values of the Ashmore Reef Marine Park include: + ecosystems representative of the northwest shelf province (Section 5.2.1) + the KEF 'Ancient coastline at the 125m depth contour' (see Section 5.3.3.1) + species listed as Threatened, Migratory or Marine or Cetacean under the EPBC Act (Section 5.3.2.1) + BIAs, including those for seabirds, marine turtles, foraging habitat for the whale shark and a migratory pathway for the humpback whale (Section 5.3.2.2). Of these natural values, those relevant to the project are discussed throughout this Chapter (as per the section references provided).	
		Cultural values – no specific Indigenous Australian cultural values were noted in the 'North-west Marine Park Management Plan' (Director of National Parks, 2018).	
		Heritage values – there are no international, Commonwealth or National heritage listings relevant to the Montebello MP.	
		Social and economic values – socio-economic values of this marine park include tourism, commercial fishing, mining and recreation. Relevant values are described further in Section 5.4.	

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[1] *IUCN categories as listed in Director of National Parks (2018) and as defined by Natural Heritage Trust (2002)*

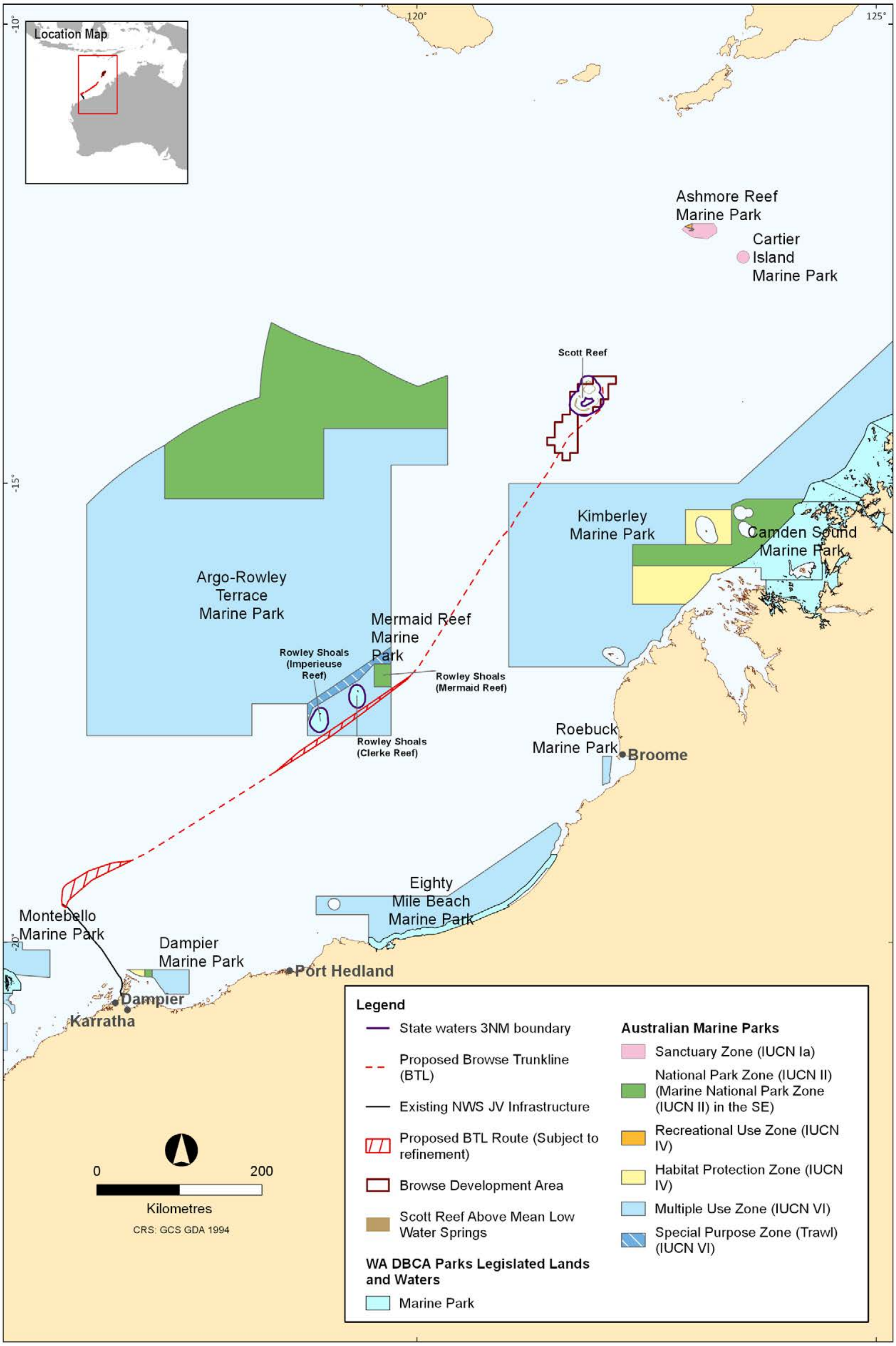

Figure 5-44 Australian Marine Parks (AMPs) and State Marine Parks within the Vicinity of the Project Area

5.3.3.3 State Marine Parks and Reserves

State Marine Parks in WA waters are managed by the Department of Biodiversity, Conservation and Attraction (DBCA). There are no State Marine Parks within the Project Area; those located within the vicinity of the Project Area are described in **Table 5-30** below and shown in **Figure 5-44**.

There is one nature reserve relevant to the Project Area; the Scott Reef Nature Reserve which was designated in 1993 and encompasses South Scott Reef (including Sandy Islet) down to the low mean water mark (Atlas of Marine Protection, 2019). This Nature Reserve protects the physical and ecological features of Scott Reef which are described throughout **Section 5**, including important nesting habitat (designated as a BIA and Habitat Critical for Survival of a Species) for the green turtle discussed in **Section 5.3.2.5.1**.

Table 5-30 State Marine Parks in the Vicinity of the Project Area (DEC, 2007a, 2007b)

State Marine Park	Description and Values	Distance from Project Area
Rowley Shoals Marine Park (877 km^2)	Major habitats of the Rowley Shoals Marine Park include intertidal and subtidal reefs, as well as reef drop offs which provide habitat for pelagic species. The Marine Park features high species richness; 184 coral, 264 mollusc, 82 echinoderms and 389 species of finfish have been recorded. It is considered a stepping stone between other islands and reefs offshore of Australia, as well as a source of recruitment for reefs south of the Rowley Shoals.	~ 3 km and ~4.5 km (Clerke Reef and Imperieuse Reef respectively) from the proposed BTL route.
Montebello Islands Marine Park (580 km^2)	The Marine Park encompasses the entirety of the Montebello Islands, with special purpose zones to protect benthic habitats and pearling areas. It features a variety of habitats and associated ecological communities (including seaward/leeward coral reef, macroalgal, seagrass, intertidal sand/mudflat and rocky shore/intertidal reef platform communities). Features important areas for turtle aggregation and nesting, and seabird breeding areas, and has a high diversity of fin fish and invertebrate species.	~ 100 km from the proposed BTL route.

5.3.3.4 Ramsar Wetlands of International Importance

A Ramsar wetland is a wetland area that has been declared so under Article 2 of the Ramsar Convention or under the EPBC Act. Ramsar wetlands are recognised as MNES under the EPBC Act. The 'Criteria for Identifying Wetlands of International Importance' (Department of the Environment and Energy, 2019) is used to determine if a site is eligible for listing and at least one of the nine criterion must be met for a site to be eligible.

The PMST report (**Chapter 10, Appendix C.1**) did not identify any Ramsar wetlands as occurring within the Project Area. There is, however, a Ramsar wetland within the vicinity of the Project Area; Ashmore Reef Marine Park (formerly Ashmore Reef National Nature Reserve) which is located approximately 200 km north-east of Scott Reef. This site provides important habitat for migratory seabirds and shorebirds.

5.3.3.5 Wetlands of National Importance

Wetlands of National Importance are classified based on criterion modified from those used to determine Ramsar wetlands (see **Section 5.3.3.4** above) to better suit an Australian context. A wetland must satisfy at least one of the six criteria to be eligible for listing.

The PMST report (**Chapter 10, Appendix C.1**) identified Mermaid Reef as the only Wetland of National Importance as occurring within the vicinity of the Project Area. Mermaid Reef is a part of the Rowley Shoals which comprises three distinct reef systems. Mermaid Reef is protected under the Commonwealth Mermaid Reef Marine Park, as described in **Section 5.3.3.2**. The proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park. Mermaid Reef is also listed on the Commonwealth Heritage List (CHL) (see **Section 5.4.3.3**) and is encompassed within the KEF, Mermaid Reef and Commonwealth waters surrounding the Rowley Shoals (see **Section 5.3.3.1**).

5.3.4 Onshore Supply and Logistical Support Bases

The proposed Browse to NWS Project will require supply chain and logistics support from the mainland during construction and operations. As described in **Chapter 3**, infrastructure and supply chain services within Western Australia may potentially be utilised. Specifically, the Port of Broome, Broome International Airport and the Karratha Supply Facility (located in the Port of Dampier) may be utilised throughout the life of the proposed Browse to NWS Project (**Figure 5-45**). In addition, the Exmouth Gulf may also support construction activities.

A PMST search was completed for the Broome and Karratha (Port of Dampier) facilities, grouped into two geographical search areas and applying a 10 km buffer (**Chapter 10, Appendix C3**). The results are summarised in **Table 5-31** and **Table 5-32**. A PMST search was also completed for the Exmouth Gulf, as summarised in **Table 5-33** (**Chapter 10, Appendix C.4**). The environment and relevant environmental sensitivities at these locations are described at a high level in the following sections. Impacts to terrestrial fauna and/or habitats as a result of increased air and vessel traffic at the existing facilities in relation to the proposed Browse to NWS Project are not expected. Therefore, only marine fauna and bird species have been discussed in the context of the existing facilities.

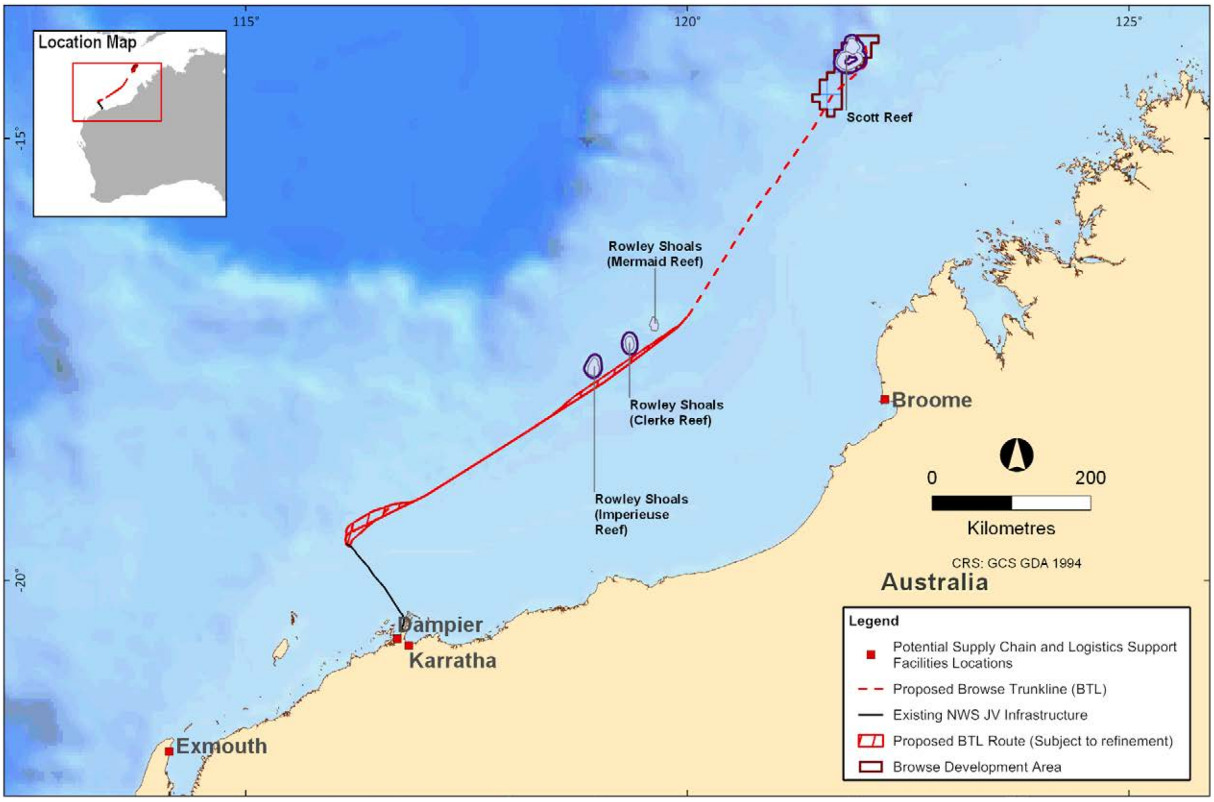

Figure 5-45 Potential Onshore Supply and Logistical Support Locations

Table 5-31 Summary of the PMST Search Undertaken for the Port of Broome and Broome International Airport

MNES	Number
World Heritage Properties	None
National Heritage Places	1
Wetlands of International Importance	1
Listed Threatened Ecological Communities	1
Listed Threatened species	31
Listed Migratory species	65
Commonwealth Marine Areas	1
Great Barrier Reef Marine Park	N/A

Table 5-32 Summary of the PMST Search Undertaken for the Karratha Supply Facilities (Port of Dampier)

MNES	Number
World Heritage Properties	None
National Heritage Places	1
Wetlands of International Importance	None
Listed Threatened Ecological Communities	None
Listed Threatened species	31
Listed Migratory species	60
Commonwealth Marine Areas	None
Great Barrier Reef Marine Park	N/A

Table 5-33 Summary of the PMST Search Undertaken for the Exmouth Gulf

MNES	Number
World Heritage Properties	1
National Heritage Places	1
Wetlands of International Importance	None
Listed Threatened Ecological Communities	None
Listed Threatened species	29
Listed Migratory species	42
Commonwealth Marine Areas	None
Great Barrier Reef Marine Park	N/A

5.3.4.1 Broome Facilities

Facility Overview

The Port of Broome is the largest deepwater port servicing the Kimberley region of WA and is the main fuel and container receiving point for the region. The port supports a variety of services and industries, including livestock export, offshore oil and gas exploration supply vessels, pearling, fishing charter boats, cruise liners (Kimberley Port Authority, 2019). Facilities at the port include an outer berth, and two inner berths, fuel and potable water distribution facilities, a laydown area, lighting suitable for night work, and a slipway. The Port of Broome is operated by the Kimberley Ports Authority.

The Broome International Airport is located in the centre of Broome, with the heliport located wholly within the boundary of the airport. The heliport opened in November 2008 in response to the increasing demand for helicopter flight operations to oil and gas platforms in the Browse Basin (Broome International Airport, 2019). The heliport comprises two hangars with provision of apron space for each hangar. A helipad is also available on site with space for four larger helicopters, 10 additional helicopter parking positions are available in the vicinity of the airport.

Local Environment

A number of the species identified by the PMST report are seabird and shorebird species (including a number previously discussed in Section 5.3.2) that are known to utilise neighbouring coastal habitats such as those at Roebuck Bay to the south of the port, as well as the coastal and offshore marine environments in the Kimberley region. Roebuck Bay features mangrove creeks and tidal mudflats, with extensive salt marshes inland of these habitats. These and the other habitats featured within Roebuck Bay, are protected by the State Marine Park Yawuru Nagulagun / Roebuck Bay Marine Park and more broadly by the Commonwealth Roebuck Marine Park.

Listed and migratory marine fauna species identified by the PMST report include the salt-water crocodile (*Crocodylus porosus*) and freshwater crocodile (*C. johnstoni*). The saltwater crocodile can reach lengths of 8 m and weigh up to 1,000 kg (Commonwealth of Australia, 2012c). The species is generally found north of the Broome area in coastal waters, as well as estuaries, marshes and inland swamps. The saltwater crocodile is particularly prevalent in the major river systems within northern WA, although the species may also be found some distance offshore (Commonwealth of Australia, 2012c). The species preferentially nests in areas with reduced tidal variability (Commonwealth of Australia, 2012c). The saltwater crocodile may occur within the waters of the Port of Broome, however, minimal interaction with vessels is expected. The freshwater crocodile occurs in brackish and freshwater habitats, occasionally occupying near coastal areas where saltwater crocodiles are absent (Australian Museum, 2018). The freshwater crocodile is, therefore, unlikely to occur within the Port of Broome area.

The following dolphin species were identified by the PMST report as potentially occurring within the area;

the Australian snubfin dolphin, *Orcaella heinsohni*, Indo-Pacific humpback dolphin, Sousa sahulensis. and spotted bottlenose dolphin, *Tursiops aduncus*. These three species have foraging, breeding and calving BIAs which encompass the Broome Port area and adjacent Roebuck Bay. All three species are presumed resident to the area due to rich and consistent prey availability. In particular, Roebuck Bay is known to be an important location for the Australian snubfin dolphin both locally and regionally as it supports the largest population reported in Australia (Department of Parks and Wildlife, 2016; Department of the Environment and Energy, 2015; DEWHA, 2008); a survey undertaken over an area approximately 100 km^2 of Roebuck Bay estimated the population of Australian snubfin dolphins to be around 133 individuals (excluding dependant calves) (Department of Parks and Wildlife, 2016). The Indo-Pacific humpback dolphin and spotted bottlenose dolphin appear to display a preference for more open coastal waters (Department of Parks and Wildlife, 2016).

Dugongs are also known to occur within Roebuck Bay. The bay has seagrass habitats containing two species of seagrass preferred by dugong; narrow-leaf seagrass (*Halophila ovalis*) and paddleweed (*Halophila ovalis*) (Department of Parks and Wildlife, 2016). A survey targeting dolphins in 2013 encountered dugongs in small groups within the northern third of Roebuck Bay, which has been supported by the findings of other studies (Department of Parks and Wildlife, 2016). The species is highly mobile, however, potentially moving out of the bay area to forage (Department of Parks and Wildlife, 2016). Population numbers for the dugong are not certain within Roebuck Bay; a 1984 survey estimated a population of 50 to 100 individuals, however, recent research indicates this figure may have been an underestimate due to the survey methods used. More recent anecdotal records indicate numbers may be declining (Department of Parks and Wildlife, 2016). Notably, the dugong is of cultural significance to the Yawuru people and customary hunting occurs outside of the birthing season (late September to November) (Department of Parks and Wildlife, 2016). Dugongs are also known to occur within Roebuck Bay. A survey targeting dolphins in 2013 encountered dugongs in small groups within the northern third of Roebuck Bay, which has been supported by the findings of other studies (Department of Parks and Wildlife, 2016). The species is highly mobile, however, potentially moving out of the bay area to forage (Department of Parks and Wildlife, 2016).

Other marine species identified by the PMST report include sea snakes, marine turtles and sawfish.

5.3.4.2 Dampier Facilities

Facility Overview

The Port of Dampier is one of the world's largest bulk export ports, with a network that services the Pilbara region and the offshore industry of the NWS (Pilbara Ports Authority, 2019). The Port of Dampier encompasses both King Bay Supply Base (KBSB) and the Burrup Materials Facility (BMF).

The KBSB covers an area of approximately 15 ha and is suitable for a wide range of vessels varying in size and configuration such as harbour tugs, supply vessels, crew and utility vessels, and transportation/heavy lift vessels. The BMF, has been used as a project/construction service facility since its establishment approximately four years ago to support offshore platforms and LNG processing facilities associated with the Woodside Pluto Project (Woodside Energy Limited, 2012).

There are specific shipping channels designated to operators within the port, including a Woodside Channel which passes through Mermaid Sound (Pilbara Ports Authority, 2019). For the year ending June 2018, a total of 3,697 vessels visited the Port of Dampier and 177,338,778 tonnage was achieved, the bulk of which was exports (Pilbara Ports Authority, 2018). Notably, the Dampier Port Authority amalgamated with the Port Hedland Port Authority in 2014 to form the Pilbara Ports Authority.

Local Environment

The Port of Dampier is partially sheltered by the Dampier Archipelago, a chain of 42 coastal islands, islets and rocks (Department of Biodiversity, Conservation and Attractions, 2019). The diverse habitats of the archipelago, such as mangroves, sandy beaches and reefs, support a variety of wildlife, as described below.

A number of the species identified by the PMST report are terrestrial species which will not interact with proposed Browse to NWS Project related vessel movements within the Port of Dampier (e.g. the Greater Bilby). Other species identified by the PMST report which may interact with proposed Browse to NWS Project vessels include marine turtles, migratory and resident cetaceans, dugongs, sharks and marine birds which may be located within the vicinity of the port.

Marine Turtles

As described in **Section 5.3.2.5**, green and flatback turtles are known to nest at the Lacepede Islands and Dampier Peninsula. A study undertaken by RPS between July 2009 and March 2010 of marine turtles in the Kimberley region, specifically along the west coast of the Dampier Peninsula and the Lacepede Islands (comprising West, Middle, Sandy Islet and East Islands) used aerial, vessel-based and onshore survey methods

(RPS Environment and Planning Pty Ltd, 2010[18]). Key findings were as follows:

Aerial Surveys

- A total of 1,875 marine turtles were recorded at the waters surface during aerial surveys between Cape Bossut and Cape Leveque (inclusive of 305 marine turtles recorded around the Lacepede Islands) between March and October 2009, with a peak in March of 975 marine turtles. The majority of turtles were recorded as being within 18 km of the coast and within 0 – 20 m water depth.
- These aerial surveys identified the nearshore areas between Coulomb Point and Quondong Point, as well as 20 km offshore of Willie Creek (coastal areas south of the Lacapede Islands) as also having high densities of marine turtles during the March 2009 survey period.
- Low densities if marine turtles were recorded at the Lacepede Islands during aerial surveys undertaken in the non-nesting period (July 2009 and September 2009).
- Low densities of marine turtles were recorded up to 118 km offshore during aerial surveys focusing on a migration corridor between Scott Reef and the Lacepede Islands (described in **Section 5.3.2.5.1**) between July and October 2009. Notably, these records were of lone and intermittent marine turtles. The majority of records were closer to Scott Reef (approximately > 270 km offshore).

Vessel Surveys

- Three marine turtle species, the green, flatback and hawksbill turtle, were identified during vessel based surveys undertaken at two survey locations (James Price Point and Pender Bay) between July and October 2009. Just four of the 70 marine turtles sighted during this survey were recorded within the Pender Bay survey area. Fourty of the 66 marine turtles sighted within the James Price Point Survey area were identified to species level; 45% were flatback turtles, 30% were green turtles and the remaining 25% were loggerhead turtles. No hawksbill turtles were identified during this survey.
- A second vessel-based survey undertaken between December 2009 and February 2010 targeted areas of high density identified by the above mentioned surveys. This survey indicated that the Lacepede Islands support high densities of green turtles (32 of 43 marine turtle sightings) and low densities of flatback turtles (5 of 43 marine turtle sightings). No hawksbill turtles were recorded at the Lacepede Islands during this survey.
- The second vessel-based survey identified 20 marine turtles (12 green turtles, 4 hawksbill turtles, 2 flatback turtles, 2 of unidentified species) along the Dampier Peninsula.

Onshore Surveys

- Onshore surveys identified the following as potential nesting beaches along the James Price Point coastal area: Jajal Beach, Quondong South Beach, Quondong Beach (Mango Farm), Murdundun Beach (James Price Point south), James Price Point Beach (main beach) and Manari Beach (between Flat Rock and Coloumb Point);
- Potential nesting beaches were identified on each of the Lacepede Islands, with a number of potential barriers to nesting identified for each (i.e. rocky substrates, sand bars, steep dunes).

Satellite Tagging

- Eight of 11 satellite tags attached to green turtles at the Lacepede Islands provided internesting data. Tagged turtles remained within 20 km of the Lacepede Islands during this period, remaining on average within 5 km of the islands. The average nesting interval was just under 11 days and individuals exhibited high site fidelity, with no individuals moving between islands during the internesting period. All tagged green turtles commenced their post-nesting migration by the end of February; eight migrated northwards and three migrated southward. Post-nesting locations for these turtles included Bathurst Island, the NT, Eighty Mile Beach, the Rowley Shoals and King Island.
- Six of 11 satellite tags attached to flatback turtles at the Lacepede Islands provided internesting data. Tagged turtles remained within 50 km of the Lacepede Islands (the majority within 5 km) and the nesting interval was just under 15 days. All tagged flatback turtles commenced their post-nesting migration by the end of February; nine travelled in a north-eastern direction and two remained within 17 km of the Lacepede Islands for the duration of the tracking. Post-nesting locations extended as far as Gale Banks in the northern Kimberley.

Summarily, internesting marine turtles at the Lacepede Islands and along the Dampier Peninsula remain close to coastal areas before commencing their post-nesting migration primarily northwards.

5.3.4.3 Exmouth Gulf

The Exmouth Gulf, approximately 1,150 km southwest of the Browse Development Area, is a large (~3,000 km^2) shallow basin enclosed by the North West Cape to the west and Locker Point to the east. Woodside (and their

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[18] *RPS Environment and Planning Pty Ltd, 2010 available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

contractors) currently undertake activities within the Exmouth Gulf throughout the year to support their nearby operations off the North West Cape. As part of the proposed Browse to NWS Project, there is the potential that the Exmouth Gulf will be utilised for logistical and support activities during construction.

Due largely to the role that the Exmouth Gulf plays in hosting listed and migratory marine fauna as well as the extensive mangroves communities on the eastern shoreline, the area is of environmental significance. The mangroves on the eastern coast of the Exmouth Gulf form the largest unit of intact arid zone mangrove ecosystems in the world (Fitzpatrick et al., 2019). The Exmouth Gulf is also known to host large numbers of humpback whales, particularly during their southern migration, when cows with calves have been observed using the area as a resting location prior to the continuation of their southward migration (Fitzpatrick et al., 2019; Jacobs, 2019; Bejder 2019; **Section 5.3.2.4.1**). The Muiron Islands (off the North West Cape) have been identified as critical nesting and internesting habitat for loggerhead turtles and also support a major green turtle rookery (**Section 5.3.2.5.2**). In addition, the Exmouth Gulf is also known to host a significant resident population of dugongs (Fitzpatrick et al., 2019; Hodgson, 2007).

The conservation significance of the Exmouth Gulf and its habitats in supporting listed resident and migratory species on both the east and west coasts, has been previously recognised by state and federal authorities through its consideration for inclusion in the Ningaloo Coast World Heritage Area (World Heritage Consultative Committee 2005) and recognition as an area of regional significance by the WA EPA (DPIRD, 2018a).

In addition to its environmental significance, the Exmouth Gulf hosts key regional commercial and recreational industries, with significant tourism, recreation and commercial fishing undertaken within its waters. An extensive prawn trawling fishery exists within the Exmouth Gulf and is one of the largest trawl fisheries in WA. The fishery covers an area of approximately 3,907 km^2, although permanent closures account for approximately 30% of the entire fishery area (DPIRD, 2018a). In 2017 the fishery consisted of six boats with an estimated annual value of $10-20 million (including by product) and a total catch of between 500 to 1400 tonnes per annum (DPIRD, 2018a).

5.3.5 Environment that May Be Affected (EMBA)

The environment that may be affected (EMBA) is the largest spatial extent where unplanned events could have an environmental consequence on the surrounding environment. The maximum extent of area that may be affected is driven by the potential area that may be exposed to hydrocarbons in the event of a worst case credible spill scenario. The EMBA has been derived by merging the maximum spatial extent for all stochastic modelling results, that is the result of 100 single trajectories run for each season for each scenario.

Four worst credible oil spill scenarios were modelled by RPS for the proposed Browse to NWS Project (RPS, 2019). These are described in detail in **Chapter 6** and summarised here:

- Scenario 1: long term (77 day) surface / sub-surface blowout of Torosa condensate at the TRA-C well.
- Scenario 2: short term (24 hour) surface release of Browse condensate after a vessel cargo tank rupture near the TRA-C well.
- Scenario 3: short-term (instantaneous) surface release of Browse condensate after a vessel offtake system failure near the TRA-C well.
- Scenario 4: short-term (instantaneous) surface release of marine diesel after a vessel fuel tank rupture near the Rowley Shoals.

Scenarios 1, 2 and 3 relate geographically to the TRA-C well located within the Torosa reservoir, whereas Scenario 4 relates geographically to the Rowley Shoals, almost 400 km south east of Scott Reef. The EMBA for the proposed Browse to NWS Project was subsequently created to encompass Scenarios 1, 2 and 3 within the Browse Development Area adjacent to Scott Reef, as well as Scenario 4 projected for the length of the proposed BTL route.

A PMST search (**Chapter 10, Appendix C.5**) was undertaken for this consolidated EMBA to identify MNES potentially occurring within this area. The results of the report are summarised in **Table 5-34**. Regional conservation values located within the EMBA are summarised in **Table 5-35**.

Table 5-34 Summary of the PMST Report Generated for the EMBA

MNES	Number
World Heritage Properties	None
Commonwealth Heritage Places	3
National Heritage Places	2
Wetlands of International Importance	1
Listed Threatened Ecological Communities	None
Listed Threatened species	44
Listed Migratory species	64
Commonwealth Marine Areas	2
Great Barrier Reef Marine Park	N/A

Table 5-35 Regional Conservation Values within the EMBA

Category	Name
KEFs	+ Canyons linking the Argo Abyssal Plain with the Scott Plateau + Mermaid Reef and Commonwealth waters surrounding Rowley Shoals + Glomar Shoal + Ancient Coastline at 125 m depth contour + Ashmore Reef and Cartier Island and surrounding Commonwealth waters + Seringapatam Reef and Commonwealth waters in the Scott Reef Complex + Continental Slope Demersal Fish Communities. + Carbonate bank and terrace system of the Sahul Shelf.
AMPs	+ Argo-Rowley Terrace Marine Park + Cartier Island Marine Park + Dampier Marine Park + Kimberley Marine Park + Montebello Marine Park + Mermaid Reef Marine Park + Ashmore Reef Marine Park
State MPs & Marine Reserves	+ Browse Island Nature Reserve + Rowley Shoals Marine Park + Scott Reef Nature Reserve + Dampier Archipelago Island Reserves + Montebello Islands Conservation Park + Montebello Islands Marine Park + Barrow Island Nature Reserve + Barrow Island Marine Park + Barrow Island Marine Management Area + Great Sandy Island Nature Reserve + Lowendal Islands Nature Reserve + Boodie, Double Middle Islands Nature Reserve (between BWI and Lowendal).
Ramsar Wetlands of International Importance	+ Ashmore Reef Marine Park
Wetlands of National Importance	+ Ashmore Reef + Mermaid Reef

A number of the MNES, regional conservation values and other environmental receptors relevant to the EMBA have been discussed in this section, particularly those relating to Scott Reef and the Rowley Shoals. Those not already discussed and those requiring description in greater detail are addressed in this sub-section.

5.3.5.1 Submerged and Emergent Reefs and Shoals

The submerged and emergent reefs and shoals whose physical environment is described in **Section 5.2.3** are located both within the Project Area and EMBA. The ecological values of these features, as well as the physical characteristics and ecological values of the other submerged and emergent reefs and shoals within the EMBA (with the exception of Scott Reef and Rowley Shoals which have been described in **Section 5.3.1**) are summarised here in **Table 5-36**. The location of these geomorphic features is shown on **Figure 5-46**.

Table 5-36 Ecological Values of the Submerged and Emergent Shoals and Reefs within the EMBA

Submerged or Emergent Shoals / Reefs	Description of Ecological Values	Distance / direction from Browse Development Area
Seringapatam Reef	Seringapatam Reef, approximately 25 km from Scott Reef, features similar marine habitats and species to those found at Scott Reef. The reef is an area of high primary productivity and high species richness with regards to both benthic and pelagic marine life. Seringapatam reef is known to historically provide habitat for sea snakes and a diverse assemblage of fish (Department of the Environment and Energy, 2019b). Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex are recognised as a KEF (see **Section 5.3.3.1**) due to the diverse aggregations of marine life that they support.	18 km north-north east
Ashmore Reef	Ashmore Reef features reef habitats as well as associated sandy and vegetated terrestrial habitats which are used by breeding seabirds, sea snakes, dugongs and marine turtles. Specifically, five wetland habitat types have been identified at Ashmore Reef in the context of its listing as a Ramsar Site; permanent shallow marine waters, marine subtidal aquatic beds (including kelp beds, sea-grass beds, and tropical marine meadows), coral reefs, sand, shingle or pebble shores (including sand bars, spits and sandy islets), Intertidal mud, sand or salt flats (Commonwealth of Australia, 2013). Seagrass, algae and coral occur within both the subtidal and lagoon habitats of Ashmore Reef. At the time of listing as a Ramsar site, 42 threatened coral species were recorded at Ashmore Reef, including 41 species of hard, reef forming coral and a single species of soft coral (Commonwealth of Australia, 2013). Ashmore Reef also supports the highest diversity of mollusc species within the Timor Province bioregion with over 600 species recorded at the site, and a high diversity of fish species compared with other reefs in the bioregion (Commonwealth of Australia, 2013).	201 km north-east
Cartier Island	Cartier Island is an unvegetated sand cay located approximately 50 km south-east of Ashmore Reef. The island is surrounded by a reef flat with extensive coral communities evident. The island and the surrounding waters form the Cartier Island Marine Park (a Commonwealth Marine Park, described in **Section 5.3.3.2**). In addition, the island forms part of the Ashmore Reef and Cartier Island and surrounding Commonwealth waters KEF (**Section 5.3.3.1**). Cartier Island features sand flats and waters which are habitat critical for the survival of the green turtle (described in **Section 5.3.2.3**), as well as important feeding grounds for migratory shorebirds during non-breeding periods, and staging grounds for migratory birds as they travel through the EAAF.	208 km north east

Submerged or Emergent Shoals / Reefs	Description of Ecological Values	Distance / direction from Browse Development Area
Browse Island	Browse Island is a vegetated sand cay surrounded by an intertidal reef platform and shallow fringing reef located approximately 150 km to the east of the Browse Development Area (URS Australia Pty Ltd, 2010). The reef rises from a depth of approximately 200 m and is oval in shape, whereas the sandy cay is triangular (approximately 700 by 400 m) (URS Australia Pty Ltd, 2010). Browse Island is a major rookery for green turtles and a nesting area for flatback turtles. Localised upwellings occur around the island and may be associated with concentrations of tropical krill, a potential source of food for blue whales in the Region. Waters surrounding Browse Island support a larger number of cetacean species than anywhere else in Western Australia, including large pods of oceanic dolphins, pygmy killer whales, false killer whales, melon-headed whales, minke whales and pilot whales (DEWHA, 2008). There is a Nature Reserve at Browse Island which protects these values. Studies undertaken by URS in 2010 found the reef habitats at Browse Island were not diverse, that there were no intertidal sand flats, and the lagoon habitat was poorly developed (URS Australia Pty Ltd, 2010). There was a noticeable lack of invertebrate marine species which would otherwise be expected on similar habitats. Only a narrow strip of beach was available to marine turtles to nest on (URS Australia Pty Ltd, 2010). It was unclear as to whether this lack of diversity and movement of sand to expose rock habitats was due to a recent storm or other damaging event, long-term trend or seasonal variation (URS Australia Pty Ltd, 2010).	150 km east
Heywood Shoal	Heywood shoal is an oval shaped reef rises steeply from the continental shelf, in approximately 100 m depths to the plateau of the shoal which lies in approximately 13m depth and covers an area of ~32 km^2 (Heyward et al., 2012). The shoal is dominated by algae, followed by hard corals. Heywood Shoal is inhabited by a diverse and abundant fauna of reef-associated fishes, sharks, rays and sea snakes. The shoal tops are dominated by fish species associated with hard coral habitats. At Heywood Shoal there are four fish assemblages associated with hard coral, and patterns in species richness, fish abundance and community structure are all primarily associated with water depth and cover of epibenthos (Heyward et al., 2017).	207 km east – north east
Eugene McDermott Shoal	Eugene McDermott Shoal is characterised by steep sides in approximately 180 m depths to the top of the shoal which lies in approximately 20 m depth (Heyward et al., 2012). The relatively shallow domed shoal top is characterised by a high cover of hard coral habitat. Eugene McDermott Shoal supports relatively diverse and abundant fish assemblages compared to the surrounding deeper continental shelf habitat. Higher fish assemblage diversity was identified by Heyward et al. (2012) at Eugene McDermott Shoal than the smaller nearby Goeree Shoal, which may be a consequence of the greater variation in benthic habitats.	275 km north east

Submerged or Emergent Shoals / Reefs	Description of Ecological Values	Distance / direction from Browse Development Area
Vulcan Shoal	Vulcan Shoal rises steeply from the continental shelf in approximately 180 m depths to the plateau of the shoal which lies in approximately 20-40 m depth (Heyward et al., 2012; Heyward et al., 2017). The Vulcan Shoal plateau is relatively large compared to other shoals in the area (12.54 km^2) and the shallow regions around the margin of the plateau are dominated by algae then hard coral communities and seagrass (as described in **Section 5.3.1.3**). Site attached fish assemblages are associated with the relatively shallow areas with high coral cover and include species such as angelfish (Chaetodontidae), butterfly fish (Pomacanthidae) and snapper (Lutjanidae; Heyward et al., 2012).	256 km north east
Goeree Shoal	Similar to Eugene McDermott Shoal, Goeree Shoal is characterised by a steep side shoal rising from approximately 170 m to < 40 m, the shoal top forms a plateau and lies at approximately 20-40 m depth. The shoal is dominated by algae and the western end of the plateau is relatively shallow and characterised by hard coral communities and seagrass (Heyward et al., 2012; Heyward et al., 2017). The relatively complex benthic habitats of Goeree Shoal support a diverse fish assemblage compared to the surrounding deeper seabed habitat surrounding the shoal.	257 km north east
Barracouta Shoal	Barracouta Shoal is comprised of two separate and distinct shoals (Barracouta East and Barracouta West) with a deep channel (~212 m depth) between them. Barracouta East is egg-shaped and covers an area of 5.8 km^2 and Barracouta West is circular in shape and covers an area 3 km^2. The shoal tops are in water depths of approximately 10 m and are dominated by algae (as described in **Section 5.3.1.3**), followed by hard corals and then seagrass coverage, as detected on Barracouta East in 2016 (Heyward et al., 2017).	247 km north east
Hibernia Reef	Hibernia Reef consists of an oval shaped reef that tapers to a point on the western side, covering an area of approximately 11.5 km^2 and is characterised by a deep central lagoon and drying sand flats. The reef has no permanent emergent features, however large areas of the reef can become exposed at low tide (ConocoPhillips Australia Exploration Pty Ltd, 2018; Shell Australian Pty Ltd, 2018). Hibernia Reef is notable for high biodiversity of marine fauna and flora, and provides feeding and breeding areas for marine turtles and critical habitat for dugongs (Whiting, 1999). As mentioned in **Section 5.3.2.7**, Hibernia Reef has also historically been known for its high diversity of sea snakes. Surveys conducted at Ashmore Reef and Hibernia Reef recorded 125 different species of sponges, 32 of which were identified as being endemic to the reefs (as described in **Section 5.3.1.4**; Hooper et al 2002). Fantome Bank, located approximately 65 km north east of Hibernia Reef and 308.9 km north east of the Browse Development Area, is also within the EMBA. There is a paucity of information available for this bank, with regard to both the physical and ecological environment.	243 km north east

Submerged or Emergent Shoals / Reefs	Description of Ecological Values	Distance / direction from Browse Development Area
Rankin Bank	Rankin Bank represents a diverse marine environment, predominantly composed of consolidated reef and algae habitat (~55% cover), followed by hard corals (~25% cover), unconsolidated sand/silt habitat (~16% cover), and benthic communities composed of macroalgae, soft corals, sponges and other invertebrates (~3% cover) (AIMS, 2014 and Wahab et al., 2018). Hard corals are a significant component of the benthic community of some parts of the bank, with abundance in the upper end of the range observed elsewhere on the submerged shoals and banks of north-west Australia (Heyward et al., 2012). The habitats featured here are likely to play an important role in the productivity of the Pilbara region (AIMS, 2014). Surveys have indicated that Rankin Bank has higher cover of hard corals, and higher abundance of fish compared with Glomar Shoal (Wahab et al., 2018). Rankin Bank has also been shown to support a diverse fish assemblage (AIMS, 2014). This is consistent with studies showing a strong correlation between habitat diversity and fish assemblage species richness (Gratwicke and Speight, 2005; Last et al., 2005).	838 km south west
Glomar Shoal	Studies undertaken at Glomar Shoal by Wahab et al. (2018) found a number of hard coral and sponge species in water depths less than 40 m. One hundred and seventy different species of fish were also detected with greatest species richness and abundance found in shallow habitats. Fish species at the Shoal included a number of commercial and recreational species such as Rankin cod, Brown striped snapper, Red emperor, Crimson snapper, Bream and Yellow-spotted triggerfish (Falkner et al., 2009; Fletcher and Santoro, 2009). These species have recorded high catch rates associated with the Glomar Shoal, indicating that the shoals are likely to be an area of high productivity. The Glomar Shoal is defined as a KEF for their high productivity and aggregations of marine life (as described in **Section 5.3.3.1**). Cyclones are also frequent in this area of the north-west and stimulate periodic bursts of productivity as a result of increased vertical mixing.	729 km south west

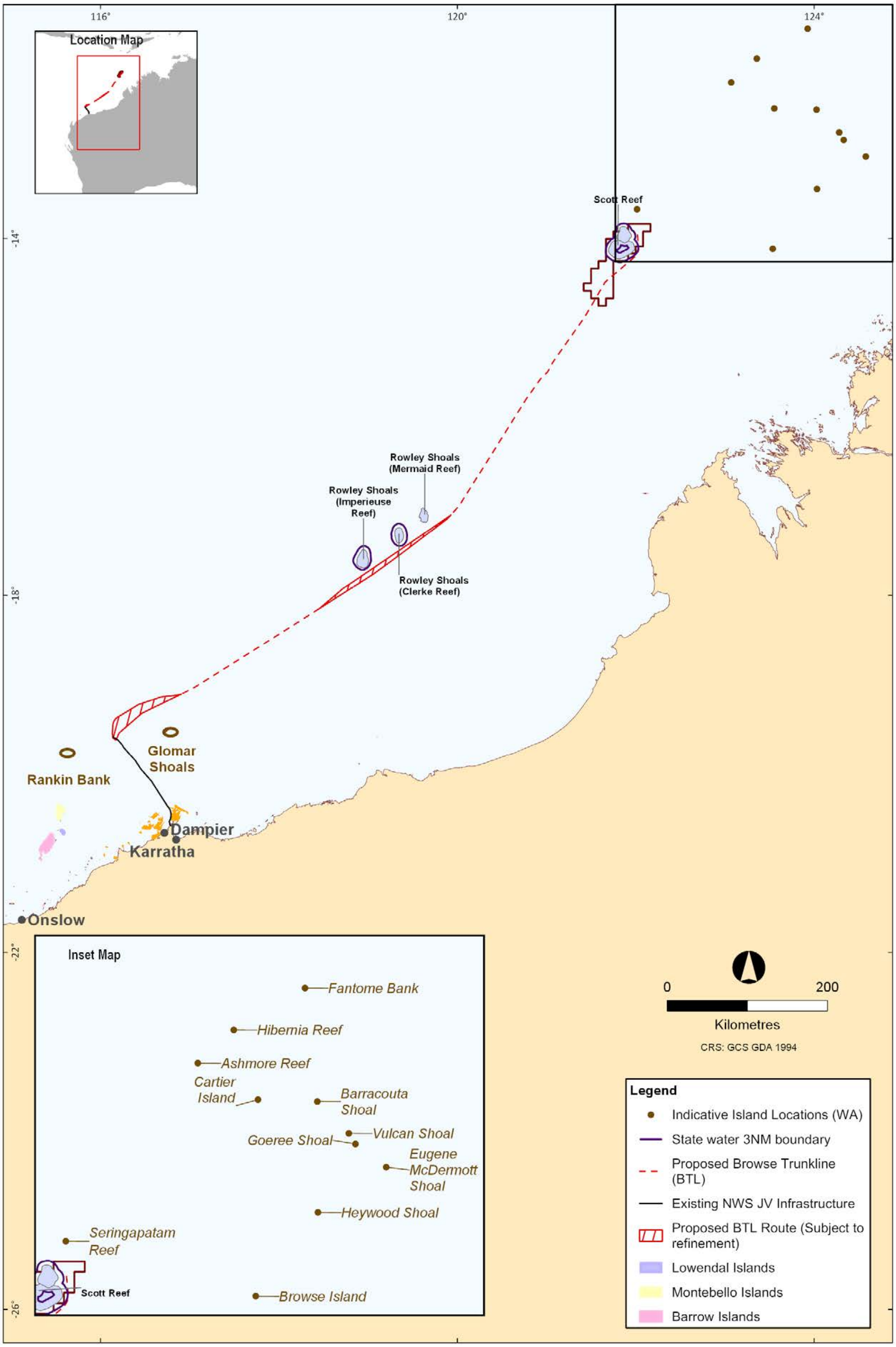


Figure 5-46 Offshore and Coastal Islands within the EMBA for the proposed Browse to NWS Project

5.3.5.2 Offshore and Nearshore Islands

The southern end of the EMBA encompasses a number of offshore and nearshore islands and island groups which are in excess of 100 km from the proposed BTL route (as shown on **Figure 5-46**). These have been broadly grouped into three categories; the Montebellow/Barrow/Lowendal Islands, the Dampier Archipelago, and the Pilbara Islands (North, Middle and Southern Island Groups). These island groups are described in this section.

Montebello/Barrow/Lowendal Islands

The marine and coastal environments of the Montebello/Barrow/Lowendal Islands group represent a unique combination of offshore islands, intertidal and subtidal coral reefs, mangroves, macroalgal communities and sheltered lagoons, and are considered a distinct coastal type with very significant conservation values (DEC, 2007b). These islands are also within the Montebello Islands Marine Park and Barrow Island Marine Park. There are also two WA Marine Management Areas relevant to these island groups; the Lowendal Islands Nature Reserve and the Barrow Island Marine Management area.

The key ecological values for each of these island groups is summarised in **Table 5-37** below.

Table 5-37 Summary of the Key Ecological Values for each of the Montebello, Barrow and Lowendal Island Groups

Island Group	Ecological Values
Montebello Islands *Comprises North West Island, Trimouille Island, Bluebell Island, Alpha Island, Hermite Island, Renewal Island.*	The Montebello Islands group comprises 256 low lying islands and islets. The islands support habitats, species and ecological communities associated with the North West Shelf Province and feature examples of the seafloor habitats and communities of the broader NWMR, as well as the Pilbara (offshore) mesoscale bioregion (Heap et al., 2005). The Montebello Islands support the largest breeding population of roseate terns in WA. Ospreys, white-bellied sea-eagles, eastern reef egrets, Caspian terns, and lesser crested terns also breed in this area. Observations suggest an area to the west of the Montebello Islands may be a minor zone of upwelling in the NWMR, supporting large feeding aggregations of terns. There is also some evidence that the area is an important feeding ground for Hutton's shearwaters and soft plumaged petrels. The islands also feature BIAs for a range of MNES, foraging areas adjacent to important nesting sites for marine turtles, and part of the migratory pathway of the protected humpback whale. Marine Parks protecting these islands include the Montebello Australian Marine Park, Montebello Islands Conservation Park (State MP) and Montebello Islands Marine Park (State MP). The State and Commonwealth Marine Park areas include shallow shelf environments with depths ranging from 15 to 150 m and provide protection for shelf and slope habitats, as well as pinnacle and terrace seafloor features.
Lowendal Islands including *Abutilon Island, Bridled Island, Varanus Island.*	The Lowendal Islands Nature Reserve incorporates the islands of the Lowendal Archipelago, approximately 15 km south of Montebello Islands. The island group is made up of 34 islands and islets, with the largest being Varanus Island at 83 ha. The islands comprise of limestone rocks that extend a few metres above the sea level and have sparse vegetation (Department of Environment and Conservation, 2007b). These islands host feeding and breeding habitat for shorebirds, including the common greenshank, common sandpiper and the red-necked stint. The islands also represent a key foraging and staging area for migratory shorebirds and an internationally significant site for six species of migratory shorebirds, supporting more than 1% of the EAAF population for these species. Seabird colonies for species such as the wedge-tailed shearwaters and bridled terns are also located within this island group. Varanus Island hosts foraging, nesting and internesting habitat for hawksbill turtles, as well as an important rookery for flatback turtles. In terms of marine mammals, bottlenose dolphins and Indo-Pacific humpback dolphins are common within the waters of the islands, with dugongs also noted feeding within the shallow seagrass habitats.

Island Group	Ecological Values
Barrow Island	Barrow Island is the second largest island off the WA coast and is an important biological refuge site due to its isolation from threatening process on the mainland (e.g. pest species). It features significant habitats, such as intertidal mudflats, rock platforms, mangroves, rock piles and cliffs, clay pans and caves. The island also hosts a significant fossil record that indicates local historical biodiversity and evolution. These values are protected by the Barrow Island Nature Reserve, Barrow Island Marine Park and Barrow Island Marine Management Area. The island contains flora that are restricted in distribution and at or near the limit of their range, as well as a high number of fauna species with high conservation value. An extensive hydrogeological karst system is located on the island that supports a subterranean community of high conservation significance. Regionally and nationally significant rookeries for green and flatback turtles as well as important habitat for migratory shorebirds are located on Barrow Island.

The Dampier Archipelago, Island Reserves and Adjacent Dampier Marine Park

The Dampier Archipelago comprises forty-two islands, islets and rocks located off the Pilbara Coast. Twenty-five of these islands are incorporated into four nature reserves (of Class A, B and C) managed by the Department of Biodiversity, Conservation and Attractions (Department of Conservation and Land Management, 1990). Key ecological values encompassed within the Dampier Archipelago Island Reserves include (Department of Conservation and Land Management, 1990):

+ important nesting and refuge sites for marine species including resident and migratory sea and shore bird species and marine turtles
+ beaches and mudflats that provide feeding and resting sites for migratory shore birds
+ mangrove communities occurring as narrow barrow bands of vegetation in sheltered locations such as tidal creeks or bays where substrate is muddy that are important habitat as feeding and refuge sites for juvenile turtles.

In addition to its environmental values, the Dampier Archipelago (including Burrup Peninsula) is an indigenous class feature on the National Heritage List, being sacred and home to Aboriginal Australians. The listing includes parts of the Burrup Peninsula, Islands of the Dampier Archipelago and the Dampier Coast. According to the Ngarda-Ngarli people, ancestral beings created the land during the Dreamtime, and the spirits of Ngkurr, Bardi and Gardi continue to live in the area. The Dampier Archipelago contains one of the largest and most diverse concentrations of rock art (petroglyphs) in the world. The place also contains Aboriginal stone features, camp sites, quarries and shell middens which show a rich cultural and spiritual history dating back tens of thousands of years. Aboriginal heritage sites range from small scatters to valleys with thousands of engravings which exhibit a degree of creativity that is unusual in Australian rock engravings (DEH, 2007). The Aboriginal Heritage Inquiry System identified about 1700 Registered Aboriginal Sites within the Dampier Archipelago (DPLH, 2018).

The Dampier Marine Park is located approximately 10 km north-east of Cape Lambert and 40 km from Dampier extending from the Western Australian state water boundary. The Marine Park covers an area of 1252 km^2 with a water depth ranging between less than 15 m and 70 m.

The marine environment encompassed by the marine park is significant as it contains habitats, species and ecological communities associated with the Northwest Shelf Province. The marine park provides protection for offshore shelf habitats adjacent to the Dampier Archipelago, and the area between Dampier and Port Hedland, and is a hotspot for sponge biodiversity. The Marine Park includes several submerged coral reefs and shoals including Delambre Reef and Tessa Shoals (Director of National Parks, 2018).

The Marine Park is assigned IUCN category VI and includes three zones assigned under this plan: National Park Zone (II), Habitat Protection Zone (IV) and Multiple Use Zone (VI).

The Pilbara Islands (North, Middle and Southern Island Groups)

Within the nearshore waters between the Muiron Islands and the Dampier Archipelago are a series of islands collectively termed the Northern, Middle and Southern Island Groups. This area has been defined as the Pilbara offshore region (greater than 10 m water depth) and includes islands, shoals and rocky outcrops. The Northern Island Group includes more than 30 islands that range from the Dampier Archipelago south to the mouth of the Robe River, 10–35 km offshore, including the Great Sandy Islands Nature Reserve and the Passage Islands. A small number of these islands fall within the southern portion of the EMBA. The EMBA does not encompass the Middle Island Group or Southern Island Group.

The nearshore habitats of these islands generally consist of fringing reefs on the seaward side and wide intertidal sand flats on the leeward side. Despite generally high turbidity in the area and relatively low abundance, hard coral biodiversity is high (Chevron Australia Pty Ltd, 2010). The coral community structure within this area, and others within the region, experiences high temporal variability due to cyclonic activity. The larger islands of the groups provide important nesting habitat for seabirds and marine turtles (Chevron Australia Pty Ltd, 2010), including wedge-tailed shearwaters which have breeding populations on islands from the Northern Island Group.

5.3.5.3 EPBC Act Listed Species

The majority of species identified by the PMST search for this EMBA have already been described in the above sections as they are associated with habitats within the Project Area. Species not previously identified are discussed in this section.

Birds

In total, 57 EPBC Act listed bird species were identified as potentially occurring within the EMBA; including forty species not previously identified by PMST searches for the Project Area. These species include terns (caspian tern, crested tern, lesser crested tern, sooty tern, fairy tern, Australian fairy tern, bridled tern), boobys (masked booby, brown booby, red-footed booby), godwits (bar-tailed godwit, northern siberian bar-tailed godwit) and other seabirds and shorebirds. These species will primarily occur within the EMBA as vagrants as a number of these seabirds and shorebirds are migratory with large foraging areas. Key sites within the EMBA for these species include Ashmore Reef, Montebello/Barrow/Lowendal Island groups and larger islands within the Dampier Archipelago and on the Pilbara coast.

Marine Mammals

Nine cetacean species not previously discussed were identified as potentially occurring within the EMBA by the PMST search. These include the southern right whale, Antarctic minke whale, minke whale, the Indo-Pacific humpback dolphin, spotted dolphin and Indian Ocean bottlenose dolphin. These species occupy both coastal and oceanic waters. There are no key sites of aggregation or of known significance for these species within the EMBA. The southern right whale, Antarctic minke whale and minke whale are present in Australian waters seasonally.

The Longman's beaked whale and gingko-toothed beaked whale were also identified by the PMST search. These two species are not expected to occur within the EMBA due to their lack of records in waters off WA; only one record of the Longman's beaked whale exists within Australia (a skull and lower jaw discovered in Queensland). Accurate distribution information for this species is not known although it is thought to be restricted to the offshore waters of the tropical Pacific and Indian Oceans (Australian Museum, 2019a). The gingko-toothed beaked whale is similarly cryptic and is known within Australia from just three stranding incidents. This species is also thought to be distributed in offshore waters of the Indian and Pacific Oceans (Australian Museum, 2019b).

The dugong was also identified as potentially occurring within the EMBA. Several sites within the EMBA are known to provide important seagrass and other habitat for dugongs, including Ashmore Reef, The Kimberley Marine Park, the Dampier Archipelago and Lowendal Islands. Dugongs are, therefore, likely to occur within the EMBA in proximity to these sites.

Marine Reptiles

The PMST search also identified three sea snake species which were not identified as potentially occurring within the Project Area; the leaf-scaled seasnake, brown-lined seasnake and spine-tailed seasnake. Ashmore Reef and Seringapatam Reef are known historically as hotspots for sea snake species. As discussed in **Section 5.3.2.6**, sea snakes are typically associated with shallow water reef habitats and it is expected that these species will be restricted to shallow coastal and island habitats.

The PMST search identified the flatback, hawksbill, loggerhead, green and leatherback turtles as potentially occurring within the EMBA. Although already identified as potentially occurring within the Project Area, it is worth noting that marine turtles (in particular green, hawksbill and flatback turtles) are known to forage in the waters surrounding Ashmore Reef, the Barrow/Montebello/Lowendal Islands, Dampier Archipelago and Pilbara Islands throughout the year with seasonal peaks in aggregations adjacent to nesting and foraging habitats at these same locations.

Fish

The dwarf and freshwater sawfish were also identified as potentially occurring within this EMBA. These species are not expected to occur in high numbers within the EMBA due to their habitat preferences; the freshwater sawfish prefers muddy substrates in fresh or weakly saline waters, typically in rivers and estuaries, and the dwarf sawfish typically frequents coastal and estuarine waters 2 to 3 m in depth (Commonwealth of Australia, 2015d).

The grey nurse shark (west coast population) was also identified by the PMST report. This species prefers inshore marine environments in sub-tropical to cool temperate waters. The grey nurse shark is typically found in southern WA, although records indicate the species may travel as far north as the NWS. This species may, therefore, occur within the EMBA (Department of the Environment and Energy, 2019r).

5.3.5.4 Potential Shoreline Receptors

In addition to the ecological values and receptors that are encompassed within the EMBA and Project Area, oil spill modelling indicates that shoreline accumulation of hydrocarbons may occur along coastal parts of Cartier Island, the Kimberley coastline (including the Buccaneer Archipelago and Camden Sound Marine Park) and Indonesia. Therefore, the key ecological characteristics of these coastal areas which may be contacted are described in Table 5-38.

Table 5-38 Description of Potential Coastal Receptors of Shoreline Accumulation

Receptor	Description	Approximate Distance from the Browse Development Area
Australia		
Kimberley coastline	The Kimberley coastline is characterised as rugged with rocky shores and 2,633 islands, many of which support marine turtle and seabird rookeries, including the green turtle and roseate tern (Conservation Commission of Western Australia, 2010). The Kimberley region has been heritage listed in recognition of its natural, Indigenous and historic values. The coral reef systems of the Kimberley are some of the least impacted in the world due to low population density of the region, making them ideal for research purposes (Richards et al., 2018). The coastline and its numerous islands demonstrate high biodiversity, hosting important habitat for numerous EPBC Act listed species (Conservation Commission of Western Australia, 2010). Economically, the wider Kimberley region supports a variety of tourist activities and commercial fisheries which are reliant on the diverse marine habitats and species of the region. There are also numerous developed and undeveloped offshore oil and gas reserves in the region (Richards et al., 2018). ***Buccaneer and Bonaparte Archipelago*** The Buccaneer and Bonaparte Archipelagos are located north of Cape Leveque and north of Camden Sound respectively. The archipelagos encompass hundreds of islands and many featuring extensive fringing coral reefs, which are unique to the region due to their ability to cope with the significant tidal variation characteristic of the region (Conservation Commission of Western Australia, 2010). Within the Buccaneer Archipelago, Koolan and Cockatoo Islands have been subject to mining for iron ore, and Troughton Island features an unsealed airstrip and a BOM weather station (Conservation Commission of Western Australia, 2010). ***Llang-Garam / Camden Sound Marine Park*** This state marine park is located in the west Kimberley, between the Buccaneer and Bonaparte Archipelagos. The marine park features a variety of complex marine habitats representative of the wider Kimberley coastline, including coral reef, rocky shoals, mangrove forests and intertidal areas, as well as a number of islands such as Champagny Island and the Montgomery Islands (Department of Parks and Wildlife, 2013). In addition, the marine park hosts a number of habitats that support a number of EPBC Act listed species, including the humpback whale (hosting critical calving habitat), marine turtles, snubfin dolphin, dugong and sawfish (Department of Parks and Wildlife, 2013).	266 km

Receptor	Description	Approximate Distance from the Browse Development Area
Indonesia		
Lombok, Sumba	The Indonesian islands of Lombok and Sumba are located within Indonesia's Lesser Sunda Ecoregion (which stretches from Bali to Timor Leste) and contain significant marine and socio-economic environmental values (Perdanahardja and Lionata, 2017). This includes subtidal benthic habitats, such as fringing coral reefs, seagrass meadows and algal beds, and mangroves, which are widely distributed throughout estuaries and deltas within the region. These habitats support a variety of marine species, including marine turtles and a number of whale species which rely on the seasonal upwelling of nutrients this region (Perdanahardja and Lionata, 2017). In addition, Sumba features a high abundance of seabirds, extensive mangroves and sandy beaches. Many of the islands in the Lesser Sunda region are separated by volcanic trenches, which limits the movement of flora and fauna between islands and has led to localised speciation. The deep waters surrounding Lombok, located west of Sumba, feature migratory corridors for sharks and dolphins (Perdanahardja and Lionata, 2017). Indonesia's marine life, including its coral communities and sandy beaches, support the country's tourism and fishing/aquaculture industries. Key commercial species include skipjack, tuna and blue swimming crab, as well as a number of shark species. The marine environment is, however, at risk of overexploitation through unsustainable fishing practices (Perdanahardja and Lionata, 2017).	440 km
Timor Leste		
	Timor-Leste boasts more than 700 km of coastline and high species diversity, including a number of endemic species (Asian Development Bank, 2014). Surveys of the marine environment have identified more than 1,200 species of reef fish and 400 reef-building coral species. Habitats include mountain ranges and shaded woods, to sandy beaches and coral reefs on the coast (Coral Triangle Center, 2019). The island has 30 declared protected areas which form the Nino Konis Santana National Park and which encompass more than 350 km2 of coral reef (Asian Development Bank, 2014; Coral Triangle Center, 2019). The nation also has an Exclusive Economic Zone which extends 200 nm offshore and features an abundance of fishing grounds (Coral Triangle Center, 2019). Timor-Leste has similar marine and socio-economic environmental values to that of Indonesia and these are also under threat from practices such as unsustainable fishing. More than 80% of the mangrove communities of Timor-Leste have been lost in the last 50 years and this loss, as well as the degradation of the nation's riparian forests, have led to siltation and subsequent damage to the coral reefs (Coral Triangle Center, 2019).	440 km

5.3.6 Assessment of adequacy of the science

Table 5-39 describes Woodsides assessment with respect to data uncertainty and the adequacy of the science that has been used in the assessment of potential impacts of the proposed Browse to NWS Project on MNES.

Table 5-39 Species of MNES and the science adequacy for the proposed Browse to NWS Project

EPBC Act Listed Threatened or Migratory Species	Adequacy of the Science
Critically Endangered or Endangered	
Balaenoptera musculus brevicauda (Pygmy Blue Whale), **Endangered and Migratory** The proposed Browse to NWS Project overlaps with the migratory BIA and possible foraging area at Scott Reef. The Browse Development Area and Proposed BTL route are within the pygmy blue whale migratory BIA.	***Pygmy Blue Whales*** Data used in the assessment of impacts and risks included the best available science and expert opinion as collated in the 2015-2025 Conservation Management Plan for Blue Whales (Commonwealth of Australia, 2015), describing the key foraging areas, possible foraging areas, northbound and southbound migration routes and distribution. More recently, passive acoustic monitoring has provided some understanding of the Eastern Indian Ocean (EIO) pygmy blue whale population with regards to residency and timing in key foraging areas (Bonney Upwelling, South Australia and Perth Canyon, Western Australia) and knowledge gaps with regards to their distribution in the wider eastern Indian Ocean, breeding/calving habitat in Indonesian waters, and population size and emerging information on growth rates based on whale calls (McCauley et al., 2018; Joliffe et al., 2019). Woodside supported studies are detailed in Table 5-24, and included: aerial and vessel-based surveys, acoustic surveys using noise loggers and satellite tracking. These studies represent the best available data, conducted by subject matter experts, and independent of Woodside. The available pygmy blue whale data, from 2002 to 2017, were determined to be adequate for the purposes of impact assessment and management planning purposes based on the lack of significantly altered regional cumulative impacts since collection (Chapter 9), ability to extrapolate population trends using existing literature, and conservative interpretation of available data where applied in Chapter 6. The existing data will be updated by targeted monitoring programs to verify impact predictions and inform adaptive management approaches at relevant times throughout the project life cycle.
Papasula abbotti (Abbott's Booby) Nests only on Christmas Island and foraging range (40-100 km) not expected to overlap with the Project Area.	***Abbott's Booby*** Knowledge available is determined to be reliable and adequate to identify that there will not be any interaction between the Abbott's booby, and the proposed Browse to NWS Project.

EPBC Act Listed Threatened or Migratory Species	Adequacy of the Science
Vulnerable	
Threatened marine turtle species: *Chelonia mydas* (Green Turtle) *Eretmochelys imbricata* (Hawksbill Turtle) *Natator depressus* (Flatback Turtle), Table 5-19. Scott Reef: Sandy Islet nesting habitat and surrounding waters (20 km internesting buffer) are habitat critical for survival of the green turtle (Scott Reef-Browse Island genetic stock).	***Green Turtles*** Data used in the assessment of impacts and risks included the best available science and expert opinion as collated in the Recovery Plan for Marine Turtles in Australia 2017-2027 (Commonwealth of Australia, 2017). Studies specific to the green turtle breeding population at Scott Reef included seven surveys, over three years, deploying satellite tags and using mark and recapture techniques. These studies represent the best available data, conducted by subject matter experts, and independent of Woodside. The available green turtle data, from 2002 to 2010, were determined to be adequate for the purposes of impact assessment and management planning purposes based on the lack of significantly altered regional cumulative impacts since collection (Chapter 9), ability to extrapolate population trends using existing literature, and conservative interpretation of available data where applied in Chapter 6. The existing data will be updated by targeted monitoring programs to verify impact predictions at relevant times throughout the project life cycle.
Threatened whale species: *Megaptera novaeangliae* (Humpback Whale) *Balaenoptera borealis* (Sei Whale) *Balaenoptera physalus* (Fin Whale) Humpback whale migration BIA is not overlapped by the proposed Browse to NWS Project.	***Humpback Whales and other whales*** Data used in the assessment of impacts and risks included the best available science and expert opinion as collated in current Conservation Advices for the humpback whale, sei whale and fin whale. Woodside supported studies are detailed in Table 5-24, and included: aerial and vessel-based surveys, acoustic surveys using noise loggers, and satellite tracking. These studies represent the best available data, conducted by subject matter experts, independent of Woodside, and determined to be reliable and adequate for an assessment of impacts and risks to these whale species.
Threatened fish species: *Rhincodon typus* (Whale Shark) *Pristis zijsron* (Green Sawfish) *Pristis pristis* (Largetooth Sawfish) The Browse Development Area is located > 20 km from the whale shark foraging BIA and proposed BTL route is located within the BIA.	***Whale Sharks and other fish species*** Data used in the assessment of impacts and risks included the best available science and expert opinion as collated in the conservation advice for the whale shark (Threatened Species Scientific Committee, 2015f). Studies specific to whale sharks have include satellite tracking and an updated literature review (Meekan and Lester, 2017), as detailed in Table 5-27, conducted by subject matter experts, independent of Woodside, and determined to be reliable and adequate for an assessment of impacts and risks to the whale shark. Knowledge on sawfish species habitat preference precludes occurrence within the Project Area.
Threatened migratory bird species: *Anous tenuiostris melanops* (Australian Lesser Noddy)	***Australian Lesser Noddy*** Data used in the assessment of impacts and risks included the best available science and expert opinion as collated in the conservation advice for the Australian Lesser Noddy. Breeding populations of this species have been recorded on limestone/sandy islands, which may include Sandy Islet, Scott Reef. Knowledge available is determined to be reliable and adequate to dismiss any interaction of the protected Australian Lesser Noddy and the proposed Browse to NWS Project.

EPBC Act Listed Threatened or Migratory Species	Adequacy of the Science
Migratory Species	
Listed migratory species: Migratory species listed in Table 5-19 and, where applicable, relevant species BIAs listed Table 5-20.	***Listed Migratory Species*** Data used in the assessment of impacts and risks included the best available science and expert opinion as collated in SPRAT Profiles, marine bioregional plans, peer-reviewed scientific literature and unpublished reports. Studies specific to migratory species were conducted by subject matter experts, independent of Woodside, and determined to be reliable and adequate for an assessment of impacts and risks to migratory species.

5.4 Socio-Economic Environment

5.4.1 Introduction

This section summarises the available information relating to the socio-economic and cultural environment pertaining to and within the vicinity of the Browse Development Area. Information on heritage and cultural values and existing uses of the Browse Development Area, such as scientific research and tourism, and related stakeholders is also provided in this section. Due to the remote location of the Browse Development Area from the WA coastline, socio-economic activities within the area are limited to commercial fishing, traditional Indonesian fishing, limited recreational fishing and tourism activities at Scott Reef; as well as oil and gas activities that occur in the wider NWMR.

Protected places of the wider NWMR that display heritage, social and cultural values, including recreational opportunities, amenity, cultural heritage, conservation and scientific significance, are also described in this section.

5.4.2 Existing Uses and Users

5.4.2.1 Commonwealth Managed Fisheries

The diverse range of habitats and species within the NWMR has allowed for various fisheries to develop and operate throughout the region. Australian Fisheries Management Authority (AFMA) manages more than twenty fisheries on behalf of the Commonwealth Government and is bound by objectives under the Commonwealth *Fisheries Management Act 1991*. Commonwealth managed fisheries located within the vicinity of the Project Area are summarised in Table 5-40 and shown on Figure 5-47.

Table 5-40 Commonwealth Managed Fisheries Located within the Vicinity of the Proposed Browse to NWS Project Area (Department of Agriculture and Water Resources (DAWR), 2018)

Commonwealth Fishery	Description	Distance from Project Area
North West Slope Trawl Fishery (NWSTF)	Operates along the north-west coast approximately between the 200 m isobath and the outer limit of the Australian Fishing Zone (AFZ), including the MoU 74 Box (**Section 5.4.2.3**). Target species is scampi; *Metanephrops australiensis, M. boschmai, M. velutinus.* Since 2008-09 season the fishery has stabilised at one to two vessels per year, with a slight increase compared with historical effort in 2016-17 season.	*Within Project Area*
Western Tuna and Billfish Fishery	Operates within Australia's Exclusive Economic Zone (EEZ), including along the WA coastline to the outer limit of the AFZ. Target species include yellowfin and bigeye tuna, striped marlin and swordfish, as well as some albacore. Since 2005 less than five vessels have been active within the fishery each season.	*Within Project Area*
Southern Bluefin Tuna Fishery	Operates within the AFZ, including the entirety of WA waters. This species, *Thunnus maccoyii*, is highly migratory, spawning in the north-east Indian Ocean, as defined by the CBD ecologically or biologically significant area; South Java Sea andtypically during spring and summer before moving southwards along the WA coastline toward South Australia. Due to the large distance over which spawning is thought to occur it is not likely that the proposed Browse to NWS will have an impact on spawning. The majority of catch is taken from the Great Australian Bight, as well as south-eastern Australia.	*Within Project Area*
Skipjack Tuna Fishery (Western Skipjack Tuna Fishery)	The Skipjack Fishery comprises an eastern and western fishery, which are assessed separately. The Western Skipjack Tuna Fishery (WSTF) operates from within the AFZ west of the South Australian/Victorian border to the Cape York Peninsula in WA. There has been no catch or effort in the WSTF since the 2008–09 fishing season.	*Within Project Area*

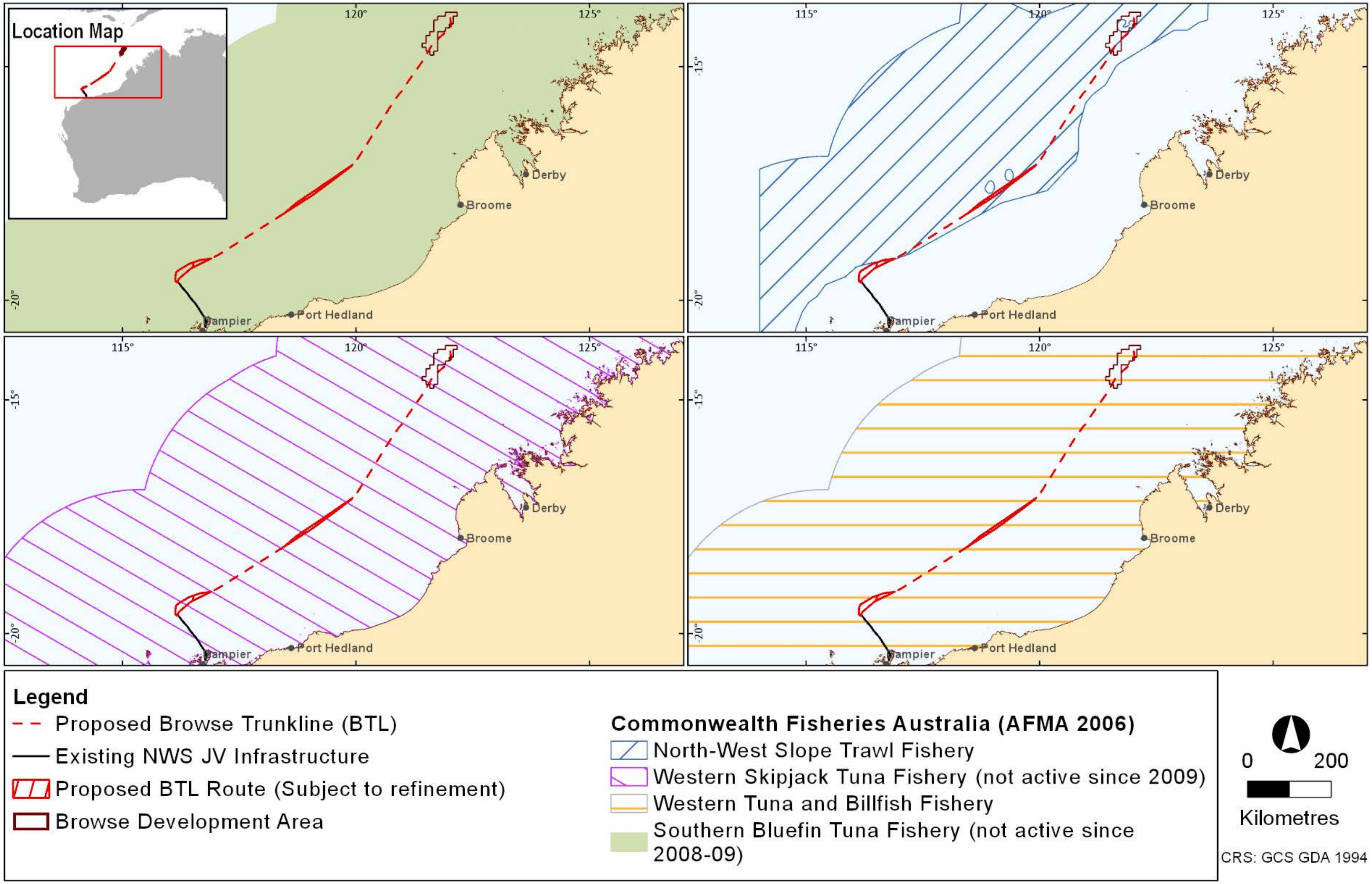


Figure 5-47 Commonwealth Managed Commercial Fisheries within the Vicinity of the Project Area

5.4.2.2 State Managed Fisheries

WA State commercial fisheries are managed by the WA Department of Fisheries (WA DOF) under the WA Fish Resources Management Act 1994 (FRMA), Fisheries Resources Management Regulations 1995, relevant gazetted notices and licence conditions, and applicable Fishery Management Plans. State managed commercial fisheries that operate within the vicinity of the Project Area are summarised in **Table 5-41** below. State managed commercial fisheries in close proximity to the Project Area are shown in **Figure 5-48** to **Figure 5-50**.

Table 5-41 State Managed Fisheries Located within the Vicinity of the Project Area (Department of Primary Industries and Regional Development, 2018b)

State Fishery	Description	Distance from Project Area
Northern Demersal Scalefish Managed Fishery (NDSF)	North-west coast of WA in the waters east of longitude 120° E to the edge of the AFZ. The fishery is divided into two fishing areas; an inshore sector (Area 1) and an offshore sector (Area 2). Area 2 is further subdivided into 3 zones: A, B and C. Zone B comprises the area with most historical fishing activity. Zone A is an inshore area and Zone C is an offshore deep slope area representing waters deeper than 200 m. The Browse Development Area is located within Fishing Area 2, Zone C. Access to Area 2 is limited to 11 licences. Since 2008, annual catch has exceeded 1000 t. Target species are demersal scalefish, including goldband snapper, crimson snapper, red emperor and bluespotted emperor.	*Within Project Area*
Mackerel Managed Fishery	Mainly operates between Geraldton and the WA/NT border and is comprised of three areas; Kimberley (Area 1), Pilbara (Area 2), and Gascoyne/ West Coast (Area 3). The Browse Development Area is located within Area 1 only. Target species include Spanish and grey mackerel.	*Within Project Area*
Western Australian North Coast Shark Fishery (WANCSF)	The WANCSF extends from the North West Cape to Koolan Island and the Joint Authority Northern Shark Fisher (JANSF) from longitude 123° 45' E to the WA/NT border. The WANCSF encompasses the Browse Development Area. No fishing effort has been reported for this fishery since the 2009/2010 season. Target species include dusky, whaler, sandbar, gummy and whiskery sharks.	*Within Project Area*
Onslow Prawn Managed Fishery	This fishery uses low opening, otter prawn trawl systems to target western king prawns *(Penaeus latisulcatus)*, brown tiger prawns *(P. esculentus)*, and endeavour prawns *(Metapenaeus endeavouri)*. The total landings for the 2016 season were 3 t, comprising 2 t of banana prawns, and <1 t each of brown tiger prawns and endeavour prawns. No western king prawns were recorded as landed.	*Within Project Area*
Abalone Fishery	This largely coastal fishery targets the Roe's, greenlip and brownlip abalone. The Project Area is located within management area 8 of the Northern Zone 2 of the Abalone commercial fishing area (Greenough River mouth to NT border). No abalone fishing is permitted within Zone 2 until further notice.	*Within Project Area*
South West Coast Salmon Fishery	This fishery encompasses all waters adjacent to WA out to the Australian AEZ from Cape Beaufort to the coastline adjacent to Kununurra. The target species is the WA Salmon *(Arripis truttaceus)*.	*Within Project Area*

State Fishery	Description	Distance from Project Area
Pilbara Fish Trawl Interim Managed Fishery (PFTIMF)	The Pilbara Fish Trawl Fishery lands the largest component of the total catch of demersal finfish in the Pilbara (and North Coast Bioregion) — comprising more than 50 scalefish species. Both the Pilbara Trap Managed Fishery and the Pilbara Line Fishery catch is made up of a similar number of fish species (45-50), although the line fishery also includes some deeper offshore species such as ruby snapper *(Eteliscarbunculus species)* and eightbar grouper *(Hyporthodus octofasciatus)*. The Pilbara Fish Trawl (Interim) Managed Fishery is managed through a combination of area closures, gear restrictions, and the use of input controls in the form of individual transferable effort allocations monitored by a satellite-based vessel monitoring system (VMS).	*Within Project Area*
Specimen Shell Fishery	This fishery expands the entire length of the WA coastline, however, effort is primarily focused near population centres such as Broome and Exmouth. Over 200 species were collected in 2016. Shells are collected by hand by divers. There is a limit of 31 licences within the fishery, 23 of which were active in 2016.	*Within Project Area*
Marine Aquarium Fish Managed Fishery (MAFMF)	Operates throughout WA waters, with concentrated effort in waters adjacent to Broome, as well as Perth, Geraldton, Exmouth and Dampier. More than 950 species are known to be collected, this includes coral, live rock, algae, seagrass and invertebrates.	*Within Project Area*
West Coast Deep Sea Crustacean Fishery	The fishery operates within WA waters between the Australian EEZ and 150 m isobath. Primary target species are crystal, champagne and giant crabs. Baited pots are used in long line formation to catch species. Limitations apply to total allowable catch.	*Within Project Area*
Pearl Oyster Managed Fishery	Operates within WA waters, from Exmouth to the NT border. The fishery is quota based and specimen are collected by hand by divers. This fishery targets pearl oysters, *Pinctada maxima*, for the production of pearls.	*Within Project Area*

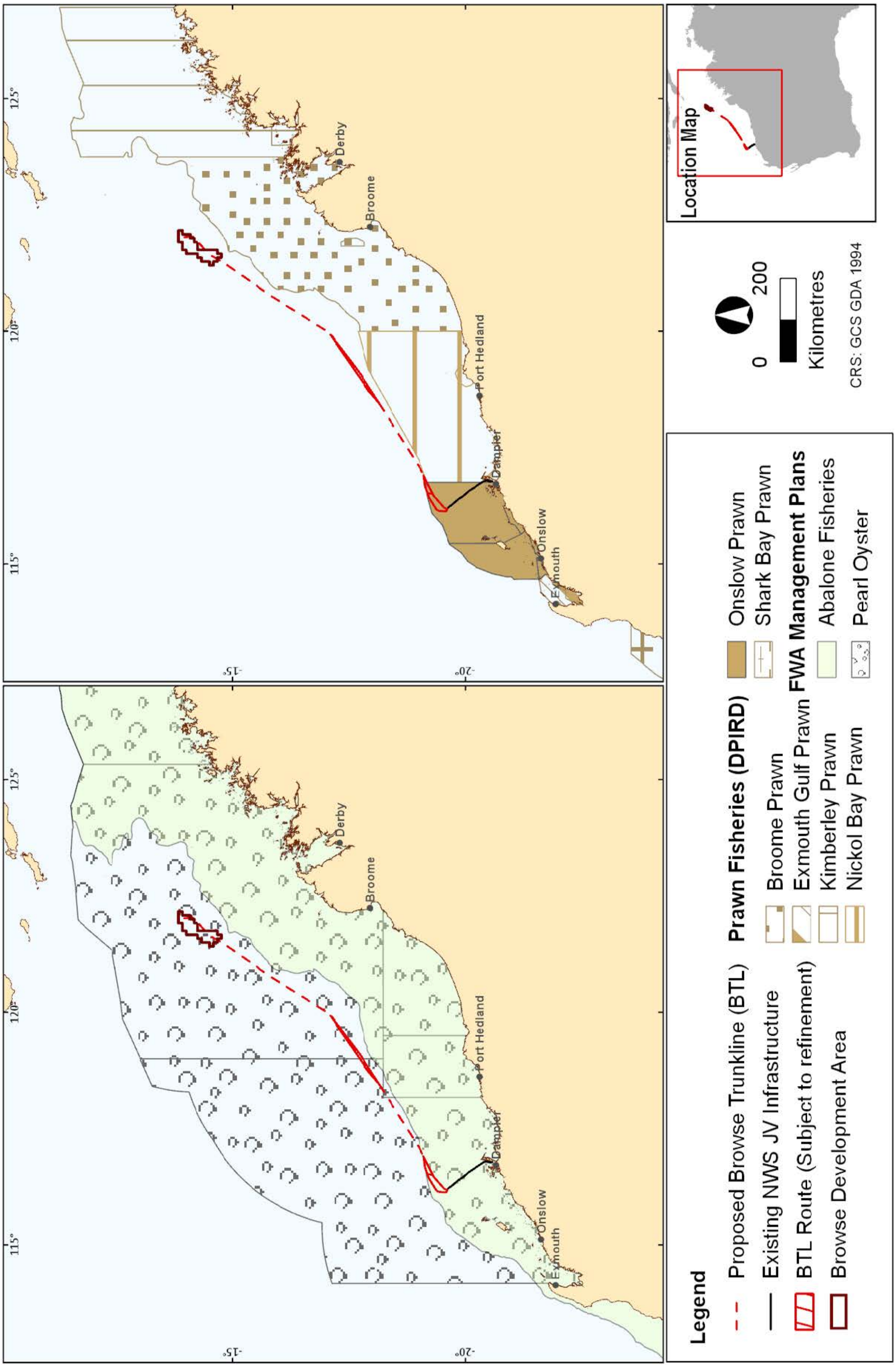


Figure 5-48 The State Managed Commercial Pearl, Abolone and Prawn Fisheries Within the Vicinity of the Project Area

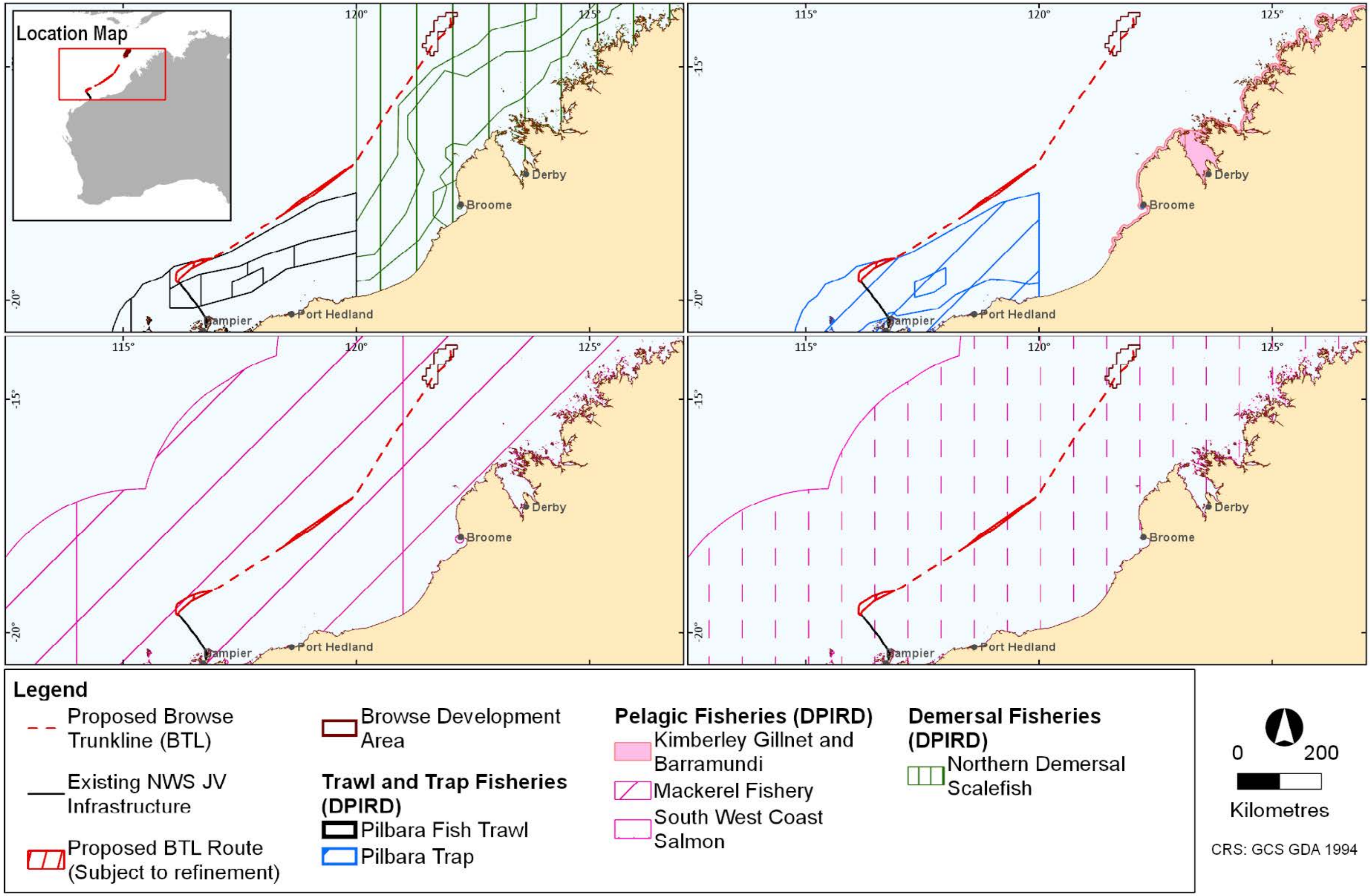


Figure 5-49 State Managed Commercial Open Water Fisheries Within the Vicinity of the Project Area

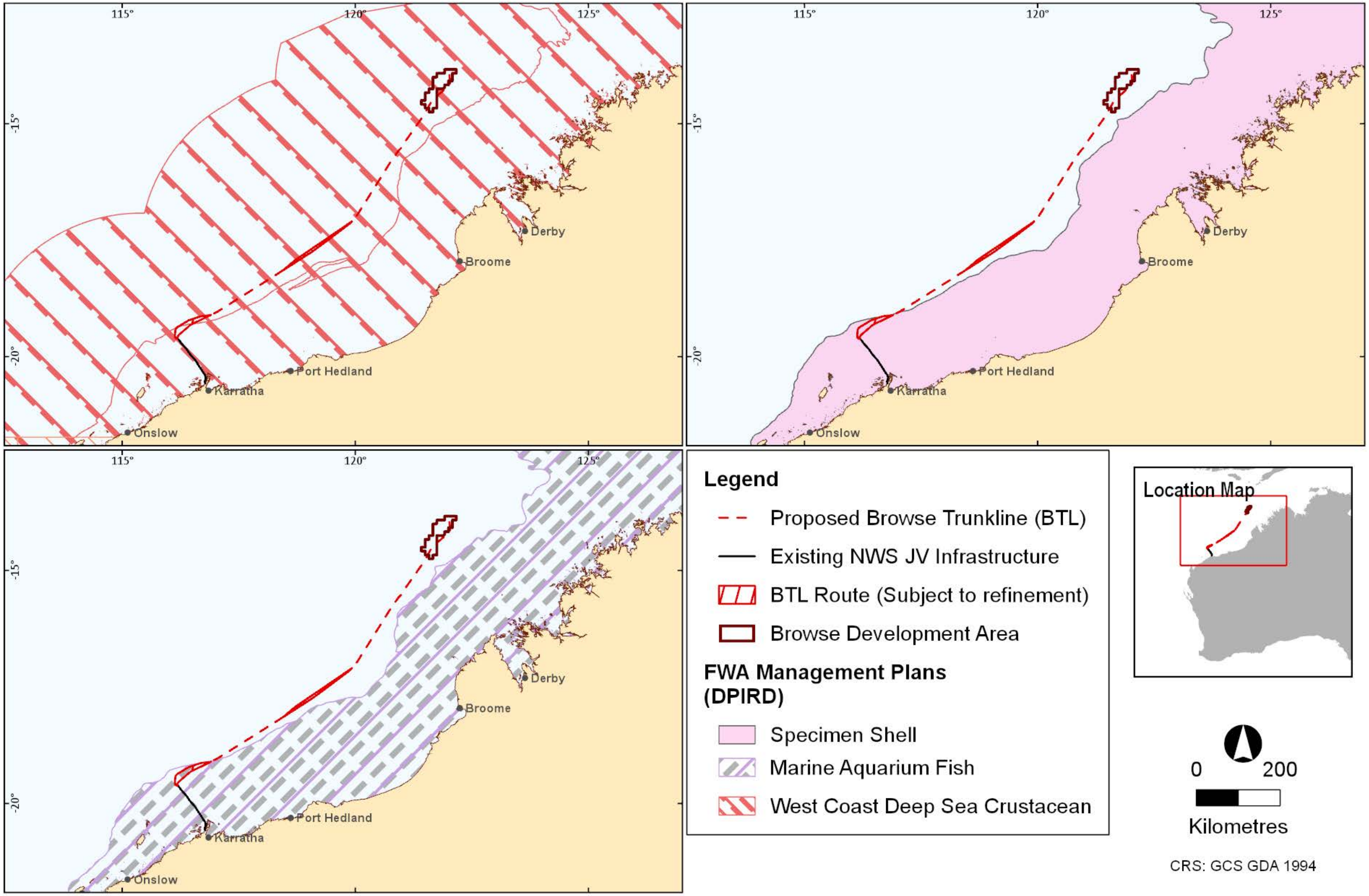


Figure 5-50 State Managed Commercial Crustacean and Ornamental Fisheries within the Vicinity of the Project Area

5.4.2.3 Traditional Fisheries

Indonesian fishers have traditionally visited reefs in the NWMR to collect marine species that are economically significant. In 1974 the Australia-Indonesia Memorandum of Understanding regarding the Operations of Indonesian Traditional Fishermen in Areas of the Australian Fishing Zone and Continental Shelf – 1974 (MoU 74) was signed by the Governments of Australia and Indonesia; this allowed Indonesian fishers to continue to fish in designated areas using traditional methods only (Department of Agriculture and Water Resources, 2016). These methods include reef gleaning, free-diving, hand lining and other non-mechanised methods.

Initially, traditional fishing was allowed within the 12 mile fishing zones that existed around the following reefs or islets in the region at that time: Ashmore Reef (Pulau Pasir), Cartier Island (Pulau Baru), Seringapatam Reef (Afringan), Scott Reef (Pulau Dato) and Browse Island (Berselan). In 1989 "Practical Guidelines" for implementing the MoU 74 were agreed, which resulted in the creation of the MoU Box that encloses the five areas formerly agreed (**Figure 5-51**) (Department of Agriculture and Water Resources, 2016). The MoU 74 and Practical Guidelines have remained in force since their adoption.

Restrictions have since been introduced around Ashmore Reef and Cartier Island following their designation as *Nature Reserves under the Commonwealth's National Parks and Wildlife Conservation Act 1975* in 1983 and 2000, respectively (Department of Agriculture and Water Resources, 2016). Ashmore Reef and Cartier Island are currently protected and managed as Commonwealth Marine Reserves under the EPBC Act. Scott Reef is currently the principal reef in the MoU 74 Box and is utilised seasonally by Indonesian fishers to harvest trepang and other reef species. The peak season is July to October due to more favourable wind conditions, and to allow fishers to sun dry their catch on their boat decks (ERM, 2009). Browse Island is also frequently visited by shark fishers who mostly fish along the eastern margin of the MoU 74 Box.

The majority of vessels that travel to Scott Reef originate from the islands of Rote (near West Timor), Tonduk and Raas (in East Java). In 2007, an estimated 800 fishers (approximately 80 vessels) travelled from these islands to Scott Reef, mainly to collect trepang (ERM, 2009). Similar numbers of vessel sailed to Scott Reef in 2008 and 2009 but coastwatch sightings have since indicated that numbers of vessels have significantly reduced over time (AFMA, 2014, pers. comm.).

The fishers focus their activities on the exposed reef flats at spring low tides and around the shallow water lagoons of Scott Reef primarily targeting trepang, trochus shells and opportunistically taking a range of other invertebrates. Crews from Rote and Alor Islands also catch fish largely for subsistence purposes. Fish are more targeted by crews from Tondok and Raas and the volume of their fish catch exceeds their trepang catch. The crews from Tondok also exploit deeper parts of the lagoon system for trepang. Free-divers use lead weights to descend rapidly and a line, hauled from the surface, is used to retrieve them. They have been observed diving to 34 m using this system. Deeper waters of the lagoons still provide some refuge from the intensive fishing on the shallow or exposed reef flats (AFMA 2014, pers. comm.).

The resources gathered by the fishers during 2007 and 2008 were estimated to value approximately AUD$370,000 and AUD$360,000 respectively. The value, for some households, is as much as 50% or more of their total annual income making the trip to Scott Reef an attractive source of income (ERM 2008, 2009). The price paid for many of the trepang species has increased at rates around 30 percent per year which has kept the fishery economically attractive (AFMA 2014, pers.comm.) despite evidence indicating that the stocks are in a depleted condition.

It is likely that Indonesian fishing vessels will occur within the vicinity of the Project Area, in particular, the Browse Development Area.

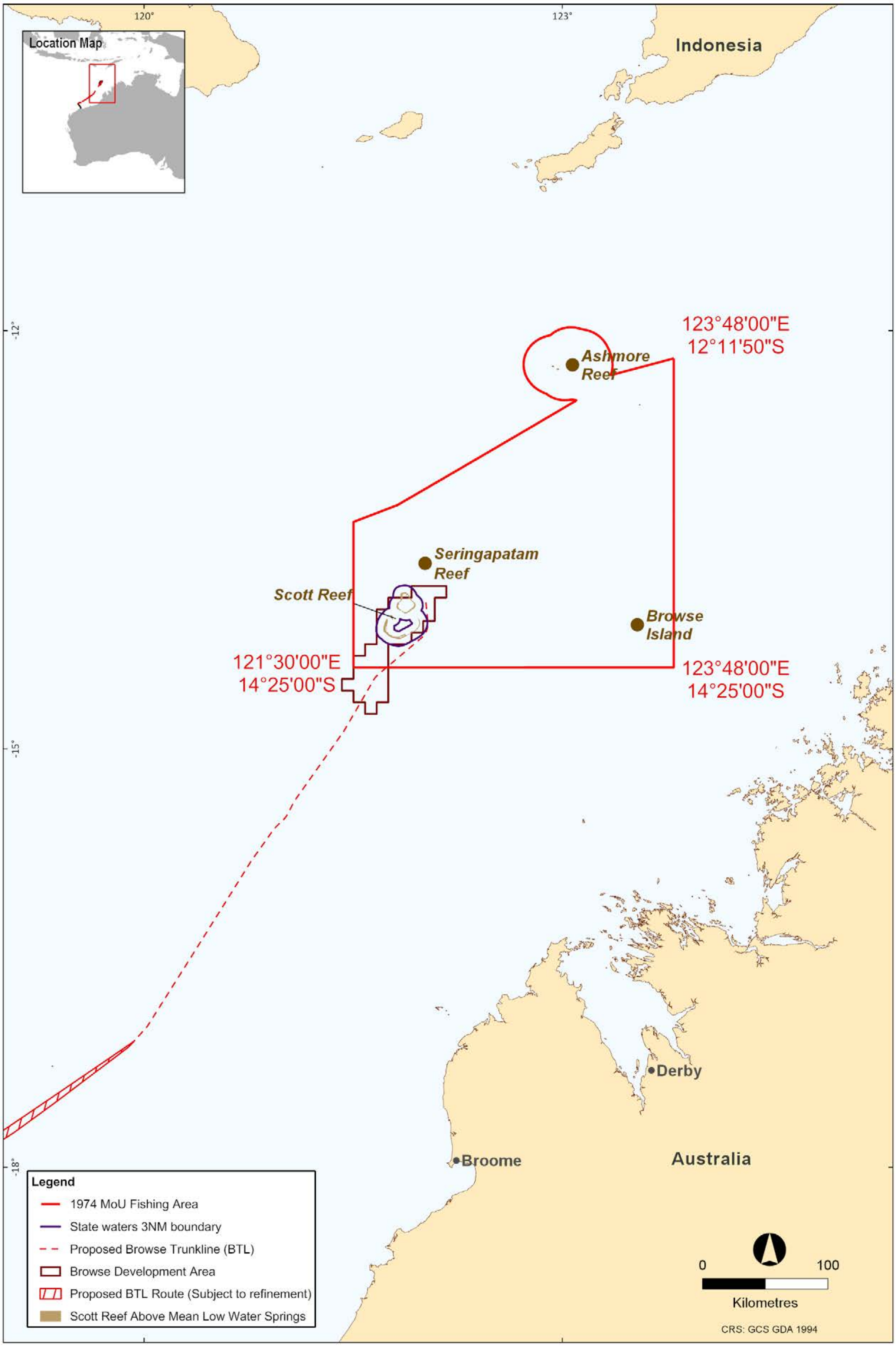


Figure 5-51 The Memorandum of Understanding (MoU 74) Box Delineating Waters in which Indonesian Fishers are Permitted to Practise Traditional Fishing Methods

5.4.2.4 Shipping

Shipping activity in and around the Browse Development Area is sparse with the main commercial shipping routes located approximately 50 to 100 km west of the Development Area, intersecting the proposed BTL route at various locations depending on the port (**Figure 5-52**). The main shipping activity in the NWMR relates to transits to and from Broome (Woodside Energy Limited, 2009b), and transportation of goods between Australian and international ports (Commonwealth of Australia, 2012a). Major ports are adjacent to the Roebuck, Montebello and Dampier Commonwealth marine reserves.

In 2012, AMSA established a network of shipping fairways off the north-west coast of Australia. The shipping fairways, while not mandatory, aim to reduce the risk of collision between transiting vessels and offshore infrastructure. The fairways are intended to direct large vessels such as bulk carriers and LNG ships trading to the major ports into pre-defined routes to keep them clear of existing and planned offshore infrastructure.

5.4.2.5 Industry

The NWMR supports a number of industries including petroleum exploration and production, as well as minerals extraction.

There are seven sedimentary petroleum basins in the NWMR: the Northern and Southern Carnarvon basins, Perth, Browse, Roebuck, Offshore Canning and Bonaparte basins. Of these, the Northern Carnarvon, Browse and Bonaparte basins hold large quantities of gas and comprise most of Australia's reserves of natural gas. The closest approved and prospective petroleum activities to the Browse Development Area are listed in shown in **Figure 5-53**.

Several other petroleum activities in the Browse Basin are currently being conducted or proposed by other petroleum operators as described in **Chapter 2**.

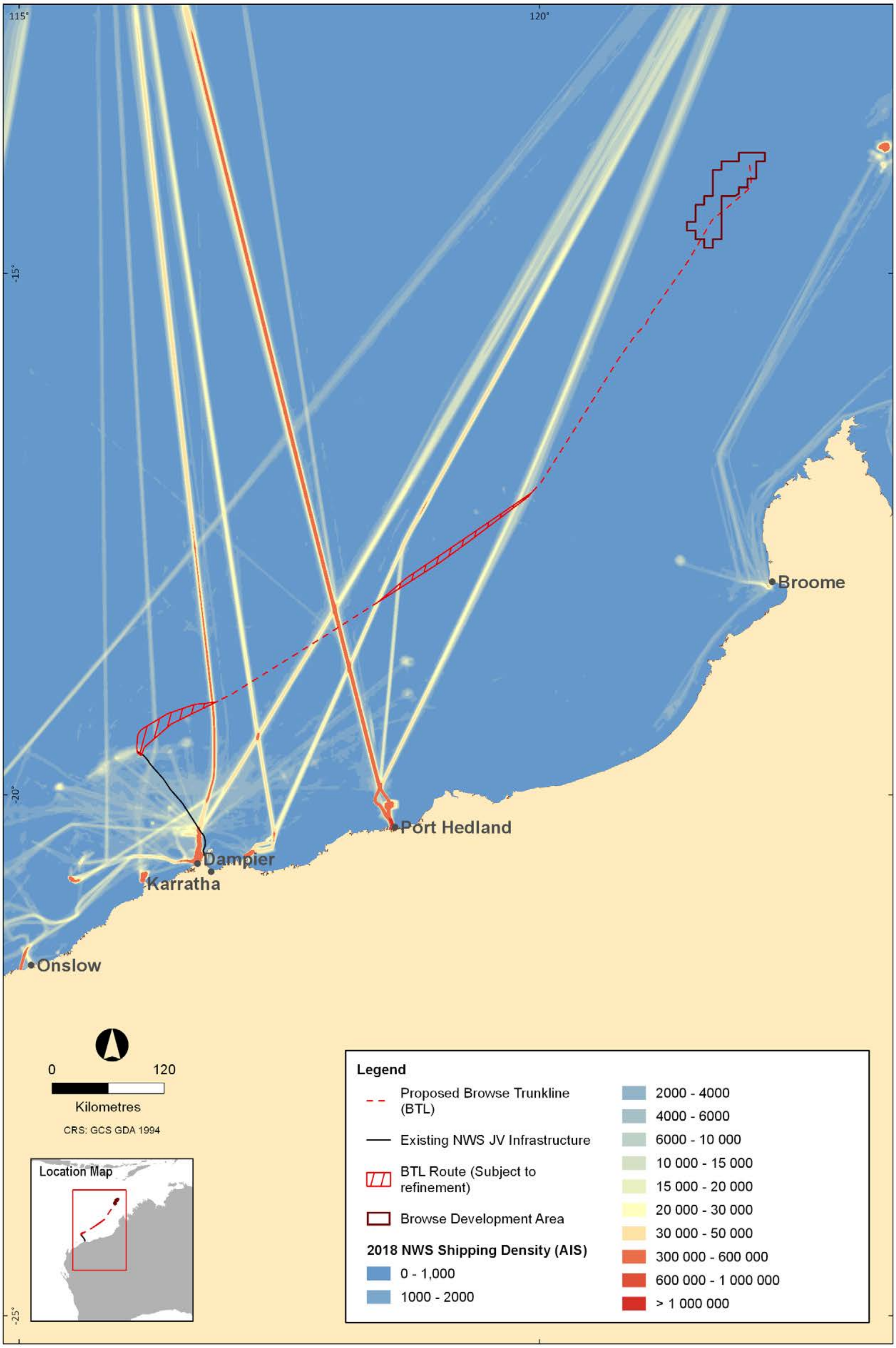


Figure 5-52 Shipping Densities within the vicinity of the Project Area in 2018

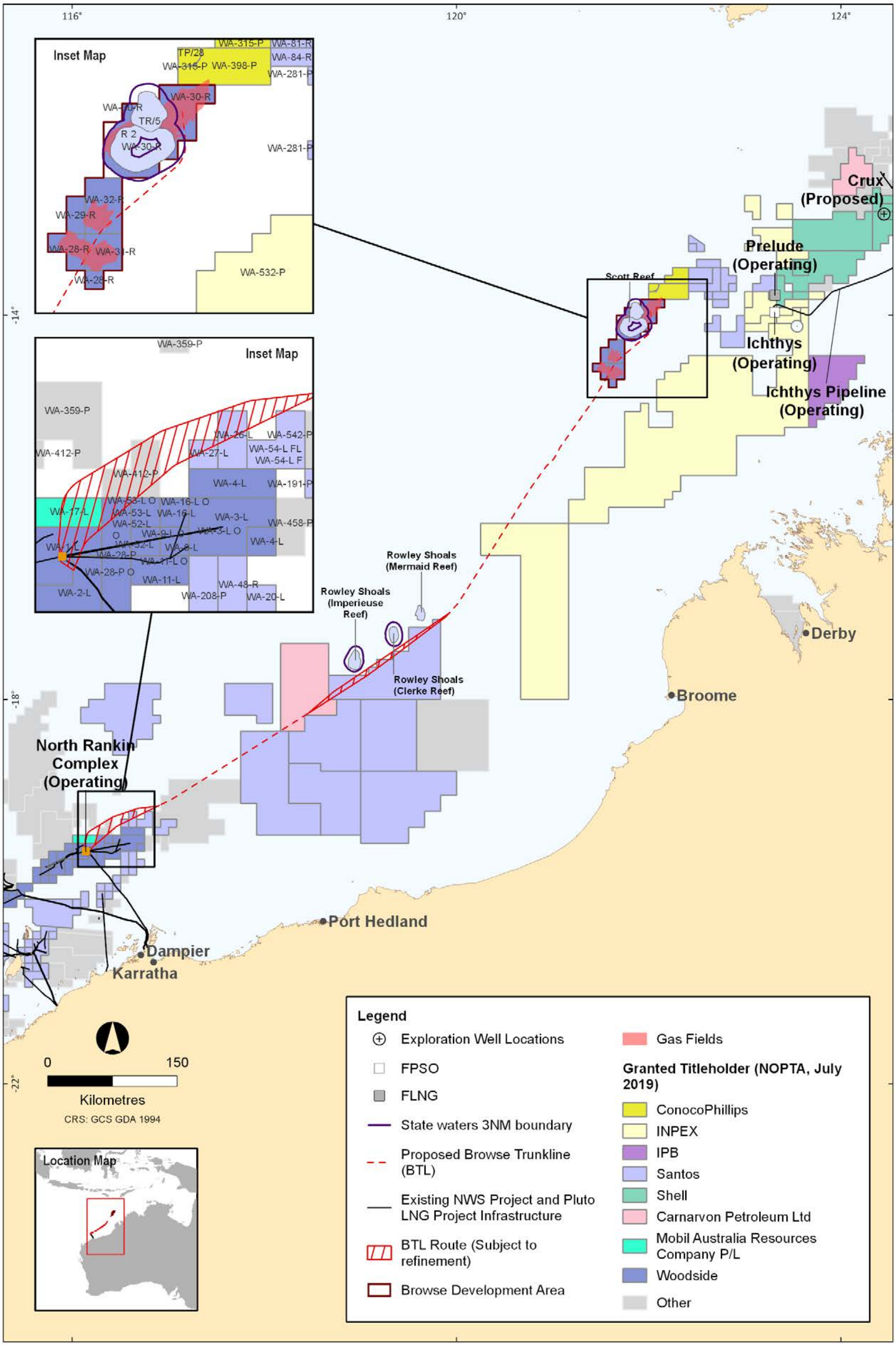


Figure 5-53 Approved and Prospective Petroleum Activities near the Browse Development Area

5.4.2.6 Tourism

Recreation and tourism activities in the NWMR occur predominantly in WA State waters (extending offshore 3 nm from the mainland), adjacent to coastal population centres (e.g. Broome), with a peak in activity during the winter months (dry season) (Commonwealth of Australia, 2012a). These activities include recreational fishing, diving, snorkelling, wildlife watching and boating.

Discussions with regional tourism groups and RecFish West in 2014 during stakeholder engagement for the previous Browse FLNG development concept indicated that only one to two recreational fishing charter operators run trips to Scott Reef. The location has the potential to provide significant opportunities for pelagic sport fishing; however, given the distance from Broome and closest landfall and associated costs, only a limited number of charter operators are prepared to take recreational fishers out to Scott Reef. Those companies that do visit Scott Reef tend to make the trip only four to five times per year, spending around five days at the reef each time. Fishing is mainly focused on the south, west and north extremities of Scott Reef, generally only going into the South Scott Reef lagoon for snorkelling and for layover at night.

5.4.2.7 Scientific Research

Within the Browse Development Area, scientific research is predominately undertaken at Scott Reef, Rowley Shoals and Ashmore Reef. A number of marine research and monitoring programs have been ongoing, particularly those conducted by AIMS and the WAM. AIMS have been monitoring coral and fish communities at Scott Reef since 1993 with regular surveys of the reef over the last 25 years. Other organisations that have been involved in undertaking or funding research activities at Scott Reef include WA Department of Fisheries (DoF), CSIRO and the Australian Research Council (ARC). The WA DoF also conducts regular monitoring and research programs in the region of the Browse Development Area. These activities are designed to collect fishery independent stock assessment data for management of each relevant fishery. Research/monitoring may take place 'on-board' existing commercial vessels or independently using dedicated research vessels.

The wider NWMR contains a number of IUCN Category Ia (Sanctuary Zone) sites which are areas managed mainly for scientific research and environmental monitoring. This research has typically been undertaken by the organisations listed above.

5.4.3 Places of Heritage Value

5.4.3.1 Indigenous Heritage

No known sites of Aboriginal Heritage significance are located within the Browse Development Area according to the WA Department of Aboriginal Affairs' Aboriginal Sites Inquiry System. The existence of any unknown Aboriginal sites or artefacts of significance within the Browse Development Area, or the wider NWMR, is considered highly unlikely due to the site's remote location offshore.

The flooded countries of Aboriginal ancestors lie beneath Commonwealth waters in the NWMR and therefore may be connected to cultural stories, sites and Dreaming tracks (Commonwealth of Australia, 2012a). Dugongs, fish and marine turtles that move between coastal and Commonwealth waters in the Region are important components of the Aboriginal people's culture and diet. Aboriginal people continue to actively manage their sea country in and adjacent to the NWMR in order to protect and manage the marine environment, its resources and cultural values.

5.4.3.2 National Heritage Sites

Australia's National Heritage Sites are those of outstanding natural, historic and/or Indigenous significance to Australia. There are no National Heritage Sites within the Project Area. The closest National Heritage Sites are the Dampier Archipelago (including the Burrup Peninsula) and the Ningaloo Coast (also a World Heritage Site; **Section 5.4.3.3**). The Dampier Archipelago is a sacred place to Aboriginal Australians and features significant collections of rock art, known as petroglyphs, as well as other sites of value to Aboriginal peoples, such as quarries, middens, fish traps and ceremonial sites (Department of the Environment and Energy, 2007).

A detailed description of the national heritage values, including Aboriginal heritage values, of the listed National Heritage Place on the Dampier Archipelago is provided within the ERD associated with the North West Shelf Project Extension Proposal (EPA 2186, EPBC 2018/8335).

Aboriginal cultural heritage management is an important consideration in Woodside's obligations to and cooperation with the Traditional Owners of the land on which it operates. In its approach to Aboriginal cultural heritage management Woodside is committed to:

- minimising impacts to Aboriginal cultural heritage
- engaging with Aboriginal communities on matters of Aboriginal cultural heritage management.

5.4.3.3 World Heritage Sites

World Heritage Sites are those sites that are important to and belong to everyone; this universal value transcends any value they may be held by any one nation (Department of the Environment and Energy, 2019s). These sites and their qualities are detailed in the *Convention concerning the Protection of the World Cultural and Natural Heritage* (the World Heritage Convention), to which Australia is a founding member.

There are no World Heritage Sites within the Project Area. The Ningaloo Coast and Shark Bay are the nearest World Heritage Sites (UNESCO World Heritage Centre, 2019), located more than 300 and 700 km from the Project Area respectively.

As described above, the Burrup Peninsula features numerous Aboriginal cultural heritage sites and places that are highly significant to Aboriginal people. The Murujuga Aboriginal Corporation (MAC) and the State government have begun the process to nominate the Burrup Peninsula for World Heritage Listing with the support of Woodside. It is anticipated that the final stages of the nomination process would culminate in 2022 and, if successful, the World Heritage Listing would highlight the Burrup Peninsula as having outstanding universal heritage values of international significance.

5.4.3.4 Commonwealth Heritage Places

Commonwealth Heritage Places are a collection of sites recognised for their Indigenous, historical and/or natural values, which are owned or controlled by the Australian Government (Department of the Environment and Energy, 2019t). A number of these sites are owned or controlled by the Department of Defence, as well as Government agencies relating to maritime safety, customs and communication (Department of the Environment and Energy, 2019t).

The PMST search identified the places listed in Table 5-42 as Commonwealth Heritage Places located within or within the vicinity of the Project Area.

Table 5-42 Commonwealth Heritage Places[1] Identified as Within the Vicinity of the Project Area

Commonwealth Heritage Place	Description	Distance from Project Area
Scott Reef and Surrounds – Commonwealth Area	This Commonwealth Heritage Place was listed in 2004 and comprises the areas of Scott Reef that are within Commonwealth waters, to the 50 m BSL bathymetric contour (approximately 7,710 ha). This includes North Scott Reef (including the associated lagoon) and parts of the lagoon of South Scott Reef (physical description of Scott Reef provided in Section 5.2.3.1). This place has been listed due to its high representation of species not found in coastal WA waters and due to the affinity of its unusual fauna species with the oceanic reef habitats of the Indo-West Pacific / Indonesian region (Department of the Environment and Energy, 2019u). The geomorphological and reef formation processes which have occurred at Scott Reef are also key to our long-term understanding of these processes. The large tidal ranges and other environmental conditions which occur at Scott Reef are also unique for a shelf atoll (Department of the Environment and Energy, 2019u). As discussed throughout Section 5, Scott Reef supports a diversity of biota.	Located within the Project Area
Ashmore Reef National Nature Reserve	The Ashmore Reef National Nature Reserve is now known as the Ashmore Reef Marine Park (described in Section 5.3.3.2). This place was listed due to its significance as a staging point for migratory shorebirds, provision of habitat for high numbers of breeding seabirds (including featuring significant seabird rookeries), provision of habitat for sea snakes, and a high diversity of marine habitats relative to other NWS reefs which in turn support a diversity of fauna species (including EPBC Act listed species) (Department of the Environment and Energy, 2019v). In addition, this place has significance due to its history of human occupation and use (including by Indonesian fisherman) since the early 18th Century, as well as the occurrence of phosphate mining (Department of the Environment and Energy, 2019v). The ecological features of Ashmore Reef are described in Section 5.3.5.1.	Located ~ 230 km north-west of the Browse Development Area

Commonwealth Heritage Place	Description	Distance from Project Area
Mermaid Reef – Rowley Shoals	This Commonwealth Heritage Place was listed in 2004 in recognition of its fauna which are both typical of the oceanic reef habitats of the Indo-West Pacific and which have affinities to fauna of the Indonesian Region, its high representation of fauna species not found in coastal WA waters (and/or not previously recorded in WA), sand cays which provide important habitat to migratory shorebirds, high fauna diversity relative to the region, and its particular physical environmental conditions (as for Scott Reef) such as high tidal range. The physical and ecological features of the Rowley Shoals are described in **Sections 5.2.3.3** and **5.3.5.1** respectively.	Located ~11.5 km from the Project Area

1 Please note, 'Seringapatam Reef and Surrounds' was delisted as a Commonwealth Heritage Place in June 2004 and remains 'ineligible' for listing (Department of the Environment and Energy, 2019w)

5.4.3.5 Marine Archaeology

The Australian National Shipwreck Database and the WA Maritime Museum Shipwreck Database lists one protected historic wreck within the Browse Development Area; the historic shipwreck of the Yarra is located at South Scott Reef (maximum latitude 14º02'3"S, maximum longitude of 121º46'0"E) (DEWHA 2008). The Yarra was an iron barque vessel carrying a load of guano which struck the reef during a gale in 1884 (Souter, 2009).

In addition, a suspected Indonesian fisherman boat was identified during the survey of the BTL route.

Other historic shipwrecks within the wider NWMR include the Trial, the Lively, the Ann Millicent, and the Crown of England. These shipwrecks are at least 200 km from the Browse Development Area. Shipwrecks are considered protected places, with shipwrecks older than 75 years protected under the Commonwealth Historic Shipwrecks Act 1976 and those dated pre-1900 protected by the WA *Maritime Archaeology Act 1973*. As of July 1st 2019, the *Historic Shipwrecks Act 1976* has been replaced by the Underwater Cultural Heritage Act 2018, which will enable shipwrecks, sunken aircraft and other underwater heritage to be listed by individual declaration after an assessment of heritage significance (Department of the Environment and Energy, 2019x).

5.4.4 Communities

The proposed Browse to NWS Project presents potential social benefits and impacts to communities within WA and particularly Broome and the Dampier Peninsula, with Broome being the potential primary supply chain and logistics support location.

Woodside undertook a Social Impact Assessment (SIA) of the proposed Browse to NWS Project (Advisian, 2019b) which included overviews of the existing socio-economic environment of these locations. A summary is included below. Stakeholder consultation undertaken as part of the SIA is presented in **Chapter 4**. The outcomes of the SIA with respect to potential social benefits and impacts are included in **Chapter 6**.

5.4.4.1 Broome

Broome is located within WA's Kimberley region, approximately 2,200 kms north of Perth. Aboriginal people have lived in the Kimberley region for tens of thousands of years and have strong cultural connections and ties to country in this area. The town of Broome, which started as a small settlement of pearling camps, with Malay crews and European boat owners at Roebuck Bay, was gazetted in 1883. By 1898 Broome was a key cargo port for north WA. Broome's fortunes, based around the pearling industry, have ebbed and flowed over time and the industry has provided Broome with a unique, multicultural character (Shire of Broome, 2018).

Over the past 50 years, tourism has become increasingly important to Broome and has led to increased flights, facilities and services for residents, including remote Aboriginal settlements (Shire of Broome, 2018). The town of Broome offers a diverse range of facilities to residents and visitors, including recently upgraded medical facilities at the Broome Health Campus, various primary and secondary schools and a diverse range of leisure and recreation facilities.

Within Broome, existing resource developments are largely associated with gas and mineral sands, including Sheffield Resources Thunderbird (mineral sands), INPEX Ichthys (LNG) and Shell Prelude (FLNG). Other proposed resource developments in the Broome region include those for oil, gas, zinc and iron ore (Department of Mines, Industry Regulation and Safety, 2018; Department of the Environment and Energy, 2018).

Broome is characterised by a diverse economic base with the community employed in a range of different industries. The main industry of employment is health care and social assistance (15.6%), followed by education and training (11.8%) and accommodation and food services (10.1%). Other key features include (Advisian, 2019b):

- population growth of 1.6% between the 2011 and 2016 census periods which is slightly less than the population growth rate of WA, 2.1%

- a high rate of cultural diversity with 28.2% of the population identifying as Indigenous compared with 3% across WA
- a relatively stable population with 35.5% residing at the same address as the previous 5 years
- 45.7% of the population of Broome, aged 15 and over, had gained a year 12 level education. The post school education profile of Broome was similar to that of WA as a whole and 17% of the population, aged 15 and over, had received a bachelor's degree or higher
- a higher rate of unemployment, 8.2% in June 2018, than that of WA, 6.2%. This reflects the fact that since 2016 the number of employment opportunities has decreased and that a number of local businesses have closed.

The community has a strong connection to its history, identity and culture, particularly its Aboriginal culture and traditions. Residents of Broome placed a high value on its natural environment and expressed a desire to preserve this. Stakeholders welcome new development and economic growth with consideration of its natural and social environment (Advisian, 2019b).

5.4.4.2 Dampier Peninsula

Dampier Peninsula is a vast and remote suburb of Broome, which spans 4,756 km^2. Within Dampier Peninsula there are three main settlements - Ardyaloon (also known as One Arm Point), Beagle Bay, Djarindjin and Lombadina. There are also more than 50 smaller settlements of various sizes in the northern part of the Dampier Peninsula, the closest to Broome is Beagle Bay which is about 130 km north. The settlements are linked to Broome via the Cape Leveque Road. Until recently this road was unsealed however over the last few years sections of the road have been sealed and a $65 million project to seal the remaining 90 km of road commenced in 2018. The sealing and upgrade of the last 90 km will be undertaken in stages over three or four years to allow communities to prepare for increased visitors and traffic to the area (Laden, 2018).

Facilities available for the community are limited. There exists two Aboriginal community clinics - Lombadina Health Centre, which operates 24 hours, and One Arm Point Health Centre, as well as three schools (Western Australia Country Health Service, 2018). Structured recreational facilities are limited, with most sports and recreational activities undertaken in local bushland and the sea.

Djarindjin Airport, largely used to service local communities and oil and gas exploration activities, is unique within Australia as it is fully staffed and managed by the local Aboriginal community and is one of the few civilian airports with staff trained to 'hot refuel' helicopters whilst they are still running. The airport currently 'hot refuels' 24 helicopters a day (Cordingley and Waddell, 2018).

Existing resource developments within or offshore from Dampier Peninsula are for gas or mineral sands. This includes the onshore mineral sands development Sheffield Resources' Thunderbird and offshore developments such as INPEX's Ichthys (LNG) and Shell Prelude (FLNG) projects.

Dampier Peninsula is characterised by a small and predominantly Aboriginal population (85.7%) and 30% of the population speak Aboriginal languages at home.

CHAPTER 6

IMPACTS AND RISK

Woodside

6. IMPACTS AND RISK

6.1 Introduction

An assessment of the impacts and risks associated with the proposed Browse to NWS Project has been undertaken in accordance with Woodside's Risk Assessment Procedure and Environment Impact Assessment Guideline. This procedure and guideline set out the broad principles and highlevel steps for assessing environmental impacts and risks across the lifecycle of Woodside's activities and their management. The key steps of the Woodside impact and risk management process are:

- the environmental impact and risk assessment
- the communication and consultation that informs the assessment and ongoing performance
- the steps required during implementation of the activity including to monitor, review and report.

The risk management process is shown in **Figure 6-1**.

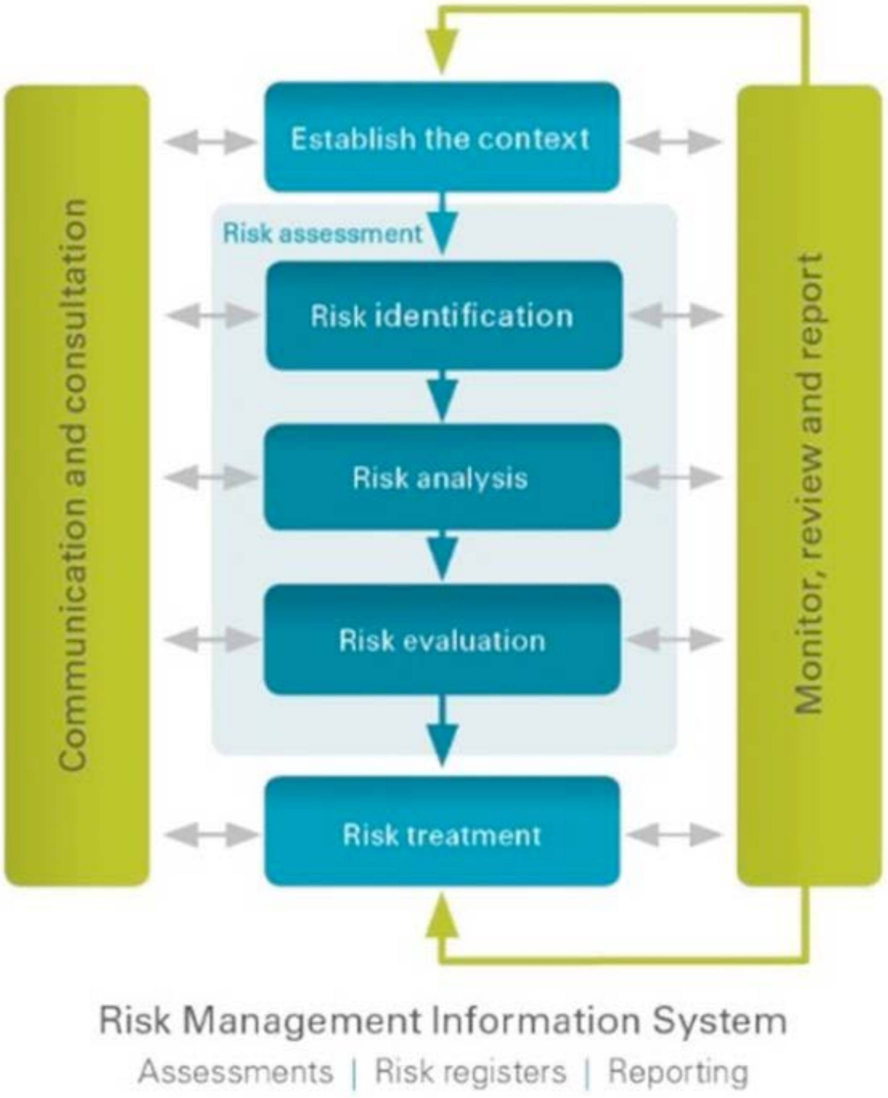


Figure 6-1 Woodside's Risk Management Process (based on European Commission, 2019)

This Section presents:

- the impact and risk assessment stage of the risk management process, including the assessment of the acceptability of the proposed Browse to NWS Project (**Section 6.2.3**)
- a detailed impact and risk assessment for each aspect, including an assessment of acceptability (**Section 6.3**), including:
  - the environmental objectives applicable for each aspect
  - relevant policy and guidance
  - the source of the aspect
  - the relevant receptors and receptor sensitivity to the aspect (including physical, ecological and socio-economic)
  - predicted environmental impact from planned routine and non-routine events
  - potential environmental risk from unplanned events
  - cumulative impacts from multiple sources of the same aspect
  - proposed mitigation and management
  - an overall assessment on the acceptability of the impacts and risks.

A qualitative assessment of cumulative impacts is presented as part of the overall conclusion in **Chapter 9**.

6.2 Impact and Risk Assessment Process

6.2.1 Overview

This Section provides an overview of Woodside's approach to undertaking impact and risk assessments for the proposed Browse to NWS Project.

The impact and risk assessment has been undertaken in accordance with Woodside's Risk Management Procedure, Impact Assessment Procedure and Environment Impact Assessment Guideline. These documents support the implementation of impact and risk assessment and set out the broad principles and high-level steps for assessing environmental impacts and risks across the lifecycle of Woodside's activities.

Within this process, a distinction is made between an 'impact' and a 'risk' as follows:

- **Environmental Impact**: An expected change to the environment, whether adverse or beneficial, wholly or partially resulting from the planned routine and non-routine project activities (e.g. routine liquid discharges).
- **Environmental Risk**: An unplanned event or incident which impacts the achievement of the stated environmental objectives.

Potential impacts and risk from activities during all phases of the proposed Browse to NWS Project have been evaluated.

The key steps of the Process are shown in **Figure 6-2**. A description of each step and how it is applied to the scope of the activity is provided in **Section 6.2.2** to **Section 6.2.3**.

6.2.2 Context Setting

6.2.2.1 Activity Description

The activity description describes the key activities associated with the proposed Browse to NWS Project and identifies the environmental aspects for each activity (i.e. the elements of the activity (planned or unplanned) that have the potential to impact on the environment). **Table 6-1** shows the relationships between the proposed Browse to NWS Project activities and the aspects. **Chapter 3** describes all components of the proposed Browse to NWS Project which are relevant to this assessment.

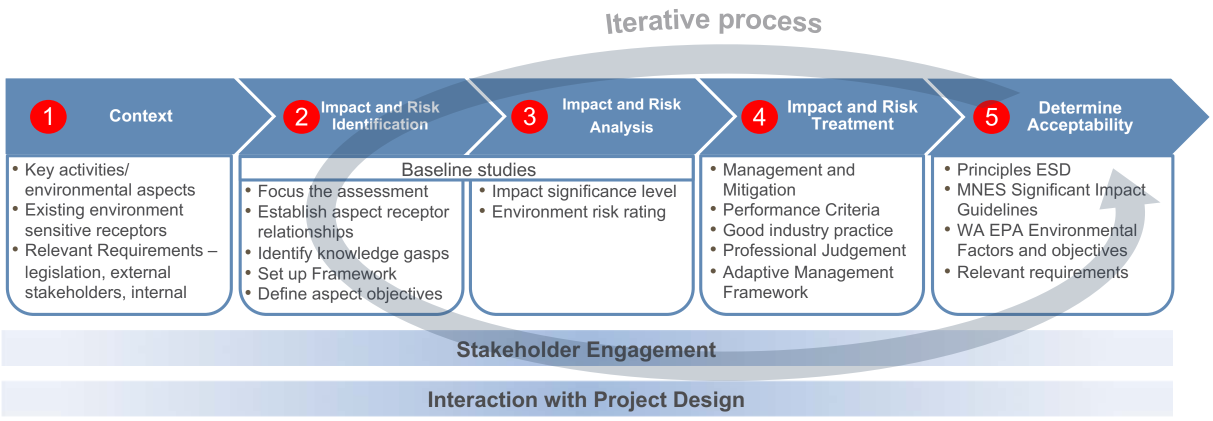


Figure 6-2 Overview of approach for impact and risk assessments

Table 6-1 Activity – Aspect Relationship

Aspect Name	Development Drilling	Installation of Subsea Umbilicals, Risers and Flowlines (SURF)	Installation of FPSO facilities	Installation of BTL and Inter-Field Spur Line	Extraction (including operation of subsea infrastructure	Processing (FPSO facilities)	Condensate Offload (FPSO facilities)	Gas Export (to NWS infrastructure)	Inspection, Maintenance and Repair (IMR) Activities	Decommissioning	Support Activities Inc. Vessels and Helicopters
Physical Presence: Seabed Disturbance	✓	✓	✓	✓					✓	✓	
Physical Presence: Disturbance to Other Users	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Physical Presence: Light	✓	✓	✓	✓		✓			✓	✓	✓
Physical Presence: Electromagnetic Emissions				✓	✓						
Atmospheric Emissions: Offshore Activities	✓	✓	✓	✓		✓	✓		✓	✓	✓
Atmospheric Noise	✓	✓	✓	✓		✓	✓		✓	✓	✓
Underwater Noise	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Marine Discharges: Sewage and Sullage	✓	✓	✓	✓		✓	✓		✓	✓	✓
Marine Discharges: Treated Utility Water, Chemical and Deck Drainage	✓	✓	✓	✓		✓	✓		✓	✓	✓
Marine Discharges: Putrescible Waste	✓	✓	✓	✓		✓	✓		✓	✓	✓
Marine Discharges: Produced Water	✓					✓					
Marine Discharges: Cooling Water	✓	✓	✓	✓		✓	✓		✓	✓	✓
Marine Discharges: Hazardous and Non-Hazardous Inorganic Waste	✓	✓	✓	✓		✓	✓		✓	✓	✓
Marine Discharges: Drilling and Completions Discharges	✓										

Aspect Name	Development Drilling	Installation of Subsea Umbilicals, Risers and Flowlines (SURF)	Installation of FPSO facilities	Installation of BTL and Inter-Field Spur Line	Extraction (including operation of subsea infrastructure	Processing (FPSO facilities)	Condensate Offload (FPSO facilities)	Gas Export (to NWS infrastructure)	Inspection, Maintenance and Repair (IMR) Activities	Decommissioning	Support Activities Inc. Vessels and Helicopters
Marine Discharges: Subsea Control Fluid	✓	✓		✓	✓				✓	✓	
Marine Discharges: Hydrotest Fluid	✓	✓		✓					✓		
Physical Presence (unplanned): Vessel Interactions with Fauna	✓	✓	✓	✓	✓		✓		✓	✓	✓
Physical Presence (Unplanned): Invasive Marine Species	✓	✓	✓	✓			✓		✓	✓	✓
Production Activities: Seabed Subsidence					✓						
Unplanned Hydrocarbon Releases	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

6.2.2.2 Defining the Existing Environment

The existing environmental context of the proposed Browse to NWS Project was defined in order to identify environmental receptors that have the potential to interact with the proposed Browse to NWS Project, including:

- physical characteristics of the environment (e.g. seabed and water quality)
- ecological characteristics of the environment (e.g. benthic communities, fish, seabirds, marine reptiles and marine mammals)
- socio-economic and cultural characteristics of the environment (e.g. heritage, fishing, shipping and tourism).

Definition of the existing environment includes environmental receptors in the Project Area and the broader EMBA by an unplanned event.

It should be noted that for the purpose of the environmental impact and risk assessment presented in this draft EIS/ERD, Scott Reef, which encompasses the reef system including all coral habitats and communities, is considered as the area "*above the 75 m bathymetric contour within the 3 nm State waters boundary and the Scott Reef and Surrounds - Commonwealth Area National Heritage Place which comprises the Commonwealth Marine Area wholly within the WA coastal waters surrounding North and South Scott Reef*". The deepwater benthic communities are defined as those communities below the 75 m bathymetric contour and make up the remainder of the Project Area.

Information on the existing environment has been primarily drawn from existing studies completed by Woodside and others. Over two decades, Woodside has commissioned approximately 60 studies within the proposed Browse Development Area, Scott Reef and the broader region. Studies have included baseline and monitoring programs for humpback whale, turtle, other marine megafauna and fish species in the region, as well as long-term monitoring of coral and fish communities at Scott Reef and the Rowley Shoals.

In addition, Woodside has undertaken an environmental survey of the proposed BTL route, including water and sediment sampling and characterisation of the deepwater seabed habitat and benthic communities.

These studies have enabled Woodside to build a comprehensive understanding of the environmental context of the proposed Browse to NWS Project, to enable identification of the potential environmental impacts and assessment and selection of the appropriate measures to manage and mitigate these.

A detailed description of the existing environment is provided in Chapter 5.

6.2.2.3 Review of significance/sensitivity of receptors and levels of protection

This step is important for establishing the context of the environment, as it identifies the more significant or sensitive receptors and proposes the level of protection. This is achieved by assessing the receptor sensitivity (i.e. the susceptibility/vulnerability/importance of the receptor) as either high, medium or low value for each receptor in the Project Area and EMBA and the criteria for determining whether impacts and risks are acceptable.

The sensitivity of each of the receptors has been determined to be either low, medium or high. Key considerations for this determination included:

+ **Quality:** Is the receptor considered to be relatively high quality/in good condition, or is it damaged/degraded?
+ **Sensitivity to change:** Is the receptor highly sensitive to environmental change and less likely to be able to adapt?
+ **Importance:** Is the receptor considered to be of local, regional or international importance?

Sensitivity considerations take into account any relevant legal protection, government policy, stakeholder views and ecosystem service value.

6.2.2.4 Environmental legislation and other requirements

It is important to know what environment legislation or other requirements are applicable. These may include:

+ legislation that identifies the manner in which specific activities should be undertaken (such as vessel activities)
+ legislation or requirements for particular impacts and risks (e.g. biosecurity legislation)
+ management plans, guidelines, or advices that are issued by government departments to aid in the protection of significant receptors.

In preparing this draft EIS/ERD, Woodside has ensured that the proposed controls and impact and risk levels are consistent with national and international standards, law and policies (including applicable plans for management and conservation advices and the *Matters of National Environmental Significance – Significant impact guidelines 1.1* (Commonwealth of Australia, 2013).

This has included undertaking this impact and risk assessment in accordance with the applicable legislation identified in Chapter 2 and incorporating relevant requirements of:

+ AMP management plans prepared under Section 370 of the EPBC Act. These outline the objectives for conserving marine habitats and the species that live and rely on these habitats within AMPs.
+ species recovery plans which are enacted under the EPBC Act and remain in force until the species is removed from the threatened list.
+ conservation advices which provide guidance on immediate recovery and threat abatement activities that can be undertaken to facilitate the conservation of a listed species or ecological communities.

This draft EIS/ERD has also considered the MNES Significant Impact Guidelines, Principles of Ecologically Sustainable Development as defined in Section 3A of the EPBC Act and the WA EPA Environmental Factors and Objectives as described in Section 6.2.3.3.

6.2.2.5 External Requirements

In addition to legal or other requirements, to establish the context for the proposed Browse to NWS Project, there is a need to understand stakeholder expectations for the area in which the proposal/proposed action is to take place. These expectations may be based on previous experience and past stakeholder consultation or may be identified during current stakeholder consultation activities and, as such, need to be tracked and considered for the impact and risk assessment.

Woodside has a long history of operating in the north-west of Australia, has established strong stakeholder relationships and recognises the importance of understanding stakeholder views with respect to oil and gas activities in the region. When establishing acceptable levels for impacts and risks, Woodside considers the expectations of potentially impacted stakeholders and factors these expectations into decision-making processes for the level of potential impact and risk of activities.

Woodside continues to undertake consultation with identified relevant stakeholders (described in Chapter 4), incorporating outcomes into the draft EIS/ERD where applicable and will continue to consider the views of stakeholders who provide comment on the proposed Browse to NWS Project through the formal consultation process and other means of ongoing consultation.

Consideration of the stakeholder views received via the draft EIS/ERD public review process will be incorporated into the proposed Browse to NWS Project EIS/ERD Supplement that will be submitted to the DoEE and EPA for their assessment following the public comment period.

6.2.2.6 Internal Requirements

As well as legal and external requirements, there are also internal requirements within Woodside that must be implemented when undertaking activities. These may be focussed on the manner in which the particular activities are undertaken (e.g., mitigation measures to ensure minimal impact to cetaceans and turtles from VSP during development drilling), for particular impacts or risks (e.g., risk assessment of project vessels for Invasive Marine Species (IMS)) or in order to protect certain receptors.

The Woodside Management System (WMS) (described in **Chapter 8**) defines how Woodside delivers its business objectives and the boundaries within which all Woodside employees and contractors are expected to work.
The objectives under the WMS define the mandatory performance requirements that apply to all Woodside activities and the performance of its employees and contractors within their areas of responsibility.

6.2.3 Impact and Risk Assessment

6.2.3.1 Identifying Impacts and Risks

Based upon the context of the proposed Browse to NWS Project, and known environmental aspects, relevant impacts and risks were identified in the scoping phase. During this phase, the relationships between the environmental aspects identified for the proposed activities and the associated potential impacts and risks for each receptor were established.
This set up the framework for the more detailed impact and risk analysis and evaluation and helped identify knowledge gaps, which may have triggered specific studies and surveys. The detailed impact and risk analysis and evaluation was undertaken by considering the identified receptors (**Chapter 5**) with the potential to be exposed to or interact with an aspect, then determining the subsequent outcomes of that interaction or exposure (impacts or risks).

These aspect–receptor relationships were first presented in the EISG/ESD and have been reviewed and refined during the preparation of the draft EIS/ERD and provided in **Table 6-2**. This table shows all the identified impacts and risks which are discussed in **Section 6.3** and highlights those that have been carried through for a detailed assessment. Within **Table 6-2**, aspects that present a potential impact from a planned activity are identified with an 'I'. Where the aspect presents a risk from an unplanned event or incident they are identified with an 'R". Where both an impact and a risk apply, this identified by 'I/R'.

Table 6-2 Aspect-Receptor Relationship

Key			
■	Detailed impact/risk assessment	□	Impact/risk considered
I	Impact	R	Risk

Aspect	Impact/Risk	Physical					Ecological											Socio-Economic									
								Benthic communities and habitats			Fauna				Regional conservation values			Other Users								Heritage	
		Sediment Quality	Water Quality	Air Quality	Ambient Light	Ambient Noise	Plankton Communities	Deepwater Benthic Communities and Habitats (>75 m depth)	Shallow Water Benthic Communities and Habitats (<75 m depth)	Coastal Habitats	Seabirds and Migratory Shorebirds	Fish	Marine Mammals	Marine Reptiles	Key Ecological Features	Australian Marine Parks	State Marine Parks & Nature Reserves	Commonwealth Managed Fisheries	State Managed Fisheries	Tourism and Recreation	Scientific Studies	Shipping	Industry	Settlements	Other Protected Places	Aboriginal and Indigenous heritage	Marine Archaeology
Physical Presence: Seabed Disturbance	Change in water quality		I/R					I/R	I/R						I/R	I/R									I/R		
	Change in sediment quality	I/R						I/R	I/R						I/R	I/R									I/R		
	Change in habitat							■ I/R	I/R						■ I/R	■ I/R									I/R		
	Injury or mortality to fauna						I/R	■ I/R	I/R						■ I/R	■ I/R									I/R		
	Change in heritage values																										I/R
Physical Presence: Disturbance to Other Users	Changes to the functions, interests or activities of other users																	■ I	■ I	I	I	I	I			I	

Aspect	Impact/Risk	Physical					Ecological											Socio-Economic									
								Benthic communities and habitats			Fauna				Regional conservation values			Other Users								Heritage	
		Sediment Quality	Water Quality	Air Quality	Ambient Light	Ambient Noise	Plankton Communities	Deepwater Benthic Communities and Habitats (>75 m depth)	Shallow Water Benthic Communities and Habitats (<75 m depth)	Coastal Habitats	Seabirds and Migratory Shorebirds	Fish	Marine Mammals	Marine Reptiles	Key Ecological Features	Australian Marine Parks	State Marine Parks & Nature Reserves	Commonwealth Managed Fisheries	State Managed Fisheries	Tourism and Recreation	Scientific Studies	Shipping	Industry	Settlements	Other Protected Places	Aboriginal and Indigenous heritage	Marine Archaeology
Physical Presence: Light	Change in ambient light				—																						
	Change in fauna behaviour						—		—		—	—		—		—	—								—		
	Injury or mortality to fauna													—													
	Changes to the functions, interests or activities of other users																	—	—	—	—						
Physical Presence: Electromagnetic Emissions	Change in fauna behaviour											—	—	—													
Atmospheric Emissions: Offshore Activities	Change in air quality			—																							
	Injury or mortality to fauna										—																
Atmospheric Emissions: Third Party Processing of Browse Gas	Change in air quality			—																						—	
Atmospheric Noise Emissions	Change in ambient noise					—																					
	Change in fauna behaviour										—	—	—	—			—										
	Changes to the functions, interests or activities of other users																			—	—			—			

Aspect	Impact/Risk	Physical					Ecological											Socio-Economic									
								Benthic communities and habitats			Fauna				Regional conservation values			Other Users								Heritage	
		Sediment Quality	Water Quality	Air Quality	Ambient Light	Ambient Noise	Plankton Communities	Deepwater Benthic Communities and Habitats (>75 m depth)	Shallow Water Benthic Communities and Habitats (<75 m depth)	Coastal Habitats	Seabirds and Migratory Shorebirds	Fish	Marine Mammals	Marine Reptiles	Key Ecological Features	Australian Marine Parks	State Marine Parks & Nature Reserves	Commonwealth Managed Fisheries	State Managed Fisheries	Tourism and Recreation	Scientific Studies	Shipping	Industry	Settlements	Other Protected Places	Aboriginal and Indigenous heritage	Marine Archaeology
Underwater Noise Emissions	Change in ambient noise					I/R																					
	Change in fauna behaviour						I/R					I/R	I/R	I/R	I/R	I	I/R								I/R		
	Injury or mortality to fauna							I/R	I/R			I/R	I/R	I/R	I/R		I/R								I/R		
	Changes to the functions, interests or activities of other users																	I/R	I/R	I/R	I/R						
Marine Discharges: Sewage and Sullage	Change in water quality		I/R					I/R	I/R						I/R	I/R									I/R		
	Change in fauna behaviour						I/R																				
	Injury or mortality to fauna											I/R	I/R	I/R													
	Changes to the functions, interests or activities of other users																	I/R	I/R	I/R	I/R						
Marine Discharges: Treated Utility Water, Chemical and Deck Drainage	Change in water quality		I/R					I/R	I/R						I/R	I/R									I/R		
	Injury or mortality to fauna						I/R					I/R	I/R	I/R											I/R		
	Changes to the functions, interests or activities of other users																	I/R	I/R	I/R	I/R						

Aspect	Impact/Risk	Physical					Ecological											Socio-Economic									
								Benthic communities and habitats			Fauna				Regional conservation values			Other Users								Heritage	
		Sediment Quality	Water Quality	Air Quality	Ambient Light	Ambient Noise	Plankton Communities	Deepwater Benthic Communities and Habitats (>75 m depth)	Shallow Water Benthic Communities and Habitats (<75 m depth)	Coastal Habitats	Seabirds and Migratory Shorebirds	Fish	Marine Mammals	Marine Reptiles	Key Ecological Features	Australian Marine Parks	State Marine Parks & Nature Reserves	Commonwealth Managed Fisheries	State Managed Fisheries	Tourism and Recreation	Scientific Studies	Shipping	Industry	Settlements	Other Protected Places	Aboriginal and Indigenous heritage	Marine Archaeology
Marine Discharges: Putrescible Waste	Change in water quality		I					I	I						I	I									I		
	Change in fauna behaviour						I				I	I	I	I											I		
	Changes to the functions, interests or activities of other users																	I	I	I	I						
Marine Discharges: Produced water	Change in water quality		I/R					I/R	I/R						I/R		I/R								I/R		
	Change in sediment quality	I/R																									
	Injury or mortality to fauna						I/R					I/R	I/R	I/R	I/R		I/R										
	Changes to the functions, interests or activities of other users																	I/R	I/R	I/R	I/R					I/R	
Marine Discharges: Cooling Water	Change in water quality		I/R					I/R	I/R						I/R	I/R	I/R								I/R		
	Injury or mortality to fauna						I/R					I/R	I/R	I/R													
	Changes to the functions, interests or activities of other users																	I/R	I/R	I/R	I/R					I/R	

Aspect	Impact/Risk	Physical					Ecological											Socio-Economic									
								Benthic communities and habitats			Fauna				Regional conservation values			Other Users								Heritage	
		Sediment Quality	Water Quality	Air Quality	Ambient Light	Ambient Noise	Plankton Communities	Deepwater Benthic Communities and Habitats (>75 m depth)	Shallow Water Benthic Communities and Habitats (<75 m depth)	Coastal Habitats	Seabirds and Migratory Shorebirds	Fish	Marine Mammals	Marine Reptiles	Key Ecological Features	Australian Marine Parks	State Marine Parks & Nature Reserves	Commonwealth Managed Fisheries	State Managed Fisheries	Tourism and Recreation	Scientific Studies	Shipping	Industry	Settlements	Other Protected Places	Aboriginal and Indigenous heritage	Marine Archaeology
Marine Discharges: Drilling and completions discharges	Change in water quality		I/R												I/R										I/R		
	Change in sediment quality	I/R													I/R										I/R		
	Injury or mortality to fauna						I/R	I/R	I/R			I/R	I/R	I/R	I/R												
	Change in habitat							I/R	I/R																		
	Changes to the functions, interests or activities of other users																	I/R	I/R	I/R	I/R					I/R	
Marine Discharges: Subsea control fluids	Change in water quality		I/R					I/R	I/R						I/R	I/R											
	Change in sediment quality	I/R													I/R	I/R											
	Injury or mortality to fauna						I/R					I/R	I/R	I/R	I/R												
	Changes to the functions, interests or activities of other users																	I/R	I/R								
Marine Discharges: Hydrotest Fluid	Change in water quality		I					I	I						I												
	Change in sediment quality	I						I							I												
	Injury or mortality to fauna						I	I				I	I	I											I		
	Changes to the functions, interests or activities of other users																	I	I	I	I						

Aspect	Impact/Risk	Physical					Ecological											Socio-Economic									
								Benthic communities and habitats			Fauna				Regional conservation values			Other Users								Heritage	
		Sediment Quality	Water Quality	Air Quality	Ambient Light	Ambient Noise	Plankton Communities	Deepwater Benthic Communities and Habitats (>75 m depth)	Shallow Water Benthic Communities and Habitats (<75 m depth)	Coastal Habitats	Seabirds and Migratory Shorebirds	Fish	Marine Mammals	Marine Reptiles	Key Ecological Features	Australian Marine Parks	State Marine Parks & Nature Reserves	Commonwealth Managed Fisheries	State Managed Fisheries	Tourism and Recreation	Scientific Studies	Shipping	Industry	Settlements	Other Protected Places	Aboriginal and Indigenous heritage	Marine Archaeology
Production Activities: Seabed Subsidence	Change in habitat							I	I		I			I			I										
	Changes to the functions, interests or activities of other users																			I	I						
	Change in heritage values																										I
Marine Discharges: Hazardous and Non-Hazardous Inorganic Waste	Change in water quality		R						R						R	R									R		
	Change in sediment quality	R													R	R											
	Injury or mortality to fauna						R	R			R	R	R	R	R	R	R										
	Changes to the functions, interests or activities of other users																	R	R	R	R						
Unplanned Vessel Interactions with Fauna	Injury or mortality to fauna											R	R	R													
Physical Presences (Unplanned): Invasive Marine Species	Change in ecosystem dynamics							R	R			R			R	R	R								R		
	Changes to the functions, interests or activities of other users																	R	R	R	R		R				

Aspect	Impact/Risk	Physical					Ecological											Socio-Economic									
								Benthic communities and habitats			Fauna				Regional conservation values			Other Users								Heritage	
		Sediment Quality	Water Quality	Air Quality	Ambient Light	Ambient Noise	Plankton Communities	Deepwater Benthic Communities and Habitats (>75 m depth)	Shallow Water Benthic Communities and Habitats (<75 m depth)	Coastal Habitats	Seabirds and Migratory Shorebirds	Fish	Marine Mammals	Marine Reptiles	Key Ecological Features	Australian Marine Parks	State Marine Parks & Nature Reserves	Commonwealth Managed Fisheries	State Managed Fisheries	Tourism and Recreation	Scientific Studies	Shipping	Industry	Settlements	Other Protected Places	Aboriginal and Indigenous heritage	Marine Archaeology
Unplanned Hydrocarbon Releases	Change in water quality		R					I	I						R	R	R								R		
	Change in sediment quality	R								R					R	R	R										
	Injury or mortality to fauna						R	R			R	R	R	R				R	R								
	Changes to the functions, interests or activities of other users																	R	R	R	R	R	R	R			
	Change in heritage values																									R	R

6.2.3.2 Impacts and Risks Assessment

The assessment of impacts and risk was undertaken through a systematic process consistent with Woodside's Impact Assessment Procedure and Environment Impact Assessment Guideline. Each activity (either planned or unplanned) was considered with respect to its potential to affect an environmental receptor. The assessment was informed by a range of environmental studies that included the review of existing data and the modelling of discharges and emissions. Inherent controls, such as design features, legislative requirements, industry good practice and applicable Woodside corporate standards were considered when identifying the credible impact and risk scenarios.

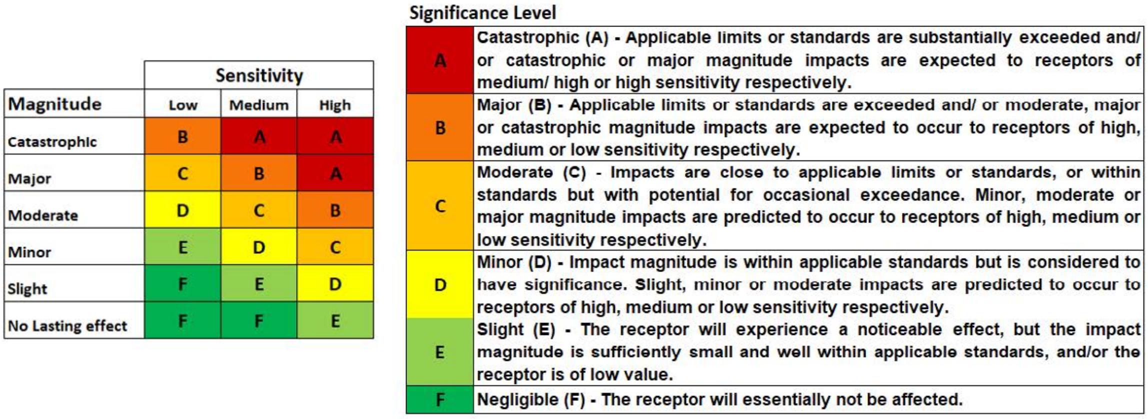
This process provides the inputs to the assessment of the impact significance for impacts and the risk rating for risks. In this impact and risk assessment approach, in the event where an impact or risk (with inherent controls considered) is deemed to be unacceptable, further mitigation and management measures are identified and applied.

6.2.3.2.1 Impact Significance Level

The environmental impact assessment approach undertaken included the following steps:

1. Identification of project **aspects** (i.e. results of planned or unplanned project activities that have the potential to impact on the environment).
2. Identification of the **receptors** (i.e. physical, biological, socio economic (i.e. cultural or human elements) of the environment that may be impacted by project aspects).
3. Assessment of the r**eceptor sensitivity** (i.e. the sensitivity/vulnerability/importance of the receptor) as either high, medium or low value.
4. Assessment of the **magnitude** (i.e. no lasting effect, slight, minor, moderate, major or catastrophic) of the credible environmental impacts from each aspect based on the extent, duration, frequency and scale. Determination of magnitude considered the frequency and scale of the impact or risk and the sensitivity of the receptors.
5. Assigning an **impact significance level** to each environmental impact based on the receptor sensitivity and the magnitude of the impact.

Impacts have been classified in accordance with the significance levels outlined in Woodside's Environment Impact Assessment Guideline. Impact significance levels were determined based on the magnitude (extent, nature, scale) of the impact and the receptor sensitivity (Figure 6-3). The impact significance levels used for evaluating impacts align closely with the consequence levels used for evaluating risks (Table 6-3).



	Sensitivity		
Magnitude	Low	Medium	High
Catastrophic	B	A	A
Major	C	B	A
Moderate	D	C	B
Minor	E	D	C
Slight	F	E	D
No Lasting effect	F	F	E

Significance Level

A	Catastrophic (A) - Applicable limits or standards are substantially exceeded and/ or catastrophic or major magnitude impacts are expected to receptors of medium/ high or high sensitivity respectively.
B	Major (B) - Applicable limits or standards are exceeded and/ or moderate, major or catastrophic magnitude impacts are expected to occur to receptors of high, medium or low sensitivity respectively.
C	Moderate (C) - Impacts are close to applicable limits or standards, or within standards but with potential for occasional exceedance. Minor, moderate or major magnitude impacts are predicted to occur to receptors of high, medium or low sensitivity respectively.
D	Minor (D) - Impact magnitude is within applicable standards but is considered to have significance. Slight, minor or moderate impacts are predicted to occur to receptors of high, medium or low sensitivity respectively.
E	Slight (E) - The receptor will experience a noticeable effect, but the impact magnitude is sufficiently small and well within applicable standards, and/or the receptor is of low value.
F	Negligible (F) - The receptor will essentially not be affected.

Figure 6-3 Impact Significance Level

6.2.3.2.2 Environment Risk Rating

Environment risk ratings are determined separately to environmental impact significance as, along with consequence (aligned with impact significance), the risk ratings additionally consider the likelihood of an unplanned event or incident in accordance with the Woodside Risk Management Procedure and Risk Matrix.

The consequence is the worst-case credible consequence associated with the event, assuming all controls (preventative or mitigative) are absent or have failed. Where more than one potential consequence applies, the highest severity consequence level is selected. Consequence levels are aligned with the impact significance levels and are determined in the same process as described in Section 6.2.3.2.1. Consequences are defined in Table 6-3.

The likelihood is determined based on the description that best fits the chance of the selected consequence occuring, assuming reasonable effectiveness of the prevention and mitigation controls in accordance with the descriptions in Table 6-4.

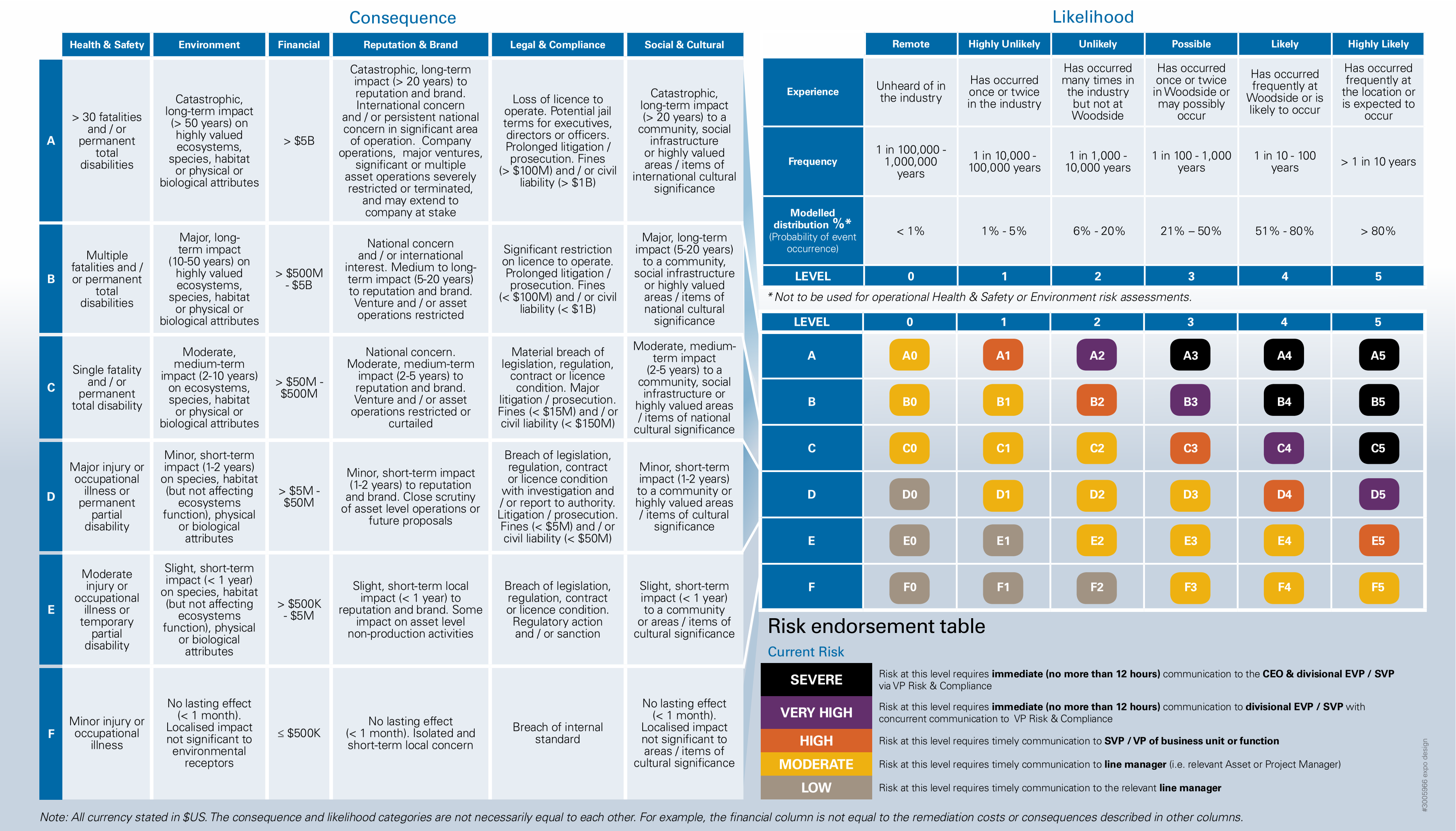
The risk rating is then derived from the consequence and likelihood levels determined above in accordance with the Risk Matrix shown in Figure 6-3.

Table 6-3 Consequence Description

Environment	Social & Cultural	Consequence Level
Catastrophic, long-term impact (>50 years) on highly valued ecosystems, species, habitat or physical or biological attributes	Catastrophic, long-term impact (>20 years) to a community, social infrastructure or highly valued areas/items of international cultural significance	A
Major, long term impact (10–50 years) on highly valued ecosystems, species, habitat or physical or biological attributes	Major, long-term impact (5–20 years) to a community, social infrastructure or highly valued areas/items of national cultural significance	B
Moderate, medium-term impact (2–10 years) on ecosystems, species, habitat or physical or biological attributes	Moderate, medium term Impact (2–5 years) to a community, social infrastructure or highly valued areas/items of national cultural significance	C
Minor, short-term impact (1–2 years) on species, habitat (but not affecting ecosystems function), physical or biological attributes	Minor, short-term impact (1–2 years) to a community or highly valued areas/items of cultural significance	D
Slight, short-term impact (<1 year) on species, habitat (but not affecting ecosystems function), physical or biological attributes	Slight, short-term impact (<1 year) to a community or areas/items of cultural significance	E
No lasting effect (<1 month). Localised impact not significant to environmental receptors	No lasting effect (<1 month). Localised impact not significant to areas/items of cultural significance	F

Table 6-4 Likelihood Description

Likelihood Description						
Frequency	1 in 100,000–1,000,000 years	1 in 10,000–100,000 years	1 in 1000–10,000 years	1 in 100–1,000 years	1 in 10–100 years	>1 in 10 years
Experience	**Remote:** Unheard of in the industry	**Highly Unlikely:** Has occurred once or twice in the industry	**Unlikely:** Has occurred many times in the industry but not at Woodside	**Possible:** Has occurred once or twice in Woodside or may possibly occur	**Likely:** Has occurred frequently at Woodside or is likely to occur	**Highly Likely:** Has occurred frequently at the location or is expected to occur
Likelihood Level	***0***	***1***	***2***	***3***	***4***	***5***



Consequence

	Health & Safety	Environment	Financial	Reputation & Brand	Legal & Compliance	Social & Cultural
A	> 30 fatalities and / or permanent total disabilities	Catastrophic, long-term impact (> 50 years) on highly valued ecosystems, species, habitat or physical or biological attributes	> $5B	Catastrophic, long-term impact (> 20 years) to reputation and brand. International concern and / or persistent national concern in significant area of operation. Company operations, major ventures, significant or multiple asset operations severely restricted or terminated, and may extend to company at stake	Loss of licence to operate. Potential jail terms for executives, directors or officers. Prolonged litigation / prosecution. Fines (> $100M) and / or civil liability (> $1B)	Catastrophic, long-term impact (> 20 years) to a community, social infrastructure or highly valued areas / items of international cultural significance
B	Multiple fatalities and / or permanent total disabilities	Major, long-term impact (10-50 years) on highly valued ecosystems, species, habitat or physical or biological attributes	> $500M - $5B	National concern and / or international interest. Medium to long-term impact (5-20 years) to reputation and brand. Venture and / or asset operations restricted	Significant restriction on licence to operate. Prolonged litigation / prosecution. Fines (< $100M) and / or civil liability (< $1B)	Major, long-term impact (5-20 years) to a community, social infrastructure or highly valued areas / items of national cultural significance
C	Single fatality and / or permanent total disability	Moderate, medium-term impact (2-10 years) on ecosystems, species, habitat or physical or biological attributes	> $50M - $500M	National concern. Moderate, medium-term impact (2-5 years) to reputation and brand. Venture and / or asset operations restricted or curtailed	Material breach of legislation, regulation, contract or licence condition. Major litigation / prosecution. Fines (< $15M) and / or civil liability (< $150M)	Moderate, medium-term impact (2-5 years) to a community, social infrastructure or highly valued areas / items of national cultural significance
D	Major injury or occupational illness or permanent partial disability	Minor, short-term impact (1-2 years) on species, habitat (but not affecting ecosystems function), physical or biological attributes	> $5M - $50M	Minor, short-term impact (1-2 years) to reputation and brand. Close scrutiny of asset level operations or future proposals	Breach of legislation, regulation, contract or licence condition with investigation and / or report to authority. Litigation / prosecution. Fines (< $5M) and / or civil liability (< $50M)	Minor, short-term impact (1-2 years) to a community or highly valued areas / items of cultural significance
E	Moderate injury or occupational illness or temporary partial disability	Slight, short-term impact (< 1 year) on species, habitat (but not affecting ecosystems function), physical or biological attributes	> $500K - $5M	Slight, short-term local impact (< 1 year) to reputation and brand. Some impact on asset level non-production activities	Breach of legislation, regulation, contract or licence condition. Regulatory action and / or sanction	Slight, short-term impact (< 1 year) to a community or areas / items of cultural significance
F	Minor injury or occupational illness	No lasting effect (< 1 month). Localised impact not significant to environmental receptors	≤ $500K	No lasting effect (< 1 month). Isolated and short-term local concern	Breach of internal standard	No lasting effect (< 1 month). Localised impact not significant to areas / items of cultural significance

Likelihood

	Remote	Highly Unlikely	Unlikely	Possible	Likely	Highly Likely
Experience	Unheard of in the industry	Has occurred once or twice in the industry	Has occurred many times in the industry but not at Woodside	Has occurred once or twice in Woodside or may possibly occur	Has occurred frequently at Woodside or is likely to occur	Has occurred frequently at the location or is expected to occur
Frequency	1 in 100,000 - 1,000,000 years	1 in 10,000 - 100,000 years	1 in 1,000 - 10,000 years	1 in 100 - 1,000 years	1 in 10 - 100 years	> 1 in 10 years
Modelled distribution %* (Probability of event occurrence)	< 1%	1% - 5%	6% - 20%	21% – 50%	51% - 80%	> 80%
LEVEL	0	1	2	3	4	5

* Not to be used for operational Health & Safety or Environment risk assessments.

LEVEL	0	1	2	3	4	5
A	A0	A1	A2	A3	A4	A5
B	B0	B1	B2	B3	B4	B5
C	C0	C1	C2	C3	C4	C5
D	D0	D1	D2	D3	D4	D5
E	E0	E1	E2	E3	E4	E5
F	F0	F1	F2	F3	F4	F5

Risk endorsement table

Current Risk

SEVERE	Risk at this level requires **immediate (no more than 12 hours)** communication to the **CEO & divisional EVP / SVP** via VP Risk & Compliance
VERY HIGH	Risk at this level requires **immediate (no more than 12 hours)** communication to **divisional EVP / SVP** with concurrent communication to VP Risk & Compliance
HIGH	Risk at this level requires timely communication to **SVP / VP of business unit or function**
MODERATE	Risk at this level requires timely communication to **line manager** (i.e. relevant Asset or Project Manager)
LOW	Risk at this level requires timely communication to the relevant **line manager**

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Note: All currency stated in $US. The consequence and likelihood categories are not necessarily equal to each other. For example, the financial column is not equal to the remediation costs or consequences described in other columns.

Figure 6-4 Environment Risk Rating Level

6.2.3.3 Impact and Risk Treatment

The overall objective of the proposed Browse to NWS Project in relation to the environmental outcomes is to conduct the activities associated with the proposed Browse to NWS Project in a manner that does not result in unacceptable impacts to MNES, does not affect ESD outcomes, is in accordance with the principles and objectives of the EPBC Act as defined in Section 3A of the EPBC Act and meets the EPA Environmental Objectives.

As part of the impact and risk assessment process, management and mitigation measures have been identified to reduce the level of impact and risk to an acceptable level and meet the environmental objectives for each aspect. The following framework tools were applied, as appropriate, to assist with identifying appropriate management and mitigation measures:

- Good industry practice – identifies further engineering control standards and guidelines which may be applied by Woodside in addition to those required to meet the legislation, codes and standards.
- Professional judgement – uses relevant personnel with the knowledge and experience to identify alternative controls.

The proposed management and mitigation measures have been developed using the following adaptive framework:

- eliminate the risk by removing the hazard
- substitute a hazard with a lesser one
- prevent a credible impact from occurring through the implementation of additional engineering control measures
- reduce the magnitude of a credible impact through the implementation of additional engineering control measures (e.g. solids control equipment onboard MODU to manage cuttings discharge)
- mitigate the credible impact on the environment through the reduction in extent, scale, duration of impact (e.g. bunding, oil spill booms, relief well)
- apply environmental offsets where justified
- carry out emergency response and contingency planning to facilitate recovery from the credible impact of an event.

The proposed aspect specific mitigation and management measures are detailed in the relevant impact and assessment sections below. An overview of the proposed Browse to NWS Project environmental management framework is provided in **Chapter 8**. This includes a description of the proposed management plans to be developed for the proposed Browse to NWS Project (noting that, where possible, the intent of the proposed management plans will be met through the content of activity specific Environment Plans required under State and Commonwealth legislation).

6.2.3.4 Determining Acceptability

For the purpose of this impact and risk assessment, achievement of the environmental objectives (**Section 6.2.3.5**) and overall acceptability (i.e. whether an environment impact or risk is acceptable) is tied to the impact significance level and the risk rating and likelihood (for unplanned events and incidents).

An assessment of the acceptability of the impacts and risks is presented for each aspect and is provided in **Section 6.3**. The assessment of acceptability considers the:

- principles of ESD as defined in Section 3A of the EPBC Act
- MNES Significant Impact Guidelines
- WA EPA Environmental Factors and Objectives
- other aspect or receptor requirements including State, Federal and international standards, laws, policies and guidelines, including Conservation and Recovery management plans and conservation advice for EPBC Act listed threatened and/or migratory species. Relevant guidelines, standards or plans are outlined each impact assessment section
- external requirements (**Section 6.2.2.5**)
- internal requirements (**Section 6.2.2.6**).

Principles of Ecologically Sustainable Development

The promotion of ecologically sustainable development is a key objective of the EPBC Act. The principles of ESD must also be considered when deciding whether or not to approve actions under the Act. These principles set out a framework for thinking about and balancing the interaction between protection of the environment and social and economic matters.

The principles of ESD are found in section 3A of the EPBC Act and are:

a. Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations.

b. If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

c. The principle of inter-generational equity applies – that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.

d. The conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making.

e. Improved valuation, pricing and incentive mechanisms should be promoted.

MNES Significant Impact Guidelines

The *Matters of National Environmental Significance – Significant impact guidelines 1.1.* outlines the significance criteria for MNES. The MNES relevant to the proposed Browse to NWS Project were detailed as the controlling provisions in the DoEE's decision notice on the referral of the proposed Browse to NWS Project under the EPBC Act (EPBC 2018/8319) for the purposes of the assessment of potential impacts. The relevant MNES and associated significance criteria are shown in Table 6-5.

Table 6-5 MNES Significant Impact Criteria

Matter of National Environmental Significance	Significance Criteria
Listed Threatened Species and Ecological Communities	An action is likely to have a significant impact on a species listed in any of the following categories if there is a real chance or possibility that it will: **Extinct in the wild** + adversely affect a captive or propagated population or one recently introduced/reintroduced to the wild, or + interfere with the recovery of the species or its reintroduction into the wild. **Critically Endangered and Endangered** + lead to a long-term decrease in the size of a population + reduce the area of occupancy of the species + fragment an existing population into two or more populations + adversely affect habitat critical to the survival of a species + disrupt the breeding cycle of a population + modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline + result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat + introduce disease that may cause the species to decline + Interfere with the recovery of the species.

Matter of National Environmental Significance	Significance Criteria
Listed Threatened Species and Ecological Communities cont.	**Vulnerable** + lead to a long-term decrease in the size of an important population of a species + reduce the area of occupancy of an important population, fragment an existing important population into two or more populations, adversely affect habitat critical to the survival of a species + disrupt the breeding cycle of an important population + modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline + result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat + introduce disease that may cause the species to decline + interfere substantially with the recovery of the species. **Threatened Ecological Communities** + An action is likely to have a significant impact on a critically endangered or endangered ecological community if there is a real chance or possibility that it will: + reduce the extent of an ecological community + fragment or increase fragmentation of an ecological community, for example by clearing vegetation for roads or transmission lines + adversely affect habitat critical to the survival of an ecological community + modify or destroy abiotic (non-living) factors (such as water, nutrients, or soil) necessary for an ecological community's survival, including reduction of groundwater levels, or substantial alteration of surface water drainage patterns + cause a substantial change in the species composition of an occurrence of an ecological community, including causing a decline or loss of functionally important species, for example through regular burning or flora or fauna harvesting + cause a substantial reduction in the quality or integrity of an occurrence of an ecological community, including, but not limited to: + assisting invasive species, that are harmful to the listed ecological community, to become established + causing regular mobilisation of fertilisers, herbicides or other chemicals or pollutants into the ecological community which kill or inhibit the growth of species in the ecological community + interfere with the recovery of an ecological community.
Listed Migratory Species	An action is likely to have a significant impact on a migratory species if there is a real chance or possibility that it will: + substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important habitat for a migratory species + result in an invasive species that is harmful to the migratory species becoming established in an area of important habitat for the migratory species + seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

Matter of National Environmental Significance	Significance Criteria
The Commonwealth Marine Area	An action is likely to have a significant impact on the environment in a Commonwealth marine area if there is a real chance or possibility that the action will: + result in a known or potential pest species becoming established in the Commonwealth marine area + modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth marine area results + have a substantial adverse effect on a population of a marine species or cetacean including its life cycle (for example, breeding, feeding, migration behaviour, life expectancy) and spatial distribution + result in a substantial change in air quality or water quality (including temperature) which may adversely impact on biodiversity, ecological integrity; social amenity or human health + result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected + have a substantial adverse impact on heritage values of the Commonwealth marine area, including damage or destruction of an historic shipwreck.
National Heritage Places	An action is likely to have a significant impact on the National Heritage values of a National Heritage place if there is a real chance or possibility that it will cause: + one or more of the National Heritage values to be lost + one or more of the National Heritage values to be degraded or damaged + one or more of the National Heritage values to be notably altered, modified, obscured or diminished.

WA EPA Environmental Factors and Objectives

The WA EPA has a series of key environmental factors that are considered when assessing the acceptability of a proposal. For each of these factors, an environmental objective has been identified. When considering significant impact or effect on an environmental factor, the EPA may have regard to various matters, including the following (EPA, 2016):

- values, sensitivity and quality of the environment which is likely to be impacted
- extent (intensity, duration, magnitude and geographic footprint) of the likely impacts
- consequence of the likely impacts (or change)
- resilience of the environment to cope with the impacts or change
- cumulative impact with other projects
- connections and interactions between parts of the environment to inform a holistic view of impacts to the whole environment
- level of confidence in the prediction of impacts and the success of proposed mitigation
- public interest about the likely effect of the proposal, if implemented, on the environment
- public information that informs the EPA's assessment.

The EPA Environmental Factors relevant to the proposed Browse to NWS Project were identified in the EPA determination on the referral of the proposed Browse to NWS Project under the EP Act. The relevant Environmental Factors and associated Environmental Objectives are shown in **Table 6-6**. While each of the EPA Environmental Factors and associated objectives are considered in the acceptability assessment presented in the Chapter, an assessment of the activities planned to be undertaken with the WA State jurisdiction is presented in the State Proposal ERD (**Chapter 10, Appendix B**).

Table 6-6 EPA Environmental Factors and Objectives

EPA Environmental Factor	Environmental Objective
Benthic Communities and Habitats	To protect benthic communities and habitats so that biological diversity and ecological integrity are maintained.
Marine Environmental Quality	To maintain the quality of water, sediment and biota so that environmental values are protected.
Marine Fauna	To protect marine fauna so that biological diversity and ecological integrity are maintained.
Air Quality	To maintain air quality and minimise emissions so that environmental values are protected.

Listed Threatened Species Management/Recovery Plans and Conservation Advices

The proposed Browse to NWS Project may trigger risks to or impacts on listed threatened species. The requirements of the species recovery plans and conservation advices have been considered to identify any requirements that may be applicable to the impact and risk assessment of the draft EIS/ERD.

Table 5-19 outlines the management/recovery plans and conservation advices relevant to those species identified as potentially occurring or having habitat within the Project Area.

The management/recovery plans and conservation advices have been taken into consideration in assessing the impacts and risks associated with the proposed Browse to NWS Project and will be further incorporated into implementation planning in activity-specific EPs.

Australia Marine Parks

Under the EPBC Act, Australian Marine Parks (AMPs), are recognised for the purpose of conserving marine habitats and the species that live and rely on these habitats. The AMPs that occur within or near the Project Area are listed in Table 5-29.

Activities in the AMPs must be undertaken in a manner that is not inconsistent with the objectives of the park zones and the values of the marine park (including natural, cultural, heritage and socio-economic values) (Director of National Parks, 2018):

- The objective of the National Park Zone (II) is to provide for the protection and conservation of ecosystems, habitats and native species in as natural a state as possible.
- The objective of the Habitat Protection Zone (IV) is to provide for the conservation of ecosystems, habitats and native species in as natural a state as possible, while allowing activities that do not harm or cause destruction to seafloor habitats.
- The objective of the Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species.

The values of the marine parks are described in Section 5.3.3.2.

6.2.3.5 Environmental Objectives

Receptor specific environmental objectives have been established for the proposed Browse to NWS Project. These objectives have been established based on the considerations regarding acceptability as described above.
Table 6-7 presents the environmental objectives.

Where relevant, Woodside has identified environmental objectives that are not inconsistent with the *Matters of National Environmental Significance – Significant impact guidelines 1.1* (Commonwealth of Australia, 2013) except in relation to the Scott Reef shallow water benthic habitat (<75 m bathymetry) where the WA EPA Technical guidance - Protecting the Quality of Western Australia's Marine Environment (EPA, 2016b) has also been utilised

It should be noted that where qualitative terms (e.g. substantial, acceptable, serious) are used in objectives, they are supported by detailed impact and risk assessment in the sections that follow such that they can be interpreted as meaning "impact and risk greater than that predicted in this draft EIS/ERD".

The term "marine ecosystem functioning or integrity" should be interpreted to mean "the structure (e.g. the variety and quantity of life forms) and functions (e.g. the food chains and nutrient cycles) of marine ecosystems"

Table 6-7 Receptor sensitivity, environmental objectives and relevant aspects

Receptor	Receptor Sensitivity Level	Environmental objective	Environmental context (local and regional)	Relevant environmental aspects
Sediment quality[1]	**Medium value (open waters)** Ambient sediment quality is typical of the surrounding environment, with low sensitivity to change and no features of conservation value	**Objective 1:** To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.[2] **Objective 2:** To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.[2]	Sediments in the Project Area are typical of an undisturbed tropical offshore environment, with low concentrations of metals and nutrients and no hydrocarbons detected from marine sediment quality seabed sampling (refer to **Section 5.2.10**).	+ Physical presence: seabed disturbance + Marine discharges: drilling or completions discharges + Marine discharges: subsea control fluids + Marine discharges: hydrotest fluid + Hazardous and non-hazardous inorganic waste + Unplanned hydrocarbon releases.
Water quality	**Medium value (open water)** Ambient water quality is typical of an open water environment, with low sensitivity to change.	**Objective 3:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.[2]	Water quality in the Project Area near the location of the proposed subsea infrastructure and facilities is typical of an undisturbed tropical offshore environment. Much of the surface waters in this area is nutrient-poor, influenced by the Indonesian Throughflow, with low levels of primary productivity (**Section 5.2.9**).	+ Physical presence: seabed disturbance + Marine discharges: sewage and sullage + Marine discharges: treated utility water, chemical and deck drainage + Marine discharges: putrescible waste + Marine discharges: produced water + Marine discharges: cooling water + Marine discharges: drilling or completions discharges + Marine discharges: subsea control fluids + Marine discharges: hydrotest fluid + Marine discharges: hazardous and non-hazardous inorganic waste + Unplanned hydrocarbon releases

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[1] *Sediment quality associated with sediments that form part of the shallow water benthic communities and habitats (<75 m depth) are embedded with that receptor*

[2] *Source of environmental objective: Significant impact criteria for an impact on the environment in a Commonwealth marine area as defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (Commonwealth of Australia, 2013)*

Receptor	Receptor Sensitivity Level	Environmental objective	Environmental context (local and regional)	Relevant environmental aspects
Air quality	**Medium value (open water)** Ambient air quality is typical of an open water environment, with low sensitivity to change.	**Objective 4:** To not result in a substantial change in air quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.[2]	Given the distance from any significant anthropogenic emissions sources, air quality within the Project Area is expected to be high (Section 5.2.6).	+ Atmospheric emissions: offshore activities + Atmospheric emissions: third party processing of Browse gas
Ambient light	**Medium value (open water)** Ambient light is typical of an open water environment, with low sensitivity to change.	**Objective 5:** To not result in a substantial change in ambient light or ambient noise which may adversely impact on biodiversity, ecological integrity, social amenity or human health.[2]	The Project Area is located approximately 260 km from the shore where there are no existing significant sources of artificial light. The proposed BTL route is also distant from sources of light emissions, except where the proposed BTL route ties in near the existing NRC facilities (Section 5.2.7).	Physical presence: light
Ambient noise	**Medium value (open water)** Ambient noise is typical of an open water environment, with low sensitivity to change.	**Objective 5:** To not result in a substantial change in ambient light or ambient noise which may adversely impact on biodiversity, ecological integrity, social amenity or human health.[2]	**Atmospheric noise** The existing anthropogenic noise environment within the vicinity of the Project Area is expected to be primarily associated with commercial shipping activities, as well as occasional petroleum exploration activities. Similar sources of anthropogenic underwater ambient noise may be expected along the proposed BTL route. **Underwater noise** Underwater noise in the Project Area is characterised by occasional general vessel traffic, seismic surveys, suspected illegal blast fishing at Scott Reef and marine fauna. Underwater noise from marine fauna recorded at the Browse Development Area included calls from humpback whales, minke and dwarf minke whales, pygmy blue whales, Bryde's whales, as well as calls from unidentified whales and fish chorus (Section 5.2.8).	+ Atmospheric noise emissions + Underwater noise emissions

Receptor	Receptor Sensitivity Level	Environmental objective	Environmental context (local and regional)	Relevant environmental aspects
Plankton	**Medium value (open water)** Plankton populations are typical of an open water environment, with low sensitivity to change due to high turnover/recovery and no species of high importance or quality.	**Objective 7:** To not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution.[2]	Plankton communities have a naturally variable distribution in both space and time in oceanic waters, noting that the NWMR is typically characterised by low planktonic productivity. Estimates of the phytoplankton biomass (measured as chlorophylla) close to Scott Reef are approximately twice that of open waters (sampled at distances greater than 50 km to the south-west of South Scott Reef). The open water location sampled is likely to be representative of the general outer shelf open water environment and so is representative of the oceanic waters of the Project Area (**Section 5.3.1.1**)	+ Physical presence: seabed disturbance + Physical presence: light + Underwater noise emissions + Marine discharges: sewage and sullage + Marine discharges: treated utility water, chemical and deck drainage + Marine discharges: putrescible waste + Marine discharges: produced water + Marine discharges: cooling water + Marine discharges: drilling or completions discharges + Marine discharges: subsea control fluids + Marine discharges: hydrotest fluid + Hazardous and non-hazardous inorganic waste + Unplanned hydrocarbon releases

Receptor	Receptor Sensitivity Level	Environmental objective	Environmental context (local and regional)	Relevant environmental aspects
Shallow water benthic communities and habitats (<75 m depth)	**High value habitat** Species of high importance with high sensitivity to change.	**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.[2] **Objective 8:** To not result in the establishment of a known or potential invasive marine species (IMS) in the Scott Reef system. **Objective 9:** To avoid direct (i.e. physical footprint) disturbance to Scott Reef shallow water benthic habitat (<75 m bathymetry). **Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry).[3]	Shallow water benthic communities and habitats in the Project Area include those at Scott Reef. In addition, the proposed BTL route passes at a distance of a few kilometres from the Rowley Shoals shallow water benthic communities and habitats. Important species within these habitats include corals, seagrass and macroalgae. **Coral** Coral reefs and communities of the NWMR include: remote oceanic reefs systems (atolls) such as Scott Reef, Seringapatam etc.; fringing reefs around offshore islands such as Browse Island and along coastlines such as the Kimberley Region; and submerged shoals on the NWS such as Rankin Bank and Glomar Shoals. Within the deep waters of the Browse Development Area (i.e. the seabed excluding Scott Reef), no deepwater soft or hard corals were observed during environmental surveys. The scleractinian corals, are considered to be of high conservation and ecological value at Scott Reef. Recent studies have found 236 species of coral at Scott Reef, in comparison of a recorded 255 species at Ashmore Reef, 159 species at Seringapatam Reef and 211 species of corals at Mermaid Reef (**Section 5.3.1.3**).	+ Physical presence: seabed disturbance + Physical presence: light + Underwater noise emissions + Marine discharges: sewage and sullage + Marine discharges: treated utility water, chemical and deck drainage + Marine discharges: putrescible waste + Marine discharges: produced water + Marine discharges: cooling water + Marine discharges: drilling or completions discharges + Marine discharges: subsea control fluids + Marine discharges: hydrotest fluid + Production activities: seabed subsidence + Marine discharges: hazardous and non-hazardous inorganic waste + Physical presences (unplanned): invasive marine species + Unplanned hydrocarbon releases

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[3] *Source of environmental objective: Technical guidance - Protecting the Quality of Western Australia's Marine Environment (EPA, 2016b)*

Receptor	Receptor Sensitivity Level	Environmental objective	Environmental context (local and regional)	Relevant environmental aspects
Shallow water benthic communities and habitats (<75 m depth) cont.			**Seagrass** In the NWMR, seagrass habitats are generally found in shallow water environments near the mainland and offshore reefs and shoals. Water depths within the Browse Development Area are generally too deep to provide suitable conditions for seagrass growth other than shallower reef and lagoon habitats in the Scott Reef system. Scott Reef supports five species of seagrass. However, the highly energetic environment and significant tidal exposure of Scott Reef restricts the area of habitats potentially suitable for seagrass establishment to a small proportion of the total area, resulting in only low abundance (Section 5.3.1.3). **Macroalgae** A total of 351 species of marine benthic red algae and 171 species of marine benthic brown and green algae have been recorded in north-western Australia. The Indo-Pacific flora is highly diverse, with some subsets of the region regarded as 'biodiversity hotspots. The growth of macroalgae in the deep waters of the Browse Development Area is restricted due to light availability and lack of hard substrate to support attachment in the predominantly soft sediment habitats of the area. A benthic habitat survey found no macroalgal beds during 11 drop camera surveys within the Browse Development Area. A total of 121 species of algae have been reported from Scott Reef. Studies found general algal cover to be approximately 5 to 10% in shallow and intertidal areas, but it was highly variable, with some areas approaching 100% cover (Section 5.3.1.3).	

Receptor	Receptor Sensitivity Level	Environmental objective	Environmental context (local and regional)	Relevant environmental aspects
Deepwater benthic communities and habitats (>75 m depth)	**Medium value** No species of high importance	**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.[2]	The benthic communities inhabiting the predominantly soft, fine sediments of the deepwater benthic habitats are characterised by infauna such as polychaetes and sparsely distributed sessile and mobile epifauna. The density of benthic fauna is typically lower in deep-sea sediments (greater than 200 m) than in shallower coastal sediment habitats, but the diversity of communities may be similar. As confirmed by deepwater surveys (**Section 5.3.1.2**).	+ Physical presence: seabed disturbance + Underwater noise emissions + Marine discharges: sewage and sullage + Marine discharges: treated utility water, chemical and deck drainage + Marine discharges: putrescible waste + Marine discharges: produced water + Marine discharges: cooling water + Marine discharges: drilling or completions discharges + Marine discharges: subsea control fluids + Marine discharges: hydrotest fluid + Hazardous and non-hazardous inorganic waste + Physical presences (unplanned): invasive marine species + Unplanned hydrocarbon releases
Coastal habitats	**High value habitat** Habitats with high sensitivity to change, such as mangroves.	**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.[2]	Given the offshore location, no coastal habitats occur in the Project Area. However, coastal habitats may occur within the EMBA. The shoreline within the northwest of Western Australia is varied, but predominantly includes tidal flats with smaller areas of rocky shores and sandy beaches. In addition, mangrove and saltmarsh environments also occur along the Pilbara coast and islands of the Dampier Archipelago.	+ Unplanned hydrocarbon releases

Receptor	Receptor Sensitivity Level	Environmental objective	Environmental context (local and regional)	Relevant environmental aspects
Seabirds and migratory shorebirds	**High value species** MNES species known to be present.	**Objective 11:** To not have a substantial adverse effect on a population of seabirds or migratory shorebirds, or the spatial distribution of the population.[4] **Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species.[4] **Objective 13**: To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species.[4]	As the only emergent land mass within the immediate vicinity of the Browse Development Area, Scott Reef serves to provide nesting and/or roosting for seabirds, albeit in small numbers in comparison to other breeding and roosting sites in the region. This includes the little tern, which has a resting BIA at Scott Reef, associated with Sandy Islet. In addition, due to the large geographical range of seabirds, most species occurring within the wider NWMR have the potential to occur and transit through the Project Area. The islands of the Rowley Shoals (which the proposed BTL route passes at a distance of a few kilometres) are known to support a wide range of seabird species, including WA's second largest breeding colony of red-tailed tropicbird. The Rowley Shoals have also been identified as BIAs for the white-tailed tropicbird. Migratory shorebirds are occasionally observed in very low numbers at Scott Reef. Sandy Islet may be used as a staging site during the migrations between the Northern Hemisphere and Australia. Given its small size, however, Sandy Islet is unlikely to support large numbers of migratory shorebirds. Due to the large geographical ranges of migratory shorebirds, many of the species known to occur within the wider NWMR have the potential to transit through the Project Area, which overlaps with the migratory shorebird corridor. Shorebird presence in the Project Area is expected to be transitory and seasonal (Section 5.3.2.3).	+ Physical presence: light + Atmospheric emissions: offshore activities + Atmospheric noise emissions + Production activities: seabed subsidence + Marine discharges: putrescible waste + Marine discharges: hazardous and non-hazardous inorganic waste + Unplanned hydrocarbon releases

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[4] *Source of environmental objective: Significant impact criteria for migratory species as defined in the Matters of National Environmental Significance – Significant impact guidelines*

1.1 (Commonwealth of Australia, 2013)

Receptor	Receptor Sensitivity Level	Environmental objective	Environmental context (local and regional)	Relevant environmental aspects
Fish	**High value species** MNES species known to be present.	**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species.[4] **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species.[4] **Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population.[2]	Fish assemblages within the Browse Development Area occupy a diverse range of habitats and are typical of the fish communities and species representative of the Timor Province. These fish assemblages include: + shallow-water, site-attached coral reef fish communities with characteristically high diversity and abundance + open water pelagic fish + deepwater, demersal fish communities EPBC Act listed fish species that may occur within the Project Area include the whale shark, shortfin mako, longfin mako, green sawfish and largetooth sawfish. The whale shark foraging BIA extends north along the northern WA coastline (predominately inshore of the Project Area) from Ningaloo almost to the Northern Territory (NT) border (Section 5.3.2.2). Based on studies undertaken of the whale shark's migratory behaviours, this species may occur within the Project Area, albeit in low numbers (Section 5.3.2.7).	+ Physical presence: light + Physical presence: electromagnetic emissions + Atmospheric noise emissions + Underwater noise emissions + Marine discharges: sewage and sullage + Marine discharges: treated utility water, chemical and deck drainage + Marine discharges: putrescible waste + Marine discharges: produced water + Marine discharges: cooling water + Marine discharges: drilling or completions discharges + Marine discharges: subsea control fluids + Marine discharges: hydrotest fluid + Marine discharges: hazardous and non-hazardous inorganic waste + Unplanned vessel interactions with fauna + Physical presences (unplanned): invasive marine species + Unplanned hydrocarbon releases

Receptor	Receptor Sensitivity Level	Environmental objective	Environmental context (local and regional)	Relevant environmental aspects
Marine mammals	**High value species** MNES species known to be present.	**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species.[4] **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species.[4] **Objective 15:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population.[2]	The PMST identified 27 marine mammal species as potentially occurring within the Project Area. Of these, the pygmy blue whale (endangered and migratory), humpback whale, sei whale, fin whale (vulnerable and migratory) and Bryde's whale (migratory) are considered most likely to occur (albeit representing a low percentage of each species populations) within the Project Area and/or interact with the proposed Browse to NWS Project (**Section 5.3.2.4**). There are BIAs for migration and breeding and calving for the humpback whale along the WA coast and within the NWMR, but there are no known BIAs within the Project Area. A migratory BIA for the pygmy blue whale extends for most of the length of the NWMR within offshore waters and encompasses Scott Reef. The Conservation Plan for Blue Whales (Commonwealth of Australia, 2015) also documents a possible foraging area which encompasses the majority of Scott Reef and its surrounds. It is expected pygmy blue whales may occur within the Browse Development Area, albeit in low numbers, and it is acknowledged that pygmy blue whales have been recorded in the channel between North and South Scott Reef; and that they may forage opportunistically in and around Scott Reef (given it is a possible foraging BIA). Other marine mammal species identified as likely to occur in the Project Area (such as the sei whale, fin whale and Bryde's whales) are expected to be limited to infrequent transient individuals (**Section 5.3.2.4.3**).	+ Physical presence: electromagnetic emissions + Atmospheric noise emissions + Underwater noise emissions + Marine discharges: sewage and sullage + Marine discharges: treated utility water, chemical and deck drainage + Marine discharges: putrescible waste + Marine discharges: produced water + Marine discharges: cooling water + Marine discharges: drilling or completions discharges + Marine discharges: subsea control fluids + Marine discharges: hydrotest fluid + Marine discharges: hazardous and non-hazardous inorganic waste + Unplanned vessel interactions with fauna + Unplanned hydrocarbon releases

Receptor	Receptor Sensitivity Level	Environmental objective	Environmental context (local and regional)	Relevant environmental aspects
Marine reptiles	**High value species** MNES species known to be present.	**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species.[4] **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species.[4] **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.[2]	The PMST identified six species of marine turtle species as potentially occurring within the Project Area; green turtle, hawksbill turtle, flatback turtle (vulnerable and migratory) and the leatherback turtle, loggerhead turtle, olive ridley turtle (endangered and migratory). The marine turtles documented to be present in the Browse Development Area include the vulnerable green turtle and loggerhead turtle. These species are described in **Section 5.3.2.5**. The Recovery Plan for Marine Turtles identifies Habitat Critical to the Survival of a Species and this has been identified for the Scott Reef – Browse Island green turtle genetic stock within the Project Area (**Section 5.3.2.5.1**). Habitat Critical for Survival is the nesting habitat of Sandy Islet and a 20 km internesting buffer at Scott Reef (Commonwealth of Australia, 2017a). There are also nesting and internesting BIAs at Scott Reef (associated with nesting at Sandy Islet) for both the green turtle and hawksbill turtle (**Section 5.3.2.5.2**).	+ Physical presence: light + Physical presence: electromagnetic emissions + Atmospheric noise emissions + Underwater noise emissions + Marine discharges: sewage and sullage + Marine discharges: treated utility water, chemical and deck drainage + Marine discharges: putrescible waste + Marine discharges: produced water + Marine discharges: cooling water + Marine discharges: drilling or completions discharges Marine discharges: subsea control fluids + Marine discharges: hydrotest fluid + Production activities: seabed subsidence + Marine discharges: hazardous and non-hazardous inorganic waste + Unplanned vessel interactions with fauna + Unplanned hydrocarbon releases

Receptor	Receptor Sensitivity Level	Environmental objective	Environmental context (local and regional)	Relevant environmental aspects
Key ecological features	**Medium value** Designated sensitive Area. Values protected by legislation.	**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.[2]	The Browse Development Area overlaps with the Continental slope demersal fish communities and Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEFs. The proposed BTL route traverses the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF and the Ancient coastline at 125 m depth contour KEF (**Section 5.3.3.1**).	+ Physical presence: seabed disturbance + Underwater noise emissions + Marine discharges: sewage and sullage + Marine discharges: treated utility water, chemical and deck drainage + Marine discharges: putrescible waste + Marine discharges: produced water + Marine discharges: cooling water + Marine discharges: drilling or completions discharges + Marine discharges: Subsea control fluids + Marine discharges: hydrotest fluid + Marine discharges: hazardous and non-hazardous inorganic waste + Physical presences (unplanned): invasive marine species + Unplanned hydrocarbon releases
Australian marine parks	**Medium value (multiple use zones)** Designated sensitive area. Values protected by legislation.	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.[2]	The proposed BTL route traverses the Multiple Use Zones (IV) of the ArgoRowley Terrace and Kimberley Marine Parks. It should also be noted that the proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park National Park Zone. Rationale for the route selection of the BTL is provided in **Chapter 3**.	+ Physical presence: seabed disturbance + Physical presence: light + Underwater noise emissions + Marine discharges: sewage and sullage + Marine discharges: treated utility water, chemical and deck drainage + Marine discharges: putrescible waste + Marine discharges: cooling water + Marine discharges: hazardous and non-hazardous inorganic waste + Physical presences (unplanned): invasive marine species + Unplanned hydrocarbon releases

Receptor	Receptor Sensitivity Level	Environmental objective	Environmental context (local and regional)	Relevant environmental aspects
State marine parks and nature reserves	**High value** Designated sensitive area. Values protected by legislation.	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.[2]	There are no State marine parks within the Project Area, however, the proposed BTL route passes approximately 3 km from the Rowley Shoals Marine Park Section 5.3.3.2). The Scott Reef Nature Reserve which was designated in 1993 and encompasses South Scott Reef (including Sandy Islet) down to the low mean water mark (Atlas of Marine Protection, 2019). This Nature Reserve protects the physical and ecological features of Scott Reef which are described throughout **Section 5**, including important nesting and internesting habitat (Habitat Critical for Survival of a Species) for the green turtle.	+ Physical presence: light + Atmospheric noise emissions + Underwater noise emissions + Marine discharges: produced water + Marine discharges: cooling water + Production Activities: seabed subsidence + Marine Discharges: hazardous and non-hazardous inorganic waste + Physical presences (unplanned): invasive marine species + Unplanned hydrocarbon releases
Other protected places	**High value** Designated sensitive area. Values protected by legislation.	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.[2] **Objective 19:** To not have a substantial adverse impact on heritage values[2]	There are no National Heritage Sites within the Project Area. The closest National Heritage Sites are the Dampier Archipelago (including the Burrup Peninsula) and the Ningaloo Coast (**Section 5.4.3.2**). There are no World Heritage Sites within the Project Area (**Section 5.4.3.3**). Commonwealth Heritage Places located within or within the vicinity of the Project Area include Scott Reef and Surrounds – Commonwealth Area, and Mermaid Reef – Rowley Shoals (**Section 5.4.3.1**).	+ Physical presence: seabed disturbance + Physical presence: light + Underwater noise emissions + Marine discharges: sewage and sullage + Marine discharges: treated utility water, chemical and deck drainage + Marine discharges: putrescible waste + Marine discharges: produced water + Marine discharges: cooling water + Marine discharges: drilling or completions discharges + Marine discharges: hydrotest fluid + Marine discharges: hazardous and non-hazardous inorganic waste + Physical presences (unplanned): invasive marine species + Unplanned hydrocarbon releases

Receptor	Receptor Sensitivity Level	Environmental objective	Environmental context (local and regional)	Relevant environmental aspects
State and Commonwealth managed fisheries	**High value marine user** Key fishing area, with high importance to stakeholders.	**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.	State managed commercial fisheries in close proximity to the Project Area include Northern Demersal Scalefish, Mackerel, WA North Coast Shark, Onslow Prawn, Abalone, South West Coast Salmon, Pilbara Fish Trawl, Specimen Shell, Marine Aquarium Fish, West Coast Deep Sea Crustacean and Pearl Oyster Managed Fisheries. The Commonwealth managed fisheries located within the vicinity of the Project Area include the North West Slope Trawl Fishery, the Western Tuna and Billfish Fishery, the Southern Bluefin Tuna Fishery and the Skipjack Tuna Fishery (Western Skipjack Tuna Fishery). In 1974 the Australia-Indonesia Memorandum of Understanding regarding the Operations of Indonesian Traditional Fishermen in Areas of the Australian Fishing Zone and Continental Shelf – 1974 (MoU 74) was signed by the Governments of Australia and Indonesia, allowing allowed Indonesian fishers to continue to fish in designated areas using traditional methods only (**Sections 5.4.2.1** and **5.4.2.2**).	+ Physical presence: disturbance to other users + Physical presence: light + Underwater noise emissions + Marine discharges: sewage and sullage + Marine discharges: treated utility water, chemical and deck drainage + Marine discharges: putrescible waste + Marine discharges: produced water + Marine discharges: cooling water + Marine discharges: drilling or completions discharges + Marine discharges: subsea control fluids + Marine discharges: hydrotest fluid + Marine Discharges: hazardous and non-hazardous inorganic waste + Physical presences (unplanned): invasive marine species + Unplanned hydrocarbon releases

Receptor	Receptor Sensitivity Level	Environmental objective	Environmental context (local and regional)	Relevant environmental aspects
Tourism and recreation	**High value users** Project area has low to medium level of utilisation by stakeholders.	**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.	Recreation and tourism activities in the NWMR occur predominantly in WA State waters adjacent to coastal population centres (e.g. Broome), with a peak in activity during the winter months (dry season) (Section 5.4.2.6). Only one to two recreational fishing charter operators run trips to Scott Reef. The location has the potential to provide significant opportunities for pelagic sport fishing; however, given the distance from Broome and closest landfall and associated costs, only a limited number of charter operators are prepared to take recreational fishers out to Scott Reef. Those companies that do visit Scott Reef tend to make the trip only four to five times per year, spending around five days at the reef each time. Fishing is mainly focused on the south, west and north extremities of Scott Reef, generally only going into the South Scott Reef lagoon for snorkelling and for layover at night.	+ Physical presence: disturbance to other users + Physical presence: light + Atmospheric noise emissions + Underwater noise emissions + Marine discharges: sewage and sullage + Marine discharges: treated utility water, chemical and deck drainage + Marine discharges: putrescible waste + Marine discharges: produced water + Marine discharges: cooling water + Marine discharges: drilling or completions discharges + Marine discharges: hydrotest fluid + Production activities: seabed subsidence + Marine Discharges: hazardous and non-hazardous inorganic waste + Physical presences (unplanned): invasive marine species + Unplanned hydrocarbon releases

Receptor	Receptor Sensitivity Level	Environmental objective	Environmental context (local and regional)	Relevant environmental aspects
Scientific studies	**High value users** Project area has low to medium level of utilisation by stakeholders.	**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.	Within the Browse Development Area, scientific research is predominately undertaken at Scott Reef, Rowley Shoals and Ashmore Reef. Given no lasting effect on the Scott Reef system or fauna that may be present in the surrounding waters, the scientific and tourism values within the Project Area are not expected to be reduced (Section 5.4.2.7).	+ Physical presence: disturbance to other users + Physical presence: light + Atmospheric noise emissions + Underwater noise emissions + Marine discharges: sewage and sullage + Marine discharges: treated utility water, chemical and deck drainage + Marine discharges: putrescible waste + Marine discharges: produced water + Marine discharges: cooling water + Marine discharges: drilling or completions discharges + Marine discharges: hydrotest fluid + Production Activities: seabed subsidence + Marine discharges: hazardous and non-hazardous inorganic waste + Physical presences (unplanned): invasive marine species + Unplanned hydrocarbon releases
Shipping	**Medium/high value users** Busy shipping area is located outside of Project Area, but shipping traffic still likely to be high.	**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.	Shipping activity in and around the Browse Development Area is sparse, with the main commercial shipping routes located approximately 50 to 100 km west, intersecting the proposed BTL route at various locations, depending on the port. The main shipping activity in the NWMR relates to transits to and from Broome and transportation of goods between Australian and international ports. Major ports are adjacent to the Roebuck, Montebello and Dampier Commonwealth marine reserves (Section 5.4.2.4).	+ Physical presence: disturbance to other users + Unplanned hydrocarbon releases

Receptor	Receptor Sensitivity Level	Environmental objective	Environmental context (local and regional)	Relevant environmental aspects
Industry	**Low value** The Project Area is not of extensive use by other Industry.	**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.	The NWMR supports a number of industries including petroleum exploration and production, as well as minerals extraction. There are seven sedimentary petroleum basins in the NWMR: the Northern and Southern Carnarvon basins, Perth, Browse, Roebuck, Offshore Canning and Bonaparte basins. Of these, the Northern Carnarvon, Browse and Bonaparte basins hold large quantities of gas and comprise most of Australia's reserves of natural gas (**Section 5.4.2.5**).	+ Physical presence: disturbance to other users + Unplanned hydrocarbon releases
Settlements	**Medium value users** Regionally important, low sensitivity to change.	**Objective 22:** To protect social surroundings from significant harm.	The proposed Browse to NWS Project presents potential social benefits and impacts to communities within WA and particularly Broome and the Dampier Peninsula, with Broome being the potential primary supply chain and logistics support location (**Section 5.4.4**).	+ Atmospheric noise emissions + Unplanned hydrocarbon releases
Aboriginal and Indigenous heritage	**High value users** Browse Development Area is of high importance to stakeholders	**Objective 19:** To not have a substantial adverse impact on heritage values. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.	No known sites of Aboriginal Heritage significance are located within the Development Area, according to the WA Department of Aboriginal Affairs' Aboriginal Sites Inquiry System. The existence of any unknown Aboriginal sites or artefacts of significance within the Browse Development Area, or the wider NWMR, is considered highly unlikely due to the site's remote location offshore (**Section 5.4.3.1**).	+ Physical presence: disturbance to other users + Atmospheric emissions: third party processing of Browse gas + Marine discharges: drilling or completions discharges + Marine discharges: produced water + Marine discharges: cooling water + Unplanned hydrocarbon releases
Marine archaeology	**High value** Maritime archaeology protected by legislation exists within the Browse Development Area	**Objective 19:** To not have a substantial adverse impact on heritage values.	The Australian National Shipwreck Database and the WA Maritime Museum Shipwreck Database list one protected historic wreck within the Browse Development Area. The historic shipwreck of the Yarra is located at South Scott Reef (**Section 5.4.3.2**).	+ Physical presence: seabed disturbance + Production activities: seabed subsidence + Unplanned hydrocarbon releases

6.3 Impact Assessment and Risk

6.3.1 Physical Presence: Seabed Disturbance

6.3.1.1 Impact and Risk Overview

Table 6-8 presents an overview of the potential impacts and risks from seabed disturbance associated with the physical presence of proposed Browse to NWS Project infrastructure.

Table 6-8 Physical presence: seabed disturbance - impact and risk overview

Aspect	Physical presence: seabed disturbance
Description	Seabed disturbance is associated with the temporary or permanent installation, placement and decommissioning of facilities, infrastructure and equipment, such as the: + FPSO facilities + BTL and inter-field spur line + subsea umbilicals + risers + flowlines + wells + manifolds + anchors + moorings. This includes other associated activities that may cause seabed disturbance such as seabed intervention, seabed preparation, trenching and secondary stabilisation for the BTL and inter-field spur line and wet storage of project infrastructure during construction. There is also a risk of additional unplanned disturbance to the seabed from dropped objects from the facilities and project vessels. The potential impacts associated with seabed disturbance specific to drilling discharges (e.g. drill cuttings and drilling fluids) during development drilling activities are covered in **Section 6.3.15**.
Area	Project Area, Browse Development Area, State Proposal Area
Project stage	All - drilling and completions, installation, commissioning, operations and decommissioning
Environmental objectives	The environmental objectives in relation to seabed disturbance associated with the proposed Browse to NWS Project are Objectives 1, 2, 3, 6, 7, 9, 10, 17, 18 and 19. These objectives are detailed in **Table 6-7**.
Policy and guidelines	The following policy and guidelines are relevant to the assessment of this aspect: + WA EPA Environmental Factor Guideline - Benthic Communities and Habitats (EPA, 2016b) + WA EPA Technical Guidance - Protection of Benthic Communities and Habitats (EPA, 2016c) + Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012) + North-west Marine Parks Network Management Plan (Director of National Parks, 2018).

<table>
<tr><th>Aspect</th><th colspan="3">Physical presence: seabed disturbance</th></tr>
<tr><td>Receptors</td><td colspan="3">The following receptors have been identified as potentially being impacted as a result of the proposed Browse to NWS Project (Table 6-2). A detailed description of each of these receptors is provided in Chapter 5.
Physical
+ sediment quality (medium value (open waters))
+ water quality (medium value (open waters))
Ecological
+ plankton (medium value (open water))
+ benthic habitat and communities
  + shallow water benthic communities and habitats (<75 m depth) (high value habitat)
  + deepwater communities and habitats (>75 m depth) (medium value habitat)
+ KEFs (medium value)
+ AMPs (medium value (multiple use zones))
+ other protected places (high value)
Socio-economic
+ maritime archaeology (high value)</td></tr>
<tr><td>Potential impacts</td><td colspan="3">+ change in water quality
+ change in sediment quality
+ change in habitat
+ injury or mortality to fauna
+ change in heritage values</td></tr>
<tr><td>Risks</td><td colspan="3">+ turbidity generated during seabed disturbance significantly greater than expected.
+ dropped objects
+ damage to unidentified maritime archaeology</td></tr>
<tr><td rowspan="2">Summary of impact evaluation for governing impact</td><td>***Magnitude***</td><td>***Impact significance level***</td><td>***Confidence***</td></tr>
<tr><td>Minor</td><td>Minor (D)</td><td>High</td></tr>
<tr><td rowspan="2">Summary of risk evaluation for governing risk</td><td>***Consequence***</td><td>***Likelihood***</td><td>***Risk rating***</td></tr>
<tr><td>Slight</td><td>Highly unlikely</td><td>Low (E0)</td></tr>
</table>

6.3.1.2 Source of Aspect

Seabed disturbance will be restricted to deep water within the Project Area and is expected to be approximately 50 km^2 (including approximately 10 km^2 allowed for contingency), including:

+ 11.34 km^2 (including 25% contingency) for wells, subsea infrastructure and moorings within the Browse Development Area (of which approximately 4.15 km^2 (including 25% contingency) of disturbance will be within the State Proposal Area)
+ 36.94 km^2 (including 25% contingency) for the BTL and inter-field spur line.
+ An indicative breakdown of the extent of seabed disturbance required for the proposed Browse to NWS Project is provided in Table 6-9. The largest impact to the seabed will result from the installation of the BTL, inter-field spur line and subsea infrastructure, including seabed intervention and preparation, trenching, secondary stabilisation operations and ongoing maintenance (i.e. IMR activities). The BTL and inter-field spur line route, which accounts for approximately three quarters of the proposed Browse to NWS Project physical footprint, has been selected to minimise seabed preparation, trenching and secondary stabilisation, by avoiding alternative routes with sand waves and shallow water (please refer Section 3.8.3.2). Seabed preparation, trenching and secondary stabilisation are required for the purpose of ensuring the stability of subsea infrastructure in its given geotechnical, bathymetric and metocean environment.

The scale of seabed disturbance from FPSO mooring (piles or anchors and mooring lines) is expected to be in the order of 1.58 km^2 (including 25% contingency), with the majority of installation and support vessels using DP systems to maintain position instead of anchoring (noting minor seabed disturbance will occur with the placement of DP transponders). Placement of anchors and/or piles for the MODU(s) and the pipelay vessel (if required during the initiation of pipelay) will be undertaken by support vessels, further reducing the area of disturbance through the minimisation of anchor drag.

Disturbance from the development of the wells will be minor (in the order of 8.49 km^2 in total including 25% contingency). The estimated disturbance area includes drilling of the wells and disturbance related to discharge of drill cuttings and cement during development drilling activities (further described in Section 6.3.15). These values are subject to refinement during the detailed design process.

Table 6-9 Indicative Extent of Seabed Disturbance

	Description	No.	Direct Disturbance (km^2)	Indirect Disturbance (km^2)	Total (km^2)
Drilling and Completions					
Wells (long term disturbance)	Calliance	19	0.15	2.24	2.39
	Torosa	29	0.23	3.42	3.64
	Brecknock	6	0.05	0.71	0.75
SURF Footprint					
Flowline network (long term disturbance)	Calliance	1	0.05	0.19	0.24
	Torosa	1	0.12	0.48	0.59
	Brecknock	1	0.04	0.15	0.19
FPSO Installation Footprint					
Pre-lay disturbance (temporary disturbance)	FPSO facilities	2	0.02	0.06	0.08
Facility mooring (long term)	Piles	36	0.07	0.21	0.28
	Mooring lines	36	0.18	0.72	0.90
BTL and Inter-Field Spur-Line Footprint					
Gas export pipelines	BTL	1	9	18	27
	Inter-field spur line	1	0.85	1.70	2.55
Total Expected			**10.75**	**27.87**	**38.62**
Contingency (25%)			2.69	6.97	9.66
Total (including contingency)			**13.44**	**34.84**	**48.28**

Basis:

1. *Wells have a direct impact radius of 50 m and a total radius of 200 m.*
2. *Flowlines have a 2 m corridor direct impact and a 10 m corridor total impact.*
3. *FPSO piles have a direct impact radius of 25 m and a total radius of 50 m.*
4. *FPSO Mooring lines have a 2 m corridor direct impact for the entire length of chain and a 10 m corridor total impact.*
5. *BTL/Spur line has a 10 m corridor direct impact and a 30 m corridor total impact.*

This estimate includes subsea disturbance from all major infrastructure sources. The contingency includes allowance for temporary wet storage during construction, pre lay and post lay of subsea infrastructure activities, allowance for a broader well radius for potential cementing and sedimentation, and other disturbance associated with piling/anchoring (if required).

6.3.1.3 Environmental Impact

Marine sediments

Change in sediment quality

The installation of the subsea infrastructure, BTL and inter-field spur line will result in temporary (in the order of minutes to a few hours) and localised (limited to the immediate disturbance area) displacement of surface sediments in the deepwater areas (125m - 600m deep) of the Project Area. This will result in very low levels of sediment deposition which is likely to be naturally reworked into surface sediment layers through bioturbation. The localised and temporary displacement of sediment and subsequent sediment deposition will not result in any lasting change to particle size distribution or the physio-chemical composition of sediment. As such, no change to sediment quality is expected to occur. Potential impacts associated with resultant sediment deposition on benthic habitats are discussed below.

Water quality

Change in water quality

The displacement of naturally occurring sediments is likely to result in low levels of highly localised (within tens of metres of the disturbance area) increases in turbidity levels at the seabed that will quickly disperse in the oceanic marine environment due to prevailing hydrodynamic conditions. As such, any reduction in water quality will be temporary (ranging in the order of minutes to a few hours) and will be limited to the waters close to the seabed immediately surrounding the disturbance area. No lasting change to the physical or chemical properties of water within the Project Area will occur as a result of seabed disturbance. As the temporary change in water quality will occur at the seabed in waters in excess of 400 m deep, no impacts to amenity will occur. Potential impacts of increased turbidity on benthic habitats are discussed below.

Plankton

Injury or mortality to fauna

Plankton are widely dispersed throughout the water column. Injury/mortality to plankton species may occur due to a change in water quality due to physical alterations to turbidity. Impacts to zooplankton from turbidity are associated with variations in predator prey dynamics which favours plankton feeders over visual feeders (Gophen, 2015), while impacts to phytoplankton occur due to decreases in available light, therefore reducing productivity (Dokulil, 1994).

Due to the temporary and localised nature of changes in water quality, impacts to plankton are not predicted.

Benthic communities and habitats

Change in water quality

Seabed disturbance has the potential to impact benthic habitats (including filter feeding communities) as a result of localised declines in water quality at the seabed due to temporary increases in turbidity. This can adversely affect marine biota by reducing light penetration, thereby reducing growth and productivity (Abdul Wahab, 2019). As described above, changes to water quality will be temporary, highly localised and restricted to near the seabed in the deep waters (125m - 600m deep) of the Project Area. Given that no light dependent biota (e.g. seagrass, corals, macroalgae) exist in these deep waters, no lasting effect to the deepwater benthic communities and habitats outside of the proposed disturbance area are expected to occur as a result of changes in water quality resulting from seabed disturbance.

Change in sediment quality

As described above, seabed disturbance is likely to result in very low levels of localised resuspension of natural sediments within the deep waters of the Project Area. This sediment resuspension and deposition is likely to be naturally reworked into surface sediment layers through bioturbation. The localised and temporary displacement of sediment and subsequent sediment deposition will not result in any change to sediment quality. As such, no lasting effect to benthic communities or habitats will occur.

Change in habitat

Seabed disturbance has the potential to permanently modify or remove the deepwater benthic communities and habitats within the Project Area. No temporary or permanent infrastructure will be placed on Scott Reef. As such, no direct disturbance to the Scott Reef shallow water benthic habitat (<75m bathymetry) will occur, with disturbance restricted to the deepwater habitats of the Project Area. Likewise, no disturbance to Rowley Shoals is expected to occur as a result of the installation of the BTL which at its closest point will be located approximately 2 km from the boundary of the Commonwealth Marine Park at Mermaid Reef. The estimated extent of seabed disturbance required for the proposed Browse to NWS Project is detailed in **Table 6-9**.

A detailed description of the deepwater benthic habitat within the Browse Development Area and along the BTL and inter-field spur line route is included in **Section 5.3.1**. Surveys indicate that the areas predicted to be impacted by the infrastructure are sparsely inhabited by benthic filter feeding invertebrate communities, which are well represented within the broader region.

The WA EPA Technical Guidance - Protection of Benthic Communities and Habitats provides the following definitions with respect to impacts to benthic communities and habitats (EPA, 2016c). These definitions have been adopted for the assessment of the proposed Browse to NWS Project as a whole:

- 'Permanent loss' refers to direct removal or mortality of benthic communities and/or their habitats. Permanent loss of benthic communities and their associated habitats would commonly be associated with activities such as excavation or burial. In almost all cases, these activities directly modify the benthic community and its habitat so significantly that the impacted community would not recover to the pre-impact state.
- 'Serious damage' means damage to benthic communities and/or their habitats that is effectively irreversible or where any recovery, if possible, would be unlikely to occur for at least 5 years. Serious damage is most often associated with indirect effects of development activities such as chronically elevated suspended sediment levels in the water column (e.g. leading to reduced benthic light and impacts on dependent seagrass or coral communities).
- 'Reversible impacts or loss' refers to the situation where impacts or losses of benthic communities occur, but there is confidence that the community, and the ecological services it provides, will fully recover within five years.

As shown in **Table 6-9**, an estimated 13.44 km^2 of direct seabed disturbance will occur as a result of the proposed Browse to NWS Project. This disturbance will result in the permanent loss of deepwater habitat associated with the development of the wells, installation of subsea infrastructure, FPSO moorings and the installation of the BTL and inter-field spur line, as well as other minor sources of permanent disturbance. This includes an allowance for any required seabed preparation and post lay stabilisation. It should be noted that this permanent loss may be partially compensated for by the creation of artificial hard substrate habitat (i.e. subsea infrastructure) which may be colonised by epifaunal organisms.

While the extent of seabed disturbance that will be required is considerable (primarily due to the significant length of the BTL), the area of permanent loss is considered insignificant due to the nature of the deepwater benthic habitat and the fact that it will be very small fraction of the widespread habitat available regionally.

Of the 13.44 km^2 direct disturbance, a small portion will be temporary disturbance resulting from activities such as wet storage and the installation of MODU transponders. This will result in reversible loss of deepwater benthic habitat, with benthic biota expected to recolonise the area once the temporary infrastructure is removed. Studies indicate that benthic infauna and epifauna are likely to recover within three to ten years (Jones et al., 2012).

The deepwater sediment habitat composition and sparse benthic biota to be disturbed is widespread and representative of the region (**Section 5.3.1.2**). Given the small area of permanent disturbance, relative to the total area of similar habitat available regionally and expected recolonisation of the seabed with similar benthic biota after the removal of temporary infrastructure, seabed disturbance within the deep waters of the Project Area is not predicted to impact biological diversity or ecological integrity.

Injury or mortality to fauna

Seabed disturbance has the potential to impact epifauna as a result of clogging and damage to the feeding and breathing apparatus of filter feeding organisms (Parr et al., 1998) and smothering when the displaced sediments settle. Given the low level and highly localised nature of such deposition, smothering of biota will be limited to the disturbance footprint in the deep waters of the Project Area and is not predicted to impact biological diversity or ecological integrity.

Key Ecological Features

The Continental slope demersal fish communities and Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEFs overlap with the Browse Development Area, while the BTL traverses the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF and the Ancient coastline at 125 m depth contour KEF.

Change in water quality

As described above, changes to water quality are expected to temporary and highly localised. As such, no adverse effect on the conservation values of KEFs within the Project Area are predicted.

Change in sediment quality

As described above, no lasting change to sediment quality are expected. As such, no adverse effect on the conservation values of KEFs within the Project Area are predicted.

Change in habitat

The Continental slope demersal fish communities KEF is regionally important due to the high levels of demersal fish species endemism and diversity found in this area relative to the region (Commonwealth of Australia, 2012). The Browse Development Area overlaps this KEF and the proposed BTL route will traverse the KEF for approximately 250 km (**Section 5.3.3.1**; **Figure 5-43**). Seabed disturbance will result in physical impacts to the seabed, which is likely to affect associated marine biota. The North-west Marine Plan identifies physical habitat modification as a pressure of 'potential concern' for this KEF (Commonwealth of Australia, 2012).

A survey of the proposed BTL route by Advisian (2019; Chapter 10, Appendix D.1) sampled six locations spread along this 250 km extent in order to inform this assessment against the ecological values associated with the Continental slope demersal fish communities KEF. The seabed at the sample locations within the KEF was dominated by bare sandy substrates with sparse epifaunal benthic invertebrates observed (Advisian, 2019). In addition, only a small portion of this KEF (< 0.08%) will be traversed by the proposed BTL route. Given this, it is considered that the identified conservation values of this KEF will not be adversely impacted by seabed disturbance associated with the proposed Browse to NWS Project.

The Seringapatam Reef and the Commonwealth waters in the Scott Reef complex KEF are regionally important as they support diverse aggregations of marine life, high primary productivity and high species richness (Commonwealth of Australia, 2012). The Browse Development Area overlaps the Seringapatam Reef and Commonwealth waters in the Scott Reef complex KEF (**Section 5.3.3.1**; **Figure 5-43**). Seabed disturbance within this KEF will occur as a result of the development activities (**Section 6.3.1.2**). Seabed disturbance will result in the modification of the physical habitat of the disturbed area, which may affect marine biota utilising these habitats. The North-west Marine Plan identifies physical habitat modification as a pressure of 'potential concern' for the Seringapatam Reef and Commonwealth waters in the Scott Reef complex KEF (Commonwealth of Australia, 2012).

As described above, seabed disturbance will only occur in deep waters (125 m - 600 m deep) with no predicted physical disturbance to shallow water habitats associated with coral, seagrass and macroalgae of Scott Reef. Surveys indicate that the areas predicted to be impacted by seabed disturbance are sparsely inhabited and well represented within the broader region. Habitat modification will occur to a very small fraction (approximately 0.1%) of the widespread available representative deepwater habitat within the KEF and, as such, are not expected to materially reduce primary production or effect species richness. Given this, it is considered that the identified conservation values of this KEF will not be adversely impacted by seabed disturbance associated with the proposed Browse to NWS Project.

Mermaid Reef and the Commonwealth waters surrounding the Rowley Shoals are recognised as areas of high species aggregation and high species richness associated with high productivity caused by wave action within the reef areas (Commonwealth of Australia, 2012). The proposed BTL route may traverse an inshore portion of the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF, although this is dependent on the final route selection (**Figure 5-43**). Should the proposed BTL route traverse the KEF, this would result in seabed disturbance and subsequent modification of the physical habitat of the disturbed area, which could affect marine biota utilising these habitats. The North-West Marine Plan identifies physical habitat modification as a pressure of 'potential concern' for the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF (Commonwealth of Australia, 2012).

A benthic habitat survey along the proposed BTL route was completed, with four sites surveyed within this KEF (Advisian 2019; **Chapter 10, Appendix D.1**). Results from the sites surveyed did not identify any complex seabed features or increased species richness, or other values associated with this KEF. Habitat modification will occur in a very small fraction of the available representative deepwater habitat within the KEF and, as such, is not expected to materially reduce primary production or effect species richness. Given this, it is considered that the identified conservation values of this KEF will not be adversely impacted by seabed disturbance associated with the proposed Browse to NWS Project.

The Ancient coastline at 125 m depth contour is regionally significant as it is a unique seafloor feature with hard substrates and complex topography, which is thought to facilitate vertical mixing of the water column (promoting productivity) and provide benthic habitats in an area otherwise dominated by soft sediments (Commonwealth of Australia, 2012). The proposed BTL route traverses approximately 40 km of this KEF at the southern end of the proposed BTL route near the NRC tie in point (**Figure 5-43**). This represents a very small portion of this KEF, which extends along much of the WA coastline.

Advisian (2019) surveyed three locations along the proposed BTL route within this KEF. Survey results did not identify values associated with this KEF (as described in the North-west Marine Plan). Substrates consisted of sand with varying proportions of silt and clay, with no evidence of harder seabed substrates or rocky escarpment (Advisian, 2019). Only a small portion of this KEF (< 0.025%) will be traversed by the proposed BTL route. Given this, it is considered that the identified conservation values of this KEF will not be adversely impacted by seabed disturbance associated with the proposed Browse to NWS Project

Injury or mortality to fauna

As described above, impacts to fauna will be limited to epifauna in a very small fraction of the deep waters of the KEFs. Given this, it is considered that the identified conservation values of KEFs will not be adversely impacted by seabed disturbance associated with the proposed Browse to NWS Project.

Summary

Table 6-10 provides an assessment of the proposed seabed disturbance in relation to the pressures on KEFs identified in the Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).

Table 6-10 Assessment of proposed activities in relation to relevant pressures on KEFs - seabed disturbance

Key Ecological Feature	Relevant plan(s)	Relevant pressures	Assessment
Continental slope demersal fish communities	Marine bioregional plan for the Northwest Marine Region (Commonwealth of Australia, 2012).	Physical habitat modification	Given that disturbance leading to physical modification of benthic communities and habitats will occur to a very small fraction of deepwater benthic habitats that are well represented both within each of the KEFs in the Project Area, and regionally, there is a high level of confidence that disturbance will not result in an adverse impact to marine ecosystem function or integrity with in the KEFs; or that any reduction in to the conservation values of the KEFs will occur.
Seringapatam Reef and Commonwealth waters in the Scott Reef Complex			
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals			
Ancient coastline at 125 m depth contour		None noted	

Australian Marine Parks

The proposed BTL route traverses the Multiple Use Zones (IV) of the Argo-Rowley Terrace and Kimberley Marine Parks. It should also be noted that the proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park National Park Zone. The rationale for selection of the BTL route is provided in **Chapter 3**. The North-west Marine Parks Network Management Plan (Director of National Parks, 2018) outlines the objectives of the Multiple Use Zone (VI) multi use zones traverse by the BTL as "to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species".

Change in water quality

As described above, changes to water quality are expected to temporary and highly localised. As such, the objectives of the AMPs within the Project Area will be achieved.

Change in sediment quality

As described above, no lasting change to sediment quality are expected. As such, the objectives of the AMPs within the Project Area will be achieved.

Change in habitat

Installation of the BTL and associated activities will result in seabed disturbance and permanent habitat modification in the Multiple Use Zones (IV) of the Argo-Rowley Terrace and Kimberley Marine Parks. No seabed disturbance is planned in the Mermaid Reef Marine Park National Park Zone.

The Argo-Rowley Terrace Marine Park provides protection for the ecological communities and habitats of the deeper offshore waters of the region, in water depths ranging from 220 to 6,000m. This includes protection for many bathymetric features, including aprons and fans, canyons, continental rise, knolls/abyssal hills and the terrace and continental slope (Director of National Parks, 2018). The proposed BTL route traverses Multiple Use Zones of the Argo-Rowley Terrace AMP for approximately 97 km (**Figure 5-44**).

The Kimberley Marine Park provides protection for habitats and ecological communities in waters offshore of the Kimberley coastline, ranging in water depths from less than 15 to 800m. The Kimberley Marine Park supports a range of protected species and BIAs. The proposed BTL route traverses through the Multiple Use Zones of the Kimberley AMP for approximately 68 km (**Figure 5-44**).

The North-West Marine Region is vulnerable to physical habitat modification due to pressure from increasing large-scale projects associated with the resources sector, therefore, physical habitat modification is a priority for conservation effort in this region (Commonwealth of Australia, 2012).

The area traversed by the proposed BTL represents a small proportion of the total area of the AMPs. The majority of the proposed BTL route traverses' depths of between 280 and 440m which are too deep for the establishment of seagrass, macroalgae or light-dependent coral communities. A benthic habitat survey along the proposed BTL route sampled six locations within the AMPs (two in the Kimberley Marine Park and four within the Argo-Rowley Terrace Marine Park). Analysis of the benthic imagery found that the seabed along the BTL route within the AMPs was predominantly composed of unconsolidated soft sand, largely devoid of epibenthic communities, with occasional solitary non-coral benthic invertebrates (Advisian, 2019).
The modification of a small fraction of the available representative deepwater habitat within the AMPs is not expected to materially reduce primary production or effect species richness. Given this, the proposed activities are considered to be not inconsistent with the objective of the Multiple Use Zone (VI) to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species.

Injury or mortality to fauna

As described above, impacts to fauna will be limited to a very small fraction of deepwater epifaunal communities within the AMPs. Given this, it is considered that seabed disturbance will not adversely affect marine fauna within the AMPs and the proposed activities are considered to be not inconsistent with the objective of the Multiple Use Zone (VI) to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species.

Summary

Table 6-11 provides an assessment of the proposed seabed disturbance in consideration of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018).

Table 6-11 Alignment with the North-west Marine Parks Network Management Plan – physical presence: seabed disturbance

Australian Marine Park	Relevant plan(s)	Australian Marine Park Objectives	Assessment
Argo-Rowley Terrace Marine Park Multi Use Zone (VI)	North-west Marine Parks Network Management Plan (Director of National Parks, 2018)	The objective of the Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species.	The BTL survey did not identify any sensitive biota or species of conservation significance within AMPs along the proposed BTL route. Given that seabed disturbance will occur in a very small fraction of deepwater benthic habitat that is well represented both within each of the AMPs in the Project Area, and regionally, there is a high level of confidence that seabed disturbance will not result in an adverse impact to marine ecosystems, habitats or native species such that the conservation values of the AMPs would be reduced. As such, it is considered that the proposed activities are not inconsistent with the requirements of the North-west Marine Parks Network Management (Director of National Parks, 2018).
Kimberley Marine Park Multi Use Zone (VI)			
Mermaid Reef Marine Park National Park Zone (II)		The objective of the National Park Zone (II) is to provide for the protection and conservation of ecosystems, habitats and native species in as natural a state as possible.	The proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park. As such, no direct or indirect impacts from seabed disturbance are predicted to occur in this AMP with no effects on ecosystems, habitats or native species in the AMP predicted. As such, it is considered that the proposed activities are not inconsistent with the requirements of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018).

Other protected places

Change in sediment quality, change in water quality, change in habitat, injury or mortality to fauna

No seabed disturbance will occur within the Scott Reef and Surrounds or the Mermaid Reef – Rowley Shoals Commonwealth Heritage Places, with planned disturbance only occurring in deep water benthic communities and habitat. As such, it is considered that the conservation values of these protected places will be maintained.

Maritime archaeology

Change in heritage values

Known maritime archaeological sites in the vicinity of the Project Area (including ship wrecks on Scott Reef) are described in Chapter 5. Due to the distance of these sites from the proposed infrastructure, impacts to these sites are not expected to occur.

6.3.1.4 Environmental Risk

Risk event: Turbidity generated during seabed disturbance significantly greater than expected

Turbidity generated during seabed disturbance significantly greater than expected would potentially result in:

- increased spatial extent of impacts to deepwater benthic communities and habitats (including within KEFs and AMPS) as a result of increased suspended sediment concentrations and sediment deposition rates
- sediment deposition on the shallow water benthic communities and habitats.

Given the sparse nature of the deepwater habitats and the small fraction of the KEFs and AMPs that would be impacted, the likelihood that increased spatial extent of impacts to deepwater benthic communities and habitats would result in adverse impacts to biological diversity or ecological integrity, or the conservation values of the KEFs or AMPs, is considered remote, with a subsequent risk rating determined to be low.

The displacement of sediments is likely to result in localised (within tens of metres of the disturbance area) and temporary increases in turbidity at the seabed. This turbidity will quickly disperse in the oceanic marine environment due to prevailing hydrodynamic conditions and, therefore, the likelihood of any resultant ecological impacts to Scott Reef, the Rowley Shoals, or nearby protected places (i.e. Mermaid Reef Marine Park, Scott Reef and Surrounds Commonwealth Heritage Place or Mermaid Reef - Rowley Shoals Commonwealth Heritage Place) occurring has been assessed as remote, with the subsequent risk rating determined to be low.

Risk event: Dropped objects

Objects such as tools and equipment may be lost as a result of being accidentally dropped from the MODU, FPSOs and vessels during the proposed Browse to NWS Project. Operator error, bad weather events or failure of equipment may lead to such loss. Depending on the size and nature of the dropped object, impacts could include temporary or permanent modification of habitat (depending on whether the object can be re-located and retrieved), localised and temporary sedimentation, temporary reduction in water quality or injury or mortality to marine fauna. Dropped objects which have the potential to cause significant seabed disturbance are limited, with the chance of this occurring restricted mainly to the construction and decommissioning phases of the proposed Browse to NWS Project.

Given the Project Area encompasses four KEFs and the BTL crosses two AMPs, there is a potential for dropped objects to occur within these areas. The likelihood of a dropped object causing significant disturbance to the seabed in the deep waters of the Project Area has been assessed as highly unlikely, with the subsequent risk rating determined to be low. Given that no activities are planned within the Scott Reef system (defined as the area above the 75 m bathymetric contour), the likelihood of a dropped object event occurring resulting in impact to Scott Reef shallow water benthic habitat (<75 m bathymetry) has been assessed as remote, with the subsequent risk rating determined to be low.

Risk event: Damage to unidentified maritime archaeology

Change in heritage values

During installation of temporary and permanent infrastructure, there is a potential for unidentified historic ship wrecks and plane wrecks to be impacted. Benthic habitat and geophysical surveys along the proposed BTL route have not identified any potential cultural heritage sites. Therefore, the likelihood of damage occurring to maritime archaeology as a result of a dropped object is considered remote, with the subsequent risk rating determined to be low.

6.3.1.5 Cumulative Impacts

Cumulative impacts resulting from seabed disturbance (both from multiple project activities and other developments in the area) are highly unlikely given the relatively small physical footprint of the proposed activities within the context of the sparsely distributed deepwater benthic communities and habitats of the Project Area, the distance to other developments in the region and the location of the proposed Browse to NWS Project in offshore waters. Given this likelihood, the magnitude of the impact (slight) and the nature of the receptors (deepwater benthic habitat), cumulative impacts from the physical presence of infrastructure, wet storage, FPSOs, MODUs and project vessels are not expected to result in reductions in biological diversity or ecological integrity in the Project Area.

6.3.1.6 Impact and Risk Assessment Summary and Acceptability Assessment

A summary of the impact and risk assessments and the adopted controls for physical presence: seabed disturbance is provided in **Table 6-12** and **Table 6-13**. The final acceptability assessment is provided in **Table 6-14**.

Table 6-12 Impact assessment summary and adopted controls – physical presence: seabed disturbance

Receptor (sensitivity)	Potential Impacts	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
Sediment quality (medium value (open waters))	+ Change in sediment quality	**Objective 1:** To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **Objective 2:** To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.	***Development drilling*** + No infrastructure will be placed on Scott Reef shallow water benthic communities and habitat (<75 m bathymetry). + No moorings for the MODUs will be installed in the Scott Reef shallow water benthic communities and habitat (<75 m bathymetry). ***Installation of subsea infrastructure*** + Moorings for the FPSO facilities will be located outside of the State waters 3 nm boundary. + No moorings will be installed within the lagoon at North and South Scott Reef. + Secondary stabilisation of subsea infrastructure will be limited to the level necessary to ensure pipeline integrity. + Vessels will be required to comply with an anchoring management plan which will include mooring analysis, with the requirement to avoid placing anchors on sensitive receptors.	No lasting effect	Negligible (F)
Water quality (medium value (open waters))	+ Change in water quality	**Objective 3:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		No lasting effect	Negligible (F)
Plankton (medium value (open water)	+ Injury or mortality to fauna	**Objective 7:** To not have a substantial adverse effect on a population of plankton, including its lifecycle and spatial distribution.		No lasting effect	Negligible (F)

Receptor (sensitivity)	Potential Impacts	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
Deepwater benthic communities and habitats (>75 m depth) – (medium value)	+ Change in water quality + Change in sediment quality + Change in habitat + Injury or mortality to fauna	**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.	***Installation of the BTL and inter-field spur line*** + The BTL and inter-field spur line will be located in Commonwealth waters at least 3 nm from Scott Reef shallow water benthic communities and habitat (<75 m bathymetry). + DP pipelay vessels will be used during BTL and inter-field spur line installation (except for initial anchoring to commence the pipelay activity). + Activities will be conducted in a manner not inconsistent with the objectives, values and principles of the multi-use zones of the AMPs which are traversed by the BTL route.	Minor	Minor (D)
Shallow water benthic communities and habitats (<75 m depth) (high value habitat)	+ Change in water quality + Change in sediment quality + Change in habitat + Injury or mortality to fauna	**Objective 9:** To avoid direct (i.e. physical footprint) disturbance to Scott Reef shallow water benthic habitat (<75 m bathymetry). **Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry)		No impact predicted	
KEFs (medium value)	+ Change in water quality + Change in sediment quality + Change in habitat + Injury or mortality to fauna	**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.		No lasting effect	Negligible (F)
Australian marine parks (medium value (multiple use zones))	+ Change in water quality + Change in sediment quality + Change in habitat + Injury or mortality to fauna	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No lasting effect	Negligible (F)
Other protected places				No impacted predicted	

Receptor (sensitivity)	Potential Impacts	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
Maritime archaeology (high value)	+ Change in heritage values	**Objective 19:** To not have a substantial adverse impact on heritage values.	Shipwrecks, plane wrecks or other underwater cultural heritage sites identified during surveys or installation activities will be avoided and reported in accordance with the Underwater Cultural Heritage Act 2018	No impact predicted	

Table 6-13 Risk assessment summary and adopted controls – physical presence: seabed disturbance

Receptor	Risk Events	Environmental objective	Adopted controls	Consequence	Likelihood	Risk Rating
Sediment quality (medium value (open waters))	+ Turbidity generated during seabed disturbance significantly greater than expected.	**Objective 1:** To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **Objective 2:** To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.	Lifting procedures and measures to avoid impact resulting from dropped objects will be implemented.	No increase to significance/consequence		
Water quality (medium value (open waters))		**Objective 3:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		No increase to significance/consequence		
Plankton (medium value (open water)		**Objective 7:** To not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution.		No increase to significance/consequence		

Receptor	Risk Events	Environmental objective	Adopted controls	Consequence	Likelihood	Risk Rating
Deepwater benthic communities and habitats (>75 m depth) – (medium value)	+ Turbidity generated during seabed disturbance significantly greater than expected. + Dropped objects	**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results		No increase to significance/consequence		
Shallow water benthic communities and habitats (<75 m depth) (high value habitat)		**Objective 9:** To avoid physical footprint disturbance to Scott Reef shallow water benthic habitat (<75 m bathymetry) **Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry).		Slight	Remote	Low (EO)
KEFs (medium value)		**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.		No increase to significance/consequence		
Australian marine parks (medium value (multiple use zones))		**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No increase to significance/consequence		
Other protected places (high value)	+ Turbidity generated during seabed disturbance significantly greater than expected.	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No increase to significance/consequence		
Maritime archaeology (high value)	+ Damage to unidentified maritime archaeology.	**Objective 19**: To not have a substantial adverse impact on heritage value.		Slight	Remote	Low (EO)

Table 6-14 Acceptability assessment – physical presence: seabed disturbance

Acceptability Assessment
Confidence in assessment Woodside has a **high** level of certainty with respect to the assessment of the potential impacts and risks associated with seabed disturbance, as: + Surveys have characterised the deepwater benthic communities and habitats that may be impacted by seabed disturbance. + The deepwater benthic biota that may be impacted are sparse and well represented both in the Project Area and regionally. + No seabed disturbance will occur to shallow water benthic habitats (e.g. at Scott Reef and Rowley Shoals). + The proposed controls are standard controls widely employed in industry and proven to mitigate the potential impacts and risks effectively. + Suitable contingency has been allowed in seabed disturbance estimates appropriate for the current design stage of the proposed Browse to NWS Project.
Principles of ESD With the application of the proposed controls it is predicted that the nominated environmental objectives for each potentially impacted receptor will be achieved. As such, it is considered that the principles of ESD will be met. **Conclusion: Acceptable**
Significant Impacts as defined by the MNES Significant Impact Guidelines ***Listed threated species and ecological communities/listed migratory species*** + No adverse impacts to listed threatened or migratory species are predicted. + No threatened ecological communities exist in the Project Area. ***Commonwealth marine environment*** As described in Table 6-12, the potential impact from physical presence: seabed disturbance to sediment quality, water quality, plankton, KEFs and AMPs has been assessed as Negligible (F). Minor (D) impacts may occur to deepwater benthic communities and habitats (>75 m depth), while no impact is predicted to occur to shallow water benthic communities and habitats (<75 m depth), other protected places or maritime archaeology. As described in Table 6-13, potential risk events present a Low risk to shallow water benthic communities and habitats (<75 m depth) and maritime archaeology. Given this, with the application of the proposed controls it is predicted that the nominated environmental objectives for each potentially impacted receptor will be achieved. As such, no significant impacts to the Commonwealth marine environmental (as defined by the Significant Impact Guidelines (Table 6-5)) are predicted ***National heritage places*** No impacts to national heritage places are predicted within the Project area. **Conclusion: Acceptable**

Acceptability Assessment

WA EPA Environmental Objectives
An assessment of the impacts of physical presence: seabed disturbance against the WA EPA Objectives is presented in the State Proposal ERD (**Chapter 10, Appendix B**). This includes State Proposal Area specific disturbance area estimates.

Marine environmental quality

As described in **Table 6-12**, the potential impact from physical presence: seabed disturbance to sediment quality, water quality and plankton has been assessed as Negligible (F). Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors and the WA EPA environmental objective "*To maintain the quality of water, sediment and biota so that environmental values are protected*" will be achieved.

Benthic communities and habitats

As described in **Table 6-12**, Minor (D) impacts may occur to deepwater benthic communities and habitats (>75 m depth), while no impact is predicted to occur to shallow water benthic communities and habitats (<75 m depth). As described in **Table 6-13**, potential risk events present a Low risk to shallow water benthic communities and habitats (<75 m depth). Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors and the WA EPA environmental objective "*to protect benthic communities and habitats so that biological diversity and ecological integrity are maintained*" will be achieved.

Marine fauna

Impacts to epifauna and infauna are included in the above assessment of impacts to benthic communities and habitats. No other impacts to marine fauna are predicted as a result of seabed disturbance.

Conclusion: Acceptable

External context
To date, there have been no specific matters raised by stakeholders regarding physical presence: seabed disturbance in relation to the proposed Browse to NWS Project.

Conclusion: Acceptable

Internal context
This impact assessment has been undertaken in accordance with Woodside's Risk Assessment Procedure and Environment Impact Assessment Guideline (**Section 6.2**) The proposed Browse to NWS Project will be executed in accordance with Woodside's Health, Safety and Environmental Management System.

Conclusion: Acceptable

Other requirements

EPBC Act recovery and conservation plans and advices

Impacts to listed threatened species form seabed disturbance are not predicted. As such, no relevant EPBC Act recovery and conservation plans and advices apply in relation to seabed disturbance.

KEFs

As detailed in **Table 6-10**, the proposed seabed disturbance will not materially increase existing relevant pressures on the conservation values of KEFs.

AMPs

As detailed in **Table 6-11**, the proposed activities are considered to be not inconsistent with the requirements of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018).

Other Protected Places

No impacts are expected to occur to the to the values of the Scott Reef and Surrounds or the Mermaid Reef – Rowley Shoals Commonwealth Heritage Places.

Conclusion: Acceptable

6.3.2 Physical Presence: Disturbance to Other Users

6.3.2.1 Impact and Risk Overview

Table 6-15 presents an overview of the potential impacts and risks from disturbance to other users associated with the physical presence of proposed Browse to NWS Project infrastructure.

Table 6-15 Physical presence: disturbance to other users impact and risk overview

Aspect	Physical presence: disturbance to other users		
Description	Disturbance or displacement of other users from the Project Area may occur due to the physical presence of infrastructure and associated exclusion zones and activities including: + surveys + vessel operations + MODU operations + helicopter operations + installation and operations of the subsea infrastructure, BTL and inter field spur line + installation and operations of the FPSO, including condensate offtake tankers + removal of infrastructure.		
Area	Project Area, Browse Development Area, State Proposal Area		
Project stage	All - drilling and completions, installation, commissioning, operations and decommissioning		
Environmental objectives	The environmental objectives in relation to disturbance to other users associated with the proposed Browse to NWS Project are Objectives 19, 20 and 21. These objectives are detailed in Table 6-7.		
Policy and guidelines	The following policy and guidelines are relevant to the assessment of this aspect: + Commonwealth Navigation Act 2012.		

Receptors	The following receptors have been identified as potentially being impacted as a result of the proposed Browse to NWS Project (Table 6-2). A detailed description of each of these receptors is provided in Chapter 5.
	Socio-economic
	+ State and Commonwealth managed fisheries (high value marine user)
	+ other users
	  + tourism and recreation (high value users)
	  + scientific studies (high value users)
	  + shipping (medium/high value users)
	  + industry (low value)
	+ Aboriginal and indigenous heritage (high value users)		

Potential impacts	Changes to the functions, interests or activities of other users		
Risks	There are no anticipated environmental risks in relation to this aspect associated with unplanned incidents or events.		
Summary of impact evaluation for governing impact	***Magnitude***	***Impact significance level***	***Confidence***
	Slight	Minor (D)	High
Summary of risk evaluation for governing risk	***Consequence***	***Likelihood***	***Risk rating***
	n/a	n/a	n/a

6.3.2.2 Source of Aspect

Disturbance or displacement of other users from the Project Area may occur due to the physical presence of infrastructure and associated exclusion zones and activities, including:

- surveys
- vessel operations
- MODU operations
- helicopter operations
- installation and operations of the subsea infrastructure, BTL and inter field spur line
- installation and operations of the FPSO, including condensate offtake tankers
- removal of infrastructure.

During development drilling, construction and operations, non-project vessel movements will be restricted in proximity to the MODU(s) and FPSO facilities via the implementation of a 500 m petroleum safety zone. The pipelay vessels will move along the BTL and inter-field spur line route at a rate of up to approximately 5 km/day (depending on the pipelay vessel and operational conditions such as sea state). A petroleum safety zone will be established around the pipelay vessel during installation of the BTL and inter-field spur line.

6.3.2.3 Environmental Impact

Physical presence of vessels, MODU, BTL and inter-field spur line, and FPSO facilities and the use of helicopters are likely to result in localised changes to the functions, interests or activities of other users. The duration of change will depend upon the activity or duration for which the vessel and/or MODU is required. In the case of the FPSO, BTL and inter field spur line, and subsea infrastructure presence, the change will be permanent for the duration of the field life.

State and Commonwealth managed fisheries

Changes to the functions, interests or activities of other users

Four Commonwealth and 11 WA State fisheries overlap the Project Area, in particular the BTL (**Figures 5-47** to **Figure 5-50**). Of these, six fisheries have been assessed as having the potential to operate within the Project Area, with two of these fisheries being of particular importance given the use of trawl fishing methods. Potential impacts to commercial fisheries include damage to fishing gear and a reduction of commercial catch due to displacement from fishing grounds. Subsea infrastructure such as flowlines, wellhead and manifolds present the greatest snag hazard risk.

During installation of the subsea infrastructure and during survey and drilling activities, the presence of vessels (and MODU) within the Browse Development Area will present a surface hazard to fishing vessels. During drilling activities, a 500 m safety exclusion zone will be designated around the MODU and, once operational, the FPSO facilities will also have a 500 m radius safety exclusion zone. This will result in short term exclusion during drilling and installation and longer-term exclusion during the operational phase.

Given the distance offshore, the Project Area is not an area of high commercial fishing activity. Furthermore, the 500 m safety exclusion zone around the MODU and FPSO comprises a relatively small area when compared to the extent of the fisheries. As such, displacement of commercial fisheries due to the proposed project activities is not expected to impact commercial fishing activities or the economic viability of the fisheries.

Following construction and development drilling, infrastructure on the seabed will present a potential snagging risk to commercial fishers. The Commonwealth North West Slope Trawl Fishery (NWSTF) and the State Pilbara Fish Trawl (Interim) Managed Fishery (PFTIMF) overlap the Project Area and the proposed BTL, where snagging is likely to be the greatest risk. However, given the low fishing effort expected within the Project Area and that the BTL, inter-field spur line and development wells will be marked on navigational charts, the risk of snagging is considered low. As the FPSO facilities and well locations are in water depths greater than 350 m, with no known subsea features of significance for fish populations in the area, it is not considered that the loss of access to fishing grounds within the petroleum safety zones (representing a fraction of the area of the fisheries) will affect current fishing levels in the region.

Recreation and tourism

Changes to the functions, interests or activities of other users

Scott Reef is used for tourism and recreation (primarily diving and fishing charters) at low levels. Given the proposed locations of the FPSO facilities, MODU and subsea infrastructure within deep waters off the reef, it is not considered that the physical presence of infrastructure will reduce the recreation and tourism value of Scott Reef.

Scientific research

Changes to the functions, interests or activities of other users

Scientific research is occasionally undertaken at Scott Reef within the Browse Development Area. A number of marine research and monitoring programs have been ongoing, particularly those conducted by AIMS and the WA Museum. WA DoF also conducts monitoring and research programs within the region. Given that no direct disturbance is planned to Scott Reef (the feature of interest for ongoing research activities), the frequency of the monitoring programs, the small area of exclusions resulting from the establishment of the 500 m petroleum safety zones and the planned ongoing consultation with relevant stakeholders, it is not anticipated that the proposed Browse to NWS Project will result in the reduction of the scientific research values of the Scott Reef system.

Shipping

Changes to the functions, interests or activities of other users

Although no main commercial shipping fairways cross the Browse Development Area, the proposed BTL route in the broader Project Area traverses a number of shipping fairways and areas of higher shipping density (**Section 5.4.2.4**). Given this, impacts to shipping traffic are expected to be limited to temporary disruptions to shipping during BTL installation activities and intermittent IMR activities along the proposed BTL route. Impacts from this disruption will be limited to vessels taking an alternate route around the exclusion areas. No impacts to shipping are expected during the operations of the BTL.

Industry

Changes to the functions, interests or activities of other users

There are several approved and prospective petroleum developments in the vicinity of the Browse Development Area, including the operating Shell Prelude FLNG and INPEX Ichthys projects located 140 km and 105 km away, respectively. In addition, the BTL passes through several exploration and production permits with a variety of titleholders, crossing existing trunklines. Displacement of, or interference with, other oil and gas activities is not expected within the Browse Development Area. However, activities associated with the trunkline, such as trunkline installation, may result in short term interference, particularly at the NRC location (5-10 km away). Once installed, the presence and operation of the trunkline will not result in significant interference with other petroleum activities e.g. seismic activities. Such facilities will be regularly serviced by offshore support vessels; however, through the implementation of a 500m petroleum safety zone, it is considered highly unlikely that the operation of these facilities to be affected.

Aboriginal and indigenous heritage

Changes to the functions, interests or activities of other users

Indonesian fishers (permitted in accordance with MoU 74) generally visit Scott Reef between July and October, fishing using traditional methods such as reef gleaning, free-diving and hand lining (**Section 5.4.2.3**). Fishing is generally limited to the shallow waters around the reef and traditional fishing vessels are only present in deep waters during transit to and from reef locations. The presence of a MODU, FPSOs and vessels may have the potential to slightly disrupt their transit within the area. Drilling and installation activities, however, will only restrict passage through a relatively small, deepwater area of the broader Scott Reef system.

6.3.2.4 Environmental Risk

There are no anticipated environmental risks in relation to disturbance to other users associated with unplanned events or incidents.

6.3.2.5 Cumulative Impacts

Cumulative impacts resulting from the physical presence of infrastructure (both from multiple project activities and other developments in the area) are highly unlikely given the large distances between developments in the area.

6.3.2.6 Impact Assessment Summary and Acceptability Assessment

A summary of the impact assessment and the adopted controls for physical presence: disturbance to other users is provided in **Table 6-16**. The final acceptability assessment is provided in **Table 6-17**.

Table 6-16 Impact assessment summary and adopted controls – physical presence: disturbance to other users

Receptor (sensitivity)	Potential Impacts	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
State and Commonwealth managed fisheries (high value marine user)	+ Changes to the functions, interests or activities of other users	**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.	***Physical presence of infrastructure*** + A 500m petroleum safety zone around the FPSO facilities, MODUs and installation vessels will be gazetted under Section 616 of the OPGGS Act. + FPSO facilities and the BTL will be gazetted and included on navigational charts, with a notice to mariners issued through the Australian Hydrographic Service to alert other users of their location. + Operational radar and vessel tracking equipment will be in place on the FPSO facilities in accordance with Marine Order 30 (Prevention of Collisions) and Marine Order 21 (Safety and Emergency Arrangements). + Ongoing consultation with commercial fishers, recreational fishing groups and other relevant stakeholders that operate in the Project Area will be undertaken. + FPSO facilities will be located away from shipping lanes and approach and exit paths to Scott Reef that traditional Indonesian fishers would be likely to take. + Activities will not be conducted in a manner inconsistent with the Objectives of the respective zones of the AMPs, the Principles of the IUCN Area Categories of the Values of the AMPs.	Slight	Minor (D)
Other users including tourism and recreation, scientific studies (high value users),	+ Changes to the functions, interests or activities of other users	**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		Slight	Minor (D)
Shipping (medium/ high value user)	+ Changes to the functions, interests or activities of other users			Slight	Minor (D)
Industry (low value user)	+ Changes to the functions, interests or activities of other users			Slight	Negligible (F)
Aboriginal and indigenous heritage (high value users)	+ Changes to the functions, interests or activities of other users	**Objective 19:** To not have a substantial adverse impact on heritage values. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		Slight	Minor (D)

Table 6-17 Acceptability assessment – physical presence: disturbance to other users

Acceptability Assessment
Confidence in assessment Woodside has a high level of certainty with respect to the assessment of the potential impacts associated with disturbance to other users as: + there is a good understanding of the users operating within the Project Area + the area across which other users operate is large in relation to the Project Area + FPSO facilities will not block shipping lanes or access to Scott Reef for traditional fishers.
Principles of ESD With the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such, it is considered that the principles of ESD will be met. **Conclusion: Acceptable**
Significant Impacts as defined by the MNES Significant Impact Guidelines Disturbance to other users is not relevant to any of the controlling provisions identified in the DoEE's decision notice on the referral of the proposed Browse to NWS Project under the EPBC Act. **Conclusion: Acceptable**
WA EPA Environmental Objectives Disturbance to other users is not relevant to any of the EPA Environmental Factors identified in the EPA determination on the referral of the proposed Browse to NWS Project under the EP Act. **Conclusion: Acceptable**
External context As part of previous stakeholder consultation undertaken for previous development concepts, stakeholders raised concerns about the potential exclusion from some areas of the NWSTF, with subsequent commercial impacts to users. Impacts on commercial fisheries are not expected to be significant and, with the proposed management measures to be implemented, significant impacts on key target species of the NWSTF and their habitats are not expected. However, Woodside appreciates that the proposed Browse to NWS Project has the potential to impact the NWSTF in areas where the fishery overlaps with the subsea infrastructure and activities associated with the Calliance reservoir and BTL. Consultation with affected and interested fisheries continue as part of broader stakeholder engagement and will be ongoing throughout the life of the proposed Browse to NWS Project. Woodside seeks to minimise the impacts of development activities through two-way communication. If there is a potential for a material ongoing impact on existing marine activities, Woodside will consult with specific individuals or groups of marine users who may be affected on a case-by-case basis. **Conclusion: Acceptable**
Internal context This impact assessment has been undertaken in accordance with Woodside's Risk Assessment Procedure and Environment Impact Assessment Guideline (**Section 6.2**) The proposed Browse to NWS Project will be executed in accordance with Woodside's Health, Safety and Environmental Management System. **Conclusion: Acceptable**
Other requirements None identified. **Conclusion: Acceptable**

6.3.3 Physical Presence: Light

6.3.3.1 Impact and Risk Overview

Table 6-18 presents an overview of the potential impacts and risks from light emissions associated with the physical presence of offshore facilities, MODU and vessels during all phases of the proposed Browse to NWS Project.

Table 6-18 Physical presence: light impact and risk overview

Aspect	Physical presence: light
Description	Light emissions will occur from the offshore facilities, MODU and project vessels during all phases of the proposed Browse to NWS Project. This will include light emission for: + navigation + operational + safety reasons + intermittent flaring and pilot gas (fuel gas supplied to keep the flare alight). The amount of light that will be emitted will vary based on a number of factors, including flaring frequency and duration, the number of activities being undertaken in the field, the location and/or placement of light fittings and the intensity and wavelength of the light source.
Area	Project Area, Browse Development Area, State Proposal Area
Project stage	All - drilling and completions, installation, commissioning, operations and decommissioning
Environmental objectives	The environmental objectives in relation to light emissions associated with the proposed Browse to NWS Project are Objectives 5, 6, 7, 10, 11, 12, 13, 14, 16, 18, 20 and 21. These objectives are detailed in **Table 6-7**.
Policy and guidelines	The following policy and guidelines are relevant to the assessment of this aspect. In addition, a number of EPBC Act conservation advices for protected fauna have been considered (**Table 6-23**). + WA Biodiversity Conservation Act 2016 (Wildlife Conservation (Specially Protected Fauna) Notice 2018) + WA Environment Protection Authority – Environmental Factor Guideline – Marine Fauna + Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) + Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a) + Draft National Light Pollution Guidelines for Wildlife Including Marine Turtles, Seabirds and Migratory Shorebirds (Commonwealth of Australia 2019) + North-west Marine Parks Network Management Plan (Director of National Parks, 2018).

Aspect	Physical presence: light		

Receptors	The following receptors have been identified as potentially being impacted as a result of the proposed Browse to NWS Project (**Table 6-2**). A detailed description of each of these receptors is provided in **Chapter 5**.
	Physical
	+ ambient light (medium value (open water))
	Ecological
	+ plankton communities (medium value (open water))
	+ benthic habitats
	  + shallow water benthic communities and habitats (<75 m depth) (high value habitat)
	+ fauna
	  + seabirds and migratory shorebirds (high value species)
	  + fish (high value species)
	  + marine reptiles (high value species)
	+ Australian marine parks (medium value (multiple use zones))
	+ State marine parks and nature reserves (high value)
	+ other protected places (high value)
	Socio-economic
	+ State and Commonwealth managed fisheries (high value marine user)
	+ other users
	  + tourism and recreation (high value users)
	  + scientific studies (high value users)		

Potential impacts	+ change in ambient light + change in fauna behaviour + injury or mortality to fauna + changes to the functions, interests or activities of other users		
Risks	There are no anticipated environmental risks in relation to this aspect associated with unplanned incidents or events.		
Summary of impact evaluation for governing impact	***Magnitude*** Slight	***Impact significance level*** Minor (D)	***Confidence*** High
Summary of risk evaluation for governing risk	***Consequence*** n/a	***Likelihood*** n/a	***Risk rating*** n/a

6.3.3.2 Source of Aspect

Lighting from the proposed project activities will be long term, that is, over the life of the project. Artificial light emissions will be generated from two main sources:

- Navigational and operational lighting – these functional lighting sources are required on vessels, MODU and FPSO facilities at levels that provide a safe working environment for personnel and ensure maritime shipping safety. This lighting typically consists of bright white (i.e. metal halide, halogen, fluorescent) lights and is not dissimilar to lighting used for other offshore activities, including fishing and shipping. Typical FPSO lighting is from LED lights, with only a small number of high-pressure sodium floodlights. On average, illumination levels of approximately 200 Lux will be used in outdoor operational areas, with the exception of lighting for navigation and collision prevention. Lighting is considered standard and is restricted to the amount required for safe operations and navigational requirements.

- Flaring - During hydrocarbon processing, flare stacks are used for burning off flammable gas released by pressure release valves (referred to as flaring). Light emissions are associated with intermittent flaring from the FPSOs and MODU. These will vary in duration and intensity. There will be no continuous flaring during normal operations, with the exception of pilot gas and compressor seal gas. Flaring most often takes place during start-ups and shutdowns or in emergency events.

Light emissions in State waters will occur only during the construction phases (i.e. drilling and installation activities) and during infrequent IMR activities during routine operations.

Light sources and, therefore, light emissions within the Browse Development Area will vary depending on the phase of the proposed Browse to NWS Project. It is likely that the footprint from light emissions will be highest during the construction phase (i.e. drilling and installation) due to the presence of multiple vessels and MODUs. Light sources are likely to be reduced during routine operations as primary light sources will be from the FPSOs. Lighting from MODU operations will be transient at each drill centre (typically in the order of two to three months per well), with flaring associated with well unloading only in the order of 1-2 days per well.

Light emissions will also be generated as part of the proposed BTL and inter-field spur installation activities, however, these emissions are likely to be temporary and minor. This is because the pipelay vessels will move along the proposed BTL route and inter-field spur line route at a rate of up to approximately 5 km/day (depending on the pipelay vessel and operational conditions such as sea state) meaning light emissions in any one area will be short term. Once the BTL and inter-field spur lines are operational, there will be no ongoing light emissions except occasional vessel lights during IMR activities.

6.3.3.3 Light Modelling Studies

To further understand the effects of light emissions on sensitive receptors (particularly green turtles), a line of sight assessment and a light density (luminous flux density) modelling study were conducted as part of the approved Browse FLNG Development EIS developed in 2014. A comparison between the proposed Browse to NWS Project and the previously proposed Browse FLNG Development is presented in **Section 3**. Given the similarities between the concepts, these previous studies adequately defined the potential impacts from artificial light emissions associated with the proposed Browse to NWS Project.

The studies of the proposed Browse FLNG Development assessed light emission impacts from:

- lighting on a drill rig during drilling activities at the TRE drill centre (ERM, 2010)[5], refer to **Figure 6-5** for location
- lighting on the proposed FLNG facilities at Torosa, Brecknock and Calliance (Jacobs and SKM, 2014)[6], refer to **Figure 6-6** for location.

The overall artificial light spill area from the proposed Browse to NWS Project is likely to be smaller than the previously proposed Browse FLNG Development due to the reduced number of facilities and the significantly reduced size, and as such presents conservative representation of the permanent infrastructure light sources.

The TRE drill centre was the closest to the most sensitive receptor location (Sandy Islet) and light emissions from the MODU are expected to exceed those of other project vessels at TRE. A MODU at TRE is therefore the governing scenario for light emissions associated with temporary activities.

Given these facilities in proximity to the sensitive receptors of Scott Reef have been identified as the governing scenarios, modelling of other light sources, which either have less light emissions or are further away from sensitive receptors, are not deemed a requirement of the impact assessment. Further, emergency flaring will be intermittent and of a short-term duration and, therefore, not assessed further.

Line of sight assessment

A line of sight assessment was undertaken to determine the maximum distance that light associated with the above activities may be visible (irrespective of the light source intensity). The maximum line of sight is based on the following:

- the location and height above sea level of the light source
- the height above sea level of the viewing location
- the distance between the light source and the viewing location
- the curvature of the earth's surface.

The line of sight assessment was undertaken using a Line of Sight Calculator (Kagstrom, 2005) based on the predicted illumination characteristics of a drill rig within the channel (TRE drill centre) at Scott Reef (ERM, 2010) and using ESRI ArcMap viewshed analysis for the proposed offshore facilities (Jacobs and SKM, 2014).

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[5] *ERM (2010) available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

[6] *Jacobs-SKM (2014) available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

The line of sight assessment for a drill rig at the TRE drill centre (ERM, 2010), **Figure 6-5**, showed that the maximum distance that direct light may be visible extended up to:

- 16.6 km for main deck lights
- 21 km for drill floor lights
- 26.6 km for derrick lights
- 45.2 km for a continuous 2 m high purge flare
- 52.4 km for an intermittent emergency flare (indicative initial flame length of 50 m).

Note that the initial emergency flaring flame length of 50m is broadly representative of the flaring flame length during well unloading, which is a temporary activity not lasting more than 1-2 days.

It should be noted that line of sight calculations did not take into account the diminishing size of the light source with distance or the decrease in light density and wavelengths as distance from the light source increased.

Due to the proximity of the TRE drill centre from Scott Reef, it was predicted that direct light emitted from a MODU at this location would be visible to some extent from all areas of Scott Reef (**Figure 6-5**).

The maximum distance at which direct light may be visible from any of the FPSO facilities under routine operational conditions, based on modelling of the previously proposed FLNG facilities (Jacobs and SKM, 2014) (**Figure 6-6**), was predicted to be:

- 18.8 km for deck lighting
- 33.5 km for topside modules/cranes lighting
- 47.7 km for the flare (noting that no continuous flaring is planned for the proposed Browse to NWS Project, with the exception of pilot gas and compressor seal gas).

At these distances the light sources would be visible as small points on the horizon. The line of sight assessment indicated that direct lights from an offshore processing facility at the previously proposed Torosa locations would be visible to some extent from all of Scott Reef, depending on the location of the facility (**Figure 6-6**). Deck lights were predicted to be visible from most of North Scott Reef and from a small portion to the east of South Scott Reef, but not from Sandy Islet. Direct light emitted from the topside modules/cranes would be visible from most of North and South Scott Reef, including Sandy Islet, while light emitted by flaring was predicted to be directly visible from any location at Scott Reef (ERM, 2010[7]). The FPSO flare at the Brecknock location was estimated to be visible from a portion of south Scott Reef, but not from Sandy Islet (**Figure 6-6**). Operational light emissions from the Brecknock and Calliance facilities were, therefore, not considered for further assessment.

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[7] *ERM 2010; https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

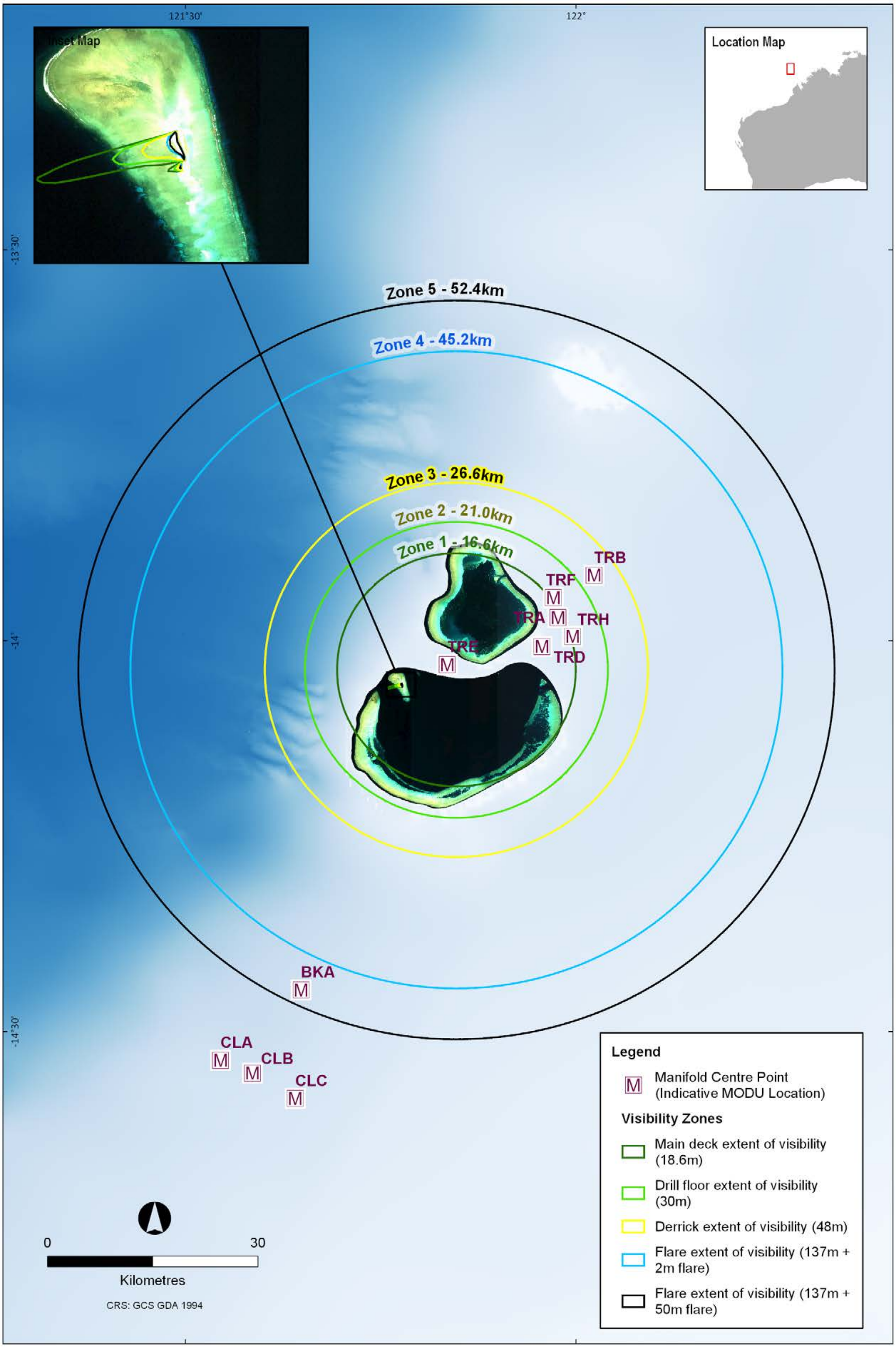

Figure 6-5 Line of sight assessment for a drill rig at TRE drill centre (ERM, 2010)

Figure 6-6 Line of sight assessment for previously proposed FLNG facilities locations at Torosa (refer to proposed Torosa FPSO), Brecknock and Calliance FPSO (Jacobs and SKM, 2014)

Light density modelling

Light density represents the intensity of light that arrives at or leaves a surface, as perceived by the human eye. Light density is measured in Lux (the unit of illuminance and luminous emittance of visible light for humans). The total amount of light as it arrives at a surface is referred to as illuminance and is the parameter that was modelled in the light density modelling study undertaken for the previously proposed Browse FLNG Development EIS (Jacobs and SKM, 2014)[8].

Light density decreases as distance increases from the source of light. Typical ambient light density levels range from 0.0001 Lux on a moonless overcast night to 130,000 Lux for direct sunlight. Typical light density levels are show in **Table 6-19**.

Table 6-19 Typical light density levels (Micron Technology 2007)

Light Type	Light Density (Lux)
Direct sunlight	100,000 to 130,000
Full daylight, indirect sunlight	10,000 to 20,000
Overcast day	1,000
Very dark day	100
Twilight	10
Deep twilight	1
Full moon	0.1
Quarter moon	0.01
Moonless clear night sky	0.001
Moonless overcast night sky	0.0001

These levels are consistent with the results of a baseline survey of light density undertaken at Scott Reef in 2008. This baseline survey was undertaken during a 'new moon' to determine the darkest natural conditions, with light density observed to range between 0.00 and 0.01 Lux (ERM and SKM, 2008)[9]. These levels were used to represent the range of background light density levels under variable natural conditions for this assessment.

It is acknowledged that the application of modelled photometric measures (i.e. lux levels) for the purposes of this impact assessment on marine fauna (specifically marine turtles) needs to take into consideration the wavelengths of light (i.e. blue and red) to which turtles are most sensitive. The following sections discuss the predicted light levels for sensitive receptors in the context of their visible wavelength ranges (**Figure 6-8**).

MODU

Light density levels representing a drill rig were predicted by using light density data measured during the drilling of the Torosa 6 (T-6) appraisal well (previously referred to as Torosa South-1 (TS-1) pilot appraisal well), located on the edge of the South Scott Reef lagoon (ERM, 2010; ERM and SKM, 2008). Although the MODUs for the proposed Browse to NWS Project early phase development drilling is yet to be confirmed and different MODUs are likely to be used throughout the Browse field life, light levels associated with drill rig lighting are expected to be comparable to that observed during the drilling of the T-6 appraisal well.

The light density from the drill rig at Scott Reef (northern edge of the southern lagoon) was highest (8.9 Lux) at 100 m from the rig, further reducing to below 1.0 Lux at 300 m from the rig and lowest (0 to 0.03 Lux) at the extremities of the survey area, approximately 1.4 km from the drill rig (**Figure 6-7**) (ERM and SKM, 2008). Light density attenuated to below 0.1 Lux between 1 km and 1.4 km from the drill rig located >12 km from Sandy Islet.

Measurements on the light emitted from the drill rig used for the T-6 appraisal well indicated that peak wavelengths emitted from the drill rig ranged from 530 to 620 nm, which is within the range that is visible to marine turtles and seabirds (**Figure 6-8**) (ERM and SKM, 2008). These wavelengths are expected to be comparable to routine light emissions from the proposed Browse to NWS Project MODU and the FPSO facilities. Light intensity and wavelength measurements of the T-6 appraisal well drilling activities did not measure flaring, as this did not occur during the activity. Natural gas flares have previously been measured to have a peak spectral signature in the invisible infrared range (750 to 900 nm), with lower levels of light emitted in the range visible to turtles (Pendoley, 2000). As the peak light wavelength from natural gas flares is not in the UV-blue region of the visible spectrum which is the

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[8] Jacobs and SKM, 2014 https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies

[9] ERM and SKM (2008) available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies

most disruptive to wildlife in general (Commonwealth of Australia, 2019) including marine turtles, the absence of an assessment of flaring impacts (as part of the ERM 2010 study) does not impact on the overall assessment.

Results of the light density modelling for a MODU at the TRE drill centre are presented in Table 6-20 and Figure 6-9. Based on these modelling results, the maximum predicted light density levels from a MODU at the TRE drill centre (closest drill centre to Scott Reef) reaching Sandy Islet are lower than 0.01 Lux, which is comparable to light levels between a moonless clear night sky and a quarter moon.

Table 6-20 Predicted light density from a MODU at the TRE drill centre (ERM, 2010)

Distance from Drill Rig	Light Density (Lux)	Ambient Level Light Comparison
Up to 800m	0.1	Full moon to twilight
800m to 1.2 km	0.01 to 0.1	Quarter moon to full moon night sky
1.2 km to 12.6 km	Lower than 0.01	Between a moonless clear night sky and a quarter moon
Beyond 12.6 km	No measurable change	n/a

FPSO facilities

Light density modelling for the previously proposed FLNG facilities at Torosa was based on a surface area of 20,500m^2 being illuminated to an average level of 200 Lux. Light sources included deck lighting, topside and crane lighting; however, light emissions from the flare of pilot flame were not included in this assessment. In the modelled scenario, the broad side of the FLNG facilities was assumed to face Scott Reef at an angle of 90 degrees, which represents a worst-case scenario for exposure to light. It should be noted that the proposed FPSO facilities will weathervane around the turret mooring system and, therefore, their actual orientation will depend on prevailing wind and current conditions.

Results of the light density modelling for an FLNG operating at Torosa are presented in Table 6-21. For a single FLNG facility operating at Torosa, light emissions were expected to attenuate to less than 0.1 Lux (comparable to a full moon) within approximately 3-7 km of the facility. Light emissions from the proposed Browse to NWS Project FPSO facilities are expected to be less than those predicted for FLNG facilities (due to the significantly smaller size of the facilities). Therefore, for the proposed operating FPSO facilities, brightness levels above the brightest natural source at night (i.e. a full moon) are not expected to reach Scott Reef or Sandy Islet.

Table 6-21 Predicted light density from the previously proposed FLNG facility operating at Torosa (Jacobs and SKM, 2014)

Distance from Facility (km)	Light Density (Lux)	Ambient Level Light Comparison
Up to 1 km	5 – 25	Between twilight and a very dark day
1 to 1.5 km	2.5 to 5	Between deep twilight and twilight
1.5 to 2 km	0.5 to 2.5	Between full moon and twilight
2 to 3 km	0.25 to 0.5	Between full moon and deep twilight
3 to 7 km	0.05 to 0.25	Between quarter moon and full moon
7 to 10 km	0.002 to 0.05	Between quarter moon and a moonless clear night sky
Beyond 33 km	Less than 0.002	Moonless clear night sky to overcast night sky

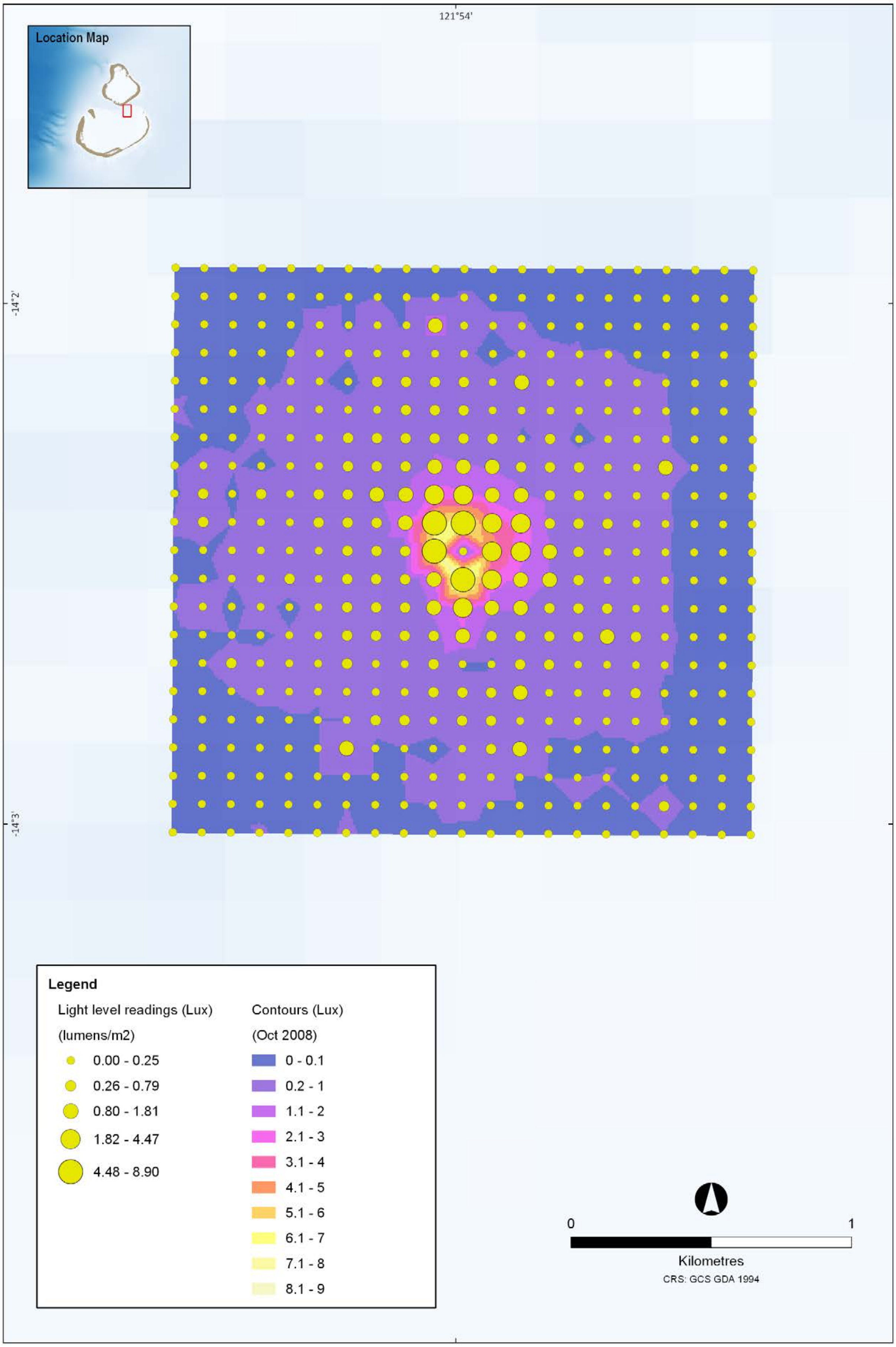

Figure 6-7 Lux Levels measured around the Torosa 6 Appraisal Well (previously referred to as Torosa South-1 pilot appraisal well) Drill Rig at South Lagoon, Scott Reef (ERM and SKM, 2008)

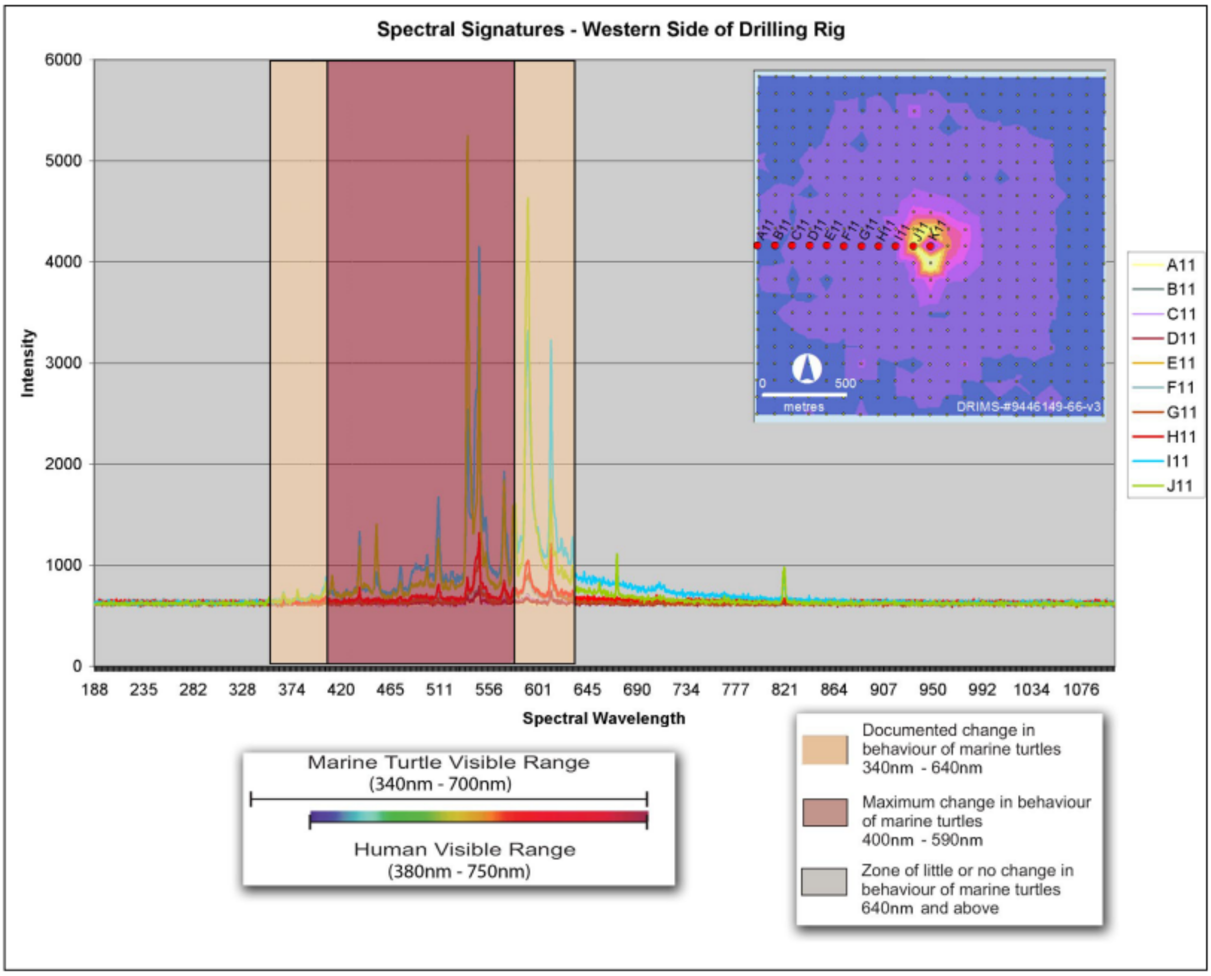

Figure 6-8 Spectral signature of the Torosa 6 Appraisal Well (previously referred to as Torosa South-1 pilot appraisal well) Drill Rig located at Scott Reef in 2008, as measured for the western direction from the drill rig towards Sandy Islet. The insert shows the modelled light density (Lux) levels (refer to Figure 6-7)

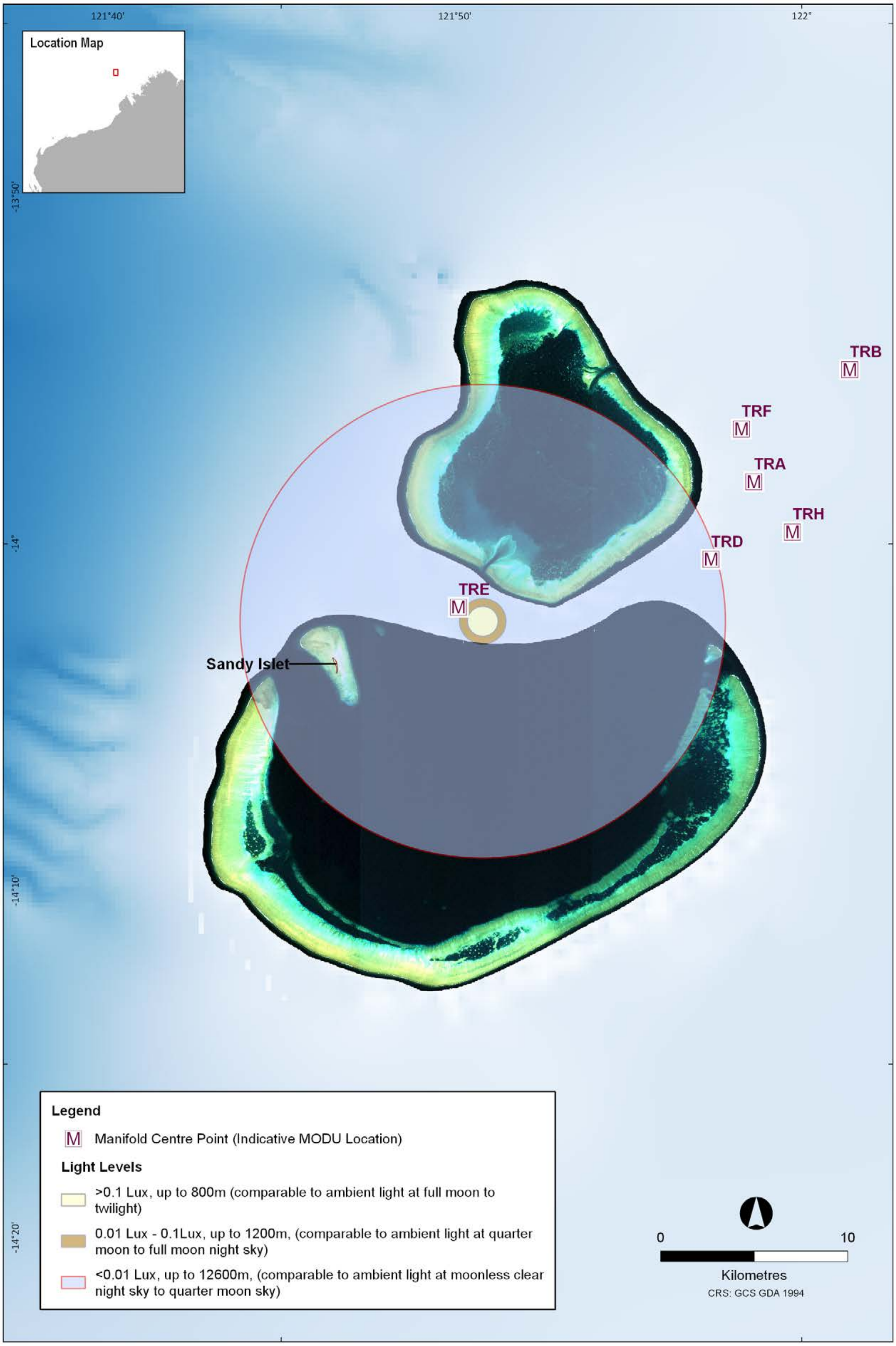

Figure 6-9 Modelled Lux Levels from a drill rig at the previously proposed TRE Drill Centre, Scott Reef (ERM, 2010)

6.3.3.4 Environmental Impact

Ambient light

Change in ambient light

The Project Area is a significant distance from coastal sources of light emissions, with no permanent sources of artificial light at the present time, except for the existing NRC facilities near the BTL tie in point. There are other existing facilities in the broader Browse Basin (i.e. Shell's Prelude FLNG and INPEX's Ichthys Development) which represent permanent light sources from their offshore facilities and supporting activities. General shipping traffic also influences the ambient light conditions within the region however, these light emissions are temporary and spatially variable.

The proposed Browse to NWS Project will contribute to localised light emissions and change the ambient light levels, particularly during drilling and completions, installation, commissioning and decommissioning when project vessel number and activity is highest, but also during operations primarily from the FPSO facilities at Torosa, Brecknock and Calliance fields. Based on the outcomes of the light emission prediction modelling, the change in ambient light will be localised around the FPSO facilities, MODU and project vessels with light levels expected to reach ambient levels comparable to a quarter moon to full moon night sky within 1200m (refer to **Figure 6-9** and **Table 6-19**) of the MODU and less than 7 km from the FPSO facilities (**Table 6-20**). Light emissions from the FPSO facilities, MODU and vessels associated with the proposed Browse to NWS Project are not expected to markedly impact ambient light.

Plankton

Change in fauna behaviour

Zooplankton often display diurnal vertical movements (Leach and Johnsen, 2003) within the ocean, migrating to surface waters at night to feed. Artificial light has, therefore the potential to reduce the amplitude of their migration if lighting levels are sufficiently high at night (Moore et al., 2000). Artificial light emissions can influence the migration of zooplankton from deep water to the surface, thereby affecting the food supply of nocturnal plankton-feeders. Alternatively, as most studies have demonstrated, the illumination of marine waters at night has the effect of increasing feeding opportunities for predators due to better visualisation of prey rather than resulting in potential plankton density reduction, however, these effects are expected to be highly localised and given the high turnover rate of plankton populations (ITOF, 2011) in open oceanic water there will be no lasting impact.

It is likely that plankton in the immediate vicinity of the FPSO facilities, MODU and project vessels that are within the light spill area (within hundreds of metres) will be impacted by light, based on the light emissions modelling. Given the highly localised effects of light emissions from the FPSO facilities, MODU and vessels associated with the proposed Browse to NWS Project, the proportion of the plankton population affected and the high turnover and recovery of plankton populations, no discernible impact on plankton communities at a population level is expected.

Benthic habitats - coral

Change in fauna behaviour

The nearest coral habitat to the proposed location of the FPSO facilities is at Scott Reef (~8 km from Torosa FPSO), where extensive shallow and deeper water coral habitat and communities are present. Coral colonies are particularly sensitive to changes in ambient environmental conditions, with natural factors (e.g. temperature, nocturnal moonlight cycles and daily light/dark cycles) providing cues for reproduction (i.e. spawning) (Harrison and Wallace, 1990)1990.

Broadcast spawning corals at Scott Reef undergo two short and distinct periods of mass spawning which occur in spring and autumn, with autumn being the dominant spawning period (Gilmour et al., 2010, 2009b, 2009a). The nights of coral spawning at Scott Reef typically occur following a full moon and during neap tides (Gilmour et al., 2013). Most coral species synchronise their spawning through detection of low light intensity (Aubrecht et al., 2008). Therefore, as corals are able to detect natural illumination at night (i.e. moonlight), increases in nocturnal illumination from artificial sources, particularly in shorter wavelengths (Gorbunov and Falkowski, 2002), may impact reproductive cycles or other natural processes (i.e. feeding).

As indicated by the light modelling, Scott Reef is expected to receive light emission levels of less than 0.1 and 0.01 Lux, respectively, from the FPSO facilities and the MODU operating in the channel between North Scott Reef and South Scott Reef. Such light levels are less than a full moon (**Table 6-20** and **Table 6-21**), therefore it is not considered that light emissions from the FPSO facilities, MODU and vessels associated with the proposed Browse to NWS Project will be of sufficient intensity to affect coral reproduction or spawning events.

Fauna

Change in fauna behaviour - seabirds and migratory shorebirds

Seabirds and migratory shorebirds at Scott Reef may be affected by light emissions associated with the proposed Browse to NWS Project, although the area does not represent a significant aggregation, nesting or roosting area. Anthropogenic disturbance is identified in the Wildlife Conservation Plan for Migratory Shorebirds as a threat to the conservation of migratory shorebirds (Commonwealth of Australia, 2015a).

The exact mechanism for navigation of migratory birds is not clear, however, it is widely thought that they use a mixture of natural cues, including the earth's magnetic field, solar and celestial orientation and polarised light patterns to determine their migratory pathway (Weindler and Liepa, 1999; Wiltschko and Wiltschko, 2001). Therefore, there is a risk that artificial light sources along migratory pathways may alter natural patterns, specifically in the absence of terrestrial landmarks (i.e. offshore).

Studies have demonstrated that light from offshore facilities has been shown to attract migrating birds, with species that migrate during the night more likely to be affected (Marquenie et al., 2008; Verheijen, 1985). Birds may either be attracted by the light source itself or indirectly as lighted structures in marine environments tend to attract marine life at all trophic levels, creating food sources and shelter for seabirds. In some cases, sources of artificial light may provide enhanced capability for seabirds to forage at night (Verheijen, 1985). Studies in the North Sea indicate that migratory birds may be attracted to lights on offshore platforms when travelling within a radius of 3 to 5 km from the light source. Outside this area their migratory paths are likely to be unaffected (Marquenie et al., 2008).

Additionally, artificial lighting may interfere with a bird's internal magnetic compass. It is thought that migratory birds require light from the blue-green part of the spectrum for magnetic compass orientation (Muheim et al., 2002; Wiltschko and Wiltschko, 2001, 1995) whereas red light, the long-wavelength component of light, is more likely to disrupt magnetic compass orientation.

Artificial light emissions from offshore facilities have the potential to impact seabirds through collisions with infrastructure due to visual disorientation, particularly during periods of low visibility (e.g. cloudy, overcast or foggy conditions) (Wiese et al., 2001). Newly fledged juvenile birds leaving breeding colonies for the first time are the most prone to disorientation by artificial light (Commonwealth of Australia, 2019). In addition, some studies have indicated the potential impact of artificial lighting on the diversion of migratory pathways of seabirds (Verheijen, 1985), particularly those dependent on visual cues.

Migratory birds that use the East Asian Australasian Flyway (EAAF) flight paths may include overlap over or near the proposed Browse to NWS Project infrastructure (**Figure 5-32**). However, light from the MODU and FPSO facilities are unlikely to attract a significant number of seabirds or shorebirds as activities are proposed to be located a considerable distance from known key aggregation areas, such as Ashmore Reef (230 km), Roebuck Bay (370 km) and Eighty Mile Beach (500 km). Seabirds and migratory shorebirds have been occasionally observed in very low numbers at Scott Reef and Sandy Islet may be used as a resting point during migrations. Given its small size, Sandy Islet does not support large numbers of visiting birds at any one time. Sandy Islet is recognised as part of a resting BIA that encompasses the whole of south Scott Reef and part of North Scott Reef for the little tern (*Sternula albifrons*).

Red light (the long-wavelength component of light) is more likely to disrupt the magnetic compass orientation of migratory birds. The expected spectral signature of light emissions from the MODU is 530 to 620 nm (based on measurements of the drill rig during drilling of the T-6 pilot appraisal well (ERM and SKM, 2008), with the red part of the spectrum outside of these ranges. Therefore, it is not expected that bird species magnetic compass orientation will be disrupted.

Given that a relatively small number of transiting birds are expected to pass in the vicinity of the Browse Development Area, behavioural effects such as disorientation and/or attraction are expected to be slight. Similarly, birds roosting at night on Sandy Islet are unlikely to be disturbed given the low level of artificial light (less than 0.01 Lux) that would be received at Sandy Islet from any permanent or temporary infrastructure within the Browse Development Area.

BIAs exist for the white-tailed topic bird (breeding BIA) and wedge-tailed shearwater (breeding and foraging BIA) along the proposed BTL route near Rowley Shoals, however, as noted above, temporary light associated with the installation of the BTL and occasional IMR activities are not considered to be a credible source of light intensity to induce discernible impacts and, as such, are not considered further.

Change in fauna behaviour – fish

The Browse Development Area hosts a rich diversity of fish species, including demersal (seabed dwelling), pelagic (open water) and site-attached (coral habitat) fish. The attraction of fish to artificial light is a well know phenomenon and is likely associated with the increased availability of plankton prey on the surface at night (due to vertical migration of zooplankton over a 24 hr period) and the increased prey detection abilities provided by the light (Marchesan et al., 2005). The response of fish to artificial light has been shown to differ depending on species and changes in behaviour due to increased light intensity acting as an attractant to fish species and potentially pose an increased risk of predation through changes to natural night time distribution (Marchesan et al., 2005; Nightingale and Simenstad, 2001). Credible light emissions from the FPSO facilities, MODU and vessels associated with the proposed Browse to NWS Project are expected to be restricted to localised fish attraction within the light spill area (several hundred metres).

The whale shark (*Rhincodon typus*) is the only migratory and threatened fish species that has the potential to occur within the Browse Development Area. Impacts from light emissions are not documented for this species, although this has been identified as an area for further research within the latest conservation advice for this species (Threatened Species Scientific Committee, 2015a). Given the low numbers and infrequent nature of whale shark presence in the Project Area, it is considered highly unlikely that adverse impacts will occur to the small number of individual whale sharks that may encounter elevated, localised light emissions around facilities, MODUs and vessels. Occasional and temporary behavioural changes such as opportunistic feeding utilising attractant aggregations of food sources (such as zooplankton) is known to occur around offshore facilities and may occur for the proposed Browse to NWS Project.

Change in fauna behaviour – marine turtles

Specific behavioural response to artificial light emissions by marine turtles relates to altered nocturnal behaviours (as described by Witherington and Martin (1996) and include:

- Disorientation: loss of orientation, being unable to maintain constant directional movement
- Misorientation: orientation in the wrong direction, for hatchling marine turtles on the beach, travel in any direction other than the general vicinity of the ocean.

There are many variables that influence the range and severity of potential impacts of light emissions on the behaviour of marine turtles including:

- Turtle vision
- Life stage (adult and hatchling).

Exposure of marine turtles to artificial light can result in changes to their natural behaviour, in particular with regards to nesting (Commonwealth of Australia, 2019). Sandy Islet (nesting habitat) and a 20 km internesting buffer of the surrounding waters are recognised as habitat critical to the survival of green turtles for the Scott Reef-Browse Island genetic stock in the Recovery Plan for Australian Marine Turtles 2017-2027 (Commonwealth of Australia, 2017a) (**Figure 5-29**). In addition, a BIA exists for internesting green and hawksbill turtles around Sandy Islet (Commonwealth of Australia, 2017a) . Green turtles predominately nest at Sandy Islet between November and February and internesting turtles have been observed to aggregate primarily in an area to the south west of Sandy Islet. Only one hawksbill turtle has been recorded nesting at Sandy Islet (**Section 5.3.2.5.2**).

The Recovery Plan for Marine Turtles in Australia (2017-2027) identifies light pollution as a moderate risk to the Scott Reef-Browse Island green turtle genetic stock and a high risk to the WA hawksbill turtle population. Actions in the recovery plan (Commonwealth of Australia, 2017a) relevant to the proposed Browse to NWS Project in relation to light emissions are:

- manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to the survival
- manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue
- artificial light within or adjacent to habitat critical to the survival of marine turtles will be managed such that marine turtles are not displaced from these habitats.

The National Light Pollution Guidelines for Wildlife Including Marine Turtles, Seabirds and Migratory Shorebirds (Commonwealth of Australia, 2019) further discuss impacts and management of artificial light in relation to marine turtles.

Female adult marine turtles spend most of their lives in open ocean environments, however, female turtles return to natal beaches to nest and lay eggs, predominantly at night. There is significant evidence that indicates artificial lighting on or near nesting beaches may disrupt adult female turtle nesting behaviour (Commonwealth of Australia, 2019; Salmon, 2005; Salmon et al., 1992). Artificial lighting may affect the location that turtles emerge on the beach, the success of nest construction, whether nesting is abandoned and even the seaward return of adults (Salmon, 2005 and Salmon et al., 1992). It was found that turtles deterred from typical nesting beaches due to artificial lighting re-emerged onto alternate beaches outside of their typical range at increasingly distant and inappropriate nesting locations (Witherington and Martin, 2000, 1996). The selection of suboptimal nesting habitat may contribute to a reduction in the success of egg deposition and hatchling production (Witherington and Martin, 2000). There is no indication whether, under natural conditions, the full moon affects rates of female adults landing on a beach to nest. Nor is there any information available in the published literature that suggests adult turtles are affected by light during foraging activity (Pendoley, 2000).

Hatchlings have a strong tendency to orient themselves to the brightest light source, which under natural conditions is the seaward horizon (in natural circumstances derived from the moon for most of the month) rather than the darker silhouetted landward horizon (Limpus, 2006). The light glow created by artificial lighting may, therefore, cause hatchlings to be attracted to this light source rather than to the water (Witherington and Martin, 2000, 1996). Hatchlings which are disoriented or mis-oriented by artificial lights often do not find the sea promptly, this may lead to predation or exhaustion. Once in the ocean, little is known of the extent to which hatchlings still use vision over wave direction and the earth's magnetic field for orientation

(Lohmann, 1992). Hatchlings swimming out to sea from the beach, however, may be attracted to light emissions from offshore structures or vessels, making them more susceptible to predation or vessel strike after they enter the water (Thums et al., 2016). Wilson et al. (2018) found that light emissions disrupted the dispersal of hatchlings and hatchlings become disoriented in nearshore environments.

The wavelength at which adult and hatchling turtles can sense light is important in determining their corresponding attraction and sensitivity to light emissions. Studies suggest that marine turtles are most sensitive to short-wavelength light in the near-ultraviolet to yellow region of the visible spectrum, from approximately 340 to 700 nm (Witherington and Martin, 2000). Studies on hatchling orientation, relative to spectrally controlled light sources, indicate that although the wavelength at which hatchlings can sense light varies between species, all turtle species are more sensitive to light in the blue and ultraviolet (UV) end of the spectrum. The most disruptive wavelengths to hatchlings are in the 300 to 500 nm range (Witherington, 1997). Light spill effects are not known to vary for different turtle species, however, green turtles are known to be attracted to light of lower wavelengths (<600 nm), with a preference for blue light (400 – 450 nm). The light intensity measurements and modelling predictions accounted for the full wavelength spectrum detected by marine turtles (340 to 700 nm) (ERM and SKM, 2008).

The actual light intensity measurements and modelled predicted light intensity for the main light sources associated with the proposed Browse to NWS Project on the green turtle population at Scott Reef is presented below and summarised in **Table 6-22**.

Based on the spectral signature of light emissions measured from the drill rig during drilling of the T-6 appraisal well detectable levels of artificial lighting associated with the proposed Browse to NWS Project is expected to be within the visible range for marine turtles. Peak wavelengths emitted from the drill rig ranged between 530 to 620 nm (**Figure 6-8**).

Based on lighting data from the drill rig, approximately 60% of the total light wavelength transmission is within the sensitive wavelength range for turtle hatchlings (300 to 500 nm) (ERM, 2010), with most common artificial light sources, such as fluorescent, generating light within these wavelengths (Witherington and Martin, 2000; Witherington, 1997). Given light intensity attenuated to 0.1 Lux at distances of 1.2 km from the studied drilling rig, the distance of the TRE drill centre location from Sandy Islet it is only in the nearfield light spill that adult breeding turtles may be impacted.

Based on the measured attenuation of light density and wavelengths from a drill rig at Scott Reef (ERM and SKM, 2008) and the predicted light levels modelled (ERM and SKM, 2008; Jacobs and SKM, 2014), light levels expected are below detection levels or so low (0.1 Lux) that no disturbance to nesting behaviour of adult female marine turtles is predicted at Sandy Islet. It should also be noted that drilling at TRE (the closet light source to Sandy Islet) is a temporary activity, with the MODU only likely to be in that location during the development drilling activities. Flaring from the MODU is not predicted to lead to impacts given its temporary nature (will only occur during well unloading activities and be of 1-2 days duration per well). The light emissions from the Torosa FPSO facility (a distance of 27 km from Sandy Islet) will not be detectable at Sandy Islet with light intensity detectable at extremely low levels <0.01 Lux.

There will be no continuous flaring from the FPSO facilities (with the exception of pilot gas and compressor seal gas). During normal operations, infrequent, non-routine flaring may be required during shut down and restart. Given the frequency and duration of such flaring and the distance of the closet FPSO facility to Sandy Islet (approximately 27 km and outside the habitat critical to survival for green turtles) no disturbance to hatchlings or nesting turtles from potential light emissions is expected.

Impact of light spill around MODU and FPSO facilities on marine turtles

Historical studies have reported that due to turtle hatchlings' vision being limited in water, other more dominant navigational cues take over (Amos, 2014; Lohmann and Lohmann, 1992) such as surface currents (Frick, 1976; Liew and Heng Chan, 1992; Okuyama et al., 2009; Salmon and Wyneken, 1987; Witherington, 1995). However, more recent studies (Limpus et al., 2003; Thums et al., 2016) have demonstrated that offshore lights have the ability to attract in-water dispersing hatchlings, causing them to linger around the light source at sea. Additionally, Whelan and Wyneken (2007) and Harewood and Horrocks (2008) reported that artificial lights onshore, can slow down hatchlings' in-water dispersal. Harewood and Horrocks (2008) also demonstrated in this study, that hatchling turtles released from dark beaches, were attracted by artificial lights from neighbouring beaches that were only visible after the hatchlings were a substantial distance from shore. Perhaps more importantly, this study reported that a number of the unsuccessful hatchlings (unsuccessful, meaning hatchlings which did not correctly orientate themselves in a seaward position from the beach) stayed within 10 m of shore and travelled parallel to the shoreline, orientating towards the lighted headlands. Harewood and Horrocks (2008) concluded that artificial lights may override the effects of wave cues in low wave energy environments.

Similarly, Truscott et al. (2017) reported that artificial light sources can attract hatchlings back to shore. More recently, Wilson et al. (2018) confirmed that in the presence of artificial light, surface currents had little effect on the bearing of hatchling swimming, with 88% of individuals' trajectories tracked, orientated towards the experimental artificial lighting. Additionally, this study showed that under ambient conditions, ocean currents affected the bearing of hatchlings as they left the shore; however, when light was present, this effect was diminished, showing that the turtles actively swam against currents in their attempts to move towards light. Hatchling behaviour onshore is not expected to be impacted given the distance of Sandy Islet to TRE and the islet's height above sea level (maximum on west side of 5 m). Hatchling emergence and sea entry were assessed for potential impact from MODU lighting. It was concluded that hatchlings being drawn to MODU lighting thereby increasing vulnerability to predation were considered unlikely, given the distance of Sandy Islet from all drill centre locations.

As surface currents within the Scott Reef channel are known to be strong (averaging approximately 0.5 knots with speeds up to and exceeding two knots), it is unlikely that hatchlings will have the ability to linger and come within the light spill area in the vicinity of a MODU operating in the channel as a result of the artificial light acting as an attractant.

Therefore, artificial lighting associated with the MODU and proposed facilities, may theoretically have the potential to override and disorientate natural hatchling cues, potentially attracting individuals towards the structure. However, the results from the line of sight assessment undertaken as part of the previously proposed FLNG Development concept (ERM, 2010; Jacobs and SKM, 2014), demonstrate that the maximum predicted direct light levels reaching Sandy Islet from a MODU at the TRE drill centre (approximately 7 km away, **Figure 6-5**) or the Torosa FPSO Facility (approximately 27 km away, **Figure 6-6**) are less than 0.1 and 0.01 Lux, respectively (**Figure 6-5** and **Figure 6-6**).

For context, the predicted light intensity at this level of light is comparable to the light level between a moonless clear night sky and a quarter moon. Therefore, this level of light is not expected to be of an intensity (and associated wavelength frequency) to alter hatchling behaviour (attraction or mis-orientation of hatchlings leaving nesting sites on Sandy Islet). In addition, spectral analysis of light emissions from a flare at Thevenard Island (Pendoley 2000) determined that this light source does not contain a high proportion of light wavelengths within the range that is most disruptive to turtle hatchlings (300 to 500 nm). Therefore, no adverse impacts to hatchlings from artificial light are anticipated, despite the fact that some studies have demonstrated the theoretical potential for misorientation to some individuals.

Adult turtles passing through the Project Area may temporarily alter their normal behaviour whilst attracted to the light spill from the offshore facilities. Light spill of at least 0.1 Lux (i.e. at least quarter moon light intensity levels) is likely to extend 1.2 km radially from the MODU and 15 km radially from FPSO facilities. While the light spill area overlaps with the internesting habitat for green turtles, it is not anticipated that large number of individuals will be present within this area given the preference to internest to the southwest of Sandy Islet and, therefore will not be subject to behavioural impacts.

In addition, given the wide migratory distribution of adult turtles outside of nesting season (i.e. several hundred kilometres) and their low-density presence within the Project Area, the zone of influence and subsequent attraction from direct lighting is expected to be relatively minor in comparison to their migratory area, resulting in only a temporary disruption to a small portion of the adult turtle population. In addition, due to the limited range of any lighting impacts, it is not deemed that the predicted lighting impacts will adversely affect habitat critical to the survival of green turtles and is, therefore not inconsistent with the recovery objectives outlined within the Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a).

Table 6-22 Summary of light intensity values at Sandy Islet and predicted impact significance to marine turtles

Source of Light Emissions	Light intensity – Sandy Islet	Potential impact to female adult nesting green turtles	Potential impact to green turtle hatchlings
Torosa FPSO	<0.01 Lux	Minor (D)	Minor (D)
TRE MODU	0.1 Lux	Minor (D)	Minor (D)

Injury of mortality to fauna – marine turtles

Attraction to the FPSO facilities and MODU may present a physical risk as a result of activities such as FPSO offloading and the facilities intakes and thrusters (i.e. DP). However, given the low number for turtles expected to be affected, the depth of the intakes and thrusters; and the fact that the turtles are expected to display avoidance behaviour from the noise generated by the thrusters this is considered highly unlikely to occur.

Assessment against EPBC Act recovery and conservation plans and advices

Table 6-23 provides an assessment of the light emissions for the proposed activities in relation to objective and actions of the relevant EPBC Act recovery and conservation plans and advices.

Table 6-23 Alignment with EPBC Act recovery and conservation plans and advices for protected fauna – light

Fauna	Relevant plan(s)/ conservation advice	Plan/advice objectives and actions	Assessment
Migratory shorebirds	Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a)	Anthropogenic threats to migratory shorebirds in Australia are minimised or, where possible, eliminated.	Potential impacts to migratory shorebirds are predicted to be limited to slight localised and temporary behavioural impacts to a small number of individuals. Therefore, it is considered that the proposed activities are not inconsistent with the Wildlife Conservation Plan for Migratory Shorebirds.
Whale shark (*Rhincodon typus*)	Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a)	Assess the impacts of offshore installations and associated environmental changes (light spill, chronic noise, changed water temperature, localised nutrient levels) on whale sharks and mitigation options for these impacts.	The potential impact of light emissions resulting from the proposed Browse to NWS Project have been assessed and mitigation measures proposed. Given the low numbers and infrequent nature of whale shark presence in the Project Area, there is a high level of confidence that light will not result in adverse impact to whale sharks.

Fauna	Relevant plan(s)/ conservation advice	Plan/advice objectives and actions	Assessment
Green turtle (Chelonia mydas) Hawksbill turtle (Eretmochelys imbricata)	The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a)	Management measures: + Manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to the survival. + Manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue. + In relation to the Scott Reef – Browse Island green turtle genetic stock, the priority action is to manage anthropogenic activities to ensure marine turtle are not displaced from identified habitat critical to their survival.	Light emissions are not predicted to impact nesting adult turtles or emerging hatchlings on Sandy Islet or internesting female adult turtles based on knowledge of their primary habitat utilisation. Light spill from the MODU and FPSO may result in behavioural impacts to adults and hatchlings in the unlikely circumstance that they are within the immediate light spill areas, however, this will only result in a temporary disruption to a small portion of the breeding population. There is a high level of confidence that light emissions will not result in displacement or disturbance of the Scott Reef – Browse Island green turtle genetic stock from identified habitat critical to their survival, or adversely affect the breeding cycle of marine turtles in the defined BIA at Scott Reef. Therefore, it is considered that the proposed activities are not inconsistent with the objectives of the Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a).

Australian Marine Parks

The proposed BTL route traverses the Multiple Use Zones (IV) of the Argo-Rowley Terrace and Kimberley Marine Parks. It should also be noted that the proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park National Park Zone. Rationale for the route selection of the BTL is provided in **Chapter 3**.

Change in fauna behaviour

Artificial light emissions will occur within the Argo-Rowley Marine Park, Kimberley Marine Park and the Mermaid Marine Park during installation of the proposed BTL and infrequent IMR activities. The values of the Argo-Rowley Marine Park that are potentially sensitive to light emissions are the BIAs for seabird resting and breeding habitat (Director of National Parks, 2018). The values potentially sensitive to light in the Kimberley Marine Park are turtles which use the marine park habitats for internesting and nesting and seabirds which use it for breeding and foraging (Director of National Parks, 2018). The Mermaid Marine Park boundary is approximately 2 km at its closest point from the proposed BTL route and contains the islands of the Rowley Shoals which support a wide range of seabird species, including WA's second largest breeding colony of red-tailed tropicbird (Department of Environment and Conservation, 2007). The Rowley Shoals have also been identified as BIAs for white-tailed tropicbirds and little terns; as well as being breeding grounds of red-tailed tropicbirds.

The North-West Marine Parks Network Management Plan recognises that the modification of natural light through the installation of lighting associated with infrastructure can cause changes in animal behaviour (Director of National Parks, 2018). Marine turtles are particularly sensitive to artificial light and the sources of onshore and offshore sources need to be managed to ensure that biologically important behaviour of nesting adults and dispersing hatchlings can continue (Commonwealth of Australia, 2017a).

Light emissions from vessels operating within the AMPs will be temporary and transient in nature (e.g. the slowest moving Project vessel will be the pipelay vessel, which will move at a rate of up to 5 km/day). Based on the predicted light levels, vessel lights are unlikely to disturb adult nesting and internesting turtles which are known to occur in the easterly portion of the Kimberley Marine Park. Similarly, for seabirds that occur in these AMPs, the temporary and short duration of artificial light associated with vessel activity for the installation of the BTL and occasional IMR activities is not considered to be a credible source of significant impact due to the highly localised light spill area and attenuation of emissions including spectral wavelengths away from the vessel light sources. Given this, it is considered that the identified conservation values of these AMPs will not be detrimentally impacted by artificial light associated with the proposed Browse to NWS Project.

Summary

Table 6-24 provides an assessment of the proposed seabed disturbance in consideration of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018).

Table 6-24 Alignment with the North-west Marine Parks Network Management Plan – physical presence: light

AMP	Relevant plan(s)	AMP Objectives	Assessment
Argo-Rowley Terrace Marine Park Multi Use Zone (VI) Kimberley Marine Park Multi Use Zone (VI)	North-west Marine Parks Network Management Plan (Director of National Parks, 2018)	The objective of the Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species.	The light emissions from vessels operating within these AMPs will be temporary and transient in nature as well as sufficient distance for attenuation of the light spill being unlikely to disturb marine turtles or seabirds in these AMPs. There is a high level of confidence that ambient light will not result in an adverse impact to marine ecosystems, habitats or native species such that the conservation values of the AMPs would be reduced. As such, it is considered that the proposed activities are not inconsistent with the requirements of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018).
Mermaid Reef Marine Park National Park Zone (II)		The objective of the National Park Zone (II) is to provide for the protection and conservation of ecosystems, habitats and native species in as natural a state as possible.	The proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park. As such, the temporary light associated with the installation of the BTL and occasional IMR activities will not be detected at light intensity levels to be considered a credible source of significant impact and no effect on ecosystems, habitats or native species in the AMP will occur. As such, it is considered that the proposed activities are not inconsistent with the requirements of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018).

State marine parks and nature reserves

Change in fauna behaviour

The Rowley Shoals Marine Park is located approximately 3 km from the BTL route at its closest point. Given this distance and that light emissions from vessels operating along the BTL route will be temporary and transient in nature (e.g. the slowest moving project vessel will be the pipelay vessel, which will move at a rate of up to 5 km/day); and light intensity within the marine park will be barely detectable (given the distance from the light source), no impacts to the conservation values of the State marine parks are predicted.

The Scott Reef Nature Reserve protects the physical and ecological features of Scott Reef, including important nesting habitat (designated as a BIA and Habitat Critical for Survival of a Species) for the green turtle Scott Reef-Browse Island genetic stock. As discussed above, the proposed activities are considered to be not inconsistent with the requirements of the Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) and, as such, no adverse impacts to the conservation values of the Scott Reef Nature Reserve are predicted.

Other protected places

Change in fauna behaviour

The Scott Reef and Surrounds Commonwealth Heritage Place is utilised by fauna including turtles, whales, dolphins and birds. Sandy Islet in particular is used by nesting green turtles (Chelonia mydas), roosting seabirds and migratory shorebirds. Light emissions from the infrastructure within the Project Area is unlikely to impact on fauna on Sandy Islet due to the low level of artificial light (less than 0.01 Lux) that would be received at Sandy Islet from any permanent or temporary infrastructure in the Browse Development Area. As such, it is considered that the conservation values of these protected places will not be detrimentally impacted by the artificial light generated from the infrastructure and project vessels within the Project Area. The same applies with respect to the potential for artificial light impacts on the Mermaid Reef - Rowley Shoals Commonwealth Heritage Place.

Other users

Changes to the functions, interests or activities of other users – State and Commonwealth managed fisheries

Where the functions, interests or activities of other users involve marine fauna (e.g. fisheries), any effect to fauna presence or abundance will indirectly impact on the functions, interests or activities of other users. Given that the impacts from light emissions to marine fauna including fish have been evaluated to be negligible, no significant subsequent impact to fisheries is expected.

Changes to the functions, interests or activities of other users – tourism and recreation, scientific studies

Scott Reef is used for tourism and recreation (primarily diving and fishing charters) and scientific studies at low levels. Given the light modelling predictions that light emissions from the FPSO, MODU and vessels reaching Scott Reef are not expected to be above natural sources of light, adverse impacts to tourism/recreation and scientific studies are not predicted.

6.3.3.5 Environmental Risk

There are no anticipated environmental risks in relation to light emissions associated with unplanned events or incidents.

6.3.3.6 Cumulative Impacts

At times (particularly during the construction phase), multiple light sources will occur from Project activities. The period where this will be most prominent will be during the drilling of the post RFSU wells where both a MODU and the FPSOs will be operating. Given the light emission from the Torosa FPSO facility will not be detectable at Sandy Islet, cumulative impacts to receptors at Sandy Islet as a result of the MODU and FPSO operating concurrently are not predicted. However, receptors such as marine turtles that may temporarily alter their normal behaviour as a result of attraction, may be exposed to light emissions from both the MODU and FPSO operating currently. However, given the distance from the post RFSU wells to the FPSO facility at Torosa, while a larger number of turtles may experience temporary behavioural impacts during these times, cumulative impacts are not expected to increase the magnitude of the individual impacts.

Light emissions associated with vessels (including for offloading) and helicopters are transient and relatively minor in nature, resulting in temporary and localised effects to sensitive receptors. These light emissions will be significantly less that the primary sources of light emissions (MODU and FPSO facilities).

As such, no significant cumulative impacts from multiple activities associated with the proposed Browse to NWS Project are expected to occur.

The main commercial shipping routes are approximately 50 to 100 km west of the Browse Development Area, intersecting the proposed BTL route at various locations depending on the port. Cumulative impacts from commercial shipping lights and proposed activity lights are not expected as shipping routes are too far from the Browse Development Area for cumulative lighting impacts to occur. In areas where commercial ships intersect the proposed BTL route it is highly unlikely that cumulative impacts will occur because commercial ships are not expected to stop (i.e. they will be continuously travelling) and the ships will need to avoid the 500 m petroleum safety zone around the pipelay vessel.

Other than normal shipping operations, the closest additional significant sources of light emissions within the Browse Basin are the current operating assets at the Prelude and Ichthys projects located over 120 km north-east of the proposed Torosa FPSO. As the distance between the nearest facility within the Project Area and the Prelude and Ichthys developments is over 120 km, no cumulative impacts are anticipated due to artificial light emissions from developments within the Browse Basin.

6.3.3.7 Impact Assessment Summary and Acceptability Assessment

A summary of the impact assessment and the adopted controls for physical presence: light is provided in Table 6-25. The final acceptability assessment is provided in Table 6-26.

Table 6-25 Impact assessment summary and adopted controls – light emissions

Receptor (sensitivity)	Potential Impacts	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
Ambient light (medium value (open water)).	Change in ambient light	**Objective 5:** To not result in a substantial change in ambient light or ambient noise which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	+ The design of the FPSO facilities will consider the Principles for Best Lighting Design. This includes the minimisation of light spill, selective use of long wavelength light sources and lighting in each operational area will be kept to the minimum required for safe passage when personnel are not required to be working in the area. + Navigation beacons and lighting will be designed in line with the safety requirements of the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) and the Navigation Act 2012 (Cth) + The FPSO facilities will be designed such that continuous flaring will be limited to pilot gas and compressor seal gas + Light monitoring will occur during drilling and completion of a well at TRE drill centre to verify modelling predictions.	Slight	Slight (E)
Plankton communities (medium value (open water))	Change in fauna behaviour	**Objective 7:** To not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution.		No lasting effect	Negligible (F)

Receptor (sensitivity)	Potential Impacts	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
Shallow water benthic communities and habitats (<75 m depth) (high value habitat)	Change in fauna behaviour	**Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry).		No impact predicted	
Seabirds and migratory shorebirds (high value species)	Change in fauna behaviour	**Objective 11:** To not have a substantial adverse effect on a population of seabirds or migratory shorebirds, or the spatial distribution of the population.		Slight	Minor (D)
Fish (high value species)	Change in fauna behaviour	**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species.		No lasting effect	Slight (E)
Marine turtles (high value species)	Change in fauna behaviour Fauna injury or mortality	**Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population		Slight	Minor (D)
AMPs (medium value (multiple use zones)	Change in fauna behaviour	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No lasting effect	Negligible (F)
State marine parks and nature reserves (high value)	Change in fauna behaviour	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No lasting effect	Slight (E)

Receptor (sensitivity)	Potential Impacts	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
Other protected places (high value).	Change in fauna behaviour	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No lasting effect	Slight (E)
State and Commonwealth managed fisheries (high value marine user)	Changes to the functions, interests or activities of other users	**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. Objective 21: To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No lasting effect	Slight (E)
Other users including tourism and recreation and scientific studies, (high value users)	Changes to the functions, interests or activities of other users	**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No lasting effect	Slight (E)

Table 6-26 Acceptability assessment – light emissions

Acceptability Assessment

Confidence in assessment

Woodside have a high level of certainty with respect to the assessment of the potential impacts associated with light emissions as:

- Light modelling studies based on light outputs from the Project infrastructure and vessels indicated that there would be minimal impact to sensitive receptors. Light level measurements taken during the T-6 pilot appraisal well drilling provide further confidence in the assessment.
- The proposed controls are standard controls widely employed in industry and proven to mitigate the potential impacts and risks effectively. This includes elements of the best practice lighting design principles within the National Light Pollution Guidelines for Wildlife including Marine Turtles, Seabirds and Migratory Shorebirds (Commonwealth of Australia, 2019).

The available green turtle data, 2002 to 2010, were determined to be adequate for the purposes of impact assessment and management planning purposes based on the lack of significantly altered regional cumulative impacts since collection (**Chapter 9**), ability to extrapolate population trends using existing literature, and conservative interpretation of available data where applied. The existing data will be updated by targeted monitoring programs to verify impact predictions at relevant times throughout the project life cycle.

Principles of ESD

With the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such, it is considered that the principles of ESD will be met.

Conclusion: Acceptable

Significant Impacts as defined by the MNES Significant Impact Guidelines

Listed threated species and ecological communities / listed migratory species

As described in **Table 6-25**, the potential impact from physical presence: light to listed threatened and migratory species has been assessed as Minor (D) for marine turtles, seabirds and migratory shorebirds, with no lasting effect predicted on fish.

Given this, with the application of the proposed controls it is predicted that the nominated environmental objectives for each of these fauna species will be achieved. As such, no significant impacts to the listed threated or migratory species (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted.

Commonwealth marine environment

As described in **Table 6-25**, the potential impact from physical presence: light to ambient light has been assessed as Slight (E). No lasting effect is predicted to other receptors within the Commonwealth marine environment (with the exception of threatened or migratory species discussed above).

Given this, with the application of the proposed controls it is predicted that the nominated environmental objectives for each potentially impacted receptor will be achieved. As such, no significant impacts to the Commonwealth marine environmental (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted.

National heritage places

No impacts to national heritage places are predicted within the Project Area.

Conclusion: Acceptable

Acceptability Assessment

WA EPA Environmental Objectives

An assessment of the impacts of physical presence: light against the WA EPA Objective is presented in the State Proposal ERD (Chapter 10, Appendix B).

Marine environmental quality

As described in Table 6-25, the potential impact from physical presence: light to plankton has been assessed as Negligible (F). Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for this receptor and the WA EPA environmental objective "*To maintain the quality of water, sediment and biota so that environmental values are protected*" will be achieved for the State Proposal.

Benthic communities and habitats

As described in Table 6-25, no impacts are predicted to corals associated with shallow water benthic communities and habitats (<75 m depth) of Scott Reef. Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for this receptor will be achieved and the WA EPA environmental objective "*to protect benthic communities and habitats so that biological diversity and ecological integrity are maintained*" will be achieved.

Marine fauna

As described in Table 6-25, the potential impact from physical presence: light to fauna has been assessed as Minor (D) for marine turtles, seabirds and migratory shorebirds, with no lasting effect predicted on fish.

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors and the WA EPA environmental objective "*to protect marine fauna so that biological diversity and ecological integrity are maintained*" will be achieved.

Conclusion: Acceptable

External context

Aspects of petroleum developments such as the potential for light emissions to impact on listed species has been raised as part of stakeholder consultations as part of previous development concepts. As described above, impacts from light emissions are not expected to result in impacts to listed species beyond temporary behavioural impacts.

Conclusion: Acceptable

Internal context

This impact assessment has been undertaken in accordance with Woodside's Risk Assessment Procedure and Environment Impact Assessment Guideline (Section 6.2). The proposed Browse to NWS Project will be executed in accordance with Woodside's Health, Safety and Environmental Management System.

Conclusion: Acceptable

Other requirements

EPBC Act recovery and conservation plans and advices

As detailed in Table 6-23, the proposed activities are considered to be not inconsistent with the actions and objectives of:

- Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a)
- Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a)
- The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a).

AMPs

As detailed in Table 6-24, the proposed activities are considered to be not inconsistent with the requirements of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018).

Conclusion: Acceptable

6.3.4 Physical Presence: Electromagnetic Emissions

6.3.4.1 Impact and Risk Overview

Table 6-27 presents an overview of the potential impacts and risks from electromagnetic emissions associated with the physical presence of proposed Browse to NWS Project Infrastructure.

Table 6-27 Physical Presence: electromagnetic emissions

Aspect	Physical presence: Electromagnetic emissions		
Description	EMF will be generated as a result of: + active heating of the subsea flowlines + the subsea power cables that distribute power generated at the FPSO to subsea infrastructure.		
Area	Project Area, Browse Development Area, State Proposal Area		
Project stage	Operations		
Environmental objectives	The environmental objectives in relation to electromagnetic emissions associated with the proposed Browse to NWS Project are Objectives 12, 13, 15 and 16. These objectives are detailed in **Table 6-7**.		
Policy and guidelines	The following policy and guidelines are relevant to the assessment of this aspect. In addition, a number of EPBC Act conservation advices for protected fauna have been considered (**Table 6-28**). + WA *Biodiversity Conservation Act 2016* (Wildlife Conservation (Specially Protected Fauna) Notice 2018) + WA Environment Protection Authority – Environmental Factor Guideline – Marine Fauna + Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) + Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015b).		

Receptors	The following receptors have been identified as potentially being impacted as a result of the proposed Browse to NWS Project (**Table 6-2**). A detailed description of each of these receptors is provided in **Chapter 5**.
	Ecological
	+ fauna
	  + marine mammals (high value species)
	  + fish (high value species)
	  + marine reptiles (high value species)		

Potential impacts	+ change in fauna behaviour		
Risks	+ There are no anticipated environmental risks in relation to this aspect associated with unplanned incidents or events.		
Summary of impact evaluation for governing impact	***Magnitude***	***Impact significance level***	***Confidence***
	No lasting effect	Slight (E)	High
Summary of risk evaluation for governing risk	***Consequence***	***Likelihood***	***Risk rating***
	n/a	n/a	n/a

6.3.4.2 Source of Aspect

Electromagnetic fields (EMF) originate from both natural and anthropogenic sources. Natural sources include the earth's magnetic field that is derived primarily from heat convection within the Earth's core (Woodruff et al., 2013) and sea currents travelling through the geomagnetic field (Fisher and Slater, 2010). Electric fields normally range 0.005–0.5 µV/cm in marine waters; however, naturally occurring electric fields as strong 500 µV/cm have been reported, particularly during storms and solar flares events (Walker, 2001). Magnetic fields are created by the flow of electrical current and are measured in microtesla (µT). The greater the current, the stronger the magnetic field. The strength of the magnetic field produced by the earth ranges from 31 µT at 0° latitude (on the equator) to 58 µT at 50° latitude. Magnetic fields penetrate most materials and therefore only attenuate via distance.

EMFs emitted from underwater power transmission cables consist of the electric field (E-field), an induced magnetic field (B-field), and induced electrical field (iE-field) created by movement of water or an organism through the magnetic field (Cada et al., 2011; Normandeau et al., 2011). An electric field will exist even when there is no current flowing, while a magnetic field is only produced once a device is switched on and current flows. However, an induced electric field (iE field) is produced whenever a magnetic field changes in time. Electric field strength is typically measured in micro volts per centimetre (µV/cm). The higher the voltage, the stronger the resultant electric field.

EMF will be generated within the Browse Development Area as a result of active heating of the subsea flowlines and power cables. The use of active heating technology in the design of the subsea system minimises the volume of Mono-ethylene Glycol (MEG) required to prevent hydrate formation. Active heating occurs using electricity and will be used in the infield flowlines and risers carrying the reservoir fluids from the subsea manifolds to the FPSOs. Active heating will prevent blockages in the flowlines which can occur when fluids cool causing hydrates and waxes to solidify. Active heating is not expected to be required continuously. While the flowlines are producing, active heating is not required, instead only being turned on for hydrate management when the flowline is not producing after a short period. Active heating remains on until the flowline recommences production and warms up. The other source of EMF will be the subsea power cables that distribute power generated at the FPSO to subsea infrastructure.

Estimates for the active heating power demand required per cable are approximately 2.2 MW with the corresponding supply voltage for such a system ranging from 1.9 kV to 6.8kV. These parameters, along with the pipe length and diameter, U-value of pipe (measure of the rate of heat loss through a material), strength of electrical current and conductance of seawater, determine the extent and range of EMFs from the source. Due to the proposed open current system and unshielded 'piggyback' power cable, electric fields will be present in the water surrounding the power cable. Typically, 50% of the current returns via the pipe and 50% via the seawater (Woodside, 2011).

The predicted electromagnetic field strength from a DEH system when activated was modelled as part of the environmental approvals for a previous Browse development concept (Woodside, 2011). The results of the study demonstrated the rapid dissipation of both electric and magnetic fields from the source (Table 6-28). Within 0.5 m, the magnetic field decreases from 506 µT to 41 µT, further dissipating to below the earth's magnetic field strength within 1 m (Woodside, 2011). The electric field is also predicted to dissipate with distance, albeit more gradually than the magnetic field (Table 6-28). The results demonstrated that within 10 m the electric field dissipates to less than half (489 µV/cm) of the source.

Table 6-28 Predicted electromagnetic field strengths at distance from pipeline (Source: Woodside, 2011)

Electromagnetic Field	Distance from Source (m)	Strength
Electric	0	1100 µV/cm
	0.5	1080 µV/cm
	1	1010 µV/cm
	5	701 µV/cm
	10	489 µV/cm
	75	46 µV/cm
Magnetic	0	506 µT
	0.5	41 µT
	1	23 µT
	5	16 µT
	10	9 µT
	75	0.07 µT

6.3.4.3 Environmental Impact

Fish

Change in fauna behaviour

It is well established that many organisms including elasmobranchs and some bony fish, can detect both natural and anthropogenic EMFs, which many species use for directional movement, foraging and migration. However, the mechanism or mechanisms by which animals can exploit these fields is not fully understood. Some species may sense magnetic fields directly through biogenic magnetite crystals that reorient as the animal moves to maintain alignment with geomagnetic field lines (e.g., (Kirschvink et al., 2001)). Alternatively, the movement of seawater through magnetic fields (e.g. via current or tidal flow) induces localized electric fields that, although small (0.05-0.5 uV/cm), may be detectable by certain species (Kalmijn, 1982).

A wide range of studies have quantified the effects of EMFs on the behaviour and physiology of fish species (Gill et al., 2005; Normandeau et al., 2011; Walker, 2001). EMF produced from anthropogenic sources within the range of detection by electroreceptors have the potential to impact these species through alteration of their behaviour (attraction or repulsion) or disorientation, leading to interference in migration and movement patterns (Gill et al., 2005; Gill and Taylor, 2005). As electric fields diminish in strength with increasing distance from the source, elasmobranchs are likely to be initially attracted to the electric field, but as the individual approaches and the electric field strength increases there will be a point where the animal will turn and swim away. Gill and Taylor (2005) observed the repulsion of elasmobranchs from electric fields >10 μV/cm (Gill and Taylor, 2005). Therefore, when considering the result of the modelling presented above (Table 6-28), it is likely that fish may be repulsed by the electric field from the DEH system within a least 75 m of the source. However, such impacts are predicted to be behavioural only with no physical impacts likely as a result of the likely avoidance of the source (Walker, 2001).

Marine turtles

Change in fauna behaviour

Marine turtles are able to detect magnetic fields rather than electric fields; however, they do not appear to be as sensitive to magnetic fields as elasmobranchs (Courtillotl et al., 1997; Normandeau et al., 2011; Walker, 2001) and furthermore the potential for behavioural disturbance or displacement is considered low as they are unlikely to be in proximity to the sources of EMF given the depth of water (>400 m) that the subsea infrastructure will be installed in.

Marine mammals

Change in fauna behaviour

Marine mammals have been observed to be affected to varying degrees by magnetic fields but not electric fields (Fisher and Slater, 2010). Whales and dolphins appear to rely on geomagnetic contours for navigation, and magnetic fields generated by cables may result in disorientation and disruption to navigation and therefore negatively affect migratory behaviour (Meißner et al., 2006). However, the magnetic field strength emitted from the active heating of the flowlines will be indistinguishable from the earth's field beyond 1 m from the source (Table 6-28). In addition, given the depth of water (>400 m) that the majority of the EMF will be in, the significance level is predicted to be slight as it is not anticipated that marine mammals will be in close enough proximity to the source to elicit any lasting effects.

Summary

In summary, EMF can be detected at various levels of sensitivity by a number of marine fauna, with some behaviour responses evident from studies outlined above. However, EMF associated with DEH of the flowlines and risers are predicted to attenuate rapidly from the source, with the magnetic field predicted to be below the earth's natural geomagnetic level within 1 m and the electric field predicted to dissipate to 46 μV/cm within 75 m (Table 6-28). Given the depth of water (>400 m) that the majority of the EMF will be in and the predicted attenuation distances of the electric and magnetic fields, impacts on marine fauna are not predicted to be significant. If marine fauna are temporarily within the area of influence of EMF, effects are expected to be limited to short-term behavioural impacts.

Assessment against EPBC Act recovery and conservation plans and advices

Table 6-29 provides an assessment of the electromagnetic emissions from the proposed activities in relation to objective and actions of the relevant EPBC Act recovery and conservation plans and advices.

6.3.4.4 Environmental Risk

There are no anticipated environmental risks in relation to electromagnetic emissions associated with unplanned events or incidents.

6.3.4.5 Cumulative Impacts

Given the geographic spread of the project subsea infrastructure as well as subsea infrastructure from other developments within the Browse Basin, cumulative impacts resulting from electromagnetic emission from the proposed Browse to NWS Project are not expected to occur.

Table 6-29 Alignment with EPBC Act recovery and conservation plans and advices for protected fauna: Electromagnetic emissions

Fauna	Relevant plan(s)/ conservation advice	Plan/advice objectives and actions	Assessment
Whale shark	Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a)	Assess the impacts of offshore installations and associated environmental changes (light spill, chronic noise, changed water temperature, localised nutrient levels) on whale sharks and mitigation options for these impacts	The potential impact of electromagnetic emissions resulting from the proposed Browse to NWS Project have been assessed and given the low numbers and infrequent nature of whale shark presence in the Project Area, there is a high level of confidence that electromagnetic emissions will not result in adverse impact to whale sharks.
Green turtle	The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a)	Management actions: + Manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to the survival. + Manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue. + In relation to the Scott Reef – Browse Island green turtle genetic stock, the priority action is to manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to their survival.	Behavioural disturbance or displacement is not predicted given the predicted attenuation distances of the electric and magnetic fields and the depth of water (>400 m) that the majority of the subsea infrastructure will be installed in. Therefore, there is a high level of confidence that electromagnetic emissions will not result in displacement of the Scott Reef – Browse Island green turtle genetic stock from identified habitat critical to their survival, or adversely affect the breeding cycle of marine turtles in the defined BIA at Scott Reef. Therefore, it is considered that the proposed activities are not inconsistent with the objectives of the Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a).
Hawksbill turtle			
Pygmy Blue Whale	Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c)	Electromagnetic emissions have not been identified as a threat to pygmy blue whales.	Given the predicted attenuation distances of the electric and magnetic fields and the depth of water (>400 m) that the majority of the subsea infrastructure will be installed in, no lasting effect to cetaceans is predicted as it is not anticipated that marine mammals will be in close enough proximity to the source to elicit any impacts. Therefore, it is considered that the proposed activities are not inconsistent with the Conservation Management Plan for the Blue Whale or the conservation advices listed.
Humpback Whale	Conservation advice *Megaptera novaeangliae*, Humpback Whale	Electromagnetic emissions have not been identified as a threat to these whale species.	
Sei Whale	Conservation advice *Balaenoptera borealis*, Sei Whale		
Fin Whale	Conservation advice *Balaenoptera physalus*, Fin Whale		

6.3.4.6 Impact Assessment Summary and Acceptability Assessment

A summary of the impact assessment for the physical presence: electromagnetic emissions is provided in Table 6-30. The final acceptability assessment is provided in Table 6-31.

Table 6-30 Impact assessment summary and adopted controls – electromagnetic emissions

Receptor (sensitivity)	Potential Impacts	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
Fish (high value species)	Change in fauna behaviour	**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population. **Objective 15:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population.	As the impact from EMFs will be within a localised area (<70 m) and not impact on MNES, management measures, other than normal practices such as shielding of the subsea power cables, are not proposed.	No lasting effect	Slight (E)
Marine turtles (high value species)	Change in fauna behaviour			No lasting effect	Slight (E)
Marine mammals (high value species)	Change in fauna behaviour			No lasting effect	Slight (E)

Table 6-31 Acceptability assessment – electromagnetic emissions

Acceptability Assessment
Confidence in assessment Woodside have a high level of certainty with respect to the assessment of the potential impacts associated with electromagnetic emissions as: + modelling studies (Woodside 2011) have indicated that there will be minimal impact to the surrounding environment as a result of EMF, with the emissions field strength decreasing rapidly with increasing distance from the source.
Principles of ESD Given the predicted lack of significant impacts, the nominated environmental objective for each potentially impacted receptor will be achieved. As such it is considered that the principles of ESD will be met. **Conclusion: Acceptable**
Significant Impacts as defined by the MNES Significant Impact Guidelines Listed threated species and ecological communities / listed migratory species As described in **Table 6-30**, no lasting effect is predicted to occur from physical presence: electromagnetic emissions to listed threatened and migratory species with the impact significance level determined to be Slight (E). Given this, with the application of the proposed controls it is predicted that the nominated environmental objectives for each of these fauna species will be achieved. As such, no significant impacts to the listed threated or migratory species (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted **Conclusion: Acceptable**
WA EPA Environmental Objectives An assessment of the impacts of electromagnetic emissions against the WA EPA Objective is presented in the State Proposal ERD (**Chapter 10, Appendix B**). *Marine fauna* As described in **Table 6-30**, no lasting effect is predicted to occur from physical presence: electromagnetic emissions to listed threatened and migratory species with the impact significance level determined to be Slight (E). Given this, with the application of the proposed controls it is predicted that the nominated environmental objectives for each of these fauna species will be achieved. As such the WA EPA Environmental Objective "*to protect marine fauna so that biological diversity and ecological integrity are maintained*" will be achieved. **Conclusion: Acceptable**
External context To date there have been no specific matters raised by stakeholders, regarding electromagnetic emissions in relation to the proposed Browse to NWS Project. **Conclusion: Acceptable**
Internal context This impact assessment has been undertaken in accordance with Woodside's Risk Assessment Procedure and Environment Impact Assessment Guideline (**Section 6.2**). The proposed Browse to NWS Project will be executed in accordance with Woodside's Health, Safety and Environmental Management System. **Conclusion: Acceptable**

Acceptability Assessment
Other requirements EPBC Act recovery and conservation plans and advices As detailed in Table 6-29 the proposed activities are considered to be not inconsistent with the actions and objectives of: + Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a) + The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a). + Conservation management plan for the Blue Whale (Commonwealth of Australia, 2015c) + Conservation advice *Megaptera novaeangliae*, Humpback Whale (Threatened Species Scientific Committee, 2015b) + Conservation advice *Balaenoptera borealis*, Sei Whale (Threatened Species Scientific Committee, 2015c) + Conservation advice *Balaenoptera physalus*, Fin Whale (Threatened Species Scientific Committee, 2015d). **Conclusion: Acceptable**

6.3.5 Atmospheric Emissions: Offshore Activities

6.3.5.1 Impact and Risk Overview

This section details the impact assessment of atmospheric emissions from the offshore activities on air quality and sensitive receptors. It does not address the emission of GHGs, which is addressed in Chapter 7. It also does not address atmospheric emissions from third party processing of the Browse gas which is addressed in Section 6.3.6.

Table 6-32 presents an overview of the potential impacts and risks from atmospheric emissions: associated with the offshore activities of the proposed Browse to NWS Project.

Table 6-32 Atmospheric emissions: offshore activities

Aspect	Atmospheric emissions: offshore activities
Description	Atmospheric emissions will occur throughout all phases of the proposed Browse to NWS Project. During drilling and completion, installation and commissioning, the main contributor to atmospheric emissions will be power generation on the: + vessels + FPSO facilities + MODU. The main fuel source for power generation during these phases will be diesel. During routine operations, the main contributor to atmospheric emissions will be associated with the: + AGRU vents + fuel gas in gas turbines used for providing power to the facilities and the export gas compressors on the FPSOs.
Area	Project Area, Browse Development Area, State Proposal Area
Project stage	All - drilling and completions, installation, commissioning, operations and decommissioning
Environmental objectives	The environmental objectives in relation to atmospheric emissions associated with the proposed Browse to NWS Project are Objectives 4, 11, 12 and 13. These objectives are detailed in Table 6-7.

<table>
<tr><th>Aspect</th><th colspan="3">Atmospheric emissions: offshore activities</th></tr>
<tr><td>Policy and guidelines</td><td colspan="3">The following policy and guidelines are relevant to the assessment of this aspect. In addition, EPBC Act conservation advice has been considered (Table 6-33).
+ MARPOL 73/78 Annex VI (Prevention of Air Pollution from Ships) requirements as defined in the Marine Order 97 (Marine Pollution Prevention, Air Pollution) (pursuant to the Commonwealth Navigation (Consequential Amendments) Act 2012)
+ WA EPA Environmental Factor Guideline - Air Quality
+ Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a).</td></tr>
<tr><td>Receptors</td><td colspan="3">The following receptors have been identified as potentially being impacted as a result of the proposed Browse to NWS Project (Table 6-2). A detailed description of each of these receptors is provided in Chapter 5.
<i>Physical</i>
+ air quality (medium value (open water))
<i>Ecological</i>
+ fauna - seabirds and migratory shorebirds (high value species)</td></tr>
<tr><td>Potential impacts</td><td colspan="3">+ change in air quality
+ injury or mortality to fauna</td></tr>
<tr><td>Risks</td><td colspan="3">There are no anticipated environmental risks in relation to this aspect associated with unplanned incidents or events.</td></tr>
<tr><td rowspan="2">Summary of impact evaluation for governing impact</td><td><i>Magnitude</i></td><td><i>Impact significance level</i></td><td><i>Confidence</i></td></tr>
<tr><td>Slight</td><td>Slight (E)</td><td>High</td></tr>
<tr><td rowspan="2">Summary of risk evaluation for governing risk</td><td><i>Consequence</i></td><td><i>Likelihood</i></td><td><i>Risk rating</i></td></tr>
<tr><td>n/a</td><td>n/a</td><td>n/a</td></tr>
</table>

6.3.5.2 Source of aspect

Atmospheric emissions refer to the discharges to the atmosphere of gases and particulates from an activity or from a facility (e.g. MODU, project vessel, FPSO facilities) which have a recognised adverse effect on human health and/or an environmental receptor. The main emissions responsible for these effects include carbon monoxide (CO), oxides of nitrogen (NOx), sulphur dioxide (SO_2), particulate matter less than 10 microns (PM10), mercury and non-methane volatile organic compounds (VOCs), such as BTEX (benzene, toluene, ethylbenzene and xylenes). Atmospheric emissions will occur throughout all phases of the proposed Browse to NWS Project.

Sources of atmospheric emissions include:

- Power generation on the project vessels and MODU. The fuel source for power generation on project vessels and MODU will be diesel.
- Power generation associated with the combustion of fuel gas in gas turbines used for providing power to the facilities and the export gas compressors on the FPSOs (as well as power general using diesel during installation and commissioning).
- Flaring - while there is no continuous flaring planned from the FPSO facilities (other than pilot gas and compressor seal gas), intermittent non-routine flaring will occur from the FPSO and the MODU during well unloading activities, resulting in atmospheric emissions.
- Venting - reservoir CO2 that is separated from the natural gas and directed to atmosphere by a vent line. While the vent location has not been finalised, it is most likely to be located on the turbine exhaust stack. GHG emissions are addressed in Chapter 7.

SOx and particulate matter emissions are heavily influenced by the fuel used and its relative sulphur content, Marine Gas Oil (MGO) having a lower sulphite content than marine diesel oil (MDO) or heavy fuel oil (HFO).

NOx and SOx

Nitrogen oxides (NOx) emissions will be produced from gas turbines and flaring operations. The generation of sulphur dioxide (SOx) emissions results from the combustion of diesel and from conversion of small amounts of hydrogen sulphide (H_2S) from the fuel gas.

NO_2 emissions from routine MODU and production platform power generation for an offshore project were modelled previously by another operator (BP, 2013). NO_2 was the focus of the modelling, on account of the larger predicted emission volumes compared to the other pollutants, and the potential for NO_2 to impact on human health (as a proxy for environmental receptors). The model demonstrated that atmospheric emissions generated by MODU operations may increase ambient NO_2 concentrations by 1 µg/m^3 (0.001 ppm) within 10 km of the source and 0.1 µg/m^3 (0.0001 ppm) within 40 km of the source. While NO2 emissions from the proposed Browse to NWS Project are likely to be higher (due to the use of two FPSO facilities) the study shows that air quality will remain well below the World Health Organisation air quality guideline for NO2 of 40 µg/m^3 annual mean. As NO_2 is the main emission that poses a threat to receptor health, it is considered conservative to use the above studies to justify potential impacts to receptors. As such, studies into the attenuation of other gasses emitted are not evaluated.

Mercury

Emissions from diesel generators may include small amounts of elemental mercury. It should be noted that a gas-phase mercury removal unit has been incorporated in the design, upstream of the AGRU. The positioning of the removal unit in the design ensures no atmospheric emissions of mercury in either AGRU vent or gas turbines above trace quantities during steady state operations.

Although elemental mercury occurs as a liquid, it is highly insoluble in marine waters. Elemental mercury readily volatises and escapes from the ocean as a gas into the atmosphere. This form of mercury has a long residency time in the atmosphere (approximately one year) which means it can be widely distributed through the atmosphere. During this time, elemental mercury slowly oxidises to inorganic mercury. It is this inorganic mercury that settles out or is washed out in precipitation (e.g. in rain) back to the Earth's surface. Most (approximately 90%) mercury inputs into the world oceans, including areas remote from human activities, are in the form of inorganic mercury from the atmosphere (J. M. Neff, 2002). In the oceans, a complex set of chemical and biologically-mediated transformations convert inorganic mercury back into elemental mercury, such that much of the mercury deposited into the ocean is cycled back into the atmosphere to begin the cycle again (J. M. Neff, 2002). Therefore, impacts from the release of elemental mercury associated with the development are expected to have no significant effects on the environment as a whole.

VOCs including BTEX

A proportion of methane and VOCs, including BTEX, are entrained within the AGRU vent stream, however during steady state operations these entrained hydrocarbons will be incinerated by thermal oxidisers (or equivalent) and converted to CO_2. In the event that thermal oxidisers are not available, for example due to temporary failure or maintenance, the methane and volatile organic compounds are vented to atmosphere unincinerated.

Small quantities of BTEX released as part of the AGRU vent stream (when the thermal oxidiser is not available (i.e. due to temporary failure or maintenance) will predominantly end up in the atmosphere although a portion may return to earth after reacting with other air pollutants. Low levels of BTEX are unlikely to damage the environment, bio-accumulation is considered unlikely to occur and does not pose a risk to people on the FPSOs or nearby vessels due to the vent location and rapid dispersion in the atmosphere. As such no significant impacts are expected to occur as a result of the release of BTEX to the atmosphere (Scottish EPA, 2019).

6.3.5.3 Environmental Impact

Ambient air quality

Change in air quality

Atmospheric emissions from the proposed Browse to NWS Project have the potential to result in a localised reduction in air quality in the immediate vicinity of the release point. While a slight reduction in air quality on a local scale will occur for the duration of the activities, given the low emissions levels, very low background levels of pollutants and distance from the emissions sources to the nearest environmental sensitive receptors, it is not anticipated that emissions from the proposed Browse to NWS Project will result in lasting effect on air quality locally or regionally.

Fauna - seabirds and migratory shorebirds

Injury or mortality to fauna

Atmospheric emissions can cause direct impacts to fauna such as seabirds and migratory shorebirds, if they are present in the immediate vicinity of significant releases. Anthropogenic disturbance is identified in the Wildlife Conservation Plan for Migratory Shorebirds as a threat to the conservation of migratory shorebirds (Commonwealth of Australia, 2015a).

The nearest roosting site for seabirds and migratory shorebird is Scott Reef (>8 km away from the Torosa FPSO) so large numbers of seabirds or migratory shorebirds are not expected to occur in close proximity to the FPSO facilities. Likewise, while the proposed BTL route intersects a number of BIAs for seabirds, atmospheric emissions from the pipelay vessel and IMR vessels will be temporary and highly localised.

Given that atmospheric emissions will be typical of other operating facilities and equipment, and that seabird and migratory shorebird numbers will be low at the point of discharge, no lasting impact to seabirds and migratory shorebirds as a result of atmospheric emissions is expected.

Table 6-33 provides an assessment of the light emissions for the proposed activities in relation to objective and actions of the relevant EPBC Act recovery and conservation plans and advices.

6.3.5.4 Environmental Risk

It is not considered that the unplanned release of atmospheric emission resulting in significant impacts to the sensitive receptors is a credible scenario. As such it is not considered that an environmental risk in relation to this aspect associated with the proposed Browse to NWS Project exists.

6.3.5.5 Cumulative Impacts

Given the geographic spread of the project vessels and facilities, cumulative impacts resulting from atmospheric emission from the proposed Browse to NWS Project are not expected to occur.

6.3.5.6 Impact and Risk Assessment Summary and Acceptability Assessment

A summary of the impact assessment and the adopted controls for the discharge of atmospheric emissions is provided in Table 6-34. The final acceptability assessment is provided in Table 6-35.

Table 6-33 Alignment with EPBC Act recovery and conservation plans and advices for protected fauna – offshore atmospheric emissions

Fauna	Relevant plan(s)/ conservation advice	Plan/advice objectives and actions	Assessment
Migratory shorebirds	Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a)	Anthropogenic threats to migratory shorebirds in Australia are minimised or, where possible, eliminated.	No lasting impacts to migratory shorebirds are predicted as a result of offshore atmospheric emissions related to the proposed Browse to NWS Project. Therefore, it is considered that the proposed activities are not inconsistent with the Wildlife Conservation Plan for Migratory Shorebirds.

Table 6-34 Impact assessment summary and adopted controls – offshore atmospheric emissions

Receptor (sensitivity)	Impact	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
Air quality (medium value (open water))	Localised reduction in air quality	**Objective 4:** To not result in a substantial change in air quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	***Operations*** + Entrained hydrocarbons will be incinerated in the acid gas vent stream (when available) via a thermal oxidizer, with routing to a safe location for dispersion as a contingency when thermal oxidizers are offline. + A gas-phase mercury removal unit upstream of the AGRU will be used to ensure no atmospheric emissions of mercury in either AGRU vent or gas turbines above trace quantities during steady state operations. + Use of a vapour recovery system on the cargo tanks to minimize VOCs vented to atmosphere from the tanks. ***Project vessel, MODU and FPSO operations*** + Fuel usage will be recorded for FPSO facilities, MODU and vessels associated with the proposed Browse to NWS Project and emissions will be derived from fuel usage. + Project vessels will not use heavy fuel oil or intermediate fuel oil. ***Project vessel operations*** + Vessels will comply with MARPOL 73/78 Annex VI (Prevention of Air Pollution from Ships), where required, as defined in the Marine Order 97 (Marine Pollution Prevention, Air Pollution) (pursuant to the Commonwealth Navigation Act 2012). This includes requirements for use of low sulphur fuel.	Slight	Slight (E)
Seabirds and migratory shorebirds (high value species)	Injury or mortality to marine fauna	**Objective 11:** To not have a substantial adverse effect on a population of seabirds or migratory shorebirds, or the spatial distribution of the population. **Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species.		No lasting effect	Slight (E)

Table 6-35 Acceptability assessment – offshore atmospheric emissions

Acceptability Assessment
Confidence in assessment Woodside have a high level of certainty with respect to the assessment of the offshore atmospheric discharges as: + there is a good understanding of the current air quality in the Project Area. + there is a good understanding of the expected atmospheric emissions from the proposed Browse to NWS Project. + the proposed controls are standard controls widely employed in industry and proven to mitigate the potential impacts and risks effectively.
Principles of ESD With the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such it is considered that the principles of ESD will be met. **Conclusion: Acceptable**
Significant Impacts as defined by the MNES Significant Impact Guidelines Listed threated species and ecological communities / listed migratory species As described in **Table 6-34**, no lasting effect to seabirds or migratory shorebirds is predicted to occur as a result of offshore atmospheric emissions. Given this, with the application of the proposed controls it is predicted that the nominated environmental objectives for seabirds and migratory shorebirds will be achieved. As such, no significant impacts to the listed threated or migratory species (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted. *Commonwealth marine environment* As described in **Table 6-34**, the potential impact from offshore atmospheric emissions to air quality has been assessed as Slight (E). No lasting effect is predicted to other receptors within the Commonwealth marine environment (including threatened or migratory species discussed above). Given this, with the application of the proposed controls it is predicted that the nominated environmental objectives for each potentially impacted receptor will be achieved. As such, no significant impacts to the Commonwealth marine environmental (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted. *National heritage places* No impacts to national heritage places in the Project Area are predicted as a result of offshore atmospheric emissions. **Conclusion: Acceptable**
WA EPA Environmental Objectives An assessment of the impacts of offshore atmospheric emissions against the WA EPA Objectives is presented in the State Proposal ERD (**Chapter 10, Appendix B**). *Marine fauna* As described in **Table 6-34**, no lasting effect to seabirds or migratory shorebirds is predicted to occur as a result of offshore atmospheric emissions. Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*to protect marine fauna so that biological diversity and ecological integrity are maintained*" will be achieved. *Air Quality* Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for air quality, and the WA EPA environmental objective "*To maintain air quality and minimise emissions so that environmental values are protected*" will be achieved. **Conclusion: Acceptable**

Acceptability Assessment
External context To date there have been no specific matters raised by stakeholders, regarding the offshore discharge of atmospheric emissions in relation to the proposed Browse to NWS Project. **Conclusion: Acceptable**
Internal context This impact assessment has been undertaken in accordance with Woodside's Risk Assessment Procedure and Environment Impact Assessment Guideline (**Section 6.2**). The proposed Browse to NWS Project will be executed in accordance with Woodside's Health, Safety and Environmental Management System. **Conclusion: Acceptable**
Other requirements As detailed in **Table 6-33**, the proposed activities are considered to be not inconsistent with the actions and objectives of the Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a) **Conclusion: Acceptable**

6.3.6 Atmospheric Emissions: Third Party Processing of Browse Gas

The assessment of any potential impacts on the national heritage values of the listed National Heritage Place on the Dampier Archipelago that may be associated with the onshore processing of the Browse gas by the NWS JV, is addressed within the ERD associated with the North West Shelf Project Extension Proposal (EPA 2186, EPBC 2018/8335).

6.3.7 Atmospheric Noise

6.3.7.1 Impact and Risk Overview

Table 6-34 presents an overview of the potential impacts and risks from atmospheric noise associated with the proposed Browse to NWS Project.

Table 6-34 Atmospheric noise impact and risk overview

Aspect	Atmospheric noise
Description	Atmospheric noise emissions will occur during all phases of the proposed Browse to NWS Project. Noise emission sources included: + helicopters between the offshore facilities and the mainland + project vessel, MODU and FPSO facilities operations + flaring from the MODU during well unloading + Intermittent flaring from the FPSO facilities + piling.
Area	Project Area, Browse Development Area, State Proposal Area
Project stage	All - drilling and completions, installation, commissioning, operations and decommissioning.
Environmental objectives	The environmental objectives in relation to atmospheric noise associated with the proposed Browse to NWS Project are Objectives 5, 6, 11, 12, 13, 14, 15, 16, 18, 21 and 23. These objectives are detailed in **Table 6-7**.

Aspect	Atmospheric noise		
Policy and guidelines	The following policy and guidelines are relevant to the assessment of this aspect. In addition, a number of EPBC Act conservation advices for protected fauna have been considered (**Table 6-36**). + Commonwealth Airspace Act 2007 + Commonwealth Air Navigation (Aircraft Noise) Regulations 2018 + International Civil Aviation Organization's (ICAO) document Annex 16, Environmental Protection - Volume I + EPBC Regulations 2000 Part 8 Division 8.3 (Regulation 8.07) + WA EPA Environmental Factor Guideline - Marine Fauna + Recovery Plan for Marine Turtles in Australia (2017-2027)(Commonwealth of Australia, 2017a) + Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015b) + Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a).		

Receptors	The following receptors have been identified as potentially being impacted as a result of the proposed Browse to NWS Project (**Table 6-2**). A detailed description of each of these receptors is provided in **Chapter 5**.
	Physical
	+ ambient noise (medium value (open water)).
	Ecological
	+ marine fauna
	+ seabirds and migratory shorebirds (high value species)
	+ fish (high value species)
	+ marine mammals (high value species)
	+ marine reptiles (high value species)
	+ state marine parks and nature reserves (high value).
	Socio-economic
	+ other users
	  + tourism and recreations (high value users)
	  + scientific studies (high value users)
	+ settlements (Broome) (medium value users).		

Potential impacts	+ change in ambient noise + change in fauna behaviour + changes to the functions, interests or activities of other users.		
Risk	+ There are no anticipated environmental risks in relation to this aspect associated with unplanned project activities.		
Summary of governing impact evaluation	***Magnitude***	***Impact significance level***	***Confidence***
	No lasting effect	Slight (E)	High
Summary of governing risk evaluation	***Consequence***	***Likelihood***	***Risk rating***
	n/a	n/a	n/a

6.3.7.2 Source of aspect

The following activities and infrastructure may cause disruption to other users due to atmospheric noise in the Project Area:

- Helicopter personnel transfer to the offshore facilities and MODU from onshore logistics bases Broome. Approximately five personnel transfers a week per FPSO facility will be required during normal operations.

  Atmospheric noise will be created as a result of helicopter flights, with sound levels typically below 162 dB at 1m (Richardson et al., 1995 and Simmonds et al., 2004). Richardson et al. (1995) reported that helicopter sound was audible in air for four minutes before it passed over underwater hydrophones, but detectable underwater for only 38 seconds at 3 m depth and 11 seconds at 18 m depth. Noise levels for a Bell 212 helicopter during fly-over were reported at 162 dB re 1 µPa and for a Sikorsky-61 helicopter were recorded at 108 dB re 1 µPa at 305 m (Simmonds et al., 2004).Atmospheric noise will be created as a result of helicopter flights, with sound levels typically below 162 dB at 1m (Richardson et al., 1995 and Simmonds et al., 2004)(Richardson et al., 1995; Simmonds et al., 2004). As noise loses energy as it travels through the atmosphere, peak-received level diminishes with increasing helicopter distance from a receptor; however, the duration of audibility often increases with increasing altitude. Richardson et al.(1995) reported that helicopter sound was audible in air for four minutes before it passed over underwater hydrophones, but detectable underwater for only 38 seconds at 3 m depth and 11 seconds at 18 m depth. Noise levels for a Bell 212 helicopter during fly-over were reported at 162 dB re 1 µPa and for a Sikorsky-61 helicopter were recorded at 108 dB re 1 µPa at 305 m (Simmonds et al., 2004).

  Noise levels for typical helicopters used in offshore operations (Eurocopter Super Puma AS332) at 150 m separation distance has been measured at up to a maximum of 90.6 dB (BMT Asia Pacific, 2005). Water has a very high acoustic impedance contrast compared to air, and the sea surface is a strong reflector of noise energy (i.e. very little noise energy generated above the sea surface crosses into and propagates below the sea surface). The angle at which the sound path meets the surface influences the transmission of noise energy from the atmosphere through the sea surface; angles ±> 13° from vertical being almost entirely reflected (Richardson et al., 1995).
- Vessel personnel transfer to the offshore facilities and MODU from onshore logistic bases. Seven transfers per week would occur during normal operations with additional transfers during shut downs and major maintenance. Atmospheric emissions from vessels are expected to be relatively minor in comparison with underwater noise emissions from vessels and are not expected to result in significant impacts to sensitive receptors. As such, atmospheric noise emissions from vessels are not considered further.
- Normal operations on the FPSO facilities (e.g. flaring). Atmospheric noise emissions from FPSO flaring will be intermittent, of short duration and will occur a significant distance from sensitive receptors. It is not considered credible that these emissions will result in significant impacts to sensitive receptors. As such, atmospheric noise emissions from FPSO flaring are not considered further.
- Flaring from the MODU during well unloading. Atmospheric noise emissions from MODU flaring will be of a short duration (1-2 days per well) and will occur a significant distance from sensitive receptors. It is not considered credible that these emissions will result in significant impacts to sensitive receptors. As such, atmospheric noise emissions from FPSO flaring are not considered further.
- Pile driving for mooring installation (if required). Some atmospheric noise emissions will occur during pile driving. If the pile driving is required for the FPSO foundations or MODU mooring, this will only occur during the construction phase. These atmospheric noise emissions are expected to be relatively minor in comparison with underwater noise emissions from the pile driving activities and are not expected to result in significant impacts. As such atmospheric noise from pile driving is not considered further.

Other noise sources

Other sources of atmospheric noise may include the operation of the FPSO facilities (i.e. machinery noise), vessels (primarily engine noise) and the MODU engines and machinery (particularly during active drilling). These noise levels are expected to be relatively minor compared to the other noise sources described above and as such are not considered further.

6.3.7.3 Environmental Impact

Ambient noise

Change in ambient noise

Atmospheric noise emissions will increase the ambient noise in the immediate vicinity of the FPSO facilities, MODU and project vessels. Given the small area that will be affected and the lack of receptors in the area, this increase in ambient noise levels is not considered significant.

Fauna

Noise can result in a variety of responses in species as described in Section 6.3.8.

Marine fauna may be exposed to helicopter noise when on the sea surface (e.g. when basking, resting or breathing). Hearing for marine fauna is adapted for the perception of underwater sound (Popper et al., 2014), where they spend most of their time, as such they are not expected to perceive noise levels from helicopters that may result in PTS or TTS. Potential behavioural impacts for fauna that are present on the surface during a helicopter flyover may include temporary 'startle' responses (e.g. diving). However, typically such responses occur at relatively short ranges (tens of metres) (Hazel et al., 2007) and as such behavioural impacts during a typical helicopter flight are highly unlikely due to the altitude and distance between the helicopter and the potential receptor. Noise levels from a Bell 212 helicopter flying at altitudes of 610 to 152 m respectively were measured at 101 – 109 dB at 3 m water depth (Richardson et al. 1995), which is well below all marine fauna behavioural response thresholds. Although this is not representative of the type of helicopters used to service offshore facilities, provides an indication of received level noise that may be expected from a helicopter.

Change in fauna behaviour - seabirds and migratory shorebirds

Seabirds and migratory shorebirds may be affected by atmospheric noise emissions from helicopters transiting between Broome Heliport and the Browse Development Area. In particular, bird species present around Roebuck Bay and Cable Beach (<1 km from the Broome Heliport) and roosting birds at Scott Reef may be affected. Anthropogenic disturbance is identified in the Wildlife Conservation Plan for Migratory Shorebirds as a threat to the conservation of migratory shorebirds (Commonwealth of Australia, 2015a).

Given the high visibility and noise levels associated with helicopter movements, bird species are expected to actively avoid interaction. Any disturbance from helicopters in transit will be of limited duration as they pass by.

Impacts to bird species in the area surrounding Broome are expected to be negligible as helicopters passing by bird aggregation areas will be at significant altitude.

Impacts to bird species at Scott Reef are also expected to be negligible given the area does not represent a significant aggregation, nesting or roosting area for seabirds and migratory shorebirds; and flight paths will actively avoid roosting areas (Sandy Islet).

Bird species along the remainder of the flight path are expected to occur in low numbers. Given the altitude the helicopters will be flying at, impacts are not considered credible.

Change in fauna behaviour - cetaceans, marine turtles and fish

Underwater noise monitoring by McCauley (2008) at Scott Reef during a drilling program in 2008, demonstrated that noise emissions from helicopters operating from the MODU were not detectable at a noise logger set 4.6 km away (McCauley, 2008). Given this, and the typical characteristics of helicopter flights from Broome Heliport to the Project Area (i.e. duration, frequency, altitude and air speed), the predicted environmental impact of helicopter generated atmospheric levels that may result in behavioural disturbance to cetaceans, marine turtles and fish is not expected to have any lasting effect.

Noise interference is identified as a key threat in both the Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) and the Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015b). Anthropogenic noise and acoustic disturbance are also identified as a key threat in the relevant conservation advise for humpback, sei and fin whales which may occur in the Project Area.

Table 6-36 provides an assessment of the light emissions for the proposed activities in relation to objective and actions of the relevant EPBC Act recovery and conservation plans and advices.

Table 6-36 Alignment with EPBC Act recovery and conservation plans and advices for protected fauna – atmospheric noise

Fauna	Relevant plan(s)/ conservation advice	Plan/advice objectives and actions	Assessment
Migratory shorebirds	Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a)	Anthropogenic threats to migratory shorebirds in Australia are minimised or, where possible, eliminated.	Potential impacts to migratory shorebirds are predicted to negligible. Therefore, it is considered that the proposed activities are not inconsistent with the Wildlife Conservation Plan for Migratory Shorebirds
Whale shark (*Rhincodon typus*)	Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a)	Assess the impacts of offshore installations and associated environmental changes (light spill, chronic noise, changed water temperature, localised nutrient levels) on whale sharks and mitigation options for these impacts.	The potential impact of atmospheric noise emissions resulting from the proposed Browse to NWS Project have been assessed in line with the conservation advice. Given the low numbers and infrequent nature of whale shark presence in the Project Area, there is a high level of confidence that atmospheric noise emissions will not result in adverse impact to whale sharks.
Green turtle (*Chelonia mydas*) Hawksbill turtle (*Eretmochelys imbricata*)	The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a)	Management Actions: + Manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to the survival. + Manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue. + In relation to the Scott Reef – Browse Island green turtle genetic stock, the priority action is to manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to their survival.	Atmospheric noise emissions from the proposed Browse to NWS Project are not expected to be of sufficient intensity to alter the behaviour of adults or hatchling turtles. Therefore, there is a high level of confidence that atmospheric noise emissions will not result in displacement of the Scott Reef – Browse Island green turtle genetic stock, from identified habitat critical to their survival, or adversely affect the breeding cycle of marine turtles in the BIA at Scott Reef Therefore, it is considered that the proposed activities are not inconsistent with the Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a).
Pygmy blue whale	Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c)	Anthropogenic noise in biologically important areas will be managed such that any blue whale continues to utilise the area without injury and is not displaced from a foraging area.	Atmospheric noise emissions from the proposed Browse to NWS Project are not expected to be of sufficient intensity to alter the behaviour of cetaceans. Therefore, it is considered that the proposed activities are not inconsistent with the objectives of the Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015b)

Fauna	Relevant plan(s)/ conservation advice	Plan/advice objectives and actions	Assessment
Humpback whale	Conservation advice *Megaptera novaeangliae* Humpback Whale	Anthropogenic noise and acoustic disturbance have been identified as a threat for the recovery of these species.	The level of atmospheric noise is not expected to be enough to alter the behaviour of the cetaceans. Therefore, there is a high level of confidence that the impacts from atmospheric noise would be minimal and that the long-term recovery objectives for these species would not be compromised.
Sei whale	Conservation advice *Balaenoptera borealis* Sei Whale		
Fin whale	Conservation advice *Balaenoptera physalus* Fin Whale		

State marine parks and nature reserves

Change in fauna behaviour

The Scott Reef Nature Reserve protects the physical and ecological features of Scott Reef, including important nesting habitat (designated as a BIA and Habitat Critical for Survival of a Species) for the green turtle. As discussed above, the proposed activities are considered to be not inconsistent with the requirements of the Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) and as such no adverse impacts to the conservation values of the Scott Reef Nature Reserve are predicted.

Other users

Changes to the functions, interests or activities of other users

Given the low frequency of helicopter movements and the distance of the flight paths from Scott Reef, impacts to the tourism, recreation and scientific studies values of Scott Reef are expected to be negligible.

Settlements

Changes to the functions, interests or activities of other users

If selected as the primary means of transfer, noise emissions from helicopter movements to and from Broome Heliport may potentially present a nuisance to Broome residents. Stakeholder consultation (**Chapter 4**) undertaken by Woodside in relation to the proposed Browse to NWS Project identified these emissions and resultant disturbance to Broome and Cable Beach suburbs residents as a concern to the community. In many cases however it was noted that the potential economic and social benefits outweighed the negatives associated with increased helicopter noise.

Given the low number of movements expected (in the order of five per week per FPSO), the regulation with respect to civil aviation, and planned mitigation measures such as restricted flight times and adjusted flight paths, noise emissions are not expected to add significantly to existing noise levels.

6.3.7.4 Environmental Risk

There are no anticipated environmental risks in relation to this aspect associated with unplanned project activities.

6.3.7.5 Cumulative Impacts

Helicopter movements to and from Broome Heliport are anticipated to occur through all phases of the proposed Browse to NWS Project, as well as during continued operation of the Prelude and Ichthys developments (operated by Shell and INPEX respectively). Broome International Airport is the primary airport for the Kimberley region and hosts regional, national and international air traffic. Between 2017 and 2018, Broome International Airport saw 5,226 aircraft movements (primarily fixed wing aircraft) (BITRE, 2019). Eight additional helicopter movements per week during operations (4 movements for each FPSO), represents an 8% increase in aircraft movements. While these additional movements are significant in the context of current traffic at Broome International Airport, they represent a marginal increase when compared to historical aircraft movements at Broome International Airport which had a peak level of 6,886 flights in 1995/6 and has had an average annual growth of -0.2% since 1997. Therefore, at a regional scale, the risk of cumulative impacts associated with additional helicopter movements associated with the proposed Browse to NWS Project activities is considered to be low.

6.3.7.6 Impact and Risk Assessment Summary and Acceptability Statement

A summary of the impact assessment for the atmospheric noise is provided in Table 6-37. No credible environmental risks have been identified in relation to atmospheric noise. The acceptability assessment is provided in Table 6-38.

Table 6-37 Impact assessment summary and adopted controls – atmospheric noise

Receptor (sensitivity)	Impact	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
Ambient noise (medium value (open water))	Change to ambient noise	**Objective 5:** To not result in a substantial change in ambient light or ambient noise which may adversely impact on biodiversity, ecological integrity, social amenity or human health	+ Helicopters will operate in accordance with EPBC Regulations 2000 – Part 8 Division 8.1 + Helicopters shall not operate lower than 1650 feet or within a horizontal radius of 500 m of a cetacean known to be present in the area, except for take-off and landing. + The number of helicopter flights required during installation and operation of the development will be optimised to maximise efficiency and reduce the number of flights where operationally possible + Compliance with Broome International Airport's "Fly Neighbourly Policy" which includes maintaining helicopter flight paths away from homes and businesses. + Scheduled helicopter flight paths will avoid known seabird roosting sites where possible. This includes no planned flights over Sandy Islet.	No lasting effect	Negligible (F)
Seabirds and migratory shorebirds (high value species)	Change in fauna behaviour	**Objective 11:** To not have a substantial adverse effect on a population of seabirds or migratory shorebirds, or the spatial distribution of the population.		No lasting effect	Slight (E)
Fish (high value species)	Change in fauna behaviour	**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species.		No lasting effect	Slight (E)
Marine mammals (high value species)	Change in fauna behaviour	**Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species.		No lasting effect	Slight (E)
Marine turtles (high value species)	Change in fauna behaviour	**Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **Objective 15:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population		No lasting effect	Slight (E)

Receptor (sensitivity)	Impact	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
Other users - scientific studies, tourism and recreation (high value users)	Changes to the function interests or activities of others and changes in aesthetic value	**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No lasting effect	Slight (E)
Settlements – Broome (medium value users)	Changes to the function interests or activities of others and changes in aesthetic value	**Objective 23:** To protect social surroundings from significant harm.		No lasting effect	Negligible (F)

Table 6-38 Acceptability assessment – atmospheric noise

Acceptability Assessment
Confidence in assessment Woodside have a high level of certainty with respect to the assessment of the potential impacts and risks associated with atmospheric noise as: + Studies have adequately characterised the marine fauna populations and distributions that may potentially be impacted by atmospheric noise. While some knowledge gaps exist with respect to pygmy blue whale and green turtle utilisation of Scott Reef, the lack of predicted impacts to these species from atmospheric noise emissions means that these knowledge gaps do not affect the impact assessment in relation to atmospheric noise emissions. + The use of the Project Area by other marine users is well known and understood + Local stakeholders and residents within Broome are known and the flight paths for helicopters leaving the Broome heliport are understood. Stakeholder consultation with Broome residents will be ongoing.
Principles of ESD With the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such it is considered that the principles of ESD will be met. **Conclusion: Acceptable**
Significant Impacts as defined by the MNES Significant Impact Guidelines *Listed threatened species and ecological communities / listed migratory species* As described in **Table 6-37**, no lasting effect to any marine fauna (including seabirds, migratory shorebirds, fish, marine mammals and marine reptiles) is predicted to occur as a result of atmospheric noise emissions. Given this, with the application of the proposed controls it is predicted that the nominated environmental objectives for these receptors will be achieved. As such, no significant impacts to the listed threated or migratory species (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted. *Commonwealth marine environment* As described in **Table 6-37**, no lasting effect to any receptors is predicted as a result of atmospheric noise emissions. Given this, with the application of the proposed controls it is predicted that the environmental objectives for each potentially impacted receptor will be achieved. As such, no significant impacts to the Commonwealth marine environment (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted. *National heritage places* No impacts to national heritage places in the Project Area are predicted as a result of atmospheric noise emissions. **Conclusion: Acceptable**
WA EPA Environmental Objectives An assessment of the impacts of atmospheric noise emissions against the WA EPA Objective is presented in the State Proposal ERD (**Chapter 10, Appendix B**). *Marine fauna* As described in **Table 6-37**, no lasting effect to any marine fauna (including seabirds, migratory shorebirds, fish, marine mammals and marine reptiles) is predicted to occur as a result of atmospheric noise emissions. Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*to protect marine fauna so that biological diversity and ecological integrity are maintained*" will be achieved. **Conclusion: Acceptable**

Acceptability Assessment

External context

Stakeholder consultation undertaken by Woodside in relation to the proposed Browse to NWS Project identified noise emissions from helicopters and resultant disturbance to Broome and Cable Beach suburbs residents as a concern to the community.

Given the low number of expected movements associated with the proposed Browse to NWS Project (in the order of five per week per FPSO), the regulation with respect to civil aviation, and planned mitigation measures such as restricted flight times and adjusted flight paths, noise emissions are not expected to add significantly to existing noise levels.

Conclusion: Acceptable

Internal context

This impact assessment has been undertaken in accordance with Woodside's Risk Assessment Procedure and Environment Impact Assessment Guideline (**Section 6.2**). The proposed Browse to NWS Project will be executed in accordance with Woodside's Health, Safety and Environmental Management System.

Woodside environmental performance procedures in relation to atmospheric noise emissions will be adhered to.

Conclusion: Acceptable

Other Requirements

EPBC Act recovery and conservation plans and advices

As detailed in **Table 6-36**, the proposed activities are considered to be not inconsistent with the actions and objectives of:

- Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a)
- Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a)
- The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a)
- Conservation Management Plan for the Blue Whale
- Conservation advice *Megaptera novaeangliae* Humpback Whale
- Conservation advice *Balaenoptera borealis* Sei Whale
- Conservation advice *Balaenoptera physalus* Fin Whale.

Conclusion: Acceptable

6.3.8 Underwater Noise

Table 6-39 presents an overview of the potential impacts and risks from underwater noise associated with the proposed Browse to NWS Project.

Table 6-39 Underwater noise impact and risk overview

Aspect	Underwater noise
Description	Underwater noise emissions will occur during all stages of the proposed Browse to NWS Project. The primary source activities for underwater noise emissions will include: + piling activities including potential pile driving + drilling and completion activities + seabed preparation prior to infrastructure installation + subsurface evaluation using well bore seismic imaging techniques + project vessel, FPSO and MODU dynamic positioning (DP) and BTL installation Vessels (DP) + subsea infrastructure operations (e.g. wellhead choke noise) + FPSO facilities operations + general project vessel and helicopter movements.
Area	Project Area, Browse Development Area, State Proposal Area
Project stage	All - drilling and completions, installation, commissioning, operations and decommissioning
Environmental objectives	The environmental objectives in relation to underwater noise associated with the proposed Browse to NWS Project are Objectives 5, 6, 7, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20 and 21. These objectives are detailed in Table 6-7.
Policy and guidelines	The following policy and guidelines are relevant to the assessment of this aspect. In addition, a number of EPBC Act conservation advices for protected fauna have been considered (Table 6-70). + EPBC Regulations 2000 Part 8 Division 8.3 (Regulation 8.07), which include the following measures + WA EPA Environmental Factor Guideline - Marine Fauna + Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) + Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015b) + Australian National Guidelines for Whale and Dolphin Watching 2017 (Commonwealth of Australia, 2017b) + Whale shark 'Industry Code of Conduct', as described in Section 4.1.6 of Department of Parks and Wildlife, 2013 + North-west Marine Parks Network Management Plan (Director of National Parks, 2018).

Aspect	**Underwater noise**

Receptors	The following receptors have been identified as potentially being impacted as a result of the proposed Browse to NWS Project (**Table 6-2**). A detailed description of each of these receptors is provided in **Chapter 5**.
	Physical
	+ ambient noise (medium value (open water))
	Ecological
	+ plankton communities (medium value (open water))
	+ benthic habitats
	    + shallow water benthic communities and habitats (<75 m depth) (high value habitat)
	    + deepwater communities and habitats (>75 m depth) (medium value habitat)
	+ marine fauna
	    + fish (high value species)
	    + marine mammals (high value species)
	    + marine reptiles (high value species)
	+ KEFs (medium value)
	+ AMPs (medium value (multiple use zones))
	+ State marine parks and nature reserves (high value)
	+ other protected places (high value)
	Socio-economic
	+ managed fisheries (high value user)
	+ other users
	    + tourism and recreation (high value users)
	    + scientific studies (high value users)
	+ aboriginal or indigenous heritage (high value users)

Potential impacts	+ change in ambient noise + change in fauna behaviour + injury or mortality to fauna + changes to the functions, interests or activities of other users
Risk	+ significantly larger presence of pygmy blue whales than predicted + subsea valves choke noise within Scott Reef channel significantly higher than predicted.

Summary of governing impact evaluation	***Magnitude***	***Impact significance level***	***Confidence***
	Slight	Minor (D)	High
Summary of governing risk evaluation	***Consequence***	***Likelihood***	***Risk rating***
	Minor (C)	Highly Unlikely (1)	Moderate (C1)

6.3.8.1 Source of aspect

Background

Impulsive vs continuous (non-pulsed) noise

Underwater noise is distinguished as two different sound categories: (1) impulsive (such as pile driving); and (2) continuous (non-pulsed) (such as the FPSO, project vessels and ambient sound). Note that impulsive sounds are typically characterised using different measures or metrics compared to continuous sound. Therefore, it is not meaningful to directly compare sound level values in dB between the two types of sound or with given threshold values, without first considering appropriate conversion between the metrics being used to characterise sound level.

Relevant terminology

There are several sound level metrics which are commonly used in underwater acoustics to evaluate impulsive and non-impulsive (continuous or non-pulse) noise and its effects on marine fauna. Relevant definitions used in this assessment reflect the ISO standard for acoustic terminology, ISO/DIS 18405.2:2017 (International Organization for Standardization (ISO), 2017):

Zero-to-Peak sound pressure level (PK; $L_{pk;}$ $L_{p,pk;}$ dB re 1 µPa) is the maximum instantaneous sound pressure level in a stated frequency band attained by an acoustic pressure signal. However, this metric does not take into account the duration of a noise event.

Sound exposure level (SEL; $L_{E;}$ $L_{E,p;}$ dB re 1 µPa^2·s) is a measure related to the acoustic energy contained in one or more acoustic events. SEL can be calculated over periods with multiple acoustic events, or over a fixed duration, the squared pressure is integrated over the duration of interest. For multiple events, the SEL can be computed by summing (in linear units) the SEL of the individual acoustic events.

Sound pressure level (SPL; L_p; dB re 1 µPa) is the root mean squared pressure level in a stated frequency band over a specified time window containing the acoustic event of interest. It is important to note that SPL always refers to a rms pressure level and therefore not instantaneous pressure. The SPL represents a nominal effective continuous sound over the duration of an acoustic event, which in this assessment is over a fixed duration of 0.125 ms for piling or VSP, and 1s for vessels.

Source activities

Activities resulting in underwater noise emissions that may be undertaken during the phases of the proposed Browse to NWS Project including drilling and completion, installation, commissioning, operations and decommissioning. Specific source activities relevant to this assessment are listed below:

- drilling and completion and installation activities:
  - drilling and completions
  - subsurface evaluation using well bore seismic techniques including VSP
  - piling to secure mooring lines for the MODU, SURF installations, FPSO turret mooring anchors and BTL export riser bases
  - MODU and project vessels DP
  - seabed preparation
  - vessels movements (including ROV)
  - helicopters movements
- commissioning and operational activities:
  - subsurface evaluation using well bore seismic techniques including VSP
  - subsea infrastructure operation
  - routine FPSO operations
  - support vessel and FPSO facility operations (offtake) use of DP
  - vessels movements (including ROV)
  - helicopters movements
  - IMR activities.
- decommissioning:
  - project vessels DP
  - vessel movements
  - helicopter movements
  - infrastructure removal.

These source activities, as they relate to underwater noise emissions, are described below.

Drilling and completion

MODUs (drilling, completion and DP)

The noise emissions from a MODU primarily depend upon the MODU being moored or under DP. MODUs can be hull-based vessels equipped with drilling derrick or platforms, or self-propelled drill ships. Drilling sound usually exhibits tones below 2 kHz, with harmonics present to 10 kHz and can vary substantially between operations (Austin et al., 2018; Kyhn et al., 2014). These two studies are the most recent and detailed published studies on noise from offshore drilling operations, and provide information about the current fleet of larger drilling units, as opposed to older, smaller units (Gales, 1982; Greene, 1987; Richardson et al., 1995), as explained in Lucke et al. (2019). The broadband drilling source levels reported in Austin et al. (2018) were 168.6, 170.1 and 174.9 dB re 1 µPa·m for a drilling unit, a semi-submersible and a drillship.

If the propulsion system of a vessel is under heavy load (acceleration, DP) the sound produced by the cavitation process on the propellers will dominate other sources of vessel sound (machinery, hull vibration, etc.). However, the source level depends upon the thruster, the total number of thrusters and the load placed on each, and as such will change depending upon environmental conditions. Source levels for MODU's drilling vessels similar to the proposed MODU under DP for this project such as those reported in Martin et al. (2019) and MacDonnell (2016) provide important context. Martin et al. (2019) reported a source level of 181.5 dB re 1 µPa·m, along with 75th and 90th percentiles of 183.7 and 186.3 dB re 1 µPa·m respectively, while the Stena IceMAX drillship (which included Offshore Support Vessel (OSV) noise) was estimated to have a broadband source level of 188 dB re µPa·m (SPL; MacDonnell, (2016)).

Acoustic modelling undertaken by Jasco Applied Science (Jasco) for the proposed Browse to NWS Project (**Section 6.3.8.2**, **Chapter 10, Appendix D.3**) presents a comparison of different source signatures (and levels). The modelling considers each thruster as an individual source; however, a MODU source level of 191 dB re 1 µPa·m, corresponding to the noise generated by eight thrusters operating simultaneously, was presented for comparison to measurement studies.

Well bore seismic imaging techniques

Well bore seismic imaging techniques, including Vertical Seismic Profiling (VSP), use a small seismic airgun array. This assessment considered a750 in^3 array operated at 6 m with a broadband (10–25,000 Hz) unweighted per-pulse SEL source level of 214 dB 1 µPa^{2}m^{2}s in the broadside and endfire direction (McPherson et al., 2019; Table 6-40) The well bore seismic process is repeated as required for different stations in the well.

Mooring installation (piling)

Existing measurements for subsea pile driving are limited but indicate that source levels are comparable with surface pile driving. Sound levels produced depend upon several factors such as pile size, hammer strike energy, and type of seabed, but field measurements of pile driving show that source, or near-source levels are typically in the range of 210 to 250 dB re 1 µPa (Bailey et al., 2010; McHugh, 2005; Tougaard et al., 2009) and frequency is predominantly <1 kHz (Matuschek and Betke, 2009; Robinson et al., 2012, 2007; Tougaard et al., 2009), although they can extend to much higher frequencies (MacGillivray, 2018), including at least 100 kHz (Tougaard et al., 2009). Deep and shallow-water conductor driving generate similar sound pressures; however, in deep water the pile can be much longer so the ensonified area (area impacted by noise) is greater (MacGillivray, 2018).

The acoustic modelling study predicted that for piling for the FPSO mooring broadband (10 Hz to 25 kHz) sound energy at 10 m for each penetration depth will range from 184.6–199.4 dB re 1 µPa^2·s (inclusive of both IHC S-600 and IHC S-1200 hammers) with the peak sound energy concentrated in the frequency range 70 to 300 Hz, with levels from the pile at the shallowest modelled penetration depth having the highest energy. Piling may also be required for mooring the MODU, however if required these piles are expected be significantly smaller than those used for the FPSO mooring system.

Table 6-40 Far-field source level specifications for the 750 in^3 array, for a 6 m operational depth. Source levels are for a point-like acoustic source with equivalent far-field acoustic output in the specified direction. Sound level metrics are per-pulse and unweighted

Direction	Peak source pressure level ($L_{S,pk;}$ dB re 1 µPa·m)	Per-pulse source SEL (LS, E; dB 1 µPa^{2}m^{2}s)	
		10–2000 Hz	2000–25,000 Hz
Broadside	239.8	214.0	168.7
Endfire	240.1	214.1	175.3
Vertical	239.7	214.0	173.2
Vertical (surface affected source level)	239.7	216.2	176.1

Vessel movements

The operation of motorised vessels involves numerous mechanical processes which create underwater sound as a by-product; these range from sound of the propeller, cavitation caused at the propeller edges, machinery or simply the flow noise of the vessel moving through the water. Sound emitted from vessel differs strongly depending mainly on size, speed, load, type and state of propulsion system, meteorological and oceanographic factors such as sea surface conditions and currents (MacGillivray et al. 2018).

The acoustic modelling study only considered vessels under DP (because moored vessels emit less noise than DP vessels and depth is likely to preclude moorings) and used the *MMA Inscription* as being a representative OSV. While the modelling considers each thruster as an individual source, a representative mean source level (MSL) of 183 dB re 1 µPa·m was used.

Commissioning and operations

FPSO

The proposed FPSO facility is a turret moored dynamically positioned production vessel, with thrusters to assist with operational heading control. It is approximately 370 m long and 67 m wide with a draft of 16 m. While in DP mode, it operates on two stern thrusters positioned laterally on the keel at the stern of the ship, right next to each other. Each thruster is proposed to be rated at 3 MW (noting that the modelling was undertaken based on 5 MW thrusters which provides a level of conservatism in the modelling results). The vessel type and specifications are similar to the Woodside FPSO facilities *Ngujima Yin* and *Nganhurra*, from which JASCO gathered measurements in 2010 (Erbe et al. 2013). The measured spectra for these two vessels were averaged and used as a surrogate for the FPSO facility. Because the *Ngujima Yin* and *Nganhurra* were moored, they were not offloading, and the weather was calm, they were not under DP when they were measured. These averaged source levels were used in this report to model FPSO operations without DP.

To model operations that include DP, sound levels of thruster noise were added to the (non-DP) source spectrum. Sound levels for DP thruster noise were based on measurements of the dive support vessel *DSV Fu Lai* (MacGillivray 2006). The composite source spectrum (i.e., non-DP and DP components) was adjusted for the difference in total operational power level between the *DSV Fu Lai* and the FPSO facility (based on early assumption the FPSO would have two 5 MW thrusters). The source spectrum was additionally modified to consider the operational level of the *Fu Lai* thrusters relative to the desired operational level for the FPSO facility. Given that DP does not require full thrust, the *Fu Lai*'s thrusters only operated at between 20% and 30% of capacity when measured. To achieve a conservative estimate, FPSO facility thrusters were modelled at 50% power capacity, at a constant speed, noting the majority of time thrusters will be operating at much lower capacity.

Noting that the design of the FPSO is not yet finalised, it is expected that the thrusters will be located at the keel of the hull, which is approximately 16m below MSL. While this depth may change during detailed design and also as the ship's load changes due to operational requirements, modelling assumes the point source for thruster noise is 16m below MSL, which is an inherently conservative approach.

The thrusters are located at the stern section of the vessel; for modelling purposes, however, the source location was placed in the planar centre of the vessel to approximate a point source. Because this assessment is focused on the far-field noise from all sources on the vessel (including not just thruster noise, but also noise from ancillary equipment for power generation, etc.) the point source location approximation is suitable.

In summary for FPSO operations including DP, such as holding position for offtake, modelling considered each thruster as an individual source with a representative broadband (10 Hz to 63 kHz) MSL of 189 dB re 1 µPa·m.

Project vessels and use of DP

The acoustic modelling study only considered vessels under DP (because moored vessels emit less noise than DP vessels and depth is likely to preclude moorings) and used the MMA Inscription as being a representative OSV. While the modelling considers each thruster as an individual source, a representative MSL of 183 dB re 1 µPa·m was used.

Subsea infrastructure operation (wellheads - choke valve)

Noise will also be generated during hydrocarbon extraction as a result of the operation of the wellheads and subsea infrastructure. McCauley (2002) recorded noise from an oil producing subsea wellhead associated with the Cossack Pioneer FPSO and estimated the broadband source level to be 161.5 dB re 1 µPa·m (SPL).

Table 6-41 Indicative noise levels for key proposed Browse to NWS Project activities

Activity/source	Indicative noise levels (dB re 1 µPa)
MODU under DP	191 dB re 1 µPa·m (SPL)
Impact piling	184.6–199.4 dB re 1 µPa²·s at 10 m (IHC S-600 and IHC S-1200 hammers, respectively)
VSP	Per-pulse SEL source level of 214 dB 1 µPa²m²s (based on a 750 in³ seismic source)
Support vessel under DP	183 dB re 1 µPa·m (SPL)
Wellheads (choke valve)	161.5 dB re 1 µPa·m (SPL)
Helicopters	Received level of 101 to 109 dB re 1µPa (SPL) at 3 m water depth for altitudes of 610 to 152 m, respectively
FPSO during normal operations	174 dB re 1µPa·m (SPL)
FPSO on DP	189 dB re 1µPa·m (SPL)
FPSO facility during offloading activities (FPSO under DP, silent condensate tanker, OSV under DP)	Received level of 180 dB re 1µPa (SPL) at 0.03 km from the centroid of the FPSO and OSV thrusters

6.3.8.2 Underwater Noise Modelling

Underwater noise modelling has been undertaken for a number of the key project activities. The modelling locations are presented in **Figure 6-10** with the results presented in the sections below. The acoustic modelling report is provided in **Chapter 10, Appendix D.3**.

Specifically, modelling was undertaken for the following activities:

1. Pile driving for the FPSO moorings at Torosa and Brecknock - Two scenarios at each location were modelled based on differing piling hammer sizes.
   a. Light hammer (i.e. 600 Kj), with a single strike of a single pile and complete driving of single pile.
   b. High energy hammer (1200 Kj), with a single strike of a single pile and complete driving of single pile.
2. FPSO operational noise during offtake, including the FPSO under DP and an OSV near each FPSO (presented in isolation). Note that the condensate tanker typically does not operate its engine during offtake and therefore is not incorporated .
3. Normal operations of the MODU on DP at Torosa (TRD drill centre) and Brecknock.
4. In well VSP at Torosa (TRD well) and Brecknock.
5. Subsea wellheads (undertaken as part of previously proposed FLNG development concept).

The modelling study specifically assessed distances from operations where underwater sound levels reached thresholds corresponding to various levels of impact to marine fauna. The animals considered here included marine mammals (pygmy blue whales), turtles, and fish (including fish eggs and larvae). Due to the variety of species considered, there are several different thresholds for evaluating effects, including: mortality, injury, temporary reduction in hearing sensitivity, and behavioural disturbance. Different approaches were used to model acoustic sources (driven piles, vessels and VSP), and outlined in detail within McPherson et al. (2019) (**Chapter 10, Appendix C.3**, McCauley (2002) and Duncan (2011)[10].

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[10] *Duncan (2011) available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

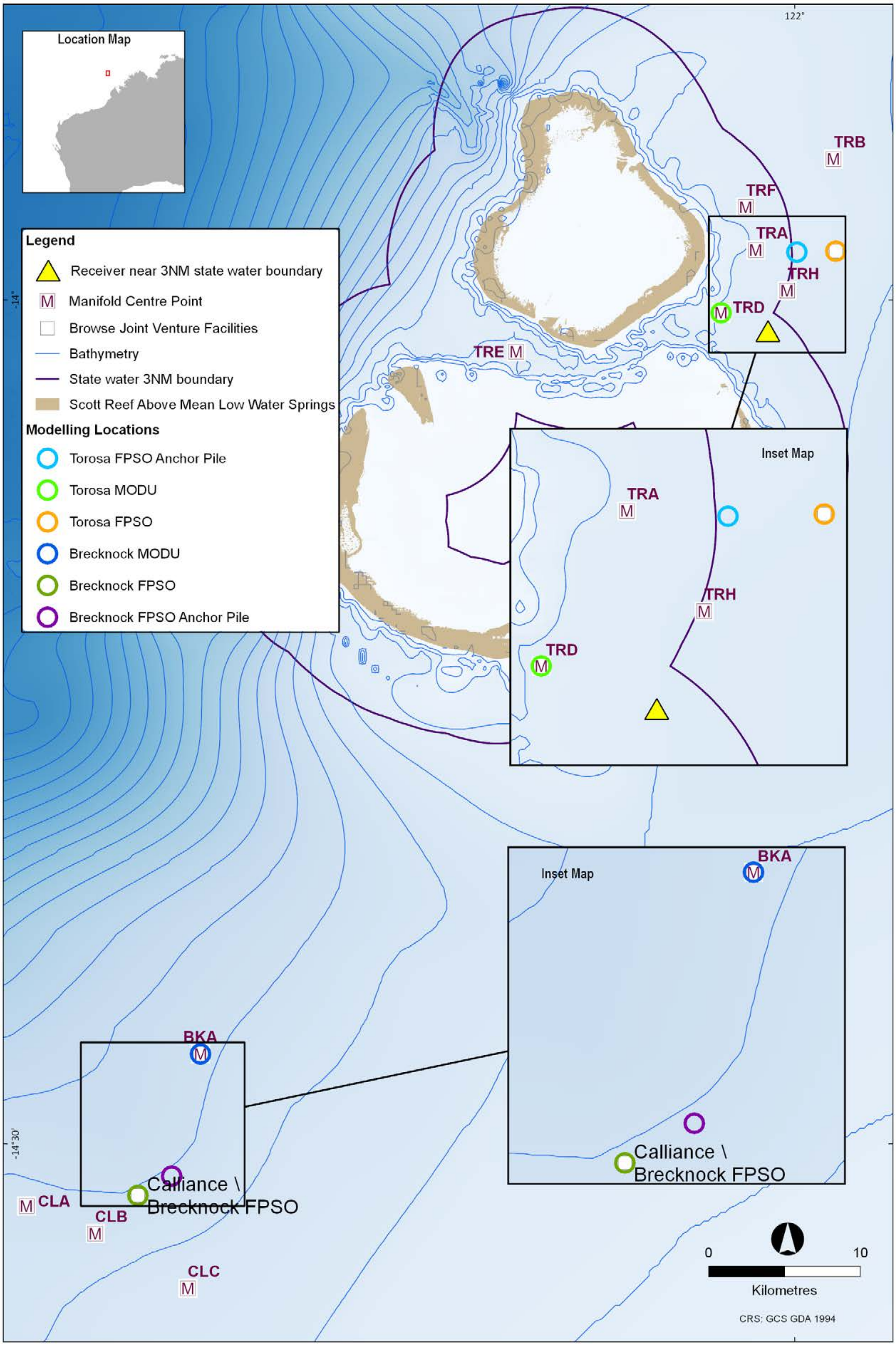

Figure 6-10 Noise modelling locations

6.3.8.2.1 Animal Movement and Exposure Modelling

In addition to the propagation modelling outlined above, McPherson et al. (2019) modelled predictions of sound levels that individual animals may receive during piling operations. This approach incorporated representative and published animal density, movement and behavioural characteristics into the propagation model (referred to as ANIMAT modelling) for the following representative scenarios;

- pygmy blue whale migration
- pygmy blue whale foraging
- green turtle migration
- green turtle internesting.

This type of animal movement and exposure modelling approach provides the most realistic prediction of the maximum expected SPL, PK, and the temporal accumulation of SEL that are considered the most relevant sound metrics for impact assessment. The most recent science in the peer-reviewed literature regarding sound propagation and animal movement modelling was used.

The JASCO Animal Simulation Model Including Noise Exposure (JASMINE) was used to predict the exposure of animats (virtual marine mammals) to sound arising from the pile driving for the Torosa and Brecknock FPSO anchor piles. Detailed information on this approach is provided in **Chapter 10, Appendix D.3**.

Sound exposure models like JASMINE integrate the predicted sound field with biologically meaningful movement rules for each marine mammal species (here: pygmy blue whales and green turtles) that result in an exposure history for each animat in the model. In JASMINE, the sound received by the animats is determined by the proposed pile driving activity pattern. Animats are programmed to behave like the marine animals that may be present in the area. The parameters used for forecasting realistic behaviours (e.g., diving and foraging depth, swim speed, surface times) are determined and interpreted from marine studies (e.g., tagging studies) where available, or reasonably extrapolated from related or comparable species. An individual animat's sound exposure levels are summed over a specified duration, such as 24 h or the entire simulation, to determine its total received energy, and then compared to the threshold criteria.

The exposure criteria for impulsive sounds (**Table 6-44**, **Table 6-45** and **Table 6-47**) were used to determine the number of animats exceeding thresholds. Model simulations were seeded with high animat densities of 15 animats/ km^2 for pygmy blue whales and 15 animats/ km^2 for green turtles to generate a statistically reliable probability density function for each species and estimate exposure ranges. To calculate the number of actual animals potentially exposed, the exposure results based on the higher seeded density of 15 animat/ km^2 were scaled down using representative 'real world' density values for each species defined in the sections below. To evaluate potential injury (PTS), TTS, and behavioural disturbance, exposure results were summed over the driving of a single pile (refer to **Section 6.3.8.2.1** for explanation of impact categories).

Specific areas of interest are defined for both pygmy blue whales and green turtles depending on behavioural mode (e.g. migrating, foraging, internesting).

Pygmy blue whales – animal behaviour

Two animat behavioral profiles were considered for pygmy blue whales, defined as foraging and migration. The research summarised in this section was used to inform the species animat behavioural profiles (**Table 6-42** and **Table 6-43**). The input values within this section are based on best available science and where uncertainty exists due to limited sample sizes, conservatism has been applied as described below.

Detailed, fine-scale diving behaviour of a migrating pygmy blue whale was derived from Owen et al. (2016) who equipped an individual with a multi-sensor tag off the west coast of Australia. The study identified areas of high residence using the horizontal movement data; the analysis of the dive data showed that the depth of migratory dives was highly consistent over time and unrelated to local bathymetry. Blue whales (*Balaenoptera musculus*) are known to primarily migrate and feed in the first few hundred metres of the water column (Goldbogen et al. 2011), with the deepest dive being reported from a pygmy blue whale being 506 m (Owen et al. 2016). Dives were identified as migratory, feeding, or exploratory behaviour. The mean depth of migratory dives (82% of all dives) was 14 m ± 4 m, and the whale spent 94% of observed time and completed 99% of observed migratory dives at water depths of less than 24 m. A total of 21 feeding dives were identified during the duration of the tag deployment (one week) with a mean maximum depth of 129 ± 183 m (range 13–505 m). The mean maximum depth of exploratory dives (107 ± 81 m, range 23–320 m) was similar to the mean maximum depth of feeding dives (129 m) and did not appear to be related to seafloor depth.

To incorporate conservatism into the modelling, the behaviour of pygmy blue whales was modelled without migration bias, i.e. the animats were resident in the ANIMAT modelling area over the entire modelling period. In reality, pygmy blue whales can be expected to transit through the area in less than half a day (based on McCauley and Jenner 2010); accordingly, the approach used is conservative as it results in higher exposure levels and higher number of animals exposed to levels exceeding the criteria thresholds.

For migratory pygmy blue whales, two dive behaviours (migratory dives (14 m ± 4 m) and exploratory dives (107 m ± 81 m) were modelled at an even probability of occurrence (i.e. probability for transitioning from one behaviour to another was 0.5 for both) while dive data published by Owen et al. (2016) suggest a higher likelihood (82%) for migratory dives (14 m ± 4 m) to occur and noted 94% of observed time the whale was at water depths less than 24m depth. This approach was chosen in the absence of quantitative information on the true proportion between the two dive behaviours and conservatively addresses any potential variability in the migratory dive depths. It represents another conservative measure, given the assumption that for sub-sea piling, exposure levels are higher at depth as compared to the surface. Table 6-42 and Table 6-43 provide a detailed overview of the behavioural input values (and associated literature) adopted for both Foraging ANIMATS and Migratory ANIMATS, respectively. Further definition on each variable is provided within Chapter 10, Appendix D.3.

Table 6-42 Foraging pygmy blue whale ANIMATS: Data values and references associated with diving behaviour

Behavioural Profile	Variable	Deep Foraging Dive -Value	Reference
Foraging pygmy blue whale	Travel direction	Correlated random walk	Houser (2006), D. Houser, pers.comm.
	Perturbation value	10	Houser (2006), D. Houser, pers.comm.
	Termination coefficient	0.2	Houser (2006), D. Houser, pers.comm.
	Travel rate (m/s)	Gaussian 1.25 (0.42)	Sears and Perrin (2009)
	Ascent rate (m/s)	Gaussian 1.6 (0.5)	Goldbogen et al. (2011)
	Descent rate (m/s)	Gaussian 2.6 (0.5)	Goldbogen et al. (2011)
	Dive depth (m)	Gaussian 129.0 (183.0)	Owen et al. (2016)
	Reversals	3.5 (1.1)	Goldbogen et al. (2011)
	Probability of reversal	0.7	Approximated
	Reversal ascent dive rate (m/s)	Random 1.7–0.37	Goldbogen et al. (2011)
	Reversal descent dive rate (m/s)	Random 1.4–0.46	Goldbogen et al. (2011)
	Time in reversal (s)	Random 26.3–52.5	Approximated
	Surface interval (s)	Gaussian 162.0 (66.0)	Goldbogen et al. (2011)
	Bout duration (s)	Gaussian 12600 (1800)	Owen et al. (2016)
General	Shore following (m)	30	Approximated
	Depth limit on seeding (m)	100.0 (minimum), 110000.0 (maximum)	Approximated

Table 6-43 Migratory pygmy blue whale ANIMATS: Data values and references associated with diving behaviour

Behavioural Profile	Variable	Migratory Dive Values	Exploratory Dive Values	Reference
Migratory pygmy blue whale*	Travel direction	Correlated random walk (i.e. no migration bias)	Correlated random walk (i.e. no migration bias)	Houser (2006), D. Houser, pers.comm.
	Perturbation value	10	10	Houser (2006), D. Houser, pers.comm.
	Termination coefficient	0.2	0.2	Houser (2006) Houser (2006), D. Houser, pers.comm.
	Travel rate (m/s)	Gaussian 0.78 (0.61)	Gaussian 1.25 (0.42)	(Sears and Perrin (2009)
	Ascent rate (m/s)	Gaussian 0.7 (0.2)	Gaussian 1.6 (0.5)	Goldbogen et al. (2011)

Behavioural Profile	Variable	Migratory Dive Values	Exploratory Dive Values	Reference
Migratory pygmy blue whale*	Descent rate (m/s)	Gaussian 1.5 (0.1)	Gaussian 2.6 (0.5)	Goldbogen et al. (2011)
	Dive depth (m)	Gaussian 14.0 (4.0)	Gaussian 107.0 (81.0)	Owen et al. (2016)
	Reversals	No	No	Owen et al. (2016)
	Surface interval (s)	Gaussian 60.0 (66.0)	Gaussian 162.0 (66.0)	Owen et al. (2016), approximated
	Bout duration (s)	Gaussian 12060 (1800)	Gaussian 516 (120)	Owen et al. (2016)
	Shore following (m)	30	30	Approximated
	Depth limit on seeding (m)	100.0 (minimum), 110000.0 (maximum)	100.0 (minimum), 110000.0 (maximum)	Approximated

* *two migratory dive behaviours (migratory dives and exploratory dives) were modelled at an even probability of occurrence (i.e. probability for transitioning from one behaviour to another was 0.5 for both)*

Pygmy blue whales – density estimates

Density estimates were derived from the acoustic detection data published by McCauley and Jenner (2010). which revealed a maximum of three pygmy blue whales on a single day passing through the area during their southward migration (November to late December). The listening range of the noise logger was estimated to be 120 km. Based on an average swimming speed for the southbound pygmy blue whales of five knots (9.26 km/hr), McCauley and Jenner (2010) calculated a transit time through the area of 0.54 days; therefore, the number of animals detected per day equates to an estimated density for vocalising animals in the area of 0.0031207 animals per km^2 for their study; using a more precautionary 60 km listening range, as opposed to the referenced 120 km. As not all animals are emitting calls during their migration, this density estimate has to be corrected for the percentage of animals calling ('calling rate'). McCauley and Jenner (2010) proposed that 8.5–20% of the animals present in an area could be vocalising, considering information relating to humpback whales (8.5%, Cato et al. (2001)), and pygmy blue whales (<20%, (McCauley et al. 2001), to take a precautionary approach this study has adopted the lower bound value (8.5%). If the vocalisation rate of pygmy blue whales in the Perth Canyon was applied, the resulting density of animals would be 2.35 times smaller than the precautionary 8.5% vocalisation rate applied in this impact assessment.

The entire region off the northwestern coast of Australia is a vast area with limited studies on the total abundance and distribution of pygmy blue whales. As described in McCauley et al. (2018), there are two estimates for the Eastern Indian Ocean pygmy blue whale population size along the coastline of Western Australia (WA), the first calculated in 2004 by McCauley and Jenner (2010) at 662–1559 southbound animals, using passive acoustics, and the second calculated over 2002–2006 by Jenner et al. (2008) of 712–1754. Neither of these estimates account for whales further west in the Indian Ocean, and there is evidence that along the WA coast north of latitude ~ 19° S that the migratory pathway spreads out (Gavrilov et al. 2018), with not all animals following the Australian coastline; therefore it is unknown what proportion of the Eastern Indian Ocean pygmy blue whale population either follow the coast or travel further west (McCauley et al. 2018). McCauley et al. (2018) provides an estimate for the annual growth rate of pygmy blue whales at Portland (Victoria) of 4.3% per year. However, described by the authors, this growth rate applies only to the proportion of the population using the south eastern Australian coast, and as such may not reflect the growth rate of the full population. However, in the absence of other population growth estimates, this estimate has been applied as a conservative estimate to the proportion of the population also using the WA coast, in particular the migratory BIA.

Considering an annual growth rate of 4.3%, the two population estimates provided in McCauley and Jenner (2010) and Jenner et al. (2008) have been considered to determine the potential current population, and thus the possible percentage increase to the density estimate derived from the McCauley and Jenner (2010) acoustic detection data, as shown in Table 19 and Table 20 within Chapter 10, Appendix D.3.

Green turtles – animal behaviour

Two behavioural profiles were considered for green turtles, internesting and migrating. The research summarised in this section inform the species behavioural definition adopted in the animal movement and exposure modelling (Table G-1 of Chapter 10, Appendix D.3). Satellite tracking of the green turtle population on Sandy Islet, Scott Reef by Guinea (2011) demonstrated satellite tracked internesting turtles have a maximum dive depth of 45 m and an average dive duration of 15–25 minutes, with a dive duration range of 20 seconds to 55 minutes (Guinea, 2011). Migratory turtle records indicate a maximum dive depth of 80 m (average: 49 m) and an average dive duration of 10–15 minutes.

Internesting turtle swimming speeds are not available for the Scott Reef green turtle population. As such an analogue based on information from a satellite tagging study of green turtle behaviour and movements conducted by the Department of Biodiversity, Conservation and Attractions (DBCA) during the 2018 and 2019 nesting period at Ningaloo has been derived. The inferred average internesting swimming speed for green turtles at Scott Reef adopted for this study was 1.4 km/h.

For the Scott Reef population, the average swim speed of migrating green turtles ranged from 1.3–2.7 km/h (Pendoley 2005, Guinea 2011).

Green turtles – ANIMAT modelling assessment areas

Three areas of interest are defined for the ANIMAT assessment of green turtles:

1. the Scott Reef (Sandy Islet) 20 km habitat critical internesting buffer, as defined in the Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a)
2. an internesting area defined by the 50 m contour around North and South Scott Reef, including the corridor connecting the two reefs. This area was based upon data from green turtle movement when internesting at Scott Reef (Guinea, 2011) which is in depths of <50 m and adopting a conservative approach by incorporating all shallow coral reef habitat for the Scott Reef system into the model.
3. a migratory area based upon data of migrating green turtles from Scott Reef (Guinea, 2011).

Green turtles – density estimates

Based on beach monitoring at Sandy Islet, Scott Reef, Guinea (2011) estimated a green turtle abundance of 779 ± 383 (± SE) in the years 2008 and 2009. For the purposes of calculating a representative density estimate for internesting green turtles, a precautionary upper value of 5000 turtles was adopted, along with the representative estimate of nesting green turtles (1162 individuals). The ANIMAT modelling conservatively assumes the entire population of turtles are evenly distributed within the defined modelling area, whereas literature suggests internesting turtles are concentrated directly adjacent to their nesting location (Guinea, 2011). Accordingly, the density of turtles per km^2 was calculated by dividing the total population number by the area of the defined internesting area. No density estimates were calculated for migrating green turtles as no data were available.

6.3.8.2.2 Modelling Thresholds

Terminology

Potential impacts to marine fauna from underwater noise emissions are typically categorised as follows:

- Mortality or potential mortality – physical injury that may result in the death of an individual.
- Impairment – recoverable injury – physical injury from which an individual is expected to recover.
- Permanent Threshold Shift (PTS) – PTS is considered a reduction in hearing sensitivity from which marine fauna do not recover (permanent hair cell or receptor damage). PTS is considered injurious. Southall et al. (2007) define the minimum exposure criterion for injury as the level at which a single exposure is estimated to cause onset of PTS. This definition is reiterated within the (Finneran, 2016) review of TTS studies where injury is classified as the level necessary to induce 40 dB of TTS. During the initial revision of the marine mammal acoustic thresholds in 2013 the US National Ocean and Atmospheric Administration (NOAA) provided guidance that PTS effects (not TTS) are considered auditory injury (National Oceanic and Atmospheric Administration (NOAA), 2010).
- Temporary Threshold Shift (TTS) or Auditory Fatigue – a temporary reduction in the ability of an individual to perceive sound associated with auditory fatigue. TTS is temporary, and full recovery has been demonstrated in a relatively short timeframes (minutes to hours) (Finneran et al., 2017). Unlike PTS, TTS is not classified as an injurious effect. Ward (1997) concludes that “TTS is within the normal bounds of physiological variability and tolerance and does not represent physical injury”. In addition, Southall et al. (2007) indicates that the onset of tissue injury from noise exposure is considered as PTS-onset, but TTS is not considered as auditory injury because the reduced hearing sensitivity following exposure to intense sound results primarily from fatigue, not loss, of cochlear hair cells and supporting structures, and is reversible. Accordingly, the NMFS does not consider TTS to constitute auditory injury and have explicitly stated this in recent ‘Incidental Take of Marine Mammals’ authorisation notices in the US Federal Register (e.g. Federal Register / Vol. 84, No. 166, August 27 2019).

More recently (Kujawa and Liberman (2009, 2015) demonstrated that high levels of TTS (>40 dB) in mice and guinea pigs can result in neuron degeneration of synaptic contacts between hair cells and nerves (cochlear synaptopathy). In these experiments mice and guinea pigs were exposed to an 8-6 kHz acoustic tone stimulus of 2-hours of continuous noise that resulted in >40 dB of TTS (measured 24 hours post exposure), before returning to normal. In other animal experiments, shorter or less intense noise exposures that result in smaller TTS changes do not result in synaptopathic injury or neuronal loss (Hickox 2014; Fernandez et al., 2015; Jensen et al., 2015, 2017). For example, in studies with animals, 20 - 30 dB TTS generally has not been associated with synaptopathic change, whereas 40 – 50 dB TTS, 24-hour post exposure clearly has been associated with synaptopathic damage (Lichtenhan et al. 2018). Considering PTS onset in marine mammals is conservatively set at the onset of 40 dB of TTS; the high-level TTS exposures in these experiments where synaptopthic injury was observed, would already be classified as a PTS injury for a marine mammal.

+ Masking – no change in the ability of an individual to perceive sound, but biologically meaningful sounds (vocal communication, echolocation, signals and sounds produced by predators or prey) may be drowned out by anthropogenic noise.
+ Behavioural disturbance – typically short-term behavioural responses such as avoidance, displacement, or increased surfacing etc. Occurrence and intensity of behavioural disturbance can be highly variable and depends on a range of factors relating to the individual and situation. Behaviour will return to normal following cessation of the anthropogenic noise.

Sound level thresholds above which injury (PTS), auditory fatigue (TTS) or behavioural disturbance may occur vary widely between species.

Cetaceans

Cetaceans use sound for communication, to navigate, to find food, and avoid predators. Current research shows that cetaceans differ in their hearing capabilities, in both absolute hearing, and as well as the frequency band of hearing (Richardson et al., 1995; Southall et al., 2007; Wartzok and Ketten, n.d.). Southall et al. (2019) defines cetacean into three functional hearing groups based on their frequency hearing ranges:

+ Low-Frequency (LF) cetaceans - all of the mysticetes, i.e. humpback and pygmy blue whale etc.
+ High-frequency (HF) cetaceans - most delphinid species, beaked whales, sperm whales, and killer whales
+ Very-high frequency (VHF) cetaceans - porpoises, most river species, pygmy/dwarf sperm whales as well a number of oceanic dolphins.

Southall et al. (2019) revisited the interim criteria published in 2007; all noise exposure criteria in NMFS (2018) and Southall et al. (2019) are identical (for impulsive and non-impulsive sounds), however the mid-frequency cetaceans from NMFS (2018) are classified as high-frequency cetaceans in Southall et al. (2019), and high-frequency cetaceans from NMFS (2018) are classified as very-high-frequency cetaceans in Southall et al. (2019). The impact assessment continues to apply the terminology from NMFS(2018) for consistency with other projects.

The type and scale of the effect on cetaceans to underwater noise emissions depends on a number of factors including the:

+ the level of exposure
+ the physical environment
+ the location of the animal in relation to the noise source
+ how long the individual is exposed to the noise source
+ the exposure history
+ how often the sound repeats (repetition period)
+ the ambient sound levels.

The context of noise exposure plays a critical and complex role in the way an animal might respond to noise (NMFS, 2018; Southall et al., 2019, 2017).

Table 6-44 and Table 6-45 summarises the impulsive and non-impulsive sound impact thresholds that may result in PTS or TTS or behavioural disturbance to LF cetaceans such as humpback whales.

Table 6-44 Acoustic effects of impulsive noise on marine mammals: unweighted SPL, SEL_{24h}, and PK thresholds

Hearing group	NMFS (2014)	NMFS (2018) & Southall et al. (2019)			
	Behaviour	PTS onset thresholds* (received level)		TTS onset thresholds* (received level)	
	SPL (L_p; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa2·s)	PK ($L_{pk;}$ dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa2·s)	PK ($L_{pk;}$ dB re 1 µPa)
Low-frequency cetaceans	160	183	219	168	213
Mid-frequency cetaceans		185	230	170	224
High-frequency cetaceans		155	202	140	196

* *Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.*

L_p denotes sound pressure level period and has a reference value of 1 µPa.

$L_{pk, flat}$ denotes peak sound pressure is flat weighted or unweighted and has a reference value of 1 µPa.

L_E denotes cumulative sound exposure over a 24 h period and has a reference value of 1 µPa²s.

Table 6-45 Acoustic effects of continuous noise on marine mammals: unweighted SPL and SEL_{24h} thresholds

Hearing group	NMFS (2013)	NMFS (2018); Southall et al. (2019)	
	Behaviour	PTS onset thresholds (received level)	TTS onset thresholds (received level)
	SPL (L_p; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)
Low-frequency cetaceans	120	199	179
Mid-frequency cetaceans		198	178
High-frequency cetaceans		173	153

Marine turtles

There is limited information on marine turtle hearing, migrating turtles may use various acoustic cues, and acoustic disturbances may potentially interfere with their navigational ability (McCauley, 1994). Turtle auditory perception probably occurs through a combination of bone and water conduction (Bartol et al., 1999; Lenhardt, 1982; Lenhardt et al., 1983; Lenhardt and Harkins, 1983). Sea turtle hearing is believed to be limited to low frequencies, between 0.25 – 0.75kHz (Bartol et al., 1999).

Studies indicate that marine turtles began to show behavioural responses to an approaching seismic array (impulsive sound) at received sound levels of 166 dB re 1 µPa (SPL) and behavioural disturbance/avoidance at around 175 dB re 1 µPa (SPL; McCauley et al., 2003; Table 6-46). Startle responses and other behavioural changes are more likely from high level pulsed noise sources such as those produced during seismic surveys, rather than continuous noise sources such as vessels.

Table 6-46 Acoustic effects of impulsive noise on turtles: Unweighted SPL, SEL_{24h}, and PK thresholds

NSF (2011)	Moein et al. (1995)	Finneran et al. (2017)			
Behaviour Response	Behavioural Disturbance/ Avoidance	PTS onset thresholds* (received level)		TTS onset thresholds* (received level)	
SPL (L_p; dB re 1 µPa)		Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	PK (L_{pk}; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	PK (L_{pk}; dB re 1 µPa)
166	175	204	232	189	226

* *Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.*

L_p *denotes sound pressure level period and has a reference value of 1 µPa.*

$L_{pk,flat}$ *denotes peak sound pressure is flat weighted or unweighted and has a reference value of 1 µPa.*

L_E *denotes cumulative sound exposure over a 24 h period and has a reference value of 1 µPa2s.*

Fish

Fish sensitivity and resilience varies greatly depending on the species, hearing capability, habits, proximity to the activity and if the noise occurs during a critical part of the fish lifecycle (McCauley and Salgado Kent, 2008). Fish vary widely in their vocalisations and hearing abilities, but generally hear best at low frequencies below 1 kHz (Ladich, 2013). Majority of fish species are hearing generalists (Amoser and Ladich, 2005) with relatively poor hearing. Hearing generalists are not as sensitive to noise and vibration as hearing specialists, which have developed hearing specialisations and can be particularly vulnerable to noise and particle motion as they possess an air-filled swim bladder (Gordon et al., 2003). Because the presence or absence of a swim bladder has a role in hearing, fish's susceptibility to injury from noise exposure varies depending on the species and the presence and role of the swim bladder in hearing (Popper et al., 2014). Therefore, different thresholds are proposed for fish without a swim bladder, fish with a swim bladder not used for hearing, and fish that use their swim bladders for hearing.

There are a number of fish species that occur in the vicinity of the Project Area, including seahorses, pipefish, sharks, skates and rays, that lack specific studies on hearing and noise sensitivity, however as these species lack a gas filled cavity or swim bladder, they are not as vulnerable to trauma from extreme pressure changes as fish with a gas-filled space. This difference has been demonstrated by comparing the effects of pile driving sounds on fish with and without a swim bladders (Halvorsen et al., 2012). Syngnathids (a family of fish including seahorses, seadragons and pipefish), for example, produce large click sounds during feeding, perhaps for communication, which indicates that sound is important to this group of fish (Bergert and Wainwright, 1997; Colson et al., 1998; Ripley and Foran, 2006). Furthermore, syngnathids can only hear up to approximately 1,500 Hz and have relatively high hearing thresholds (SVT, 2010). Behavioural effects of noise on fish may include changes to schooling behaviour and avoidance of the noise source (Simmonds and MacLennan, 2005).

In contrast, elasmobranches rely on low frequency sound to locate prey (Myrberg, 2001). Elasmobranches or cartilaginous fish (such as sharks and rays) lack a swim bladder and are considered less sensitive to sound than bony fish. The hearing capabilities of the whale shark have not been studied, but it has been suggested that they are likely to be most responsive to low frequency sounds (Myrberg, 2001). Silky sharks (*Carcharhinus falciformis*) have been observed to dive upon ignition of nearby inboard vessel motors, which may be a response to the low frequency sound signature of such motors (Myrberg, 1978)

Pelagic species may avoid sound exposure by swimming away from the source, with one example being recorded by Slotte et al. (2004) who used sonar to observe pelagic blue whiting and Norwegian herring swimming to greater depths after exposure to a seismic source. Review work by Turnpenny and Nedwell (1994) also indicated that pelagic fish swim horizontally away from the sound source, while demersal fish most likely dive toward the bottom or into deeper waters. At some noise level, demersal fish also respond by forming tight schools and reducing their depth (R.D McCauley et al., 2000). However, fish of different sizes (ages) within a single species may show differences in behaviour (Normandeau Associates, 2012).

Furthermore, noise exposure studies conducted by Miller and Cripps (2013) at Scott Reef showed no significant effect of a seismic survey on the overall abundance or species richness of the small demersal site attached Pomacentridae family and non-Pomacentridae larger roving demersal species. The six most abundant fish species were also analysed individually. In all cases no detectable effect of the seismic survey was found on the abundance of these fish species at Scott Reef associated with received cumulative sound exposure levels up to 187 dB re 1 μPa^2.s. This received level is just above the referenced TTS 186 dB re 1 μPa^2.s SEL$_{24h}$ threshold for pile driving as articulated in Popper et al. (2014).

Table 6-47 summarises approximate threshold levels of noise that may result in mortality and potential mortal injury, recoverable injury, TTS, masking and behavioural disturbance to fish, sharks and rays. Although these potential impacts from pile driving and seismic noise are likely to be variable and context-specific, these thresholds are widely accepted as appropriate for the assessment of impacts on receptors from underwater noise, being based on peer-reviewed and published scientific research.

Sea snakes

There is limited information available on hearing in sea snakes, but they are known to be capable of detecting pressure changes (Mick Guinea pers. comm.). However, it is likely that sea snakes rely more heavily on vision and olfaction than on hearing (Hibbard, 1975). Scientific evidence demonstrates that snakes have dual auditory pathways to detect both airborne and ground-borne vibrations using the surface of their body and their inner ears (Young, 2003), and their lower jaws may be stimulated by surface waves and vibrations (Christensen et al., 2012; Friedel et al., 2008).

The research and monitoring program on the potential effects on marine life conducted at Scott Reef for the Woodside Maxima 3D seismic survey demonstrated that the survey did not cause any observed physiological effects or mortality in marine fauna, including sea snakes (Woodside, 2007a, 2007b). In the absence of observations of sea snakes exposed to air gun noise, either of captive individuals or in the field, a conservative and precautionary approach would presume that sea snakes will respond in a similar way as other marine reptiles (e.g. marine turtles), such as exhibiting behavioural change to a sound source. As such, the acoustic impact criterion thresholds for marine turtle behavioural response to anthropogenic sounds are considered a reasonable proxy for sea snakes. However, as quantifiable distances for assessing impacts from continuous sounds only exist for fish, fish have been used as a surrogate for this assessment.

Table 6-47 Criteria for pile driving and seismic noise exposure for fish, adapted from Popper et al. (2014)

Type of animal	Mortality and potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Fish: No swim bladder (particle motion detection)	> 219 dB SEL$_{24h}$ or > 213 dB PK	> 216 dB SEL$_{24h}$ or > 213 dB PK	>> 186 dB SEL$_{24h}$	Pile driving: (N) Moderate (I, F) Low Seismic: (N, I, F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder not involved in hearing (particle motion detection)	210 dB SEL$_{24h}$ or > 207 dB PK	203 dB SEL$_{24h}$ or > 207 dB PK	>> 186 dB SEL$_{24h}$	Pile driving: (N) Moderate (I, F) Low Seismic: (N, I, F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder involved in hearing (primarily pressure detection)	207 dB SEL$_{24h}$ or > 207 dB PK	203 dB SEL$_{24h}$ or > 207 dB PK	186 dB SEL$_{24h}$	Pile driving: (N, I) High (F) Moderate Seismic: (N, I) Low (F) Moderate	(N, I) High (F) Moderate
Fish eggs and fish larvae	> 210 dB SEL$_{24h}$ or > 207 dB PK	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	Pile driving: (N) Moderate (I, F) Low Seismic: (N, I, F) Low	(N) Moderate (I, F) Low

Peak sound pressure level dB re 1 μPa; SEL$_{24h}$ dB re 1μPa^2·s.

All criteria are presented as sound pressure even for fish without swim bladders since no data for particle motion exist.

Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

Plankton

Plankton are a diverse group of organisms defined by their pelagic habitat and inability to swim actively against a current. Some organisms form part of the plankton for only part of their life cycle, e.g. as eggs and larvae. Excluding fish eggs, larvae and other minute planktonic organisms within a few metres of an airgun, no planktonic organisms are likely to be affected significantly by acoustic array discharges (McCauley, 1994). Most studies on effects of impulsive sound have reported damage in fish larvae when they were 1.5 m or closer to airguns and little or no effect has been observed at distances of >5 m with the exception of (Carroll et al., 2017; Fields et al., 2019). McCauley et al. (2017), demonstrated increased mortality at distances up to 1200 m; however, the results in this study are inconsistent with the low mortalities reported in both existing and more recent literature, raising speculation that causes of the higher mortality could be unrelated to the airgun source and rather associated with the cavitation produced from the small sampling boat (Fields et al., 2019). Various aspects of the McCauley et al. (2017) study methodology were reviewed by the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO), which noted that there were some aspects of the study that warrant further investigation (Richardson et al., 2017).

More recently Fields et al.(2019) demonstrated an impulsive airgun source had limited effects on the mortality of Clanus sp (zooplankton) within 10 m of the source and no measurable impact at greater distances.

Sound exposure guidelines published by Popper et al. (2014) are considered the most relevant impulsive noise acoustic threshold for fish eggs and larvae. This threshold indicates that accumulated SEL levels >210 dB re 1 µPa^2.s (SEL$_{24h}$) or >207 dB re 1 µPa (PK) may incur mortality or potential mortal injury to fish eggs and larvae (**Table 6-47**). These thresholds are based on a study by Bolle et al. (2012) using pile driving noise emissions, which found no damage to larval fish at these sound exposure and pressure levels.

Coral and benthic organisms

Currently, there is limited published literature on potential impacts of noise on hard and soft corals. Benthic invertebrates, such as coral, are keystone features of shoals and reefs, but are only sensitive to noise in the nearfield (10-20 m) and therefore will not be sensitive to noise more than 1 km away. Woodside's Maxima study on the potential effects on marine life from seismic noise on Scott Reef estimated that corals required received levels of PK-PK exceeding 260 dB re 1 µPa (SPL) to induce injury (Woodside, 2007a).

Heyward et al. (2018) monitored scleractinian corals, in families Agariciidae and Acroporidae, and soft corals in situ before, during and after the Maxima 3D seismic survey and found no detectable impacts on scleractinian coral mortality, skeletal damage or visible signs of stress immediately after and up to four months following the 3D marine seismic survey. Corals were exposed to noise levels up to 204 dB re 1 µPa^2.s (SEL) and 226 dB re 1 µPa PK (L_{pk}) during this study. It noted that there are studies which have demonstrated sub-lethal impacts to invertebrates from impulsive sound; however' the disparate results between these studies points to the differences in received sound exposure levels and particle motion along with potential noise interference and propagation issues associated with undertaking sound exposure experiments in artificial tanks (Carroll et al., 2017; Popper et al., 2019).

Existing field-based studies that showed no increased mortality on adult populations of marine invertebrates from impulsive seismic sources were articulated by Carroll et al. (2017) and include no increased mortality to; scallops up to ten months after exposure (Harrington et al., 2010; Parry et al., 2002; Przeslawski et al., 2018), clams two days after exposure (La Bella et al., 1996), or lobsters up to eight months after exposure (Day et al., 2016; Payne et al., 2007). Similarly, there was no evidence of mortality-associated population effects such as reduced abundance or catch rates in reef associated invertebrates four days after exposure (Wardle et al., 2001), snow crabs up to 12 days after exposure (Christian et al., 2003), shrimp two days after exposure (Andriguetto-Filho et al., 2005) or lobsters weeks or years after exposure (Parry and Gason, 2006). However, Day et al. (2016) found dose-dependent increase in mortality in transplanted scallops reared in suspended lantern nets four months after repeated exposures to an airgun at very close ranges (5-10 m); however, the observed increase in mortality was still well within the natural mortality range for that species.

6.3.8.2.3 Driven Piling Modelling Results

Cetaceans

At the Torosa piling location the results of the modelling studies indicate the maximum distance to the NMFS (2018) PTS and TTS criteria (SEL$_{24h}$) for LF cetaceans (Table 6-48) are predicted to be within 5.15 km (R$_{max}$) and 26.10 km (R$_{max}$), respectively for the IHC S-600 hammer and within 5.35 km (R$_{max}$) and 29.46 km (R$_{max}$) respectively for the IHC S-1200 hammer (McPherson et al., 2019). For the Brecknock piling location the modelling studies indicate that the maximum distance to the NMFS (2018) PTS and TTS criteria (SEL$_{24h}$) for LF cetaceans (Table 6-48) are predicted to be within 4.58 km (R$_{max}$) and 23.11 km (R$_{max}$), respectively for the IHC S-600 hammer and within 4.62 km (R$_{max}$) and 24.75 km (R$_{max}$) respectively for the IHC S-1200 hammer (McPherson et al., 2019).

However, the radii that correspond to SEL$_{24h}$ typically represent an unlikely worst-case scenario for SEL-based exposure. More realistically, marine fauna (mammals or fish) would not stay in the same location or at the same range for an extended period. Therefore, a reported radius of SEL$_{24h}$ criteria does not mean that any animal travelling within this radius of the source *will* be impacted, but rather that it could be impacted if it remained stationary in that range for the entire period of piling. Because of the conservative nature of the SEL$_{24h}$ criteria when applied in this manner, animal movement and exposure modelling was also undertaken for pygmy blue whales, providing a more accurate and representative assessment of sound exposure.

The maximum distances to the NMFS (2014) PTS and TTS criteria (PK) are associated with the shallowest penetration of 17 m for the both the IHC S-600 and IHC S-1200 hammers (Table 6-48)

Sound level contour maps for piling at each FPSO location have been provided (Figure 6-11 and Figure 6-12).

Table 6-48 Marine mammal injury and hearing sensitivity changes: Maximum-over-depth distances (in km) from the pile to Torosa piling: Maximum-over-depth distances (in km) to frequency-weighted SEL$_{24h}$ based marine mammal PTS and TTS thresholds (NMFS 2018)

Hearing group	PTS				TTS			
	IHC S-600		IHC S-1200		IHC S-600		IHC S-1200	
	R$_{max}$ (km)	R$_{95\%}$ (km)	R$_{max}$ (km)	R$_{95\%}$ (km)	R$_{max}$ (km)	R$_{95\%}$ (km)	R$_{max}$ (km)	R$_{95\%}$ (km)
Torosa								
LF cetaceans	5.15#	5.00#	5.35#	5.12#	26.10#	20.79#	29.46#	22.60#
MF cetaceans	<0.02†		<0.02†		0.03#		0.06#	0.06#
HF cetaceans	0.21†		0.26†		0.35†	0.30#	2.20#	2.06#
Brecknock								
LF cetaceans	4.58#	4.05#	4.62#	4.40#	23.11#	20.04#	24.75#	20.80#
MF cetaceans	<0.02†		<0.02†		<0.02†		0.05#	0.05#
HF cetaceans	0.19†		0.26†		0.36†	0.31#	2.33#	2.20#

† PK (L_{pk}; dB re 1 µPa)

 # Frequency weighted SEL$_{24h}$ ($L_{E,24h}$; dB re 1 µPa^2·s)

For the SEL$_{24h}$ criteria, the model does not account for shutdowns.

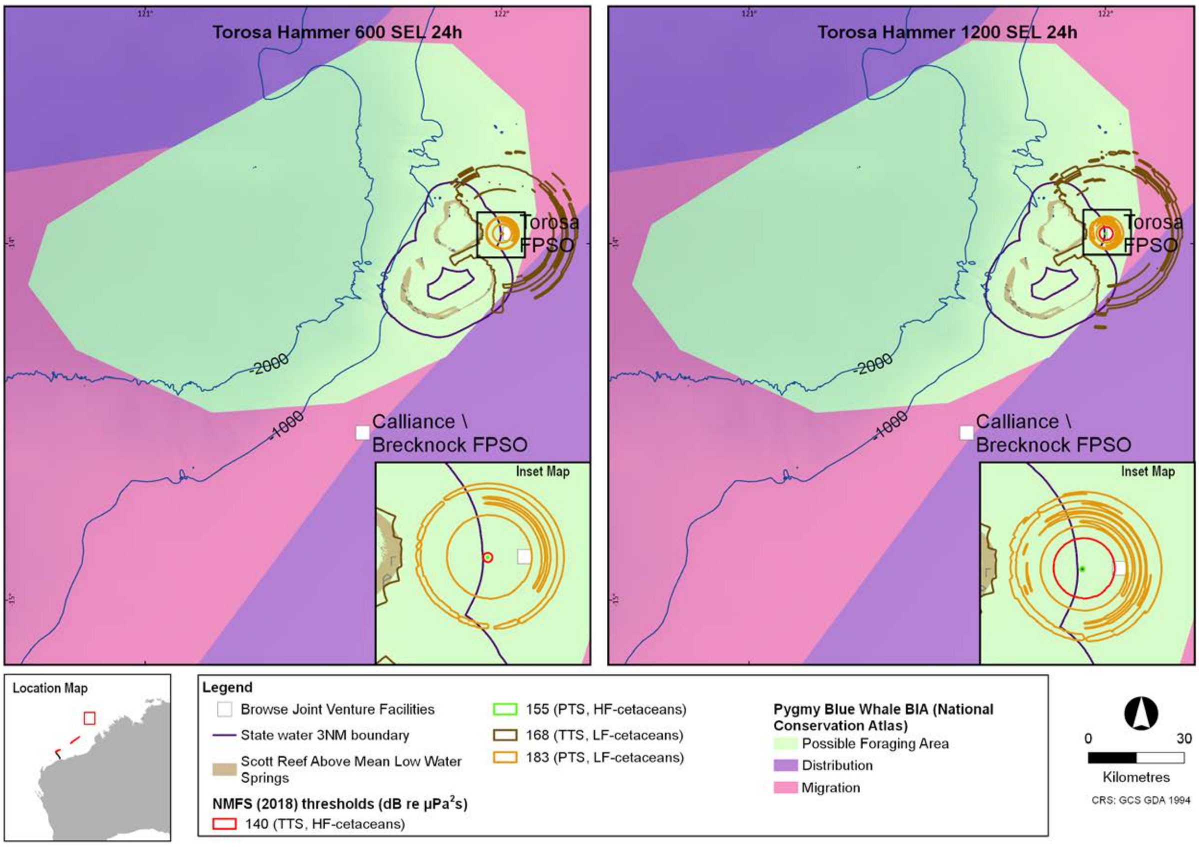

Figure 6-11 Torosa piling - IHC S-600 and IHC S-1200 SPL, 17 m penetration depth: Sound level contour map, showing maximum-over-depth results – cetaceans

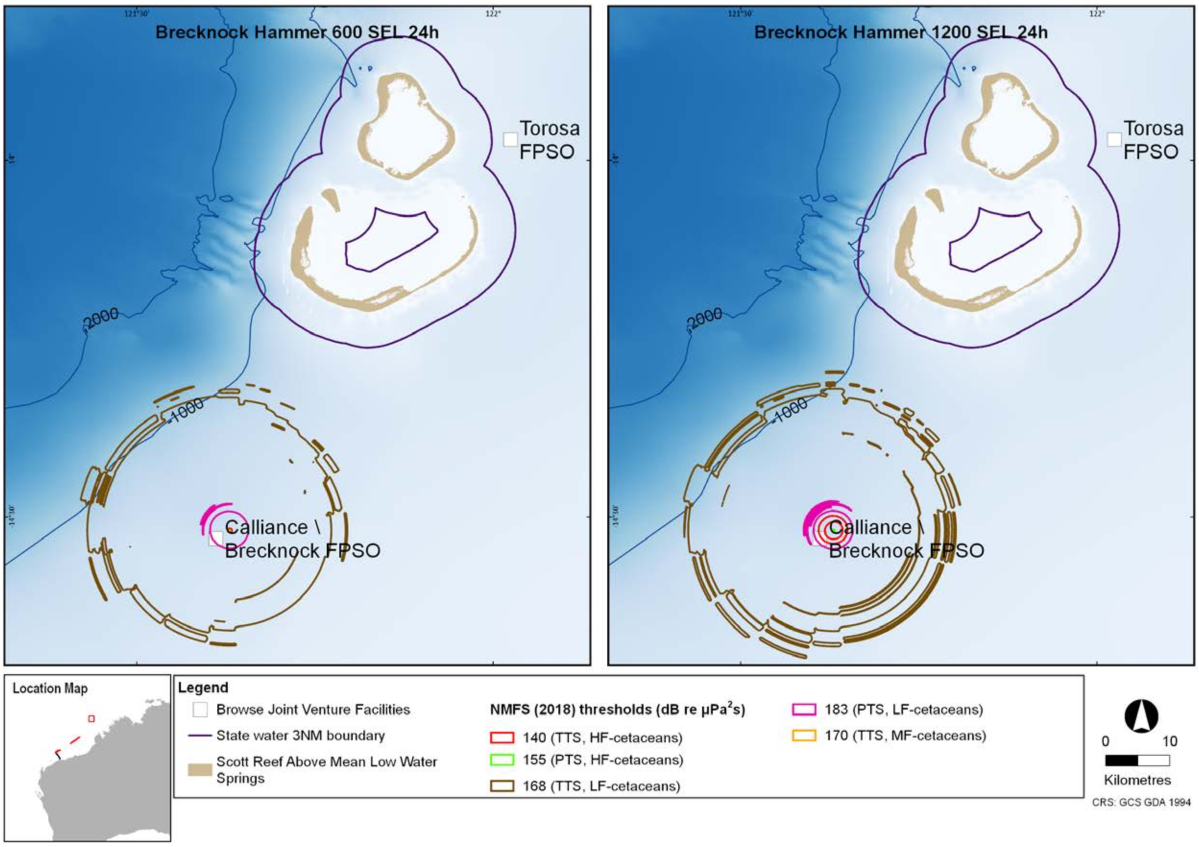

Figure 6-12 Brecknock piling - IHC S-600 and , IHC S-1200 SPL: Sound level contour map, showing maximum-over-depth results - cetaceans

For the Torosa piling location the maximum distances to the NMFS (2014) marine mammal behavioural response criterion of 160 dB re 1 µPa (SPL) are associated with the shallowest penetration of 17 m for the both the IHC S-600 and IHC S-1200 hammers, with the maximum distances of behavioural impacts predicted to be within 10.48 km (R_{max}) and 17.15 km (R_{max}), respectively (Table 6-49 and Figure 6-13). Note that as the pile penetration depth continues to increase the associated behavioral response distance reduces significantly. At the Torosa piling location and for the 45 m penetration depth, distances to behavioural impacts are predicted to reduce to 5.28 km (R_{max}) and 9.68 km (R_{max}) for the IHC S-600 and IHC S-1200 hammers, respectively (Table 6-49)

For the Brecknock piling location the maximum distances to the NMFS (2014) marine mammal behavioural response criterion of 160 dB re 1 µPa (SPL) are also associated with the shallowest penetration of 17 m for the both the IHC S-600 and IHC S-1200 hammers, with the maximum distances of behavioural impacts predicted to be within 7.06 km (R_{max}) and 13.97 km (R_{max}), respectively and reduce further as the piling penetration depth increases (Table 6-49 and Figure 6-14).

Table 6-49 Torosa piling, marine mammal behavioural response thresholds, 160 dB re 1 µPa SPL: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) to modelled maximum-over-depth isopleths per penetration depth

Piling Location	IHC S-600						IHC S-1200					
	Penetration depth (m)						Penetration depth (m)					
	17		31		45		17		31		45	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
Torosa	10.48	6.74	9.14	5.57	5.28	5.11	17.15	11.63	16.29	10.95	9.68	5.51
Brecknock	7.06	6.40	6.40	5.78	4.54	4.41	13.97	11.87	11.51	10.26	6.19	5.61

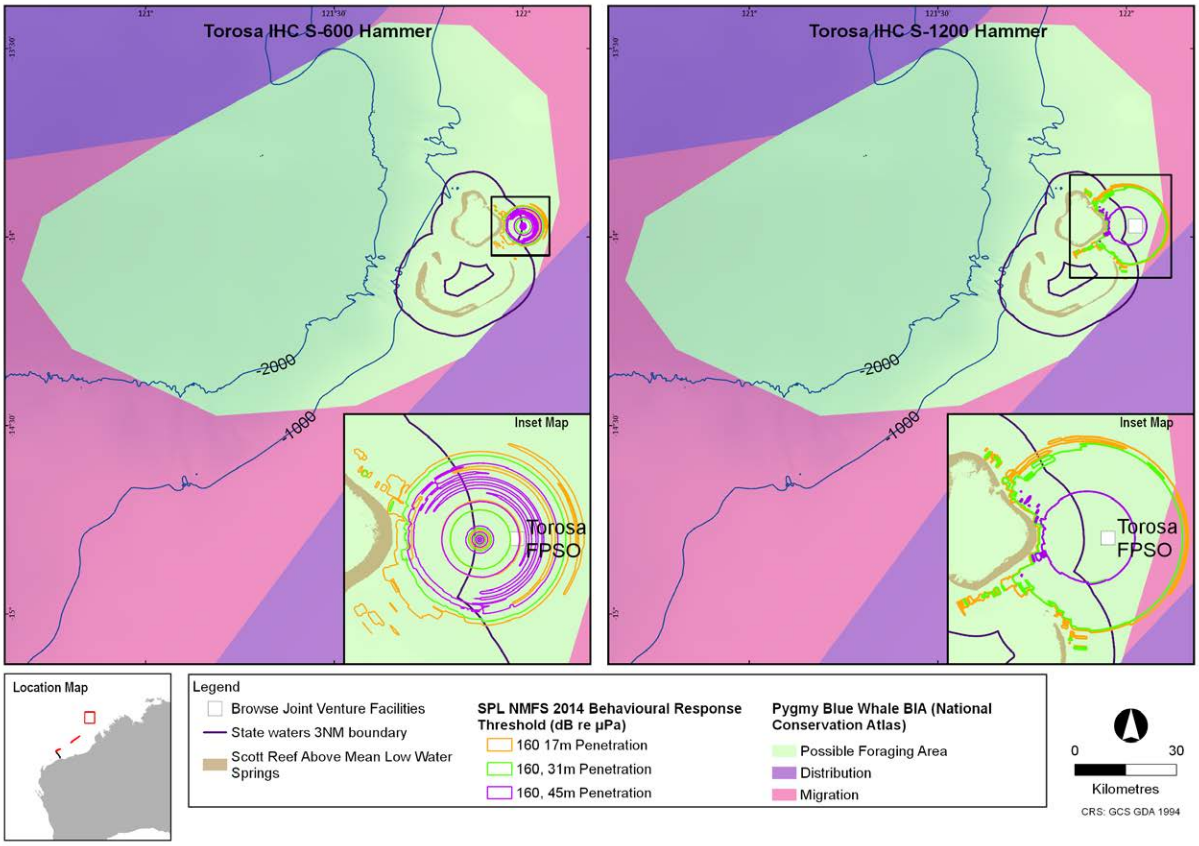

Figure 6-13 Torosa piling - marine mammal behavioural response thresholds, 160 dB re 1 µPa SPL: Maximum (R_{max}) horizontal distances (in km) to modelled maximum-over-depth isopleths per penetration depth

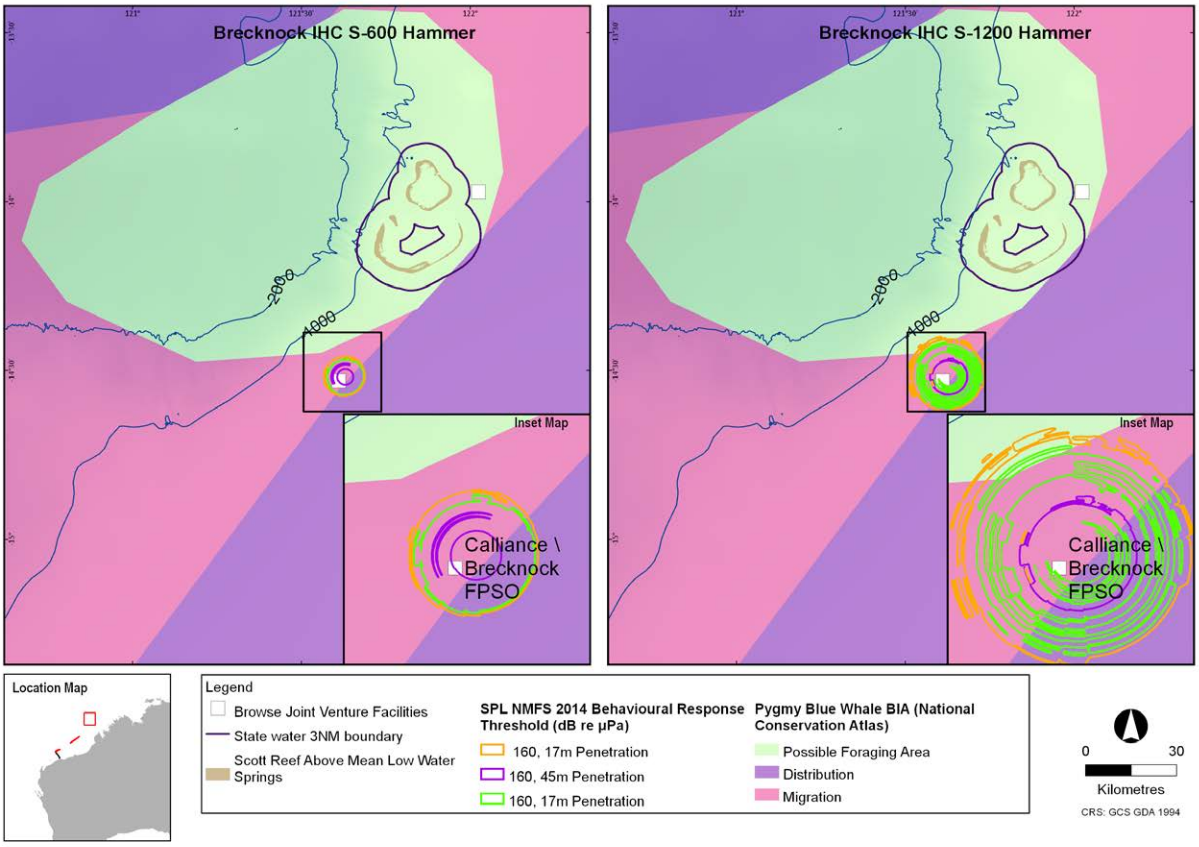

Figure 6-14 Brecknock piling - marine mammal behavioural response thresholds, 160 dB re 1 µPa SPL: Maximum (R_{max}) horizontal distances (in km) to modelled maximum-over-depth isopleths per penetration depth

Pygmy blue whales

The estimated sound fields produced by source and propagation models for the driving of a single pile were incorporated into an animal movement and sound exposure model to estimate the number of potential foraging or migrating pygmy blue whales potentially exposed to levels above defined thresholds. A detailed description of the specific pygmy blue whale behaviour and density inputs that have been incorporated into the model are provided within **Section 6.3.8.2.1**. The range within which 95% of the exposure exceedances occur is reported below, along with the number of individuals that could potentially be exposed above relevant thresholds. Tabulated results are provided in **Table 30** (Torosa) and **Table 39** (Brecknock) of **Chapter 10, Appendix D.3**. A summary of the animal movement and exposure modelling results for Torosa and Brecknock is provided in **Table 6-50**.

Injury - PTS

For both Brecknock and Torosa piling, animal movement modelling simulation results showed that incorporation of shutdowns eliminated any potential for injury to both migrating and possible foraging pygmy blue whales within the DoEE migratory and possible foraging BIAs.

Auditory Fatigue - TTS

For migrating whales at the Torosa location, the IHC S-600 and IHC S-1200 hammers are estimated to expose only 1.05 and 1.13 individual migrating pygmy blue whales per pile above the defined TTS threshold with an estimated exposure range of approximately 7.75 km and 8.58 km (P_{95}), respectively; assuming no mitigation measures are applied. Similarly, at the Brecknock location the IHC S-600 and IHC S-1200 hammers are estimated to expose only 1.26 and 1.45 individual migrating pygmy blue whales above the defined TTS threshold with an estimated exposure range of approximately 7.67 km and 8.18 km (P_{95}).

For possible foraging whales at the Torosa location, the IHC S-600 and IHC S-1200 hammers are estimated to expose only 1.52 and 1.64 individual foraging pygmy blue whales per pile above the defined TTS threshold with an estimated exposure range of approximately 10.84 km and 12.03 km (P_{95}), respectively; assuming no mitigation measures are applied. This equates to only 3.39% overlap with the pygmy blue whale possible foraging area. Similarly, at the Brecknock location the IHC S-600 and IHC S-1200 hammers are estimated to expose only 0.02 and 0.08 individual migrating pygmy blue whales above the defined TTS threshold with an estimated exposure range of approximately 11.19 km and 12.05 km (P_{95}) and only 0.02% and 0.07% of the pygmy blue whale possible foraging area.

Behavioral Response

For migrating whales at the Torosa location, the IHC S-600 and IHC S-1200 hammers are estimated to expose only 0.32 and 1.22 individual animals per pile above the defined behavioral response threshold with an estimated exposure range of approximately 6.87 km and 9.73 km (P95) respectively, assuming no mitigation measures are applied. Similarly, at the Brecknock location the IHC S-600 and IHC S-1200 hammers are estimated to expose only 0.32 and 1.56 individual migrating pygmy blue whales above the defined behavioral response threshold with an estimated exposure range of approximately 3.91 km and 8.73 km (P_{95}). It should be noted that as the pile increases its penetration depth the associated behavioral response levels will decrease significantly (**Table 6-49**); however, when assessing behavioral response the animal movement and exposure modelling only assessed the largest range penetration depth (17 m).

For possible foraging whales at the Torosa location, the IHC S-600 and IHC S-1200 hammers are estimated to expose up to 0.32 and 1.22 individual foraging pygmy blue whales per pile above the defined behavioral response threshold with an estimated exposure range of approximately 6.91 km and 10.83 km (P_{95}), respectively. This equates to approximately 1.2% and 2.8% overlap with the pygmy blue whale possible foraging area. At the Brecknock location, the larger IHC S-1200 hammer is estimated to expose approximately 0.08 individual migrating pygmy blue whales above the defined behavioral response threshold with only 0.07% of the pygmy blue whale possible foraging are ensonifed. Behavioural response levels associated with smaller IHC S-600 hammer piles did not reach the possible foraging area boundary.

The potential number of individual whales exposed to TTS or behavioral response represents a very small proportion of the estimated Eastern Indian Ocean pygmy blue population and reflects the small area of the migratory or possible foraging BIA ensonifed (up to 3.39%). It is important to note that these values are considered a precautionary estimate as the values do not incorporate migration movement, behavioral avoidance, pre-start observations, soft starts, potential TTS recovery between pulses or likely reduction of accumulated sound exposure associated with piling shutdown periods.

Table 6-50 Torosa and Brecknock piling – Summary of animal behaviour and exposure modelling simulation results for migratory and foraging pygmy blue whales (results per individual pile)

Potential Impact	IHC S-600 Hammer – Threshold Exceedance (with 2000 m shutdown exclusion)		IHC S-1200 Hammer - Threshold Exceedance (with 2000 m shutdown exclusion)	
Torosa Piling Location				
	Possible Foraging Area (% spatial overlap)	**Migrating BIA**	**Possible Foraging Area** (% spatial overlap)	**Migrating BIA**
PTS - Injury	No	No	No	No
TTS – Auditory Fatigue	1.52 Individuals* (2.8%)	1.05 individuals*	1.64 individuals* (3.39%)	1.65 individuals*
Behavioural Response (17m penetration depth)	0.43 Individuals* (1.2%)	0.32 individuals*	1.28 individuals* (2.84%)	1.22 individuals*
Brecknock Piling Location				
	Possible Foraging BIA (% spatial overlap)	**Migrating BIA**	**Possible Foraging BIA** (% spatial overlap)	**Migrating BIA**
PTS - Injury	No	No	No	No
TTS – Auditory Fatigue	0.02 Individuals* (0.02%)	1.26 individuals*	0.08 individuals* (0.07%)	1.45 individuals*
Behavioural Response (17m penetration depth)	No	0.32 individuals*	0.08 individuals* (0.7%)	1.65 individuals*

* *Animal movement and exposure modelling results are precautionary as they do not incorporate migratory travel direction, behavioural avoidance, industry standard pre-start observations and soft starts, reduction of cumulative sound exposure associated with pausing and restarting piling to account for potential shutdowns or potential TTS recovery between pulses.*

Marine turtles

At the Torosa piling location the results of the acoustic modelling indicated the maximum distance to the Finneran et al. (2017) PTS and TTS criteria (SEL_{24h}) for marine turtles are predicted to be within 0.25 km (R_{max}) and 5.07 km (R_{max}), respectively (**Figure 6-15**). As displayed within **Table 6-20**, the maximum range (R_{max}) of TTS associated with Torosa piling is considered conservative, as there is a large portion of this R_{max} distance that is not ensonifed above TTS levels. For example, the $R_{95\%}$ distance for the IHC S-600 hammer is significantly smaller than the R_{max} distance, 2.36 km and 4.79 km, respectively.

At the Brecknock piling location the maximum distance to the Finneran et al. (2017) PTS and TTS criteria (SEL_{24h}) for marine turtles are predicted to be within 0.25 km (R_{max}) and 2.06 km (R_{max}), respectively (**Figure 6-16**). These impact ranges are based on the cumulative SEL_{24h} metric; therefore, PTS would only occur if individuals remained stationary within these ranges for the duration of piling at the depth of the loudest received level, without consideration of the turtle's behaviour or movement, which is unlikely to occur.

At the Torosa piling location the maximum distances to the NSF (2011) marine turtle behavioural response criterion of 166 dB re 1 μPa (SPL) are associated with the shallowest penetration of 17 m for the both the IHC S-600 and IHC S-1200 hammers, with the maximum distances predicted to be within 5.11 km (R_{max}) and 9.11 km (R_{max}), respectively. The maximum distances to the Moein et al. (1995) turtle behavioural disturbance criterion of 175 dB re 1 μPa (SPL) are also associated with the shallowest penetration of 17 m for the both the IHC S-600 and IHC S-1200 hammers (McPherson et al., 2019). As the piling penetration depth increases, the behavioural response and disturbance distances reduce significantly; for example, at 45 m penetration depth the IHC-600 hammer range to behavioural response and behavioural disturbance reduces to 950 m and 250 m, respectively (**Table 6-51**).

For the Torosa FPSO piling location only the larger IHC S-1200 hammer exceeds the marine turtle behavioural response criteria (166 dB re 1 μPa; 17 m penetration, greatest distance) within the Scott Reef (Sandy Islet) 20 km habitat critical internesting buffer area. The area ensonified) is predicted to overlap 0.2% of the Scott Reef (Sandy Islet) 20 km habitat critical internesting buffer area, therefore highly unlikely to displace internesting turtles from this habitat. Moreover, as outlined above, as the pile reaches deeper penetration depths (30 m and 43 m below seabed), the behavioural response range reduces significantly and no longer overlaps the Scott Reef (Sandy Islet) 20 km habitat critical internesting buffer area.

For the Brecknock piling location, for both the IHC S-600 and IHC S-1200 hammer, there is no overlap of the predicted behavioural response ensonified area with the Scott Reef (Sandy Islet) 20 km habitat critical internesting buffer area. At the Brecknock piling location the maximum distances to the NSF (2011) turtle behavioural response criterion of 166 dB re 1 μPa (SPL) are associated with the shallowest penetration of 17 m for the both the IHC S-600 and IHC S-1200 hammers, with the maximum distances of behavioural impacts predicted to be within 2.87 km (R_{max}) and 6.38 km (R_{max}), respectively. The maximum distances to the Moein et al. (1995) turtle behavioural disturbance criterion of 175 dB re 1 μPa (SPL) are also associated with the shallowest penetration of 17 m for the both the IHC S-600 and IHC S-1200 hammers, with the maximum distances of behavioural impacts predicted to be within 0.67 km (R_{max}) and 1.87 km (R_{max}), respectively (McPherson et al., 2019). As the piling penetration depth increases, the behavioural response and disturbance distances reduce significantly; for example, at 45 m penetration depth the IHC-600 hammer range to behavioural response (166 dB) and behavioural disturbance (175 dB) reduces to 840 m and 280 m, respectively (**Table 6-52**).

When incorporating green turtle movement into the sound exposure model for both IHC S-600 and IHC S-1200 hammers at Torosa and Brecknock locations, results demonstrate that it is not credible that any green turtle (internesting or migrating) would be exposed to levels associated with injury (PTS) (**Table 6-53**). Accordingly, no turtles within the Scott Reef (Sandy Islet) 20 km habitat critical internesting buffer area would be exposed to received levels associated with injury.

When incorporating green turtle movement into the sound exposure model for FPSO anchor piling, results demonstrate that green turtles within the Scott Reef (Sandy Islet) 20 km habitat critical internesting buffer area are not exposed to sound levels associated with injury (PTS), auditory fatigue (TTS) or behavioural disturbance (175 dB). Only the larger IHC S-1200 hammer exceeded the behavioural response (166 dB) threshold within the Scott Reef (Sandy Islet) 20 km habitat critical internesting buffer area and this is limited to the 17 m shallow penetration depth. Results demonstrate it is highly unlikely (0.15 turtles per pile) that turtles would be exposed to received sound levels above behavioural response thresholds. This is a conservative assessment as it assumes a population of 5000 turtles, all distributed evenly within the Scott Reef (Sandy Islet) 20 km habitat critical internesting buffer area. The 'Recovery Plan for Marine Turtles in Australia 2017-2027' (Commonwealth of Australia, 2017) states a population of between 1,000 and 5,000 individuals utilise Sandy Islet for breeding. When scaling results for a lower estimated population of 1,162 turtles (Guinea, 2011), evenly distributed within the Scott Reef (Sandy Islet) 20 km habitat critical internesting buffer area, results demonstrate 0.03 turtles per pile would be exposed to received sound levels above behavioural response thresholds.

Furthermore, the available literature indicates that green turtles are highly unlikely to exceed depths greater than 40 m during internesting (Hays et al., 2000; Guinea, 2010). Therefore, an assessment against the Scott Reef 50 m contour internesting area, demonstrates that received sound levels that could cause behavioural responses in turtles are not exceeded within this area with no animals exposed.

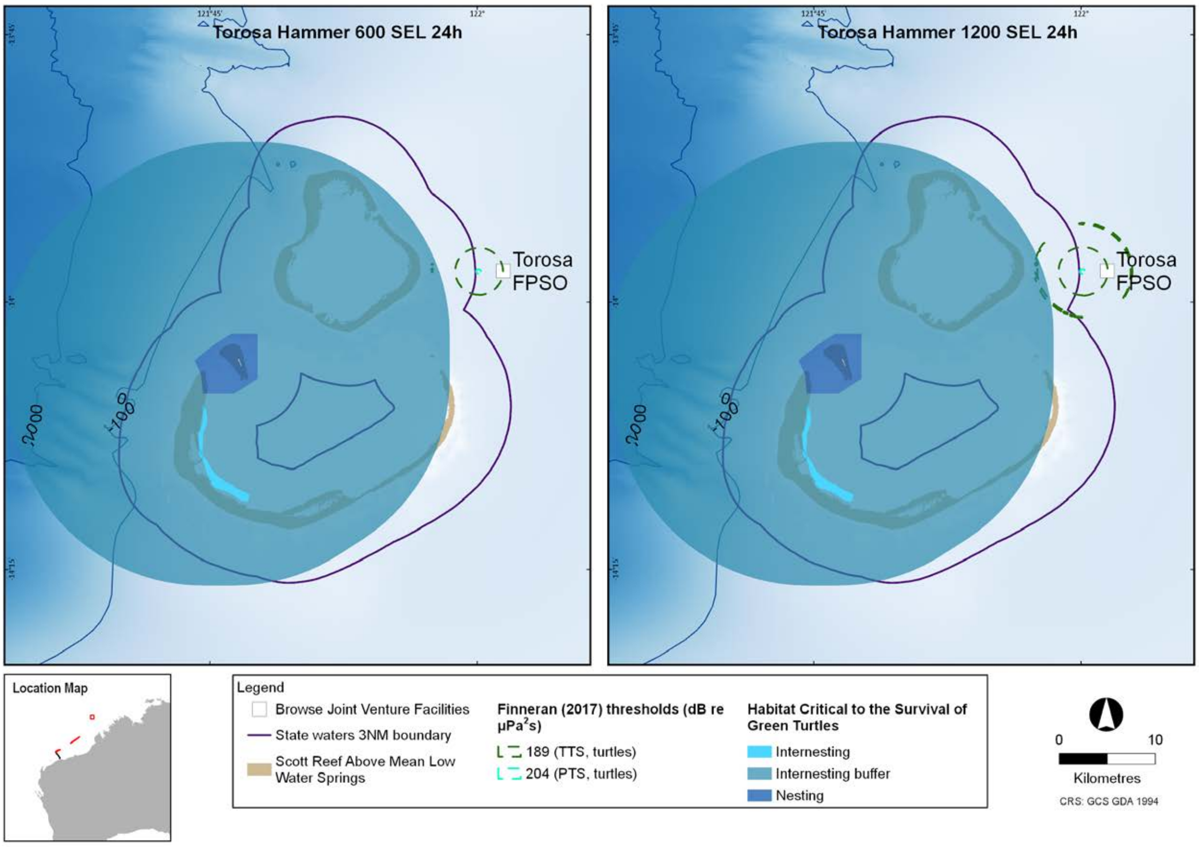

Figure 6-15 Torosa piling - IHC S-600 and , IHC S-1200 SPL: Sound level contour map, showing maximum-over-depth results – marine turtles

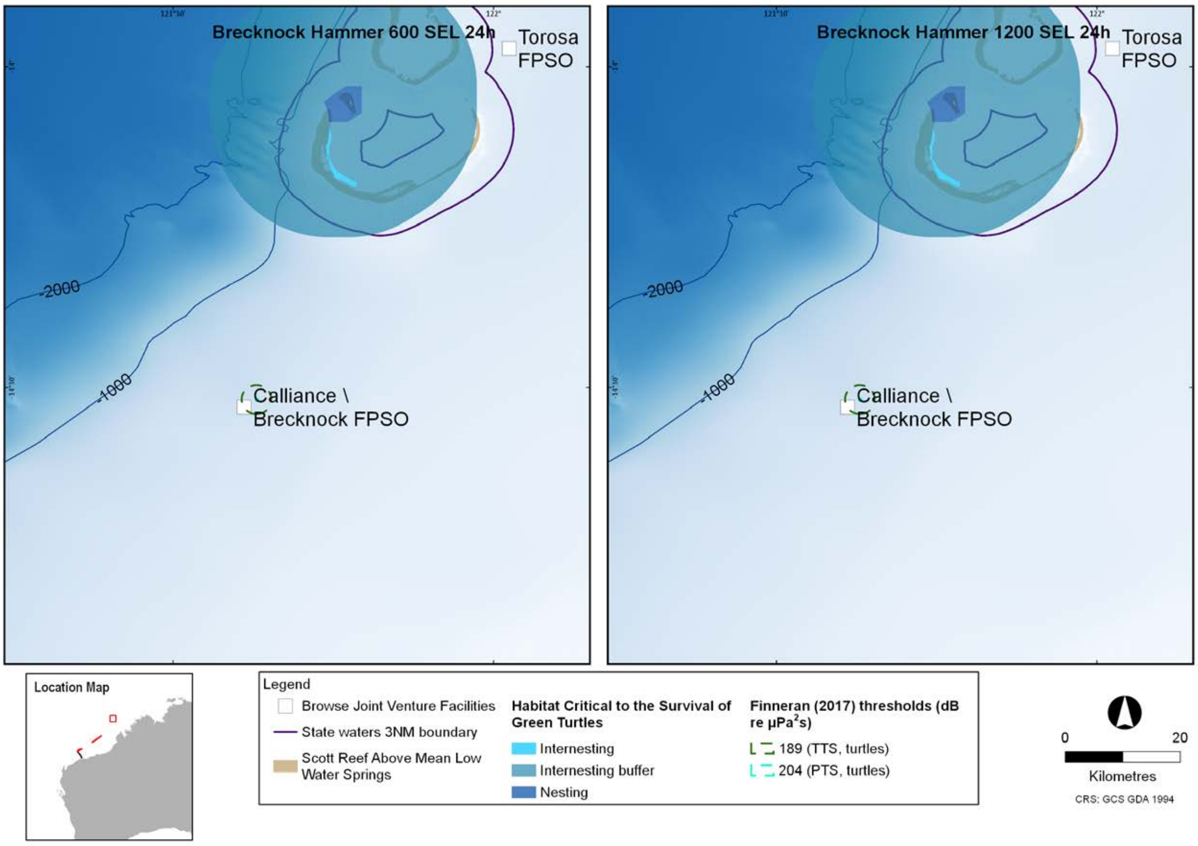

Figure 6-16 Brecknock piling – IHC S-600 and , IHC S-1200 SPL,: Sound level contour map, showing maximum-over-depth results – marine turtles

Table 6-51 Torosa piling, turtle behavioural response thresholds, SPL: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the pile to modelled maximum-over-depth isopleths per penetration depth

Threshold	IHC S-600						IHC S-1200					
	Penetration depth (m)						Penetration depth (m)					
	17		31		45		17		31		45	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
Turtle behaviour, SPL: 166 dB re 1 µPa (NSF 2011)	5.11	4.99	2.07	1.97	0.95	0.91	9.11	5.66	9.06	5.46	4.84	4.46
Turtle behaviour, SPL: 175 dB re 1 µPa (Moein et al., 1995)	0.68	0.64	0.43	0.40	0.29	0.28	1.87	1.79	0.72	0.69	0.48	0.46

Table 6-52 Brecknock piling, turtle behavioural response thresholds, SPL: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the pile to modelled maximum-over-depth isopleths per penetration depth

Threshold	IHC S-600						IHC S-1200					
	Penetration depth (m)						Penetration depth (m)					
	17		31		45		17		31		45	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
Turtle behaviour, SPL: 166 dB re 1 µPa (NSF 2011)	2.87	2.70	2.06	1.95	0.84	0.80	6.38	5.92	5.93	5.51	2.12	2.04
Turtle behaviour, SPL: 175 dB re 1 µPa (Moein et al. 1995)	0.67	0.63	0.42	0.39	0.28	0.26	1.87	1.77	0.69	0.64	0.45	0.42

Table 6-53 Torosa FPSO piling – Summary of animal behaviour and exposure modelling (ANIMAT) for migratory and internesting turtles

Potential Impact	IHC S-600 Hammer – Threshold Exceedance (no shutdown exclusion)			IHC S-1200 Hammer – Threshold Exceedance (no shutdown exclusion)		
	Green turtle habitat critical (20 km radius internesting buffer around Sandy Islet)	*Internesting – Scott Reef 50 m depth contour*	*Migrating turtles*	*Green turtle habitat critical (20 km radius internesting buffer around Sandy Islet)*	*Internesting – Scott Reef 50 m depth contour*	*Migrating Turtles*
PTS - Injury	No	No	No	No	No	No
TTS – Auditory Fatigue	No	No	1.69 km*	No	No	1.81 km*
Behavioural Response	No	No	2.54 km*	No	6.4 km* (0.15 individuals per pile)	4.71 km*
Behavioural Disturbance/ Avoidance	No	No	No	No	No	1.78 km*

* *Animal movement and exposure modelling results presented here do not incorporate shutdowns, behavioural avoidance, migratory travel direction, or industry standard pre-start observations or soft starts. Distances from source are presented as 95% probability of exposure.*

Fish

For the most sensitive fish groups (fish with swim bladder involved in hearing) the distance from pile driving at the Torosa location at which sound levels could exceed mortality and potential mortal injury are predicted to be within 210 m (SEL_{24h}) for the IHC S-600 hammer, and 220 m (SEL_{24h}) for the IHC S-1200 hammer (Table 6-54; Figure 6-17). For the Brecknock location, the distance at which sound levels could exceed mortality and potential mortal injury are predicted to be within 200 m (SEL_{24h}) for the IHC S-600 hammer, and 220 m (SEL_{24h}) for the IHC S-1200 hammer (Table 6-55; Figure 6-18).

For fish, including sharks, the distance from pile driving at the Torosa location, which sound levels could exceed TTS are predicted to be within 9.05 km (SEL_{24h}) for the IHC S-600 hammer, and 9.15 km (SEL_{24h}) for the IHC S-1200 hammer (Table 6-54). For the Brecknock location, the distance which sound levels could exceed TTS are predicted to be within 6.12 km (SEL_{24h}) for the IHC S-600 hammer, and 6.27 km (SEL_{24h}) for the IHC S-1200 hammer (Table 6-55).

However, the radii that correspond to SEL_{24h} typically represent an unlikely worst-case scenario for SEL-based exposure. More realistically, marine fauna (pelagic and demersal fish species) would not stay in the same location or at the same range for an extended period. Therefore, a reported radius of SEL_{24h} criteria does not mean that any animal travelling within this radius of the source *will* be impacted, but rather that it *could* be impacted if it remained in that range for the entire period of driving a single pile.

Table 6-54 Torosa piling fish effect thresholds - Summary of maximum fish, fish eggs, and larvae injury and TTS onset distances for single impulse and SEL_{24h} modelled scenarios

Relevant hearing group	Effect criteria	IHC S-600		IHC S-1200	
		Metric associated with longest distance to effect criteria	R_{max} (km)	Metric associated with longest distance to effect criteria	R_{max} (km)
Fish: No swim bladder	Injury	PK	0.08	PK	0.1
	TTS	SEL_{24h}	9.05	SEL_{24h}	9.15
Fish: Swim bladder not involved in hearing	Injury	SEL_{24h}	0.15	PK	0.17
	TTS	SEL_{24h}	9.05	SEL_{24h}	9.15
Fish: Swim bladder involved in hearing	Injury	SEL_{24h}	0.21	SEL_{24h}	0.22
	TTS	SEL_{24h}	9.05	SEL_{24h}	9.15
Fish eggs, and larvae	Injury	SEL_{24h}	0.15	PK	0.17

Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing

Table 6-55 Brecknock piling fish effect thresholds - Summary of maximum fish, fish eggs, and larvae injury and TTS onset distances for single impulse and SEL_{24h} modelled scenarios

Relevant hearing group	Effect criteria	IHC S-600		IHC S-1200	
		Metric associated with longest distance to effect criteria	R_{max} (km)	Metric associated with longest distance to effect criteria	R_{max} (km)
Fish: No swim bladder	Injury	PK	0.04	PK	0.07
	TTS	SEL_{24h}	6.12	SEL_{24}	6.27
Fish: Swim bladder not involved in hearing	Injury	SEL_{24h}	0.14	PK	0.16
	TTS	SEL_{24h}	6.12	SEL_{24h}	6.27
Fish: Swim bladder involved in hearing	Injury	SEL_{24h}	0.20	SEL_{24h}	0.22
	TTS	SEL_{24h}	6.12	SEL_{24h}	6.27
Fish eggs, and larvae	Injury	SEL_{24h}	0.14	PK	0.16

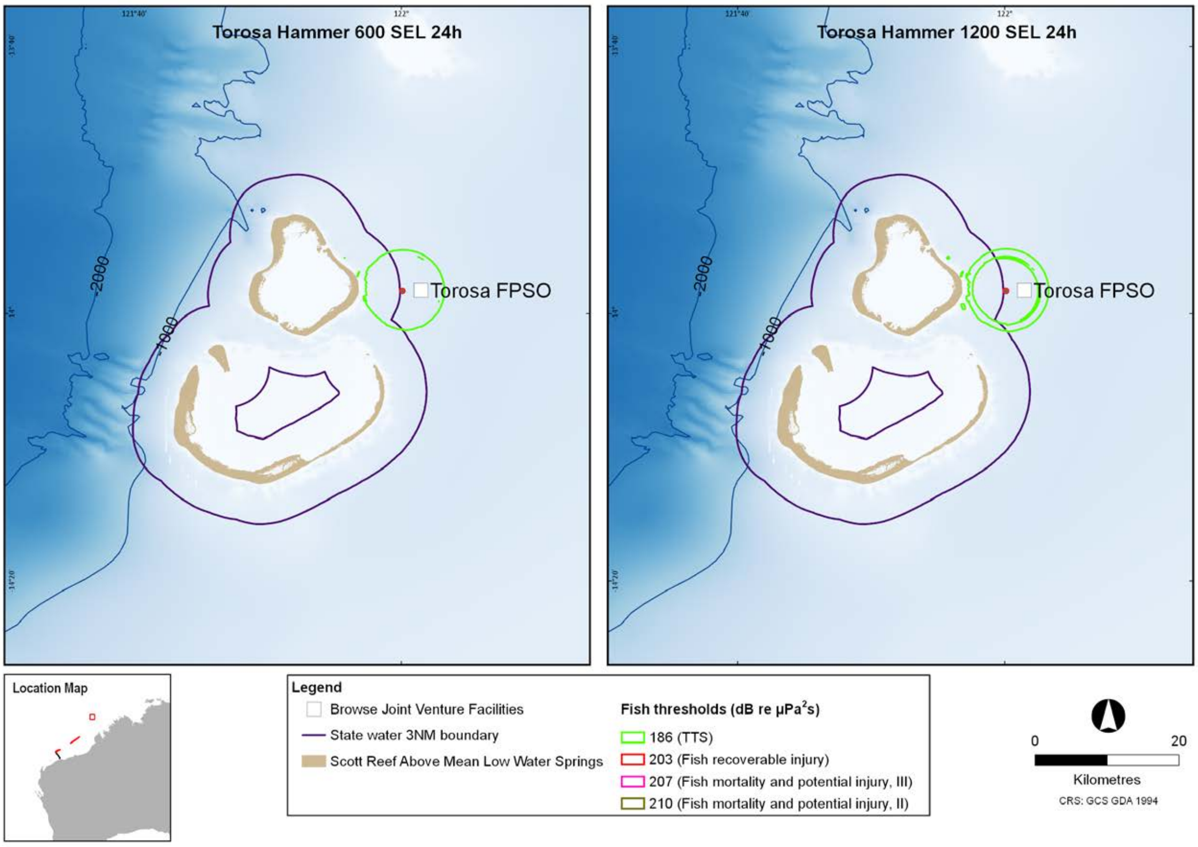

Figure 6-17 Torosa piling - IHC S-600 and IHC S-1200 SPL, 17 m penetration depth: sound level contour map, showing maximum-over-depth results. Isopleths for fish (SEL_{24h}) mortality and potential injury, fish recoverable injury and TTS criteria are shown

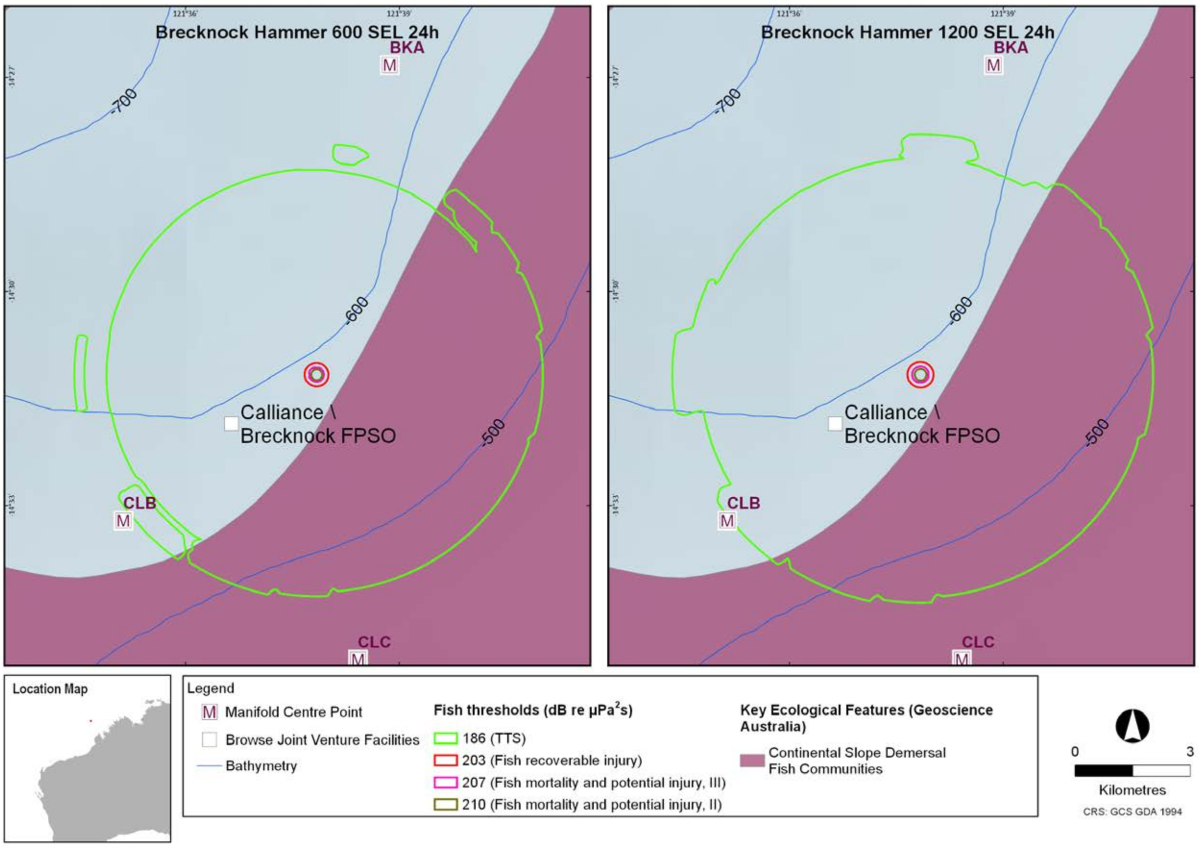

Figure 6-18 Brecknock piling - IHC S-600 and IHC S-1200 SPL, 17 m penetration depth: sound level contour map, showing maximum-over-depth results. Isopleths for fish (SEL_{24h}) mortality and potential injury, fish recoverable injury and TTS criteria are shown

Plankton

At the Torosa and Brecknock piling locations the results of the modelling studies indicate the maximum distance to the (Popper et al., 2014) criteria (SEL_{24h}) for plankton, fish eggs and larvae mortality and potential mortal injury are predicted to be within 150 m and 170 m, respectively (**Table 6-55**; **Table 6-56**) Distances to the maximum mortality and potential mortal recoverable injury thresholds (PK) distances are predicted to be within 127 m of the IHC S-600 hammer and within 166 m of the IHC S-1200 hammer. Therefore, at both locations, during piling noise levels of 210 dB re 1 μPa^2.s (SEL_{24h}) or 210 dB re 1 μPa (PK) using the IHC S-600 and IHC S-1200 hammer are not predicted to reach the reef edge at Scott Reef.

6.3.8.2.4 MODU with DP Modelling Results

Cetaceans

At the Torosa TRD location for the MODU with DP, the results of the modelling studies indicate the maximum distance to the NMFS (2018) PTS and TTS criteria (SEL_{24h}; R_{max}) for LF cetaceans are predicted to be within 110 m (PTS) and 1.49 km (TTS) of the MODU (**Table 50**, **Chapter 10, Appendix D.3**). The results of the modelling studies also indicated that the maximum distance to the NMFS (2014) marine mammal behavioural response to continuous noise criteria (SPL; $R_{max)}$ is predicted to be within 10.5 km of the MODU.

At the Brecknock location for the MODU with DP, the results of the modelling studies indicate the maximum distance to the NMFS (2018) PTS and TTS criteria (SEL_{24h}; R_{max}) for LF cetaceans are predicted to be within 110 m (PTS) and 1 km (TTS) of the MODU. The results of the modelling studies also indicated the maximum distance to the NMFS (2014) marine mammal behavioural response to continuous noise criteria (SPL; R_{max}) are predicted to be within 8.84 km of the MODU.

The above ranges to PTS and TTS do not incorporate animal movement and behaviour are based on the assumption the marine mammal is stationary within these ranges for a 24-hour period, which is highly unlikely to occur.

At the Torosa TRD location, MODU with DP noise levels of 120 dB re 1 μPa (SPL) are predicted to reach the reef edge of North and South Scott Reef, as well as within the channel between North and South Scott Reef, along the southern edge of North Scott Reef (**Figure 6-19**), whereas at Brecknock, noise levels of 120 dB re 1 μPa (SPL) are not predicted to reach the reef edge of South Scott Reef.

At the Torosa TRD location, the area ensonified from the MODU within the marine mammal behaviour criteria (120 dB re 1 μPa) is predicted to overlap 0.9% of the pygmy blue whale possible foraging area, leaving 99% of the possible foraging area available to pygmy blue whales and uninterrupted foraging.

At the Brecknock location, the area ensonified from the MODU within the marine mammal behaviour criteria (120 dB re 1 μPa) is predicted to overlap 1.5% of the pygmy blue whale possible foraging BIA leaving ~98% of the possible foraging BIA available to pygmy blue whales and uninterrupted foraging.

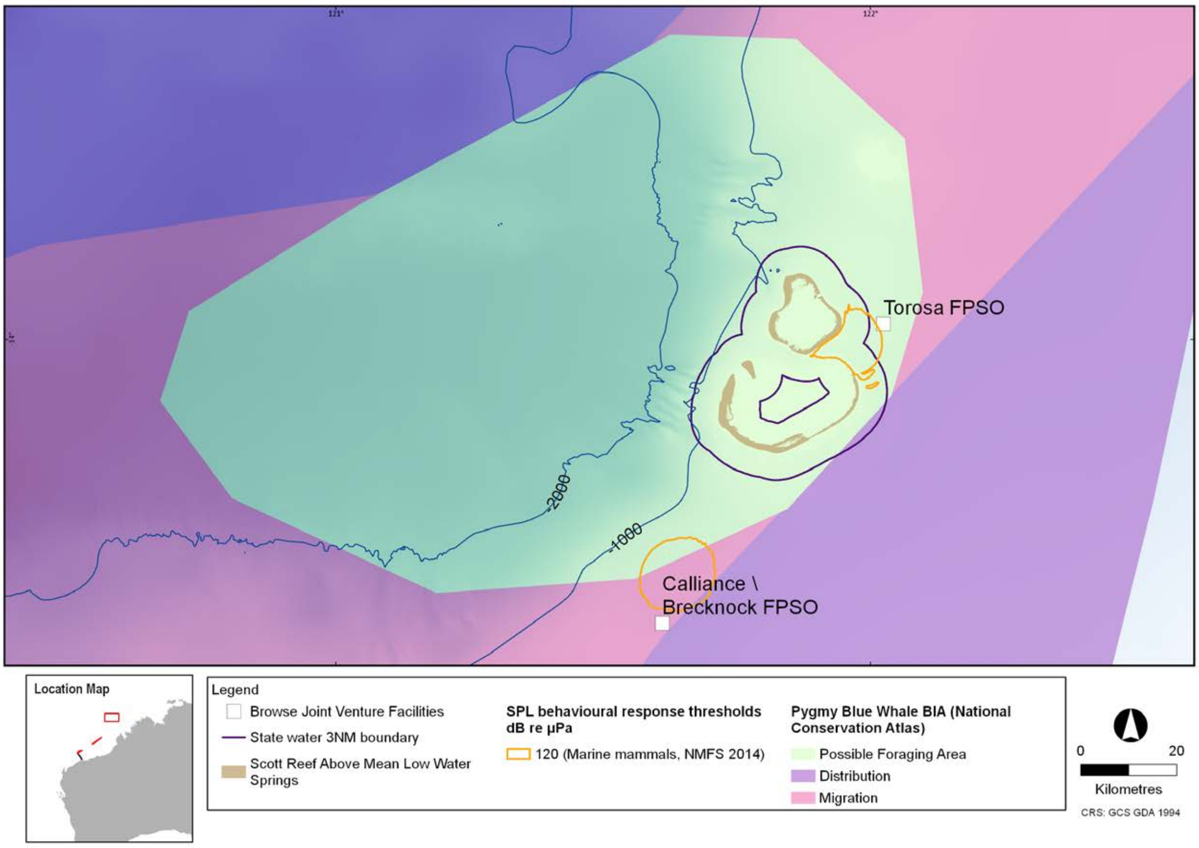

Figure 6-19 MODU SPL: Sound level contour map showing maximum-over-depth results. Isopleths for marine mammal (120 dB re 1 µPa) behavioural criteria are shown

Marine turtles

At the Torosa TRD location the results of the modelling studies in Table 6-56 indicate the maximum distance to the Finneran et al. (2017) PTS and TTS criteria (SEL_{24h}; R_{max}) for marine turtles are predicted to be associated with the MODU with DP within 60 m and 130 m, respectively (Table 6-56; McPherson et al., 2019).

As previously described above, radii that correspond to SEL_{24h} typically represent an unlikely worst-case scenario for SEL-based exposure that doesn't incorporate animal movement or behaviour. Therefore, the reported radius of SEL_{24h} criteria does not mean that any animal travelling within this radius of the source *will* be impacted, but rather that it could be impacted if it remained stationary in that range for a 24-hour period.

Fish

Sound produced by the MODU operations on DP could cause physiological effects, and recoverable injury, to some fish species, but only if the animals are in very close proximity to the sound sources–within a planar distance of 60 m, for 48 hours (McPherson et al., 2019). Temporary impairment due to TTS could occur at similar short distances if fish remain at the same point within the sound field for long periods of time (12 h) (Table 6-57).

Table 6-56 MODU with DP, SEL_{24h}: Maximum-over-depth distances (in km) to PTS and TTS turtles (Finneran et al. 2017)

SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Distance R_{max} (km)
	MODU with DP
Torosa (TRD)	
PTS - 220†	0.06
TTS - 200†	0.13
Brecknock	
PTS - 220†	0.06
TTS - 200†	0.13

A dash indicates the level is not reached.

Table 6-57 MODU with DP SPL, fish effect thresholds: maximum (R_{max}) horizontal distances (km) from the vessels to modelled maximum-over-depth SPL thresholds based on the quantifiable thresholds for fish with a swim bladder involved in hearing (Popper et al. 2014)

SPL (L_p; dB re 1 µPa)	MODU with DP	
	R_{max} (km)	$R_{95\%}$ (km)
Torosa (TRD)		
170†	0.06	0.06
158#	0.06	0.06
Brecknock		
170†	0.06	0.06
158#	0.06	0.06

† Recoverable injury

 # TTS

6.3.8.2.5 Well VSP Modelling Results

Cetaceans

At the Torosa TRD Well location the results of the VSP modelling studies indicate the maximum distance to the NMFS (2018) PTS and TTS criteria (SEL_{24h}) for LF cetaceans (**Table 6-58**) are predicted to be within 200 m and 1.69 km, respectively, for 150 impulses. PTS levels will not be reached until there has been > 9 impulses, i.e. after 10 impulses the modelling study predicts PTS within 40 m of the source. TTS levels will be reached after 1 impulse at 90 m from the source.

At the Brecknock well location the results of the VSP modelling studies indicate the maximum distance to the NMFS (2018) PTS and TTS criteria (SEL_{24h}) for LF cetaceans (**Table 6-59**) are predicted to be within 200 m and 1.69 km, respectively for 150 impulses. Correspondingly, PTS levels will not be reached until there has been > 9 impulses, i.e. after 10 impulses the modelling study predicts PTS within 40 m of the source. TTS levels will be reached after 1 impulse at 90 m from the source.

The results for the criteria applied for marine mammal PTS (NMFS, 2018), consider both metrics within the criteria (PK and SEL_{24h}), and a range of impulses within 24 hours, from 1 to 150. The applicable metric from the criteria, associated with the longest distance associated with either metric, depends upon the number of impulses within 24 hours. The ranges presented are based upon no more than 150 impulses within 24 hours.

PTS and TTS are not predicted to occur in mid-frequency cetaceans. For PTS in high-frequency cetaceans, the PK metric is always associated with the longest range (68 m; Torosa and Brecknock), while for PTS in low-frequency cetaceans, for less than 10 impulses the range is greater due to the PK metric (12 m; Torosa and Brecknock), but otherwise the range is determined by SEL_{24h}, with the maximum distance of 200 m being associated with 150 impulses at either Torosa TRD Well or Brecknock.

For TTS in high-frequency cetaceans the PK metric is always associated with the longest range (141 m), while for TTS in low-frequency cetaceans the range for five or more impulses is determined by SEL_{24h}, with the maximum distance of 1.69 km for 150 impulses at both the Torosa and Brecknock well locations (**Table 6-60**).

As previously described above, radii that correspond to SEL_{24h} typically represent an unlikely worst-case scenario for SEL-based exposure that doesn't incorporate animal movement or behaviour. Therefore, the reported radius of SEL_{24h} criteria does not mean that any animal travelling within this radius of the source *will* be impacted, but rather that it *could* be impacted if it remained stationary in that range for the entire period of VSP.

At both the Torosa TRD and Brecknock well locations, the results of the VSP modelling studies indicate that the maximum distances to the NMFS (2014) marine mammal behavioural response criterion of 160 dB re 1 µPa (SPL; impulsive noise) are predicted within 1.60 km and 1.70 km of the well location, respectively (**Figure 6-20**; **Figure 6-21**).

For VSP activities at the Torosa TRD Well location, behavioural response noise levels of 160 dB re 1 µPa (SPL) are not predicted to reach the reef edge of Scott Reef, or within the channel between North and South Scott Reef (**Figure 6-20**).

Noise levels predicted from well evaluation using VSP demonstrate that potential behaviour impacts may occur within 1.6 - 1.7 km from the well location; however, these would be limited to a very short duration as this type of activity will only occur for up to 10 hours per well. If VSP is conducted at a drill centre, it will be subject to pre-start marine fauna observations and procedures to ensure sensitive marine fauna are not in the vicinity.

Table 6-58 Torosa VSP, multiple-pulse SEL: Maximum (R_{max}) horizontal distances to frequency-weighted SEL_{24h} based marine mammal PTS and TTS thresholds NMFS (2018) from VSP operations, assuming different numbers of impulses during a 24 h period

Hearing group	Effect	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 $\mu Pa^2 \cdot s$)	Number of impulses							
			1 R_{max} (km)	5 R_{max} (km)	10 R_{max} (km)	15 R_{max} (km)	25 R_{max} (km)	50 R_{max} (km)	100 R_{max} (km)	150 R_{max} (km)
LF cetaceans	PTS	183	-	-	0.04	0.06	0.08	0.11	0.17	0.20
	TTS	168	0.09	0.22	0.29	0.36	0.46	0.65	1.10	1.69
MF cetaceans	PTS	185	-	-	-	-	-	-	-	-
	TTS	170	-	-	-	-	-	-	-	-
HF cetaceans	PTS	155	-	-	-	-	-	-	-	-
	TTS	140	-	-	-	-	-	0.04	0.06	0.09

A dash indicates the level is not reached.

Table 6-59 Brecknock VSP, multiple-pulse SEL: Maximum (R_{max}) horizontal distances to frequency-weighted SEL_{24h} based marine mammal PTS and TTS thresholds NMFS (2018) from VSP operations, assuming different numbers of impulses during a 24 h period

Hearing group	Effect	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 $\mu Pa^2 \cdot s$)	Number of impulses							
			1 R_{max} (km)	5 R_{max} (km)	10 R_{max} (km)	15 R_{max} (km)	25 R_{max} (km)	50 R_{max} (km)	100 R_{max} (km)	150 R_{max} (km)
LF cetaceans	PTS	183	-	-	0.04	0.06	0.08	0.11	0.16	0.20
	TTS	168	0.09	0.22	0.29	0.36	0.46	0.64	1.10	1.69
MF cetaceans	PTS	185	-	-	-	-	-	-	-	-
	TTS	170	-	-	-	-	-	-	-	-
HF cetaceans	PTS	155	-	-	-	-	-	-	-	-
	TTS	140	-	-	-	-	-	0.04	0.06	0.09

A dash indicates the level is not reached.

Table 6-60 VSP, PTS and TTS PK thresholds: Maximum (R_{max}) horizontal distances from the 750 in^3 VSP array to modelled maximum-over-depth peak pressure level (PK) thresholds based on the NOAA Technical Guidance (NMFS 2018) for cetaceans at the modelled sites

Hearing group	PK threshold ($L_{pk;}$ dB re 1 μPa)	Distance R_{max} (m)	
		Torosa TRD Well	Brecknock
Low-frequency cetaceans (PTS)	219	12	12
Low-frequency cetaceans (TTS)	213	21	21
Mid-frequency cetaceans (PTS)	230	-	-
Mid-frequency cetaceans (TTS)	224	-	-
High-frequency cetaceans (PTS)	202	68	68
High-frequency cetaceans (TTS)	196	141	139

A dash indicates the level is not reached.

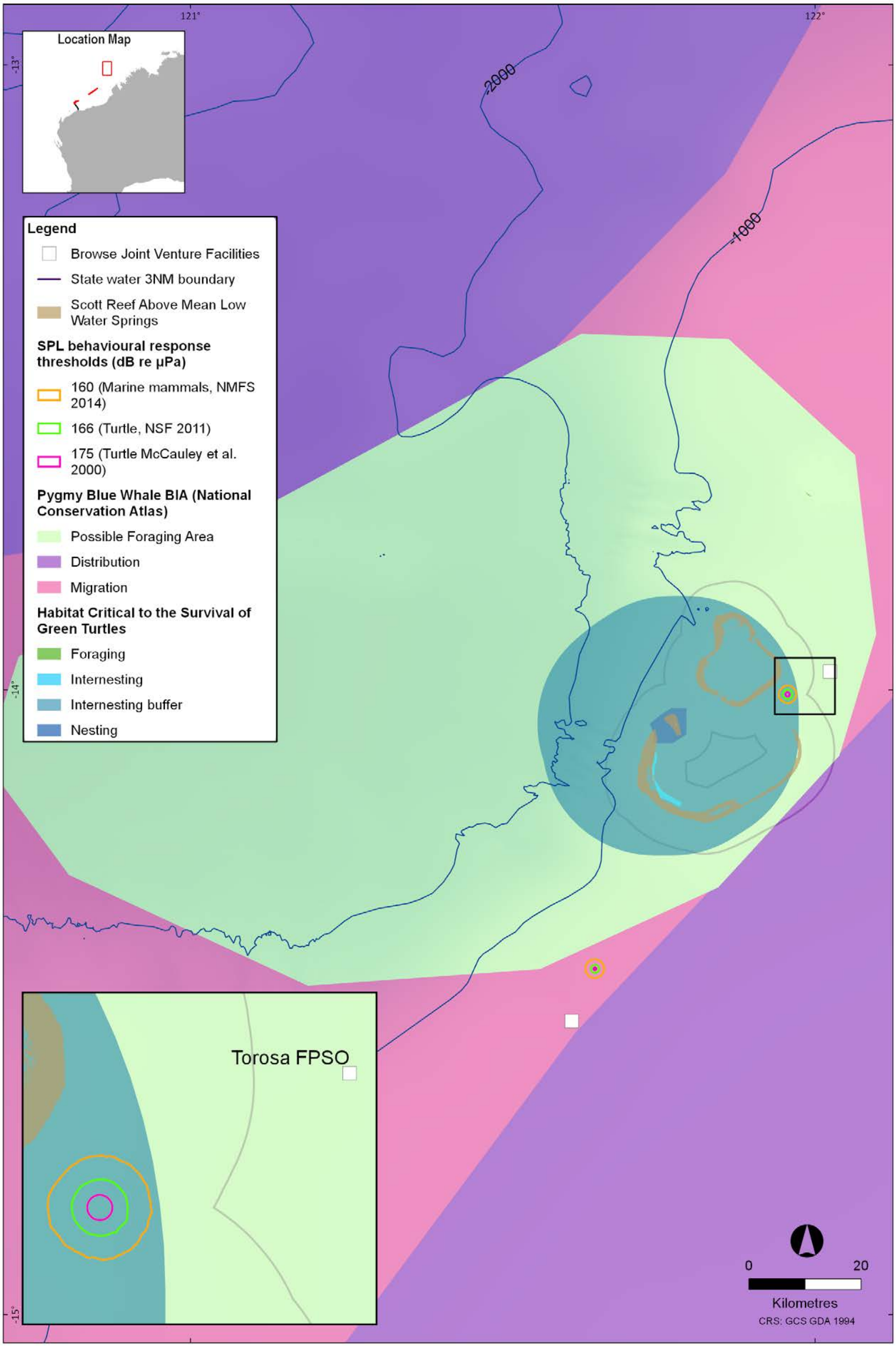

Figure 6-20 Torosa - VSP sound level contour map showing isopleths for marine mammal and turtle behavioural criteria

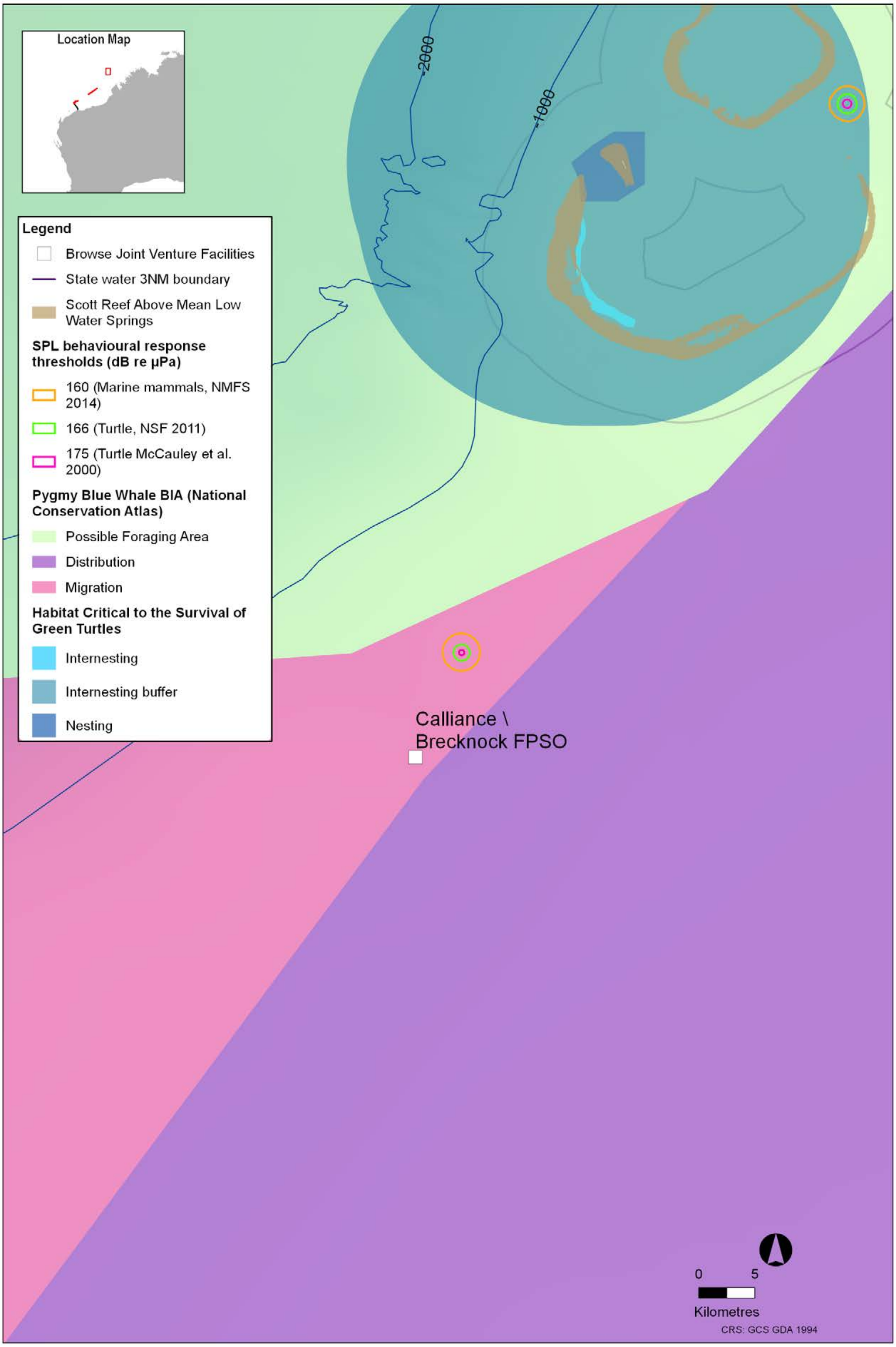

Figure 6-21 Brecknock - VSP sound level contour map showing isopleths for marine mammal and turtle behavioural criteria

Marine turtles

At the Torosa TRD and Brecknock well locations the results of the VSP modelling studies indicate the maximum distance to the Finneran et al. (2017) TTS criteria (SEL_{24h}) for marine turtles (Table 6-61; Table 6-62) are predicted to be within 160 m, for 150 impulses. PTS levels will not be reached for the modelled 150 impulses. TTS levels will be reached after 10 impulses at 40 m from the source (Table 6-63).

Table 6-61 Torosa VSP, multiple-pulse SEL: maximum (R_{max}) horizontal distances to frequency-weighted SEL_{24h} based turtle PTS and TTS thresholds (Finneran et al., 2017) from VSP operations, assuming different numbers of impulses during a 24 h period

Hearing group	Effect	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 $\mu Pa^2 \cdot s$)	Number of impulses							
			1 R_{max} (km)	5 R_{max} (km)	10 R_{max} (km)	15 R_{max} (km)	25 R_{max} (km)	50 R_{max} (km)	100 R_{max} (km)	150 R_{max} (km)
Turtles	PTS	204	-	-	-	-	-	-	-	-
	TTS	189	-	-	0.04	0.04	0.06	0.09	0.13	0.16

A dash indicates the level is not reached.

Table 6-62 Brecknock VSP, multiple-pulse SEL: maximum (R_{max}) horizontal distances to frequency-weighted SEL_{24h} based turtle PTS and TTS thresholds (Finneran et al., 2017) from VSP operations, assuming different numbers of impulses during a 24 h period

Hearing group	Effect	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 $\mu Pa^2 \cdot s$)	Number of impulses							
			1 R_{max} (km)	5 R_{max} (km)	10 R_{max} (km)	15 R_{max} (km)	25 R_{max} (km)	50 R_{max} (km)	100 R_{max} (km)	150 R_{max} (km)
Turtles	PTS	204	-	-	-	-	-	-	-	-
	TTS	189	-	-	0.04	0.04	0.06	0.09	0.13	0.16

A dash indicates the level is not reached.

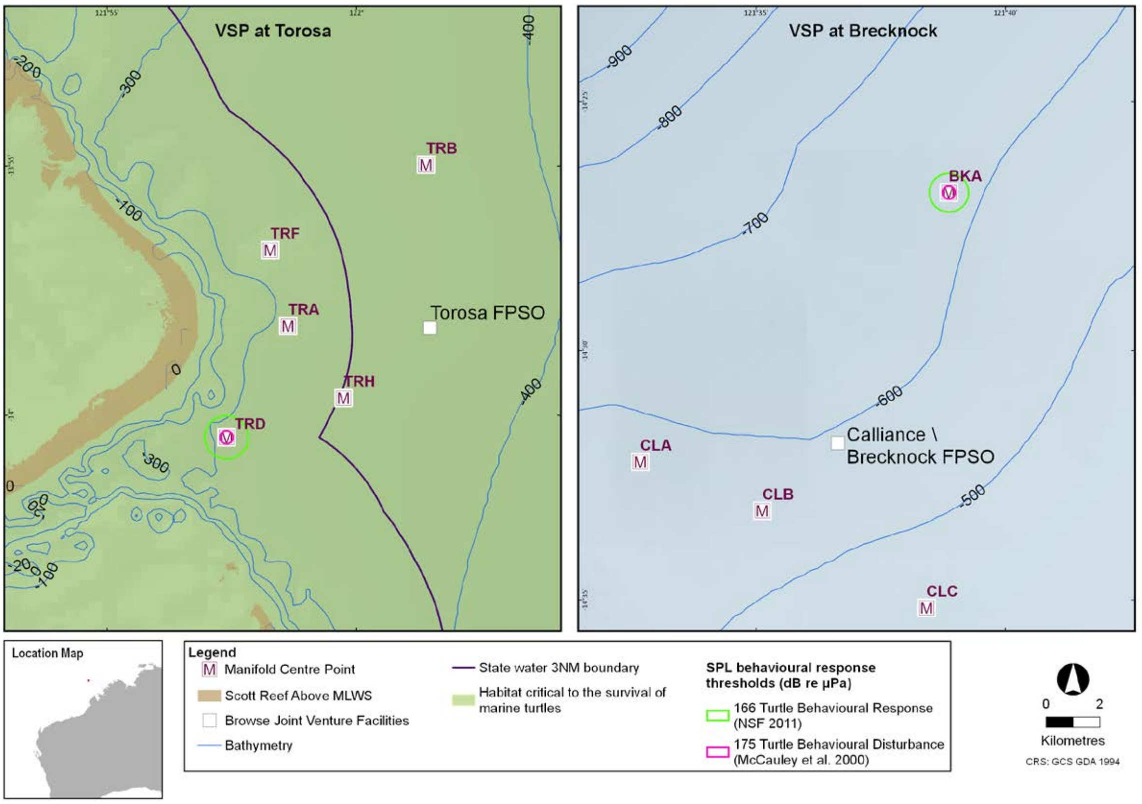

Figure 6-22 Torosa and Brecknock VSP: sound level contour map, showing marine turtle behaviour response thresholds

Table 6-63 VSP, PTS and TTS PK thresholds: maximum (R_{max}) horizontal distances from the 750 in^3 VSP array to modelled maximum-over-depth peak pressure level (PK) thresholds based on the Finneran et al. (2017) for turtles, at the modelled sites

Hearing group	PK threshold ($L_{pk;}$ dB re 1 µPa)	Distance R_{max} (m)	
		Torosa TRD Well	Brecknock
Turtles (PTS)	232	-	-
Turtles (TTS)	226	-	-

A dash indicates the level is not reached.

For both the Torosa TRD and Brecknock well locations the VSP source is not predicted to cause PTS in turtles, as it doesn't result in an exceedance of either the PK or SEL_{24h} criteria from Finneran et al. (2017) at a distance greater than the horizontal modelling resolution (20 m) from the source.

As with marine mammals, the SEL_{24h} considers a range of impulses within 24 h, from 1 to 150. While the TTS criteria due to the PK metric isn't exceeded, depending upon the number of impulses, the TTS SEL_{24h} criteria can be exceeded at up to 160 m for 150 impulses at Torosa TRD Well or Brecknock respectively.

At the Torosa TRD well location the results of the VSP modelling studies indicate that the maximum distances to the NSF (2011) and turtle behavioural response and behavioural disturbance criterion of 166 and 175 dB re 1 µPa (SPL; impulsive noise) are predicted within 810 m and 230 m of the well, respectively (Table 6-64; McPherson et al., 2019). For VSP activities at the Torosa TRD Well location, noise levels of 166 or 175 dB re 1 µPa (SPL) are not predicted to reach the reef edge of Scott Reef, or within the channel between North and South Scott Reef (Figure 6-22).

Table 6-64 Distances to turtle behavioural response criteria for VSP

SPL (L_p; dB re 1 µPa)	Torosa TRD Well		Brecknock	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
175† (Behavioural Disturbance)	0.23	0.23	0.23	0.23
166‡ (Behavioural Response)	0.81	0.77	0.72	0.69

† (Moein et al. 1995).

‡ (NSF 2011).

Fish

At the Torosa TRD and Brecknock well locations the maximum-over-depth (MOD) results of the VSP modelling studies indicate the maximum distance to the Popper et al. (2014) criteria for mortality and potential mortal injury and impairment thresholds (PK) are predicted to be within 21 m for fish with no swim bladder and sharks, and 39 m for fish; swim bladder not involved in hearing; swim bladder involved with hearing (Table 6-65). Therefore, at these distances, for VSP activities at both the Torosa TRD and Brecknock well locations, noise levels of 213 and 207 dB re 1 µPa (PK) are not predicted to reach the reef edge of Scott Reef, or within the channel between North and South Scott Reef.

Received sound levels at the seafloor do not exceed any of the criteria (Table 6-66).

Plankton

At the Torosa TRD and Brecknock well locations the MOD results of the VSP modelling studies indicate the maximum distance to the Popper et al. (2014) criteria for mortality and potential mortal injury and impairment thresholds (PK) are predicted to be within 39 m and 40 m respectively for fish eggs and larvae (Table 6-65). Therefore, at these distances, for VSP activities at the both well locations, noise levels of 207 dB re 1 µPa (PK) are not predicted to reach the reef edge of Scott Reef.

Received sound levels at the seafloor do not exceed any of the criteria for impacts to fish eggs and larvae (Table 6-66).

Table 6-65 VSP, PK thresholds: Maximum (R_{max}) horizontal distances from the 750 in³ VSP array to modelled maximum-over-depth peak pressure level (PK) thresholds (Popper et al., 2014)

Hearing group	PK threshold ($L_{pk;}$ dB re 1 µPa)	Distance R_{max} (m)	
		Torosa TRD Well	Brecknock
Fish: No swim bladder (also applied to sharks)	213	21	21
Fish: Swim bladder not involved in hearing; Swim bladder involved in hearing Turtles, fish eggs, and larvae	207	39	40

Table 6-66 VSP, seafloor PK: Maximum (R_{max}) horizontal distances from the 750 in³ VSP array to modelled seafloor peak pressure level thresholds (PK) at the modelled sites

Hearing group/animal type	PK threshold ($L_{pk;}$ dB re 1 µPa)	Distance R_{max} (m)	
		Torosa TRD Well	Brecknock
Fish: No swim bladder (also applied to sharks)	213	-	-
Fish: Swim bladder not involved in hearing; Swim bladder involved in hearing Turtles, fish eggs, and larvae	207	-	-

A dash indicates the level is not reached.

Coral and benthic organisms

To assist with assessing the potential effects on sponges and coral receptors, the PK sound level at the seafloor directly underneath the VSP source was estimated in the modelling studies. For both Torosa TRD and Brecknock well locations, it was found that the sound level of 226 dB re 1 µPa PK, a sound level associated with no effect (Heyward et al., 2018) was not reached (**Table 6-67**). Therefore, for VSP activities at both well locations, noise levels of 226 dB re 1 µPa (PK) are not predicted to reach the reef edge of Scott Reef.

Table 6-67 VSP, seafloor PK: Maximum (R_{max}) horizontal distances from the 750 in³ VSP array to modelled seafloor peak pressure level thresholds (PK) for sponges and corals at the modelled sites

Hearing group/animal type	PK threshold ($L_{pk;}$ dB re 1 µPa)	Distance R_{max} (m)	
		Torosa TRD Well	Brecknock
Sound levels for sponges and corals†	226	—	—

† Heyward et al. (2018)

A dash indicates the level is not reached.

6.3.8.2.6 FPSO Offtake Aggregate Modelling Scenario Results

Cetaceans

At the Torosa location during FPSO offtake, the results of the modelling studies indicate the maximum distance to the NMFS (2018) PTS and TTS criteria (SEL_{24h}; R_{max}) for LF cetaceans are predicted to be within 120 m (PTS) and 1.74 km (TTS) (McPherson et al., 2019a). The results of the modelling studies also indicated the maximum distance to the NMFS (2014) marine mammal behavioural response to continuous noise criteria (SPL; R_{max}) are predicted to be within 8.89 km of the FPSO offtake.

At the Brecknock location during FPSO offtake, the results of the modelling studies indicate the maximum distance to the NMFS (2018) PTS and TTS criteria (SEL_{24h}; R_{max}) for LF cetaceans are predicted to be within 120 m (PTS) and 1.68 km (TTS) (McPherson et al., 2019a) . The results of the modelling studies also indicated that the maximum distance to the NMFS (2014) marine mammal behavioural response to continuous noise criteria (SPL; R_{max}) are predicted to be within 8.89 km of the FPSO offtake.

The above ranges to PTS and TTS do not incorporate animal movement and behaviour and are based on the assumption the marine mammal is stationary within these ranges for a 24-hour period, which is highly unlikely to occur.

During FPSO offtake operations at the Torosa location, noise levels of 120 dB re 1 µPa (SPL) are not predicted to reach the reef edge of Scott Reef, or within the channel between North and South Scott Reef and only 1.5% of the pygmy blue whale possible foraging area is expected to exceed the behavioural response threshold. Offtake operations are unlikely to displace any individuals from the possible foraging area given only a small portion of this area overlaps with the potential for behavioural response. Furthermore, offtake activities are temporary in nature and expected to take place for approximately 30 hours (total activity time – i.e. including mooring operations) every 2 to 4 weeks.

At the Brecknock location during offtake operations noise levels of 120 dB re 1 µPa (SPL) are not predicted to reach the reef edge of Scott Reef or overlap into the pygmy blue whale possible foraging area (**Figure 6-23**).

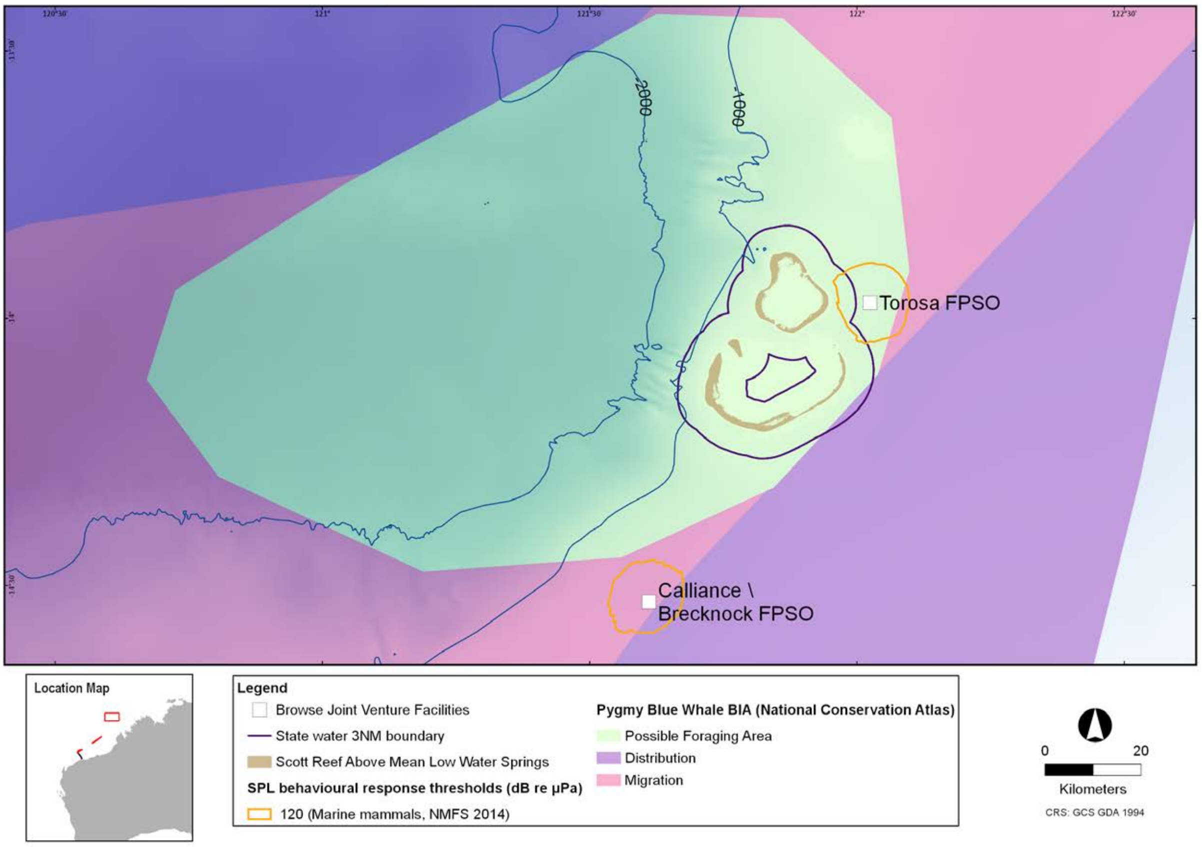

Figure 6-23 Torosa FPSO, tanker, and OSV maximum-over-depth (SPL) aggregate noise results

Marine turtles

For the Torosa location, the maximum distance to the Finneran et al. (2017) PTS and TTS criteria (SEL$_{24h;}$ R$_{max}$) for marine turtles are predicted to be associated with the FPSO offtake within <20 m (Table 6-68).

As described above, radii that correspond to SEL$_{24h}$ typically represent an unlikely worst-case scenario for SEL-based exposure that doesn't incorporate animal movement or behaviour. Therefore, the reported radius of SEL$_{24h}$ criteria does not mean that any animal travelling within this radius of the source *will* be impacted, but rather that it *could* be impacted if it remained stationary in that range for a 24-hour period.

Table 6-68 FPSO Offtake aggregate, SEL$_{24h}$: maximum-over-depth distances to PTS and TTS threshold criteria for turtles (Finneran et al. 2017)

SEL$_{24h}$ ($L_{E,24h}r$; dB re 1 µPa^2·s)	Distance R$_{max}$ (km)			
	OSV	FPSO on DP	FPSO without DP	FPSO Offtake
Torosa				
PTS - 220†	0.06	<0.02	-	<0.02
TTS - 200†	0.05	<0.02	-	<0.02
Brecknock				
PTS - 220†	0.06	<0.02	-	<0.02
TTS - 200†	0.06	<0.02	<0.02	0.06

A dash indicates the level is not reached.

Fish

Sound produced by the vessel operations could cause physiological effects, and recoverable injury, to some fish species, but only if the animals are in very close proximity to the sound sources–within a planar distance of 60 m, for 48 hours (McPherson et al., 2019a). For offtake operations at both the Torosa and Brecknock locations, recoverable injury and temporary impairment could happen if fish remain within planar distances of <20 m and 40 m, respectively, from the FPSO or the OSV thrusters (Table 6-69). There is no increased risk to fish from aggregate scenarios, with ranges to thresholds from the individual sources unchanged.

Table 6-69 FPSO Offtake aggregate, SPL, fish effect thresholds: Maximum (R_{max}) horizontal distances from the vessels to modelled maximum-over-depth SPL thresholds based on the quantifiable thresholds for fish with a swim bladder involved in hearing (Popper et al. 2014)

SPL (L_p; dB re 1 μPa)	OSV		FPSO on DP		FPSO without DP		FPSO Offtake	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
Torosa								
170†	0.05	0.05	<0.02	<0.02	-	-	0.04	0.04
158#	0.05	0.05	0.04	0.04	-	-	0.06	0.06
Brecknock								
170†	0.06	0.06	<0.02	<0.02	<0.02	<0.02	0.04	0.04
158#	0.06	0.06	0.04	0.04	<0.02	<0.02	0.06	0.06

† Recoverable injury

 # TTS FPSO offtake includes an FPSO under DP, a noiseless condensate tanker and an OSV.

6.3.8.2.7 Cumulative Modelling Scenario - FPSO Offtake and MODU Results

Representative cumulative scenario

In order to assess the potential cumulative impacts associated with multiple noise sources operating concurrently during the proposed Browse to NWS Project, a representative cumulative scenario was modelled. The scenario considers both FPSO facilities during offtake along with operations of a MODU under DP at either a Torosa TRD well or Brecknock. The FPSO operational noise during offtake includes: the FPSO under DP;and an OSV near each FPSO (presented in isolation also). It should be noted that this scenario, will only occur at times where drilling of wells within the State Proposal Area, and offtake activities are occurring simultaneously (i.e. only 30 hours, every 2-4 weeks and only during drilling activities). During offloading, the main engines of the condensate tankers will not typically be operating.

Cetaceans

During the representative cumulative scenario of an FPSO offtake operations at both locations with the MODU operating at Torosa TRD well, the results of the modelling studies indicate noise levels of 120 dB re 1 μPa (SPL) (the NMFS (2014) marine mammal behavioural response threshold) are predicted to reach the reef edge of North and South Scott Reef, and within the channel between North and South Scott Reef. The modelling indicates that the NMFS (2018) PTS and TTS criteria (SEL_{24h}; R_{max}) for LF cetaceans are predicted to be reached within an area of 160 m^2 (PTS) and 30.05 km^2 (TTS). These PTS and TTS predictions represent up to 0.3% of the possible pygmy blue foraging area and do not incorporate animal movement and behaviour and are based on the assumption the marine mammal is stationary within these ranges for a 24-hour period, which is highly unlikely to occur.

The modelling studies also indicate the NMFS (2014) marine mammal behavioural response to continuous noise criteria (120 dB re 1 μPa L_p) are predicted to be reached within an area of 481.9 km^2 (Figure 6-24). Of this area, 274.6 km^2 overlaps the pygmy blue whale possible foraging area. This corresponds to 2.2% of the possible foraging area. In comparison, during normal operations, i.e. the FPSO without DP, results of the modelling studies also indicated the NMFS (2014) marine mammal behavioural response to continuous noise criteria (120 dB re 1 μPa L_p) are predicted to be within an area of 1 km^2 (all of which is located within the pygmy blue whale possible foraging area).

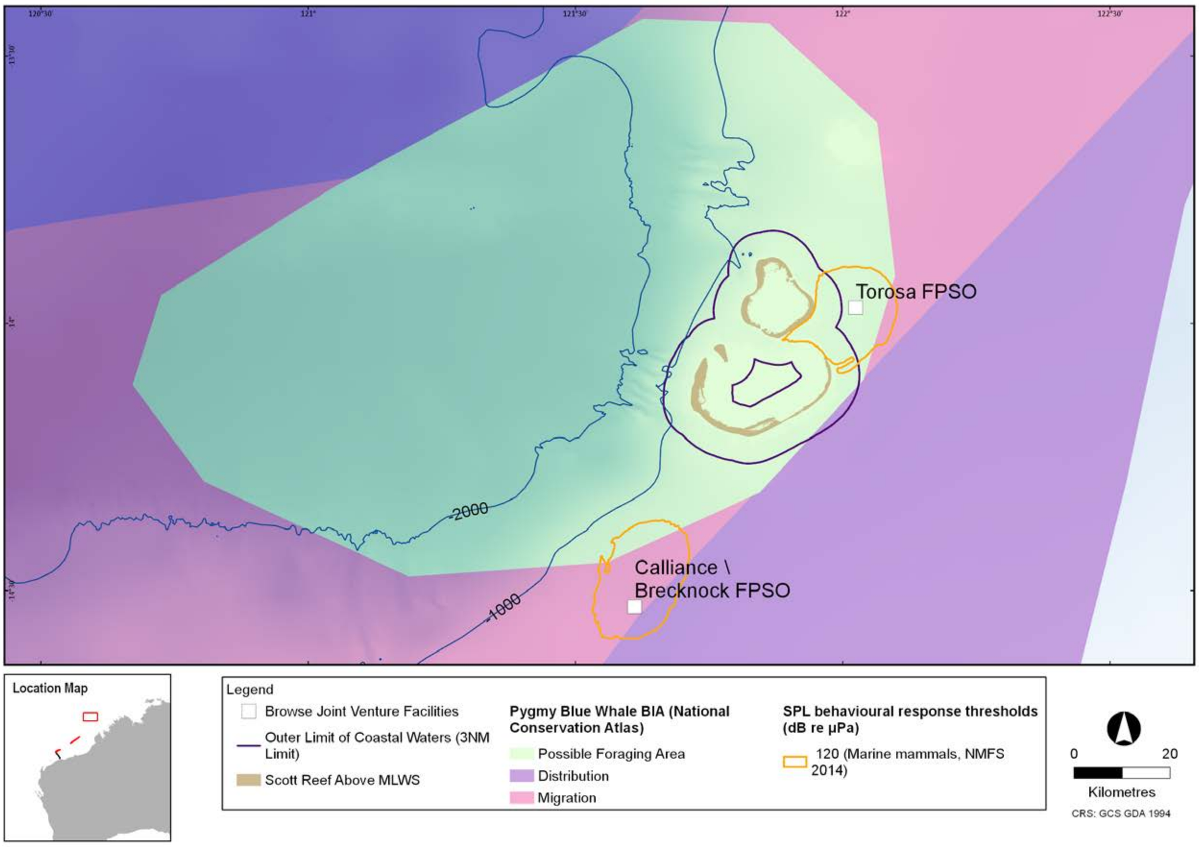

Figure 6-24 FPSO offtake at both Torosa and Brecknock and MODU at Torosa maximum-over-depth (SPL) aggregate noise results

Marine turtles

During FPSO offtake operations at both locations with the MODU at Torosa TRD well, the results of the modelling studies indicate the Finneran et al. (2017) PTS and TTS criteria (SEL_{24h}; R_{max}) for marine turtles are predicted to be reached within an area of 17 m^2 (PTS) and 130 m^2 (TTS). This corresponds up to 0.00008% of the Scott Reef (Sandy Islet) 20 km habitat critical internesting buffer area.

As previously described above, radii that correspond to SEL_{24h} typically represent an unlikely worst-case scenario for SEL-based exposure that doesn't incorporate animal movement or behaviour. Therefore, the reported radius of SEL_{24h} criteria does not mean that any animal travelling within this radius of the source *will* be impacted, but rather that it *could* be impacted if it remained stationary in that range for a 24-hour period.

Fish

The modelling of the representative cumulative scenario indicated that the ranges to the threshold was unchanged from the modelled individual scenarios.

6.3.8.2.8 Wellhead Noise Modelling Results

Subsea choke valve noise propagation was undertaken as part of a previously proposed Development Concept. The modelling was undertaken based on the previously proposed locations of the TRD and TRE drill centres (). Underwater noise from subsea wellheads was modelled to determine the geographical range over which noise from the Browse subsea wellheads might be expected to occur (Duncan, 2011). The source level recorded by McCauley (2002) from an oil producing wellhead associated with the Cossack Pioneer FPSO was used in the modelling. The modelling was based on configurations of seven wellheads at the TRD drill centre and six wellheads at the TRE drill centre, spaced 20 to 40 m apart and 4.5 m above the seabed in a water depth of approximately 400 m.

Received levels were calculated for cross-sections of the channel at the TRD and TRE drill centres (**Figure 6-25**). The modelling indicated that noise levels will fall below 120 dB re 1 µPa (SPL) within approximately 500 m of the wellheads and are not expected to propagate more than 1 km under optimal conditions. It is noted that the operating state of the Cossack Pioneer FPSO wellhead was not known at the time of measurement. However, in the absence of measured data at the Browse reservoirs, the Cossack Pioneer wellhead data is considered a reasonable proxy. In recognition of the absence of data for Browse reservoirs **Section 6.3.8.2.4** presents the risk of the subsea wellhead noise being higher than that predicted within this section.

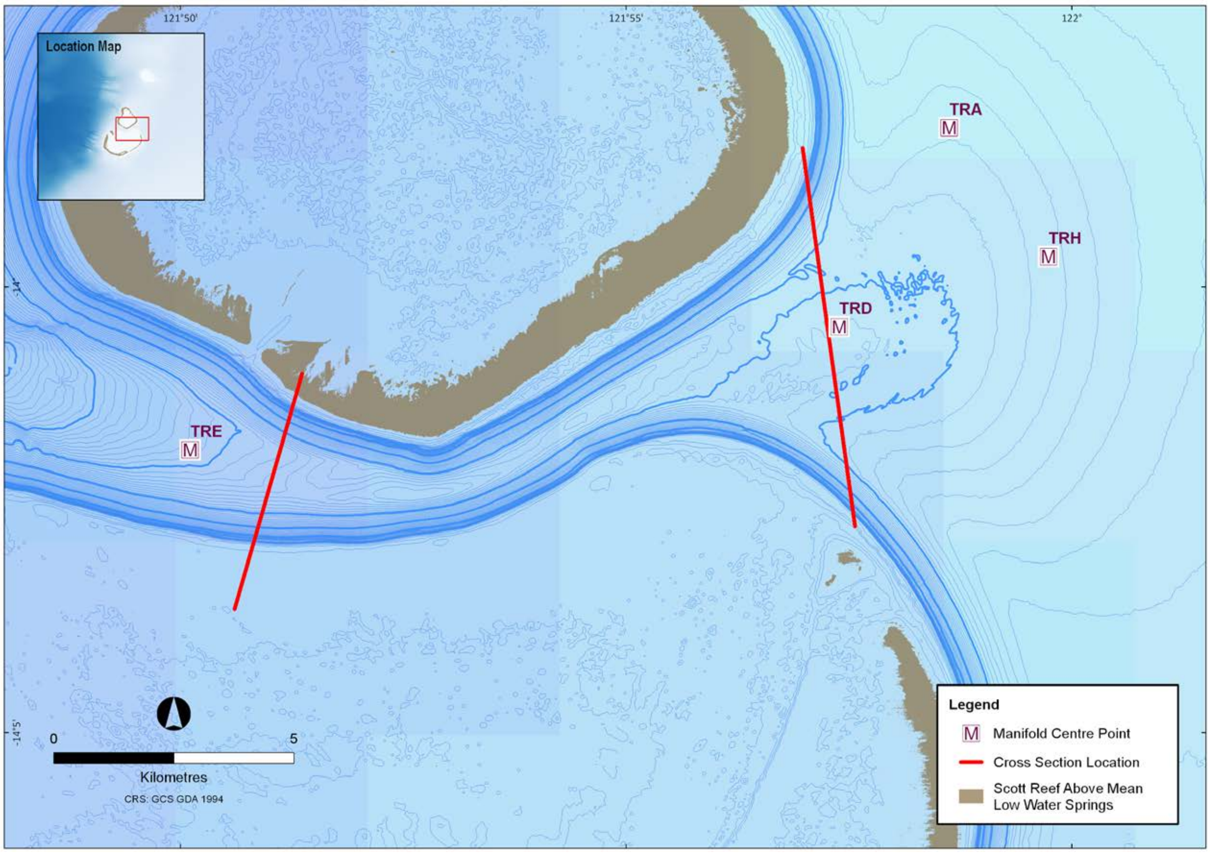

Figure 6-25 Previously proposed locations of the TRD and TRE drill centres for modelling of subsea choke valve noise propagation

6.3.8.3 Environmental Impact

Impacts on receptors associated with the predicted underwater noise emissions outlined in **Section 6.3.8.2.2** are discussed below. In considering such impacts several factors have been considered, including:

- predicted source levels generated by an activity
- the spectral characteristics of the noise emissions (i.e. frequency)
- the distance a receptor is likely to be from the noise source (i.e. range)
- the level of transmission loss between the noise source and the receptor
- the hearing threshold and frequency sensitivity of the receptor.

Each of these factors has been considered in determining the likely environmental impact associated with the predicted underwater noise emissions.

Ambient noise

Change in ambient noise

Given the temporary nature of the primary noise sources during construction (such as piling), and the highly localised nature of the operations-based noise emissions, impacts to underwater ambient noise as a result of underwater noise emissions from the proposed Browse to NWS Project are considered negligible.

Plankton communities

Injury or mortality to fauna

The modelling indicates that mortality and potential mortal injury to plankton will be highly localised near the sound source (in the order of 170 m for piling, and 40 m for VSP). Plankton are expected to rapidly recover once the activity ceases, as they are known to have high levels of natural mortality and a rapid replacement rate (ITOPF, 2011). As impacts to plankton will be highly localised, they are not expected to have a significant impact on plankton communities in a region.

Benthic Habitats

Injury or mortality to fauna - Corals

As discussed in **Section 6.3.8.2.2** Woodside's Maxima Study on seismic noise on Scott Reef estimated that corals would require received levels of PK-PK exceeding 260 dB re 1 µPa (SPL) to induce injury (Hastings, 2010). The modelling indicates that sound levels reaching Scott Reef from the proposed activities do not reach these levels and as such no impact to corals from underwater noise resulting from the proposed activities is predicted to occur.

Likewise modelling of the VSP activities indicates that the sound level associated with no effect (Heyward et al., 2018) was not reached. As such, no impacts to corals are expected to occur.

Furthermore, studies on the dispersion of coral larvae at Scott Reef (Done et al., 2015; Foster and Gilmour, 2018) demonstrates that while there is significant movement of larvae within the reef system itself (particularly for spawning corals), there is no evidence to suggest the coral larvae travel outside the reef system (i.e. off the reef) before re-settling on the reef. Therefore, impacts to coral larvae as a result of noise emissions are not likely to impact the recruitment of corals within the Scott Reef system as any affect coral larvae would not have been available to resettle on the reef regardless of if the impact had occurred or not.

Injury or mortality to fauna - Epifauna and infauna

Although sparsely distributed, epifauna and infauna in the deepwater habitats of the Project Area consists of invertebrates including small burrowing worms and crustaceans. Few marine invertebrates have sensory organs that can perceive sound pressure, but many have organs or elaborate arrays of tactile 'hairs', called mechanoreceptors, that are sensitive to hydro-acoustic disturbances. Close to an impulsive noise source, the mechano-sensory system of many benthic crustaceans will perceive the 'sound' of compressed air pulses. However, for most species such stimulation would only occur within the near-field or closer, perhaps within distances of several metres from the source (McCauley, 1994).

Decapod crustaceans have a variety of external and internal sensory receptors that are potentially responsive to sound and vibration. However, the exoskeleton and body plan of aquatic decapods are more capable of responding to particle displacement components of an impinging sound field than pressure changes. The limited acoustic sensitivity of decapods is also related to their lack of any gas-filled spaces such as those associated with pressure detection in fishes. However, many decapods have extensive arrays of hair-like receptors both on and inside their exoskeleton that most probably respond to water- or substrate-borne displacements. They also have many proprioceptive organs that may perceive vibrations (Christian et al., 2003).

Although previous studies observed little effect of impulsive noise on invertebrate behaviour and population (as inferred from commercial catch rates), Day et al., (2016) found evidence of behavioural responses and sub-lethal effects from repeated exposure to impulsive noise. Therefore, it is possible that a small number of individuals may present similar effects. However, given the relative sparsity of marine invertebrates in the Browse Development Area, and the short-term nature of the piling activities, no lasting impacts are expected, and these impacts are not considered to be significant.

Marine fauna

Change in fauna behaviour and injury or mortality to fauna - cetaceans

As detailed in **Section 5.3**, 27 cetacean species were identified by the PMST search as potentially occurring within the Project Area. Of these species, the humpback whale, pygmy blue whale, sei whale, fin whale, Bryde's whale, and spinner dolphin are expected to occur within the Project Area. Additionally, the Project Area overlaps the humpback whale migration BIA; the pygmy blue whale migration BIA and possible foraging area located at Scott Reef. Noise interference is identified as a key threat to pygmy blue whales in the Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015b) and in the conservation advice for humpback, sei and fin whales.

While humpback and pygmy blue whales are known to occur within the Browse Development Area during their annual migrations, studies indicate that these species occur in relatively low numbers within the area. The Browse Development Area is >140 km away from the humpback whale calving BIA on the Kimberley coastline. In addition, the proposed BTL route is located outside of the humpback whale migration BIA (approximately 40 km distance at closest point) and as such impacts to humpback whales are likely to be limited to individuals transiting through the Browse Development Area during noise generating activities.

The Browse Development Area and BTL are both within the pygmy blue whale possible foraging and migration BIA, with individuals observed and recorded (McCauley, 2011) within the vicinity of Scott Reef; however, the majority of pygmy blue whales are expected to migrate within deep waters to the west of Scott Reef.

As discussed in **Section 6.3.8.2.2** incorporation of animal behaviour and exposure into the acoustic modelling of piling activities at both Torosa and Brecknock indicates that with exclusion zones in place, exposures to injury threshold criteria (PTS) for pygmy blue whales were reduced to zero.

During piling activities exposure to TTS is estimated to be limited to a few individuals, however given the precautionary way in which these exposures are calculated, specifically; they do not incorporate migratory travel direction, behavioural avoidance or industry standard pre-start observations and soft starts, the likelihood of actual TTS exposure is very low. Furthermore, the potential reduction of cumulative sound exposure associated with pausing and restarting piling to account for potential shutdowns also will significantly reduce potential TTS exposure to individuals. The currently adopted cumulative SEL approach for quantifying TTS onset also assumes that exposures with equal SEL result in equal effects, regardless of the duration or duty cycle of the sound (i.e. continuous or impulsive) (Finerran et al. 2015). It is well-known that this 'equal energy' rule over-estimates the effects of intermittent noise such as piling, since the quiet periods between piling pulses will allow some recovery of hearing compared to noise that is continuously present with the same total SEL (Ward, 1997)

Modelling also indicates that for other activities including the MODU on DP and FPSO offtake activities using DP the maximum distance to the NMFS (2018) PTS criteria is 120 m and the maximum distance to the NMFS (2018) TTS criteria (SEL_{24h}; R_{max}) for LF cetaceans is predicted to be within 1.74 km. For the scenarios of FPSO under offtake at Torosa and Brecknock, the area ensonified within the marine mammal behavioural response criteria of 120 dB re 1 µPa (SPL) is estimated to overlap 1.4% to 1.5% of the pygmy blue whale possible foraging BIA, leaving ~98% of the foraging BIA available to pygmy blue whales and uninterrupted foraging. Given these results do not incorporate animal movement and behaviour, and they are based on the assumption the marine mammal is stationary within this distance for a 24 hour period (which is highly unlikely to occur), it is considered highly unlikely that marine mammals will be exposed to underwater noise levels above the PTS or TTS threshold as a result of these activities associated with the proposed Browse to NWS Project.

Furthermore, for the aggregate scenario of FPSOs under offtake at both locations and the MODU at Torosa TRD well location the area ensonified within the marine mammal behavioural response criteria of 120 dB re 1 µPa (SPL) is estimated to overlaps 2.2% of the pygmy blue whale possible foraging area, leaving ~98% of the potential foraging area available to pygmy blue whales and uninterrupted foraging. In comparison, at the Torosa TRD well location during normal operations (FPSO, no DP) the area ensonified within the 120 dB re 1 µPa (SPL) is estimated to be 1 km^2.

The onset and severity of behavioural responses in cetaceans depends on a number of factors, such as whether the frequencies and characteristics of the noise are of any biological significance to the animal; the animals' activities at the time it is heard (e.g. feeding, resting, migrating, socialising); and their motivation to remain, approach or avoid. These factors can vary further between each individual or group. Another key consideration involves differentiating brief, minor, biologically unimportant reactions from profound, sustained, and/or biologically meaningful responses that may influence survival (Southall et al., 2007). For example, Croll et al. (2001) did not observe any response from feeding blue and fin whales receiving noise levels between 140 and 150 dB re 1 µPa (SPL) from continuous, low frequency sonar transmissions. The sound spectrum of the sonar within this study is comparable to the dominant frequency band associated with vessel DP noise (130 – 160 hz and 260 - 320 hz). Results showed whale movements were instead found to be influenced by the distribution and movement of prey, indicating that the generated noise levels were not a direct significant disturbance to the whales during feeding.

The North West Shelf Project has been operating for more than 30 years, and offshore activities such as seismic exploration, piling, drilling, and well operations have been conducted within the humpback whale migratory corridor. During this time the humpback whale population continues to recover exponentially, and data from aerial surveys conducted in 2000, 2001, 2006, 2007, and 2008, shows no avoidance of the area nor has the migration route changed (Jenner and Jenner, 2010; Salgado Kent et al., 2012).

The most discernible behavioural reactions in cetaceans tend to occur at the sudden onset of noise, when noise sources change or increase suddenly, or when they occur unexpectedly (Richardson et al., 1995). Stationary and continuous industrial noise sources are typically observed to result in less dramatic avoidance reactions than moving noise sources, and in numerous cases cetaceans have been known to approach the noise source. For example, whales are often observed in close proximity to operating offshore infrastructure such as platforms and vessels that emit underwater noise.

Whales have been recorded and reported to DoEE by Woodside in close proximity to operating facilities such as the Nganhurra FPSO on numerous occasions. The noise source level of the Nganhurra FPSO has been recorded to be 172 dB re 1 µPa (Erbe et al., 2013), which is comparable to predicted operational noise levels at the FPSO facilities (without DP) and higher than the expected source level of the subsea wellheads (Duncan, 2014, 2011)[11].

Elevated underwater noise can result in changes to marine fauna behaviour by masking or interfering with other biologically important sounds, including vocal communication, echolocation, signals and sounds produced by predators or prey, and through disturbance leading to behavioural changes or displacement from important areas (Richardson et al., 1995). The sensitivity of fauna behaviour to elevated noise levels vary both inter- and intra-specifically, with individual responses often being influenced by the present behaviour, such as reproductive behaviours, foraging or migration.

Startle responses from vessel and drilling activities are unlikely as source levels at the higher end of the potential range (e.g. from operation of bow thrusters or drilling) are not likely to occur suddenly in isolation. Project vessels and the MODU will already be operating and emitting noise at lower levels prior to commencement of potentially noisier activities.

ANIMAT modelling (**Section 6.3.8.2.3**) of the pile driving activities indicates that with a 2000 m exclusion zone:

- behavioural impact thresholds for pygmy blue whales are not exceeded in the possible foraging area during Brecknock piling when using a smaller IHC S-600 hammer
- behavioural impact thresholds for pygmy blue whales are exceeded within 0.07% of the possible foraging area during Brecknock piling when using a smaller IHC S-1200 hammer with exposure to 0.08 individuals per pile predicted
- behavioural impacts to 0.32 individual migrating pygmy blue whales per pile are predicted during Brecknock piling when using a smaller IHC S-600 hammer
- behavioural impacts to 1.65 individual migrating pygmy blue whales per pile are predicted during Brecknock piling when using a smaller IHC S-1200 hammer
- behavioural impact thresholds for pygmy blue whales are exceeded within 1.2% of the possible foraging area during Torosa piling when using a smaller IHC S-600 hammer with exposure to 0.43 individuals per pile predicted
- behavioural impact thresholds for pygmy blue whales are exceeded within 2.84% of the possible foraging area during Torosa piling when using a larger IHC S-1200 hammer with exposure to 1.28 individuals per pile predicted
- behavioural impacts to 0.32 individual migrating pygmy blue whales per pile are predicted during Torosa piling when using a smaller IHC S-600 hammer
- behavioural impacts to 1.22 individual migrating pygmy blue whales per pile are predicted during Torosa piling when using a smaller IHC S-1200 hammer.

These estimates do not include individual's behavioural avoidance, or industry standard pre-start observations or soft starts, and as such the actual number of individuals will likely be less. These impacts are expected to be limited to temporary avoidance behaviour, are not expected to be significant and have been demonstrably minimised.

Behavioural impacts may also occur as a result of the MODU on DP and the FPSO offtake activities using DP. Modelling indicates that behavioural impacts may occur during offtake and MODU DP to a distance of 8.9 km and 10.5 km, respectively. As with the piling noise, these impacts are expected to be limited to temporary avoidance behaviour and would only occur during MODU activities or offtake activities requiring DP.

Noise levels predicted from well evaluation using VSP demonstrate that potential behaviour impacts may occur within 1.6-1.7 km from the well; however, these would be limited to a very short duration as this type of activity will only occur for up to 10 hours per well. Due to the temporary and localised nature of these behavioural impacts, they are not considered to be significant.

Underwater noise levels from subsea wellheads will likely fall below the 120 dB re 1 µPa (SPL) cetacean behavioural response threshold within approximately 500 m of the wellheads at the TRD and TRE drill centres and are not predicted to reach the top 100 m of the water column, even directly above the wellheads. Potential impacts to whales and other cetaceans from increased noise levels in the vicinity of the wellheads are therefore expected to be minor and highly localised and are not expected to cause disturbance to individuals.

Migrating humpback and pygmy blue whales may occur along the proposed BTL route and as such behavioural responses may occur to a small number of individuals during installation of the BTL. Such behavioural responses will likely be limited to avoidance and will be localised around the pipelay vessel which will be continually moving at a slow speed.

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[11] *AIMS (2014) available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

Given the width of the migration BIAs of the pygmy blue whales; and the fact that the proposed BTL route is outside of the humpback whale BIA, the operation of the pipelay vessel is unlikely to present a barrier to migration. As any disturbance that does occur will be temporary and localised at the individual level, these impacts are not considered to be significant.

Other sources of noise include helicopters used for crew transfers. Depending on the final method chosen for crew transfers, helicopter transfers may occur during all phases of the proposed Browse to NWS Project.). In general, helicopter noise is of short duration, peaking as the helicopter passes directly overhead. Received levels are expected to be low during transit when helicopter altitude is greatest. The highest received levels will occur at lower altitudes on approach to landing. Some behavioural disturbance may occur for short periods if marine mammals are present near the surface in the vicinity of landing helicopters. These impacts are not considered to be significant.

In summary, predicted underwater noise emissions associated with key activities for the proposed Browse to NWS Project may result in localised avoidance and/or behavioural disturbance of marine mammals within the vicinity of the project activities. Given that relatively low numbers of transient marine mammals are expected to seasonally occur within the Project Area, only slight behavioural impacts are expected to occur, with no long-term effects at a species population level. These impacts are not considered to be significant, based on the MNES significant impact criteria for listed endangered species (**Table 6-5**), have been demonstrably minimised, and are not inconsistent with the recovery objectives within the Conservation Management Plan for the Blue Whale (2015-2025) (Commonwealth of Australia, 2015c).

Change in fauna behaviour and Injury or mortality turtles

Sandy Islet and the surrounding waters (20 km internesting buffer) have been identified as habitat critical to the survival of green turtles in the Recovery Plan for Marine Turtles 2017-2027 (Commonwealth of Australia, 2017a) (**Figure 5-29**). In addition, a BIA exists for internesting green turtles around Sandy Islet with internesting occurring just offshore in waters 4-15 m deep (Commonwealth of Australia, 2017a). The recovery plan identifies noise interference (acute and chronic) as a key threat to the recovery of turtles.

As discussed in **Section 6.3.8.2.3** when incorporating representative green turtle animal movement and behaviour into the impact piling propagation model for both migratory and internesting turtles (as described in **Section 6.3.8.2.3**) during the Torosa piling the injury PTS threshold is not exceeded, with no individual turtles exposed to injury levels. Additionally, when incorporating representative migratory green turtle animal movement and behaviour, the 95th percentile exposure ranges to the recoverable auditory fatigue (TTS) threshold are 1.79 km and 1.65 km for the IHC S-1200 and IHC S-600 hammer, respectively. It should be noted that these results do not incorporate potential behavioural avoidance and soft starts.

The results of the animal movement and behaviour modelling also demonstrated that no migrating or internesting green turtles within the habitat critical are likely to be exposed to injury (PTS), auditory fatigue (TTS) or behavioural response or disturbance during the Brecknock piling activities.

Modelling shows that for other key activities associated with the proposed Browse to NWS Project, the turtle injury PTS threshold is either not reached, or only extends a distance in the order of 100 m. Given these results do not incorporate animal movement and behaviour is based on the assumption the marine turtle is stationary within this distance for a 24 hour period (which is highly unlikely to occur), therefore it is considered highly unlikely that marine turtles will be exposed to underwater noise levels above the PTS threshold as a result of activities associated with the proposed Browse to NWS Project.

Modelling indicates that the recoverable auditory fatigue (TTS) threshold extends in the order of 1.50 to 2.0 km for other modelled activities including the MODU on DP, VSP and FPSO offtake activities on DP. For the aggregate scenario of FPSOs under offtake at both locations and the MODU at Torosa TRD well location the area ensonified within the marine turtle PTS and TTS criteria (SEL_{24h}; $R_{95\%}$) is estimated to be 17 m^2 (PTS) and 130 m^2 (TTS), respectively.

It should be noted again that these results do not incorporate animal movement and behaviour is based on the assumption the marine turtle is stationary within this distance for a 24-hour period (which is highly unlikely to occur). Given this, the planned mitigation measures (including exclusion zones and shut downs during piling), the small exposure area, the temporary nature of the piling activities and the likely avoidance behaviour of marine turtles, it is not considered that these impacts will be limited to behavioural (avoidance) impacts and would not result in any lasting effect. The avoidance activities are likely to be most evident in relation to the MODU on DP, FPSO offtake activities on DP and piling. While some of the proposed noise generating activities (drilling activities including the MODU on DP, MODU anchor piling and subsea choke value noise) will occur within the internesting critical habitat buffer (20 km radius) surrounding Sandy Islet, the temporary nature of the piling and drilling activities as well as the predicted noise attenuation means that any potential behavioural impacts are not expected to result in a significant impact to nesting success, internesting or migrating marine turtles based on the MNES significant impact criteria for listed vulnerable species (**Table 6-5**).

Therefore, it is determined that the underwater noise activities associated with the proposed project activities are not inconsistent with the recovery objectives within the Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a).

Migrating marine turtles may occur along the BTL route and as such behavioural responses may occur to a small number of individuals during installation of the BTL. Such behavioural responses are likely limited to avoidance and will be localised around the pipelay vessel which will be continually moving at a slow speed. Given the low number of individuals that are likely to be impacted, these behavioural impacts are not considered to be significant.

Turtles may be exposed to helicopter noise when on the sea surface (e.g. when basking or breathing). Hearing in marine turtles is adapted for the perception of sound underwater (Popper et al., 2014), where they spend most of their time. As such, turtles are not expected to perceive noise levels from helicopters; impacts may consist of 'startle' responses such as diving, which are exhibited when turtles are exposed to other disturbances such as the passage of vessels. Given the nature of the impact and the low number of marine turtles likely to be affected, these impacts are not considered to be significant.

Change in fauna behaviour and Injury or mortality to fauna - fish

The modelling indicates that for the most sensitive fish groups (fish with swim bladder involved in hearing) sounds levels from the piling activities could exceed mortality levels within 200-210 m of the noise source. For fish species including sharks sound levels could exceed TTS threshold are predicted to extend to in the order of 9 km at Torosa and 6 km at Brecknock. However, for these impacts to occur, exposure would be required to occur for a 24 hours period. Given the mobility of fish species and the likely avoidance behavior, it is considered highly unlikely that such exposure would occur or that significant impacts will occur to fish species as a result of the piling activities.

The modelling indicates that the sound levels from the piling, VSP, MODU with DP and FPSO offtake using DP activities expected to reach the south Scott Reef lagoon are not expected to result in any impacts to site attached fish.

For the other modelled activities including the MODU on DP, VSP and the FPSO Offtake activities, the modelling indicates that fish will not be exposed to sound levels that could cause permanent injury or mortality. Physiological effects, and recoverable injury, to some fish species, could occur but only if the animals are in very close proximity to the sound sources (within a planar distance of 60 m) for a 48-hour period which as discussed above, is considered highly improbable.

Temporary impairment due to TTS could occur at similar short distances if fish remain at the same point within the sound field for long periods of time (12 hours) which is also considered highly improbable.

As such, it is considered that any impacts to fish will be limited to temporary avoidance behaviour. Most pelagic and open water fish species (including whale sharks) are expected to swim away when impulsive noise reaches levels at which it might cause physiological effects. BPM (2008) recorded no exposure mortality from the Woodside Maxima 3D MSS Phase I and Phase II survey of fish species such as mackerel (Decapterus macarellus), barracuda (Sphyraena barracuda), large billfish (sailfish or marlin), schooling bait fish and a number of species of rays and sharks. Behavioural responses are expected to be short-lived, with duration of effect less than or equal to the duration of exposure. For some fish, strong 'startle' responses have been observed at sound levels of 200 to 205 dB re 1 μPa, indicating that sounds at or above this level may cause fish to move away from the sound source. Other studies (McCauley et al., 2003) have found that active avoidance may occur in some fish species at sound levels of ~161–168 dB re 1 μPa SPL (~186–193 PK). While fish may initially be startled and move away from the sound source, once the source moves on fish would be expected to move back into the area. As such these behavioural impacts are not considered to be significant.

There is a paucity of data about responses of sharks, including whale sharks, and rays to underwater noise. It is expected that the potential impacts to whale sharks associated with impulsive noise will be the same as for other fish. Given whale sharks do not have swim bladders, they are categorised as fish that are less sensitive to noise and therefore, unlikely to be impacted by impulsive noise unless at close distances to the source location (Popper et al., 2014).

Fish, including migrating whale sharks, may occur along the BTL route. Given the above regarding potential effects of noise emission on fish; and the temporary nature of the pipelay activities, no noise related impacts are expected to occur to fish as a result the pipelay activities.

Change in fauna behaviour and Injury or mortality to fauna - sea snakes

As discussed in **Section 6.3.8.1**, there is limited information available on hearing in sea snakes, but they are known to be capable of detecting pressure changes (Mick Guinea pers. comm.). Due to this and as quantifiable distances for assessing impacts from continuous sounds only exist for fish, fish have been used as a surrogate for this assessment. As discussed above, no significant impacts to fish are expected to occur as a result of noise emissions from the proposed Browse to NWS Project. Given this, no significant impacts to sea snakes are expected to occur as a result of underwater noise emissions from proposed Browse to NWS Project.

Summary

Table 6-70 provides an assessment of the underwater noise emissions from the proposed activities in relation to objectives and actions of the relevant EPBC Act recovery and conservation plans and advices.

Table 6-70 Alignment with EPBC Act recovery and conservation plans and advices for protected fauna – underwater noise

Fauna	Relevant plan(s)/ conservation advice	Plan/advice objectives and actions	Assessment
Whale shark	Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a)	Assess the impacts of offshore installations and associated environmental changes (light spill, chronic noise, changed water temperature, localised nutrient levels) on whale sharks and mitigation options for these impacts.	The potential impact of underwater noise emissions resulting from the proposed Browse to NWS Project have been assessed. Given the low numbers and infrequent nature of whale shark presence in the Project Area, there is a high level of confidence that underwater noise will not result in and adverse impact to whale sharks.
Green turtle Hawksbill turtle	The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a)	Management actions: + Manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to the survival. + Manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue. + In relation to the Scott Reef – Browse Island green turtle genetic stock, the priority action is to manage anthropogenic activities to ensure marine turtle are not displaced from identified habitat critical to their survival	The potential impact to marine turtles from underwater noise emission has been assessed as minor given: + the predicted extent of underwater noise emissions affects a very small portion of the offshore waters, limited to hundreds of metres from the source + low risk of any injury to marine turtles from vessel noise (the only credible impact is expected to be behavioural). + behavioural changes, e.g. avoidance and diving, are only predicted within a very small portion (0.004% to 0.0004%) of the area identified as habitat critical to the survival of green turtles. As such, displacement of marine turtles from identified habitat critical to the survival, is not predicted. As such, it is considered that the activity is not inconsistent with the Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a).

Fauna	Relevant plan(s)/ conservation advice	Plan/advice objectives and actions	Assessment
Pygmy blue whale	Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c)	Anthropogenic noise and acoustic disturbance have been identified as a threat for the recovery of these species. Anthropogenic noise in biologically important areas will be managed such that any blue whale continues to utilise the area without injury and is not displaced from a foraging area.	Displacement of pygmy blue whales from the potential foraging area is not predicted, as only 2.2% of the potential foraging area is predicted to be ensonified at levels above behaviour response thresholds for the governing scenario - Offtake activities with a MODU present. This leaves 98% of the potential foraging area available to pygmy blue whales for uninterrupted foraging. Potential impacts are therefore likely to be restricted to a small number of individuals that may be travelling through the area. Therefore, the impacts from underwater noise emissions to pygmy blue whales has been assessed as minor. Brecknock and Torosa piling animal movement modelling simulation results demonstrate that incorporation of shutdowns eliminate any potential for injury to both migrating and possible foraging pygmy blue whales within the migratory and possible foraging BIAs. Furthermore, for vessel related noise as it is not credible that a whale would remain within the required close proximity to a either the FPSO or a MODU for a continuous 24-hour duration, it is not considered credible for continuous noise sources to result in injury to pygmy blue whales. This is not inconsistent with the Blue Whale Conservation Management Plan that assessed shipping and industrial noise as 'minor – individuals are affected but no affect at the population level'. Therefore, it is considered that the proposed activities are not inconsistent with the Conservation Management Plan for the Blue Whale or the conservation advices listed.
Humpback whale	Conservation advice *Megaptera novaeangliae*, Humpback Whale		
Sei whale	Conservation advice *Balaenoptera borealis*, Sei Whale		
Fin whale	Conservation advice *Balaenoptera physalus*, Fin Whale		

Key Ecological Features

Change in fauna behaviour and Injury or mortality to fauna

Underwater noise emissions will occur in the Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEF and the Continental slope demersal fish communities KEF during all phases of the proposed Browse to NWS Project. The sources of these noise emissions are detailed in **Section 6.3.8.1**. These KEFs are recognised for their high species richness and for the high diversity of demersal fish respectively. The Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012) recognises noise pollution as a pressure 'of less concern' in the relation to the Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEF and a pressure 'not of concern' in relation to the Continental slope demersal fish communities KEF.

As described above, no significant impacts to marine fauna including fish and plankton are expected to occur and as such; subsequent impacts to the conservation values of these KEFs are not expected.

Underwater noise emissions will also occur within Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF (depending on the final route of the BTL) and the Ancient coastline at 125 m depth contour KEF. The Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012) recognises noise pollution as a pressure 'not of concern' in relation to these KEFs. Underwater noise emissions in these KEFs will be temporary and limited to noise related to the installation of the BTL and vessel noise associated with intermittent IMR activities. These underwater noise emissions are considered highly unlikely to affect marine fauna or the conservation values of these KEFs.

Table 6-71 provides an assessment of the proposed underwater noise emissions in relation to the pressures on KEFs identified in the Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).

Table 6-71 Alignment with protection of conservation values of KEFs – underwater noise

Key Ecological Feature	Relevant plan(s)	Relevant pressures	Assessment
Seringapatam Reef and Commonwealth waters in the Scott Reef Complex	Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).	Noise pollution - currently identified as 'less of concern'	Underwater noise emissions from the proposed project activities within these KEFs will be low level, temporary and transient in nature and therefore there is a high level of confidence that such emissions will not result in an adverse impact to marine ecosystem function or integrity with in the KEFs; or any reduction in to the conservation values of the KEFs will occur.
Continental slope demersal fish communities		Noise pollution - currently identified as 'not of concern'	
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals			
Ancient coastline at 125 m depth contour			

Australian Marine Parks

Change in fauna behaviour

Noise emissions will occur from vessels associated with the installation of the BTL and intermittent IMR activities within the Argo-Rowley Terrace and Kimberley AMPs. The proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park.

The Argo-Rowley Terrace and Kimberley AMP protects a variety of values that could be potentially impacted by underwater noise. The Marine bioregional plan for the North-west Marine Region places noise pollution as a priority for conservation effort in this region because it is of potential concern for multiple conservation values and the pressure in increasing in the region (Commonwealth of Australia, 2012). This plan recognises that anthropogenic noise poses a significant threat to cetaceans in particular because it may mask sounds that are vital for their essential activities and behaviour.

Given the distance from the source activities (>100 km to the boundary of the Kimberly AMP and >180 km to the boundary of the Argo-Rowley Terrace AMP), underwater noise emissions generated at the Browse Development Area are not predicted to have any impacts on the values or users of the AMPs.

Due to the short duration and temporary nature of the underwater noise emissions associated with the installation of the proposed BTL and IMR activities within the AMPs, no significant impacts are expected from these proposed activities.

Table 6-72 provides an assessment of the proposed underwater noise emissions in consideration of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018)

Table 6-72 Alignment with the North-west Marine Parks Network Management Plan – underwater noise

Australia Marine Park	Relevant plan(s)	Australian Marine Park Objectives	Assessment
Argo-Rowley Terrace Marine Park Multi Use Zone (VI) Kimberley Marine Park Multi Use Zone (VI)	North-west Marine Parks Network Management Plan (Director of National Parks, 2018)	The objective of the Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species.	Underwater noise emissions from the proposed project activities within these AMPs will be low level, temporary and transient in nature and therefore unlikely to disturb marine turtles or seabirds in these AMPs. There is a high level of confidence that ambient light will not result in an adverse impact to marine ecosystems, habitats or native species such that the conservation values of the AMPs would be reduced. As such, it is considered that the proposed activities are not inconsistent with the requirements of the North-west Marine Parks Network Management (Director of National Parks, 2018).
Mermaid Reef Marine Park National Park Zone (II)		The objective of the National Park Zone (II) is to provide for the protection and conservation of ecosystems, habitats and native species in as natural a state as possible.	The proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park. As such, underwater noise emissions associated with the installation of the BTL and occasional IMR activities are not considered a credible source of significant impact and no effect on ecosystems, habitats or native species in the AMP will occur. As such, it is considered that the proposed activities are not inconsistent with the requirements of the North-west Marine Parks Network Management (Director of National Parks, 2018).

State Marine Parks and Nature Reserves

Change in fauna behaviour and Injury or mortality to fauna

The Scott Reef Nature Reserve is utilised by fauna including turtles. Sandy Islet in particular is used by nesting green turtles. As described above, no injury or mortality to marine turtle is predicted, with impacts restricted to temporary behavioural impact to a very small portion of the population. As such, not adverse impact to the conservation values of the Scott Reef Nature Reserve is predicted.

Other Protected Places

Change in fauna behaviour and Injury or mortality to fauna

The Scott Reef and Surrounds - Commonwealth Area Commonwealth Heritage Place comprises the Commonwealth Marine Area wholly within the WA coastal waters surrounding North and South Scott Reef. The Commonwealth Heritage Place is utilised by seabirds, marine mammals and marine turtles; and supports diverse fish and coral communities. As described above no injury or mortality to marine fauna is predicted, with impacts restricted to temporary behavioural impact to a very small of the population. Given this, it is considered that the identified conservation values of these other protected places will not be detrimentally impacted by underwater noise associated with the proposed Browse to NWS Project

Other users

Changes to the functions, interests or activities of other users – State and Commonwealth fisheries

Where the functions, interests or activities of other users involve marine fauna (e.g. fisheries), any effect to fauna presence or abundance will indirectly impact on the functions, interests or activities of other users. Given that the impacts from underwater noise emissions to marine fauna including fish are not expected to be significant, no significant subsequent impact to fisheries is expected.

Changes to the functions, interests or activities of other users – tourism and recreation, scientific studies

Scott Reef is used for tourism and recreation (primarily fishing charters) and scientific studies at low levels. Given the underwater noise modellings predictions demonstrate noise emissions will attenuate significantly prior to reaching Scott Reef, impacts to tourism/ recreation and scientific studies are expected to be negligible.

6.3.8.4 Environmental Risk

Risk event: Displacement of pygmy blue whales from Scott Reef channel as a result of subsea choke valve noise

There is a risk that the number of individuals that would be impacted may be higher than predicted. It should be noted however that the simulated impacts to each individual would remain unchanged.

The assessment presented within the draft EIS/ERD is based on current available information and indicated no significant impact is expected to occur to marine fauna (such as pygmy blue whales) utilising the channel between north and south Scott Reef as a result of subsea choke valve noise. In the event that subsea choke valve noise is significantly higher than predicted, there is the potential for this noise to result in an increased behavioural response to whales within the channel. Further, as the drill centres planned for within the Scott Reef channel will not be developed as part of phase one RFSU, underwater noise monitoring of RFSU operational wells will be undertaken prior the development of any wells within the channel which will allow for adaptive management and mitigation to be applied prior to the development of any wells within the channel. As such, it is considered highly unlikely that subsea choke valve noise significantly above predicted resulting in significant impacts to pygmy blue whales will occur.

6.3.8.5 Cumulative Impacts

Underwater noise during the drilling, installation and commissioning phases of the project will be temporary and localised to the source of the activity. Therefore, the risk of cumulative impacts resulting from the generation of underwater noise associated with the drilling, installation and commissioning phases of the proposed Browse to NWS Project is low when considering other potential sources within the broader Project Area or region.

The results indicated that underwater noise emissions during offloading activities at Torosa and Brecknock with the MODU at Torosa TRD well predicted noise emissions to exceed 120 dB re 1 µPa (SPL) within an area of 274.6 km^2 of the pygmy blue whale possible foraging area. This corresponds to 2.2% of the possible foraging area, leaving ~98% of the possible foraging area available to pygmy blue whales and uninterrupted foraging.

These noise levels are sufficiently distant from other oil and gas infrastructure (i.e. Prelude and Ichthys developments) so as no cumulative impacts are anticipated.

6.3.8.6 Impact and Risk Assessment Summary and Acceptability Assessment

A summary of the impact and risk assessment for the underwater noise emission is provided in Table 6-73 and Table 6-74 respectively. The acceptability assessment is provided in Table 6-75.

Table 6-73 Impact assessment summary and adopted controls – underwater noise

Receptor (sensitivity)	Impact	Environmental objective	Adopted controls	Magnitude	Impact Significance Level

Ambient noise (medium value (open water))	Change in ambient noise	**Objective 5:** To not result in a substantial change in ambient light or ambient noise which may adversely impact on biodiversity, ecological integrity, social amenity or human health	***Project vessel operations***
			+ Vessels will operate in accordance with EPBC Regulations 2000 – Part 8 Division 8.1 and Australian National Guidelines for Whale and Dolphin Watching whereby:
			  + Vessels will not knowingly travel greater than six knots within 300 m of a whale or 100 m of a dolphin.
			  + Vessels will not knowingly approach closer than 100 m to a whale or 50 m to a dolphin (except if bow riding).
			  + Vessels will not knowingly restrict the path of cetaceans.
			+ Interactions between support vessels and whale sharks will be not inconsistent with the Whale Shark Code of Conduct
			Operations
			+ VSP operations will have trained vessel crew as a marine fauna observer[12] and will be subject to pre-start up visual observations, operational, and shut-down procedures, as follows:
			  + 500 m shut down zone for whales
			  + 500 m shut down zone for marine turtles.
			+ Impact pile driving activities will have trained vessel crew as a marine fauna observer and will be subject to pre-start up visual observations, soft start, operational, and shut-down procedures, as follows:
			  + 2 km shut down zone for whales
			  + 500 m shut down zone for marine turtles.
			+ During impact piling, thermal imaging will be used during night time / times of low visibility to assist in detecting whales within the shutdown zones.
			+ Underwater noise monitoring of an operational well will be undertaken to inform an adaptive management approach for noise management for the TRD and TRE wells if required.
				Slight	Slight (E)

Plankton communities (medium value (open water))	Change in fauna behaviour	**Objective 7:** To not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution.		No lasting effect	Negligible (F)
Shallow water benthic communities and habitats (<75 m depth) (high value habitat)	Injury or mortality to fauna	**Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the S Scott Reef shallow water benthic habitat (<75 m bathymetry).		No impact predicted	
Deepwater communities and habitats (>75 m depth) (medium value habitat)	Injury or mortality to fauna	**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.		No lasting effect	Negligible (F)
Fish (high value species)	Change in fauna behaviour and Injury or mortality to fauna	**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **Objective 15:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population		No lasting effect	Slight (E)
Marine mammals (high value species)	Change in fauna behaviour and Injury or mortality to fauna			Slight	Minor (D)
Marine reptiles (high value species)	Change in fauna behaviour and Injury or mortality to fauna			Slight	Minor (D)

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[12] *Marine fauna observer – a dedicated and suitably trained person who must not have any other duties that impede their ability to engage in visual observations for whale and marine turtles*

Receptor (sensitivity)	Impact	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
KEFs (medium value)	Change in fauna behaviour and Injury or mortality to fauna	**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.		No lasting effect	Negligible (F)
AMPs (medium value (multiple use zones))	Change in fauna behaviour	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No lasting effect	Negligible (F)
State Marine Parks and nature reserves (high value)	Change in fauna behaviour and Injury or mortality to fauna			No lasting effect	Slight (E)
Other protected places (high value)	Change in fauna behaviour and Injury or mortality to fauna			No lasting effect	Slight (E)
Managed fisheries (high value marine user)	Changes to the function interests or activities of others	**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No lasting effect	Slight (E)
Other users including tourism and recreation and scientific studies (high value users)	Changes to the function interests or activities of others	**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No lasting effect	Slight (E)

Table 6-74 Risk assessment summary and adopted controls – Underwater Noise

Receptor	Risk Event	Environmental objective	Adopted controls	Consequence	Likelihood	Risk Rating
Ambient noise (medium value (open water))	Displacement of pygmy blue whales from Scott Reef Channel as a result of subsea choke valve noise	**Objective 5:** To not result in a substantial change in ambient light or ambient noise which may adversely impact on biodiversity, ecological integrity, social amenity or human health	No further controls (in addition to those described in Table 6-73 adopted).	No increase to significance/consequence		
Plankton (medium value (open water))		**Objective 7:** To not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution.		No increase to significance/consequence		
Shallow water benthic communities and habitats (<75 m depth) (high value habitat)		**Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry).		No increase to significance/consequence		
Deepwater communities and habitats (>75 m depth) (medium value habitat)		**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.		No increase to significance/consequence		
Fish (high value species)		**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **Objective 15:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population		No increase to significance/consequence		
Marine mammals (high value species)				Minor (C)	Highly Unlikely (1)	Moderate (C1)
Marine reptiles (high value species)				No increase to significance/consequence		
KEFs (medium value)		**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.		No increase to significance/consequence		
AMPs (medium value (multiple use zones))		**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No increase to significance/consequence		
State Marine Parks and nature reserves (high value)				No increase to significance/consequence		
Other protected places (high value)				No increase to significance/consequence		
Managed fisheries (high value marine user)		**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No increase to significance/consequence		
Other users including tourism and recreation and scientific studies (high value users)		**Objective 21**: To not interfere with other marine users to a greater extent than is necessary for the execution of the Browse to NWS Project.		No increase to significance/consequence		

Table 6-75 Acceptability Assessment – Underwater Noise

Acceptability Assessment
Certainty in Assessment Woodside have a high level of certainty with respect to the assessment of the potential impacts associated with underwater noise emissions as: + A robust underwater noise modelling study has indicated that there would be minimal impact to sensitive receptors. + The proposed controls are likely to effectively mitigate the potential impacts associated with the underwater noise emissions. The available pygmy blue whale and green turtle data, 2002 to 2017, were determined to be adequate for the purposes of impact assessment and management planning purposes based on the lack of significantly altered regional cumulative impacts since collection (Chapter 9), ability to extrapolate population trends using existing literature, and conservative interpretation of available data where applied. The existing data will be updated by targeted monitoring programs to verify impact predictions and inform adaptive management approaches at relevant times throughout the project life cycle.
Principles of ESD With the application of the proposed controls it is predicted that the nominated environmental objectives for each potentially impacted receptor will be achieved. As such it is considered that the principles of ESD will be met. **Conclusion: Acceptable**
Significant Impacts as defined by the MNES Significant Impact Guidelines ***Listed threated species and ecological communities / listed migratory species*** As described in Table 6-73, no lasting effect is predicted to occur as a result of underwater noise emissions to listed threatened and migratory fish with the impact significance level determined to be Slight (E). Slight impacts are predicted to occur to listed threatened and migratory marine mammals (pygmy blue whales) and marine turtles with the impact significance level determined to be Minor (D). As described in Table 6-74, potential risk events associated with underwater noise present a Moderate risk to marine mammals (pygmy blue whales) noting that the identified risk event is considered highly unlikely to occur. Given this, with the application of the proposed controls it is predicted that the nominated environmental objectives for each of these fauna species will be achieved. As such, no significant impacts to the listed threated or migratory species (as defined by the Significant Impact Guidelines (Table 6-5)) are predicted. ***Commonwealth Marine Environment*** As described in Table 6-73, the potential impacts resulting from underwater noise emissions to plankton, deepwater communities and habitats (>75 m depth), KEFs and AMPs has been assessed as Negligible (F). Slight (E) impacts may potentially occur to ambient noise, fish, other protected places, managed fisheries and other users. Minor (D) impacts are predicted to marine mammals (pygmy blue whale) and marine turtles, while no impact is predicted to occur to shallow water benthic communities and habitats (<75 m depth). As described in Table 6-74, potential risk events associated with underwater noise present a Moderate risk to marine mammals (pygmy blue whales) noting that the identified risk event is considered highly unlikely to occur. Given this, with the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such no significant impacts to the Commonwealth marine environmental (as defined by the Significant Impact Guidelines (Table 6-5)) are predicted. **Conclusion: Acceptable**

Acceptability Assessment

WA EPA Environmental Objectives

An assessment of the impacts of underwater noise against the WA EPA Objective is presented in the State Proposal ERD (Chapter 10, Appendix B).

Marine environmental quality

As described in **Table 6-73**, the potential impact from underwater noise emissions to plankton and deepwater water benthic communities and habitats (>75 m depth) has been as Negligible (F). Slight (E) impacts are predicted to fish. Minor (D) impacts are predicted to occur to marine mammals (pygmy blue whales) and marine turtles, while no impact is predicted to occur to shallow water benthic communities and habitats (<75 m depth).

As described in **Table 6-74**, potential risk events associated with underwater noise present a Moderate risk to marine mammals (pygmy blue whales) noting that the identified risk event is considered highly unlikely to occur.

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*to maintain the quality of water, sediment and biota so that environmental values are protected*" will be achieved.

Marine Fauna

As described in **Table 6-73**, no lasting effect is predicted to occur as a result of underwater noise emissions to fish with the impact significance level determined to be Slight (E). Slight impacts are predicted to occur to marine mammals (pygmy blue whales) and marine turtles with the impact significance level determined to be Minor (D).

As described in **Table 6-74**, potential risk events associated with underwater noise present a Moderate risk to marine mammals (pygmy blue whales) noting that the identified risk event is considered highly unlikely to occur.

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*To protect marine fauna so that biological diversity and ecological integrity are maintained*" will be achieved.

Benthic communities and habitats

As described in **Table 6-73**, the potential impacts resulting from underwater noise emissions to deepwater benthic communities and habitats (>75 m depth) has been assessed as Negligible (F), while no impact is predicted to occur to shallow water benthic communities and habitats (<75 m depth).

No risk event associated with underwater noise emissions that may potentially impact benthic habitats have been identified.

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*to protect benthic communities and habitats so that biological diversity and ecological integrity are maintained*" will be achieved.

Conclusion: Acceptable

External context

To date there have been no specific matters raised by stakeholders regarding underwater noise emissions from activities associated with the proposed Browse to NWS Project.

Conclusion: Acceptable

Internal context

There are no specific Woodside internal environmental requirements, including policies, procedures and standards regarding underwater noise emissions.

Conclusion: Acceptable

Acceptability Assessment
Other requirements As detailed in Table 6-70, the proposed activities are considered to be not inconsistent with the actions and objectives of: + Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a) + Conservation Management Plan for the Blue Whale: A recovery plan under the *Environment Protection and Biodiversity Conservation Act 1999* 2015-2025 (Commonwealth of Australia, 2015b) + The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) + Conservation Advice for *Megaptera novaeangliae* (humpback whale) (Threatened Species Scientific Committee, 2015b) + Conservation Advice *Balaenoptera borealis* sei whale (Threatened Species Scientific Committee, 2015c) + Conservation Advice *Balaenoptera physalus* fin whale (Threatened Species Scientific Committee, 2015d).
KEFs As detailed in Table 6-71 proposed underwater noise emissions will not materially increase existing relevant pressures on the conservation values of KEFs.
AMPs As detailed in Table 6-72 the proposed activities are considered to be not inconsistent with the requirements of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018).
Conclusion: Acceptable

6.3.9 Marine Discharges: Sewage and Sullage

6.3.9.1 Impact and Risk Overview

Table 6-76 presents an overview of the potential impacts and risks from sewage and sullage discharges associated with the proposed Browse to NWS Project.

Table 6-76 Sewage and sullage impact and risk overview

Aspect	Marine discharges: sewage and sullage
Description	Sewage and sullage (grey water generated from domestic processes such as dish washing, laundry and showers) associated with the operation of MODU(s), project vessels and the FPSO facilities will be discharged during all phases of the proposed Browse to NWS Project.
Area	Project Area, Browse Development Area, State Proposal Area
Project stage	All - drilling and completions, installation, commissioning, operations and decommissioning
Environmental objectives	The environmental objectives in relation to sewage and sullage discharges associated with the proposed Browse to NWS Project are Objectives 3, 6, 7, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20 and 21. These objectives are detailed in Table 6-7**.**
Policy and guidelines	The following policy and guidelines are relevant to the assessment of this aspect. In addition, a number of EPBC Act conservation advices for protected fauna have been considered (Table 6-77). + Commonwealth Protection of the Sea (Prevention of Pollution from Ships) Act 1983. This is the primary federal legislative instrument for Australia’s implementation of the International Convention for the Prevention of Pollution from Ships (MARPOL). + Commonwealth Navigation Act 2012 + Marine Order 96 (Marine pollution prevention—sewage) + WA EPA Environmental Factor Guideline - Marine Environmental Quality (EPA, 2016d) + North-west Marine Parks Network Management Plan (Director of National Parks, 2018) + Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) + Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c) + Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).

<table>
<tr><th>Aspect</th><th colspan="3">Marine discharges: sewage and sullage</th></tr>
<tr><td>Receptors</td><td colspan="3">The following receptors have been identified as potentially being impacted as a result of the proposed Browse to NWS Project (Table 6-2). A detailed description of each of these receptors is provided in Chapter 5.
Physical
+ water quality (medium value (open water))
Ecological
+ plankton communities (low value (open water))
+ benthic habitats
  + shallow water benthic communities and habitats (<75 m depth) (high value habitat)
  + deepwater communities and habitats (>75 m depth) (medium value habitat
+ fauna
  + fish (high value species)
  + marine reptiles (high value species)
  + marine mammals (high value species)
+ KEFs (high value)
+ AMPs (high value)
+ other protected places (high value)
Socio-economic
+ State and Commonwealth managed fisheries (high value marine user)
+ other users
  + tourism and recreation (high value user)
  + scientific studies (high value user)</td></tr>
<tr><td>Potential impacts</td><td colspan="3">+ change in water quality
+ change in fauna behaviour
+ injury or mortality to fauna
+ changes to the functions, interests or activities of other users</td></tr>
<tr><td>Risk</td><td colspan="3">unplanned discharge significantly above discharge specifications</td></tr>
<tr><td rowspan="2">Summary of governing impact evaluation</td><td>Magnitude</td><td>Impact significance level</td><td>Confidence</td></tr>
<tr><td>No lasting effect</td><td>Slight (E)</td><td>High</td></tr>
<tr><td rowspan="2">Summary of governing risk evaluation</td><td>Consequence</td><td>Likelihood</td><td>Risk rating</td></tr>
<tr><td>Slight</td><td>Remote</td><td>Low (E0)</td></tr>
</table>

6.3.9.2 Source of Aspect

Sewage and sullage (grey water generated from domestic processes such as dish washing, laundry and showers) will be generated on the MODU, project vessels and the FPSO facilities throughout the various proposed Browse to NWS Project phases. Sewage and sullage volumes generated will vary depending on the number of people on board each FPSO facility, vessel and MODU. There are no planned discharges of untreated sewage or sullage within the State Proposal Area; however, discharges of treated sewage and sullage from the MODU and vessels within the State Proposal Area will occur.

Approximate sewage and sullage volumes for the largest sources have been determined using a rate of 0.375 m^3/person/day (NERA, 2017) as a guide, and are as follows:

- Vessels – The number of vessels and persons on board (POB) will peak during construction and commissioning. The largest construction vessel is the pipelay vessel for the BTL installation, which may have approximately 700 POB, and therefore have the largest discharge volume (262 m^3/day). Note that the pipelay vessel is only expected to be present during installation and commissioning. Support vessels for anchoring, towage, installation, and commissioning are expected to have between 20 and 60 POB each vessel.
- MODUs - MODUs typically have up to approximately 180 people, depending on the type of MODU selected. During these peak times A MODU would be expected to generate around 67.5m^3/day of waste water per day.
- FPSO facilities - Sewage and sullage generation is dependent on the number of POB. The routine operational workforce will number up to approximately 60 people onboard each FPSO facility. During peak times only (e.g. hookup and major shutdown events), additional people may be required and each FPSO facility will have the capacity to accommodate approximately 180 people. During operations, the FPSO will discharge between 20 - 70 m^3/day depending on manning. A support vessel may also be present which may discharge approximately 9.4 m^3/day.

The FPSOs are located in deep oceanic Commonwealth waters away from sensitive receiving environments such as Scott Reef (the closest being the Torosa FPSO facility approximately 8 km from the reef). The FPSOs will have a Sewage Treatment Plant onboard to process sewage, which as per MARPOL73/78 is required for discharge within 3 nm of land despite their location being greater than 3 nm from land.

Discharges of treated sewage and sullage in proximity to Scott Reef will be primarily related to the drilling and completion activities and the installation of the subsea infrastructure, with no permanent vessel presence in the State Proposal Area during operations. Under normal operating conditions, drilling and completion and vessel activity (and associated marine discharges) will be limited to the deep waters in proximity to the location of the proposed development wells and subsea infrastructure.

6.3.9.3 Environmental Impact

Water quality

Change in water quality

Discharged sewage and sullage has the potential to alter the physical characteristics of local marine water quality, primarily through eutrophication as a result of increased nutrient levels (e.g. ammonia, nitrite, nitrate and orthophosphate). Eutrophication occurs when the addition of nutrients, such as nitrates and phosphates, causes adverse changes to the ecosystem, such as increased growth of primary producers (e.g. phytoplankton) which can deplete oxygen in the water column and result in changes in biological processes.

Sewage and sullage may also include some particulate matter which can cause an increase in the turbidity of the receiving waters close to the point of discharge. Discharges will disperse and dilute rapidly, with concentrations of wastes significantly dropping with distance from the discharge point. Several studies have quantified the high levels of dilution, including Loehr et al. (2006). A study by the US EPA (2002) found that discharge plumes behind cruise ships moving at between 9.1 and 17.4 knots are diluted by a factor of between 200,000:1 and 640,000:1. The discharges and level of effluent dilution in the studies did not present significant localised toxicity impacts to marine biota from any changes in water quality.

The effects of sewage and sullage discharges on the water quality at Scott Reef were investigated during the drilling campaign for the Torosa-6 well in 2008. The drilling rig was operating near the edge of the deepwater lagoon area at South Scott Reef (ERM and SKM, 2008). The rig was equipped with a MARPOL approved sewage treatment plant producing approximately 10 m^3/day of sewage/sullage during operations, which is likely to be comparable to the rates estimated for routine operations on the MODU and FPSO facilities. Water quality sampling at stations 50, 100 and 200 m downstream of the platform at different water depths determined that discharges were rapidly diluted in the upper (less than 10 m) water layer to 1% of its original concentration within 50 m, with no elevations above background in nutrients or metals recorded at any sampling station.

Plankton communities

Change in fauna behaviour

Although organic materials from the discharges will likely exert biological oxygen demand on the receiving waters, this is unlikely to reach levels below background ambient dissolved oxygen concentrations. Similarly, while the nutrient inputs from discharged effluent will rapidly be taken up by phytoplankton, pronounced increases in productivity as evidenced by increased chlorophyll a concentration are not expected. This is largely due to the assimilative capacity of the open ocean, with any potential additive nutrients not expected to accumulate in the vicinity of the discharge location. As such no lasting impacts to plankton communities are expected.

Benthic habitats

Change in water quality

Given the minimum water depth at the discharge locations (i.e. 125 m at the NRC tie-in), it is not predicted that changes in water quality resulting from the discharge of sewage and sullage will affect the deepwater benthic habitats of the Project Area.

Given the distance from the main sewage and sullage discharge location in relation to Scott Reef (FPSO > 8 km away) impacts to high value benthic habitats at Scott Reef are not anticipated. Furthermore, studies on the dispersion of coral larvae at Scott Reef (Done et al., 2015; Foster and Gilmour, 2018)we examine distance decay among coral communities in a common habitat on northwestern Australian reefs, seeking to better understand the roles of disturbance and coral life history strategies in the changing reefscape. In established communities in 1997, when coral cover and generic richness were uniformly high, there was high similarity (~81 % demonstrates that while there is marked movement of larvae within the reef system itself (broadcast spawning corals), there is no evidence to suggest that those coral larvae that initially dispersed off the reef return to Scott Reef to settle. Therefore, sewage and sullage discharge is not likely to impact the recruitment of corals within the Scott Reef system.

Marine fauna

Injury or mortality to fauna – fish, marine mammals, marine turtles

Chemicals within sewage and sullage discharges may include organics (e.g. volatile and semi-volatile organic compounds, oil and grease, phenols, endocrine disrupting compounds) and inorganics (e.g. hydrogen sulphide, metals and metalloids, surfactants, phthalates, residual chlorine). There is also the potential for biological pathogens, such as bacteria, viruses, protozoa and parasites.

Discharge will also occur from project vessels, the MODU and the Torosa FPSO facility in a possible foraging area and a migration BIA for pygmy blue whales as identified in the Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c). This plan identified chronic chemical pollution as a potential risk to pygmy blue whales. Conservation advices for other EPBC listed marine mammals that may occur in the Project Area do not identify chemical pollution as a key threat (Table 5-19).

Marine fauna such as fish, marine mammals and marine turtles may come into contact with these discharges, however given that the discharges will disperse rapidly close to the discharge point and that any contact with the discharge with marine fauna will be of extremely short duration, it is not considered credible that toxic affects to marine fauna will occur and therefore, in summary, it is not predicted that adverse impacts would occur to marine fauna as a result of sewage and sullage discharge.

Assessment against EPBC Act recovery and conservation plans and advices

Table 6-77 provides an assessment of the sewage and sullage discharge from the proposed activities in relation to objectives and actions of the relevant EPBC Act recovery and conservation plans and advices.

Table 6-77 Alignment with EPBC Act recovery and conservation plans and advices for protected fauna – sewage and sullage

Fauna	Relevant plan(s)/ conservation advice	Plan/Advice objectives and actions	Assessment
Whale shark	Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a)	Assess the impacts of offshore installations and associated environmental changes (light spill, chronic noise, changed water temperature, localised nutrient levels) on whale sharks and mitigation options for these impacts.	The potential impact of sewage and sullage discharges resulting from the proposed Browse to NWS Project have been assessed. Given the low numbers and infrequent nature of whale shark presence in the Project Area, there is a high level of confidence that sewage and sullage discharges will not result in adverse impact to whale sharks.
Green turtle Hawksbill turtle	The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a)	Manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to the survival. Manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue. In relation to the Scott Reef – Browse Island green turtle genetic stock, the priority action is to manage anthropogenic activities to ensure marine turtle are not displaced from identified habitat critical to their survival.	Potential impacts to turtles have been assessed and will be managed in accordance with the Recovery Plan for Marine Turtles in Australia (2017-2027) which includes the minimisation of chemical discharge as an overarching action area (Commonwealth of Australia, 2017a). Given the nature, volume and dispersion of the sewage or sullage drainage discharges, adverse impacts to marine turtles are not expected. As such, in relation to the Scott Reef – Browse Island green turtle genetic stock, the priority action to manage anthropogenic activities to ensure marine turtle are not displaced from identified habitat critical to their survival is predicted to be met. Likewise, it is not predicted that sewage and sullage discharge will adversely affect the breeding cycle of marine turtles in the BIA at Scott Reef. Therefore, it is considered that the proposed activities are not inconsistent with the objectives of the Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a).

Fauna	Relevant plan(s)/ conservation advice	Plan/Advice objectives and actions	Assessment
Pygmy blue whale	Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c)	Chronic chemical pollution is identified as a potential risk to pygmy blue whales, however there are no specific actions identified	Occasional exposure of individuals of these species to the sewage and sullage discharge may occur. However, given the nature, volume and dispersion of the predicted discharges, and the highly mobile nature of marine mammals, exposure would be temporary and is not expected to have any lasting impacts on the listed whale species. Therefore, it is considered that the proposed activities are not inconsistent with the Conservation Management Plan for the Blue Whale or the conservation advices listed.
Humpback whale	Conservation advice *Megaptera novaeangliae*, Humpback Whale	Marine discharges have not been identified as a direct threat to these whale species; however, habitat degradation has been identified as a threat and unmanaged discharges may contribute to this threat. The conservation advice relevant for this threat – identifies modification to the coastal region in areas of importance to listed whales may result in reduced occupancy, compromised reproductive success and even mortality.	
Sei whale	Conservation advice *Balaenoptera borealis*, Sei Whale		
Fin whale	Conservation advice *Balaenoptera physalus*, Fin Whale		

KEFs

Change in water quality

The Continental slope demersal fish communities KEF and Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEFs overlap with the Browse Development Area. Sewage and sullage discharges will occur within these KEFs from project vessels, MODU and the FPSO facilities. The BTL traverses the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF (depending on the final BTL route) and the Ancient coastline at 125 m depth contour KEF. Discharge of sewage and sullage will occur within these KEFs from project vessels during the BTL installation and intermittent IMR activities. The conservation values of these KEFs are described in **Section 5.3.3.1**.

As described above, changes to water quality as a result of sewage and sullage discharge are predicted to be temporary and highly localised. As such no lasting impacts to the conservation values of these KEFs is predicted. No impact is predicted to the reefs associated with the Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEF.

Table 6-78 provides an assessment of the proposed sewage and sullage discharges in relation to the pressures on KEFs identified in the Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).

Table 6-78 Alignment with protection of conservation values of KEFs – sewage and sullage

Key Ecological Feature	Relevant plan(s)	Relevant pressures	Assessment
Continental slope demersal fish communities	Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).	Chemical pollution / contaminants and nutrient pollution - currently identified as 'not of concern'.	Given that any sewage and sullage discharges will occur in surface waters with changes in water quality predicted to be temporary and highly localised, there is a high level of confidence that such discharges will not result in an adverse impact to marine ecosystem function or integrity with in the KEFs; or any reduction in to the conservation values of the KEFs will occur.
Seringapatam Reef and Commonwealth waters in the Scott Reef Complex			
Ancient coastline at 125 m depth contour			
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals		Chemical pollution / contaminants and nutrient pollution - currently identified as 'data deficient or not assessed	

Australian Marine Parks

Change in water quality

Vessels associated with the installation of the BTL, IMR vessels during operations and transiting project vessels will discharge sewage and sullage within the Multiple Use Zones (IV) of the Argo-Rowley Terrace and Kimberley AMPs. Discharges from vessels operating within the AMPs will be temporary and transient in nature (e.g. the slowest moving Project vessel will be the pipelay vessel, which will move at a rate of up to 5 km/day). In addition, vessels operating along the BTL will discharge sewage and sullage in accordance with the approved allowed activities of the multiple use zoning (IUCN VI), which permits the disposal of waste from the normal operations of vessels in accordance with MARPOL requirements. It should also be noted that the proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park and it is unlikely that the effluent would reach this AMP from the discharge point.

The Kimberley Marine Park ranges in water depth from less than 15 m to 800 m, providing protection for habitats and ecological communities in waters offshore of the Kimberley coastline. Fauna that utilise this AMP include seabirds, marine turtles, inshore dolphins, humpback whales, pygmy blue whales, dugongs and whale sharks. The Argo-Rowley Terrace AMP provides protection for the ecological communities and habitats of the deeper offshore waters, and key features include Mermaid, Clerke and Imperieuse Reefs. This AMP also protects threatened, migratory, marine and cetacean species as well as BIAs for seabirds and migratory pathways for the pygmy blue whale (Director of National Parks, 2018).

The release of effluents that could locally affect the quality of receiving marine waters is recognised as pressure in the North-west marine region (Commonwealth of Australia, 2012). The Marine Bioregional Plan for the North West Marine Region recognises that fauna and ecosystems may be vulnerable to marine discharges that include chemicals and toxins (Director of National Parks, 2018).

As described above, it is expected that the sewage and sullage effluent will disperse in very close proximity to the discharge point. Given the water depths along the BTL route >250 m, it is not predicted that the effluent will impact on the deepwater benthic habitats in the AMPs.

As described above, marine fauna within the AMPs are unlikely to be adversely impacted due to the dispersive action on the effluent and the transient nature of the fauna that could potentially be exposed to the discharge.

Given this, it is considered that the identified conservation values of these AMPs will not be adversely impacted by the discharge of sewage and sullage from project vessels associated with the proposed Browse to NWS Project.

Table 6-79 provides an assessment of the proposed sewage and sullage discharges in consideration of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018)

Table 6-79 Alignment with the North-west Marine Parks Network Management Plan – sewage and sullage discharge

Australia Marine Park	Relevant plan(s)	Australian Marine Park Objectives	Assessment
Argo-Rowley Terrace Marine Park Multi Use Zone (VI)	North-west Marine Parks Network Management Plan (Director of National Parks, 2018)	The objective of the Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species.	As outlined above, sewage and sullage discharges from vessels operating within these AMPs will be of a small volume (highest discharge is approximately 262 m^3/day from the pipelay vessel), temporary and transient in nature and therefore unlikely to impact marine fauna or benthic habitats in these AMPs. Therefore, there is a high level of confidence that sewage and sullage discharges will not result in any adverse impacts to marine ecosystems, habitats or native species such that the conservation values of the AMPs would be reduced. As such, it is considered that the proposed activities are not inconsistent with the requirements of the North-west Marine Parks Network Management (Director of National Parks, 2018)
Kimberley Marine Park Multi Use Zone (VI)			
Mermaid Reef Marine Park National Park Zone (II)		The objective of the National Park Zone (II) is to provide for the protection and conservation of ecosystems, habitats and native species in as natural a state as possible.	The proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park. As such, the sewage and sullage discharges associated with the installation of the BTL and occasional IMR activities are not considered a credible source of impact and no effect on ecosystems, habitats or native species in the AMP will is predicted. As such, it is considered that the proposed activities are not inconsistent with the requirements of the North-west Marine Parks Network Management (Director of National Parks, 2018).

Other protected places

Change in water quality

The Scott Reef and Surrounds - Commonwealth Area Commonwealth Heritage Place comprises the Commonwealth Marine Area wholly within the WA coastal waters surrounding North and South Scott Reef. The Commonwealth Heritage Place is utilised by seabirds, marine mammals and marine turtles; and supports diverse fish and coral communities. Project vessels will not operate within this area under normal operations.

Given this, and the dispersive nature of the effluent in close proximity to the discharge point, no impacts is predicted to occur to this Commonwealth Heritage Place as a result of sewage and sullage discharge. The same applies with respect to the potential for marine discharge impacts on the Mermaid Reef - Rowley Shoals Commonwealth Heritage Place.

As such, it is considered that the identified conservation values of these other protected places will not be adversely impacted by sewage and sullage discharge associated with the proposed Browse to NWS Project.

Other users

Changes to the functions, interests or activities of other users – State and Commonwealth managed fisheries

Where the functions, interests or activities of other users involve marine fauna (e.g. fisheries), any effect to fauna presence or abundance will indirectly impact on the functions, interests or activities of other users. Given that no lasting effect to fish have been predicted, no significant subsequent impact to fisheries is expected.

Changes to the functions, interests or activities of other users – tourism and recreation, scientific studies

Activities such as tourism and recreation and scientific studies at Scott Reef are unlikely to be impacted due to due the distance between Scott Reef and the discharge locations and the rapid dispersal of the discharges.

6.3.9.4 Environmental Risk

Risk event: Unplanned discharge of sewage and sullage significantly above discharge specifications

Though unlikely, discharges of sewage and sullage at levels significantly above the discharge specifications resulting from human error or equipment failure may occur. This would potentially result in a larger area being impacted (a temporary larger mixing zone), although the plume would still be expected to rapidly disperse. As per **Section 6.3.9.3**, it would remain unlikely that exposure to marine fauna would be sufficient to elicit a toxic response. As such no change to the significance of the impact to water quality, plankton communities, benthic habitat, marine fauna, KEFs, AMPs, other Protected Places, managed fisheries or other users would be expected.

In the event that the discharge of sewage and sullage at levels significantly above the indicative discharge specifications occurs from the MODU or vessels operating near Scott Reef at a time where the prevailing conditions result in the plume moving towards Scott Reef, there is a risk of resultant impacts to the Scott Reef habitats shallow water benthic habitats. This impact would be expected to be temporary and localised in nature. Given the controls in place and the distance from the closest source (i.e. MODU during drilling at TRE), the likelihood of such an event occurring and resulting in adverse effects on Scott Reef shallow water benthic habitat (<75 m bathymetry) is considered remote, with the subsequent risk assessed to be low.

6.3.9.5 Cumulative Impacts

Cumulative impacts resulting from the discharge of sewage and sullage from the two FPSO facilities, project vessels, MODU(s), other marine users or other operating facilities within the region are not expected, given the predicted volumes of waste, the highly localised nature of impacts and the large geographic spread of the facilities and activities.

6.3.9.6 Impact and Risk Assessment Summary and Acceptability Assessment

A summary of the impact and risk assessment for the discharge of sewage and sullage is provided in **Table 6-80** and **Table 6-81** respectively. The acceptability assessment is provided in **Table 6-82**.

Table 6-80 Impact assessment summary and adopted controls – marine discharges: sewage and sullage

Receptor (sensitivity)	Potential Impact	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
Water quality (medium value (open water))	Change in water quality	**Objective 3:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	***Project vessel and FPSO operations*** + Project vessels will comply with MARPOL 73/78 Annex IV: Sewage – (as applied in Australia under Commonwealth Protection of the Sea (Prevention of Pollution from Ships) Act 1983) and Marine Orders 96 (Marine pollution prevention—sewage). + The FPSO facilities will be equipped with sewage treatment systems compliant with the MARPOL73/78 9.1.1 requirements required for discharge within 3 nm of land despite their location being greater than 3 nm from land. ***Installation of the BTL and inter-field spur line*** + Sewage discharge will be conducted in a manner not inconsistent with the objectives, values and principles of the multi-use zones of the AMPs, which are traversed by the proposed BTL route. ***Operations*** + Discharge of sewage will occur in accordance with the WA Department of Transport sewage strategy within State waters. + There will be no discharge of untreated sewage within 3 nm of Scott Reef.	Slight	Slight (E)
Plankton (medium value (open water))	Change in fauna behaviour	**Objective 7:** To not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution.		No lasting effect	Negligible (F)
Deepwater benthic communities and habitats (>75 m depth) – (medium value	Change in water quality	**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.		No impact expected	
Shallow water benthic communities and habitats (<75 m depth) (high value habitat)	Change in water quality	**Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry).		No impact expected	
Fish (high value species)	Injury or mortality to fauna	**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **Objective 15:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.		No lasting effect	Slight (E)
Marine turtles (high value species)	Injury or mortality to fauna			No lasting effect	Slight (E)
Marine mammals (high value species)	Injury or mortality to fauna			No lasting effect	Slight (E)
KEFs (Medium value)	Change in water quality	**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.		No lasting effect	Negligible (F)
AMPs (Medium value)	Change in water quality	Objective 18: To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No lasting effect	Negligible (F)
Other protected places (high value)	Change in water quality	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No lasting effect	Slight (E)
State and Commonwealth managed fisheries (high value marine user)	Changes to the functions, interests or activities of other users	**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No lasting effect	Slight (E)
Other users including tourism and recreation and scientific studies (high value users)	Changes to the functions, interests or activities of other users	**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No lasting effect	Slight (E)

Receptor	Risk Event	Environmental objective	Adopted controls	Consequence	Likelihood	Risk Rating
Water quality (medium value (open water))	Unplanned discharge significantly above discharge specifications	**Objective 3:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	No further controls (in addition to those described in Table 6-80) adopted.	No increase to significance/consequence		
Plankton (medium value (open water))		**Objective 7:** To not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution.		No increase to significance/consequence		
Deepwater benthic communities and habitats (>75 m depth) – (medium value)		**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results. **Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry).		No increase to significance/consequence		
Shallow water benthic communities and habitats (<75 m depth) (high value habitat)				Slight	Remote	Low (E0)
Fish (high value species)		**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **Objective 15:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.		No increase to significance/consequence		
Marine turtles (high value species)				No increase to significance/consequence		
Marine mammals (high value species)				No increase to significance/consequence		
KEFs (medium value)		**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.		No increase to significance/consequence		
AMPs (medium value)		**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No increase to significance/consequence		
Other protected places (high value)		**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No increase to significance/consequence		
State and Commonwealth managed fisheries (high value marine user)		**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No increase to significance/consequence		
Other users including tourism and recreation and scientific studies (high value users)		**Objective 21:** To not interfere with other marine users to a greater extent than is necessary for the execution of the Browse to NWS Project.		No increase to significance/consequence		

Table 6-82 Acceptability assessment – marine discharges: sewage and sullage

Acceptability Assessment
Confidence in assessment Woodside have a high level of certainty with respect to the assessment of the potential impacts and risks associated with sewage and sullage discharges as: + Studies of the effects of sewage and sullage discharges on the water quality at Scott Reef were undertaken during the drilling campaign for the Torosa-6 well in 2008 which showed sewage and sullage discharges were rapidly diluted in the upper (less than 10 m) water layer to 1% of its original concentration within 50 m. + Controls listed in **Table 6-80**, including the implementation of MARPOL 73/78 Annex IV: Sewage – (as applied in Australia under Commonwealth Protection of the Sea (*Prevention of Pollution from Ships) Act 1983*) and *Marine Orders 96* (Marine pollution prevention—sewage), will be implemented to mitigate potential impacts. + In consideration of the lack of significant potential impacts, it is considered that studies have adequately characterised the marine fauna populations and distributions that may potentially be impacted by such discharges.
Principles of ESD With the application of the proposed controls in **Table 6-80** it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such it is considered that the principles of ESD will be met. **Conclusion: Acceptable**
Significant Impacts as defined by the MNES Significant Impact Guidelines *Listed threated species and ecological communities / listed migratory species* As described in **Table 6-80**, no lasting effect is predicted to occur from sewage and sullage discharge to listed threatened and migratory species such as fish, marine turtle and marine mammals, with the impact significance level determined to be Slight (E). As described in **Table 6-81**, potential risk events associated with sewage and sullage discharge are not predicted increased the significance/consequence of impacts to listed threatened and migratory species. Given this, with the application of the proposed controls it is predicted that the nominated environmental objectives for each of these fauna species will be achieved. As such, no significant impacts to the listed threated or migratory species (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted *Commonwealth Marine Environment* As described in **Table 6-80**, the potential impact from sewage and sullage discharge to plankton, KEFs and AMPs has been assessed as Negligible (F). Slight (E) impacts may potentially occur to water quality, marine fauna, other protected places, managed fisheries and other users, while no impact is predicted to occur to deepwater benthic communities and habitats (>75 m depth) and shallow water benthic communities and habitats (<75 m depth). As described in **Table 6-81**, potential risk events associated with sewage and sullage discharge present a Low risk to shallow water benthic communities and habitats (<75 m depth). As such, with the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such no significant impacts to the Commonwealth marine environmental (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted **Conclusion: Acceptable**

Acceptability Assessment

WA EPA Environmental Objectives

An assessment of the impacts of sewage and sullage against the WA EPA Objective is presented in the State Proposal ERD (**Chapter 10, Appendix B**).

Marine environmental quality

As described in **Table 6-80**, the potential impact from sewage and sullage discharge to plankton, has been assessed as Negligible (F). Slight (E) impacts may potentially occur to water quality.

As described in **Table 6-81**, potential risk events associated with sewage and sullage discharge are not predicted increased the significance/consequence of impacts to plankton or water quality.

Given this, it is considered that with the application of the proposed controls, the environmental objectives for these receptors, and the WA EPA environmental objective "*To maintain the quality of water, sediment and biota so that environmental values are protected*" will be achieved.

Marine Fauna

As described in **Table 6-80**, no lasting effect is predicted to occur from sewage and sullage discharge to marine fauna such as fish, marine turtle and marine mammals, with the impact significance level determined to be Slight (E).

As described in **Table 6-81**, potential risk events associated with sewage and sullage discharge are not predicted increased the significance/consequence of impacts to marine fauna species.

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*To protect marine fauna so that biological diversity and ecological integrity are maintained.*" will be achieved.

Benthic communities and habitats

As described in **Table 6-80** no impact is predicted to occur as a result of sewage and sullage discharge to deepwater benthic communities and habitats (>75 m depth) or shallow water benthic communities and habitats (<75 m depth).

As described in **Table 6-81**, potential risk events associated with sewage and sullage discharge present a Low risk to shallow water benthic communities and habitats (<75 m depth).

Given this, it is considered that with the application of the proposed controls in **Table 6-80**, the environmental objectives for these receptors, and the WA EPA environmental objective "*to protect benthic communities and habitats so that biological diversity and ecological integrity are maintained*" will be achieved.

Conclusion: Acceptable

External context

To date there have been no specific matters raised by stakeholders, regarding discharge of sewage and sullage in relation to the proposed Browse to NWS Project.

Conclusion: Acceptable

Internal context

This impact assessment has been undertaken in accordance with Woodside's Risk Assessment Procedure and Environment Impact Assessment Guideline (**Section 6.2**) The proposed Browse to NWS Project will be executed in accordance with Woodside's Health, Safety and Environmental Management System.

Chemicals that may be operationally released or discharged to the marine environment must be subject to Woodside's chemical selection and assessment process and approved prior to use. Woodside will implement its internal requirement "*Chemicals must be selected with the lowest practicable environmental impacts and risks subject to technical constraints.*"

Conclusion: Acceptable

Acceptability Assessment
Other requirements
EPBC Act recovery and conservation plans and advices
As detailed in Table 6-77, the proposed activities are considered to be not inconsistent with the actions and objectives of:
+ Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a) + The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) + Conservation management plan for the Blue Whale (Commonwealth of Australia, 2015c) + Conservation advice *Megaptera novaeangliae*, Humpback Whale (Threatened Species Scientific Committee, 2015b) + Conservation advice *Balaenoptera borealis*, Sei Whale (Threatened Species Scientific Committee, 2015c) + Conservation advice *Balaenoptera physalus*, Fin Whale (Threatened Species Scientific Committee, 2015d).
KEFs
As detailed in Table 6-78, the proposed discharges will not materially increase existing relevant pressures on the conservation values of KEFs.
AMPs
As detailed in Table 6-79 the proposed activities are considered to be not inconsistent with the requirements of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018).
Other Protected Places
No impacts are expected to occur to the to the values of the Scott Reef and Surrounds or the Mermaid Reef – Rowley Shoals Commonwealth Heritage Places.
Conclusion: Acceptable

6.3.10 Marine Discharges: Treated Utility Water, Chemical and Deck Drainage

6.3.10.1 Impact and Risk Overview

Table 6-83 presents an overview of the potential impacts and risks from treated utility water, chemical and deck drainage discharges associated with the proposed Browse to NWS Project.

Table 6-83 Treated utility water, chemical and deck drainage impact and risk overview

Aspect	Marine discharges: treated utility water, chemical and deck drainage
Description	Treated utility water, chemical and deck drainage discharges will occur from the FPSO facilities, project vessels and MODU and comprise: + discharge from drains and bilges + non-process chemicals (e.g. clearing chemicals) + fire suppression systems + chemical storage drains + desalination brine.
Area	Project Area, Browse Development Area, State Proposal Area
Project stage	All - drilling and completions, installation, commissioning, operations and decommissioning
Environmental objectives	The environmental objectives in relation to treated utility water, chemical and deck drainage associated with the proposed Browse to NWS Project are Objectives 3, 6, 7, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20 and 21. These objectives are detailed in Table 6-7.

<table>
<tr><th>Aspect</th><th colspan="3">Marine discharges: treated utility water, chemical and deck drainage</th></tr>
<tr><td>Policy and guidelines</td><td colspan="3">The following policy and guidelines are relevant to the assessment of this aspect.
In addition, a number of EPBC Act conservation advices for protected fauna have been considered (Table 6-84).
+ Commonwealth Protection of the Sea (Prevention of Pollution from Ships) Act 1983 (Part II Prevention of pollution from oil) (which applies MARPOL 74/78)
+ Marine Orders 91 (Marine pollution prevention – Oil)
+ WA Pollution of Waters by Oil and Noxious Substances Act 1987
+ Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018)
+ WA EPA Environmental Factor Guideline - Marine Environmental Quality (EPA, 2016d)
+ WA EPA Technical Guidance – Protecting the Quality of Western Australia’s Marine Environment (EPA, 2016b).
+ North-west Marine Parks Network Management Plan (Director of National Parks, 2018)
+ Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a)
+ Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015b)
+ Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).</td></tr>
<tr><td>Receptors</td><td colspan="3">The following receptors have been identified as potentially being impacted as a result of the proposed Browse to NWS Project (Table 6-2). A detailed description of each of these receptors is provided in Chapter 5.
<i>Physical</i>
+ water quality (medium value (open water))
<i>Ecological</i>
+ plankton communities (low value (open water))
+ benthic habitats
  + shallow water benthic communities and habitats (<75 m depth) (high value habitat)
  + deepwater communities and habitats (>75 m depth) (medium value habitat
+ fauna
  + fish (high value species)
  + marine reptiles (high value species)
  + marine mammals (high value species)
+ KEFs (high value)
+ AMPs (high value)
+ other protected places (high value)
<i>Socio-economic</i>
+ State and Commonwealth managed fisheries (high value marine user)
+ other users
  + tourism and recreation (high value user)
  + scientific studies (high value user)</td></tr>
<tr><td>Potential impacts</td><td colspan="3">+ change in water quality
+ change in fauna behaviour
+ changes to the functions, interests or activities of other users</td></tr>
<tr><td>Risk</td><td colspan="3">+ unplanned discharge significantly above discharge specifications</td></tr>
<tr><td rowspan="2">Summary of governing impact evaluation</td><td><i>Magnitude</i></td><td><i>Impact significance level</i></td><td><i>Confidence</i></td></tr>
<tr><td>No lasting effect</td><td>Slight (E)</td><td>High</td></tr>
<tr><td rowspan="2">Summary of governing risk evaluation</td><td><i>Consequence</i></td><td><i>Likelihood</i></td><td><i>Risk rating</i></td></tr>
<tr><td>Slight</td><td>Remote</td><td>Low (E0)</td></tr>
</table>

6.3.10.2 Source of Aspect

Treated utility water will be generated from three main sources, the project vessels, MODU(s) and FPSO facilities.

The MODU and FPSO facilities will have open and closed drainage systems. The open system collects deck drainage (firewater, stormwater, and wash down water), drip trays, and sample returns. Deck drainage typically contains particulate matter and residual chemicals such as cleaning chemicals, oil and grease in small volumes. The open system is routed through slop tanks for treatment prior to discharge. Deck drainage is equipped with an overflow arrangement, which allows heavy rainfall and testing/operation of the fire deluge system to be discharged directly overboard.

Bilge water (drainage) from within machinery spaces will be captured in bilge drains and also routed to slops tank, where treated water (below 15 ppm in accordance with MARPOL 73/78 Annex I[13], will be discharged overboard. The recovered oil will likely be recovered into the Process and exported as condensate.

Closed drain systems collect liquids drained directly from the process, as opposed to the machinery spaces or the deck. The closed drain systems are returned to process and not discharged.

Chemical drains and amine drains systems are also provided. The chemical drains systems route chemicals to a waste tank for onshore disposal. During heavy rainfall the chemical drains will be routed to the open drains system. The amine drains systems routes to the amine slops tank. During heavy rainfall the bulk of the water will be directed overboard to prevent filling the amine slops tank.

Fire-fighting foams which contain organic and fluorinated surfactants can deplete dissolved oxygen in water. In the event that firefighting foam is required (in the event of an emergency or for infrequent testing), the foam systems mix the concentrates (~3%) with water (~97%) prior to application. There is then further dilution and dispersion following discharge to the open-water environment around the facility. Its expected ~5 m^3 could be discharged to the surface during infrequent testing, which would rapidly disperse.

Desalinisation brine will also be generated through the production of freshwater for potable and other uses on the FPSO facilities, MODU and project vessels. The FPSO reverse osmosis units will result in a supply of fresh and demineralised water at a total rate of 21.5 m^3/h. The MODU and vessels may either produce fresh water by means of reverse osmosis or thermal desalination or load fresh water at port.

The discharge of desalination brine, which consists of water with elevated salinity (typically 20 to 50% higher than the intake seawater) and low concentrations of anti-scale chemicals, is expected to be continuous throughout the life of the proposed Browse to NWS Project, although volumes will vary depending on potable water requirements on each FPSO facility, MODU and project vessels. Discharge of desalination brine from the FPSO facilities will likely occur below sea level. The FPSO facilities represent the most significant sources of desalination brine for the proposed Browse to NWS Project.

6.3.10.3 Environmental Impact

Water Quality

Change in water quality

Collected drainage water will be treated onboard prior to discharge to meet regulatory requirements (15 ppm oil in water). Considering the composition of the drain discharges (i.e. small quantities of residual hydrocarbons and detergents), and assimilative capacity of the receiving environment at the discharge points, it is expected that drain discharges will rapidly dilute within the surrounding waters. As such, these discharges will result in temporary (lasting a few minutes) change in water quality in the immediate vicinity of the discharge.

Firefighting foams containing organic and fluorinated surfactants are unlikely to be used and as such no impacts to water quality would be expected.

Desalination brine discharge is expected to be 20 to 50% more saline than the intake seawater (depending on the desalination process used) and therefore only a small number of dilutions will be required to achieve ambient salinity levels. Studies undertaken by the US EPA (Frick et al., 2001) determined that brine discharges from the surface dilute 40–fold approximately 4 m from the source. This modelling can be used as an indicator for predicting horizontal attenuation and diffusion of brine discharges. Given the proposed discharge volumes from the FPSO facilities (21.5 m^3/hr), which is the largest source of such discharges, dilution to ambient levels is likely to be achieved within a very short distance from the discharge point (<100 m). Therefore, owing to the likely high number of dilutions achieved following discharge from the proposed sources (i.e. FPSO, vessels and MODU), elevated salinity levels (above ambient) will be highly localised at the discharge point and unlikely to have a perceptible effect on ambient salinity concentrations in the water column.

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[13] *as applied in Australia under the Commonwealth Protection of the Sea (Prevention of Pollution from Ships) Act 1983 (Part II Prevention of pollution from oil); Marine Orders 91 (Marine pollution prevention – Oil) as applicable to vessel class; and the WA Pollution of Waters by Oil and Noxious Substances Act 1987.)*

Plankton communities

Injury or mortality to fauna

Plankton in close proximity to the discharge point may be exposed to the discharges. However, given the predicted dilutions, resulting in a very localised mixing zone, the proportion of the plankton population affected will be negligible. In addition, the wide spread nature and rapid turn-over of plankton populations leading to relatively quick recovery times, ensures that any impact on local communities would be expected to recover relatively quickly (within weeks or months) (ITOPF, 2011).

Benthic habitat

Change in water quality

Given the minimum water depth at the discharge locations (i.e. ~125 m at the NRC tie-in), it is not predicted that change in water quality resulting from the discharge of treated utility water, chemical and deck drainage will affect the deepwater benthic habitats of the Project Area.

Given the distance from the main discharge location in relation to Scott Reef (FPSO > 8 km away) and the expected rapid dilution of the discharge within 100 m, adverse impacts to Scott Reef shallow water benthic habitat (<75 m bathymetry) are not anticipated.

Studies on the dispersion of coral larvae at Scott Reef (Done et al., 2015; Foster and Gilmour, 2018)we examine distance decay among coral communities in a common habitat on northwestern Australian reefs, seeking to better understand the roles of disturbance and coral life history strategies in the changing reefscape. In established communities in 1997, when coral cover and generic richness were uniformly high, there was high similarity (~81 % demonstrates that while there is marked movement of larvae within the reef system itself (broadcast spawning corals), there is no evidence to suggest that those coral larvae that initially dispersed off the reef return to Scott Reef to settle. Therefore, the discharges are not likely to impact the recruitment of corals within the Scott Reef system.

Marine fauna

Injury or mortality to fauna – fish, marine mammals, marine turtles

While marine fauna (including fish, marine mammals and marine turtles) are known to be present within the Project Area, it is unlikely that large numbers of individuals will occur within close proximity to the discharge locations on the facilities, vessels or MODU. While marine fauna may come into contact with these discharges, any contact with the discharge with marine fauna will be of extremely short duration as the discharges are expected to be rapidly diluted in the prevailing currents, and due to the small volume and the short, intermittent nature of the discharge

Further, the potential for toxicity effects to marine biota from chemicals such as anti-scale and biocides is unlikely as these chemicals have low inherent toxicity (i.e. fit for human consumption in potable water) and will be consumed and neutralised in the desalination system, with any residual chemicals rapidly diluted following discharge.

As such it is not considered credible that toxic affects to marine fauna will occur as a result of the discharge of treated utility water, chemical and deck drainage associated with the proposed Browse to NWS Project.

With respect to desalination brine, studies have demonstrated that most marine species are able to tolerate short-term fluctuations in salinity of 20 to 30% (Walker and McComb, 1990), and can move away from discharge locations. Therefore temporary, localised salinity increases in the immediate vicinity of the discharge (diluted to ambient levels within meters) are not expected to have a lasting impact on marine biota.

It is noted that acute and chronic effects of chemical discharges are highlighted within the Recovery Plan for Marine Turtles in Australia (2017-2027) as a threat to green turtles within the Scott Reef and Browse Island area (Commonwealth of Australia, 2017a). Treated utility water, chemical and deck drainage discharge from the Torosa FPSO facility, project vessels and the MODU will occur in the green turtle BIA around Sandy Islet. Discharge will occur from vessels and the MODU in an area defined as habitat critical to the survival of green turtles in the Recovery Plan for Marine Turtles in Australia (2017-2027). The recovery plan includes the minimisation of chemical discharge as an overarching action area (Commonwealth of Australia, 2017a).

Discharge from project vessels, MODU and the Torosa FPSO facility will also occur in the potential foraging area and a migration BIA for pygmy blue whales as identified in the Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c). This plan identified chronic chemical pollution as a potential risk to pygmy blue whales. Conservation advices for other EPBC listed marine mammals that may occur in the Project Area do not identify chemical pollution as a key threat (**Table 5-19**). Given the above and the low numbers of pygmy blue whales and other marine mammals in the Project Area, it is not predicted that adverse impacts would occur to marine mammals as a result of treated utility water, chemical and deck drainage discharges.

Assessment against EPBC Act recovery and conservation plans and advices

Table 6-84 provides an assessment of the discharge of treated utility water, chemical and deck drainage from the proposed activities in relation to objectives and actions of the relevant EPBC Act recovery and conservation plans and advices.

Table 6-84 Alignment with EPBC Act recovery and conservation plans and advices for protect – treated utility water, chemical and deck drainage

Fauna	Relevant plan(s)/ conservation advice	Plan/Advice objectives and actions	Assessment
Whale shark	Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a)	Assess the impacts of offshore installations and associated environmental changes (light spill, chronic noise, changed water temperature, localised nutrient levels) on whale sharks and mitigation options for these impacts.	The impact of treated utility water, chemical and deck drainage discharges resulting from the proposed Browse to NWS Project have been assessed. Given the low numbers and infrequent nature of whale shark presence in the Project Area, there is a high level of confidence that treated utility water, chemical and deck drainage discharges will not result in adverse impact to whale sharks.
Green turtle	The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a)	Manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to the survival. Manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue. In relation to the Scott Reef – Browse Island green turtle genetic stock, the priority action is to manage anthropogenic activities to ensure marine turtle are not displaced from identified habitat critical to their survival.	Impacts to turtles have been assessed and will be managed in accordance with the Recovery Plan for Marine Turtles in Australia (2017-2027) which includes the minimisation of chemical discharge as an overarching action area (Commonwealth of Australia, 2017a). Given the nature, volume and dispersion of the treated utility water, chemicals and deck drainage discharges, adverse impacts to marine turtles are not expected. As such, in relation to the Scott Reef – Browse Island green turtle genetic stock, the priority action to manage anthropogenic activities to ensure marine turtle are not displaced from identified habitat critical to their survival is predicted to be met. Likewise, it is not predicted that treated utility water, chemical and deck drainage discharge will adversely affect the breeding cycle of marine turtles in the BIA at Scott Reef. Therefore, it is considered that the proposed activities are not inconsistent with the objectives of the Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a).
Hawksbill turtle			

Fauna	Relevant plan(s)/ conservation advice	Plan/Advice objectives and actions	Assessment
Pygmy blue whale	Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c)	Chronic chemical pollution is identified as a potential risk to pygmy blue whales, however there are no specific actions identified	Occasional exposure of individuals of these species to the that treated utility water, chemical and deck drainage discharge may occur. However, given the nature, volume and dispersion of the predicted discharges, and the highly mobile nature of marine mammals, exposure would be temporary and is not expected to have any lasting impacts on the listed whale species. Therefore, it is considered that the proposed activities are not inconsistent with the Conservation Management Plan for the Blue Whale or the conservation advices listed.
Humpback whale	Conservation advice *Megaptera novaeangliae*, Humpback Whale	Marine discharges have not been identified as a direct threat to these whale species; however, habitat degradation has been identified as a threat and unmanaged discharges may contribute to this threat. The conservation advice relevant for this threat – identifies modification to the coastal region in areas of importance to listed whales may result in reduced occupancy, compromised reproductive success and even mortality.	
Sei whale	Conservation advice *Balaenoptera borealis*, Sei Whale		
Fin whale	Conservation advice *Balaenoptera physalus*, Fin Whale		

Key Ecological Features

Injury or mortality to fauna and Change in water quality

The Continental slope demersal fish communities KEF and Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEFs overlap with the Browse Development Area. Treated utility water, chemical and deck drainage discharges will occur within these KEFs from project vessels, MODU and the FPSO facilities. The BTL traverses the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF (depending on the final BTL route) and the Ancient coastline at 125 m depth contour KEF. Treated utility water, chemical and deck drainage discharges will occur within these KEFs from project vessels during the BTL installation and intermittent IMR activities. The conservation values of these KEFs are described in Section 5.3.3.1.

As described above, changes to water quality as a result of treated utility water, chemicals and deck drainage discharge are predicted to be temporary and highly localised. As such no lasting impacts to the conservation values of these KEFs is predicted. No impact is predicted to the reefs associated with the Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEF.

Table 6-85 provides an assessment of the proposed treated utility water, chemical and deck drainage discharge in relation to the pressures on KEFs identified in the Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).

Table 6-85 Alignment with protection of conservation values of KEFs – treated utility water, chemical and deck drainage discharges

Key Ecological Feature	Relevant plan(s)	Relevant pressures	Assessment
Continental slope demersal fish communities	Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).	Chemical pollution / contaminants - currently identified as 'not of concern'	Given that any treated utility water, chemical and deck drainage discharges will occur in surface waters with changes in water quality predicted to be temporary and highly localised, there is a high level of confidence that such discharges will not result in an adverse impact to marine ecosystem function or integrity with in the KEFs; or any reduction in to the conservation values of the KEFs will occur.
Seringapatam Reef and Commonwealth waters in the Scott Reef Complex			
Ancient coastline at 125 m depth contour			
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals		Chemical pollution / contaminants - currently identified as 'data deficient or not assessed	

Australian marine parks

Change in water quality

Vessels associated with the installation of the BTL and transiting project vessels will discharge treated utility water, chemicals and deck drainage within the Multiple Use Zones (IV) of the Argo-Rowley Terrace and Kimberley AMPs. Discharges from vessels operating within the AMPs will be temporary and transient in nature (e.g. the slowest moving Project vessel will be the pipelay vessel, which will move at a rate of up to 5 km/day). In addition, vessels operating along the BTL will discharge in accordance with the approved allowed activities of the multiple use zoning (IUCN VI), which permits the disposal of waste from the normal operations of vessels in accordance with MARPOL requirements as applied in Australia under the Commonwealth Protection of the Sea (*Prevention of Pollution from Ships) Act 1983 (Part II Prevention of pollution from oil*); Marine Orders 91 (Marine pollution prevention – Oil) as applicable to vessel class; and the WA *Pollution of Waters by Oil and Noxious Substances Act 1987*.). It should also be noted that the proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park and it is not expected that the effluent would reach this AMP from the discharge point.

The Kimberley Marine Park ranges in water depth from less than 15 m to 800 m, providing protection for habitats and ecological communities in waters offshore of the Kimberley coastline. Fauna that utilise this AMP include seabirds, marine turtles, inshore dolphins, humpback whales, pygmy blue whales, dugongs and whale sharks. The Argo-Rowley Terrace AMP provides protection for the ecological communities and habitats of the deeper offshore waters, and key features include Mermaid, Clerke and Imperieuse Reefs. This AMP also protects threatened, migratory, marine and cetacean species as well as BIAs for seabirds and migratory pathways for the pygmy blue whale (Director of National Parks, 2018).

The release of effluents that could locally affect the quality of receiving marine waters is recognised as pressure in the North-west marine region (Commonwealth of Australia, 2012). The Marine Bioregional Plan for the North West Marine Region recognises that fauna and ecosystems may be vulnerable to marine discharges that include chemicals and toxins (Director of National Parks, 2018).

As described above, it is expected that discharges from vessels will disperse in very close proximity to the discharge point. Given the water depths along the BTL route >250 m, it is not predicted that the discharges will impact on the deepwater benthic habitats in the AMPs. As described above, marine fauna within the AMPs are unlikely to be adversely impacted due to the dispersive action on the effluent and the transient nature of the fauna that could potentially be exposed to the discharge.

Given this, it is considered that the identified conservation values of these AMPs will not be adversely impacted by treated utility water, chemical or deck discharges associated with the proposed Browse to NWS Project.

Table 6-86 provides an assessment of the proposed discharge of treated utility water, chemical and deck drainage in consideration of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018).

Table 6-86 Alignment with the objectives of AMPs – treated utility water, chemical and deck drainage

Australia Marine Park	Relevant plan(s)	Australian Marine Park Objectives	Assessment
Argo-Rowley Terrace Marine Park Multi Use Zone (VI) Kimberley Marine Park Multi Use Zone (VI)	North-west Marine Parks Network Management Plan (Director of National Parks, 2018)	The objective of the Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species.	Treated utility water, chemical and deck drainage discharges from vessels operating within these AMPs will be of a small volume, temporary and transient in nature and therefore unlikely to impact marine fauna or benthic habitats in these AMPs. Therefore, there is a high level of confidence that such discharges will not result in any adverse impacts to marine ecosystems, habitats or native species such that the conservation values of the AMPs would be reduced. As such, it is considered that the proposed activities are not inconsistent with the requirements of the North-west Marine Parks Network Management (Director of National Parks, 2018).
Mermaid Reef Marine Park National Park Zone (II)		The objective of the National Park Zone (II) is to provide for the protection and conservation of ecosystems, habitats and native species in as natural a state as possible.	The proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park. As such, discharges associated with the installation of the BTL and occasional IMR activities are not considered a credible source of impact and no effect on ecosystems, habitats or native species in the AMP is predicted. As such, it is considered that the proposed activities are not inconsistent with the requirements of the North-west Marine Parks Network Management (Director of National Parks, 2018).

Other protected places

Change in water quality

The Scott Reef and Surrounds - Commonwealth Area Commonwealth Heritage Place comprises the Commonwealth Marine Area wholly within the WA coastal waters surrounding North and South Scott Reef. The Commonwealth Heritage Place is utilised by seabirds, marine mammals and marine turtles; and supports diverse fish and coral communities. Project vessels will not operate within this area under normal operations.

Given this, and the dispersive nature of the effluent in close proximity to the discharge point, no impact is predicted to occur to this Commonwealth Heritage Place as a result of treated utility water, chemicals and deck drainage discharge. The same applies with respect to the potential for marine discharge impacts on the Mermaid Reef - Rowley Shoals Commonwealth Heritage Place.

As such, it is considered that the identified conservation values of these other protected places will not be adversely impacted by treated utility water, chemicals and deck drainage discharge associated with the proposed Browse to NWS Project.

Other users

Changes to the functions, interests or activities of other users – State and Commonwealth managed fisheries

Where the functions, interests or activities of other users involve marine fauna (e.g. fisheries), any effect to fauna presence or abundance will indirectly impact on the functions, interests or activities of other users. Given that no lasting effect to fish have been predicted, no significant subsequent impact to fisheries is expected.

Changes to the functions, interests or activities of other users – tourism and recreation, scientific studies

Activities such as tourism and recreation and scientific studies at Scott Reef are unlikely to be impacted by discharges from the FPSO facilities given the distance from Scott Reef (Torosa FPSO is approximately 8 km away). Similarly, discharge from project vessels and the MODU are unlikely to have any impact on other marine users at Scott Reef given the distance and the small volumes, low toxicity, and temporary nature of these discharges in the context of the open ocean receiving environment.

6.3.10.4 Environmental Risk

Risk event: Unplanned discharge of treated utility water, chemical and deck drainage significantly above discharge specifications

Though unlikely, unplanned discharges of treated utility water, chemical and deck drainage resulting from human error or equipment failure on project vessels, MODU or FPSO facilities may occur. This would potentially result in a larger area being impacted (a temporary larger mixing zone), although the plume would still be expected to rapidly disperse. As per **Section 6.3.10.3**, it would remain unlikely that exposure to marine fauna would be sufficient to elicit a toxic response. As such no change to the significance of the impact to water quality, plankton communities, benthic habitat, marine fauna, KEFs, AMPs, other protected places, managed fisheries or other users would be expected.

In the event that the discharge of treated utility water, chemical and deck drainage at levels significantly above the indicative discharge specifications occurs from the MODU or project vessels operating near Scott Reef at a time where the prevailing conditions result in the plume moving towards Scott Reef, there is a risk of resultant impacts to the Scott Reef habitats shallow water benthic habitats. This impact would be expected to be temporary and localised in nature. Given the controls in place and the distance from the closest source (i.e. MODU during drilling at TRE) to Scott Reef, the likelihood of such an event occurring and resulting in adverse effects on Scott Reef shallow water benthic habitat (<75 m bathymetry) habitats is considered remote, with the subsequent risk assessed to be low.

6.3.10.5 Cumulative Impacts

Cumulative impacts resulting from the discharge of treated utility water, chemical and deck drainage from the two FPSO facilities, project vessels, MODU(s), other marine users or other operating facilities within the region are not expected, given the predicted volumes of waste, the highly localised nature of impacts and the large geographic spread of the facilities and activities.

6.3.10.6 Impact and Risk Assessment Summary and Acceptability Assessment

A summary of the impact and risk assessment for the discharge of treated utility water, chemical and deck drainage is provided in **Table 6-87** and **Table 6-88**. The final acceptability assessment is provided in **Table 6-89**.

Table 6-87 Impact assessment summary and adopted controls – marine discharges: treated utility water, chemical and deck drainage

Receptor (sensitivity)	Potential Impact	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
Water quality (medium value (open water))	Change in water quality	**Objective 3:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	*Project vessels, MODU and FPSO operations* + Areas of potential contamination such as machinery and bulk liquid storage areas will be bunded to capture any spilled chemicals or oil residues. Drainage from these areas will be directed to holding tanks for treatment prior to discharge, subject to overflow arrangements. + An oil-in-water separator will be available onboard the FPSO facilities, MODU and vessels (as applicable to vessel class), which will be maintained and operated so that bilge water is treated to reduce hydrocarbon concentrations below 15 ppm in accordance with MARPOL 73/78 Annex I, as applied in Australia under the Commonwealth *Protection of the Sea (Prevention of Pollution from Ships)* Act 1983 (Part II Prevention of pollution from oil); Marine Orders 91 (Marine pollution prevention – Oil) as applicable to vessel class; and the WA *Pollution of Waters by Oil and Noxious Substances Act 1987.*	Slight	Slight (E)
Plankton (medium value (open water))	Injury or mortality to fauna	**Objective 7:** To not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution.		No lasting effect	Negligible (F)
Deepwater benthic communities and habitats (>75 m depth) – (medium value)	Change in water quality	**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.		No impact expected	
Shallow water benthic communities and habitats (<75 m depth) (high value habitat)	Change in water quality	**Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry).		No impact expected	
Fish (high value species)	Injury or mortality to fauna	**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **Objective 15:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.		No lasting effect	Slight (E)
Marine turtles (high value species)	Injury or mortality to fauna			No lasting effect	Slight (E)
Marine mammals (high value species)	Injury or mortality to fauna			No lasting effect	Slight (E)
KEFs (medium value)	Change in water quality	**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.		No lasting effect	Negligible (F)
AMPs (medium value)	Change in water quality	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No lasting effect	Negligible (F)
Other protected places (high value)	Change in water quality	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No lasting effect	Slight (E)
State and Commonwealth managed fisheries (high value marine user)	Changes to the functions, interests or activities of other users	**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No lasting effect	Slight (E)
Other users including tourism and recreation and scientific studies (high value users)	Changes to the functions, interests or activities of other users	**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No lasting effect	Slight (E)

Table 6-88 Risk assessment summary and adopted controls – Treated Utility Water, Chemical and Deck Drainage

Receptor	Risk Event	Environmental objective	Adopted controls	Consequence	Likelihood	Risk Rating
Water quality (medium value (open water))	Unplanned discharge significantly above discharge specifications	**Objective 3:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	+ Discharges from FPSO slops holding tanks will be monitored to ensure specifications are met. Where discharge specification cannot be met for FPSO facility discharges, the discharge stream will be reprocessed or sent onshore for disposal. + FPSO facility hazardous open drains systems integrity will be maintained, and open hazardous and closed drain caisson sump pumps will be available to support hydrocarbon recovery.	No increase to significance/ consequence		
Plankton (medium value (open water))		**Objective 7:** To not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution.		No increase to significance/ consequence		
Deepwater benthic communities and habitats (>75 m depth) – (medium value)		**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.		No increase to significance/ consequence		
Shallow water benthic communities and habitats (<75 m depth) (high value habitat)		**Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry).		Slight	Remote	Low (E0)
Fish (high value species)		**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species.		No increase to significance/ consequence		
Marine turtles (high value species)		**Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population.		No increase to significance/ consequence		
Marine mammals (high value species)		**Objective 15:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.		No increase to significance/ consequence		
KEFs (medium value)		**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.		No increase to significance/ consequence		
AMPs (medium value)		**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No increase to significance/ consequence		
Other protected places (high value)		**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No increase to significance/ consequence		
State and Commonwealth managed fisheries (high value marine user)		**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No increase to significance/ consequence		
Other users including tourism and recreation and scientific studies (high value users)		**Objective 21:** To not interfere with other marine users to a greater extent than is necessary for the execution of the proposed Browse to NWS Project.		No increase to significance/ consequence		

Table 6-89 Acceptability Assessment – treated utility water, chemical and deck drainage

Acceptability Assessment

Confidence in assessment

Woodside have a high level of certainty with respect to the assessment of the potential impacts and risks associated with treated utility water, chemical and deck drainage discharges as:

- In consideration of the lack of significant potential impacts, it is considered that studies have adequately characterised the marine fauna populations and distributions that may potentially be impacted by such discharges.
- Studies have demonstrated that such discharges from project infrastructure and vessels will rapidly dilute within the immediate vicinity of the discharge point, with no impact to sensitive receptors or species.
- Controls, including the implementation of MARPOL 73/78 Annex I, as applied in Australia under the Commonwealth Protection of the Sea (Prevention of Pollution from Ships) Act 1983 (Part II Prevention of pollution from oil); Marine Orders 91 (Marine pollution prevention – Oil) as applicable to vessel class; and the WA Pollution of Waters by Oil and Noxious Substances Act 1987, will be implemented to mitigate potential impacts.

Principles of ESD

With the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such it is considered that the principles of ESD will be met.

Conclusion: Acceptable

Significant Impacts as defined by the MNES Significant Impact Guidelines

Listed threated species and ecological communities / listed migratory species

As described in **Table 6-87**, no lasting effect is predicted to occur from the discharge of treated utility water, chemical and deck drainage to listed threatened and migratory species such as fish, marine turtle and marine mammals, with the impact significance level determined to be Slight (E).

As described in **Table 6-88**, potential risk events associated with the discharge of treated utility water, chemical and deck drainage are not predicted increased the significance/consequence of impacts to listed threatened and migratory species.

Given this, with the application of the proposed controls it is predicted that the nominated environmental objectives for each of these fauna species will be achieved. As such, no significant impacts to the listed threated or migratory species (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted

Commonwealth Marine Environment

As described in **Table 6-87**, the potential impact from the discharge of treated utility water, chemical and deck drainage to plankton, KEFs and AMPs has been assessed as Negligible (F). Slight (E) impacts may potentially occur to water quality, marine fauna, other protected places, managed fisheries and other users, while no impact is predicted to occur to deepwater benthic communities and habitats (>75 m depth) and shallow water benthic communities and habitats (<75 m depth).

As described in **Table 6-88**, potential risk events associated with the discharge of treated utility water, chemical and deck drainage present a Low risk to shallow water benthic communities and habitats (<75 m depth).

As such, with the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such no significant impacts to the Commonwealth marine environmental (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted

Conclusion: Acceptable

Acceptability Assessment

WA EPA Environmental Objectives

An assessment of the impacts of treated utility water, chemical and deck drainage discharges against the WA EPA Objective is presented in the State Proposal ERD (**Chapter 10, Appendix B**).

Marine environmental quality

As described in **Table 6-87**, the potential impact from the discharge of treated utility water, chemical and deck drainage to plankton has been assessed as Negligible (F). Slight (E) impacts may potentially occur to water quality.

As described in **Table 6-88**, potential risk events associated with the discharge of treated utility water, chemical and deck are not predicted increased the significance/consequence of impacts to plankton or water quality

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*To maintain the quality of water, sediment and biota so that environmental values are protected*" will be achieved.

Marine Fauna

As described in **Table 6-87**, no lasting effect is predicted to occur from the discharge of treated utility water, chemical and deck drainage to marine fauna such as fish, marine turtle and marine mammals, with the impact significance level determined to be Slight (E).

As described in **Table 6-88**, potential risk events associated with the discharge of treated utility water, chemical and deck drainage are not predicted increased the significance/consequence of impacts to marine fauna species.

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*To protect marine fauna so that biological diversity and ecological integrity are maintained.*" will be achieved.

Benthic communities and habitats

As described in **Table 6-87** no impact is predicted to occur as a result of the discharge of treated utility water, chemical and deck drainage to deepwater benthic communities and habitats (>75 m depth) or shallow water benthic communities and habitats (<75 m depth).

As described in **Table 6-88**, potential risk events associated with the discharge of treated utility water, chemical and deck drainage present a Low risk to shallow water benthic communities and habitats (<75 m depth).

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*to protect benthic communities and habitats so that biological diversity and ecological integrity are maintained*" will be achieved.

Conclusion: Acceptable

External context

To date there have been no specific matters raised by stakeholders, regarding discharge of treated utility water in relation to the proposed Browse to NWS Project.

Conclusion: Acceptable

Internal context

This impact assessment has been undertaken in accordance with Woodside's Risk Assessment Procedure and Environment Impact Assessment Guideline (**Section 6.2**) The proposed Browse to NWS Project will be executed in accordance with Woodside's Health, Safety and Environmental Management System.

Chemicals that may be operationally released or discharged to the marine environment must be subject to Woodside's chemical selection and assessment process and approved prior to use. Woodside will implement its internal requirement "*Chemicals must be selected with the lowest practicable environmental impacts and risks subject to technical constraints.*"

Conclusion: Acceptable

Acceptability Assessment
Other requirements
EPBC Act recovery and conservation plans and advices
As detailed in Table 6-84, the proposed activities are considered to be not inconsistent with the actions and objectives of: + Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a) + The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) + Conservation management plan for the Blue Whale (Commonwealth of Australia, 2015c) + Conservation advice *Megaptera novaeangliae*, Humpback Whale (Threatened Species Scientific Committee, 2015b) + Conservation advice *Balaenoptera borealis*, Sei Whale (Threatened Species Scientific Committee, 2015c) + Conservation advice *Balaenoptera physalus*, Fin Whale (Threatened Species Scientific Committee, 2015d).
KEFs
As detailed in Table 6-85, the proposed discharges will not materially increase existing relevant pressures on the conservation values of KEFs.
AMPs
As detailed in Table 6-86, the proposed activities are considered to be not inconsistent with the requirements of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018).
Other Protected Places
No impacts are expected to occur to the to the values of the Scott Reef and Surrounds or the Mermaid Reef – Rowley Shoals Commonwealth Heritage Places.
Conclusion: Acceptable

6.3.11 Marine Discharges: Putrescible Waste

6.3.11.1 Impact and Risk Overview

Table 6-90 presents an overview of the potential impacts and risks from putrescible waste discharges associated with the proposed Browse to NWS Project.

Table 6-90 Putrescible waste impact and risk overview

Aspect	Marine discharges: putrescible waste
Description	Food scraps and other putrescible waste will be discharged from the: + FPSO facilities (approximately 1L/person/day) + MODU + project vessels.
Area	Project Area, Browse Development Area
Project stage	All - drilling and completions, installation, commissioning, operations and decommissioning
Environmental objectives	The environmental objectives in relation to putrescible waste associated with the proposed Browse to NWS Project are Objectives 3, 6, 10, 11, 12, 13, 14, 17, 18, 19, 20 and 21. These objectives are detailed in Table 6-7.

Aspect	**Marine discharges: putrescible waste**		
Policy and guidelines	The following policy and guidelines are relevant to the assessment of this aspect. + Commonwealth Protection of the Sea (Prevention of Pollution from Ships) Act 1983. This is the primary federal legislative instrument for Australia's implementation of the International Convention for the Prevention of Pollution from Ships (MARPOL) + Commonwealth Navigation Act 2012 (Cth) + Marine Order 95 (Marine pollution prevention – garbage) + WA EPA Environmental Factor Guideline - Marine Environmental Quality (EPA, 2016d) + North-west Marine Parks Network Management Plan (Director of National Parks, 2018) + Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).		

Receptors	The following receptors have been identified as potentially being impacted as a result of the proposed Browse to NWS Project (**Table 6-2**). A detailed description of each of these receptors is provided in **Chapter 5**.
	Physical
	+ water quality (medium value (open water))
	Ecological
	+ plankton communities (low value (open water))
	+ benthic habitats
	  + shallow water benthic communities and habitats (<75 m depth) (high value habitat)
	  + deepwater communities and habitats (>75 m depth) (medium value habitat
	+ fauna
	  + seabirds and migratory shorebirds (high value species)
	  + fish (high value species)
	+ KEFs (high value)
	+ AMPs (high value)
	+ other protected places (high value)
	Socio-economic
	+ State and Commonwealth managed fisheries (high value marine user)
	+ other users
	  + tourism and recreation (high value user)
	  + scientific studies (high value user)		

Potential impacts	+ change in water quality + change in fauna behaviour + changes to the functions, interests or activities of other users		
Risk	+ there are no anticipated environmental risks in relation to this aspect associated with unplanned project activities		
Summary of governing impact evaluation	***Magnitude***	***Impact significance level***	***Confidence***
	Slight	Slight (E)	High
Summary of governing risk evaluation	***Consequence***	***Likelihood***	***Risk rating***
	n/a	n/a	n/a

6.3.11.2 Source of Aspect

Putrescible waste will be generated from three main sources:

- FPSO facilities
- MODUs
- project vessels.

FPSO facilities, MODU and vessel operations used for the proposed Browse to NWS Project include accommodation facilities for crew and passengers. The crew and passengers will generate waste including putrescible waste which will be discharged to the marine environment in a controlled manner, in accordance with the Navigation Act 2012, MARPOL and the various Marine Orders (as appropriate to vessel class) enacted under this Act. The average volume of food waste discharged overboard will vary depending on the number of personnel on board at any time, and the types of meals prepared. This is estimated to be in the order of 1–2 kg per person per day. Discharged putrescible waste will be restricted to the immediate vicinity of the discharge location and is expected to be undetectable further than 500 m from the discharge source.

Macerated putrescible waste will be discharged throughout all phases of the proposed Browse to NWS Project. The FPSO and MODU will discharge putrescible waste from a stationary point over the term of their operations (months to years). Support vessels and pipelay vessels will typically discharge over short-term operations (weeks to months), possibly while in transit.

It is anticipated that putrescible waste will disperse and break up rapidly in the marine environment, with some of the waste being consumed by marine fauna upon discharge.

6.3.11.3 Environmental Impact

Water quality

Change in water quality

The discharge of macerated putrescible waste has the potential to change the local water quality for a short period through the addition of a temporary nutrient source resulting in potential temporary reduction to biological oxygen demand. However, studies into the effects of nutrient enrichment indicate that the influence of nutrients in open marine areas such as the locations for the proposed Browse to NWS Project, is much less significant than that experienced in enclosed areas (McIntyre and Johnston, 1975) Due to the nature of the open ocean receiving environment and relatively small volumes of discharge, this nutrient loading would rapidly return to background conditions following dispersion through surface currents and wave action. Therefore, the extent of this potential impact will be restricted to the immediate vicinity of the discharge locations.

Plankton communities

Change in fauna behaviour

Plankton in close proximity to the discharge points may be exposed to the macerated putrescible waste. Organic materials from the discharges will likely exert biological oxygen demand on the receiving waters, although this is unlikely to reach levels below background ambient dissolved oxygen concentrations. Similarly, while the nutrient inputs from discharged will rapidly be taken up by phytoplankton, pronounced increases in productivity as evidenced by increased chlorophyll a concentration are not expected. This is largely due to the assimilative capacity of the open ocean, with any potential additive nutrients not expected to accumulate in the vicinity of the discharge locations. As such no lasting impacts to plankton communities are expected.

Benthic habitats

Change in water quality

Given the minimum water depth at the discharge locations (i.e. 125 m at the NRC tie-in), it is not predicted that change in water quality resulting from the discharge of putrescible waste will affect the deepwater benthic habitats of the Project Area.

Given the distance from the putrescible waste discharge locations in relation to nearby sensitive receptors (e.g. >3 nm from Scott Reef and 2 km from the boundary of the Mermaid Reef Marine Park) and the likelihood that such discharges would disperse and break up rapidly in the marine environment, impacts to Scott Reef shallow water benthic habitat (<75 m bathymetry) including coral and seagrass are not anticipated.

Marine fauna

Change in fauna behaviour

There is potential that some opportunistic fish and seabirds may be attracted to the discharge of macerated putrescible waste either directly, in response to increased food availability, or indirectly as a result of attraction of prey species. Food waste is not identified as a threat in any EPBC listed threatened species recovery plans or conservation advice. Furthermore, given the small quantities of macerated putrescible waste to be disposed, any attraction of marine fauna is likely to be localised and temporary and is not expected to result in lasting effects to marine fauna.

Key Ecological Features

Change in water quality

The Continental slope demersal fish communities KEF and Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEFs overlap with the Browse Development Area. Putrescible waste discharges will occur within these KEFs from project vessels, MODU and the FPSO facilities. The BTL traverses the Mermaid

Reef and Commonwealth waters surrounding Rowley Shoals KEF (depending on the final BTL route) and the Ancient coastline at 125 m depth contour KEF. Discharge of putrescible waste will occur within these KEFs from project vessels during the BTL installation and intermittent IMR activities. The conservation values of these KEFs are described in **Section 5.3.3.1**.

As described, change to water quality resulting from the discharge of putrescible waste will be limited, temporary and localised increase in nutrient levels, and such are not predicted to reduce the conservation values of the KEFs within the Project Area.

Table 6-91 provides an assessment of the proposed putrescible waste discharge in relation to the pressures on KEFs identified in the Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).

Table 6-91 Alignment with protection of conservation values of KEFs – putrescible waste

Key Ecological Feature	Relevant plan(s)	Relevant pressures	Assessment
Continental slope demersal fish communities	Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).	Nutrient pollution - currently identified as 'not of concern'	Given that any putrescible waste discharges will occur in surface waters with changes in water quality predicted to be temporary and highly localised, there is a high level of confidence that such discharges will not result in an adverse impact to marine ecosystem function or integrity with in the KEFs; or any reduction to the conservation values of the KEFs.
Seringapatam Reef and Commonwealth waters in the Scott Reef Complex			
Ancient coastline at 125 m depth contour			
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals		Nutrient pollution - currently identified as 'data deficient or not assessed	

Australian Marine Parks

Change in water quality

Vessels associated with the installation of the BTL and transiting project vessels will discharge putrescible waste within the Multiple Use Zones (IV) of the Argo-Rowley Terrace and Kimberley AMPs. Discharges from vessels operating within the AMPs will be temporary and transient in nature (e.g. the slowest moving Project vessel will be the pipelay vessel, which will move at a rate of up to 5 km/day). In addition, vessels operating along the BTL will discharge putrescible waste in accordance with the approved allowed activities of the multiple use zoning (IUCN VI), which permits the disposal of waste from the normal operations of vessels in accordance with MARPOL requirements. It should also be noted that the proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park and it is unlikely that the discharge would reach this AMP from the discharge point.

As described above, the discharge of putrescible waste may temporarily change the water quality (on a very localised scale) within the AMP and lead to an alteration to fauna (seabirds and fish) behaviour associated with food and/or prey availability. The release of effluents that could locally affect the quality of receiving marine waters is recognised as pressure in the North-west marine region (Commonwealth of Australia, 2012).

The Argo-Rowley Terrace and Kimberley AMPs protect values including seabirds, marine turtles, inshore dolphins, humpback whales, pygmy blue whales, dugongs and whale sharks (Director of National Parks, 2018). Additionally, the Kimberley AMP supports benthic habitats including macroalgae (Walker, 1995; Walker et al., 1996) and coral (Veron and Marsh, 1988).

As described above, change in water quality will be temporary and highly localised. Impacts on fauna through a reduction in water quality are not expected due to the small discharge volumes and the ability of the surface currents and wave motion to disperse it. Any alternations in fauna behaviour based on their attraction to food and/or prey availability is likely to be only temporary due also to the rapid dispersion of the waste.

The BTL is located in deep water where inputs at the surface would be unlikely to impact on any deepwater benthic habitats within the AMP. Benthic habitat surveys of the proposed BTL confirmed that there were no sensitive benthic communities present (Advisian, 2019).

Given the above, it is considered that the identified conservation values of the Argo-Rowley Terrace and Kimberley AMPs will not be detrimentally impacted by putrescible waste discharges associated with the proposed Browse to NWS Project.

Summary

Table 6-92 provides an assessment of the proposed discharge of putrescible waste in consideration of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018)

Table 6-92 Alignment with the objectives of AMPs – putrescible waste

Australia Marine Park	Relevant plan(s)	Australian Marine Park Objectives	Assessment
Argo-Rowley Terrace Marine Park Multi Use Zone (VI) Kimberley Marine Park Multi Use Zone (VI)	North-west Marine Parks Network Management Plan (Director of National Parks, 2018)	The objective of the Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species.	Putrescible waste discharges from project vessels operating within these AMPs will be of a small volume, temporary and transient in nature and therefore unlikely to impact marine fauna or benthic habitats in these AMPs. Therefore, there is a high level of confidence that putrescible waste discharges will not result in any adverse impacts to marine ecosystems, habitats or native species such that the conservation values of the AMPs would be reduced. As such, it is considered that the proposed activities are not inconsistent with the requirements of the North-west Marine Parks Network Management (Director of National Parks, 2018).
Mermaid Reef Marine Park National Park Zone (II)		The objective of the National Park Zone (II) is to provide for the protection and conservation of ecosystems, habitats and native species in as natural a state as possible.	The proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park. As such, the putrescible waste discharges associated with the installation of the BTL and occasional IMR activities are not considered a credible source of significant impact and no effect on ecosystems, habitats or native species in the AMP will occur. As such, it is considered that the proposed activities are not inconsistent with the requirements of the North-west Marine Parks Network Management (Director of National Parks, 2018).

Other protected places

Change in water quality

The Scott Reef and Surrounds - Commonwealth Area Commonwealth Heritage Place comprises the Commonwealth Marine Area wholly within the WA coastal waters surrounding North and South Scott Reef. The Commonwealth Heritage Place is utilised by seabirds, marine mammals and marine turtles; and supports diverse fish and coral communities. Project vessels will not operate within this area under normal operations.

Given this, the small discharge volumes and the expected dispersion of the discharge in proximity to the discharge point, no impacts are predicted to occur to this Commonwealth Heritage Place as a result of putrescible waste discharge. The same applies with respect to the potential for marine discharge impacts on the Mermaid Reef - Rowley Shoals Commonwealth Heritage Place.

As such, it is considered that the identified conservation values of these other protected places will not be adversely impacted by putrescible waste discharge associated with the proposed Browse to NWS Project.

Other users

Changes to the functions, interests or activities of other users – State and Commonwealth managed fisheries

Where the functions, interests or activities of other users involve marine fauna (e.g. fisheries), any effect to fauna presence or abundance will indirectly impact on the functions, interests or activities of other users. Given that no lasting effect to fish have been predicted, no significant subsequent impact to fisheries is expected.

Changes to the functions, interests or activities of other users – tourism and recreation, scientific studies

Activities such as tourism and recreation and scientific studies at Scott Reef are unlikely to be impacted due to the distance between Scott Reef and the discharge locations (noting no discharges of putrescible waste will occur within State waters and the rapid dispersal of the discharges.

6.3.11.4 Environmental Risk

There are no anticipated environmental risks in relation to this aspect associated with unplanned project activities.

6.3.11.5 Cumulative Impacts

Cumulative impacts resulting from the discharge of putrescible waste from two FPSO facilities, project vessels, MODU(s), other marine users or other operating facilities within the region are not expected, given the predicted volumes of waste, the highly localised nature of impacts and the large geographic spread of the facilities and activities.

Impact and Risk Assessment Summary and Acceptability Assessment

A summary of the impact assessment for the discharge of putrescible waste is provided in Table 6-93. The acceptability assessment is provided in Table 6-94.

Table 6-93 Impact assessment summary and adopted controls – marine discharges: putrescible waste

Receptor (sensitivity)	Potential Impact	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
Water quality (medium value (open water))	Change in water quality	**Objective 3:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	*MODU and FPSO operations* + Putrescible waste will be macerated to a diameter of less than 25 mm prior to disposal overboard, in accordance with MARPOL 73/78 Annex V: Garbage and Section 26F of the Commonwealth Protection of the Sea (Prevention of Pollution from Ships) Act 1983. *Project vessel operations* + Vessel discharges will be conducted in a manner not inconsistent with the objectives, values and principles of the multi-use zones of the AMPs, which are traversed by the trunkline route. + No putrescible waste will be discharged within the 3nm State waters boundary.	Slight	Slight (E)
Plankton (medium value (open water))	Change in fauna behaviour	**Objective 7:** To not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution.		No lasting effect	Negligible (F)
Deepwater benthic communities and habitats (>75 m depth) – (medium value)	Change in water quality	**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.		No impact expected	
Shallow water benthic communities and habitats (<75 m depth) (high value habitat)	Change in water quality	**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results. **Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry).		No impact expected	
Seabirds and migratory shorebirds (high value species)	Change in fauna behaviour	**Objective 11:** To not have a substantial adverse effect on a population of seabirds or migratory shorebirds, or the spatial distribution of the population. **Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species.		No lasting effect	Slight (E)
Fish (high value species)	Change in fauna behaviour	**Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population.		No lasting effect	Slight (E)
KEFs (medium value)	Change in water quality	**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.		No lasting effect	Negligible (F)
AMPs (medium value)	Change in water quality	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No lasting effect	Negligible (F)
Other protected places (high value)	Change in water quality	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No lasting effect	Slight (E)

Receptor (sensitivity)	Potential Impact	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
State and Commonwealth managed fisheries (high value marine user)	Changes to the functions, interests or activities of other users	**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No lasting effect	Slight (E)
Other users including tourism and recreation and scientific studies (high value users)	Changes to the functions, interests or activities of other users	**Objective 21:** To not interfere with other marine users to a greater extent than is necessary for the execution of the Browse to NWS Project.		No lasting effect	Slight (E)

Table 6-94 Acceptability assessment – marine discharges: putrescible waste

Acceptability Assessment
Confidence in assessment Woodside have a **high** level of certainty with respect to the assessment of the potential impacts and risks associated with putrescible waste discharges as: + The implementation of relevant acts and legislative requirements, including MARPOL 73/78 Annex V: Garbage and the Commonwealth *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*, will mitigate potential impacts.
Principles of ESD With the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such it is considered that the principles of ESD will be met. **Conclusion: Acceptable**
Significant Impacts as defined by the MNES Significant Impact Guidelines *Listed threatened species and ecological communities / listed migratory species* As described in **Table 6-93**, no lasting effect is predicted to occur from the discharge of putrescible waste to listed threatened and migratory species such as fish, marine turtle and marine mammals, with the impact significance level determined to be Slight (E). Given this, with the application of the proposed controls it is predicted that the nominated environmental objectives for each of these fauna species will be achieved. As such, no significant impacts to the listed threatened or migratory species (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted *Commonwealth Marine Environment* As described in **Table 6-93**, the potential impact from the discharge of putrescible waste to plankton, KEFs and AMPs has been assessed as Negligible (F). Slight (E) impacts may potentially occur to water quality, marine fauna, other protected places, managed fisheries and other users, while no impact is predicted to occur to deepwater benthic communities and habitats (>75 m depth) and shallow water benthic communities and habitats (<75 m depth). As such, with the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such no significant impacts to the Commonwealth marine environmental (as defined by the Significant Impact Guidelines (**Table 6-5**) are predicted. **Conclusion: Acceptable**
WA EPA Environmental Objectives In accordance with accordance with MARPOL 73/78 Annex V: Garbage, no putrescible waste will be discharged within the State Proposal Area. **Conclusion: Acceptable**
External context To date there have been no specific matters raised by stakeholders regarding discharge of putrescible waste in relation to the proposed Browse to NWS Project. **Conclusion: Acceptable**
Internal context This impact assessment has been undertaken in accordance with Woodside's Risk Assessment Procedure and Environment Impact Assessment Guideline **Section 6.2.3.4**.The proposed Browse to NWS Project will be executed in accordance with Woodside's Health, Safety and Environmental Management System. **Conclusion: Acceptable**

Acceptability Assessment
Other requirements
EPBC Act recovery and conservation plans and advices
No adverse impacts to species where an EPBC Act management plan of conservation advice applies is predicted to occur as a result of the discharge of putrescible waste.
KEFs
As detailed in Table 6-91, the proposed discharges will not materially increase existing relevant pressures on the conservation values of KEFs.
AMPs
As detailed in Table 6-92 the proposed activities are considered to be not inconsistent with the requirements of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018).
Other Protected Places
No impacts are expected to occur to the to the values of the Scott Reef and Surrounds or the Mermaid Reef – Rowley Shoals Commonwealth Heritage Places.
Conclusion: Acceptable

6.3.12 Marine Discharges: Produced Water

6.3.12.1 Impact and Risk Overview

Table 6-95 presents an overview of the potential impacts and risks from produced water (PW) discharges associated with the proposed Browse to NWS Project.

Table 6-95 Produced water impact and risk overview

Aspect	Marine discharges: produced water
Description	When hydrocarbons are recovered from the reservoir a by-product is produced water (PW), which is separated out from the hydrocarbons during the production process and disposed of. This PW may consist of a combination of formation water (water that occurs naturally within the hydrocarbon-bearing geological formations that is drawn into the well during hydrocarbon recovery), and condensed water (water vapour contained in the gaseous phase of the reservoir fluids that condenses out of the gas as the pressure and temperature is reduced when the reservoir fluids are brought up to the surface). PW will be produced during operations where it will be treated on board the FPSO facilities prior to discharge to the marine environment. Low levels of PW may also be discharged from the MODU at the drill centre locations, during well unloading. PW discharged to the marine environment may include: + trace amounts of hydrocarbon compounds + trace amounts of metals + MEG + Naturally occurring radioactive materials (NORMS) + nutrients such as ammonia.
Area	Project Area, Browse Development Area, State Proposal Area
Project stage	Drilling and completions, operations
Environmental objectives	The environmental objectives in relation to produced water associated with the proposed Browse to NWS Project are Objectives 3, 6, 7, 10, 11, 12, 13, 14, 15, 16, 17, 18, 20 and 21. These objectives are detailed in Table 6-7.

Aspect	Marine discharges: produced water
Policy and guidelines	The following policy and guidelines are relevant to the assessment of this aspect. In addition, a number of EPBC Act conservation advices for protected fauna have been considered (**Table 6-99**). + Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018) + WA EPA Environmental Factor Guideline - Marine Environmental Quality (EPA, 2016d) + WA EPA Technical Guidance – Protecting the Quality of Western Australia's Marine Environment (EPA, 2016b) + Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) + Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c) + Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).

Receptors	The following receptors have been identified as potentially being impacted as a result of the proposed Browse to NWS Project (**Table 6-2**). A detailed description of each of these receptors is provided in **Chapter 5**.
	Physical
	+ Sediment quality (medium value (open water))
	+ water quality (medium value (open water))
	Ecological
	+ plankton (medium value (open water))
	+ benthic habitats
	  + shallow water benthic communities and habitats (<75 m depth) (high value habitat)
	  + deepwater communities and habitats (>75 m depth) (medium value habitat
	+ fauna
	  + fish (high value species)
	  + marine reptiles (high value species)
	  + marine mammals (high value species)
	+ KEFs (medium value)
	+ State marine parks and nature reserves (high value)
	+ other protected places (high value)
	Socio-economic
	+ State and Commonwealth managed fisheries (high value marine user)
	+ other users
	  + tourism and recreation (high value user)
	  + scientific studies (high value user)
	+ aboriginal or indigenous heritage (high value users)

Potential impacts	+ change in water quality + Injury or mortality to fauna + changes to the functions, interests or activities of other users
Risk	+ Unplanned discharge of PW significantly above discharge specifications

Aspect	**Marine discharges: produced water**		
Summary of governing impact evaluation	***Magnitude***	***Impact significance level***	***Confidence***
	Minor	Minor	High
Summary of governing risk evaluation	***Consequence***	***Likelihood***	***Risk rating***
	Minor	Remote	Low (D0)

6.3.12.2 Source of Aspect

When hydrocarbons are recovered from the reservoir, PW is a by-product, which is separated out from the hydrocarbons during the production process and disposed of. This PW may consist of a combination of formation water (water that occurs naturally within the hydrocarbon-bearing geological formations that is drawn into the well during hydrocarbon recovery), and condensed water (water vapour contained in the gaseous phase of the reservoir fluids that condenses out of the gas as the pressure and temperature is reduced when the reservoir fluids are brought up to the surface). Formation water is typically expected to be saline, while condensed water is fresh.

PW is typically high temperature, due to the high temperature of the reservoir and other reservoir fluids. Key contaminants of PW discharge are:

- trace amounts of hydrocarbon compounds remaining in the water after treatment (IOGP, 2005)
- trace amounts of metals
- nutrients such as ammonia, which occur naturally within the reservoir
- MEG, which is commonly used as a hydrate inhibitor within oil and gas developments
- NORMS, which under certain conditions can become bound to scale deposits within the production wells, pipelines and process equipment on the offshore facilities.

Produced Water in the offshore oil and gas industry

While condensed water is typically present in the gaseous component of the reservoir, formation water is actively avoided during reservoir recovery. However, over time as hydrocarbons are extracted, formation water is drawn towards the well and it is produced. Formation water (and therefore PW) is therefore generally expected to increase over time and be highest towards the end of the reservoir life. Produced water rates are typically influenced by the reservoir characteristics as well as the capacity of the facility design.

Oil and gas facilities typically have a PW treatment system which removes the contaminants from the PW prior to discharge. The PW treatment system typically focusses on the reduction of oil-in-water to acceptable levels. Accepted industry practice in Australia is to treat PW to below 30 mg/L oil-in-water content (average over a 24-hour period) during steady state operations, which aligns well with the internationally recognised IFC standard of 29 mg/L average over a 30-day period.

Through the environmental impact assessment process, it is typical for proponents to quantify the impact of discharge of PW by describing a mixing zone, defined as the area where the Predicted Environmental Concentration (PEC) exceeds the Predicted No Effect Concentration (PNEC). This mixing zone size can be reduced by increasing the depth at which the PW is discharged to facilitate dispersion, which occurs from mixing action as the buoyant plume rises through the water column.

Examples of PW impact from other proponents summarised in **Table 6-96**. In each instance the proponents identified a mixing zone based on an acceptable discharge of 30 mg/L oil-in-water content (average over a 24-hour period). This mixing zone is typically verified in Operations using a variety of techniques, including whole of effluent toxicity testing.

Table 6-96 Overview of Produced Water in the offshore oil and gas industry

	Barossa Offshore Project Proposal (OPP)	Ichthys EIS
Disposal Mechanism	Treatment and overboard	Treatment and overboard
Maximum Processing Rates	3,260 m^3/day	5,000 m^3/day
99% species protection of condensate	0.007 mg/L (0.456 mg/L[14])	*Not presented*
Mixing zone sizes	6.1 km (based on 4,285 dilutions)	3.6 km (based on 5,000 dilutions)

Produced Water from the proposed Browse to NWS Project

For the proposed Browse to NWS Project, the primary source of PW discharges will occur from the FPSO facilities in Commonwealth waters, with low levels also discharged from the MODU. The FPSO facilities have been designed to minimise the impact of PW, both through the treatment system design and the discharge depth of PW from the FPSO hull.

The PW stream discharged from the FPSO facilities will be treated using a tertiary treatment system, such as a Macro Porous Polymer Extraction (MPPE) system that meets Woodside and accepted industry standards prior to being discharged overboard, below the sea surface. The planned use of a tertiary treatment system onboard the FPSO facilities is considered to represent best practice in the management of PW discharge in relation to an offshore gas processing facility. The selection of the tertiary treatment system is subject to further detailed engineering, however will consider MPPE, with the technology proven and commercially operational on a number of facilities within Australia (e.g. Shell Prelude FLNG facility, INPEX Ichthys LNG Project).

For the FPSO facilities a discharge depth of 14 m below mean sea level was selected to facilitate dispersion and reduce the mixing zone size due to the buoyant plume. While the PW arrives at the FPSOs at a high temperature, in order to facilitate tertiary treatment of the PW stream, it is expected it will be cooled to 50°C prior to discharge. The FPSO PW treatment circuit will be designed for a maximum processing capacity of 5,723 m^3/day on each FPSO. At Phase 1 RFSU, actual PW rates are expected to be significantly less than the design. PW that does not meet these standards will be stored on board the FPSOs before being blended and processed via the PW treatment system to meet specifications prior to discharge.

While PW rates will vary over the life of the proposed Browse to NWS Project, there are two key scenarios that are applicable:

- Scenario 1: Maximum processing capacity of the FPSO facilities, which is not expected until late field life. This corresponds to 5,723 m^3/day.
- Scenario 2: Flowrate of the FPSO facility shortly after start-up or on facility restart when MEG is typically expected to be discharged.

Low levels of PW may also be discharged from the MODU (or a well unloading capable vessel) during well unloading at the well locations, including within deep water areas (> 300m). Generation of this PW would result from condensed water in the hydrocarbon gas stream during well unloading. This PW will be discharged as part of the discharge of well clean up fluids, which will include drilling fluids (see Section 6.3.15 for the assessment of drilling or completions discharges). The PW component of the discharge is generally limited to small volumes of condensed water and will constitute a very small proportion of the discharge stream, with the discharge dominated by suspension fluids. Well unloading is anticipated to take 1-2 days per well (i.e. the amount of time that the well is flowing). The PW component of the discharge may contain inorganic salts from geological formations, dissolved organic compounds, dissolved gases (including H_2S and CO_2), dissolved and dispersed hydrocarbons, metals and low levels of NORMs.

Due to the nature, scale and duration of the FPSO discharge compared the MODU discharges, the detailed impact evaluation with modelling has been completed for FPSO facilities.

Constituents of proposed Browse to NWS Project FPSO Produced Water

Similar to the PW discharges of other offshore oil and gas facilities in Australia, the proposed Browse to NWS Project PW discharge is anticipated to contain a number of toxicants, which include:

- Trace amounts of hydrocarbon compounds remaining in the water after treatment. As hydrocarbon characteristics may vary between oil and gas facilities, the toxicity of the remaining hydrocarbon compounds post treatment also varies. To understand Browse hydrocarbon ecotoxicity better, ecotoxicity testing of Torosa condensate samples has been performed. Based on ecotoxicological studies of Torosa condensate samples the PNEC for chronic exposure at the 99% species protection level is 0.09 mg/L (ESA 2009).

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[14] Barossa Offshore Project Proposal based on 0.007 mg/L but acknowledges toxicity of hydrocarbons tested from Barossa is 0.456 mg/L

The laboratory-based ecotoxicology tests used a range of WAF hydrocarbon concentrations on the six species representing six major taxonomic groups of ecological relevance.

In line with Woodside and accepted industry standards in Australia, and the internationally recognised IFC standard, hydrocarbon compounds are discharged at a concentration of 30 mg/L oil-in-water content (average over a 24-hour period) or less during steady state operations. Therefore, to achieve the PNEC identified in ESA 2009 ecotoxicity testing, approximately 333 dilutions are required between the discharge point and the edge of the mixing zone.

- Mercury in the Browse reservoirs has been studied and there is some inherent uncertainty about the amount of mercury that may be produced. There are only a limited number of reliable mercury measurements taken in samples from the Browse reservoirs. The amount of mercury produced to the FPSOs will be dependent on numerous operational factors, such as how the reservoir pressure changes, the proportional split of condensed water to formation water as well as the chemical composition of the arrival fluids. Once onboard the FPSOs, mercury is expected to partition and preferentially follow gas processing, then condensate processing, with only a remnant being discharged as PW. Operational factors influencing the variability of mercury in PW include processing rates, processing temperature and pressure variation and the chemical composition of the PW stream.

  Notwithstanding uncertainty in reservoir production and subsequent partitioning, some mercury in PW streams is expected to occur in the relatively low toxicity form (Hg (0)), with some potential for production of HgII (e.g. mercury chloride and mercury sulphide). Elemental mercury (Hg (0)), which is relatively unreactive, has little tendency to dissolve in water or rapidly deposit, and instead readily volatises into the atmosphere (Neff, 2002).
  Of the different mercury forms, methyl-mercury (MeHg) is of most concern because it is readily bioavailable and can be responsible for toxicological effects at very low doses; however, MeHg is not expected to be produced from the Browse reservoirs.

  The 99% species protection limit for mercury is 0.1µg/L (non-bioaccumulating) (ANZG, 2018). Assuming the mixing zone is to be governed by oil in-water content (see previous), a maximum mercury discharge concentration of 0.03 mg/L has been specified (based on 300 dilutions). This approach is inherently conservative as it does not account for the ready volatilisation of Hg (0) into the atmosphere (Neff, 2002), and hence is expected to remain in surface water for much less time than oil-in-water, leading to a smaller mixing zone.

- MEG will be used as part of the hydrate management strategy, with continuous injection of MEG during steady state operations not required due to the adoption of active heating of the flowlines and risers. However, intermittent MEG injection is still required during start up (when active heating is not effective) and on shut down for components of the subsea infrastructure which do not have active heating.

  MEG is listed as 'E' category fluids under the OCNS and considered to 'pose little or no risk to the environment' (PLONOR). In addition, the compound has little or no capacity to bind to particulates and will be mobile in soil (WHO, 2000). Direct toxicity testing of neat MEG, on eight, mainly tropical species, representing seven taxonomic groups, established the lowest no observable effect concentration (NOEC) for sea urchin fertilisation of 130 mg/L (Jacobs 2019). Rapid degradation has been reported in surface waters, with a generally low toxicity to aquatic organisms. As such, and as MEG is an intermittent discharge occurring only when the facility starts up, a 156,000 mg/L limit is proposed.

- Typically, at other Woodside operating facilities ammonia occurs in the PW stream at concentrations around ~20 mg/L. While no 99% species protection limit has been assigned by ANZECC, the 95% species protection limit is 0.95 mg/L. Given this only ~20-25 dilutions are required to reach the 95% species protection limit. As such ammonia is not a toxicant of concern and is not carried further in this assessment.

- Maintenance of wells, pipelines and process pipework or equipment may require the disposal of scale if it has built up as a solid. Based on an analysis of the reservoir formation water, the potential for scale deposition containing NORMS has been determined to be low given the low likelihood of NORMS being present within the reservoirs. In addition, the build-up of scale within the subsea and process equipment will be controlled by the use of scale inhibitors if required.

In addition to dissolved and dispersed constituents, it is recognised that there is some potential for inert substances i.e. salts to precipitate into sediment, although these are expected to only occur in very small amounts, with little potential of settling or flocculation due to small particle sizes.

Produced water toxicity uncertainty

For the proposed Browse to NWS project, whole of effluent toxicity data is not currently available as water samples from the appraisal wells are considered unlikely to be representative. Instead the toxicity testing results for Torosa condensate has been identified as the most representative to determine PW toxicity. Oil-in-water content has therefore been used as the governing constituent in PW and has been applied as the basis for impact evaluation for both the Torosa FPSO and the Brecknock/Calliance FPSO PW discharges (for Scenario 1).

This approach has inherent uncertainty as the whole of effluent toxicity of the PW stream has the potential to fluctuate over the life of the field due to varying reservoir characteristics and associated rates of formation water. Therefore, the mixing zone for whole of effluent toxicity may vary from the mixing zone described for the 30mg/L oil-in-water content.

During steady state FPSO operations, an adaptive management process premised on monitoring will be applied to verify that the defined threshold values (i.e. 99% species protection or no effect concentrations) will be met at the edge of the mixing zone and State waters 3 nm boundary, 95% of the time based on dispersion modelling results. The adaptive management process includes:

FPSO PW discharge will be monitored so that its hydrocarbon content is no greater than an average of 30 mg/L over any period of 24 hours during steady-state operations (excluding start-up, shut-downs etc.).

+ Periodic and 'for cause' toxicity testing and characterisation of the physical and chemical composition of the PW stream prior to discharge will be undertaken. This toxicity testing will determine the whole of effluent toxicity used to define the mixing zone, while the chemical characterisation will verify that the discharge limits specified in this draft EIS/ERD are met.
+ In the event the FPSO PW discharge does not meet the defined thresholds in the range predicted for any constituent concentrations, an adaptive management strategy will be implemented (developed during the future Environment Plans).

In addition, baseline and periodic water and sediment quality monitoring at a gradient away from the FPSO facility in the receiving environment will be undertaken to detect changes as a result of FPSO PW discharge.

In the event that the mixing zone is larger than anticipated, posing a significant increase in impact than that described in this draft EIS/ERD (below) then corrective actions will be implemented onboard the FPSOs to reduce the risk, such as storing PW on board the FPSOs (i.e. temporarily halting discharge) and additional engineering to produce a change in discharge characteristics.

6.3.12.3 FPSO Produced Water Modelling

Modelling of the PW discharge from the Torosa FPSO (as the closest discharge point to sensitive receptors at Scott Reef) was undertaken to predict the spatial extent of the impact of PW discharge, based on the temperature and toxicity of the plume ((RPS, 2019a); **Chapter 10, Appendix D.4**). As PW treatment system and discharge characteristics for the Calliance/Brecknock FPSO are the same as for the Torosa FPSO; and the receiving environment at the FPSO locations are similar, the modelling undertaken at the Torosa FPSO location has been used as a surrogate for the Calliance/Brecknock FPSO facility.

Modelling scenarios and discharge characteristics

The model inputs are provided in **Table 6-97**, which are based on the current design specification which have been optimised to facilitate dilution outcomes; but remain conservative for modelling purposes.

A summary of the discharge characteristics, as described in **Section 6.3.12.2**, for the two scenarios is provided in **Table 6-97**. Scenario 1 is representative of the maximum PW processing capacity of the FPSO facilities during steady state operations (i.e. maximum flow rate), while Scenario 2 represents discharges during start-ups (i.e. lower flow rates, with MEG a key constituent).

Table 6-97 Discharge Characteristics

Parameter	Scenario 1	Scenario 2
Description	***Maximum PW processing capacity***	***Expected PW FPSO Start-Ups (i.e. MEG discharge)***
Oil-in-water content (mg/L)	30	30
Flow rate (m^3/d)	5,723	490
Outlet pipe internal diameter (m)	0.15	0.15
Discharge depth below sea surface (m)	14	14
Salinity (ppt)	9.5	0
Temperature (°C)	50	50

Modelling Thresholds

For the purpose of risk and impact assessment in this draft EIS/ERD, the following thresholds have been adopted for individual toxicants. These thresholds have been derived from ecotoxicological testing and guidelines, and are used as the basis for determining the mixing zone for the FPSO PW discharges:

- Oil-in-water threshold: 0.09 mg/L which represents the predicted no effect concentration for chronic exposure at the 99% species protection level based on ecotoxicological studies of Torosa condensate samples (ESA, 2009).
- MEG threshold: 130 mg/L was derived from direct toxicity testing of neat MEG using the lowest no observable effect concentration (NOEC) for sea urchin fertilisation (Jacobs 2019), noting it is not a continuously injected chemical.
- temperature threshold[15]: differential of 3°C above ambient was applied to the modelling based on environmental, health and safety guidelines by the International Finance Corporation (IFC) (IFC, 2007).[16]

Modelling studies

To determine the fate, transport and dilution of the PW discharge, both near-field (close range) and far-field (distant range) modelling was undertaken for the Torosa FPSO as these are used to describe different processes and scales of effect[17]. The principal aim of the dispersion modelling was to calculate the likely extents of the near-field and far-field mixing zones of discharged PW plumes as they disperse through the water column and are transported away from the source locations. The model was set up to determine the number of dilutions achieved out to the model extent. It allows for determination of plume toxicity anywhere in the model extent by applying a discharge concentration of individual contaminants (i.e. oil-in-water) or whole of effluent toxicity measured during operations. The outcomes of the modelling efforts mean the distances and orientations – relative to the source locations – can be determined at which the concentrations of a variety of discharged contaminants will be below defined environmental threshold concentrations.

It should be noted that the model conservatively assumes that only dilution processes reduce the concentration of various components in PW. Reductions due to weathering processes (e.g. evaporation of volatile compounds) or mixing processes (e.g. wave action in the upper water column) are not taken into account. This results in an overestimation of concentrations in modelling predictions.

The dispersion of the PW discharge will depend, initially, on the geometry and hydrodynamics of the discharges themselves, where the induced momentum and buoyancy effects dominate over background processes. This region is generally referred to as the near-field zone, which ends where the discharged plume reaches the same density as the ambient water. While the far-field modelling expands on the outcomes of the near-field mixing by allowing the time-varying nature of currents to be included, and the potential for recirculation of the plume back to the discharge location to be assessed.

The physical mixing of the discharges was first investigated in the near-field zone under stationary current flows statistically representative of the range of speeds expected at the source locations. The near-field zone limits are defined as the area where levels of mixing and dilution are controlled by a plume's initial jet momentum (lateral or vertical motion of the plume) and buoyancy flux (tendency of the plume to float or sink once initial momentum is lost). Should the plume encounter a physical boundary such as the water surface, near-field mixing is judged to be complete and the plume is considered to have entered the far-field zone.

The near-field mixing and dispersion of the PW discharge was simulated using the Updated Merge (UM3) flow model, with the far-field mixing and dispersion of the PW discharges was predicted using the three-dimensional discharge and plume behaviour model, MUDMAP (Khondaker, 2000; Koh and Chang, 1973). The initial state of the far-field model was tuned to align its predictions against those of the near-field model in terms of plume centreline dilutions, average dilutions and cross-sectional dimensions under three stationary-flow conditions.

The far-field modelling expanded on the near-field work by allowing the time-varying nature of water currents and the potential for recirculation of the plume back to the source location to be assessed. A stochastic modelling procedure, where the characteristics of a single discharge are simulated many times under randomly-selected samples of environmental conditions selected from a long hindcast record of currents and winds, was applied in order to map the potential aggregated spatial distribution of contaminants discharged at any time during a particular season or across the whole year. This methodology ensures that the calculated movement and fate of each discharge is representative of the range of prevailing currents at the discharge location. The same modelling approach was applied to cooling water (**Section 6.3.13**) and hydrotest discharge modelling (**Section 6.3.17**).

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[15] *This threshold has been based on the well-established IFC EHS Guidelines for Offshore Oil and Gas Development and has been used a default threshold value for other recent offshore petroleum approvals within Australia and is therefore deemed appropriate for use in this context.*

[16] *Given the very small mixing zone for thermal impacts resulting from produced water discharge from the FPSO facilities, there is no impact pathway to State waters for this discharge. As such Woodside have used the accepted industry standard used in Environment Plans and OPPs assessed by NOPSEMA.*

[17] *It is important to note that near-field and far-field modelling are used to describe different processes and scales of effect, and therefore the far-field modelling results will not necessarily correspond to the outcomes at the end of the near-field mixing zone for any given discharge scenario.*

Both the near-field and far-field modelling outcomes were expressed conservatively as minimum[18] dilution contours calculated as the ratios of dispersing contaminant concentrations in the receiving waters to the initial concentrations in the discharges. Although indicative initial concentration (based on engineering design advice at a relatively early stage of the proposed Browse to NWS Project) were used as input to the modelling, expressing the results in units of dilution (as a proxy for concentration) allowed the impacts of alternative initial concentrations to be assessed during analysis. The constituents were modelled as conservative tracers, with the assumption that the background concentration of the constituent in the receiving waters is zero[19] and there is no significant biodegradation of the discharged constituent over the short duration of the dispersion process. Furthermore, in order to provide a conservative representative illustration of the spatial extent of potential for impacts, modelling plots and dilution contours are based on 95th percentile values and show the highest value that would be achieved for 95% of the time.

Hydrodynamic Model Validation

The proposed Browse to NWS Project is located within the influence of the Indonesian Throughflow, a large-scale current system characterised as a series of migrating gyres and connecting jets that are steered by the continental shelf. As these gyres migrate through the area, large spatial variations in the speed and direction of currents will occur at a given location over time. On the continental shelf, in shallower waters around Scott Reef and closer to the inshore region of the Kimberley Coast, surface winds and tidal dynamics dominate over the large-scale current flows. In comparison to drift currents, tidal currents generate only relatively short tidal migrations that follow an elliptical path. Hence, tidal currents add variability to the longer-term drift patterns of portions of an effluent discharge. Wind shear on the water surface also generates local-scale currents that can persist for extended periods and result in long trajectories.

The marine discharge dispersion modelling studies required current speeds and directions to be specified over a spatial domain covering the potential migration trajectories of the plumes. The available measured data was not adequate for this purpose and therefore the analysis relied upon hindcasts of the circulation generated by numerical modelling. Predictions of the drift currents, available from mesoscale ocean models, were combined with estimates of the tidal currents generated using RPS's three-dimensional hydrodynamic model, HYDROMAP, setup for the study area. Two mesoscale ocean current data sets were considered for the study: CSIRO's global ocean model, BRAN (Bluelink Reanalysis); and the HYCOM (Hybrid Coordinate Ocean Model) Consortium's global ocean model, HYCOM. The suitability of the modelled tidal and drift current data products was evaluated by comparing the predicted currents to those measured within the Project Area.

The tidal model validation included an evaluation of both tidal elevations and tidal currents. Visual comparisons of tidal elevations at 20 locations revealed that the model produced a very good match to the known tidal behaviour for a wide range of tidal amplitudes and clearly represented the varying diurnal and semi-diurnal nature of the tidal signal. Statistical analysis of tidal elevation comparisons over the 20 locations also indicated excellent model performance over a wide region. Tidal current comparisons at three selected measurement locations showed that the tidal model produced a good match in the magnitude, timing and direction of the current velocity at two sites, with a reasonable match in timing and direction – albeit some overprediction of magnitude – at the third site. Across all sites, the current magnitudes and directions were well matched by the model and, considering also the good validation of water elevations, the tidal model was considered suitable for use in the marine dispersion modelling studies.

The mesoscale ocean model current predictions were validated through both quantitative and qualitative comparisons between measured and modelled data at a range of depths through the water column at three selected measurement locations. The comparisons revealed that, at two of the sites, both ocean models offered a good match in magnitude and direction of the measured current velocity in the upper water column; however, the magnitudes of the peaks and troughs were often underpredicted at the deeper levels in both ocean models. At the third site, both ocean models captured the range in current magnitude at each depth; however, the timing of peaks and troughs in the measured current velocity and direction was not well-matched. Given the location of this site in close proximity to Scott Reef, with steep gradients in the bathymetry and the relatively coarse resolution of the ocean models (relative to the tidal model), this was not unexpected. Overall, the BRAN model data offered a slightly better correlation to the field measurements within the Project Area than the HYCOM model data. Both models, however, showed a reasonable match with measurements – particularly in the upper water column – and either one could justifiably have been selected for use in this

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[18] The minimum dilution is calculated as the lowest value in any individual non-zero grid cell within the specified radial distances (e.g. 100 m), including the buffer zone.

[19] Background concentrations were considered zero based on the water quality results described in Chapter 5, which demonstrated the majority of constituents were below their respective limits of reporting, providing for an essentially pristine receiving environment.

study. Given the stochastic methodology applied in far-field modelling, the use of a ten-year hindcast of BRAN current data allowed a realistic spatial distribution of potential plume trajectories and extents to be captured in aggregate. The BRAN model was considered suitable for use in the marine dispersion modelling studies.

Further details relating to the sources of both the modelled and measured data, the comparison methodologies, and the outcomes of the comparisons for both tidal and drift current components can be found in RPS, (2019a) (**Chapter 10, Appendix D.4**)

Near-field modelling results

For both scenarios, the results show that due to the momentum of the discharges, a turbulent mixing zone is created in the immediate vicinity of the discharge point. Within the near-field, the horizontally oriented discharge is predicted to rise towards the water surface after the momentum of the initial discharge is lost, with increased ambient current strengths increasing the horizontal distance travelled by the plume. Near-field average dilution and temperature results for constant medium annualised currents afor Scenario 1 and Scenario 2 are provided in **Figure 6-26** and **Figure 6-27** respectively.

For both scenarios, residual temperature at the point of discharge was assumed to be 50°C. The temperature differential between the discharge and the ambient water is predicted to achieve the threshold level (3°C above ambient temperature) within the near-field (maximum distance of 44 m across all seasons) in all conditions (i.e. current speeds) and therefore no far-field results are portrayed or discussed.

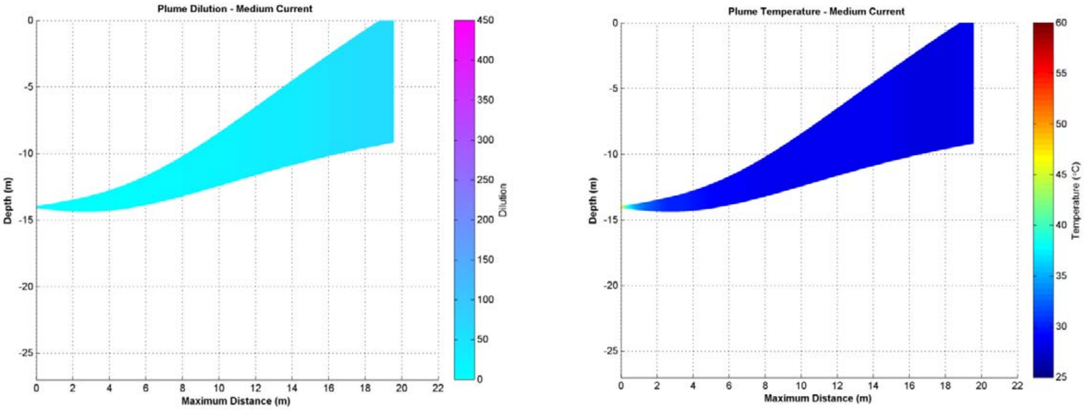

Figure 6-26 Near-field average dilution and temperature results for constant medium annualised currents for Scenario 1 (14 m depth discharge at 5,723 m³/d flow rate).

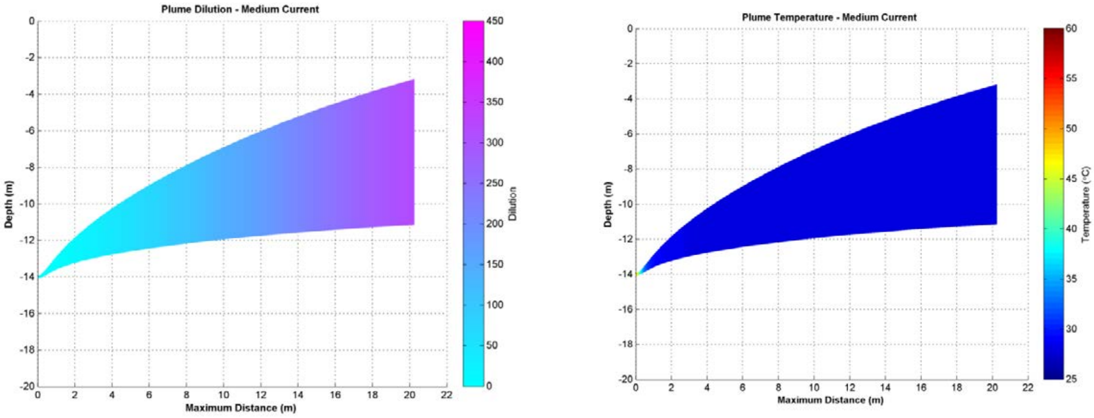

Figure 6-27 Near-field average dilution and temperature results for constant medium annualised currents for Scenario 2 (14 m depth discharge at 490 m³/d flow rate).

Far-field modelling results

Table 6-98 provides a summary of the far field modelling results and demonstrates that the mixing zone for Scenario 1 and 2 PW discharges is achieved well before the 3 nm State waters boundary, with the maximum horizontal distance of 1,200 km from the discharge source (FPSO facility).

Figure 6-28[20] illustrates the predicted annualised minimum dilutions at the 95th percentile for Scenario 1, which is the continuous PW discharge representing the maximum PW processing capacity on the FPSO facilities. The figure shows that the point at which the 99% species protection level is met for oil in water (333 dilutions) is a significant distance from Scott Reef. Oil in water was chosen as it represents the highest toxicity constituent in a continuous discharge, particularly in the context of nearby sensitive receptors within the Browse Development Area (i.e. Scott Reef). It should be noted that while the modelling has not taken the degradation process of the hydrocarbons within the receiving environment into consideration, this natural process will occur due to the inherent biological nature of oil-in-water, further reducing the concentration within the dispersed produced water.

Figure 6-29 illustrates the predicted annualised minimum dilutions at the 95th percentile for Scenario 2, which is the expected rate of the PW discharge during start-up on the FPSO facilities. The figure shows that the 99% species protection level for MEG (1,200 dilutions), which represents the highest toxicity constituent in an intermittent discharge, is met within 200 m of the discharge point (FPSO facility).

To contextualise the stochastic modelling results, Figure 6-30 shows example time series snapshots of predicted dilutions during a single simulation of Scenario 1 at 3-hour intervals over a nominated period (from 1200 on 29 December 2009 to 0300 on 30 December 2009). These images are representative of typical conditions for the discharge[21] and demonstrate the spatially-varying orientation of the plume with the currents. The snapshots also show the combined effect of the tide and the drift currents, with a clear tidal oscillation.

Table 6-98 PW Far Field Modelling Results Summary

Parameter	Scenario 1	Scenario 2
Description	***Maximum PW Processing Capacity***	***Expected PW FPSO Start-Ups (i.e. MEG discharge)***
Selected governing Constituent	Oil in water	MEG
Indicative discharge specification limit	30 mg/L	156,000 mg/L
Threshold (as described above)	0.09 mg/L	130 mg/L
Minimum dilutions required to achieve threshold	333	1,200
Maximum horizontal distance required to achieve threshold)	1,200 m	200 m
Prevailing direction of mixing zone	NNW - SSE	NNW - SSE
Total area of coverage to achieve threshold	0.94 km^2	0.044 km^2
Maximum depth from sea surface	17	25
Governing mixing zone	Yes	No
Minimum dilution at 3 nm State waters boundary	1,507	17,674
Met at the 3 nm State waters boundary	Yes	Yes

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[20] *Note that the figures do not represent the location of a plume at any point in time; they are a statistical and spatial summary of the percentage of time that dilution values occur across all multiple replicate simulations.*

[21] *Based on the 95%th percentile annualised predictions.*

Typically, the whole of effluent toxicity is considered to be the primary driver of the mixing zone, and therefore the governing modelling scenario on which an impact assessment is based. However whole of effluent toxicity data is not available at this stage of the Project (refer to **Produced Water Toxicity Uncertainty**), and therefore the Scenario 1 oil-in-water mixing zone is considered the governing scenario and the basis of impact evaluation for both the Torosa FPSO and the Brecknock/Calliance FPSO PW discharges. During the operate phase the whole of effluent toxicity may vary from the mixing zone described in this modelling – please refer **Produced Water Toxicity Uncertainty** for how this is managed. Note, the modelled mixing zone for Scenario 1 is similar to the mixing zone established for other operational facilities and provides for a significant distance between the edge of the mixing zone and the 3 nm State waters boundary.

Model verification

Modelling is a predictive tool and as such has a number of inherent uncertainties which are typically compensated through the application of conservatism. As such during steady state FPSO operations, infield verification using a range of monitoring techniques will be completed to verify the model predictions and confirm that the mixing zone, including at the 3 nm State waters boundary is met.

In the event that the mixing zone is larger than anticipated, posing a significant increase in risk than that described in this draft EIS/ERD (below) then corrective actions will be implemented onboard the FPSO to reduce the risk, such as storing PW on board the FPSOs (i.e. halting discharge) and additional engineering to produce a change in discharge characteristics.

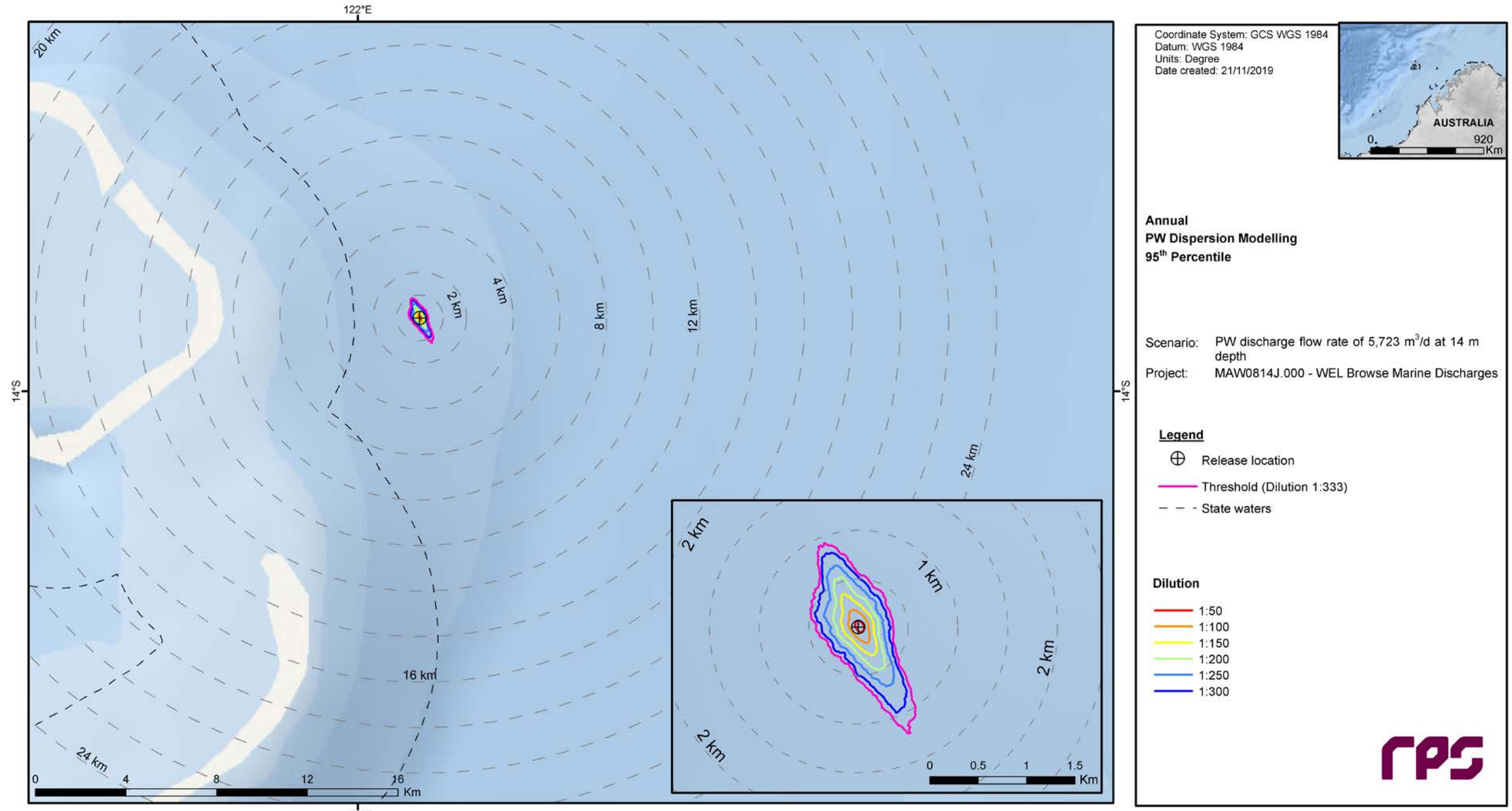

Figure 6-28 Predicted annualised minimum dilutions at the 95th percentile for Scenario 1 (Torosa FPSO release location, 14 m depth discharge at 5,723 m³/d flow rate)

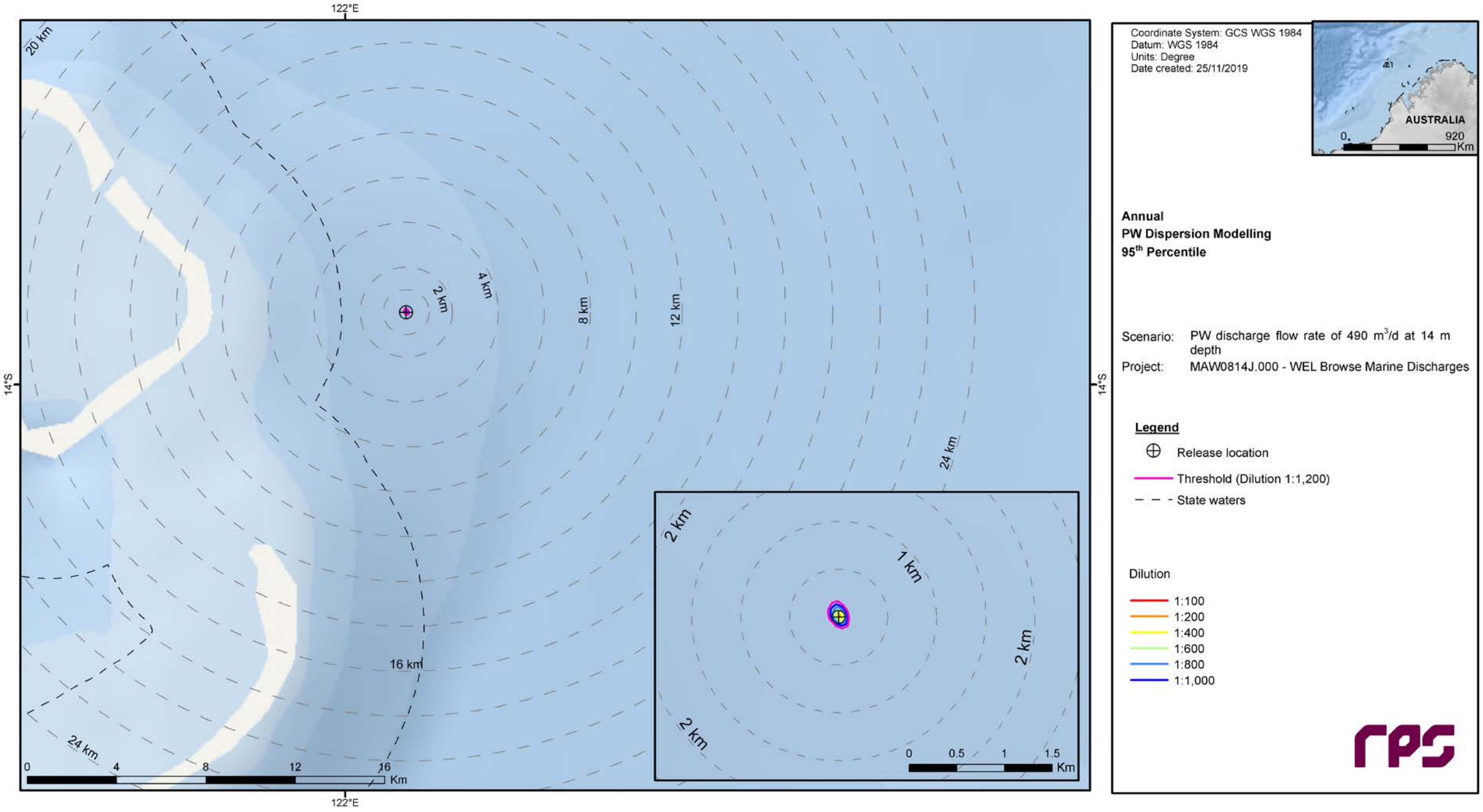

Figure 6-29 Predicted annualised minimum dilutions at the 95th percentile for Scenario 2 (Torosa FPSO release location, 14 m depth discharge at 490 m^3/d flow rate)

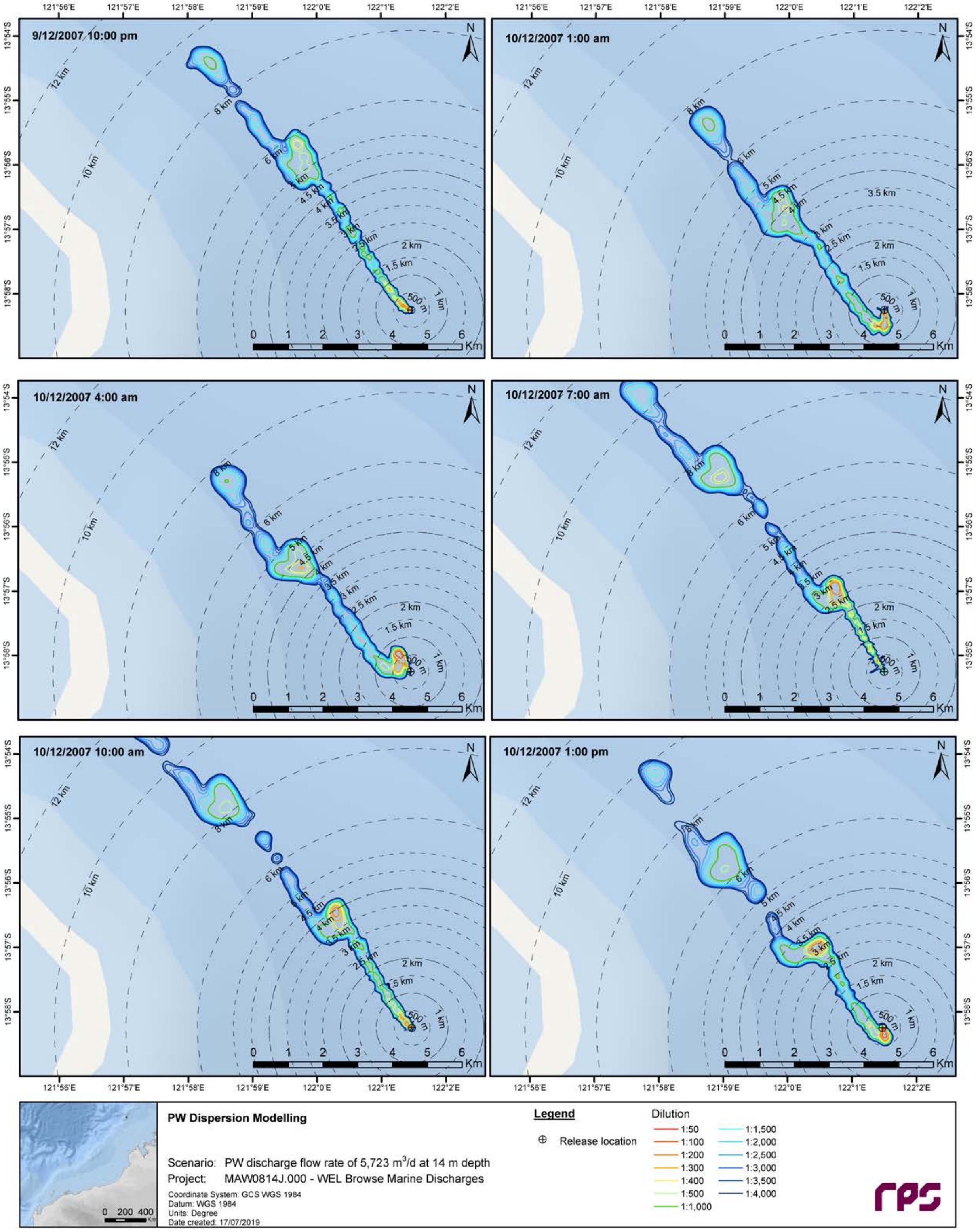

Figure 6-30 Snapshots of predicted dilution levels, at 3-hour intervals from 22:00 on 9th December 2007 to 13:00 on 10th December 2007 (Torosa FPSO release location, 14 m depth discharge at 5,723 m^3/d flow rate)

6.3.12.4 Environmental Impact

Water quality

Changes to water quality

PW discharge may change water quality due to thermal impacts (increased water temperature) and toxicity impacts relating to the residual hydrocarbons and chemical concentration within the PW discharge.

Within the immediate area of influence of the discharge, water temperatures will be elevated temporarily impacting water quality. However, as outlined within the modelling results, the temperature differential between the discharge and the ambient water is predicted to achieve the threshold level (3°C above ambient temperature) within the near-field such thermal impacts are not predicted to occur outside of a maximum of 44 m from the discharge location. As such are not further discussed within the impact assessment.

A change in water quality due to residual hydrocarbons and chemical concentration within the PW discharge will occur in the vicinity of the PW discharge point. The change will be relatively localised, limited to the 1, 200 m mixing zone defined by the modelling as described in **Section 6.3.12.3**, with no predicted impacts to Scott Reef or waters within the State waters boundary (3nm). PW discharges from the FPSO will be managed in Commonwealth waters to ensure the defined threshold values (e.g. 99% species protection or no effect concentrations) at the State waters 3 nm boundary are met 95% of the time based on dispersion modelling results.

Studies have found significant emission of Hg(0) in surface waters of the marine environment, and that marine environments are typically net emitters of Hg, indicating net reduction of Hg(II) to Hg(0) (Obrist et al., 2018; Rolfhus and Fitzgerald, 2004)including best estimates of Hg concentrations and pool sizes in major environmental compartments and exchange processes within and between these reservoirs. Recent advances include the availability of new global datasets covering areas of the world where environmental Hg data were previously lacking; integration of these data into global and regional models is continually improving estimates of global Hg cycling. New analytical techniques, such as Hg stable isotope characterization, provide novel constraints of sources and transformation processes. The major global Hg reservoirs that are, and continue to be, affected by anthropogenic activities include the atmosphere (4.4–5.3 Gt. It is believed that the process of mercury exchange at the interface between the ocean surface and the atmosphere unfolds relatively quickly (Gworek et al., 2016). It is therefore anticipated that the majority of the discharged elemental mercury will be volatilised to the atmosphere. This is particularly so as elevated concentrations of mercury will occur close to the surface given the buoyant nature of the PW plume. It is recognised that there is potential for deposition of a small component of the mercury into sediment, particularly if Hg(0) is oxidised to Hg(II).

Of the different mercury forms, methyl-mercury (MeHg) is of most concern because it is readily bioavailable and can be responsible for toxicological effects at very low doses; however, MeHg is not expected to be produced from the reservoirs. Conversion of other mercury forms to MeHg does not occur in well-oxygenated marine waters (J. Neff, 2002) such as those of the Browse Development Area. Generally, methylation of mercury is a natural process mediated by bacterial decomposers in anoxic environments that has the potential to occur in the deep sea (Hamdy and Noyes, 1975; J. Neff, 2002). It should also be noted that in sediments, methylmercury which has formed through methylation typically represents less than 1.5 % of the total quantity of deposited mercury(Gworek et al., 2016). Thus, the risk for bio-accumulation to occur due to trace amounts of mercury in PW discharge is remote.

MODU discharges (i.e. during well unloading) will be significantly smaller in volume compared to the FPSO discharges and will be discharged as a component of the drill discharges (drill cutting and fluids). Given the PW component is a fraction of the overall discharge during well unloading, this discharge is addressed in assessment of drilling or completions discharges (**Section 6.3.15**).

Sediment quality

Changes to sediment quality

In addition to dissolved and dispersed constituents, it is recognised that there is some potential for inert substances i.e. salts to precipitate into sediment. These salts will be of an inert nature and will disperse rapidly within the receiving environment, with no lasting effect on sediment quality.

Plankton communities

Injury or mortality to fauna

The change in water quality as a result of PW discharges has the potential to result in the injury or death of plankton species within the water column through toxicity effects. Any potential for acute toxicity impacts to plankton would be expected to be limited to within the modelled mixing zone confined to a small portion of the water column (i.e. surface layer). Early life stages of fish (embryos, larvae) and other plankton would be the most susceptible organisms to exposure from hydrocarbons and chemicals in the PW discharges, as they have limited mobility and are therefore likely to be exposed to the plume within the mixing zone. Communities of these types of organisms are expected to rapidly recover once the activity ceases, as they are known to have high levels of natural mortality and a rapid replacement rate (ITOPF, 2011).

As impacts to plankton will be limited to within the mixing zone, they are not expected to have a lasting impact on plankton communities or ecosystem function locally or regionally.

Benthic habitat

Change in water quality

As described above, the model predicted that the PW plume from the FPSO facilities would disperse to below toxicity threshold concentrations within 1,200 m from the discharge point and well prior to the 3 nm State waters boundary. Therefore, no adverse impact to Scott Reef shallow water benthic habitats (< 75 m water depth) are predicted. This includes high value benthic communities and habitats including coral and seagrass.

Furthermore, studies on the dispersion of coral larvae at Scott Reef (Done et al., 2015; Foster and Gilmour, 2018) we examine distance decay among coral communities in a common habitat on northwestern Australian reefs, seeking to better understand the roles of disturbance and coral life history strategies in the changing reefscape. In established communities in 1997, when coral cover and generic richness were uniformly high, there was high similarity (~81 % demonstrates that while there is marked movement of larvae within the reef system itself (broadcast spawning corals), there is no evidence to suggest that those coral larvae that initially dispersed off the reef return to Scott Reef to settle. Therefore, the PW plume is not likely to impact the recruitment of corals within the Scott Reef system. Furthermore, any coral larvae affected by the PW plume would not have been available to resettle on the reef regardless of if the impact had occurred or not.

The modelling predicts that the PW plume will remain within surface waters and as such will not come into contact with deepwater benthic habitats of the Browse Development Area. While there is the potential for insoluble naturally occurring salts to precipitate out of the PW discharge, these salts will be of an inert nature and will disperse rapidly within the receiving environment, with no lasting effect to benthic habitats or communities. As such no adverse impact to epifauna and infauna in the deepwater habitats of the Browse Development Area are predicted.

Marine fauna

Injury or mortality to fauna – fish, marine reptiles, marine mammals

The model predicted that there is potential for marine organisms present in surface waters (e.g. fish, marine mammals and marine reptiles) to be exposed to PW above threshold concentrations if encountering the plume as it is transported by prevailing currents downstream from the FPSO facilities.

Any potential for toxicity to marine organisms would be expected to be limited to surface waters within the mixing zone in the vicinity of the FPSO, and therefore these concentrations will only potentially affect a limited number of marine fauna individuals. It should be noted that the threshold concentrations and the subsequent mixing zone have been determined through the application of chronic exposure threshold based on ecotoxicological tests on larval marine fauna (i.e. during their most sensitive life stage). Therefore, transient marine fauna (i.e. potentially exposed to toxicity for short periods) within the receiving environment adjacent to the discharge location are unlikely to be exposed to sufficient concentrations or durations of the discharge constituents to result in a toxicological impact.

The predicted toxicity effects on marine fauna within this area of influence is considered conservative given the assumptions included in the model. For example, the actual PW discharge rates are likely to be lower than the those modelled, with the chemical constituents also likely to be subject to weathering and natural degradation following discharge.

Furthermore, the direction of the plume emanating away from the discharge point will change depending on the current direction primarily driven by the tides, such that exposure to the discharges in surrounding waters will not be continuous, with transient marine fauna, such as cetaceans, turtles and fish not likely to be exposed to the discharge for enough time to elicit a toxic response.

Fish

Pelagic fish are likely to be exposed to the PW plume above threshold concentrations (within the mixing zone). However, given the above and the high mobility of pelagic fish species, it is not predicted that fish will be exposed to the discharge constituents in sufficient concentrations or durations to elicit a response.

The whale shark is the only threatened fish species that has the potential to occur within the Browse Development Area. Given the above and the low numbers and infrequent nature of whale shark presence in the Browse Development Area, it is not predicted that adverse impacts would occur as a result of PW discharge.

Marine turtles

Acute and chronic effects of chemical discharges are highlighted within the Recovery Plan for Marine Turtles in Australia (2017-2027) as a threat to green turtles within the Scott Reef and Browse Island area (Commonwealth of Australia, 2017a). Modelling predicts that the PW plume from the FPSO facilities will not reach the area defined as habitat critical to the survival of green turtles in the Recovery Plan for Marine Turtles 2017-2027. However, discharge will occur in an area defined as a green turtle internesting BIA . The recovery plan includes the minimisation of chemical discharge as an overarching action area (Commonwealth of Australia, 2017a).

It should be noted that studies have shown that while internesting areas ranged up to 14 km out from the Sandy Islet, most stayed within 5 km of the islet (Guinea, 2011). As such it is not expected that a large number of marine turtles will be exposed to the Torosa FPSO PW discharge mixing zone. As described above it is not predicted that any marine turtles in the mixing zone will be exposed to the discharge constituents in sufficient concentrations or durations to elicit a response.

Marine mammals

Chronic chemical pollution is identified as a potential risk to pygmy blue whales in the Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c); however, conservation advices for other EPBC listed marine mammals that may occur in the Project area do not identify chemical pollution as a key threat (**Table 5-19**). While the maximum mixing zone for PW (1.2 km; **Table 6-98**) overlaps with the foraging and migration BIAs for pygmy blue whales, the relatively low densities of pygmy blue whales and other cetaceans within the Browse Development Area, means that it is not predicted that any adverse impacts to marine mammals will occur as a result of PW discharge.

Assessment against EPBC Act recovery and conservation plans and advices

Table 6-99 provides an assessment of the discharge of PW discharge from the proposed activities in relation to objectives and actions of the relevant EPBC Act recovery and conservation plans and advices.

Table 6-99 Alignment with EPBC Act recovery and conservation plans and advices for protected fauna – PW discharge

Fauna	Relevant plan(s)/ conservation advice	Plan/Advice objectives and actions	Assessment
Whale shark (*Rhincodon typus*)	Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a)	Assess the impacts of offshore installations and associated environmental changes (light spill, chronic noise, changed water temperature, localised nutrient levels) on whale sharks and mitigation options for these impacts.	The potential impact of PW discharges resulting from the proposed Browse to NWS Project have been assessed and mitigation measures proposed. Given the low numbers and infrequent nature of whale shark presence in the Project Area, there is a high level of confidence that PW discharges will not result in adverse impact to whale sharks.
Green turtle (*Chelonia mydas*) Hawksbill turtle (*Eretmochelys imbricata*)	The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a)	Management actions + Manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to the survival. + Manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue. + In relation to the Scott Reef – Browse Island green turtle genetic stock, the priority action is to manage anthropogenic activities to ensure marine turtle are not displaced from identified habitat critical to their survival.	Potential impacts to turtles have been assessed and will be managed in accordance with the Recovery Plan for Marine Turtles in Australia (2017-2027) which includes the minimisation of chemical discharge as an overarching action area (Commonwealth of Australia, 2017a). In relation to the Scott Reef – Browse Island green turtle genetic stock, the priority action to manage anthropogenic activities to ensure marine turtle are not displaced from identified habitat critical to their survival is predicted to be met. PW discharges from the FPSO will be managed in Commonwealth waters to ensure the defined threshold values (e.g. 99% species protection or no effect concentrations) at the State waters 3 nm boundary are met 95% of the time based on dispersion modelling results. Given this, and evidence that most internesting turtles at Scott Reef stay within 5 km of Sandy Islet, it is not expected that a large number of marine turtles will be exposed to the Torosa FPSO PW discharge mixing zone. Further, it is unlikely that any exposure will be of sufficient concentration or duration to elicit a toxic response. Therefore, there is a high level of confidence that any impacts will not compromise the long-term recovery objectives for marine turtles or result in the displacement of the Scott Reef – Browse Island green turtle genetic stock, from identified habitat critical to their survival, or adversely affect the breeding cycle of marine turtles in the BIA at Scott Reef. Therefore, it is considered that the proposed activities are not inconsistent with the Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a).

Fauna	Relevant plan(s)/ conservation advice	Plan/Advice objectives and actions	Assessment
Pygmy blue whale	Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c)	Chronic chemical pollution is identified as a potential risk to pygmy blue whales, however there are no specific actions identified.	Occasional exposure of individuals of these species to the PW discharge plume may occur. However, given the highly mobile nature of marine mammals, exposure would be temporary. As such, it is unlikely that any exposure will be of sufficient concentration or duration to elicit a toxic response. Therefore, it is considered that the proposed activities are not inconsistent with the Conservation Management Plan for the Blue Whale or the conservation advices listed.
Humpback whale	Conservation advice *Megaptera novaeangliae*, Humpback Whale	Marine discharges have not been identified as a direct threat to these whale species; however, habitat degradation has been identified as a threat and unmanaged discharges may contribute to this threat. The conservation advice relevant for this threat – identifies modification to the coastal region in areas of importance to listed whales may result in reduced occupancy, compromised reproductive success and even mortality.	
Sei whale	Conservation advice *Balaenoptera borealis*, Sei Whale		
Fin Whale	Conservation advice *Balaenoptera physalus*, Fin Whale		

Key Ecological Features

Change in water quality - Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEF

Discharge of PW (and subsequent PW mixing zone) from the Torosa FPSO will occur within the Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEF. The primary values of this KEF relate to high primary productivity, diverse aggregations of marine life and high species richness of the coral reefs. The relevant pressure related to PW discharge (chemical pollution / contaminants) is identified as not being of concern for this KEF within the Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).

As described above, while a change in water quality is predicted to occur within the modelled mixing zone, subsequent adverse impacts to fauna such as fish, marine mammals and marine turtles are not predicted. Impacts to plankton are predicted to be localised and not expected to have any lasting effect on plankton communities due to the rapid turn-over of plankton populations leading to relatively quick recovery times (within weeks or months) (ITOPF, 2011).

Modelling indicated that the PW plume from the FPSO facilities will remain in surface waters so is not predicted to impact deepwater benthic habitats. Based on the modelling, the Torosa FPSO PW discharge is not predicted to impact Scott Reef shallow water benthic habitat (<75 m bathymetry). As such adverse impacts to the conservation values of the Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEF are not predicted.

Change in water quality - Continental slope demersal fish communities KEF

The mixing zone of the PW discharge from the Calliance/Brecknock FPSO is predicted to extend into the Continental slope demersal fish communities KEF. This KEF is recognised mainly for its high diversity of demersal fish. As described above, fish are not likely to be exposed to the discharge for enough time to elicit a toxic response and as such adverse impacts to the values of the Continental slope demersal fish communities KEF are not predicted. The relevant pressure related to PW discharge (chemical pollution / contaminants) is identified as not being of concern for this KEF within the Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).

Table 6-100 provides an assessment of the proposed PW discharge in relation to the pressures on KEFs identified in the Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).

Table 6-100 Alignment with protection of conservation values of KEFs – PW discharge

Key Ecological Feature	Relevant plan(s)	Relevant pressures	Assessment
Continental slope demersal fish communities	Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).	Chemical pollution / contaminants - currently identified as 'not of concern'	As described above, PW discharges are not predicted to add to existing or potential pressures or adversely impact the conservation values of these KEFs.
Seringapatam Reef and Commonwealth waters in the Scott Reef Complex			

State Marine Parks and nature reserves

Change in water quality – Scott Reef nature reserve

PW discharges from the FPSO facilities will be managed in Commonwealth waters to ensure the defined threshold values (e.g. 99% species protection or no effect concentrations) are met at the edge of the mixing zone and at the State waters 3 nm boundary, 95% of the time based on dispersion modelling results. Given that the Torosa FPSO PW plume is not predicted to reach Scott Reef, no impact to the values of the Scott Reef Nature Reserve are predicted.

Other protected places

Change in water quality – Scott Reef and Surrounds Commonwealth Area National Heritage Place

The Scott Reef and Surrounds - Commonwealth Area National Heritage Place comprises the Commonwealth Marine Area wholly within the WA coastal waters surrounding North and South Scott Reef. PW discharges from the FPSOs will be managed in Commonwealth waters to ensure the defined threshold values (e.g. 99% species protection or no effect concentrations) are met at the edge of the mixing zone and at the State waters 3 nm boundary, 95% of the time based on dispersion modelling results. As such the FPSOs PW discharge plume is not predicted to reach the Scott Reef and Surrounds - Commonwealth Area National Heritage Place and no impacts to the conservation values of the protected place are predicted.

Other users

Changes to the functions, interests or activities of other users – State and Commonwealth managed fisheries

Where the functions, interests or activities of other users involve marine fauna (e.g. fisheries), any effect to fauna presence or abundance will indirectly impact on the functions, interests or activities of other users. Given that no adverse impacts to fish from PW discharge have been predicted, subsequent impact to fisheries is also not predicted.

Changes to the functions, interests or activities of other users – tourism and recreation, scientific studies

PW discharges from the FPSO will be managed in Commonwealth waters to ensure the defined threshold values (e.g. 99% species protection or no effect concentrations) are met at the edge of the mixing zone and at the State waters 3 nm boundary, 95% of the time based on dispersion modelling results. Due to a 500 m petroleum safety zone around the FPSO facilities and their remote location, there will be limited use of the marine waters in close proximity by other users and as such there is not expected to be any significant impact to other users. Activities such as scientific studies, tourism and recreation at Scott Reef are unlikely to be impacted because Scott Reef is approximately 8 km away from the Torosa FPSO facility which is well away from the edge of the FPSOs PW discharge mixing zone.

Aboriginal or indigenous heritage (high value users)

Changes to the functions, interests or activities of other users

Given that no lasting effect to fish from PW discharge have been predicted, subsequent impact to traditional Indonesian fishers is also not predicted.

Environmental Risk

Risk Event: Unplanned discharge of PW significantly above discharge specifications or whole effluent toxicity

Though unlikely, discharges of PW from the FPSOs at levels significantly above the indicative discharge specifications resulting from human error or equipment failure may occur. This would potentially result in a larger area being impacted (a temporary larger mixing zone), although the plume would still be expected to rapidly disperse. As per **Section 6.3.12.4**, it would remain unlikely that exposure to marine fauna would be sufficient to elicit a toxic response. As such no change to the significance of the impact to water quality, plankton communities, marine fauna, KEFs, State marine parks and nature reserves, managed fisheries or other users would be expected. Deepwater benthic habitats may be greater than the negligible impact predicted due to the unexpected interaction within the marine environment of heavy metals or contamination of solids such as precipitated salts. In this case the impact would increase to slight. Refer to Produced Water Toxicity Uncertainty in **Section 6.3.12.2** for proposed management of PW discharge toxicity.

In the event that the discharge of PW at levels significantly above the indicative discharge specifications occurs at the Torosa FPSO at a time where the prevailing conditions result in the plume moving towards Scott Reef, there is a risk of resultant impacts to Scott Reef shallow water benthic habitat (<75 m bathymetry) including coral and seagrass. This impact would be expected to be slight due to its temporary and localised nature. Given the controls in place and the distance from the Torosa FPSO to Scott Reef, the likelihood of such an event occurring and resulting in adverse effects on Scott Reef shallow water benthic habitat (<75 m bathymetry) is considered remote, with the subsequent risk assessed to be low.

Risk event: Discharge mixing zone significantly greater than modelled

If the dispersal and fate of produced water discharges is greater than expected, there is a risk of impact to Scott Reef benthic communities and habitats. This risk is particularly relevant for cooling water discharges at the Torosa FPSO. To manage this during steady state FPSO operations, produced water mixing zone modelled will be verified infield.

6.3.12.5 Cumulative Impacts

Given the results of the modelling which demonstrate the localised nature of the impacts associated with the PW discharge from the proposed FPSO facilities, no cumulative effects from the separate discharges of PW are expected given the geographic spread between sources (i.e. FPSO facilities at Torosa, Calliance/Brecknock and MODU during well unloading). Similarly, no regional cumulative impacts are expected when considering oil and gas activities within the broader Browse Basin, (i.e. Shell's Prelude FLNG facility and INPEX's Ichthys LNG Project).

6.3.12.6 Impact and Risk Assessment Summary and Acceptability Assessment

A summary of the impact and risk assessment for the discharge of PW is provided in **Table 6-101** and **Table 6-102** respectively. The acceptability assessment is provided in **Table 6-103**.

Table 6-101 Impact assessment summary and adopted controls – marine discharges: produced water

Receptor (sensitivity)	Potential Impact	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
Sediment quality (medium value (open waters))	Change in sediment quality	**Objective 1:** To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **Objective 2:** To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.	*FPSO Operations* + Where practicable, design of the proposed Browse to NWS Project infrastructure will take into consideration opportunities to reduce the need for chemical additives (e.g. the use of active heating for hydrate management). + Chemicals that may be operationally released or discharged to the marine environment will be subject to Woodside's chemical selection and assessment process and approved prior to use. + FPSO PW will be treated prior to being discharged overboard using a tertiary treatment system, such as a Macro Porous Polymer Extraction (MPPE) system that meets Woodside and accepted industry standards. + PW discharge from the FPSO facilities will be conducted below the water surface to promote dispersion and mixing. + For the FPSO PW discharge, the defined threshold values (i.e. 99% species protection or no effect concentrations) will be met at the edge of the mixing zone and the State waters 3 nm boundary, 95% of the time based on dispersion modelling results. + Periodic and 'for cause' toxicity testing and characterisation of the physical and chemical composition of the FPSO PW stream prior to discharge will be undertaken. + Baseline and periodic water and sediment quality monitoring at a gradient away from the FPSO facility in the receiving environment will be undertaken to detect changes as a result of FPSO PW discharge.	No lasting effect	Negligible (F)
Water quality (medium value (open waters))	Change in water quality	**Objective 3:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		Minor	Minor (D)
Plankton (medium value (open water))	Injury or mortality to marine fauna	**Objective 7:** To not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution.		Slight	Slight (E)
Deepwater benthic communities and habitats (>75 m depth) – (medium value)	Change in water quality	**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.		No lasting effect	Negligible (F)
Shallow water benthic communities and habitats (<75 m depth) (high value habitat)	Change in water quality	**Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry).		No impact expected	
Fish (high value species)	Injury or mortality to marine fauna	**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species.		No lasting effect	Slight (E)
Marine turtles (high value species)	Injury or mortality to marine fauna	**Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species.		No lasting effect	Slight (E)
Marine mammals (high value species)	Injury or mortality to marine fauna	**Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **Objective 15:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.		No lasting effect	Slight (E)

Receptor (sensitivity)	Potential Impact	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
KEFs (medium value)	Change in water quality	**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.		No lasting effect	Negligible (F)
State marine parks and nature reserves (high value)	Change in water quality	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No impact expected	
Other protected places (high value)	Change in water quality	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No impact expected	
State and Commonwealth managed fisheries (high value marine user)	Changes to the function interests or activities of other users	**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No lasting effect	Slight (E)
Other users including tourism and recreation and scientific studies (high value users)	Changes to the function interests or activities of other users	**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No impact expected	
Aboriginal or indigenous heritage (high value users)	Changes to the function interests or activities of other users	**Objective 19:** To not have a substantial adverse impact on heritage values.[1] **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No lasting effect	Slight (E)

Table 6-102 Risk assessment summary and adopted controls – marine discharges: produced water

Receptor	Risk Event	Environmental objective	Adopted controls	Consequence	Likelihood	Risk Rating
Sediment quality (medium value (open waters))	Discharge of PW at levels significantly above the indicative discharge specifications resulting from human error or equipment failure	**Objective 1:** To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **Objective 2:** To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.	*FPSO operations* + Hydrocarbon content in the FPSO PW discharge will be no greater than an average of 30 mg/L over any period of 24 hours during steady-state operations (excluding start-up, shut-downs etc.) as demonstrated by monitoring. + During steady state FPSO operations, PW modelling and infield verification will be completed to verify the modelling predictions. + In the event the PW discharge does not meet the defined thresholds in the range predicted for any constituent concentrations, an adaptive management strategy will be implemented which will be included during the Environment Plan process.	Slight	Highly unlikely	Low (E1)
Water quality (medium value (open waters))		**Objective 3:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		No increase to significance/consequence		
Plankton (medium value (open water))		**Objective 7:** To not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution.		No increase to significance/consequence		
Shallow water benthic habitats – (high value habitat)		**Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry).		Minor	Remote	Low (D0)
Deepwater benthic habitat (epifauna and Infauna) – medium value habitat		**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.		Slight	Highly unlikely	Low (E1)
Fish (high value species)		**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species.		No increase to significance/consequence		
Marine turtles (high value species)		**Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species.		No increase to significance/consequence		
Marine mammals (high value species)		**Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **Objective 15:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.		No increase to significance/consequence		
KEFs (medium value)		**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.		No increase to significance/consequence		
State marine parks and nature reserves (high value)		**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No increase to significance/consequence		
Other protected places (high value).		**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No increase to significance/consequence		

Receptor	Risk Event	Environmental objective	Adopted controls	Consequence	Likelihood	Risk Rating
State and Commonwealth managed fisheries (high value marine user)		**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No increase to significance/consequence		
Other users including tourism and recreation and scientific studies (high value users)		**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No increase to significance/consequence		
Aboriginal or indigenous heritage (high value users)		**Objective 19:** To not have a substantial adverse impact on heritage values.1 **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No increase to significance/consequence		

Table 6-103 Acceptability Assessment – marine discharges: produced water

Acceptability Assessment
Confidence in assessment Woodside have a high level of certainty with respect to the assessment of the potential impacts associated with the discharge of produced water as: + PW dispersion modelling has been undertaken with a validate hydrodynamic model (refer to **Section 6.3.12.3**). Further, during steady state FPSO operations, infield verification using a range of monitoring techniques will be completed to verify the model predictions and confirm that the mixing zone, including at the 3 nm State waters boundary is met. + PW dispersion modelling indicates that the PW plume will disperse to below toxicity threshold concentrations within 1,200 m which is well before the 3 nm State waters boundary at Scott Reef. + The modelling undertaken is conservative in that it assumes that only dilution processes reduce the concentration of various components in PW. Reductions due to weathering processes (e.g. evaporation of volatile compounds) or mixing processes (e.g. wave action in the upper water column) are not taken into account. This results in an overestimation of concentrations in modelling predictions. + Periodic and 'for cause' toxicity testing and characterisation of the physical and chemical composition of the PW stream prior to discharge will be undertaken. This toxicity testing will determine the whole of effluent toxicity used to define the mixing zone, while the chemical characterisation will verify that the discharge limits specified in this draft EIS/ERD are met. + In the event the PW discharge does not meet the defined thresholds in the range predicted for any contaminant concentrations, an adaptive management strategy which will be developed during the Environment Plan process, will be implemented. The available pygmy blue whale and green turtle data, 2002 to 2017, were determined to be adequate for the purposes of impact assessment and management planning purposes based on the lack of significantly altered regional cumulative impacts since collection (**Chapter 9**), ability to extrapolate population trends using existing literature, and conservative interpretation of available data where applied. The existing data will be updated by targeted monitoring programs to verify impact predictions and inform adaptive management approaches at relevant times throughout the project life cycle.
Principles of ESD With the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such it is considered that the principles of ESD will be met. **Conclusion: Acceptable**

Acceptability Assessment

Significant Impacts as defined by the MNES Significant Impact Guidelines

Listed threated species and ecological communities / listed migratory species

As described in **Table 6-101**, no lasting effect is predicted to occur from the discharge of PW to listed threatened and migratory species such as fish, marine turtle and marine mammals, with the impact significance level determined to be Slight (E).

As described in **Table 6-102**, potential risk events associated with the discharge of PW are not predicted increased the significance/consequence of impacts to listed threatened and migratory species.

Given this, with the application of the proposed controls it is predicted that the nominated environmental objectives for each of these fauna species will be achieved. As such, no significant impacts to the listed threated or migratory species (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted.

Commonwealth Marine Environment

As described in **Table 6-129**, the potential impact from the discharge of PW to deepwater benthic communities and habitats (>75 m depth) and KEFs has been assessed as Negligible (F). Slight (E) impacts may potentially occur to plankton, fauna and managed fisheries. Minor (D) impacts are predicted to water quality, while no impact is predicted to occur to, shallow water benthic communities and habitats (<75 m depth), other protected places and other marine users.

As described in **Table 6-130**, potential risk events associated with the discharge of PW present a Low risk to shallow water benthic communities and habitats (<75 m depth) and deepwater benthic habitat (epifauna and Infauna).

Given this, with the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such no significant impacts to the Commonwealth marine environmental (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted.

Conclusion: Acceptable

Acceptability Assessment

WA EPA Environmental Objectives

An assessment of the impacts of PW discharge against the WA EPA Objectives is presented in the State Proposal ERD (**Chapter 10, Appendix B**). In summary:

Marine environmental quality

As described in **Table 6-101**, the potential impact from the discharge of PW to plankton and marine fauna has been as Slight (E). Minor (D) impacts are predicted to water quality, while no impact is predicted to occur to or shallow water benthic communities and habitats (<75 m depth).

As described in **Table 6-102,** potential risk events associated with PW discharge present a Low risk to shallow water benthic communities and habitats (<75 m depth).

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*to maintain the quality of water, sediment and biota so that environmental values are protected*" will be achieved.

Marine Fauna

As described in **Table 6-101**, no lasting effect is predicted to occur from PW discharge to marine fauna species such as fish, marine turtle and marine mammals, with the impact significance level determined to be Slight (E).

As described in **Table 6-102**, potential risk events associated with PW discharge are not predicted increased the significance/consequence of impacts to marine fauna.

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*To protect marine fauna so that biological diversity and ecological integrity are maintained*" will be achieved.

Benthic communities and habitats

As described in **Table 6-101**, no impact from PW discharge to deepwater benthic communities and habitats (>75 m depth) is predicted.

As described in **Table 6-102**, potential risk events associated with PW discharge present a Low risk to shallow water benthic communities and habitats (<75 m depth).

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*to protect benthic communities and habitats so that biological diversity and ecological integrity are maintained*" will be achieved.

Conclusion: Acceptable

External Context

To date there have been no specific matters raised by stakeholders regarding discharge of PW in relation to the proposed Browse to NWS Project.

Conclusion: Acceptable

Internal Context

This impact and risk assessment has been undertaken in accordance with Woodside's Risk Assessment Procedure and Environment Impact Assessment Guideline (**Section 6.2**) The proposed Browse to NWS Project will be executed in accordance with Woodside's Health, Safety and Environmental Management System.

Chemicals that may be operationally released or discharged to the marine environment must be subject to Woodside's chemical selection and assessment process and approved prior to use. Woodside will implement its internal requirement that states that chemicals must be selected with the lowest practicable environmental impacts and risks subject to technical constraints.

Conclusion: Acceptable

Acceptability Assessment
Other Requirements EPBC Act recovery and conservation plans and advices As detailed in Table 6-99, the proposed activities are considered to be not inconsistent with the actions and objectives of: + Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a) + The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) + Conservation management plan for the Blue Whale (Commonwealth of Australia, 2015c) + Conservation advice *Megaptera novaeangliae*, Humpback Whale (Threatened Species Scientific Committee, 2015b) + Conservation advice *Balaenoptera borealis*, Sei Whale (Threatened Species Scientific Committee, 2015c) + Conservation advice *Balaenoptera physalus*, Fin Whale (Threatened Species Scientific Committee, 2015d).
KEFs As detailed in Table 6-100 proposed PW discharge will not materially increase existing relevant pressures on the conservation values of KEFs.
Other protected places No impacts are expected to occur to the to the values of the Scott Reef and Surrounds or the Mermaid Reef – Rowley Shoals Commonwealth Heritage Places.
Conclusion: Acceptable

6.3.13 Marine Discharges: Cooling Water

6.3.13.1 Impact and Risk Overview

Table 6-90 presents an overview of the potential impacts and risks from cooling water discharges associated with the proposed Browse to NWS Project.

Table 6-104 Cooling water impact and risk overview

Aspect	Marine discharges: cooling water
Description	Seawater is used as a cooling media for heat exchangers to remove excess heat from the production processes on the FPSO facilities as well as from machinery systems on: + project vessels + FPSO facilities + MODUs. Seawater cooling systems draw seawater from the ocean which is then pumped through heat exchangers where it absorbs heat. It is then discharged overboard at a higher temperature than source. Cooling water is often treated with additives including scale inhibitors and biocide (such as chlorine) to avoid biofouling of pipework. These chemicals are usually added at low dosages, and are typically consumed in the inhibition process, so there is little or no residual chemical concentration remaining upon discharge.
Area	Project Area, Browse Development Area, State Proposal Area
Project stage	All - drilling and completions, installation, commissioning, operations and decommissioning
Environmental objectives	The environmental objectives in relation to cooling water associated with the proposed Browse to NWS Project are Objectives 3, 6, 7, 10, 12, 13, 14, 15, 16, 17, 18, 20 and 21. These objectives are detailed in Table 6-7.

<table>
<tr><th>Aspect</th><th colspan="3">Marine discharges: cooling water</th></tr>
<tr><td>Policy and guidelines</td><td colspan="3">The following policy and guidelines are relevant to the assessment of this aspect. In addition, a number of EPBC Act conservation advices for protected fauna have been considered (Table 6-106).
+ Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018)
+ WA EPA Environmental Factor Guideline - Marine Environmental Quality (EPA, 2016d)
+ WA EPA Technical Guidance – Protecting the Quality of Western Australia's Marine Environment (EPA, 2016b)
+ Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a)
+ Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c)
+ North-west Marine Parks Network Management Plan (Director of National Parks, 2018).</td></tr>
<tr><td>Receptors</td><td colspan="3">The following receptors have been identified as potentially being impacted as a result of the proposed Browse to NWS Project (Table 6-2). A detailed description of each of these receptors is provided in Chapter 5.
<i>Physical</i>
+ water quality (medium value (open waters))
<i>Ecological</i>
+ plankton (low value (open water)
+ benthic habitats
  + shallow water benthic communities and habitats (<75 m depth) (high value habitat)
  + deepwater communities and habitats (>75 m depth) (medium value habitat)
+ fauna
  + fish (high value species)
  + marine reptiles (high value species)
  + marine mammals (high value species)
+ KEFs (high value)
+ AMPs (high value)
+ State marine parks and nature reserves (high value)
+ other protected places (high value)
<i>Socio-economic</i>
+ managed fisheries (high value user)
+ other users
  + tourism and recreation (high value user)
  + scientific studies (high value user)
+ aboriginal or indigenous heritage (high value users)</td></tr>
<tr><td>Potential impacts</td><td colspan="3">+ change in water quality
+ injury or mortality to fauna
+ changes to the functions, interests or activities of other users</td></tr>
<tr><td>Risk</td><td colspan="3">+ unplanned discharge of cooling water significantly above discharge specifications</td></tr>
<tr><td rowspan="2">Summary of governing impact evaluation</td><td><i>Magnitude</i></td><td><i>Impact significance level</i></td><td><i>Confidence</i></td></tr>
<tr><td>Minor</td><td>Minor (D)</td><td>High</td></tr>
</table>

Aspect	**Marine discharges: cooling water**		
Summary of governing risk evaluation	***Consequence***	***Likelihood***	***Risk rating***
	Minor	Remote	Low (D0)

6.3.13.2 Source of Aspect

Seawater is used as a cooling media for heat exchangers to remove excess heat from machinery systems on all vessels including the FPSOs and MODUs, as well as from the production processes on the FPSOs. Seawater cooling systems draw seawater from the ocean which is then pumped through heat exchangers where it absorbs heat. It is then discharged overboard at a higher temperature than source. Cooling water is often treated with additives including scale inhibitors and biocide (such as chlorine) to avoid biofouling of pipework. These chemicals are usually added at low dosages, and are typically consumed in the inhibition process, so there is little or no residual chemical concentration remaining upon discharge.

For the proposed Browse to NWS Project, the primary source of cooling water discharges will occur from the FPSO facilities in Commonwealth waters. The FPSOs are proposed to have a cooling water system where seawater is pumped up to the facility, treated with hypochlorite and passed through heat exchangers prior to discharge overboard.

The cooling water system consists of both a Process Seawater System and an Essential Seawater System. In addition to passing through heat exchangers, the Process Seawater System will also cool the inlet gas stream although will not cool any process streams with liquid hydrocarbons. It is estimated that the Process Seawater System demand will be in the order of 720,000 m^3/day per FPSO facility, which will be routinely discharged overboard below the water line, at a design temperature of approximately 50°C. The volumes and discharge criteria of the Process Seawater System is comparable with other offshore facilities within the region. For comparison Shell's Prelude FLNG facility discharges approximately 1,200,000 m^3/day at between 39°C and 42°C (Shell, 2009), while ConocoPhillips' Barossa FPSO discharges 360,576 m^3/day at 45°C (ConocoPhillips, 2018) and INPEX's Ichthys Development central processing platform was stated to discharge 250,000 m^3/day at a maximum temperature of 50°C (INPEX, 2010).

The Essential Seawater System demand is significantly smaller (expected to be <5% of the Process Seawater System). The Process Seawater System and Essential Seawater System are expected to be discharged from different locations on the FPSO hull below the water line.

The hypochlorite system will inject chlorine to protect the seawater cooling system from biofouling. The majority of the chlorine injected into the cooling water system will react and be neutralised in the system. Residual chlorine will be discharged overboard as part of the cooling water discharge stream in the order of 0.2 to 1.0 ppm. Residual chlorine levels will be monitored, and the system routinely maintained so residual chlorine levels at the point of discharge are such that the defined threshold values are achieved at the Scott Reef State waters 3 nm (nautical mile) boundary (95% of the time based on dispersion modelling results).

Cooling water discharges will also occur from the MODUs and vessels operating in both Commonwealth and State waters. However, the discharge volumes are anticipated to be significantly less that then FPSO facilities in the order of approximately 50 m^3/day, depending on vessel size. The impacts associated with these cooling water discharges are expected to be limited to temporary changes in water quality downstream of the discharge point. For vessels this discharge will also be transient in nature based on the operating profile of the vessel. Noting the largest vessel is likely to be the pipelay vessel for the installation of the BTL, which will move along the BTL and inter-field spur line route at a rate of up to approximately 5 km/day (depending on the pipelay vessel and operational conditions such as sea state). Further, MODU and vessel related cooling water impacts will be primarily limited to the construction phase of the project, with the exception of operations support vessels and IMR activities.

As such the detailed impact evaluation with modelling has been completed for FPSOs due to the nature, scale and duration of the discharge compared to all other sources. It should be noted that the actual discharge rates, temperatures, concentrations and engineering design discussed in this section may be further refined during detailed engineering, however these values have been conservatively selected for the purpose of modelling to support impact and risk assessment and in the determination of acceptability in the context of the receiving environment and relevant receptors.

6.3.13.3 FPSO Cooling Water Modelling

Modelling of the cooling water discharge from the Torosa FPSO (as the closest significant discharge point to sensitive receptors at Scott Reef) was undertaken to predict the plume size, location, concentrations of residual chlorine, and the distance where the plume temperatures approach ambient conditions (RPS, 2019a); Chapter 10, Appendix D.4). As cooling water discharge characteristics for the Calliance/Brecknock FPSO are the same as for the Torosa FPSO; and the receiving environment at the FPSO locations are similar, the modelling undertaken at the Torosa FPSO location has been used as a surrogate for the Calliance/Brecknock FPSO facility.

As cooling water rates for the FPSOs are significantly in excess of the cooling water rates for the vessels and MODUs, the FPSOs cooling water discharge is the governing scenario for determining environmental impacts and risks. As such, no modelling for MODU or vessel cooling water discharge has been conducted.

Modelling scenarios and discharge characteristics

The model inputs are provided in **Table 6-105**, which are based on the current design specification which have been optimised to facilitate dilution outcomes; however, remain conservative for modelling purposes.

The modelling assumed a maximum discharge rate of 720,000 m^3/day as a conservative upper limit. The discharge depth of 12 m below mean sea level was selected, which has been optimised during design to facilitate dispersion. The buoyant nature of the discharge stream means dispersion is increased with depth of discharge due to the mixing action that occurs as it rises through the water column. The flow was assumed to occur through twin horizontal outlets of 0.91 m diameter, with a salinity of 35 parts per thousand (ppt). The design temperature of the cooling water system discharge is 50°C.

Table 6-105 Cooling Water Discharge Characteristics

Parameter	Specifications
Discharge constituents	Treated cooling water
Flow rate (m^3/d)	720,000
Outlet pipe internal diameter (m)	0.91
Discharge depth below sea surface (m)	12
Salinity (ppt)	35
Temperature (°C)	50

Modelling thresholds

The proposed threshold values for the key constituents of concern are provided below. These thresholds have been derived from ecotoxicological testing and guidelines; and are used as the basis for determining the mixing zone for the FPSO cooling water discharges.

- acute chlorine threshold for intermittent/shock dosing: 13 ppb (0.013 mg/L) which represents the predicted no effect concentration for acute exposure at the 99% species protection level (Charlton and Stuber 2008)
- chronic chlorine threshold for continuous discharges: 2 ppb (0.002 mg/L) which represents the predicted no effect concentration for chronic exposure at the 99% species protection level (Charlton and Stuber 2008)
- temperature threshold: differential of 3°C above ambient was applied to the modelling based on the Environmental, Health and Safety (EHS) Guidelines for Offshore Oil and Gas Development by the International Finance Corporation (IFC) (IFC, 2015).

Modelling studies

To determine the fate, transport and dilution of the cooling water discharge, both near-field and far-field modelling was undertaken as these are used to describe different processes and scales of effect. The same modelling approach has been used for PW discharge, cooling water discharge and hydrotest discharge; and is described in **Section 6.3.12.3**. The only exception is that the mixing and dispersion of the cooling water discharges was predicted using the three-dimensional discharge and plume behaviour model, CHEMMAP (French-McCay et al., 2006; McCay and Isaji, 2004). A further description of the modelling approach and hydrodynamic model validation is described in **Section 6.3.12.3** and RPS, (2019a) (**Chapter 10, Appendix D.4**).

It should be noted that the modelling took a conservative approach and assumed that no processes other than dilution would reduce the source concentrations over time. The modelling assumed no natural degradation or decay of the chlorine would occur and further reduce the mixing zone. It also did not take account of all mixing processes due to wave action in the upper water column which will likely serve to increase the magnitude of dilution acting on the cooling water plume. This is likely to result in an underestimation of mixing and dilution and overestimation of cooling water concentrations in modelling predictions.

Near-field modelling results

The results show that due to the momentum of the discharge, a turbulent mixing zone is created in the immediate vicinity of the discharge point, which is 12 m below the water surface. For all combinations of discharge scenario and season, the primary factor influencing dilution of the plume is the strength of the ambient current. Medium and strong currents are shown to increase the extent of the turbulent mixing zone, with increased ambient current strengths increasing the horizontal distance travelled by the plume from the discharge point. Following initial mixing, the positively-buoyant plume is predicted to rise in the water column to the surface. The maximum depth of the plume is predicted to be 16 m below the sea surface for all seasons, with the maximum horizontal distance travelled under annualised current speeds predicted to be 42.4 m. Refer to **Figure 6-31** representing the near-field mixing under medium annualised currents.

The results also indicate that the temperature differential between the discharge and the ambient water is predicted to achieve the threshold level (3°C above ambient temperature) within the near-field (maximum distance of 120 m across all seasons) in all conditions and therefore no far-field results are illustrated or discussed.

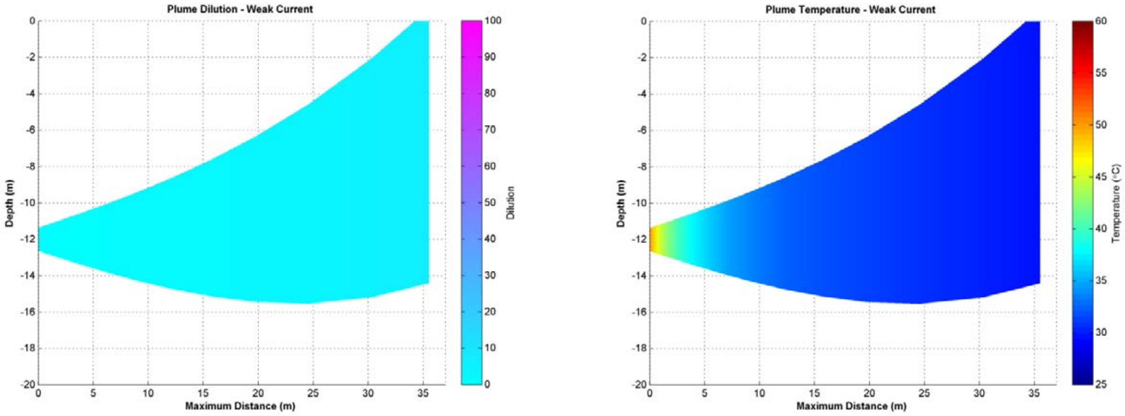

Figure 6-31: Near-field average dilution and temperature results for constant medium annualised currents (12 m depth discharge at 720,000 m^3/d flow rate).

Far-field modelling results

Figure 6-32[22] illustrates the spatial distribution of the cooling water discharge and the point at which the 99% species protection level is met for continuous discharge, particularly in the context of nearby sensitive receptors within the Browse Development Area (i.e. Scott Reef). It should be noted that while the modelling has not taken the degradation process of the chlorine within the receiving environment into consideration, this natural process will occur due to the inherent reactive nature of the chemical, further reducing the concentration within the dispersed cooling water.

The results demonstrate that the:

- minimum number of dilutions achieved at 3 nm State waters boundary is 125 dilutions
- based on the application of the 99% species protection threshold of 0.002 mg/L for chronic exposure this is equivalent to 0.25 mg/L at the discharge point for continuous discharges
- based on the application of the 99% species protection threshold of 0.013 mg/L for acute exposure this is equivalent to 1.6 mg/L at the discharge point for intermittent discharges
- maximum horizontal distance till 125 dilutions is achieved is 4.8 km along the prevailing hydrodynamic flow (i.e. NNW – SSE)
- total area of coverage till 125 dilution is achieved is 5.15 km^2
- maximum depth from discharge is 29 m.

To contextualise the stochastic modelling results, Figure 6-33 shows example time series snapshots of predicted dilutions during a single simulation at 3-hour intervals over a nominated period (from 01:00 to 16:00 on 20th January 2013). These images are representative of typical conditions for the cooling water discharge and demonstrate the spatially-varying orientation of the plume with the currents. The rapidly-varying nature of the concentrations around the source can also be observed. The snapshots show the combined effect of the tide and the drift currents, with a clear tidal oscillation.

Based on the modelling results, 125 dilutions was used to define the full spatial extent of the mixing zone in context of both Scott Reef and the broader open ocean environment. This mixing zone has therefore been applied as the basis of impact evaluation for both the Torosa FPSO and the Brecknock/Calliance FPSO cooling water discharges.

For comparison, the maximum distance required to achieve the acute (0.013 mg/L) and chronic (0.002 mg/l) 99% species protection threshold for chlorine for the ConocoPhillips Barossa Development was 4.6 km and 20.5 km respectively (ConocoPhillips, 2018).

Ongoing development of the FPSO design may impact cooling water discharge parameters, i.e. rate and depth/orientation of discharge, such that the resultant minimum dilutions achieved at the Scott Reef 3 nm State waters boundary will increase (i.e. the mixing

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[22] *Note that the figures do not represent the location of a plume at any point in time; they are a statistical and spatial summary of the percentage of time that dilution values occur across all multiple replicate simulations.*

zone size will reduce). The current expected view of minimum dilutions is considered conservative given the predefined assumptions and instantaneous nature of the model (60 time steps), however it is adopted as the result of far-field modelling for the purposes of this impact assessment. Further modelling and the proposed source concentrations will be defined in the secondary approvals process (via relevant Environment Plans).

Model verification

Modelling is a predictive tool and as such has a number of inherent uncertainties which are typically compensated through the application of conservatism. As such during steady state FPSO operations, infield verification using a range of monitoring techniques will be completed to verify the model predictions and confirm that the mixing zone, including at the 3 nm State waters boundary is met. In the event that the mixing zone is larger than anticipated, posing a significant increase in impact than that described in this draft EIS/ERD (below) then corrective actions will be implemented onboard the FPSOs to reduce the impact. Corrective actions include additional engineering to produce a change in discharge characteristics.

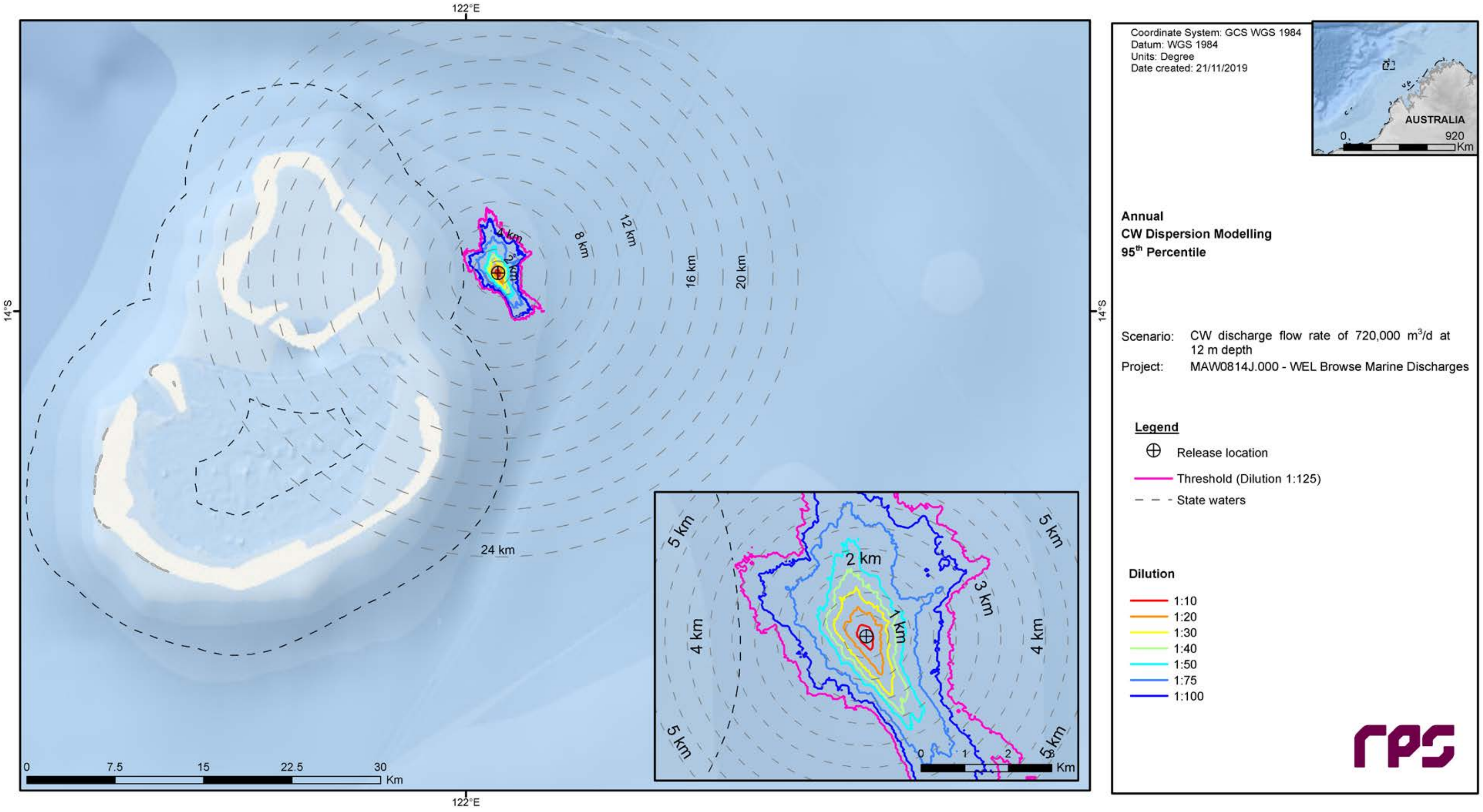

Figure 6-32 Predicted annualised minimum dilutions at the 95th percentile for Scenario 1 (12 m depth discharge at 720,000 m³/d flow rate with no chlorine degradation)

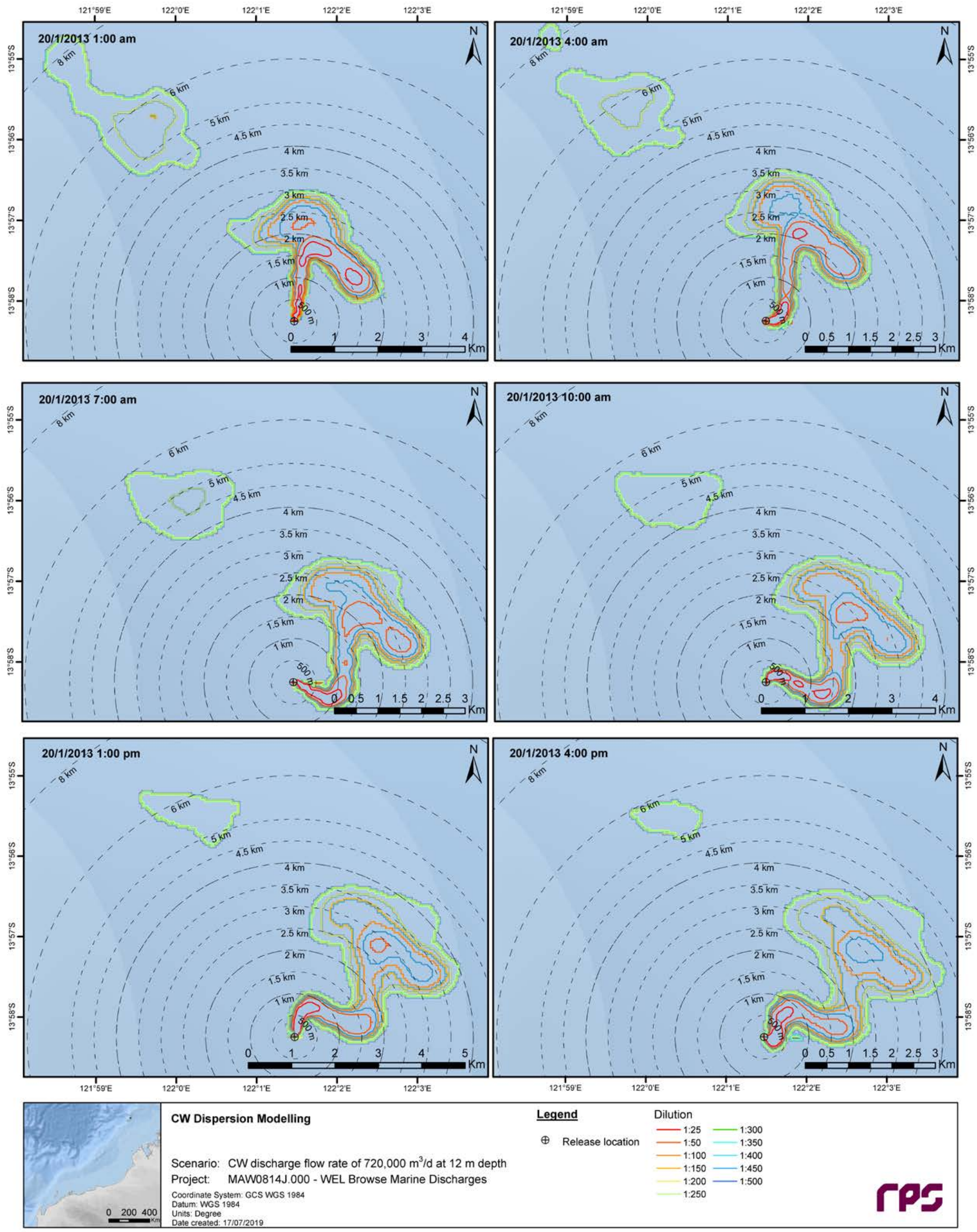

Figure 6-33 Snapshots of predicted dilution levels, at 3-hour intervals from 01:00 to 16:00 on 20th January 2013, for Scenario 1 (Torosa FPSO release location, 12 m depth discharge at 720,000 m^3/d flow rate with no chlorine degradation)

6.3.13.4 Environmental Impact

Water quality

Change in water quality

Cooling water discharge may change water quality due to thermal impacts (increased water temperature) and toxicity impacts relating to the residual chlorine concentration within the cooling water discharge.

Within the immediate area of influence of the discharge, water temperatures will be elevated temporarily impacting water quality. However, as outlined within the modelling results, the temperature differential between the discharge and the ambient water is predicted to achieve the threshold level (3°C above ambient temperature) within the near-field (maximum distance of 120 m across all seasons) in all conditions such thermal impacts are not predicted to occur outside of a maximum of 120 m from the discharge location.

A change in water quality due to residual chlorine concentrations within the cooling water will also occur around the cooling water discharge point. The change will be relatively localised (limited to the mixing zone defined by the modelling; **Section 6.3.13**). Cooling water discharges from the FPSO will be managed in Commonwealth waters to ensure the required number of dilutions (e.g. 125) to achieve the threshold value at 3 nm State waters boundary (e.g. 99% species protection or no effect concentrations) are met 95% of the time based on dispersion modelling results.

MODU and vessel discharges will be significantly smaller in volume compared to the FPSO discharges. Given this, and the distance from such sources to Scott Reef (under normal operating conditions, drilling and vessel activity within the Browse Development Area will be limited to deep waters away from Scott Reef); no effect on Scott Reef benthic communities and habitats is expected to result from the discharge cooling water. Similarly, vessel discharges during installation and intermittent IMR activities along the BTL will occur well away from any sensitive receptors (the proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park (the closest point to the Rowley Shoals)) and are not predicted to impact these receptors.

Plankton communities

Injury or mortality to fauna

There is the potential for plankton present within surface waters to be exposed to residual chlorine above toxicological threshold levels if encountering the cooling water plume as it is transported down-current away from the facilities. Early life stages of fish (embryos, larvae) and other plankton would be the most susceptible organisms to exposure from chlorine in the cooling water discharges, as they have limited mobility and are therefore likely to be exposed to the plume within the mixing zone. Given the fact that the plume will be mobile due to variable metocean conditions and the weathervaning of the facilities, plankton organisms are expected to have the opportunity to recover following any exposure to the plume, due to their fast population turn-over (ITOPF, 2011). Any potential for acute toxicity impacts to plankton would be expected to be limited to within the modelled mixing zone and confined to a small portion of the water column (i.e. to a maximum of 29 m from the surface). Therefore, it is not expected that there will be any lasting impacts on plankton communities or ecosystem function locally or regionally.

Benthic habitats

Change in water quality (change in water temperature)

Elevated water temperatures have the potential to have a significant impact on benthic habitats, resulting in coral bleaching and mortality of seagrass and macroalgae. Modelling results show that the FPSO cooling water discharge plumes will be within surface layers (max depth of 29 m) and will not interact with the seabed. Therefore, thermal impacts to deepwater benthic communities (> 400 m water depth) are not predicted. No thermal impacts to Scott Reef shallow water benthic habitat (<75 m bathymetry) (> 8 km distant form the FPSO facilities) are predicted as modelling indicated a rapid reduction in cooling water temperature from the FPSO discharge point (to within 3°C of ambient within 120 m).

As stated earlier, MODU and vessel discharges will be significantly smaller in volume compared to the FPSOs discharges. Given this, and the distance from such sources to the shallow water benthic habitats of Scott Reef; no effect on Scott Reef benthic communities and habitats is expected to result from the discharge cooling water. Similarly, the proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park (the closest point to the Rowley Shoals) and therefore cooling water discharges from the pipelay vessel are not predicted to affect benthic habitats within the Rowley Shoals.

Change in water quality (toxicity impacts)

Chlorine has the potential to significantly impact benthic habitats, resulting in coral bleaching and mortality of seagrass and macroalgae. Modelling results show that the discharge plumes will be within surface layers and will not interact with the seabed. Therefore, toxicity impacts to deepwater benthic communities (> 400 m water depth) are not predicted.

The modelling demonstrates that for 95% of the time, residual chlorine concentrations above threshold levels are not expected to reach the 3 nm State waters boundary around Scott Reef (**Figure 6-32**), with a minimum dilutions of 125 dilutions achieved at Scott Reef 3 nm State waters boundary. Therefore, no impacts to Scott Reef shallow water benthic habitat (<75 m bathymetry) or coral larvae from cooling water discharge are predicted.

Furthermore, studies on the dispersion of coral larvae at Scott Reef (Done et al., 2015; Foster and Gilmour, 2018) we examine distance decay among coral communities in a common habitat on northwestern Australian reefs, seeking to better understand the roles of disturbance and coral life history strategies in the changing reefscape. In established communities in 1997, when coral cover and generic richness were uniformly high, there was high similarity (~81 % demonstrates that while there is marked movement of larvae within the reef system itself (broadcast spawning corals), there is no evidence to suggest that those coral larvae that initially dispersed off the reef return to Scott Reef to settle. Therefore, the cooling water plume is not likely to impact the recruitment of corals within the Scott Reef system as larvae affected by the cooling water plume would not have been available to resettle on the reef regardless if the impact had occurred or not.

MODU and vessel discharges will be significantly smaller in volume compared to the FPSO discharges. These discharged are expected to dilute to below threshold levels within tens of metres of the discharge point. Given this, and the distance from the discharge to Scott Reef; no effect on Scott Reef benthic communities and habitats is expected to result from the discharge of cooling water from vessels.

Marine fauna

Injury or mortality to fauna (thermal impacts) – fish, marine mammals, marine turtles

Elevated water temperatures have the potential to induce minor physical stress in marine fauna and may result in potential mortality from prolonged exposure.

Elevated seawater temperatures have the potential to alter the physiological processes of exposed biota (Wolanski, 1994). These alterations may cause a variety of effects, ranging from behavioural responses (including attraction and avoidance behaviour), minor stress and potential mortality for prolonged exposure (Walkuska and Wilczek, 2010).

For the proposed Browse to NWS Project, the potential for thermal impacts and associated reduction in oxygen is limited due to the rapid reduction in cooling water temperature in the receiving waters (maximum distance of 120 m from the discharge point to achieve threshold levels and restricted to surface waters) and subsequent highly localised affected area.

While the proposed facilities are within an area known to host a variety of mobile marine fauna (e.g. cetaceans, fish and marine turtles) individuals are likely to be transient within the discharge area of influence and therefore it is unlikely that such fauna would be sufficiently exposed to elevated seawater temperatures to elicit a significant impact. In addition, as the plume is positively-buoyant, impacts to demersal and pelagic species are unlikely.

Injury or mortality to fauna (toxicity impacts) - fish, marine mammals, marine turtles

The effect of chlorine on marine organisms is well known, given its common use as a biocide. Sublethal effects can include growth reduction in some juvenile life stages, alteration of the permeability of membranes and modification of blood composition (Walkuska and Wilczek, 2010).

The results demonstrate that there is potential for marine organisms present in the surface layer of the sea (above 16 m water depth) to be exposed to residual chlorine levels above threshold levels if the organisms encounter the cooling water plume as it is transported down-current away from the FPSO facility discharge point.

It is important to note however that the direction of the plume emanating away from the discharge point will change depending on the current direction, such that exposure to cooling discharges of specific areas surrounding the FPSO facilities will not be continuous. Furthermore, it should be noted that the threshold concentrations and the subsequent mixing zone have been determined through the application of chronic exposure ecotoxicological tests on marine fauna (over days) and therefore if marine fauna are transient within the receiving environment adjacent to the discharge location, they are unlikely to be exposed to sufficient concentrations or durations of the discharge constituents to elicit a response.

Fish

Pelagic fish are likely to be exposed to the cooling water plume above threshold concentrations (within the mixing zone). Exposure will be minimal however, given the buoyant nature of the plume Given the above and the high mobility of pelagic fish species, it is not predicted that fish will be exposed to the discharge constituents in sufficient concentrations or durations to elicit a response.

The whale shark is the only threatened fish species that has the potential to be present within the Browse

Development Area. Given the above and the low numbers and infrequent nature of whale shark presence in the Browse Development Area, it is predicted that no lasting effects to fish will occur as a result of cooling water discharge.

Marine turtles

Acute and chronic effects of chemical discharges are highlighted within the Recovery Plan for Marine Turtles in Australia (2017-2027) as a threat to green turtles within the Scott Reef and Browse Island area (Commonwealth of Australia, 2017a). Modelling predicts that the cooling water plume from the FPSO facilities will not reach the area defined as habitat critical to the survival of green turtles in the Recovery Plan for Marine Turtles 2017-2027. However, cooling water discharge from the Torosa FPSO will occur in an area defined as a green turtle internesting BIA. Cooling water discharge from vessels will occur within both the area defined as habitat critical to the survival of green turtles in the Recovery Plan for Marine Turtles 2017-2027 and the green turtle internesting BIA. The Recovery Plan includes the minimisation of chemical discharge as an overarching action area (Commonwealth of Australia, 2017a).

It should be noted that studies have shown that while internesting areas ranged up to 14 km out from the Sandy Islet, most stayed within 3 km of the islet (Guinea, 2011). As such, it is not expected that a large number of marine turtles will be exposed to cooling water discharges from the operating FPSO at Torosa, MODU or project vessels. Furthermore, it is not predicted that any marine turtles within the discharge mixing zone of the facility will be exposed to sufficient concentrations or long enough durations of toxicants to elicit an impact.

Marine mammals

The mixing zone for the Torosa FPSO overlaps a possible foraging area for pygmy blue whales, while the mixing zones for both FPSOs overlaps the migration BIAs for pygmy blue whales. Chronic chemical pollution is identified as a potential risk to pygmy blue whales in the Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c). Conservation advices for other EPBC listed marine mammals that may occur in the Project area do not identify chemical pollution as a key threat (Table 5-19). Given the low numbers of marine mammals within the Browse Development Area and the relatively small area of the predicted mixing zones for each FPSO facility, it is not predicted that adverse impacts would occur to marine mammals as a result of cooling water discharges form the operating facilities, MODU or project vessels.

Assessment against EPBC Act recovery and conservation plans and advices

Table 6-106 provides an assessment of the discharge of cooling water discharge from the proposed activities in relation to objectives and actions of the relevant EPBC Act recovery and conservation plans and advices.

Table 6-106 Alignment with EPBC Act recovery and conservation plans and advices for protected fauna – cooling water

Fauna	Relevant plan(s)/ conservation advice	Plan/advice objectives and actions	Assessment
Whale shark (*Rhincodon typus*)	Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a)	Assess the impacts of offshore installations and associated environmental changes (light spill, chronic noise, changed water temperature, localised nutrient levels) on whale sharks and mitigation options for these impacts.	The potential impact of cooling water discharges resulting from the proposed Browse to NWS Project have been assessed and mitigation measures proposed. Given the low numbers and infrequent nature of whale shark presence in the Project Area, dynamic nature of the plume, and mobility of the species, there is a high level of confidence that cooling water discharges will not result in adverse impact to whale sharks.

Fauna	Relevant plan(s)/ conservation advice	Plan/advice objectives and actions	Assessment
Green turtle (*Chelonia mydas*) Hawksbill turtle (*Eretmochelys imbricata*)	The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a)	Management actions: + Manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to the survival. + Manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue. + In relation to the Scott Reef – Browse Island green turtle genetic stock, the priority action is to manage anthropogenic activities to ensure marine turtle are not displaced from identified habitat critical to their survival.	Potential impacts to turtles have been assessed and will be managed in accordance with the Recovery Plan for Marine Turtles in Australia (2017-2027) which includes the minimisation of chemical discharge as an overarching action area (Commonwealth of Australia, 2017a). In relation to the Scott Reef – Browse Island green turtle genetic stock, the priority action to manage anthropogenic activities to ensure marine turtle are not displaced from identified habitat critical to their survival is predicted to be met. Cooling water discharges from the FPSOs will be managed in Commonwealth waters to ensure the defined threshold values (e.g. 99% species protection) at the State waters 3 nm boundary are met 95% of the time based on dispersion modelling results. Given this, and evidence that most internesting turtles at Scott Reef stay within 5 km of Sandy Islet, it is not expected that a large number of marine turtles will be exposed to the Torosa FPSO cooling water discharge mixing zone. Further, it is unlikely that any exposure will be of sufficient concentration or duration (given plume dynamics and fauna mobility) to elicit a toxic response. Therefore, there is a high level of confidence that any impacts will not compromise the long-term recovery objectives for marine turtles or result in the displacement of the Scott Reef – Browse Island green turtle genetic stock, from identified habitat critical to their survival, or adversely affect the breeding cycle of marine turtles in the BIA at Scott Reef. Therefore, it is considered that the proposed activities are not inconsistent with the objectives of the Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a).

Fauna	Relevant plan(s)/ conservation advice	Plan/advice objectives and actions	Assessment
Pygmy blue whale	Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c)	Discharges in biologically important areas will be managed such that blue whales continues to utilise the area and are not displaced from a foraging area.	Occasional exposure of individuals of these species to the cooling water discharge plume may occur. However, given the highly mobile nature of marine mammals, exposure would be temporary. As such, it is unlikely that any exposure will be of sufficient concentration or duration to elicit a response. Therefore, it is considered that the proposed activities are not inconsistent with the Conservation Management Plan for the Blue Whale or the conservation advices listed.
Humpback Whale	Conservation advice *Megaptera novaeangliae*, Humpback Whale	Marine discharges have not been identified as a direct threat to these whale species; however, habitat degradation has been identified as a threat and unmanaged discharges may contribute to this threat. The conservation advice relevant for this threat – identifies modification to the coastal region in areas of importance to listed whales may result in reduced occupancy, compromised reproductive success and even mortality.	
Sei Whale	Conservation advice *Balaenoptera borealis*, Sei Whale		
Fin Whale	Conservation advice *Balaenoptera physalus*, Fin Whale		

Key Ecological Features

Change in water quality - Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEF

Discharge of cooling water from the MODU, project vessels and the Torosa FPSO will occur within the Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEF. The primary values of this KEF relate to high primary productivity, diverse aggregations of marine life and high species richness of the coral reefs. The relevant pressure related to cooling water discharge (chemical pollution / contaminants) is identified as not being of concern for this KEF within the Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).

As described above, while a change in water quality is predicted to occur within the modelled mixing zone, subsequent adverse impacts to fauna such as fish, marine mammals and marine turtles are not predicted. Impacts to plankton are predicted to be localised and not expected to have any lasting affect with plankton communities expected to rapidly recover, as they are known to have high levels of natural mortality and a rapid replacement rate (ITOPF, 2011). Modelling indicated that the cooling water plume will remain in surface waters so is not predicted to impact deepwater benthic habitats. Based on the modelling, the cooling water discharge is not predicted to impact Scott Reef shallow water benthic habitat (<75 m bathymetry). As such adverse impacts to the conservation values of the Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEF are not predicted.

Change in water quality - Continental slope demersal fish communities KEF

Cooling water discharge will also occur from MODUs, project vessels and the Calliance/Brecknock FPSO into the Continental slope demersal fish communities KEF. This KEF is recognised mainly for its high diversity of demersal fish. As described above, fish are not likely to be exposed to the discharge for enough time to elicit a toxic response and as such adverse impacts to the values of the Continental slope demersal fish communities KEF are not predicted. The relevant pressure related to cooling water discharge (chemical pollution / contaminants) is identified as not being of concern for this KEF within the Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).

Change in water quality - Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF

Depending on the final route of the BTL, determined during detailed engineering, cooling water discharge may occur from project vessels within the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF. This KEF is recognised mainly for its high productivity and aggregations of marine life. Cooling water discharges from vessels within this KEF will be very small compared to the FPSO facilities, transient in nature (as vessels will move along the BTL route rather than remain in one location) and will only occur during installation of the BTL and during intermittent IMR activities. Given this, biota are not likely to be exposed to the discharge for enough time to elicit a toxic response and as such adverse impacts to the values of the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF are not predicted. The relevant pressure related to cooling water discharge (chemical pollution / contaminants) is identified as not being ‘data deficient or not assessed’ for this KEF within the Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).

Change in water quality - Ancient coastline at 125 m depth contour KEF

Cooling water discharge will also occur from project vessels into the Ancient coastline at 125 m depth contour KEF. This KEF is recognised mainly for its unique seafloor feature with ecological properties of regional significance. Cooling water discharges from vessels within this KEF will be very small compared to the FPSO facilities, transient in nature (as vessels will move along the BTL route rather than remain in one location), restricted to surface waters, and will only occur during installation of the BTL and during intermittent IMR activities. Given the buoyant nature of cooling water discharges, no contact with the seafloor will occur and as such adverse impacts to the values of the Ancient coastline at 125 m depth contour KEF. The relevant pressure related to cooling water discharge (chemical pollution / contaminants) is identified as not being of concern for this KEF within the Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012)

Summary

Table 6-107 provides an assessment of the proposed cooling water discharge in relation to the pressures on KEFs identified in the Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).

Table 6-107 Alignment with protection of conservation values of KEFs – cooling water

Key Ecological Feature	Relevant plan(s)	Relevant pressures	Assessment
Continental slope demersal fish communities	Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).	Chemical pollution / contaminants - currently identified as ‘not of concern’	Given that only minor localised changes in water temperature are expected and no significant changes to water quality are expected within these KEFs, there is a high level of confidence that changes in water quality will not result in an adverse impact to marine ecosystem function or integrity within the KEFs; or any reduction in to the conservation values of the KEFs will occur.
Seringapatam Reef and Commonwealth waters in the Scott Reef Complex			
Ancient coastline at 125 m depth contour			
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals		Chemical pollution / contaminants - currently identified as ‘data deficient or not assessed	

Australian marine parks

Change in water quality

Vessels associated with the installation of the BTL and transiting project vessels will be discharging cooling water within the Multiple Use Zone (VI) of the Argo-Rowley Terrace and Kimberley AMPs (see Section 5.3.3.2 for a description of the values of these AMPs). Cooling water discharges from vessels operating within the AMPs will be temporary and transient in nature (e.g. the slowest moving Project vessel will be the pipelay vessel, which will move at a rate of up to 5 km/day). Cooling water discharges from the operational facilities are not expected within any AMPs due to the distance from the facilities. The Argo-Rowley Terrace and Kimberley AMPs protect values including seabirds, marine turtles, inshore dolphins, humpback whales, pygmy blue whales, dugongs and whale sharks (Director of National Parks, 2018). The introduction of cooling water has the potential impact marine fauna within the AMP through thermal and toxicity effects.

The discharge of cooling water from project vessels within AMPs will be undertaken in accordance with the requirements of the applicable zoning. Cooling water discharges from vessels within the AMPs will be very small compared to the FPSO facilities, transient in nature (as vessels will move along the BTL route rather than remain in one location) and will only occur during installation of the BTL and during intermittent IMR activities. Any impacts on fauna through thermal or toxicity impacts is unlikely due to the dispersive action on the cooling water discharge and the transient nature of the fauna. It is considered that the identified conservation values of the Argo-Rowley Terrace and Kimberley AMPs will not be detrimentally impacted by cooling water discharges associated with the proposed Browse to NWS Project. It should also be noted that the proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park therefore it is unlikely that the cooling water would reach this AMP from the discharge point.

Summary

Table 6-108 provides an assessment of the proposed discharge of cooling water in consideration of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018).

Table 6-108 Alignment with the North-west Marine Parks Network Management Plan – marine discharges: cooling water

Australian Marine Park	Relevant plan(s)	Australian Marine Park objectives	Assessment
Argo-Rowley Terrace Marine Park Multi Use Zone (VI) Kimberley Marine Park Multi Use Zone (VI)	North-west Marine Parks Network Management Plan (Director of National Parks, 2018)	The objective of the Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species.	Cooling water discharges from vessels operating within these AMPs, will cause temporary change in water quality. However, given the low discharge rate from project vessels and the dynamic nature of the open water marine environment, discharges are expected to dilute to below threshold values within metres to tens of metres of the discharge point. Therefore, there is a high level of confidence that cooling water discharges will not result in any adverse impacts to marine ecosystems, habitats or native species such that the conservation values of the AMPs would be reduced As such, it is considered that the proposed activities are not inconsistent with the requirements of the North-west Marine Parks Network Management (Director of National Parks, 2018).
Mermaid Reef Marine Park National Park Zone (II)		The objective of the National Park Zone (II) is to provide for the protection and conservation of ecosystems, habitats and native species in as natural a state as possible.	The proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park. As such, no cooling water discharge will occur in this AMP and no affect to ecosystems, habitats or native species in the AMP will occur. As such, it is considered that the proposed activities are not inconsistent with the requirements of the North-west Marine Parks Network Management (Director of National Parks, 2018).

State Marine Parks and nature reserves

Change in water quality – Scott Reef nature reserve

Cooling water discharges from the FPSO facilities will be managed in Commonwealth waters to ensure the defined threshold values (i.e. 99% species protection) at the State waters 3 nm boundary are met 95% of the time based on dispersion modelling results. Given this the cooling water plume is not predicted to reach Scott Reef, no impact to the values of the Scott Reef Nature Reserve are predicted.

Other protected places

Change in water quality – Scott Reef and Surrounds Commonwealth Area National Heritage Place

The Scott Reef and Surrounds - Commonwealth Area National Heritage Place comprises the Commonwealth Marine Area wholly within the WA coastal waters surrounding North and South Scott Reef. Cooling water discharges from the FPSO will be managed in Commonwealth waters to ensure the defined threshold values (e.g. 99% species protection) at the State waters 3 nm boundary are met 95% of the time based on dispersion modelling results. As such the cooling water discharge plume is not predicted to reach the Scott Reef and Surrounds - Commonwealth Area National Heritage Place and no impacts to the conservation values of the protected place are predicted.

Other users

Changes to the functions, interests or activities of other users – State and Commonwealth managed fisheries

Where the functions, interests or activities of other users involve marine fauna (e.g. fisheries), any effect to fauna presence or abundance will indirectly impact on the functions, interests or activities of other users. Given that no lasting effects to fish from cooling water discharge have been predicted, subsequent impact to fisheries is also not predicted.

Changes to the functions, interests or activities of other users – tourism and recreation, scientific studies

Cooling water discharges from the FPSO will be managed in Commonwealth waters to ensure the defined threshold values (e.g. 99% species protection) at the State waters 3 nm boundary are met 95% of the time based on dispersion modelling results. Due to a 500 m petroleum safety zone around the FPSO facilities and their remote location, there will be limited use of the marine waters in close proximity by other users and as such there is not expected to be any significant impact to other users. Activities such as scientific studies, tourism and recreation at Scott Reef are unlikely to be impacted because Scott Reef is approximately 8 km away from the Torosa FPSO facility which is well away from the edge of the cooling water discharge mixing zone. MODU and vessel discharges will be significantly smaller in volume compared to the FPSO discharges. Given this, and the distance from such sources to Scott Reef (under normal operating conditions, drilling and vessel activity will be limited to deep waters away from Scott Reef); no effects on users of Scott Reef are expected from cooling water discharge.

Aboriginal or indigenous heritage (high value users)

Changes to the functions, interests or activities of other users

Given that no lasting effect to fish from cooling water discharge have been predicted, subsequent impact to traditional Indonesian fishers is also not predicted.

6.3.13.5 Environmental Risk

Risk Event: Unplanned discharge of cooling water significantly above discharge specifications

Though unlikely, discharges of cooling water at levels significantly above the planned discharge specifications resulting from human error or equipment failure may occur. These risks could potentially result in a larger area being impacted (a temporary larger mixing zone), although the plume would still be expected to rapidly disperse. Furthermore, it would remain unlikely that exposure to marine fauna would be sufficient to elicit a toxic response. As such no change to the significance of the impact to water quality, plankton communities, benthic habitats, marine fauna, KEFs, AMPs, State marine parks and nature reserves, other protected places, managed fisheries or other users would be expected.

In the event that the discharge of cooling water at levels significantly above the indicative discharge specifications occurs at the Torosa FPSO at a time where the prevailing conditions result in the plume moving towards Scott Reef, there is a risk of resultant impacts to Scott Reef shallow water benthic habitat (<75 m bathymetry) including coral and seagrass. This impact would be expected to be slight due to its temporary and localised nature. Given the controls in place, conservatism built into the above modelling, and the distance from the Torosa FPSO to Scott Reef, the likelihood of such an event occurring and resulting in adverse effects on Scott Reef shallow water benthic habitat (<75 m bathymetry) is considered remote, with the subsequent risk assessed to be low.

Risk event: Discharge mixing zone significantly greater than modelled

If the dispersal and fate of cooling water discharges is greater than expected, there is a risk of impact to Scott Reef benthic communities and habitats. This risk is particularly relevant for cooling water discharges at the Torosa FPSO. To manage this during steady state FPSO operations, cooling water mixing zone modelled will be verified infield.

6.3.13.6 Cumulative Impacts

Impacts resulting from the cooling water discharge are expected to be localised to each discharge location with no expected cumulative effects from the separate discharges given the geographic spread of the proposed discharge points (i.e. Torosa and Calliance/Brecknock FPSO facilities). Cooling water discharge from project vessels and MODU(s) will be at levels considerably less than the FPSO facilities and are not expected to result in significantly cumulative impacts.

6.3.13.7 Impact and Risk Assessment Summary and Acceptability Assessment

A summary of the impact assessment and risk assessments, and the adopted controls for marine discharges: cooling water is provided in Table 6-109 and Table 6-110. The acceptability assessment is provided in Table 6-111.

Table 6-109 Impact assessment summary and adopted controls – Cooling Water

Receptor (sensitivity)	Impact	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
Water quality (medium value (open water))	Change in water quality	**Objective 3:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	*FPSO operations* + Cooling water discharge from the FPSO facilities will be conducted below the water surface to promote dispersion and mixing. + Hypochlorite will be used to control fouling in sea water systems in line with best practice, due to its solubility in water and rapid biodegradability. + For FPSO cooling water discharges, the defined threshold value (i.e. 99% species protection; 3°C above ambient) will be met at the edge of the mixing zone and the State waters 3 nm boundary, 95% of the time based on dispersion modelling results.	Minor	Minor (D)
Plankton (medium value (open water))	Injury or mortality to marine fauna	**Objective 7:** To not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution.		Slight	Slight (E)
Shallow water benthic communities and habitats (<75 m depth) (high value habitat)	Change in water quality	**Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry).		No impact expected	
Deepwater communities and habitats (>75 m depth) (medium value habitat)		**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.		No impact expected	
Fish (Marine fauna (high value species)	Injury or mortality to marine fauna	**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **Objective 15:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.		No lasting effect	Slight (E)

Receptor (sensitivity)	Impact	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
Marine turtles (high value species)	Injury or mortality to marine fauna	**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.		No lasting effect	Slight (E)
Marine mammals (high value species)	Injury or mortality to marine fauna	**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 15:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population.		No lasting effect	Slight (E)
KEFs (medium value)	Change in water quality	**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.		No lasting effect	Negligible (F)
AMPs (medium value)	Change in water quality	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No lasting effect	Negligible (F)
State marine parks and nature reserves (high value)	Change in water quality	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No impact expected	
Other protected places (high value)	Change in water quality	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No impact expected	
State and Commonwealth managed fisheries (high value marine users)	Changes to the function interests or activities of other users	**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No lasting effect	Slight (E)
Other users including tourism and recreation and scientific studies (high value users)	Changes to the function interests or activities of other users	**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No lasting effect	Slight (E)
Aboriginal or indigenous heritage (high value users)	Changes to the function interests or activities of other users	**Objective 19:** To not have a substantial adverse impact on heritage values.1 **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No lasting effect	Slight (E)

Table 6-110 Risk assessment summary and adopted controls – Cooling water

Receptor	Risk Event	Environmental objective	Adopted controls	Consequence	Likelihood	Risk Rating
Water quality (medium value (open waters))	Unplanned release of cooling water at significantly elevated discharge concentrations that would lead to water quality impacts within the State waters 3 nm boundary	**Objective 3:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	*FPSO operations* + The FPSO facilities' cooling water systems have been designed to be segregated from process liquid hydrocarbon streams to prevent potential contamination of the cooling water. + During steady state FPSO operations, cooling water modelling and infield verification will be completed to verify the modelling predictions.	No increase to significance/ consequence		
Plankton (medium value (open water))		**Objective 7:** To not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution.		No increase to significance/ consequence		
Deepwater benthic communities and habitats (>75 m depth) – (medium value)		**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.		No increase to significance/ consequence		
Shallow water benthic communities and habitats (<75 m depth) (high value habitat)		**Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry).		Minor	Remote	Low (D0)
Fish (high value species)		**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species.		No increase to significance/ consequence		
Marine turtles (high value species)		**Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species.		No increase to significance/ consequence		
Marine mammals (high value species)		**Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **Objective 15:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.		No increase to significance/ consequence		
KEFs (medium value)		**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.		No increase to significance/ consequence		
AMPs (medium value)		**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No increase to significance/ consequence		
Managed fisheries (high value users)		**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No increase to significance/ consequence		
Other protected places (high value)		**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No increase to significance/ consequence		

Receptor	Risk Event	Environmental objective	Adopted controls	Consequence	Likelihood	Risk Rating
State and Commonwealth managed fisheries (high value marine user)		**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No increase to significance/ consequence		
Other users including tourism and recreation and scientific studies (high value users)		**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No increase to significance/ consequence		
Aboriginal or indigenous heritage (high value users)		**Objective 19:** To not have a substantial adverse impact on heritage values.1 **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No increase to significance/ consequence		

Table 6-111 Acceptability Assessment – Cooling Water

Acceptability Assessment
Confidence in assessment Woodside have a high level of certainty with respect to the assessment of potential impacts and risks associated with cooling water as: + Modelling of the FPSO facilities cooling water discharge demonstrate that for 95% of the time, residual chlorine concentrations above threshold levels are not expected to reach the 3 nm State waters boundary around Scott Reef. + The modelling took a conservative approach and assumed that no processes other than dilution would reduce the source concentrations over time. The modelling assumed no natural degradation or decay of the chlorine would occur and further reduce the mixing zone. It also did not take account of all mixing processes due to wave action in the upper water column which will likely serve to increase the magnitude of dilution acting on the cooling water plume. This is likely to result in an underestimation of mixing and dilution and overestimation of cooling water concentrations in modelling predictions. + Temperature thresholds are expected to be reached within 120 m of the release location. + During steady state FPSO operations, cooling water modelling and infield verification will be completed to verify the mixing zone and demonstrate that the defined threshold are met at the State waters 3 nm boundary. The available pygmy blue whale and green turtle data, 2002 to 2017, were determined to be adequate for the purposes of impact assessment and management planning purposes based on the lack of significantly altered regional cumulative impacts since collection (Chapter 9), ability to extrapolate population trends using existing literature, and conservative interpretation of available data where applied. The existing data will be updated by targeted monitoring programs to verify impact predictions and inform adaptive management approaches at relevant times throughout the project life cycle.
Principles of ESD With the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such it is considered that the principles of ESD will be met. **Conclusion: Acceptable**
Significant Impacts as defined by the MNES Significant Impact Guidelines Listed threated species and ecological communities / listed migratory species As described in **Table 6-109**, no lasting effect is predicted to occur from the discharge of cooling water to listed threatened and migratory species such as fish, marine turtle and marine mammals, with the impact significance level determined to be Slight (E). As described in **Table 6-110**, potential risk events associated with the discharge of cooling water are not predicted increased the significance/consequence of impacts to listed threatened and migratory species. Given this, with the application of the proposed controls it is predicted that the nominated environmental objectives for each of these fauna species will be achieved. As such, no significant impacts to the listed threated or migratory species (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted. *Commonwealth Marine Environment* As described in **Table 6-109**, the potential impact from the discharge of cooling water to KEFs and AMPs has been assessed as Negligible (F). Slight (E) impacts may potentially occur to plankton, fauna and managed fisheries. Minor (D) impacts are predicted to water quality, while no impact is predicted to occur to deepwater benthic communities and habitats (>75 m depth), shallow water benthic communities and habitats (<75 m depth), other protected places and other marine users. As described in **Table 6-110**, potential risk events associated with the discharge of cooling water present a Low risk to shallow water benthic communities and habitats (<75 m depth). Given this, with the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such no significant impacts to the Commonwealth marine environmental (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted. **Conclusion: Acceptable**

Acceptability Assessment

WA EPA Environmental Objectives

An assessment of the impacts of cooling water discharge against the WA EPA Objectives is presented in the State Proposal ERD (Chapter 10, Appendix B). In summary:

Marine environmental quality

As described in Table 6-109, the potential impact from the discharge of cooling water to plankton and marine fauna has been as Slight (E). Minor (D) impacts are predicted to water quality, while no impact is predicted to occur to deepwater benthic communities and habitats (>75 m depth) or shallow water benthic communities and habitats (<75 m depth).

As described in Table 6-110, potential risk events associated with cooling water discharge present a Low risk to shallow water benthic communities and habitats (<75 m depth).

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*to maintain the quality of water, sediment and biota so that environmental values are protected*" will be achieved.

Marine Fauna

As described in Table 6-109, no lasting effect is predicted to occur from cooling water discharge to marine fauna species such as fish, marine turtle and marine mammals, with the impact significance level determined to be Slight (E).

As described in Table 6-110, potential risk events associated with cooling water discharge are not predicted increased the significance/consequence of impacts to marine fauna.

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*To protect marine fauna so that biological diversity and ecological integrity are maintained*" will be achieved.

Benthic communities and habitats

As described in Table 6-109, no impact from cooling water discharge to deepwater benthic communities and habitats (>75 m depth) is predicted.

As described in Table 6-110, potential risk events associated with cooling water discharge present a Low risk to shallow water benthic communities and habitats (<75 m depth).

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*to protect benthic communities and habitats so that biological diversity and ecological integrity are maintained*" will be achieved.

Conclusion: Acceptable

External context

To date there have been no specific matters raised by stakeholders regarding discharge of cooling water in relation to the proposed Browse to NWS Project.

Conclusion: Acceptable

Internal context

This impact and risk assessment has been undertaken in accordance with Woodside's Risk Assessment Procedure and Environment Impact Assessment Guideline (Section 6.2) The proposed Browse to NWS Project will be executed in accordance with Woodside's Health, Safety and Environmental Management System.

Chemicals that may be operationally released or discharged to the marine environment must be subject to Woodside's chemical selection and assessment process and approved prior to use. Woodside will implement its internal requirement that states that Chemicals must be selected with the lowest practicable environmental impacts and risks subject to technical constraints.

Conclusion: Acceptable

Acceptability Assessment

Other requirements

EPBC Act recovery and conservation plans and advices

As detailed in Table 6-106, the proposed activities are considered to be not inconsistent with the actions and objectives of:

- Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a)
- The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a)
- Conservation management plan for the Blue Whale (Commonwealth of Australia, 2015c)
- Conservation advice *Megaptera novaeangliae*, Humpback Whale (Threatened Species Scientific Committee, 2015b)
- Conservation advice *Balaenoptera borealis*, Sei Whale (Threatened Species Scientific Committee, 2015c)
- Conservation advice *Balaenoptera physalus*, Fin Whale (Threatened Species Scientific Committee, 2015d).

KEFs

As detailed in Table 6-107, proposed cooling water discharge will not materially increase existing relevant pressures on the conservation values of KEFs.

AMPs

As detailed in Table 6-108, the proposed activities are considered to be not inconsistent with the requirements of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018).

Other protected places

No impacts are expected to occur to the to the values of the Scott Reef and Surrounds or the Mermaid Reef – Rowley Shoals Commonwealth Heritage Places.

Conclusion: Acceptable

6.3.14 Marine Discharges: Hazardous and Non-Hazardous Inorganic Waste

6.3.14.1 Impact and Risk Overview

Table 6-112 presents an overview of the potential impacts and risks from hazardous and non-hazardous inorganic wastes associated with marine discharges from proposed Browse to NWS Project infrastructure and vessels.

Table 6-112 Hazardous and non-hazardous inorganic waste impact and risk overview

Aspect	Marine discharges: hazardous and non-hazardous inorganic waste
Description	Hazardous and non-hazardous inorganic waste will be generated from three main sources: + project vessels + FPSO facilities + MODUs. Hazardous wastes are defined as an object or substance that displays toxic, explosive, poisonous or flammable characteristics, which can no longer fulfil its intended use and requires disposal. Hazardous waste that may be accidentally lost to the marine environment includes: + batteries, aerosol cans, empty paint cans, printer cartridges, fluorescent tubes + hydrocarbon-contaminated materials (e.g. oily rags, oil filters) + contaminated personal protective equipment + hazardous process waste, including chemicals (i.e. amine and TEG). Non-hazardous wastes are those which are not classified as hazardous (as per the characteristics described above) but which, if released into the marine environment, may pose a threat to receptors through smothering, entanglement or ingestion. Non-hazardous waste includes: + paper and cardboard + wooden pallets + scrap steel, metal, aluminium, cans, etc + glass.
Area	Project Area, Browse Development Area, State Proposal Area
Project stage	All - drilling and completions, installation, commissioning, operations and decommissioning
Environmental objectives	The environmental objectives in relation to hazardous and non-hazardous inorganic waste associated with the proposed Browse to NWS Project are Objectives 1, 2, 3, 6, 7, 9, 10, 12, 13, 14, 15, 16, 17, 18, 20 and 21. These objectives are detailed in Table 6-7.

Aspect	Marine discharges: hazardous and non-hazardous inorganic waste
Policy and guidelines	The following policy and guidelines are relevant to the assessment of this aspect. In addition, a number of EPBC Act conservation advices for protected fauna have been considered (Table 6-113). + Commonwealth Protection of the Sea (Prevention of Pollution from Ships) Act 1983. This is the primary federal legislative instrument for Australia's implementation of the International Convention for the Prevention of Pollution from Ships (MARPOL). + Commonwealth Navigation Act 2012 + Threat abatement plan for the impacts of marine debris on vertebrate marine life (DEWHA, 2009) + Marine Order 93 (Marine pollution prevention—noxious liquid substances) + Marine Order 94 (Marine pollution prevention—packaged harmful substances) + Marine Order 95 (Marine pollution prevention – garbage) + WA EPA Environmental Factor Guideline - Marine Environmental Quality (EPA, 2016d) + WA EPA Technical Guidance – Protecting the Quality of Western Australia's Marine Environment (EPA, 2016b). + North-west Marine Parks Network Management Plan (Director of National Parks, 2018) + Threat abatement plan for the impacts of marine debris on vertebrate wildlife of Australia's coasts and oceans (Commonwealth of Australia, 2018) + Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a) + Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) + Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c) + Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012)

Aspect	**Marine discharges: hazardous and non-hazardous inorganic waste**		

Receptors	The following receptors have been identified as potentially being impacted as a result of the proposed Browse to NWS Project (**Table 6-2**). A detailed description of each of these receptors is provided in **Chapter 5**.
	Physical
	+ sediment quality (low value (open waters))
	+ water quality (low value (open waters))
	Ecological
	+ plankton communities (low value (open water))
	+ benthic habitats
	  + shallow water benthic communities and habitats (<75 m depth) (high value habitat)
	  + deepwater communities and habitats (>75 m depth) (medium value habitat
	+ fauna
	  + seabirds and migratory shorebirds (high value species)
	  + fish (high value species)
	  + marine reptiles (high value species)
	  + marine mammals (high value species)
	+ KEFs (high value)
	+ AMPs (high value)
	+ State marine parks and nature reserves (high value)
	+ other protected places
	Socio-economic
	+ State and Commonwealth managed fisheries (high value marine user)
	+ other users
	  + tourism and recreation (high value users)
	  + scientific studies (high value users)		

Potential impacts	As there is no planned discharge of hazardous or non-hazardous inorganic waste, there are no environmental impacts expected relating to this aspect.		
Risks	Unplanned discharge of hazardous or non-hazardous inorganic waste leading to: + change in water quality + change in sediment quality + injury or mortality to fauna + changes to the function, interests or actions of other users		
Summary of governing impact evaluation	***Magnitude***	***Impact significance level***	***Confidence***
	n/a	n/a	n/a
Summary of governing risk evaluation	***Consequence***	***Likelihood***	***Risk rating***
	Slight	Unlikely	Moderate (E2)

6.3.14.2 Source of Aspect

Hazardous and non-hazardous inorganic waste will be generated from three main sources the project vessels, MODUs and FPSO facilities.

Hazardous wastes are defined as an object or substance that displays toxic, explosive, poisonous or flammable characteristics, which can no longer fulfil its intended use and requires disposal. Hazardous waste that may be accidentally lost to the marine environment includes:

- batteries, aerosol cans, empty paint cans, printer cartridges, fluorescent tubes
- hydrocarbon-contaminated materials (e.g. oily rags, oil filters)
- contaminated personal protective equipment
- hazardous process waste, including chemicals (i.e. amine and TEG). PW and MEG may also be treated as hazardous waste for disposal onshore if PW discharge specifications cannot be met – please refer **Section 6.3.12**.

Non-hazardous wastes are those which are not classified as hazardous (as per the characteristics described above) but which, if released into the marine environment, may pose a threat to receptors through smothering, entanglement or ingestion. Non-hazardous waste includes:

- paper and cardboard
- wooden pallets
- scrap steel, metal, aluminium, cans, etc
- glass.

These wastes are handled and stored onboard and are transported to shore to be disposed of at licensed onshore facilities.

Hazardous and non-hazardous inorganic wastes can further be separated into three general classifications: buoyant materials, non-buoyant materials and liquids. While each type of waste is generally inert, they demonstrate differing impact pathways:

- Buoyant materials - Buoyant material such as sacks, wooden pallets, plastic containers or packing/shipping materials are generally inert and non-hazardous. Their release has the potential to directly impact marine fauna due to entanglement, ingestion or smothering, particularly for air breathing marine fauna, which spend a significant amount of time at the surface.
- Solid non-buoyant materials - These materials are likely to be items such as batteries or scrap metal, which if released to the marine environment are likely to sink, physically impacting the seabed and/or benthic habitats.
- Liquids - Hazardous liquids include chemicals, hydrocarbons (e.g. oils and lubricants) and paints, where the receptor sensitivity is in relation to toxicity impacts and a reduction in water quality if discharged to the receiving environment.

It is likely that larger volumes of wastes will be generated during drilling, installation, commissioning and decommissioning phases, compared to during operations, where smaller quantities will be generated from routine operational activities such as maintenance facilities). Waste material may be lost to the marine environment because of:

- human error
- incorrect or inappropriate waste storage
- mechanical failure or breakdown of equipment used to store wastes
- inadequate hazardous waste management.

6.3.14.3 Environmental Impact

In accordance with MARPOL 73/78 and Protection of the Sea (*Prevention of Pollution from Ships) Act 1983*, such waste will not be discharged overboard and will be transferred onshore for recycling or disposal at a licenced waste disposal facility. Therefore, no impacts within the marine environment or Project Area are expected from the generation of general hazardous and non-hazardous inorganic waste during all phases of the proposed Browse to NWS Project.

6.3.14.4 Environmental Risk

Risk event: Unplanned release of hazardous or non-hazardous inorganic waste

An unplanned release of hazardous or non-hazardous inorganic waste during transfer, handling and storage may be caused by human error, equipment or poor weather conditions. An accidental discharge or release of hazardous waste to the marine environment in particular may adversely affect water quality and result in toxicity effects to marine flora or fauna, depending on the nature, volume spilled and location (relative to sensitive receptors) of the accidental discharge, as well as its behaviour in the marine environment (e.g. settlement to seabed, rapid dispersion).

Accidentally released waste has the potential to impact the marine environment in a number of ways depending on the nature of the waste. For non-buoyant waste, the materials would be expected to sink to the seabed, resulting in direct localised impacts to benthic habitats and epibenthic fauna or localised physical impacts on the seabed. The discharge of buoyant materials has the potential to impact marine fauna due to ingestion or smothering, particularly for air breathing marine fauna, which need to come to the sea surface to breathe.

Marine Sediments

Change in sediment quality

The accidental discharge of hazardous waste (in liquid or sludge form) to the marine environment, may potentially result in a localised change in sediment quality. However, even in the unlikely event of such a discharge, it would likely be dispersed and diluted by prevailing currents in the open oceanic waters in the Project Area. Given the location of the activities (minimum depth approximately 125 m near the NRC tie-in point) and the expected rapid dispersion of the discharged waste, the likelihood of a change in sediment quality occurring is considered remote with the subsequent risk assessed to be low.

Water quality

Change in water quality

The accidental discharge of waste (in liquid or sludge form) to the marine environment may potentially result in a localised change in water quality. However, even in the unlikely event of such a discharge it would be subject to rapid dispersion and dilution by prevailing currents, due to the open oceanic waters of the Project Area. Given the typical small volumes and temporary duration of accidental discharge events, these would result in a temporary and highly localised change in water quality. The likelihood of an accidental discharge of waste occurring and resulting in change in water quality is considered unlikely with the subsequent risk assessed to be moderate.

Plankton

Injury or mortality to fauna

Plankton populations may be affected by the accidental release of hazardous waste (in liquid or sludge form). Given the localised nature of any changes to water quality, impacts to plankton would be highly localised (limited the immediate area of the release). Given the fast population turnover of open water plankton populations (ITOPF, 2011), the potential impacts are expected to be localised and temporary. The likelihood of an accidental discharge of waste resulting in impacts to plankton is considered unlikely with the subsequent risk assessed to be low.

Benthic habitats

Injury or mortality to fauna – epifauna and infauna

Accidentally discharged non-buoyant waste has the potential to sink to the seabed and impact epifauna. Given the minimum water depth at potential discharge locations (i.e. 125 m at the NRC tie-in), impacts would be limited to the deepwater habitats of the Project Area. Given the likely small size of any accidentally discharged waste, the subsequent impact to these deepwater habitats is expected to be negligible. The likelihood of an accidental discharge of waste resulting in impacts to deepwater habitats is considered highly unlikely, with the subsequent risk assessed to be low.

Change in water quality – shallow water benthic habitats

Accidentally discharged waste can behave in a number of ways depending on the types of waste e.g. buoyant waste would float and eventually degrade (e.g. cardboard) or persist (e.g. plastic), or liquid waste would dissolve and disperse in the water leading to localised and temporary decline in water quality. It should be noted that under normal operating conditions, drilling and vessel activity will be limited to the deep waters in proximity to the location of the proposed development wells and subsea infrastructure or the BTL (> 2 km from Rowley Shoals).

Further, given the small volume of waste that could be accidentally released, it is not considered that even if the accidentally discharged waste reached these sensitive receptors that this would result in lasting impacts to these receptors. The likelihood of an accidental discharge of waste resulting in impacts to shallow water habitats associated with Scott Reef or Rowley Shoals, is considered highly unlikely with the subsequent risk assessed to be low.

Marine fauna

Injury or mortality to fauna

Seabirds

Sandy Islet is used for roosting by seabirds and supports minor seabird breeding colonies including for the little tern. Scott Reef is recognised as a resting BIA for the little tern. The islands of the Rowley Shoals are known to support a wide range of seabird species, including WA's second largest breeding colony of red-railed tropicbird. The Rowley Shoals have also been identified as BIAs for white-tailed tropicbirds and little terns.

Seabirds and migratory shorebirds have the potential to be impacted by hazardous and non-hazardous inorganic waste associated with the proposed Browse to NWS Project. Anthropogenic disturbance is identified in the Wildlife Conservation Plan for Migratory Shorebirds as a moderate threat to the conservation of migratory shorebirds (Commonwealth of Australia, 2015a). The threat abatement plan for the impacts of marine debris on vertebrate wildlife of Australia's coasts and oceans (Commonwealth of Australia, 2018) identifies birds as being adversely impacted by marine debris.

Entanglement of seabirds and shorebirds in marine debris can lead to restricted mobility, drowning, starvation and smothering. Ingestion of debris can occur with seabirds and shorebirds confuse the debris with prey species and some species can feed non-selectively and may consume marine debris, particularly ones accumulated in the vicinity of food items leading to physical blockage of the digestive system, leading to internal injuries and pain.

Accidentally discharged buoyant waste has the potential to be carried by currents and reach Scott Reef where seabirds and migratory shorebirds may be present.

Given the controls in place and the distance of the proposed activities from the main aggregation areas, it is considered highly unlikely that an unplanned discharge leading to impacts on seabirds and migratory shorebirds would occur. In the event, this did occur, impacts would be limited to injury or mortality to a small number of individuals. As such this risk has been assessed to be low.

Fish

Injury or mortality to pelagic fish may result from the unplanned discharge of waste, either via toxicity effects or through entanglement with debris. As detailed above, any change in water quality will be highly localised and subject to rapid dispersion and dilution by prevailing currents, due to the open oceanic waters of the Project Area. As such, it is not predicted that fish would be exposed to discharge at concentration or durations enough to elicit a toxic response. The entanglement of fish could potentially occur in the event certain solids wastes (such as nets) were accidentally discharged. Given the controls in place and the types of material used on the vessels, MODU and the FPSO facilities, it is considered highly unlikely that injury or mortality to fish will occur as a result of the unplanned discharge of waste. In the event that it did occur, impacts would be limited to a small number of individuals.

Marine mammals

There are BIAs for migration and breeding and calving for the humpback whale along the WA coast and within the NWMR, but there are no known BIAs within the Project Area. A migratory BIA exists for the pygmy blue whale which extends for most of the length of the NWMR within offshore waters and encompasses Scott Reef. It also documents a possible foraging area at Scott Reef which encompasses the majority of Scott Reef. The threat abatement plan for the impacts of marine debris on vertebrate wildlife of Australia's coasts and oceans (Commonwealth of Australia, 2018) identifies whales as being adversely impacted by marine debris.

Entanglement in marine debris has been identified as a threat for the recovery of the Humpback whale in the Conservation advice for this species (Threatened Species Scientific Committee, 2015e), in addition, marine debris is listed as presenting a possible threat with minor consequences to pygmy blue whales in the conservation management plan for the Blue whale (Commonwealth of Australia, 2015c). Humpback whales and pygmy blue whales could potentially become entangled in marine debris causing restricted mobility and starvation. Given the controls in place, the types of material used on the vessels and the FPSO facilities, and the low numbers of whales likely to occur in proximity to the proposed activities, it is considered the likelihood that injury or mortality to whales occurring as a result of the unplanned discharge of waste is remote.

Marine turtles

Sandy Islet and the surrounding waters have been identified as habitat critical to the survival of green turtles in the DoEE's Recovery Plan for Marine Turtles 2017-2027 (Commonwealth of Australia, 2017a) (**Figure 5-27**). In addition, a BIA exists for internesting green and hawksbill turtles around Sandy Islet with internesting occurring just offshore in waters 4-15 m deep (Commonwealth of Australia, 2017a). Marine debris (entanglement and/or ingestion) is highlighted within the Recovery Plan for Marine Turtles in Australia as a moderate threat to green turtles within the Scott Reef and Browse Island area (Commonwealth of Australia, 2017a). The Threat Abatement Plan for the impacts of marine debris on vertebrate wildlife of Australia's coasts and oceans (Commonwealth of Australia, 2018) identifies marine turtles as being adversely impacted by marine debris.

Marine turtles frequently ingest plastic bags, confusing them with jelly fish which is common prey for all turtles. Their flippers can also become entangled in waste which may lead to restricted mobility, drowning and amputation of limbs.

Given the controls in place and the distance of the proposed activities from Sandy Islet (where marine turtles nest), it is considered highly unlikely that an unplanned discharge leading to impacts on marine turtles would occur. In the event, this did occur, impacts would be limited to injury or mortality to a small number of individuals. As such this risk has been assessed to be low.

Assessment against EPBC conservation plans and advices

Table 6-113 provides an assessment of the risk related to hazardous and non-hazardous inorganic waste in relation to objectives and actions of the relevant EPBC Act recovery and conservation plans and advices.

Table 6-113 Alignment with EPBC Act recovery and conservation plans and advices for protected fauna – hazardous and non-hazardous inorganic waste

Fauna	Relevant plan(s)/ conservation advice	Plan/advice objectives and actions	Assessment
Vertebrate wildlife	The threat abatement plan for the impacts of marine debris on vertebrate wildlife of Australia's coasts and oceans (Commonwealth of Australia, 2018)	Contribute to long-term prevention of the incidence of marine debris. No explicit management actions for non-related industries.	Controls will be in place to prevent the discharge of solid waste and resultant marine debris. Therefore, it is considered that the proposed activities are not inconsistent with the Threat Abatement Plan.
Migratory shorebirds	Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a)	Anthropogenic threats to migratory shorebirds in Australia are minimised or, where possible, eliminated.	It is considered the risk of impacts to migratory shorebirds as a result of unplanned discharge of hazardous and non-hazardous inorganic waste is low. Therefore, it is considered that the proposed activities are not inconsistent with the Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a) .
Whale shark	Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a)	Assess the impacts of offshore installations and associated environmental changes (light spill, chronic noise, changed water temperature, localised nutrient levels) on whale sharks and mitigation options for these impacts.	Given the low number and infrequent nature of whale shark presence in the Project Area, it is considered the risk of impacts to whale sharks as a result of unplanned discharge of hazardous and non-hazardous inorganic waste is low. Therefore, it is considered that the activities are not inconsistent with the conservation advice.
Green turtle	The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a)	Support the implementation of the EPBC Act Threat Abatement Plan for the impacts of marine debris on vertebrate marine life. In relation to the Scott Reef – Browse Island green turtle genetic stock, the priority action is to manage anthropogenic activities to ensure marine turtle are not displaced from identified habitat critical to their survival is predicted to be met	Controls will be in place to prevent the discharge of solid waste and resultant marine debris. Therefore, it is considered that the proposed activities are not inconsistent with threat abatement plan. In relation to the Scott Reef – Browse Island green turtle genetic stock, as the risk posed to marine turtles from the unplanned discharge of hazardous and non-hazardous inorganic waste has been assess as low, the priority action to manage anthropogenic activities to ensure marine turtle are not displaced from identified habitat critical to their survival is predicted to be met. Therefore, it is considered that the proposed activities are not inconsistent with the objectives of the Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a).
Hawksbill turtle			
Pygmy blue whale	Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c)	Marine debris is identified as a potential threat with minor consequences in the plan, however no specific management actions identified.	Controls will be in place to prevent the discharge of solid waste and resultant marine debris. Therefore, it is considered that the proposed activities are not inconsistent with the Conservation Management Plan for the Blue Whale or the conservation advices listed.
Humpback whale	Conservation Advice for *Megaptera novaeangliae* (humpback whale) (Threatened Species Scientific Committee, 2015e)	Entanglement in marine debris is identified as a threat to humpback whale in the advice, however no specific management actions identified.	

Key Ecological Features

The Continental slope demersal fish communities KEF and Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEFs overlap with the Browse Development Area. The BTL traverses the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF (depending on the final BTL route) and the Ancient coastline at 125 m depth contour KEF. The conservation values of these KEFs are described in **Section 5.3.3.1**. Unplanned discharge of hazardous and non-hazardous inorganic waste could potentially occur from project vessels, MODU or FPSO facilities within these KEFs. The relevant pressure related to hazardous and non-hazardous inorganic waste discharge is not identified as a concern for this KEF within the Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).

Change in sediment quality

As discussed above, the risk presented by the unplanned discharge of hazardous or non-hazardous inorganic wastes to sediment quality in the deep waters of the Project Area has been assessed as low. As such no impacts to the conservation values of these KEFs is predicted.

Change in water quality

As discussed above, the risk presented by the unplanned discharge of hazardous or non-hazardous inorganic wastes to water quality has been assessed as low. As such no impacts to the conservation values of these KEFs is predicted.

Injury or mortality to fauna

As discussed above, the risk presented by the unplanned discharge of hazardous or non-hazardous inorganic wastes to plankton and other marine fauna such as seabirds and migratory shorebirds, fish, marine mammals and marine reptiles has been assessed as low. As such no impacts to the conservation values of these KEFs is predicted.

Summary

Table 6-114 provides an assessment of the risk associated with unplanned hazardous and non-hazardous waste discharge in relation to the pressures on KEFs identified in the Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).

Table 6-114 Alignment with protection of conservation values of KEFs – hazardous and non-hazardous inorganic waste

Key Ecological Feature	Relevant plan(s)	Relevant pressures	Assessment
Continental slope demersal fish communities	Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).	Chemical pollution/ contaminants Marine debris Oil pollution	It is considered the risk of adverse impacts to water quality and marine fauna as a result of unplanned discharge of hazardous and non-hazardous inorganic waste is low. Therefore, there is a high level of confidence that there will not be an adverse impact to marine ecosystem function or integrity with in the KEFs; or any reduction to the conservation values of the KEFs will occur.
Seringapatam Reef and Commonwealth waters in the Scott Reef Complex			
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals			
Ancient coastline at 125 m depth contour			

Australian marine parks

Vessels associated with the installation of the BTL and transiting project vessels will discharge sewage and sullage within the Multiple Use Zones (IV) of the Argo-Rowley Terrace and Kimberley AMPs. Unplanned discharge of hazardous and non-hazardous inorganic waste could potentially occur from project vessels facilities within these AMPs during installation of the BTL and intermittent IMR activities. It should be noted that the risk of accidental discharge of hazard and non-hazardous inorganic waste in the AMPs is low given proposed activities within the AMPs will only occur for a short duration of time.

Change in sediment quality

As discussed above, the risk presented by the unplanned discharge of hazardous or non-hazardous inorganic wastes to sediment quality in the deep waters of the Project Area has been assessed as low. As such no impacts to the conservation values of these AMPs is predicted.

Change in water quality

As discussed above, the risk presented by the unplanned discharge of hazardous or non-hazardous inorganic wastes to water quality has been assessed as low. As such no impacts to the conservation values of these AMPs is predicted.

Injury or mortality to fauna

As discussed above, the risk presented by the unplanned discharge of hazardous or non-hazardous inorganic wastes to plankton and other marine fauna such as seabirds and migratory shorebirds, fish, marine mammals and marine reptiles has been assessed as low. As such no impacts to the conservation values of these AMPs is predicted.

Summary

Table 6-115 provides an assessment of the risk associated with hazardous and non-hazardous inorganic waste in consideration of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018).

Table 6-115 Alignment with the North-west Marine Parks Network Management Plan – hazardous and non-hazardous inorganic waste

Australian Marine Park	Relevant plan(s)	AMP Objectives	Assessment
Argo-Rowley Terrace Marine Park Multi Use Zone (VI) Kimberley Marine Park Multi Use Zone (VI)	North-west Marine Parks Network Management Plan (Director of National Parks, 2018)	The objective of the Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species.	It is considered the risk of adverse impacts to water quality and marine fauna as a result of unplanned discharge of hazardous and non-hazardous waste inorganic is low. Therefore, there is a high level of confidence that unplanned discharge of hazardous and non-hazardous inorganic wastes will not result in an adverse impact to marine ecosystems, habitats or native species such that the conservation values of the AMPs would be reduced. As such, it is considered that the proposed activities are not inconsistent with the requirements of the North-west Marine Parks Network Management (Director of National Parks, 2018).
Mermaid Reef Marine Park National Park Zone (II)		The objective of the National Park Zone (II) is to provide for the protection and conservation of ecosystems, habitats and native species in as natural a state as possible.	

State marine parks and nature reserves

Injury or mortality to fauna

Accidentally discharged buoyant waste has the potential to be carried by currents and reach State marine parks and nature reserves such as the Rowley Shoals Marine Park and the Scott Reef Nature Reserve. There is potential that the fauna species utilising these areas are impacted by debris reaching the area. As discussed above, the risk presented by the unplanned discharge of hazardous or non-hazardous inorganic wastes to marine fauna such as seabirds and migratory shorebirds, fish, marine mammals and marine reptiles has been assessed as low. As such no impacts to the conservation values of these State marine parks and nature reserves are predicted.

Other protected places

Change in water quality

The Scott Reef and Surrounds - Commonwealth Area Commonwealth Heritage Place comprises the Commonwealth Marine Area wholly within the WA coastal waters surrounding North and South Scott Reef. The Commonwealth Heritage Place is utilised by seabirds, marine mammals and marine turtles; and supports diverse fish and coral communities. Project vessels will not operate within this area under normal operations. Given the above assessment of potential changes to sediment quality and water quality; and the potential impacts to marine fauna, the risk posed by the accidental discharge of hazardous or non-hazardous inorganic waste to the conservation values of the Scott Reef and Surrounds, Commonwealth Area and Mermaid Reef, Rowley Shoals Commonwealth Heritage Places is considered low.

Other users

Changes to the functions, interests or activities of other users – State and Commonwealth managed fisheries

Where the functions, interests or activities of other users involve marine fauna (e.g. fisheries), any effect to fauna presence or abundance will indirectly impact on the functions, interests or activities of other users. Given that the risk to marine fauna including fish has been assessed as low no subsequent impact to fisheries is expected.

Changes to the functions, interests or activities of other users – tourism and recreation, scientific studies

As described above, the risk posed by unplanned discharge of hazardous and non-hazardous organic waste on water quality, Scott Reef shallow water benthic habitat (<75 m bathymetry) and marine fauna has been assessed as low. As such activities such as tourism and recreation and scientific studies at Scott Reef are highly unlikely to be impacted.

6.3.14.5 Cumulative Impacts

No hazardous or non-hazardous inorganic waste discharge to the environment is proposed during any phase of the proposed Browse to NWS Project and as such no cumulative impacts are predicted.

6.3.14.6 Impact and Risk Assessment Summary and Acceptability Assessment

A summary of the risk assessments, and the adopted controls for marine discharges: hazardous and non-hazardous inorganic waste is provided in **Table 6-116**. The acceptability assessment is provided in **Table 6-117**.

Table 6-116 Risk assessment summary and adopted controls – marine discharges: hazardous and non-hazardous inorganic waste

Receptor	Risk Event	Environmental objective	Adopted controls	Consequence	Likelihood	Risk Rating
Sediment quality (medium value (open waters))	Unplanned discharge of hazardous and non-hazardous organic waste	**Objective 1:** To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **Objective 2:** To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.	*MODU and project vessel operations* + Waste storage areas will allow segregation into recyclable and non-recyclable wastes. + Segregated waste will be securely stored through the provision of appropriate waste receptacles and suitable containment measures such as lids and netting to prevent any loss of wastes to the marine environment. + Non-hazardous solid waste will not be discharged into the marine environment and will be transported onshore to a recycling contractor or appropriate waste disposal site in accordance with MARPOL 73/78 Annex V: Garbage (as implemented in Commonwealth waters by the Protection of the Sea (Prevention of Pollution from Ships) Act 1983) and Marine Order 95 (Marine Pollution Prevention – Garbage). + Hazardous waste will not be discharged to the marine environment and will be transported to shore for disposal in accordance with MARPOL 73/78 Annex III: Packaged Harmful Substances (as implemented in Commonwealth waters by the Protection of the Sea (Prevention of Pollution from Ships) Act 1983) and Marine Orders 93 (Marine Pollution Prevention – noxious liquids), 94 (Marine Pollution Prevention – packaged harmful substances) and 95 (Marine Pollution Prevention – Garbage). + In the event that hazardous or non-hazardous inorganic waste is released to the marine environment, any surface residue will be recovered where safe to do so. + Hazardous waste will be handled and stored in accordance with the relevant SDS and tracked from source to its final destination, where applicable. + Waste management measures will be included in the relevant Environment Plans and will specify the appropriate disposal method for hazardous waste, including NORM and mercury-contaminated solids (if encountered).	Negligible	Remote	Low (F1)
Water quality (medium value (open waters))		**Objective 3**: To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		Slight	Unlikely	Moderate (E2)
Plankton (medium value (open water)		**Objective 7:** To not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution.		Negligible	Unlikely	Low (F2)
Shallow water benthic communities and habitats (<75 m depth) (high value habitat)		**Objective 9:** To avoid direct (i.e. physical footprint) disturbance to Scott Reef shallow water benthic habitat (<75 m bathymetry). **Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry).		Slight	Highly unlikely	Low (E1)
Deepwater benthic communities and habitats (>75 m depth) – (medium value)		**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.		Slight	Highly unlikely	Low (E1)

Receptor	Risk Event	Environmental objective	Adopted controls	Consequence	Likelihood	Risk Rating
Seabirds and migratory shorebirds (high value species)		**Objective 11:** To not have a substantial adverse effect on a population of seabirds or migratory shorebirds, or the spatial distribution of the population. **Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **Objective 15:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.		Slight	Highly unlikely	Low (E1)
Fish (high value species)				Slight	Highly unlikely	Low (E1)
Marine turtles (high value species)				Slight	Highly unlikely	Low (E1)
Marine mammals (high value species)				Slight	Highly unlikely	Low (E1)
KEFs (medium value)		**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.		Slight	Highly unlikely	Low (E1)
AMPs (medium value)		**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		Slight	Highly unlikely	Low (E1)
State marine parks and nature reserves (high value)		**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		Slight	Highly unlikely	Low (E1)
Other protected places (high value)		**Objective 18:** TWo not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		Slight	Highly unlikely	Low (E1)
Managed fisheries (high value user)		**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		Slight	Highly unlikely	Low (E1)
Other users (scientific studies, tourism and recreation) (high value users)		**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		Slight	Highly unlikely	Low (E1)

Table 6-117 Acceptability assessment – hazardous and non-hazardous inorganic waste

Acceptability Assessment
Confidence in assessment Woodside have a high level of certainty with respect to the assessment of the potential impacts and risks associated with hazardous and non-hazardous inorganic waste as: + Controls, including the implementation of Navigation Act 2012, MARPOL and the various Marine Orders (as appropriate to vessel class) will be implemented to mitigate potential impacts. + There is a good understanding of the hydrodynamic regime in the Project Area and it is expected that if there was an accidental discharge of liquid waste there would be rapid dispersion and dilution by prevailing currents, due to the open oceanic waters of the Project Area so that any changes in water quality would be temporary and localised.
Principles of ESD There are no planned discharges of hazardous or non-hazardous inorganic waste. With the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such it is considered that the principles of ESD will be met. **Conclusion: Acceptable**
Significant Impacts as defined by the MNES Significant Impact Guidelines *Listed threatened species and ecological communities / listed migratory species* There are no planned discharges of hazardous or non-hazardous inorganic waste. As such, no impact to listed threatened species or migratory species is predicted to occur. As described in **Table 6-116**, potential risk events associated with the unplanned discharge of hazardous and non-hazardous waste are predicted to present a Low risk to marine fauna species such as seabirds and migratory shorebirds, fish, marine mammals and marine turtles. Given this, with the application of the proposed controls it is predicted that the nominated environmental objectives for each of these fauna species will be achieved. As such, no significant impacts to the listed threatened or migratory species (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted *Commonwealth Marine Environment* There are no planned discharges of hazardous or non-hazardous inorganic waste. As such, no impact to the Commonwealth marine environment is predicted to occur. As described in **Table 6-116**, potential risk events associated with the unplanned discharge of hazardous and non-hazardous waste are predicted to present a Low risk to sediment quality, water quality, plankton, deepwater benthic communities and habitats (>75 m depth), shallow water benthic communities and habitats (<75 m depth), marine fauna, KEFs, AMPs and other protected places. As such, with the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such no significant impacts to the Commonwealth marine environmental (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted **Conclusion: Acceptable**

Acceptability Assessment

WA EPA Environmental Objectives

An assessment of the risks associated with unplanned hazardous and non-hazardous inorganic waste discharge against the WA EPA Objective is presented in the State Proposal ERD (**Chapter 10, Appendix B**).

Marine environmental quality

There are no planned discharges of hazardous or non-hazardous inorganic waste. As such, no impact to marine environmental quality within the State Proposal Area is predicted to occur.

As described in **Table 6-116**, potential risk events associated with the unplanned discharge of hazardous and non-hazardous waste are predicted to present a moderate risk to water quality and a low risk to sediment quality and plankton, deepwater benthic communities and habitats (>75 m depth), shallow water benthic communities and habitats (<75 m depth) and marine fauna.

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*to maintain the quality of water, sediment and biota so that environmental values are protected*" will be achieved.

Marine Fauna

There are no planned discharges of hazardous or non-hazardous inorganic waste. As such, no impact to marine fauna within the State Proposal Area is predicted to occur.

As described in **Table 6-116**, potential risk events associated with the unplanned discharge of hazardous and non-hazardous waste are predicted to present a Low risk to marine fauna species such as seabirds and migratory shorebirds, fish, marine mammals and marine turtles.

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*To protect marine fauna so that biological diversity and ecological integrity are maintained.*" will be achieved.

Benthic communities and habitats

There are no planned discharges of hazardous or non-hazardous inorganic waste. As such, no impact to benthic habitats and communities within the State Proposal Area is predicted to occur.

As described in **Table 6-116**, potential risk events associated with the unplanned discharge of hazardous and non-hazardous waste are predicted to present a Low risk to deepwater benthic communities and habitats (>75 m depth) and shallow water benthic communities and habitats (<75 m depth).

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*to protect benthic communities and habitats so that biological diversity and ecological integrity are maintained*" will be achieved.

Conclusion: Acceptable

External context

To date there have been no specific matters raised by stakeholders regarding general waste in relation to the proposed Browse to NWS Project.

Conclusion: Acceptable

Internal context

This impact and risk assessment has been undertaken in accordance with Woodside's Risk Assessment Procedure and Environment Impact Assessment Guideline (**Section 6.2**) The proposed Browse to NWS Project will be executed in accordance with Woodside's Health, Safety and Environmental Management System.

Conclusion: Acceptable

Acceptability Assessment

Other requirements

EPBC Act recovery and conservation plans and advices

As detailed in Table 6-113, the proposed activities are considered to be not inconsistent with the actions and objectives of:

- The threat abatement plan for the impacts of marine debris on vertebrate wildlife of Australia's coasts and oceans (Commonwealth of Australia, 2018)
- Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a)
- Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a)
- The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a)
- Conservation management plan for the Blue Whale (Commonwealth of Australia, 2015c)
- Conservation advice *Megaptera novaeangliae*, Humpback Whale (Threatened Species Scientific Committee, 2015b).

Key Ecological Features

As detailed in Table 6-114, unplanned discharge of hazardous and non-hazardous inorganic waste will not materially increase existing relevant pressures on the conservation values of the KEFs.

AMPs

As detailed in Table 6-115, the proposed activities are considered to be not inconsistent with the requirements of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018).

Other Protected Places

No impacts are expected to occur to the to the values of the Scott Reef and Surrounds or the Mermaid Reef – Rowley Shoals Commonwealth Heritage Places.

Conclusion: Acceptable

6.3.15 Marine Discharges: Drilling or Completions Discharges

6.3.15.1 Impact and Risk Overview

Table 6-118 presents an overview of the potential impacts and risks from the discharge of drilling or completions discharges associated with drilling activities for proposed Browse to NWS Project.

Table 6-118 Marine discharges: drilling or completions discharges impact and risk overview

Aspect	Marine discharges: drilling or completions discharges
Description	During development drilling for the proposed Browse to NWS Project, up to 54 production wells will be drilled and completed, 24 of which will be in the State Proposal Area, with the remaining 30 located Commonwealth waters. Drilling of production wells will generate drill cuttings, require cementing of the casing, and require the use of a range of fluids, that may be discharged to the marine environment, typically at the seabed and at or near the sea surface depending on the hole section.
Area	Project Area, Browse Development Area, State Proposal Area
Project stage	Drilling and Completions
Environmental objectives	The environmental objectives in relation to drilling or completions discharges (drill cuttings and drilling or completion fluids) associated with the proposed Browse to NWS Project are: Objectives 1, 2, 3, 6, 7, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20 and 21. These objectives are detailed in Table 6-7.

Aspect	Marine discharges: drilling or completions discharges
Policy and guidelines	The following policy and guidelines are relevant to the assessment of this aspect. In addition, a number of EPBC Act conservation advices for protected fauna have been considered (**Table 6-120**). + Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018) + WA EPA Environmental Factor Guideline - Benthic Communities and Habitats (EPA, 2016c) + WA EPA Technical Guidance - Protection of Benthic Communities and Habitats (EPA, 2016d) + WA EPA Environmental Factor Guideline - Marine Environmental Quality (EPA, 2016) + Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) + Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c) + Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).

Receptors	The following receptors have been identified as potentially being impacted as a result of the proposed Browse to NWS Project (**Table 6-2**). A detailed description of each of these receptors is provided in **Chapter 5**.
	Physical
	+ sediment quality (low value (open waters))
	+ water quality (low value (open waters))
	Ecological
	+ plankton (low value (open water))
	+ benthic habitats
	  + shallow water benthic communities and habitats (<75 m depth) (high value habitat)
	  + deepwater communities and habitats (>75 m depth) (medium value habitat
	+ fauna
	  + fish (high value species)
	  + marine reptiles (high value species)
	  + marine mammals (high value species)
	+ KEFs (high value)
	+ Other protected places (high value)
	Socio-economic
	+ State and Commonwealth managed fisheries (high value marine users)
	+ other users
	  + tourism and recreation (high value user)
	  + scientific studies (high value user)
	+ aboriginal or indigenous heritage (high value users)

Potential impacts	+ change in water quality + change in sediment quality + injury or mortality to fauna + change in habitat + changes to the functions, interests or activities of other users

Aspect	Marine discharges: drilling or completions discharges		
Risk	Distribution of drilling or completions discharges significantly greater than expected leading to increased spatial extent of: + change in water quality + change in sediment quality + injury or mortality to fauna + change in habitat		
Summary of governing impact evaluation	***Magnitude***	***Impact significance level***	***Confidence***
	Minor	Minor (D)	High
Summary of governing risk evaluation	***Consequence***	***Likelihood***	***Risk rating***
	Moderate	Remote	Low (D0)

6.3.15.2 Source of Aspect

Development well construction activities associated with the proposed Browse to NWS Project involve the drilling and completion of up to 54 production wells, with 24 wells in the State Proposal Area and the remaining 30 in Commonwealth waters. Drilling and completion of production wells will generate drill cuttings, require cementing of the casing, and require the use of a range of fluids, that may be discharged to the marine environment, typically at the seabed and at or near the sea surface depending on the hole section.

During the life of the proposed Browse to NWS Project, well components will require maintenance, repair or replacement. This will require well intervention and/or well workovers. Relevant discharge types generated from these activities may include subsea control fluid (control of subsea tree) (refer to **Section 6.3.16** and completions fluids).

In addition, well abandonment activities can result in discharges to the marine environment including but not limited to installation and pressure testing of the blow out preventer (BOP), cutting/perforation of casing or production tubing; and installation of permanent reservoir and surface barrier (cementing). Relevant discharge types generated from these activities may include subsea control fluids (refer to **Section 6.3.16**), well completion fluids and cement.

Drilling and completion activities required for the proposed Browse to NWS Project are expected to be broadly similar to that of the previous development concepts (**Section 2.7.1**).

Drill cuttings

Drilling generates drill cuttings due to the breakup of solid material from within the borehole. The resultant drill cuttings are basically rock particles of various shapes, with sizes typically ranging from very fine to very coarse. Cuttings generated during drilling of the top-hole sections are typically discharged to the seabed at the well site.

Once the top-hole sections are complete, installation of the riser and BOP provides a conduit back to the MODU, forming a closed circulating system. The bottom hole sections will be drilled with a marine riser in place that enables cuttings and drilling fluids to be circulated back to the MODU, where the cuttings are separated from the drilling fluids by the solids control equipment (SCE). The SCE comprises equipment such as shale shakers, cuttings dryer(s) and centrifuges. The SCE uses shale shakers to remove coarse cuttings from the drilling fluid. The recovered fluids from the cuttings may then be directed to centrifuges, which are used to remove fine solids (4.5 to 6 μm). The cuttings are usually discharged below the water line and the fluid is recirculated into the fluid system.

The drilling fluid retained on cuttings is determined by the SCE and typically, treated water based fluid (WBF) cuttings may retain 5 to 25% of the drilling fluid after passage through SCE (Neff, 2005) and treated cuttings when drilling with non water based fluid (NWBF) may retain 5 to 15% of the drilling fluid (Neff et al., 2000). The cuttings with retained NWBF also pass through a cutting's dryer and associated SCE, to reduce the average oil on cuttings to 6.9% wt/wt or less on wet cuttings, prior to discharge.

The fate and dispersion of the cuttings once discharged into the marine environment is determined by particle size and the density of the unrecoverable fluids. The larger cuttings particles will drop out of suspension and deposit in close proximity to the well site (tens of metres) with potential for localised spreading downstream. In contrast, the finer particles will remain in suspension and be transported away from the well site, rapidly diluting and eventually depositing over a widespread area (hundreds of metres) downstream of the well site.

Drill cuttings and unrecoverable fluids are discharged at the seabed at each well site for the top-hole sections drilled riser-less (no closed loop with the MODU). This results in a localised area of sediment deposition (known as a cuttings pile) in close proximity to the well site. The spread of cuttings and associated water based fluids is expected to be up to 50-200 m downstream from the discharge location based on a review of seven studies summarised by International Association of Oil and Gas Producers (IOGP, 2016). Drill cuttings and retained NWBF (<6.9% OOC) released at or below the surface after treatment on the MODU for the bottom-hole well sections are generally dispersed and settle within a seabed area confined to a maximum of 500 m distance of the discharge point (IOGP, 2016).

Drilling fluids

Drilling fluids (also termed drilling muds) serve many purposes including maintaining borehole stability and hydrostatic pressure, reducing friction and cleaning/cooling of the drill bit, in addition to acting as a medium to carry cuttings from the well bore and return them to the surface at seabed or on the MODU. Drilling fluids are either mixed on the MODU or received pre-mixed, then stored and maintained in a series of mud pits aboard the MODU or a suitable vessel. There are two main types of drilling fluids, including water based fluids (WBF) and non-water based fluids (NWBF).

Water based drilling fluids

The proposed Browse to NWS Project will use WBF as the preferred option. WBF consists mainly of seawater with the addition of chemical and mineral additives to aid in its function. Drilling additives typically used may include chlorides (e.g. sodium, potassium), bentonite (clay), cellulose polymers, guar gum, barite or calcium carbonate. These additives are either completely inert in the marine environment, naturally occurring benign materials, or readily biodegradable organic polymers with a very fast rate of biodegradation in the marine environment.

WBF will be discharged to the marine environment at the location of the well being drilled under the following scenarios:

- at the seabed when drilling the top-hole (riser less) sections
- below sea surface as fluid remaining on drill cuttings, after passing through SCE (bottom-hole sections, drilled with riser in place)
- from the mud pits via a discharge pipe below the sea surface, If WBF cannot be re-used due to bacterial deterioration or does not meet required drilling fluid properties, it may be discharged to the marine environment using seawater flushing. WBF may not be able to be reused between drilling sections due to the drilling sequence, technical requirements of the fluid (i.e. no tolerance for deterioration of fluid during storage) and maintenance of productivity/injectivity. Unused or spent WBFs may be disposed from the MODU as a bulk discharge (defined as a discrete discharge of large quantities) at the end of each well section.

Additional products such as barite and bentonite may be discharged in bulk/single discharge at the end of the activity if they cannot be reused or taken back to shore. Use and discharge of all chemicals will be performed in line with Woodside's chemical selection and assessment process and approved prior to use. Discharge may be in the form of dry bulk or as a slurry; however, discharges will not be contaminated with hydrocarbons. Planned bulk discharges at wells within the State Proposal Area will be managed in accordance with the **Management Approach for Torosa wells in State Proposal Area** (refer to later sub-section).

Non water based drilling fluids

Non-water-based fluids (NWBF) refers to drill fluids that are hydrocarbon rather than water based fluid. NWBF may be used to manage well stability to safe levels based on the offset history, geohazards assessment and borehole stability studies. Like a WBF system, a range of standard solid and liquid additives may be added to alter specific fluid properties for each section of the well, dependent on the conditions encountered while drilling. NWBFs will be selected in accordance with Woodside's chemical selection and assessment process on the basis of lowest health, safety and environmental risks while meeting operational requirements.

During drilling operations, the NWBF (like WBF) are pumped by high pressure pumps down the drill string and out through the drill bit, returning via the annulus between the drill string and the casing of the well bore, and back to the MODU via the riser. Discharge scenarios are much the same as that described for WBF, however NWBF will not be used for top-hole section drilling (riserless); therefore, no direct seabed discharge of NWBF will occur.

The NWBF that cannot be re-used (i.e. do not meet required drilling fluid properties or are mixed in excess of required volumes) are recovered from the mud pits and returned to the shore base for onshore processing for recycling and/or disposal. The mud pits and associated equipment/ infrastructure are cleaned when NWBF is no longer required, with wash water discharged with mud pit washings, or returned to shore for disposal if discharge criteria cannot be achieved.

There are typically a number of mud pits (tanks) on the MODU that provide a capacity to mix, maintain and store fluids required for drilling activities. The mud pits form part of the drilling fluid circulating system. The mud pits, any supply vessel storage tanks carrying WBF or NWBF, and associated equipment/infrastructure are cleaned out during and at the end of drilling and completions operations. Mud pit wash residue is operationally discharged from the MODU with less than 1% oil contamination by volume. Where the mud pit residue exceeds 1% by volume, the residue will be retained and disposed onshore.

Drilling fluids toxicity

Components of the WBF system have a low toxicity. Bentonite and guar gum are listed as 'E' category fluids under the OCNS and is included on the Oslo Paris (OSPAR) Commission PLONOR (chemicals that 'pose little or no risk to the environment') list (OSPAR, 2019). They may, however, cause physical damage to benthic organisms by abrasion or clogging, or through changes in sediment texture that can inhibit the settlement of planktonic larvae, such as polychaete and mollusc early life stages (Swan et al., 1994). However, these impacts are not expected to be significant due to the rapid biodegradation and dispersion of WBFs (Terrens et al., 1998).

NWBF may contain a range of synthetic hydrocarbons, such as paraffins and olefins; however, such additives are designed to be low in toxicity and biodegradable, as well as not being readily bioavailable or likely to bioaccumulate amongst the deepwater benthic biota that live within the seabed (infauna) or on the seabed (epifauna). However, it is noted that microbial biodegradation can result in oxygen reduction within sediments. Nedwed et al. (2004), however, found that depth is an important factor for residual concentrations of NWBF once they reach the seabed, suggesting that loss of base fluid during settling acted to significantly reduce chemical effects from discharges. It is also noted that NWBF cuttings tend to clump and settle to the seabed rapidly adding to the cuttings pile in proximity to the well site. The Nedwed et al. (2004) study concluded that NWBF discharged in deep water caused very limited environmental impacts (from analysis of differences in benthic fauna between pre- and post-drilling samples).

Cement

Once each of the top-hole sections are drilled, casing is installed in the wellbore and secured in place by pumping cement into the annular space and may involve a discharge of excess cement at the seabed (~80 m^3/well). Wherever possible, the cement line flush volumes are included in the planned cement jobs. When a job is completed, the cement unit is cleaned, and the residual cement discharged overboard. The discharge volumes of residual cement products are approximately 1 m^3.

At the commencement of the drilling campaign there may be a requirement to run a cement unit test to test the functionality of the cement unit and the cement bulk delivery system prior to performing an actual cement job. This test would result in a small volume of approximately 10 m^3 of cement slurry being discharged at surface to sea. The slurry is usually a mix of cement and water however may sometimes contain stabilisers or chemical additives. Excess cement (dry bulk) after well operations are completed, will be held onboard and used for subsequent wells, provided to the next operator at the end of the program, or discharged to the marine environment. Planned bulk discharges at wells within the State Proposal Area will be managed under the **Management Approach for Torosa wells in State Proposal Area** (refer to later sub-section).

Completion fluids

Completion fluids are usually brines (i.e. a mixture of seawater or formation water) with additives that can include chlorides (often sodium, potassium or calcium), bromides, hydrate inhibitor (MEG), biocide and/or oxygen scavenger. They are designed to have the proper density and flow characteristics to be compatible with the reservoir formation. Completion fluids may also include solids-free fluid, gravel pack carrier fluid and loss circulation material. Completion fluids are used during wellbore clean-up, while running completions, and may be returned to surface during well unload activities. Most of the gravel pack carrier fluid is bulk discharged.

Wellbore and casing clean-up are required at various stages of the operations to ensure the contents of the well are free of contaminants before the next stage of well construction. A chemical wellbore cleanout fluid train may be used to remove residual fluids (including NWBF, if used) from the wellbore. The wellbore cleanout fluid is usually brine (similar to completion fluid) that can include several chemicals, such as biocide and surfactant. During the wellbore clean-out process, fluids are circulated back to the MODU, and, if required, analysed before they are discharged overboard. Discharge volume would be ~400 m^3 (based on the designs of the proposed production wells).

A brine of adequate density to control formation pressure may also be used during well suspension or well abandonment.

Well unload

During well unloading activities, all completion and reservoir fluids will be flared or discharged to the environment. The base oil column, completion fluid, some drilling fluid remnants, hydrocarbons and produced/condensed water will be measured, handled, separated, treated for overboard discharge (non-hydrocarbon) and flared/burned (hydrocarbon) through the temporary production system on the MODU.

The well test water treatment package will be used to treat produced/reservoir water before discharge. Prior to discharging, the fluids are cycled through an oilbond filtration system and gauge tank. Water filtration is standard practice for well unloading operations.

Discharges will occur during well unloading to a MODU or suitable vessel. These discharges will constitute leftover drilling fluids, completion fluids and small amounts of produced water (PW; refer to Section 6.3.12). Well unloading is anticipated to take 1-2 days per well, and discharge of fluids during this time has been indicatively estimated at approximately 100 m^3 to 130 m^3 per well.

Well annular fluids

Annular fluids fall within the category of completion fluids and refer to the fluids that remain in the annular spaces between the casing and previous casing strings or formation. It may consist of weighted drilling fluid and cement-contaminated mud, seawater, barite, cement, polymer, and may include small amounts of hydrocarbon. For the proposed Browse to NWS Project, the reference case annular fluid is base oil with no additivities apart from a demulsifier.

If a well is underperforming, or surveillance indicates debris is contained within the well, the contents of the wellbore may be flowed to a MODU. This displaces the well fluids (i.e. suspension/completion fluids). These are discharged overboard, as potential gas content makes it too dangerous for personnel to filter or treat them.

WBF used during riserless drilling will be released to the marine environment when the well head is removed during abandonment. Upon wellhead removal, small volumes (~ 1 m^3) of fluid exchange between the annular spaces and the ocean may occur. The exchange will not be instantaneous as the annular spaces are small and the fluids are typically heavier than seawater, however, as the fluids are released it is expected that they will be rapidly diluted within metres of the release location.

Overview of drill cuttings and drilling fluids

An indicative well profile is shown in Table 6-119. During drilling of the top-hole well sections drill cuttings (~ 625 m^3) and drilling fluids (~ 1,095 m^3) based on a typical well profile are generated and will be released from the well directly onto the seabed. During drilling of the bottom-hole well sections, drill cuttings (~ 225 m^3) and drilling fluids (~ 1,020 m^3) based on a typical well profile are generated and may be discharged at or below the sea surface.

Contingent drilling activities include well side-track and well respud. If either of these activities are required, they will result in additional volumes of drilling discharges equal to the re-drilled sections of the well. The impacts of these unlikely scenarios are broadly covered by the base case impact assessment considerations.

It should be noted that the detailed impact evaluation with modelling is based on the primary drilling discharges (cuttings and residual fluids) due to the nature, scale and duration of the discharge compared to other sources (e.g. completion fluids). These results have been used to support impact and risk assessment and in the determination of acceptability in the context of the receiving environment and relevant receptors.

Table 6-119 Indicative cuttings volumes and fluid type for a typical Browse well

Indicative well section diameter	Indicative Drill Length (m)	Indicative Cuttings Volume (m^3)	Indicative Fluids Volume (m^3)	Indicative Fluid Type
42”	100	89 m^3	427	Seawater with bentonite sweeps
26”	440	151 m^3	1327	Seawater with bentonite sweeps
16”	2970	385 m^3	965	Weighted Gel (Bentonite) WBF
12 ¼	2799	213 m^3	925	WBF or NWBF
9 7/8	243	12 m^3	790	WBF or NWBF
Total per well	**6,552 m**	**850 m^3**	**4,435 m^3**	

6.3.15.3 Modelling

Modelling was undertaken by DHI (DHI Water & Environment Pty Ltd (DHI), 2011, 2010)[23] to assess the dispersion of and sedimentation by drill cuttings (and residual fluids) from the drilling of wells proposed within the Torosa reservoir, as part of the previous JPP development concept for the Browse resource. The modelling was subsequently used for the previous FLNG development concept, given that the change in development concept does not alter well installation methodology.

Torosa was selected for modelling given its proximity to Scott Reef and, hence, elevated potential for impacts to high value shallow water benthic habitats (i.e. worst-case scenario). The assessment focused on identifying sedimentation impacts to coral habitats at Scott Reef to inform the management approach (and associated effectiveness of controls) that may be adopted for the drilling campaign. Furthermore, the modelling provided an indication of dispersion for all other wells associated with the proposed Browse to NWS Project.

It is considered that this modelling remains representative for the proposed Browse to NWS project due to the governing hydrodynamics, similar input data and commitment with regard to undertaking the activity in such a manner that it results in no impacts to the Scott Reef shallow water benthic communities and habitats (<75 m water depth). Additional modelling will be completed to support Environment Plans under Petroleum legislation, following further detailed design.

Modelling scenarios and discharge volume

For the previous development concept, production wells within the Torosa reservoir were proposed within three main locations, namely the TRE drill centre (approximately 2 km from South Scott Reef), the TRD drill centre (approximately 3 km from North Scott Reef) and the previous TRA/TRB drill centre (approximately 8 km from North Scott Reef) (DHI, 2011) (**Figure 6-34** to **Figure 6-36**).

To appropriately assess the potential for impacts to Scott Reef (including potential cumulative impacts), the model simulated drilling 25 wells at the three locations (6 at the TRE drill centre, 7 at the TRD drill centre and 12 at the TRA/TRB drill centre) over an 18-month period. This provides a comparative approach for the assessment of the proposed Browse to NWS Project given 24 wells are proposed within the State Proposal Area.

At each of the three previously proposed drilling locations, modelling parameters for each well included:

- Seabed discharge from top-hole sections of each well equivalent to a cuttings volume of 584 m^3, which is comparable to the current well design volume of ~625 m^3.
- Sea surface discharge from bottom-hole sections of each well equivalent to a cuttings volume of 181 m^3, which is comparable to the current well design volume of ~225 m^3.

Modelling studies

Modelling was undertaken using the calibrated and validated 3D hydrodynamic model (MIKE 3 Classic) for Scott Reef and surrounds to run the Lagrangian-based particle module for simulating sediment dispersion, sedimentation and resuspension of the drill cuttings releases.

Although actual volumes, discharge rates and scheduling of drilling activities are yet to be confirmed, modelling assumptions provided for a conservative assessment of potential impacts from drill cuttings disposal. This is based on the assumption of no intervals between the drilling of different well sections, and the highest number of wells that could be constructed in a year at a location, both of which resulted in higher intensity of cuttings discharge than is likely to occur under actual conditions. Further, the Particle Size Distribution (PSD) of the cuttings adopted in the modelling was based on cuttings PSD measured from the Torosa-5 exploration well, which was expected to provide a good proxy of the sediment particle size for cuttings expected from the proposed drilling locations.

Modelling results

The thresholds for ecological impact to Scott Reef habitats are defined as <10 mg/L for Total Suspended Solids (TSS) concentrations (based on Nelson et al. (2016) and 20 g/m^2 as a daily net sedimentation rate (based on a low level impact to corals (Negri et al., 2008))

The modelling undertaken in support of the previously approved development concept indicated that, at all three drill centre locations, the sea surface discharge of drill cuttings from well bottom-hole sections resulted in incursions of sediment plumes and associated increased deposition at some parts of North and South Scott Reef including within the lagoons. As a result, Woodside has committed to manage drilling discharges (in particular bottom-hole well section discharges) at drill centre locations in the State Proposal Area (i.e. TRA, TRD, TRE and TRF) in such a manner to avoid potential impacts to Scott Reef shallow water benthic communities and habitats (<75 m water depth) will occur. This management approach is further described in the following section.

In contrast, the seabed discharge of drill cuttings from top-hole well sections may result in sediment plumes and associated deposition of sediment to the surrounding seabed and was confined to the deeper layers of the water column with no contact with deeper water or shallow water coral habitats at Scott Reef. As outlined in **Section 5.2.5.7**, while there is some evidence of localised

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[23] *DHI (2011) available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies*

intrusions of cooler water around the western and eastern entrances to the channel between North and South Scott Reef during spring tides, there is no evidence of persistent upwelling or downwelling currents around Scott Reef (Green et al., 2019) and therefore, no transport mechanisms to mobilise drill cuttings from deep waters to the shallower waters of the reef system. As such, given the location of the drill centres in deep water, which experience strong surface and subsurface currents, drill cuttings and fluid discharge disposal at seabed would be expected to settle rapidly. Therefore, any reduction in water quality such as elevated TSS is expected to occur in a localised area around the drill centre and will be temporary in nature.

To further inform the impact assessment, for the seabed discharge of drill cuttings generated from the top-hole sections of the wells, the modelling results indicated that at the:

- previously proposed TRE drill centre location (water depths of 360 m):
  - Sediment plume predominantly extended westward, driven by the stronger ebb tide, with some eastward extension during the flood tide (**Figure 6-34**).
  - Cuttings sedimentation would be limited to the deep seabed and water layers of the channel, with no sedimentation on Scott Reef shallow water benthic communities and habitats (<75 m water depth) including in the lagoons of North and deeper water coral habitat of South Scott Reef.
  - Maximum net sediment deposition at seabed over the duration of the 12-month drilling program is estimated at approximately 46 cm at the previously proposed TRE drill centre location (**Figure 6-34**).
- previously proposed TRD drill centre location (water depths of 400 m):
  - Sediment plume confined to the deep-water layers of the water column (**Figure 6-35**).
  - Modelling did not predict elevated suspended sediment concentrations or net sedimentation at Scott Reef Scott Reef shallow water benthic communities and habitats (<75 m water depth) including in the lagoons of North and deeper water coral habitat of South Scott Reef.
  - Net sediment deposition at seabed over the duration of the drilling program is approximately 35 cm at the previously proposed TRD drill centre location (**Figure 6-35**).
- previously proposed TRA/TRB drill centre location (water depths of 460 m):
  - Sediment plume confined to the deep-water layers and was not expected to reach Scott Reef Scott Reef shallow water benthic communities and habitats (<75 m water depth) including in the lagoons of North and deeper water coral habitat of South Scott Reef (**Figure 6-36**).
  - Sedimentation was predicted to extend eastwards of Scott Reef, influenced by the north-west south-east tidally-induced currents.
  - Net sediment deposition at seabed over the duration of the drilling program is approximately 21 cm at the previously proposed TRA/TRB drill centre location (**Figure 6-36**).

Maximum suspended sediment concentrations in the water column in the vicinity of the release points (near the seabed) was predicted to reach 1250 mg/L at TRE, 1530 mg/L at TRD and 2500 mg/L at the previously proposed TRA/TRB drill centre location.

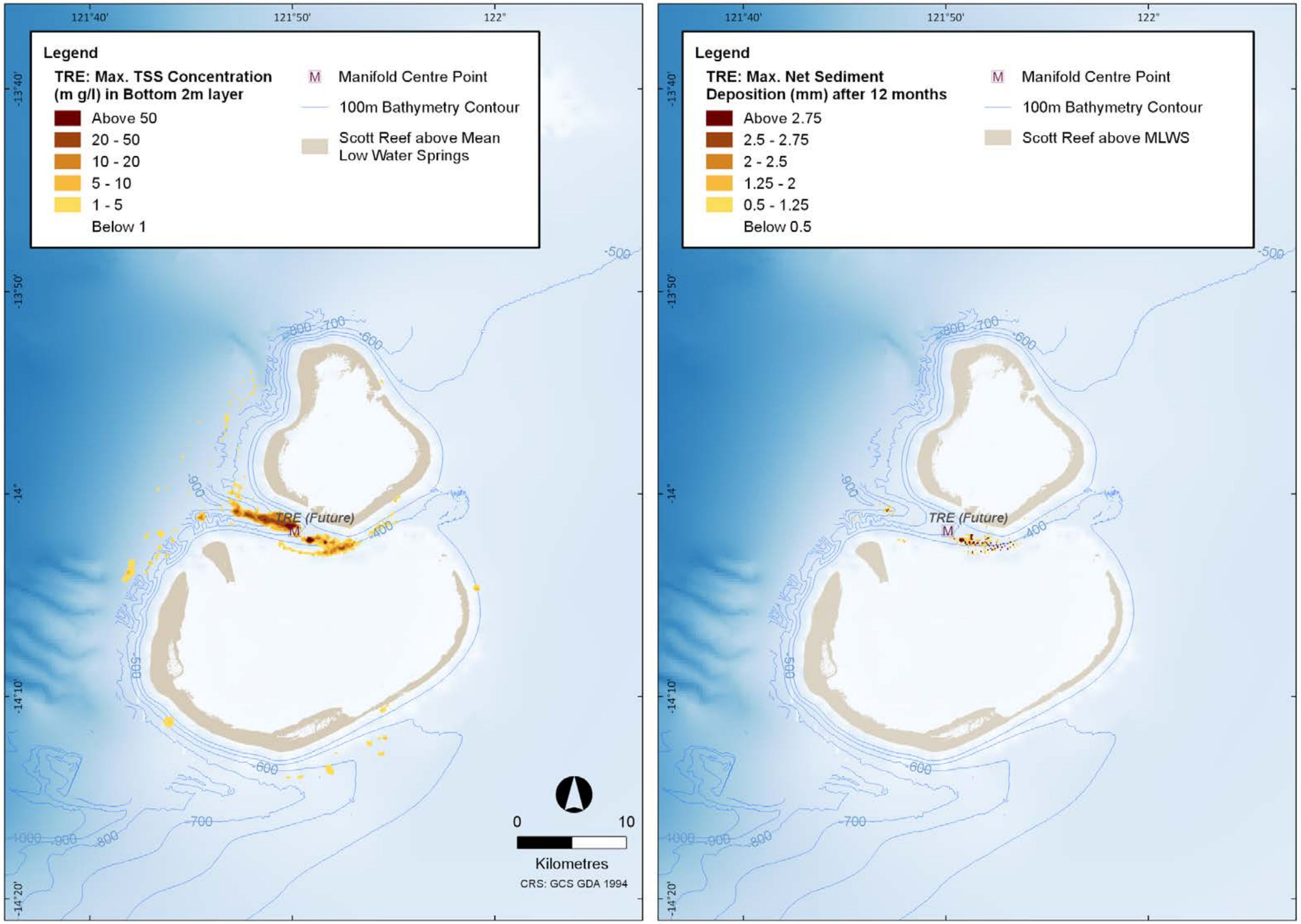

Figure 6-34: Drill Cuttings Discharge at the Seabed at TRE Drill Centre Showing: Maximum TSS Concentration (mg/L) in the Bottom 2 m (left) and Maximum Net Sedimentation (mm) (right) (DHI 2011b)

Note: The contour plots illustrate the overall footprint of elevated suspended solid concentrations and sedimentation over the entire course of the drilling program (12 months) at TRE. It is important to note the occurrence of elevated TSS concentrations and sedimentation shown in the contour plots are cumulative and represent the maximum concentrations for the whole modelled drilling program. This approach allows for the prediction of any areas at Scott Reef where elevated turbidity or sedimentation may occur over the modelled drilling period.

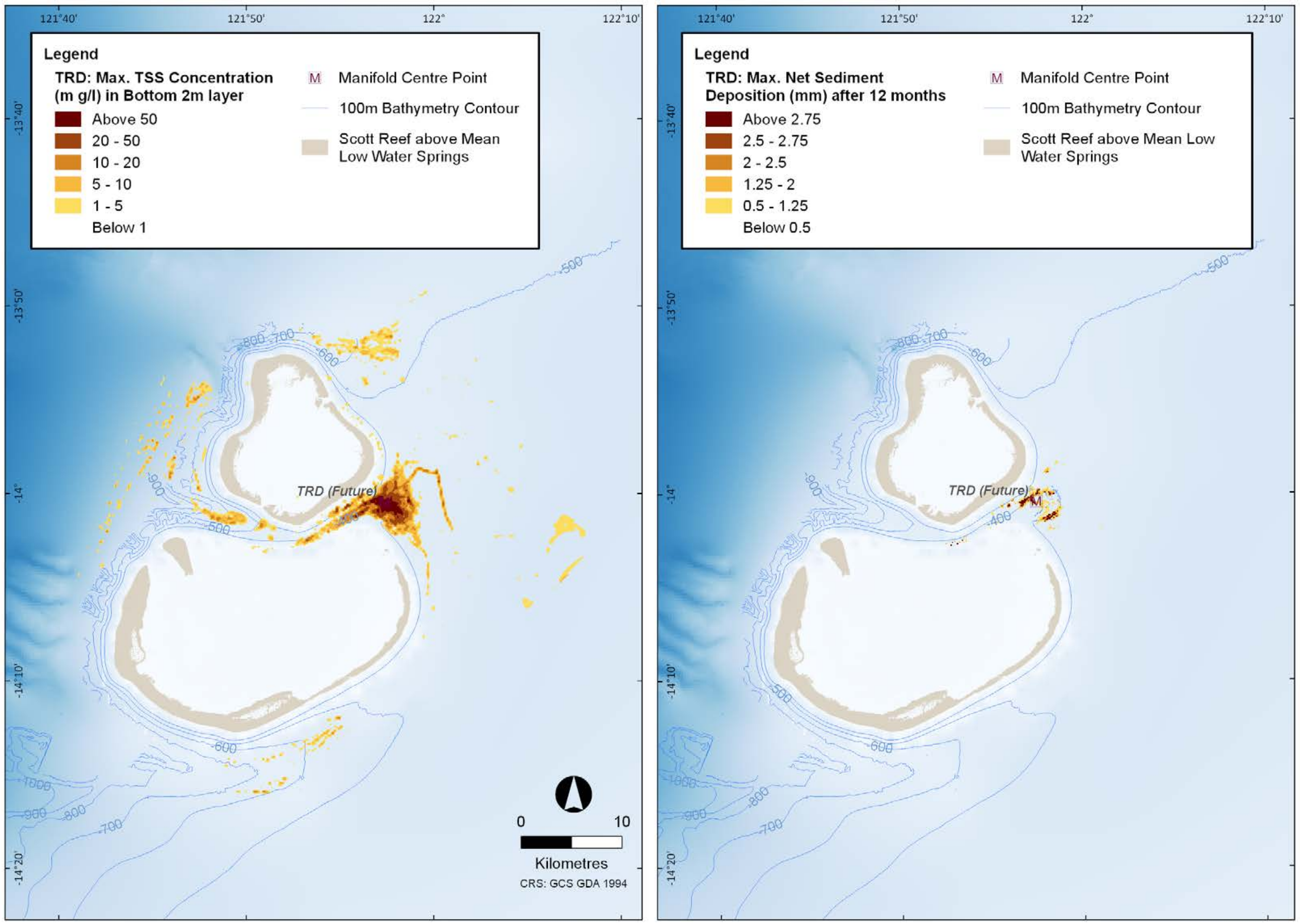

Figure 6-35: Drill Cuttings Discharge at the Seabed at the previously proposed TRD Drill Centre Showing: Maximum TSS Concentration (mg/L) in the Bottom 2 m (left) and Maximum Net Sedimentation (mm) (right) (DHI 2011b)

Note: The contour plots illustrate the overall footprint of elevated suspended solid concentrations and sedimentation over the entire course of the drilling program (12 months) at the previously proposed TRD drill centre location. It is important to note the occurrence of elevated TSS concentrations and sedimentation shown in the contour plots are cumulative and represent the maximum concentrations for the whole modelled drilling program. This approach allows for the prediction of any areas at Scott Reef where elevated turbidity or sedimentation may occur over the modelled drilling period.

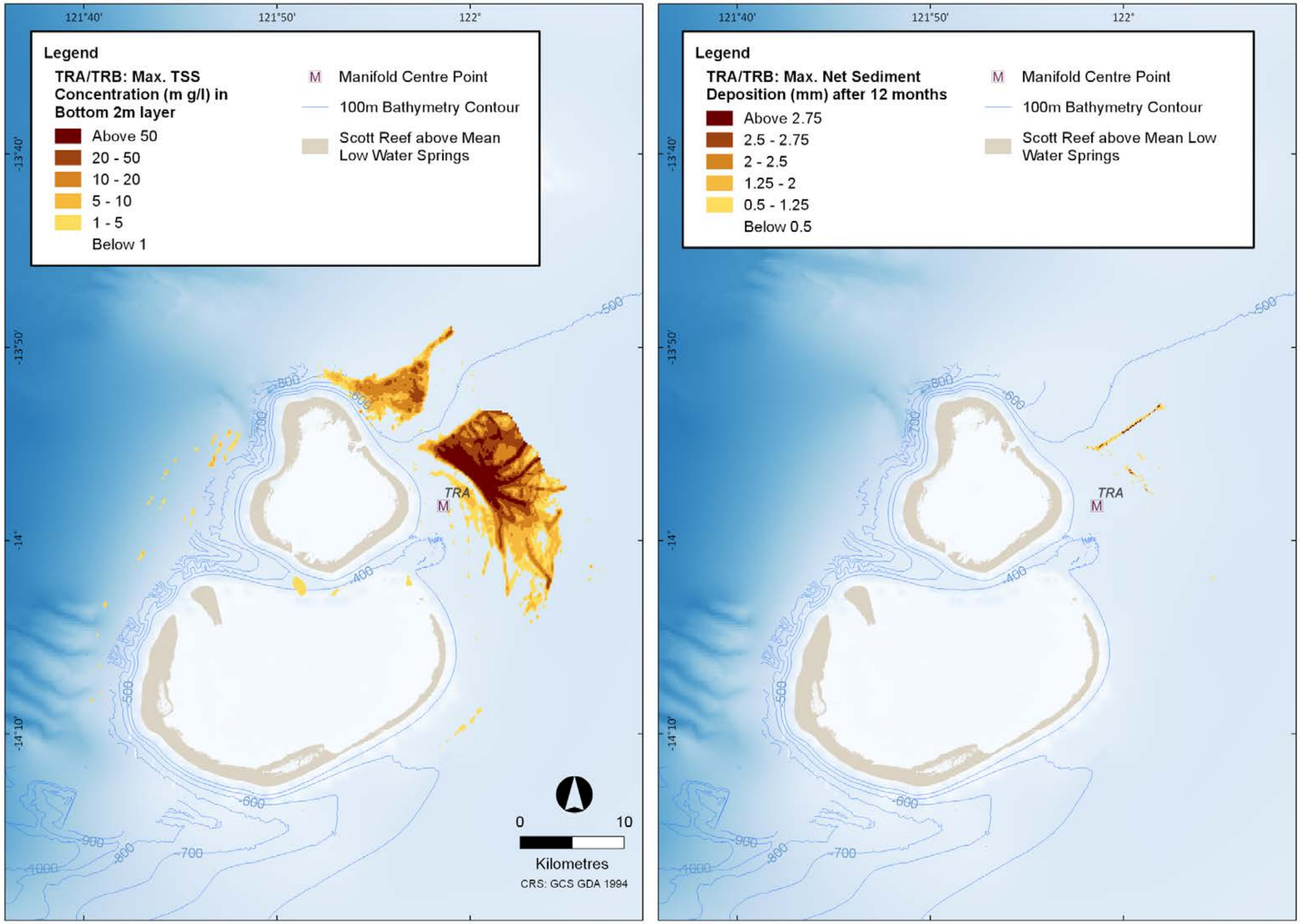

Figure 6-36: Drill Cuttings Discharge at the Seabed at the previously proposed TRA/TRB Drill Centre Location Showing: A. Maximum TSS Concentration (mg/L) in the Bottom 2 m (left) and Maximum Net Sedimentation (mm) (right) (DHI 2011b)

Note: The contour plots illustrate the overall footprint of elevated suspended solid concentrations and sedimentation over the entire course of the drilling program (18 months) at TRA/TRB. It is important to note the occurrence of elevated TSS concentrations and sedimentation shown in the contour plots are cumulative and represent the maximum concentrations for the whole modelled drilling program. This approach allows for the prediction of any areas at Scott Reef where elevated turbidity or sedimentation may occur over the modelled drilling period.

Management approach - Torosa wells in the State Proposal Area

Modelling indicated that the sea surface discharge of drill cuttings from the bottom-hole sections generated at the previously proposed TRE and TRD drill centre locations would potentially result in incursions of sediment plumes and associated increased sedimentation to portions of North and South Scott Reef including within the lagoons.

Given the potential sensitivities of Scott Reef shallow water benthic habitat (<75 m bathymetry) to sedimentation from drilling discharges, Woodside has committed to managing the drilling discharges (in particular, bottom-hole section discharges) at drill centre locations in the State Proposal Area (i.e. TRA, TRD, TRE and TRF) in such a manner to avoid potential impacts to Scott Reef shallow water benthic communities and habitats (<75 m water depth). This approach is as follows:

1. For each identified drill centre, drilling discharge modelling will be completed using final design data to assess the dispersion and fate of drill cuttings, residual drilling fluids on cuttings, as well as bulk discharge (collectively referred to as drilling or completions discharges). This information will be provided in the relevant Environment Plan.
    a. Where modelling can demonstrate that the discharge techniques and operational parameters (e.g. depth, rate and duration) are such that no impact to Scott Reef shallow water benthic communities and habitats (<75 m water depth) are predicted, drilling will be undertaken accordingly.
    b. For those scenarios where modelling suggests impact to Scott Reef shallow water benthic communities and habitats (<75 m water depth) may occur, alternative drilling discharge techniques and operational parameters (e.g. depth, rate and duration) will be assessed and selected to avoid potential impacts.
2. Where bottom-hole section drilling discharges are planned to be undertaken at the specified drill centre locations based on outcomes from the drilling discharge modelling, monitoring at discharge source will be undertaken to verify the model predictions and ensure they are appropriately conservative.
3. For those scenarios where modelling predicts impact to Scott Reef shallow water benthic communities and habitats (<75 m water depth), and no alternative discharge techniques and operational parameters are available, then the relevant drilling or completions discharges predicted to cause the impact will be transported to a suitable location (e.g. at a sufficient distance from the reef or onshore) for disposal.
4. For those scenarios where verification monitoring at the discharge point indicates a potential impact to Scott Reef shallow water benthic communities and habitats (<75 m water depth), then the management of drilling or completions discharges (as predicted to cause the impact) will be addressed by transportation to a suitable location (e.g. at a sufficient distance from Scott Reef or onshore) for disposal.

These management objectives are supported by a range of both feasible and industry proven management measures.

6.3.15.4 Environmental Impact

Background

The impacts of drilling or completions discharges on water and sediment properties, and benthic communities are well documented. The United Kingdom Offshore Operators Association (UKOOA) sponsored an extensive initiative to assess the issue of cuttings piles in the North Sea from operations between 1970 and 2000 (Danielsson et al., 2005). More recently, the International Association of Oil and Gas Producers (IOGP) published a report which reviews scientific literature on the fate and effects of ocean discharge of drill cuttings and associated drilling fluids from offshore oil and gas operations (IOGP, 2016). Drill cuttings have been studied specifically on the NWS of Australia (Oliver and Fisher, 1999; SKM, 2007). The effects of turbidity and sediment deposition on sensitive ecological receptors such as corals have also been the subject of many peer-reviewed studies (e.g. Fabricius, 2005).

Drilling or completions discharges have the potential to impact the marine environment through:

- temporary increase in TSS in the water column
- attenuation of light penetration as an indirect consequence of the elevation of TSS and the rate of sedimentation
- sediment deposition to the seabed leading to the alteration of the physio-chemical composition of sediments, and burial and potential smothering effects to sessile benthic biota
- potential contamination and toxicity effects to benthic and in-water biota from drilling fluids.

It should be noted that the following assessment is restricted to potential impacts to open ocean receiving environment of the Brecknock and Calliance drill centres, and deepwater habitats around Scott Reef, given Woodside's commitment (see **Management approach - Torosa wells in the State Proposal Area**) to not undertake sea surface discharge from the bottom-hole sections that could potentially affect Scott Reef habitats.

Sediment quality

Change in sediment quality

Seabed sediment characteristics of the Brecknock, Calliance and Torosa reservoirs within the Browse Development Area, were generally soft silt and clay including the seabed areas surrounding Scott Reef, and the channel separating North and South Scott Reefs comprised well-rounded cobble/rubble and very coarse shell fragments. Seabed sediments sampled as part of previous studies (see **Section 5.2.10**) have demonstrated nutrient levels do not exceed background concentrations, variable metal concentrations and no detectable hydrocarbon contamination.

Cuttings discharged at the seabed will result in localised cuttings piles on the seabed surrounding the wellhead, with a greater spread of cuttings expected to occur down current from the well site. Sediment quality can be impacted by drilling or completions discharges as the drill cuttings alter the particle size distribution and physico-chemical composition of sediments and from the introduction of contaminants (e.g. hydrocarbons and metals) from drilling fluids. This in turn can have an impact on benthic communities through sediment deposition causing burial and smothering, or toxicity effects from drilling fluids.

The modelling indicates that sediment deposition would potentially occur to a distance in the order of a couple of hundred metres from each well location (in the direction of the prevailing current). This assessment aligns with several studies which indicate that the spread of cuttings can be expected to be up to about 150 m from the discharge location (IOGP., 2016).

Given the localised nature of potential changes to sediment quality, the deepwater biota and widespread, representative deepwater habitat where drilling or completions discharges will be disposed at the seabed and the low toxicity of the drilling or completions discharges (refer to **Section 6.3.15.2**), changes to sediment quality are not expected to be significant.

Water quality

Change in water quality

The discharge of drill cuttings and unrecoverable fluids is expected to increase turbidity and TSS levels in the water column. Drilling or completions discharges are generally intermittent and of relatively short duration for each production well drilling activity. Nelson et al. (2016) identified <10 mg/L as no effect or sub lethal minimal effect concentration, with Boesch and Rabalais (1987) demonstrating that surface discharges are likely to affect water quality and be confined to within 350 m - 1,500 m downstream from the discharge location.

The modelling (**Section 6.3.15.2**) indicates that both seabed and surface drilling or completions discharges would result in impacts to water quality as a result of elevations in TSS and the introduction of low toxicity contaminants. This reduction in water quality will be temporary (i.e. limited to the duration of the activity) and subject to rapid dispersion and dilution by prevailing currents, due to the open oceanic waters of the Browse Development Area. Increased turbidity due to surface discharges at the Brecknock and Calliance drill centres, may have indirect impacts on plankton (discussed further below). Note, the implementation of the proposed management approach for the proposed Torosa drill centres mitigates the potential for impacts to Scott Reef water quality values.

Overall, given the predicted rapid dispersion of suspended sediments within the open ocean environment of the Browse Development Area, the short period of intermittent discharge and the generally low concentration of TSS within the plume tens of metres from the release location, any change in water quality associated with drilling or completions discharges are expected to be temporary with a slight effect and with no long-term reduction in the environmental values of the Browse Development Area.

Plankton communities

Injury or mortality to fauna

Surface discharges may potentially impact photosynthetic processes of phytoplankton due to increased turbidity. However, any impacts on plankton are predicted to be temporary and not expected to have any lasting effect on plankton communities, as they are known to have high levels of natural mortality and a rapid turnover rate (ITOPF, 2011). Therefore, discharge of drill cuttings is not expected to measurably impact local productivity within the water column at the Brecknock, Calliance, or Torosa reservoirs.

Benthic habitats

Change in habitat, injury or mortality to fauna

Following the discharge of drill cuttings and fluids, the coarser fractions (sand and gravel-sized particles), will rapidly settle to the seabed. Where cuttings are discharged to the seabed, a cuttings pile will develop immediately around the well site. The nature and size of the pile will depend on a number of factors including particle size of the cuttings, tidal and current forces and water depth. Discharge of cuttings at the surface will result in a sediment plume with the dispersion and settlement of cuttings dependent on the particle sizes of cuttings, water depth, as well as the prevailing wind, tidal influence and current directions. In addition, the overspill of cement associated with the cementing of the well casing will result in an irreversible loss of an area (0.008 km^2) of the seabed immediately adjacent to the well (within a <50 m radius).

Potential impacts resulting from deposition of discharges are expected to be confined to sessile biota such as sediment burrowing infauna and epifauna (where present) in or on the seabed in the immediate proximity to the well location. Ecological impacts to such biota are predicted when sediment deposition is equal to or greater than 6.5 mm (in thickness) (IOGP, 2016). Modelling (**Section 6.3.15.2**) indicated that such deposition would potentially occur out from the well location to approximately 200 m (following the direction of the prevailing current). This aligns with IOGPl., (2016) review of seven studies, which indicated that the spread of drill cuttings and WBFs is expected to be up to about 150 m from the discharge location. It should also be noted that sedimentation was modelled concurrently for multiple wells at the drill centres, resulting in a likely overestimation of net sedimentation given that in reality wells will be drilled sequentially and therefore further dispersion of deposited sediments will occur in between individual well drilling activities.

This deposition may result in the reversible loss in the order of 0.13 km^2 of deepwater benthic habitat per well based on an assumption of an expected spread radius of 150 m from each well (in addition to the irreversible loss of 50 m). Balcom et al., (2012) concluded that impacts associated with the discharge of cuttings and NWBFs are minimal, with impacts highly localised to the area of the discharge. Changes to benthic communities are normally not severe. Organic enrichment can occur leading to anoxic conditions in the surface sediments and a loss of infauna species that have a low tolerance to low oxygen concentrations, and to a lesser extent chemical toxicity near the well location. These impacts are highly localised with short-term recovery that may include changes in community composition with the replacement of infauna species that are hypoxia-tolerant (IOGP et al., 2016).

Recovery of affected benthic infauna, epifauna and demersal communities is expected to occur. Jones et al., (2012) compared pre- and post-drilling ROV surveys and documented physical smothering effects from WBF cuttings within 100 m of a well. Outside the area of smothering, fine sediment was visible on the seafloor up to at least 250 m from the well. After three years, there was significant removal of cuttings particularly in the areas with relatively low initial deposition (Jones et al., 2012). The area impacted by complete cuttings cover had reduced from 90 m to 40 m from the drilling location, and faunal density within 100 m of the well had increased considerably and was no longer significantly different from conditions further away. As such, the impacts to the deepwater benthic habitats are considered reversible with benthic biota expected to recolonise the area on completion of the drill cuttings discharge at each well.

Based on the modelling (**Section 6.3.15.2**), the sedimentation footprint associated with discharge of drilling or completions discharges at the seabed, indicates that away from the immediate area around the well (i.e. 50 m radius associated with the permanent impact from well casing cement overspill), sedimentation over the course of the drilling program would be low, equating to a thin veneer of settled drilling discharges away from the immediate deposition area around the well (in the order of 200 m from the well) which will likely be naturally reworked into surficial sediment through processes including bioturbation (US EPA, 2002). Ecological impacts in these areas are not expected for mobile benthic fauna such as crabs and shrimps or pelagic and demersal fish, given their mobility (IOGP, 2016).

Summary

In summary, likely impacts to benthic communities and habitats from seabed drilling discharges (i.e. drill cuttings and drilling fluids) and cement will be restricted to the burial of deepwater benthic biota and likely changes to sediment quality within the vicinity each well (in the order of several hundreds of metres). However, outside of approximately 200 m from each well, little to no impact to the deepwater benthic communities and habitats is expected.

Impacts associated with the surface discharge of drill cuttings at Torosa outside the State Proposal Area and at Brecknock and Calliance will be dependent on the rate of sedimentation determined by the fate and dispersion of the drill cuttings and retained drilling fluids based on particle size. Given water depths at the subsea well centres at these reservoirs (Brecknock: approximately 530 to 590 m; Calliance: approximately 410 to 590 m), surface cuttings discharges are likely to sink rapidly and deposit on the seabed in proximity to the drill centre and the fines associated with the drilling fluids are likely to disperse over a wider area (downstream of the drill centre), resulting in extremely low sedimentation levels and little to no impacts on the deepwater biota associated with the widespread sediment habitat. MODUs at Brecknock and Calliance drill centres may discharge from near the sea surface, as well as MODUs at Torosa outside the State Proposal Area where it can be demonstrated that there is no potential for impact to Scott Reef shallow water benthic communities and habitats from the discharges.

Overall, the loss (both reversible and irreversible) of benthic biota associated with the deep-water sediment habitat that are well represented both in the Browse Development Area and regionally, is not expected to reduce biological diversity and ecological integrity in the region.

Marine fauna

Injury or mortality to fauna – fish, marine reptiles, marine mammals

Marine fauna such as fish, marine turtles and marine mammals may be exposed to drill cuttings and fluid discharge if present in the immediate vicinity of the discharge.

As discussed in **Section 5.3.2**, fish assemblage species richness and habitat complexity have been shown to decrease with increasing depth in the NWMR (Last et al., 2005). Due to the predominantly featureless, sediment habitat of the Browse Development Area and depth, the demersal fish presence will be low and representative of a deepwater area. Impacts to fish habitat will occur on a local scale (hundreds of metres) and the area outside the immediate 50 m radius of the well locations will return to previous condition. Adult fish are likely to move away and avoid elevated TSS associated with sedimentation and this will be limited in extent on spatial and temporal scales. Air breathing fauna, marine turtles and marine mammals are not expected to be adversely impacted by any encounters with elevated TSS. The green turtle breeding population has been shown to inhabit the shallow waters surrounding Sandy Islet and will not be exposed to drilling discharges disposed at the seabed (top-hole well sections) at deepwater drill centre locations. In addition, most visual orientated fish/fauna species would likely relocate to an unaffected area to avoid the plume or simply pass unaffected through turbid waters.

Acute and chronic effects of chemical discharges are highlighted within the Recovery Plan for Marine Turtles in Australia (2017-2027) as a threat to green turtles of the Scott Reef-Browse Island genetic stock (Commonwealth of Australia, 2017a). Chronic chemical pollution is identified as a potential risk to pygmy blue whales in the Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c). Conservation advices for other EPBC listed marine mammals that may occur in the Project area do not identify chemical pollution as a key threat (**Table 5-19**).

There is a large body of knowledge indicating a discharge of cuttings with adhered fluids dilutes rapidly. These studies have found that that within 100 m of the discharge point, a drilling cuttings and fluid plume released at the surface will have diluted by a factor of at least 10,000, while Neff (2005) states that in well-mixed oceans waters (as is likely to be the case within the proposed drilling area), drilling fluid is diluted by more than 100-fold within 10 m of the discharge. While marine fauna such as fish, marine mammals and marine turtles may come into contact with these discharges, given that the discharges will disperse rapidly close to the discharge point and that any contact with the discharge will be of extremely short duration, it is not considered credible that toxic affects to marine fauna will occur as a result of the discharge of drill cuttings and fluids within the Browse Development Area.

Assessment against EPBC Act recovery and conservation plans and advices

Table 6-120 summarises how the proposed drilling or completion discharges align with the objectives/actions of the relevant EPBC Act recovery and conservation management and recovery plans and advices.

Table 6-120 Alignment with protection of fauna conservation values – drilling or completion discharges

Fauna	Relevant plan(s)/ Conservation Advice	Plan/advice objectives and actions	Assessment
Whale shark	Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a)	Assess the impacts of offshore installations and associated environmental changes (light spill, chronic noise, changed water temperature, localised nutrient levels) on whale sharks and mitigation options for these impacts.	The impact of drilling or completions discharges resulting from the proposed Browse to NWS Project have been assessed and mitigation measures proposed. Given the low numbers and infrequent nature of whale shark presence in the Project Area, and mobility of the species, there is a high level of confidence that drilling or completions discharges will not result in adverse impact to whale sharks.
Green turtle	The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a)	**Management actions:** + Manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to the survival. + Manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue. + In relation to the Scott Reef – Browse Island green turtle genetic stock, the priority action is to manage anthropogenic activities to ensure marine turtle are not displaced from identified habitat critical to their survival.	Given the commitment to implement a management approach for the proposed Torosa drill centres adjacent to Scott Reef (including habitat critical for green turtles), as well as the inherent low toxicity and temporary nature of the drill cuttings discharges, impacts to turtles will be managed in accordance with the Recovery Plan for Marine Turtles in Australia (2017-2027) which includes the minimisation of chemical discharge as an overarching action area (Commonwealth of Australia, 2017a). There is a high level of confidence that any impacts will not compromise the long-term recovery objectives for marine turtles or result in the displacement of the Scott Reef – Browse Island green turtle genetic stock, from identified habitat critical to their survival, or adversely affect the breeding cycle of marine turtles in the defined BIA at Scott Reef. Therefore, it is considered that the proposed activities are not inconsistent with the objectives of the Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a).
Hawksbill turtle			
Pygmy blue whale	Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c)	Chronic chemical pollution is identified as a potential risk to pygmy blue whales, however there are no specific actions identified.	Given the predicted temporary change in water quality and lack of significant impacts on plankton communities, the discharge of drilling or completions discharges is not expected to have any lasting effect on threatened whale species, particularly the possible foraging area for pygmy blue whales. As such, no adverse impacts are predicted to occur. It is considered that the proposed activities are not inconsistent with the Conservation Management Plan for the Blue Whale or the conservation advices listed for other migratory whale species
Humpback whale	Conservation advice *Megaptera novaeangliae*, Humpback Whale	Marine discharges have not been identified as a direct threat to these whale species; however, habitat degradation has been identified as a threat and unmanaged discharges may contribute to this threat. The conservation advice relevant for this threat – identifies modification to the coastal region in areas of importance to listed whales may result in reduced occupancy, compromised reproductive success and even mortality.	
Sei whale	Conservation advice *Balaenoptera borealis*, Sei Whale		
Fin whale	Conservation advice *Balaenoptera physalus*, Fin Whale		

Key Ecological Features

The discharge of drill cuttings and fluid will occur in:

- the Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEF, which is recognised for high primary productivity, diverse aggregations of marine life and high species richness.
- the Continental slope demersal fish communities KEF, which is recognised for its high diversity of demersal fish.

Change in sediment quality

As discussed above, changes to sediment quality as a result of drilling or completions discharges will be localised to an area (approximately 12 ha) adjacent to each well location. As such no lasting change to sediment quality within the KEFs is expected, with no subsequent adverse effect on the conservation values of KEFs predicted.

Change in water quality

As described above, any change in water quality as a result of drilling discharge is expected to be temporary and highly localised. Woodside has committed to, and demonstrated that feasible management measures exist to ensure drilling or completions discharges at TRA, TRD, TRE and TRF drill centre locations occur in such a manner that no impacts are predicted to Scott Reef shallow water benthic communities and habitats (<75 m water depth) associated with the Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEF. As such no impacts to the conservation values of these KEFs is predicted.

Injury or mortality to fauna

As discussed above, no lasting impacts to fish, marine mammals or marine reptiles are predicted to occur as a result of the drilling or completions discharges. As such no impacts to the conservation values of these KEFs is predicted.

Summary

Table 6-121 summarises how the drilling or completion discharges will not materially increase existing relevant pressures on the conservation values of KEFs.

Table 6-121 Alignment with protection of conservation values of KEFs – drilling or completions discharges

Key Ecological Feature	Relevant plan(s)	Relevant pressures	Assessment
Continental slope demersal fish communities	Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).	Physical habitat modification Chemical pollution/ contaminants	Given that drilling or completion discharges leading to physical modification of benthic communities and habitats will occur to a very small portion (0.01% for Continental slope demersal fish communities and 0.16% for Seringapatam Reef and Commonwealth waters in the Scott Reef Complex) of deepwater benthic habitats that are well represented both within each of the KEFs in the Browse Development Area, and regionally, there is a high level of confidence that such disturbance will not result in an adverse impact to marine ecosystem function or integrity within the KEFs; or any reduction in conservation values of the KEFs will occur.
Seringapatam Reef and Commonwealth waters in the Scott Reef Complex			

Other protected places

Change in water quality, change in sediment quality

The Scott Reef and Surrounds - Commonwealth Area Commonwealth Heritage Place comprises the Commonwealth Marine Area wholly within the WA coastal waters surrounding North and South Scott Reef.

As described above, Woodside has committed to managing drilling or completions discharges at TRA, TRD, TRE and TRF drill centre locations in such a manner to avoid impacts to Scott Reef shallow water benthic communities and habitats (<75 m water depth) will occur. As such no impacts to the conservation values of the Scott Reef and Surrounds - Commonwealth Area Commonwealth Heritage Place is predicted.

Other users

Changes to the functions, interests or activities of other users – State and Commonwealth managed fisheries

Where the functions, interests or activities of other users involve marine fauna (e.g. fisheries), any effect to fauna presence or abundance will indirectly impact on the functions, interests or activities of other users. Given that no adverse impacts to fish from drilling or completions discharges have been predicted, subsequent impact to fisheries is also not predicted.

Changes to the functions, interests or activities of other users – tourism and recreation, scientific studies

As described above, Woodside has committed to a management approach, implementing feasible mitigation measures, to manage the drilling or completions discharges at TRA, TRD, TRE and TRF drill centre locations in such a manner that no impacts to Scott Reef shallow water benthic communities and habitats (<75 m water depth) will occur. Given the tourism, recreation and scientific studies values of the area relate primarily to Scott Reef, no impacts to these other users is predicted.

Aboriginal or indigenous heritage (high value users)

Changes to the functions, interests or activities of other users

Given that no lasting effect to fish from hydrotest fluid discharge have been predicted, subsequent impact to traditional Indonesian fishers is also not predicted.

6.3.15.5 Environmental Risk

Risk event: Distribution of drilling or completion discharges significantly greater than expected leading to impacts for Scott Reef shallow water benthic habitat (<75 m bathymetry)

If the dispersal and fate of drilling or completion discharges is greater than expected, there is a risk of impact to Scott Reef benthic communities and habitats, including high sensitivity and light-dependent photosynthetic communities. This risk would be particularly relevant for any surface drilling discharges at the TRA, TRD, TRE and TRF drill centre locations, which has led Woodside to implement the proposed management strategy (including monitoring) to manage drilling or completions discharges at these locations (Section 6.3.15.2)

Scott Reef is renowned for its high-water clarity, with these conditions being essential to the health and survival of its coral assemblages, particularly in deep lagoonal waters of South Reef. TSS concentrations in the central lagoon are reported to be persistently low (<1 mg/L) and sediment deposition rates are low (<0.8 mg/cm^2/day) (Brinkman et al., 2010). These conditions allow reef development at deep depths (>30 m) with corals deeper than 50 m likely to be occurring at the lower limits of their light regime tolerance (Cooper et al., 2010; Falkowski et al., 1990; Titlyanov et al., 2001; Titlyanov et al., 2001). Corals that inhabit low turbidity offshore reefs have long been recognised as among the most sensitive to elevated sedimentation compared to corals that inhabit coastal environments where larger fluctuations in sedimentation conditions occur (Anthony, 1999; Fabricius, 2005; Gilmour et al., 2006; Rogers, 1990). As such, impacts to these communities in the event that drilling or completions discharges reach a broader spatial area than predicted could potentially lead to moderate impacts to Scott Reef.

Although modelling indicated that the sediment plume and associated deposition of sediment from drilling or completions discharges released at the seabed is expected to be confined to the seabed (**Section 6.3.15.3**), there are inherent uncertainties associated with modelling results and assumptions that these results are based on (e.g. oceanographic conditions). Despite this, modelling outputs are supported by research findings at Scott Reef which show that there is no evidence of persistent upwelling or downwelling currents around Scott Reef (Green et al., 2019), with a year-round strong stratification in the water column. Therefore cold denser water masses deeper than 200 m are unlikely to be upwelled and reach Scott Reef (Brinkman et al., 2009). Given this and considering the water depths and locations of the proposed wells, it is considered highly unlikely that impacts to Scott Reef shallow water benthic habitat (<75 m bathymetry) will occur.

6.3.15.6 Cumulative Impacts

As discussed in the preceding sections, cumulative impacts associated with the discharge of drill cuttings are predicted to deep-water benthic habitats. Such impacts will range from short-term reductions in water quality to potentially permanent impacts to the seabed surrounding the drill centres, resulting in the loss of deep-water biota. Up to 54 wells will be drilled, with up to 24 wells occurring in State waters within the Torosa reservoir (see **Section 6.3.15.2**). The proposed Browse to NWS Project will result in an approximately cumulative volume of 45,900 m^3 of drill cuttings discharged to the seabed, resulting in an irreversible loss of 0.42 km^2 and a reversible loss of 6.79 km^2 within the Browse Development Area. The wells are expected to be located in proximity to each drill centre and therefore these estimates are considered to be conservative as the impacted areas will likely overlap.

6.3.15.7 Impact and Risk Assessment Summary and Acceptability Assessment

A summary of the impact and risk assessments for drilling or completions discharges is provided in Table 6-122 and Table 6-123. The acceptability assessment is provided in Table 6-124.

Table 6-122 Impact assessment summary and adopted controls – drilling or completions discharges

Receptor (sensitivity)	Potential Impact	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
Sediment quality (medium value (open waters)	Change in sediment quality	**Objective 1:** To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **Objective 2:** To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.	*Development drilling operations* + The number of wells will be optimised to meet hydrocarbon recovery objectives and operational requirements and thereby reduce unnecessary use of drilling fluids and generation of drill cuttings. + For technical, operational and environmental reasons NWBFs will be selected in accordance with Woodside's chemical selection and assessment processes. + Risers will be used to ensure that NWBF and associated cuttings are recirculated to the MODU, where cuttings will be treated prior to discharge. + There will be no discharge of unused NWBF at sea during drilling and completion operations. + Drill cuttings will be tested to confirm that the average oil on cuttings for the entire well (sections using NWBF) will not exceed 6.9% by wet weight.	Minor	Minor (D)
Water quality (medium value (open waters).	Change in water quality	**Objective 3:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		Slight	Slight (E)
Plankton (low value (open water))	Injury or mortality to fauna	**Objective 7:** To not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution.		No lasting effect	Negligible (F)
Shallow water benthic communities and habitats (<75 m depth) (high value habitat)	Change in habitat and Injury or mortality to fauna	**Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry).		No impact expected	
Deepwater benthic communities and habitats (>75 m depth) – (medium value)		**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.		Slight	Slight (E)
Fish (high value species)	Injury or mortality to fauna	**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population.		No lasting effect	Slight (E)
Marine turtles (high value species)	Injury or mortality to fauna	**Objective 15:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population.		No lasting effect	Slight (E)
Marine mammals (high value species)	Injury or mortality to fauna	**Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.		No lasting effect	Slight (E)

Receptor (sensitivity)	Potential Impact	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
KEFs (medium value)	Change in water quality, Change in sediment quality and Injury or mortality to fauna	**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.		No lasting effect	Negligible (F)
Other protected places (high value)	Change in water quality and change in sediment quality	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No impact expected	
Managed fisheries (high value user)	Changes to the functions, interests or activities of other users	**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No lasting effect	Slight (E)
Other users including tourism and recreation and scientific studies (high value users)	Changes to the functions, interests or activities of other users	**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No lasting effect	Slight (E)
Aboriginal or indigenous heritage (high value users)	Changes to the function interests or activities of other users	**Objective 19:** To not have a substantial adverse impact on heritage values.1 **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No lasting effect	Slight (E)

Table 6-123 Risk assessment summary and adopted controls – drilling or completions discharges

Receptor	Risk Event	Environmental objective	Adopted controls	Consequence	Likelihood	Risk Rating
Sediment quality (low value (open waters)	Dispersal of drilling discharges greater than predicted resulting in impacts to Scott Reef shallow water benthic habitat (<75 m bathymetry).	**Objective 1:** To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **Objective 2:** To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.	Drilling or completions discharges (in particular, bottom hole discharges) at drill centre locations in the State Proposal Area (i.e. TRA, TRD, TRE and TRF) will be managed in such a manner to avoid impacts to Scott Reef shallow water benthic communities and habitats (<75 m water depth) (see **Management approach - Torosa** wells in the State Proposal Area).	No increase to significance/consequence		
Water quality (low value (open waters).		**Objective 3:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		No increase to significance/consequence		
Plankton (low value (open water))		**Objective 7:** To not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution.		No increase to significance/consequence		
Fish (high value species)		**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **Objective 15:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.		No increase to significance/consequence		
Marine turtles (high value species)				No increase to significance/consequence		
Marine mammals (high value species)				No increase to significance/consequence		
Benthic habitat (Scott Reef) – (high value habitat)		**Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry).		Minor	Highly unlikely	Moderate (D1)
Benthic habitat (epifauna and Infauna) (low value habitat)		**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.		No increase to significance/consequence		
KEFs - high value		**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.		No increase to significance/consequence		
Other protected places - high value		**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No increase to significance/consequence		
State and Commonwealth managed fisheries (high value marine user)		**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No increase to significance/consequence		

Receptor	Risk Event	Environmental objective	Adopted controls	Consequence	Likelihood	Risk Rating
Other users (scientific studies, tourism and recreation) - High value users		**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No increase to significance/consequence		
Aboriginal or indigenous heritage (high value users)		**Objective 19:** To not have a substantial adverse impact on heritage values.1 **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No increase to significance/consequence		

Table 6-124 Acceptability assessment – drilling or completions discharges

Acceptability Assessment
Confidence in assessment Woodside has a high level of certainty with respect to the assessment of the potential impacts and risks associated with drilling or completions discharges as: + Surveys have characterised the deepwater benthic communities and habitats that may potentially be impacted by the drilling or completions discharges as sparse and well represented both in the Project Area and regionally. + The proposed controls are standard controls widely employed in industry and proven to mitigate the potential impacts and risks effectively. + Woodside has committed to manage drilling or completions discharges (in particular bottom-hole section discharges) at drill centre locations in the State Proposal Area (i.e. TRA, TRD, TRE and TRF) in such a manner that no impacts to Scott Reef shallow water benthic communities and habitats (<75 m water depth) will occur. This management approach is further described **Section 6.3.15.2**.
Principals of ESD With the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such it is considered that the principles of ESD will be met. **Conclusion: Acceptable**
Significant impacts as defined by the MNES Significant Impact Guidelines *Listed threated species and ecological communities / listed migratory species* As described in **Table 6-122**, no lasting effect is predicted to occur from the drilling or completions discharges to listed threatened and migratory species such as fish, marine turtles and marine mammals, with the impact significance level determined to be Slight (E). As described in **Table 6-123**, potential risk events associated with drilling or completions discharges are not predicted to increase the significance/consequence of impacts to listed threatened and migratory species. Given this, with the application of the proposed controls it is predicted that the nominated environmental objectives for each of these fauna species will be achieved. As such, no significant impacts to the listed threated or migratory species (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted. *Commonwealth Marine Environment* As described in **Table 6-122**, no lasting effect is predicted to occur from the drilling or completions discharges to plankton, and KEFs with the impact assessed as Negligible (F). Slight (E) impacts may potentially occur to water quality, deepwater benthic communities and habitats (>75 m depth), marine fauna, managed fisheries and other users. The planned management approach aims to avoid impacts to shallow water benthic communities and habitats (<75 m depth) and other protected places. As described in **Table 6-123**, potential risk events associated with drilling or completions discharges present a Moderate risk to shallow water benthic communities and habitats (<75 m depth). As such, with the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such no significant impacts to the Commonwealth marine environmental (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted. **Conclusion: Acceptable**

Acceptability Assessment

WA EPA Environmental Objectives

Marine environmental quality

As described in **Table 6-122**, the potential impact from drilling or completions discharges to plankton has been assessed as Negligible (F). Slight (E) impacts may potentially occur to water quality, while Minor (D) impacts may occur to sediment quality.

As described in **Table 6-123**, potential risk events associated with drilling or completions discharges is not predicted increased the significance/consequence of impacts to plankton, sediment quality or water quality.

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*to maintain the quality of water, sediment and biota so that environmental values are protected*" will be achieved.

Marine Fauna

As described in **Table 6-122**, no lasting effect is predicted to occur as a result of drilling or completions drilling discharges to marine fauna such as fish, marine turtle and marine mammals, with the impact significance level determined to be Slight (E).

As described in **Table 6-123**, potential risk events associated with the drilling or completions discharges are not predicted increased the significance/consequence of impacts to marine fauna species.

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*To protect marine fauna so that biological diversity and ecological integrity are maintained*" will be achieved.

Benthic communities and habitats

As described in **Table 6-122**, a Slight (E) impact is predicted to occur as a result of drilling or completions discharges to deepwater benthic communities and habitats (>75 m depth). The planned management approach will ensure that no impacts will occur to shallow water benthic communities and habitats (<75 m depth).

As described in **Table 6-123**, potential risk events associated drilling or completions discharges present a Moderate risk to shallow water benthic communities and habitats (<75 m depth).

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*to protect benthic communities and habitats so that biological diversity and ecological integrity are maintained*" will be achieved.

Conclusion: Acceptable

External context

To date there have been no specific matters raised by stakeholders regarding drilling or completions discharges in relation to the proposed Browse to NWS Project.

Conclusion: Acceptable

Internal context

This impact and risk assessment has been undertaken in accordance with Woodside's Risk Assessment Procedure and Environment Impact Assessment Guideline (**Section 6.2**) The proposed Browse to NWS Project will be executed in accordance with Woodside's Health, Safety and Environmental Management System.

Chemicals that may be operationally released or discharged to the marine environment must be subject to Woodside's chemical selection and assessment process and approved prior to use. Woodside will implement its internal requirement that states that Chemicals must be selected with the lowest practicable environmental impacts and risks subject to technical constraints.

Conclusion: Acceptable

Acceptability Assessment
Other requirements
EPBC Act recovery and conservation plans and advices
As detailed in Table 6-120, the proposed activities are considered to be not inconsistent with the objectives and actions of:
+ Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a) + The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) + Conservation management plan for the Blue Whale (Commonwealth of Australia, 2015c) + Conservation advice *Megaptera novaeangliae*, Humpback Whale (Threatened Species Scientific Committee, 2015b) + Conservation advice *Balaenoptera borealis*, Sei Whale (Threatened Species Scientific Committee, 2015c) + Conservation advice *Balaenoptera physalus*, Fin Whale (Threatened Species Scientific Committee, 2015d).
KEFs
As detailed in Table 6-121 proposed drill cuttings and fluid discharge will not materially increase existing relevant pressures on the conservation values of KEFs.
Other protected places
No impacts are expected to occur to the to the values of the Scott Reef and Surrounds Commonwealth Heritage Place.
Conclusion: Acceptable

6.3.16 Marine Discharges: Subsea Control Fluid

6.3.16.1 Impact and Risk Overview

Table 6-125 presents an overview of the potential impacts and risks from subsea control fluid discharges associated with the proposed Browse to NWS Project.

Table 6-125 Marine discharges: subsea control fluid impact and risk overview

Aspect	Marine discharges: subsea control fluid
Description	Subsea control fluids are used on control systems of: + valves on the subsea manifolds + valves on the Christmas tree at the wellheads + valves on the BOP during drilling + valves on ROVs during construction and maintenance activities. Control systems that are under consideration include open (industry standard) and a hybrid system that will be configured such that it can operate in closed loop mode when the spare injection line is not required.
Area	Project Area, Browse Development Area, State Proposal Area
Project stage	All - drilling and completions, installation, commissioning, operations and decommissioning
Environmental objectives	The environmental objectives in relation to subsea control fluid associated with the proposed Browse to NWS Project are Objectives 1, 2, 3, 6, 7, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19 and 20. These objectives are detailed in Table 6-7.

Aspect	Marine discharges: subsea control fluid		
Policy and guidelines	The following policy and guidelines are relevant to the assessment of this aspect. In addition, a number of EPBC Act conservation advices for protected fauna have been considered (**Table 6-126**). + Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018) + WA EPA Environmental Factor Guideline - Marine Environmental Quality (EPA, 2016e). + WA EPA Technical Guidance – Protecting the Quality of Western Australia's Marine Environment (EPA, 2016b) + Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) + Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c) + Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).		

Receptors	The following receptors have been identified as potentially being impacted as a result of the proposed Browse to NWS Project (**Table 6-2**). A detailed description of each of these receptors is provided in **Chapter 5**.
	Physical
	+ sediment quality (medium value (open waters))
	+ water quality (medium value (open waters))
	Ecological
	+ plankton (low value (open water))
	+ benthic habitats:
	  + shallow water benthic communities and habitats (<75 m depth) (high value habitat)
	  + deepwater communities and habitats (>75 m depth) (medium value habitat
	+ marine fauna
	  + fish (high value species)
	  + marine mammals (high value species)
	  + marine reptiles (high value species)
	+ KEFs (medium value)
	+ AMPs (medium value)
	Socio-economic
	+ Commonwealth and state managed fisheries (high value user)		

Potential impacts	+ change in water quality + change in sediment quality + injury or mortality to marine fauna + changes to the function interests or activities of others		
Risk	+ Unplanned discharge at a volume significantly greater than predicted		
Summary of governing impact evaluation	***Magnitude***	***Impact significance level***	***Confidence***
	Slight	Slight (E)	High
Summary of governing risk evaluation	***Consequence***	***Likelihood***	***Risk rating***
	Slight	Remote	Low (E0)

6.3.16.2 Source of Aspect

Potential impacts associated with the discharge of subsea control fluid will be generated from the following subsea sources:

- valves on the subsea manifolds
- valves on the christmas tree at the wellheads
- valves on the BOP during drilling
- valves on ROVs during construction and maintenance activities.

The subsea hydraulic control system has high pressure (HP) and low pressure (LP) circuits. The HP system operates the downhole safety valve and the LP system operates all other subsea valves. An open loop subsea control system will be adopted for the HP control systems, whereby the control fluid is pressurised on the FPSO facilities by the hydraulic accumulators and delivered to subsea valves via umbilicals. For the LP control system, a hybrid solution will be used.

Control fluids are sourced from proprietary suppliers and are composed of low toxicity water-based fluids. The specific control fluid has not yet been selected; however, such fluids are typically water based with additives such as MEG (usually about 40% of the total volume), lubricants, corrosion inhibitors, biocides and surfactants.

The open loop HP hydraulic system will discharge a small amount (0.1 L) when testing or operating the downhole safety valve. The release will be at the wellhead subsea control module, typically at 350 m water depth or greater. The hybrid LP hydraulic system utilizes a contingency injection line in the umbilical in order to achieve a closed loop configuration. This hybrid system has no planned discharges and will only release hydraulic fluid if the system leaks or the contingency injection line is required due to failure of the primary. Drill centres will be placed in deep water, away from Scott Reef shallow water benthic habitat (<75 m bathymetry) (wells are laterally deviated to reach reservoir targets under Scott Reef) which will inherently reduce the risk of impacts occurring to the Scott Reef system.

During drilling activities, control fluids will be discharged during function and pressure testing of the BOP control system. The maximum volume of control fluid that will be released to the marine environment per manifold is 1,900 l per year of water-based fluid containing about ~3% active ingredient (i.e. 40–68 L of control fluid additive).

6.3.16.3 Environmental Impact

Water quality

Change in water quality

Given the small volumes and solubility of the proposed water-based discharges, it is anticipated the fluids would be rapidly diluted (within tens of metres) in the prevailing currents adjacent to the discharge location on the seabed. The intermittent discharge of small volumes of subsea control fluid may result in a reduction in water quality that will be temporary (limited to the duration of the activity), restricted to deep water and subject to rapid dispersion and dilution by prevailing currents, due to the open oceanic waters. Given this and the sparse nature of the deepwater benthic habitats within the Project Area, no impacts to biota are predicted. Further, given the distance from the subsea infrastructure to Scott Reef and the depth of the discharge, this reduction in water quality is not expected to result in any lasting impacts to the environmental values within the including the Scott Reef system.

Sediment quality

Change in sediment quality

Given the expected rapid dispersion and dilution by prevailing currents, discharged subsea fluid is not predicted to accumulate in sediments and as such no lasting change to sediment quality is predicted.

Plankton

Injury or mortality to fauna

Given the minimum water depth at potential discharge locations (i.e. 125 m at the NRC tie-in and greater than 350 m in the Browse Development Area), and the expected rapid dispersion and dilution by prevailing currents, exposure of plankton to the discharge is predicted to be negligible. In addition, the wide spread nature and rapid turn-over of plankton populations leading to relatively quick recovery times, ensures that any impact on local communities would be expected to recover relatively quickly (within weeks or months) (ITOPF, 2011).

Benthic habitats

Change in water quality

As described above, the intermittent discharge of small volumes of subsea control fluid may result in a change in water quality that will be temporary (limited to the duration of the activity), restricted to deepwater (i.e. not affecting Scott Reef benthic communities or habitats) and subject to rapid dispersion and dilution by prevailing currents, due to the open oceanic waters of the Project Area including the State Proposal Area. While benthic biota associated with the deep-water habitats of the Project Area may come into contact with these discharges, given that the discharges will disperse rapidly close to the discharge point and that any contact with the discharge with benthic biota will be of extremely short duration, it is not considered credible that toxic affects to benthic biota will occur as a result of the discharge of subsea fluids. It should be noted that at the depths where the subsea control fluid discharges will occur, benthic fauna has been demonstrated (See Section 5.3) to be sparse with no sensitive communities recorded.

Given the highly localised nature of the reduction in water quality, and the depth at which the discharges of subsea control fluids would occur, no impact to Scott Reef shallow water benthic habitat (<75 m bathymetry) are predicted.

Marine fauna

Injury or mortality to fauna – fish, marine turtles, marine mammals

Given the low toxicity, the volume and the location of the discharges (at the seabed in water depths exceeding 125 m at the NRC tie in point and 350 m in the Browse Development Area), it is not considered credible that impacts to marine fauna such as fish, marine turtles or marine mammals will occur as a result of the discharge of subsea control fluids within the Project Area.

Assessment against EPBC Act recovery and conservation plans and advices

Table 6-126 provides an assessment of the discharge of subsea control fluids from the proposed activities in relation to objectives and actions of the relevant EPBC Act recovery and conservation plans and advices

Table 6-126 Alignment with EPBC Act recovery and conservation plans and advices for protected fauna – subsea control fluid discharge

Fauna	Relevant plan(s)/ conservation advice	Plan/advice objectives and actions	Assessment
Whale shark	Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a)	Assess the impacts of offshore installations and associated environmental changes (light spill, chronic noise, changed water temperature, localised nutrient levels) on whale sharks and mitigation options for these impacts.	Given the depth of the proposed discharges and the expected rapid dispersion of the subsea fluid, (and the low numbers and infrequent nature of whale shark presence in the Project Area), there is a high level of confidence that subsea control fluid discharges will not result in adverse impact to whale sharks.
Green turtle Hawksbill turtle	The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a)	Management actions: + Manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to the survival. + Manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue. + In relation to the Scott Reef – Browse Island green turtle genetic stock, the priority action is to manage anthropogenic activities to ensure marine turtle are not displaced from identified habitat critical to their survival.	Impacts to turtles have been assessed and will be managed in accordance with the Recovery Plan for Marine Turtles in Australia (2017-2027) which includes the minimisation of chemical discharge as an overarching action area (Commonwealth of Australia, 2017a). Given the depth of the proposed discharges and that the change in water quality will be highly localised and temporary, the discharge of subsea control fluid is not expected to have significant impacts on marine turtles. Therefore, there is a high level of confidence that any impacts will not compromise the long-term recovery objectives for marine turtles or result in the displacement of the Scott Reef – Browse Island green turtle genetic stock, from identified habitat critical to their survival, or adversely affect the breeding cycle of marine turtles in the BIA at Scott Reef. Therefore, it is considered that the proposed activities are not inconsistent with the objectives of the Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a).

Fauna	Relevant plan(s)/ conservation advice	Plan/advice objectives and actions	Assessment
Pygmy blue whale	Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c)	Acute chemical discharge (oil or condensate spill) pollution is identified as a potential risk to pygmy blue whales, however there are no specific actions identified.	Given the depth of the discharges and that change in water quality will be highly localised and temporary, subsea control fluid discharges are not expected to have any lasting impacts on the listed whale species. It is therefore considered that the proposed activities are not inconsistent with the Conservation Management Plan for the Blue Whale or the conservation advices listed.
Humpback whale	Conservation advice *Megaptera novaeangliae*, Humpback Whale	Marine discharges have not been identified as a direct threat to these whale species; however, habitat degradation has been identified as a threat and unmanaged discharges may contribute to this threat. The conservation advice relevant for this threat – identifies modification to the coastal region in areas of importance to listed whales may result in reduced occupancy, compromised reproductive success and even mortality.	
Sei whale	Conservation advice *Balaenoptera borealis*, Sei Whale		
Fin whale	Conservation advice *Balaenoptera physalus*, Fin Whale		

Key Ecological Features

Injury or mortality to fauna, change in sediment quality and change in water quality

The Continental slope demersal fish communities KEF and Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEFs overlap with the Browse Development Area. Subsea fluid discharges will occur within these KEFs from the subsea infrastructure and ROVs during construction and IMR activities. The BTL traverses the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF (depending on the final BTL route) and the Ancient coastline at 125 m depth contour KEF. Subsea fluid discharges will occur within these KEFs from ROVs during construction and IMR activities. The conservation values of these KEFs are described in **Section 5.3.3.1**.

As described above, changes to sediment quality and water quality as a result of subsea fluid discharges are predicted to be temporary and highly localised. Likewise, no lasting impacts to marine fauna are predicted. As such no lasting impacts to the conservation values of these KEFs is predicted. No impact is predicted to the reefs associated with the Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEF.

Table 6-127 provides an assessment of the proposed discharge of subsea control fluids in relation to the pressures on KEFs identified in the Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).

Table 6-127 Alignment with protection of conservation values of KEFs – subsea control fluids

Key Ecological Feature	Relevant plan(s)	Relevant pressures	Assessment
Continental slope demersal fish communities	Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).	Chemical pollution / contaminants - currently identified as 'not of concern'	Given the depth of the discharges and that change in water quality will be highly localised and temporary, subsea control fluid discharges are not expected to have any significant impacts on the conservation values of these KEFs.
Seringapatam Reef and Commonwealth waters in the Scott Reef Complex			
Ancient coastline at 125 m depth contour			
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals		Chemical pollution / contaminants - currently identified as 'data deficient or not assessed	

Australian Marine Parks

Change in sediment quality, change in water quality

ROV operations associated with the installation of the BTL and IMR activities will discharge subsea control fluids within the Multiple Use Zones (IV) of the Argo-Rowley Terrace and Kimberley AMPs. The Marine Bioregional Plan for the North West Marine Region recognises that fauna and ecosystems may be vulnerable to marine discharges that include chemicals and toxins (Director of National Parks, 2018).

As described above, it is expected that discharges will disperse in very close proximity to the discharge point. Given this, it is considered that the identified conservation values of these AMPs will not be adversely impacted by subsea fluid discharges.

Table 6-128 provides an assessment of the proposed discharge of subsea control fluids in consideration of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018).

Other users

Changes to the functions, interests or activities of other users – State and Commonwealth managed fisheries

Where the functions, interests or activities of other users involve marine fauna (e.g. fisheries), any effect to fauna presence or abundance will indirectly impact on the functions, interests or activities of other users. Given that no adverse impacts to fish from subsea control fluid discharge have been predicted, subsequent impact to fisheries is also not predicted.

6.3.16.4 Environmental Risk

Risk Event: Unplanned discharge at a volume significantly greater than predicted

Though unlikely, discharges of subsea control fluid at volumes significantly larger than expected resulting from human error or equipment failure may occur. This would potentially result in a larger area being impacted. As per Section 6.3.16.3 it would remain unlikely that exposure to marine fauna would be sufficient to elicit a toxic response. As such no change to the significance of the impact to water quality, sediment quality, marine fauna, KEFs or managed fisheries would be expected.

If the discharge of subsea control fluid at volumes significantly greater than expected occurs at well locations near Scott Reef at a time where the prevailing conditions result in the discharge moving towards Scott Reef, there is a risk of resultant impacts to the benthic habitats of Scott Reef. This impact would not be expected to be significant due to its temporary and localised nature.

6.3.16.5 Cumulative Impacts

Cumulative impacts associated with the discharge of subsea control fluid from the proposed Browse to NWS Project, and other projects within the broader Browse Basin (i.e. Prelude and Ichthys) are not expected, given the geographic spread of the facilities and highly localised area where the intermittent reduction in water quality will occur.

Table 6-128 Alignment with the North-west Marine Parks Network Management Plan – subsea control fluid discharge

Australia Marine Park	Relevant plan(s)	Australian Marine Park Objectives	Assessment
Argo-Rowley Terrace Marine Park Multi Use Zone (VI) Kimberley Marine Park Multi Use Zone (VI)	North-west Marine Parks Network Management Plan (Director of National Parks, 2018)	The objective of the Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species.	Subsea fluid discharges from ROVs operating within these AMPs will be of a small volume, temporary and transient in nature and therefore unlikely to impact marine fauna or benthic habitats in these AMPs. Therefore, there is a high level of confidence that such discharges will not result in any adverse impacts to marine ecosystems, habitats or native species such that the conservation values of the AMPs would be reduced. As such, it is considered that the proposed activities are not inconsistent with the requirements of the North-west Marine Parks Network Management (Director of National Parks, 2018).
Mermaid Reef Marine Park National Park Zone (II)		The objective of the National Park Zone (II) is to provide for the protection and conservation of ecosystems, habitats and native species in as natural a state as possible.	The proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park. As such, discharges associated with the installation of the BTL and occasional IMR activities are not considered a credible source of impact and no effect on ecosystems, habitats or native species in the AMP is predicted. As such, it is considered that the proposed activities are not inconsistent with the requirements of the North-west Marine Parks Network Management (Director of National Parks, 2018).

6.3.16.6 Impact and Risk Assessment Summary and Acceptability Assessment

A summary of the impact and risk assessment for the discharge of subsea control fluids is provided in Table 6-129 and Table 6-130. The acceptability assessment is provided in Table 6-131.

Table 6-129 Impact assessment summary and adopted controls – subsea control fluids

Receptor (sensitivity)	Impact	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
Water quality (medium value (open water))	Change in water quality	**Objective 3:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	*Subsea control fluid discharges* + No infrastructure will be placed on Scott Reef shallow water benthic communities and habitat (<75 m bathymetry). + Chemicals that may be operationally released or discharged to the marine environment will be subject to Woodside's chemical selection and assessment process and approved prior to use. + For the subsea LP control system, a hybrid solution in closed loop configuration will be used which returns fluids to the FPSOs and minimises discharges. The system will revert to an open loop system if the return lines to the FPSOs are no longer available to support the LP hydraulic system.	Slight	Slight (E)
Sediment quality (medium value (open water))	Change in sediment quality	**Objective 1:** To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **Objective 2:** To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.		Slight	Slight (E)
Plankton (medium value (open water))	Injury or mortality to marine fauna	**Objective 7:** To not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution		No lasting effect	Negligible (F)
Shallow water benthic communities and habitats (<75 m depth) (high value habitat)	Change in water quality	**Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry).		No impact expected	
Deepwater benthic communities and habitats (>75 m depth) – (medium value)	Change in water quality	**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.		No lasting effect	Negligible (F)

Receptor (sensitivity)	Impact	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
Fish (high value species)	Injury or mortality to marine fauna	**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **Objective 15:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.		No lasting effect	Slight (E)
Marine turtles (high value species)				No lasting effect	Slight (E)
Marine mammals (high value species)				No lasting effect	Slight (E)
KEFs (medium value)	Change in water quality Change in sediment quality Injury or mortality to fauna	**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.		No lasting effect	Negligible (F)
AMPs (medium value)	Change in water quality Change in sediment quality	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No lasting effect	Negligible (F)
State and Commonwealth managed fisheries (high value marine user)	Changes to the function interests or activities of others	**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No lasting effect	Slight (E)

Table 6-130 Risk assessment summary and adopted controls – Subsea Control Fluids

Receptor	Risk Event	Environmental objective	Adopted controls	Consequence	Likelihood	Risk Rating
Water quality (medium value (open water))	Unplanned discharge at a volume significantly greater than predicted	**Objective 3:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. For chronic discharges 99% species protection levels (or equivalent) will be met by the edge of the modelled mixing zone.	No further controls (in addition to those described in Table 6-129 adopted.)	No increase to significance/consequence		
Sediment quality (medium value (open water))		**Objective 1:** To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **Objective 2:** To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.		No increase to significance/consequence		
Plankton (medium value (open water))		**Objective 7:** To not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution		No increase to significance/consequence		

Receptor	Risk Event	Environmental objective	Adopted controls	Consequence	Likelihood	Risk Rating
Shallow water benthic communities and habitats (<75 m depth) (high value habitat)		**Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry).		Slight	Remote	Low (E0)
Deepwater benthic communities and habitats (>75 m depth) – (medium value)		**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.		No increase to significance/consequence		
Fish (high value species)		**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **Objective 15:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.		No increase to significance/consequence		
Marine turtles (high value species)				No increase to significance/consequence		
Marine mammals (high value species)				No increase to significance/consequence		
KEFs (medium value)		**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.		No increase to significance/consequence		
AMPs (medium value)		**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No increase to significance/consequence		
State and Commonwealth managed fisheries (high value marine user)		**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No increase to significance/consequence		

Table 6-131 Acceptability assessment – subsea control fluids

Acceptability Assessment
Confidence in assessment Woodside have a high level of certainty with respect to the assessment of the potential impacts and risks associated with the discharge of subsea control fluids as: + Given the small volumes and solubility of the proposed water-based discharges, it is anticipated that the fluids would be rapidly diluted in the prevailing currents. + The proposed controls are standard controls widely employed in industry and proven to mitigate the potential impacts and risks effectively.
Principles of ESD With the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such it is considered that the principles of ESD will be met. **Conclusion: Acceptable**
Significant impacts as defined by the MNES Significant Impact Guidelines *Listed threated species and ecological communities / listed migratory species* As described in **Table 6-129**, no lasting effect is predicted to occur from the discharge of subsea control fluids to listed threatened and migratory species such as fish, marine turtle and marine mammals, with the impact significance level determined to be Slight (E). As described in **Table 6-130**, potential risk events associated with the discharge of subsea control fluids are not predicted increased the significance/consequence of impacts to listed threatened and migratory species. Given this, with the application of the proposed controls it is predicted that the nominated environmental objectives for each of these fauna species will be achieved. As such, no significant impacts to the listed threated or migratory species (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted. *Commonwealth Marine Environment* As described in **Table 6-129**, the potential impact from the discharge of subsea control fluids to plankton, deepwater benthic communities and habitats (>75 m depth), KEFs and AMPs has been assessed as Negligible (F). Slight (E) impacts may potentially occur to sediment quality, water quality, marine fauna and managed fisheries, while no impact is predicted to occur to shallow water benthic communities and habitats (<75 m depth). As described in **Table 6-130**, potential risk events associated with the discharge of subsea control fluids present a Low risk to shallow water benthic communities and habitats (<75 m depth). Given this, with the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such no significant impacts to the Commonwealth marine environmental (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted. **Conclusion: Acceptable**

Acceptability Assessment

WA EPA Environmental Objectives

An assessment of the impacts of subsea control fluid against the WA EPA Objective is presented in the State Proposal ERD (**Chapter 10, Appendix B**).

Marine environmental quality

As described in **Table 6-129**, the potential impact from the discharge of subsea control fluids to plankton and deepwater benthic communities and habitats (>75 m depth) has been assessed as Negligible (F). Slight (E) impacts may potentially occur to sediment quality, water quality and marine fauna, while no impact is predicted to occur to shallow water benthic communities and habitats (<75 m depth).

As described in **Table 6-130**, potential risk events associated with the discharge of subsea control fluids present a Low risk to shallow water benthic communities and habitats (<75 m depth).

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*to maintain the quality of water, sediment and biota so that environmental values are protected*" will be achieved.

Marine Fauna

As described in **Table 6-129**, no lasting effect is predicted to occur from the discharge of subsea control fluids to marine fauna species such as fish, marine turtle and marine mammals, with the impact significance level determined to be Slight (E).

As described in **Table 6-130**, potential risk events associated with the discharge of subsea control fluids are not predicted increased the significance/consequence of impacts to marine fauna.

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*To protect marine fauna so that biological diversity and ecological integrity are maintained.*" will be achieved.

Benthic communities and habitats

Commonwealth Marine Environment

As described in **Table 6-129**, the potential impact from the discharge of subsea control fluids to deepwater benthic communities and habitats (>75 m depth) has been assessed as Negligible (F), while no impact is predicted to occur to shallow water benthic communities and habitats (<75 m depth).

As described in **Table 6-130**, potential risk events associated with the discharge of subsea control fluids present a Low risk to shallow water benthic communities and habitats (<75 m depth).

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*to protect benthic communities and habitats so that biological diversity and ecological integrity are maintained*" will be achieved.

Conclusion: Acceptable

External Context

To date there have been no specific matters raised by stakeholders regarding discharge of subsea control fluids in relation to the proposed Browse to NWS Project.

Conclusion: Acceptable

Internal Context

This impact and risk assessment has been undertaken in accordance with Woodside's Risk Assessment Procedure and Environment Impact Assessment Guideline (**Section 6.2**) The proposed Browse to NWS Project will be executed in accordance with Woodside's Health, Safety and Environmental Management System.

Chemicals that may be operationally released or discharged to the marine environment must be subject to Woodside's chemical selection and assessment process, and approved prior to use. Woodside will implement its internal requirement that states that Chemicals must be selected with the lowest practicable environmental impacts and risks subject to technical constraints.

Conclusion: Acceptable

Acceptability Assessment
Other Requirements
EPBC Act recovery and conservation plans and advices
As detailed in Table 6-126, the proposed activities are considered to be not inconsistent with the actions and objectives of: + Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a) + The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) + Conservation management plan for the Blue Whale (Commonwealth of Australia, 2015c) + Conservation advice *Megaptera novaeangliae*, Humpback Whale (Threatened Species Scientific Committee, 2015b) + Conservation advice *Balaenoptera borealis*, Sei Whale (Threatened Species Scientific Committee, 2015c) + Conservation advice *Balaenoptera physalus*, Fin Whale (Threatened Species Scientific Committee, 2015d).
KEFs
+ As detailed in Table 6-127 proposed subsea fluid discharge will not materially increase existing relevant pressures on the conservation values of KEFs.
AMP
+ As detailed in Table 6-128, the proposed activities are considered to be not inconsistent with the requirements of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018).
Conclusion: Acceptable

6.3.17 Marine Discharges: Hydrotest Fluid

6.3.17.1 Impact and Risk Overview

Table 6-132 presents an overview of the potential impacts and risks from hydrotest fluid discharge associated with the physical presence of proposed Browse to NWS Project.

Table 6-132 Marine discharges: hydrotest fluid impact and risk overview

Aspect	Marine discharges: hydrotest fluid
Description	In-situ hydrostatic pressure testing which will be performed following installation of all flowlines, subsea infrastructure and unless dry-commissioning is deemed feasible; the BTL (including existing NWS Project infrastructure (2TL)) and inter-field spur line. This would occur during pre-commissioning, commissioning and during operations as flowlines are installed to accommodate field layout change or repair. Hydrotesting may also be undertaken on the temporary production system on the MODU for the well unloading activities.
Area	Project Area, Browse Development Area, State Proposal Area
Project stage	Pre-commissioning, commissioning and operations
Environmental objectives	The environmental objectives in relation to hydrotest water associated with the proposed Browse to NWS Project are Objectives 1, 2, 3, 6, 7, 9, 10, 12, 13, 14, 15, 16, 17, 18, 20 and 21. These objectives are detailed in Table 6-7.

Aspect	Marine discharges: hydrotest fluid
Policy and guidelines	The following policy and guidelines are relevant to the assessment of this aspect. In addition, a number of EPBC Act conservation advices for protected fauna have been considered. + Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018) + WA EPA Environmental Factor Guideline - Marine Environmental Quality (EPA, 2016e) + WA EPA Technical Guidance – Protecting the Quality of Western Australia's Marine Environment (EPA, 2016b). + DNV-GL Recommended Practice (DNVGL-RP-F115) – Pre-commissioning of submarine pipelines (DNV 2016) + DNV ST F101 Submarine Pipeline Systems + Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) + Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c) + Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012)

Receptors	The following receptors have been identified as potentially being impacted as a result of the proposed Browse to NWS Project (**Table 6-2**). A detailed description of each of these receptors is provided in **Chapter 5**.
	Physical
	+ water quality (medium value (open waters))
	+ sediment quality (medium value (open waters)).
	Ecological
	+ plankton (medium value (open water))
	+ benthic habitats
	  + shallow water benthic communities and habitats (<75 m depth) (high value habitat)
	  + deepwater communities and habitats (>75 m depth) (medium value habitat
	+ Marine fauna
	  + fish (high value species)
	  + marine mammals (high value species)
	  + marine reptiles (high value species)
	+ KEFs (medium value)
	+ other protected places (high value).
	Socio-economic
	+ State and Commonwealth managed fisheries (high value user)
	+ other users
	  + tourism and recreation (high value user)
	  + scientific studies (high value user).

Potential impacts	+ change in water quality + change in sediment quality + injury or mortality to fauna + changes to the functions, interests or activities of other users
Risk	+ There are no anticipated environmental risks in relation to this aspect associated with unplanned incidents or events.

Aspect	**Marine discharges: hydrotest fluid**		
Summary of governing impact evaluation	***Magnitude***	***Impact significance level***	***Confidence***
	No lasting effect	Slight (E)	High
Summary of governing risk evaluation	***Consequence***	***Likelihood***	***Risk rating***
	n/a	n/a	n/a

6.3.17.2 Source of aspect

Hydrotest fluids are used for two distinct purposes; testing of the integrity of the pipeline and flowlines and for preservation of the pipelines and flowlines prior to the introduction of reservoir fluids. Hydrotest fluids may consist of a combination of seawater, biocides, corrosion inhibitors, oxygen scavenger, MEG and fluorescent dye. The period of time the hydrotest fluid is left within the infrastructure as a preservation fluid will depend on the type of fluid selected and the Project schedule for construction and installation activities. If treated water is selected as the hydrotest fluid, it may only be suitable to be left in-situ for a period of approximately 12 to 24 months, after which it is typically discharged at sea and the flowline refilled, if required. If MEG is selected, it is likely that it could be left in-situ for longer, therefore reducing the frequency of discharge to sea.

BTL

Once installation and hook up of the subsea infrastructure and the BTL and inter-field spur line is complete, pre-commissioning (leak testing) to test the integrity of the subsea infrastructure, BTL and the inter-field spur line will occur. Three options for the discharge of hydrotest fluid from the BTL, inter-field spur line and 2TL are being considered as described **Table 6-133** Note that under the base case scenario, the discharge of the BTL will subsequently be followed by the discharge of 2TL, which has an inventory of 110,000 m^3. It is currently planned for these discharges to occur at least six months apart, and therefore have not been modelled as a single scenario. These include:

- Base case - scenario 1 (NRC PLET): 736,000 m^3 hydrotest fluid (BTL and inter-field spur line) is discharged at the NRC PLET location, followed by 110,000 m^3 hydrotest fluid (2TL) at least 6 months later.
- Alternative scenario 2 (Torosa PLET): 846,000 m^3 hydrotest fluid (BTL, inter-field spur line and NWS Project's 2TL) is discharged at the Torosa PLET.
- Alternative scenario 3a / 3b (Brecknock/ Calliance PLET and Torosa PLET): BTL and NWS Project's 2TL hydrotest fluid (790,000 m^3) is discharged at the Calliance/ Brecknock PLET, while the hydrotest fluid from the inter-field spur line (56,000 m^3) is discharged at the Torosa PLET.

Dry pre-commissioning of BTL eliminates the introduction and subsequent discharge of hydrotest water from BTL and inter-field spur line. If dry-commissioning of the BTL and inter-field spur line is deemed feasible, hydrotesting of this infrastructure would not be required.

For the BTL and inter-field spur line, the hydrotest fluids are likely to consist primarily of seawater which is chemically treated at an appropriate concentration (e.g. 600 ppm or similar) with chemicals such as biocides, corrosion inhibitors and oxygen scavenger to prevent corrosion from oxidation and microbial action for the required preservation period and maintain trunkline integrity. In addition, a fluorescein dye will be added to the hydrotest fluid to visually identify leaks during hydrotesting. The combination of hydrotest fluid constituents for the BTL depends on the trunkline material type and the required preservation period.

For comparison, INPEX's Ichthys Development required a total of approximately 1,000,000 m^3 of treated seawater for the hydrotesting and preservation of the 890 km gas export pipeline (INPEX 2010).

SURF infrastructure

For the SURF infrastructure, the flowline and riser hydrotest fluid will most likely be returned to the FPSO facility and then discharged to sea in Commonwealth waters. However, discharge may occur in deep water at the manifolds or riser base FLETS for rigid flowlines.

For flowlines where the manifold is in the State Proposal Area, discharge will occur at the FPSO location (either from the FPSO or from the riser base FLETS) in order to maximise distance of the discharge from Scott Reef. However, for flowlines which are terminated at both ends within the State Proposal Area (specifically for TRE and TRF manifolds only), discharge of flowline hydrotest fluid in the State Proposal Area may be unavoidable. Given that the TRE and TRF manifolds are daisy-chain connected to other manifolds in the State Proposal Area and are not part of Torosa Phase 1 RFSU equipment, future engineering will consider the viability of alternatives to flowline hydrotest fluid discharge in the State Proposal Area, which will be described in a future Environment Plans. Minor hydrotest discharges associated with smaller pieces of subsea equipment may also occur in situ.

For the SURF flowlines (including those in the State Proposal Area), hydrotest fluids may consist of chemically treated seawater (as described above for the BTL) or a MEG/water mixture. The combination of constituents for the SURF flowlines are dependent on the flowline material type and on the period of preservation required. [24]

Hydrotest fluid volumes being discharged to the marine environment will vary depending on the flowline section to be tested. Volumes are estimated to be up to approximately 950 m^3 of hydrotest fluid for the TRE flowline and up to approximately 250 m^3 for TRF flowline. A subsea flowline hydrotest discharge is likely to take less than a day to complete. These discharges will occur for each piece of infrastructure during pre-commissioning.

Previous modelling of SURF infrastructure

The size of the mixing zone associated with a hydrotest discharge from flowlines is dependent on the discharge characteristics (e.g. rate, volume, density etc.) and prevailing hydrodynamics. Woodside has previously performed hydrotest modelling for a range of discharge rates (4.8 m^3/min, 3.7 m^3/min, 1.85 m^3/min and 1.5 m^3/min), in water depths ranging from 130 m to 830 m on the North West Shelf, which is considered appropriate to support the impact assessment, in recognition that further hydrotest modelling will completed to support the relevant Environment Plan.

The nearfield dispersion modelling indicated that due to the momentum of the discharges a turbulent mixing zone is created in the immediate vicinity of the discharge points. Following this initial mixing, the negatively-buoyant plumes are predicted to travel laterally in the water column and remain close to the seabed.

The far-field dispersion modelling indicated that based on an in-pipe chemical concentration of 600 ppm, the plume would achieve 600 dilutions to dilute to below 1 ppm (based on LC50 over 96 hours) in proximity to the discharge location, ranging at a distance from 50 m (130 m water depth; 1.5 m^3/min; summer; 95th percentile) to 300 m (844 m water depth; 4.8 m^3/min; summer; 95th percentile) downstream of the discharge point. Given the negative buoyancy of the plume, bathymetry of the location (steep reef slopes surrounding the discharge location), and lack of upwelling processes from the depth of discharge, regardless of the size of the mixing zone the zone of influence will remain restricted to depth and avoid Scott Reef shallow water benthic habitat (<75 m bathymetry).

While the modelling for the planned dewatering discharges are not directly comparable with regards to depth of discharge, the typical density and nearfield mixing profile near the seabed provides a good indication that potential impacts to benthic communities, fish or pelagic invertebrates would be limited and restricted to the deepwater location where the SURF infrastructure is located. Noting the results presented are also conservative as they assume that no processes other than dilution would reduce the source concentrations over time, and therefore can be considered as conservative outcomes.

MODU

The temporary production system on the MODU will be hydrotested for well unloading activities. This will be conducted using hydrotest fluids, whereby the temporary production system on the MODU flowlines will be pressurised with fluids and the pressure will be monitored to detect leaks, prior to discharge of the hydrotest fluids.

Contingency discharge

Contingency discharge of hydrotest fluids during construction (e.g. buckling and leaking of the pipeline during installation) are possible but are a contingent planned activity to be undertaken due to an unplanned event. The requirement for contingency discharge is determined by the technical design specifications and performance criteria of the subsea infrastructure. Should these be compromised (i.e. failed welding joint) various repair strategies will be assessed and a decision made should the contingency be required. The volume of hydrotest fluid that would be discharged in the event of a wet buckle depends on the location, extent and repair method. The worst case scenario would be complete dewatering of the BTL. The planned hydrotest discharge would not occur at the same time as contingency discharge . As such, it is considered that the impacts relating to this contingency activity (as a worst case) are consistent with the below assessment and no cumulative impacts would occur.

Hydrotest fluid toxicity

Due to the proposed chemical additives with the hydrotest fluid (i.e. biocides, corrosion inhibitors, oxygen scavenger, fluorescent dyes and MEG), the discharges have the potential to impact sensitive receptors within the discharge area of influence, primarily through toxicological effects ranging from the inhibition of key biological processes (e.g. reproduction) to mortality. In considering the potential impacts to receptors it should be noted that the activity is planned during commissioning, with no ongoing discharge of hydrotest fluids during the normal operations.

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[24] *While the majority of subsea infrastructure will be flooded with hydrotest fluid post installation, some components will be pre-flooded with hydrotest fluid prior to installation.*

For the purpose of the impact assessment, the hydrotest chemical treatment is assumed to be Hydrosure 0-3670R as a conservative analogue for other chemical treatments. Hydrosure 0-3670R is a proprietary chemical mixture designed for the treatment of water (neutralising bacteria and dissolved oxygen). The chemical contains 10-30% quaternary ammonium chloride as a biocide, along with an oxygen scavenger and corrosion inhibitor. To identify the potential toxicity of the hydrotest fluids following discharge to the marine environment, Chevron Australia Pty Ltd (2015) conducted whole effluent toxicity (WET) testing on Hydrosure 0-3670R (Champion Chemicals Pty Ltd), diluted in seawater. WET testing was undertaken on five locally relevant species from four different taxonomic groups based on ANZECC & ARMCANZ (2000). Since Hydrosure 0-3670R is a mixture containing both the biocide and oxygen scavenger for chemical treatment, only one assay in each test species was necessary to evaluate the toxicity of the product. The results from study established a 99% species protection value of 0.06 mg/L, which was applied in the modelling over a 48-hr rolling median (Chevron Australia Pty Ltd, 2015).

MEG, which may be used in the SURF flowlines, is commonly used as a hydrate inhibitor within oil and gas developments. The chemical itself is clear and colourless, with a low volatility and miscible with water; however, no hydrolysis of the compound is expected in surface waters (WHO, 2000). MEG is listed as 'E' category fluids under the Offshore Chemical Notification Scheme (OCNS) and are listed on the Oslo Paris Commission (OSPAR) PLONOR ('pose little or no risk to the environment') list. In addition, the compound has little or no capacity to bind to particulates and will be mobile in soil (WHO, 2000). Rapid degradation has been reported in surface waters, with a generally low toxicity to aquatic organisms. Direct toxicity testing of neat MEG, on eight, mainly tropical species, representing seven taxonomic groups, established the lowest no observable effect concentration (NOEC) for sea urchin fertilisation of 130 mg/L (Jacobs, 2019). While MEG may result in highly localised, temporary and minor change in water quality in the immediate vicinity of the discharge point, it will dilute rapidly below levels that could cause impacts to marine biota.

Fluorescein dye is typically selected for use as a leak detection dye due to its low toxicity, availability, low cost, water solubility and stability, and ease of detection. In addition, rapid breakdown of fluorescein dye following exposure to sunlight suggests that concentrations likely to be encountered by organisms in the receiving environment would be low (Walthall and Stark, 1999). During discharge the dye may result in a temporary localised discoloration in the immediate vicinity of the discharge point on the seabed; however, as the dye is water soluble, it will rapidly dilute in the marine environment with no anticipated toxicity effects on marine organisms.

Due to the addition of oxygen scavengers within the hydrotest fluid, the discharge will have a lower dissolved oxygen level than the surrounding seawater. However, oxygen levels are anticipated to rapidly achieve background levels soon after discharge with any impacts on the surrounding waters expected to be temporary and highly localised. In addition, as the hydrotest fluid is planned to remain inside the pipelines and infrastructure for several months, the toxicity of residual chemicals will be markedly reduced over time, through natural decay and degradation, further reducing the potential impacts associated with the discharge.

6.3.17.3 BTL and Interfiled Spur Line Hydrotest Modelling

In order to further understand the potential impacts and risks associated with the discharge of hydrotest fluid under the worst case scenario (i.e. dewatering of BTL and inter-field spur line), Woodside commissioned RPS to model the fate and transport of the discharge at various considered locations (RPS, 2019a); Chapter 10, Appendix D.4). Note, discharge of hydrotest fluid from the subsea flowlines will be significantly less volume when compared to the BTL discharge. As such, it is considered that the impact assessment for these discharges are adequately represented by the BTL hydrotest discharge dispersion modelling.

It should be noted that the modelling undertaken to support the assessment of the hydrotest fluid discharges represents the current understanding of the discharge characteristics and is appropriate for the purposes of this risk assessment, in determining acceptability in the context of the receiving environment and relevant receptors. However, as detailed engineering is undertaken through FEED, hydrotest discharge characteristics and engineering design may change, with renewed modelling undertaken, if required, as part of the Environment Plan assessment process.

Modelling scenarios and discharge characteristics

Three discharge options are being assessed for the dewatering of the BTL and inter-field spur line. For the alternative scenarios, hydrotest fluid required within the existing 2TL as part of the change of use of the pipeline would be discharged with the BTL and inter-field spur line fluid and has been taken into account in the modelling and in the assessment, as detailed in Table 6-133.

Table 6-133 Hydrotest fluid discharge characteristics

Scenario	Details	Modelling inputs
Base case - scenario 1 (NRC PLET)	All hydrotest fluid (BTL and inter-field spur line) is discharged at the NRC PLET location.	736,000 m^3 at 117 m water depth over 490 hours. Note this does not include 110,000m^3 from the 2TL, which is discharged at least 6 months later.
Alternative scenario 2 (Torosa PLET)	All hydrotest fluid (BTL, inter-field spur line and NWS Project's 2TL) is discharged at the Torosa PLET.	846,000 m^3 at 461 m over 564 hours.
Alternative scenario 3a / 3b (Brecknock/ Calliance PLET and Torosa PLET)	BTL and NWS Project's 2TL hydrotest fluid is discharged at the Calliance/ Brecknock PLET, while the hydrotest fluid from the inter-field spur line is discharged at the Torosa PLET.	790,000 m^3 at 539 m over 527 hours at Calliance/Brecknock PLET combined with 56,000 m^3 at 461 m over 37 hours at Torosa PLET.
All scenarios	N/A	For all scenarios a continuous discharge flow was assumed to occur through a single outlet at the seabed of 0.2 m diameter at a maximum rate of 25 m^3/min with temperature and salinity equivalent to ambient conditions at the seabed.

Modelling threshold

The source concentration of the proposed chemical treatment was based on Hydrosure 0-3670R as discussed earlier. The results from study established a 99% species protection value of 0.06 mg/L, which was applied in the modelling over a 48-hr rolling median (Chevron Australia Pty Ltd, 2015).

The 99% species protection level concentration is suggested by the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018) for the development of environmental criteria for high conservation ecosystems or chemicals that have a tendency to bioaccumulate. It was assumed that the residual discharge concentration of the chemicals within the fluid is the same as the initial dosing concentration with no degradation or decay during residence within the pipeline. This represents a conservative approach as it likely over represents the residual toxicity of the fluid following discharge.

Modelling studies

To determine the fate, transport and dilution of the hydrotest discharge, both near-field and far-field modelling was undertaken as these are used to describe different processes and scales of effect. The same modelling approach has been used for PW discharge, cooling water discharge and hydrotest discharge; and is described in Section 6.3.12.3.

A three-dimensional, spatially-varying current data set surrounding the NRC, Torosa and Calliance/Brecknock PLET locations for a ten-year (2006-2015) hindcast period were used, with summer, winter and transitional seasons modelled. The data set included the combined influence of drift and tidal currents and was suitably long as to be indicative of interannual variability in ocean currents. The current data set was validated against metocean data collected in the Browse Development Area.

A further description of the modelling approach and hydrodynamic model validation is described in Section 6.3.12.3 and RPS, (2019a) (Chapter 10, Appendix D.4).

Near-field modelling results

The results show that due to the momentum of the discharges a turbulent mixing zone is created in the immediate vicinity of the discharge point for each scenario. Following this initial mixing, the near neutrally-buoyant plume is predicted to travel laterally in the water column (Figure 6-37 to Figure 6-40). Increased ambient current strengths are shown to increase the horizontal distance travelled by the plume from the discharge point. For all combinations of discharge scenario and season, the primary factor influencing dilution of the plume is the strength of the ambient current.

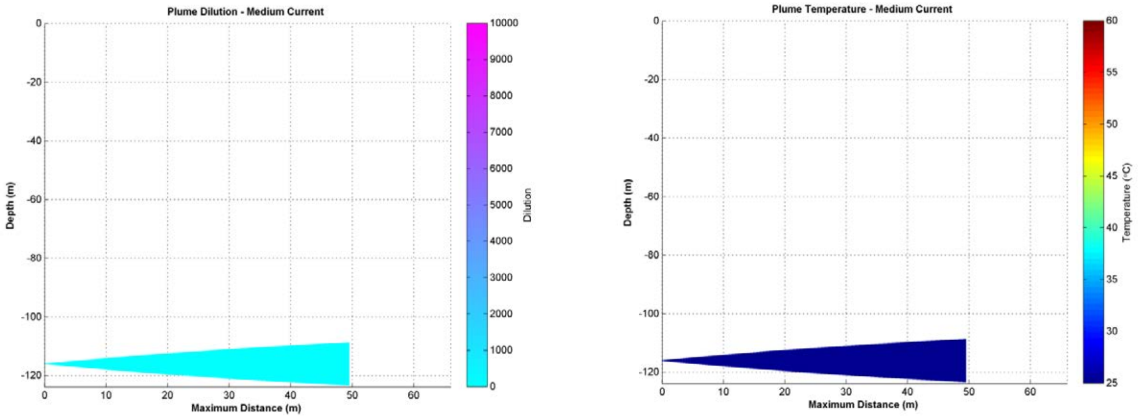

Figure 6-37: Near-field average dilution and temperature results for constant medium annualised currents for Scenario 1 (NRC tie-in 736,000 m³ hydrotest discharge).

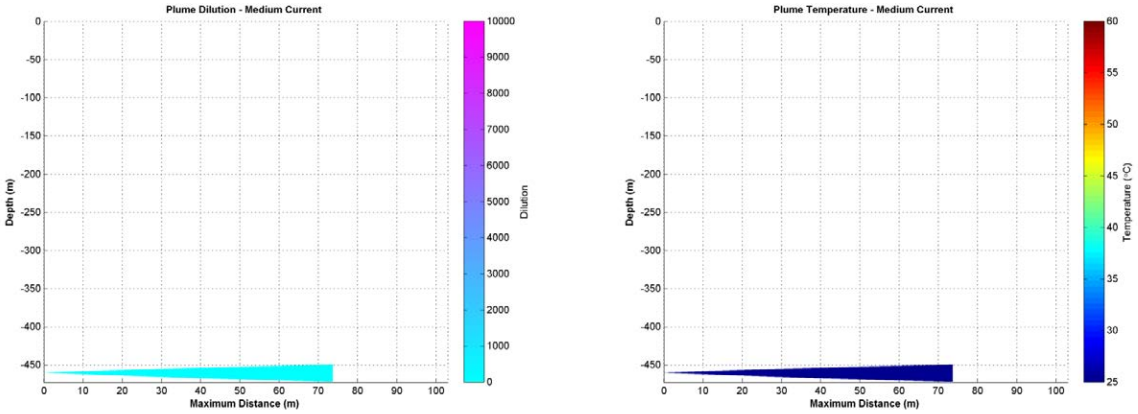

Figure 6-38: Near-field average dilution and temperature results for constant medium annualised currents for Scenario 2 (Torosa 846,000 m³ hydrotest discharge).

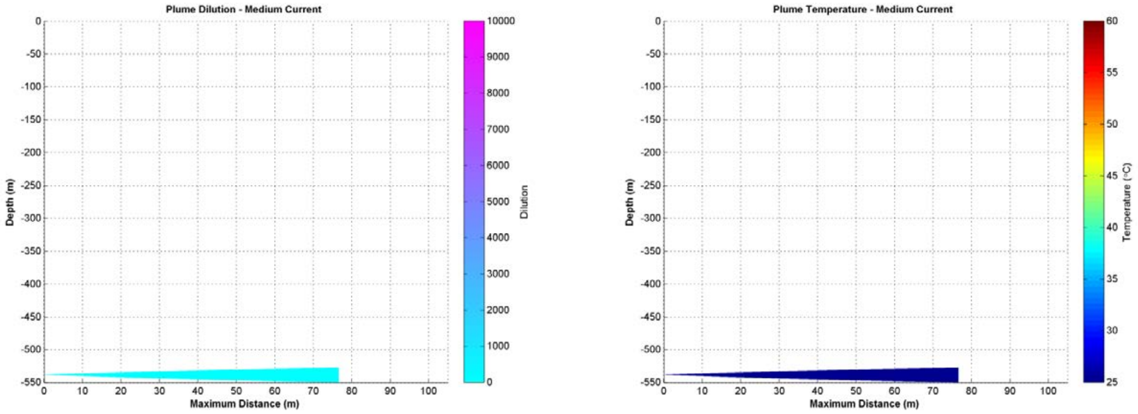

Figure 6-39: Near-field average dilution and temperature results for constant medium annualised currents for Scenario 3a (Brecknock/Calliance 790,000 m³ hydrotest discharge).

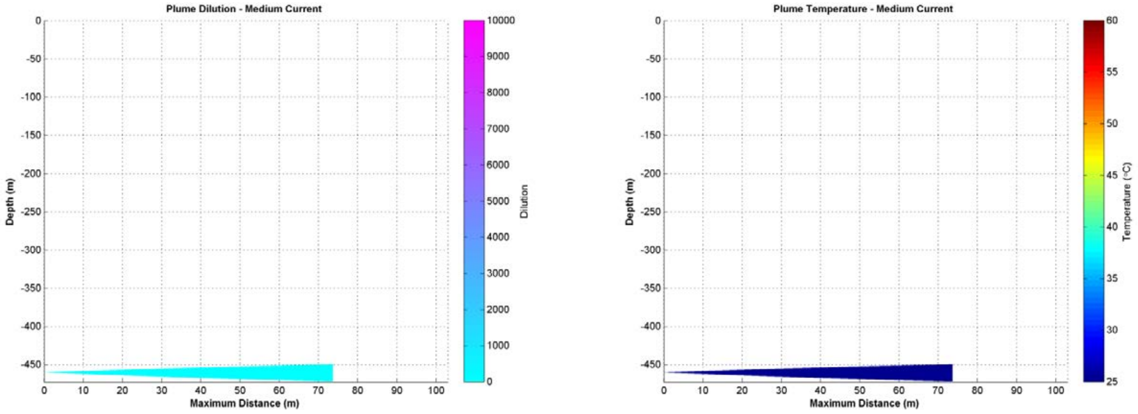

Figure 6-40: Near-field average dilution and temperature results for constant medium annualised currents for Scenario 3b (Torosa 56,000 m³ hydrotest discharge).

Far-field modelling results

The results indicate that dilutions required to reach the threshold concentration (0.6 ppm) at the 95th percentile (48-hour median) is achieved within a maximum distance (based on minimum dilutions) of 16.1 km (Scenario 1); 12.5 km (Scenario 2), 23.4 km (Scenario 3a) and 8.23 km (Scenario 3b) from the discharge point.

Figure 6-41 to **Figure 6-44** portray the spatial distribution of these discharges, particularly in the context of nearby sensitive receptors (e.g. Scott Reef). It should be noted that the figures do not represent the location of a plume at any point in time; they are a statistical and spatial summary of the percentage of time that dilution values occur across all multiple replicate simulations (i.e. stochastic representation).

The results demonstrate that the distribution and extent of the discharges are largely a function of the predominant drift current trajectories at each location, as well as the bathymetry. Hence, despite the extent of the discharges at the Torosa location, no contact with Scott Reef habitats is predicted due to the depth of the discharge (461 m), with the plume staying in deep water, following the contours at the base of the reef and the prevailing bed currents.

To contextualise the stochastic modelling results, **Figure 6-45** shows example time series snapshots of predicted dilutions during a single simulation at 4-hour intervals on the 12th January 2010. These images are representative of typical conditions for the Scenario 1 discharge and demonstrate the spatially-varying orientation of the plume with the currents. The images also show the combined effect of the tide and the drift currents, with a clear tidal oscillation evident.

Table 6-134 BTL Hydrotest Far Field Modelling Results Summary

Parameter	Scenario 1	Scenario 2	Scenario 3a	Scenario 3b
Description	Base case - (NRC PLET)	Alternative scenario - (Torosa PLET)	Brecknock/ Calliance PLET	Torosa PLET
Indicative discharge specification	600 ppm	600 ppm	600 ppm	600 ppm
Threshold	0.06 mg/L	0.06 mg/L	0.06 mg/L	0.06 mg/L
Minimum dilutions required to achieve threshold	10,000	10,000	10,000	10,000
Maximum horizontal distance required to achieve threshold	16.1 km	12.5 km	23.4 km	8.2 km
Prevailing direction of mixing zone	SW	NNW - SSE	NE (transitional); SW (winter); NE-SW (summer)	NNW - SSE
Total area of coverage to achieve threshold	79.4 km^2	87.1 km^2	89.4 km^2	40.6 km^2
Maximum depth from sea surface	117	461	539	539
Minimum dilutions at 3 nm State Waters boundary	N/A	4,431	>20,000	2,711

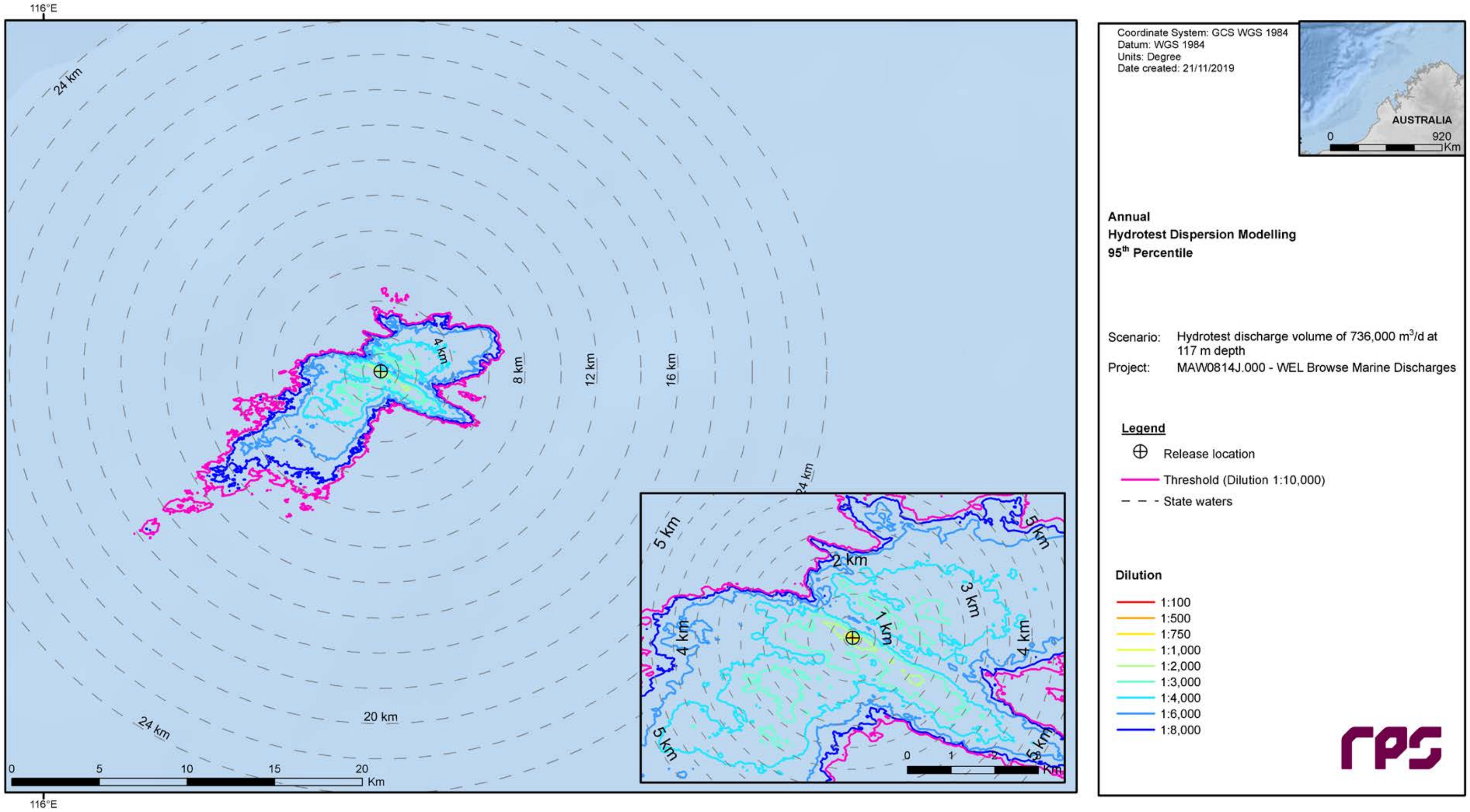

Figure 6-41 Predicted annualised minimum dilutions at the 95th percentile for Scenario 1 (NRC release location), applied to a rolling 48-hour median of the dilution data (note discharge remains at depth)

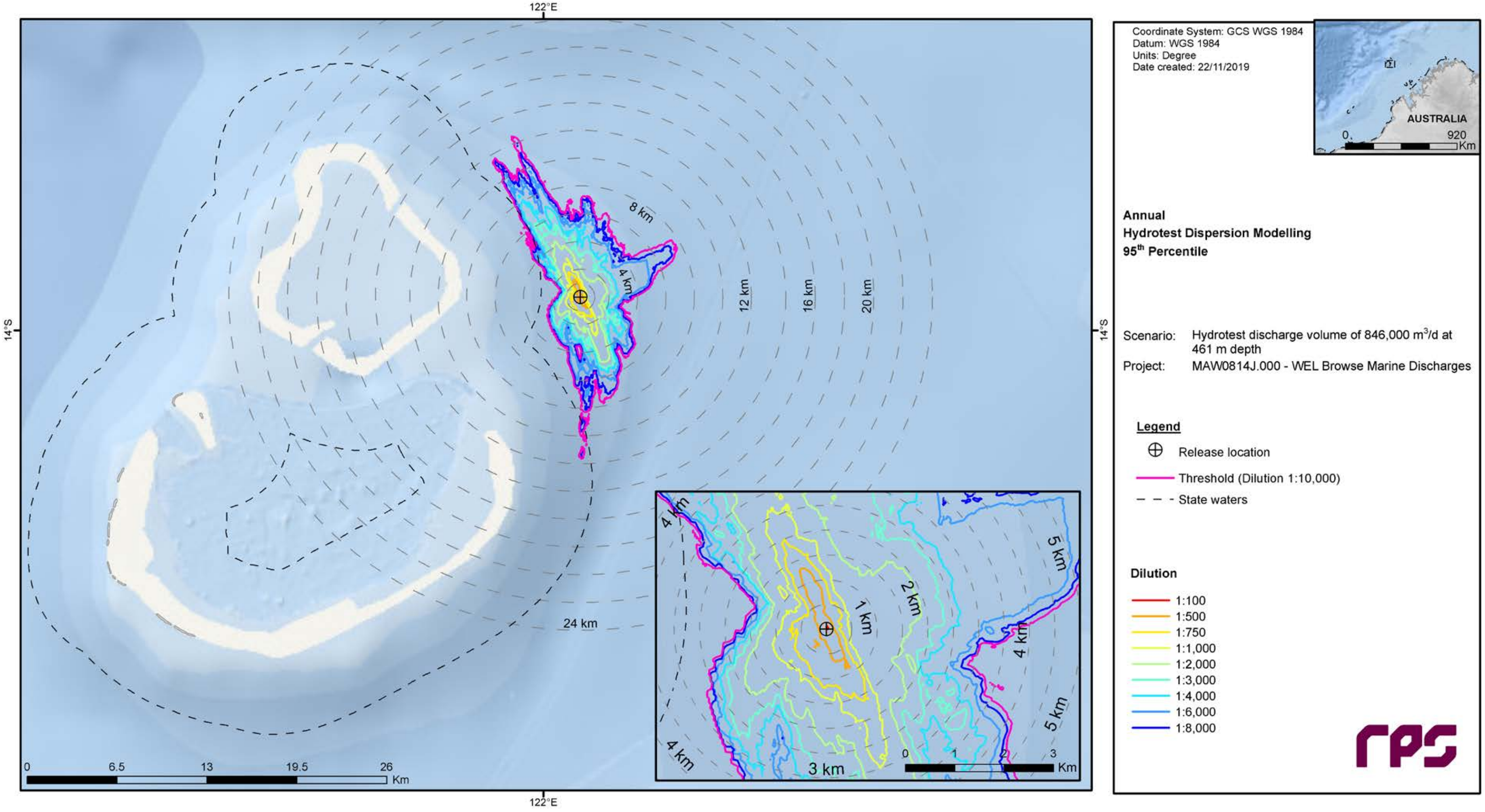

Figure 6-42 Predicted annualised minimum dilutions at the 95th percentile for Scenario 2 (Torosa release location), applied to a rolling 48-hour median of the dilution data (note discharge remains at depth)

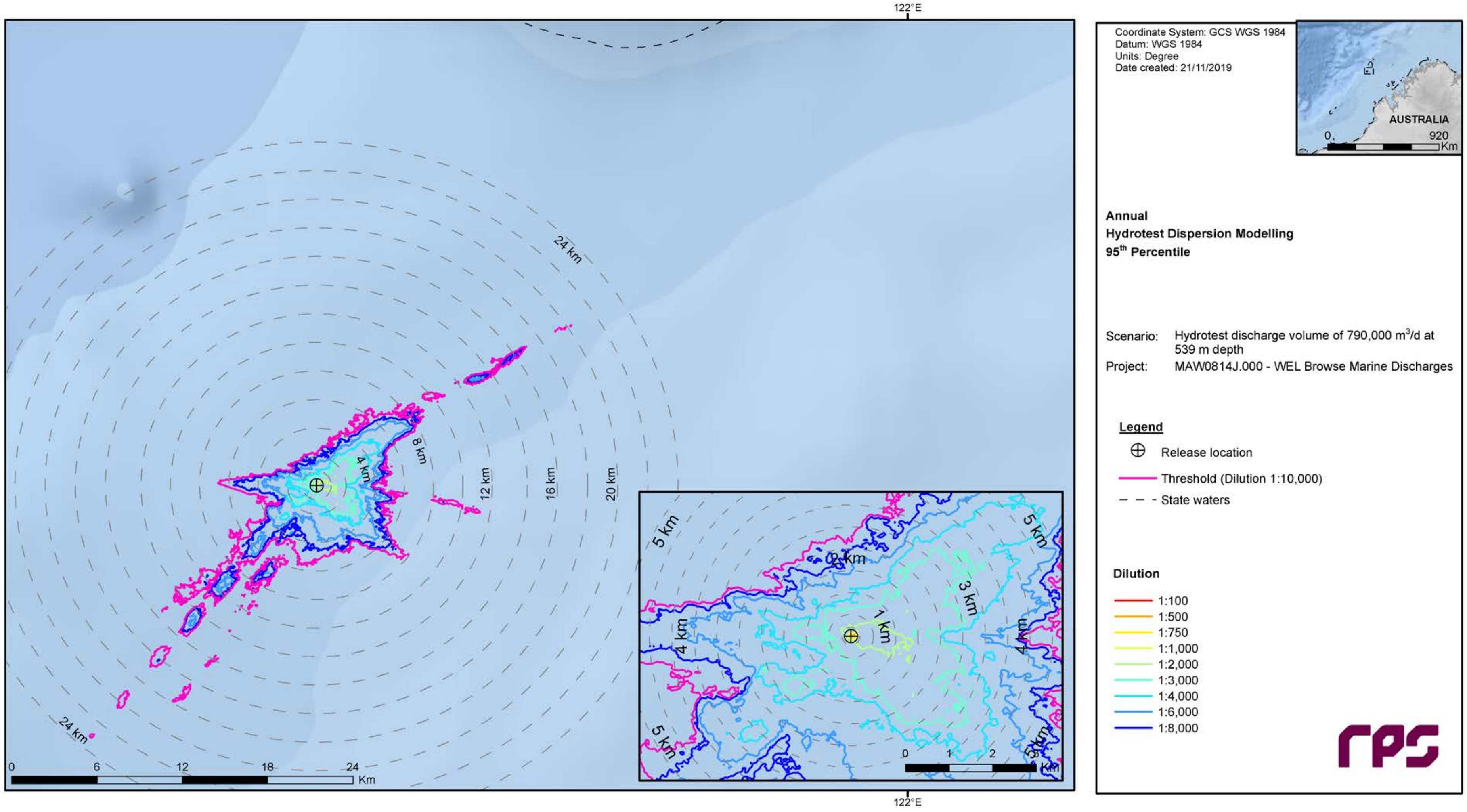

Figure 6-43 Predicted annualised minimum dilutions at the 95th percentile for Scenario 3a (Calliance/Brecknock release location), applied to a rolling 48-hour median of the dilution data (note discharge remains at depth)

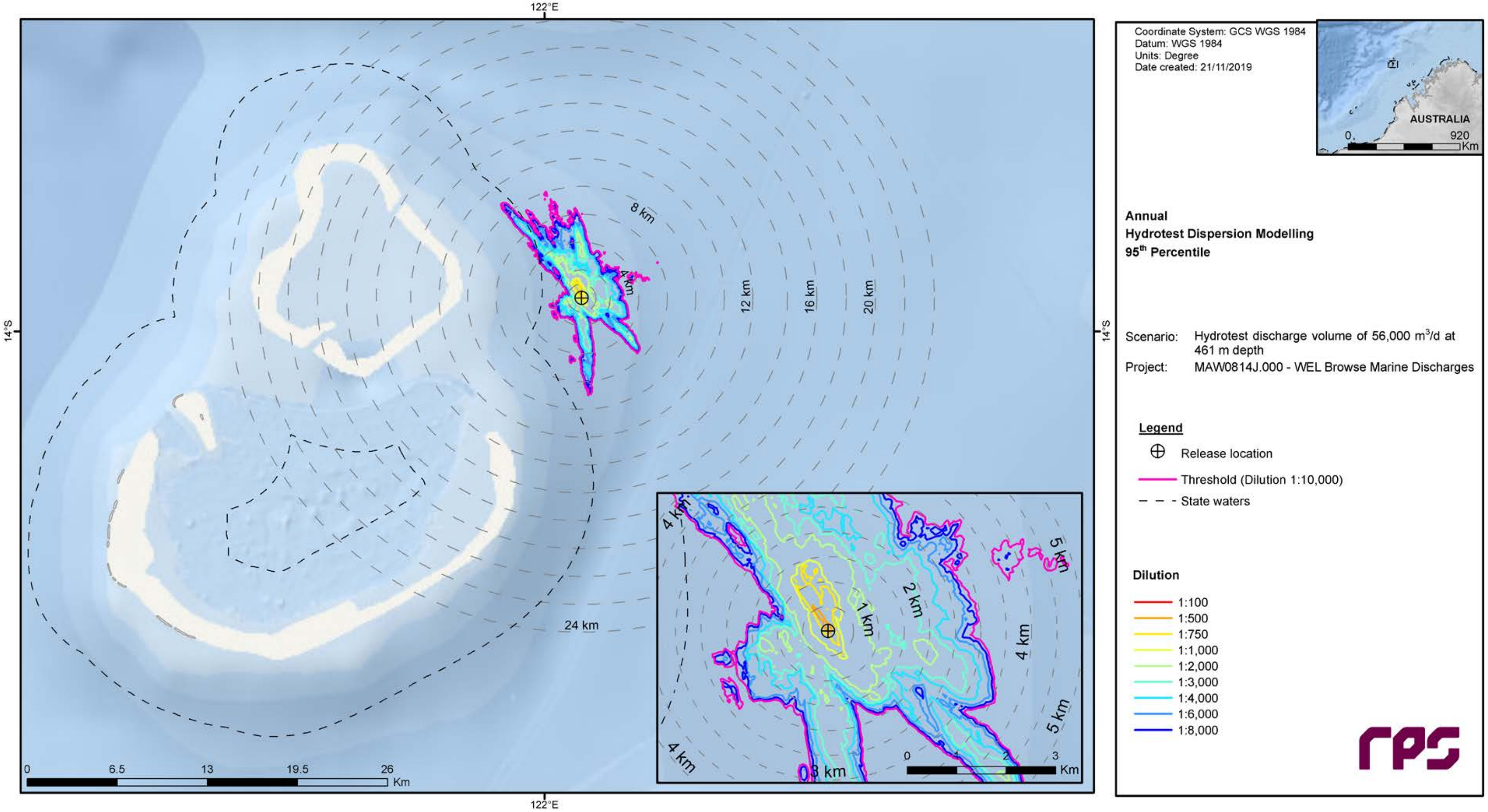

Figure 6-44 Predicted annualised minimum dilutions at the 95th percentile for Scenario 3b (Torosa release location), applied to a rolling 48-hour median of the dilution data (note discharge remains at depth)

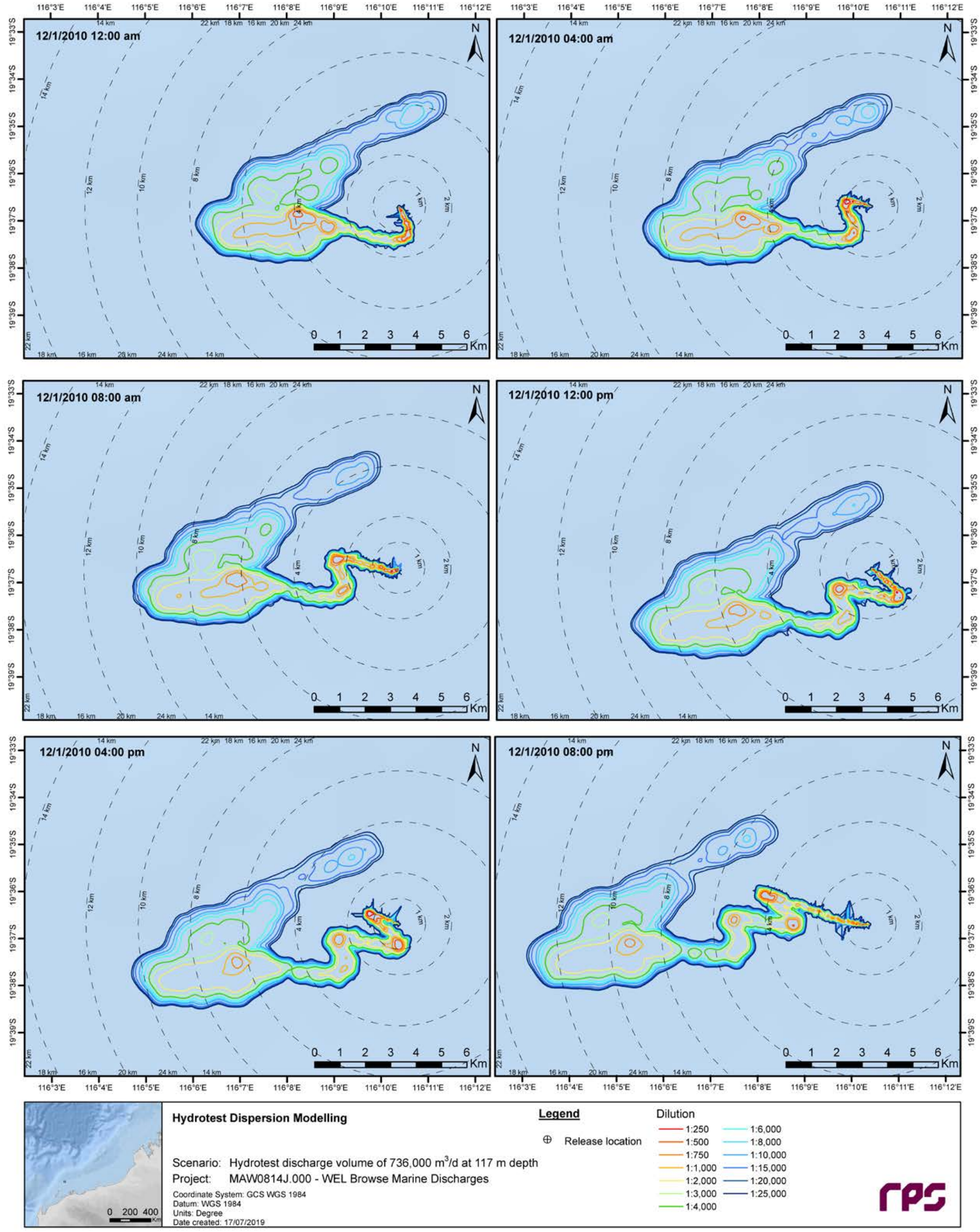

Figure 6-45 Snapshots of predicted dilution levels, at 4-hour intervals from 00:00 to 20:00 on 12 January 2010, for Scenario 1 (NRC 736,000 m^3 hydrotest discharge)

6.3.17.4 Environmental Impact

Water quality

Change in water quality

The presence of chemical additives in discharged hydrotest fluids is expected to result in a temporary decline in water quality around the discharge locations. For the BTL and SURF discharges, the plume is expected to travel in close proximity to the seabed which means the temporary change in water quality will be restricted to deep waters. As outlined in **Section 5.2.5.7**, while there is some evidence of localised intrusions of cooler water around the western and eastern entrances to the channel between North and South Scott Reef during spring tides, there is no evidence of persistent upwelling or downwelling currents around Scott Reef (Green et al., 2019). Hence, the discharge would be subject to rapid dispersion and dilution by prevailing currents, due to the open oceanic waters of the Project Area. In addition, the low toxicity hydrotest fluids will degrade and decay once released. As such no lasting effect on water quality is predicted.

Sediment quality

Change in sediment quality

As the hydrotest discharge plume is expected to travel in close proximity to the seabed, a temporary change in sediment quality may occur. However, as demonstrated by the modelling, the chemical additives will degrade and dilute rapidly following discharge with no predicted accumulation within seabed sediments and as such no lasting effect on sediment quality is predicted.

Plankton communities

Injury or mortality to fauna

Plankton populations within the predicted mixing zones may be affected by hydrotest discharges; however, given the expected rapid dispersion and dilution of the plume by prevailing currents and the temporary nature of the discharge, impacts to plankton are likely to only occur in the immediate area of the discharge plume, over a period of weeks. Given the fast population turnover of open water plankton populations (ITOPF, 2011), the potential impacts are expected to be localised and temporary.

Benthic habitat including epifauna and infauna

Change in sediment quality, change in water quality, injury or mortality to fauna

While the modelling demonstrates that the extent of the area of influence of the hydrotest discharge (associated with the dilution of the biocide additive) is large (**Figure 6-41** and **Figure 6-44**); the discharge is predicted to be restricted to the sparse deepwater habitats, with impacts to Scott Reef shallow water benthic habitat (<75 m bathymetry) not predicted.

Modelling shows that discharge at the NRC and Calliance/Brecknock locations is not predicted to impact high value benthic habitat due to the distance from these locations that the discharge would occur. Modelling also shows that impacts to Scott Reef are not predicted as a result of discharge at the Torosa site due to the proposed depths of the discharge (approximately 461 m). Green et al. (2019b) stated that there is no evidence of persistent upwelling or downwelling currents around Scott Reef and therefore, as demonstrated by the modelling, the plume stays in deep water, following the contours at the base of the reef where benthic habitat is sparse with no sensitive communities recorded (**Section 5.3**).

Given the significantly lower volume of hydrotest fluid to be discharged from the flowlines within the State Proposal Area (950 m^3 of hydrotest fluid for the TRE flow line and up to approximately 250 m^3 for TRF flowline), the depth of the discharge (> 400 m); and the distance of the proposed discharge from Scott Reef it is not predicted that any impacts will occur to Scott Reef benthic communities and habitats from hydrotest discharge in the State Proposal Area.

Furthermore, studies on the dispersion of coral larvae at Scott Reef (Done et al., 2015; Foster and Gilmour, 2018) we examine distance decay among coral communities in a common habitat on northwestern Australian reefs, seeking to better understand the roles of disturbance and coral life history strategies in the changing reefscape. In established communities in 1997, when coral cover and generic richness were uniformly high, there was high similarity (~81 % demonstrates that while there is marked movement of larvae within the reef system itself (broadcast spawning corals), there is no evidence to suggest that those coral larvae that initially dispersed off the reef return to Scott Reef to settle. Therefore, the hydrotest discharge is not likely to impact coral larvae available for local recruitment of corals within the Scott Reef system.

Epifauna and infauna sensitivity to dewatering discharges is expected to be similar to pelagic invertebrate species such as plankton. No sensitive benthic habitats have been identified within the discharge plume given the water depth of the area (>100 m) receives insufficient light to sustain ecologically sensitive primary producers. Discharges of hydrotest fluid may result in temporary and localised impact to epifauna and infauna populations with a temporary decline in abundance. However, recolonization is expected to occur rapidly.

Marine fauna

Injury or mortality to fauna - Fish

Any potential for toxicity to fish would be expected to be limited to deep waters within the mixing zone of the discharge location and therefore will only potentially affect a limited number of individuals. Furthermore, the toxicity threshold concentrations and the subsequent mixing zone have been determined through the application of chronic exposure ecotoxicological tests on marine fauna and therefore given that fish are likely to be transient within the receiving environment adjacent to the discharge location, they are unlikely to be exposed to sufficient concentrations or durations of the discharge constituents to elicit a response. In addition, the predicted toxicity effects on fish within the mixing zone are considered conservative given that the chemical constituents within the BTL and flowlines are likely to be subject to natural degradation following discharge. In addition, fish and other marine fauna have the capacity to adapt their behaviour in response to changes in environmental conditions and can be expected to move away from the discharge if exposed. The depth of the plume and the lack of significant benthic habitats for demersal fish will also limit the number of fish that may potentially be affected. As such, no lasting effects to fish as a result of hydrotest fluid discharge are predicted.

Injury or mortality to fauna - Other marine fauna

Due to the depth of the discharge plume, it is considered highly unlikely that other marine fauna such as marine turtles or cetaceans will be affected by the discharge of hydrotest water.

Key Ecological Features

Change in sediment quality, change in water quality

Depending on the location of the hydrotest fluid discharge, discharge may occur in (or the discharge plume may enter) the Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEF, the Continental slope demersal fish communities KEF or the Ancient coastline at 125 m depth contour KEF.

As described above, hydrotest fluid discharges within these KEFs will result only in a temporary (over weeks) change in water and sediment quality with no lasting impacts to marine fauna or high value benthic habitats.

No impacts to reefs associated with the Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEF are predicted.

Given the above, no impact to the conservation values of these KEFs is predicted.

Table 6-135 provides an assessment of the proposed hydrotest fluids discharge in relation to the pressures on KEFs identified in the Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).

Table 6-135 Alignment with protection of conservation values of KEFs – hydrotest fluids

Key Ecological Feature	Relevant plan(s)	Relevant pressures	Assessment
Continental slope demersal fish communities	Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).	Chemical pollution / contaminants - currently identified as 'not of concern'	As described above, hydrotest fluid discharges are not predicted to add to existing or potential pressures or adversely impact the conservation values of these KEFS.
Seringapatam Reef and Commonwealth waters in the Scott Reef Complex			
Ancient coastline at 125 m depth contour			

Other protected places

Injury or mortality to fauna

As the hydrotest plume is not predicted to contact Scott Reef, no impacts to the values of the Scott Reef and Surrounds Commonwealth Heritage Place or the Scott Reef Nature Reserve are predicted.

Other users

Changes to the functions, interests or activities of other users – State and Commonwealth managed fisheries

Where the functions, interests or activities of other users involve marine fauna (e.g. fisheries), any effect to fauna presence or abundance will indirectly impact on the functions, interests or activities of other users. Given that no lasting impacts to marine fauna including fish are predicted, no significant subsequent impact to fisheries is expected.

Changes to the functions, interests or activities of other users – tourism and recreation, scientific studies

As no impact to Scott Reef from the discharge of hydrotest fluid is predicted, no significant impact to the scientific, tourism or recreation is expected.

6.3.17.5 Environmental Risk

There are no anticipated environmental risks in relation to this aspect associated with unplanned project activities.

6.3.17.6 Cumulative Impacts

Impacts resulting from the discharge of hydrotest fluid are expected to be limited to the deepwater mixing zones described in **Section 6.3.17.3** with no expected cumulative effects from the other surface discharges and other project activities within the Project Area or from other operational projects within the Browse Basin (i.e. Shell Prelude FLNG facility and INPEX Ichthys LNG Project) given the geographic spread of the activities.

6.3.17.7 Impact and Risk Assessment Summary and Acceptability Assessment

A summary of the impact assessment for the discharge of hydrotest fluids is provided in Table 6-136. The acceptability assessment is provided in Table 6-137.

Table 6-136 Impact assessment summary and adopted controls – Hydrotest Fluids

Receptor (sensitivity)	Impact	Environmental objective	Adopted controls	Magnitude	Impact significance level
Water quality (medium value (open waters))	Change in water quality	**Objective 3:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	*Installation of subsea infrastructure* + The subsea infrastructure installation schedule will be optimised to minimise the requirement for discharge and refill of hydrotest fluid. + Chemicals that may be operationally released or discharged to the marine environment will be subject to Woodside's chemical selection and assessment process and approved prior to use. + For flowlines connected to those production manifolds that are located within 3nm of Scott Reef, the discharge of flowline hydrotest fluid will occur from the end of the flowline furthest from Scott Reef, where technically feasible. + Future engineering will consider the viability of alternatives to flowline hydrotest fluid discharge in the State Proposal Area, which will be described in a future Environment Plan.	No lasting effect	Negligible (F)
Sediment quality (medium value (open waters))	Change in sediment quality	**Objective 1:** To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **Objective 2:** To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.		No lasting effect	Negligible (F)
Plankton (medium value (open water))	Injury or mortality to fauna	**Objective 7:** To not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution.		No lasting effect	Negligible (F)
Fish (high value species)	Injury or mortality to fauna	**Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **Objective 15:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.		No lasting effect	Slight (E)
Marine mammals (high value species)	Injury or mortality to fauna			No lasting effect	Slight (E)
Marine reptiles (high value species)	Injury or mortality to fauna			No lasting effect	Slight (E)
Shallow water benthic communities and habitats (<75 m depth) (high value habitat)	Change in sediment quality Change in water quality	**Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry).		No impact expected	
Deepwater benthic communities and habitats (>75 m depth) – (medium value)		**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.		No lasting effect	Negligible (F)
KEFs (medium value)	Change in sediment quality Change in water quality	**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.		No lasting effect	Negligible (F)
Other protected places (high value)	Injury or mortality to fauna	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		No impact expected	

Receptor (sensitivity)	Impact	Environmental objective	Adopted controls	Magnitude	Impact significance level
State and Commonwealth managed fisheries (high value marine user)	Changes to the function interests or activities of other users	**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No lasting effect	Slight (E)
Other users including tourism and recreation, scientific studies (high value user)	Changes to the function interests or activities of other users	**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No lasting effect	Slight (E)

Table 6-137 Acceptability assessment – hydrotest fluids

Acceptability Assessment

Confidence in assessment

Woodside have a high level of certainty with respect to the assessment of the potential impacts associated with the discharge of hydrotest fluids as:

- Dispersion modelling indicates that hydrotest fluids discharged from the BTL will disperse to below toxicity threshold concentrations prior to the 3 nm State waters boundary at Scott Reef (95% of the time based on dispersion modelling results). With the plume staying at depth.
- The modelling undertaken is conservative as it was assumed that the residual discharge concentration of chemical additives is the same as the initial dosing concentration with no degradation or decay of the biocide during residence within the pipeline. This approach over represents the residual toxicity of the biocide following discharge, because biocide will degrade and decay prior to discharge.

Principles of ESD

With the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such it is considered that the principles of ESD will be met.

Conclusion: Acceptable

Significant Impacts as defined by the MNES Significant Impact Guidelines

Listed threated species and ecological communities / listed migratory species

As described in **Table 6-136** no lasting effect is predicted to occur from the discharge of hydrotest fluid to listed threatened and migratory species such as fish, marine turtle and marine mammals, with the impact significance level determined to be Slight (E).

Given this, with the application of the proposed controls it is predicted that the nominated environmental objectives for each of these fauna species will be achieved. As such, no significant impacts to the listed threated or migratory species (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted.

Commonwealth Marine Environment

As described in **Table 6-136**, the potential impact from the discharge of hydrotest fluid to water quality, sediment quality, plankton, deep-water benthic communities and habitats (>75 m depth) and KEFs has been assessed as Negligible (F). Slight (E) impacts may potentially occur to marine fauna, managed fisheries and other users, while no impact is predicted to occur to shallow water benthic communities and habitats (<75 m depth) and other protected places.

As such, with the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such no significant impacts to the Commonwealth marine environmental (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted.

Conclusion: Acceptable

Acceptability Assessment

WA EPA Environmental Objectives

An assessment of the impacts of hydrotest discharge against the WA EPA Objectives is presented in the State Proposal ERD (**Chapter 10, Appendix B**). In summary:

Marine environmental quality

As described in **Table 6-136**, the potential impact from the discharge of hydrotest fluid to water quality, sediment quality and plankton has been assessed as Negligible (F).

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*to maintain the quality of water, sediment and biota so that environmental values are protected*" will be achieved.

Marine Fauna

As described in **Table 6-136**, no lasting effect is predicted to occur from the discharge of hydrotest fluid to marine fauna such as fish, marine turtle and marine mammals, with the impact significance level determined to be Slight (E).

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*To protect marine fauna so that biological diversity and ecological integrity are maintained*" will be achieved.

Benthic communities and habitats

As described in **Table 6-136**, the potential impact from the discharge of hydrotest fluid to deepwater benthic communities and habitats (>75 m depth) and KEFs has been assessed as Negligible (F), while no impact is predicted to occur to shallow water benthic communities and habitats (<75 m depth).

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*to protect benthic communities and habitats so that biological diversity and ecological integrity are maintained*" will be achieved.

Conclusion: Acceptable

External context

To date there have been no specific matters raised by stakeholders regarding discharge of hydrotest water in relation to the proposed Browse to NWS Project.

Conclusion: Acceptable

Internal context

This impact and risk assessment has been undertaken in accordance with Woodside's Risk Assessment Procedure and Environment Impact Assessment Guideline (**Section 6.2**) The proposed Browse to NWS Project will be executed in accordance with Woodside's Health, Safety and Environmental Management System.

Chemicals that may be operationally released or discharged to the marine environment must be subject to Woodside's chemical selection and assessment process, and approved prior to use. Woodside will implement its internal requirement that states Chemicals must be selected with the lowest practicable environmental impacts and risks subject to technical constraints.

Further, Woodside will continue to pursue the dry commissioning of the BTL and inter-field spur line as an option. If deemed technically feasible, dry commissioning of the BTL and inter-field spur line will significantly reduce the volume of hydrotest fluid to be discharged in relation to the proposed Browse to NWS Project.

Conclusion: Acceptable

Acceptability Assessment
Other requirements
KEFs
As detailed in Table 6-135 the proposed hydrotest fluid discharge will not materially increase existing relevant pressures on the conservation values of KEFs.
Other protected places
Modelling has indicated that hydrotest fluid discharge is not expected to reach the Scott Reef and Surrounds Commonwealth Heritage Place.
Conclusion: Acceptable

6.3.18 Physical Presence (unplanned): Vessel Interactions with Fauna

6.3.18.1 Impact and Risk Overview

Table 6-138 presents an overview of the risks associated with potential vessel interactions with fauna associated with the proposed Browse to NWS Project.

Table 6-138 Vessel interactions with fauna impact and risk overview

Aspect	Physical presence (unplanned): vessel interactions with fauna
Description	Vessel movements during all phases of the proposed Browse to NWS Project have the potential to cause injury or mortality to marine fauna as a result of accidental collisions. During drilling and construction and, project vessels will include barges, tugs, survey vessels, supply vessels, installation and pipelay vessels. During operations project vessels will include supply vessels, tugs, IMR vessels, FCTVs (as discussed below) and condensate tankers.
Area	Project Area, Browse Development Area, State Proposal Area
Project stage	All - drilling and completions, installation, commissioning, operations and decommissioning
Environmental objectives	The environmental objectives in relation to vessel interactions with fauna associated with the proposed Browse to NWS Project are Objectives 14, 15 and 16. These objectives are detailed in Table 6-7.
Policy and guidelines	The following policy and guidelines are relevant to the assessment of this aspect. In addition, a number of EPBC Act conservation advices for protected fauna have been considered (Table 6-140). + EPBC Regulations 2000: Part 8 Interacting with cetaceans and whale watching - Division 8.1 Interacting with cetaceans + WA *Biodiversity Conservation Act 2016* (Wildlife Conservation (Specially Protected Fauna) Notice 2018) + WA Environment Protection Authority – Environmental Factor Guideline – Marine Fauna + Australian National Guidelines for Whale and Dolphin Watching 2017 (Commonwealth of Australia, 2017b) + Whale shark ‘Industry Code of Conduct’ (Department of Parks and Wildlife, 2013) + North-west Marine Parks Network Management Plan (Director of National Parks, 2018) + Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) + National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna (Commonwealth of Australia, 2017c) + Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c).

Aspect	Physical presence (unplanned): vessel interactions with fauna		
Receptors	+ The following receptors have been identified as potentially being impacted as a result of the proposed Browse to NWS Project (Table 6-2). A detailed description of each of these receptors is provided in Chapter 5. *Ecological* + fish (high value species) + marine mammals (high value species) + marine turtles (high value species)		
Potential impacts	+ There are no anticipated environmental impacts in relation to this aspect associated with unplanned project activities.		
Risk	+ Vessel strike leading to injury or mortality to fauna		
Summary of governing impact evaluation	***Magnitude***	***Impact significance level***	***Confidence***
	n/a	n/a	n/a
Summary of governing risk evaluation	***Consequence***	***Likelihood***	***Risk rating***
	Moderate	Unlikely	Low (C2)

6.3.18.2 Source of Aspect

Vessel movements during all phases of the proposed Browse to NWS Project have the potential to cause injury or mortality to marine fauna as a result of accidental collisions. During drilling and construction and, project vessels will include barges, tugs, survey vessels, supply vessels, installation and pipelay vessels. During operations project vessels will include supply vessels, tugs, IMR vessels, FCTVs (as discussed below) and condensate tankers.

The type and number of vessels in the Project Area (and transiting to and from the Project Area) at any one time, and the duration of presence, will differ depending on the project phase. Vessel presence is expected to be greatest for short term project phases (e.g. drilling and completions, subsea installation including BTL, and commissioning), with the longer-term operational phase requiring fewer vessels.

In addition, in the instance flowlines are installed as towed bundles up to 10 km in length, the movement of these towed bundles have the potential to result in accidental collisions due to their length and limitations in manoeuvrability. Although it is noted that there will be far fewer movements of towed bundles (when compared with traditional installation techniques such as pipelay vessels) which are only required during construction. Towed bundle movements will occur at a significantly slower speed than regular vessel movements.

Vessel movements can affect marine fauna in a number of ways, including the disruption of behaviour (e.g. feeding, nursing, mating, migrating) displacement from habitats due to vessel noise emissions and collisions leading to injury or mortality. Impacts to fauna from vessel noise emissions is discussed in Section 6.3.8.

Vessel speed has been demonstrated as a key factor in collisions with marine fauna (Laist et al., 2001). Large (>80 m), fast moving vessels pose the highest risk. Collisions are difficult to avoid as the vessels are potentially not able to slow down or evade marine fauna upon sighting (Laist et al., 2001). All project vessels will not travel at speeds greater than 12 knots within the State Proposal Area, or 6 knots in the Scott Reef channel, which will reduce the risk of accidental collisions (Laist et al., 2001).

Fast Crew Transfer Vessel (FCTV)

Fast crew transfer vessels (FCTVs) may be used for crew transfer. These FCTVs are capable of travelling at 50 – 55 knots. It is anticipated that one transfer per day would occur during normal operations, with additional transfers during shut downs and major maintenance.

If a FCTV is utilised, Woodside would select a FCTV design which inherently minimises the risk of unplanned interaction with marine fauna. The vessel has no propeller, has a shallow draught (<1 m) and can rapidly slow down, for example reaching dead stop within approximately 150 m from a cruising speed of 30 knots[25].

Figure 6-46 provides an indicative route from Broome to the Browse Development Area. It is recognised that the route passes through a number of BIAs for protected marine fauna. The route avoids habitat critical for the survival of a species near Scott Reef, as defined by the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia, 2017a). The route also avoids habitat critical of the survival of a species near the Lacepede islands during sensitive times (as defined in Table 6-139). The figure does not present seasonality of marine fauna, which is further discussed below.

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[25] *FCTVs will not travel at speeds greater than 30 knots within sensitive areas (e.g. migratory corridors) during sensitive times (e.g. migration seasons). The maximum allowable speed within the defined sensitive areas may be increased if incorporated engineering controls are able to achieve an equal or greater effectiveness as the speed restriction.*

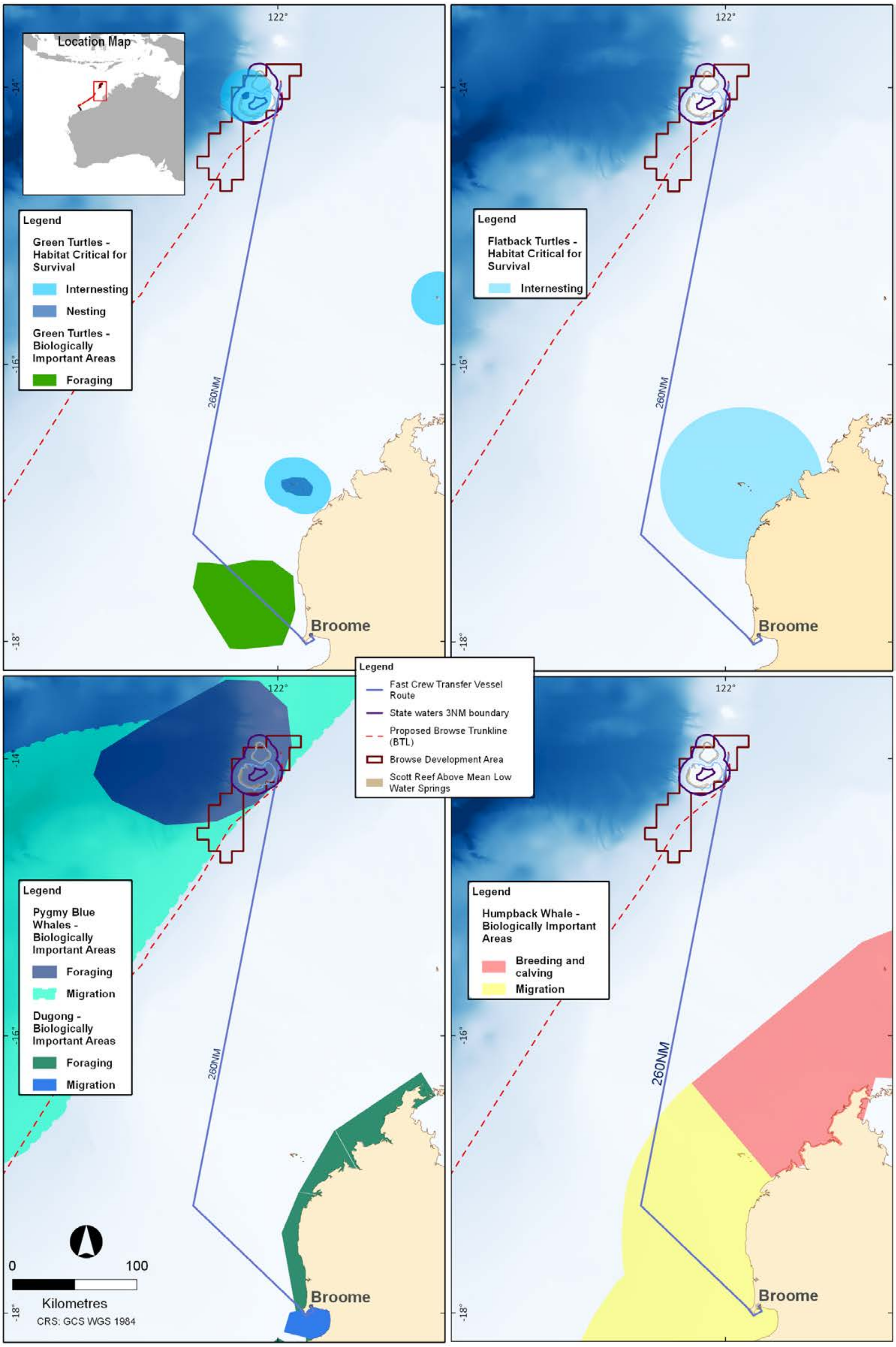

Figure 6-46 Indicative FCTV route in relation regional marine fauna BIAs.

Proposed Management Approach for the FCTV

Recognising that interactions are most likely to coincide with increased fauna presence particularly within BIAs, consideration has been given to control measures beyond standard practice to specifically manage the risk of vessel strike within sensitive areas at sensitive times. In developing this management approach for the potential FCTV, consideration has been given to the National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna (Commonwealth of Australia, 2017c).

Objective 3: *Mitigation – reduce the likelihood and severity of mega-fauna vessel collision,* describes a number of key actions under the Strategy:

- identify best practice mitigation measures and emerging technologies
- develop and improve mitigation measures
- encourage innovation and collaboration between research organisations and industry
- develop a mitigation measures toolkit that provides guidance to stakeholders and managers on what measures are most suited to specific locations, species and vessel types
- encourage the development and implementation of vessel strike management plans in locations where the relative risk of vessel strike is high, as determined by a risk assessment
- encourage the use of monitoring programs to measure the success of mitigation measures implemented and identify potential improvements
- evaluate and review mitigation measures on a regular basis.

There are a number of uncertainties outlined in the *Draft National Vessel Strike Strategy* associated with the selection of additional control measures to manage this specific risk. These uncertainties include:

- emerging technologies, such as detection controls including front-of-bow detection, aerial/satellite detection, and detection along the path through fixed infrastructure
- the establishment of any local vessel strike management plan (to be incorporated into subsequent EPs) which would apply to the FCTV
- changes in scientific understanding of the existing environment, such as the special and temporal variability and extent of sensitive receptors.

Given the key actions in the National Strategy for Reducing Vessel Strike around the identification and development of mitigation measures and the implementation of vessel strike management strategies, and the identified uncertainties, an ongoing management approach is required to select appropriate additional control measures to specifically manage vessel strike risk for a FCTV, within sensitive areas at sensitive times. The management approach will follow the Impact and Risk Treatment process outlined in **Section 6.2.3.3**, giving preference to additional engineering control measures (i.e. detection controls) before considering speed restrictions.

These controls will be applied during the sensitive areas at sensitive times as outlined in **Table 6-139**. Please note that these sensitive areas and times are indicative, the precise spatial and temporal variability and extent of the sensitive receptors will be subject to approval of the management approach to be included in secondary environmental approvals (e.g. future Environment Plans).

Table 6-139 Sensitive areas and sensitive times for FCTV Proposed Management Approach

Marine Fauna	Sensitive Area	Sensitive Time
Dugong	Foraging Area - coastline	All year
Humpback Whale	Migratory Corridor	Humpback whale migration July – September
Pygmy Blue Whale	Possible Foraging Area (Commonwealth)	Pygmy blue whale migration September – December (southward migration) March – May (northward migration)
	Possible Foraging Area (State)	
Marine Turtles – Green and Flatback	Habitat Critical - Internesting Buffer – Lacepede Island	Green and flatback turtle nesting season October – March
	Habitat Critical - Internesting Buffer – Sandy Islet (Green turtles only)	Green and flatback turtle nesting season November – March

It is recognised that there are engineering controls in various stages of maturity that could be adopted for FCTV activities, either from FCTV commencement, or as they become available in the future. While Passive Acoustic Monitoring (PAM) has often been used to detect cetaceans during seismic activities, Thermal IR and RADAR have been identified in literature as emerging complementary technologies which increase the ability detect marine fauna (Verfuss et al., 2018). The Centre for Whale Research has previously used similar detection technology that is currently available on the market, called the Night Navigator 3, which was found to highly effective. Due to the current level of the proposed Browse to NWS Project definition, no decision on incorporation of engineering controls has been taken, however this will be further considered in the proposed management approach.

Examples of marine traffic moving through the humpback whale migratory corridor include iron ore carriers (15 knots) and LNG carriers (22 knots). Recognising this risk, Woodside would select a FCTV design which is inherently safe in that it has no propeller (i.e. no slice risk), has a shallow draught (<1 m) and can reach dead stop within approximately 150 m from a cruising speed of 30 knots.

The FCTV will comply with the requirements of the EPBC Regulations 2000 – Part 8 Division 8.1 and the National Guidelines for Whale and Dolphin Watching. Travelling at 30 knots, in the event of sighting a whale at the edge of the caution zone, the FCTV can reach dead stop before being within the 100 m no approach zone. This speed is consistent with the advertised speed of whale watching vessels (i.e. Whale Watch Western Australia), which is a similar sized vessel as the proposed FCTV design.

Therefore, a speed restriction of 30 knots will be in place in the defined sensitive areas at sensitive times in **Table 6-139**. The maximum allowable speed within the defined sensitive areas may be increased if incorporated engineering controls are able to achieve an equal or greater effectiveness as the speed restriction. Furthermore, FCTVs will not travel at speeds greater than 12 knots with the State Proposal Area, or 6 knots in the Scott Reef channel (if entry is even necessary), further reducing the risk of accidental collisions.

6.3.18.3 Environmental Impact

There are no planned vessel interactions with marine fauna as part of the proposed Browse to NWS Project activities and therefore no impacts are expected during any phase of the proposed Browse to NWS Project.

6.3.18.4 Environmental Risk

Risk Event: Vessel strike on marine fauna

Fauna in Project Area that are highly unlikely to co-occur with project vessels

Injury or mortality to fauna - fish

Given the size of the Project Area, a diverse range of fish are likely to inhabit the area; however, in the context of this aspect (unplanned vessel collisions with fauna) the type of fish most likely to be impacted are larger pelagic species, particularly large sharks. **Section 5.3.2.8** provides an overview of the fish communities that occur within both the Project Area and the NWMR.

Fish species most vulnerable to collision with vessels are large sharks which frequent the upper portions of the water column. Whale sharks are at particular risk due to their slow swimming behaviour and propensity to spend significant portions of time at the surface. Studies have indicated that whale sharks spend approximately 25% of their time less than 2 m from the surface and greater than 40% in the upper 15 m of the water column (Gleiss et al., 2013; Wilson et al., 2006). Conservation advice for the whale shark (Threatened Species Scientific Committee, 2015f) identifies vessel strike from large vessels as a key threat. However, based on the available information, it is expected that while whale sharks may occur within the Project Area, they are likely to occur in low numbers and as vagrant individuals (Meekan and Radford, 2010; Wilson et al., 2006). Given this, and the proposed vessel speed restrictions, it is considered highly unlikely that a vessel strike on a whale shark will occur.

Other fish are thought to be generally less vulnerable to vessel strike due to size, natural flee responses and preferred habitat use. Smaller fish may be at risk of mortality through being caught in vessel thrusters during station keeping operations. However, the noise emissions generated by the operation of dynamic positioning thrusters will generally deter fish from the vicinity of these operations.

Injury or mortality to fauna - marine mammals (cetaceans other than humpback whales)

Twenty-seven cetacean species have been identified as potentially occurring within the Project Area. Of these, the pygmy blue whale, humpback whale, fin whale, Bryde's whale and sei whale are considered likely to occur within the Project Area. These marine mammals are discussed in **Section 5.3.2.5**.

Conservation advice for humpback whales, sei whales and fin whales; as well as the Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015b), each recognise vessel disturbance as key threats to the conservation of the species.

Large whales are more vulnerable to vessel collisions, particularly those species whose behaviour includes extended surface 'milling' time (Laist et al., 2001) and which demonstrate a lack of avoidance behaviour to approaching vessels (Nowacek et al., 2004). Cetacean calves and juveniles also have a higher risk of impact (Stevick, 1999), possibly due to less frequent and shorter dives (Szabo and Duffus, 2008).

Pygmy blue whales demonstrate limited behavioural responses to avoiding vessel collisions, with some undertaking slow shallow dives; however, active flee responses from vessels have not been observed (McKenna et al., 2015). While it is acknowledged that pygmy blue whales are vulnerable to vessel collisions, they are not expected to occur in high densities within the Project Area or on the route that vessels will traverse when transiting to and from the Project Area. It is noted that the Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015b) documents a possible foraging area within the vicinity of the Scott Reef. The plan also recognises vessel disturbance as a key threat to blue whales.

However, while studies indicate that pygmy blue whales pass through the Scott Reef area and that this area represents a potential foraging area for the species (as outlined in Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c)), multiple surveys, have failed to observe significant numbers of individuals present or evidence of foraging.

Therefore, co-occurrence of project vessels with pygmy blue whales is considered to be highly unlikely.

With respect to the other large cetacean species that may occur in the Project Area, neither the Bryde's whale, sei whale or fin whale are expected to occur in large numbers in the Project Area or in the area along the route project vessels would take when transiting to and from the Project Area.

Although spinner dolphins are very agile in the water and often display positive behaviours to the presence of vessels (e.g. bow-riding), there are a significant numbers of recorded vessel collisions with dolphins across Australia (DoEE, 2017). However, it is likely that the majority of such occurrences occur within more confined coastal areas subject to high vessel-traffic, significantly increasing the chance of vessel collision. It is thought that the risk of collision within deeper offshore waters with less vessel traffic, is significantly reduced (DoEE, 2017).

Given the low likelihood of co-occurrence of vessels with these species and the proposed speed restrictions within sensitive areas at sensitive times (**Table 6-139**), the likelihood of vessel interaction with these species resulting in injury or mortality to fauna is considered highly unlikely, with the subsequent risk rated as low.

Fauna in Project Area that may co-occur with project vessels

Injury or mortality to fauna - humpback whales

Considering the densities, distributions and migratory pathways of the key marine fauna within the Project Area, humpback whales are considered to be the main species at risk from vessel interactions related to the proposed project activities, and in particular the possible use of FCTVs to transfer personnel from Broome to the offshore facilities during operations. A comprehensive review of ship strikes on large whales by Jensen and Silber (2004) revealed that humpback whales were the second highest reported species struck (44 records).

During their annual migration, humpback whales occur in relatively high densities between the Project Area and the Western Australian coast, which represents a migratory BIA for the species (see **Section 5.3** for a detailed discussion on humpback whale distribution). Project vessels including FCTVs will traverse this BIA during transit from logistic bases (in Broome and Dampier) and the Project Area (**Figure 6-46**). The risk of collision is likely to be higher during the southern migration given the broader migratory corridor and the presence of cow and calf pairs travelling at slower speeds with a higher proportion of time spent at the surface (Bejder et al., 2019; Zoidis and Lomac-MacNair, 2017)2017. Vessel disturbance and strike is identified as a threat to humpback whales within the Conservation advice *Megaptera novaeangliae*, Humpback Whale (Threatened Species Scientific Committee, 2015b).

Given this risk to high value fauna, Woodside has developed mitigation measures to reduce the likelihood and severity of potential vessel collision with humpback whales. These measures have been developed in consideration of the National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna (Commonwealth of Australia, 2017c).

While research into these potential methods to reduce the risk of vessel collisions is limited in the existing scientific literature, a key action of the National Strategy for Reducing Vessel Strike is to identify and adopt best-practice mitigation measures and emerging technologies and encourage the development of new mitigation measures. It is therefore considered emerging technologies may offer an equivalent reduction in risk to speed reductions and may in future eliminate the need for speed reductions in sensitive areas at sensitive times.

The proposed management approach (outlined above), including engineering controls and speed restrictions, is sufficient to manage the risk of unplanned vessel interaction with humpback whales.

Injury or mortality to fauna - dugongs

As described in **Section 5.3.2.5** dugongs are known to inhabit the coastal regions of the Dampier Peninsula, with high concentrations noted at Roebuck Bay adjacent to Broome (RPS, 2010). Dugongs typically spend the majority of time submerged, surfacing on average every 1-4 minutes (Anderson and Birtles, 1978; Cox, 2002; De Iongh et al., 1997) and typically spending less than 5% of the time resting on the surface (Hodgson, 2004). Threats to dugongs in Australian waters are identified in *The Action Plan for Australian Mammals 2012* (Woinarski et al 2014). Because of their size, dugongs are susceptible to injury or mortality resulting from interaction with vessels, particularly when they rise to the surface to breathe, rest or forage in shallow waters (Woinarski et al 2014). One of the primary responses of dugongs to approaching vessels is to move towards deeper water (Hodgson, 2004).

Similarly, dugongs are susceptible to injury or mortality resulting from interaction with vessels, particularly when they rise to the surface to breathe, rest or forage in shallow coastal waters as opposed to deeper offshore waters.

The proposed management approach (outlined in **Section 6.3.18.2**), including engineering controls and speed restrictions, is considered sufficient to manage the risk of unplanned vessel interaction with dugongs, particularly given the likely lower densities of individuals within the proposed FCTV route and the minimal overlap between the proposed route and dugong foraging BIA.

Injury or mortality to fauna - Turtles

Turtles that are known to occur in the NWMR are described in **Section 5.3.2.6**. The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) recognises vessel strikes as a moderate threat to the Scott Reef – Browse Island green turtle genetic stock. It also defines the area around Scott Reef (including the Torosa FPSO location) as habitat critical to the survival of green turtles, and the area around the Lacepede Islands as an important nesting location for green turtles and flatback turtles.

Turtles may be particularly vulnerable to vessel strike while surfacing to rest or breathe. However, it has been reported that turtles spend a comparatively limited amount of time (3–6%) at the surface, with dives lasting between 15 and 60 minutes in general (Milton and Lutz, 2003). Turtles have been observed to avoid approaching vessels by moving away from the vessel's track (Hazel et al., 2007). Hazel et al. (2007) suggest that this avoidance behaviour is based primarily on visual cues (although the authors acknowledge vessel noise is within range of turtle hearing), and the success of this behaviour in avoiding a vessel strike largely depends on the speed of the approaching vessel and the prevailing water clarity. It is also likely that the propagation characteristics of underwater noise, particularly in high-use areas, would make it difficult for turtles to determine the direction of an oncoming vessel to elicit an appropriate flee response (Hazel et al., 2007). In the event of a collision, a turtle's carapace provides a level of protection from serious injury, although the type and severity of the injuries would depend on the force of the collision and structure and size of the vessel.

Turtles generally aggregate in shallow coastal areas adjacent to nesting beaches or in areas where sufficient food is available; they are unlikely to be present in high numbers within deep offshore waters of the Project Area. Therefore, vessel interactions with turtles will be primarily restricted to coastal areas and in proximity to offshore nesting beaches (e.g. Scott Reef) where vessel movements would be limited, significantly reducing the likelihood of vessel collision.

The proposed management approach (outlined above), including engineering controls and speed restrictions, is sufficient to manage the risk of unplanned vessel interaction with marine turtles, particularly as the proposed FCTV route will avoid habitat critical for flatback turtles around the Lacepedes during sensitive times and habitat critical for green turtles around Sandy Islet.

Summary

While within the Browse Development Area, project vessels will predominately travel at relatively slow speeds in accordance with standard maritime practices and nominated speed restrictions; and as such do not demonstrate a significant risk to marine fauna, particularly within the context of existing regular commercial shipping within the broader region.

While the risk of general vessel collisions with marine fauna within the Project Area is considered to be low, the use of FCTVs between the mainland and the FPSO facilities during the operations phase of the proposed Browse to NWS Project will require additional management measures to mitigate for the increased risk associated with this vessel type. The strategy for applying these management measures is described above and will ensure the FCTV does not present a significant increase in the vessel strike risk that is already presented by routine marine traffic

Considering of the total extent of available habitat, distribution of key receptors, vessel routes, and the application of mitigation measures such as speed reductions, it is considered unlikely that collisions will occur between humpback whales and project vessels (and highly unlikely for the other cetaceans, fish and marine turtle assessment). If a collision does occur, this would result in localised impacts on a small number of individuals. However, this is not anticipated to result in population level impacts.

Assessment against EPBC Act recovery and conservation plans and advices

Table 6-140 provides an assessment of the risks associated with unplanned vessel interactions with fauna in relation to objectives and actions of the relevant EPBC Act recovery and conservation plans and advices.

Table 6-140 Alignment with EPBC Act recovery and conservation plans and advices for protected fauna – unplanned interaction with fauna

Fauna	Relevant plan(s)/ conservation advice	Plan/Advice Objectives and actions	Assessment
Cetaceans and other Marine Megafauna	National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna (Commonwealth of Australia, 2017c)	Objective 3: Mitigation – reduce the likelihood and severity of mega-fauna vessel collision.	It is considered that the proposed management approach (Section 6.3.18.2) will reduce the likelihood and severity of project vessels colliding with marine fauna. As such, it is considered that the proposed activities are not inconsistent with the National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna (Commonwealth of Australia, 2017c).
Whale shark	Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a)	Vessel strike from large vessels identified as a key threat. Management action: + Minimise offshore developments and transit time of large vessels in areas close to marine features likely to correlate with whale shark aggregations (Ningaloo Reef, Christmas Island and the Coral Sea) and along the northward migration route that follows the northern Western Australian coastline along the 200 m isobath.	As described above, it is considered highly unlikely that a vessel strike on a whale shark will occur as a result of the proposed activities with the associated risk being deemed low.
Green turtle Hawksbill turtle	The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a)	Vessel strikes as a moderate threat to the Scott Reef – Browse Island green turtle genetic stock. Management actions: + Manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to the survival. + Manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue. + In relation to the Scott Reef – Browse Island green turtle genetic stock, the priority action is to manage anthropogenic activities to ensure marine turtle are not displaced from identified habitat critical to their survival.	As described above, it is considered highly unlikely that a vessel strike on a marine turtle will occur as a result of the proposed activities with the associated risk being deemed low. Therefore, there is a high level of confidence that any impacts will not compromise the long-term recovery objectives for marine turtles or result in the displacement of the Scott Reef – Browse Island green turtle genetic stock, from identified habitat critical to their survival, or adversely affect the breeding cycle of marine turtles in the BIA at Scott Reef. Therefore, it is considered that the proposed activities are not inconsistent with the objectives of the Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a).

Fauna	Relevant plan(s)/ conservation advice	Plan/Advice Objectives and actions	Assessment
Pygmy Blue Whale	Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c)	Vessel collisions are listed as a moderate risk to pygmy blue whales with the following actions relevant: + Ensure all vessel strike incidents are reported in the National Ship Strike Database + Ensure the risk of vessel strikes on blue whales is considered when assessing actions that increase vessel traffic in areas where blue whales occur and, if required, appropriate mitigation measures are implemented.	As described above, the risk of vessel strikes on whales (including pygmy blue whales) has been considered in the assessment and mitigation measures such as vessel speed restrictions applied. While considered highly unlikely to occur, any vessel strike on a whale species will be reported in the National Ship Strike Database. Therefore, it is considered that the proposed activities are not inconsistent with the Conservation Management Plan for the Blue Whale or the conservation advices listed.
Humpback Whale	Conservation advice *Megaptera novaeangliae*, Humpback Whale	Conservation advices recognise vessel disturbance as key threats to the conservation of these species.	
Sei Whale	Conservation advice *Balaenoptera borealis*, Sei Whale		
Fin Whale	Conservation advice *Balaenoptera physalus*, Fin Whale		

6.3.18.5 Cumulative Impacts

Vessel movements will occur through all phases of the proposed Browse to NWS Project, as well as general shipping and vessel movements during operations at facilities in the region such as Shell's Prelude FLNG facility and INPEX's Ichthys LNG Project. The majority of vessel movements associated with each facility will occur within open oceanic waters and will be in close proximity to each development's specific infrastructure, therefore it is not anticipated that there will be overlap between vessel movements associated with other operational facilities. There will be increased supply vessel movements from local ports such as Broome. However, such increases in vessel movements are not significant in the context of the normal operations at such ports and therefore no significant cumulative impacts are anticipated.

6.3.18.6 Impact and Risk Assessment Summary and Acceptability Assessment

As vessel interaction with fauna is an unplanned activity, no impact is expected. A summary of the risk assessment for the unplanned vessel interaction with fauna is provided in Table 6-141. The acceptability assessment is provided in Table 6-142.

Table 6-141 Risk assessment summary and adopted controls – unplanned vessel interactions with fauna

Receptor	Risk Event	Environmental objective	Adopted controls	Consequence	Likelihood	Risk Rating

Fish (high value species)	Injury or mortality to fauna	**Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species.
		Objective 14: To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population.
		Objective 15: To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population.
		Objective 16: To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.
			Project vessel operations
			+ Project vessels will only enter the channel between north and south Scott Reef during construction/installation, IMR, contingent activities, decommissioning and emergency situations
			+ Project vessels will not travel at speeds greater than 12 knots with the State Proposal Area, or 6 knots in the Scott Reef channel.
			+ FCTV will operate under a FCTV Management strategy (to be detailed in subsequent Environment Plans as required) which will describe the appropriate additional control measures to manage vessel strike risk for the FCTV. Subject to the potential for technological innovation and additional engineering controls, FCTVs will not travel at speeds greater than 30 knots in sensitive areas at sensitive times (**Table 6-139**).
			+ Interactions between vessels and whale sharks will be not be inconsistent with the Whale Shark Code of Conduct (DPaW, 2013), whereby unless in an emergency situation vessels will not knowingly travel at speeds greater than eight knots within 250 m of a whale shark and not intentionally approach closer than 30 m of a whale shark.
			+ Vessels will operate in accordance with EPBC Regulations 2000 – Part 8 Division 8.1 and Australian National Guidelines for Whale and Dolphin Watching whereby:
			  + Vessels will not knowingly travel greater than six knots within 300 m of a whale or 100 m of a dolphin.
			  + Vessels will not knowingly approach closer than 100 m to a whale or 50 m to a dolphin (except if bow riding).
			  + Vessels will not knowingly restrict the path of cetaceans.
			+ Vessels will take direct routes where practicable.
			+ FCTVs design will intrinsically reduce the risk of vessel strikes, including a shallow vessel draught (i.e. approximately 1 m or less) and no propeller.
			+ FCTV will have trained vessel crew as a marine fauna observer[26].
				Moderate	Highly unlikely	Low (C1)

Marine mammals (high value species)				Moderate	Unlikely	Moderate (C2)
Marine turtles (high value species)				Moderate	Highly unlikely	Low (C1)

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[26] Marine fauna observer – a dedicated and suitably trained person who must not have any other duties that impede their ability to engage in visual observations for whale and marine turtles

Table 6-142 Acceptability assessment – unplanned vessel interactions with fauna

Acceptability Assessment

Certainty in Assessment

Woodside have a high level of certainty with respect to the assessment of the potential impacts associated with vessel interactions with fauna as:

- Studies have adequately characterised the marine fauna populations and distributions that may potentially be impacted by such vessel interactions.
- vessel movement.

Principles of ESD

With the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such it is considered that the principles of ESD will be met.

Conclusion: Acceptable

Significant Impacts as defined by the MNES Significant Impact Guidelines

Listed threated species and ecological communities / listed migratory species

As described in **Table 6-141**, the risk of unplanned vessel interaction with fauna resulting in injury mortality to fauna presents a Low risk to fish and marine turtles, and a Moderate risk to marine mammals (noting this rating is driven by the risk to humpback whales from the FCTVs, with risk to other marine mammals considered to be Low.

The Moderate risk rating for humpback whales is driven by the potential Moderate consequences to high value fauna. It should be noted however that with the implementation of the proposed controls, it is unlikely that such an event would occur. As such no significant impacts to listed threated or migratory species (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted.

Conclusion: Acceptable

WA EPA Environmental Objectives

An assessment of the impacts of vessel interactions with fauna against the WA EPA Objective is presented in the State Proposal ERD (**Chapter 10, Appendix B**).

Marine fauna

As described in **Table 6-141**, the risk of unplanned vessel interaction with fauna resulting in injury mortality to fauna presents a Low risk to fish and marine turtles, and a Moderate risk to marine mammals (noting this rating is driven by the risk to humpback whales from the FCTVs, with risk to other marine mammals considered to be Low. It should be noted however that risk to marine fauna within State waters including the State Proposal Area will be considerably lower as vessel movements in the State Proposal Area will be temporary and limited to construction and project support vessels including those required for IMR activities. Vessel movements within coastal State waters (near the Broome and Dampier logistics bases) will be limited to supply vessels and FCTV. Vessels will not travel at speeds greater than 12 knots within the State Proposal Area, or 6 knots in the Scott Reef channel, further reducing the risk of accidental collisions.

Vessel movements within coastal State waters (near the Broome and Dampier logistics bases) will be limited to supply vessels and FCTV. Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*To protect marine fauna so that biological diversity and ecological integrity are maintained.*" will be achieved.

Conclusion: Acceptable

External context

To date there have been no specific matters raised by stakeholders, regarding vessel interactions with marine fauna within the Project Area.

Conclusion: Acceptable

Acceptability Assessment

Internal context

This impact and risk assessment has been undertaken in accordance with Woodside's Risk Assessment Procedure and Environment Impact Assessment Guideline (**Section 6.2**) The proposed Browse to NWS Project will be executed in accordance with Woodside's Health, Safety and Environmental Management System.

Conclusion: Acceptable

Other requirements

EPBC Act recovery and conservation plans and advices

As detailed in **Table 6-140**, the proposed activities are considered to be not inconsistent with the actions and objectives of:

- Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a)
- The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a)
- Conservation Management Plan for the Blue Whale: A recovery plan under the Environment Protection and Biodiversity Conservation Act 1999 2015-2025 (Commonwealth of Australia, 2015b)
- Conservation Advice for *Megaptera novaeangliae* (humpback whale) (Threatened Species Scientific Committee, 2015b)
- Conservation Advice *Balaenoptera borealis* sei whale (Threatened Species Scientific Committee, 2015c)
- Conservation Advice *Balaenoptera physalus* fin whale (Threatened Species Scientific Committee, 2015d)

Conclusion: Acceptable

6.3.19 Physical Presence (unplanned): Invasive Marine Species

6.3.19.1 Impact and Risk Overview

Table 6-143 presents an overview of the risks associated with the unplanned introduction of invasive marine species (IMS) as a result of the proposed Browse to NWS Project.

Table 6-143 Invasive Marine Species Impact and Risk Overview

Aspect	Physical presence (unplanned): invasive marine species
Description	Potential risks associated with unplanned introduction of IMS from proposed project activities to the Project Area and in particular the State Proposal Area and/or nearby receptors. Non-indigenous Marine Species (NIMS) are species which are translocated into a recipient environment where they are not historically found. Invasive marine species are NIMS that are translocated into a marine environment where they have the potential to establish and disrupt the natural balance of marine ecosystems. Not all NIMS that are translocated to a receiving location will survive through to establishment and only a subset of these species that become established will impact on social/cultural, human health, economic and/or environmental values are considered IMS (Wells, 2018). IMS can be introduced through a variety of natural and human mediated vectors. The key pathways for introduction of IMS to the Project Area is within biofouling on external surfaces of vessels and within internal niche areas and systems, and through vessel's ballast water. The vectors for translocation are via project vessels, MODU(s) and FPSO facilities from international waters, and the translocation by project vessels and MODUs from locations within Australian waters.
Area	Project Area, Browse Development Area, State Proposal Area
Project stage	All - drilling and completions, installation, commissioning, operations and decommissioning

Aspect	Physical presence (unplanned): invasive marine species
Environmental objectives	The environmental objectives in relation to invasive marine species associated with the proposed Browse to NWS Project are Objectives 6, 8, 10, 14, 17, 18, 19, 20 and 21. These objectives are detailed in **Table 6-7**.
Policy and guidelines	The following policy and guidelines are relevant to the assessment of this aspect. + Commonwealth *Biosecurity Act* 2015 + *Aquatic Resources Management Act 2016* (WA) + OPGGS (Environment) Regulations 2009 (OPGGS (E) Regulations) + International Convention for the Control and Management of Ships' Ballast Water and Sediments 2004 (BWM Convention) + International Maritime Organization - Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species (Biofouling Guidelines) + Australian ballast water management requirements version 7 (Commonwealth of Australia, 2017d) + Anti-fouling and In-water Cleaning Guidelines (Commonwealth of Australia, 2015d) + National biofouling management guidelines for the petroleum production and exploration industry (Commonwealth of Australia, 2009) + National System for the Prevention and Management of Marine Pest Incursions (the National System) + WA DoF Biofouling Biosecurity Policy + Aquatic Biosecurity Policy + North-west Marine Parks Network Management Plan (Director of National Parks, 2018) + Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).

Receptors	The following receptors have been identified as potentially being impacted as a result of the proposed Browse to NWS Project (**Table 6-2**). A detailed description of each of these receptors is provided in **Chapter 5**.
	Ecological
	+ benthic habitats
	  + shallow water benthic communities and habitats (<75 m depth) (high value habitat)
	  + deepwater communities and habitats (>75 m depth) (medium value habitat
	+ fauna
	  + fish (high value species)
	+ KEFs (high value)
	+ AMPs (high value)
	+ State marine parks and nature reserves
	+ other protected places (high value).
	Socio-economic
	+ managed fisheries (high value users)
	+ scientific studies, tourism and recreation (high value users)

Potential impacts	+ There are no anticipated environmental impacts in relation to this aspect associated with unplanned project activities

Aspect	**Physical presence (unplanned): invasive marine species**		
Risk	Introduction and establishment of IMS leading to: + change in ecosystem dynamics + changes to the functions, interests or activities of other users		
Summary of governing impact evaluation	***Magnitude***	***Impact significance level***	***Confidence***
	n/a	n/a	n/a
Summary of governing risk evaluation	***Consequence***	***Likelihood***	***Risk rating***
	Major	Remote	Moderate (B0)

6.3.19.2 Source of Aspect

Pathways of introduction

There is a potential for NIMS to be translocated into the marine environment of the Project Area during installation, commissioning and support operations. Vessels will be used throughout all stages of the proposed Browse to NWS Project. Vessels used may be mobilised from within or outside Australian waters.

All vessels are inherently subject to some level of marine fouling. Organisms attach to the vessel hull, particularly in areas where organisms can find a good surface (e.g. seams, strainers and unpainted surfaces) or where turbulence is lowest (e.g. niches, sea chests, etc.). Previously, ballast water discharges from commercial vessels were thought to be the most significant mechanism for the translocation of NIMS, however research suggests that more NIMS translocations are attributable to vessel biofouling more than any other mechanism (Hewitt et al., 1999, 2004; Mineur et al., 2007).

NIMS may establish within the shallower parts Project Area (<75m depth) where available substrate and light could facilitate establishment and growth, under several scenarios:

- NIMS could be present as biofouling on project vessels/MODUs or infrastructure and be translocated to the Project Area and transferred directly to the seafloor or subsea structures where they establish.
- NIMS could be present in ballast water and translocated to the Project Area where they are transferred directly to the seafloor or subsea structures where they establish.

If NIMS are translocated to the Project Area via the mechanisms above, they could be subsequently transferred between project vessels/MODUs/ infrastructure and by extension to the marine environments beyond the Project Area (including ports).

Ballast water

Ballast water is carried in ships' ballast tanks to improve stability, balance and trim. It is taken up or discharged when cargo is unloaded or loaded, or when a ship needs extra stability in adverse weather. When a ship takes on ballast water, plants and animals that live in the ocean are also picked up. Ballast water exchange involves the substitution of water in ship's ballast tanks using either a sequential, flow-through, dilution or other exchange method, potentially releasing ballast water at a location foreign to where it was taken on. Ballasting and de-ballasting a vessel is essential in achieving maximum vessel performance through a range of functions such as vessel propulsion, stress reduction on ship hull, stability and manoeuvrability, among others.

Release of unmanaged ballast water could transfer a range of NIMS into a recipient environment, depending on the location that ballast water was taken onboard. The major vector pathways for the introduction of marine pest species into Australia are ballast water carried in vessels and biofouling on vessels (or internal parts of the vessel that are exposed to sea water) (DAWR, 2018). A study done by Gollasch et al. (2002) on 1508 samples identified a total of 990 different species within the ballasts of ships. The species varied in taxa from fungi, bacteria, algae and protozoans to small fish and invertebrates at varying life stages.

Ballast water has been recognised as a major pathway for introducing IMS into new environments, giving rise to adoption of the International Convention for the Control and Management of Ships' Ballast Water and Sediments (Ballast Water Convention), which is given effect through the Commonwealth *Biosecurity Act 2015*. The Ballast Water Convention aims to prevent the spread of IMS from one region to another, by establishing standards and procedures for the ballast water management, including phasing out the use of ballast water exchange. In Australian waters, vessels are required to demonstrate compliance to Australian Ballast Water Management Requirements (Commonwealth of Australia, 2017d) which outlines approved methods of ballast water management in line with the Ballast Water Convention, including:

- use of a ballast water management system
- ballast water exchange conducted in an acceptable area

- use of low risk ballast water (such as fresh potable water, high seas water or freshwater from an on-board fresh water production facility
- retention of high-risk ballast water on board the vessel
- discharge to an approved ballast water reception facility.

Vessels may be required to ballast (e.g. take on or discharge water) within the Project Area. Should this be the case, ballast water will be managed via the acceptable methods detailed in the Australian Ballast Water Management Requirements (Commonwealth of Australia, 2017c) and in accordance with the *Biosecurity Act 2015*.

Biofouling

Biofouling can be defined as the accumulation of living organisms on artificial surfaces by adhesion, growth and reproduction (Cao et al., 2011). Surfaces commonly affected by biofouling on vessels include internal niches and areas subjected to low turbulence, such as seawater intakes and sea chests.

Biofouling poses a risk to biosecurity if organisms are translocated from a donor location and become established in a recipient location. For this is occur, Lewis et al. (2010) suggest that biofouling organisms must be successful in the following process:

- colonise a vessel (or other infrastructure) in donor location
- survive translocation from the donor to the recipient location
- adults, offspring and/or fragments transfer from the vessel to the surrounding recipient environment
- survive and colonise available substrata or habitat in the recipient location
- undergo ongoing reproduction in the recipient location to establish a viable population.

Biofouling usually begins as a biofilm (e.g. bacteria, diatoms and cyanobacteria) gradually developing to support a range of taxa, including; algae, sessile animals (e.g. barnacles), mobile benthic and epibenthic organisms (e.g. worms, starfish and crabs) along with commensals, parasites and pathogens. Biofouling may occur on the FPSO facilities, BTL and inter-field spur line trunkline and the subsea infrastructure over time.

Establishment of IMS

Although there is a potential for IMS to establish themselves in a foreign environment via ballast water and biofouling, not all IMS that enter Australian waters and are released into the marine environment are successful in establishing a population. For successful establishment to occur, a NIMS must first enter the ballast during water uptake and/or establish on a vector (e.g. hull), survive translocation from donor to recipient region, and then successfully be transferred, colonise and spread in the recipient environment to establish a new viable population. The following biotic and abiotic factors can influence the survival probability of translocated NIMS and establish IMS:

Biotic:

- presence of natural predators
- level of physical disturbance (disturbed environments are typically more susceptible)
- dispersion rate
- reproductive rate
- diet type
- level of environmental adaptability
- level of competitive strength
- level of similarity of source and receiving environment
- level of injury received throughout voyage or
- removal
- sedimentation rates (fouling organisms).

Abiotic:

- water depth
- environmental conditions (i.e. salinity, nutrient concentration, water temperature, light availability, etc.)
- transport conditions (i.e. vessel ballast water age, vessel speeds, etc.).

Notably, the majority of species introduced to an area outside of their natural range will not survive to establish or subsequently become invasive or a pest (Wells et al., 2009; Bax et al., 2003)marine industries (including fishing and tourism. The discharge of marine organisms into oceanic, higher saline environments, for example, may lead to salinity and temperature 'shock' which can be fatal to some species (Molina and Drake, 2016). Notably, many species cannot survive transport in the ballast water tank conditions due to the lack of available light and the physical water quality properties within the tanks.

Assessment of project specific pathways

FPSO facilities

The FPSO facilities are likely to be built within a ship yard in Asia and subsequently transported to the Project Area for hook-up, commissioning and operation. The FPSOs will be risk assessed, inspected and if required cleaned outside of Australian waters prior to arrival on site. Given this, and as the FPSOs will be in deep oceanic waters and a significant distance from Scott Reef (approximately 8 km for the Torosa FPSO) it is considered that the likelihood of IMS becoming established at these locations is remote.

Construction support vessels, installation vessels, IMR Vessels and MODU

It is likely that the construction support vessels and installation vessels (e.g. pipelay vessel), IMR vessels and MODUs will transit to site from international waters, which increases the risk of IMS translocation to the Project Area. Project vessels will be subject to the risk assessment process outlined below.

Operations vessels

Project vessels during operations (including FCTVs and supply vessels) will regularly travel between the Project Area and Australian mainland ports, with occasional international travel. Vessels originating from international waters (i.e. with an increased risk of IMS translocation to the Project Area), will be subject to a thorough risk assessment process as outlined below. Vessels arriving from within Australian waters (most often from Port of Broome and Port of Dampier) also present some risk (albeit a low risk) of translocating IMS due to the frequency of travel to the Project Area, especially when originating from ports where IMS is known to be established. Such domestic Project vessels will also be subject to the risk assessment process outlined below.

Overview of the risk assessment process

As described above, project vessels will be subject to a risk assessment process that addresses relevant risk factors such as vessel type and origin, dry dock and/or inspection history, details of antifouling system applied (e.g. age and suitability), internal treatment system (e.g. presence or absence of marine growth prevention system (MGPS)), the periods of layup/inactivity since last dry dock and the vessels operating profile. One of the key factors is the time a vessel spends in a location, which increases the likelihood of colonisation or uptake in a source, and release in a recipient location This is due to increased propagule pressure, which is a combination of the frequency of colonisation events and the magnitude of these events. Based on the outcome of the risk assessment process, management measures will be implemented commensurate to the risk (e.g. time restrictions, cleaning etc.). This process aligns with the approach adopted by WA Department of Primary Industries and Regional Development (e.g. Vessel Check tool) and has been proven effective in minimising the potential for IMS introduction. Woodside has successfully implemented this process for several large construction projects and ongoing operations over the last decade.

6.3.19.3 Environmental Impact

The introduction of IMS is considered an unplanned event for the purposes of the proposed Browse to NWS Project and, as such, no environmental impacts are expected.

6.3.19.4 Environmental Risk

Risk Event: Introduction and establishment of an IMS at Scott Reef

Once an IMS is established, they have the potential to impact on native species diversity and abundance in a variety of ways which may result in changes to ecosystem dynamics. This can occur via:

- Competition for natural resources: IMS may compete with native species for available resources (e.g. food, shelter) and, assuming native species are unable to attain the resource elsewhere, result in a reduction in survival probability. Displacement of native species is more likely to occur should IMS occupy a similar niche or use similar resources.
- Reduced natural resources: Due to lack of evolutionary equilibrium, an IMS may drastically reduce resources in an area due to lack of natural predators, abundant food source or other resource.
- Predation: As organisms within the recipient environment have not co-evolved with the IMS, native prey species are more vulnerable to predation if the IMS is predatory due to a lack of adaptive response strategies. Reduction in species abundance as a product of increased predation may also impact on population dynamics and distribution of native species with cascading impacts throughout the ecosystem. Predation of native species may improve survivability of other native species as a product of decreased pre-existing ecosystem stresses such as interspecific competition or predator-prey interactions. This may have further flow on effects to existing environment and may not necessarily be a positive impact.
- Change nutrient cycling processes: Establishment of IMS can result in local changes in nutrient cycles as a product of variations in nutrient uptake. Alteration of available nutrients can impact the species who use them, with cascading impacts throughout the wider ecosystem.

- Change in habitat: Establishment of IMS may change habitat composition leading to creation of new habitats, or fragmentation of existing habitats. A new habitat type may allow other native species to increase distribution or range, influencing population process of existing species. In species with limited dispersal, habitat fragmentation can result in isolation of subpopulations with secondary impacts to population genetics, population dynamics, species distribution, ecosystem processes, resource consumption and nutrient cycling processes.
- Spread of disease: IMS may be a virus or pathogen, or may be vector to viruses, bacteria or pathogens. The introduction of disease through IMS could have devastating effects to native species which lack inherent resistance to introduced diseases. A decrease in native species abundance can have knock on affects at the ecosystem level through processes related to predator-prey interactions or competition for resources.

Benthic habitats

Change in ecosystem dynamics

The majority of the Project Area, as outlined within Section 5.3.1 consists of deep offshore open waters, away from shallow habitats, that are not conducive to the settlement and establishment of IMS, due to the lack of benthic light (required to support the photosynthetic processes required for many NIMS) or suitable hard substrates to allow attachment and growth.

The primary receptors with respect to IMS in the context of the proposed Browse to NWS Project are shallow-water marine habitats, species and ecosystem function at Scott Reef. Shallow water marine habitats, such as coral reefs, are considered susceptible to the introduction and subsequent establishment of IMS due to the availability of light and complex habitats. IMS introduced to shallow water marine habitats are, therefore, much more likely to successfully establish than those introduced to deep oceanic waters.

Sites subject to existing disturbance such as Scott Reef are also considered to be more susceptible to IMS. This includes artificial structures (e.g. the two shipwrecks at Scott Reef; Section 5.4.3.2), sites effected by coral bleaching and/or extreme weather events (as described for Scott Reef in Section 5.3.1.3), and those areas impacted by tourism or fishing (e.g. tourism and Indonesian fishers at Scott Reef). The cumulative pressure of these disturbances may lead to weakened ecosystem function and reduced resilience to external pressures such as IMS. Note, an IMS surveillance program at Scott Reef is proposed to be undertaken, with a survey completed prior to the commencement of the proposed Browse to NWS Project activities in the State Proposal Area to verify baseline condition, and periodic surveys over the life of the proposed Browse to NWS Project.

Given this sensitivity and the regional significance of Scott Reef, the consequence of the introduction and successful establishment of an IMS has been determined to represent a consequence level of Major, (due to the potential for regionally significant impacts to high value habitat). However, given the legislative and Woodside management controls in place to prevent translocation and establishment of IMS in the Project Area it is considered that the likelihood that IMS would be introduced, establish a self-sustaining population and cause environmental impacts to sensitive ecological communities within the vicinity of Project Area, including the State Proposal Area (e.g. Scott Reef) is remote.

Marine fauna

Change in ecosystem dynamics - fish

A change in ecosystem dynamics as a result of the establishment of IMS at Scott Reef would potentially have significant effects on site attached fish that are dependent on the reef as a result of competition for natural resources, predation and spread of disease. While the consequence of such an event would be 'major, the 'remote' likelihood of such an event means that this risk is determined to be Moderate.

Key Ecological Features

Change in ecosystem dynamics

The Continental slope demersal fish communities and Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEFs overlap with the Browse Development Area, while the BTL traverses the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF and the Ancient coastline at 125 m depth contour KEF.

The Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012) identifies invasive species as pressure of potential concern for Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEF and the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF, a pressure of less concern for The Continental slope demersal fish communities KEF.

As described above, while the likelihood of occurring is considered remote, the establishment of an IMS in the Scott Reef shallow water benthic habitat (<75 m bathymetry) would potentially have major consequences on ecosystem dynamics. The same applies to Rowley Shoals, although, the likelihood would be even less, given the short duration and significantly few project vessels that will enter the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF.

Given the water depths of the Continental slope demersal fish communities KEF and the Ancient coastline at 125 m depth contour KEF, the likelihood of an IMS establishing within these KEFs is considered remote.

Table 6-144 provides an assessment of the risk posed by the introduction and establishment of IMS in relation to the pressures on KEFs identified in the Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).

Table 6-144 Alignment with protection of conservation values of KEFs – invasive marine species

Key Ecological Feature	Relevant plan(s)	Relevant pressures	Assessment
Seringapatam Reef and Commonwealth waters in the Scott Reef Complex	Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).	Invasive species – of potential concern	Given the existing Woodside and legislative controls in place that minimise the introduction of IMS and noting the deepwater habitats of the KEFS, it is considered that even if IMS were introduced, the likelihood that it would become established is remote. Therefore, there is a high level of confidence that the establishment of IMS within these KEFs will not result in an adverse impact to marine ecosystem function or integrity with in the KEFs; or any reduction in to the conservation values of the KEFs will occur.
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals			
Continental slope demersal fish communities		Invasive species – of less concern	
Ancient coastline at 125 m depth contour		Invasive species – not of concern	

Australian marine parks

Change in ecosystem dynamics

The proposed BTL route traverses the Multiple Use Zones (IV) of the Argo-Rowley Terrace and Kimberley Marine Parks. It should also be noted that the proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park National Park Zone. Rationale for the route selection of the BTL is provided in **Chapter 3**. The North-west Marine Parks Network Management Plan (Director of National Parks, 2018) outlines the objectives of the Multiple Use Zone (VI) multi use zones traverse by the BTL as "*to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species*". Invasive marine species is identified as a threat to AMPs in the North-west Marine Parks Network Management Plan (Director of National Parks, 2018).

As described above, the introduction and establishment of an IMS in an AMP would potentially have major consequences on ecosystem dynamics. However, given the water depths where the proposed project activities will occur and the distance to any shallow water habitats where IMS could potentially establish a viable population, the likelihood of that occurring is considered remote.

Summary

Table 6-145 provides an assessment of the risk posed by the introduction and establishment of IMS in consideration of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018)

State marine parks and nature reserves

Change in ecosystem dynamics

The significant distance from the Project Area to any State marine parks means that the likelihood of the introduction and establishment of IMS within a State marine park resulting from activities associated with the proposed Browse to NWS Project is remote. Given the Scott Reef Nature Reserve encompasses an area above mean low tide springs, establishment of an IMS on the reserve from the proposed activities is not credible, nevertheless, an assessment of the risk has been undertaken for Scott Reef's shallow benthic habitats and surrounds.

Table 6-145 Alignment with the North-west Marine Parks Network Management Plan – invasive marine species

Australian Marine Park	Relevant plan(s)	Australian Marine Park objectives	Assessment
Argo-Rowley Terrace Marine Park Multi Use Zone (VI) Kimberley Marine Park Multi Use Zone (VI)	North-west Marine Parks Network Management Plan (Director of National Parks, 2018)	The objective of the Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species.	Given the existing Woodside and legislative controls in place to control the introduction of IMS from project vessels, there is a high level of confidence that the activities can be managed to ensure no there is no establishment of IMS within the AMPs and hence will not result in an adverse impact to marine ecosystems, habitats or native species such that the conservation values of the AMPs would be reduced. As such, it is considered that the proposed activities are not inconsistent with the requirements of the North-west Marine Parks Network Management (Director of National Parks, 2018).
Mermaid Reef Marine Park National Park Zone (II)		The objective of the National Park Zone (II) is to provide for the protection and conservation of ecosystems, habitats and native species in as natural a state as possible.	The proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park, with no project vessels proposed to enter the park. As such, there is no anticipated risk of IMS introduction within the AMP and therefore no likely affect in ecosystems, habitats or native species in the AMP will occur. As such, it is considered that the proposed activities are not inconsistent with the requirements of the North-west Marine Parks Network Management (Director of National Parks, 2018).

Other protected places

Change in ecosystem dynamics

Given the water depths in the Scott Reef and Surrounds Commonwealth Heritage Place, the introduction and establishment of IMS that the introduction of IMS from activities associated with the proposed Browse to NWS Project is not considered credible.

Other users

Changes to the functions, interests or activities of other users – managed fisheries

The Northwest Slope Trawl Fishery (Commonwealth) and the Pilbara Trawl Fishery (State) overlap the Browse Development Area. The establishment of IMS may cause changes to the target prey abundance, distribution or behaviour of commercial fish species, and in turn result in impacts to the activities of commercial fisheries and traditional Indonesian fishers under MOU 74. In addition, IMS may also transport pathogens and or disease harmful to target species.

The likelihood of project activities resulting in the translocation and establishment of IMS to locations where fishing activity occurs (i.e. due to distance from shore and water depth) is remote and therefore the likelihood that commercial fishing activities will be negatively affected is also considered remote.

Changes to the functions, interests or activities of other users – tourism and recreations, scientific studies

The successful establishment of IMS at Scott Reef and subsequent impacts to biota, would negatively impact the tourism and recreation values of the Reef. As discussed above, the likelihood of this establishment occurring is considered remote.

6.3.19.5 Cumulative Impacts

The establishment of IMS is not a planned activity. As such there are no predicted cumulative impacts associated with IMS.

6.3.19.6 Impact and Risk Assessment Summary and Acceptability Assessment

There are no environmental impacts predicted as there is no planned introduction of IMS. A summary of the risk assessment associated with the unplanned introduction of IMS is provided in Table 6-146. The final acceptability assessment is provided in Table 6-147.

Table 6-146 Risk assessment summary and adopted controls – physical presence (unplanned): invasive marine species

Receptor	Risk Event	Environmental objective	Adopted controls	Consequence	Likelihood	Risk Rating

Shallow water benthic communities and habitats (<75 m depth) - (high value habitat)	Introduction and establishment of IMS leading to change in ecosystem dynamics	**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.
		Objective 8: To not result in the establishment of a known or potential invasive marine species (IMS).
		Objective 10: To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry).
			+ Compliance with in force Commonwealth and State ballast water and biofouling legislation. This includes Biosecurity Act 2015, Australian Ballast Water Management Requirements and relevant State legislative requirements.
			+ No project vessels will enter the state Rowley Shoals Marine Park or Mermaid Reef Australian Marine Park unless required for SOLAS.
			+ Project vessels and MODUs will be subject to a risk assessment process to assess the likelihood of introducing IMS when transiting to the Project Area. Based on the outcomes of risk assessment, management measures commensurate with the risk (such as the treatment of internal systems, IMS inspections or cleaning) will be implemented.
			+ Internationally sourced Project vessels and MODUs required within 3 nm of Scott Reef (State Proposal Area) for longer than 48 hours will be inspected by an experienced IMS expert/marine scientist for IMS; and cleaned where required[27].
			+ For the FPSOs the following adaptive management framework will be implemented during construction of FPSO facilities:
			  + a biofouling management plan will be developed by an experienced IMS expert/marine scientist and describe a monitoring, inspection and cleaning schedule.
			  + the biofouling management plan will be implemented during the construction, with the actions adapted based on the findings of monitoring/inspection events.
			  + FPSO facilities will be inspected by an experienced IMS expert/marine scientist prior to entry into Australian waters.
			  + IMS surveillance program will be undertaken at Scott Reef, consisting of a baseline survey prior to the commencement of activities in the State Proposal Area, and periodic surveys over the life of the proposed Browse to NWS Project.
				Major	Remote	Moderate (B0)

Deepwater benthic communities and habitats (>75 m depth) – (medium value)				Minor	Remote	Low (D0)
Fish (high value species)		**Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population.		Major	Remote	Moderate (B0)

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[27] *Subject to confirmation, vessel/rig may be permitted re-entry within Scott Reef State waters (3 nm) without re-inspection provided its movements outside Scott Reef State waters at stationary or at slow speeds (less than three knots) in waters less than 50 metres deep do not exceed a period totalling greater than seven accumulative days prior to returning to Scott Reef State waters (3 nm).*

Receptor	Risk Event	Environmental objective	Adopted controls	Consequence	Likelihood	Risk Rating
KEFs (medium value)		**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.		Major	Remote	Moderate (B0)
AMPs (medium value)		**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		Major	Remote	Moderate (B0)
State marine parks and reserves (high value)				Major	Remote	Moderate (B0)
Other protected places (high value)				Major	Remote	Moderate (B0)
Managed fisheries (high value user)		**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing.		Major	Remote	Moderate (B0)
Other users including tourism and recreation and scientific studies (high value users)		**Objective 21:** To not interfere with other marine users to a greater extent than is necessary for the execution of the Browse to NWS Project.		Major	Remote	Moderate (B0)

Table 6-147 Acceptability assessment – physical presence (unplanned): invasive marine species

Acceptability Assessment
Confidence in assessment Woodside have a high level of certainty with respect to the assessment of the potential impacts and risks associated with invasive marine species as: + Woodside will comply with all regulatory requirements and will apply a vessel risk-based assessment to mitigate and manage any potential impacts of IMS. + The proposed controls are standard controls widely employed in industry and proven to mitigate the potential risks effectively.
Principles of ESD There is no planned introduction of IMS. With the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such it is considered that the principles of ESD will be met. **Conclusion: Acceptable**
Significant Impacts as defined by the MNES Significant Impact Guidelines *Listed threated species and ecological communities / listed migratory species* As described in **Table 6-146**, the risk of the unplanned introduction of an IMS presents a Moderate risk to listed threatened and migratory species. This risk rating is driven by the potential Major where regional impacts affecting species at a population level could occur. It should be noted however that with the implementation of the proposed controls, the likelihood that such an event would occur is considered remote. As such no significant impacts to listed threated or migratory species (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted. *Commonwealth marine environment* As described in **Table 6-146**, the risk of an unplanned hydrocarbon release presents a Low risk to deepwater benthic communities and habitats (>75 m depth), and a Moderate risk to shallow water benthic communities and habitats (<75 m depth), marine fauna, KEFs, AMPs, other protected places and managed fisheries. As above, these risk ratings are driven by the potential Major consequences where regional impacts affecting the marine environment and users could occur. As above however, with the implementation of the proposed controls, the likelihood that such an event would occur is considered remote. As such no significant impacts to the Commonwealth Marine Environment (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted. **Conclusion: Acceptable**

Acceptability Assessment

WA EPA Environmental Objectives

Marine environmental quality

As described in **Table 6-146**, the risk of the unplanned introduction of an IMS presents a Low risk to deep water benthic communities and habitats (>75 m depth), and a Moderate risk to shallow water benthic communities and habitats (<75 m depth) and marine fauna. This risk rating is driven by the potential Major where regional impacts affecting species at a population level could occur. It should be noted however that with the implementation of the proposed controls, the likelihood that such an event would occur is considered remote.

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors will be achieved, and the WA EPA environmental objective "*To maintain the quality of water, sediment and biota so that environmental values are protected*" will be achieved for the State Proposal.

Benthic communities and habitats

As described in **Table 6-146** the risk of the unplanned introduction of an IMS presents a Low risk to deep water benthic communities and habitats (>75 m depth) and a Moderate risk to shallow water benthic communities and habitats (<75 m depth). As above, the Moderate risk rating is driven by the potential Major consequences where regional impacts affecting the marine environment and users could occur. As above however, with the implementation of the proposed controls, the likelihood that such an event would occur is considered remote.

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors will be achieved, and the WA EPA environmental objective "*To protect benthic communities and habitats so that biological diversity and ecological integrity are maintained*" will be achieved for the State Proposal.

Marine fauna

As described in **Table 6-146**, the risk of the unplanned introduction of an IMS presents a Moderate risk to marine fauna.

As above, these risk ratings are driven by the potential Major consequence where regional impacts affecting the marine fauna within the State Proposal Area and other State waters including adjacent to the mainland could occur. As above however, with the implementation of the proposed controls, the likelihood that such an event would occur is considered remote.

Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors will be achieved, and the WA EPA environmental objective "*To protect marine fauna so that biological diversity and ecological integrity are maintained*" will be achieved for the State Proposal.

Conclusion: Acceptable

External context

To date there have been no specific matters raised by stakeholders regarding IMS in relation to the proposed Browse to NWS Project.

Conclusion: Acceptable

Internal context

This impact and risk assessment has been undertaken in accordance with Woodside's Risk Assessment Procedure and Environment Impact Assessment Guideline (**Section 6.2**) The proposed Browse to NWS Project will be executed in accordance with Woodside's Health, Safety and Environmental Management System.

Further, Woodside will implement the requirements of its internal IMS Management Plan.

Conclusion: Acceptable

Acceptability Assessment
Other requirements
Key Ecological Features
As detailed in **Table 6-144**, risks associated with the introduction and establishment of IMS will not materially increase existing relevant pressures on the conservation values of the KEFs.
AMPs
As detailed in **Table 6-145**, the proposed activities are considered to be not inconsistent with the requirements of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018).
Other Protected Places
No impacts are expected to occur to the to the values of the Scott Reef and Surrounds or the Mermaid Reef – Rowley Shoals Commonwealth Heritage Places.
Conclusion: Acceptable

6.3.20 Production Activities: Seabed Subsidence

6.3.20.1 Impact and Risk Overview

Table 6-148 presents an overview of the potential impacts and risks from seabed subsidence associated with the proposed Browse to NWS Project.

Table 6-148 Seabed subsidence Impact and Risk Overview

Aspect	Production activities: seabed subsidence
Description	Production activities through the extraction of naturally high-pressured reservoir fluids, will cause a reduction in the reservoir's pressure, which has the potential to result in the compaction of the geological layers overlying the reservoir leading to potential gradual subsidence (sinking) of the seabed within the field location.
Area	Project Area, Browse Development Area, State Proposal Area
Project stage	Operations
Environmental objectives	The environmental objectives in relation seabed subsidence associated with the proposed Browse to NWS Project are Objectives 6, 10, 11, 12, 13, 16, 18, 19 and 21. These objectives are detailed in **Table 6-7**.
Policy and guidelines	The following policy and guidelines are relevant to the assessment of this aspect. In addition, a number of EPBC Act conservation advices for protected fauna have been considered (**Table 6-149**). + Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) + WA EPA Environmental Factor Guideline - Coastal Processes (EPA, 2016e) + WA EPA Environmental Factor Guideline - Marine Fauna (EPA, 2016b) + WA EPA Environmental Factor Guideline - Benthic Communities and Habitats (EPA 2016c) + WA EPA Technical Guidance - Protection of Benthic Communities and Habitats (EPA 2016d) + Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a).

<table>
<tr><th>Aspect</th><th colspan="3">Production activities: seabed subsidence</th></tr>
<tr><td>Receptors</td><td colspan="3">The following receptors have been identified as potentially being impacted as a result of the proposed Browse to NWS Project (Table 6-2). A detailed description of each of these receptors is provided in Chapter 5.
Ecological
+ benthic habitats:
  + shallow water benthic communities and habitats (<75 m depth) (high value habitat)
  + deepwater communities and habitats (>75 m depth) (medium value habitat)
+ fauna:
  + seabirds and migratory shorebirds (high value species)
  + marine reptiles (high value species)
+ State Marine Parks and nature reserves (high value)
Socio-economic
+ other users:
  + tourism and recreation (high value users)
  + scientific studies (high value users)
+ marine archaeology (high value)</td></tr>
<tr><td>Potential impacts</td><td colspan="3">+ Change in habitat
+ Changes to the functions, interests or activities of other users
+ Change in heritage values</td></tr>
<tr><td>Risk</td><td colspan="3">+ Given peer reviewed modelling studies undertaken and verification monitoring for seabed subsidence planned there is no anticipated environmental risks in relation to this aspect associated with seabed subsidence resulting from production activities.</td></tr>
<tr><td rowspan="2">Summary of governing impact evaluation</td><td>***Magnitude***</td><td>***Impact significance level***</td><td>***Confidence***</td></tr>
<tr><td>Slight</td><td>Minor (D)</td><td>High</td></tr>
<tr><td rowspan="2">Summary of governing risk evaluation</td><td>***Consequence***</td><td>***Likelihood***</td><td>***Risk rating***</td></tr>
<tr><td>N/A</td><td>n/a</td><td>n/a</td></tr>
</table>

6.3.20.2 Source of aspect

Subsea subsidence may manifest as a result of production activities, through the extraction of hydrocarbons from the Torosa reservoir causing a reduction in the reservoir's pressure.

The phenomenon of subsidence due to oil and gas production is considered rare and is mostly imperceptible or low magnitude. Only a few reported instances are known in the industry worldwide (Nagel, 2001). Instances where higher magnitude production-induced subsidence has been recorded are likely related to specific geologic conditions at these locations These have included reservoirs located in the offshore North Sea region (44 cm/year at Ekofisk), onshore California (22 cm/year at Wilmington and up to 20 cm/year at South Belridge), offshore Malaysia (M3), offshore Indonesia (Arun) and offshore Oman (4.5 cm/year at Yibal) (Nagel, 2001).

6.3.20.3 Seabed Subsidence Modelling

It is estimated for the proposed Browse to NWS Project that the average vertical seafloor movement is a total of approximately 5.4 cm (range 2.6 – 8.9 cm) over 40 years based on modelling; this is equivalent to 0.06-0.22 cm/year.

Subsidence associated with oil and gas extraction is a physical response of the seabed due to pressure reduction inside the reservoir. Woodside has modelled the magnitude of potential subsidence and associated horizontal movements for the Browse reservoirs (Woodside, 2014). Analyses took into account a range of parameters, including the geological/fault structure of the reservoir, its spatial dimensions, the hydrocarbon reservoir thickness and its depth, reservoir temperature and pressure as well as pore compressibility in the reservoir. These analyses were supported by field measurements and laboratory tests on core samples obtained from exploration wells within the Browse reservoirs.

Average subsidence was predicted to occur over a radius of about 10 km centred on a point in deep water on the eastern side of North Scott Reef. The magnitude of subsidence is predicted to diminish away from this point up to 18 km. Beyond 20 km, the magnitude of subsidence would be virtually nil (Woodside, 2012).

This analysis has been peer reviewed by Baker Hughes GMI Geomechanics Services (Hughes, 2012)[28] who concluded that the method and supplied data was appropriate. The DoEE sought further independent review by CO2 Geological Storage Solutions Pty Ltd (CGSS) (CGSS, 2012)[29] who found that the report conclusions were reasonable. Woodside therefore has a high level of confidence that any production related subsidence at Scott Reef will be less than 10 cm over field life.

6.3.20.4 Environmental Impact

The predicted environmental impact of seabed subsidence at Scott Reef is presented below. This assessment is based on the peer reviewed modelling results described above with a maximum subsidence of less than 10 cm over field life.

Benthic communities

Change in habitat

An increase in water depth at light dependent benthic communities around Scott Reef, in particular coral habitats, could alter or restrict the area available or suitable for these communities to inhabit. No effect on the sparse deepwater habitats (<75 m water depth) of the Browse Development Area are predicted as there are no light dependent benthic communities present in these areas.

Potential impacts of subsidence on corals at Scott Reef are dependent on the rate of coral accretion expected at Scott Reef over the life of the proposed Browse to NWS Project. Analyses of cores taken from the margin of Scott Reef (Collins et al., 2009) indicated that Scott Reef has previously experienced sea level changes, with five growth phases identified over the past 400,000 years, each 30 to 50 m thick, corresponding to episodes of sea level rise through time. Based on these analyses, vertical accretion rates of corals at Scott Reef were found to vary from 1.4 to 3.5 mm/yr. The modelled subsidence rates compared against the likely coral accretion rates at Scott Reef indicate that coral communities would successfully adapt to sea level changes associated with production activities at Torosa, with predicted subsidence well within natural vertical accretion rates observed.

A study by AIMS (2012)[30] to assess the potential impacts of subsidence on Scott Reef's coral habitats and Sandy Islet in the context of climate change has been undertaken (Cooper et al., 2010; AIMS, 2012). The assessment was conducted based on the following information:

- the range of subsidence derived from Woodside's modelling studies
- historical coral accretion rates at Scott Reef (Collins et al., 2009)
- sea level change predictions (IPCC, 2007)
- coral growth rates under the influence of climate change induced increases in sea temperature and increased ocean acidity due to increased atmospheric CO2 concentration.

AIMS (2012) assessed the impact of net sea level rise (from subsidence and climate change induced sea level rise) and its predicted impacts on reef flat habitat (0 to 5 m depth), shallow water coral habitats (5 to 30 m), deepwater coral habitat (30 to 70 m) and Sandy Islet, for three scenarios (worse case, intermediate case and best case).

Overall the study concluded that minor seabed subsidence over the life of the Torosa reservoir affecting a part of Scott Reef and Sandy Islet is not predicted to significantly contribute to sea level changes and predicted associated impacts.

Reef flat habitat

Reef flat benthic habitat represents a harsh environment for the establishment and growth of benthic primary producers due to wave exposure, periodic exposure at spring low tide and the occasional elevated water temperatures. Corals in this habitat have low cover (less than 5%) and comprise stunted hardy robust forms due to tidal exposure and storm impacts (Smith et al., 2006). Similarly, seagrass is not abundant on the reef flat; however, macroalgae (Halimeda spp.) is commonly present within this zone. The AIMS (2012) study predicted the following impacts to reef flats at Scott Reef:

- Worst case: Any significant changes in reef flat coral communities due to adaptation to increased mean sea level and climate change related effects would occur regardless of the maximum predicted subsidence and as such the impact to reef flat corals contributed by production-induced subsidence would be negligible.

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[28] Hughes (2012) available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies

[29] CGSS (2012) available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies

[30] AIMS (2012) available at: https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies

- Intermediate case: It is considered that the change in wave exposure and water depth conditions would not be enough to elicit any perceptible changes to reef flat coral communities on its own. Conditions associated with this level of subsidence are unlikely to result in significant adverse impacts to reef flat corals.
- Best case: Reef flat benthic habitats would be expected to continue to be limited in their upward growth by sea levels. As such no adverse impacts to reef flat corals are predicted.

Shallow water coral

Shallow water coral habitats are the most diverse coral habitats at Scott Reef. They are also susceptible to natural impacts such as thermally induced coral bleaching and cyclone damage, as demonstrated by past recent disturbances (Gilmour et al., 2018; Gilmour et al., 2019; **Chapter 10, Appendix D.2**). The AIMS (2012) study predicted the following impacts to shallow water corals at Scott Reef

- Worst case: There is potential for increased wave action to occur, however, it is unlikely that increased wave exposure would adversely impact shallow water corals on its own. Any significant impacts to shallow water corals will arise due to cyclone, bleaching and ocean acidification effects, which, under this scenario, are assumed to have the potential to occur regardless of subsidence.
- Intermediate case: The magnitude of change is not expected to result in a change in hydrodynamic or light conditions affecting reef morphology or community composition and structure.
- Best case: Alterations to hydrodynamic conditions at Scott Reef would be negligible.

Deepwater coral

Deepwater coral habitats at Scott Reef, including sheltered deepwater coral assemblage habitat, have not been susceptible to thermally induced bleaching and cyclone damage. The AIMS (2012) study predicted the following impacts to deepwater corals at Scott Reef

- Worst case: Deepwater corals can photo-acclimatise to changes in light conditions over short time scales by changing the density of zooxanthellae and/or changing the concentration of photosynthetic pigments. Given the gradual nature of the subsidence over 40 years, corals would be able to photo-acclimatise, and impacts are not predicted.
- Intermediate case: Impacts to deepwater corals are not expected as changes in irradiance would have negligible effects on the photo-physiology of corals.
- Best case: Impacts to deepwater corals are not expected as changes in irradiance would have negligible effects on the photo-physiology of corals.

Marine fauna

Marine turtles - change in habitat

Sandy Islet is an unvegetated, 4.5 m high, linear-shaped sandy cay with a sandy spit at its southern end, serving as an important turtle nesting ground (identified as habitat critical to turtle survival) and used for roosting by seabirds. Habitat modification is highlighted within the Recovery Plan for Marine Turtles in Australia (2017-2027) as a high threat to the Scott Reef – Browse Island genetic green turtle stock (Commonwealth of Australia, 2017a).

A reduction in the area of Sandy Islet could impact marine turtles, through a reduction in available or suitable nesting locations, thereby impact nesting success rates. Scott Reef and Sandy Islet have experienced considerable natural variability in sea level over different time scales. For example, the tidal regime at Scott Reef is semi-diurnal with a maximum daily range of approximately 4 m. Similarly, sea levels can temporarily vary by tens of centimetres in response to large-scale oceanographic and atmospheric processes, such as the passage of mesoscale ocean eddies and inverse barometer effects with the passing of cyclonic and anticyclonic pressure systems. During El Nino years, up to 20 to 30 cm increases in sea levels occur from the eastern Pacific Ocean to the eastern Indian ocean. Satellite data (ToPEX/Poseidon) from 1992 to 2009 show intra- and inter-annual sea level variability in the vicinity of Scott Reef to be from 30 cm below to 40 cm above MSL (Cooper et al., 2010). Given the natural variability in sea level at Scott Reef described above, nesting turtles (primarily green turtles) demonstrate the ability to cope with variability in the sea level at Sandy Islet.

The AIMS (2012) study concluded that with worst case net sea level rises there is potential for wave action at high tide to reduce the height of the islet. This could affect the stability of Sandy Islet due to erosional processes associated with increased wave height, and thus impacts to availability of turtle nesting habitat. These impacts would still occur in the absence of subsidence albeit over a slightly longer time period, with the most important factor influencing the persistence of the islet being the frequency of Category five cyclones. The study concluded that for the worst-case scenario, given the highly variable nature of sea level rise, cyclone occurrence and sediment dynamics, it is not possible to reliably predict the timing or just how much earlier any major changes to Sandy Islet might occur. The AIMS (2012) study concluded that impacts to Sandy Islet from the intermediate and best-case scenarios would be negligible.

Given the above, no significant change is predicted in terms of available turtle nesting locations or nesting success as a result of seabed subsidence.

Seabirds and migratory shorebirds - change in habitat

Sandy Islet is used for roosting by seabirds and supports minor seabird breeding colonies including for the little tern. Scott Reef is recognised as a resting BIA for the little tern. The Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a) identify habitat loss, degradation or modification as key threats to migratory shorebirds. As discussed above, no significant change to the size of Sandy Islet is predicted as a result of seabed subsidence, therefore no significant impacts to seabirds are expected.

Assessment against EPBC Act recovery and conservation plans and advices

Table 6-149 provides an assessment of seabed subsidence in relation to objectives and actions of the relevant EPBC Act recovery and conservation plans and advices.

Table 6-149 Alignment with EPBC Act recovery and conservation plans and advices for protected fauna – seabed subsidence

Fauna	Relevant plan(s)/ conservation advice	Plan/advice objectives and actions	Assessment
Migratory shorebirds	Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a)	Protection of important habitats for migratory shorebirds throughout the EAAF.	No significant change to the size of Sandy Islet is predicted as a result of seabed subsidence. As such the habitat is protected and objective met.
Green turtle Hawksbill turtle	The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a)	Management actions: + Manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to the survival. + Manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue. + In relation to the Scott Reef – Browse Island green turtle genetic stock, the priority action is to manage anthropogenic activities to ensure marine turtle are not displaced from identified habitat critical to their survival.	Studies have indicated that no significant change in terms of available turtle nesting locations or nesting success as a result of seabed subsidence will occur. Therefore, there is a high level of confidence that seabed subsidence will not result in displacement of the Scott Reef – Browse Island green turtle genetic stock, from identified habitat critical to their survival, or adversely affect the breeding cycle of marine turtles in the BIA at Scott Reef. Therefore, it is considered that the proposed activities are not inconsistent with the objectives of the Recovery Plan for Marine Turtles in Australia(2017-2027) (Commonwealth of Australia, 2017a).

State marine parks and nature reserves and other protected places

Change in habitat

As described above, seabed subsidence will not result in significant impacts to Scott Reef shallow water benthic habitat (<75 m bathymetry) Sandy Islet or fauna that utilise Sandy Islet. As such, impacts to the values of the Scott Reef Nature Reserve are not predicted. No State marine parks will be affected by seabed subsidence.

Other users

Changes to the functions, interests or activities of other users

As no significant change to the size of Sandy Islet and no significant impacts to Scott Reef shallow water benthic habitat (<75 m bathymetry), or fauna that utilise Sandy Islet are predicted, no impact to the tourism and recreation or scientific studies values of Scott Reef are expected to occur as a result of seabed subsidence.

Maritime archaeology

Change in heritage values

Given the magnitude of predicted subsidence (in the order of less than 10 cm), no adverse impact to the shipwrecks on Scott Reef are expected to occur.

6.3.20.5 Environmental Risk

Given peer reviewed modelling studies undertaken and monitoring planned, there are no anticipated environmental risks in relation to this aspect associated with seabed subsidence resulting from production activities.

6.3.20.6 Cumulative Impacts

Potential subsidence associated with the project activities is forecast to be gradual (0.06-0.22 cm/year) and highly localised, with effects predicted to extend no further than approximately 20 km from the affected reservoir. Therefore, given the distance between other developments and reservoirs to the Browse Development Area, no cumulative impacts associated with subsidence at Torosa and Scott Reef are expected.

6.3.20.7 Impact and Risk Assessment Summary and Acceptability Assessment

A summary of the impact assessment for seabed subsidence is provided in **Table 6-150**. The final acceptability assessment is provided in **Table 6-151**.

Table 6-150 Impact assessment summary and adopted controls – Seabed Subsidence

Receptor (sensitivity)	Impact	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
Shallow water benthic communities and habitats (<75 m depth) (high value habitat)	Change in habitat	**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results. **Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m bathymetry).	***Production activities*** + Further modelling of likely subsidence will be conducted based on known reservoir performance during operations. + Based on the revised modelled subsidence estimates, further investigation would be initiated into any potential short term and longer-term biological and ecological implications for Scott Reef and Sandy Islet. This would include further engagement with appropriate scientific organisations to provide expert opinion and advice on potential impacts to the Scott Reef, if required as a result of higher than predicted subsidence rates. + Verification monitoring for seabed subsidence will be undertaken.	Slight	Minor (D)
Deepwater communities and habitats (>75 m depth) (medium value habitat)	Change in habitat	**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.		No lasting effect	Negligible (F)
Seabirds and migratory shorebirds (high value species)	Change in habitat	**Objective 11:** To not have a substantial adverse effect on a population of seabirds or migratory shorebirds, or the spatial distribution of the population. **Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.		No lasting effect	Slight (E)
Marine turtles (high value species)	Change in habitat			No lasting effect	Slight (E)

Receptor (sensitivity)	Impact	Environmental objective	Adopted controls	Magnitude	Impact Significance Level
State marine parks and nature reserves (high value)	Change in habitat	**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		Slight	Minor (D)
Other users including tourism and recreation and scientific studies, (high value users)	Changes to the functions, interests or activities of other users	**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		No lasting effect	Slight (E)
Maritime archaeology (high value)	Change in heritage values	**Objective 19:** To not have a substantial adverse impact on heritage values.		No impact expected	

Table 6-151 Acceptability assessment – seabed subsidence

Acceptability Assessment

Confidence in assessment

Woodside have a high level of certainty with respect to the assessment of the potential impacts associated with seabed subsidence as:

- Independently verified modelling studies have demonstrated that the magnitude of predicted subsidence will in the order of less than 10 cm
- A study by AIMs (2012) concluded that minor seabed subsidence over the life of the Torosa reservoir affecting a part of Scott Reef and Sandy Islet is not predicted to significantly contribute to sea level associated impacts and the reef system has a high capacity to adapt to change.
- Verification monitoring for seabed subsidence will be undertaken during operations.

Principles of ESD

With the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such it is considered that the principles of ESD will be met.

Conclusion: Acceptable

Significant Impacts as defined by the MNES Significant Impact Guidelines

Listed threated species and ecological communities / listed migratory species

As described in **Table 6-150**, no lasting effect is predicted to occur to listed threatened or migratory species such as seabird and migratory shorebirds and, marine turtle as a result of seabed subsidence, with the impact significance level determined to be Slight (E).

Given this, it is predicted that the nominated environmental objectives for each of these fauna species will be achieved. As such, no significant impacts to the listed threated or migratory species (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted

Commonwealth Marine Environment

As described in **Table 6-150**, the potential impact of seabed subsidence on deepwater benthic communities and habitats (>75 m depth) has been assessed as Negligible (F). Slight (E) impacts may potentially occur to, marine fauna (as discussed above) and maritime archaeology. Minor (D) impacts may occur to shallow water benthic communities and habitats (<75 m depth).

Given this, it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such no significant impacts to the Commonwealth marine environmental (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted.

Conclusion: Acceptable

Acceptability Assessment

WA EPA Environmental Objectives

Marine fauna

As described in Table 6-150, no lasting effect is predicted to occur to marine fauna such as seabird and migratory shorebirds and, marine turtle as a result of seabed subsidence, with the impact significance level determined to be Slight (E).

Given this, it is considered that the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*To protect marine fauna so that biological diversity and ecological integrity are maintained.*" will be achieved.

Benthic communities and habitats

As described in Table 6-150, the potential impact of seabed subsidence on deepwater benthic communities and habitats (>75 m depth) has been assessed as Negligible (F). Slight (E) impacts may potentially occur to, marine fauna (as discussed above) and maritime archaeology. Minor (D) impacts may occur to shallow water benthic communities and habitats (<75 m depth).

Given this, it is considered that the nominated environmental objectives for these receptors, and the WA EPA environmental objective "*to protect benthic communities and habitats so that biological diversity and ecological integrity are maintained*" will be achieved.

Conclusion: Acceptable

External context

To date there have been no specific matters raised by stakeholders regarding subsea subsidence in relation to the proposed Browse to NWS Project.

Conclusion: Acceptable

Internal context

This impact assessment has been undertaken in accordance with Woodside's Risk Assessment Procedure and Environment Impact Assessment Guideline (Section 6.2.3.4). The proposed Browse to NWS Project will be executed in accordance with Woodside's Health, Safety and Environmental Management System.

Conclusion: Acceptable

Other requirements

EPBC Act recovery and conservation plans and advices

As detailed in Table 6-151, the proposed activities are considered to be not inconsistent with the actions and objectives of:

- Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a)
- The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a).

Conclusion: Acceptable

6.3.21 Unplanned Hydrocarbon Releases

6.3.21.1 Impact and Risk Overview

Table 6-152 presents an overview of the potential impacts and risks from an unplanned release of hydrocarbons associated with the proposed Browse to NWS Project.

Table 6-152 Unplanned hydrocarbon releases impact and risk overview

Aspect	Unplanned hydrocarbon releases
Description	Unplanned hydrocarbon releases include the potential for both gas and liquid hydrocarbons to be unintentionally be released into the marine environment. Activities and facilities associated with proposed Browse to NWS Project which may result in the unplanned discharge of gas or liquid hydrocarbons to the marine environment are: + drilling and completion operations + commissioning + hydrocarbon extraction + hydrocarbon processing + gas export + condensate offtake + project vessel and MODU operations + helicopter operations + decommissioning. Large hydrocarbon spills have the potential to result in significant impacts on a regional scale. As such, the risk of unplanned hydrocarbon release will be the subject of comprehensive engineering design and management measures to reduce the risk of an event occurring, and extensive hydrocarbon spill response planning to reduce the spatial and temporal impact in the highly unlikely event that a large spill occurs.
Area	Project Area, Browse Development Area, State Proposal Area
Project stage	All - drilling and completions, installation, commissioning, operations and decommissioning
Environmental objectives	The environmental objectives in relation to the unplanned release of hydrocarbons associated with the proposed Browse to NWS Project are Objectives 1, 2, 3, 6, 7, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 and 21. These objectives are detailed in Table 6-7.

Aspect	Unplanned hydrocarbon releases
Policy and guidelines	The following policy and guidelines are relevant to the assessment of this aspect. In addition, a number of EPBC Act conservation advices for protected fauna have been considered (Table 6-159). + Commonwealth *Navigation Act 2012* + Commonwealth *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* + Commonwealth Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011 + Commonwealth Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 + Commonwealth Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009 + Commonwealth *Underwater Cultural Heritage Act 2018* + WA *Emergency Management Act 2005* + WA *Pollution of Waters by Oil and Noxious Substances Act 1987* + IOPER Guiding Principles for Regulating Oil Spill Response Preparedness for Offshore Petroleum November 2014 + IOGP 2019 Report 594 – Source Control Emergency Response Planning Guide for Subsea Wells + IMO International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC) May 1995 + NOPSEMA Oil pollution risk management (Guidance note GN1488 Rev 2) February 2018 + NOPSEMA Oil spill modelling (Bulletin #1) April 2019 + Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012) + North-west Marine Parks Network Management Plan (Director of National Parks, 2018) + Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) + Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a) + Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015b) + AMSA National Plan for Maritime Environmental Emergencies 2014 (2019 Edition) + State Hazard Plan – Maritime Environmental Emergencies (MEE) (Department of Transport, 2018) + Oil Spill Contingency Plan 2015 (Department of Transport, 2015) + WA EPA Environmental Factor Guideline - Benthic Communities and Habitats + WA EPA Technical Guidance - Protection of Benthic Communities and Habitats + WA EPA – Environmental Factor Guideline – Marine Fauna (EPA, 2016b) + WA *Biodiversity Conservation Act 2016* (Wildlife Conservation (Specially Protected Fauna) Notice 2018).

Aspect	Unplanned hydrocarbon releases

Receptors	The following receptors have been identified as potentially being impacted as a result of the proposed Browse to NWS Project (**Table 6-2**). A detailed description of each of these receptors is provided in **Chapter 5**.
	Physical
	+ sediment quality (medium value (open waters))
	+ water quality (medium value (open waters))
	Ecological
	+ plankton (medium value (open water))
	+ benthic habitat and communities
	    + shallow water benthic communities and habitats (<75 m depth) (high value habitat)
	    + deep water communities and habitats (>75 m depth) (medium value habitat)
	+ coastal habitats
	    + saltmarsh (high value habitat)
	    + mangroves (high value habitat)
	    + shoreline habitats (high value habitat)
	+ fauna
	    + seabirds and migratory shorebirds (high value species)
	    + fish (high value species)
	    + marine mammals (high value species)
	    + marine reptiles (high value species)
	+ KEFs (medium value)
	+ AMPs (medium value)
	+ State marine parks and nature reserves (high value)
	+ other protected places (high value)
	Socio-economic
	+ State and Commonwealth managed fisheries (high value marine user)
	+ other users
	    + tourism and recreation (high value user)
	    + scientific studies (high value user)
	    + shipping (medium/high value users)
	    + industry (low value users)
	+ settlements (medium value users)
	+ aboriginal and indigenous heritage (high value users)
	+ marine archaeology (high value)

Potential impacts	+ No impacts from planned activities have been identified in relation to this aspect
Risks	Unplanned hydrocarbon spill resulting in: + change in sediment quality + change in water quality + injury or mortality to fauna + changes to the functions, interests or activities of other users + change in heritage values

Aspect	**Unplanned hydrocarbon releases**		
Summary of impact evaluation for governing impact	***Magnitude***	***Impact significance level***	***Confidence***
	n/a	n/a	n/a
Summary of risk evaluation for governing risk	***Consequence***	***Likelihood***	***Risk rating***
	Catastrophic	Highly unlikely	High (A1)

6.3.21.2 Source of Aspect

There are various sources of potential unplanned hydrocarbon releases associated with the proposed Browse to NWS Project. This section provides a general description of the sources. More details will be provided in secondary environmental approvals (i.e. activity-specific Environment Plans) and associated Oil Pollution Emergency Plans (OPEPs) that will be prepared for the proposed Browse to NWS Project and submitted for regulatory approval before activities commence.

Drilling or Completion operations

During drilling or completion operations, a loss of well control (LOWC) could result in an uncontrolled subsea release of hydrocarbons (I.e. unstabilised condensate) resulting from an over-pressurised reservoir and barrier failure. The major causes of a LOWC are identified as equipment failure, dropped objects, intersection with shallow gas and human error.

Commissioning

During commissioning, hydrocarbons from the reservoirs (gas and unstabilised condensate) will be introduced into the subsea infrastructure. There is a risk of leaks in the newly installed infrastructure that would result in the loss of hydrocarbons to the marine environment. It should be noted that the planned hydrotesting (**Section 6.3.17**) to assess integrity and detect leaks will significantly mitigate this risk. In addition, there will also be a series of production chemical and fuel import activities that will last for extended durations to reach operational and storage volumes.

Hydrocarbon extraction, processing and export

During operations, hydrocarbons extracted from the reservoir will flow from the wellheads via the christmas trees and manifolds through the flowlines to the FPSO facilities. Equipment failure could result in hydrocarbon leaks or the loss of containment of reservoir hydrocarbons (gas and unstabilised condensate) from production flowlines.

It is also possible that failure of down-well barriers or physical damage to a completed well could result in a loss of control of a production well.

On the FPSO, the condensate will be separated from the gas stream before the gas is processed and compressed for export via the BTL to the existing NWS JV infrastructure. During this process, structural failure of the subsea infrastructure, FPSO facilities, individual equipment (e.g. cranes, flare tower), the BTL or the inter-field spurline could result in unplanned release of hydrocarbons. This could include loss of containment from subsea infrastructure such as pipeline, flowlines, risers, the BTL or inter-field spurline; or the FPSO, including non-process hydrocarbon inventories (fuel tanks) and condensate storage tanks. Potential causes of structural failure could include internal corrosion, external corrosion, equipment failure, extreme weather, seismic events/seabed instability and dropped objects fire/explosion event.

Condensate offtake

Every two to four weeks during operations, stabilised condensate will be loaded onto condensate tankers using flexible hoses. Condensate tankers will be positioned astern of the FPSO facility and supported by tugs as required. During offtake, vessel collision (between the condensate tanker and the FPSO or project vessel), or the rupture of condensate offtake hoses, could result in the loss of stabilised condensate to the marine environment.

Project vessel and MODU operations

Project vessels will be used during all phases of proposed Browse to NWS Project throughout the Project Area. Project vessels will not use heavy fuel oil or intermediate fuel oil. Unplanned hydrocarbon releases could occur during project vessel and MODU operations due to bunkering failure (where the partial or total failure of a bulk transfer hose or fittings results in loss of containment) or the rupture of a vessel fuel tank (as a result of a collision between project vessels or between a project vessel and a third-party vessel such as commercial fishing or shipping vessels).

For a vessel collision to result in the worst-case scenario of a hydrocarbon spill potentially impacting an environmental receptor, several factors must align:

+ Vessel interaction must result in a collision.
+ The collision must have enough force to penetrate the vessel hull.
+ The collision must be in the exact location of the fuel tank.
+ The fuel tank must be full, or at least have a volume of fuel in the tank such that the level of the fuel is higher than the point of penetration.

6.3.21.3 Hydrocarbon Spill Modelling

Spill Scenarios

Risk assessments using specific and historic spill data were undertaken to identify worst-case credible spill scenarios that could arise from the proposed Browse to NWS Project. The following information was reviewed as part of the risk assessment:

- events that could result in a hydrocarbon spill
- the likelihood of these spill events
- the resulting spill volumes released to the marine environment.

The worst-case credible spill scenarios evaluated for the proposed Browse to NWS Project are presented in Table 6-153. It should be noted that unstabilised condensate is condensate that has not yet been processed on board via the FPSO topsides facilities.

Table 6-153 Evaluation of possible proposed Browse to NWS Project worst-case credible spill scenarios

Scenario	Description of worst-case scenario	Credibility of spill scenario
Loss of well containment (well blowout)	A well blowout from the TRA-C well within the State Proposal Area releasing hydrocarbons in proximity to Scott Reef. It is estimated that approximately 142,154 m^3 of unstabilised Torosa condensate could be released.	***Credible*** Scenario selected for spill modelling
Loss of containment from production flowlines	Loss of the entire contents of the TRD/TRE combined flowline (considered worst-case due to its length and proximity to Scott Reef). It is estimated that 25 m^3 of unstabilised Torosa condensate could be released.	***Credible*** Scenario not selected for further assessment (i.e. spill modelling) due to the relatively small volume of condensate that could be lost compared to other credible spill scenarios at a nearby location.
Catastrophic loss of FPSO structural stability	Foundering (sinking) of the FPSO and rupture of multiple cargo tanks.	***Not credible*** Due to the design of the FPSO, which will comply with MARPOL Annex 1 (Regulations for the Prevention of Pollution by Oil) Regulation 28 (Damage Stability), the foundering of the FPSO and loss of Browse condensate from multiple cargo tanks is not considered to be a credible scenario. This is consistent with (AMSA, 2015) guidance for credible spill scenarios.
FPSO loss of station	Loss of station resulting in the impact of the Torosa FPSO on Scott Reef and rupture of multiple cargo tanks.	***Credible*** Scenario not selected for spill modelling – see further details below.
Loss of hydrocarbons from a cargo tank on either the FPSO or a condensate tanker	Loss of the entire volume of a single cargo tank of stabilised Torosa condensate from the FPSO or a condensate tanker. It is estimated that approximately 18,000 m^3 could be released.	***Credible*** Scenario selected for spill modelling
Loss of hydrocarbons during condensate offtake	Loss of the entire hose inventory (i.e. the contents of the hose) due to failure of the hose or couplings, as well as additional stabilised Torosa condensate pumped through the offtake hose during the time taken to react to the spill. It is estimated that approximately 768 m^3 of condensate could be released.	***Credible*** Scenario selected for spill modelling

Scenario	Description of worst-case scenario	Credibility of spill scenario
Loss of containment from the process equipment on the FPSO topsides	The LP Separator has the largest inventory, which would result in a maximum release of 165.3 m^3 of unstabilised condensate.	***Credible*** Scenario not selected for further assessment (i.e. spill modelling) due to the relatively small volume of condensate relative to the worse cases presented for this location.
Loss of containment from diesel bunkering	Loss of containment during diesel bunkering to the FPSO or other vessels due to the partial or total failure of the bulk transfer hose or fittings. It is estimated that the partial or total failure of a bulk transfer hose or fittings during bunkering, combined with a failure in procedure to shutoff fuel pumps for a period of up to five minutes, could result in approximately 8 – 13 m^3 of marine diesel being released.	***Credible*** Scenario not selected for further assessment due to the relatively small volume of marine diesel that could be lost compared to other credible spill scenarios.
Loss of containment from the BTL	A pipeline rupture resulting in an uncontrolled subsea release of dry gas (methane) from the BTL. It is estimated that 850,000 m^3 of dry gas could be released.	***Credible*** Scenario not selected for spill modelling due to the lack of liquid hydrocarbons that could be released. See further details below.
Loss of containment from an activity vessel	Loss of containment due to a collision between activity vessels, with the maximum volume that could be released estimated to be 2,000 m^3 of marine diesel from the rupture of a single tank on the pipelay vessel or fuel tanker in proximity to Rowley Shoals (the most sensitive receptor along the BTL route).	***Credible*** Scenario selected for spill modelling

These scenarios were based on spill locations and volumes applicable to a range of spill events deemed to be representative, as described in **Section 6.3.21.2**. Spill volumes were determined based on a review of hydrocarbon volumes likely to be stored within equipment, infrastructure and vessels, as well as expected volumes from reservoirs. To determine the worst-case credible spill volumes, equipment and the maximum inventory of indicative vessel types were considered, along with loading/unloading rates and reaction times for spill detection/mitigation. Design features incorporated into infrastructure and equipment, which would inherently reduce the likelihood of a spill occurring, were also factored in where applicable.

Further detail – FPSO loss of station

The scenario "FPSO loss of station" refers to the risk of an FPSO mooring system failure resulting in grounding of a FPSO, rupture of multiple cargo tanks, and subsequent release of condensate onto Scott Reef. If this were to occur, the potential consequence would be a significant spill at Scott Reef, causing environmental impact to the reef. The impact of a potential spill to a Scott Reef receptor would be similar in nature and scale to a well blowout in close proximity to Scott Reef, such as the TRA-C well or the loss of hydrocarbons from a cargo tank on either the FPSO or a condensate tanker. The nature of an FPSO loss of station event means that it is not able to be modelled following the standard approach. In particular, the Environment that May Be Affected (EMBA) is typically defined using a stochastic modelling approach, in order to identify receptors that may be impacted under different metocean conditions. It is not reasonable to apply a stochastic approach to a FPSO loss of station scenario, as this is only considered credible under cyclonic conditions and not under the full range of metocean conditions applied during stochastic modelling.

The likelihood of the FPSO loss of station scenario is considered to be remote. The FPSO mooring system is designed to maintain FPSO station, including in cyclonic metocean conditions up to and including the 1 in 10,000 year sea state. Once off station, the typical drift speed of an FPSO is approximately 8 knots, which is unlikely to be sufficient to have enough impact force to rupture the hull of the FPSO if the FPSO were to drift into Scott Reef. The FPSO design is based on cargo tanks as centre tanks only, with ballast tanks as wing tanks. Furthermore, the FPSO has a draft of approximately 16 m. The central location of the cargo tanks and the draft of the FPSO makes direct impact to FPSO hull cargo tanks from a collision with Scott Reef inherently unlikely.

If FPSO loss of station and subsequent grounding were to occur, grounding would most likely occur on the nearest face to the FPSO, which is the eastern side of Scott Reef. The well blowout modelling at the TRA-C well also occurred near the eastern side of Scott Reef, in regional terms, and the total volume of condensate released in a well blowout significantly exceeded two cargo tank volumes of the FPSO.

Therefore, as it is not reasonable to apply stochastic modelling, the remote likelihood of the event and the impact of a spill being assessed as similar to Scott Reef as the well blowout scenario (which is also the governing scenario for a risk assessment of an accidental hydrocarbon release in proximity to Scott Reef), a hydrocarbon loss of containment resulting from FPSO loss of station has not been modelled or considered further.

Further detail - loss of containment from the BTL

The scenario "Loss of containment from the BTL" refers to a dry gas subsurface release related to the proposed BTL (located at seabed depths that range between approximately 125 m and 400 m). If a pipeline rupture occurred, the majority of the methane gas released would immediately dissolve into the water column (methane is highly soluble in water), with a small proportion expected to reach the sea surface and 'flash-off' on exposure to the atmosphere.

Studies show methane oxidation in deep water, and water column characteristics like pynoclines (stratification of the water column due to differences in density) and thermoclines (stratification of the water column due to differences in water temperature), limit the amount of methane that is transported upwards to the sea surface. Even in relatively shallow water depths (less than 100 m water depths) only minor amounts of methane are actually released to the atmosphere (Deimling et al., 2015; Gentz et al., 2014; Schmale et al., 2010). Given stratification occurs year round within the Browse Development Area (**Section 5.2.5.7**), it is expected that methane would be effectively trapped within cooler deeper waters, should a rupture or leak occur in the BTL. In this scenario, it is expected that any transfer of methane to warmer surface waters would be restricted and, therefore, air-sea exchange would be limited (Gentz et al., 2014).

Gentz et al. (2014) found approximately 80% of methane dissolution occurs below the water column stratification, such as with a pynocline, and that methane levels return to background concentrations rapidly above the pyncoline. Methane dissolved in the water column is also subject to microbial oxidation, which further restricts transfer of methane into the upper surface water layer and the atmosphere (Gentz et al., 2014; Valentine et al., 2001). When methane is oxidised it forms water and carbon dioxide. Dissolved methane and carbon dioxide exist naturally in water and pose no risk to the marine environment.

Following the 2012 gas leak from the Elgin platform in the North Sea, monitoring of water and sediment (Webster et al., 2012a,b) and fish health (Webster et al., 2012b,c) found no evidence of hydrocarbon contamination above background levels. Although the sea temperatures were colder than those in the Project Area, natural processes such as microbial oxidation would be expected to occur in the Project Area which would greatly reduce any dry gas release to the atmosphere or impacts to the marine environment.

Given this, changes in the chemistry of the water column or sediment from a gas release are expected to be localised, short-term and not significant to any sensitive receptor or environmental aspect. Therefore, potential impacts from this scenario are not considered further and potential environmental impacts from hydrocarbon releases will be sufficiently addressed through impact assessment of other scenarios.

Hydrocarbon Spill Modelling

As it is not practicable for spill modelling to be undertaken at every potential spill location within the Project Area, a subset of the scenarios have been selected to be modelled.

As per Table 6-153, the following credible hydrocarbon spill scenarios were selected for risk assessment:

- Scenario 1: A long-term (77-day) uncontrolled release of 142,154 m^3 of unstabilised Torosa condensate from the TRA-C well (13° 58’ 12.5” S, 121° 58’ 37.7” E), with a 5-day surface release phase followed by a 72-day subsea release phase, representing loss of containment after a loss of well control. Note that the 77-day period for an uncontrolled release has been estimated based on early information regarding rig mobilisation time and relief well drill time. This estimate may be further refined under subsequent EPs.
- Scenario 2: A medium-term (24-hour) uncontrolled surface release of 18,000 m^3 of stabilised Torosa condensate at the Torosa FPSO location (13° 58’ 15.1” S, 122° 01’ 28.5” E), representing loss of containment after a vessel cargo tank rupture.
- Scenario 3: A short-term (instantaneous) surface release of 768 m^3 of stabilised Torosa condensate at the Torosa FPSO location (13° 58’ 15.1” S, 122° 01’ 28.5” E), representing loss of containment after a vessel offtake system failure.
- Scenario 4: A short-term (instantaneous) surface release of 2,000 m^3 of marine diesel near the Rowley Shoals (17° 16’ 52.8” S, 119° 39’ 30.8” E), representing loss of containment after a vessel fuel tank rupture.

Smaller minor spills, such as the loss of containment from FPSO topsides or loss during diesel bunkering, were also identified as a source of risk as they also have the potential to occur during the proposed Browse to NWS Project. However, the selected scenarios for spill modelling are considered to be representative of worst-case credible spill scenarios and, therefore, determine the overall hydrocarbon spill risk associated by the proposed Browse to NWS Project.

Hydrocarbon Characteristics

Condensate

For condensate release scenarios, multiple oil characteristics have been modelled, which describe how the fluid is expected to behave in different scenarios. During a release of unstabilised Torosa condensate, less dense components exposed to a sudden change in pressure flash off as gases, leaving behind a liquid spill that is denser than the original fluid. The greater the change in pressure, the more light components flash off, and the denser/heavier components remain in liquid. The change in pressure at surface is much greater than the change in pressure at seabed (due to the pressure exerted in deep water) and, therefore, unstabilised Torosa condensate released at surface is expected to be denser (and have a higher proportion of low volatility components) than unstabilised Torosa condensate released at seabed.

During the stabilisation process, the condensate is treated to allow the lighter components to be retained in the liquid, through a series of controlled changes in temperature and pressure. Stabilised Torosa condensate is typically stored in near-atmospheric conditions. If a release of stabilised Torosa condensate were to occur, there would be relatively little flashing off of lighter components. The remaining liquid is expected to be less dense (and have a higher proportion of high volatility components) than unstabilised Torosa condensate.

Marine Diesel

Marine Diesel is a blend of distillates and heavy fuel oil, but with a very low fuel oil content. Marine diesel has low viscosity and is readily dispersed across the sea surface and in the water column. It is relatively toxic but dissipates and evaporates relatively rapidly. Depending on the proportion of heavy fuel oil, elements of the marine diesel may persist in the environment longer than distillate-only diesel.

Characteristics of condensate and marine diesel are summarised in Table 6-154.

Table 6-154: Characteristics of the oil types used for modelling of Scenarios 1-4

Oil Type	Density (g/cm³)	Viscosity (cP)	Component	Volatile (%)	Semi-Volatile (%)	Low Volatility (%)	Residual (%)	Aromatics (%)
			Boiling point (°C)	<180 C_4-C_{10}	180-265 C_{11}-C_{15}	265 - 380 C_{16}-C_{20}	>380 >C_{20}	Of whole oil <380 BP
Unstabilised Torosa Condensate (seabed)	0.780 at 20 °C	1.092 at 20 °C	% of total	14.5	39.9	20.7	24.9	26.2
			% aromatics	2.5	8.8	14.9	-	-
Unstabilised Torosa Condensate (surface)	0.813 at 25 °C	2.519 at 25 °C	% of total	1.0	15.5	32.7	50.8	26.9
			% aromatics	0.2	3.1	23.6	-	-
Stabilised Torosa Condensate	0.780 at 20 °C	1.092 at 20 °C	% of total	57.0	21.0	8.0	14.0	19.6
			% aromatics	10.3	4.3	5.0	-	-
Marine Diesel	0.829 at 25 °C	4.000 at 25 °C	% of total	6.0	34.6	54.4	5.0	3.0
			% aromatics	1.8	1.0	0.2	-	-

Modelling methodology

Quantitative hydrocarbon spill modelling was undertaken by RPS, on behalf of Woodside, using a three-dimensional hydrocarbon spill trajectory and weathering model SIMAP (Spill Impact Mapping and Analysis Program) (RPS, 2019b; Chapter 10, Appendix D.5). SIMAP is designed to simulate the transport, spreading and weathering of specific hydrocarbon types under the influence of changing meteorological and oceanographic forces (RPS, 2019b).

Stochastic modelling was carried out for the five governing credible hydrocarbon release scenarios, whereby SIMAP was applied to repeatedly simulate the defined scenarios using different randomly-selected conditions. Stochastic modelling simulations provide insight into the probable behaviour of a potential spill under the meteorological conditions expected to occur. Stochastic modelling simulations are used to define the EMBA. The models predict the most probable path and transport rates for unplanned releases using historical wind and ocean current data. The model runs many single trajectories (e.g. 100 scenarios per release location per season, including summer, winter and transitional), varying the start time (and hence prevailing wind and current conditions). This approach ensures that the predicted transport and weathering of a hydrocarbon slick is subjected to a range of oceanic conditions.

Deterministic modelling was also carried out to provide probable examples of single worst-case credible spill events, rather than the statistical representation of 100 spill events as represented by stochastic modelling and presented for the EMBAs.

Table 6-157 and Table 6-158 provide the summarised results from hydrocarbon spill modelling for Scenarios 1 through 4.

Hydrocarbon exposure thresholds

The outputs of the quantitative hydrocarbon spill modelling were used to assess the extent of potential environmental risk should a credible hydrocarbon spill scenario occur, by delineating which receptors could be exposed to hydrocarbon levels exceeding selected hydrocarbon threshold concentrations.

The outer extent of all points where selected hydrocarbon thresholds could be exceeded by any of the simulations modelled is defined as the Environment that May Be Affected (EMBA). The thresholds selected for informing the EMBA and the rationale for their selection is provided in Table 6-155. Further details of the EMBA are discussed later in this chapter.

Table 6-155: Summary of thresholds selected for determining the EMBA from the quantitative hydrocarbon spill risk modelling results

Parameter	Exposure Thresholds	Justification
Surface hydrocarbon	1 g/m^2	The surface threshold of ≥1 g/m^2 is based on the relationship between film thickness on the sea surface and appearance and represents a 'rainbow' presented as a range of colours (Bonn Agreement, 2015). This threshold has been used to approximate ranges of socio-economic effects for condensate and marine diesel, and to identify potential additional socio-economic receptors which may be affected from an unplanned hydrocarbon release *outside* of the defined EMBA (e.g. AMPs). This concentration is considered a suitable threshold for the extent to which socio-economic effects may occur (NOPSEMA, 2019), however, the threshold is considered below levels which would cause ecological impacts, and instead represents potential for visual amenity impacts. Additional receptors identified at this concentration have been identified in **Table 6-158** and, where relevant, impacts are described in **Section 6.3.21.5**.
	10 g/m^2	The surface threshold of ≥10 g/m^2 is based on the relationship between film thickness on the sea surface and appearance and represents a 'dull metallic colour' (Bonn Agreement, 2015). Thresholds for registering biological impacts resulting from contact of sea surface slicks have been estimated by different researchers at 10–25 g/m^2 (French et al., 1999; Koops et al., 2004; National Oceanic and Atmospheric Administration, 1996)which are asked by oil spill responders as well as those assessing potential impacts, are: (1. Potential impacts of surface slick concentrations in this range for floating hydrocarbons may include harm to seabirds through ingestion from preening of contaminated feathers, or the loss of the thermal protection of their feathers. The 10 g/m^2 threshold is the reported level of oiling to instigate impacts to seabirds and is also applied to other wildlife, although it is recognised that 'unfurred' animals, where hydrocarbon adherence is less, may be less vulnerable. 'Oiling' at this threshold is taken to be of a magnitude that can cause a response from the most vulnerable wildlife such as seabirds. Due to weathering processes, sea surface hydrocarbons decrease in toxicity due to change in their composition over time. Potential impacts to shoreline sensitive receptors may be markedly reduced in instances where there is extended duration until contact. This threshold of 10 g/m^2 of floating oil has been selected to inform the EMBA.

Parameter	Exposure Thresholds	Justification
Dissolved aromatic hydrocarbon	50 ppb (condensate) 500 ppb (marine diesel)	Dissolved aromatic hydrocarbons are the soluble component of the released hydrocarbon present throughout the water column. Dissolved aromatics are generally considered to represent the bioavailable form of oil that dictates toxicity in the water column. The thresholds represent potential toxic effects, particularly sublethal effects to highly sensitive species. *Condensate* Woodside has undertaken ecotoxicology testing on a number of condensates obtained during exploration and production activities, including for the Browse Basin (Calliance, Brecknock and Torosa gas fields) unweathered condensate (ESA, 2009). The ecotoxicity tests were undertaken on the six species representing six major taxonomic groups of ecological relevance, focusing on the early life stages of test organisms, when organisms are typically at their most sensitive: + Sea urchin (Heliocidaris tuberculate) + Rock oyster (Saccostrea commercialis) + Marine micro-alga (Isochrysis aff. galbana) + Marine macro-alga (Hormosia banksia) + Penaeid prawn (Penaeus monodon) + Barramundi fish (Lates calcarifer). The laboratory-based ecotoxicology tests used a range of Water Accommodated Fractions (WAF) hydrocarbon concentrations to expose the different test organisms. The range of no observed effect concentrations (NOEC) for the organisms tested ranged from 1280 ppb to 77,310 ppb. NOPSEMA (2019) allows use of ecotoxicology testing to justify project specific thresholds. However, it also recommends a generic exposure threshold of 50 ppb as appropriate for approximating potential toxic effects, particularly sublethal effects to sensitive species. As such, this threshold, while considered highly conservative given the above, has been selected for informing the EMBA.

Parameter	Exposure Thresholds	Justification
		Diesel Woodside has undertaken ecotoxicology testing on Marine Diesel Oil (Ecotox Services Australia, 2013), on a broad range of taxa of ecological relevance for which accepted standard test protocols are well established. These ecotoxicology tests are focused on the early life stages of test organisms, when organisms are typically at their most sensitive. The nine ecotoxicology tests were conducted on seven mainly tropical-subtropical species representatives from six major taxonomic groups. The seven species were tested for chronic (function of life) effects of immobilisation, early life stage development/growth and acute toxicity (i.e. mortality). The laboratory-based ecotoxicology tests used a range of water accommodated fraction (WAF) concentrations to expose the different test organisms. For each ecotoxicology test, samples of the WAF were analysed to determine the TPH concentration of the solution. The reported NOECs for organisms tested ranged from 520 ppb to 3500 ppb. For seven of the nine tests, no statistically significant effect on the test organisms was observed even at the highest WAF concentration used in the testing. Based on these ecotoxicology tests, a conservative threshold of 500 ppb has been adopted. This 500 ppb threshold is below the lowest NOEC for the most sensitive organism tested. These thresholds are calculated based on exposure of organisms to dissolved aromatic hydrocarbons for periods of 1 to 96 hours and are, therefore, conservative when used for instantaneous contact.

Parameter	Exposure Thresholds	Justification
Entrained hydrocarbon	100 ppb (condensate) 500 ppb (marine diesel)	Entrained hydrocarbons are present in the water column as buoyant microbubbles of hydrocarbons and are a potential source of soluble (dissolved) hydrocarbons. It is noted that entrained hydrocarbons are less biologically available to organisms through absorption into their tissues than dissolved aromatic hydrocarbons and, therefore, adoption of a threshold based on toxicity data is a conservative approach. ***Condensate*** The condensate threshold concentration value for entrained hydrocarbons (i.e. 100 ppb) is considered highly conservative and has been set with reference to the entrained exposure values recommended in NOPSEMA Bulletin #1 Oil Spill Modelling (2019), and is considered highly conservative in the context of ecotoxicity tests results from Torosa condensate. The threshold concentration of entrained hydrocarbons that could result in a biological impact cannot be determined directly using available ecotoxicity data for WAF of oil hydrocarbons. However, it is likely this data specific to dissolved oil hydrocarbon represents a worst-case scenario. This is because entrained oil hydrocarbons are less biologically available to organisms through absorption into their tissues than dissolved hydrocarbons. The selected threshold of 100 ppb is an order of magnitude below the NOEC for the six sensitive organisms tested in relation to dissolved hydrocarbons and is, therefore, considered to be conservative, and has been selected for informing the EMBA. ***Diesel*** The entrained threshold for diesel has been selected with reference to the ecotoxicology test results for marine diesel (i.e. lowest NOEC 520 ppb (Ecotox Services Australia, 2013). As described above, entrained droplets may contain soluble compounds and hence have the potential for generating elevated concentrations of dissolved hydrocarbons. However, the potential for physical and chemical effects from direct contact with entrained oil droplets, which are less biologically available, is more applicable. An entrained threshold of 500 ppb, consistent with the threshold for toxicity from dissolved components is, therefore, also considered to be conservative and has been selected for informing the EMBA.
Shoreline	100 g/m^2	Accumulated hydrocarbons are defined as a detectable hydrocarbon level representing the build-up of hydrocarbons on shorelines that may result from all three hydrocarbon fates (surface, entrained and dissolved). Owens and Sergy, (1994) defined accumulated hydrocarbon <100 g/m^2 as having an appearance of a stain on shorelines. French-McCay (2009) defined accumulated hydrocarbons ≥100 g/m^2 to be the threshold that could impact the survival and reproductive capacity of benthic epifaunal invertebrates living in intertidal habitat. A threshold of ≥100 g/m^2 has been adopted as the threshold for shoreline accumulation. This threshold has been selected to inform the EMBA for shoreline accumulation for condensate and marine diesel.

Weathering characteristics

Table 6-156 outlines the predicted weathering characteristics and persistence of unstabilised and stabilised Torosa condensate and marine diesel. For all hydrocarbon types, the influence of entrainment will regulate the degree of mass retention in the environment. The following describes the likelihood for entrainment and dissolution of hydrocarbons to occur for each of the four scenarios.

During the subsea release phase of Scenario 1, high pressure and low temperatures experienced at the depths in the Browse Development Area are likely to cause released gas to combine with water to form hydrates. The hydrates may rise through the water column and, upon reaching shallower water depths, are likely to decompose into methane and water. Unstabilised condensate is likely to be released as small oil droplets. The small oil droplets rapidly transported to the sea surface by the rising gas plume would be susceptible to re-entrainment into the wave mixed layer under typical wind conditions. It is likely that the bulk of the oil mass would remain entrained in the water column until degradation processes occurred. Due to the weak buoyancy of the oil droplets, the formation of floating slicks is unlikely and, therefore, only a small fraction of the volatile compounds is likely to be exposed to the atmosphere. Considering the spill volume and low levels of evaporation expected, there is a high potential for dissolution of soluble aromatic compounds.

During the surface release of Scenarios 2, 3 and 4, floating hydrocarbons may be susceptible to entrainment into the wave-mixed layer under typical wind conditions. Evaporation rates in the first 24 hours of exposure to the atmosphere may be significant, given the significant proportions of volatile compounds in the oils (41-78%) (Table 6-156). The low-volatility fraction of the oils (8-54%) would take longer durations (days) to evaporate, and the residual fraction of 5-14% is expected to persist in the environment until degradation processes occur. Considering the spill volumes, there is a low to moderate potential for dissolution of soluble aromatic compounds.

Table 6-156: Summary of weathering behaviour of hydrocarbons from quantitative modelling

Hydrocarbon type	% Evaporation 24 hours after a spill	% Evaporation within a few days of a spill	% Expected to persist in the marine environment
Unstabilised Torosa condensate	11-54%	21-33%	25-51%
Stabilised Torosa condensate	78%	8%	14%
Marine Diesel	41%	54%	5%

Table 6-157: Summarised results from hydrocarbon spill modelling for Scenarios 1 through 4 – Extents of contact and maximum concentrations

Scenario	Model Parameter	Summary
Scenario 1: A long-term (77-day) uncontrolled release of 142,154 m^3 of unstabilised Torosa condensate from the TRA-C well, with a 5-day surface release phase followed by a 72-day subsea release phase, representing loss of containment after a loss of well control.	Floating	+ Exposures above the threshold are predicted to occur within 143 km from the source.
	Entrained	+ Exposures above the threshold are predicted up to around 863 km from the source. + The maximum entrained oil concentration for any receptor is predicted as 23,600 ppb at Scott Reef North. + Concentrations above 25,000 ppb are expected to extend from the sea surface to depths of around 20 m.
	Dissolved	+ Exposures above the threshold are predicted up to around 673 km from the source. + The maximum dissolved aromatic hydrocarbon concentration forecast for any receptor is predicted as 13,900 ppm at Scott Reef North. + Concentrations above 10,000 ppb are expected to extend from the sea surface to depths of around 20 m.
	Shoreline	+ A maximum accumulated volume of 827 m^3 (across all receptors) and a maximum local accumulated concentration of 34.3 kg/m^2 is predicted at Scott Reef.
Scenario 2: A short-term (24-hour) uncontrolled surface release of 18,000 m^3 of stabilised condensate at the Torosa FPSO location, representing FPSO cargo tank or condensate tanker loss of containment.	Floating	+ Exposures above the threshold are predicted to occur within 126 km from the source.
	Entrained	+ Exposures above the threshold are predicted up to around 890 km from the source. + The maximum entrained oil concentration for any receptor is predicted as 30,500 ppb at Scott Reef North. + Concentrations show that concentrations above 25,000 ppb are expected to extend from the sea surface to depths of around 20 m.
	Dissolved	+ Exposures above the threshold are predicted up to around 517 km from the source. + The maximum dissolved aromatic hydrocarbon concentration forecast for any receptor is predicted as 12,700 ppb at Scott Reef North. + Concentrations above 10,000 ppb are expected to extend from the sea surface to depths of around 15 m.
	Shoreline	+ A maximum accumulated volume of 212 m^3 (across all receptors) and a maximum local accumulated concentration of 9.5 kg/m^2 is predicted at Scott Reef.

Scenario	Model Parameter	Summary
Scenario 3: A short-term (instantaneous) surface release of 768 m^3 of stabilised condensate at the Torosa FPSO location, representing loss of containment after a vessel offtake system failure.	Floating	+ Exposures above the threshold are predicted to occur within 67 km from the source.
	Entrained	+ Exposures above the threshold are predicted up to around 242 km from the source. + The maximum entrained oil concentration for any receptor is predicted as 6,400 ppb at Scott Reef North. + Concentrations show that concentrations above 15,000 ppb are expected to extend from the sea surface to depths of around 15 m.
	Dissolved	+ Exposures above the threshold are predicted to be found up to around 203 km from the source. + The maximum dissolved aromatic hydrocarbon concentration forecast for any receptor is predicted as 1,800 ppb at Scott Reef North. + Concentrations above 1,000 ppb are expected to extend from the sea surface to depths of around 10 m.
	Shoreline	+ A maximum accumulated volume of 8 m^3 (across all receptors) and a maximum local accumulated concentration of 0.7 kg/m^2 is predicted at Scott Reef.
Scenario 4: A short-term (instantaneous) surface release of 2,000 m^3 of marine diesel near the Rowley Shoals, representing loss of tank inventory from a fuel tanker.	Floating	+ Exposures above the threshold are predicted to occur within 82 km from the source.
	Entrained	+ Exposures above the threshold are predicted to around 371 km from the source. + The maximum entrained oil concentration for any receptor is predicted as 167,600 ppb. + Concentrations above 25,000 ppb are expected to extend from the sea surface to depths of around 20 m.
	Dissolved	+ Exposures above the threshold are predicted to around 43 km from the source. + The maximum dissolved aromatic hydrocarbon concentration forecast for any receptor is predicted as 2,200 ppb. + Concentrations above 2,000 ppb are expected to extend from the sea surface to depths of around 10 m.
	Shoreline	+ Total maximum accumulated volume of 6 m^3 (across all receptors) and a maximum local accumulated concentration of 491 g/m^2 is predicted at Rowley Shoals – Mermaid Reef AMP.

Environment that may be affected

The weathering of surface entrained and dissolved hydrocarbons differs due to the influence of the metocean mechanism of transportation, therefore, the EMBA considers the potential spatial extent of the three different hydrocarbon fates. The EMBA also includes areas that are predicted to experience shoreline contact with hydrocarbons above threshold concentrations.

Based on the modelling outcomes, the EMBA was derived from the outer extent of the combined spill scenarios at a threshold above the level detailed in **Table 6-155**.

Given Scenario 4 (instantaneous releases from vessels) was modelled for a specific point (near Rowley Shoals) selected near sensitive environmental receptors (i.e. worst case/conservative approach), the trajectory modelling results for those scenarios were extrapolated/extended along the length of the BTL to inform the EMBA.

The EMBA covers a larger area than that likely to be affected during any one single spill event, as the model was run for a variety of weather and metocean conditions (100 simulations in total). The EMBA, therefore, represents the combined total extent of all locations where hydrocarbon thresholds could be exceeded, as determined from all modelling runs.

Surface and accumulated shoreline hydrocarbon concentrations are expressed as grams per square metre (g/m^2), with entrained and dissolved aromatic hydrocarbon concentrations expressed as parts per billion (ppb).

Figure 6-47 to **Figure 6-50** present contour maps showing individual EMBAs for Scenarios 1 - 4 based on the stochastic modelling results. The contour maps do not represent a single hydrocarbon spill (floating slick or water column plume at any one point in time). Instead, the contour maps are a composite of a large number of potential slick and plume paths combined into one area. The largest area (the entrained hydrocarbons contour for Scenario 1) has been used to inform the overall EMBA around the Scott Reef region, while the largest area for Scenario 4 (the entrained hydrocarbons contour) has been used to inform the overall EMBA around the Rowley Shoals region.

Figure 6-51 to **Figure 6-54** present examples of quantitative deterministic hydrocarbon spill modelling results for Scenarios 1, 2, 3 and 4. This provides a representative example of the extent and trajectory of a potential spill resulting from each of these unplanned scenarios. The images, which represent the progression of an individual spill event over a period of several weeks, illustrate the transition of the spilled hydrocarbon above threshold levels in different phases, from initial floating hydrocarbons to shoreline accumulated hydrocarbons. This information can be used to inform planning and response actions in the event of a spill. As stated elsewhere, the deterministic spill events illustrated are one of many used to inform the areal extent of the wider EMBA. **Table 6-158** summarises the worst-case probabilities for contact at each relevant location and identified environmental sensitive receptor(s) and the associated aspects of that receptor that may be impacted by each of the credible spill scenarios. Greyed cells in **Table 6-158** identify the relevant physical, ecological and socio-economic aspects for each receptor/location; a 'y' in this cell indicates a potential for this aspect to be impacted if the location/environmental receptor is contacted, while a dash (-) indicates the aspect would not be impacted.

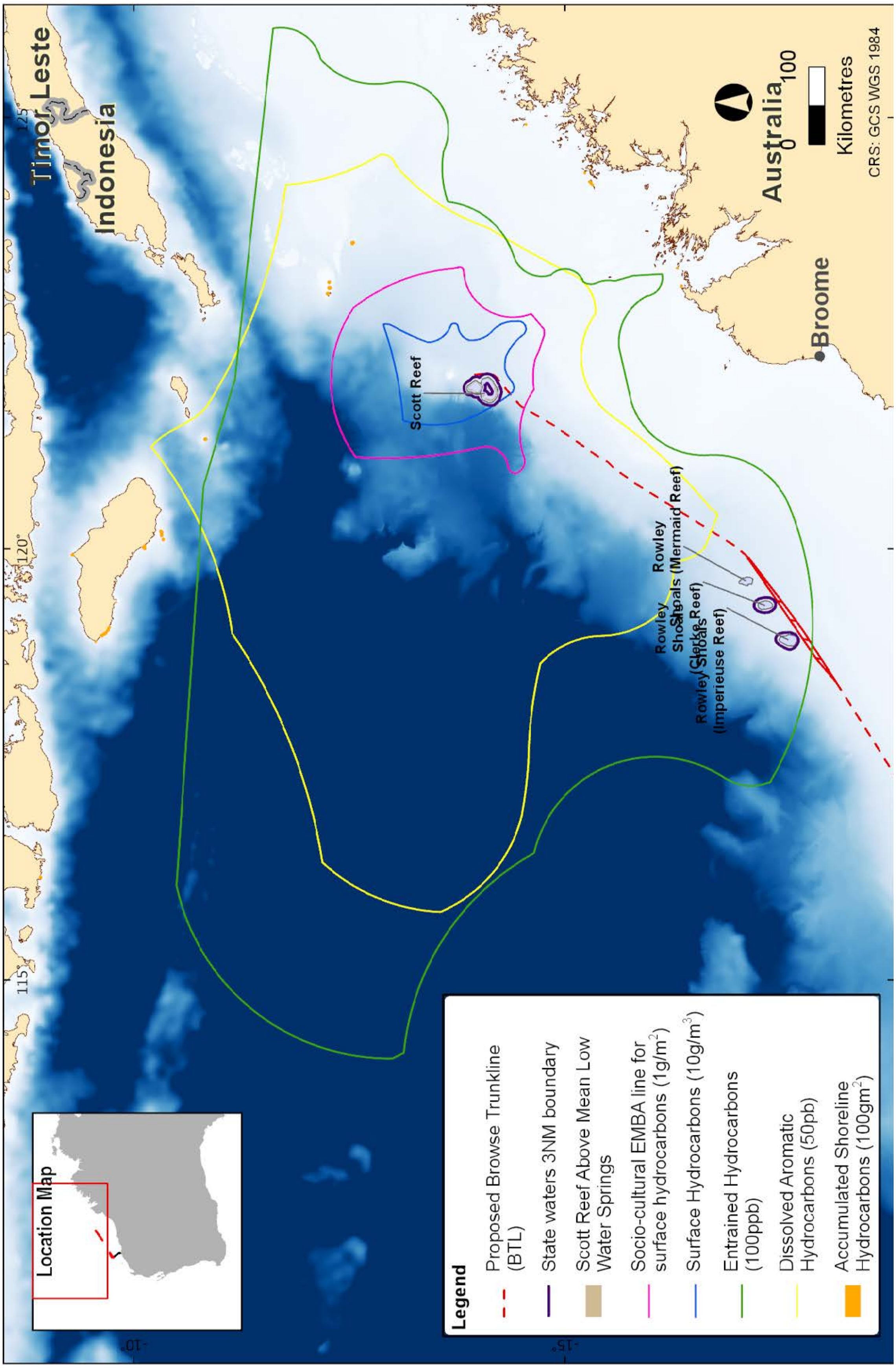


Figure 6-47: Scenario 1 (loss of well containment) – EMBA

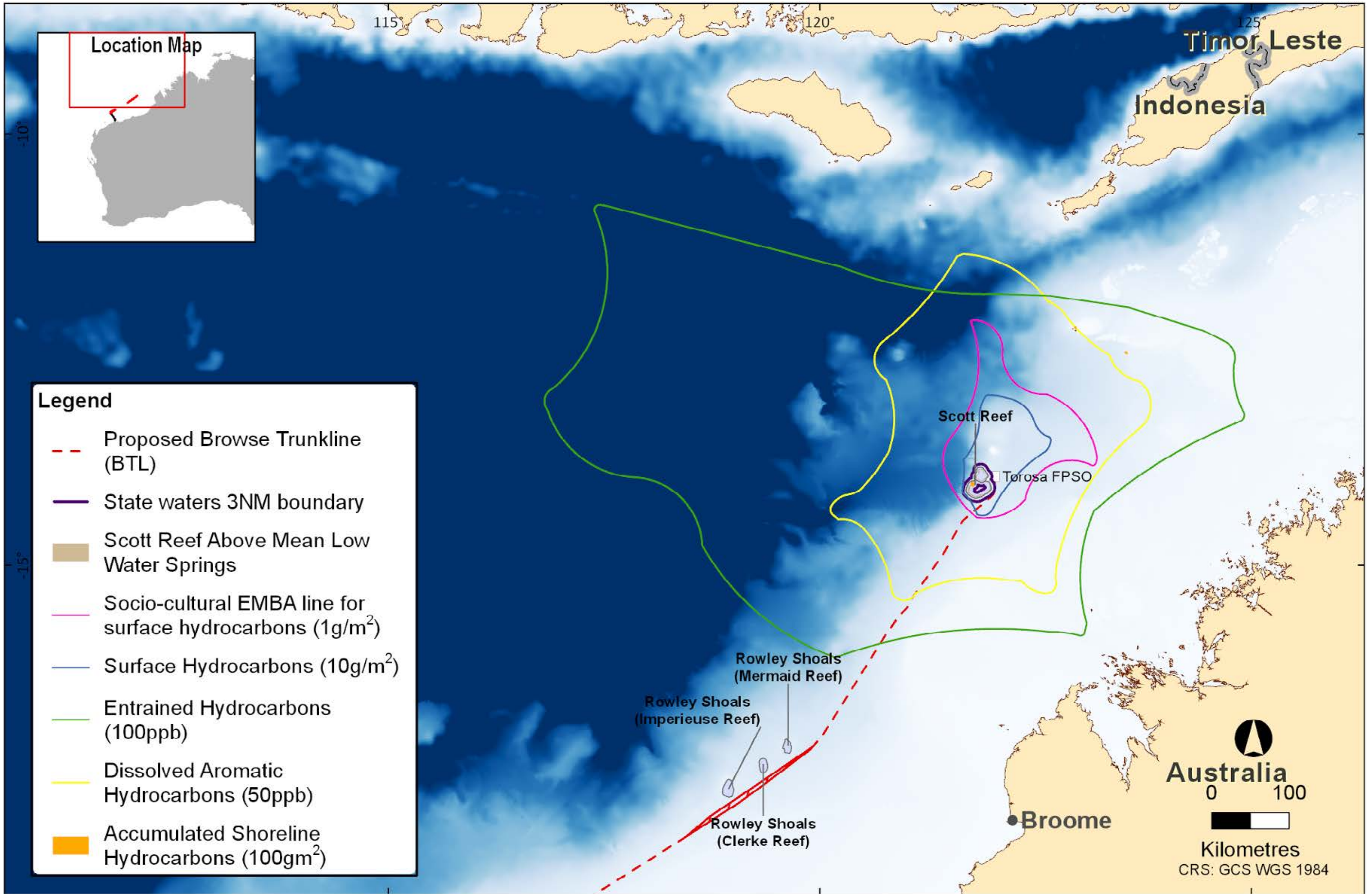


Figure 6-48: Scenario 2 (FPSO cargo tank or condensate tanker loss of containment) – EMBA

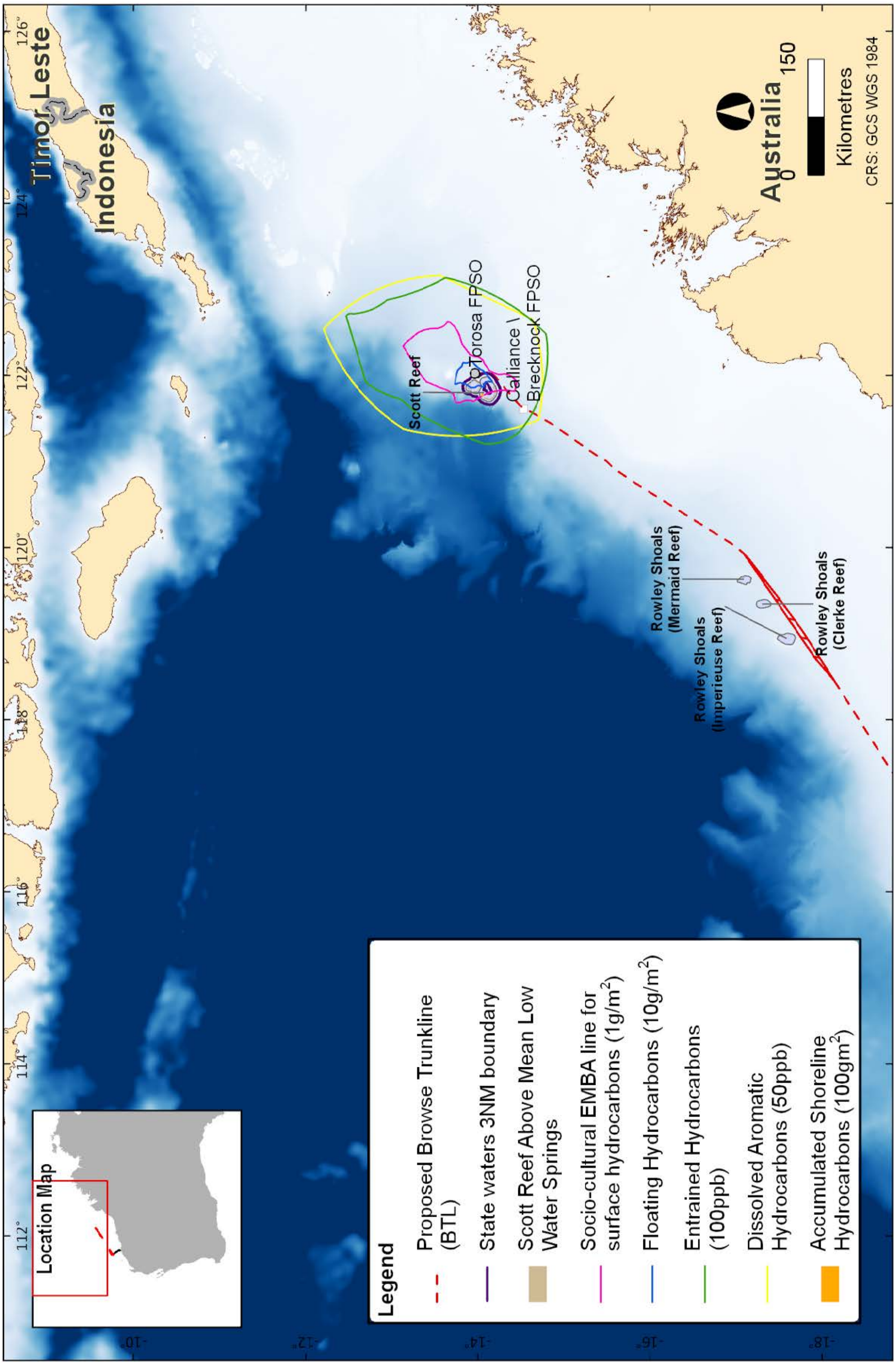


Figure 6-49: Scenario 3 (loss of containment during condensate offtake operations) – EMBA

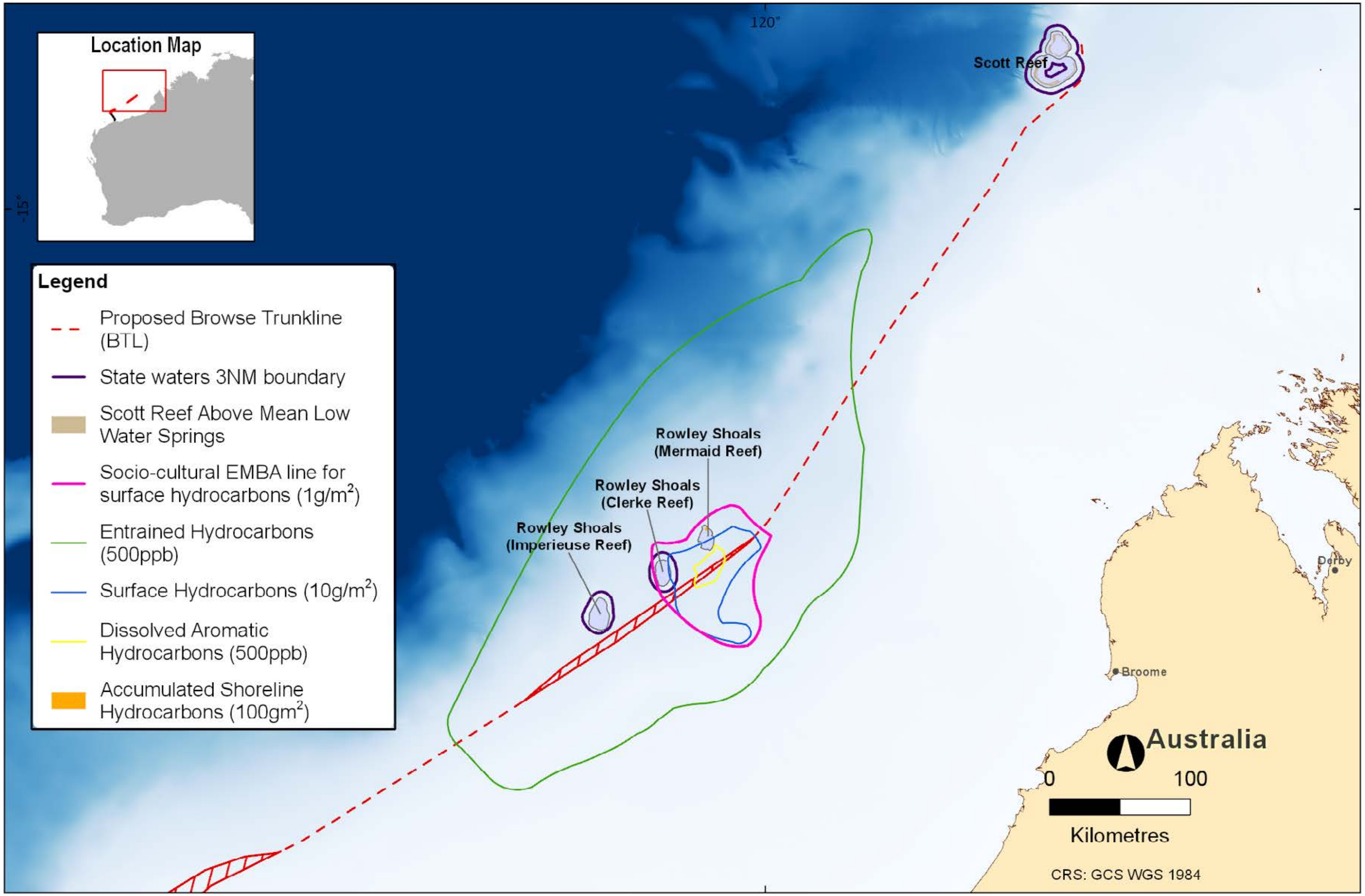


Figure 6-50: Scenario 4 (vessel fuel tank inventory loss due to vessel collision) – EMBA

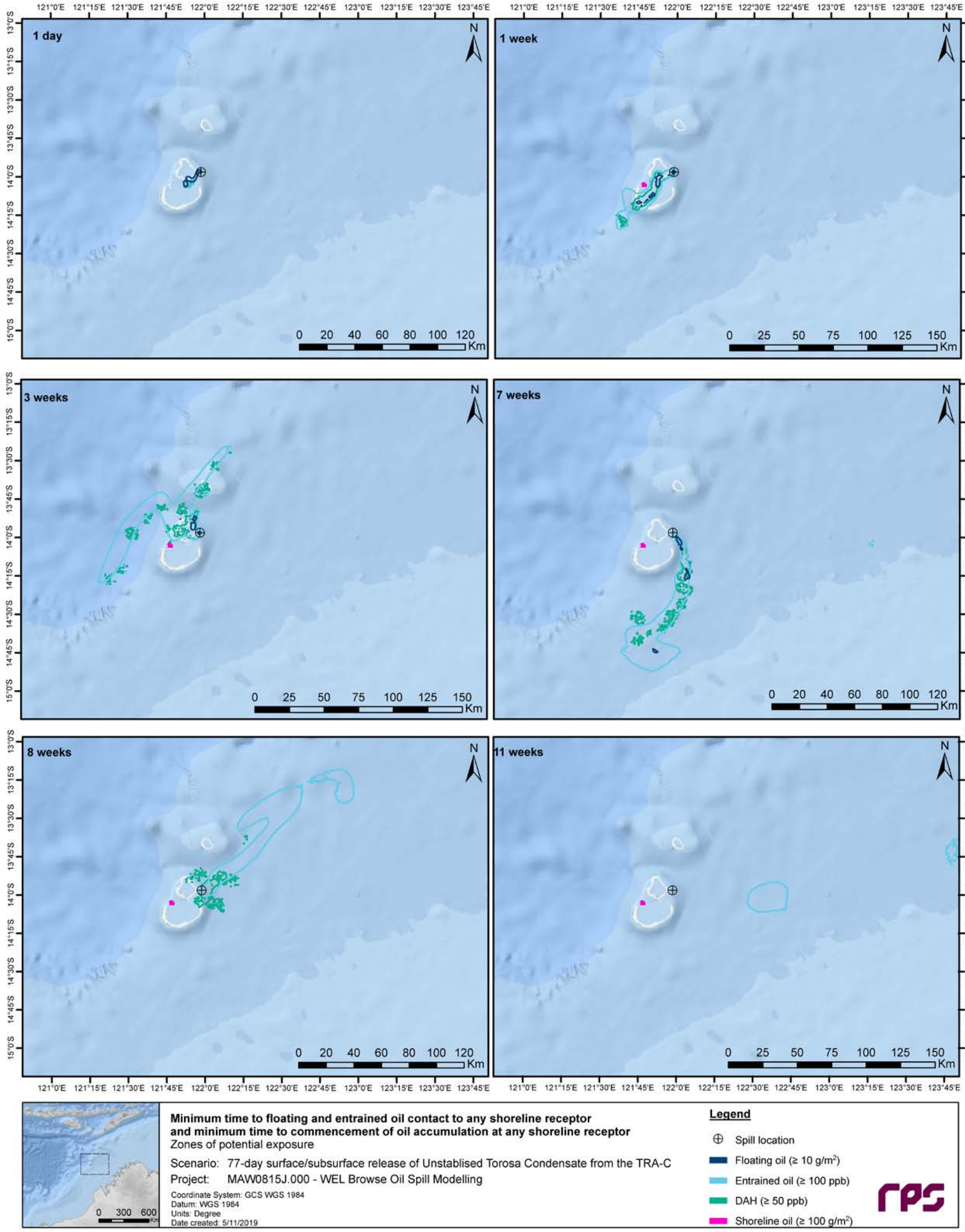


Figure 6-51: Scenario 1 (loss of well containment) example deterministic spill extent – minimum time to floating oil and entrained oil contact to any shoreline receptors and minimum time to commencement of oil accumulation at any shoreline receptor

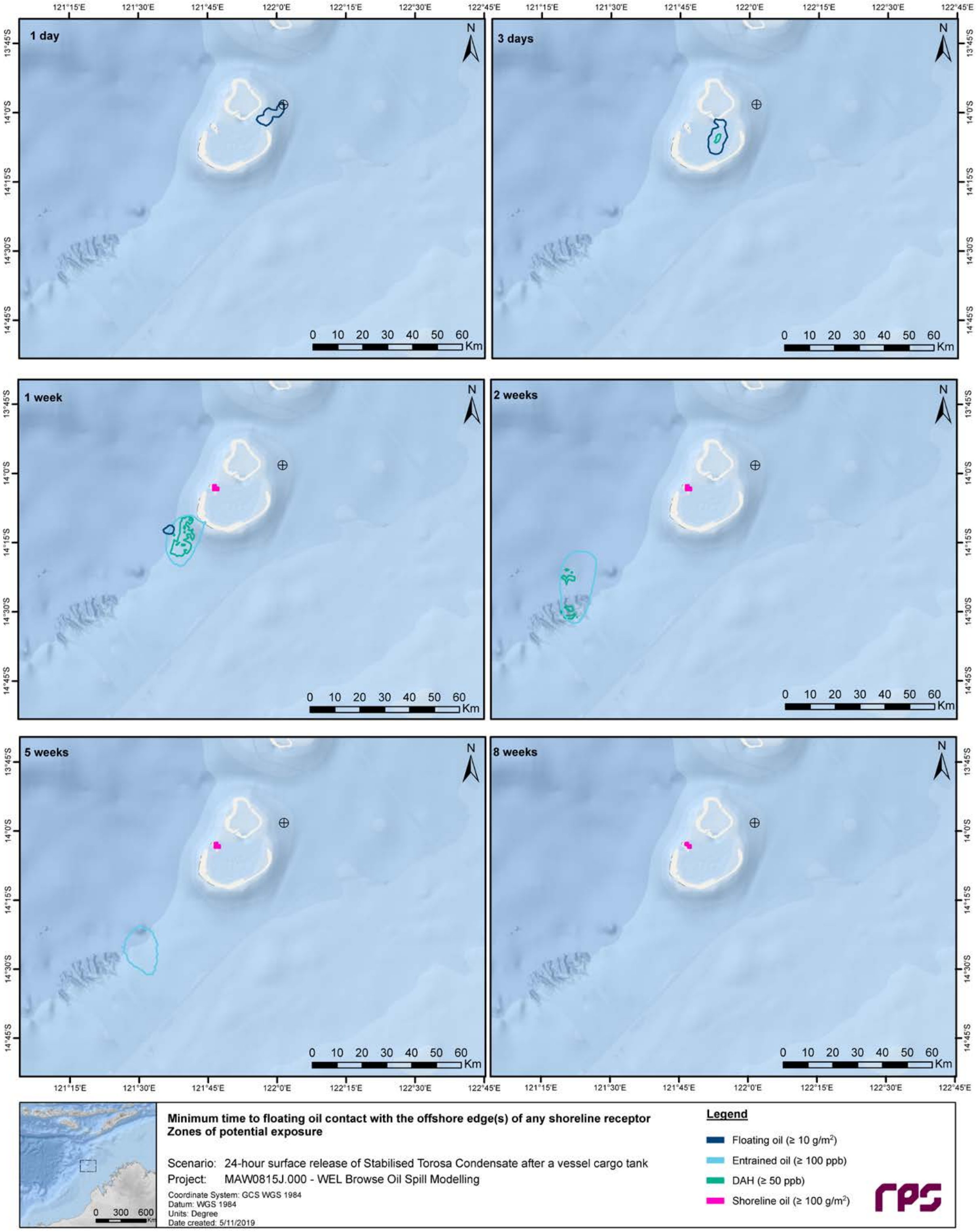


Figure 6-52: Scenario 2 (FPSO cargo tank or condensate tanker loss of containment) - example deterministic spill extent – minimum time to floating oil contact to offshore edges of any shoreline receptors

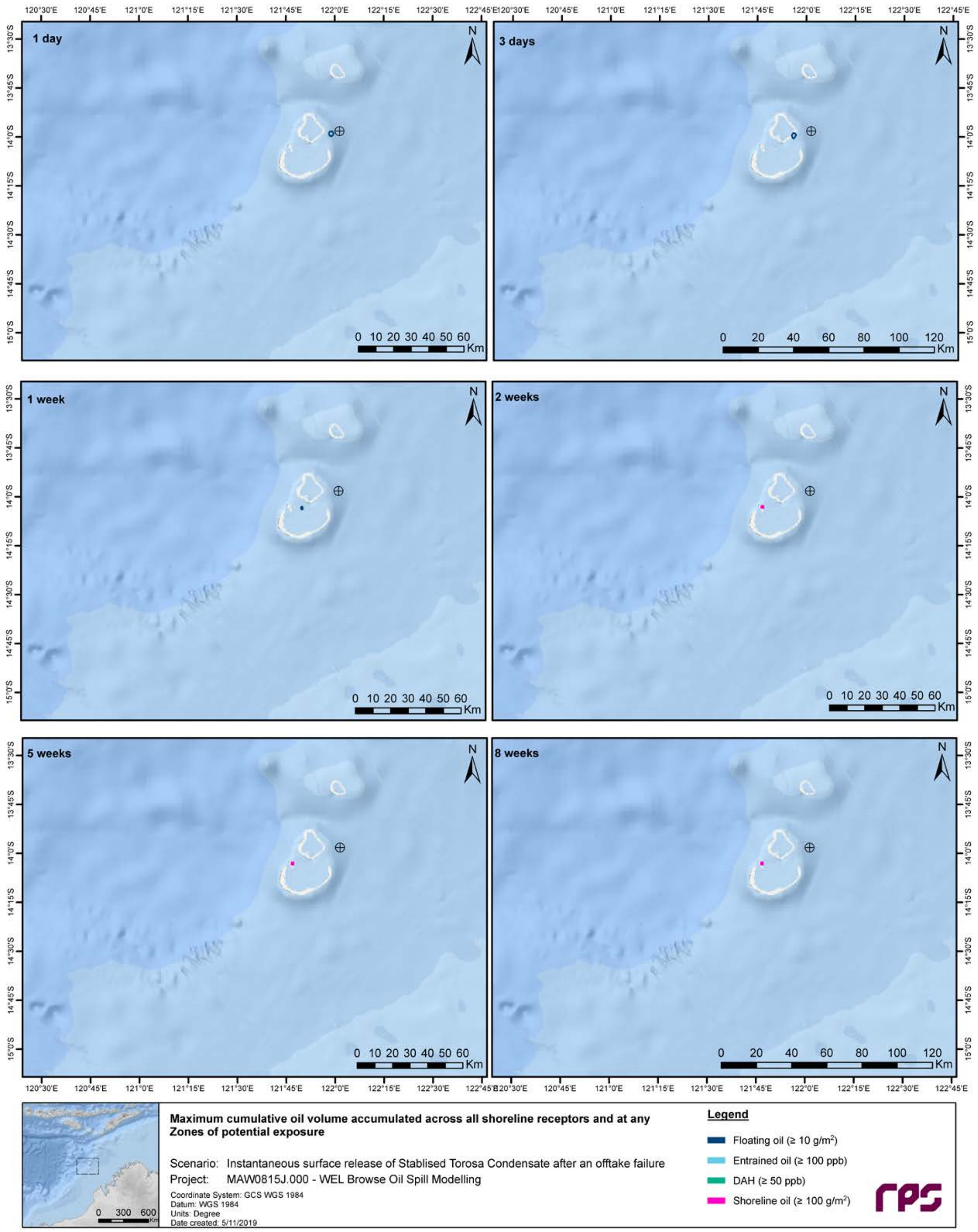


Figure 6-53: Scenario 3 (loss of containment during condensate offtake operations) - example deterministic spill extent – maximum cumulative oil volume accumulated across all shoreline receptors

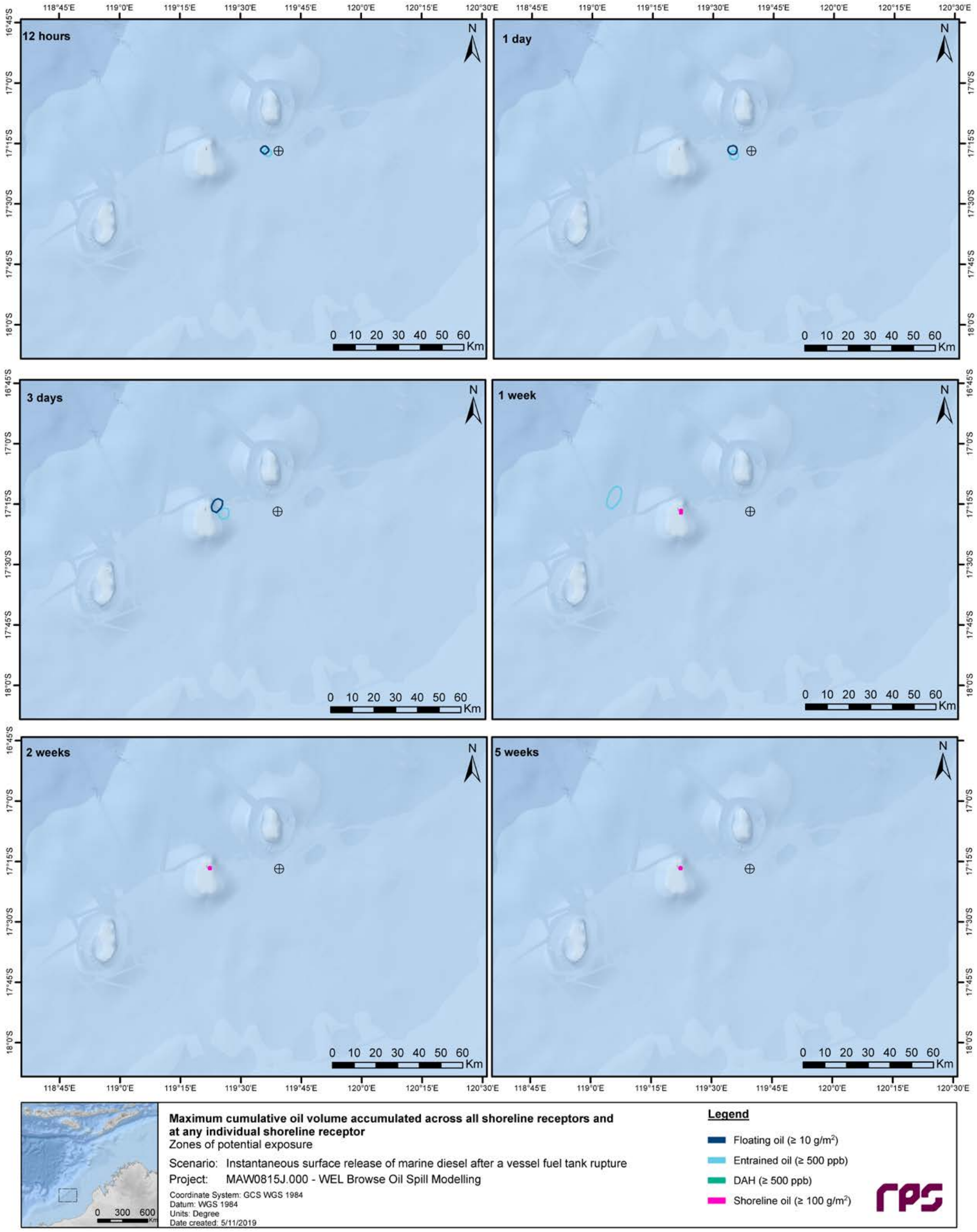


Figure 6-54: Scenario 4 (vessel fuel tank inventory loss due to vessel collision) - Example deterministic spill extent – maximum cumulative oil volume accumulated across all shoreline receptors

Table 6-158: Summarised results from hydrocarbon spill modelling for Scenarios 1 through 4 – key receptor locations and sensitivities with potential hydrocarbon spill contact. Environmental, social, cultural, heritage and economic aspects that are associated with each location or receptor are shown as greyed cells. Note that impacts relate to the type of hydrocarbon that is expected to reach a location as well as the characteristics of the aspect (e.g. locations which are only predicted to be contacted by shoreline accumulation will not have impacts to open ocean associated aspects)

Environmental setting	Location/Receptor name	Modelled Scenario[1]	Environmental, Social, Cultural, Heritage and Economic Aspects presented as per the Environmental Risk Definitions (Woodside's Risk Management Procedure (WM0000PG10055394))																													Probability of Hydrocarbon contact (Condensate/ Marine Diesel)				
			Physical		Biological																						Socio-economic and Cultural									
			Water Quality	Sediment Quality	Marine Primary Producers			Marine Primary Producers								Protected Species									Other Species										
			Open water – (pristine)	Open water – (pristine)	Open water – (pristine)	Seagrass beds/macroalgae	Mangroves	Spawning/nursery areas	Open water – productivity/ upwelling	Non biogenic reefs	Offshore filter feeders and/or deepwater benthic communities	Nearshore filter feeders	Sandy shores	Estuaries/tributaries/creeks/ lagoons (including mudflats)	Rocky shores	Cetaceans – migratory whales	Cetaceans – dolphins and porpoises	Dugongs	Pinnipeds (sea lions and fur seals)	Marine turtles (including foraging and internesting areas and significant nesting beaches)	Sea snakes	Whale sharks	Sharks and rays	Sea birds and/or migratory shorebirds	Pelagic fish populations	Resident/demersal Fish	Fisheries – commercial	Fisheries – traditional	Tourism and recreation	Protected Areas/Heritage – European and Indigenous/Shipwrecks	Offshore oil and gas infrastructure (topside and subsea)	Surface hydrocarbon (≥ 1 g/m²)	Surface hydrocarbon (≥ 10 g/m²)	Entrained hydrocarbon (S1-S3 ≥ 100 ppb, S4 ≥ 500 ppb)	Dissolved aromatic hydrocarbon (S1-S3 ≥ 50 ppb, S4 ≥ 500 ppb)	Accumulated hydrocarbons (> 100 g/m²)[3]
Offshore	Argo-Rowley Terrace AMP	S1	y	y					y							y	y			y			y	y	y		y			y		-	-	21%	10%	NA
		S2	y	y					y							y	y			y			y	y	y		y			y		-	-	1.5%	1.5%	
		S3	-	-					-							-	-			-			-	-	-		-			-		-	-	-	-	
		S4	y	y					y							y	y			y			y	y	y		y			y		100%	100%	57%	8.5%	
	Kimberley AMP	S1	y	y	y	y		y	y		y					y	y	y		y	y		y	y	y	y			y	y		-	-	31%	19%	NA
		S2	y	y	y	y		y	y		y					y	y	y		y	y		y	y	y	y			y	y		-	-	4.5%	2%	
		S3	-	-	-	-		-	-		-					-	-	-		-	-		-	-	-	-			-	-		-	-	-	-	
		S4	-	-	-	-		-	-		-					-	-	-		-	-		-	-	-	-			-	-		-	-	-	-	
	Oceanic Shoals Marine Park	S1	y	y	y				y		y					y	y			y	y		y	y	y	y	y		y	y		-	-	1%	-	NA
		S2	-	-	-				-		-					-	-			-	-		-	-	-	-	-		-	-		-	-	-	-	
		S3	-	-	-				-		-					-	-			-	-		-	-	-	-	-		-	-		-	-	-	-	
		S4	-	-	-				-		-					-	-			-	-		-	-	-	-	-		-	-		-	-	-	-	

Environmental setting			Remote oceanic reef systems, submerged Shoals and Banks											
Location/Receptor name			Rowley Shoals (including State MPs and AMP)				Barracouta Shoal				Eugene McDermott Shoal			
Modelled Scenario[1]			S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Environmental, Social, Cultural, Heritage and Economic Aspects presented as per the Environmental Risk Definitions (Woodside's Risk Management Procedure (WM0000PG10055394))														
Physical	Water Quality	Open water – (pristine)	Y	-	-	Y	Y	-	-	-	Y	Y	-	-
	Sediment Quality	Open water – (pristine)	Y	-	-	Y	Y	-	-	-	Y	Y	-	-
Biological	Marine Primary Producers	Open water – (pristine)	Y	-	-	Y	Y	-	-	-	Y	Y	-	-
		Seagrass beds/macroalgae												
		Mangroves												
	Marine Primary Producers	Spawning/nursery areas	Y	-	-	Y	-	-	-	-	-	-	-	-
		Open water – productivity/ upwelling	Y	-	-	Y	Y	-	-	-	Y	Y	-	-
		Non biogenic reefs												
		Offshore filter feeders and/or deepwater benthic communities	Y	-	-	Y	Y	-	-	-	Y	Y	-	-
		Nearshore filter feeders												
		Sandy shores												
		Estuaries/tributaries/creeks/ lagoons (including mudflats)												
		Rocky shores												
	Protected Species	Cetaceans – migratory whales					Y	-	-	-	Y	Y	-	-
		Cetaceans – dolphins and porpoises	Y	-	-	Y	Y	-	-	-	Y	Y	-	-
		Dugongs												
		Pinnipeds (sea lions and fur seals)												
		Marine turtles (including foraging and internesting areas and significant nesting beaches)												
		Sea snakes	Y	-	-	Y	Y	-	-	-	Y	Y	-	-
		Whale sharks												
		Sharks and rays	Y	-	-	Y	Y	-	-	-	Y	Y	-	-
		Sea birds and/or migratory shorebirds												
	Other Species	Pelagic fish populations	Y	-	-	Y	Y	-	-	-	Y	Y	-	-
		Resident/demersal Fish	Y	-	-	Y	Y	-	-	-	Y	Y	-	-
Socio-economic and Cultural		Fisheries – commercial	Y	-	-	Y	Y	-	-	-	Y	Y	-	-
		Fisheries – traditional												
		Tourism and recreation	Y	-	-	Y	-	-	-	-	-	-	-	-
		Protected Areas/Heritage – European and Indigenous/Shipwrecks	-	-	-	-	-	-	-	-	-	-	-	-
		Offshore oil and gas infrastructure (topside and subsea)												
Probability of Hydrocarbon contact (Condensate/ Marine Diesel)		Surface hydrocarbon ($\geq 1 g/m^2$)	-	-	-	23%	-	-	-	-	-	-	-	-
		Surface hydrocarbon ($\geq 10 g/m^2$)	-	-	-	15%	-	-	-	-	-	-	-	-
		Entrained hydrocarbon (S1-S3 ≥ 100 ppb, S4 ≥ 500 ppb)	8%	-	-	33.5%	8%	-	-	-	6%	1.5%	-	-
		Dissolved aromatic hydrocarbon (S1-S3 ≥ 50 ppb, S4 ≥ 500 ppb)	-	-	-	2%	1%	-	-	-			-	-
		Accumulated hydrocarbons ($> 100 g/m^2$)[3]	9%	-	-	1.5%	NA				NA			

Environmental setting	Location/Receptor name	Modelled Scenario[1]	Environmental, Social, Cultural, Heritage and Economic Aspects presented as per the Environmental Risk Definitions (Woodside's Risk Management Procedure (WM0000PG10055394))																												Probability of Hydrocarbon contact (Condensate/ Marine Diesel)				
			Physical		Biological																						Socio-economic and Cultural								
			Water Quality	Sediment Quality	Marine Primary Producers			Marine Primary Producers								Protected Species									Other Species										
			Open water – (pristine)	Open water – (pristine)	Open water – (pristine)	Seagrass beds/macroalgae	Mangroves	Spawning/nursery areas	Open water – productivity/ upwelling	Non biogenic reefs	Offshore filter feeders and/or deepwater benthic communities	Nearshore filter feeders	Sandy shores	Estuaries/tributaries/creeks/ lagoons (including mudflats)	Rocky shores	Cetaceans – migratory whales	Cetaceans – dolphins and porpoises	Dugongs	Pinnipeds (sea lions and fur seals)	Marine turtles (including foraging and internesting areas and significant nesting beaches)	Sea snakes	Whale sharks	Sharks and rays	Sea birds and/or migratory shorebirds	Pelagic fish populations	Resident/demersal Fish	Fisheries – commercial	Fisheries – traditional	Tourism and recreation	Protected Areas/Heritage – European and Indigenous/Shipwrecks	Offshore oil and gas infrastructure (topside and subsea)	Surface hydrocarbon (≥ 1 g/m^2)	Surface hydrocarbon (≥ 10 g/m^2)	Entrained hydrocarbon (S1-S3 ≥ 100 ppb, S4 ≥ 500 ppb)	Dissolved aromatic hydrocarbon (S1-S3 ≥ 50 ppb, S4 ≥ 500 ppb)	Accumulated hydrocarbons (> 100 g/m^2)[3]
Remote oceanic reef systems, submerged Shoals and Banks	Heywood Shoal	S1	y	y	y			-	y		y					y	y				y		y		y	y	y		-	-		-	-	5%	-	NA
		S2	y	y	y			-	y		y					y	y				y		y		y	y	y		-	-		-	-	1.5%	-	
		S3	-	-	-			-	-		-					-	-				-		-		-	-	-		-	-		-	-	-	-	
		S4	-	-	-			-	-		-					-	-				-		-		-	-	-		-	-		-	-	-	-	
	Hibernia Reef	S1	y	y	y			-	y		y					y	y				y		y		y	y	y		-	-		-	-	8%	3%	NA
		S2	-	-	-			-	-		-					-	-				-		-		-	-	-		-	-		-	-	-	-	
		S3	-	-	-			-	-		-					-	-				-		-		-	-	-		-	-		-	-	-	-	
		S4	-	-	-			-	-		-					-	-				-		-		-	-	-		-	-		-	-	-	-	
	Vulcan and Goeree Shoals	S1	y	y	y	y		-	y		y					y	y				y		y		y	y	y		-	-		-	-	10%	2%	NA
		S2	y	y	y	y		-	y		y					y	y				y		y		y	y	y		-	-		-	-	2.5%	-	
		S3	-	-	-			-	-		-					-	-				-		-		-	-	-		-	-		-	-	-	-	
		S4	-	-	-			-	-		-					-	-				-		-		-	-	-		-	-		-	-	-	-	
	Fantome Bank	S1	y	y	y			-	y		y					y	y				y		y		y	y	y		-	-		-	-	1%	1%	NA
		S2	-	-	-			-	-		-					-	-				-		-		-	-	-		-	-		-	-	-	-	
		S3	-	-	-			-	-		-					-	-				-		-		-	-	-		-	-		-	-	-	-	
		S4	-	-	-			-	-		-					-	-				-		-		-	-	-		-	-		-	-	-	-	

Environmental setting	Location/Receptor name	Modelled Scenario[1]	Environmental, Social, Cultural, Heritage and Economic Aspects presented as per the Environmental Risk Definitions (Woodside's Risk Management Procedure (WM0000PG10055394))																													Probability of Hydrocarbon contact (Condensate/ Marine Diesel)				
			Physical		Biological																					Socio-economic and Cultural									
			Water Quality	Sediment Quality	Marine Primary Producers			Marine Primary Producers								Protected Species									Other Species											
			Open water – (pristine)	Open water – (pristine)	Open water – (pristine)	Seagrass beds/macroalgae	Mangroves	Spawning/nursery areas	Open water – productivity/ upwelling	Non biogenic reefs	Offshore filter feeders and/or deepwater benthic communities	Nearshore filter feeders	Sandy shores	Estuaries/tributaries/creeks/ lagoons (including mudflats)	Rocky shores	Cetaceans – migratory whales	Cetaceans – dolphins and porpoises	Dugongs	Pinnipeds (sea lions and fur seals)	Marine turtles (including foraging and internesting areas and significant nesting beaches)	Sea snakes	Whale sharks	Sharks and rays	Sea birds and/or migratory shorebirds	Pelagic fish populations	Resident/demersal Fish	Fisheries – commercial	Fisheries – traditional	Tourism and recreation	Protected Areas/Heritage – European and Indigenous/Shipwrecks	Offshore oil and gas infrastructure (topside and subsea)	Surface hydrocarbon (≥ 1 g/m²)	Surface hydrocarbon (≥ 10 g/m²)	Entrained hydrocarbon (S1-S3 ≥ 100 ppb, S4 ≥ 500 ppb)	Dissolved aromatic hydrocarbon (S1-S3 ≥ 50 ppb, S4 ≥ 500 ppb)	Accumulated hydrocarbons (> 100 g/m²)[3]
Remote oceanic reef systems (of which some with Islands)	Scott Reef (North, Central and South	S1	y	y	y	y		Y	y		y		y			y	y			y	y	y	y	y	y	y		y	y	y		100%	100%	100%	100%	92%
		S2	y	y	y	y		y	y		y		y			y	y			y	y	y	y	y	y	y		y	y	y		34%	22.5%	48.5%	41.5%	20.5%
		S3	y	y	y	y		y	y		y		y			y	y			y	y	y	y	y	y	y		y	y	y		11.5%	5.5%	28%	23%	2.5%
		S4	-	-	-	-		-	-		-		-			-	-			-	-	-	-	-	-	-		-	-	-		-	-4	-	-	-
	Seringapatam Reef	S1	y	y	y	y		y	y		y		y				y			y	y		y	y	y	y		y	y	y		46%	10%	87%	85%	NA
		S2	y	y	y	y		y	y		y		y				y			y	y		y	y	y	y		y	y	y		7%	4%	22.5%	15.5%	
		S3	y	y	y	y		y	y		y		y				y			y	y		y	y	y	y		y	y	y		3.5%	-	7.5%	7.5%	
		S4	-	-	-	-		-	-		-		-				-			-	-		-	-	-	-		-	-	-		-	-4	-	-	
	Ashmore Reef (including AMP)	S1	y	y	y	y		y	y				y			y	y	y		y	y		y	y	y	y		y	y	y		-	-	8%	6%	18%
		S2	y	y	y	y		y	y				y			y	y	y		y	y		y	y	y	y		y	y	y		-	-	2.5%	1.5%	1%
		S3	-	-	-	-		-	-				-			-	-	-		-	-		-	-	-	-		-	-	-		-	-	-	-	-
		S4	-	-	-	-		-	-				-			-	-	-		-	-		-	-	-	-		-	-	-		-	-	-	-	-
	Cartier Island (including AMP)	S1	y	y	y	y		y	y				y			y	y			y	y		y	y	y	y		y		y		-	-	13%	10%	22%
		S2	y	y	y	y		y	y				y			y	y			y	y-		y	y	y	y		y		y		-	-	1.5%	-	1%
		S3	-	-	-	-		-	-				-			-	-			-	-		-	-	-	-		-		-		-	-	-	-	-
		S4	-	-	-	-		-	-				-			-	-			-	-		-	-	-	-		-		-		-	-	-	-	-

Environmental setting	Location/Receptor name	Modelled Scenario[1]	Environmental, Social, Cultural, Heritage and Economic Aspects presented as per the Environmental Risk Definitions (Woodside's Risk Management Procedure (WM0000PG10055394))																														Probability of Hydrocarbon contact (Condensate/ Marine Diesel)				
			Physical		Biological																						Socio-economic and Cultural									
			Water Quality	Sediment Quality	Marine Primary Producers			Marine Primary Producers								Protected Species									Other Species											
			Open water – (pristine)	Open water – (pristine)	Open water – (pristine)	Seagrass beds/macroalgae	Mangroves	Spawning/nursery areas	Open water – productivity/ upwelling	Non biogenic reefs	Offshore filter feeders and/or deepwater benthic communities	Nearshore filter feeders	Sandy shores	Estuaries/tributaries/creeks/ lagoons (including mudflats)	Rocky shores	Cetaceans – migratory whales	Cetaceans – dolphins and porpoises	Dugongs	Pinnipeds (sea lions and fur seals)	Marine turtles (including foraging and internesting areas and significant nesting beaches)	Sea snakes	Whale sharks	Sharks and rays	Sea birds and/or migratory shorebirds	Pelagic fish populations	Resident/demersal Fish	Fisheries – commercial	Fisheries – traditional	Tourism and recreation	Protected Areas/Heritage – European and Indigenous/Shipwrecks	Offshore oil and gas infrastructure (topside and subsea)	Surface hydrocarbon (≥ 1 g/m^2)	Surface hydrocarbon (≥ 10 g/m^2)	Entrained hydrocarbon (S1-S3 ≥ 100 ppb, S4 ≥ 500 ppb)	Dissolved aromatic hydrocarbon (S1-S3 ≥ 50 ppb, S4 ≥ 500 ppb)	Accumulated hydrocarbons (> 100 g/m^2)[3]
	Browse Island	S1	y	y	y	y		y	y				y			y	y			y	y		y	y	y	y		-		y		-	-	3%	1%	-
		S2	-	-	-	-		-	-				-			-	-			-	-		-	-	-	-		-		-		-	-	-	-	-
		S3	-	-	-			-	-				-			-	-			-	-		-	-	-	-		-		-		-	-	-	-	-
		S4	-	-	-			-	-				-			-	-			-	-		-	-	-	-		-		-		-	-	-	-	-
Mainland (nearshore waters)	West Australian Coast	S1	-	-	-	-	-	-	-			y	y	y	y	-	-	-		y	-		-	y	-	-	-	-	y	y		-	-	-	-	2%
		S2	-	-	-	-	-	-	-			-	-	-	-	-	-	-		-	-		-	-	-	-	-	-	-	-		-	-	-	-	-
		S3	-	-	-	-	-	-	-			-	-	-	-	-	-	-		-	-		-	-	-	-	-	-	-	-		-	-	-	-	-
		S4	-	-	-	-	-	-	-			-	-	-	-	-	-	-		-	-		-	-	-	-	-	-	-	-		-	-	-	-	-
	Buccaneer & Bonaparte Archipelagos	S1	-	-	-	-	-	-	-			y	y	y	y	-	-	-		y	-		-	y	-	-	-	-	y	y		-	-	-	-	2%
		S2	-	-	-	-	-	-	-			-	-	-	-	-	-	-		-	-		-	-	-	-	-	-	-	-		-	-	-	-	-
		S3	-	-	-	-	-	-	-			-	-	-	-	-	-	-		-	-		-	-	-	-	-	-	-	-		-	-	-	-	-
		S4	-	-	-	-	-	-	-			-	-	-	-	-	-	-		-	-		-	-	-	-	-	-	-	-		-	-	-	-	-
	Lalang-garram/ Camden Sound MP	S1	-	-	-	-	-	-	-			y	y	y	y	-	-	-		y	-		-	y	-	-	-	-	y	y		-	-	-	-	1%
		S2	-	-	-	-	-	-	-			-	-	-	-	-	-	-		-	-		-	-	-	-	-	-	-	-		-	-	-	-	-
		S3	-	-	-	-	-	-	-			-	-	-	-	-	-	-		-	-		-	-	-	-	-	-	-	-		-	-	-	-	-
		S4	-	-	-	-	-	-	-			-	-	-	-	-	-	-		-	-		-	-	-	-	-	-	-	-		-	-	-	-	-

Environmental setting	Location/Receptor name	Modelled Scenario[1]	Environmental, Social, Cultural, Heritage and Economic Aspects presented as per the Environmental Risk Definitions (Woodside's Risk Management Procedure (WM0000PG10055394))																													Probability of Hydrocarbon contact (Condensate/ Marine Diesel)				
			Physical		Biological																					Socio-economic and Cultural										
			Water Quality	Sediment Quality	Marine Primary Producers			Marine Primary Producers								Protected Species									Other Species											
			Open water – (pristine)	Open water – (pristine)	Open water – (pristine)	Seagrass beds/macroalgae	Mangroves	Spawning/nursery areas	Open water – productivity/ upwelling	Non biogenic reefs	Offshore filter feeders and/or deepwater benthic communities	Nearshore filter feeders	Sandy shores	Estuaries/tributaries/creeks/ lagoons (including mudflats)	Rocky shores	Cetaceans – migratory whales	Cetaceans – dolphins and porpoises	Dugongs	Pinnipeds (sea lions and fur seals)	Marine turtles (including foraging and internesting areas and significant nesting beaches)	Sea snakes	Whale sharks	Sharks and rays	Sea birds and/or migratory shorebirds	Pelagic fish populations	Resident/demersal Fish	Fisheries – commercial	Fisheries – traditional	Tourism and recreation	Protected Areas/Heritage – European and Indigenous/Shipwrecks	Offshore oil and gas infrastructure (topside and subsea)	Surface hydrocarbon (≥ 1 g/m^2)	Surface hydrocarbon (≥ 10 g/m^2)	Entrained hydrocarbon (S1-S3 ≥ 100 ppb, S4 ≥ 500 ppb)	Dissolved aromatic hydrocarbon (S1-S3 ≥ 50 ppb, S4 ≥ 500 ppb)	Accumulated hydrocarbons (> 100 g/m^2)[3]
Mainland (nearshore waters)	Indonesia (including Sumba)	S1	y	y	y	y	y	y				y	y	y	y	y	y	y		y	y	y	y	y	y	y		y	y	y		-	-	-	1%	3%
		S2	-	-	-	-	-	-				-	-	-	-	-	-	-		-	-	-	-	-	-	-		-	-	-		-	-	-	-	-
		S3	-	-	-	-	-	-				-	-	-	-	-	-	-		-	-	-	-	-	-	-		-	-	-		-	-	-	-	-
		S4	-	-	-	-	-	-				-	-	-	-	-	-	-		-	-	-	-	-	-	-		-	-	-		-	-	-	-	-
	Timor Leste	S1	-	-	-	-	-	-				y	y	y	y	-	-	-		y	-	-	-	y	-	-		-	y	y		-	-	-	-	1%
		S2	-	-	-	-	-	-				-	-	-	-	-	-	-		-	-	-	-	-	-	-		-	-	-		-	-	-	-	-
		S3	-	-	-	-	-	-				-	-	-	-	-	-	-		-	-	-	-	-	-	-		-	-	-		-	-	-	-	-
		S4	-	-	-	-	-	-				-	-	-	-	-	-	-		-	-	-	-	-	-	-		-	-	-		-	-	-	-	-

6.3.21.4 Environmental Impact

There are no anticipated environmental impacts in relation to this aspect associated with planned or routine project activities. The environmental risk (i.e. a change to the environment resulting from an unplanned event or incident) is discussed below.

6.3.21.5 Environmental Risk

Likelihood of a major hydrocarbon release

In undertaking this risk assessment of a potential major hydrocarbon release, the spill likelihood was evaluated using Blowout and Well release Frequencies based on SINTEF offshore blowout database 2012 (Scandpower, 2013). This uses data from 1991-2010 to determine likelihood for well blowouts and releases. For a gas well, the SINTEF calculated probability of blowout during drilling and completion is 2.93 X 10-4. The SINTEF data supports a likelihood of 'Highly unlikely' for a well blowout with potential to result in the worst case credible spill. However, the dataset does not account for Woodside and Industry Process Safety Improvements since the Gulf of Mexico Macondo event and is, therefore, likely to be conservative. The SINTEF data set is January 1991 – December 2010, whilst the Macondo blowout occurred in April 2010. Significant strengthening of barriers is now in place post the data set period, including, but not limited to:

- Revised and more stringent API 53 Subsea BOP requirements are in force.
- Competency assessments of offshore personnel is now more stringent for both Woodside and drilling contractors, for example, through implementation of improvements to well control training as recommended by IOGP and requirements for Woodside personnel in safety critical roles to complete the Process Safety Management training requirements.
- The Woodside barrier installation and verification process has been revised, including acceptance criteria and change control management.

Overview

The Project Area and EMBA overlap a number of sensitive environmental, social and economic receptors, including protected and culturally significant areas. Depending on its severity (i.e. volume, hydrocarbon type and location), a hydrocarbon release resulting from the proposed Browse to NWS Project would have the potential to impact water and sediment quality and alter habitats. This could subsequently alter fauna behaviour, cause fauna injury or mortality, impact the aesthetic value of an area and alter the function, interests and activities of other users.

Sediment quality

Change in sediment quality

In the event of a hydrocarbon release, sediment quality within offshore and nearshore waters (seabed sediments, offshore islands and the mainland) could be affected. Studies of hydrocarbon concentrations in deep sea sediments surrounding and at distance from the Macondo well following the blowout of the Deepwater Horizon indicated that hydrocarbons were incorporated into sediments (Romero et al., 2015). Proposed mechanisms for hydrocarbon contamination of sediments included deposition of hydrocarbons and direct contact between submerged plumes and the seabed (Romero et al., 2015).

In the event of a major hydrocarbon release at the seabed (Scenario 1), modelling indicated that a pressurised release of condensate would generate a cone of rising gas that would entrain droplets and transport them to the surface. Marine sediment quality would be reduced as a consequence of hydrocarbon contamination in the immediate release site for a medium to long-term period and over a larger area as a result of the entrained and dissolved hydrocarbons, as discussed below.

Entrained and dissolved hydrocarbons (at or above the defined thresholds) could potentially contact shallow, nearshore waters of islands and mainland coastline and hydrocarbons may accumulate (at or above the ecological threshold) at a range of nearshore receptors (**Table 6-158**). Stochastic modelling results indicated that:

- Scenario 1 had a high probability of affecting sediments associated with Scott Reef and Seringapatam Reef, but a low probability of contacting sediments of the Argo-Rowley Terrace Marine Park, Kimberley Marine Park, Rowley Shoals (including associated marine parks), Barracouta Shoal, Eugene McDermott Shoal, Heywood Shoal, Hibernia Reef, Vulcan and Goeree Shoals, Fantome Bank, Cartier Island, Browse Island, Ashmore Reef and Indonesia (**Table 6-158**).
- Scenario 2 had a moderate probability of affecting Scott Reef and Seringapatam Reef sediments and a low probability of contacting sediments associated with Ashmore Reef (including the AMP), Eugene McDermott Shoal, Heywood Shoal, Vulcan Shoal and Goeree Shoal (**Table 6-158**).
- Stochastic modelling predicted low potential for Scenario 3 to contact sediments at Scott Reef and Seringapatam Reef.
- Scenario 4 had a moderate potential to contact sediments associated with the Argo-Rowley Terrace Marine Park and Rowley Shoals (including associated marine parks) (**Table 6-158**).

Such hydrocarbon contact may lead to reduced marine sediment quality by several processes, including adherence to sediment and deposition on shores or seabed habitat. Where shoreline contact occurs, toxic constituents of the hydrocarbon release may accumulate within marine sediment. This may result in subsequent impacts to high value benthic habitats and communities (which is described in the sections below).

Based on the outcomes of quantitative spill modelling, hydrocarbon spills resulting from the proposed Browse to NWS Project have the potential to significantly impact regional sediment quality. However, the occurrence of hydrocarbon spills is considered highly unlikely and the extent of impacts would depend on exposure concentration, duration and degree of weathering of the hydrocarbons.

Water quality

Change in water quality

In the event of a hydrocarbon release, water quality would be affected, due to hydrocarbon exposure and subsequent contamination. This is described in terms of the biological effect concentrations. These effect concentrations are defined by the hydrocarbon thresholds (**Table 6-155**) for each of the hydrocarbon fates and inform their predicted extents in **Table 6-157** and **Table 6-158**.

The highly-mixed, open water location of the Project Area would result in rapid dispersion and evaporation of high-volatile components of released hydrocarbons. Unstabilised Torosa condensate, stabilised Torosa condensate and marine diesel all have varying proportions of volatile and persistent (e.g. low-volatile, residual) components, as described in **Sections 6.3.21.3**. Persistent components tend to physically entrain into the upper water column in the presence of moderate winds (i.e. >12 knots) and breaking waves but may refloat to the surface if these conditions abate. In the highly unlikely event that a substantial spill occurred, the heavier components could remain entrained or remain on the sea surface for an extended period and travel significant distances from the source, albeit at low levels.

It should be noted that the ambient water quality of the Project Area may be influenced by the presence of natural hydrocarbon seepage from the seabed. In a 2017 study,CSIRO (2017) identified multiple seeps of varying intensity across the Browse Basin. Importantly, the study concluded that in the event of an incident, the low baseline concentrations recorded during the study would permit the BTEX compounds and PAHs introduced during the incident to be distinguished from background concentrations.

Table 6-156 summarises the weathering behaviour for each of the modelled hydrocarbon types (RPS, 2019, **Chapter 10, Appendix D.5**).

Fate and extent of a spill depends on the hydrocarbon released. Entrained hydrocarbons that result from a potential spill could travel between 242 and 863 km from the release location depending on the scenario. Depending on the scenario, concentrations of entrained hydrocarbons of 15,000 to 25,000 ppb would be expected to extend from the sea surface to depths of around 20 m.

Dissolved hydrocarbons could travel between 43 and 673 km, depending on the scenario, and concentrations of dissolved hydrocarbons of 1000 to 10,000 ppb would be expected to extend from the sea surface to depths of around 20 m.

Floating hydrocarbons would travel significantly smaller distances of between 82 and 143 km. Changes in water quality have the potential to result in short-term to long term impacts on multiple high value habitats and protected and migratory species on a regional scale. For example, in scenario 1, concentrations of entrained hydrocarbons of 23,600 ppb are predicted to occur at North Scott Reef (**Table 6-157**).

Based on the outcomes of quantitative spill modelling, hydrocarbon spills resulting from the proposed Browse to NWS Project have the potential to significantly impact regional water quality. However, the occurrence of hydrocarbon spills is considered highly unlikely and the extent of impacts would depend on the exposure concentration, duration and degree of weathering of the hydrocarbons.

Plankton

Injury or mortality to fauna

Primary production by plankton (supported by upwelling events) is an important component of the marine food web. Plankton communities generally consist of a mix of phytoplankton (cyanobacteria and other microalgae) and secondary consuming zooplankton (e.g. crustaceans such as copepods) and meroplankton (the eggs and larvae of fish and invertebrates). Productivity hotspots identified within the EMBA include the waters surrounding Scott Reef and a number of areas within the Kimberley AMP (**Section 5.3.1.1**).

Plankton have the potential to be impacted by exposure to hydrocarbons through smothering and coating, restriction of sunlight through the upper water column, and exposure to dissolved and entrained hydrocarbons. Any surface and subsea hydrocarbon release could impact plankton populations, as they are widely dispersed throughout the water column. Exposure may result in sublethal and lethal effects from restriction of respiration, decreased rates of photosynthesis (Tomajka, 1985), changes in behaviour or changes in species composition that make them more susceptible to predation (Batten et al., 1998), as well as from the toxicity of the hydrocarbons themselves.

For zooplankton and meroplankton, such as fish, coral, invertebrate eggs and larvae, direct effects of contamination may include toxicity, suffocation, changes in behaviour or environmental changes that make them more susceptible to predation (Villanueva et al., 2008).

Based on the outcomes of quantitative spill modelling, hydrocarbon spills resulting from the proposed Browse to NWS Project have the potential to significantly impact plankton communities, particularly in productivity hotspots in waters surrounding Scott Reef (for Scenarios 1, 2 and 3) and the Kimberley AMP (for Scenarios 1 and 2). However, the occurrence of hydrocarbon spills is considered highly unlikely and significance of the impact would depend on the specific parameters of the release. Given the wide spread nature and rapid turn-over of plankton populations leading to relatively quick recovery times of plankton, communities would be expected to recover relatively quickly (within weeks or months) (ITOPF, 2011). Therefore, impacts would be restricted to short-term, with no lasting effects even for worst-case credible spill scenarios.

Benthic habitats

Change in water quality - coral

Scott Reef is the closest coral habitat to hydrocarbon release locations for Scenarios 1 to 3 and, therefore, the most vulnerable. The shallow coral habitats are most vulnerable to hydrocarbon coating by direct contact with surface slicks during periods when corals are tidally-exposed, particular during spring low tides. Coral communities have the potential to be impacted from exposure to floating hydrocarbons through smothering and coating, and exposure to dissolved and entrained hydrocarbons. This may result in sublethal and lethal effects from restriction of feeding and respiration as well as from toxicity of the hydrocarbons to the individual coral colonies and species within the different coral habitats and communities of Scott Reef. This particularly applies to branching corals which are reported to be more sensitive than massive corals (Shigenaka, 2001).

Exposure to dissolved and entrained hydrocarbons (≥50 ppb and 100 ppb, respectively) has the potential to result in lethal or sub-lethal toxic effects to corals and other sensitive sessile benthos within the upper water column, including upper reef slopes (subtidal corals) and reef flat (intertidal corals). Sub-lethal effects to corals may include polyp retraction, changes in feeding, bleaching (loss of zooxanthellae), increased mucous production resulting in reduced growth rates and impaired reproduction (Negri and Heyward, 2000).

Should a hydrocarbon release occur at the time of coral spawning (at potentially affected coral locations), there is the potential for a significant reduction in successful fertilisation and coral larval survival, due to the sensitivity of early life stages of corals to hydrocarbon exposure (Negri and Heyward, 2000).

Studies have shown that corals in tropical shallow water reefs are at increased risk of hydrocarbon pollution due to the presence of ultraviolet light (Negri et al., 2016, Nordborg et al., 2017). This is based on Laboratory studies, such as for the branching coral Acropora tenuis coral larvae which were shown to be more sensitive to hydrocarbons (e.g. heavy fuel oil, diesel and light crude oil fractions) in the presence of ultraviolet light (Negri et al., 2016; Nordborg et al., 2018)partially due to the absence of studies that adequately assess toxicity to relevant coral reef species. Here we experimentally tested the acute toxicity of condensate, representing a fraction of light crude oil, to coral (Acropora tenuis. Exposure to light crude oil fractions with ultraviolet light increased the inhibition of larvae metamorphosis by 40% compared to exposure to light crude oil fractions without ultraviolet light (Negri et al., 2016). Similarly, ultraviolet light doubled the toxicity of dissolved HFO effects on larval settlement success (Nordborg et al., 2017).

A review of research into the effects of hydrocarbons on corals and coral reefs found that reported impacts to corals ranged from no detectable impacts to a variety of impacts including coral tissue loss, increased coral mortality, changes in the abundance and diversity of coral communities, physiological changes, sublethal effects (e.g. increased mucous production and decreased growth rate) and changes in reproduction (Turner and Renegar, 2017). The review found that experiments examining the impacts of hydrocarbons on corals in situ found exposure to hydrocarbons resulted in slight (not significant) reductions in coral cover but exposure to chemically dispersed hydrocarbons resulted in significant impacts to coral communities, with both coral cover and growth affected (Turner and Renegar, 2017

Reef flat habitat is considered the coral habitat most vulnerable to direct exposure from surface hydrocarbons (NOAA, 2010). Scott Reef hash extensive reef flat habitat (0-4 m depth). However, compared to other coral habitats, the reef flat habitat at Scott Reef has the lowest coral cover (less than 5%) and lowest diversity due to the harsh conditions for coral growth resulting from daily tidal and periodic high wave action exposure, as well as cyclone and coral bleaching events.

Below 4 m water depths, coral colonies would be generally not directly contacted by surface slicks on the overlying waters (Shigenaka, 2001, NOAA, 2010). Although not subject to smothering by surface hydrocarbons, these shallow water subtidal corals may be subject to exposure to soluble toxic compounds that dissolve from hydrocarbon droplets (dissolved and entrained hydrocarbons) in the upper water column by wave action on surface hydrocarbons (IPIECA, 1992; NOAA, 2010).

The model predicted higher probabilities of exposure to surface hydrocarbons across the southern portion of North Scott Reef, Sandy Islet and its surrounding reef flats and the north-western and north-eastern portions of South Scott Reef. Given the minimum contact times (in the order of a few hours for Scenario 1) to reach the closest parts of reef flat habitats at North Scott Reef and potential for exposure to surface, dissolved and entrained hydrocarbons above threshold concentrations, there is potential for near total coral mortality in the worst affected areas of tidally exposed reef flats and the potential for sublethal stress and significant incidence of coral mortality among the most sensitive species in deeper subtidal communities (predicted exposure to 20 m depth).

Studies have demonstrated that Scott Reef is a 'self-sustaining' coral community, with mass coral spawning known to only occur twice a year (**Section 5.3.1.3**). This makes hydrocarbon exposure from an unplanned hydrocarbon release at either of these predicted annual spawning events of particular high ecological impact on vulnerable coral larvae, as it is likely to result in the failure of recruitment and settlement of new coral population cohorts. However, it should also be noted that due to the short and discrete spawning periods, the vulnerability of coral plankton stages to surface hydrocarbons would be largely confined to a period of up to three weeks after spawning events.

Quantitative spill modelling predicted that a number of shallower reef and lagoon habitats could be contacted in Scenarios 1 to 4. Depending on the specific scenario, coral habitats predicted to be contacted by floating hydrocarbons include Scott Reef, Seringapatam Reef and the Rowley Shoals (within the Argo-Rowley Terrace AMP) (**Table 6-158**). Additional locations which may be contacted by dissolved and entrained hydrocarbons at a lower probability include Barracouta Shoal, Eugene McDermott Shoal, Heywood Shoal, Hibernia Reef, Vulcan and Goeree Shoals, Fantome Bank, Browse Island, Cartier Island AMP, Ashmore Reef AMP and the Kimberley AMP. Of these areas, Scott Reef is considered to be the most vulnerable, given its proximity to release locations for Scenarios 1 to 3 and predicted contact volumes and probabilities for contact by each hydrocarbon fate. However, the occurrence of hydrocarbon spills is considered highly unlikely and the extent of impacts would depend on exposure concentration, duration and degree of weathering of the hydrocarbons.

Change in water quality - seagrass and macroalgae

Seagrass and macroalgae toxicity effects can occur when soluble fractions of hydrocarbons are absorbed into tissues (Runcie et al., 2010). The potential for toxicity effects of entrained hydrocarbons may be reduced by weathering processes that lower the content of soluble aromatic components before contact occurs. Exposure to entrained hydrocarbons may result in mortality, depending on actual entrained aromatic hydrocarbon concentrations and duration of exposure. Physical contact with entrained hydrocarbon droplets could cause sub-lethal stress, leading to reduced growth rates and reduced tolerance to other stress factors (Zieman et al., 1984).

Although water depths within the Project Area and EMBA are generally too deep to provide suitable conditions for these intertidal and subtidal communities, quantitative spill modelling did predict that a number of shallow habitats could be contacted for Scenarios 1 through 4. Areas predicted to be reached by entrained hydrocarbons that may comprise these habitats include Scott Reef and Seringapatam Reef, with a high probability of impact from Scenario 1, and a low (3%) probability of entrained hydrocarbons impacting Browse Island from Scenario 1. Seagrass and macroalgal beds in the intertidal and subtidal zone within these receptors may be susceptible to impacts from entrained hydrocarbons. At lower probabilities Ashmore Reef (Scenario 1 and 2), Cartier Island (Scenario 1 and 2) and Kimberley AMP (Scenario 1) were also predicted to have the potential to be contacted (**Table 6-158**).

Based on the outcomes of quantitative spill modelling, hydrocarbon spills resulting from the proposed Browse to NWS Project have the potential to significantly impact localised intertidal and subtidal communities of seagrass and macroalgae at Scott Reef, Seringapatam Reef and, to a lesser extent and likelihood, Browse Island, Cartier Island, Ashmore Reef and Kimberley AMPs. However, the occurrence of hydrocarbon spills is considered highly unlikely and the extent of impacts would depend on exposure concentration, duration and degree of weathering of the hydrocarbons.

Change in water quality - shoreline habitats

Hydrocarbons that contact sandy shores may be incorporated into fine sediments through mixing in the surface layers from wave energy, penetration down worm burrows and root pores (vegetated shorelines). Hydrocarbons in the intertidal zone can adhere to sand particles, however, high tide may remove some or most of the hydrocarbons from the sediment particles. Accumulated hydrocarbons ≥ 100 g/m² could impact the survival and reproductive capacity of benthic epifaunal and infaunal invertebrates living in intertidal habitat (French-McCay, 2009). Impacts to socio-economic receptors are discussed below.

The impact of hydrocarbons on rocky shores would be largely dependent on the incline and energy levels received at shoreline rocky environments. On steep/vertical rock faces on wave exposed coasts there is likely to be no impact from a spill event because the high energy of the waves would wash hydrocarbons from the steep slopes of the rocks. However, a gradually sloping boulder shore in calm water can potentially trap large amounts of hydrocarbon (IPIECA, 2000).
The impact of the spill on marine organisms along the rocky coast would depend on the toxicity and

weathering of the hydrocarbons. Similar to sandy shores, accumulated hydrocarbons ≥100 g/m^2 could affect the epifauna along rocky coasts and impact the reproductive capacity and survival of such biota.

Tidal flats are susceptible to potential impacts from hydrocarbons as they are typically low energy environments and, therefore, trap hydrocarbons. The extent of exposure is influenced by the neap and spring tidal cycle and seasonal highs and lows affecting mean sea level. Potential impacts to tidal flats include heavy accumulations covering these areas at low tide. It is unlikely that hydrocarbons would penetrate the water-saturated sediments, although hydrocarbons can penetrate sediments through animal burrows and root pores (where vegetated).

The proximity of a potential spill to the coast would influence hydrocarbon volumes and concentrations that reach the shoreline. Furthermore, hydrocarbons would weather over time, with only between 5% and 51% of the initial volume remaining after a few days following a worst-case credible spill scenario. The modelling predicted potential hydrocarbon accumulation at shorelines at defined thresholds at Scott Reef, Ashmore Reef, Cartier Island, and Rowley Shoals (**Table 6-158**). Maximum accumulated volumes and minimum times to contact for the worst-case credible spill scenarios to these sensitive receptors are:

+ Scott Reef: minimum time to contact of 39 hours (Scenario 2); maximum accumulated volume of 824 m^3 (Scenario 1).
+ Ashmore Reef: minimum time to contact of 23 days; maximum accumulated volume of 157 m^3 (Scenario 1).
+ Cartier Island: minimum time to contact of 35 days (Scenario 2); maximum accumulated volume of 38 m^3 (Scenario 1).
+ Rowley Shoals: minimum time to contact of 4 days (Scenario 4); maximum accumulated volume of 25 m^3 (Scenario 1).

The modelling also demonstrated that localised areas of coastline in the Buccaneer and Bonaparte Archipelagos and Lalang-garram/Camden Sound MP within the Kimberley, as well as in Indonesia and Timor Leste, could receive hydrocarbons above the accumulated threshold (Scenario 1 only). However, these areas are only predicted to be contacted at 3% or less probabilities and no dissolved, entrained or floating hydrocarbons are predicted to reach these locations. Given maximum accumulated volumes and minimum time to contact for these receptors (between 6 and 14 m^3 and 98 to 100 days for the locations along the Kimberley coast and 7 and 52 m^3 and 72 to 99 days for international shorelines) hydrocarbons would be significantly weathered and unlikely to reach the receptor at the modelled volumes. Given this and the initial low likelihood of a spill occurring, no impacts are predicted to these shorelines.

Based on the outcomes of quantitative spill modelling, hydrocarbon spills resulting from the proposed Browse to NWS Project have the potential to significantly impact shoreline habitats at Scott Reef, Ashmore Reef, Cartier Island and Rowley Shoals. However, the occurrence of hydrocarbon spills is considered highly unlikely and the extent of impacts would depend on exposure concentration, duration and degree of weathering of the hydrocarbons.

Fauna

Injury or mortality to fauna - seabirds and migratory shorebirds

Seabirds and migratory shorebirds have the potential to be impacted by exposure to hydrocarbons through direct contact while at or breaking through the water surface (e.g. feeding, resting or moulting), coating and contamination of feathers, ingestion and vapour inhalation particularly during self-cleaning/preening of feathers, and ingestion from contaminated prey. This may result in sublethal and lethal effects such as irritation and external injury to eyes, skin and cavities, damage to internal airways and organs, immune system and reproductive success, loss of buoyancy of feathers and insulation leading to drowning or lethal heat loss, and loss of mobility leading to starvation/dehydration or becoming easy prey.

Seabirds and shorebirds are particularly vulnerable to hydrocarbon spills given their high potential for exposure with the sea surface or shoreline where they feed, rest or moult. While impacts to birds can occur in offshore open waters, the most pronounced impacts are often experienced if spills reach coastal waters near major seabird colonies, where intensive feeding occurs during the breeding season. Bird feeding methods typically involve complete or partial submersion of the bird, making them highly susceptible to exposure. As most fish in the water column survive beneath surface hydrocarbons, foraging seabirds, which typically do not exhibit avoidance behaviour, continue to feed within waters exposed to surface hydrocarbons. In contrast, migrant shorebirds and waders that feed along shorelines are generally less susceptible to severe exposure and associated physical effects (Scholz et al., 1992, French-McCay, 2009).

Exposure to surface hydrocarbons can result in lethal or sublethal physical and toxic effects. Physical contact with surface hydrocarbons and associated vapours may cause irritation and injury to a bird's eyes, skin, and mouth cavities. Hydrocarbons will also adhere to feathers, causing them to matt and lose their insulating, buoyancy and water repelling properties.
The overriding behaviour of a bird with 'oiled' feathers is preening to the exclusion of all other normal activities. As an affected bird preens, it ingests and inhales hydrocarbons, which can cause damage to internal

organs. Suppression of the immune system can also occur, and other effects include impacts to reproductive success through decreased fertility of eggs and reduction in egg shell thickness.

Offshore waters of the Project Area and EMBA are potential foraging grounds for seabirds. For Scenarios 1 to 4, modelling predicted floating hydrocarbons above threshold concentrations could reach distances of between 67 km to 143 km from the spill source. Locations predicted to be contacted include Scott Reef and Seringapatam Reef (Scenarios 1 through 3) and Rowley Shoals (Scenario 4) (**Table 6-158**). Shoreline accumulation above outlined thresholds was predicted at Scott Reef (92% probability), Ashmore Reef (18%), Cartier Island (22%), and Rowley Shoals (8%).

Several important habitats for seabirds and migratory shorebirds occur in the EMBA, in particular at Ashmore Reef and Cartier Island, Browse Island, islands along the Kimberley coastline (such as the Lacepede Islands) and Rowley Shoals. These areas are used by birds for breeding/nesting, roosting and resting, and waters surrounding these areas are used for foraging. However, in the unlikely event that hydrocarbons reach these locations, it is predicted that they would be significantly weathered and likely to be less toxic than in areas closer to potential release locations, thereby further reducing the likelihood of any significant impacts on nesting, roosting or resting and foraging seabirds or shorebirds at these locations.

Scott Reef also supports minor seabird breeding colonies, including for the little tern. BIAs for nine bird species overlap the EMBA (white-tailed tropicbird, wedge-tailed shearwater, roseate tern, red-footed, little tern, lesser frigatebird, lesser crested tern, great frigatebird, and brown booby). BIAs for seabirds and shorebirds are primarily restricted to within tens of kilometres of emergent features where nesting may occur. Hence there is the potential to impact on nesting populations, which has the potential to affect species recruitment at a local population level.

Four bird species which have been identified as occurring within the Project Area have specific conservation advice which identifies key threats to the species that are relevant to hydrocarbon spills (i.e. habitat degradation, loss or modification). These species are the Australian lesser noddy, Abbott's booby, ruddy turnstone and common sandpiper.

Based on the outcomes of quantitative spill modelling, hydrocarbon spills resulting from the proposed Browse to NWS Project have the potential to significantly impact bird species, including protected species, within the Project Area and EMBA. Although potential impacts could include mortality or sub-lethal injury/illness of birds, this would be expected to comprise a small proportion of the resident and transitory population. Impacts may be more significant if hydrocarbons, particularly floating and shoreline hydrocarbons, reach key aggregation and breeding areas listed above.

Injury or mortality to fauna - marine mammals

Habitat loss or degradation is highlighted in the conservation advices for humpback whales, sei whales and fin whales. Marine mammals have the potential to be impacted by exposure to hydrocarbons through contact at the water surface (feeding, surfacing, breaching, travelling, socialising, resting), hydrocarbon adherence following coating (although this is considered minor due to their mainly smooth skin and minor area of both hair (pelage) and rough-skinned areas), ingestion and vapour inhalation, and ingestion from contaminated prey. Hydrocarbon impacts may result in sublethal and lethal effects from irritation and injury to eyes, skin and mouth cavity; damage to internal organs; and (if high vapour concentrations are present) narcosis and drowning. Fresh hydrocarbons (i.e. typically in the vicinity of the release location) are likely to have a higher potential to result in toxic effects, while weathered hydrocarbons are considered to be less likely to result in toxic effects.

Cetaceans that have direct physical contact with entrained or dissolved aromatic hydrocarbons may suffer ingestion of hydrocarbons (from prey, water and sediments), aspiration of contaminated water or droplets and inhalation of toxic vapours (Deepwater Horizon Natural Resource Damage Assessment Trustees, 2016). This may result in the irritation of sensitive membranes such as the eyes, mouth, digestive and respiratory tracts and organs, impairment of the immune system, neurological damage (Helm et al., 2015), reproductive failure, adverse health effects (e.g. lung disease, poor body condition) and potentially mortality (Deepwater Horizon Natural Resource Damage Assessment Trustees, 2016). A review of cetacean observations in relation to large scale hydrocarbon spills was undertaken for the Deepwater Horizon spill. It is worth noting that the Deepwater Horizon hydrocarbon release was crude oil, which is much more persistent in the environment than the condensate that may be released during the proposed Browse to NWS Project and also more amenable to the formation of surface slicks, which cetaceans may be exposed to when breathing. The review concluded that exposure to oil from the Deepwater Horizon resulted in increased mortality to cetaceans in the Gulf of Mexico (Deepwater Horizon Natural Resource Damage Assessment Trustees, 2016). Given the relatively non-persistent nature of the hydrocarbons that have the potential to be released during the proposed Browse to NWS Project, and the possible floating hydrocarbon spill extents (between 67 km and 143 km; **Table 6-157**), the area where potential impacts from inhalation could occur would be localised around the release location.

Cetacean populations that are resident within the EMBA (e.g. Indo-Pacific humpback dolphin) may be more susceptible to impacts from spilled hydrocarbons given they may be less likely to avoid an area of a spill and, therefore, could have increased exposure durations. However, resident species are more likely to occupy coastal waters where probabilities for hydrocarbon contact are very low (e.g. 1% probability to contact Kimberley coast; **Table 6-158**). In the unlikely event that hydrocarbons reached the coastline, they would be significantly weathered and likely to be less toxic than in areas closer to potential release locations. Suitable habitat for these species is also broadly distributed throughout the region and, as such, impacts are unlikely to affect an entire population.

Resident spinner dolphins, which are known to occur at offshore islands including at Scott Reef, are an exception to this. Resident spinner dolphins at Scott Reef have a higher probability of being impacted than coastal resident mammal populations, with a potential for a significant portion of this local population to be impacted in the event of a worst-case hydrocarbon spill.

Migratory cetaceans which have transient interactions with the EMBA (e.g. pygmy blue whales and humpback whales) have the potential to be impacted if a spill occurs during their annual migration periods, or if a spill is severe enough to result in significant long-term impacts to prey species' populations. Physical contact with hydrocarbons is likely to have biological consequences for individuals present in the area. However, it is unlikely to affect an entire population or impact overall population viability as migration periods are spatially and temporally varied, meaning only a small portion of the population is likely to be present within the spill extent.

Pygmy blue whales are known to migrate seasonally through the Project Area and EMBA. The Project Area overlaps a migration BIA and a possible foraging area for pygmy blue whales. Studies have shown small numbers of pygmy blue whales pass through the wider region of Scott Reef up to twice a year during their annual migrations (Gavrilov et al., 2018, McCauley, 2011). Occurrences have been recorded between October and January (southbound migration), with a peak in November, and April to August (northbound migration) (Blue Planet Marine, 2019; Commonwealth of Australia, 2015b). Individuals typically transited to the west of Scott Reef, however, have also been recorded transiting through the channel between north and south Scott Reef and in deep waters adjacent to the rim of Scott Reef (Jenner and Jenner, 2009). While there have been no direct observations of pygmy blue whales feeding at Scott Reef, the species has been recorded at Scott Reef during periods of elevated plankton biomass (Blue Planet Marine, 2019).

Humpback whales also migrate seasonally through the Project Area and EMBA. Humpback whales are not likely to occur in high numbers within the Development Area, however, will occur seasonally in high numbers within the EMBA (from June to October with a peak between late July and mid-August) (RPS, 2012). A migration BIA along the Pilbara and Kimberly coast overlaps the EMBA; spill modelling predicted entrained and dissolved hydrocarbons to contact the area (Kimberley AMP) at probabilities of between 2% and 31% for Scenarios 1 and 2 only. Based on historical observations (Jenner et al., 2001) and studies by RPS (2010b) and McCauley (2011), it is likely that there may be low numbers of transient individuals occurring within the Browse Development Area and, in particular, within the vicinity of Scott Reef.

Pygmy blue and humpback whales are baleen whales and the most likely to be significantly impacted by toxic effects when feeding. However, feeding during migrations is low level and opportunistic, with most feeding for both species occurring in the Southern Ocean prior to migration. As such, the risk of ingestion of hydrocarbons is low. Migrations of both pygmy blue whales and humpback whales are protracted through time and space (i.e. the whole population would not be within the EMBA at one time), and as such, a hydrocarbon spill is unlikely to affect an entire population.

Based on the outcomes of quantitative spill modelling, hydrocarbon spills resulting from the proposed Browse to NWS Project have the potential to significantly impact marine mammal species, including protected species, within the Project Area and EMBA. In particular, impacts may occur to a small percentage of the migratory populations of pygmy blue whales and humpback whales if a spill occurs during their annual migrations. Given the mobile migratory nature of most marine mammal species and the relatively localised extent of floating hydrocarbons, impacts are not expected to have a substantial adverse effect on an ecologically significant proportion of any migratory marine mammal species populations. In addition, the occurrence of hydrocarbon spills is considered highly unlikely and the extent of impacts would depend on exposure concentration, duration and degree of weathering of the hydrocarbons.

Injury or mortality to fauna - Marine reptiles

Marine turtles are vulnerable to the effects of hydrocarbons at all life stages (eggs, hatchlings, juveniles and adults) (NOAA, 2010). Marine turtles are in frequent contact with the sea surface and they may also feed at or below the water surface or rest at the surface. This frequent contact with the sea surface and a lack of avoidance behaviour makes turtles susceptible to exposure to surface hydrocarbons and associated vapours. On contact with surface hydrocarbons, turtles may experience irritation and injury to airways or lungs, eyes and mucous membranes of the mouth and nasal or other cavities. Exposure can also irritate and injure skin, which is most evident on particularly pliable areas such as the neck and flippers. Ingestion of hydrocarbons through contaminated food or tar balls may also injure the salt-gland, digestive tract or other organs with potentially lethal effects. When crossing beaches contacted with hydrocarbons, gravid adult females and hatchlings are likely to be in turn exposed to hydrocarbons.

Although buried eggs are unlikely to be directly impacted by hydrocarbon accumulated at the shoreline, they may become directly exposed to hydrocarbons as a result of the gravid female turtles becoming oiled as they cross the shore. This may result in the transfer of hydrocarbons onto eggs during nest laying, which may cause impaired embryo development or embryo mortality. Weathered hydrocarbons have been shown to have little impact on egg survival, while fresh hydrocarbons significantly reduced egg survival (Milton and Lutz, 2003).

Locations predicted to be contacted are Scott Reef and Seringapatam Reef, Ashmore Reef and Cartier Island, and the Kimberley AMP and Argo-Rowley Terrace AMP (**Table 6-157**).

Several important habitats for marine turtle species, including key breeding/nesting areas, internesting and foraging areas, occur in the Project Area and EMBA, in particular Scott Reef, Ashmore Reef, Cartier Island, ArgoRowley Terrace and Kimberley AMPs. Scott Reef has the highest probabilities for hydrocarbon contact above thresholds and, therefore, is the most vulnerable area. Sandy Islet, a part of South Scott Reef, supports nesting green turtles and hawksbill turtles. The breeding population of these species, particularly green turtles, also internest in the surrounding lagoonal waters of South Scott Reef adjacent to Sandy Islet (between 4-15 m water depth) and, as such, marine turtles present during the nesting season (November to February) are highly vulnerable in the event of a hydrocarbon spill. Short-term impacts include significant mortality amongst adults and hatchlings and reduced egg survival. Sublethal stress to individuals may also reduce breeding and nesting success. Such impacts would have the potential for longer-term effects on the Scott Reef – Browse Island genetic stock of green turtles. As the breeding population at Scott Reef forms part of a limited genetic stock that is geographically isolated, this could have implications for recovery time of the population depending on the extent of impacts. However, female turtles are reported to return to Sandy Islet every two to eight years and the turtles present at Scott Reef in any one breeding season, therefore, represent only a portion of the population (Guinea, 2010). In addition, in any given breeding season different turtles may only be present for part of the season due to different arrival times. In this way, the potential for mortality among breeding turtles and hatchlings would affect a portion of and not the entire breeding green turtle population nesting at Sandy Islet. Acute and chronic chemical discharges are highlighted within the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia, 2017) as a key risk to green turtles within the Scott Reef and Browse Island area. The Recovery Plan identifies ensuring spill risk strategies and response programs include management for turtles and their habitats.

The Project Area and EMBA overlap BIAs and habitat critical to the survival of a species for four marine turtle species, including the green turtle, olive ridley turtle, flatback turtle and hawksbill turtle. Given this, there is the potential to impact on breeding populations, which has the potential to affect species recruitment at a local population level.

PMST searches identified 17 sea snakes as potentially occurring within the Project Area, including threatened and migratory species. Conservation Advice for the short-nosed sea snake (DSEWPaC, 2011) includes ensuring there is no anthropogenic disturbance in areas where the species occurs, excluding necessary actions to manage the conservation of the species. Sea snakes are expected to occur predominately in shallow regions of the EMBA, such as Scott Reef, Ashmore and Cartier, Rowley Shoals and other small offshore shoals and reefs. Given this, there is potential to impact on local populations of sea snakes.

Based on the outcomes of quantitative spill modelling, hydrocarbon spills resulting from the proposed Browse to NWS Project have the potential to significantly impact marine reptile species, including protected species, within the Project Area and EMBA. However, the occurrence of hydrocarbon spills is considered highly unlikely and the extent of impacts would depend on exposure concentration, duration and degree of weathering of the hydrocarbons.

Injury or mortality to fauna - fish

Fish, including sharks and rays, have the potential to be impacted by exposure to hydrocarbons through exposure to dissolved and entrained hydrocarbons, ingestion of entrained hydrocarbons, and contact with surface slick (if travelling/skim feeding at the surface e.g. whale shark). This could result in sublethal and lethal effects from toxicity effects or damage to internal organs. Any surface and subsea hydrocarbon release could impact fish, as they are widely dispersed throughout the water column.

Hydrocarbons may contaminate fish tissues and internal organs, either through direct contact or via the food chain (consumption of prey). As gill breathing organisms, bony fishes and elasmobranchs (sharks and rays) may be vulnerable to toxic effects of dissolved hydrocarbons (entering the body via the gills) and entrained hydrocarbons (coating of the gills inhibiting gas exchange).

Fish mortalities are rarely observed as a result of hydrocarbon spills (ITOPF), 2011). This has generally been attributed to the possibility that pelagic fish are able to detect and avoid surface waters underneath hydrocarbon spills by swimming into deeper water or away from the affected areas. Laboratory studies have shown that adult fish can detect hydrocarbons in water at very low concentrations, and large numbers of dead fish have rarely been reported after hydrocarbon spills (Hjermann et al., 2007). Where fish mortalities have been recorded, the spills (resulting from the groundings of the tankers Amoco Cadiz in 1978 and the Florida in 1969) occurred in sheltered bays.

Fish that have been exposed to dissolved aromatic hydrocarbons are capable of eliminating the toxicants once placed in clean water; hence, individuals exposed to a spill are likely to recover (King et al., 1996). The effects of exposure to hydrocarbons on the metabolism of fish appear to vary according to the organs involved, exposure concentrations and route of exposure (waterborne or food intake). Hydrocarbon reduces the aerobic capacity of fish exposed to aromatics in the water, and to a lesser extent affects fish consuming contaminated food (Cohen et al., 2005). The liver, a major detoxification organ, appears to be where anaerobic activity is most impacted, probably increasing anaerobic activity to help eliminate ingested hydrocarbons from the fish (Cohen et al., 2005).

Fish are most susceptible to the effects of hydrocarbons in their early life stages, particularly during egg and planktonic larval stages (see assessment above regarding plankton), which can become entrained in spilled hydrocarbons. Contact with droplets can mechanically damage feeding and breathing apparatus of embryos and larvae (Fodrie and Heck, 2011). The toxic hydrocarbons in water can result in genetic damage, physical deformities and altered developmental timing for larvae and eggs exposed to even low concentrations over prolonged timeframes (days to weeks) (Fodrie and Heck, 2011). More subtle, chronic effects on the life history of fish from hydrocarbon exposure in early life stages include disruption to complex behaviour such as predator avoidance, reproductive and social behaviour (Hjermann et al., 2007). Prolonged exposure of eggs and larvae to weathered concentrations of hydrocarbons in water has also been shown to cause immunosuppression and allows expression of viral diseases (Hjermann et al., 2007).

The NWMR is known for its demersal slope fish assemblages; it is the second richest area for demersal fish species across the entire Australian continental slope. Additionally, a number of threatened and migratory fish species are found within the Project Area and EMBA, such as the whale shark, shortfin and longfin mako sharks, and the green and largetooth sawfish. A foraging BIA for whale sharks overlaps the Project Area. Shortfin and longfin mako sharks are pelagic species and likely to occur in small numbers throughout the year. Sawfish are generally resident to coastal and estuarine areas, occurring throughout the Kimberley and north WA coast.

The Whale Shark Recovery Plan, although no longer in effect, identified habitat degradation/modification as a key threat to the species (DEH, 2005). Whale sharks migrate along the northern WA coastline, broadly following the 200 m isobath, between July and November (DEWHA, 2015). The extents predicted from hydrocarbon spill modelling suggested that hydrocarbons above thresholds could extend into the northern edge of the whale shark BIA. It is predicted that only low numbers of whale sharks will occur seasonally within the Project Area and EMBA. Given this, and that whale sharks occur globally in tropical and warm temperate waters and are thought to form one single genetic population (Yender et al., 2002; DEWHA, 2015), impacts to this species would be restricted to a small number of whale sharks if a spill occurred during their annual migration or if prey populations were impacted.

Although fish populations occur throughout the EMBA and Project Area, areas of particularly high fish diversity or abundances that are predicted to be contacted above thresholds include Scott Reef and Seringapatam Reef, Browse Island, Ashmore Reef and Cartier Island, Rowley Shoals, the Kimberley AMP and the Argo-Rowley Terrace AMP (probabilities of contact in relation to specific hydrocarbon fate are provided in **Table 6-158**). Fish assemblages in these areas are likely to include various species of site-attached reef fish assemblages and also species of pipefish and seahorses that are protected under the EPBC Act. Submerged banks and shoals that have low probability of contact above entrained and/or dissolved thresholds are also expected to support higher fish abundances than surrounding featureless, deepwater habitat, these being Barracouta Shoal, Eugene McDermott Shoal, Heywood Shoal, Hibernia Reef, Vulcan and Goeree Shoals and Fantome Bank. Coral reef fish generally have small home ranges and as reef residents they are at higher risk from hydrocarbon exposure than non-resident, more wide-ranging fish species. The exact direct impact on resident fish populations would be entirely dependent on actual hydrocarbon concentration, duration of exposure and water depth of the affected communities. In addition, the could be indirect consequences to site-attached fish assemblages due to the loss of coral habitat and subsequent recovery of the reef system. It is also noted that the early life stages (larval and fingerling) of resident fish populations are particularly sensitive to hydrocarbon exposure.

A number of KEFs also overlap the EMBA, with many of these associated with high fish abundances and diversity. Impacts to KEFs and AMPs are discussed below.

Based on the outcomes of quantitative spill modelling, hydrocarbon spills resulting from the proposed Browse to NWS Project have the potential to significantly impact fish species, including protected species, within the Project Area and EMBA. Although such potential impacts could include mortality or sub-lethal injury/illness of fish, for most mobile species this would be expected to comprise a small proportion of the transitory populations (i.e. whale sharks, shortfin and long fin mako sharks). For species which are considered site-attached, such as reef fish and pipefish and seahorses, a hydrocarbon spill could potentially have higher level impacts (e.g. site-attached coral fish assemblages of Scott Reef).

Assessment against EPBC Act recovery and conservation plans and advices

Table 6-159 summarises how the risk of an unplanned hydrocarbon release associated with the proposed Browse to NWS Project is not inconsistent with the objectives and actions of the relevant EPBC Act recovery and conservation plans and advice for protected fauna.

Table 6-159 Alignment with EPBC Act recovery and conservation plans and advices for protected fauna – unplanned hydrocarbon release

Fauna	Relevant plan(s)/ Conservation Advice	Plan/advice objectives and actions	Assessment
Migratory shorebirds	Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a)	Anthropogenic threats to migratory shorebirds in Australia are minimised or, where possible, eliminated.	With the implementation of controls, it is considered highly unlikely that impacts will occur to migratory shorebirds as a result of unplanned hydrocarbon release. Therefore, it is considered that the proposed activities are not inconsistent with the Wildlife Conservation Plan for Migratory Shorebirds.
Whale shark	Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a)	Assess the impacts of offshore installations and associated environmental changes (light spill, chronic noise, changed water temperature, localised nutrient levels) on whale sharks and mitigation options for these impacts.	No specific reference to hydrocarbon pollution is provided in the conservation advice. Given the low number and infrequent nature of whale shark presence in the Project Area, and the implementation of controls, it is considered highly unlikely impacts to whale sharks will occur as a result of an unplanned hydrocarbon release. Therefore, it is considered that the proposed activities are not inconsistent with the conservation advice.

Fauna	Relevant plan(s)/ Conservation Advice	Plan/advice objectives and actions	Assessment
Green turtle	The Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia, 2017)	Management actions: + Manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to the survival. + Manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue. + In relation to the Scott Reef – Browse Island green turtle genetic stock, the priority action is to manage anthropogenic activities to ensure marine turtle are not displaced from identified habitat critical to their survival.	Risk to marine turtles have been assessed and will be managed in accordance with the Recovery Plan for Marine Turtles in Australia which includes the minimisation of chemical discharge as an overarching action area (Commonwealth of Australia, 2017a). In relation to the Scott Reef – Browse Island green turtle genetic stock, the priority action to manage anthropogenic activities to ensure marine turtle are not displaced from identified habitat critical to their survival is predicted to be met as the likelihood of an unplanned hydrocarbon release impacting marine turtles has been assessed as highly unlikely. Therefore, it is considered that the proposed activities are not inconsistent with the Recovery Plan for Marine Turtles.
Hawksbill turtle			
Pygmy blue whale	Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c)	Acute chemical discharge (oil or condensate spill) is identified as a moderate risk to pygmy blue whales, however, there are no specific actions identified.	With the implementation of controls, it is considered highly unlikely that impacts will occur to cetaceans as a result of unplanned hydrocarbon release. Therefore, it is considered that the proposed activities are not inconsistent with the Conservation Management Plan for the Blue Whale or the conservation advices listed.
Humpback whale	Conservation advice *Megaptera novaeangliae*, Humpback Whale	Marine discharges have not been identified as a direct threat to these whale species; however, habitat degradation has been identified as a threat and unmanaged discharges may contribute to this threat. The conservation advice relevant for this threat – identifies modification to the coastal region in areas of importance to listed whales may result in reduced occupancy, compromised reproductive success and even mortality.	
Sei whale	Conservation advice *Balaenoptera borealis*, Sei Whale		
Fin whale	Conservation advice *Balaenoptera physalus*, Fin Whale		

Key Ecological Features

Change in sediment quality, change in water quality, injury or mortality to fauna

KEFs have the potential to be impacted through exposure to hydrocarbons in the event of an unplanned hydrocarbon release. Based on the outcomes of quantitative spill modelling for Scenarios 1 to 4, the following KEFs have the potential to be impacted at varying probabilities of exposure above threshold concentrations for floating, dissolved and entrained hydrocarbons (see Table 6-158):

- Continental slope demersal fish communities
- Seringapatam Reef and Commonwealth waters in the Scott Reef complex
- Ancient coastline at 125 m depth contour
- Mermaid Reef and Commonwealth waters surrounding Rowley Shoals
- Ashmore Reef and Cartier Island and surrounding Commonwealth waters

Although these KEFs are primarily defined by seabed geomorphological features, they are described to identify the potential for increased biological productivity and, therefore, ecological significance. The values and sensitivities of these KEFs primarily relate to seafloor features and demersal fish species (i.e. that live close to the seafloor). Therefore, water depth can determine whether any hydrocarbons (i.e. dissolved and entrained) can potentially interact with these values and sensitivities. Some KEFs, such as those defined around Scott Reef, Ashmore Reef and Cartier Island, and Rowley Shoals, also have shallow and emergent features and are, therefore, more vulnerable to the impacts of hydrocarbon spills. These KEFs have added protection of being Commonwealth and State protected marine parks.

Potential impacts to KEFs include the contamination of sediments, impacts to benthic fauna/habitats and associated impacts to demersal fish populations and reduced biodiversity. Most of the KEFs within the EMBA have relatively broad-scale distributions and are unlikely to be significantly impacted.

Summary

Table 6-160 provides an assessment of the risk of unplanned hydrocarbon discharge in relation to the pressures on KEFs identified in the Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).

Table 6-160 Alignment with protection of conservation values of KEFs – unplanned hydrocarbon release

Key Ecological Feature	Relevant plan(s)	Relevant pressures	Assessment
Ashmore Reef and Cartier Island and surrounding Commonwealth waters	Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia, 2012).	Oil pollution currently identified as "of potential concern"	With the implementation of controls, it is considered highly unlikely that impacts will occur to KEFs as a result of unplanned hydrocarbon release. Therefore, there is a high level of confidence that there will not be an adverse impact to marine ecosystem function or integrity with in the KEFs; or any reduction to the conservation values of the KEFs will occur.
Seringapatam Reef and Commonwealth waters in the Scott Reef Complex			
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals			
Ancient coastline at 125 m depth contour		Oil pollution currently identified as "of less concern"	
Continental slope demersal fish communities		Oil pollution currently identified as "no of concern"	

Australian marine parks

Change in sediment quality, change in water quality, injury or mortality to fauna

AMPs have the potential to be impacted through exposure to hydrocarbons in the highly unlikely event of an unplanned hydrocarbon release. Based on the outcomes of quantitative spill modelling for Scenarios 1 through 4, the following AMPS have the potential to be impacted at varying probabilities (Table 6-158):

- Kimberley Marine Park (highest probability is 31% probability for entrained hydrocarbons)
- Argo-Rowley Terrace Marine Park (highest probability is 100% probability for surface hydrocarbons)
- Rowley Shoals Marine Park (highest probability is 34% for entrained hydrocarbons)
- Ashmore Reef Marine Park (highest probability is 18% probability for accumulated hydrocarbons)
- Cartier Island Marine Park (highest probability is 22% for accumulated hydrocarbons)
- Mermaid Reef Marine Park (highest probability is 34% for entrained hydrocarbons).

In the highly unlikely event of a worst-case scenario release, the open water environment protected within the AMPs may be affected by floating, dissolved, entrained, and/or shoreline hydrocarbons above thresholds. If hydrocarbons contact key receptor locations within these protected areas, such as islands and mainland coastlines or defined BIAs, significant impacts may occur, including the contamination of sediments and water, impacts to benthic fauna/habitats, impacts to protected and other marine fauna, and a potential to result in ecosystem level impacts (including a reduction in biodiversity).

Conservation values of these areas are described in Section 5.3.3. Potential impact on the values of these AMPs is discussed in the relevant sections above for ecological and physical (water quality) values and below for social (socio-economic) values.

Table 6-161 provides an assessment of the proposed seabed disturbance in consideration of the North-west Marine Parks Network Management Plan (Director of National Parks, 2018).

Table 6-161 Alignment with the North-west Marine Parks Network Management Plan – Risk of unplanned release of hydrocarbons

Australian Marine Park	Relevant plan(s)	Australian Marine Park objectives	Assessment
Argo-Rowley Terrace Marine Park Kimberley Marine Park Mermaid Reef Marine Park Cartier Island Marine Park Ashmore Reef Marine Park	North-west Marine Parks Network Management Plan (Director of National Parks, 2018)	**Sanctuary Zone (1a)** The objective of the Sanctuary Zone (1a) is to conserve ecosystems, habitats and native species in as natural and undisturbed a state as possible **National Park Zone (II)** The objective of the National Park Zone (II) is to provide for the protection and conservation of ecosystems, habitats and native species in as natural a state as possible. **Habitat Protection Zone (IV)** The objective to the Habitat Protection Zone (IV) is to allow activities that do not harm or cause destruction to seafloor habitats, while conserving ecosystems, habitats and native species in as natural a state as possible. **Multiple Use Zone (VI)** The objective of the Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species.	If a large hydrocarbon spill occurred as a result of the proposed Browse to NWS Project, AMPs could potentially be impacts (depending In the nature and location of the spill). However, as described above, it is considered highly unlikely that such a spill will occur. Therefore, it is considered that the risk of unplanned release of hydrocarbons as a result of the proposed activities is not inconsistent with the North-west Marine Parks Network Management Plan.

State marine parks and nature reserves

Change in sediment quality, change in water quality, injury or mortality to fauna

Based on the outcomes of quantitative spill modelling for Scenarios 1 through 4, the following State marine parks and nature reserves have the potential to be impacted at varying probabilities (Table 6-158):

- Scott Reef Nature Reserve
- Rowley Shoals Marine Park
- Lalang-garram/Camden Sound Marine Park (however, modelling only predicted the area to be contacted by localised shoreline accumulation above thresholds, i.e. not dissolved, entrained or floating hydrocarbons, at a probability of 1%).

In the highly unlikely event of a worst-case scenario release, these State marine parks and nature reserves may be affected by floating, dissolved, entrained, and/or shoreline hydrocarbons above thresholds. If hydrocarbons contact key receptor locations within these protected areas, significant impacts may occur including the contamination of sediments and water, impacts to benthic fauna/habitats, impacts to protected and other marine fauna, and a potential to result in ecosystem level impacts including a reduction in biodiversity.

Conservation values of these areas are described in Section 5.3.3. Potential impact on the values of these State marine park and nature reserves is discussed in the relevant sections above for ecological and physical (water quality) values and below for social (socio-economic) values.

Other protected places

Change in sediment quality, change in water quality, injury or mortality to fauna

In the event of an unplanned hydrocarbon release, the Scott Reef and Surrounds or the Mermaid Reef – Rowley Shoals Commonwealth Heritage Places may be affected by floating, dissolved, entrained and/or shoreline hydrocarbons above thresholds. If hydrocarbons contact key receptor locations within these protected areas, significant impacts may occur, including the contamination of sediments and water, impacts to benthic fauna/habitats, impacts to protected and other marine fauna, and a potential to result in ecosystem level impacts (including a reduction in biodiversity).

Conservation values of these areas are described in Section 5.4.3. Impact on the values of these protected areas is discussed in the relevant sections above for ecological and physical (water quality) values.

Other users

Changes to the functions, interests or activities of other users - Commonwealth and State managed fisheries

Four Commonwealth and 11 WA State fisheries overlap the Project Area, in particular the BTL (**Section 5.4.2.2**). Of these, six have been assessed as having the potential to actively operate within the Project Area (Development Area and BTL) and, therefore, be most likely to be impacted in the event of a hydrocarbon spill given their proximity to potential release locations.

In general, fisheries have the potential to be impacted by an unplanned hydrocarbon release through direct impacts to target populations or prey species and fishing gear and from the exclusion of users from a fishing area, potentially resulting in lost revenue.

Fish exposure to hydrocarbons can result in 'tainting' of their tissues. Even very low levels of hydrocarbons can impart a taint or 'off' flavour or smell in seafood. Tainting is reversible over time through the process of depuration which removes hydrocarbons from tissues by metabolic processes, although it depends on the magnitude of the contamination. Fish have a high capacity to metabolise these hydrocarbons while crustaceans (such as prawns) have a reduced ability (Yender et al., 2002).

Seafood safety is a major concern associated with spill incidents. Actual or potential contamination of seafood can affect commercial and recreational fishing and can impact seafood markets long after any actual risk to seafood from a spill has subsided (Yender et al., 2002). A major spill could result in the establishment of an exclusion zone around the spill-affected area, leading to temporary prohibition on fishing activities and subsequent potential economic impacts to affected commercial fishing operators. Additionally, hydrocarbons can foul fishing equipment such as traps and trawl nets, requiring cleaning or replacement. Depending on the release scenario and its severity, an exclusion zone could be a temporary localised area around the immediate vicinity of the release point or could cover a large portion of fishery or management zones and extend over a number of fishing seasons.

Based on the outcomes of quantitative spill modelling, hydrocarbon spills resulting from the proposed Browse to NWS Project would have the potential to impact commercial fisheries., with potential impacts including mortality or sub-lethal injury/illness of fish, with subsequent impacts to fishers as a result of reduction in catch.

Changes to the functions, interests or activities of other users – tourism and recreation, scientific studies

Tourism, recreation and scientific users have the potential to be impacted by an unplanned hydrocarbon release due to exclusion from an area or indirectly from a change in marine fauna behaviour, injury or mortality to marine fauna. Hydrocarbons can also accumulate on recreation areas predicted to be contacted and impact access to such areas due to any clean-up or decontamination activities. Tourists and recreational users may also avoid areas due to perceived impacts, including after the hydrocarbon spill has dispersed. Any impact to receptors that provide nature-based tourism opportunities may cause a subsequent negative impact to recreation and tourism activities.

Charter fishing, diving, snorkelling, whale, marine turtle and dolphin watching and cruising are the main commercial tourism activities in and adjacent to the North-west Marine Region. With the exception of offshore charter fishing, most marine tourism activities occur in State waters (DEWHA, 2008a). Recreational fishing tends to be concentrated in State waters adjacent to population centres (e.g. Broome) (DEWHA, 2008a). Engagement with regional tourism groups and Recfishwest indicate that only one to two recreational fishing charter operators run trips to Scott Reef approximately four to five times per year. Scott Reef has the potential to provide significant opportunities increased tourism; however, given the distance from closest landfall and costs, only a limited number of charter operators are prepared to take recreational fishers out to Scott Reef.

Similar activities occur or have the potential to occur at other key locations within the EMBA such as the Kimberley AMP, Seringapatam Reef, Ashmore Reef, Cartier Island and Rowley Shoals. However, the offshore waters of the Project Area and EMBA are not expected to support significant tourism or recreational activities. Should shoreline contact occur in the event of a spill, restricted access to beaches for a period of days to weeks may occur until natural weathering or tides and currents remove the hydrocarbons. Modelling results found localised areas of the Kimberley coast, as well as Timor Leste and Indonesia, have the potential to be contacted by shoreline hydrocarbons, however, as discussed in impacts to shoreline habitat, these areas are not expected to be significantly impacted. Hydrocarbons are not expected to reach any major inhabited areas.

Based on the outcomes of quantitative spill modelling, hydrocarbon spills resulting from the proposed Browse to NWS Project have the potential to impact tourism, recreational, scientific and traditional fishing activities in localised offshore areas such as Scott Reef and Rowley Shoals. However, even in the highly unlikely event of a large spill, potential impacts are likely to be restricted to short-term exclusion to an area with a potential for long term impacts to a small number of operators and users that visit these areas.

Changes to the functions, interests or activities of other users – shipping

Shipping has the potential to be impacted from an unplanned hydrocarbon release through exclusion to an area resulting in altered shipping routes and from increased operating costs (e.g. fuel consumption). Shipping activity is widespread across the NWS region. Shipping is sparse near the Browse Development Area, with the nearest main shipping channels approximately 50 to 100 km west of Scott Reef. However, a number of shipping channels do overlap or come in proximity to the BTL corridor.

In the highly unlikely event of a large spill, an exclusion zone may be established around the spill-affected area. This could result in exclusion of other users such as shipping vessels or vessels used by the mining and petroleum industries. Any exclusion zone established would probably be limited to the projected extent of floating hydrocarbons, estimated from spill modelling to be a maximum of between 67 and 143 km for Scenarios 1 through 4. The exclusion zone would probably be temporary, given the significant weathering predicted to take place within a few days of a worst-case scenario spill, therefore, physical displacement of vessels is unlikely to be a significant impact. Modelling did not predict surface hydrocarbons to reach any active port, therefore, there will be no impacts to these areas.

Changes to the functions, interests or activities of other users – industry

Industry, including other oil and gas operators, has the potential to be impacted from an unplanned hydrocarbon release through exclusion to an area or from a change to the functions, interests or activities of other users. The NWMR supports a number of industries including petroleum exploration and production, as well as minerals extraction.

In the highly unlikely event of a large spill, an exclusion zone may be established around the spill-affected area. The exclusion zone would extend from the spill source to encompass the projected limit of floating hydrocarbons (67 to 143 km for Scenarios 1 to 4). This could result in exclusion of other users such as vessels used by the mining and petroleum industries. The exclusion zone would probably be temporary, as significant weathering is predicted to occur within a few days of a worst-case scenario spill, therefore, physical displacement of vessels or impacts to other oil and gas operators is unlikely to be a significant impact. Modelling did not predict that surface hydrocarbons would reach any shoreline where significant industry occurs, therefore, there will be no impacts to these areas (e.g. Broome, Karratha, Dampier).

Changes to the functions, interests or activities of other users – aboriginal and indigenous heritage

Aboriginal heritage has the potential to be impacted from an unplanned hydrocarbon release through direct contact with heritage sites and impacts to Indigenous fishing activities. Although no known sites of significant Aboriginal heritage have been identified within the Project Area or EMBA, modelling indicated that localised shoreline contact above thresholds could occur at the Bardi Jawi, Uunguu and Dambimangari Indigenous Protected Areas on the Kimberley Coast at probabilities of 1-2% (Scenario 1 only). As discussed in impacts to shoreline habitats, no dissolved, entrained or floating hydrocarbons were predicted to reach these areas and contact was highly localised with maximum accumulated volumes of between 8 and 14 m^3. Furthermore, the minimum time to contact was 98 days, meaning hydrocarbons would be significantly weathered and unlikely to reach the receptor at the modelled volumes. Given this and the initial low likelihood of a spill occurring, no significant impacts are predicted to these protected areas.

Although no designated traditional fisheries have been identified, it is recognised that Indigenous communities' fish in shallow coastal and nearshore waters of the Kimberley coastline and, therefore, may be potentially impacted in the highly unlikely event that a hydrocarbon spill was to reach the coastline in significant quantities. Given no contact is predicted by floating, entrained and dissolved hydrocarbons and only minimal volumes of shoreline accumulation are predicted, no significant impacts to indigenous fishing are expected.

In addition, traditional Indonesia fishermen visiting Scott Reef and Seringapatam Reef as part of the MOU 74 provisions may be impacted in the highly unlikely event of a spill within the Browse Development Area, potentially contaminating and restricting access to their traditional fishing grounds. However, the extent of impacts will depend on exposure concentration, duration and degree of weathering of the hydrocarbons.

Marine archaeology and other cultural heritage

Change in heritage values

Marine archaeology sites such as historic shipwrecks have the potential to be impacted from an unplanned hydrocarbon release through direct contact with hydrocarbons resulting in toxicity impacts to marine life that shelter in and around these wrecks. The consequences of such hydrocarbon exposure may include all or some of the following: large fish species moving away and/or resident fish species and sessile benthos (such as hard corals) exhibiting sub-lethal and lethal impacts (which may range from physiological issues to mortality).

Within the EMBA a number of places are designated National and Commonwealth heritage places. These places are also covered by other designations such as marine parks, and listed shipwrecks. Potential impacts have, therefore been discussed in the sections above.

6.3.21.6 Cumulative Impacts

The risk of cumulative impact of hydrocarbons spills from other development activities within the Browse Basin is low, as large scale events, although they could occur, are extremely rare. Titleholders undertaking petroleum activities are required to have in place an approved OPEP detailing its oil spill response. These OPEPs are backed up by State and national response plans.

6.3.21.7 Prevention and response

In order to prevent a potential unplanned release of hydrocarbons, the following management measures will be put in place:

Drilling and completion activities

- During drilling, proven systems and procedures will be employed. These will be applied and supervised by highly competent and experienced personnel. The industry is also highly regulated.
- Drilling and completion activities will only be undertaken when metocean conditions are deemed suitable for safe operations.
- Reservoirs will be isolated from the surface by a minimum of two independent and verifiable barriers. The configuration of isolation barriers during the drilling phase typically includes:
  - Overbalanced hydrostatic pressure maintained on the reservoir via the drilling fluids.
  - Seabed BOPs which can be activated to “shut in” the well in the event that well control via overbalanced drilling fluids is lost.
- A 500 m petroleum safety zone will be implemented around the MODU.
- Relief well planning will be outlined in the OPEP.
- Accepted Safety Case for MODU.

Commissioning, operational and IMR activities

- Testing will be undertaken prior to commissioning to confirm integrity of SURF and BTL system.
- IMR activities to manage integrity of subsea systems will occur throughout operations.
- The configuration of reservoir isolation barriers during the operations phase typically includes:
  - production tubing from the reservoir to valving on the subsea tree
  - cemented casing and associated valving on the subsea tree, plus a production packer to isolate the annulus between the casing and production tubing from the reservoir
  - a Surface Controlled Subsurface Safety Valve (SCSSV) fitted on all production wells.
- the wells, subsea system and FPSO facilities will use corrosion resistant materials, where applicable and be designed to protect against integrity threats (e.g. corrosion, impact, erosion, low temperature embrittlement).
- Wellhead valve design and configuration will allow safe operation and control of the well.
- FPSO facilities will be designed to include compartmentalised condensate storage.
- FPSO facilities are assessed against one in 10,000-year return period weather conditions to mitigate risk of extreme weather conditions.
- FPSO facilities will include double sided hull design to minimise risk of hydrocarbon release in the event of a collision.
- 500 m petroleum safety zones will be maintained at the FPSO facilities.
- Design codes and material specifications for all risers and flowlines will be compliant with the relevant Australian and international standards.
- SURF and BTL monitoring will be undertaken including:
  - monitoring of corrosion protection system
  - periodic integrity inspections in line with risk-based inspection outcomes.
- Export trunkline volumes will be able to be isolated to prevent an ongoing fire impacting the FPSO
- accepted Safety Case for FPSOs.

Offloading and refuelling activities during drilling and operations

- Condensate offtake hoses will be fitted with ‘dry break’ or ‘breakaway’ couplings.
- Scuppers and save-alls (receptacles or enclosures to contain minor leakages around machinery), including those around tank vents, will be in place before commencement of refuelling activities.
- The diesel refuelling hose inventory will be drained before disconnection.
- The diesel refuelling station will be isolated and equipment stowed when not in use.
- Offloading and refuelling hoses will be certified as suitable for a safe operating pressure range. The hoses and fittings will also be compatible with support vessel/condensate tanker pump pressures.
- Support vessel/condensate tanker pumps will be fitted with relief valves to allow diverting back of fluids to source in the event of excessive pressure build up in the transfer hose.
- Where practicable, refuelling of support vessels will be conducted in port.
- Diesel storage tank levels will be continuously

monitored to prevent overflow, and tank level indication and level alarms will be provided for diesel storage tanks.

- Vessels (as appropriate to vessel class) will be required to have in place a Shipboard Oil Pollution Emergency Plan (SOPEP)/ Shipboard Marine Pollution Emergency Plan (SMPEP), as required by Marine Order 91 (Marine Pollution Prevention) 2014. Offloading and refuelling will only be undertaken when metocean conditions are deemed suitable for safe operations.
- Condensate tankers will be piloted during berthing and offloading operations.
- Offloading and refuelling will be undertaken by trained personnel using defined procedures.
- Responsibilities and accountabilities will be defined for hydrocarbon spill response and notifications to Woodside and relevant authorities.
- A loading plan (volume to be transferred) will be agreed between the supply point (vessel) and the delivery point, and a pre-load checklist completed.
- Transfer equipment and emergency shutdown functions will be checked immediately prior to commencement of offtake.
- The diesel transfer pumps emergency shutdown system onboard condensate tankers will be tested at the commencement of transfer.
- Communication (visual and/or radio) between the support vessel/condensate tanker will be maintained throughout refuelling and offloading operations.

Spill response techniques

In the event of a spill, Woodside will respond in accordance with the Environment Plans and OPEPs specifically developed for the proposed Browse to NWS Project, which will be not inconsistent with the *National Plan for Maritime Environmental Emergencies 2019*. The Environment Plans and OPEPs will detail the spill response and mitigation measures adopted by Woodside following the rigorous risk assessment of a range of spill response strategies available. These will include strategies to limit the volume of hydrocarbons being released to the marine environment and strategies to reduce the volume of hydrocarbons reaching sensitive receptors.

A comprehensive Oil Spill Preparedness and Response Mitigation Assessment (OSPRMA) will be undertaken to evaluate and determine which techniques may be incorporated into a Browse to NWS Project spill response. This OSPRMA will use the detailed environmental assessment in the EP, including the identified environmental values and sensitivities, to conduct a Net Environmental Benefit Analysis (NEBA).

The NEBA is a systematic process undertaken during both planning and response that supports the assessment and selection of response techniques to manage and reduce the overall impact of an incident. The IPIECA/IOGP good practice Spill Impact Mitigation Assessment (SIMA) methodology is adopted to undertake the NEBA. The NEBA considers the potential feasibility and effectiveness of various techniques in monitoring, treating and/or removing spilled materials. It also assists in identifying and evaluating any subsequent impacts that may be generated from the adopted response actions and which require further measures.

A NEBA is undertaken as part of the development of the OSRPRMA, using simulated oil spill modelling scenarios. Feasibility and effectiveness of the following response techniques, together with the potential exposure of environmental receptors, are considered by assessing this modelling scenario data:

- **Monitoring and evaluation of a hydrocarbon spill** includes Operational Monitoring methods that may be activated:
  - satellite tracking drifter buoy(s)
  - aerial monitoring including use of UAVs where feasible
  - satellite radar imagery
  - water quality monitoring
  - shoreline assessment: pre-emptive assessment as well as clean-up assessment
  - modelling:
    - ADIOS 2 – a hydrocarbon model that estimates the expected characteristics and behaviour of hydrocarbons spilled into the marine environment.
    - trajectory modelling – Woodside has access to both an in-house rapid modelling tool and 24/7 scenario-specific modelling capabilities.
- **Activation of a Subsea First Response Toolkit (SFRT)**, maintained by AMOSC in a constant state of readiness. The SFRT provides the following capability:
  - pressure injection to close the BOPs
  - preparing a subsea wellhead for a capping stack including removal of damaged/obstructing equipment
  - injecting dispersant subsea (including a supporting stockpile of dispersant).
- **Deployment of a well capping stack**, to be installed on the subsea well where feasible and safe to do so.
- **Drilling of a relief well** to kill the well.
- **Application of dispersants:** Dispersion of hydrocarbons into the water column reduces the volume on the ocean surface, which then reduces the potential for direct impact on emergent receptors. Dispersants break hydrocarbons down into smaller droplets which are rapidly diluted into

the water column, aiding the process of natural dispersion and accelerating biodegradation. It can also reduce surface volatile or organic compounds when dispersants are applied subsea.

Many light hydrocarbons, including Torosa condensate, may not be amenable to dispersants, as the droplet sizes are already below the point that can be achieved with dispersants. In Australia, AMSA maintains a list of approved Oil Spill Control Agents (OSCA) that includes dispersants. In the highly unlikely event of an unplanned hydrocarbon spill from the Browse to NWS Project, dispersant use would only be considered for use in areas that are within the dispersant 'Zone of Application' (ZoA) defined in the Browse Environment Plans and OPEPs. In defining the ZoA for dispersant use, Woodside would expressly prohibit the use of dispersants within areas such as Scott Reef.

The decision to apply dispersants during a spill would still be subject to a rigorous risk assessment, including revalidation of the NEBA undertaken in the OSPRMA using modelling and monitoring of actual data from the spill. If dispersant is assessed to be an appropriate technique, only OSCA dispersants approved by the regulator will be utilised. They will only be applied to surface hydrocarbons where appropriate concentration thresholds are present, and continuous monitoring of the dispersed oil plume will be undertaken to ensure ongoing effectiveness. Dispersant application will cease when operational monitoring shows that its use is no longer effective.

- **Containment and recovery:** Physical containment and removal of hydrocarbons from the marine environment minimises damage to sensitive resources. This technique may be triggered when monitoring indicates that a floating hydrocarbon threshold has been reached, making it a potentially effective technique. Some limitations also include current and wind conditions, which may inhibit effectiveness.
- **Protection and deflection:** Use of booms to create physical barriers to separate hydrocarbons from sensitive resources. This technique can be effective on some hydrocarbons where surface accumulation exceeds thresholds required. Browse hydrocarbons will be assessed against viability for using protection and deflection.
- **Shoreline clean-up:** Recovery of hydrocarbons accumulated on shorelines to minimise environmental damage. Typical techniques that may be used for shoreline clean-up include:
  - nearshore booming and skimming
  - use of sorbents
  - manual clean-up
  - waste collection facilities – temporary storage or vessels with waste tanks.
- **In-situ burning:** A NEBA will consider in-situ burning to determine its suitability as a response technique for Browse and to support identifying any restrictions that may apply to its use, if it is identified as a suitable response technique. However, potential long-term damage to the subsea ecology due to particulates as a result of in-situ burning is not well understood scientifically and its benefits versus risks have not been proven. Although this remains a potential technique, it is unlikely to be used for the Browse to NWS Project.
- **Oiled wildlife response:** Undertaken to minimise impacts on at-risk wildlife populations, oiled wildlife response activities would be carried out in accordance with the Western Australian Oiled *Wildlife Response Plan (WA OWRP)*, to ensure it is conducted in accordance with legislative requirements, and additionally following Woodside's *Oiled Wildlife Response Operational Plan*. Woodside has access to oiled wildlife response kits from AMOSC and OSRL and trained personnel via AMOSC, OSRL, Woodside and Sea Alarm.
- **Scientific monitoring:** Undertaken to quantify and monitor impacts and recovery to a range of environmental receptors, such as (but not limited to) water quality, sediment quality, benthic primary producers and fauna. Scientific monitoring will also be used to inform response techniques and longer term recovery programs. The types of scientific monitoring needed would be assessed as part of the OSPRMA. Scientific monitoring would be carried in accordance with Woodside's Scientific Monitoring Program. Woodside has access to a range of equipment and trained personnel via standby contract with selected environmental consultancies. Each EP and OPEP will include an assessment of any additional risks and impacts that may be generated from the adopted response techniques, including further reduction and mitigation measures. From previous assessments, Woodside has identified a series of treatment measures to mitigate further potential impacts and risks generated from implementing response techniques. An indicative list of these measures are described below.

Vessel operations and access in the nearshore environment

- Booms will be monitored and maintained to ensure trapped fauna are released as early as possible, with containment and recovery activities only occurring in daylight hours.
- If vessels are required for accessing areas, anchoring locations will be selected to minimise disturbance to benthic primary producer habitats.
- Shallow draft vessels will be used to access remote shorelines to minimise the impacts associated with seabed disturbance.

Dispersant

- Surface dispersant will only be applied within the approved zone and to hydrocarbons at the appropriate concentration thresholds.
- Continuous monitoring of dispersed oil plume will be undertaken to monitor effectiveness.
- Regulator-approved dispersants will be prioritised for surface and subsea use.

Presence of personnel on the shoreline

- Oversight will be provided by trained personnel who are aware of the risks.
- Trained unit leaders will brief personnel of the risks prior to operations.
- Shoreline access routes (foot, car, vessel and helicopter) with the least environmental impact will be selected by trained specialists.
- Vehicular access will be restricted on dunes, turtle nesting beaches and in mangroves.

Waste generation

- All shorelines will be zoned and marked before clean-up operations commence to prevent secondary contamination and minimise the mixing of clean and oiled materials.
- Removal of vegetation will be limited to moderately or heavily oiled vegetation.

Additional stress or injury caused to wildlife

- Operations will be conducted with advice from the Department of Biodiversity, Conservation and Attractions (DBCA) Oiled Wildlife Advisor and in accordance with the WA OWRP.

Review of major incidents

Woodside periodcally reviews major incidents and updates (as appropriate) practices, emergency response and oil spill contingency plans to ensure that the systems in place are comprehensive and appropriate to design for, maintain and manage primary and secondary well control. Woodside also evaluates and improves the adequacy of procedural controls such as management of change, engineering assurance and competency assessments of personnel to ensure that the mechanisms outlined above are correctly and consistently applied.

6.3.21.8 Impact and Risk Assessment Summary and Acceptability Assessment

A summary of the risk assessments for the highly unlikely event of an unplanned release of hydrocarbons is provided in **Table 6-162**.Assessment has been given for the worst-case predicted consequences from any unplanned hydrocarbon release, including modelled Scenarios 1 through 4.

These tables provide the environmental objectives relevant to each potentially impacted receptor, as well as the risk rating for unplanned events and incidents.

For unplanned incidents and events, the environment objective is predicted to be achieved and the risk deemed acceptable where the risk rating has been assessment as Low, or where the risk rating has been assessed as Moderate or High, with the risk likelihood of the event occurring assessed as remote or highly unlikely.

The final acceptability assessment is provided in Table 6-163.

Table 6-162 Risk assessment summary and adopted controls – Unplanned Hydrocarbon Releases (Modelled Scenarios 1 to 4) (Hold: added scenario 4)

Receptor	Risk Event	Environmental objective	Adopted controls	Scenario	Consequence	Likelihood	Risk Rating
Marine sediments (medium value (open waters))	Unplanned hydrocarbon release leading to: + Change in sediment quality + Change in water quality + Injury or mortality to fauna + changes to the functions, interests or activities of other users + change in heritage values.	**Objective 1:** To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **Objective 2:** To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.	Refer to Section 6.3.21.7 for details of the planned preventive measures and approach to hydrocarbon spill response.	Scenario 1: Well loss of containment	Catastrophic	Highly unlikely	High (A1)
				Scenario 2: Cargo tank rupture	Major		Moderate (B1)
				Scenario 3: Vessel offtake system failure	Minor		Moderate (D1)
				Scenario 4: Vessel fuel tank rupture	Moderate		Moderate (C1)
Water quality (medium value (open waters))		**Objective 3:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		Scenario 1: Well loss of containment	Catastrophic	Highly unlikely	High (A1)
				Scenario 2: Cargo tank rupture	Major		Moderate (B1)
				Scenario 3: Vessel offtake system failure	Minor		Moderate (D1)
				Scenario 4: Vessel fuel tank rupture	Moderate		Moderate (C1)
Plankton communities (medium value (open water))		**Objective 7:** To not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution.		Scenario 1: Well loss of containment	Moderate	Highly unlikely	Moderate (C1)
				Scenario 2: Cargo tank rupture	Moderate		Moderate (C1)
				Scenario 3: Vessel offtake system failure	Minor		Moderate (D1)
				Scenario 4: Vessel fuel tank rupture	Minor		Moderate (D1)
Shallow water benthic communities and habitats (<75 m depth)		**Objective 10:** To avoid changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota that form part of the Scott Reef shallow water benthic habitat (<75 m water depth).		Scenario 1: Well loss of containment	Catastrophic	Highly unlikely	High (A1)
				Scenario 2: Cargo tank rupture	Catastrophic		High (A1)
				Scenario 3: Vessel offtake system failure	Moderate		Moderate (C1)
				Scenario 4: Vessel fuel tank rupture	Major		Moderate (B1)
Deep water benthic communities and habitats (>75 m depth) – (medium value)		**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.		Scenario 1: Well loss of containment	Catastrophic	Highly unlikely	High (A1)
				Scenario 2: Cargo tank rupture	Major		Moderate (B1)
				Scenario 3: Vessel offtake system failure	Minor		Moderate (D1)
				Scenario 4: Vessel fuel tank rupture	Moderate		Moderate (C1)

Receptor	Risk Event	Environmental objective	Adopted controls	Scenario	Consequence	Likelihood	Risk Rating
Seabirds and migratory shorebirds (high value species)		**Objective 11:** To not have a substantial adverse effect on a population of seabirds or migratory shorebirds, or the spatial distribution of the population. **Objective 12:** To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 14:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **Objective 15:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **Objective 16:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.		Scenario 1: Well loss of containment	Catastrophic	Highly unlikely	High (A1)
				Scenario 2: Cargo tank rupture	Catastrophic		High (A1)
				Scenario 3: Vessel offtake system failure	Moderate		Moderate (C1)
				Scenario 4: Vessel fuel tank rupture	Major		Moderate (B1)
Fish (high value species)				Scenario 1: Well loss of containment	Catastrophic	Highly unlikely	High (A1)
				Scenario 2: Cargo tank rupture	Catastrophic		High (A1)
				Scenario 3: Vessel offtake system failure	Moderate		Moderate (C1)
				Scenario 4: Vessel fuel tank rupture	Major		Moderate (B1)
Marine mammals (high value species)				Scenario 1: Well loss of containment	Catastrophic	Highly unlikely	High (A1)
				Scenario 2: Cargo tank rupture	Catastrophic		High (A1)
				Scenario 3: Vessel offtake system failure	Moderate		Moderate (C1)
				Scenario 4: Vessel fuel tank rupture	Major		Moderate (B1)
Marine reptiles (high value species)				Scenario 1: Well loss of containment	Catastrophic	Highly unlikely	High (A1)
				Scenario 2: Cargo tank rupture	Catastrophic		High (A1)
				Scenario 3: Vessel offtake system failure	Moderate		Moderate (C1)
				Scenario 4: Vessel fuel tank rupture	Major		Moderate (B1)
KEFs (medium value)		**Objective 17:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.		Scenario 1: Well loss of containment	Moderate	Highly unlikely	Moderate (C1)
				Scenario 2: Cargo tank rupture	Minor		Moderate (D1)
				Scenario 3: Vessel offtake system failure	No lasting effect		Low (F1)
				Scenario 4: Vessel fuel tank rupture	Slight		Low (E1)
Australian marine parks (medium value (multiple use zones))		**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		Scenario 1: Well loss of containment	Catastrophic	Highly unlikely	High (A1)
				Scenario 2: Cargo tank rupture	Catastrophic		High (A1)
				Scenario 3: Vessel offtake system failure	Moderate		Moderate (C1)
				Scenario 4: Vessel fuel tank rupture	Major		Moderate (B1)
State marine parks and nature reserves and other protected places (high value)		**Objective 18:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.		Scenario 1: Well loss of containment	Catastrophic	Highly unlikely	High (A1)
				Scenario 2: Cargo tank rupture	Catastrophic		High (A1)
				Scenario 3: Vessel offtake system failure	Moderate		Moderate (C1)
				Scenario 4: Vessel fuel tank rupture	Major		Moderate (B1)

Receptor	Risk Event	Environmental objective	Adopted controls	Scenario	Consequence	Likelihood	Risk Rating
State and Commonwealth managed fisheries (high value marine users)		**Objective 20:** To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		Scenario 1: Well loss of containment	Catastrophic	Highly unlikely	High (A1)
				Scenario 2: Cargo tank rupture	Catastrophic		High (A1)
				Scenario 3: Vessel offtake system failure	Moderate		Moderate (C1)
				Scenario 4: Vessel fuel tank rupture	Major		Moderate (B1)
Other users including tourism and recreation and scientific studies (high value users)		**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		Scenario 1: Well loss of containment	Major	Highly unlikely	Moderate (B1)
				Scenario 2: Cargo tank rupture	Moderate		Moderate (C1)
				Scenario 3: Vessel offtake system failure	Slight		Low (E1)
				Scenario 4: Vessel fuel tank rupture	Minor		Moderate (D1)
Shipping (Medium/ high value users)		**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		Scenario 1: Well loss of containment	Major	Highly unlikely	Moderate (B1)
				Scenario 2: Cargo tank rupture	Moderate		Moderate (C1)
				Scenario 3: Vessel offtake system failure	Slight		Low (E1)
				Scenario 4: Vessel fuel tank rupture	Minor		Moderate (D1)
Industry (low value)		**Objective 21:** To not interfere with other marine users to a greater extent than is described in the EIS/ERD.		Scenario 1: Well loss of containment	Slight	Highly unlikely	Low (E1)
				Scenario 2: Cargo tank rupture	No lasting effect		Low (F1)
				Scenario 3: Vessel offtake system failure	No lasting effect		Low (F1)
				Scenario 4: Vessel fuel tank rupture	No lasting effect		Low (F1)
Aboriginal and indigenous heritage (high value)		**Objective 19:** To not have a substantial adverse impact on heritage value.		Scenario 1: Well loss of containment	Minor	Highly unlikely	Moderate (D1)
				Scenario 2: Cargo tank rupture	Slight		Low (E1)
				Scenario 3: Vessel offtake system failure	Slight		Low (E1)
				Scenario 4: Vessel fuel tank rupture	Slight		Low (E1)
Marine archaeology (high value)		**Objective 19:** To not have a substantial adverse impact on heritage value.		Scenario 1: Well loss of containment	Minor	Highly unlikely	Moderate (D1)
				Scenario 2: Cargo tank rupture	Slight		Low (E1)
				Scenario 3: Vessel offtake system failure	Slight		Low (E1)
				Scenario 4: Vessel fuel tank rupture	Slight		Low (E1)

Table 6-163 Acceptability assessment – unplanned hydrocarbon releases

Acceptability Assessment

Confidence in assessment

Woodside has a high level of certainty with respect to the risks and consequences of an unplanned hydrocarbon release as:

- Quantitative hydrocarbon spill modelling utilising established methods has been undertaken of the worst-case credible spill scenarios.
- The worst-case impact magnitudes to receptors, although significant, are based on worst-case scenarios which are highly unlikely to occur given the controls implemented and, therefore, within the applicable standards.
- As an experienced and reputable operator, Woodside has a proven track record with respect to spill prevention and response preparedness.
- In the event of a spill, Woodside will respond in accordance with the Environment Plans and OPEPs specifically developed for the proposed Browse to NWS Project, which will be not inconsistent with the *National Plan for Maritime Environmental Emergencies 2019*. The Environment Plans and OPEPs will detail the spill response and mitigation measures adopted by Woodside following the rigorous risk assessment of a range of spill response strategies available.

Principles of ESD

There are no planned release of hydrocarbons to the environment. The likelihood of an unplanned hydrocarbon release is considered highly unlikely, particularly given the stringent controls in place.

With the application of the proposed controls it is predicted that the nominated environmental objective for each potentially impacted receptor will be achieved. As such, it is considered that the principles of ESD will be met.

Conclusion: Acceptable

Significant impacts as defined by the MNES Significant Impact Guidelines

Listed threated species and ecological communities/listed migratory species

As described in **Table 6-162**, the risk of an unplanned hydrocarbon release presents a Moderate to High risk to all listed threatened and migratory species (depending on the scenario).

These risk ratings are driven by the potential Moderate to Catastrophic consequence (depending on the scenario) where regional impacts affecting species at a population level could occur. It should be noted, however, that with the implementation of the proposed controls it is highly unlikely that such an event would occur. As such, no significant impacts to listed threated or migratory species (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted.

Commonwealth marine environment

As described in **Table 6-162**, the risk of an unplanned hydrocarbon release presents a Moderate to High risk to all ecological receptors (depending on the scenario) and a Low to High risk to other marine users (depending on the user and the scenario). As above, these risk ratings are driven by the potential Moderate to Catastrophic consequence (depending on the scenario) where regional impacts affecting the marine environment could occur. As above, with the implementation of the proposed controls, it is highly unlikely that such an event would occur. As such, no significant impacts to the Commonwealth marine environment (as defined by the Significant Impact Guidelines (**Table 6-5**)) are predicted.

National Heritage Places

Even the highly unlikely event of an unplanned hydrocarbon release, no impact to National Heritage Places would be expected.

Conclusion: Acceptable

Acceptability Assessment

WA EPA Environmental Objectives

An assessment of the risk presented in relation to unplanned hydrocarbon release against the WA EPA Objectives is presented in the State Proposal ERD (**Chapter 10, Appendix B**).

Marine environmental quality

As described in **Table 6-162**, the risk of an unplanned hydrocarbon release presents a Moderate to High risk to sediment quality and water quality and a Moderate risk to plankton (depending on the scenario). As above, these risk ratings are driven by the potential Moderate to Catastrophic consequence (depending on the scenario) where regional impacts affecting the marine environmental quality both within the State Proposal Area and other State waters including adjacent to the mainland could occur. As above, with the implementation of the proposed controls, it is highly unlikely that such an event would occur. Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors will be achieved, and the WA EPA environmental objective "*To maintain the quality of water, sediment and biota so that environmental values are protected*" will be achieved for the State Proposal.

Benthic communities and habitats

As described in **Table 6-162**, the risk of an unplanned hydrocarbon release presents a Moderate to High risk to benthic habitats including regional shallow water benthic habitats. As above, these risk ratings are driven by the potential Minor to Catastrophic consequence (depending on the scenario) where regional impacts affecting benthic communities and habitats both within the State Proposal Area and other State waters including adjacent to the mainland could occur. As above, with the implementation of the proposed controls, it is highly unlikely that such an event would occur. Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors will be achieved, and the WA EPA environmental objective "*To protect benthic communities and habitats so that biological diversity and ecological integrity are maintained*" will be achieved for the State Proposal.

Marine fauna

As described in **Table 6-162**, the risk of an unplanned hydrocarbon release presents a Moderate to High risk to marine fauna. As above, these risk ratings are driven by the potential Moderate to Catastrophic consequence (depending on the scenario) where regional impacts affecting the marine fauna within the State Proposal Area and other State waters including adjacent to the mainland could occur. As above, with the implementation of the proposed controls, it is highly unlikely that such an event would occur. Given this, it is considered that with the application of the proposed controls, the nominated environmental objectives for these receptors will be achieved, and the WA EPA environmental objective "*To protect marine fauna so that biological diversity and ecological integrity are maintained*" will be achieved for the State Proposal.

Conclusion: Acceptable

External context

To date, there have been no specific matters raised by stakeholders regarding hydrocarbon spills in relation to the proposed Browse to NWS Project.

Conclusion: Acceptable

Internal context

Hydrocarbon spill prevention and response will be managed in accordance with regulatory requirements, including Safety Cases, EPs, OPEPs and a Well Operations Management Plan to manage credible spill risks, capability and response, which require acceptance by NOPSEMA. In addition, vessels will have a valid and appropriate SOPEP and/or SMPEP.

Conclusion: Acceptable

Acceptability Assessment

Other requirements

EPBC Act recovery and conservation plans and advices

As detailed in Table 6-159, the proposed activities are considered to be not inconsistent with the objectives and actions of:

- Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a)
- Conservation advice *Rhincodon typus* whale shark (Threatened Species Scientific Committee, 2015a)
- Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a)
- Conservation Management plan for the Blue Whale (Commonwealth of Australia, 2015c)
- Conservation advice *Megaptera novaeangliae*, Humpback Whale (Threatened Species Scientific Committee, 2015b)
- Conservation advice *Balaenoptera borealis*, Sei Whale (Threatened Species Scientific Committee, 2015c)
- Conservation advice *Balaenoptera physalus*, Fin Whale (Threatened Species Scientific Committee, 2015d)

KEFs

As detailed in Table 6-160, the proposed activities are not predicted to materially increase existing relevant pressures on the conservation values of KEFs.

AMPs

As detailed in Table 6-161, proposed activities are considered to be within the objectives of AMPs.

Other protected places

No impacts are expected to occur to the to the values of the Scott Reef and Surrounds or the Mermaid Reef – Rowley Shoals Commonwealth Heritage Places.

Conclusion: Acceptable

6.4 Social and Economic Considerations

Introduction

Assessment under the EPBC Act and EP Act requires consideration of the social, economic, aesthetic and cultural aspects of the physical and biological environment. Under the EPBC Act, the Minister must also consider economic and social matters in deciding whether to approve an action and what conditions to impose.

6.4.1 Social Impact Assessment

To inform the assessment of social matters and potentially to identify any social aspects relevant to stakeholders in relation to the physical environment, in 2018, Woodside commissioned a SIA for the proposed Browse to NWS Project to identify potential impacts and opportunities and provide recommendations for management and mitigation while also ensuring the opportunities presented are maximised.

The Browse to NWS Project SIA study area incorporated the community of Broome, the Dampier Peninsula, the wider Kimberley region and the State of Western Australia (Advisian, 2019).

Broome and the Dampier Peninsula are considered most likely to be affected by the potential social benefits and impacts due to Broome being considered the potential primary supply chain and logistic locations for the proposed Browse to NWS Project. The SIA addressed socio-economic impacts and risks related directly to offshore activities associated with the proposed Browse to NWS Project. These impacts and risks are addressed for each relevant aspect in Section 6.3.

This section summaries the results of the SIA to assess the potential social impacts and opportunities which may arise from the proposed Browse to NWS Project, including potential changes resulting from the construction and operation phases.

6.4.2 Method

Potential social impacts and opportunities on Broome and the Dampier Peninsula communities arising from the proposed Browse to NWS Project were assessed in terms of how potential Browse to NWS Project activities may interact with communities and stakeholders that are likely to be affected.

At the direction of Woodside, the SIA methodology included targeted stakeholder engagement. Key stakeholders were consulted and provided input into the identification and assessment of impacts as well as the understanding of local and regional dynamics. Refer to Chapter 4 for further detail on stakeholders.

Identified impacts and opportunities were rated with a significance and ranked. This process facilitated an understanding of the overall magnitude and significance of each issue.

Following this process, mitigation and management measures to enhance opportunities and minimise potential impacts for the local communities were developed. The process sought to align measures with regional planning initiatives to maximise outcomes for communities rather than duplicate existing services or programs. They were also aligned with, or serve to enhance, Woodside's current activities in the region (Advisian, 2019).

6.4.3 Key Findings

6.4.3.1 Economic Development, Local Business and Employment Opportunities

The economic development, business and employment opportunities were the primary opportunities for local communities, particularly within Broome.

The findings of the ACIL Allen Economic Impact Assessment (further detailed in Chapter 3) suggests that the proposed Browse to NWS Project is projected to provide direct economic benefit into the Western Australian economy, as well as indirect benefits through utilisation of service and support industries. With a 44-year project lifecycle, this represents a significant opportunity to contribute to the economic development of Broome and the Kimberley more broadly.

Woodside's commitment to using Broome as the supply chain and logistics hub offers increased potential to contribute to the economy of Broome and has generated a level of excitement within the town for the potential this offers in terms of economic development, employment and skills development.

The proposed Browse to NWS Project presents Woodside with an opportunity to utilise an increased regional approach building employment opportunities and a skilled labour force. It was acknowledged that the opportunity would be incremental, and expectations should be managed through transparent engagement with communities.

The long potential project lifecycle of the proposed Browse to NWS Project presents an opportunity for Woodside to identify social investment options designed to support local capability development for a number of communities within the project impact areas, specifically Indigenous communities.

6.4.3.2 Community Amenity and Cohesion

Community amenity concerns were identified, for example, these included helicopter noise in Broome and the 'visibility' and behaviour of the workforce. Amenity related impacts will be more concentrated during construction.

As a workforce transit point for offshore and onshore developments, workforce behaviour was identified as an issue by some stakeholders.

Stakeholders emphasised that while the oil and gas industry and the tourism industry can co-exist, the 'visibility' of the oil and gas industry through poor workforce behaviour and a lot of 'high-vis' can detract from the overall amenity and lifestyle in the town. While these impacts can be significant, they are also readily mitigated.

A further attraction contributing to amenity and lifestyle in Broome is its location. However, it is this location, primarily the distance and sometimes excessive costs to travel in and out of Broome. Airfare costs also impact on residents and local businesses, particularly the tourism industry. With the exception of some seasonal direct flights from the east coast of Australia to Broome, almost all flights transit via Perth. SIA consultations revealed a concern that once construction of the proposed Browse to NWS Project begins, flights in and out of Broome, specifically to Perth, will again become excessively expensive. It should be noted expensive airfares are the result of a number of factors, and while the proposed Browse to NWS project may contribute to price increases, clear attribution for this will be difficult to quantify. Consultations did reveal that measures have been made by airlines to manage excessive flight costs for Broome residents.

6.4.3.3 Housing and Accommodation

The proposed Browse to NWS Project is likely to have minimal negative or positive impacts on the housing and accommodation market in Broome. The offshore nature of the proposed Browse to NWS Project and the small operations workforce will not see a significant increase in demand for housing and accommodation.

6.4.3.4 Population Growth

The SIA identified a desire among the Broome community for the population to grow, but in a sustained way that contributes to a vibrant community with a strong economy. Population growth could translate into economic growth and stability if this growth is sustained in the long-term. SIA findings indicate that Broome can accommodate an increase in population and there will be limited to no impact on existing service providers such as health providers, who all indicated capacity to meet increased demands.

6.4.3.5 Cultural Heritage

The impact of the proposed Browse to NWS Project on sites of cultural significance was considered in the context of the offshore nature of the project.

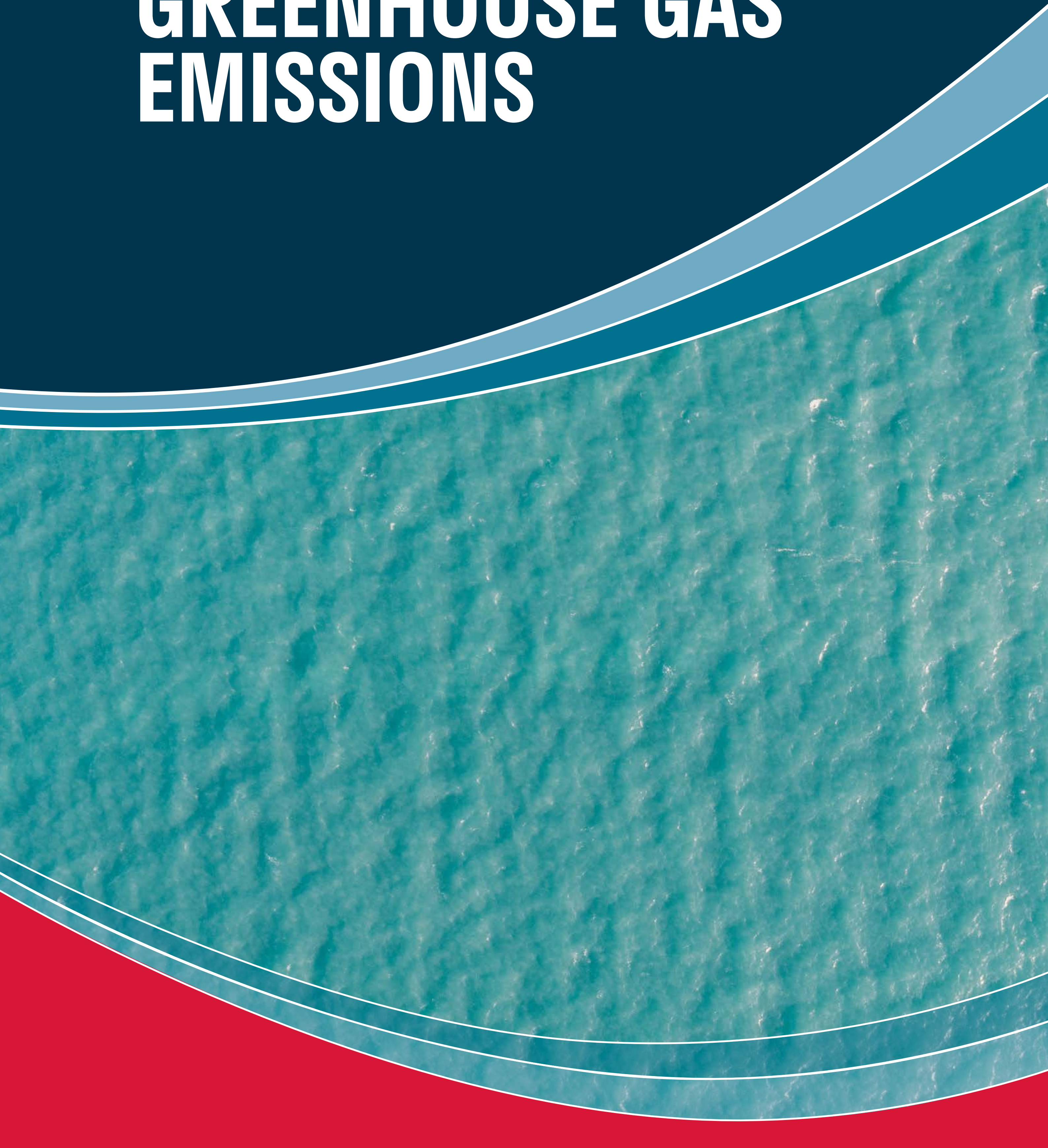
SIA consultations with Dampier Peninsula communities highlighted the strong linkage that exists between Aboriginal stakeholders and the sea, as an important food source, but also as an important cultural resource.

6.4.4 Proposed Approach to Mitigation and Management

Mitigation and management measures proposed in this assessment will be implemented through social impact management plans prepared in the usual course as part of the implementation of Woodside Management System.

CHAPTER 7

GREENHOUSE GAS EMISSIONS



Woodside

7. GREENHOUSE GAS EMISSIONS

7.1 Overview

This chapter details the assessment of greenhouse gas (GHG) emissions, including the potential impact on sensitive receptors within Australian jurisdictions and the contribution of GHG emissions from the proposed Browse to NWS Project.

GHG emissions are those that absorb infrared radiation in the atmosphere and release this energy as heat, consequently increasing global temperatures. This increase in temperature is predicted to have an adverse effect on natural ecosystems as a result of reductions in the bioclimatic range within which a given species or ecological community exists.

The main categories of human-induced activities that emit GHGs are:

- energy
- industrial processes including use of synthetic gases
- waste emissions
- agriculture
- land use, land use change and forestry.

Ecosystems which are particularly susceptible to adverse effects of climate change include alpine habitats, coral reefs, wetlands and coastal ecosystems, polar communities, tropical forests, temperate forests and arid and semi-arid environments (Department of the Environment and Energy, 2019). In Australia, the most affected ecosystems include coral reefs, alpine regions, rainforests, arid and semi-arid environments, mangroves, grasslands, temperate forests and sclerophyll forests. Future climate change (increased temperature and decreased rainfall) has the potential to have a range of impacts on ecological factors and threaten biodiversity in the Australian Mediterranean ecosystem (CSIRO, 2017).

7.2 Environment Objective

The key environmental objectives of the proposed Browse to NWS Project in relation to GHG emissions are:

- To not result in a substantial change in air quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.
- To optimise efficiencies in air emissions and reduce greenhouse emissions to acceptable levels.

7.3 Policy and Guidance

7.3.1 International Policy

The United Nations Framework Convention on Climate Change (UNFCCC) came into force in 1994 and has been ratified by 197 countries. The UNFCCC established a goal of preventing dangerous anthropogenic interference with the climate system. Subordinate treaties and agreements have been ratified by parties to the UNFCCC, including the Paris Agreement in 2015. The Paris Agreement establishes a series of targets including:

- Keeping "global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit temperature increase to 1.5°C" (Article 2.1(a)).
- Reaching "global peaking of GHG emissions as soon as possible…achieve a balance between anthropogenic emissions by sources and removals by sinks in the second half of this century" (Article 4.1).

The ratification of the Paris Agreement under decision 1/CP.21 (UNFCCC, 2016) acknowledged that the Nationally Determined Contributions (NDCs) made by countries as commitments under the Paris Agreement were insufficient to meet the goals of the Paris Agreement. To manage this, the Paris Agreement includes a process to update, or 'ratchet-up' NDCs every 5 years.

Australia's NDC is for an absolute economy-wide emissions reduction by 2030, to be developed into an emissions budget covering the period 2021-2030 (Australia, 2015). Australia is expected to restate its NDC in 2020 and update it in 2025.

7.3.2 Commonwealth Legislation and Policy

The following key legislation relating to GHG is administered by the Clean Energy Regulator:

- *National Greenhouse & Energy Reporting Act 2007* (Cth) (NGERS) established the NGER scheme which require companies such as Woodside to report on GHG emissions, energy production and energy consumption.
- *National Greenhouse and Energy Reporting Regulations 2008* (Cth) sets out the details that establish compliance rules and procedures for administering the NGERS.

- *National Greenhouse and Energy Reporting (Measurement) Determination 2008* (Cth) sets the methods, criteria and measurement standards for calculating greenhouse gas emissions and energy data.
- *The National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015* (Cth) (SGM) sets out the details that establish compliance rules and procedures for administering the safeguard mechanism.

The Safeguard Mechanism (see 7.3.2 below) is one of a number of mechanisms by which Australia intends to meet its NDC. It was developed to ensure that emission reductions implemented through the Emissions Reduction Fund (ERF) are not offset or exceeded by significant GHG emissions (above 'business-as-usual levels') emanating from other industrial or economic sectors. The SGM currently applies to facilities which emit greater than 0.1 $MtCO_2$-e per annum, requiring annual covered emissions to be reported against a designated emissions 'baseline'.

In March 2019, modifications to the SGM were introduced to transition facilities from current 'reported' baselines (an absolute value based on the historical high-point of emissions) to a 'calculated' baseline (set based on production forecasts and emissions intensity). There is now an expectation that existing facilities will transition to calculated baselines within the next two years.

This change to the SGM also provides direction for future transition from calculated baselines, which are valid for a fixed period, to 'production adjusted' baselines which are annually updated in line with production.

New facilities after 1 July 2020 will be subject to a 'benchmark baseline', which is expected to be defined by the DoEE and be based on leading-practice emissions intensities (top 10% of comparable facilities).

At the time of writing, three schedules within the SGM remain unpublished. These will include the benchmark parameters, production adjusted production variables and emissions intensities and fixed production variables and emissions intensities (Schedules 1, 2 and 3 respectively). The publication of this data is intrinsic to determining a baseline emissions figure under the SGM amendments.

The Federal Government climate change policy is the Climate Solutions Package (CSP), "a $3.5 billion investment to deliver on Australia's 2030 Paris climate commitments" (DOEE, 2019). In addition to the SGM, the CSP includes a range of programs to reduce emissions, including a $A2 billion 'Climate Solutions Fund' to provide additional budget for the operational Emissions Reduction Fund, support for energy efficiency and electric vehicles, two large projects to manage additional intermittent renewables and an education campaign to encourage households and business to regularly maintain air conditioning equipment (COA, 2019).

The compliance of Browse with the SGM is discussed in **Section 7.7.2**.

As described in Chapter 2, the controlling provisions under the EPBC Act for the proposed Browse to NWS Project include "the Commonwealth marine area, the protected matter being the environment generally". Under the EPBC Act, the 'environment' includes consideration of:

- ecosystems and their constituent parts including people and communities
- natural and physical resources
- qualities and characteristics of locations, place and areas
- heritage values of places
- social, economic and cultural components of the environment.

These receptors and sensitivities with respect to global GHG emissions are further discussed in **Section 7.5**.

7.3.3 State Legislation and Policy

The Western Australian Government released a GHG Emissions Policy for Major Projects on 28 August 2019. The Policy included an aspirational target of net zero greenhouse gas emissions by 2050. The Minister for Environment will consider how the Policy relates to major proposals assessed under Part IV of the EP Act (Government of Western Australia, 2019).

Public consultation on the WA EPA's draft Environmental Factor Guideline and Technical Guidance relating specifically to GHG emissions closed on 2 September 2019.

Woodside is continuing to work to reduce (net) emissions intensity through improvements in energy efficiency, investments in biosequestration projects and innovation in our production processes. Woodside has a Climate Change Policy described on the website https://www.woodside.com.au/sustainability/climate-change.

7.4 Source Activity

7.4.1 Origin of GHG Emissions

The EIS Guidelines/Environmental Scoping Document for the proposed Browse to NWS Project requires quantification and impact assessment for GHG emissions associated with both the proposed Browse Joint Venture infrastructure and proposed processing of Browse feed gas through North West Shelf Project Extension third party tolling facility infrastructure (EPA 2186, EPBC 2018/8335).

GHG emissions associated with gas extraction and LNG processing activities are typically from two key sources; the combustion of the hydrocarbon-based fuel (Coulson et al., 2010) and pre-existing CO_2 in the hydrocarbon reservoir. Combustion of hydrocarbon-based fuel is used to power export compression and associated processing and utilities. CO_2 content in the hydrocarbon reservoir is a naturally occurring geological phenomenon that must be treated as a waste product during LNG liquefaction. It is not influenced by the design of the processing facilities.

Contemporary large operating and proposed developments off the west coast of Australia include a number of developments where the levels of CO_2 in the reservoir are comparatively high (at an average of *circa* 10 - 20 mol%) compared to historical development on the NWS. The relative proportion of CO_2 emissions associated with reservoir and fuel combustion components are modified accordingly. For example:

- Barossa Development (proposed): *circa* 16–20 mol%
- Gorgon LNG Development (operating): *circa* <1-14 mol%
- Ichthys Project (operating): *circa* 8-17 mol%
- Prelude FLNG: *circa* 9 mol%
- Proposed Browse to NWS Project: *circa* 7-12 mol%.

In terms of the feed gas, the removal of reservoir CO_2 is essentially a purification process, but is also a critical pre-cursor to liquefaction, preventing the formation of solids during that process and the associated plugging of system elements (particularly the heat exchanger) (Li et al., 2011). A variety of methodologies and technologies have been employed to achieve the effective separation and removal of CO_2 from the LNG stream.

In the upstream environment, the separation of reservoir CO_2 from hydrocarbon gas takes place principally within the Acid Gas Removal Unit (AGRU). The CO_2 removed at this point is vented to the atmosphere and this represents one of the principal sources of carbon emissions for the proposed Browse to NWS Project.

Not all the reservoir CO_2 is removed by upstream processing. Further removal may take place in the downstream environment, allowing for installation of a smaller offshore AGRU. This both improves the overall safety profile of the offshore facilities and also results in a slight reduction in overall emissions (due to reduced overall fuel consumption). Under current plans, between 1 mol% and 2.8 mol% CO_2 will be exported via the BTL from the FPSO facilities along with the hydrocarbon gas, with an expected target of 2.5 mol% CO_2. In the downstream environment, a second phase of acid gas removal at KGP will remove the remaining proportion of the reservoir CO_2 and it is expected to be described in the proposed NWSJV's 'North West Shelf Project Extension ERD' (EPA 2186, EPBC 2018/8335). The proportion of reservoir CO_2 that will be emitted at the NWS infrastructure is anticipated to be broadly consistent with the historical reservoir emissions associated with NWS feed gas, subject to the outcome of commercial arrangements. At each AGRU it is possible that hydrocarbons, in particular methane, may be entrained in the reservoir CO_2. Typically, these hydrocarbons are converted to CO_2 by a thermal oxidiser on the vent stream which processes the vent stream of the AGRU. When the thermal oxidiser is not online, the hydrocarbons are vented to atmosphere. These emissions form a small part of the overall CO_2-e vented from the AGRU. Estimates of vented reservoir emissions are inclusive of vented hydrocarbons.

As the separation of reservoir CO_2 from the gas stream occurs prior to liquefaction, the total (i.e. upstream and downstream) reservoir CO_2 emissions are a function of the CO_2 content of the reservoir.

A further source of CO_2 emissions is flaring and fugitive emissions. Flaring refers to the combustion of hydrocarbons that are not able to be processed. The flare is a safety feature to prevent the risk of creating explosive atmosphere in case of a process blowdown. Flaring from the FPSO facilities is expected to be minimal relative to other processing emissions and reservoir emissions. Further information on flaring is provided in **Chapter 3**. Fugitive emissions refer to minor leaks of hydrocarbon gases that occur from the process, or uncombusted hydrocarbons that pass through the flare or gas turbines. Fugitive emissions are expected to be minimal relative to flaring, other processing emissions and reservoir emissions.

Finally, some combustion of fuel and flaring will be associated with downstream processing at KGP. It is noted that the emissions for downstream processing at KGP are expected to be assessed under the NWSJV's 'North West Shelf Project Extension ERD' (EPA 2186, EPBC 2018/8335).

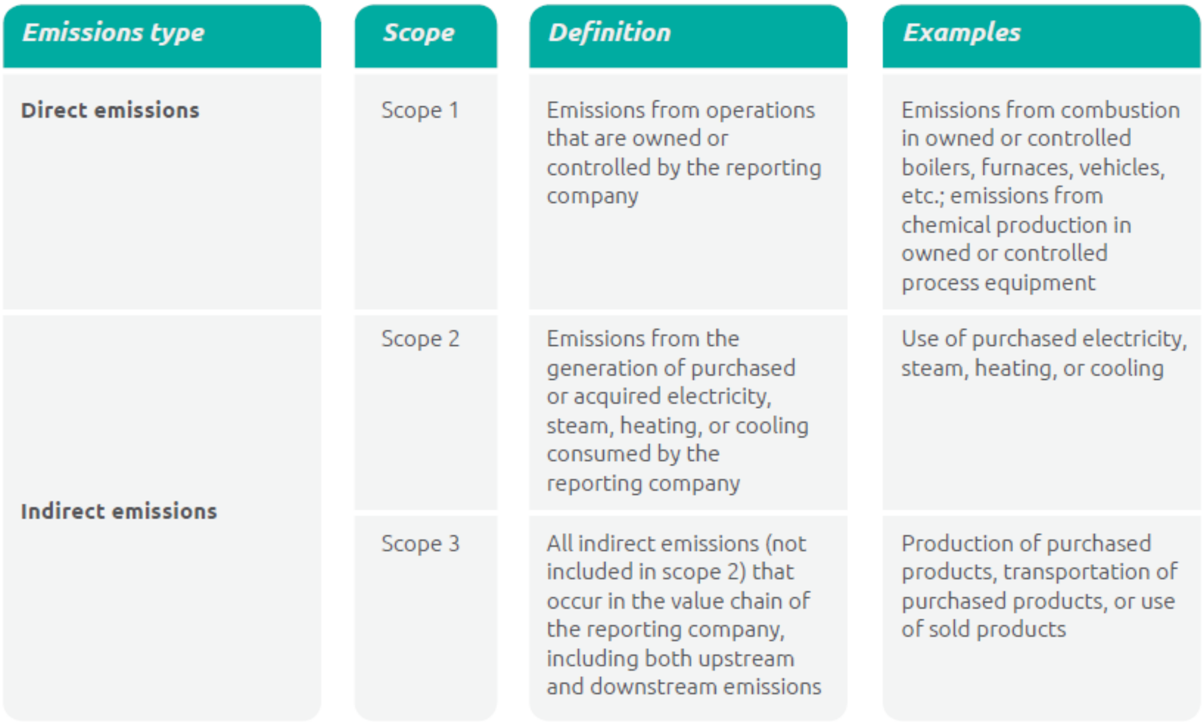
7.4.2 GHG Accounting Principles

GHG emissions are typically characterised by reference to the GHG Protocol Corporate Standard. Originally published in 2001, the GHG Protocol represents a collaboration between the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), with the objective of developing an international standard for corporate GHG accounting and reporting. One of the most important outcomes of developing the Protocol has been the widespread recognition of a high-level emissions classification scheme that allows organisations and industries to better define key focus areas for abatement activities. This scheme has been adapted and deployed by national and local regulators and represents a globally accepted subdivision of GHG emissions for evaluation and reporting purposes.

Direct emissions are most commonly associated with the generation of energy, manufacturing processes, transportation and intentional or unintentional GHG ('fugitive') emissions. Indirect emissions are most commonly associated with the consumption of electricity, although numerous other sources exist.

In this context, the GHG Protocol emissions classification scheme is defined in terms of Scope as shown in **Figure 7-1**.

The GHG Protocol is aligned to the definitions for Scope 1 and Scope 2 emissions as defined by the *National Greenhouse and Energy Reporting Regulations 2008 (Cth).*



Emissions type	*Scope*	*Definition*	*Examples*
Direct emissions	Scope 1	Emissions from operations that are owned or controlled by the reporting company	Emissions from combustion in owned or controlled boilers, furnaces, vehicles, etc.; emissions from chemical production in owned or controlled process equipment
Indirect emissions	Scope 2	Emissions from the generation of purchased or acquired electricity, steam, heating, or cooling consumed by the reporting company	Use of purchased electricity, steam, heating, or cooling
	Scope 3	All indirect emissions (not included in scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions	Production of purchased products, transportation of purchased products, or use of sold products

Figure 7-1 GHG Protocol Emissions Classification Scheme

7.4.3 Emissions Classification

On the basis of the definitions that support the GHG Protocol's emissions classification scheme, the nature and origin of the main sources of GHG emissions from the proposed Browse to NWS Project are shown in **Table 7-1**.

Table 7-1 Classification of GHG emissions according to the GHG Protocol

Description	Location	Jurisdiction	Emissions Source/Process	Scope
Installation and Construction	Upstream	State	Indirect GHG emissions generated from activities associated with construction, installation and commissioning* of upstream facilities to process Browse gas and operations (by third parties)	Scope 3
	Upstream	Commonwealth	Indirect GHG emissions generated from activities associated with construction, installation and commissioning* of upstream facilities to process Browse gas and operations (by third parties)	Scope 3
Processing and Reservoir CO_2 Emissions	Upstream	State	Direct GHG emissions generated in the State Proposal Area from operational activities associated with upstream processing of Browse gas	Scope 1 (BJV)
	Upstream	Commonwealth	Direct GHG emissions from venting of reservoir CO_2 extracted from the production stream via the FPSOs AGRUs	Scope 1 (BJV)

Description	Location	Jurisdiction	Emissions Source/Process	Scope
	Upstream	Commonwealth	Direct emissions from combustion of hydrocarbon-based fuels required for processing, compression of hydrocarbon gas on the FPSO prior to pipeline export and other operational activities	Scope 1 (BJV)
	KGP	State	Indirect GHG emissions from venting of reservoir CO_2 extracted from the gas exported from the FPSO and vented from the downstream NWSJV AGRU	Scope 1 (NWSJV)
	KGP	State	Indirect emissions from combustion of hydrocarbon-based fuels required for processing of hydrocarbon gas downstream prior to export	Scope 1 (NWSJV)
Third Party Consumption	Transit	Subject to consumer location**	Indirect emissions from transportation of products to the markets into which they will be sold by each Joint Venture Participant, including Domgas	Scope 3
	Market	Subject to consumer location**	Indirect emissions from combustion of products as part of power generation and other energy solutions within final market environment, including Domgas	Scope 3

* *Commissioning emissions in the State Proposal Area are anticipated to be minor, as the FPSO facilities are located in Commonwealth waters.*

** *There are presently no specific contracts for Browse gas. No transport contracts are in place.*

7.4.4 GHG Emissions Estimates

This section provides the carbon emissions estimate for the proposed Browse to NWS Project and describes the approach taken to estimate the forecast GHG emissions for the proposed Browse to NWS Project, based on the GHG Protocol emissions classification scheme. The estimate is based on the current level of concept definition and assumptions regarding commercial arrangements, the feed gas (final composition) and the scale, efficiency, interaction and complexity of the extraction, processing, anticipated production and compression of the product stream.

Forecast GHG emissions incorporate the following sources of GHG emissions:

- Section 7.4.4.1 Installation and Construction
- Section 7.4.4.2 Processing Emissions and Reservoir CO_2 Emissions
    - Processing Emissions Methodology
    - Reservoir CO_2 Methodology
    - Processing and Reservoir CO_2 Emissions Estimate
    - Impact of Browse Gas Export Spec on apportionment of Reservoir CO_2 to the upstream and downstream facilities.
- Section 7.4.4.3 Third Party Consumption Emissions
    - Methodology
    - Estimate.

Key assumptions for all the major sources of GHG emissions relate to:

- The timing and phasing of production well commissioning and start-up across the Calliance, Torosa and Brecknock fields.
- The expected average and maximum production rates from those wells and its decline over life of field.

Emissions from the proposed Browse to NWS Project are expected to be broadly linked to the rate of production. For the first five years following production start-up, currently anticipated to be mid-2020s for the Calliance/Brecknock FPSO, CO_2-e emissions from the proposed Browse to NWS Project lifecycle are expected to increase as production increases. Emissions are expected to stabilise as the FPSOs achieve a steady state until circa 2040.

Once reservoir pressure falls such that the FPSOs no longer achieve a steady state production, emissions progressively reduce in line with production. Some variation in forecast CO_2-e emissions year-on-year is expected for numerous factors, in particular due to commencement of compression, which starts up at different times on different fields and which is subject to a step-wise reduction during production decline.

Emissions Estimate Scenarios

Given the inherent uncertainty of estimating GHG emissions, a range of scenarios have been presented. Explanations for these scenarios are presented below in Table 7-2.

Table 7-2 Description of scenarios presented for GHG emissions estimates

Scenario	Description
Annual Scenarios	
Average year	+ Average (mean) GHG emissions produced over expected field life of 31 years. + Range provided for expected (10.2%) and high (11.6%) reservoir CO_2 composition (weighted average of reservoirs).
Peak production year	+ Peak GHG emissions produced at peak possible production rates (2150mmscfd export), assuming 95% availability. + Range provided for expected (10.2%) and high (11.6%) reservoir CO_2 composition (weighted average of reservoirs).
Total Inventory Scenarios	
Expected field life (31 years)	+ GHG emissions produced over expected field life, achieving expected plateau duration. + Range provided for expected (10.2%) and high (11.6%) reservoir CO_2 composition (weighted average of reservoirs).
Extended Field Life Outcome (44 years)	+ GHG emissions produced over extended field life, achieving extended plateau duration. + Range provided for expected (10.2%) and high (11.6%) reservoir CO_2 composition (weighted average of reservoirs).

7.4.4.1 Installation and Construction

Installation and construction are expected to form a minor component of the overall emissions associated with the proposed Browse to NWS Project. Total installation emissions across the life of the proposed Browse to NWS Project are estimated to be ~1.0 MT CO_2-e (total over field life), with approximately ~0.4MT CO_2-e of the total occurring within State Proposal Area.

7.4.4.2 Processing emissions and reservoir CO_2 emissions

Processing Emissions Methodology

Processing emissions includes the following emissions sources:

- fuel gas consumed
- flaring
- fugitive emissions.

Processing emissions are predominantly generated through the consumption of fuel gas.

An assessment of the quantity of fuel gas required to power the offshore Browse to NWS Project facilities has been completed. This assessment is based on the estimated efficiency of the equipment that has been selected to provide compression power, electricity generation and surplus heat. The power and heat demand of the system has been estimated based on the estimated compression demand, electrical load list demand and heating system demand. The demand for power is expected to be broadly linked to the rate of production and has been forecast based on the expected production in each year. Using the expected composition of the fuel gas, an emissions factor has been developed in accordance with NGERs Method 2.

An assessment on the average flaring rate per day has also been completed, considering both continuous sources (i.e. pilot gas) and episodic flaring associated with planned and unplanned production system events (start-ups and shutdowns). The assessment of episodic flaring considered both the expected frequency of flaring events and the expected quantity flared during the flaring events. An emissions factor for flaring has been taken from NGERs Method 1.

The expected fugitive emissions has been estimated based on the production rate of the facility. An emissions factor has been taken from NGERs Method 1.

In each instance for upstream processing emissions, the estimate of CO_2-e emissions is equal to the quantity of gas consumed, flared or released as fugitives, multiplied by the respective emissions factor. For a summary of emissions factors used in determining upstream processing emissions, refer to Table 7-3.

GHG emissions associated with the proposed Browse to NWS Project in the State Proposal Area will arise from activities in the Torosa field. Due to the position of the FPSOs outside of the State Proposal Area, operational emissions in the State jurisdiction will be limited to IMR activities on subsea infrastructure and contingent drilling and completions activities on installed wells.

Downstream processing GHG emissions have been apportioned based on the proportion of NWS processing plant capacity that Browse gas utilises, relative to the greenhouse gas footprint currently approved for the facility as per Ministerial Statement 536. These are expected to be further described in the NWSJV's 'North West Shelf Project Extension ERD' (EPA 2186, EPBC 2018/8335).

Table 7-3 Emissions Factors used for Browse to NWS Project Processing Emissions

Source/fuel	Energy Content	kg CO_2-e/ GJ (CO_2)	kg CO_2-e/ GJ (CH_4)	kg CO_2-e/ GJ (N_2O)	kg CO_2-e/ kg Product	NGERs Reference
Fuel Gas Upstream (Scope 1 BJV)	40.0 x 10^{-3} (GJ/m^3)	52.7	0.11	0.03	2.88 (per kg fuel gas)	S2.21-2 Method 2
Flaring Upstream	N/A	2.7 (per kg flared)	0.1 (per kg flared)	0.03 (per kg flared)	2.83 (per kg flare)	S3.67 Method 1
Fugitives Total	1.2kg CO_2-e (CH_4) Total (per tonne LNG produced) + 1.4kg CO_2-e (CH_4) Total (per tonne condensate produced)					S3.72 Method 1
Processing Emissions Downstream (Scope 1 NWSJV)	Please refer NWS JV's proposed 'North West Shelf Project Extension ERD' (EPA 2186, EPBC 2018/8335)					

Please note, as the emissions factor for fuel gas upstream has been developed based on the composition of the proposed Browse to NWS Project fuel gas (in accordance with NGERs Method 2), the emissions factor varies slightly from other similar upstream gas projects. The emissions factor used for flaring is the same for all projects described below in Table 7-4, as it takes the emissions factor described in NGERs Method 1 (S3.67).

Table 7-4 Comparison of Emissions Factors used for Fuel Gas across comparable upstream facilities

Project – Fuel Gas	Energy Content (GJ/m^3)	kg CO_2-e/ GJ (CO_2)	kg CO_2-e/ GJ (CH_4)	kg CO_2-e/ GJ (N_2O)	kg CO_2-e/ GJ (Total)
Browse to NWS Project	40.0 x 10^{-3}	52.7	0.11	0.03	52.84
Barossa	39.3 x 10^{-3}	51.4	0.1	0.03	51.53
Icthys	Emissions factor not provided in draft EIS/ERD. Methodology used was consistent with the National Greenhouse Account Factors.				
APLNG	37.7 x 10^{-3}	51.1	0.2	0.03	51.33

* *Note all emissions data for Australian facilities has been sourced from regulatory authorisations (i.e. environmental impact statements, environmental review documents and management plans)*

Reservoir CO_2 Emissions Methodology

An assessment of the total quantity of reservoir CO_2 emitted has been completed. The assessment assumed that all reservoir CO_2 must be removed prior to liquefaction of the gas, either at the upstream or downstream facility. The estimate of reservoir CO_2 was based on the expected CO_2 composition of the reservoirs. Due to uncertainty of composition in the reservoir, a high reservoir CO_2 composition case has also been provided.

The amount emitted at each location will be dependent on the proportion of reservoir CO_2 exported from the BJV FPSO to the NWS facilities, i.e. the Browse export gas specification. There is some inherent uncertainty in the Browse export gas specification, which is further addressed below. Upstream and downstream reservoir emissions have been estimated **Table 7-5**, based on a gas export specification target of 2.5mol% CO_2.

Processing and Reservoir CO_2 Emissions Estimate

A summary inventory of the estimated GHG emissions is provided in **Table 7-5**. For the proposed Browse to NWS Project, SGM baseline requirements are expected to be achieved through use of offsets (described in **Section 7.7.2**). To account for the impact of SGM baseline requirements, estimates for both gross forecast emissions and net forecast emissions have been provided. These terms have the following definitions:

- **Gross Forecast Emissions**: All greenhouse gas emissions from the final design of the proposed Browse to NWS Project facilities (upstream and downstream), after energy efficiency and emissions reductions design measures (described in **Section 7.7.1**) have been incorporated.
- **Net Forecast Emissions**: The Gross Forecast Emissions minus those offset by carbon credits (described in **Section 7.7.2**).

Forecast Scope 1 (BJV and NWS JV) GHG emissions using the emissions factors are shown in **Table 7-5** below.

While CO_2 accounts for the majority of GHG emissions associated with the proposed Browse to NWS Project, other related emissions will also occur across the full scope of proposed project activities, including methane and nitrous oxide. All estimates for CO_2-e include both methane and nitrous oxide. The Global Warming Potential (GWP) adopted to determine the amount of CO_2-e contributed from both methane and nitrous oxide aligns to the *National Greenhouse and Energy Reporting Regulations 2008*, which at time of writing reflected the IPCC's Fourth Assessment Report. A breakdown of the relative contribution of these emissions on a gas-by-gas basis to forecast FPSO GHG emissions by CO_2-e equivalent is presented in **Table 7-6**.

Note that hydrochlorofluorocarbons/chlorofluorocarbons (HFCs/CFCs) will not be used as refrigerants on the FPSO facilities.

GHG emissions have been estimated based on NGERs emissions factors for Australia.

Table 7-5 Forecast Scope 1 (BJV and NWS JV) GHG emissions summary

CO_2-e MT	Average year	Peak production year	Total expected field life	Total extended field life
Upstream (BJV Scope 1)				
Reservoir Emissions[1]	2.3 (2.6)[2]	4.0 (4.6)	70 (81)	93 (107)
Fuel Gas	1.3	2.1	40	53
Flaring	0.07	0.07	2	3
Fugitives	0.01	0.02	0.3	0.4
Upstream Total	**3.6 (4.0)**	**6.2 (6.8)**	**112 (123)**	**149 (163)**
Downstream (Apportioned NWSJV Scope 1)				
Reservoir Emissions[1]	0.5	0.9	16	24
Processing Emissions (fuel and flare)	2.3	4.3	72	98
Downstream Total	**2.8**	**5.2**	**88**	**122**
Installation				
Installation	Not Estimated		1.0	1.0
SGM Carbon Credit Requirements				
SGM Carbon Credit Requirements	1.61	1.61	50	N/A[3]
Totals				

CO_2-e MT	Average year	Peak production year	Total expected field life	Total extended field life
Sub-total (reservoir)	**2.8 (3.2)**	**4.9 (5.5)**	**87 (98)**	**117 (131)**
Gross Total (Upstream + Downstream)	**6.4 (6.8)**	**11.4 (12.0)**	**200 (211)**	**272 (285)**
Net Total (Upstream + Downstream – Carbon Credits)	**4.8 (5.2)**	**9.8 (10.4)**	**150 (161)**	**N/A[3]**

[1] *Upstream and downstream reservoir emissions have been estimated based on the maximum expected case given a gas export specification target of 2.5mol% CO_2. The sub-total (reservoir) reflects the total upstream plus downstream emissions, regardless of export CO_2 specification. Estimates of emission implications for a 1 mol% to 2.8 mol% CO_2 gas export specification are presented in Table 7-7. Note the gas export specification is dependent on the outcome of final commercial arrangements.*

[2] *Bracketed emissions refer to high reservoir CO_2 composition scenario. Note that downstream reservoir emissions are impacted by the gas export specification and so, in the high reservoir CO_2 scenario, the additional reservoir CO_2 is vented upstream.*

[3] *Based on current SGM requirements, it is anticipated that reservoir CO_2 emissions will contribute to the proposed Browse to NWS Project exceeding facility baseline by approximately 50Mt CO_2-e, which would need to be offset in accordance with the rules of the SGM. This estimate is based on a mid-case reservoir outcome and is subject to change should a different reservoir outcome be realised or if the rules and assumptions which underpin the SGM baseline also change (including the production variables, default and leading practice emission intensities required to define any potential alternative, which are yet to be published in the Schedules associated with the National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015).*

[4] *As it is a regulatory requirement to determine the baseline on the mid-case forecast emissions, no estimate of baseline or carbon credit requirements has been made for an extended field life scenario.*

A gas-by-gas breakdown of gross forecast BJV Scope 1 greenhouse gas emissions has been provided in Table 7-6. Please note that the gas-by-gas breakdown on an annual basis will depend on the availability of the thermal oxidiser on the AGRU vent stream.

Table 7-6 Gross Forecast GHG emissions summary – gas by gas (BJV Scope 1)

CO_2-e MT	Average year	Total expected field life	Proportion of CO_2-e
Total CO_2	3.6 (4.0)	112 (123)	99.0%
Total CH_4	0.03	1.12	1.0%
Total N_2O	<0.01	0.03	0.03%

Browse Gas Export Specification - Apportionment of Reservoir CO_2 (Upstream-Downstream)

While an estimate for reservoir emissions based on expected reservoir outcomes is provided in Table 7-5, the individual BJV (Scope 1) and NWSJV (Scope 1) reservoir related emissions are indicative, as the amount emitted at each location is dependent on the proportion of reservoir CO_2 exported from the BJV FPSO to the NWS facilities, i.e. the Browse export gas specification. It is anticipated that the Browse export gas specification will allow a CO_2 composition range of between 1 mol% and 2.8 mol%. However, this is dependent on the outcome of final commercial arrangements between the Browse JV and NWS JV.

To account for this range in potential outcomes, which impacts the relative quantity of reservoir emissions released at each location (but not the total quantity), the reservoir emissions estimated to occur in each jurisdiction under the range of expected export gas specification outcomes has been provided in Table 7-7. This is dependent on the outcome of final commercial arrangements between the Browse JV and NWS JV.

Table 7-7 Forecast individual reservoir related emissions, dependant on the Browse export gas specification

Export Specification Scenario	CO_2-e MT	Average year	Peak production year	Total expected field life	Total extended field life
High CO_2 FPSO Export Specification (Less at FPSO, more at NWS)	Upstream BJV Scope 1	2.2 (2.6)[1]	3.9 (4.5)	68 (79)	91 (105)
	Downstream Apportioned NWSJV Scope 1	0.6	1.1	19	27
	Total (reservoir)	**2.8 (3.2)**	**4.9 (5.5)**	**87 (98)**	**117 (131)**
Low CO_2 FPSO Export Spec (More at FPSO, less at NWS)	Upstream BJV Scope 1	2.6 (2.9)	4.5 (5.1)	80 (91)	108 (122)
	Downstream Apportioned NWSJV Scope 1	0.2	0.4	7	10
	Total (reservoir)	**2.8 (3.2)**	**4.9 (5.5)**	**87 (98)**	**117 (131)**

[1] *Bracketed emissions refer to high reservoir CO_2 composition scenario. Note that downstream reservoir emissions are impacted by the gas export specification, and so, in the high reservoir CO_2 scenario, the additional reservoir CO_2 is vented upstream.*

7.4.4.3 Third party consumption

Methodology

An estimate of the quantity of greenhouse gas emissions arising from third party consumption has been completed.

For the consumption of LNG anticipated to be produced from the proposed Browse to NWS Project, which is expected to predominately occur internationally, an emissions factor has been sourced from the Ecoinvent v3.5 database. This emissions factor considers the transport, regasification, distribution and final combustion of LNG.

For the consumption of Domgas anticipated to be produced from the proposed Browse to NWS Project, which is expected to predominately occur domestically, an emissions factor has been developed based on NGERs. This emissions factor considers the distribution and final combustion of natural gas. Fugitive emissions of the gas during transmission (i.e. along BTL pipeline and subsequently the Bunbury to Dampier Pipeline) have been estimated in accordance with *NGERs Measurement Determination* S3.76 and are not significant. Therefore, they are not presented further.

NGERs end point combustion factors have been used for third party consumption of LPG and condensate, as these constitute a minority of the total products anticipated to be produced from the proposed Browse to NWS Project. The transportation and distribution emissions associated with these products are considered to be negligible when compared to the total Scope 3 emissions estimate.

In each instance for Scope 3 Emissions, the estimate of CO_2-e emissions is equal to the based on the quantity of product consumed, multiplied by the respective emissions factor.

Table 7-8 contains the emissions factors used to inform GHG estimates.

Table 7-8 Emissions Factors used for Browse to NWS Project Transit and Market Emissions

Source/fuel	Energy Content	kg CO_2-e/ GJ (CO_2)	kg CO_2-e/ GJ (CH_4)	kg CO_2-e/ GJ (N_2O)	kg CO_2-e/ GJ (unless otherwise stated)	NGERs Determination Reference
Third Party – LNG	N/A	N/A	N/A	N/A	3.13 (per kg product)	Ecoinvent 3.5
Third Party – Domgas	N/A	N/A	N/A	N/A	2.93 (per kg product)	Schedule 1 (Consumption) S3.80 (Distribution)
Third Party – LPG	25.7 (GJ/kL)	60.2	0.2	0.2	60.6	Schedule 1
Third Party – Condensate	46.5 (GJ/t)	61	0.1	0.2	61.3	Schedule 1

The methodology used by Ecoinvent v3.5 follows the international standards for lifecycle assessment. The Ecoinvent v3.5 emissions factor is based on individual production processes which contain Scope 1 emission factors, covering all greenhouse gas emissions, as connected along a production chain to deliver intermediate or final production processes. The methodology includes infrastructure, manufacturing processes, fugitive emissions as well as all energy-related emissions. Allocation between coproducts is done based on physical parameters, where available, such as energy content for coproduced energy products and, where a physical basis cannot be established, allocation is based on relative economic value of coproducts.

Ecoinvent v3.5 represents arguably the largest public collection of inventory data in the world, covering over 5000 products and containing 17000 unit processes. It has been recognised as emission factor source for the European Union Renewable Energy Direction greenhouse gas methodology and sits in the background of many of the National Carbon Offset Scheme (NCOS) emission factors. The Ecoinvent factors are therefore aligned in methodology to the principles of the NGERs methodology.

Estimate

Third party consumption emissions, as per the emissions factors used in **Table 7-8**, reflect emissions associated with the final combustion and use of the product and are shown in **Table 7-9**. Third party consumption emissions form the largest part of the overall emissions related to the Browse to NWS Project. It is expected that the majority of these GHG emissions will occur internationally and be managed and mitigated through local and international emissions control frameworks.

Table 7-9 Forecast Third Party consumption GHG emissions summary

CO_2-e MT	Average year	Peak production year	Total expected field life	Total extended field life
Third Party Consumption (Scope 3)				
Consumption – LNG (transport, regasification and distribution, and combustion)	22	38	691	944
Consumption – Domgas (distribution and combustion)	3.3	5.6	103	134
Consumption – LPG (Combustion only)	0.9	1.5	28	12
Consumption – Condensate (Combustion only)	5.6	10.6	173	241
Total	**32**	**55**	**995**	**1330**

The sum of all average year Scope 1 (BJV and NWS JV) (**Table 7-5**, total average year) and Scope 3 (**Table 7-9**, total average year) emissions is 36.8 MT.

7.4.5 Emissions Lifecycle and Intensity

7.4.5.1 Estimate lifecycle emissions and emissions intensity

Assessing the potential climate change impact of a proposed project requires an understanding of both direct and indirect GHGs. A lifecycle approach is useful to both collate this information into a single value and to compare impact between different products or value chains.

When conducting a lifecycle assessment, boundaries between upstream and downstream value chain components must be set. For example, **Figure 7-2** represents the anticipated emissions intensity of proposed processing Browse feedgas at the KGP and delivering product to China for use in a combined cycle gas turbine. This shows that electricity sourced from Browse gas has a lifecycle emissions intensity of 550 $kgCO_2$-e/MWh.

The IPCC summarised the lifecycle emissions intensity of electricity from various emissions sources (IPCC, 2011). This showed that the median emissions intensity of gas fuelled electricity was circa 450$kgCO_2$-e/MWh and that the Browse emissions intensity fits within the interquartile range for global gas fired electricity of 400-550kg CO_2-e/MWh. IPCC also showed that oil and coal power electricity generates 1000kg CO_2-e/MWh, whilst renewables and nuclear generate 0-50kg CO_2e/MWh.

Based on the comparison between electricity generated from Browse LNG and the electricity generated from coal, 121 $kgCO_2$e/kWh is emitted in Australia (22% of 550) and 450 $kgCO_2$e/kWh is saved in the global energy system. In this case, every tonne of GHG emitted in Australia could displace 3.7 tonnes of GHG elsewhere in the global energy system.

7.4.5.2 Natural gas in the context of global emissions

The scientific consensus on climate change, and the commitment of global governments to reduce emissions, is clear. There is also a need to both improve local air quality and increase access to modern energy sources. Access to clean, affordable and reliable energy improves living standards dramatically and the world's growing population is driving increased energy demand.

Numerous independent energy and climate bodies agree that natural gas has a significant role to play in achieving both a reduction in net global emissions and an increased access to a reliable modern energy supply that supports a progressive transition to renewable energy sources. The IPPC's 2014 Synthesis Report said that "GHG emissions from energy supply can be reduced significantly" by switching to gas. According to the IPCC, electricity generated from gas has on average half the GHG emissions of electricity generated from coal (IPCC, 2014). According to the International Energy Agency (IEA), in 2018 coal-to-gas switching helped avert 95 MT of CO_2 emissions (IEA, 2019).

A key technical challenge with the widespread deployment of renewables is the low capacity factor, as renewable power such as from wind and solar can be intermittent or inconsistent. As a readily dispatchable and reliable power source, gas-fired power is an ideal partner with renewables, as it can be quickly turned on to provide system stability when renewable power generation or electricity demand fluctuates. By providing this firming capacity, gas-fired power allows high renewable penetration in the form of a reliable power source to help resolve intermittency issues.

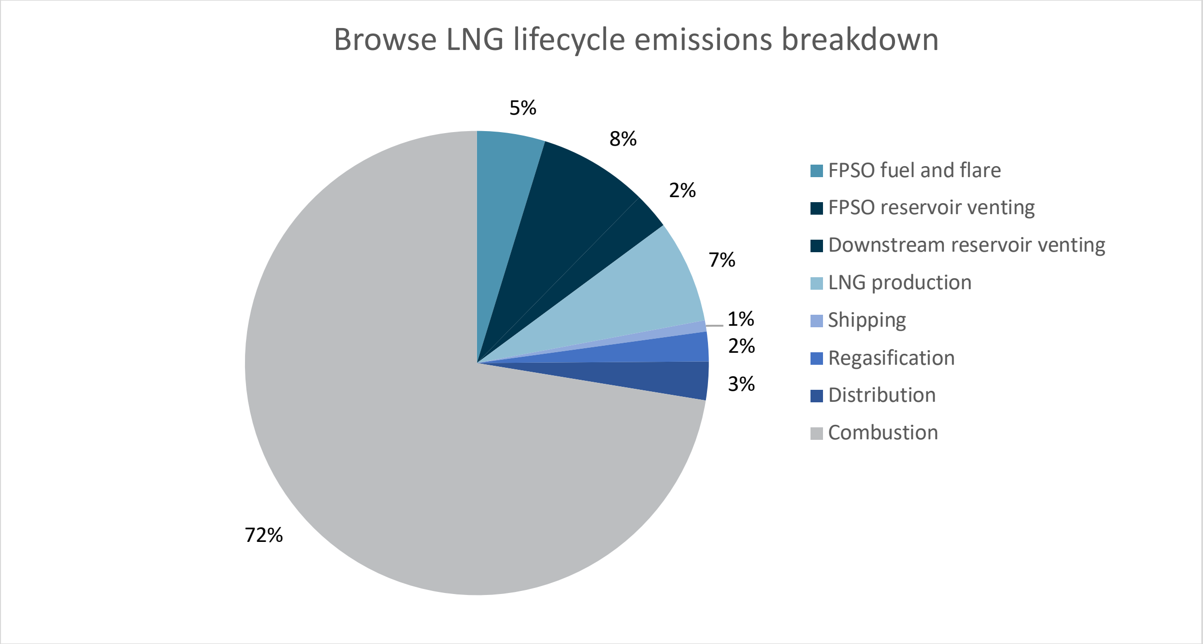


Figure 7-2 Proposed Browse to NWS Project lifecycle emissions intensity

Each year the IEA publishes a World Energy Outlook (WEO). Since 2017, the WEO has included a Sustainable Development Scenario (SDS), which describes an energy system that satisfies the three objectives of mitigating climate change, providing universal energy access by 2030 and reducing the severe health impacts of air pollution. Emissions projections in the SDS are "lower than most published decarbonisation scenarios based on limiting long-term global average temperature rise to 1.7-1.8°C" (IEA, 2019).

The SDS shows that natural gas continues to increase until at least 2040, the end of the period modelled (**Figure 7-3**). In the consumer countries relevant to the proposed Browse to NWS Project, gas consumption grows by 130% between 2017 and 2040. This suggests that increased gas use is not only consistent with the SDS but necessary if the goals of climate change mitigation, air quality improvements and energy access are to be achieved.

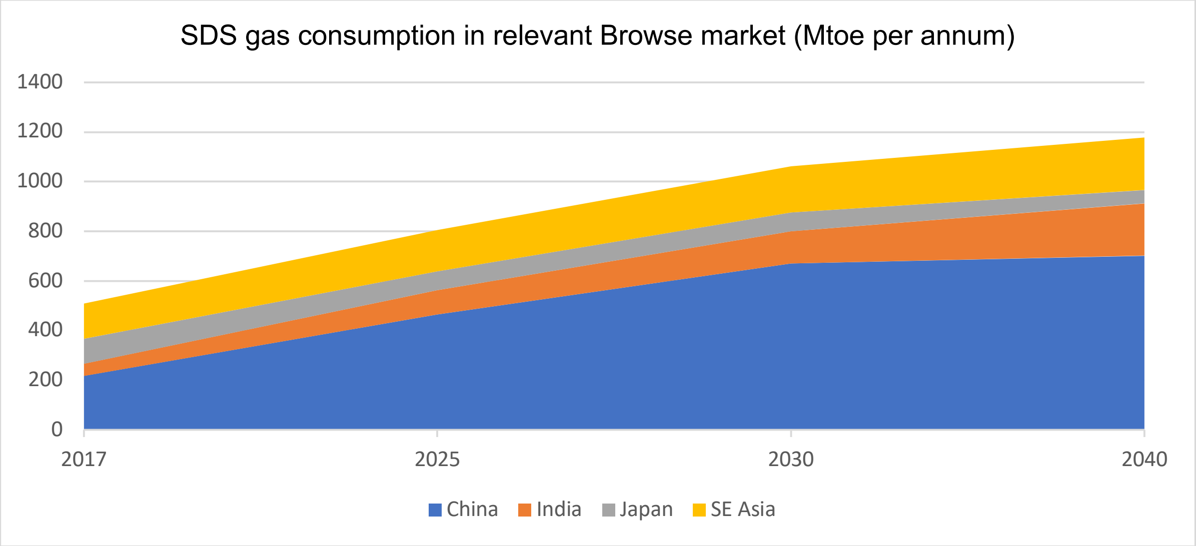


Figure 7-3 Forecast gas consumption in the IEA's SDS in relevant Browse markets (Mtoe)

7.5 Receptors and Receptor Sensitivity to Global GHG emissions

A recent Intergovernmental Panel on Climate Change (IPCC) Report (Hoegh-Guldberg et al., 2018) summarised the potential impact of human-induced climate change (at 1.5 and 2°C) on a range of climatic variables (e.g. temperature, precipitation, drought, extreme events) and the likely consequence to different ecosystems and ecosystem services, at a range of spatial scales.

Modelling indicated that temperatures will increase across Australia, rainfall patterns will change significantly and extreme events such as droughts, floods and wildfires will become more common. These changes are likely to impact on individual species, ecosystems and ecosystem services such as food and water availability. Within decades, environments across Australia may be substantially different. Biodiversity will be affected by climate change in a variety of ways and there will be much spatial variation in ecological change (CSIRO, 2015).

A report by Australia's Biodiversity and Climate Change Advisory Group (Steffen et al., 2009) in 2009 gives a summary of potential impacts to marine and terrestrial species, habitats and ecosystems across Australia. The impacts to taxa are outlined in **Table 7-10** and the impacts to ecosystems in **Table 7-11**.

7.5.1 Species-related Impacts from Global GHG Emissions

Extensive modelling and monitoring studies over the last twenty years provide considerable evidence that global climate change is already affecting and will continue to affect species (Hoegh-Guldberg et al., 2018). In addition, climate-change related impacts to flora and fauna are likely to be highly species-dependent and spatially variable. However, fauna distribution patterns are likely to shift in response to a changing climatic regime. Species distributions are likely to shift towards the poles and upwards in elevation and shifts in phenology (earlier spring and later autumn life history events) are the most frequently observed and cited ecological responses to climate change (Dunlop et al., 2012).

Climate change may not only change species distribution patterns but also life-history traits such as migration patterns, reproductive seasonality and sex-ratios (see **Table 7-10**). For example, Dunlop (2009) highlighted that in Australia, migratory birds have undergone changes in the first arrival date (3.5 days/decade), and last date of departure (5.1 days/decade) (Beaumont et al., 2006). Pairing of sleepy lizards has been observed to start earlier and last longer when the last months of winter are warmer (Bull and Burzacott, 2002). Climate change may account for earlier arrival of bird species in the Australian Alps, but the change appears not to be a simple consequence of incremental annual warming resulting from earlier snow-melt (Green, 2006; Norment and Green, 2004)

Table 7-10 Overview of impacts of climate change to the future vulnerability of particular taxa (modified after Steffen et al 2009)

Taxa	Potential vulnerability
Mammals	Narrow-ranged endemics susceptible to rapid climate change in situ (Williams et al., 2003); changes in competition between grazing macropods in tropical savannas mediated by changes in fire regimes and water availability (Ritchie and Bolitho, 2008); herbivores affected by decreasing nutritional quality of foliage as a result of CO_2 fertilisation.
Birds	Changes in phenology of migration and egg-laying; increased competition of resident species; breeding of waterbirds susceptible to reduction; top predators vulnerable to changes in food supply; rising sea levels affecting birds that nest on sandy and muddy shores, saltmarshes, intertidal zones, coastal wetlands and low-lying islands; saltwater intrusion into freshwater wetlands affecting breeding habitat.
Reptiles	Warming temperatures may alter sex ratios of species with environmental sex determination to cope with warming in situ.
Amphibians	Frogs may be the most at-risk terrestrial taxa. Amphibians may experience altered interactions between; pathogens, predators and fires.
Fish	Freshwater species vulnerable to reduction in water flows and water quality; limited capacity for freshwater species to migrate to new waterways; all species susceptible to flow-on effects of warming on the phytoplankton base of food webs.
Invertebrates	Expected to be more responsive than vertebrates due to short generation times, high reproduction rates and sensitivity to climatic variables.
Plants	Climate change may impact various functional dynamics of plants due to changes in; increasing CO_2, fires, plant phenology and specific environmental characteristics.

7.5.2 Projected Climate Change Impacts to Ecosystems from Global GHG Emissions

The results of climate change, such as altering temperature, rainfall patterns and fire regimes, are likely to lead to changes in vegetation structure across all terrestrial ecosystems within Australia (**Table 7-11**; Dunlop et al., 2012). Increases in fire regimes will impact Australian ecosystems by altering composition structure, habitat heterogeneity and ecosystem processes. Changes in climate variability, as well as averages, could also be important drivers of altered species interactions, both native and invasive species (Dunlop et al., 2012). Climate change could result in significant ecosystem shifts, as well as alterations to species ranges and abundances within those ecosystems (Hoegh-Guldberg et al., 2018).

Table 7-11 Projected impacts of CO_2 rise and climate change on Australian ecosystems (modified after Steffen et al 2009)

Key component of environmental change	Projected impacts on ecosystems
Coral reefs	
CO_2 increases leading to increased ocean acidity	Reduction in ability of calcifying organisms, such as corals, to build and maintain skeletons.
Sea surface temperature increases, leading to coral bleaching	If frequency of bleaching events exceeds recovery time, reefs will be maintained in an early successional state or be replaced by communities dominated by macroalgae.
Oceanic systems (including planktonic systems, fisheries, sea mounts and offshore islands)	
Ocean warming	Many marine organisms are highly sensitive to small changes in average temperature (1–2 degrees), leading to effects on growth rates, survival, dispersal, reproduction and susceptibility to disease.

Key component of environmental change	Projected impacts on ecosystems
Changed circulation patterns, including increase in temperature stratification and decrease in mixing depth, and strengthening of East Australian Current	Distribution and productivity of marine ecosystems is heavily influenced by the timing and location of ocean currents; currents transfer the reproductive phase of many organisms. Climate change may suppress upwelling in some areas and increase it in others, leading to shifts in location and extent of productivity zones.
Changes in ocean chemistry	Increasing CO_2 in the atmosphere is leading to increased ocean acidity and a concomitant decrease in the availability of carbonate ions.
Estuaries and coastal fringe (including benthic, mangrove, saltmarsh, rocky shore, and seagrass communities)	
Sea level rise	Landward movement of some species as inundation provides suitable habitat, changes to upstream freshwater habitats will have flow-on effects to species.
Increase in water temperature	Impacts on phytoplankton production will affect secondary production in benthic communities.
Savannas and grasslands	
Elevated CO_2	Shifts in competitive relationships between woody and grass species due to differential responses.
Increased rainfall in north and northwest region	Increased plant growth will lead to higher fuel loads, in turn leading to fires that are more intense, frequent and occur over large areas.
Tropical rainforests	
Warming and changes in rainfall patterns	Increased probability of fires penetrating into rainforest vegetation resulting in shift from fire-sensitive vegetation to communities dominated by fire-tolerant species.
Change in length of dry season	Altered patterns of flowering, fruiting and leaf flush will affect resources for animals.
Rising atmospheric CO_2	Differential response of different growth forms to enhanced CO_2 may alter structure of vegetation.
Temperate forests	
Potential increases in frequency and intensity of fires	Changes in structure and species composition of communities with obligate seeders may be disadvantaged compared with vegetative resprouters.
Warming and changes in rainfall patterns	Potential increases in productivity in areas where rainfall is not limiting; reduced forest cover associated with soil drying projected for some Australian forests.
Inland waterways and wetlands	
Reductions in precipitation, increased frequency and intensity of drought	Reduced river flows and changes in seasonality of flows.
Changes in water quality, including changes in nutrient flows, sediment, oxygen and CO_2 concentration	May affect eutrophication levels, incidence of blue-green algal outbreaks.
Sea level rise	Saltwater intrusion into low-lying floodplains, freshwater swamps and groundwater; replacement of existing riparian vegetation by mangroves.
Arid and semi-arid regions	
Increasing CO_2 coupled with drying in some regions	Interaction between CO_2 and water supply critical, as 90% of the variance in primary production can be accounted for by annual precipitation.
Shifts in seasonality or intensity of rainfall events	Any enhanced runoff redistribution will intensify vegetation patterning and erosion cell mosaic structure in degraded areas. Changes in rainfall variability and amount will also impacts on fire frequency. Dryland salinity could be affected by changes in the timing and intensity of rainfall.

Key component of environmental change	Projected impacts on ecosystems
Warming and drying, leading to increased frequency and intensity of fires	Reduction in patches of fire-sensitive mulga in spinifex grasslands potentially leading to landscape-wide dominance of spinifex.
Alpine/montane areas	
Reduction in snow cover depth and duration	Potential loss of species dependent on adequate snow cover for hibernation and protection from predators; increased establishment of plant species at higher elevations as snow pack is reduced.

7.5.2.1 Terrestrial Ecosystems

All terrestrial ecosystems are likely to be impacted by a changing climate (Table 7-11; Steffen et al 2009; Hughes 2010; Dunlop et al. 2012; Hoegh-Guldberg et. al. 2018). The predicted impact of climate change on these ecosystems is highly variable, both between ecosystems and within individual ecosystems ((Dunlop et al., 2012). Below is a summary of impacts to key terrestrial ecosystems (other ecosystems are summarised in Table 7-11).

Tropical Rainforests

Projections of future climate changes in the wet tropics of Australia under different scenarios are outlined by Mcinnes (2015). It is likely that temperatures in the wet tropics will become hotter and potentially fires and cyclones will be more intense. Consequently, there is an increased probability of fires penetrating into rainforest vegetation resulting in a shift from fire-sensitive vegetation to communities dominated by fire-tolerant species; and changing rainforest disturbance regime as cyclones become more intense) (Hughes, 2011; Steffen et al., 2009). Changes in the timing of seasons (e.g. extended summer) could cause change in the seasonal response of plants, and alterations to species ranges and abundances (Hoegh-Guldberg et al., 2018).

Alpine/ Montane Areas

Alpine systems are generally considered to be among the most vulnerable to future climate change (Hughes 2003). The extent of true alpine habitat in Australia is very small (0.15% of the Australian land surface) with limited high-altitude refuge (Hughes, 2003).

Australian alpine regions are home to a variety of alpine vertebrates who rely on snow cover for their survival. There is evidence of a reduction in populations of dusky antechinus, broad-toothed rats and the mountain pygmy possum. The first two species are active under the snow throughout winter and are therefore subject to increased predation by foxes when snow is reduced (Hughes, 2003). The pygmy possum depends upon snow cover for stable, low temperatures during hibernation (Hughes, 2003).

7.5.2.2 Marine Ecosystems

Sea surface temperatures have increased across the globe over recent decades which poses a significant threat to marine ecosystems including changes to species abundance, community structure and increased frequency and intensity of thermally induced coral bleaching events (CSIRO, 2017).

Between 1920 and 2000, sea level is estimated to have risen on average 1.2 mm per year due to climate change (Church et al., 2006). In addition to changes in sea level, oceanic warming has also served to alter ocean currents around Australia. In response to both ocean warming and stratospheric ozone depletion the East Australian Current has increased in strength by about twenty percent since 1978 (Cai and Cowan, 2006).

Sea-surface temperatures are projected to continue to increase, with estimates of warming in the Southern Tasman Sea of between 0.6 and 0.9°C and between 0.3 and 0.6°C elsewhere along the Australian coast by 2030 (Church et al., 2006). Sea levels are predicted to increase by 18 to 59 cm by 2100 in response to both thermal expansion and melting of ice-sheets (Solomon et al., 2007). This would lead to some coastal inundation affecting mangroves, salt marshes and coastal freshwater wetlands. Furthermore, as CO_2 is gradually absorbed by oceans and fresh water, the water becomes more acidic, which increases the solubility of calcium carbonate, the principal component of the skeletal material in aquatic organisms (Steffen et al., 2009). Below is a summary of potential climate change impacts to two key ecosystems - mangroves and coral reefs.

Mangroves

Mangrove ecosystems in Australia could face higher temperatures, increased evaporation rates and warmer oceans (McInnes, 2015) as well as an associated sea-level rise (Hoegh-Guldberg et al., 2018). Modelling indicates an increased likelihood of future severe and extended droughts across parts of Northern Australia (Dai, 2013). Consequently, mangrove ecosystems may increase their southern range as a result of warmer temperatures. However, higher temperatures and evaporation rates, and extended droughts could lead to die-offs in northern Australia and a change in mangrove distribution and abundance (Duke et al., 2017). Mangrove systems should cope with rising sea-level by accumulating more peat or mud, giving them the opportunity to adjust to a rising sea level (Field, 1995).

Coral Reefs

Climate change has emerged as a threat to coral reefs, with temperatures of just 1°C above the long-term summer maximum for an area over 4–6 weeks being enough to cause mass coral bleaching and mortality (Baker et al., 2008; Hoegh-Guldberg, 1999; Hughes et al., 2017; Spalding and Brown, 2015). Coral mortality or die off following coral bleaching events can stretch across thousands of square kilometres of ocean (Gilmour et al., 2016; Hoegh-Guldberg, 1999; Hughes et al., 2017). The impacts associated with a warming ocean, coupled with increasing acidification, are expected to undermine the ability of tropical coral reefs to provide habitat for fish and invertebrates, which together provide a range of ecosystem services (e.g., food, livelihoods, coastal protection); (Hoegh-Guldberg et al., 2018).

As described in Chapter 5, evidence of thermal-induced bleaching and the associated impacts has been observed during long term monitoring of the corals at Scott Reef which lie within the proposed Browse Development Area. These corals have experienced four thermally induced bleaching events since 1998. While Scott Reef showed rapid recovery of corals after bleaching events, the increasing frequency of these events due to climate change has the potential to affect this recovery (Gilmour et al., 2016).

7.5.3 Projected Climate Change Impacts to Social, Economic and Cultural Aspects from Global GHG Emissions

Noting the inherent uncertainty in estimating the impacts of climate change, Table 7-12 below provides a summary of possible impacts of climate change on social and economic components from global GHG emissions. The data is drawn from existing Australian Government resources (Climate Change Authority, 2014; DoEE 2019).

Table 7-12 Possible impacts of CO_2 rise and climate change on Australian social, economic and cultural aspects

Social/economic categories & impact causes	Possible impacts
Cities and the built environment	
Sea level rise, flooding, ocean acidification, wildfire and other extreme events	Both gradual changes (sea-level and temperature rise, ocean acidification) and extreme events (flash floods, heatwaves and bushfires) may increase repair frequency and drive relocation.
Agriculture, forestry, fisheries, broader industries and employees	
Decrease in rain fall	Reduced agricultural yields in Southern Australia.
Change in temperature	Livestock under greater heat stress resulting in reduced productivity and reproductive rates.
Change in climate	Changes in growing season and location may impact food transport costs and availability
	Increased severity and frequency of extreme weather events, water shortages and exposure to tropical diseases may impact industry and labor mobility. Tourism and agricultural industries may be the most vulnerable.
Water resources	
Changes in groundwater	Altered groundwater recharge rates and supplies, seawater intrusion to coastal aquifers, reduction of freshwater availability on small islands, and increased demand from communities and industries.

Social/economic categories & impact causes	Possible impacts
Change in temperature	Potential increase in the risk of bacterial contamination in water supplies, blue-green algal outbreaks and acid-sulphate soil issues.
Health and wellbeing, human factors	
Changes to ecosystem services	Impaired services such as clean air, fresh water, and protection from natural disasters.
Increase in temperature and rainfall patterns	Increased risk of temperature related injury, disease and death. This includes an increased area of land suitable for mosquitoes that transmit disease.
Increase in extreme events	Increased risk of injuries, disease, and disruption to health services.
Change in climate	Drought has been linked to decreased mental health, particularly in rural communities.
	Aboriginal Australians may experience a higher impact from climate change due to close connections to the natural environment (both cultural and income related) and higher rates of socio-economic disadvantage.

7.5.4 Projected Effect of Global Emissions on Receptor Trends

The IPCC Special Report describes the impacts of warming above pre-industrial levels to key receptor groups including terrestrial ecosystems, mangroves, warm-water corals, unique and threatened systems, and arctic regions (Hoegh-Guldberg et. al. 2018). These receptor groups show varying sensitivity to warming conditions, with a range of responses shown at 1°C warming; from corals suffering moderate impacts, to mangroves not showing any impacts that are detectable and attributable to climate change (Hoegh-Guldberg et al., 2018). Once warming reaches 1.5°C, all receptor groups show impacts attributable to climate change, with severity ranging from moderate impacts that are detectable and attributable to climate change (mangroves), to impacts that are severe and widespread (warm-water corals) (Hoegh-Guldberg et al., 2018). At the point where global temperature rise due to climate change reaches 2°C, increasing numbers of receptor groups suffer impacts which are high to very high, and likely to be irreversible (terrestrial ecosystems, warm-water corals, unique and threatened systems, and arctic regions) (Hoegh-Guldberg et al., 2018).

7.6 Browse to NWS Project Relative to Global GHG Emissions

While it is not feasible to directly correlate the potential impact of the proposed Browse to NWS Project GHG emissions on receptors (be that impact negative or positive in the case of replacing higher carbon fuels), the direct contribution of the proposed Browse to NWS Project GHG lifecycle emissions (including NWSJV Scope 1 emissions) to global emissions can be estimated. Table 7-13 shows the estimated average GHG contribution compared to five United Nations Environment Program NDCs Scenarios. As per Section 7.4.5, the proposed Browse to NWS Project total lifecycle emissions are anticipated to be less than if equivalent energy were to be generated from coal.

Table 7-13 Proposed Net Browse to NWS Project average GHG lifecycle emissions contribution to NDC Scenarios

Lifecycle emissions	Total global GHG emissions (MTCO$_2$-e/ year) (UN Environment, 2018)	Proposed Browse to NWS Project Scope 1 (Net average (upstream and downstream) of 4.8 MtCO$_2$-e/ year (%))	Proposed Browse to NWS Project total lifecycle emissions (Average of 36.8 MtCO$_2$-e/ year (%))
2030 (no policy baseline)	65,000	0.01	0.06
2030 (current policy scenario)	59,000	0.01	0.06
2030 (2°C pathway)	40,000	0.01	0.09
2030 (1.5°C pathway)	24,000	0.02	0.15

It should be noted that the 2030 emissions forecasts are United Nations Environment Program estimates only and total global GHG emissions reflect anthropogenic emissions only.

Woodside Energy Ltd is operator for and on behalf of a number of Joint Ventures and is currently proposing other developments in the region. For more information on greenhouse gas emissions associated with each development, please refer to:

- North West Shelf Project Extension ERD (EPA 2186, EPBC 2018/8335)
- Scarborough OPP (NOPSEMA A679881)
- Pluto LNG Development (EPA 1632, EPBC 2006/2968).

Please note, greenhouse gas emissions associated with the developments listed above is not addressed further in this draft EIS/ERD, as they are assessed in their respective assessment documents.

Under the Paris Agreement, Australia has a target of reducing emissions by 26-28 per cent below 2005 levels by 2030. Australia stated in its Nationally Determined Contribution that it would develop its target into an emissions budget covering the period 2021-2030. The cumulative emission budget for this period is 4800 MT to reach the 26% reduction target (DoEE, 2018). Scope 1 and 2 GHG emissions from the upstream component of the proposed Browse to NWS Project are expected to contribute to 0.8 % of this cumulative emissions budget. The Australia's emissions projections 2018 report provides an indicative summary of how Australia is tracking to achieve its Nationally Determined Contribution of 26 to 28 per cent below 2005 levels in 2030. Projected emissions to 2030 from the LNG sector (direct combustion and fugitive) are included in the methodology used to underpin these projections. The methodology is based on an export capacity of 80MPTA of LNG in 2020 with the addition of one new LNG train in the mid-2020s.

The emissions reduction task to achieve the 2030 target is currently 328 MT CO_2-e. The Australian government has outlined a plan to closing this gap in the Climate Solutions Package.

7.7 Management and Mitigation of GHG Emissions

7.7.1 Processing Emissions

The following key energy efficiency and emissions reductions measures have been incorporated into the design of the proposed Browse to NWS Project. The associated emissions reductions achieved by these initiatives have been estimated and presented in square brackets next to each initiative. Note that estimates are presented as being across two FPSO facilities, operating at maximum pipeline throughout (i.e. the "max" scenario). The measures are:

- waste heat recovery units on gas turbines [0.70 MT CO_2-e/annum]
- active heating system used to prevent hydrate formation in flowlines avoiding the requirement for an energy intensive MEG regeneration plant [0.20 MT CO_2-e/annum]
- batteries for peak power supply [0.10 MT CO_2-e/annum]
- efficient aero-derivative gas turbines [0.02 MT CO_2-e/annum]
- use of nitrogen to purge the flare stack rather than hydrocarbon gas [expected less than <0.1 MT CO_2-e/annum].

Note that without the above key energy efficiency and emissions reductions measures, the Scope 1 forecast gross emissions associated with the Browse to NWS Project would be higher. By saving approximately up to 1 MT of CO_2-e on average per year, this has reduced the expected average annual net Scope 1 Project emissions from up to 5.8 MT CO_2-e to 4.8 MT CO_2-e per year and saved 31 MT CO_2-e of Scope 1 emissions over the expected life of the Project.

To compare processing emissions for upstream facilities, it is important to recognise that for upstream developments such as the Browse to NWS Project, the amount of energy required to process and export the gas is principally driven by:

- The amount of CO_2 that needs to be removed from the gas stream, as the process to remove the CO_2 from the gas stream is heat-intensive.
- The distance that the gas needs to be transported, as the amount of energy required to achieve the required gas export rate and pressure increases as the distance increases.

As the above variables are highly reservoir and location specific it is difficult to draw comparisons between projects. However, as Browse has a relatively high reservoir CO_2 content, and the Browse Trunkline is approximately 900 km long to NWS facilities, then the most comparable facilities are those with:

- Long pipelines or pipeline networks to reach the downstream LNG facility (i.e. have similar compression requirements).
- High reservoir CO_2 content, and therefore either need to consume energy to remove the CO_2 or consume more energy to export it to the downstream LNG facility.

On this basis the two most comparable facilities identified are the proposed Borossa-Caldita project and the Ichthys project, due to somewhat similar reservoir CO_2 content and distance to the LNG facilities.

For completeness based on distance to LNG facilities an unconventional reservoir for APLNG has also been selected due to its substantial gas gathering network and distance to LNG facilities. **Figure 7-4** provides benchmarking between the processing emissions for the proposed Browse FPSOs and identified comparable facilities in Australia, to demonstrate the effectiveness of the upstream design in consuming energy to process the gas stream and pressurise it for export. Intensity has been calculated on a fuel gas use only and **Figure 7-4** does not include the reservoir CO_2 emissions. The CO_2 percentage has been provided as an indicator of the likely energy expenditure on CO_2 removal for each project. Note the data used to calculate other operators' emissions intensity is of varying quality and has been sourced from regulatory authorisations (i.e. environmental impact statements, environmental review documents and management plans), actual emissions intensity of facilities in operation may differ from that presented.

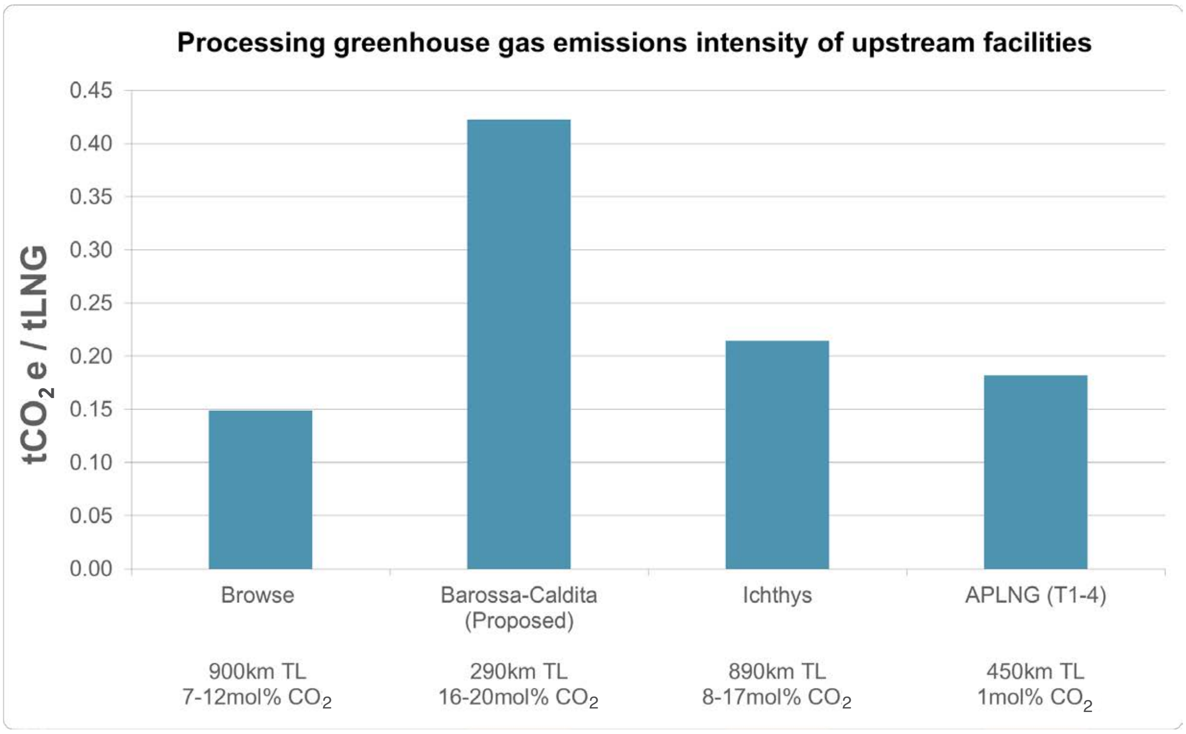


*Figure 7-4 Processing CO_2-e Emissions Intensity of Comparable Upstream Facilities**

* *Note all emissions data for Australian facilities has been sourced from regulatory authorisations (i.e. environmental impact statements, environmental review documents and management plans)*

Mitigation and management measures associated with anticipated processing emissions for the NWS Extension Project are described in the NWSJV's 'North West Shelf Project Extension ERD' (EPA 2186, EPBC 2018/8335).

7.7.2 Carbon Credits

Under the National Greenhouse and Energy Reporting scheme, the BJV will be required to surrender Australian carbon credit units (ACCUs) to offset emissions over the SGM baseline. Offsets may be secured by the Operator (Woodside) or separately by individual Joint Venture Participants for their equity emissions. Offsetting opportunities that will be investigated include industry methods or land-based solutions for carbon sequestration, which may include savanna burning, environmental planning, native tree planting and human induced land restoration.

By way of example, Woodside has recently entered into a Heads of Agreement (HoA) with Greening Australia to co-create large-scale, native tree planting projects that generate quality carbon offsets. Woodside and Greening Australia will assess environmental and economic viability of a range of opportunities across Australia, with an initial focus in Western Australia. The agreement is scalable and the first phase will involve planting up to 5000 hectares in 2020, in an ecologically and scientifically responsible manner, primarily in Western Australia.

The generation of GHG offsets through approved and validated carbon farming methodologies is a significantly lower risk and more cost-effective solution than geosequestration of Browse reservoir CO_2. GHG offsets also offer co-benefits resulting from the additional ecosystem services provided when carbon is bio-sequestered, as well as social, economic and environmental benefits (e.g. improvements to air quality, employment opportunities in remote communities or provision of additional habitat for fauna).

It is also anticipated that there will be emissions associated with the proposed processing of Browse feed gas through third party infrastructure as described above in Section 7.7.1. The BJV is a party seeking long term processing services from the NWSJV. It is anticipated that these emissions will be mitigated and managed by the NWSJV in accordance with regulatory requirements applicable to the proposed NWS Extension Project. It must be noted that the NWSJV will not solely process Browse gas as existing NWSJV reserves will continue to be produced, and there is potential for additional resource owners to secure processing services with NWSJV. The BJV is presently negotiating commercial arrangements with the NWSJV regarding the provision of gas processing services.

7.7.3 Geosequestration

There are two main CO_2 emission streams (Figure 7-2) that could be considered for geosequestration – the AGRU and emissions from the gas turbines. This would involve the capture of CO_2 at the outlet of a major gas stream, such as the vent stream from the offshore AGRU or from the exhaust stream of the gas turbines. While the offshore AGRU stream is predominantly CO_2, the gas turbine exhaust stream would likely require further processing to strip the CO_2 from the stream for capture. Further processing of the exhaust stream would add significant complexity and is prohibitive in an offshore environment where space is restricted. LNG projects that do geosequester typically geosequester the AGRU vent stream only.

Once CO_2 emissions are captured, the stream would then be pressurised and re-injected into a suitable subsurface disposal target. Over 30 potential re-injection sites near the proposed Browse Development Area were identified and screened based on their cost, subsurface suitability and risk profile (including non-technical risks such as gaining access to land, complexity of commercial agreements, etc.).

Based on this screening, the Calliance reservoir was identified as a potentially viable re-injection site. As the Calliance reservoir will be a producing gas and condensate field, its use as a geosequestration site would carry significant technical, operational and safety risks. These include:

- Technical feasibility as offshore geosequestration at the required scale is unproven.
- Subsurface inject-ability risk; by reinjecting into a producing reservoir, there is a risk that more CO_2 is produced from the reservoir (i.e. the CO_2 ‘recycles’), reducing the impact of geosequestration as a mitigation measure.
- Safety risk during operations as an additional safety hazard (CO_2 asphyxiation) is added to the FPSO, associated with additional processing and compression.

Geosequestration is, therefore, a high risk, high cost mitigation option for Browse reservoir CO_2.

7.8 Acceptability Assessment

An assessment of the acceptability of proposed Browse to NWS Project GHG emissions is provided in Table 7-10.

The assessment of acceptability has been undertaken in consideration of:

- principles of ESD as defined in Section 3A of the EPBC Act
- MNES Significant Impact Guidelines (EPBC Act)
- WA EPA Environmental Factors and Objectives (EP Act)
- other aspect or receptor requirements including State, Federal and international standards, laws, policies and guidelines, including management plans and conservation advice
- external requirements
- internal requirements.

Further details in relation to these criteria are set out in Chapter 6.

Overall, in the context of Australia’s international commitments and local legislation and policy, it is considered that given the proposed mitigation of emissions, safeguard mechanism obligations and the importance of gas as a clean and reliable source of energy in the current and future energy mix, GHG emissions from the proposed Browse to NWS Project are acceptable.

Table 7-14 Acceptability Assessment – GHG emissions

Acceptability Assessment
Principals of ESD As described in Section 7.4.5 the provision of clean and reliable energy is paramount to the lifting of worldwide living standards. As a clean and reliable energy source, gas is expected to play a key role in the future energy mix (as a partner to renewables). In addition, gas has the potential to contribute significantly to the reduction in global GHG emissions by displacing higher carbon intensive power generation (e.g. coal burning). Given the importance of gas in the current and future energy mix, the planned emissions mitigation and offsetting (Section 7.7) to reduce GHG emissions; and the broader socio-economic benefits to both Australia and the State of Western Australian of the proposed Browse to NWS Project, it is considered that the principals of ESD have been met. **Conclusion: Acceptable**
Significant impacts as defined by the MNES Significant Impact Guidelines No direct impacts to listed threatened and migratory species, threatened ecological communities, the Commonwealth Marine Area or the environment are predicted to occur as a result of GHG emissions from the proposed Browse to NWS Project. Climate change induced impacts to listed or threatened species, threatened ecological communities, the Commonwealth Marine Area or the environment resulting from the proposed Browse to NWS Project are difficult to predict and likely immeasurable. Global GHG emissions will continue to have an effect on trends in receptor condition and potential impacts to listed threatened and migratory species, threatened ecological communities or the Commonwealth Marine Area or environment may occur as a result (Section 7.5). As a stand-alone project, however, taking into account all planned emissions reduction and offsetting measures (Section 7.7), it is estimated that Scope 1 and 3 emissions from the proposed Browse to NWS Project could contribute in the range of 0.06% to 0.15% global GHG emissions depending on the NDC scenario considered (Table 7-13). As a stand-alone project, GHG emissions from the proposed Browse to NWS Project will not have a significant impact (as defined by the MNES Significant Impact Guidelines) on listed threatened species or migratory species, threatened ecological communities, the Commonwealth Marine Area or the environment. The proposed Browse to NWS Project has proposed a GHG Abatement Plan to continuously review mechanisms to mitigate and manage GHG emissions and compliance with NGER/SGM baseline requirements through ACCUs to offset anticipated excess emissions over baseline. Further, as discussed in Section 7.7.1, gas use is not only consistent with the WEO's SDS but required to achieve the goals of climate change mitigation, air quality improvements and energy access. As such, the proposed Browse to NWS Project may potentially have a positive impact via the reduction of global emissions with potential subsequent reduction in impacts to sensitive receptors resulting from climate change. However, this is acknowledged as being uncertain in a global context and therefore is appropriately categorised as gas having benefits over the use of coal in generating electricity. **Conclusion: Acceptable**

Acceptability Assessment

WA EPA Environmental Objectives

No direct impacts to benthic communities and habitats, marine environmental quality or marine fauna are predicted to occur as a result of GHG emissions from the proposed Browse to NWS Project.

Climate change induced impacts to benthic communities and habitats, marine environmental quality or marine fauna resulting from the proposed Browse to NWS Project are difficult to predict and likely immeasurable. Global GHG emissions will continue to have an effect on trends in receptor condition and potential significant impacts to benthic communities and habitats, marine environmental quality or marine fauna may occur as a result (**Section 7.5**). As a stand-alone project however, taking into account all planned emissions reduction and offsetting measures (**Section 7.7**), it is estimated that Scope 1 and 3 emissions from the proposed Browse to NWS Project will contribute in the range of 0.06% to 0.15% of global GHG emissions depending on the NDC scenario considered (**Table 7-13**). As such, it is not considered credible that as a stand-alone project, GHG emissions from the proposed Browse to NWS Project will significantly impact benthic communities and habitats, marine environmental quality or marine fauna and, as such, the relevant EPA objectives for these environmental factors will be met.

Further, as discussed in **Section 7.7.1**, gas has the potential to contribute significantly to the reduction in global GHG emissions by displacing higher carbon intensive power generation (e.g. coal-gas energy switch). As such, the proposed Browse to NWS Project may potentially have a positive impact via the reduction of global GHG emissions, with potential subsequent reduction in impacts to sensitive receptors resulting from climate change. However, this is acknowledged as being uncertain in a global context and therefore is appropriately categorised as gas having benefits over the use of coal in generating electricity.

Conclusion: Acceptable

External Context

GHG emissions from petroleum developments was identified as a stakeholder issue during stakeholder engagement (**Chapter 4**). It is considered that the proposed mitigation and management of GHG emissions and likely NGER/SGM offset obligations address this issue.

Conclusion: Acceptable

Internal Context

Woodside has a Climate Change Policy and a Woodside Management System (**Chapter 8**). For more details on the Policy, see https://www.woodside.com.au/sustainability/climate-change.

As part of the management of the proposed Browse to NWS Project, a GHG Abatement Plan will be developed and implemented to achieve the environmental objective (**Section 7.2** and **Chapter 8**).

Conclusion: Acceptable

Other Requirements

The Paris Agreement

The targets set by the Paris Agreement are detailed in **Section 7.3.1**. As a clean and reliable energy source (described in **Section 7.7.1**), gas is expected to play a key role in the future energy mix and it has the potential to contribute to the reduction in global GHG emissions by displacing higher carbon intensive power generation (e.g. coal burning).

Australia's Nationally Determined Contributions

Australia's NDC is for an absolute economy-wide emissions reduction by 2030. Given the emission estimates and the likely NGER/SGM offset obligations, it is not expected that the proposed Browse to NWS Project will prevent Australia meeting its NDC commitments.

Safeguard Mechanism (SGM)

Woodside is committed to its obligations under the NGER/SGM. Based on current regulatory NGER Act SGM emissions baseline requirements, it is anticipated that CO_2 emissions derived from the Browse reservoirs will contribute to emissions from the proposed Browse to NWS Project, exceeding any anticipated facility baseline. This would likely result in SGM offset obligations, which at this stage are anticipated to be met in the form of ACCUs.

It is also anticipated that there will be emissions associated with the processing of Browse feed gas through third party infrastructure as described above in **Section 7.4.1**. It is anticipated that these emissions will be mitigated and managed by the NWSJV in accordance with regulatory requirements applicable to the proposed NWS Extension Project.

Conclusion: Acceptable

CHAPTER 8

ENVIRONMENTAL MITIGATION, MANAGEMENT AND MONITORING

8. ENVIRONMENTAL MITIGATION, MANAGEMENT AND MONITORING

8.1 Introduction

This chapter describes how Woodside intends to implement the environmental management program throughout the life of the proposed Browse to NWS Project. It demonstrates the mitigation and management approach that Woodside will use to avoid or minimise environmental impacts and risks identified in this draft EIS/ERD to an acceptable level.

8.2 Woodside's Health, Safety and Environmental Management System

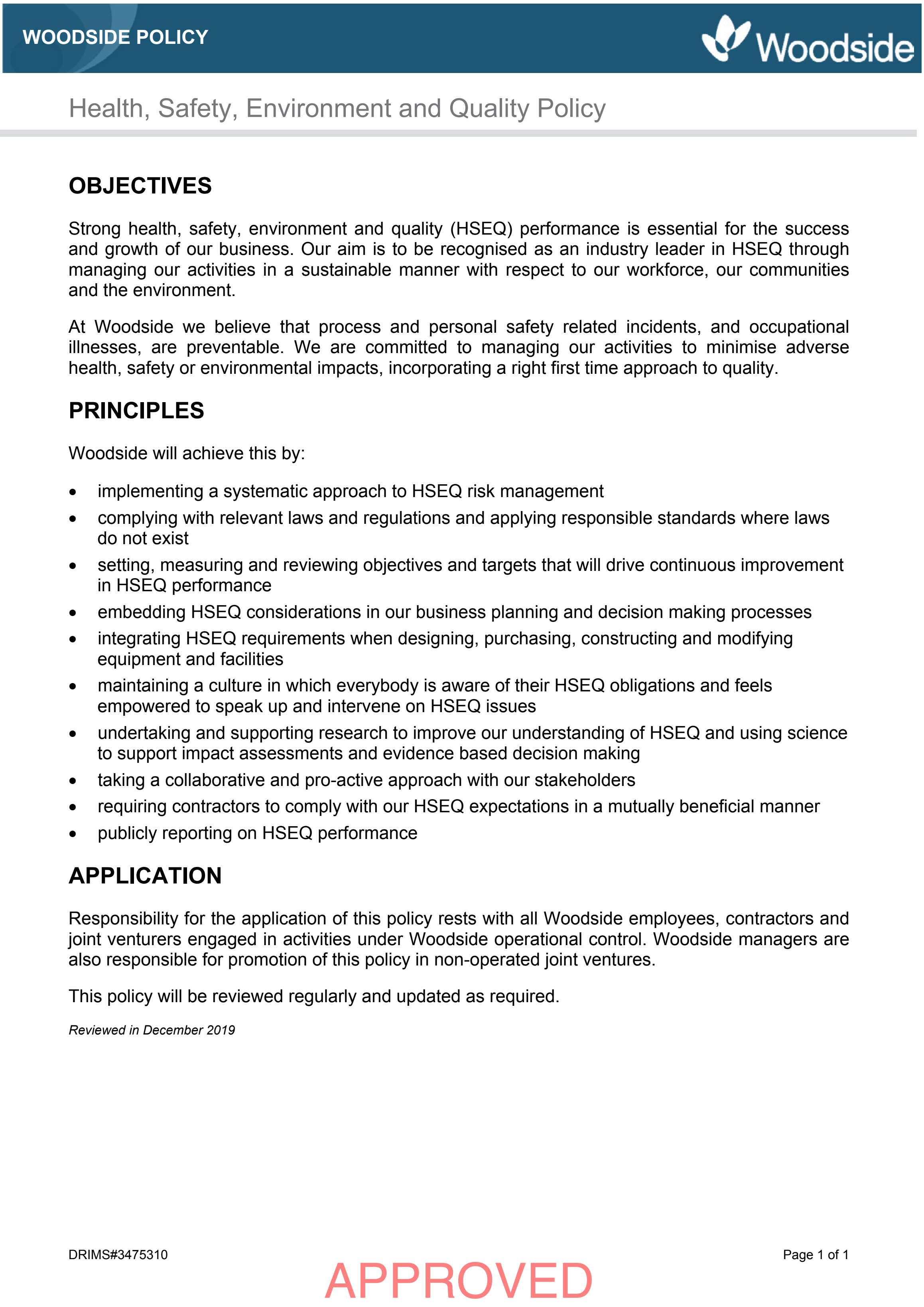
8.3 Overview

The Woodside Management System (WMS) defines how Woodside will deliver its business objectives and the boundaries within which all Woodside employees and contractors are expected to work. The WMS consists of a mission statement, policies, decision making committees, frameworks of authorities and standards, that when applied, provide management, governance and assurance. Environmental management is one of the components of the overall WMS.

8.4 Health, Safety, Environment and Quality Policy

Within the WMS, the overall direction for Environment is set through Woodside's corporate Health Safety, Environment and Quality Policy (**Figure 8-1**). The policy provides a public statement of Woodside's commitment to minimising adverse effects on the environment from its activities and to improving environmental performance. It sets out the principles for achieving the objectives for the environment and how these are to be applied. The policy is applied to all Woodside's activities, and all employees, contractors and Joint Venture partners engaging in activities under Woodside operational control.

In addition, Woodside's Climate Change Policy (refer to **Chapter 7**) demonstrates a commitment to be part of a solution to climate change. This includes promoting and pursuing a culture of energy efficiency and improving resource use in design and operation.



WOODSIDE POLICY

Health, Safety, Environment and Quality Policy

OBJECTIVES

Strong health, safety, environment and quality (HSEQ) performance is essential for the success and growth of our business. Our aim is to be recognised as an industry leader in HSEQ through managing our activities in a sustainable manner with respect to our workforce, our communities and the environment.

At Woodside we believe that process and personal safety related incidents, and occupational illnesses, are preventable. We are committed to managing our activities to minimise adverse health, safety or environmental impacts, incorporating a right first time approach to quality.

PRINCIPLES

Woodside will achieve this by:

- implementing a systematic approach to HSEQ risk management
- complying with relevant laws and regulations and applying responsible standards where laws do not exist
- setting, measuring and reviewing objectives and targets that will drive continuous improvement in HSEQ performance
- embedding HSEQ considerations in our business planning and decision making processes
- integrating HSEQ requirements when designing, purchasing, constructing and modifying equipment and facilities
- maintaining a culture in which everybody is aware of their HSEQ obligations and feels empowered to speak up and intervene on HSEQ issues
- undertaking and supporting research to improve our understanding of HSEQ and using science to support impact assessments and evidence based decision making
- taking a collaborative and pro-active approach with our stakeholders
- requiring contractors to comply with our HSEQ expectations in a mutually beneficial manner
- publicly reporting on HSEQ performance

APPLICATION

Responsibility for the application of this policy rests with all Woodside employees, contractors and joint venturers engaged in activities under Woodside operational control. Woodside managers are also responsible for promotion of this policy in non-operated joint ventures.

This policy will be reviewed regularly and updated as required.

Reviewed in December 2019

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APPROVED

Figure 8-1 Woodsides Corporate Health, Safety, Environment and Quality Policy

8.5 Woodside's Management System

The WMS provides a structured framework of documentation to set common expectations governing how all employees and contractors at Woodside will work. WMS documentation, which is comprised of four elements (Compass & Policies; Expectations; Processes & Procedures; and Guidelines) is outlined below and illustrated in Figure 8-2:

- **Compass & Policies:** Set the enterprise-wide direction for Woodside by governing behaviours, actions and business decisions and ensuring Woodside meets its legal and other external obligations.
- **Expectations:** Set essential activities or deliverables required to achieve the objectives of the Key Business Activities and provide the basis for development of processes and procedures.
- **Processes & Procedures:** Processes identify the set of interrelated or interacting activities which transforms inputs into outputs, to systematically achieve a purpose or specific objective. Procedures specify what steps, by whom and when required to carry out an activity or a process.
- **Guidelines:** Provide recommended practice and advice on how to perform the steps defined in procedures, together with supporting information and associated tools. Guidelines provide advice on how activities or tasks may be performed; information that may be taken into consideration; or how to use tools and systems.

The WMS is organised within a business process hierarchy based upon key business activities to ensure the system remains independent of organisation structure and is globally applicable and scalable as required. These key business activities are grouped into management, support and value stream activities as shown in Figure 8-3. The value stream activities capture, generate and deliver value through the exploration and production lifecycle. The management activities influence all areas of the business, while support activities may influence one or more value stream activities.

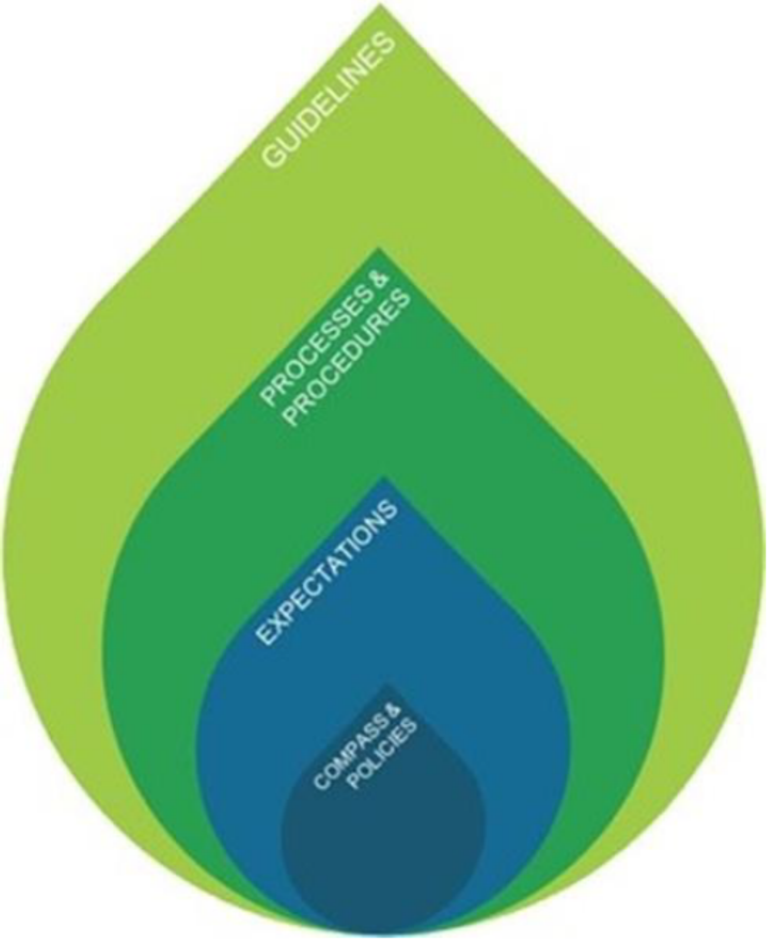

Figure 8-2 The Four Major Elements of the WMS Seed

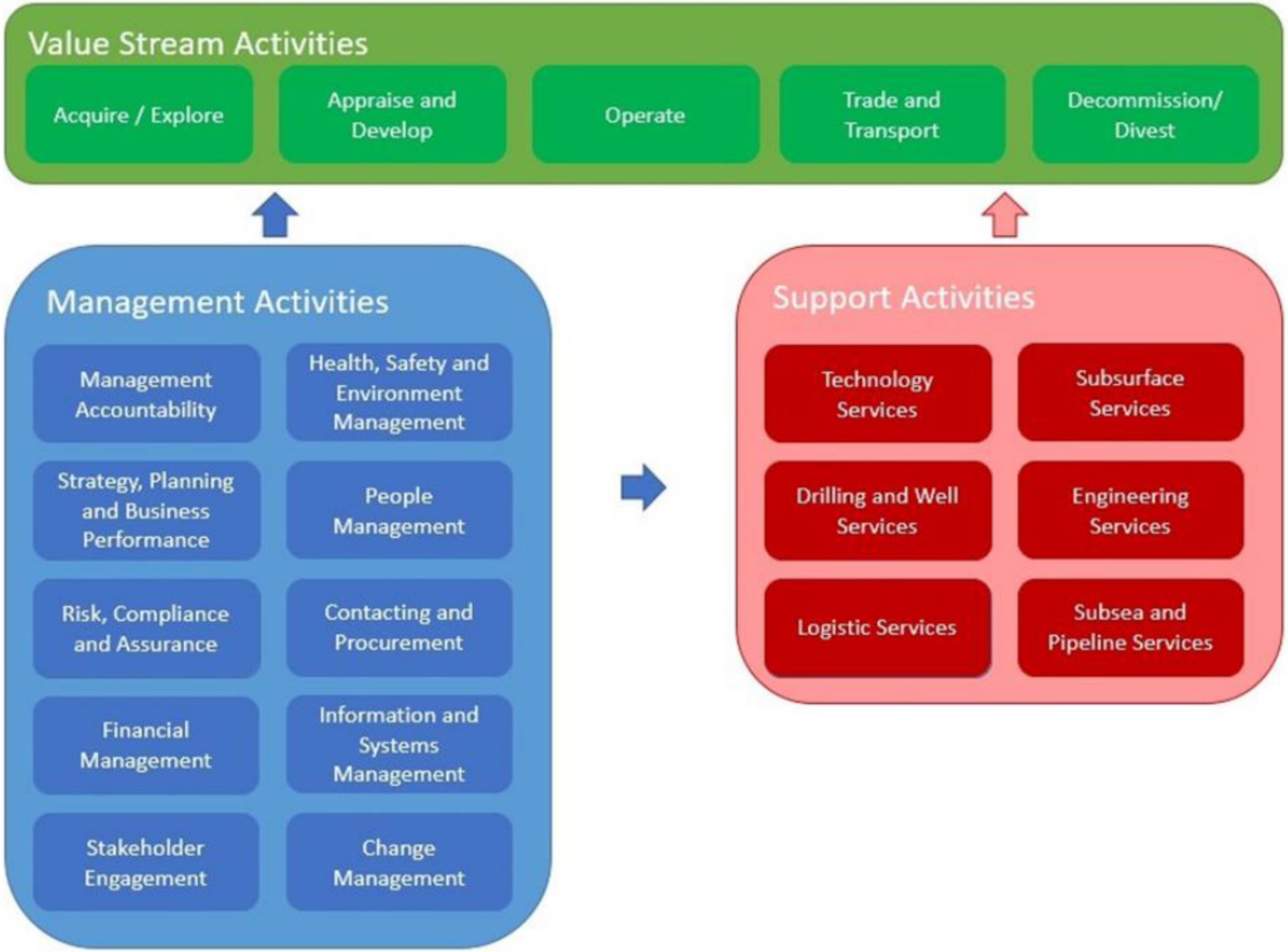

Figure 8-3 The WMS Business Process Hierarchy

8.6 Relationship of the WMS and the draft EIS/ERD

The objectives under the WMS define the mandatory performance requirements that apply to all Woodside activities, and the performance of its employees and contractors within their area of responsibilities. The management commitments made in this draft EIS/ERD and subsequent Environment Plans will be implemented through the WMS and supplemented where required by documentation specific to the proposed Browse to NWS Project.

8.7 Planning framework

Woodside sets environmental performance requirements through the life-cycle of projects and operations. This approach is based on:

- a robust environmental risk-management process
- credible and defensible science to underpin this approach
- strong relationships with local and international researchers
- ongoing stakeholder engagement
- transparency of our environmental knowledge.

Credible and defensible science is core to Woodside's environmental management approach and processes. Woodside's strong capability in environmental studies enables the acquisition of environmental data critical to inform impact assessments and decision making. Furthermore, strong relationships, sound research and transparency are the key elements of Woodside's approach to the environment.

Woodside has an established methodology that identifies impacts and risks and assesses the potential consequence of an activity. This methodology mandates that a risk hierarchy of controls be applied to management measures that are identified. This approach identifies ways to eliminate or avoid an impact before measures are considered to reduce or minimise it. The management measures include, as a minimum, those that are considered good international industry practice.

The end result of this risk-based process is that the residual impacts and risks of an activity are at a level considered to be acceptable.

8.8 Environmental record of person(s) undertaking the Proposed Action

8.8.1 Record of environmental management

Woodside, as operator for and on behalf of the BJV, believes excellence in environmental performance is essential to our business success worldwide and is compatible with balancing the economic, social and environmental needs of sustainable development.

Woodside employs a structured approach to the management of the environment via the formal and documented WMS. Through policies, processes, procedures and standards the WMS requires that impacts from Woodside's operations are either avoided or kept to ALARP. It also drives continuous improvement in the company's environmental performance.

Woodside's commitment to responsible environmental management was recognised by the Australian Petroleum Production and Exploration Association (APPEA) as the recipient of the Environment Excellence Award in 2009, 2012, 2015, 2016, 2017 and 2019. Woodside was recognised in 2009 for appraisal activities at Scott Reef, including environmental research undertaken at Scott Reef in association with the Maxima 3D marine seismic survey and the Gigas 2D Pilot Ocean Bottom Cable marine seismic survey. This recognition was for Woodside's approach to undertaking activities in a highly sensitive environmental setting. The 2012 and 2017 APPEA Environment Awards recognised Woodside's partnerships with AIMS and Western Australian Museum (WAM). These long-term relationships have contributed shared scientific knowledge to academic, government, industry and the broader community's understanding of biodiversity and ecological function in WA's tropical marine ecosystems.

8.8.2 Past or present procedures

Woodside has not been subject to any proceedings, either past or present, under a Commonwealth or State law for the protection of the environment or the conservation and sustainable use of natural resources.

8.9 Environmental management and mitigation

8.9.1 Overview

As part of the development of this draft EIS/ERD, management and mitigation measures have been identified and will be implemented to reduce the level of impact and risk of the proposed Browse to NWS Project to an acceptable level in consideration of the EPBC Act, EP Act and other relevant policy instruments (**Chapter 6**). This includes any practices that will reduce the impacts and risks in order to meet the identified environmental objectives, any relevant legal requirements (related specifically to the impact/risk), internal company requirements and any practices that will be adopted to manage stakeholder concerns identified through the consultation process. It should be noted that further review and potential adoption of additional controls will be undertaken in subsequent phases of the project, such as during the preparation of Environment Plans for activities under the scope of the approved action.

In accordance with Woodside's risk procedures and processes and for the purpose of the draft EIS/ERD, where an impact or risk has been assessed to be acceptable, no further management beyond legislative requirements and industry codes and standards will be required. Where the impact or risk level is not acceptable, additional management and mitigation measures have been considered.

The following framework tools have been applied, as appropriate, to assist with identifying appropriate management and mitigation measures:

- Good Industry Practice – identifies further engineering control standards and guidelines which may be applied by Woodside in addition to those required to meet the legislation, codes and standards.
- Professional Judgement – uses relevant personnel with the knowledge and experience to identify alternative controls.

Using these tools, the following hierarchy of controls have been used to identify appropriate management and mitigation measures for the proposed Browse to NWS Project:

- eliminate the risk by removing the hazard
- substitute a hazard with a lesser one
- prevent a credible impact from occurring by implementing additional engineering control measures
- reduce the magnitude of a credible impact by implementing additional engineering control measures (e.g. solids control equipment onboard MODU to manage cuttings discharge)
- mitigate the credible impact on the environment by reducing the extent, scale, duration of impact (e.g. bunding, oil spill booms, relief well)
- emergency response and contingency planning to facilitate recovery from the credible impact of an event.

Environmental objectives and proposed mitigation and management measures are presented in **Chapter 6**.

8.9.2 Central management and monitoring commitments

The central management and monitoring commitments are detailed in **Chapter 6** and summarised in **Chapter 1** and **Chapter 9**.

The measures presented in this draft EIS/ERD will be incorporated into activity-specific Environment Plans (**Section 8.14.1.1**) to be submitted for acceptance by NOPSEMA for Commonwealth waters and DMIRS for State waters, prior to the activity commencing where required.

8.10 Management Plans

Under the environmental management framework, specific environmental management plans will be prepared for the proposed Browse to NWS Project. These will include activity-specific Environment Plans (**Section 8.14.1.1**) and an Environmental Quality Management Plan applicable to the State Proposal Area (**Section 8.14.1.2**). Contractors will also be required to prepare environmental management plans for Woodside approval that detail how the project requirements will be met.

8.10.1 Environment Plans

8.10.1.1 Environment Plans

Accepted activity-specific Environment Plans will be required under both the OPGGS (E) Regulations (for Commonwealth waters) and the Petroleum (Submerged Lands) (Environment) Regulations 2012 (for State waters).

The Environment Plans must be appropriate for the nature and scale of the activity and describe the activity, the existing environment, details of environmental impacts and risks and the control measures for the activity. In addition, the Environment Plans must include an implementation strategy to demonstrate that the impacts and risks can be managed to ALARP and to describe how appropriate environmental performance outcomes, standards and measurement criteria outlined in the Environment Plans will be met. The Environment Plans must also provide a summary of all consultation undertaken with relevant persons.

The Environment Plans required in support of the proposed Browse to NWS Project will address activities related to:

- drilling development wells in both State and Commonwealth waters
- installing, commissioning and operating subsea

infrastructure in both State and Commonwealth waters

- installing, commissioning and operating the FPSO facilities (Commonwealth waters only)
- installing, commissioning and operating the BTL and Inter-field spur line (Commonwealth waters only)
- decommissioning activities at the end of the proposed Browse to NWS Project life.

Environment Plans will be supported by appropriate Oil Pollution Emergency Plans (OPEPs) and Operational and Scientific Monitoring Programs (OSMPs), which are required as a part of an Environment Plan's implementation strategy, noting that these may be developed to support a range of activities or phases of a project. The Environment Plans will be submitted for acceptance by NOPSEMA (Commonwealth waters) or DMIRS (State waters) before the activities listed above can commence.

8.10.1.2 Environmental Quality Management Plan (State Proposal Area)

As recommended in the WA EPA Technical Guidance – Protecting the Quality of Western Australia's Marine Environment (EPA, 2016), an Environmental Quality Management Plan (EQMP) will be prepared and implemented for the Proposal. The EQMP will only apply to the State Proposal Area. The EQMP will be developed using the principles and approaches outlined in the EPA's technical guidance. Refer to State ERD (**Chapter 10, Appendix B**).

8.10.1.3 Environmental Offset Plan

In the event that impacts cannot be avoided or mitigated to an acceptable level, an Environmental Offset Plan will be developed. Offsets associated with GHG emissions are specifically addressed in **Chapter 7** and will not be included in this offset plan.

The Environmental Offset Plan will provide details of offsets proposed to compensate for residual impacts on EPBC listed species, including the following:

- the type of offsets proposed
- the extent to which the proposed offset actions correlate to, and adequately compensate for, the impacts to EPBC listed species
- for proposed land-based offsets, the suitability of the location of proposed offset sites, including the current land tenure and method of securing and managing the offset for the life of the impact
- for non-land-based offsets, details of the proposed offset and how it will compensate for the proposal's residual significant impacts
- the conservation gains to be achieved by the offset (for example, positive management strategies that improve the site, or how the future loss, degradation or damage of the protected matter will be averted or mitigated)
- the time it will take to achieve the proposed conservation gains
- the level of certainty that the proposed offset will be successful.

The Environmental Offset Plan would be developed in accordance with the EPBC Act Environmental Offsets Policy (Commonwealth of Australia, 2012). (Commonwealth of Australia, 2012) or other relevant legislation or policy applicable at the time.

8.10.1.4 Environmental management Implementation approach

Roles and Responsibilities

Key roles and responsibilities for Woodside and Contractor personnel in relation to the implementation of controls identified in this draft EIS/ERD and subsequent Environment Plans are described in **Table 8-1**. In addition to these identified roles, it is the responsibility of all Woodside employees and contractors to implement the Woodside Corporate Health, Safety, Environment and Quality Policy in their areas of responsibility and that the personnel are suitably trained and competent in their respective roles.

Table 8-1 Roles and Responsibilties

Title (role)	Environmental Responsibilities
Woodside Project Manager	+ Verify implementation of the receptor or aspect-specific environmental management plans related to the proposed Browse to NWS Project. + Verify systems and procedures are in place to manage the activity so it is undertaken as per the relevant standards and commitments in this draft EIS/ERD and subsequent Environment Plans. + Verify that contractors meet environmental related contractual obligations.
Woodside Delivery Manager (FPSO, SURF, BTL)	+ Verify that environment expectations are understood by team members in line with the commitments set out in this draft EIS/ERD and subsequent Environment Plans. + Communicate environment performance, relevant information and Lessons Learnt to team members and contractors. + Verify application of contractor's management of environment requirements, in accordance with the draft EIS/ERD and subsequent Environment Plans.
Woodside Environment Adviser	+ Track and report on compliance against environmental commitments as per the requirements of this draft EIS/ERD and subsequent Environment Plans. + Prepare environmental components of relevant Induction Package. + Provide advice to Woodside personnel and contractors to assist them with understanding their environment responsibilities.
Woodside Drilling Superintendent	+ Verify that the drilling program meets the requirements detailed in this draft EIS/ERD and subsequent Environment Plans.
Woodside Drilling and Subsea Engineers	+ Verify that all chemicals and drilling fluids proposed to be used for Browse drilling and completion activities are assessed and approved as per the requirements of the draft EIS/ERD and subsequent Environment Plans.
Woodside Corporate Affairs Adviser	+ Prepare and implement the Stakeholder Consultation Plan for the proposed Browse to NWS Project activities.
Woodside Marine Assurance Superintendent	+ Conduct relevant audits and inspections to confirm vessels are compliant with relevant Marine Orders and Woodside Marine Charters Instructions requirements to meet safety, navigation and emergency response requirements.
Offshore Installation Manager (OIM) (MODU, FPSOs)	+ Verify that the WMS is implemented. + Verify that personnel receive an environmental induction that meets the requirements specified in this draft EIS/ERD and subsequent Environment Plans.
Woodside Site Representative	+ Verify that proposed Browse to NWS Project scopes are undertaken as detailed in this draft EIS/ERD and subsequent Environment Plans. + Verify the management measures detailed in this draft EIS/ERD and subsequent EPs are implemented on the MODU/FPSO/Vessels.
Offshore HSE Adviser/ Vessel HSE Advisers	+ Support Woodside Site Representatives to ensure that the controls detailed in this draft EIS/ERD and subsequent Environment Plans. relevant to offshore activities are implemented and assist in collection and recording of evidence of implementation. + Confirm that periodic environmental inspections/reviews are completed and corrective actions from inspections are developed, tracked and closed out in a timely manner.
Vessel Master	+ Verify that the vessel management system and procedures are implemented. + Verify that personnel commencing work on the vessel receive an environmental induction that meets the requirements specified in this draft EIS/ERD and subsequent Environment Plans.
Vessel Logistics Coordinators	+ Confirm that waste is managed appropriately on the relevant support vessels as per the requirements of this draft EIS/ERD and subsequent Environment Plans.
Contractor Project Manager	+ Verify that activities are undertaken in accordance with this draft EIS/ERD and subsequent EPs, as detailed in the Woodside approved Contractor's Environmental Management Plans. + Verify that personnel commencing work on the project receive a relevant environmental induction that meets the requirements of this draft EIS/ERD and subsequent Environment Plans.

Emergency Preparedness and Response

Woodside will have an Emergency Response Plan (ERP) in place for all petroleum activities associated with the proposed Browse to NWS Project. The ERP will provide procedural guidance specific to the activity to control, coordinate and respond to an emergency or incident, including hydrocarbon spills.

Under Regulations 14(8) of the OPGGS (E) Regulations, the implementation strategy for Environment Plans in Commonwealth waters must contain an OPEP and provide for the updating of the OPEP. Regulation 14(8AA) outlines the requirements for the OPEP, which must include adequate arrangements for responding to and monitoring of oil pollution. For State waters Environment Plans under the Petroleum (Submerged Lands) (Environment) Regulations 2012, an oil spill contingency plan (OSCP) is required under regulation 12 (as part of the Environment Plan).

A significant hydrocarbon spill during the petroleum activities associated with the proposed Browse to NWS Project is unlikely but, should such an event occur, it will be managed in accordance with Woodside's overarching emergency response system and supporting documents. Supporting documents include the relevant ERPs, OPEPs, OSCPs and specific plans that provide tactical response guidance to the activity/area.

Monitoring of Environmental Performance

Environmental objectives have been developed for each environmental aspect (**Section 6**). In addition, Environmental Performance Objectives (EPOs) standards and measurement criteria will be developed and monitored as part of the development and subsequent implementation of Environment Plans.

To verify that requirements are met, Woodside and its contractors will monitor compliance during execution of the proposed Browse to NWS Project. The monitoring will be described in detail in the various management plans (**Section 8.14**) and Environment Plans for the specific activities and will make use of tools and systems that are appropriate to the activity and the project teams.

Auditing

During the execution of project activities, environmental performance auditing will be undertaken to:

- identify potential new environmental impacts and risks or changes to existing environmental impacts and risks
- confirm that any controls that are applied to manage impacts and risks to an acceptable level are effective
- confirm compliance with the controls and environmental performance standards detailed in future Environment Plans.

Reporting

Woodside will undertake external reporting at a number of levels. These reporting arrangements are outlined below.

Environmental Performance Reporting

In accordance with applicable environmental legislation, Woodside, as operator for and on behalf of the BJV, is required to report information on environmental performance during the implementation of the proposed Browse to NWS Project including:

- Annual compliance reporting addressing compliance with any conditions of approvals under the EPBC Act and EP Act.
- Monthly Recordable Incident Reports – submitted monthly to NOPSEMA and DMIRS, with details of recordable incidents that have occurred during the previous month (if any).
- Environmental Performance Reports – submitted annually to NOPSEMA and DMIRs and addressing compliance with the EPOs outlined in subsequent Environment Plans developed for activities associated with the proposed Browse to NWS Project.
- Notification of reportable incidents to NOPSEMA or DMIRs according to the requirements of Regulations 26, 26A and 26AA of the Environment Regulations or Regulation 28 of the Petroleum (Submerged Lands) (Environment) Regulations 2012, respectively.

Management of Change

Management of changes to activity scope that are relevant to this draft EIS/ERD (**Chapter 3**) will be in accordance with Regulation 17 of the Environment Regulations. These changes may include:

- review of advances in technology at stages where new equipment may be selected
- changes in understanding of the environment, including all current advice on species protected under the EPBC Act
- current requirements for AMPs (**Chapter 5**)
- potential new advice from external stakeholders (**Chapter 4**).

Risk will be assessed in accordance with the Environmental Risk Management Methodology (**Chapter 6**) to determine the significance of any potential new environmental impacts or risks not provided for in this draft EIS/ERD or subsequently submitted Environment Plans. Risk assessment outcomes will be reviewed in compliance with Regulation 17 of the Environment Regulations.

CHAPTER 9

OVERALL CONCLUSIONS

9. OVERALL CONCLUSIONS

9.1 Summary

Woodside, on behalf of the BJV, has prepared this draft EIS/ERD for the proposed Browse to NWS Project to meet the requirements of the EPBC Act and EP Act, as set out in the approved EISG/ESD. Significant work has been completed by Woodside and the BJV participants to understand the environmental context of the proposed Browse to NWS Project and develop a proposal for the development of the Browse resources that aligns with the principles of Ecologically Sustainable Development (ESD).

This Chapter provides a qualitative assessment of the cumulative impacts by receptor, based on the detailed aspect-based impact and risk assessment provided in **Chapter 6**. It also provides an overall conclusion as to the environmental acceptability of the proposed Browse to NWS Project and includes discussion on alignment with the principles of ESD and the objectives and requirements of the EPBC Act and EP Act. Consideration has also been made of the potential cumulative environmental impacts of the proposed Browse to NWS Project and any existing and future concurrent activities.

The significance of the potential impacts to key receptor groups associated with each aspect of the proposed Browse to NWS Project are detailed in **Chapter 6**, including the acceptability of predicted impacts and potential risks for each aspect in terms of the defined acceptability criteria. In addition, **Chapter 7** specifically addresses GHG emissions, including estimated contributions to global emissions.

9.2 Overall Assessment of Impacts on Receptors (Cumulative Impacts)

9.2.1 Aspect-based cumulative impacts

An aspect-based cumulative impact assessment (i.e. assessment of cumulative impacts from the same aspect resulting from multiple project activities and other developments in the area) is presented for each aspect in **Chapter 6**. This assessment has shown that aspect-based cumulative impacts resulting from the proposed Browse to NWS Project are unlikely to result in significant impacts. The majority of emissions and discharges will be within the Browse Development Area, which is in a remote, offshore location and unlikely to result in significant interactions with other activities/ developments.

9.2.2 Receptor based cumulative impacts

Table 6-2 outlines all the aspect-receptor relationships identified during the assessment of impacts and risks associated with the proposed Browse to NWS Project. Each of these relationships are discussed in **Chapter 6** and **Table 6-2** also highlights where multiple aspects may impact common receptors (i.e. receptor-based cumulative impacts). The cumulative impact assessment focuses on predicted impacts from planned routine and non-routine activities and evaluates the nature of any aspect interaction (e.g. whether one aspect exacerbates the impact of another) and the scale of the cumulative impact as a result. This assessment has not been completed for risks, as the likelihood of the events coinciding is low. An overall assessment of the environmental risks from unplanned events and incidents is presented in **Section 9.3**.

Regional facility/activity context

The Prelude, Ichthys and Crux facilities are located >100 km to the north east of the Browse Development Area and the south western end of the BTL is located in close proximity to the North Rankin Complex (NRC).

Shipping activity in and around the Browse Development Area is sparse, with the main commercial shipping routes located approximately 50 to 100 km west of the Development Area, intersecting the proposed BTL route at various locations depending on the port. Future seismic survey activities may be undertaken by Woodside and/or other operators in the region.

9.2.2.1 Physical Receptors

Marine sediment quality (medium value (open waters))

Table 9-1 Marine sediment quality cumulative assessment

<table>
<tr><th>Receptor</th><th colspan="3">Sediment Quality</th></tr>
<tr><td>Local environment context</td><td colspan="3">Sediments in the Project Area are typical of an undisturbed tropical offshore environment, with low concentrations of metals and nutrients and no hydrocarbons detected from marine sediment quality seabed sampling (refer to Section 5.2.10).</td></tr>
<tr><td>Receptor sensitivity</td><td colspan="3">Medium value (open waters)
Ambient sediment quality is typical of the surrounding environment, with low sensitivity to change and no features of conservation value</td></tr>
<tr><td>Environmental objective</td><td colspan="3">Objective 1: To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.
Objective 2: To not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected.</td></tr>
<tr><td rowspan="6">Relevant aspects: Proposed Browse to NWS Project</td><td><i>Aspect</i></td><td><i>Magnitude</i></td><td><i>Impact significance level</i></td></tr>
<tr><td>Physical Presence: Seabed disturbance</td><td>No lasting effect</td><td>Negligible (F)</td></tr>
<tr><td>Marine Discharges: Produced water</td><td>No lasting effect</td><td>Negligible (F)</td></tr>
<tr><td>Marine Discharges: Drilling discharges</td><td>Minor</td><td>Minor (D)</td></tr>
<tr><td>Marine Discharges: Subsea control fluids</td><td>Slight</td><td>Slight (E)</td></tr>
<tr><td>Marine Discharges: Hydrotest Fluid</td><td>No lasting effect</td><td>Negligible (F)</td></tr>
<tr><td colspan="4"><i>Aspect Interaction Assessment and Conclusion</i></td></tr>
<tr><td colspan="4">Given the isolated FPSO locations, cumulative impacts on sediment resulting from interactions with other facilities and regional vessel/air traffic are not considered credible.
As described throughout Chapter 6, discharges from construction activities and during operations will be managed to ensure no change to sediment quality within the Scott Reef shallow water benthic habitats (<75 m water depth), therefore impacts to sediment will be confined to deep water.
Impacts to sediment from the Browse to NWS Project are expected to primarily result from drilling discharges (e.g. cementing, cuttings/fluids). There is potential for overlap of impact from drilling discharges and subsea control fluids in the immediate vicinity around the wells. Control fluid impacts will occur in the area previously impacted by drilling discharges. Impacts associated with hydrotest discharges may overlap with impacts from prior drilling discharges where the discharge point is in the vicinity of a drill centre, however, they will be short lived and localised. There is also potential for interaction between BTL hydrotest discharges at NRC and existing discharges (e.g. PW) from that facility. These impact interactions are not expected to exacerbate the aspect-based impacts previously described in Chapter 6, due to their localised scale and temporary nature (e.g. hydrotest discharges), dynamic receiving environment and general lack of reactivity between the discharges.
The overall impact significance level of impacts on sediment quality has been assessed as Minor (D) (based on the assessment of impacts resulting from drilling discharges). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objectives for this receptor will be achieved and this impact is assessed as Acceptable.</td></tr>
</table>

Water quality (medium value (open waters))

Table 9-2 Water quality cumulative assessment

Receptor	Water Quality		
Local environment context	Water quality in the Project Area near the location of the proposed subsea infrastructure and facilities is typical of an undisturbed tropical offshore environment. Much of the surface waters in this area is nutrient-poor, influenced by the Indonesian Throughflow, with low levels of primary productivity (Section 5.2.9).		
Receptor sensitivity	**Medium value (open water)** Ambient water quality is typical of an open water environment, with low sensitivity to change.		
Environmental objective	**Objective 3:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.[1]		
Relevant aspects: Proposed Browse to NWS Project	***Aspect***	***Magnitude***	***Impact significance level***
	Physical Presence: Seabed Disturbance	No lasting effect	Negligible (F)
	Marine Discharges: Sewage and Sullage	Slight	Slight (E)
	Marine Discharges: Treated Utility Water, Chemical and Deck Drainage	Slight	Slight (E)
	Marine Discharges: Putrescible Waste	Slight	Slight (E)
	Marine Discharges: Produced Water	Minor	Minor (D)
	Marine Discharges: Cooling Water	Minor	Minor (D)
	Marine Discharges: Drilling and Completions	Slight	Slight (E)
	Marine Discharges: Subsea control fluids	Slight	Slight (E)
	Marine Discharges: Hydrotest Fluid	No lasting effect	Negligible (F)

Receptor	**Water Quality**
Aspect Interaction Assessment and Conclusion	
Given the isolated FPSO locations, cumulative impacts on water quality resulting from interactions with other facilities and regional vessel/air traffic are not considered credible. There is potential for interaction between the BTL hydrotest discharge at NRC and existing discharges (e.g. PW) from that facility, however, this is likely to be of a short duration (**Section 6**) and the peak concentrations will be physically separated as the BTL will be discharged near seabed and the NRC PW plume is positively buoyant. Impacts to water quality are predicted to primarily arise from the discharge of PW (**Section 6.3.12**) and cooling water (**Section 6.3.13**) from the FPSO facilities during the operations phase, as these discharges are persistent for the field life. Less significant impacts are predicted as a result of short-term or temporary discharges (i.e. discharge of drill cuttings and fluids during development drilling, subsea control fluids, hydrotest fluids, treated sewage and sullage, treated utility water and putrescible waste). As described in **Chapter 6**, operational discharges (PW and cooling water from the FPSO facilities) will be managed to meet the defined threshold values (i.e. 99% species protection or no effect concentrations) at the edge of the mixing zone and at the State waters 3 nm boundary 95% of the time, based on dispersion modelling results. As such, no impacts from operational discharges to water quality within the Scott Reef shallow water benthic habitat (<75m) are predicted. It is recognised that plumes from operational discharges (PW, cooling water and sewage and sullage) occur simultaneously from the same facility. This has the potential to result in chemical interactions between the constituents of the discharges. However, given the reactive and volatile nature of constituents as well as the low concentrations of constituents in the discharges (ie chlorine <1ppm), it is considered that the constituents of a single discharge will react faster with the marine environment than they will with other plumes. For example, dosing of cooling water with chlorine (as sodium hypochlorite) may give rise to chlorine-produced oxidants comprising weak hypochlorous acid, hypochlorite ions and hypobromous acid, depending on the conditions of the marine environment. The decay of these chlorine-produced oxidants is already rapid in the marine environment (DHI 2011a), and therefore unlikely to react with other discharges. This is particularly true as the plumes caused by the discharges dilute rapidly in the marine environment, and are unlikely to immediately come into contact with other plumes before they are diluted. It is therefore highly likely that any undesirable molecular compounds generated from temporary plume co-occurrence and chemical reactions will be below detectable/background thresholds, particularly towards sensitive receptors ie Scott Reef. As per the management approach for Produced Water, baseline and periodic monitoring in the receiving environment will be undertaken to detect changes to water and sediment quality as a result of FPSO facility PW discharge. The effect of these changes in water quality is not expected to be cumulative in the context of the broader region, given the assimilative capacity of the open ocean receiving environment, physical separation of discharge point and the localised scale of the impacts. As such, the overall impact significance level of impacts on water quality has been assessed as Minor (D) (based on the assessment of impacts resulting from PW and cooling water discharges from the FPSO facilities). As per the criteria outlined in **Section 6.2.3.4**, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.	

Air quality (medium value (open waters))

Table 9-3: Air quality cumulative assessment

<table>
<tr><th>Receptor</th><th colspan="3">Air Quality</th></tr>
<tr><td>Local environment context</td><td colspan="3">Given the distance from any significant anthropogenic emissions sources, air quality within the Project Area is expected to be high (Section 5.2.6).</td></tr>
<tr><td>Receptor sensitivity</td><td colspan="3">Medium value (open water)
Ambient air quality is typical of an open water environment, with low sensitivity to change</td></tr>
<tr><td>Environmental objective</td><td colspan="3">Objective 4: To not result in a substantial change in air quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.</td></tr>
<tr><td rowspan="2">Relevant aspects: Proposed Browse to NWS Project</td><td><i>Aspect</i></td><td><i>Magnitude</i></td><td><i>Impact significance level</i></td></tr>
<tr><td>Atmospheric emissions: offshore activities</td><td>Slight</td><td>Slight (E)</td></tr>
<tr><td colspan="4"><i>Aspect Interaction Assessment and Conclusion</i></td></tr>
<tr><td colspan="4">Given the isolated FPSO locations, cumulative impacts on air quality resulting from interactions with other facilities and regional vessel/air traffic are not considered credible. Impacts to local air quality resulting from atmospheric emissions (excluding GHG) associated with the offshore activities are predicted to be negligible (Section 6.3.5) and, therefore, the potential for cumulative impacts from multiple sources is considered low.
As such, the overall impact significance level of impacts on air quality has been assessed as Slight (E). As per the criteria outlined in Section 6.2.3.4, this impact is assessed as Acceptable.
Potential impacts associated with atmospheric emissions resulting from the onshore processing of the Browse gas by the NWS JV on the national heritage values of the listed National Heritage Place on the Dampier Archipelago (including aboriginal heritage values) are assessed in the ERD associated with the North West Shelf Project Extension Proposal (EPA 2186, EPBC 2018/8335). Given the distance between the offshore activities and the NWS JV onshore facility, no cumulative impacts are predicted.
GHG emissions, including estimated contributions of NWS scope 1 emissions attributable to the proposed processing of Browse feed gas by the NWS JV and scope 1 and 3 emissions from the proposed Browse to NWS Project to global GHG emissions, are addressed in Chapter 7. This assessment considered the Principals of ESD, MNES Significant Impact Guidelines and the WA EPA Environmental Objectives; as well as GHG specific requirements such as the Paris Agreement, Australia’s Nationally Determined Contributions and the Safeguard Mechanism (SGM). The assessment concluded that in consideration of these requirements the proposed Browse to NWS Project is Acceptable.</td></tr>
</table>

Ambient light (medium value (open waters))

Table 9-4: Ambient light cumulative assessment

<table>
<tr><th>Receptor</th><th colspan="3">Ambient light</th></tr>
<tr><td>Local environment context</td><td colspan="3">The Project Area is located approximately 260 km from the shore where there are no existing significant sources of artificial light. The proposed BTL route is also distant from sources of light emissions, except where the proposed BTL route ties in near the existing NRC facilities (Section 5.2.7).</td></tr>
<tr><td>Receptor sensitivity</td><td colspan="3">Medium value (open water)
Ambient light is typical of an open water environment, with low sensitivity to change.</td></tr>
<tr><td>Environmental objective</td><td colspan="3">Objective 5: To not result in a substantial change in ambient light or ambient noise which may adversely impact on biodiversity, ecological integrity, social amenity or human health.</td></tr>
<tr><td rowspan="2">Relevant aspects: Proposed Browse to NWS Project</td><td><i>Aspect</i></td><td><i>Magnitude</i></td><td><i>Impact significance level</i></td></tr>
<tr><td>Physical presence: light</td><td>Slight</td><td>Slight (E)</td></tr>
<tr><td colspan="4"><i>Aspect Interaction Assessment and Conclusion</i></td></tr>
<tr><td colspan="4">Given the isolated FPSO locations, cumulative impacts on ambient light resulting from interactions with other facilities and regional shipping activities are not considered credible. Impacts to ambient light levels resulting from light emissions associated with the proposed Browse to NWS Project, including the FPSO facilities, vessels and MODUs, are predicted to be slight (Section 6.3.3) and, therefore, the potential for cumulative impacts from multiple sources is considered low.
As such, the overall impact significance level of impacts on ambient light has been assessed as Slight (E). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as Acceptable.</td></tr>
</table>

Ambient noise (medium value (open waters))

Table 9-5: Ambient noise cumulative assessment

<table>
<tr><th>Receptor</th><th colspan="3">Ambient noise</th></tr>
<tr><td>Local environment context</td><td colspan="3">Atmospheric noise
The existing anthropogenic noise environment within the vicinity of the Project Area is expected to be primarily associated with commercial shipping activities, as well as occasional petroleum exploration activities. Similar sources of anthropogenic underwater ambient noise may be expected along the proposed BTL route.
Underwater noise
Underwater noise in the Project Area is characterised by occasional general vessel traffic, seismic surveys, suspected illegal blast fishing at Scott Reef and marine fauna. Underwater noise from marine fauna recorded at the Browse Development Area included calls from humpback whales, minke and dwarf minke whales, pygmy blue whales, Bryde’s whales, as well as calls from unidentified whales and fish chorus (Section 5.2.8).</td></tr>
<tr><td>Receptor sensitivity</td><td colspan="3">Medium value (open water)
Ambient noise is typical of an open water environment, with low sensitivity to change.</td></tr>
<tr><td>Environmental objective</td><td colspan="3">Objective 5: To not result in a substantial change in ambient light or ambient noise which may adversely impact on biodiversity, ecological integrity, social amenity or human health.</td></tr>
<tr><td rowspan="3">Relevant aspects: Proposed Browse to NWS Project</td><td><i>Aspect</i></td><td><i>Magnitude</i></td><td><i>Impact significance level</i></td></tr>
<tr><td>Atmospheric Noise Emissions</td><td>No lasting effect</td><td>Negligible (F)</td></tr>
<tr><td>Underwater Noise Emissions</td><td>Slight</td><td>Slight (E)</td></tr>
<tr><td colspan="4"><i>Aspect Interaction Assessment and Conclusion</i></td></tr>
<tr><td colspan="4">Given the isolated FPSO locations, cumulative impacts on ambient noise resulting from interactions with other facilities and regional shipping activities are not considered credible. There may, on occasion, be overlap between facility operational noise and regional seismic surveys completed by Woodside and/or other operators. This interaction would be managed in Environment Plans required under Petroleum Legislation.
Atmospheric (Section 6.3.7) and underwater (Section 6.3.8) noise emissions are predicted to occur during all phases of the proposed Browse to NWS Project. Impacts of these noise emissions on ambient atmospheric noise levels are, however, expected to be Negligible (F). Impacts from underwater noise are expected to be Slight (E). Sensitive receptors to underwater noise are generally different to the receptors for atmospheric noise, and primary sources of atmospheric noise at the Browse Development Area (helicopters, piling, flaring) will be intermittent, no significant cumulative impact to ambient atmospheric noise levels is predicted.
As such, the overall impact significance level of impacts on ambient noise has been assessed as Slight (E). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as Acceptable.</td></tr>
</table>

9.2.2.2 Ecological Receptors

Plankton communities (medium value (open waters))

Table 9-6: Plankton communities cumulative assessment

Receptor	Plankton Communities		
Local environment context	Plankton communities have a naturally variable distribution in both space and time, noting that the NWMR is typically characterised by low planktonic productivity. Estimates of the phytoplankton biomass (measured as chlorophyll a) close to Scott Reef are approximately twice that of open waters (sampled at distances greater than 50 km to the south-west of South Scott Reef). The open water location sampled is likely to be representative of the general outer shelf open water environment and so is representative of the oceanic waters of the Project Area (Section 5.3.1.1).		
Receptor sensitivity	**Medium value (open water)** Plankton populations are typical of an open water environment, with low sensitivity to change due to high turnover/recovery and no species of high importance or quality.		
Environmental objective	**Objective 7:** To not have a substantial adverse effect on a population of plankton, including its lifecycle and spatial distribution.		
Relevant aspects: Proposed Browse to NWS Project	***Aspect***	***Magnitude***	***Impact significance level***
	Physical Presence: Seabed Disturbance	No lasting effect	Negligible (F)
	Physical Presence: Light	No lasting effect	Negligible (F)
	Underwater Noise Emissions	No lasting effect	Negligible (F)
	Marine Discharges: Sewage and Sullage	No lasting effect	Negligible (F)
	Marine Discharges: Treated Utility Water, Chemical and Deck Drainage	No lasting effect	Negligible (F)
	Marine Discharges: Putrescible Waste	No lasting effect	Negligible (F)
	Marine Discharges: Produced water	Slight	Slight (E)
	Marine Discharges: Cooling Water	Slight	Slight (E)
	Marine Discharges: Drilling Discharges	No lasting effect	Negligible (F)
	Marine Discharges: Subsea control fluids	No lasting effect	Negligible (F)
	Marine Discharges: Hydrotest Fluid	No lasting effect	Negligible (F)

Receptor	Plankton Communities
Aspect Interaction Assessment and Conclusion	
Given the isolated FPSO locations, cumulative impacts on plankton resulting from interactions with other facilities and regional vessel/air traffic are not considered credible. Slight impacts to plankton communities may result from multiple but separated discharge streams, including PW (Section 6.3.12) and cooling water (Section 6.3.13) discharges from the FPSO facilities during operations. Less significant impacts, expected to have no lasting effect on plankton populations, may occur during construction, commissioning and operations as a result of discharges including hydrotest fluid, vessel cooling water, treated utility water and putrescible waste; as well underwater noise emissions. As described above, no significant increase in toxicity is predicted as a result of potential comingling of the PW and cooling water plumes after discharge. Furthermore, plankton populations are widespread and have a high turnover. The predicted cumulative impacts resulting from the multiple discharge streams are not expected to be significant. As such, the overall impact significance level of impacts on plankton has been assessed as Slight (E) (based on the assessment of impacts resulting from PW and cooling water discharges from the FPSO facilities). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.	

Shallow water benthic communities and habitats (<75 m water depth) (high value habitat)
As detailed in Chapter 6, no infrastructure is planned to be placed on or near any shallow water benthic habitats (e.g. Scott Reef and the Rowley Shoals). In addition, discharges during construction, commissioning and operations will be managed to avoid impact to these shallow water benthic habitats. This will include a commitment to manage operational discharges (PW and cooling water from the FPSO facilities) to meet the defined threshold values (i.e. 99% species protection or lowest no effect concentration) at the edge of the mixing zone and at the State waters 3 nm boundary, 95% of the time; and a commitment to manage drilling discharges (in particular bottom hole discharges) at drill centre locations in the State Proposal Area (i.e. TRA, TRD, TRE and TRF) in such a manner to avoid impacts to Scott Reef shallow water benthic communities and habitats (<75 m water depth). These management objectives are supported by a range of both feasible and industry proven management measures. As such, no cumulative impact assessment is warranted for this receptor.

Deepwater benthic communities and habitats (>75 m water depth) (medium value habitat)

Table 9-7: Deepwater benthic communities and habitats cumulative assessment

Receptor	Deepwater benthic communities and habitats
Local environment context	The benthic communities inhabiting the predominantly soft, fine sediments of the deepwater benthic habitats are characterised by infauna such as polychaetes and sparsely distributed sessile and mobile epifauna. The density of benthic fauna is typically lower in deep-sea sediments (greater than 200 m) than in shallower coastal sediment habitats, but the diversity of communities may be similar. As confirmed by deepwater surveys (Section 5.3.1.2).
Receptor sensitivity	**Medium value** No species of high importance.
Environmental objective	**Objective 6:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity results.

Receptor	**Deepwater benthic communities and habitats**		
Relevant aspects: Proposed Browse to NWS Project	***Aspect***	***Magnitude***	***Impact significance level***
	Physical Presence: Seabed Disturbance	Minor	Minor (D)
	Underwater Noise Emissions	No lasting effect	Negligible (F)
	Marine Discharges: Sewage and Sullage	No impact expected	
	Marine Discharges: Treated Utility Water, Chemical and Deck Drainage	No impact expected	
	Marine Discharges: Putrescible Waste	No impact expected	
	Marine Discharges: Produced water	No impact expected	
	Marine Discharges: Cooling Water	No impact expected	
	Marine Discharges: Drilling Discharges	Slight	Slight (E)
	Marine Discharges: Subsea control fluids	No lasting effect	Negligible (F)
	Marine Discharges: Hydrotest Fluid	No lasting effect	Negligible (F)

Aspect Interaction Assessment and Conclusion

Cumulative impact from oil and gas infrastructure within the Browse Development Area and broader Browse Basin effects a relatively small proportion of deepwater benthic habitat and community types present in these areas. The habitat types affected are typically of low sensitivity (relatively benign, see above) as infrastructure typically avoids areas of complex bathymetry and inferred higher habitat sensitivity. Minor impacts to the deepwater benthic habitats and communities are predicted within the Project Area as a result of the localised physical footprint of the installed subsea infrastructure, BTL and inter-field spur line (including seabed preparation and installation activities) (**Section 6.3.1**). In addition, discharges during construction, commissioning and operations (including the drilling discharges, subsea control fluids and hydrotest fluids) may impact these deepwater benthic habitats and communities.

Combined impacts to deepwater benthic habitats and communities within the Project Area as a result of the installation of the subsea infrastructure and drilling discharges (**Section 6.3.15**) are not expected to be significant as they will be restricted to areas largely composed of sediment habitat and sparse benthic biota and the physical footprint represents a small fraction of the widespread and representative deepwater benthic habitat type within the region. Further, there are no predicted lasting impacts to these deepwater benthic habitats from other discharges related to the proposed Browse to NWS Project.

As such, the overall impact significance level of impacts on deepwater benthic habitats has been assessed as Minor (D) (based on the assessment of impacts resulting from seabed disturbance (Minor (D)) and drilling discharges (Slight (S)). As per the criteria outlined in **Section 6.2.3.4**, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.

Fauna (high value species)

Seabirds and migratory shorebirds

Table 9-8: Seabirds and migratory shorebirds cumulative assessment

<table>
<tr><th>Receptor</th><th colspan="3">Seabirds and migratory shorebirds</th></tr>
<tr><td>Local environment context</td><td colspan="3">As the only emergent land mass within the immediate vicinity of the Browse Development Area, Scott Reef serves to provide nesting and/or roosting for seabirds, albeit in small numbers in comparison to other breeding and roosting sites in the region. This includes the little tern, which has a resting BIA at Scott Reef, associated with Sandy Islet. In addition, due to the large geographical range of seabirds, most species occurring within the wider NWMR have the potential to occur and transit through the Project Area.
The islands of the Rowley Shoals (which the BTL route passes by at a distance of a few kilometres) are known to support a wide range of seabird species, including WA's second largest breeding colony of red-tailed tropicbird. The Rowley Shoals have also been identified as BIAs for the white-tailed tropicbird.
Migratory shorebirds are occasionally observed in very low numbers at Scott Reef and Sandy Islet may be used as a staging ground during the migration between the Northern Hemisphere and Australia. However, given its small size, Sandy Islet is unlikely to support large numbers of migratory shorebirds. Due to the large geographical ranges of migratory shorebirds, many of the species known to occur within the wider NWMR have the potential to transit through the Project Area, which overlaps with the migratory shorebird corridor. Shorebird presence in the Project Area is expected to be transitory and seasonal (Section 5.3.2.3).</td></tr>
<tr><td>Receptor sensitivity</td><td colspan="3">High value species
MNES species known to be present.</td></tr>
<tr><td>Environmental objective</td><td colspan="3">Objective 11: To not have a substantial adverse effect on a population of seabirds or migratory shorebirds, or the spatial distribution of the population.
Objective 12: To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species.
Objective 13: To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species.</td></tr>
<tr><td rowspan="6">Relevant aspects: Proposed Browse to NWS Project</td><td><i>Aspect</i></td><td><i>Magnitude</i></td><td><i>Impact significance level</i></td></tr>
<tr><td>Physical Presence: Light</td><td>Slight</td><td>Minor (D)</td></tr>
<tr><td>Atmospheric Emissions: Offshore Activities</td><td>No lasting effect</td><td>Slight (E)</td></tr>
<tr><td>Atmospheric Noise Emissions</td><td>No lasting effect</td><td>Slight (E)</td></tr>
<tr><td>Marine Discharges: Putrescible Waste</td><td>No lasting effect</td><td>Slight (E)</td></tr>
<tr><td>Production Activities: Seabed Subsidence</td><td>No lasting effect</td><td>Slight (E)</td></tr>
</table>

Receptor	Seabirds and migratory shorebirds
Aspect Interaction Assessment and Conclusion	
Given the isolated FPSO locations, cumulative impacts on seabirds and migratory shorebirds resulting from interactions with other facilities and regional vessel/air traffic are not considered significant. As nesting and feeding aggregation areas are generally in coastal locations, the greatest potential for cumulative industrial impacts in the region is due to increased prevalence of light sources that may interrupt migratory behaviour. Given the extremely low density of oil and gas infrastructure, cumulative impact at a population level is considered unlikely. Some slight behavioural impact on seabirds and migratory shorebirds may occur as a result of atmospheric noise from helicopters and flaring and light emissions from vessels, MODUs and the FPSO facilities. However, the slight magnitude of these light impacts and the infrequent nature of the atmospheric noise emissions means that no increase to the significance of the predicted impacts due to exposure to multiple aspects is predicted. As such, the overall impact significance level of impacts on seabirds and migratory shorebirds has been assessed as Minor (D) (based on the assessment of impacts resulting from light emissions (Minor (D)) and atmospheric noise (Slight (S)). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objectives for this receptor will be achieved and this impact is assessed as **Acceptable**.	

Fish

Table 9-9: Fish cumulative assessment

Receptor	Fish
Local environment context	Fish assemblages within the Browse Development Area occupy a diverse range of habitats and are typical of the fish communities and species representative of the Timor Province. These fish assemblages include : + shallow-water, site-attached coral reef fish communities with characteristically high diversity and abundance + open water pelagic fish + deepwater, demersal fish communities (**Section 5.3.2.8**). EPBC Act listed fish species that may occur within the Project Area include the whale shark, shortfin mako, longfin mako, green sawfish and largetooth sawfish. The whale shark foraging BIA extends north along the northern WA coastline (predominately inshore of the Project Area) from Ningaloo almost to the Northern Territory (NT) border (Section 5.3.2.2). Based on studies undertaken of the whale shark's migratory behaviours, this species may occur within the Project Area, albeit in low numbers (Section 5.3.2.7).
Receptor sensitivity	**High value species** MNES species known to be present.
Environmental objective	**Objective 12**: To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13**: To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 14**: To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population.

Receptor	**Fish**		
Relevant aspects: Proposed Browse to NWS Project	***Aspect***	***Magnitude***	***Impact significance level***
	Physical Presence: Light	No lasting effect	Slight (E)
	Physical Presence: Electromagnetic Emissions	No lasting effect	Slight (E)
	Atmospheric Noise Emissions	No lasting effect	Slight (E)
	Underwater Noise Emissions	No lasting effect	Slight (E)
	Marine Discharges: Sewage and Sullage	No lasting effect	Slight (E)
	Marine Discharges: Treated Utility Water, Chemical and Deck Drainage	No lasting effect	Slight (E)
	Marine Discharges: Putrescible Waste	No lasting effect	Slight (E)
	Marine Discharges: Produced water	No lasting effect	Slight (E)
	Marine Discharges: Cooling Water	No lasting effect	Slight (E)
	Marine Discharges: Drilling Discharges	No lasting effect	Negligible (F)
	Marine Discharges: Subsea control fluids	No lasting effect	Slight (E)
	Marine Discharges: Hydrotest Fluid	No lasting effect	Slight (E)

Aspect Interaction Assessment and Conclusion

Given the isolated FPSO locations, cumulative impacts on fish resulting from interactions with other facilities and regional vessel/air traffic are not considered credible. Mitigation measures detailed in **Chapter 6** for whale sharks will ensure no impact on migration patterns. Slight impacts with no lasting effect may occur to fish as a result of discharges during construction, commissioning and operations, including hydrotest fluid, cooling water, PW, treated utility water, sewage and sullage and putrescible waste. Slight impacts with no lasting effect may also occur as a result of underwater noise emissions during construction (e.g. piling, VSP, MODU on DP) and operations (e.g. subsea infrastructure operations, routine FPSO operations, use of DP). Given the nature of these discharges and emissions (location and frequency) it is possible that any fish may be exposed to multiple aspects concurrently (e.g. concurrent exposure to underwater noise emissions and marine discharges from the FPSO facilities such as PW and cooling water). However, given no lasting effect on fish are expected to occur from these aspects, no significant cumulative impacts are predicted.

As such, the overall impact significance level of impacts on fish has been assessed as Slight (E). As per the criteria outlined in **Section 6.2.3.4**, it is considered that the environmental objectives for this receptor will be achieved and this impact is assessed as **Acceptable**.

Marine mammals

Table 9-10: Marine mammals cumulative assessment

Receptor	Marine mammals
Local environment context	The PMST identified 27 marine mammal species as potentially occurring within the Project Area. Of these, the pygmy blue whale (endangered and migratory), humpback whale, sei whale, fin whale (vulnerable and migratory) and Bryde's whale (migratory) are considered most likely to occur (albeit representing a low percentage of each species populations) within the Project Area and/or interact with the proposed Browse to NWS Project (**Section 5.3.2.4**). There are BIAs for migration and breeding and calving for the humpback whale along the WA coast and within the NWMR, but there are no known BIAs within the Project Area. A migratory BIA for the pygmy blue whale extends for most of the length of the NWMR within offshore waters and encompasses Scott Reef. The Conservation Plan for Blue Whales (Commonwealth of Australia, 2015) also documents a possible foraging area which encompasses the majority of Scott Reef and its surrounds. It is expected pygmy blue whales may occur within the Browse Development Area, albeit in low numbers, and it is acknowledged that pygmy blue whales have been recorded in the channel between North and South Scott Reef; and that they may forage opportunistically in and around Scott Reef (given it is a possible foraging BIA). Other marine mammal species identified as likely to occur in the Project Area (such as the sei whale, fin whale and Bryde's whales) are expected to be limited to infrequent transient individuals (**Section 5.3.2.4.3**).
Receptor sensitivity	**High value species** MNES species known to be present.
Environmental objective	**Objective 12**: To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species. **Objective 13**: To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species. **Objective 15**: To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population.

Receptor	**Marine mammals**		
Relevant aspects: Proposed Browse to NWS Project	***Aspect***	***Magnitude***	***Impact significance level***
	Physical Presence: Electromagnetic Emissions	No lasting effect	Slight (E)
	Atmospheric Noise Emissions	No lasting effect	Slight (E)
	Underwater Noise Emissions	Slight	Minor (D)
	Marine Discharges: Sewage and Sullage	No lasting effect	Slight (E)
	Marine Discharges: Treated Utility Water, Chemical and Deck Drainage	No lasting effect	Slight (E)
	Marine Discharges: Produced water	No lasting effect	Slight (E)
	Marine Discharges: Cooling Water	No lasting effect	Slight (E)
	Marine Discharges: Drilling Discharges	No lasting effect	Slight (E)
	Marine Discharges: Subsea control fluids	No lasting effect	Slight (E)
	Marine Discharges: Hydrotest Fluid	No lasting effect	Slight (E)

Aspect Interaction Assessment and Conclusion

Given the isolated FPSO locations, cumulative impacts on marine mammals resulting from interactions with other facilities and regional vessel/air traffic are considered minor. Regional oil and gas infrastructure is located in the migratory pathways, but not in known aggregation areas for key marine mammal species such as Pygmy Blue Whales and Humpback Whales. Both species have shown recovery since the cessation of whaling despite increased oil and gas (and general shipping) activities on the North West Shelf (**Chapter 5**). The primary source of potential impacts to marine mammals such as pygmy blue whales is from underwater noise emissions during construction (e.g. piling, VSP, MODU on DP) and operations (e.g. subsea infrastructure operations, routine FPSO operations, use of DP) (**Section 6.3.8**). No lasting effect on marine mammals is predicted as a result of other aspects, including marine discharges.

As described in **Section 6.3.8**, modelling has indicated that while no injury or mortality to marine mammals is predicted to occur, there is potential for some degree of behavioural disturbance as a result of underwater noise emissions associated with the proposed Browse to NWS Project. These impacts are expected to be localised behavioural disturbance of marine mammals within the vicinity of the noise source. Modelling of a representative cumulative scenario indicated that this behavioural response would be limited to less than 2% of the area identified as a possible foraging area for pygmy blue whales, leaving 98% available for uninterrupted foraging.

Given no other aspect is predicted to have any lasting effect on marine mammals and cumulative impact from multiple aspects is not expected to be significant.

As such, the overall impact significance level of impacts on marine mammals has been assessed as Minor (D) (based on the assessment of impacts resulting from underwater noise emissions). As per the criteria outlined in **Section 6.2.3.4**, it is considered that the environmental objectives for this receptor will be achieved and this impact is assessed as **Acceptable**.

Marine reptiles

Table 9-11: Marine reptiles cumulative assessment

<table>
<tr><th>Receptor</th><th colspan="3">Marine reptiles</th></tr>
<tr><td>Local environment context</td><td colspan="3">The PMST identified six species of marine turtle species as potentially occurring within the Project Area; the leatherback turtle, loggerhead turtle, olive ridley turtle, green turtle, hawksbill turtle and flatback turtle. These species are described in Section 5.3.2.5.
The Recovery Plan for Marine Turtles identifies Habitat Critical to the Survival of a Species and this has been identified for the Scott Reef – Browse Island green turtle genetic stock within the Project Area (Section 5.3.2.5.1). The habitat includes Sandy Islet at Scott Reef and a 20 km internesting buffer (Commonwealth of Australia, 2017).
There are also nesting and internesting BIAs at Scott Reef (associated with nesting at Sandy Islet) for both the green turtle and hawksbill turtle (Section 5.3.2.5.2).</td></tr>
<tr><td>Receptor sensitivity</td><td colspan="3">High value species
MNES species known to be present.</td></tr>
<tr><td>Environmental objective</td><td colspan="3">Objective 12: To not substantially modify, destroy or isolate an area of important habitat for a threatened or migratory species.
Objective 13: To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a threatened or migratory species.
Objective 16: To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.</td></tr>
<tr><td rowspan="12">Relevant aspects: Proposed Browse to NWS Project</td><td><i>Aspect</i></td><td><i>Magnitude</i></td><td><i>Impact significance level</i></td></tr>
<tr><td>Physical Presence: Light</td><td>Slight</td><td>Minor (D)</td></tr>
<tr><td>Physical Presence: Electromagnetic Emissions</td><td>No lasting effect</td><td>Slight (E)</td></tr>
<tr><td>Atmospheric Noise Emissions</td><td>No lasting effect</td><td>Slight (E)</td></tr>
<tr><td>Underwater Noise Emissions</td><td>Slight</td><td>Minor (D)</td></tr>
<tr><td>Marine Discharges: Sewage and Sullage</td><td>No lasting effect</td><td>Slight (E)</td></tr>
<tr><td>Marine Discharges: Treated Utility Water, Chemical and Deck Drainage</td><td>No lasting effect</td><td>Slight (E)</td></tr>
<tr><td>Marine Discharges: Produced water</td><td>No lasting effect</td><td>Slight (E)</td></tr>
<tr><td>Marine Discharges: Cooling Water</td><td>No lasting effect</td><td>Slight (E)</td></tr>
<tr><td>Marine Discharges: Drilling Discharges</td><td>No lasting effect</td><td>Slight (E)</td></tr>
<tr><td>Marine Discharges: Subsea control fluids</td><td>No lasting effect</td><td>Slight (E)</td></tr>
<tr><td>Marine Discharges: Hydrotest Fluid</td><td>No lasting effect</td><td>Slight (E)</td></tr>
</table>

Receptor	Marine reptiles
Aspect Interaction Assessment and Conclusion	
Given the isolated FPSO locations, cumulative impacts on marine reptiles resulting from interactions with other facilities and regional vessel/air traffic are considered minor. The greatest potential for cumulative impact to marine reptiles in the region is considered to result from light pollution on nesting areas. The primary sources of potential impacts to marine turtles are artificial light emissions from the MODU and FPSO facilities operating at Torosa; and underwater noise emissions resulting from potential pile driving activities, drilling and the MODU DP. Chemical discharges are noted as a threat to marine turtles in the Recovery Plan for Marine Turtles in Australia 2017-2027' (Commonwealth of Australia, 2017), however, marine discharges from the proposed Browse to NWS Project are not predicted to result in any last lasting affect on marine turtles. As described in **Chapter 6**, impacts from these aspects on marine turtles are not predicted to be significant and it is considered that they can be managed to an acceptable level through the implementation of mitigation measures. Cumulative impacts may occur as a result of simultaneous exposure to these aspects. For example, nesting turtles or hatchling attracted by light emissions from the Torosa FPSO facility or a MODU operating at Torosa would subsequently be exposed to noise emissions and marine discharges from the FPSO or MODU (e.g. DP noise). These cumulative impacts would be limited to behavioural responses in a small number of adult marine turtles and are not expected to be significant. Cumulative impacts to marine turtles may also occur as a result of attraction resulting from light emissions and concurrent exposure to other temporary, higher intensity noise emissions such as pile driving and VSP noise emissions. However, with the implementation of a proposed 500 m shut down zone during pile driving and VSP operations, as well as pre-start up visual observations, soft starts, operational and shutdown procedures; significant cumulative impacts resulting from light and noise emission from pilling and VSP operations are not expected to occur. Cumulative impacts could also occur as a result of non-simultaneous exposure to light and noise emissions. For example, decreased nesting success as a result of behavioural impacts from noise emissions (i.e. females avoiding nesting habitat at Sandy Islet) combined with decreased hatchling survival rates due to disorientation from light emissions would have a combined impact on the overall population success of green turtles. However, as described in **Chapter 6**, light and noise emissions are not expected to significantly impact the breeding cycle of marine turtles at Sandy Islet, Scott Reef (predominately green turtles) and given the temporary nature of pile driving activities and the MODU's presence at a single location, no significant cumulative impacts on the nesting success or hatchling survival rates are expected as a result of the proposed Browse to NWS Project. Potential impacts may also occur to sea snakes as a result of marine discharges and underwater noise emissions resulting from the proposed Browse to NWS Project. As described in **Chapter 6**, impacts to water quality are not expected to be significant and impacts to sea snakes from noise emissions are expected to be limited to slight behavioural/avoidance impacts. No significant cumulative impacts to sea snakes within the Project Area are predicted. As such, the overall impact significance level of impacts on marine reptiles has been assessed as Minor (D) based on the assessment of impacts resulting from underwater noise emissions (Minor (D)) and light emissions (Minor (D)). As per the criteria outlined in **Section 6.2.3.4**, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.	

Key Ecological Features (KEF) (medium value)

Table 9-12: KEF Features cumulative assessment

Receptor	KEF Features		
Local environment context	The Browse Development Area overlaps with the Continental slope demersal fish communities and Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEFs. The proposed BTL route traverses the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF and the Ancient coastline at 125 m depth contour KEF (**Section 5.3.3.1**).		
Receptor sensitivity	**Medium value** Designated sensitive Area. Values protected by legislation.		
Environmental objective	**Objective 17**: To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in an area defined as a Key Ecological Feature.		
Relevant aspects: Proposed Browse to NWS Project	***Aspect***	***Magnitude***	***Impact significance level***
	Physical Presence: Seabed Disturbance	No lasting effect	Negligible (F)
	Underwater noise	No lasting effect	Negligible (F)
	Marine Discharges: Sewage and Sullage	No lasting effect	Negligible (F)
	Marine Discharges: Treated Utility Water, Chemical and Deck Drainage	No lasting effect	Negligible (F)
	Marine Discharges: Putrescible Waste	No lasting effect	Negligible (F)
	Marine Discharges: Produced water	No lasting effect	Negligible (F)
	Marine Discharges: Cooling Water	No lasting effect	Negligible (F)
	Marine Discharges: Drilling Discharges	No lasting effect	Negligible (F)
	Marine Discharges: Subsea control fluids	No lasting effect	Negligible (F)
	Marine Discharges: Hydrotest Fluid	No lasting effect	Negligible (F)

Receptor	**KEF Features**
Aspect Interaction Assessment and Conclusion	
Seabed disturbance and marine discharges will occur within these KEFs, however, no lasting effect is predicted to occur to the conservation values of these KEFs. The Project will be the first permanent infrastructure installed in the following KEFs: + Seringapatam Reef and Reef and Commonwealth waters in the Scott Reef Complex KEF + Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF Existing anthropogenic impacts for these KEFs include climate change related impacts, physical habitat modification (shipping anchorage, offshore construction and fishing practices (Commonwealth of Australia, 2012). The Project is likely to represent the largest (yet negligible) impact in terms of physical habitat modification in these KEFs therefore the impact described in **Chapter 6** is considered an accurate depiction of cumulative impact. The Continental Slope Demersal Fish Communities and Ancient Coastline at 125 m depth contour KEFs contain other existing oil and gas infrastructure (pipelines and the North Rankin Complex). Given the small Project footprint relative to the total KEF area, and narrow footprint of pipeline infrastructure (allowing connectivity to be retained), the cumulative increase is not considered significant. The values of the Continental slope demersal fish communities KEF, the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF and the Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEF are primarily related to high productivity and aggregations of marine life. As described earlier, no significant cumulative impacts to plankton or fish are expected to occur from concurrent exposure to localised reduced water quality (resulting from marine discharges) and underwater noise emissions. As such, no cumulative impacts to the values of these KEFS (high productivity and aggregations of marine life) are expected. Likewise, seabed disturbance is unlikely to significantly impact productivity or marine life aggregation, and is not expected to contribute to any cumulative impacts to the values of the KEFs. Similarly, impacts to the Ancient coastline at 125 m depth contour KEF may occur where the proposed BTL crosses this KEF near the NRC tie-in point, as a result of the permanent installation of the BTL and temporarily due to vessel-based marine discharges during construction and IMR activities. The values of the Ancient coastline at 125 m depth contour KEF relate primarily to its unique seafloor geology, which are unlikely to be impacted by marine discharges associated with the proposed Browse to NWS Project. As such, no cumulative impacts to this KEF are predicted. As such, the overall impact significance level of impacts on KEFs has been assessed as Negligible (F). As per the criteria outlined in **Section 6.2.3.4**, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.	

Australian Marine Parks (medium value (multiple use zones))

Table 9-13: AMP Features cumulative assessment

<table>
<tr><th>Receptor</th><th colspan="3">AMP Features</th></tr>
<tr><td>Local environment context</td><td colspan="3">The proposed BTL route traverses the Multiple Use Zones (IV) of the ArgoRowley Terrace and Kimberley Marine Parks. It should also be noted that the proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park National Park Zone. Rationale for the route selection of the BTL is provided in Chapter 3.</td></tr>
<tr><td>Receptor sensitivity</td><td colspan="3">Medium value (multiple use zones)
Designated sensitive area. Values protected by legislation.</td></tr>
<tr><td>Environmental objective</td><td colspan="3">Objective 18: To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.</td></tr>
<tr><td rowspan="8">Relevant aspects: Proposed Browse to NWS Project</td><td><i>Aspect</i></td><td><i>Magnitude</i></td><td><i>Impact significance level</i></td></tr>
<tr><td>Physical Presence: Seabed Disturbance</td><td>No lasting effect</td><td>Negligible (F)</td></tr>
<tr><td>Underwater noise</td><td>No lasting effect</td><td>Negligible (F)</td></tr>
<tr><td>Physical Presence: Light</td><td>No lasting effect</td><td>Negligible (F)</td></tr>
<tr><td>Marine Discharges: Sewage and Sullage</td><td>No lasting effect</td><td>Negligible (F)</td></tr>
<tr><td>Marine Discharges: Treated Utility Water, Chemical and Deck Drainage</td><td>No lasting effect</td><td>Negligible (F)</td></tr>
<tr><td>Marine Discharges: Putrescible Waste</td><td>No lasting effect</td><td>Negligible (F)</td></tr>
<tr><td>Marine Discharges: Cooling Water</td><td>No lasting effect</td><td>Negligible (F)</td></tr>
<tr><td colspan="4"><i>Aspect Interaction Assessment and Conclusion</i></td></tr>
<tr><td colspan="4">Impacts to AMPs may occur as a result of the permanent installation of the proposed BTL and temporarily due to vessel-based marine discharges of cooling water, putrescible waste and sewage and sullage during construction and IMR activities. Threatening processes for the Kimberley Marine Park and Argo-Rowley Terrace Marine Park are similar to those described above for the affected KEFs and cumulative impacts are also considered similar.
The impact of seabed disturbance on the Multiple Use Zone of the two AMPs has been minimised, as far as practicable, based on the route selection process (Chapter 3). Impacts have been assessed as negligible as the area traversed by the proposed BTL represents a small proportion of the total area of the AMPs. The activities are considered to be consistent with the objective of the Multiple Use Zone (VI) to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species.
As described in Chapter 6, given their temporary and transient nature, the impact of the vessel-based marine discharges are not expected to result in any lasting effect on the values of the two AMPs traversed (i.e. the Kimberley Marine Park and Argo-Rowley Terrace Marine Park). No cumulative impacts are expected to occur to AMPs as a result of marine discharges and seabed disturbance related to the installation of the subsea infrastructure.
As such, the overall impact significance level of impacts on AMPs has been assessed as Negligible (F). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as Acceptable.</td></tr>
</table>

State marine parks and nature reserves (high value)

Table 9-14: State marine parks and nature reserves cumulative assessment

<table>
<tr><th>Receptor</th><th colspan="3">State marine parks and nature reserves</th></tr>
<tr><td>Local environment context</td><td colspan="3">There are no State marine parks within the Project Area, however, the BTL route passes approximately 3 km from the Rowley Shoals Marine Park (Section 5.3.3.2).
The Scott Reef Nature Reserve which was designated in 1993 and encompasses South Scott Reef (including Sandy Islet) down to the low mean water mark (Atlas of Marine Protection, 2019). This Nature Reserve protects the physical and ecological features of Scott Reef which are described throughout Chapter 5, including important nesting habitat (Habitat Critical for Survival of a Species) for the green turtle.</td></tr>
<tr><td>Receptor sensitivity</td><td colspan="3">High value
Designated sensitive area. Values protected by legislation.</td></tr>
<tr><td>Environmental objective</td><td colspan="3">Objective 18: To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place.</td></tr>
<tr><td rowspan="6">Relevant aspects: Proposed Browse to NWS Project</td><td><i>Aspect</i></td><td><i>Magnitude</i></td><td><i>Impact significance level</i></td></tr>
<tr><td>Physical Presence: Light</td><td>No lasting effect</td><td>Slight (E)</td></tr>
<tr><td>Atmospheric noise emissions</td><td>No lasting effect</td><td>Slight (E)</td></tr>
<tr><td>Marine Discharges: Produced water</td><td colspan="2">No impact expected</td></tr>
<tr><td>Marine Discharges: Cooling water</td><td colspan="2">No impact expected</td></tr>
<tr><td>Production Activities: Seabed Subsidence</td><td>Slight</td><td>Minor (D)</td></tr>
<tr><th colspan="4">Aspect Interaction Assessment and Conclusion</th></tr>
<tr><td colspan="4">Given the distance of the proposed activities from State Marine Parks (the Rowley Shoals Marine Park is located approximately 3 km from the BTL route at its closest point), no impacts to State Marine Parks as a result of the proposed activities are predicted.
Slight impacts are predicted to occur to the Scott Reef Nature Reserve as a result of potential seabed subsidence.
As described above, no significant cumulative impacts are expected to occur to Scott Reef or the fauna that utilise the reef and Sandy Islet. No cumulative impacts to the Scott Reef Nature Reserve are expected.
As such, the overall impact significance level of impacts on State marine parks and nature reserves has been assessed as Minor (D) (based on the assessment of impacts resulting from subsea subsidence). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as Acceptable.</td></tr>
</table>

Other protected places (high value)

Table 9-15: Other protected places cumulative assessment

Receptor	**Other protected places**		
Local environment context	There are no National Heritage Sites within the Project Area. The closest National Heritage Sites are the Dampier Archipelago (including the Burrup Peninsula) and the Ningaloo Coast (Section 5.4.3.2). There are no World Heritage Sites within the Project Area (Section 5.4.3.3). Commonwealth Heritage Places located within or within the vicinity of the Project Area include Scott Reef and Surrounds – Commonwealth Area, and Mermaid Reef – Rowley Shoals (Section 5.4.3.1).		
Receptor sensitivity	**High value** Designated sensitive area. Values protected by legislation.		
Environmental objective	**Objective 18**: To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity of a Protected Place. **Objective 19**: To not have a substantial adverse impact on heritage values[1]		
Relevant aspects: Proposed Browse to NWS Project	***Aspect***	***Magnitude***	***Impact significance level***
	Physical Presence: Seabed Disturbance	No impacts predicted	
	Physical Presence: Light	No lasting effect	Slight (E)
	Marine Discharges: Sewage and Sullage	No lasting effect	Negligible (F)
	Marine Discharges: Treated Utility Water, Chemical and Deck Drainage	No lasting effect	Slight (E)
	Marine Discharges: Putrescible Waste	No lasting effect	Slight (E)
	Marine Discharges: Produced water	No impact expected	
	Marine Discharges: Cooling water	No impact expected	
	Marine Discharges: Drilling Discharges	No impact expected	
	Marine Discharges: Hydrotest Fluid	No impact expected	
Aspect Interaction Assessment and Conclusion			
As described above, project activities will be managed to avoid impacts occurring to Scott Reef shallow habitats (<75m) or the waters surrounding the reef and no cumulative impacts to the Scott Reef and Surrounds Commonwealth Heritage Place are expected. Likewise, no impacts are predicted to occur to the Mermaid Reef – Rowley Shoals Commonwealth Heritage Place. As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.			

9.2.2.3 Socio-Economic Receptors

State and Commonwealth managed fisheries (high value user)

Table 9-16: State and Commonwealth managed fisheries cumulative assessment

Receptor	State and Commonwealth managed fisheries		
Local environment context	State managed commercial fisheries in close proximity to the Project Area include Northern Demersal Scalefish, Mackerel, WA North Coast Shark, Onslow Prawn, Abalone, South West Coast Salmon, Pilbara Fish Trawl, Specimen Shell, Marine Aquarium Fish, West Coast Deep Sea Crustacean and Pearl Oyster Managed Fisheries. The Commonwealth managed fisheries located within the vicinity of the Project Area include the North West Slope Trawl Fishery, the Western Tuna and Billfish Fishery, the Southern Bluefin Tuna Fishery and the Skipjack Tuna Fishery (Western Skipjack Tuna Fishery). In 1974 the Australia-Indonesia Memorandum of Understanding regarding the Operations of Indonesian Traditional Fishermen in Areas of the Australian Fishing Zone and Continental Shelf – 1974 (MoU 74) was signed by the Governments of Australia and Indonesia, allowing allowed Indonesian fishers to continue to fish in designated areas using traditional methods only (**Section 5.4.2.1** and **Section 5.4.2.2**).		
Receptor sensitivity	**High value marine user** Key fishing area, with high importance to stakeholders.		
Environmental objective	**Objective 20**: To not have a substantial adverse effect on the sustainability of commercial fishing. **Objective 21**: To not interfere with other marine users to a greater extent than is described in the draft EIS/ERD.		
Relevant aspects: Proposed Browse to NWS Project	***Aspect***	***Magnitude***	***Impact significance level***
	Physical Presence: Disturbance to Other Users	Slight	Minor (D)
	Physical Presence: Light	No lasting effect	Slight (E)
	Marine Discharges: Sewage and Sullage	No lasting effect	Slight (E)
	Marine Discharges: Treated Utility Water, Chemical and Deck Drainage	No lasting effect	Slight (E)
	Marine Discharges: Putrescible Waste	No lasting effect	Slight (E)
	Marine Discharges: Produced water	No lasting effect	Slight (E)
	Marine Discharges: Cooling water	No lasting effect	Slight (E)
	Marine Discharges: Subsea control fluids	No lasting effect	Slight (E)
	Marine Discharges: Hydrotest Fluid	No lasting effect	Slight (E)

Aspect Interaction Assessment and Conclusion
The cumulative impact of the Project through disturbance to other users in addition to other anthropogenic sources is unlikely to be significant due to relatively small exclusion zones (typically 500 m) and compatibility with certain fishery types, such as line and trap fishing, which may benefit from the creation of artificial habitat. The total seabed area restricted from trawling activities (due to snag risk) in the region as a result of anthropogenic seabed infrastructure is a relatively small proportion of the available fishery managed zones. Where the functions, interests or activities of other users involve marine fauna (e.g. fisheries), any effect to fauna presence or abundance will indirectly impact on the functions, interests or activities of other users. As described above, no lasting effect on fish are expected to occur as a result of the proposed activities, with the impact significance level of impacts on fish assessed as Slight (E). Further, slight impacts (disturbance to other users) are predicted to occur to managed fisheries as a result of the physical presence of infrastructure (exclusion from a very small portion of potential fishing grounds) associated with the proposed Browse to NWS Project. Given no lasting impact to target fish species is predicted, no cumulative impacts to managed fisheries are expected as a result of impacts to target fish species and the exclusion from some fishing grounds as a result of the physical presence of infrastructure. As such, the overall impact significance level of impacts on State and Commonwealth fisheries has been assessed as Minor (D) (based on the assessment of impacts of disturbance to other users from the physical presence of infrastructure). As per the criteria outlined in **Section 6.2.3.4**, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.

Tourism and Recreation/Scientific Studies (high value user)

Table 9-17: Tourism and Recreation/Scientific studies cumulative assessment

Receptor	Tourism and Recreation/ Scientific studies
Local environment context	Recreation and tourism activities in the NWMR occur predominantly in WA State waters adjacent to coastal population centres (e.g. Broome), with a peak in activity during the winter months (dry season) (**Section 5.4.2.6**). Only one to two recreational fishing charter operators run trips to Scott Reef. The location has the potential to provide significant opportunities for pelagic sport fishing; however, given the distance from Broome and closest landfall and associated costs, only a limited number of charter operators are prepared to take recreational fishers out to Scott Reef. Those companies that do visit Scott Reef tend to make the trip only four to five times per year, spending around five days at the reef each time. Fishing is mainly focused on the south, west and north extremities of Scott Reef, generally only going into the South Scott Reef lagoon for snorkelling and for layover at night.
Receptor sensitivity	**High value users** Project area has low to medium level of utilisation by stakeholders.
Environmental objective	**Objective 21**: To not interfere with other marine users to a greater extent than is described in the draft EIS/ERD.

Receptor	**Tourism and Recreation/ Scientific studies**		
Relevant aspects: Proposed Browse to NWS Project	***Aspect***	***Magnitude***	***Impact significance level***
	Physical Presence: Disturbance to Other Users	Slight	Minor (D)
	Physical Presence: Light	No lasting effect	Slight (E)
	Atmospheric noise emissions	No lasting effect	Slight (E)
	Underwater noise emissions	No lasting effect	Slight (E)
	Marine Discharges: Sewage and Sullage	No lasting effect	Slight (E)
	Marine Discharges: Treated Utility Water, Chemical and Deck Drainage	No lasting effect	Slight (E)
	Marine Discharges: Putrescible Waste	No lasting effect	Slight (E)
	Marine Discharges: Produced water	No impacted expected	
	Marine Discharges: Cooling water	No lasting effect	Slight (E)
	Marine Discharges: Drilling Discharges	No lasting effect	Slight (E)
	Marine Discharges: Hydrotest Fluid	No lasting effect	Slight (E)
	Production Activities: Seabed Subsidence	No lasting effect	Slight (E)

Aspect Interaction Assessment and Conclusion

No lasting effect is predicted to occur to the tourism, recreation, or scientific studies values in the Project Area (and in particular Scott Reef). As described above, no significant cumulative impacts are expected to occur to the Scott Reef system or fauna that may be present in the surrounding waters. Given this, no significant cumulative impacts to tourism, recreation or scientific studies values are expected to occur as a result of the proposed Browse to NWS Project.

As such, the overall impact significance level of impacts on tourism, recreation and scientific studies has been assessed as Slight (E). As per the criteria outlined in **Section 6.2.3.4**, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.

Shipping (medium to high value user)

Table 9-18: Shipping cumulative assessment

Receptor	Shipping		
Local environment context	Shipping activity in and around the Browse Development Area is sparse, with the main commercial shipping routes located approximately 50 to 100 km west, intersecting the proposed BTL route at various locations, depending on the port. The main shipping activity in the NWMR relates to transits to and from Broome and transportation of goods between Australian and international ports. Major ports are adjacent to the Roebuck, Montebello and Dampier Commonwealth marine reserves (Section 5.4.2.4).		
Receptor sensitivity	**Medium/high value users** Busy shipping area is located outside of Project Area, but shipping traffic still likely to be high.		
Environmental objective	**Objective 21**: To not interfere with other marine users to a greater extent than is described in the draft EIS/ERD.		
Relevant aspects: Proposed Browse to NWS Project	***Aspect***	***Magnitude***	***Impact significance level***
	Physical Presence: Disturbance to Other Users	Slight	Minor (D)
Aspect Interaction Assessment and Conclusion			
Impacts to shipping will be limited to slight temporary impacts during construction of the proposed BTL and infrequent IMR activities. As no other activities are expected to impact shipping, no cumulative impacts to shipping are expected to occur as a result of the proposed Browse to NWS Project. The overall impact significance level of impacts on shipping has been assessed as Minor (D). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.			

Industry (low value user)

Table 9-19: Industry cumulative assessment

Receptor	Industry		
Local environment context	The NWMR supports a number of industries including petroleum exploration and production, as well as minerals extraction. There are seven sedimentary petroleum basins in the NWMR: the Northern and Southern Carnarvon basins, Perth, Browse, Roebuck, Offshore Canning and Bonaparte basins. Of these, the Northern Carnarvon, Browse and Bonaparte basins hold large quantities of gas and comprise most of Australia's reserves of natural gas (Section 5.4.2.5).		
Receptor sensitivity	**Low value** The Project Area is not of extensive use by other Industry.		
Environmental objective	**Objective 21**: To not interfere with other marine users to a greater extent than is described in the draft EIS/ERD.		
Relevant aspects: Proposed Browse to NWS Project	***Aspect***	***Magnitude***	***Impact significance level***
	Physical Presence: Disturbance to Other Users	Slight	Negligible (F)

Aspect Interaction Assessment and Conclusion
Displacement of, or interference with, other oil and gas activities is not expected within the Browse Development Area. However, activities associated with the BTL, such as BTL installation, may result in short term interference, particularly at the NRC location (5-10 km away). No cumulative impacts to industry are expected to occur as a result of the proposed Browse to NWS Project. As such, the overall impact significance level of impacts on industry has been assessed as Negligible (F). As per the criteria outlined in **Section 6.2.3.4**, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.

Settlements (medium value users)

Table 9-20: Settlements cumulative assessment

Receptor	Settlements		
Local environment context	The proposed Browse to NWS Project presents potential social benefits and impacts to communities within WA and particularly Broome and the Dampier Peninsula, with Broome being the potential primary supply chain and logistics support location (**Section 5.4.4**).		
Receptor sensitivity	**Medium value users** Regionally important, low sensitivity to change.		
Environmental objective	**Objective 22**: To protect social surroundings from significant harm.		
Relevant aspects: Proposed Browse to NWS Project	***Aspect***	***Magnitude***	***Impact significance level***
	Atmospheric Noise Emissions	No lasting effect	Negligible (F)

Aspect Interaction Assessment and Conclusion
Atmospheric noise emissions from helicopters (transiting from logistic locations and the Project Area) are not predicted to have any lasting effect on settlements. Atmospheric noise emissions from helicopters are the only aspect predicted to result in potential impacts to settlements. As such, there are no predicted receptor-based cumulative impacts for settlements. As such, the overall impact significance level of impacts on settlements has been assessed as Negligible (F). As per the criteria outlined in **Section 6.2.3.4**, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.

Aboriginal and indigenous heritage (high value users)

Table 9-21: Aboriginal and indigenous heritage cumulative assessment

Receptor	Aboriginal and indigenous heritage		
Local environment context	No known sites of Aboriginal Heritage significance are located within the Development Area, according to the WA Department of Aboriginal Affairs' Aboriginal Sites Inquiry System. The existence of any unknown Aboriginal sites or artefacts of significance within the Browse Development Area, or the wider NWMR, is considered highly unlikely due to the site's remote location offshore (Section 5.4.3.1).		
Receptor sensitivity	**High value users** Browse Development Area is of high importance to stakeholders		
Environmental objective	**Objective 21**: To not interfere with other marine users to a greater extent than is described in the draft EIS/ERD.		
Relevant aspects: Proposed Browse to NWS Project	***Aspect***	***Magnitude***	***Impact significance level***
	Physical Presence: Disturbance to Other Users	Slight	Minor (D)
	Marine Discharges: Produced water	No lasting effect	Slight (E)
	Marine Discharges: Cooling water	No lasting effect	Slight (E)
	Marine Discharges: Drilling Discharges	No lasting effect	Slight (E)

Aspect Interaction Assessment and Conclusion

No impact to aboriginal heritage is expected to occur as a result of the proposed Browse to NWS Project.

Slight impacts to traditional Indonesian fisher utilising the MOU 74 area may occur as a result of the physical presence of infrastructure. As no lasting impacts to fish are predicted, no cumulative impacts to Indonesian fishers as a result of impacts to target species and disturbance from the physical presence of infrastructure are predicted.

As such, the overall impact significance level of impacts on settlements has been assessed as Minor (D) (based on the assessment of impacts of disturbance to other users from the physical presence of infrastructure on Indonesian fishers). As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor (Table 6-7) will be achieved and this impact is assessed as **Acceptable**.

It is noted that potential impacts associated with atmospheric emissions resulting from the onshore processing of the Browse gas by the NWS JV on the national heritage values of the listed National Heritage Place on the Dampier Archipelago (including aboriginal heritage values) are addressed in the North West Shelf Project Extension ERD (EPA 2186, EPBC 2018/8335).

Maritime archaeology

Table 9-22: Maritime archelogy cumulative assessment

Receptor	Maritime archelogy		
Local environment context	The Australian National Shipwreck Database and the WA Maritime Museum Shipwreck Database list one protected historic wreck within the Browse Development Area. The historic shipwreck of the Yarra is located at South Scott Reef. The Yarra was an iron barque vessel carrying a load of guano which struck the reef during a gale in 1884 (Section 5.4.3.2).		
Receptor sensitivity	**High value** Maritime archaeology protected by legislation exists within the Browse Development Area		
Environmental objective	**Objective 19**: To not have a substantial adverse impact on heritage values.		
Relevant aspects: Proposed Browse to NWS Project	***Aspect***	***Magnitude***	***Impact significance level***
	Physical Presence: Seabed Disturbance	No impact predicted	
	Production Activities: Seabed Subsidence	No impact predicted	
Aspect Interaction Assessment and Conclusion			
No impacts to the marine archaeology within the Project Area (i.e. shipwrecks at Scott Reef) are predicted and, therefore, no cumulative impacts to maritime archaeology are expected to occur as a result of the proposed Browse to NWS Project. As per the criteria outlined in Section 6.2.3.4, it is considered that the environmental objective for this receptor will be achieved and this impact is assessed as **Acceptable**.			

9.3 Overall Assessment of Risks from Unplanned Events or Incidents

Environmental risks from unplanned events or incidents may have significant consequences to multiple high value receptors on a regional scale. However, it is important to note that with the implementation of industry best practice mitigation and management measures by Woodside, a highly experienced operator, as well as significant legislative requirements and regulatory oversight, the likelihood of a significant risk event occurring and resulting in significant impacts is highly unlikely to remote.

Chapter 6 provides an assessment of the risk events identified during the impact and risk assessment. The following risks were identified as having a low risk rating due to the likelihood of the risk event occurring, along with the subsequent consequence:

- accidental dropped objects from vessels, the MODU or the FPSO facilities impacting benthic habitats – Section 6.3.1
- damage to unidentified maritime archaeology (ship or plane wrecks) during the placement of subsea infrastructure or the BTL and inter-field spur line – Section 6.3.1
- unplanned release of treated sewage and sullage above regulatory limits – Section 6.3.9
- unplanned release of treated utility water above regulatory limits – Section 6.3.10
- unplanned release of PW at significantly elevated discharge concentrations that would lead to water quality impacts within the State waters 3 nm boundary – Section 6.3.12
- unplanned release of cooling water at significantly elevated discharge concentrations that would lead to water quality impacts within the State waters 3 nm boundary – Section 6.3.13
- unplanned discharge of hazardous and non-hazardous inorganic waste – Section 6.3.14
- dispersal of drill cuttings and fluids being greater than predicted, resulting in impacts to high value Scott Reef shallow water benthic habitats (<75 m depth) be greater than predicted – Section 6.3.15
- unplanned discharge of subsea control fluid at a volume significantly greater than predicted – Section 6.3.16
- unplanned vessel interactions with marine turtles and fish (whale sharks) – Section 6.3.18.

Environmental risks that were ranked as moderate or high included the following:

- the risk posed by the potential higher utilisation of the Browse Development Area by pygmy blue whales and subsequent increased impact of underwater noise (moderate risk) – Section 6.3.8

- the unplanned vessel interactions with marine mammals (moderate risk) – **Section 6.3.18**
- the introduction and establishment of IMS at Scott Reef (moderate risk) – **Section 6.3.19**
- unplanned hydrocarbon releases (moderate to high risk) – **Section 6.3.21**.

It should be noted that the moderate and high-risk rating for these risks was driven by the significance of the potential consequences to high value receptors, on a regional scale. The likelihood of these risks occurring and resulting in subsequent impacts is considered highly unlikely to remote. It is also noted that different receptor groups would be impacted by each of the risk events. As such, it is considered that the likelihood of multiple risk events occurring, cumulatively resulting in a significant impact (inclusive of impacts from planned activities) on receptors, is remote.

With respect to the risks that are assessed as moderate or high risk, as significant impacts from one of these risk events could occur on a regional scale, cumulative impacts could take place if an unplanned risk event and other regional (natural or anthropogenic) stressors occurred at the same time. For example, a significant hydrocarbon spill impacting Scott Reef would potentially impact the recovery of the reef from recent natural perturbations (i.e. the 2016-2017 coral bleaching event). Likewise, the introduction and establishment of an IMS at Scott Reef could also potentially impact the ecosystem integrity of the reef system.

The planned mitigation and management actions for each of these risk events are described in **Chapter 6**. Given that the likelihood of any of these risk events occurring is considered unlikely to remote, the planned mitigation and management measures, and in consideration of the criteria outlined in **Section 6.2.3.4**, it is considered that the environmental objective for each receptor (**Table 6-7**) potentially impacted by these risk events will be achieved and, as such, these risks are assessed as **Acceptable**.

9.4 Mitigation, Management and Monitoring

Chapter 8 presents the overarching HSE management approach that Woodside will implement for the proposed Browse to NWS Project. It demonstrates the mitigation and management approach that Woodside will use to avoid environmental impacts and risks identified in this draft EIS/ERD or minimise them to an acceptable level. Where practicable, potential impacts have been avoided through the design and engineering process. Additional work will be undertaken during the detailed engineering phase of the proposed Browse to NWS Project to further refine design and reduce potential impacts.

Specific proposed measures to mitigate and manage unavoidable impacts from planned activities and reduce the environmental risk associated with unplanned events and incidents are presented in **Chapter 6**. These measures include compliance with regulatory requirements as well as industry best practice.

Central management and monitoring commitments for the proposed Browse to NWS Project include, but not limited to the following:

- Key management strategies:
  - Underwater noise monitoring of a RFSU operational well will be undertaken to inform an adaptive management approach for noise management for the TRD and TRE wells if required.
  - FPSO PW will be treated prior to being discharged overboard using a tertiary treatment system, such as a Macro Porous Polymer Extraction (MPPE) system that meets Woodside and accepted industry standards.
  - Project vessels will not travel at speeds greater than 12 knots with the State Proposal Area, or 6 knots in the Scott Reef channel.
  - Fast Crew Transfer Vessels (FCTVs) will operate under an approved FCTV Management strategy (to be detailed in subsequent Environment Plans as required) which will describe the appropriate additional control measures to manage vessel strike risk for the FCTV. Without additional engineering controls, FCTVs will not travel at speeds greater than 30 knots in sensitive areas at sensitive times.
  - Project vessels and MODUs will be subject to a risk assessment process to assess the likelihood of introducing IMS when transiting to the Project Area. Based on the outcomes of risk assessment, management measures commensurate with the risk (such as the treatment of internal systems, IMS inspections or cleaning) will be implemented.
  - Internationally sourced Project vessels and MODUs required within 3 nm of Scott Reef (State Proposal Area) for longer than 48 hours will be inspected by an experienced IMS expert/marine scientist for IMS; and cleaned where required[1].

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[1] *Subject to confirmation, vessel/rig may be permitted re-entry within Scott Reef State waters (3 nm) without re-inspection provided its movements outside Scott Reef State waters at stationary or at slow speeds (less than three knots) in waters less than 50 metres deep do not exceed a period totalling greater than seven accumulative days prior to returning to Scott Reef State waters (3 nm).*

- Assurance:
  - Light monitoring will occur during drilling and completion of a well at TRE drill centre to verify modelling predictions.
  - Periodic and ‘for cause’ toxicity testing and characterisation of the physical and chemical composition of the PW stream prior to discharge will be undertaken.
  - During steady state FPSO operations, PW modelling and infield verification will be completed to verify the modelling predictions.
  - Baseline and periodic water and sediment quality monitoring at a gradient away from the FPSO facility in the receiving environment will be undertaken to detect changes because of FPSO PW discharge.
  - During steady state FPSO operations, cooling water modelling and infield verification will be completed to verify the modelling predictions.
  - Verification monitoring for seabed subsidence will be undertaken.
  - IMS surveillance program will be undertaken at Scott Reef, consisting of baseline survey prior to the commencement of activities in the State Proposal Area, and periodic surveys over the life of the proposed Browse to NWS Project.
  - Project vessels will not use heavy fuel oil or intermediate fuel oil.
- Verifying science:
  - Continuation of the Scott Reef long term monitoring program to monitor the functionality and status of the reef system, throughout the full lifecycle of the proposed Browse to NWS Project.
  - The existing pygmy blue whale data will be updated by targeted monitoring programs to verify impact predictions and inform adaptive management approaches at relevant times throughout the proposed Browse to NWS Project life cycle.
  - The existing turtle data will be updated by targeted monitoring programs to verify impact predictions at relevant times throughout the proposed Browse to NWS Project life cycle.
  - Targeted monitoring programs of pygmy blue whales and green turtles will be undertaken to verify impact predictions and inform adaptive management approaches at relevant times throughout the proposed Browse to NWS Project life cycle.

In the event that impacts cannot be avoided or mitigated to an acceptable level, an environmental offset plan will be developed as described in Section 8.7.

The measures presented in this draft EIS/ERD will be incorporated into activity-specific Environment Plans to be submitted for acceptance by NOPSEMA for Commonwealth waters and DMIRS for State waters, prior to the activity commencing where required. As described in Chapter 8, these Environment Plans will include strategies to reduce the impacts from planned (routine and non-routine) activities and risks from unplanned events and incidents to ALARP. In addition, EPs will include response strategies to be implemented in the highly unlikely event of a moderate to high risk event being realised.

9.5 Overall Assessment of Acceptability

This draft EIS/ERD presents the predicted impacts from planned activities and the environmental risks associated with unplanned events and incidents.

Chapter 6 presents the assessment of these impacts and risks for each aspect as well as an assessment of the acceptability of the impacts and risks in terms of the defined acceptability criteria which considers the Principals of ESD, the EPBC Act Significant Impacts Guidelines, the WA EPA Environmental Objectives, external and internal context and other requirements such as the requirements of the North-west Marine Parks Network Management Plan, specific EPBC Act conservation management and recovery plans and conservation advices for protected fauna. The conclusion of this assessment is that the impacts and risks presented by each aspect are **Acceptable**.

Section 9.2.2 presents an overall qualitative assessment of the cumulative impacts to the key sensitive receptors that may be affected by the proposed Browse to NWS Project. This assessment concludes that no significant receptor based cumulative impacts are expected to occur, the stated environmental objective for each receptor (Table 6-7) is expected to be achieved; and that the impacts to each sensitive receptor are **Acceptable**.

Section 9.3 presents an overall assessment of the environmental risks associated with unplanned events or incidents. The assessment finds that the stated environmental objective for each receptor (Table 6-7) is expected to be achieved and the overall risk posed in relation to unplanned events or incidents is **Acceptable**.

Chapter 7 presents the GHG emissions predicted to occur in a range of scenarios as a result of the proposed Browse to NWS Project and also provides a framework for consideration of those emissions in a cumulative context. The assessment details the emissions abatement measures that have been undertaken to date in the design process to reduce predicted emissions to an acceptable level. It also provides an overview of the potential benefits natural gas can present in the context of reducing global greenhouse gas emissions, whilst acknowledging the uncertainties associated with predicting future global greenhouse gas emissions. The assessment concludes that GHG emissions from the proposed Browse to NWS Project are considered **Acceptable**.

Finally, an assessment of the predicted impacts from the proposed Browse to NWS Project to the environment as a whole has been undertaken and is presented below. This assessment has been undertaken against the requirements of the principles of ESD and the objectives, requirements of the EPBC Act and EP Act, and other requirements such as the requirements of the North-west Marine Parks Network Management Plan and specific EPBC conservation plans.

Principles of Environmentally Sustainable Development

An assessment of the proposed Browse to NWS Project against the principles of ESD as defined in the EPBC Act is provided in Table 9-23.

Table 9-23 Assesment of proposed Browse to NWS Project against the principles of Environmentally Sustainable Development

Principles of ESD	Assessment
Decision making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations.	As described in Section 3.8, the selection of the concept for the proposed Browse to NWS Project was based on a set of primary drivers including environment, safety, economic performance and optimising economic recovery and supported by key drivers including global competitiveness, flexibility and robustness, stakeholder acceptance and marketability. The stakeholder acceptance driver is underpinned by the ability to achieve stakeholder alignment and government approvals, with all health, safety and environmental impacts and risks managed to an acceptable level, and to seek to apply inherently safe principles. Ongoing decision making will be driven by the objectives of the proposed Browse to NWS Project outlined in Chapter 2, which include the minimisation of the environmental footprint, managing HSE in accordance with industry standards and maximising socio-economic benefits. Chapter 7 presents a climate change impact assessment and concludes that Browse gas has the potential to play a significant role in enabling provision of clean and reliable energy as a partner to renewables. In addition, gas has the potential to contribute significantly to the reduction in global GHG emissions by displacing higher carbon intensive power generation (e.g. coal combustion). As such, it is considered that this principle of ESD has been considered in determining appropriate management and mitigation measures.
If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.	Key aspects of the project will not result in any significant impacts (as defined in the MNES significant impact criteria) to endangered and vulnerable species—refer to Chapter 6. The available threatened species data (pygmy blue whales and green turtles), 2002 to 2017 and 2002 to 2010 respectively, were determined to be reliable and adequate for an assessment of impacts and risks to vulnerable species, and for the identification of suitable control measures, to ensure that the environmental objectives for the project are met. The existing data will be updated by a targeted monitoring program to verify impact predictions and inform adaptive management approaches at relevant times throughout the project life cycle, refer to Chapter 8, Table 8-1. Scientific knowledge will continue to be a key input into the detailed engineering phase and the implementation of the environmental mitigation, management and monitoring programs. Woodside has committed to the continuation of the Scott Reef long-term monitoring program to monitor the functionality and status of the reef system throughout the full lifecycle of the proposed Browse to NWS Project.

Principles of ESD	Assessment
The principle of inter-generational equity – that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.	As described above and in **Chapter 6** , all of the stated environmental objectives of the proposed Browse to NWS Project (**Table 6-7**) are predicted to be achieved and all impacts from planned activities have been assessed as acceptable. In addition, environmental risks have been reduced to an acceptable level, with the likelihood of significant impacts occurring as a result of unplanned events or incidents considered highly unlikely to remote. As such, it is considered that maintenance of the health, diversity and productivity of the environment will not be adversely impacted by the proposed Browse to NWS Project. Further, environmental benefits are expected to be realised as part of the ongoing monitoring of the remote reef systems within and outside the Project Area and research collaborations with appropriate science partners. Design and management measures set out in **Chapter 8** will ensure key environmental features in the Browse Development Area (Scott Reef) will be preserved for and accessible to future generations. As such, it is considered that this principle of ESD has been and will continue to be met.
The conservation of biological diversity and ecological integrity should be a fundamental consideration in decision making.	As described above and throughout this draft EIS/ERD, the conservation of biological diversity and ecological integrity has been and will continue to be integral to the decision making process associated with the proposed Browse to NWS Project. This is demonstrated by: + integration of conservation of biological diversity and ecological integrity into decision making during the selection of the development concept for the commercialisation of the Browse reservoirs + selection of environmental objectives that align with the principles of Ecologically Sustainable Development and the adoption of management and migration measures to achieve each objective + The commitment to manage operational discharges (PW and cooling water from the FPSO facilities) from the FPSOs to meet the defined threshold values (i.e. 99% species protection or lowest no effect concentration) at the State waters 3 nm boundary, 95% of the time + a commitment to manage drilling discharges (in particular bottom hole discharges) at drill centre locations in the State Proposal Area (i.e. TRA, TRD, TRE and TRF) in such a manner to avoid impacts to Scott Reef shallow water benthic communities and habitats (<75 m water depth) + monitoring programs for marine reptiles, cetaceans, and coral reef communities to verify impact predictions and aid management. As such, it is considered that this principle of ESD has been and will continue to be met.
Improved valuation, pricing and incentive mechanisms should be promoted.	In line with its corporate policies and procedures, Woodside will endeavour to use valuation, pricing and incentive mechanisms during procurements associated with the proposed Browse to NWS Project to balance economic and HSE outcomes. As such, it is considered that this principle of ESD has been and will continue to be met.

EPBC Act Controlling Provisions

An assessment of the proposed Browse to NWS Project against the MNES Significant Impact Guidelines for the controlling provisions is provided in **Table 9-24**. The significant impact criteria is provided in **Table 6-3**.

Table 9-24 Assessment of proposed Browse to NWS Project against the significant impact criteria for the controlling provisions

Controlling Provisions	Assessment
Listed Threatened Species and Ecological Communities	As per the overall impact assessment provided in **Section 9.2.2**: + No impact to any species listed as extinct in the wild is predicted as a result of the proposed Browse to NWS Project. + No significant impact is predicted to occur to any critically endangered, endangered or vulnerable species. This includes no significant impact, at a population level, to a species habitat (including habitat critical to a species survival) or to a species breeding cycle as a result of the proposed Browse to NWS Project. + The proposed Browse to NWS Project is not expected to affect the recovery of any species that has a species recovery plan in place (see EPBC conservation management plans below). + The likelihood that the proposed Browse to NWS Project results in the introduction and establishment of IMS or disease that may affect listed threatened species has been assessed as Remote. + No impact to Threatened Ecological Communities is predicted as a result of the proposed Browse to NWS Project. The environmental objectives for the proposed Browse to NWS Project have been developed in consideration of the significant impact criteria outline in **Table 6-5**. The assessment has concluded that all environment objectives relevant to listed threatened species are predicted to be achieved. As such, no significant impacts, as defined by MNES Significant Impact Guidelines, are expected to occur in relation to this controlling provision.
Listed Migratory Species	As per the impacts and risk assessment provided in **Chapter 6** and cumulative impact assessment provided above: + It is not expected that the proposed Browse to NWS Project will modify, destroy, fragment or isolate important areas for migratory species. + The proposed Browse to NWS Project is not expected to result in the introduction and establishment of IMS or disease that may affect listed threatened species. + It is not expected that the proposed Browse to NWS Project will seriously disrupt the lifecycle of an ecologically important proportion of the population of a migratory species. The environmental objectives for the proposed Browse to NWS Project have been developed in consideration of the significant impact criteria outline in **Table 6-5**. The assessment has concluded that all environment objectives relevant to listed migratory species are predicted to be achieved. As such, the assessment has concluded that no significant impacts, as defined by MNES Significant Impact Guidelines, are expected to occur in relation to this controlling provision.

Controlling Provisions	Assessment
The Commonwealth marine area, the protected matter being the environment generally.	As per the impacts and risk assessment provided in **Chapter 6** and cumulative impact assessment provided above: + The proposed Browse to NWS Project is not expected to result in the introduction and establishment of IMS or disease that may affect listed threatened species. + It is not expected that the proposed Browse to NWS Project will modify, destroy, fragment, isolate or disturb substantial areas of habitat, such that an adverse impact results in a reduction of marine ecosystem function or integrity within the Commonwealth marine area. + It is not expected that the proposed Browse to NWS Project will have a substantial adverse effect on a population of a marine species, including its life cycle and distribution. + It is not expected that the proposed Browse to NWS Project will result in a substantial change in air quality or water quality (including temperature) which may adversely impact on biodiversity, ecological integrity, social amenity or human health. + It is not expected that the proposed Browse to NWS Project will result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected. + It is not expected that the proposed Browse to NWS Project will have a substantial adverse impact on heritage values of the Commonwealth marine area, including damage or destruction of an historic shipwreck or plane wreck. The environmental objectives for the proposed Browse to NWS Project have been developed in consideration of the significant impact criteria outline in **Table 6-5**. The assessment has concluded that all environment objectives relevant to the Commonwealth Marine Environment are predicted to be achieved. As such, the assessment has concluded that no significant impacts, as defined by MNES Significant Impact Guidelines, are expected to occur in relation to this controlling provision.
National heritage values of a National Heritage Place	There are no National Heritage Places identified within the Project Area that may be affected by the proposed Browse to NWS Project. The assessment of any potential impacts on the national heritage values, including aboriginal heritage values, of the listed National Heritage Place on the Dampier Archipelago that may be associated with the onshore processing of the Browse gas by the NWS JV, is addressed within the ERD associated with the North West Shelf Project Extension Proposal (EPA 2186, EPBC 2018/8335).

WA EPA Environmental Objectives

An assessment of the State waters component of the proposed Browse to NWS Project against the relevant WA EPA's Environmental Objectives (as determined by the WA EPA) is provided in **Table 9-25**.

Table 9-25 Assessment of State waters component of the proposed Browse to NWS Project against the relevant WA EPA Environmental Objectives

EPA Environmental Objective	Assessment
Benthic Communities and Habitats - To protect benthic communities and habitats so that biological diversity and ecological integrity are maintained.	As per the impacts and risk assessment provided in **Chapter 6** and above, the environmental objectives in relation to deepwater benthic habitat (>75 m water depth) and Scott Reef shallow water benthic habitats (<75 m water depth) are predicted to be met. As detailed in **Chapter 8** and as recommended in the WA EPA Technical Guidance – Protecting the Quality of Western Australia's Marine Environment (EPA, 2016), Levels of Ecological Protection (LEPs) have been assigned within the State Proposal Area which include a maximum LEP for all Scott Reef shallow water benthic communities (<75 m water depth) and the majority of deepwater benthic communities (> 75 m water depth) during both construction and operations. A Environmental Quality Management Plan will be prepared and implemented to achieve these LEPs. As such, it is predicted that the WA EPA environmental objective *"to protect benthic communities and habitats so that biological diversity and ecological integrity are maintained"* will be achieved.
Marine Environmental Quality - To maintain the quality of water, sediment and biota so that environmental values are protected.	As per the impacts and risk assessment provided in **Chapter 6** and above, the environmental objectives in relation to marine environmental quality (specifically sediment quality, water quality and biota) are predicted to be met. As detailed in **Chapter 8** and as recommended in the WA EPA Technical Guidance – Protecting the Quality of Western Australia's Marine Environment (EPA, 2016), Levels of Ecological Protection (LEPs) have been assigned within the State Proposal Area which include a maximum LEP for all Scott Reef shallow water benthic communities (<75 m water depth) and the majority of remaining State Proposal area, with High or Moderate LEPs assigned directly around the proposed subsea infrastructure within deepwater benthic communities (> 75 m water depth) during both construction and operations. An Environmental Quality Management Plan will be prepared and implemented to achieve these LEPs. As such, it is predicted that the WA EPA environmental objective *"to maintain the quality of water, sediment and biota so that environmental values are protected"* will be achieved.
Marine Fauna - To protect marine fauna so that biological diversity and ecological integrity are maintained.	As per the impacts and risk assessment provided in **Chapter 6** and above, the environmental objectives in relation to marine fauna (specifically seabirds and migratory shorebirds, fish, marine mammals, marine reptile, epifauna and infauna) are predicted to be met. As per the impacts and risk assessment provided in **Chapter 6** and cumulative impact assessment presented in **Section 9.2**, no significant impacts to marine fauna, including their life cycle or distribution are expected to occur. Potential impacts that may occur are expected to be limited to temporary behavioural (avoidance) impacts as a result of noise emissions, however, these are not expected to be significant. As such, it is predicted that the WA EPA environmental objective *"To protect marine fauna so that biological diversity and ecological integrity are maintained"* will be achieved.
Air Quality - To maintain air quality and minimise emissions so that environmental values are protected.	No significant impacts to air quality from offshore atmospheric emissions are expected to occur as a result of the proposed Browse to NWS Project. As such, it is predicted that the WA EPA environmental objective *"To maintain air quality and minimise emissions so that environmental values are protected"* will be achieved" . Atmospheric Emissions from third party processing of Browse Gas are addressed in the NWS JV 'North West Shelf Project Extension ERD' (EPA 2186, EPBC 2018/8335).

North-west Marine Parks Network Management Plan

As described in Section 9.2.2.2, the proposed BTL route traverses the Multiple Use Zones (IV) of the Argo-Rowley Terrace and Kimberley Marine Parks. It should also be noted that the proposed BTL route passes approximately 2 km from the boundary of the Mermaid Reef Marine Park National Park Zone. Rationale for the route selection of the BTL is provided in Chapter 3.

The conservation values and objectives of the marine parks are outlined in the North-west Marine Parks Network Management Plan (Director of National Parks, 2018).

Impacts to AMPs will occur as a result of the permanent installation of the proposed BTL and temporarily due to vessel-based marine discharges of cooling water, putrescible waste and sewage and sullage during construction and IMR activities.

The impact of seabed disturbance on the Multiple Use Zone of the two AMPs has been minimised as far as practicable during the route selection process (Chapter 3). Impacts have been assessed as negligible as the area traversed by the proposed BTL represents a small proportion of the total area of the AMPs and the activities are considered to be consistent with the objective of the Multiple Use Zone (VI) to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species.

As described in Chapter 6, given their temporary and transient nature, the impact of the vessel-based marine discharges is not expected to result in any lasting effect on the values of the two AMPs traversed (i.e. the Kimberley Marine Park and Argo-Rowley Terrace Marine Park). As such, no cumulative impacts are expected to occur to AMPs as a result of marine discharges and seabed disturbance related to the installation of the subsea infrastructure.

As such, it is considered that the proposed activities are not inconsistent with the requirements of the North-west Marine Parks Network Management (Director of National Parks, 2018).

Assessment against EPBC conservation plans

Wildlife Conservation Plan for Migratory Shorebirds

Sandy Islet is used for roosting by seabirds and supports minor seabird breeding colonies, including for the little tern. Scott Reef is recognised as a resting BIA for the little tern. The Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a) has an objective that “Anthropogenic threats to migratory shorebirds in Australia are minimised or, where possible, eliminated”.

Mitigation and management measures described in Chapter 6 (particularly with respect to light emissions (Section 6.3.3), atmospheric noise emissions (Section 6.3.7), hazardous and nonhazardous waste (Section 6.3.14) and unplanned hydrocarbon releases (Section 6.3.21)), have been specifically developed to reduce the impact of planned activities and reduce the risk of unplanned events and incidents to an acceptable level.

As described in Section 9.2.2.2, the overall impact significance level of impacts on seabirds and migratory shorebirds has been assessed as Minor (D), based on the assessment of impacts resulting from light emissions (Minor (D)) and atmospheric noise (Slight (S)). These impacts are predicted to be limited to temporary behavioural impacts. Therefore, it is considered that the proposed activities are not inconsistent with the Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015a).

The Recovery Plan for Marine Turtles in Australia (2017-2027)

Sandy Islet and the surrounding waters (20 km internesting buffer) are recognised as habitat critical to the survival of green turtles for the Scott Reef-Browse Island genetic stock in the Recovery Plan for Australian Marine Turtles 2017-2027 (Commonwealth of Australia, 2017) (Figure 5-27). In addition, a BIA exists for internesting green and hawksbill turtles around Sandy Islet. (Figure 5-26).

The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017) has specific requirements to:

- Manage anthropogenic activities to ensure marine turtles are not displaced from identified habitat critical to the survival.
- Manage anthropogenic activities in BIAs to ensure that biologically important behaviour can continue.
- In relation to the Scott Reef – Browse Island green turtle genetic stock, the priority action is to manage anthropogenic activities to ensure marine turtle populations are not displaced from identified habitat critical to their survival.

Mitigation and management measures described in Chapter 6 (particularly with respect to light emissions (Section 6.3.3), underwater noise emissions (Section 6.3.8) and unplanned hydrocarbon releases (Section 6.3.21)) have been specifically developed to reduce the impact of planned activities and reduce the risk of unplanned events and incidents to an acceptable level.

As described in **Section 9.2.2.2**, the overall impact significance level of impacts on marine turtles has been assessed as Minor (D), based on the assessment of impacts resulting from underwater noise emissions (Minor (D) and light emissions (Minor (D)). These impacts are predicted to be limited to temporary behavioural impacts which are not expected to reduce nesting success. No displacement of marine turtles from identified habitat critical to the survival is predicted.

Therefore, it is considered that the proposed activities are not inconsistent with the objectives of the Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017).

Conservation Management Plan for the Blue Whale

The Project Area overlaps the pygmy blue whale migration BIA and possible foraging area located at Scott Reef, as identified in Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015b). The conservation plan identifies noise interference and vessel disturbance as threats to the recovery of pygmy blue whales and notes an action that “Anthropogenic noise in biologically important areas will be managed such that any blue whale continues to utilise the area without injury, and is not displaced from a possible foraging area”.

Mitigation and management measures described in **Chapter 6**(particularly with respect to underwater noise emissions (**Section 6.3.8**), unplanned vessel interactions with fauna (**Section 6.3.18**) and unplanned hydrocarbon releases (**Section 6.3.21**)) have been specifically developed to reduce the impact of planned activities and reduce the risk of unplanned events and incidents to an acceptable level.

As described in **Section 9.2.2.2**, the overall impact significance level of impacts on marine mammals has been assessed as Minor (D). The impacts from underwater noise emissions have been assessed as minor. Behavioural modification of pygmy blue whales accessing a possible foraging area is not predicted as only 2% of the potential foraging area is predicted to be ensonified at levels above behaviour impact thresholds, leaving 98% of the possible foraging area available to pygmy blue whales and uninterrupted foraging. Potential impacts are likely to be restricted to a small number of individuals that may be travelling through the area and have been demonstrably minimised.

Therefore, it is considered that the proposed activities are not inconsistent with the Conservation Management Plan for the Blue Whale.

Overall conclusion

Woodside has considered the outcomes of the impact and risk assessment process and developed a range of mitigation and management measures to be implemented throughout the life cycle of the proposed Browse to NWS Project. In consideration of the unique values of Scott Reef and surrounds, the principles of ESD, the objects of the EPBC Act and EP Act and other relevant requirements, Woodside has concluded that the nominated environmental objectives for the proposed Browse to NWS Project will be met, the predicted impacts from planned activities and the potential risks from unplanned events and incidents have been reduced to an **Acceptable** level and that the proposed Browse to NWS Project can be implemented in a manner that will result in significant socio-economic benefits, while avoiding unacceptable environmental impacts.

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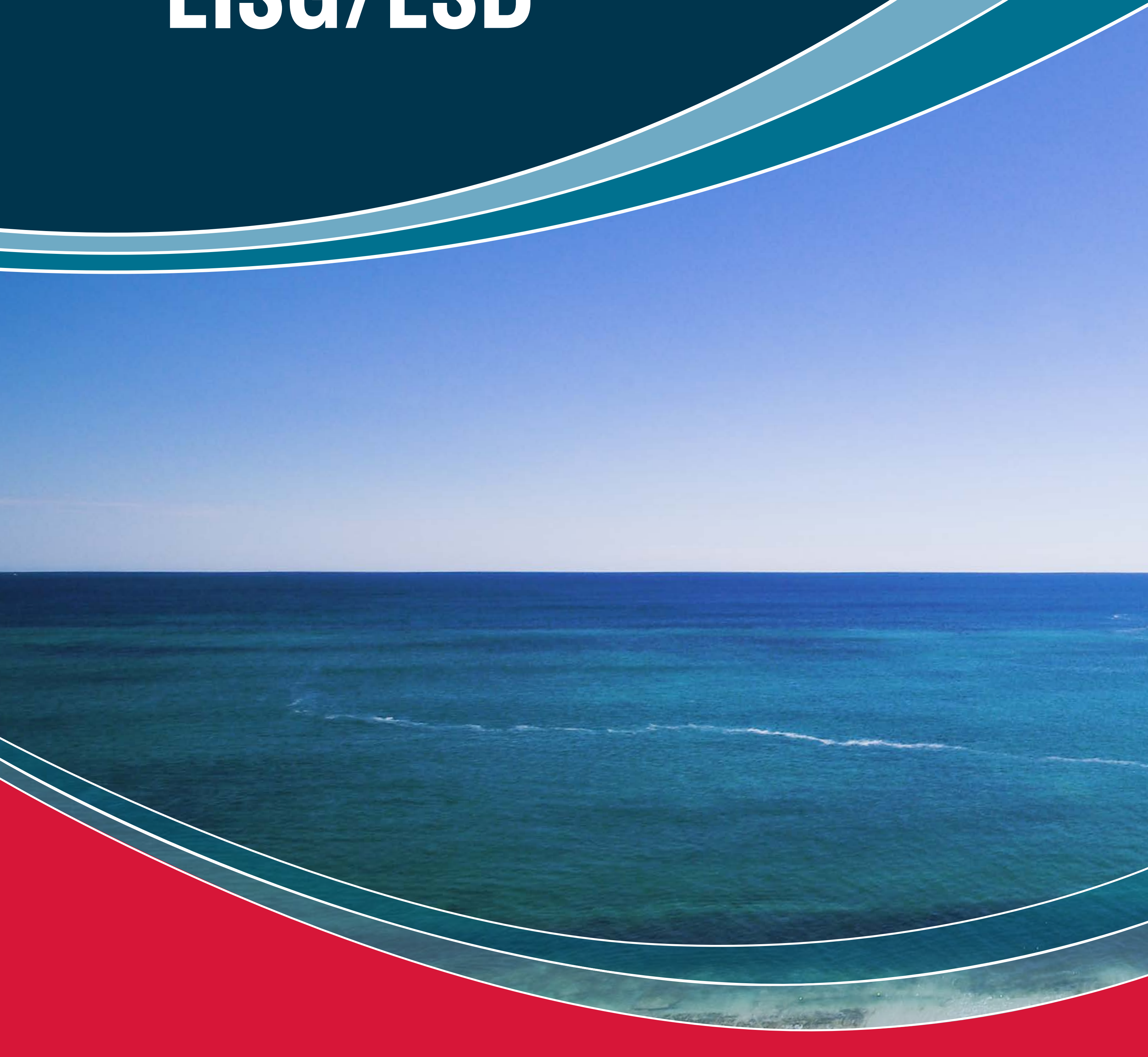
CHAPTER 10, APPENDIX A

PROPOSED BROWSE TO NWS PROJECT EISG/ESD



Woodside

EIS Guidelines / Environmental Scoping Document

Browse to North West Shelf Project

(EPBC 2018/8319, EPA 2191)

Under Environment Protection and Biodiversity Conservation Act 1999 (Cwlth)

and

Part 4 of the Environmental Protection Act 1986 (WA)

July 2019
Rev 2

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1. INTRODUCTION

1.1 Background

1.1.1 Overview of Browse to North West Shelf Project

The Browse Joint Venture (BJV) propose to develop the Brecknock, Calliance and Torosa fields (collectively known as the Browse resources) using two 1100 Million standard cubic feet per day (MMscfd) (annual daily export average) Floating Production Storage and Offloading (FPSO) facilities. The FPSO facilities will be supplied by a subsea production system and will transport gas to existing North West Shelf (NWS) Project infrastructure via a ~85 km spur line and a ~900 km Browse Trunkline (BTL), which will tie in near the existing North Rankin Complex (NRC) (note NRC is owned by North West Shelf Joint Venture (NWS JV).

Woodside Energy Ltd (Woodside) is Operator for and on behalf of the BJV (Woodside Browse Pty Ltd, Shell Australia Pty Ltd (Shell), BP Developments Australia Pty Ltd (BP), Japan Australia LNG Pty Ltd (MIMI Browse) and PetroChina International Investment (Australia) Pty Ltd (PetroChina)).

In September 2018, the proposed Browse to NWS Project entered Concept Definition phase. The proposed Browse to NWS Project is predominately based on proven technologies, including:

- two floating production storage and offloading (FPSO) facilities delivering around 11.4 Mtpa of LNG/LPG and domestic gas; and
- an approximately 900 km pipeline to existing NWS infrastructure.

Optimisation studies and other assessments are ongoing, which may result in changes being made to the reference case.

1.1.2 Project History

Woodside has conducted multiple ‘Concept Select’ phases for the Browse reservoirs; and has undertaken various studies to characterise the environment and understand the impacts and risks associated with the various development concepts. Details of these studies are included in **Table 5** and **Table 11**. These studies have informed the environmental approvals process for two previous development concepts being:

- The James Price Point (JPP) development concept in 2010 which was progressed through both State and Commonwealth environmental approvals (upstream: EPBC 2008/4111, downstream: referral and request that the proposal be declared a derived proposal under Ministerial Statement 917).
- The FLNG development concept which was referred under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) (EPBC 2013/7079) and received approval in August 2015. Note that the portion of the FLNG development concept that lies in State waters (the Torosa Subsea Development) was also referred to the Western Australian Environmental Protection Authority (WA EPA) under the Environmental Protection Act 1986 (EP Act) in December 2014 and was determined to not require assessment by the WA EPA in February 2015.

Over a 7-month period between September 2016 and April 2017, the BJV completed a development concept narrowing process with the aim of having ‘line of sight to at least one globally competitive and investable development concept which all stakeholders can support’.

Since April 2017, this development concept has been progressed through the Concept Select phase. Engineering and technical studies appropriate for the Concept Select phase have confirmed the preliminary feasibility of the Browse to NWS development concept which is the subject of this Environmental Impact Statement Guidelines (EISG) / Environmental Scoping Document (ESD).

1.1.3 Environmental Assessment Process

1.1.3.1 Environmental Referrals

The Proposed Action was referred to the Department of the Environment and Energy (DoEE) under the EPBC Act in October 2018. On 22 February 2019, the DoEE advised Woodside that the delegate for the Minister for the Environment had determined that the Proposed Action is a controlled action and requires assessment and approval under the EPBC Act before it can proceed. This assessment would be by Environmental Impact Statement. The following controlling provisions were identified in the decision notice:

- National heritage values of a National Heritage place
- Listed threatened species and communities
- Listed migratory species
- Commonwealth marine area, the protected matter being the environment generally.

The Western Australian (WA) State waters component of the proposed Browse to NWS Project was referred to the WA Environmental Protection Authority (EPA) under the EP Act in October 2018. On 22 January 2019, the WA EPA determined that the Proposal requires assessment under Section 39 of the EP Act and set a Public Environmental Review (PER) level of assessment.

The determination identified the following WA EPA Environmental Factors as being relevant for the Proposal within State waters.

- Benthic Communities and Habitats
- Marine Environmental Quality
- Marine Fauna
- Air Quality.

The determination requires Woodside to prepare an Environmental Scoping Document (ESD) and set a public review period for the Environmental Review Document (ERD) of 6 weeks.

1.1.3.2 Assessment Process

The assessment of the Proposed Action under the EPBC Act and EP Act is planned to be undertaken as a coordinated assessment between the DoEE and WA EPA. The National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) will be engaged to provide technical advice to the DoEE in relation to the assessment.

This approach includes the following:

- Simultaneous referrals for the Proposed Action/Proposal under the EPBC Act and EP Act, which was completed in October 2018.
- The development of an EIS Guidelines (EISG) / ESD (this document) which describes the proposed content of an Environment Impact Statement/Environmental Review Document (EIS/ERD). This EISG/ESD will be issued to DoEE and EPA for review and endorsement.
- The development of a single draft EIS/ERD document that is issued to DoEE and EPA for comment on adequacy and approval, prior to release for public comment.
- The preparation of a single final EIS/ERD document. The final EIS/ERD will be submitted to the DoEE and WA EPA for assessment and to be published.

- Decision on the acceptability of the Proposed Action by the Commonwealth and State.

The environmental assessment process including expected timeframes is provided in **Table 1**. Timeframe and schedule will be documented in a DoEE issued Client Service Charter.

Table 1 Environmental Assessment Process

Stage	Action	Timeframe/Schedule
Pre-referral	Project definition meeting between Woodside, WA EPA and DoEE	Completed
Referral	Simultaneous referrals for the Proposed Action under the EP Act and EPBC Act	Completed: 17 October 2018
	Agency and public comment on referrals and Woodside response	Completed: January 2019
	Level of Assessment set by DoEE	Completed:22 February 2019
	Level of Assessment set by WA EPA	Completed: 22 January 2019
Scoping	Woodside prepare draft EISG/ESD in consultation with DoEE, WA EPA and NOPSEMA	Completed: 3 May 2019
	DoEE and WA EPA approves EISG/ESD	Target: June 2019
Draft EIS/ERD	Woodside prepare draft EIS/ERD	Target: Mid 2019
	DoEE (in consultation with NOPSEMA) and WA EPA review draft EIS/ERD for adequacy	
	Woodside revise EIS/ERD and resubmit	
	DoEE (in consultation with NOPSEMA) and WA EPA approve release of draft EIS/ERD	
	Public comment on draft EIS/ERD	DoEE = 4 weeks EPA = 6 weeks
Final EIS/ERD	Woodside address public comments and prepare final EIS/ERD	
	DoEE and WA EPA review final EIS/ERD for adequacy	
	Woodside revise EIS/ERD and resubmit	
	DoEE (in consultation with NOPSEMA) and WA EPA approve release of final EIS/ERD	
Evaluation of Project Proposal	DoEE (in consultation with NOPSEMA) and WA EPA assess final EIS/ERD and prepare draft assessment reports and recommendations	
	Woodside review draft assessment reports and recommendations	
	DoEE (in consultation with NOPSEMA) and WA EPA assess final EIS/ERD and prepare final assessment reports and recommendations	
	Relevant Ministers make decision on project approval	Target: Q2 2020

Subsequent to a favourable decision on the acceptability of the proposed Browse to NWS Project, and prior to any development activity occurring in Commonwealth waters, Environment Plans (EPs) including Oil Pollution Emergency Plan (OPEP) will be developed for approval by NOPSEMA in accordance with the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009.

1.2 Purpose of the EISG/ESD

The EISG/ESD has been jointly developed by Woodside, the DoEE and the WA EPA to address assessment requirements specified in the EPBC Act and EP Act. In general, the EISG/ESD aims to describe the proposed content of the EIS/ERD and set the scope of studies required to allow assessment and decision on the appropriateness of the proposed Browse to NWS Project.

In relation to the EP Act, the purpose of the EISG/ESD is to define the form, content, timing and procedure of the ERD, required by s. 40(3) of the EP Act. The EPA requires that proponents use the ESD template for all proponent prepared ESDs, which is fulfilled in Section 3.

1.3 Scope of the combined EIS/ERD

A combined EIS/ERD document is proposed to meet Commonwealth and State requirements respectively. However, with respect to the WA EPA’s assessment under the EP Act, the scope of the Proposal is infrastructure and related activities within State waters.

The scope of the combined EIS/ERD document is limited to construction and operation of the upstream component of the proposed Browse to NWS Project including:

- development drilling, completion and well unload activities (drilling and completion) of the Brecknock, Calliance and Torosa reservoirs
- installation and commissioning of subsea infrastructure, including anchors and mooring lines, umbilicals, flowlines, flexible risers, and manifolds
- installation and commissioning of the Browse Trunkline (BTL) and inter-field spur line including tie-in to existing NWS Project infrastructure near NRC
- installation, hook-up and commissioning of the FPSO facilities
- operation of the subsea infrastructure, including wells/wellheads, umbilicals, flowlines, risers, and manifolds, including inspection, maintenance and repair activities
- operation of the FPSO facilities, including condensate stabilisation, storage and offtake, gas processing (CO_2 and water removal and gas compression) and export
- transmission of gas from the FPSO facilities to the NWS Project infrastructure tie in point
- inspection, maintenance and repair activities
- decommissioning of subsea infrastructure (including well plug and abandonment), BTL, inter-field spur line and FPSO facilities at the end of reservoir field life (approximately 50 years).

The transportation and processing of Browse resources from the tie in point near NRC will be undertaken via the use of existing NWS Project infrastructure, which are the subject of different joint venture arrangements. These activities are covered by separate referrals submitted by the NWS JV under the EP Act (Assessment number 2186) and EPBC Act (EPBC 2018/8335). The relationship between these activities will be explained in the EIS/ERD.

The Proposed Action will involve vessel and helicopter movements in order to support the offshore facilities; however, it is not dependent on the development of new onshore infrastructure in order to proceed.

As the location(s) for supply chain and logistics support infrastructure are not yet determined, vessel and helicopter movements from a range of potential locations to the proposed Browse to

NWS Project are being considered similar to the previously approved FLNG concept. Existing infrastructure and related services will be utilised.

1.4 EISG/ESD structure

To demonstrate assessment requirements specified by the DoEE and WA EPA for the preparation of an EISG/ESD have been addressed, and to facilitate review, this EISG/ESD has been divided in three parts:

- Section 2 - PART A Description of Proposed Action
- Section 3 - PART B Specific content of the combined EIS/ERD
- Section 4 - PART C State ESD.

2. PART A: DESCRIPTION OF PROPOSED ACTION

2.1 Proposed Project Area

The Browse hydrocarbon resource is located in the Brecknock, Calliance and Torosa reservoirs approximately 425 km north of Broome and approximately 290 km off the Kimberley coastline.

The Project area consists of:

- the proposed Browse Development Area comprising the Brecknock, Calliance and Torosa fields, the FPSO facilities and the subsea production systems, including wells. The proposed Browse Development Area is approximately 2,897 ha in size
- the pipeline corridor within which the proposed BTL and inter-field spur line will be located from the proposed Browse Development Area to the tie in point near NRC. The pipeline corridor is approximately 985 ha in size and lies entirely within Commonwealth waters.

The total size of the Project Area is approximately 3,827 ha (noting that approximately 55 ha of the pipeline corridor lies within the proposed Browse Development Area).

The Browse Development Area consists of seven petroleum retention leases under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (OPGGS Act), the State *Petroleum (Submerged Lands) Act 1982* (PSL Act) and the *Petroleum and Geothermal Energy Resources Act 1967* (WA). Five of the leases (WA-28-R, WA-29-R, WA-30-R, WA-31-R and WA-32-R) are located in Commonwealth waters. Two leases (TR/5 and R2) are within the State jurisdiction.

The pipeline corridor runs approximately ~900 km south west from the Calliance/Brecknock FPSO facility to the tie-in point with the NWS Project infrastructure near NRC. The pipeline corridor also includes a ~85 km inter-field spur line connecting the Torosa FPSO to the Calliance/Brecknock FPSO.

2.2 Key Characteristic of proposed Browse to NWS Project

2.2.1 Overview

The proposed Browse to NWS Project comprises subsea infrastructure and two FPSO facilities connected to existing NWS Project infrastructure via a ~900 km trunkline. To achieve optimal hydrocarbon recovery, it is anticipated that in the order of 13 wells are required for Ready for Start-up (RFSU) of the two FPSO facilities, and up to 49 wells are currently anticipated over field life. Indicative numbers of wells are presented in **Table 2**. The number and locations of the wells are subject to detailed design and refinement. The final number and approximate locations of the development wells and an appropriate project-specific assessment of impacts will be presented in the EIS/ERD.

Seabed disturbance within the Project area is expected to be approximately 1,200 ha of the approximately 3,900 ha Project area (210 ha for subsea infrastructure and moorings plus 985 ha for the proposed BTL and inter-field spur line). These values are subject to refinement during the design process.

The proposed Browse Development Area is shown in **Figure 1**. The BTL and inter-field spur line route are shown in **Figure 2**.

Table 2 Proposed Development Components

Component	State waters*	Overall development*
Development well count (up to)	21	49 (including 20 wells at Calliance, 22 wells at Torosa and 7 wells at Brecknock)
Subsea infrastructure	Wellheads, manifolds, flowlines and umbilicals, (seabed disturbance approximately 20 ha)	Wellheads, manifolds, flowlines, umbilicals, risers, anchors and moorings (seabed disturbance approximately 210 ha)
Surface facilities	None	Two ~1100 MMscf/d (annual daily average) FPSO facilities
Browse Trunkline (BTL)	None	~900 km 42” diameter trunkline with adequate capacity for export of 1,800 MMscf/d (maximum of 2,150 MMscf/d)*.
Inter-field spur line	None	~85 km 34” diameter spur line with adequate capacity for export of up to 1100 MMscf/d (annual daily average).

*Subject to detailed design and refinement

2.2.2 Development Infrastructure

The proposed Browse to NWS Project comprises of the key infrastructure components listed in Section 1.2, and described in detail below.

Wells

It is anticipated that the proposed Browse to NWS Project will require drilling and completion of up to 49 production wells at the Brecknock, Calliance and Torosa reservoirs over the life of the Project. Production wells will be drilled from a number of central drill centres. The number and location of these wells and drill centres will depend on reservoir target areas, seabed bathymetry and features to optimise reservoir recovery. Up to an estimated 21 of the production wells will be located within State waters.

Subsea Infrastructure and Flexible Risers

The wells at each drill centre will be connected to manifolds to allow reservoir fluids to be carried from the wells to the manifolds. The manifolds connect the wells to corrosion resistant alloy (CRA) flowlines that are routed back to the FPSO facilities. Connection between the flowlines and the FPSO facilities is achieved using flexible risers through a Flowline End Termination (FLET) or riser base manifold. Other subsea infrastructure includes the FPSO anchors and mooring lines and potentially permanent moorings for support vessels.

Each of the subsea infrastructure types described above will be located in both State and Commonwealth waters except for the flexible risers, mooring turrets and permanent FPSO mooring anchors which are only located in Commonwealth waters.

FPSO Facilities

Two FPSO facilities are proposed for the development. The FPSO facilities will have ship-shaped hulls ((nominally 335 m (up to 370 m) long x 67 m wide x 35 m deep)) with approximately 1,000,000 barrels’ effective condensate storage. The FPSO facilities will be permanently moored on location by mooring turrets. The FPSO facilities will be located in Commonwealth waters.

BTL and Inter-Field Spur Line

An approximately 85 km 34” inter-field spur line will connect the Torosa FPSO facility to the 42” trunkline near Calliance/Brecknock FPSO. Gas will be exported from the FPSO facilities via the 42” carbon steel BTL that runs approximately 900 km south west from the Calliance/Brecknock FPSO facility to the tie-in point with the NWS Project infrastructure near NRC.

The entire length of the inter-field spur line and BTL will be located in Commonwealth waters.

2.2.3 Development Activities

Development Drilling

It is anticipated that a mobile offshore drilling unit (MODU), which is either moored or dynamically positioned, will be used to drill and complete the wells. A moored MODU is anticipated to be moored using anchors, suction piles or driven piles, similar but most likely smaller, than those used for the FPSO facilities. Production wells will be drilled to depths of between 3,500 and 4,500 m beneath sea level to intersect the reservoirs. Once the reservoir is reached, the well may be drilled at inclination (up to horizontally) to optimise the length of the well within the reservoir and the recovery of reservoir fluids. Wireline logging activities may be undertaken for formation evaluation during drilling. This may include Vertical Seismic Profiling (VSP) or other logging activities, which may contain radioactive sources.

Installation of Subsea Umbilicals, Risers and Flowlines (SURF)

Subsea infrastructure required for start-up will be installed prior to the arrival of the FPSO facilities, with further infrastructure installed throughout the life of the proposed development, as required. Subsea infrastructure such as manifolds, flowlines, umbilicals, mooring systems and risers will be transported to site by a combination of installation vessels and cargo barges. Subsea installation of equipment will be performed by specialist DP vessels. Subsea equipment will typically be lowered into place from a vessel with a crane. Up to 20 piles may be installed to secure the riser bases, if required. Installation and hook up of the equipment on the seabed is typically achieved using submersible Remotely Operated Vehicles (ROVs). The ROVs will also aid in commissioning processes.

Seabed preparation works may be required to position flowlines on a level surface, to provide stability to the subsea gathering system. Seabed preparation works will most likely be undertaken using ploughing and/or mass flow excavation techniques. Protection and additional stabilisation methods, such as trenching and rock placement, may also be required to limit potential damage to flowlines and subsea infrastructure.

Installation of FPSO facilities

A turret mooring system will be installed for each FPSO facility using a DP installation vessel. The configuration is expected to comprise three groups of six mooring lines per group (pending completion of mooring analysis), arranged around the turret. The turret mooring system will include a non-rotating component to support the mooring lines, risers and umbilicals. This configuration allows the facility to freely weathervane with prevailing metocean conditions. Once on location, each FPSO facility will be connected to the mooring system.

The mooring lines will be preferentially secured to the seabed by suction piles. The suction piles will typically be 6 m to 10 m in diameter, and up to 30 m in length, with each weighing approximately 450 tonnes.

Installation of BTL and Inter-Field Spur Line

The BTL and inter-field spur line will be installed via a pipelay vessel. Sections of pipe will be welded together on the vessel before being laid directly onto the sea floor from the stern of the vessel. Typically, these vessels are held in place via DP systems or conventional mooring systems. Initiation anchors may be required temporarily at each end of the pipeline to support installation. The pipeline pieces will typically be manufactured overseas and transported directly to the pipelay vessel by barge.

Commissioning

Once installation and hook up of subsea infrastructure is complete, the subsea infrastructure will be subject to pre-commissioning, which is required to test the integrity of the subsea infrastructure. This will be conducted using hydrotest fluids, whereby the flowline pressure will be monitored to detect leaks. Fluids will then be left in place to provide corrosion protection prior to the introduction of reservoir fluids. Hydrotest fluid will either be discharged to sea at depth or returned to the FPSO facilities and discharged overboard. Hydrotesting will also be conducted on the BTL and inter-field spur line. The majority of the BTL hydrotest water will be discharged directly to sea at the Brecknock/Calliance FPSO, while the hydrotest water from the inter-field spur line will be discharged directly to sea at the Torosa FPSO.

As the FPSO facilities will be constructed at an existing fabrication yard overseas, pre-commissioning of the facilities will be preferentially carried out at the yard, and may include checking, inspection, cleaning, tightness testing, drying and inerting and first fill of process chemicals and adsorbents for the gas treatment system.

2.2.4 Operations

Extraction

During operations, hydrocarbons extracted from the reservoirs will flow via christmas trees and manifolds through the flowlines to the FPSO facilities. The flow rate of hydrocarbons will be controlled by subsea choke valves at the wellheads. Subsea hydraulic control fluids will be used to operate the choke valves.

Processing

Processing on the FPSO facilities topsides commences with the reservoir fluids being separated into a gas stream and a liquid stream (condensate and process water (PW)). The condensate and PW are then further separated with the PW sent for treatment prior to discharge overboard.

The condensate stream is stabilised and sent to compartmentalised condensate storage tanks prior to offloading. The gas will be sent to an acid gas removal unit (AGRU) for treatment. It will then be dehydrated, cooled and compressed prior to export to the NWS infrastructure via the BTL.

Condensate Offload

Up to 50,000 bbls of condensate will be produced daily. Condensate will be loaded on to condensate tankers using flexible hoses every two to four weeks (depending on the production rate), resulting in approximately 12 to 24 oil tanker movements a year per FPSO facility. The oil tankers will then transport the condensate to market.

Gas Export

Transport of the dry gas to the NWS Project onshore processing facility will be via the inter-field spur line and BTL to the NWS infrastructure at NRC. Transportation of the Browse resources from the tie in point near NRC using existing third party trunkline infrastructure and processing of the gas onshore is outside the scope of the Proposed Action. Liquids will not be present in the inter-field spur line and BTL.

2.2.5 Inspection, Maintenance and Repairs

The facility subsea infrastructure is designed to require only minor degrees of intervention. Inspection and maintenance is undertaken to ensure the integrity of the infrastructure and identify any problems before they present a risk of loss of containment. Intervention may be required to repair identified problems. Subsea activities can be broadly categorised into the following groups:

- Inspection - the process of physical verification and assessment of components in order to detect changes to its as-installed state in comparison to previous or baseline inspections.

Typical subsea inspection activities may include visual inspection, cathodic protection (CP) surveys, side scan sonar / multi-beam echo sounding, photogrammetry, process composition testing, corrosion probes, corrosion mitigation checks, metocean and seismic monitoring, cathodic protection testing and non-destructive measurement / testing, which may be supported by ROV or diver.

- Maintenance - required at regular and/or planned intervals to prevent deterioration or failure of equipment, or to maintain performance or reliability before failure or unacceptable deteriorations occurs. Maintenance activities may include cycling of valves, and leak and pressure testing.
- Repair - activities required when a subsea system or component is degraded, damaged or has deteriorated to a level outside of acceptance limits as defined by design codes. Damage sustained may not necessarily pose an immediate threat to continued system integrity, but may present an elevated level of risk to safety, health and environment or production reliability. Repair activities may also be associated with response to an emergency scenario.

2.2.6 Decommissioning

At the end of the Development life, the facilities will be decommissioned in accordance with all applicable existing legislation and good oilfield practice at the time. Decommissioning will occur once the Brecknock, Calliance and Torosa reservoirs have reached the end of their economic life and may occur in stages. This will likely include well suspension and plugging and abandoning wells.

2.2.7 Communications

Due to the distance of the proposed Browse to NWS Project from the mainland, a reliable high-speed communication network will be required between facilities offshore and the mainland. The network will be supplied by connection to an existing fibre optic cable.

2.2.8 Support Activities and Helicopters

The drilling and completion, installation and commissioning phases will be supported by barges, tugs, survey vessels, supply vessels (thereafter referred to as support vessels) and installation and pipelay vessels. Vessel requirements during the decommissioning phase are unknown at this stage due to uncertainty regarding the methodology to be applied, but it can be expected that decommissioning will use similar vessels to those engaged for installation activities.

The operations phase will require a small number of vessels in attendance in the vicinity of the FPSO facilities for transporting personnel, stores and equipment on a routine basis. The supply vessels will travel between the supply chain and logistics support facility (or facilities) and the FPSO facilities, while tugs will travel to the facility to support offloading as required.

Transfer to offshore facilities will be via helicopter or vessel. It is anticipated that up to two personnel transfers a week per FPSO facility will be required during normal operations. In times of high activity such as crew changes, shutdowns and major maintenance, it is anticipated that there could be two to three flights per day, or equivalent vessel transfers, per facility.

2.2.9 Development Schedule

Subject to all necessary joint venture and regulatory approvals being obtained and appropriate commercial arrangements being finalised, the indicative timeframes for the proposed Browse to NWS Project are as follows:

- commencement of construction and drilling and completion activities from approximately 2021 – 2022,
- followed by installation and commissioning activities,

- RFSU and commencement of operations occurring in the mid-2020s, and
- operations continuing for up to 50 years.

Following operations, decommissioning activities will be carried out as part of the Proposed Action.

3. PART B: SPECIFIC CONTENT OF THE EIS/ERD

3.1 Information and Advice Related to the Preparation of an EIS/ERD

3.1.1 The Objectives of the EIS/ERD

Environmental impact assessment depends on adequately defining those elements of the environment that may be affected by a proposed development, and on identifying the significance, risks and consequences of the potential impacts of the Proposed Action at a local, regional and national level. The EIS/ERD will be a significant source of information on which the public and government decision-makers will assess the potential environmental impacts of the Proposed Action.

It is expected that additional ecological and socio-economic investigations will be required to be undertaken to provide sufficient information for the EIS/ERD. The nature and level of investigations will be related to the likely extent and gravity of the potential impacts (likelihood, consequence, magnitude, extent and scale of impacts, including worst case scenarios). All relevant impacts of the Proposed Action on MNES and the State waters proposal on WA EPA environmental factors are to be investigated and analysed, and commitments to avoid, mitigate and offset any adverse impacts are to be detailed in the EIS/ERD.

The aims of the EIS/ERD and public review process are:

- to provide a source of information from which interested individuals and groups may gain an understanding of the Proposed Action, the need for the Proposed Action, the alternatives, the environment which it could potentially affect, the impacts that may occur and the measures proposed to be taken to avoid or minimise these impacts
- to provide a forum for public consultation and informed comment on the Proposed Action
- to provide a framework in which decision-makers can consider the environmental aspects of the Proposed Action including biophysical, cultural, social, heritage, economic, technical and other factors (as applicable).

The EIS/ERD will discuss compliance with the objectives of the EPBC Act, EP Act and the principles of ecologically sustainable development, as set out in the EPBC Act. The EIS/ERD will also identify and address, as fully as possible, all matters relevant to the Proposed Action and State waters proposal and their potential impacts.

The EIS/ERD will provide a description of the existing environment in the area affected by the Proposed Action and any decommissioning of existing infrastructure, construction, operations and future decommissioning proposed. All potential impacts and risks on the environment are to be investigated and analysed. The EIS/ERD will present an evaluation of the potential environmental impacts using an accepted risk-based methodology and describe proposed measures to avoid, minimise or offset the expected, likely, or potential impacts. Any prudent and feasible alternatives will be discussed in detail and the reasons for selection of the preferred option will be clearly given. The State waters proposal will be similarly assessed.

3.1.2 General Advice

The EIS/ERD will be a stand-alone document. It will contain sufficient information from studies and/or investigations undertaken to avoid the need to refer to previous or supplementary reports. Headers and/or footers will be used to denote which section the page relates to (i.e. based on the table of contents).

The EIS/ERD will enable interested stakeholders and the assessing agencies to understand the environmental consequences of the proposed development. Information provided in the EIS/ERD will be objective, clear, succinct and, where appropriate, be supported by maps, plans, diagrams or other descriptive detail. The body of the EIS/ERD is to be written in a style that is easily understood by a member of the public. Technical jargon will be avoided wherever possible and a full glossary included. Cross-referencing will be used to avoid unnecessary duplication of text.

If it is necessary to make use of material that is considered to be of a confidential nature, the proponent will consult with the DoEE and WA EPA on the preferred presentation of that material, before submitting it for approval for publication.

Detailed technical information, studies or investigations necessary to support the main text will be included as appendices issued with the EIS/ERD. Any additional supporting documentation and relevant studies, reports or literature not normally available to the public from which information has been extracted will be made available at appropriate locations during the period of public display of the EIS/ERD.

Where specific information requirements are set out within this EISG/ESD, they should be read as a requirement for as much detail as is appropriate and reasonably available at this stage of planning. The EIS/ERD will clearly identify any gaps in the information presented and include discussion on the effect of these gaps on the overall results of the assessment and possible methods for addressing them.

An executive summary will be provided and made available as a stand-alone document for public information.

The EIS/ERD will state the criteria adopted in assessing the Proposed Action and its potential impacts, such as: compliance with relevant legislation, policies, standards and best practice; community acceptance; maximisation of environmental benefits (if any); and minimisation of risks and harm. The State waters proposal will be similarly assessed.

Any and all unknown variables or assumptions made in the assessment will be clearly stated and qualified. The extent to which the limitations, if any, of available information may influence the conclusions of the environmental assessment will be discussed.

Woodside will ensure that the personnel providing information to address this EIS/ERD have the relevant qualifications and experience in their relevant fields.

The EIS/ERD will comprise three elements:

a) The executive summary
b) The main text of the document, written in a clear and concise manner so as to be readily understood by a member of the public.
c) Appendices containing a copy of this EISG/ESD and detailed technical information which may include other sensitive commercial or cultural information (if required).

The EIS/ERD will be written so that any conclusions reached can be independently assessed. To this end all sources will be appropriately referenced.

3.2 Invitation to make a submission

The draft EIS/ERD will include an invitation to make a submission including:

1. details on how and when public submissions will be addressed in the assessment and decision-making process
2. how submissions can be made
3. what form submissions should take
4. when submissions should be made.

3.3 Executive Summary

An executive summary that outlines the key findings of the EIS/ERD will be provided. The executive summary will briefly:

1. state the background and the need for the Proposed Action and State waters proposal.
2. discuss alternatives to the Proposed Action, State waters proposal and the reasons for selecting the preferred option and rejecting alternatives
3. summarise the installation, operational and decommissioning activities associated with putting the Proposed Action and State waters proposal into practice
4. state the proposed schedule for key activities and the expected duration of the Proposed Action and State waters proposal
5. provide an overview of the existing regional and local environments, summarising the features of the physical, biological, social and economic environment relating to the Proposed Action, State waters proposal and associated activities with each
6. describe the expected, likely and potential impacts of the Proposed Action and State waters proposal on the environment during the installation, operational and decommissioning phases
7. summarise the environmental protection measures and safeguards, monitoring and decommissioning procedures to be implemented for the Proposed Action and State waters proposal
8. provide an outline of the environmental record of Woodside.

3.4 General Information

The EIS/ERD should provide the background of the proposed Browse to NWS Project including:

1. the title of the action
2. the full name and postal address of the designated proponent
3. a clear outline of the objective of the action
4. the location of the action
5. the background to the development of the action
6. how the action relates to any other actions (of which the proponent should reasonably be aware) that have been, or are being, taken or that have been approved in the region affected by the action
7. the current status of the action
8. the consequences of not proceeding with the action
9. a brief explanation of the scope, structure and legislative basis of the EIS/ERD

10. the specific EPBC Act MNES and WA EPA Environmental factors affected by the action
11. a description of government planning policies and statutory controls which will influence the proposed Browse to NWS Project. All applicable jurisdictions and areas of responsible authorities within the area will be listed and shown on maps at appropriate scales.

3.5 Description of the Action

3.5.1 Development Description

All installation, operational, IMR and decommissioning components of the action will be described in sufficient detail to understand the Proposed Action and State waters proposal and assist in determining the associated potential environmental impacts. This will include the location (including coordinates) of all works to be undertaken, structures to be built or elements of the action that may have relevant impacts (on MNES and/or WA EPA Environmental Factors) and other social or economic impacts. In addition, proposed safeguards and mitigation measures to deal with relevant impacts of the action will be included.

The description of the action will also include details on how the works are to be undertaken (including all stages of development and their timing) and design parameters for those aspects of the structures or elements of the action, including how the operation is to be managed, that may have relevant impacts and other social or economic impacts.

The description will include the use of aerial photographs, maps, figures and diagrams, where appropriate. A general location map will be provided that illustrates the existing and proposed infrastructure and will include the location of known potential future expansions or new developments in the vicinity. Reference will be made to detailed technical information in appendices where relevant.

The description will also include any other requirements for approval or conditions that apply, or that Woodside reasonably believes are likely to apply, to the Proposed Action or State waters proposal.

3.5.2 Feasible Alternatives

Any feasible alternatives to the action to the extent reasonably practicable, including:

1. if relevant, the alternative of taking no action and/or part of the Proposed Action and State waters proposal
2. a comparative description of the adverse and beneficial impacts of each alternative on MNES and WA Environmental Factors
3. sufficient detail to make clear why any alternative is preferred to another and if approval is being sought for feasible alternatives as part of this assessment process.

Short, medium and long-term advantages and disadvantages of the options will be discussed.

3.5.3 Social and Economic Matters

For the purpose of the assessment under the EPBC Act, information will be provided on the broader social and economic impacts (positive or negative) of the Proposed Action. Any information provided for this purpose will be in a separately identified section or appendix of the EIS/ERD. Such information provided may address:

1. the broader economic benefits of the Proposed Action going ahead versus alternatives
2. any effects on employment that may occur beyond the immediate scope of the Proposed Action (including versus alternatives). Any methodology used to calculate indirect effects associated with employment will be provided

3. information on the amount of domestic and/or overseas investment for capital infrastructure (including versus alternatives)
4. any other social or economic issues that may relate directly or indirectly.

3.6 Stakeholder Engagement

The EIS/ERD will provide details of any consultation in relation to the Proposed Action and State waters proposal including:

1. consultation that has already taken place
2. documented response or results of the consultation that has taken place
3. any further proposed consultation.

Woodside will consult with relevant stakeholders in relation to the proposed Browse to NWS Project. These stakeholders include decision-making authorities, other relevant government agencies and authorities (local, state, and Commonwealth), the local community, local indigenous groups, academics, research authorities and environmental non-government organisations. The EIS/ERD will describe the consultation method adopted, existing stakeholder forums and skills and techniques used to ensure effective communication of the nature and detail of proposed Browse to NWS Project. This will include the means used to identify concerns and to gauge and progress mitigation strategies.

The assessment documentation must provide details of the potential indirect impacts of the proposed action on the (Indigenous rock art) values of the Dampier Archipelago (including the Burrup Peninsula) National Heritage Place, and the extent to which these values may potentially be impacted by the proposed action following any planned mitigations.

3.7 Description of the Environment

3.7.1 Overview

Section 528 of the EPBC Act defines the environment as including:

(a) ecosystems and their constituent parts, including people and communities; and

(b) natural and physical resources; and

(c) the qualities and characteristics of locations, places and areas; and

(d) the social, economic and cultural aspects of a thing mentioned in paragraph (a), (b) or (c).

Subsection 3(1) of the EP Act defines the environment as meaning "… living things, their physical, biological and social surroundings, and interactions between all of these"

The EIS/ERD will include a detailed description of the environment within the Project Area and the surrounding areas (including State waters) that may be affected by the Proposed Action.

The environment that may be affected (EMBA) by the proposed Browse to NWS Project, which is the largest spatial extent where unplanned events could have an environmental consequence on the surrounding environment will be described. The spatial areas of the defined EMBA and Project Area will be used to identify and describe all environmental values, including environmental and socio-economic, that are relevant to the project. The relevant receptors (based on the preliminary impact and risk assessment) and their relationship with the MNES categories and the WA EPA Factors are presented in **Table 3** and **Table 4** respectively.

This EIS/ERD chapter will describe the following elements of the environment within the Project Area:

- Physical environment including
  - Climate and atmospheric characteristics
  - Oceanographic conditions, bathymetric and geotechnical information
  - Marine water and marine sediment characteristics
- Ecological environment including
  - An overall evaluation of the flora and fauna communities identified with reference to:
    - habitat values in a local, regional and national context
    - presence of endemic species
    - regional representation; conservation and biodiversity values
    - economic and cultural values of species
    - unique habitats.
  - Particular attention will be given to the conservation values within Scott Reef and surrounds (e.g. diverse aggregations of marine life, higher primary production relative to other parts of the regions, high species richness and heritage values) and their importance in a local, regional and national context as described in the Marine bioregional plan for the North-west Marine Region (Commonwealth of Australia 2012).
  - A broader description of the biodiversity and biogeography of the receiving environment, including the identification of sensitive environments along with key ecological relationships and interdependencies (e.g. coral spawning, fish spawning aggregations, flora and fauna relationships).
  - A description of listed threatened species and ecological communities (EPBC Act sections 18 & 18A), listed migratory species (EPBC Act sections 20 & 20A) and protected species under the Biodiversity Conservation Act 2016 that are likely to be present in the vicinity of the proposed Browse to NWS Project. Descriptions will include the predicted temporal and spatial variability in occurrence within the Project Area, known habitat utilisation or requirements and relevant identified threats to their survival. Details of the scope, timing and scientifically robust methodology for studies or surveys used to provide information on the listed species/communities/habitats at the site (and in areas that may be impacted by the project) will also be included. Species to be addressed in the EIS/ERD include, but are not be limited to the following. Additional EPBC Act listed threatened and listed migratory species will be considered following completion of the relevant modelling studies to be undertaken to determine the species that may be affected:
    - Pygmy blue whale (*Balaenoptera musculus brevicauda*)
    - Humpback whale (*Megaptera novaeangliae*)
    - Sei Whale (*Balaenoptera borealis*)
    - Fin Whale (*Balaenoptera physalus*)
    - Green Turtle (*Chelonia mydas*)
    - Loggerhead Turtle (*Caretta caretta*)
    - Leatherback Turtle (*Dermochelys coriacea*)
    - Hawksbill Turtle (*Eretmochelys imbricata*)

    - Olive Ridley Turtle (*Lepidochelys olicacea*)
    - Flatback Turtle (*Natator depressus*)
    - Common Noddy (*Anous stolidus*)
    - Streaked Shearwater (*Calonectris leucomelas*)
    - Lesser Frigatebird (*Fregeta ariel*)
    - Little Tern (*Stenula albifrons*)
    - Barn Swallow (*Hirundo rustica*)
    - Common Sandpiper (*Actitis hypoleucos*)
    - Green Sawfish (*Pristis zijsron*)
    - Large Sawfish (*Pristis prisis*)
    - Whale shark (*Rhincodon typus*).
  - A description of the marine environment (EPBC Act sections 23 & 24A and EP Act) relevant to the action, including, but not limited to, habitat, species and values of listed Western Australian and Commonwealth Heritage places, Key Ecological Features (identified in the relevant Marine Bioregional Plan) and Western Australian and Commonwealth Marine Parks including:
    - distance from the Proposed Action
    - reserve characteristics
    - status
    - IUCN category
    - Conservation value
    - relevant management strategies
  - Appropriate resources will be reviewed and cited throughout, including all relevant government issued conservation advice and recovery plans, and recent ecological studies where available (e.g. AIMS North West Shoals to Shore Research Program).
  - The extent of existing disturbance to flora and fauna, and the incidence of introduced pest species will be discussed.
- Socio-economic environment including:
  - a description of all existing uses and users of the Project Area including discussion of scientific research, tourism, commercial, traditional and recreational fishing, military areas and shipping routes (where relevant)
  - a description of government planning policies and statutory controls which will influence the project, surrounding areas of future, planned and current use. All applicable jurisdictions and areas of responsible authorities within the area will be listed and shown on maps at appropriate scales
  - any places with known or anticipated heritage, social or cultural values, such that they have been recognised with listing or recording under relevant State or Commonwealth legislation or are anticipated to be listed under such legislation
  - a description of any historic shipwrecks within the area pursuant to the Commonwealth Underwater Cultural Heritage Act 2018 (which will replace the Historic *Shipwrecks Act 1976* on 01 July 2019) and State *Maritime Archaeology Act 1973*, including locations.

3.7.2 Format of Chapter

The chapter will be set out in a format broadly similar to the following outline:

1. Existing Environment
    - 1.1. Receptor Group (e.g. Marine Fauna)
        - 1.1.1. Receptor (e.g. Marine Mammals)
            - 1.1.1.1. Background and Regional Overview
            - 1.1.1.2. Browse Development Area
                - 1.1.1.2.1. Scott Reef
                - 1.1.1.2.2. Remainder of area
            - 1.1.1.3. Trunkline and Inter field Spur-line Route

3.7.3 Relevant Receptors in relation to MNES and WA EPA Factors

Table 3 indicates the relevant receptors for the Proposed Action (based on the preliminary impact and risk assessment) and their relationship to the MNES.

Table 3 Relevant Receptors in relation to Matters of National Environmental Significance

Matters of National Environmental Significance	Physical Receptors					Ecological Receptors														Socio-Economic Receptors								
	Marine Sediments	Marine Water quality	Air Quality	Ambient Light	Ambient Noise	Planktonic Communities	Epifauna and Infauna	Coral	Seagrass	Macroalgae	Saltmarsh	Mangroves	Seabirds and Migratory Shorebirds	Fish	Marine Mammals	Marine Reptiles	Key Ecological Features	Australian Marine Parks	State Marine Parks and Reserves	Commonwealth Managed Fisheries	State Managed Fisheries	Tourism and Recreation	Shipping	Industry	Settlements	Other Protected Places	Indigenous heritage	Marine Archaeology
National heritage values of a national Heritage place																											✓	
Listed threatened species and communities													✓	✓	✓	✓												
Listed migratory species													✓	✓	✓	✓												
The Commonwealth marine area	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓		✓		✓	✓	✓			✓	✓

Table 4 indicate the relevant receptors for the State waters proposal (based on the preliminary impact and risk assessment) and their relationship to the WA Environmental Factors.

Table 4 Relevant Receptors in relation to WA EPA Environmental Factors

WA EPA Factors	Physical Receptors					Ecological Receptors														Socio-Economic Receptors								
	Marine Sediments	Marine Water quality	Air Quality	Ambient Light	Ambient Noise	Planktonic Communities	Epifauna and Infauna	Coral	Seagrass	Macroalgae	Saltmarsh	Mangroves	Seabirds and Migratory Shorebirds	Fish	Marine Mammals	Marine Reptiles	Key Ecological Features	Australian Marine Parks	State Marine Parks and Reserves	Commonwealth Managed Fisheries	State Managed Fisheries	Tourism and Recreation	Shipping	Industry	Settlements	Other Protected Places	Indigenous heritage	Marine Archaeology
Benthic Communities and Habitats	✓	✓					✓	✓	✓	✓																		
Marine Environmental Quality	✓	✓				✓	✓	✓	✓	✓			✓	✓	✓	✓			✓									
Marine Fauna				✓	✓								✓	✓	✓	✓												
Air Quality			✓																									

3.7.4 Previous studies to characterise the existing environment

Information on the existing environment for the EIS/ERD will primarily be drawn from existing literature and studies previously completed by Woodside including long-term monitoring. Woodside has commissioned approximately 60 studies within the proposed Browse Development Area, Scott Reef and the broader region that span approximately two decades. Studies have included baseline and annual programs for humpback whale, turtle, other marine megafauna and fish species in the region, as well as long-term monitoring of coral and fish communities at Scott Reef.

These studies have enabled Woodside to build a comprehensive understanding of the environmental context of developing the Browse resources, to enable identification of the potential environmental impacts and development of the appropriate measures to manage and mitigate these.

Further, Woodside has continued to support the undertaking of studies and monitoring programs for species and communities that exhibit marked temporal changes in population dynamics or spatial distribution variability. For example, AIMS has continued to monitor annual changes in coral and fish communities at Scott Reef (dataset 1993-2018). These studies have identified dramatic changes to Scott Reef related to the impact from cyclones and thermal-induced bleaching.

For species or communities that are unlikely to have major changes in either population numbers, seasonality or distribution patterns Woodside will utilise historical Woodside datasets (supplemented with any additional non-Woodside studies) to describe current receptors and inform the impact assessment. **Table 5** outlines the previous studies undertaken to support the potential development of the Browse resource.

Table 5 Previous studies undertaken to characterise the environment in relation to development of the Browse resource

A full index of previous Browse technical studies is available at https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies

Organisation	Study Name	Link to Report	Receptor
AIMS	The Status of Shallow-water Coral and Fish Communities at Scott Reef 2008	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f19---gilmour-et-al_-2008---the-status-of-shallow-water-coral-and-fish-communities-at-scott-reef-2008_.pdf?sfvrsn=c2b428aa_2	Scott Reef and surrounds (Fish and Benthic Habitat)
	Technical Report - Project 3.1 Understanding Water Column and Pelagic Ecosystem Processes Affecting the Lagoon of South Reef, Scott Reef – 2009	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f05---brinkman-et-al_-2009a---understanding-water-column-and-pelagic-ecosystem-processes-affecting-the-lagoon-of-south-reef_-scott-reef_.pdf?sfvrsn=ba399510_2	Scott Reef and surrounds (Water Quality)
	Annual Report - Project 3.1 Understanding Water Column and Pelagic Ecosystem Processes Affecting the Lagoon of South Reef, Scott Reef – 2009	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f06---brinkman-et-al_-2009b---understanding-water-column-and-pelagic-ecosystem-processes-affecting-the-lagoon-of-south-reef_-scott-reef_.pdf?sfvrsn=ea38c18d_2	Scott Reef and surrounds (Water Quality)
	Final Report - Project 3.1. Understanding Water Column and Pelagic Ecosystem Processes Affecting the Lagoon of South Reef, Scott Reef	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f07---brinkman-et-al_-2010---understanding-water-column-and-pelagic-ecosystem-processes-affecting-the-lagoon-or-south-reef_-scott-reef_.pdf?sfvrsn=51b32958_2	Scott Reef and surrounds (Water Quality)
	Characterising the Genetic Connectivity and Photobiology of Deep Water Reef Building Corals at South Scott Reef, Western Australia – 2010	Relevant information is intended to be made publicly available for the EIS/ERD review	Scott Reef and surrounds (Fish and Benthic Habitat)
	Long-term Monitoring of Coral and Fish Communities at Scott Reef 2009	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f22---gilmour-et-al_2010---long-term-monitoring-of-coral-and-fish-communities-at-scott-reef_.pdf?sfvrsn=e480e4fd_2	Scott Reef and surrounds (Fish and Benthic Habitat)
	Long-term Monitoring of Shallow-water Coral and Fish Communities at Scott Reef, Technical Report 2008 (2009)	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f20---gilmour-et-al_-2009a---long-term-monitoring-of-shallow-water-coral-and-fish-communities-at-scott-reef_.pdf?sfvrsn=d29af749_2	Scott Reef and surrounds (Fish and Benthic Habitat)
	Long-term Monitoring of Shallow-water Coral and Fish Communities at Scott Reef, Annual Report 2008 (2009)	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f21---gilmour-et-al_-2009b---long-term-monitoring-of-shallow-water-coral-and-fish-communities-at-scott-reef_.pdf?sfvrsn=3f4a6840_2	Scott Reef and surrounds (Fish and Benthic Habitat)
	Long-term Monitoring of Coral and Fish Communities at Scott Reef Annual Report 2010	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f22---gilmour-et-al_2010---long-term-monitoring-of-coral-and-fish-communities-at-scott-reef_.pdf?sfvrsn=e480e4fd_2	Scott Reef and surrounds (Fish and Benthic Habitat)
	Long-term Monitoring of Shallow Water Coral and Fish Communities at Scott Reef 2011	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-	Scott Reef and surrounds (Fish and

Organisation	Study Name	Link to Report	Receptor
		files/browse---documents-and-files/index-of-previous-browse-studies/f23---gilmour-et-al_-2011---long-term-monitoring-of-shallow-water-coral-and-fish-communities-at-scott-reef_.pdf?sfvrsn=4fbd8630_2	Benthic Habitat)
	Long-term Monitoring of Shallow Water Coral and Fish Communities at Scott Reef 2012	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f24---gilmour-et-al_-2013a---long-term-monitoring-of-shallow-water-coral-and-fish-communities-at-scott-reef-2012_.pdf?sfvrsn=be5660c0_2	Scott Reef and surrounds (Fish and Benthic Habitat)
	Long-term Monitoring of Shallow-water Coral and Fish Communities at Scott Reef 2014	Relevant information is intended to be made publicly available for the EIS/ERD review	Scott Reef and surrounds (Fish and Benthic Habitat)
	Long-term monitoring at Scott Reef and the Rowley Shoals 2017	Relevant information is intended to be made publicly available for the EIS/ERD review	Scott Reef and surrounds (Fish and Benthic Habitat)
	Migration Patterns of Whale Sharks: A Summary of 15 Satellite Tag Tracks from 2005 to 2008	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f30---meekan-amp-radford-2010---migration-patterns-of-whale-sharks-a-summary-of-15-satellite-tag-tracks-from-2005-to-2008_.pdf?sfvrsn=f996a7e4_2	Whale sharks
Australian Marine Mammal Centre (AMMC)	Satellite Tracking of South-bound Female Humpback Whales in the Kimberley Region of Western Australia	Relevant information is intended to be made publicly available for the EIS/ERD review	Humpback whales
	Satellite tracking of northbound humpback whales (*Megaptera novaeangliae*) off Western Australia	Relevant information is intended to be made publicly available for the EIS/ERD review	Humpback whales
Centre for Marine Science and Technology (CMST) (Curtin University of Technology)	Woodside Kimberley Sea Noise Logger Program, September 2006 to June 2009 - 2011	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f29---mccauley-2011---woodside-kimberley-sea-noise-logger-program_-sept-2006-to-june-2009-whales_-fish-and-man-made-noise_.pdf?sfvrsn=ba55f587_2	Underwater noise
Centre for Whale Research (CWR)	Humpback Whale Distribution and Abundance in the Near Shore SW Kimberley During Winter 2008 Using Aerial Surveys - 2008	Relevant information is intended to be made publicly available for the EIS/ERD review	Humpback whales
	Near-shore Vessel Surveys in the SW Kimberley Region During the Humpback Whale Southern Migration - 2008	Relevant information is intended to be made publicly available for the EIS/ERD review	Humpback whales
	Mega-Fauna Distribution and Relative Abundance in the Scott Reef and Southwest Kimberley Region During - 2008	Relevant information is intended to be made publicly available for the EIS/ERD review	Marine Fauna
	Cetacean Distribution and Oceanography in the Scott Reef/Browse Basin Project areas - 2008	Relevant information is intended to be made publicly available for the EIS/ERD review	Cetaceans
	Double, M. C., Andrews-Goff, V., Jenner, K. C. S., Jenner, M. N., Laverick, S. M., Branch, T. A., & Gales, N. J. (2014). Migratory movements of pygmy blue whales (*Balaenoptera musculus brevicauda*) between Australia and Indonesia as revealed by satellite telemetry. PloS one, 9(4), e93578.	Relevant information is intended to be made publicly available for the EIS/ERD review	Pygmy Blue Whales
Charles Darwin University	Long Term Monitoring of the Marine Turtles of Scott Reef 2010	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f26---guinea-2010---long-term-monitoring-of-the-marine-turtles-of-scott-reef-february-2010_.pdf?sfvrsn=2339899b_2	Marine turtles
	Long Term Monitoring of the Marine Turtles of Scott Reef, February 2010 Field Survey Report	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f26---guinea-2010---long-term-monitoring-of-the-marine-turtles-of-scott-reef-february-2010_.pdf?sfvrsn=2339899b_2	Marine turtles

Organisation	Study Name	Link to Report	Receptor
CSIRO	Characterising the Seabed Biodiversity and Habitats of the Deep Continental Shelf and Upper Slope off the Kimberly Coast, NW Australia – 2010	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f38---williams-et-al_-2010---characterising-the-seabed-biodiversity-amp-habitats-of-the-deep-continental-shelf-amp-upper-slope-off-the-kimberley-coast_.pdf?sfvrsn=16f5d1c_2	Satellite data study of oceanography and plankton
DHI	Hydrodynamic Model Validation at Scott Reef and Surrounds – 2009	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f10---dhi-2009---browse-environmental-modelling-phase-1-hydrodynamic-model-validation-at-scott-reef-and-surrounds_.pdf?sfvrsn=7deb2a9b_2	Metocean
Fugro Survey Pty Ltd (Fugro)	Offshore Geophysical Surveys 2006: Volume 2A Browse Basin Survey Results	Relevant information is intended to be made publicly available for the EIS/ERD review	Hydrographic and geophysical surveys
Gardline Marine Services Pty Ltd (Gardline)	Browse LNG Development Environmental Survey - 2009	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f18---gardline-2009---browse-lng-development-environmental-survey-june-to-july-2009-environmental-baseline-report_.pdf?sfvrsn=e9cc49c6_2	Water quality, sediment quality and benthic habitats
J P Kenny Pty Ltd (JP Kenny)	Channel Pipelines - Pipe Installation and Trenching Study - 2008	Relevant information is intended to be made publicly available for the EIS/ERD review	Sediment quality survey
MetOcean Engineers	Preliminary Metocean Conditions for the Browse Development (Prospective Production Facilities / Areas, Pipeline Routes / Shore Crossings and Flow-lines / Seabed Manifolds), Scott Reef Vicinity to Shore - 2005	Relevant information is intended to be made publicly available for the EIS/ERD review	Metocean data
RPS Environment and Planning Pty Ltd (RPS)	Marine Megafauna Report - 2009	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f31---rps-2010a---marine-megafauna-report_.pdf?sfvrsn=9273be06_2	Marine mega fauna
	DFS 17 & DFS 20 MMF 2009 Humpback Whale Survey Report	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f32---rps-2010b---humpback-whale-survey-report_.pdf?sfvrsn=bcb9973e_2	Humpback Whales
	Ecology of Marine Turtles of the Dampier Peninsula and the Lacepede Island Group - 2010	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f33---rps-2010c---ecology-of-marine-turtles-of-the-dampier-peninsula-and-the-lacepede-island-group_-2009-2010_.pdf?sfvrsn=ece0e3ba_2	Marine turtles
	Marine Megafauna Study - 2010	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f34---rps-2011a---marine-megafauna-study-2010_.pdf?sfvrsn=1d25716d_2	Marine Megafuna
	Marine Megafauna Survey Report 2011	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f36---rps-2012---marine-megafauna-survey-report-2011_.pdf?sfvrsn=f970949f_2	Marine Megafuna
	Humpback Whale Survey Report - 2010	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f32---rps-2010b---humpback-whale-survey-report_.pdf?sfvrsn=bcb9973e_2	Humpback Whales

Organisation	Study Name	Link to Report	Receptor
	Turtle Supplementary Report - 2010	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f35---rps-2011c---turtle-supplementary-report-2010_.pdf?sfvrsn=b37eac02_2	Marine Turtles
RPS MetOcean	Study of Meteorological Conditions for the Production Facility for Scott Reef Development - 2007	Relevant information is intended to be made publicly available for the EIS/ERD review	Metocean conditions
	Detailed Metocean Conditions for the Browse Development - 2008	Relevant information is intended to be made publicly available for the EIS/ERD review	
Sinclair Knight Merz Ltd (SKM) ERM	Scott Reef Invasive Marine Species - 2008	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f37---skm-ltd-2009---scott-reef-invasive-marine-species-survey_.pdf?sfvrsn=7588df36_2	Nearshore benthic habitat
	Aerial survey of Inshore Marine Megafauna Along the Dampier Peninsula - 2009	Relevant information is intended to be made publicly available for the EIS/ERD review	Scott Reef IMS
	Scott Reef Green Turtle Satellite Tracking Report - 2011	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f27---guinea-2011---long-term-monitoring-of-the-marine-turtles-of-scott-reef-satellite-tracking-of-green-turtles-from-scott-reef_.pdf?sfvrsn=6fd7a6bf_2	Marine Turtles
URS Australia Pty Ltd (URS)	Report on Environmental Surveys Undertaken at Scott Reef in February 2006	Relevant information is intended to be made publicly available for the EIS/ERD review	Scott Reef
	Scott Reef Environmental Survey 4: ROV Inspection of Deep Habitats in Scott Reef Lagoons - 2007	Relevant information is intended to be made publicly available for the EIS/ERD review	Scott Reef
	Scott Reef Environmental Survey 5: ROV Inspection of Deep Water Outer Reef Habitats - 2007	Relevant information is intended to be made publicly available for the EIS/ERD review	Scott Reef
	Scott Reef Environmental Surveys – 2007	Relevant information is intended to be made publicly available for the EIS/ERD review	Scott Reef
Western Australian Museum (WAM)	Marine Biodiversity Survey of Mermaid Reef (Rowley Shoals), Scott and Seringapatam Reef - 2006	Relevant information is intended to be made publicly available for the EIS/ERD review	Ecology of Mermaid, Scott and Seringapatam Reefs

3.7.5 Summary of Workplan

Although the development concept for the Browse resources has changed to the proposed Browse to NWS Project concept, the environmental footprint of the facilities and subsea infrastructure (other than the BTL and inter-field spur line) is expected to be similar to that of the FLNG development concept where a significant amount of work has already been undertaken, especially around Scott Reef.

An overview of the current level of understanding and workplan for each relevant receptor is provided in **Table 6**. The studies outlined in **Table 6** would inform the design and implementation of any environmental monitoring programs that may be mandated as part of the assessment process. Woodside notes that should environmental monitoring be required to verify impact predictions during construction and/or operations, appropriate studies may be required to inform the baseline status of some environmental receptors prior to monitoring.

Table 6 Existing Environment Workplan

Receptor Group	Receptor	Key Areas of Consideration	Assessment of Current Level of Understanding and information gaps	Environmental Studies Workplan
Physical	Marine sediments	Seabed in Browse Development Area, BTL corridor and surrounds	As there is likely to be little or no significant change to marine sediments within the Browse Development Area since previous studies were undertaken, Woodside will rely on historical datasets (~3 years collection period) to support existing environmental baseline knowledge. The basis for the baseline assessment of sediment quality values within the Browse Development Area are the findings from three principal surveys undertaken within the area (Brinkman et al., 2009a; Gardline Marine Services Pty Ltd, 2009a; URS Australia Pty Ltd, 2007). The most recent Gardline survey (2009) including sediment and analysis at 31 stations including seven at the Calliance field and eight at the Torosa field. The studies demonstrated that sediments within the Browse Development Area were generally classified as muddy sand with variable gravel components, with sediments at the Brecknock, Calliance and Torosa reservoirs generally soft silt and clay, with areas of sand and stiff, hard and/or cemented material (Fugro Survey Pty Ltd, 2006; Gardline Marine Services Pty Ltd, 2009a). No evidence of hydrocarbon contamination in sampled seabed sediments was reported in the Browse Development Area (Gardline Marine Services Pty Ltd, 2009a; URS Australia Pty Ltd, 2007). Gardline (2009a) reported that the concentration of total petroleum hydrocarbons (TPH) in all collected samples across the Browse Development Area was below the limits of detection (Gardline Marine Services Pty Ltd, 2009). With the exception of a slight exceedance in Ni concentrations at two locations and Hg concentrations at one location, metal concentrations (As, Cd, Cu, Cr, Co, Hg, Pb and Zn) in sampled sediments were below SQG-High trigger levels outlined in the revised Australian and New Zealand sediment quality guidelines (Simpson et al. 2013). The available studies and literature cited above provide a good understanding of the marine sediment quality within the Browse Development area. Given the nature of the marine sediments within the area and the lack of anthropogenic inputs, it is unlikely that there have been significant changes in the physical and chemical characteristics of the sediments. Consequently, these studies are deemed to provide a good understanding of the current marine sediment quality values within the Browse Development Area to support the impact assessment process for the project. In addition, such parameters will be used to support the interpretation of the discharge modelling results. However, there is currently a lack of specific information on marine sediment quality along the BTL route with current information limited to general regional values. As such an environmental survey is being undertaken to determine the sediment quality values along the proposed BTL route. This does not apply in the area near the NRC tie in point, where Woodside has a good understanding of marine sediment via studies undertaken in relation to existing Woodside assets and projects in the area. It also does not apply in the area adjacent to the Browse Development Area where studies have been undertaken in relation to the previously proposed pipeline route from Browse to James Price Point.	Literature review of Woodside information and publicly available information. Implementation of a marine environmental survey of the BTL corridor including sampling and characterisation of marine sediments.
Physical	Marine Water quality	Browse Development Area and BTL corridor and surrounds	As there is likely to be little or no significant change to water quality within the Browse Development Area since previous studies were undertaken, Woodside will rely on historical datasets (~3 years collection period) to support existing environmental baseline knowledge. As with marine sediments, the basis for the baseline assessment of water quality values within the Browse Development Area are the findings from three principal surveys undertaken within the area (Brinkman et al., 2009a; Gardline Marine Services Pty Ltd, 2009a; URS Australia Pty Ltd, 2007). The most recent Gardline survey (2009) including water sampling and analysis at 34 stations including seven at the Calliance field and eight at the Torosa field. The studies reinforced the fact that given the distance from potential contamination sources or anthropogenic inputs, water quality within the Browse Development Area is typical of an unpolluted tropical offshore environment within the North West Marine Region (NWMR) with low turbidity, nutrient poor oceanic waters. The studies undertaken, in particularly Gardline (2009), demonstrate the lack of anthropogenic contamination of the waters, with metal analyte levels below the limit of reporting (LoR), with concentrations of cobalt (Co), chromium (Cr), Cu, lead (Pb) and Ni at or below 0.001 mg/L. The available studies and literature cited above provide a good understanding of the marine water quality within the Browse Development area. Given the nature of the water quality and the lack of anthropogenic inputs, it is unlikely that there have been significant changes in the physical and chemical characteristics of the receiving environment. Consequently, these studies are deemed to provide a good understanding of the current marine water quality values within the Browse Development Area to support the impact assessment process for the project. In addition, such parameters will be used to support the interpretation of the discharge modelling results. However, there is currently a lack of specific information on marine water quality along the BTL route with current information limited to general regional values. As such an environmental survey is being undertaken to determine the baseline water quality values along the proposed BTL route. This does not apply in the area near the NRC tie in point, where Woodside has a good understanding of marine water quality via studies undertaken in relation to existing Woodside assets and projects in the area. It also does not apply in the area close the Browse Development Area where studies have been undertaken in relation to the previously proposed pipeline	Literature review of Woodside information and publicly available information. Implementation of a marine environmental survey of the BTL corridor including sampling and characterisation of marine water quality.

Receptor Group	Receptor	Key Areas of Consideration	Assessment of Current Level of Understanding and information gaps	Environmental Studies Workplan
			route from Browse to James Price Point.	
Physical	Air quality	Browse Development Area	Woodside has sufficient information on air quality in the Browse Development Area on the basis that the area is offshore and remote from urban or industrial areas; and as such is not likely to be significantly influenced by anthropogenic sources.	Literature review of Woodside information and publicly available information.
Physical	Ambient light	Browse Development Area and BTL corridor and surrounds	Woodside has sufficient information on ambient light in the Browse Development Area and BTL corridor on the basis that the area is offshore and remote from urban or industrial areas. Other than light emissions associated with the NRC facility, local light emissions via anthropogenic sources are limited to shipping.	Literature review of Woodside information and publicly available information.
Physical	Ambient noise	Browse Development Area and BTL corridor and surrounds	Woodside has sufficient information on ambient underwater noise in the Browse Development Area and BTL corridor on the basis that the area is offshore and remote from urban or industrial areas, with ambient noise characterised by natural ecological and hydrodynamic processes. In addition, noise monitoring program was implemented from September 2006 to May 2011 by Curtin (2011) which included deployment of sea noise loggers at 23 sites around Scott Reef. This programme was specifically designed to characterise the noise environment within and adjacent to the reef during ambient conditions and during a drilling programme within the Browse Development Area in 2008. Other than underwater noise emissions associated with the NRC facility, and shipping routes near the BTL route, local underwater noise emissions via anthropogenic sources are likely limited to occasional vessels.	Literature review of Woodside information and publicly available information.
Ecological	Planktonic communities	Browse Development Area and BTL corridor and surrounds	Three years of data (Brinkman et al. 2009a, 2009b, 2010) have been collected to understand seasonality and ecological drivers of the plankton communities within the Browse Development Area. There is unlikely to have been any significant changes to these processes since the study was undertaken. Consequently, it is determined that this data provides Woodside with a good baseline knowledge of planktonic communities within the Browse Development Area to support impact assessment process. Similarly, it is considered that there is sufficient understanding of planktonic communities within the broader NWMR, including along the BTL corridor from regional studies (Brewer et al. 2007).	Literature review of Woodside information and publicly available information.
Ecological	Epifauna and Infauna	Browse Development Area and BTL corridor and surrounds	The available studies and literature provide a good understanding of the deep water epifauna and infauna communities within the Browse Development area. Given the nature of these communities and the lack of significant disturbances within the deeper waters of the Browse Development Area, it is unlikely that there have been significant changes in these communities since the studies were carried out. Consequently, these studies are deemed to provide a good understanding of these ecological values within the Browse Development Area to support the impact assessment process for the project. In addition, such parameters will be used to support the interpretation of the discharge modelling results. It is considered that there is sufficient understanding of epifauna and infauna assemblages along the BTL corridor which are expected to be typical of the offshore waters in the region as described in Williams et al. 2010. However additional information will be gained from the pipeline environmental survey.	Literature review of Woodside information and publicly available information. Implementation of a marine environmental survey of the BTL corridor including characterisation of infauna and epifauna assemblages.
Ecological	Coral	Browse Development Area including Scott Reef, Rowley Shoals	Major changes to coral in the Browse Development Area over recent years are possible due to cyclones and thermal-induced bleaching. As such Woodside will utilise ongoing long-term monitoring and research program (1994-2018), which provides current and historical data, to support existing environmental baseline knowledge. This, together with previous studies undertaken in the area including studies undertaken in relation to the previous Browse Development concepts, provides Woodside with a good understanding of coral communities in the Browse Development Area including Scott Reef. This includes habitat mapping of Scott Reef undertaken by Smith *et al* 2006. In addition, Woodside, in partnership with AIMs continues to undertake long term monitoring of shallow water corals at Scott Reef and Rowley Shoals (Gilmour et al 2018). Given the proposed water depths along the BTL it is not anticipated that any coral communities will be encountered. Nevertheless, the BTL environmental survey will investigate benthic habitats at selected sample locations along the trunkline route. Such locations have been chosen based on a number of criteria outlined in **Section 3.7.6**. This does not apply in the area near the NRC tie in point, where Woodside has a good understanding of coral. It also does not apply in the area adjacent to the Browse Development Area where studies have been undertaken.	Literature review of Woodside information and publicly available information. Preparation of habitat maps with demonstrated ground truthing for areas where proposed infrastructure will be installed on the seabed within the Browse Development Area. Implementation of a marine environmental survey of the BTL corridor including benthic habitat characterisation (noting that due to water depths, it is considered highly unlikely that hard coral communities will occur along the BTL corridor).
Ecological	Seagrass	Browse Development Area including Scott Reef, Rowley Shoals	Given the previous and ongoing benthic habitat studies undertaken in the area, Woodside has a good understanding of the status of seagrass communities within Scott Reef area. Given the proposed water depths along the BTL it is not anticipated that any seagrass communities will be encountered. Nevertheless, the BTL environmental survey will investigate benthic habitats at selected sample locations along the trunkline route. Such locations have been chosen based on a number of criteria outlined in **Section 3.7.6**. This does not apply in the area near the NRC tie in point, where Woodside has a good understanding of seagrass. It also does not apply in the area adjacent to the Browse Development Area where studies have been undertaken.	Literature review of Woodside information and publicly available information. Preparation of habitat maps with demonstrated ground truthing for areas where proposed infrastructure will be installed on the seabed within the Browse Development Area. Implementation of a marine environmental survey of the BTL corridor including benthic habitat characterisation (noting that due to water depths, it is considered highly unlikely that seagrass will occur along the BTL corridor).

Receptor Group	Receptor	Key Areas of Consideration	Assessment of Current Level of Understanding and information gaps	Environmental Studies Workplan
Ecological	Macroalgae	Browse Development Area including Scott Reef, Rowley Shoals	Woodside has a good understanding of macroalgae in the Browse Development Area including Scott Reef via previous studies undertaken in the area including studies undertaken in relation to the previous Browse Development concepts (e.g. Gardline 2009). Sufficient information on macroalgae at Rowley shoals exists in the literature (e.g. Gilmour et al. 2018) to support the impact assessment for the project. There is currently a lack of specific information on macroalgae along the BTL route although it is considered unlikely that they will would occur due to the water depth. This does not apply in the area near the NRC tie in point, where Woodside has a good understanding of macroalgae. It also does not apply in the area adjacent to the Browse Development Area where studies have been undertaken.	Literature review of Woodside information and publicly available information. Preparation of habitat maps with demonstrated ground truthing for areas where proposed infrastructure will be installed on the seabed within the Browse Development Area. Implementation of a marine environmental survey of the BTL corridor including benthic habitat characterisation (noting that due to water depths, it is considered highly unlikely that macroalgae will occur along the BTL corridor).
Ecological	Seabirds and migratory shorebirds	Scott Reef, Rowley Shoals	The East Asian-Australasian Flyway (EAAF) is of most relevance to the Project Area and associated shorebird and seabird species. This flyway extends from north-eastern Asia and western Alaska in the north, to Australia and New Zealand in the south, encompassing 23 countries (Hansen et al., 2016). There are 37 species of shorebird and seabird which annually migrate to Australia using the EAAF (Hansen et al., 2016). Seabirds within the North West Marine Region (NWMR) consist of tropical and sub-tropical breeding species and non-breeding migratory species. Recent surveys around Ashmore Reef, Seringapatam Reef, Scott Reef and the wider Browse Basin region identified 26 species of seabird, including the brown booby, Abbott's booby, streaked shearwater and lesser frigatebird (Jenner et al., 2009; Milton, 1999; Smith et al., 2004; Jenner et al. 2009; WAM 2009). A number of offshore islands within the NWMR support breeding colonies of seabirds, with the islands at Ashmore Reef are regarded as supporting some of the most important seabird breeding colonies on the NWS. Due to the large geographical range of seabirds, there is potential that most species occurring within the wider NWMR may occur transitionally within the Project Area. An initial PMST search identified two species of threatened seabird as potentially occurring within the Development Area; the Abbott's booby (Endangered, Marine) and Australian lesser noddy (Vulnerable, Marine). In addition, six other species of listed marine and/or migratory seabird species were identified as having the potential to occur within and/or interact with the Proposed Action. As Scott Reef is the only emergent land mass within the immediate vicinity of the Development Area it may serve to provide nesting and / or roosting for migratory seabirds along the flyway. However, Seabirds around Scott Reef are predominately associated with Sandy Islet and occur in relatively small numbers in comparison to other key breeding and roosting sites within the region. Smith et al. (2004) recorded little tern (500 individuals), brown booby (6), ruddy turnstone (50), Australian lesser noddy (200) and the common noddy (30) during a survey at Scott Reef in 2003. More recent surveys at Scott Reef observed greater numbers of birds during spring than winter (Jenner et al., 2009), with seabird typically roosting on Sandy Islet at night and presumably foraging within the nearby and offshore waters during the day. Migratory shorebirds are occasionally observed in very low numbers at Scott Reef, with Sandy Islet potentially acting as a stopping point during the migration between the Northern Hemisphere and Australia (Commonwealth of Australia, 2008). Despite the fact that seabirds and shorebirds are regularly observed at Scott Reef, given the size of the available landmass at Sandy Islet, it is unlikely to be a critical location or support large numbers of migratory birds. Based on the available studies and literature, Woodside has a good understanding of the seabirds and shorebirds that may occur within the Development Area to support the impact assessment process for the project.	Literature review of Woodside information and publicly available information including a review of applicable State and Commonwealth guidance and conservation plans Protected Matters Search and SPRAT profile review of relevant species.
Ecological	Fish	Browse Development Area including Scott Reef, Rowley Shoals, BTL Corridor	Woodside has a good understanding of fish that may occur at Scott Reef and Rowley Shoals via available literature and previous studies undertaken in the area (e.g. DEC 2007). In addition, Woodside, in partnership with AIMs continues to undertake long term monitoring of shallow water fish communities at Scott Reef. Fish that may occur along the BTL corridor are expected to be reflective of the open waters of the North-west Marine Region for which significant information is available in existing literature. With respect to the protected whale shark, Woodside previously studied migration patterns using tagging and tracking (Meekan *et al* 2010) with this information considered sufficient to inform the impact assessment.	Literature review of Woodside information and publicly available information including a review of applicable State and Commonwealth guidance and conservation plans Protected Matters Search and SPRAT profile review of relevant species. Implementation of a marine environmental survey of the BTL corridor including the opportunist recording of marine megafauna.
Ecological	Marine mammals	Browse Development Area including Scott Reef, BTL Corridor	A large number of surveys have been undertaken on marine mammals in relation to previous Browse Development concepts. These have included habitat association surveys (Sutton et al., 2018), long term sea noise logger deployment (McCauley 2011), aerial and vessel surveys (Jenner & Jenner 2009a, 2009b, RPS 2010a, 2010b, 2010c, 2011a, 2011b, 2011c) and satellite tagging (Double et al. 2010, 2012, 2014). An additional study was recently commissioned by Woodside in Q4 2017 to review the current state of knowledge for blue whales which may be affected by the Proposed Action, including reviewing current understanding of migration, foraging, distribution, and breeding behaviours, and identifying major knowledge gaps. Pygmy blue whales are recognised as a key species for consideration in the EIS/ERD. The Conservation Management Plan for Blue Whales (Commonwealth of Australia, 2015) documents a possible foraging area within the vicinity of Scott Reef which has been defined as a BIA for foraging. Unlike the Perth Canyon which is recognised as a seasonally important foraging area for pygmy blue whales, as shown by both visual and acoustic surveys (Balcazar et al., 2015; McCauley et al., 2000, 2004), there is no observational or recorded evidence to confirm Scott Reef is a feeding ground for this species. Rather, pygmy blue whales have been encountered	Literature review of Woodside information, including the recently completed study on the current state of knowledge for blue whales, and publicly available information including a review of applicable State and Commonwealth guidance and conservation plans Protected Matters Search and SPRAT profile review of relevant species. No further marine mammal specific surveys are considered necessary to inform the impact assessment. However, the implementation of a marine environmental survey of the BTL corridor will include the opportunist recording of marine mega fauna.

Receptor Group	Receptor	Key Areas of Consideration	Assessment of Current Level of Understanding and information gaps	Environmental Studies Workplan
			during periods of elevated biomass at Scott Reef, and feeding has not been directly observed (Sutton et al., 2018). It is likely that pygmy blue whales feed opportunistically while migrating, however, Scott Reef is unlikely to represent critical habitat for pygmy blue whales. A literature review identified that there is no evidence of population increases in pygmy blue whales and as such Woodside will primarily rely on historical Woodside-funded datasets (~3 years collection period) and other recent non-Woodside datasets to support existing environmental baseline knowledge. Given potential for opportunistic foraging at Scott Reef, Woodside will describe Scott Reef and the surrounding area as a potential area of importance for the sub-species, including for opportunistic feeding, and undertake assessments of impacts and risk to PBW in this context. A literature review undertaken by WAMSI in 2018 highlights that only a small number of humpback whales utilise the Browse Development Area. As such, Woodside will primarily rely on historical Woodside-funded datasets (~3 years collection period) and other recent non-Woodside datasets to support existing environmental baseline knowledge for humpback whales.	
Ecological	Marine reptiles (turtles)	Browse Development Area including Scott Reef	Woodside has a good understanding with respect to the presence and behaviour of marine turtles in the Development Area. Sandy Islet, a part of Scott Reef, is a known nesting site for green turtles, with a number of long-term studies, funded by Woodside, undertaken to establish a baseline of turtle nesting activity (including breeding, internesting and nesting behaviours) at Scott Reef. A total of 435 nesting green turtles were tagged at Sandy Islet over seven surveys undertaken during 2006, 2008 and 2009 (Guinea, 2009), with the peak breeding season observed to be from late November to February. Nesting turtles have been observed to utilise the entire available area of Sandy Islet for nesting, with seasonal variation recorded in the areas used. In terms of internesting habitat, the studies demonstrated that two areas of sandy substrate located to the south of Sandy Islet were identified as a preferred internesting area for the green turtles at Sandy Islet. Tracking of 12 green turtles was undertaken at Sandy Islet in 2010 (Guinea, 2011). These turtles were found to re-nest at Sandy Islet up to five times with an average internesting interval of 10 days. Internesting habitat for these individuals ranged up to 14 km out from the Sandy Islet (Guinea, 2011). Following nesting, these individuals were found to disperse from Sandy Islet toward the WA mainland via two distinct post-nesting migration pathways; travelling east and north toward the Bonaparte Archipelago and then north along the coast to the NT or travelling south to Cape Leveque and then south along the coast to the De Grey River in the Pilbara (Guinea, 2011). It should be noted that while the green turtles at Scott Reef and Browse Island represent a distinct genetic stock, the relatively small available nesting area on Sandy Islet ensures that this location is likely to represent a marginal nesting habitat for the broader population of green turtles within the region, with more significant rookeries located at the Lacepede Islands and Ashmore Reef (both noted as nesting and internesting BIAs for green turtles). The turtle studies undertaken at Scott Reef have provided Woodside with a comprehensive understanding of the nesting carrying capacity of Scott Reef, as well as the population dynamics, preferential nesting and internesting behaviours of marine turtles within the proposed Browse Development Area. The inter-annual nesting population of green turtles at Sandy Islet varies greatly (by at least an order of magnitude) and it is known that a significant proportion of the Scott Reef/ Browse Island green turtle meta-population nest at Sandy Islet. Given the large variability in inter-annual turtle numbers, additional data collection is unlikely to add to this knowledge base.	Literature review of Woodside information and publicly available information including a review of applicable State and Commonwealth guidance and conservation plans. Protected Matters Search and SPRAT profile review of relevant species. No further marine reptile specific surveys are considered necessary to inform the impact assessment. However, the implementation of a marine environmental survey of the BTL corridor will include the opportunist recording of marine mega fauna.
Ecological	Marine reptiles (Sea snakes)	Browse Development Area including Scott Reef	Udyawer et al. (2016) has recently analysed data collected from 2290 Baited Remote Underwater Video Stations (BRUVS) between 1999 and 2016 to better define the range and distribution of sea snake families in the NWMR and to produce predictive models to assess the likelihood of occurrence for major families of sea snakes. From this data, 582 sea snakes were recorded with the highest rates of sea snake sightings observed in the Northern Oceanic Shoals. The majority of sea snakes were of genus Aipysurus (63%) followed by Hydrophis (12%) and Emydocephalus (11%) (Udyawer et al., 2016). Probability of occurrence maps based on available habitats and other environmental parameters indicate that Scott Reef and other remote reef systems within the Northern Oceanic Shoals, as well as mid-shelf shoal habitat along the Kimberley and Pilbara coasts were likely ideal habitat for two IUCN and DoEE listed critically endangered sea snake species, the short-nosed sea snake and the leaf-scaled sea snake (Udyawer et al., 2016, and available at: https://vinayudyawer.github.io/SeaSnake-NicheModels/ModelMap.html). Historically these two species were only recognised as occurring at Ashmore and Hibernia reefs (Cogger, 2014; Guinea, and Whiting, 2005; Storr et al., 2002), although they have not been observed in these locations since 2001 despite considerable effort between 2005 and 2013 (Guinea, 2013). These species have also not been recorded at Scott Reef. Preliminary Protected Matters Searches have identified the short-nosed sea snake as potentially occurring within the Project Area, however, did not identify occurrence of the leaf-scaled sea snake. Recent genetic analysis and field surveys have provided further evidence that these threatened species are more widely distributed than previously thought (D'Anastasi et al., 2016; Sanders et al., 2015). Sanders et al. (2015) found significant molecular and morphological variation between specimens of short-nosed and leaf-scaled sea snakes collected at offshore locations and those collected in coastal areas which were previously considered vagrant. The study indicates specimens of short-nosed seasnakes collected on Barrow Island in 2010 and leaf-scaled seasnakes collected in Exmouth Gulf in 2004 and Broome in 2012 were from distinct coastal breeding populations of sea snakes (Sanders et al., 2015). D'Anastasi et al. (2016) confirmed a wider distribution for these species, providing live records of the short-nosed and leaf-scaled sea snakes outside of Ashmore and Hibernia. The study, which conducted intensive field surveys, assessed previous survey and	Literature review of Woodside information and publicly available information including a review of applicable State and Commonwealth guidance and conservation plans. Protected Matters Search and SPRAT profile review of relevant species. No further marine reptile specific surveys are considered necessary to inform the impact assessment. However, the implementation of a marine environmental survey of the BTL corridor will include the opportunist recording of marine mega fauna and sea snakes.

Receptor Group	Receptor	Key Areas of Consideration	Assessment of Current Level of Understanding and information gaps	Environmental Studies Workplan
			habitat data and molecular genetics data to resolve gaps regarding these two species' distributions, abundances, habitat requirements and conservation statuses in coastal WA, observed sixteen leaf-scaled sea snakes within Shark Bay and seven short-nosed sea snakes within Exmouth Gulf (D'Anastasi et al., 2016). These studies significantly increase the known geographic range of these threatened species, as well as expands their preferred habitat to include seagrass meadows, and are significant given the critically endangered conservation statuses of these species are based off the understanding that their range is restricted to Ashmore and Hibernia (i.e. < 10 km^2). Comprehensive surveys of sea snakes at Scott Reef were undertaken in February, September and November in 2006 (URS, 2007; URS Australia Pty Ltd, 2006) did not observe these two threatened species, however, recorded similar abundances of sea snakes as observed on Hibernia and Cartier Island during the same year. The abundance of sea snakes was found to be dependent on habitat type and ranged between 0 to 2 individuals per hectare. The majority of sea snakes recorded were olive sea snakes and turtle-headed seasnakes, with other species including the dusky sea snake, Dubois's sea snake, horned sea snake, and slender-neck sea snake (Guinea 2013). Sea snakes that were recorded were most common in the more complex reef habitats, although no key sites for juveniles or adults were identified at Scott Reef. No seasonal peaks were detected indicating the majority of individuals were likely residential. Based on the available studies and literature, Woodside has sufficient information on sea snakes that may occur within the Development Area, and specifically within the area of Scott Reef to support the impact assessment process for the project.	
Ecological	Key Ecological Features (KEFs)	Relevant KEFS: • Continental slope demersal fish communities • Seringapatam Reef and Commonwealth waters in the Scott Reef complex • Ancient coastline at 125 m depth contour • Mermaid Reef and Commonwealth waters surrounding Rowley Shoals.	Sufficient information exists on the relevant KEFs for the purpose of impact assessment within the North West Marine Bioregional Plan (Commonwealth of Australia 2012). However additional information will be gained from the pipeline environmental survey.	Literature review of Woodside information and publicly available information. Implementation of a marine environmental survey of the BTL corridor including the benthic habitat survey, sediment sampling and water quality sampling within each intersected KEF.
Ecological	Australian marine parks	Relevant Australian marine parks: • Kimberley Marine Park • Argo-Rowley Terrace Marine Park • Mermaid Reef Marine Park (not intersected)	Sufficient information exists on the relevant Australian marine parks for the purpose of impact assessment within the North-west Marine Parks Network Management Plan 2018 (Director of National Parks 2018). However additional information will be gained from the pipeline environmental survey.	Literature review of Woodside information and publicly available information. Implementation of a marine environmental survey of the BTL corridor including the benthic habitat survey, sediment sampling and water quality sampling within each intersected Australian marine park.
Ecological	State marine parks and reserves	Relevant state marine parks and reserves: • Rowley Shoals	Sufficient information exists on the relevant state marine parks and reserves for the purpose of impact assessment (e.g. DEC 2007).	Literature review of Woodside information and publicly available information.

Receptor Group	Receptor	Key Areas of Consideration	Assessment of Current Level of Understanding and information gaps	Environmental Studies Workplan
		Marine Park (not intersected) • Scott Reef Nature Reserve		
Socio-Economic	Commonwealth managed fisheries	Relevant Commonwealth managed fisheries including: • North West Slope Trawl Fishery (NWSTF) • Western Tuna and Billfish Fishery • Southern Bluefin Tuna Fishery • Western Skipjack Tuna Fishery.	Woodside has sufficient information on the relevant Commonwealth managed fisheries (Patterson et al. 2018) for the purpose of impact assessment via work undertaken on the previously proposed Browse development concepts and ongoing stakeholder consultation.	Literature review of Woodside information and publicly available information. Ongoing stakeholder consultation.
Socio-Economic	State managed fisheries	Relevant State managed fisheries including: • Northern Demersal Scalefish Managed Fishery (NDSF) • Mackerel Managed Fishery • Western Australia North Coast Shark Fishery (WANCSF) • Onslow Prawn Managed Fishery • Abalone Fishery • South west Coast Salmon • Pilbara Fish Trawl and Trap Fishery • Specimen	Woodside has sufficient information on the relevant State managed fisheries (Gaughan et al. 2018) for the purpose of impact assessment via work undertaken on the previously proposed Browse development concepts and ongoing stakeholder consultation.	Literature review of Woodside information and publicly available information. Ongoing stakeholder consultation.

Receptor Group	Receptor	Key Areas of Consideration	Assessment of Current Level of Understanding and information gaps	Environmental Studies Workplan
		Shell - Marine Aquarium Fish - West Coast Deep Sea Crustacean - Pearl Oyster Managed Fishery.		
Socio-Economic	Tourism and recreation	Scott Reef, Rowley Shoals	Sufficient information exists on the use of Scott Reef and Rowley Shoals for tourism and recreation purposes for the purpose of impact assessment.	Literature review of Woodside information and publicly available information. Ongoing stakeholder consultation.
Socio-Economic	Shipping	Browse Development Area, BTL Corridor	Sufficient information exists on the use of the Project area and surrounds for shipping for the purpose of impact assessment.	Literature review of Woodside information and publicly available information. Ongoing stakeholder consultation.
Socio-Economic	Industry	Regional	Sufficient information exists on industry in the region including petroleum exploration and production for the purpose of impact assessment.	Literature review of Woodside information and publicly available information. Ongoing stakeholder consultation.
Socio-Economic	Indigenous heritage	Scott Reef, Dampier Archipelago (including Burrup Peninsula) National Heritage place	Sufficient information exists on indigenous heritage (Traditional Indonesian fishers) in the water surrounding Scott Reef for the purpose of impact assessment. Woodside will point to and provide context for the assessment of the potential impacts of the North West Shelf Project Extension Proposal (EPBC 2018/8335) on values specifically related to the National Heritage listing on the Burrup Peninsula.	Literature review of Woodside information and publicly available information. The assessment documentation must provide details of any potential indirect impacts of the proposed action on the (Indigenous rock art) values of the Dampier Archipelago (including the Burrup Peninsula) National Heritage Place, and the extent to which these values may be impacted by the proposed action following any planned mitigations.
Socio-Economic	Maritime archaeology	Browse Development Area, BTL Corridor	Sufficient information exists on maritime archaeology including known ship wrecks in the Project area for the purpose of impact assessment.	Literature review of Woodside information and publicly available information.

3.7.6 Scope of Technical Studies informing Existing Environment

The following technical studies will be undertaken to inform the existing environment description. It should also be noted that Woodside is committed to the continuation of the long-term monitoring at Scott Reef and the Rowley Shoals undertaken in conjunction with the Commonwealth research agency, the Australian Institute of Marine Science (AIMS).

Environmental Survey of BTL Corridor

The objectives of this study are to:

- confirm the environmental characteristics (physical and biological attributes) of the seabed along the BTL route which will include identification and semi qualitative descriptions of seabed habitat types, infauna and epifauna and their general distribution
- determine the baseline condition and physico-chemical composition of seabed sediments and water quality at selected locations along the BTL corridor
- document presence of marine mega fauna sighted opportunistically along the BTL corridor.

The data and information (including habitat mapping) from the environmental survey will be utilised to describe the existing environment and baseline conditions along the BTL route and to inform a regional understanding of marine environmental values through which the BTL traverses. The determination of the baseline environmental values at selected locations of the BTL route will be used as part of the environmental impact and risk assessment process of the EIS/ERD to determine the impacts (if any) to the receiving environment from the installation and physical presence of the BTL.

A reconnaissance survey of the BTL corridor (geophysical) has been undertaken and has been used to identify sampling locations along the BTL corridor. The sampling locations have been selected to characterise the marine environment in proximity to the proposed BTL, with consideration given to regional environmental sensitivities and key ecological features.

At each of the sampling locations the following environmental parameters will be collected:

- water, seabed sediment, infauna and epifauna
- benthic habitat imagery for habitat classification and description (semi-quantitative analysis of seabed imagery (High Resolution video and stills)
- opportunist sightings of marine mega fauna.

3.8 Impacts and Risk

3.8.1 Overview

The purpose of this chapter is to present the environmental impact and risk assessment undertaken including the source activities, the magnitude and extent of potential impacts, proposed mitigation strategies, environmental objectives and performance criteria.

3.8.2 Format of Chapter

The impact and risk chapter will provide a high-level overview of the sources of each risk and impact aspect as well as the potential receptors groups that may be affected. This will be followed by a detailed description of each relevant impact and risk, proposed mitigation measures and an overall conclusion on the predicted environmental outcome, in relation to the aspect, and with reference to the relevant MNES significance criteria and/or WA EPA Environmental Objective.

The description of each aspect will be set out in a format broadly similar to the following outline:

1. Aspect (e.g. Noise Emissions)
   1.1. Environmental Objective
   1.2. Policy and Guidance
   1.3. Source Activities
   1.4. Receptor and Receptor Sensitivity
   1.5. Environmental Impact
   1.6. Environmental Risk
   1.7. Cumulative Impacts
   1.8. Mitigation and Management
   1.9. Other Considerations
   1.10. Performance Criteria
   1.11. Impact and Risk Assessment Summary and Acceptability Assessment

3.8.3 Impact and Risk Assessment Requirements

This section will include:

- description of all relevant potential impacts and risks of the action
- a detailed assessment of the nature and extent of the potential short term and long term relevant impacts, including on MNES and WA EPA Environmental Factors including the natural Heritage values of 'Scott Reef and surrounds'
- a statement whether any relevant potential impacts are likely to be unknown, unpredictable or irreversible
- analysis of the significance of the relevant potential impacts and risks
- any technical data, any sources of authority, and other information used or needed to make a detailed assessment of the relevant potential impacts. Reliability of forecasts and predictions, confidence limits and margins of error will be indicated as appropriate.

In discussing potential impacts, particular emphasis is to be given to providing details on the potential impacts to the receiving environment's unique flora and fauna, as identified and to any protected areas in the vicinity.

In particular the EIS/ERD will address the following.

General impacts

The following encompasses a list of general impact considerations:

- discuss the effects of the overall action on the functioning of the marine environment, including effects to the marine environment surrounding the proposed development
- identify the source of potential impacts, e.g. ship-movements, artificial lighting, noise
- discuss potential impacts which may arise through the transportation, storage and use of dangerous goods (if any), fuels and chemicals, such as accidental spills
- consider the application of a waste management hierarchy (e.g. reduce, reuse, recycle, treat, dispose) and potential impacts caused by the need for waste disposal and management of emissions, refuse, effluent and hazardous waste (if any)

- in discussing potential impacts, consider how the interaction of extreme environmental events and any related safety response may impact on the environment
- consider potential impacts throughout the life of the proposed Browse to NWS Project – from construction, commissioning, IMR activities and operations through to decommissioning.

Physical and biodiversity impacts

The following encompasses a list of physical and biodiversity impact considerations:

- consider potential impacts to the sea floor through anchoring and direct placement, sediment disturbance, as well as any impacts of removal. The zone of likely seabed disturbance will be identified.
- consider potential impacts to fauna and flora species, including rare, threatened, or otherwise valuable flora and fauna, communities (particularly listed threatened species and communities, listed marine species including whales and other cetaceans and listed migratory species). In assessing impacts, consideration will be given to factors such as population composition and density including changes to communities, breeding success, habitat, or disturbances to migration or migratory patterns and other wildlife movements.
- consider potential impacts to the recovery of species where a species recovery plan is in place including factors called up in the requirements of the relevant recovery plans.
- consider potential impacts, if any, on and habitat, conservation areas, biological important areas, key ecological features and protected areas (including Australian Marine Parks), and in particular Scott Reef and surrounds.
- consider potential impacts arising from the introduction and/or spread of exotic pest species.

Impacts of emissions to air and water

The following encompasses a list of emissions to air and water impact considerations:

- discuss the potential impact of solid, liquid and gaseous emissions and waste produced by the operation, including greenhouse gas emissions.
- refer to the NWS Extension assessment being progressed by the NWS JV under the EP Act (Assessment number 2186) and EPBC Act (EPBC 2018/8335) in relation to potential impacts resulting from the processing of Browse gas by a third party on the Burrup Peninsula.
- include a discussion on the eventual fate of the waste.
- provide a full evaluation of PW, CW and hydrotest discharges including anticipated composition of discharge, modelling of the mixing zones and discussion on the potential impacts of discharge, including the spatial and temporal impacts of discharged PW and hydrotest fluid on marine fauna and key benthic ecological receptors (e.g. corals, seagrass, magroalgae), which may provide habitat and food resources for listed threatened species (e.g. marine turtles).
- consider the potential impacts of water clarity, salinity and temperature changes with specific reference to stratification of the water column.
- discuss potential impacts related to the discharge of sewage, sullage and other production related discharges.
- discuss impacts of potential spillage of hydrocarbons related to construction, production, storage and shipping. Modelling of spills will take into account seasonal variations throughout the year. Modelling will also take into account proximity to sensitive marine areas, in particular Scott Reef and surrounds. The evaluation of the potential impacts of oil spills is to be carried out using a thorough risk-assessment methodology.

Socio-economic and cultural impacts

Discussion of the potential socio-economic and cultural impacts of the proposed Browse to NWS Project as required. This will include a description and discussion of potential impacts (both positive and negative):

- caused by any short, medium and long-term changes, interruption, alteration or curtailment of activities and uses of the area due to the Proposed Action, including changes affecting traditional uses, recreational uses, conservation and tourism
- on sites of historical or cultural significance
- on existing industry and commerce
- to employees in terms of workplace health and safety
- on shipping and any potential traffic hazards
- on visual and aesthetic values, impacts to tourism and access for conservation purposes
- to historic shipwrecks in the area, including potential impacts on, as yet, unknown shipwrecks or those in unsurveyed areas.

Cumulative Impacts

Cumulative impacts will also be identified and addressed. Cumulative impacts from the proposed Browse to NWS Project may occur in two ways:

- Aspect-based – Cumulative or combination effects from concurrent and/or sequential activities associated with the proposed Browse to NWS project, and other activities/projects resulting in the same aspects as those identified for the proposed Browse to NWS Project
- Receptor-based – Cumulative or combination effects on a receptor, both from multiple aspects of the proposed Browse to NWS Project and similar/multiple aspects resulting from other activities/projects.

The aspect based cumulative impacts will be presented within each aspects chapter (e.g. noise emissions).

Aspect-based cumulative impacts resulting from concurrent activities with the same aspect (e.g. concurrent underwater noise emissions from different project activities) will be assessed as part of the impact and risk assessment for each aspect. Where appropriate, modelling studies will take into account the multiple sources to inform a robust impact and risk assessment of each aspect on each relevant receptor.

The assessment of aspect-based cumulative impacts resulting from activities/projects not associated with the proposed Browse to NWS project will include assessment of reasonably foreseeable activities and projects. These activities may include:

- Woodside and other operator exploration activities
- Other oil and gas developments (including those known potential future expansions or developments in the vicinity)
- Commonwealth and State Managed Fisheries
- Other users such as tourism and recreation, traditional fishing and commercial fishing.

Other activities/project considered in the cumulative impact assessment will be selected based on the type of activity, spatial scale and time scale. Activities will only be taken into account if they:

- Have not already been taken into consideration previously in the impact assessment (i.e. as part of baseline conditions)

- Have aspects that may cause impacts on the same receptors as the proposed Browse to NWS Project
- Activities that exist or have a high degree of certainty of proceeding in the future, such as those with construction activities underway or for which approvals and budget have been obtained
- Activities for which sufficient information is available to conduct a qualitative assessment to a reasonable standard.

Once each potential cumulative impact from other activities/projects is identified an assessment of the significance of the cumulative impact will be undertaken and documented. Note that due to the inherent difficulties associated with accessing data associated with other proposed developments, the evaluation will be based on a qualitative assessment.

Receptor-based cumulative impacts resulting from concurrent activities generating common pressures (e.g. sequential drilling over the project and its light emissions) will be addressed in the overall conclusions section which will include a qualitative assessment of the cumulative impacts on each key receptor and assess impacts on a more holistic, whole-ecosystem level, considering the potential cumulative impacts of the proposed project, and any existing and future concurrent activities, on the existing environment.

3.8.4 Impact and Risk Assessment Process

An environmental risk and impact assessment will be undertaken in accordance with Woodside's Environment Impact Assessment Guideline. This guideline and associated Environment Impact Assessment Guidance Tool and Environment Risk Assessment Guidance Tool support the implementation of impact assessments and set out the broad principles and high-level steps for assessing environmental impacts across the lifecycle of Woodside's activities.

Within this process, a distinction is made between an 'impact' and a 'risk' as follows:

Environmental Impact: An expected change to the environment, whether adverse or beneficial, wholly or partially resulting from the planned and routine project activities including mitigation measures (e.g. routine liquid discharges).

Environmental Risk: A change to the environment resulting from an unplanned event or incident (e.g. oil spill resulting from vessel collision).

The environmental impact assessment approach undertaken will include the following steps:

1. Identification of project **aspects** (i.e. results of planned or unplanned project activities that have the potential to impact on the environment).
2. Identification of the **receptors** (i.e. physical, biological, cultural or human elements of the environment that may be impacted by project aspects).
3. Assessment of the **receptor sensitivity** (i.e. the sensitivity/vulnerability/importance of the /receptor) as either high, medium or low value.
4. Assessment of the **magnitude** (i.e. no lasting effect, slight, minor, moderate, major or catastrophic) of the credible environmental impacts from each aspect based on the extent, duration, frequency and scale.
5. Assigning an **impact significance level** to each environmental impact based on the receptor sensitivity and the magnitude of the impact.
6. Assigning an **environment risk consequence** to each environmental risk based on the receptor sensitivity and magnitude of the impact; and the likelihood of occurrence.
7. Utilising the impact significant level and environmental risk consequence to undertake an assessment of the Proposed Action against the EPBC Act Significant Impacts Criteria, Western

Australian EPA Objectives and other policy instruments including Australian Marine Park management plans and species recovery plans.

The following impact significant levels may be assigned for the environmental impacts:

- Catastrophic (A) - Applicable limits or standards are substantially exceeded and/ or catastrophic or major magnitude impacts are expected to receptors of medium/ high or high sensitivity respectively.
- Major (B) - Applicable limits or standards are exceeded and/ or moderate, major or catastrophic magnitude impacts are expected to occur to receptors of high, medium or low sensitivity respectively.
- Moderate (C) - Impacts are close to applicable limits or standards, or within standards but with potential for occasional exceedance. Minor, moderate or major magnitude impacts are predicted to occur to receptors of high, medium or low sensitivity respectively.
- Minor (D) - Impact magnitude is within applicable standards but is considered to have significance. Slight, minor or moderate impacts are predicted to occur to receptors of high, medium or low sensitivity respectively.
- Slight (E) - The receptor will experience a noticeable effect, but the impact magnitude is sufficiently small and well within applicable standards, and/or the receptor is of low value.
- Negligible (F) - The receptor will essentially not be affected.

Environment risk consequences are determined slightly differently than impact significant levels due to the requirement to consider the likelihood that the unplanned event or incident occurs.

The likelihood of a risk event occurring can be considered:

- Remote (0) – unheard of in the industry
- Highly unlikely (1) – has occurred once or twice in the industry
- Unlikely (2) – has occurred many times in the industry by not at Woodside
- Possible (3) – may possible occur
- Likely (4) – is likely to occur
- Highly likely (5) – is expected to occur

The following risk levels may be assigned for the environmental risks:

- Severe
- Very High
- High
- Moderate
- Low.

The outcomes of the preliminary environment impact assessment of planned activities are shown in **Table 7**. The outcomes of the preliminary assessment in relation to environmental risks from unplanned incidents or risk events are shown in **Table 8**. The preliminary impact and risk assessments were undertaken as part of the EPBC Act and EP Act referral process and have been provided to provide context to the workplan detailed in this EISG/ESD. It should be noted that the impact and risk assessment outcomes may change as further information comes available and more detailed analysis and evaluation is undertaken in preparing the EIS/ERD. Further change may also occur as a result of considering any feedback received from Stakeholders on the draft EIS/ERD.

3.8.5 Source, Aspect and Receptor Scoping

Preliminary scoping of the relationship between the proposed activities and the aspects has been undertaken and is presented in **Table 9.**

Each of these relationships will be considered when assessing the impact (from planned routine and non-routine events) and risk (from unplanned events) of the aspect. Scoping of the receptors that could be conceivably (in consideration of the location of the receptors) be affected by the potential impacts and risks has been undertaken and is presented in **Table 10.**

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Table 7 Preliminary Environmental Impact Assessment (Woodside 2018)

Ref.	Aspect	Source/Activity	Receptor Sensitivity Level	Predicted Impact	Impact Significance Level
IMP-1	Underwater noise emissions	• Drilling and completion of wells including vertical seismic profiling (VSP) • Installation of SURF, BTL and inter-field spur line • Suction piling for mooring installation (FPSO and MODU) • Pile Driving as a contingent planned activity • MODU dynamic positioning • Wellhead operations • Routine FPSO operations (thrusters, compressors, pumps) • Condensate tanker operations • Construction and support vessel operations • Inspection, maintenance and repair activities including ROVs • Routine helicopter operations • Decommissioning activities.	High value species (e.g. cetaceans)	Slight impact (behavioural, avoidance) on high value species on a near-field scale for duration of activities.	D – Minor
IMP-2a	Light emissions – MODU and FPSO	• Routine FPSO operations • Intermittent FPSO flaring • MODU operations.	High value species (e.g. marine turtles)	Slight impact (attraction/repulsion, disorientation) on high value species on a near-field scale for duration of the activities.	D – Minor
IMP-2b	Light emissions - Vessels	• Construction and support vessel operations.	High value species (e.g. seabirds and migratory birds)	Slight impact (attraction/repulsion, disorientation) on high value species on a near-field scale for duration of the activities.	D – Minor
IMP-3a	Physical presence of infrastructure during construction	• Seabed disturbance from seabed preparation, MODU anchors and FPSO anchoring and mooring lines.	Medium value habitat (not impacting Scott Reef or Rowley Shoals)	Slight impact (due to short duration) to medium value habitat on a localised scale during construction activities.	E – Slight
IMP-3b	Physical presence of infrastructure during operations	• Seabed disturbance from the installation of infrastructure (wells, SURF, BTL and inter-field spur line) • Construction and support vessel operations.	Medium value habitat (not impacting Scott Reef or Rowley Shoals)	Slight impact (due to low magnitude) to medium value habitat on a localised scale for the duration of the activities.	E - Slight
IMP-4a	Gaseous emissions - direct air emissions	• Power generation on construction vessels, support vessels, FPSO facilities • Condensate tankers • Flaring	Low value (remote location with limited sensitive receivers)	Slight reduction in air quality on a local scale for the duration of the activities.	F - Negligible

Ref.	Aspect	Source/Activity	Receptor Sensitivity Level	Predicted Impact	Impact Significance Level
		• Venting • PW degassing • Gas export compression units • AGRU - venting of hydrocarbons in waste Acid gas stream			
IMP-4b	Gaseous emissions – indirect air emissions	Woodside will point to and provide context for the assessment of the potential impacts of the North West Shelf Project Extension Proposal (EPBC 2018/8335) on values specifically related to the National Heritage listing on the Burrup Peninsula.			
IMP-4b	Gaseous emissions -GHG	Refer to Section 3.9.			
IMP-5	Treated sewage	• Discharge of sewage and sullage (within regulatory discharge limits) from FPSO, condensate tanker and construction and support vessels.	Medium value (open offshore waters)	Slight impact as a result of near-field nutrient enrichment of surrounding waters in offshore open ocean waters.	E - Slight
IMP-6	Treated PW and NORMs.	• Discharge of PW from the FPSOs to the marine environment (within accepted industry standards limits) • Discharge of formation water from MODU during well clean-up activities • Release of NORMs contained in produced sand and scale (if produced) to marine environment • Discharge of MEG as part of PW (MEG injection on start-up and shutdown) • Discharge of mercury within PW to the marine environment (within accepted industry standards limits)	Medium value (open offshore waters)	Minor impact as a result of near-field contamination to surrounding waters above relevant guidance/ background levels for the duration of the activity.	D – Minor
IMP-7a	Treated utility water	• Oily water drainage from machinery and storage areas discharged to sea (within regulatory discharge limits) from the FPSO facilities, MODU, construction vessels and support vessels • Discharge (within regulatory discharge limits) of water used in power generation (blade washing) on FPSO • Discharge of bilge water (within regulatory discharge limits) from FPSO, MODU, construction vessels and support vessels • Discharge of ballast water including biocides from the FPSO.	Medium value (open offshore waters)	Negligible impact as a result of temporary localised contamination to surrounding waters.	F - Negligible
IMP-7b	Treated utility water – desalination brine	• Discharge of brine from potable water maker on FPSO, MODU, construction vessels and support vessels	Medium value (open offshore waters)	Negligible impact as a result of temporary localised contamination to surrounding waters.	F - Negligible
IMP-8	Cooling water	• Discharge of cooling water from the FPSO facilities.	Medium value (open offshore waters)	Minor, near-field contamination to surrounding waters above relevant guidance/ background levels for the duration of the activity.	D – Minor
IMP-9	Putrescible organic waste	• Disposal of food scraps and other	Medium value (open offshore waters)	Negligible, localised impact to surrounding waters as a result of nutrient enrichment for	F - Negligible

Ref.	Aspect	Source/Activity	Receptor Sensitivity Level	Predicted Impact	Impact Significance Level
		putrescible wastes from offshore facilities.		the duration of the activity.	
IMP-10	Inorganic waste	• Generation and disposal (at a licensed onshore facility) of general inorganic non-hazardous wastes from offshore activities • Generation and disposal at a licensed onshore facility) of hazardous wastes from offshore activities (e.g. tank cleaning waster, contaminated amine, waste, produced sand, mercury waste)	Low (licensed disposal facility)	Negligible localised impacts to a low value environment (licensed disposal facility) for the duration of the activities.	F - Negligible
IMP-12	Drilling cuttings and fluids	• Generation of drill cuttings during drilling and completion activities. • Discharge of cement slurry	Medium value (sparse deep water benthic habitats)	1. Slight, short term decrease in water quality on near field scale. 2. Slight, localised impact on benthic habitat that is permanent.	E - Slight
IMP-13	Subsea control fluid	• Discharge of subsea control fluid during operations of the SURF.	Medium value (open offshore waters)	Negligible impact as a result of contamination to surrounding waters that is temporary and localised which may occur sporadically for the duration of the activities.	F – Negligible
IMP-14	Hydrotest and preservation fluid	• Discharge of hydrotest and preservation fluid from the SURF • Discharge of hydrotest and preservation fluid from the BTL and inter-field spur line.	Medium value (open offshore waters)	Negligible impact as a result of contamination to surrounding waters that is temporary and localised and will occur only once during commissioning.	F – Negligible
IMP-15	Atmospheric Noise	Helicopter movements between mainland and project area.	High value species (e.g. cetaceans)	Slight impact (behavioural, avoidance) on high value species on a near-field scale for duration of activities.	D - Minor

* IMP-11 Hazardous Waste combined with IMP 10 – inorganic waste

Table 8 Preliminary Environmental Risk Assessment (Woodside 2018)

Ref.	Aspect	Risk Event	Receptor Sensitivity Level	Risk Consequences	Risk Consequence Level	Likelihood	Risk Rating
Risk-1	IMS	Vessel (including FPSO) and MODU movements or ballast water exchange leads to the introduction and establishment of IMS	High value habitat (Scott Reef, Rowley Shoals etc)/native species	Moderate, medium term impact to high value habitat/ native species on a regional scale.	B – Major	1 – Highly unlikely	Moderate
Risk-2	Treated PW	Discharge of PW to the marine environment at levels significantly higher than expected levels	High value habitat (Scott Reef)/native species	Minor, short term impact (contamination) to high value habitat (Scott Reef)/native species.	C - Moderate	0 - Remote	Moderate
Risk-3	Utility Water – drain discharges	Unplanned discharge of drain waters potentially containing oil and grease	High value habitat (Scott Reef)/native species	Negligible short term impact (contamination) to high value habitat (Scott Reef)/native species.	E - Slight	1 – Highly unlikely	Low
Risk-4	Cooling water	Cooling water mixing zone significantly larger than predicted resulting in impacts to Scott Reef or high value species	High value habitat (Scott Reef)/native species	Slight short term impact (contamination) to high value habitat (Scott Reef)/native species.	D - Minor	0 - Remote	Low
Risk-5	Non-hazardous inorganic waste	Unplanned discharge of non-hazardous inorganic waste to the marine environment	High value habitat (Scott Reef)/native species	Negligible short term impact (contamination) to high value habitat (Scott Reef)/native species.	E - Slight	1 – Highly unlikely	Low
Risk-6	Hazardous Waste	Unplanned discharge of hazardous waste to the marine environment	High value habitat (Scott Reef)/native species	Slight short term impact (contamination) to high value habitat (Scott Reef)/native species.	D - Minor	2 – Unlikely	Moderate
Risk-7	Drilling cutting and fluids	Distribution and impact of drill cuttings significantly wider than predicted resulting in impacts to Scott Reef	High value habitat (Scott Reef)/native species	Slight short term impact (contamination) to high value habitat/native species.	D - Minor	2 – Unlikely	Moderate
Risk-8	Seabed subsidence	Removal of hydrocarbons from Torosa results in seabed subsidence impacting on the ecological function of Scott Reef	High value habitat (Scott Reef)/native species	Permanent event with negligible impact to high value habitat (Scott Reef)/native species.	E - Slight	1 – Highly unlikely	Low
Risk-9	Hydrocarbon spill	1. Loss of well controls 2. Subsea loss of control 3. Loss of hydrocarbons from topsides 4. Loss of control from substructure (storage of condensate or diesel) 5. Loss of containment from export BTL (gas only) 6. Loss of containment from vessel collision	Multiple high value habitats and high values species	Long term contamination to multiple high value habitats and native species at levels above standards and on a regional scale.	A - Catastrophic	1 – Highly unlikely	High
Risk-10	Vessel interaction with fauna	Vessel collision (including fast crew transfer vessel) with fauna resulting in injury or death to individual	High Value Species	Slight impact (Injury or mortality to single individual) of high value species	C - Moderate	2 – Unlikely	Moderate

Table 9 Activity-Aspect Relationships

Aspect Name	Development Drilling	Installation of Subsea Umbilicals, Risers and Flowlines (SURF)	Installation of FPSO facilities	Installation of BTL and Inter-Field Spur Line	Extraction	Processing (FPSO facilities)	Condensate Offload (FPSO facilities)	Gas Export (to NWS infrastructure)	IMR Activities	Decommissioning	Support Activities and Helicopters
Underwater noise emissions	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Atmospheric noise emissions	✓	✓	✓	✓		✓	✓		✓	✓	✓
Light emissions	✓	✓	✓	✓		✓			✓	✓	✓
Physical presence of infrastructure	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Gaseous emissions	✓	✓	✓	✓		✓	✓			✓	✓
Marine Discharges	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Drill cuttings and fluids	✓										
IMS	✓	✓	✓	✓			✓		✓	✓	✓
Seabed subsidence					✓						
Hydrocarbon spill	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 10 Impact-Receptor Relationships

Aspect	Physical					Ecological															Socio-Economic								
	Marine Sediments	Water quality	Air Quality	Ambient Light	Ambient Noise	Planktonic Communities	Epifauna and Infauna	Coral	Seagrass	Macroalgae	Saltmarsh	Mangroves	Shoreline Habitats	Seabirds and Migratory Shorebirds	Fish	Marine Mammals	Marine Reptiles	Key Ecological Features	Australian Marine Parks	State Marine Parks and Reserves	Commonwealth Managed Fisheries	State Managed Fisheries	Tourism and Recreation	Shipping	Industry	Settlements	Other Protected Places	Indigenous heritage	Marine Archaeology
Underwater noise emissions					✓									✓	✓	✓	✓				✓	✓	✓						
Atmospheric noise emissions					✓									✓		✓	✓						✓						
Light emissions				✓										✓	✓		✓						✓						
Physical presence of infrastructure	✓						✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓			✓	✓
Gaseous emissions			✓																									✓	
Marine Discharges	✓	✓				✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					✓	✓
Drill cuttings and fluids	✓	✓				✓	✓	✓	✓	✓			✓		✓	✓	✓	✓			✓	✓	✓					✓	✓
IMS							✓	✓	✓	✓			✓	✓	✓		✓	✓	✓	✓	✓	✓	✓					✓	
Seabed								✓	✓	✓			✓	✓			✓	✓										✓	✓

Aspect	**Physical**					**Ecological**															**Socio-Economic**								
	Marine Sediments	**Water quality**	**Air Quality**	**Ambient Light**	**Ambient Noise**	**Planktonic Communities**	**Epifauna and Infauna**	**Coral**	**Seagrass**	**Macroalgae**	**Saltmarsh**	**Mangroves**	**Shoreline Habitats**	**Seabirds and Migratory Shorebirds**	**Fish**	**Marine Mammals**	**Marine Reptiles**	**Key Ecological Features**	**Australian Marine Parks**	**State Marine Parks and Reserves**	**Commonwealth Managed Fisheries**	**State Managed Fisheries**	**Tourism and Recreation**	**Shipping**	**Industry**	**Settlements**	**Other Protected Places**	**Indigenous heritage**	**Marine Archaeology**
subsidence																													
Hydrocarbon spill	✓	✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					✓	

3.8.6 Previous studies to assess impacts and risks

Throughout the approvals process of the previous Browse development concepts (JPP and FLNG) various technical studies were undertaken to inform the assessment of the impacts and risks associated with the development concept. These technical studies are detailed in **Table 11**. Many of the potential environmental impacts associated with offshore drilling and completion, installation and operational activities of the previous Development concepts remain unchanged and relevant to the proposed Browse to NWS Project. Similarities between the concepts include the number and locations of wells and subsea tiebacks which have either reduced or remain broadly unchanged. The notable differences are the addition of the inter-field spur line and the BTL.

Due to these similarities, significant work has previously been undertaken with respect to understanding, assessing and mitigating potential environmental impacts and risk. With respect to the environmental aspects, the proposed Browse to NWS Project is expected to lead to the following when compared to the approved FLNG development concept:

- A reduction in the number of offshore facilities (2 x FPSO vs 3 x FLNG). Only one FPSO will be located at Torosa (compared to 2 x FLNG)
- A reduction in the number of development wells from 64 over Development life to a maximum of 49
- A reduction in shipping near Scott Reef as there is no LNG offtake
- A reduction in cooling water discharge
- Approximately the same amount of condensate storage per FPSO and offtake (reduction overall due to 2 x FPSO vs 3 x FLNG)
- Increased produced water (PW) during later field life
- Approximately the same distance between the facilities and Scott Reef
- A reduction in noise sources (fewer offshore facilities and less well drilling, completion and well unload (drilling and completion) activities)
- A reduction in mono ethylene glycol (MEG) injection requirements relating to a change from continuous MEG injection to active heating (noting that MEG injection will still be required for start-up and shutdown)
- A change to MEG discharge within the FPSO PW stream as opposed to recovery on a FLNG facility. This will result in higher MEG concentrations discharged but only at flowline or well restarts as opposed to continuous trace MEG concentrations in the PW stream
- Decreased energy consumption (CO_2) for offshore processing as compared to FLNG based on removal of liquefaction requirements from the proposed offshore development concept. This decrease is partially offset by additional requirement for export compression
- Increased seabed disturbance due to installation of the BTL and the inter-field spur line.

Table 11 Previous studies undertaken to understand the impacts and risks in relation to development of the Browse resource

A full index of previous Browse technical studies is available at https://www.woodside.com.au/our-business/burrup-hub/index-of-previous-browse-studies.

Organisation	Study Name	Link to Report	Aspect / Impact / Risk
Asia Pacific Applied Science Associates (APASA)	Browse FLNG Development - Quantitative Spill Risk Assessment	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f01---apasa-2014---browse-flng-development-quantitative-spill-risk-assessment_.pdf?sfvrsn=b722b339_2	Hydrocarbon spills
CGSS	Review of Reports on possible Subsidence at Scott Reef: Torosa Field – 2012	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f08---cgss-2012---review-of-possible-subsidence-scott-reef-torosa-field_.pdf?sfvrsn=fd8e45af_2	Seabed subsidence
	Follow-up Review of Reports on Possible Subsidence at Scott Reef: Torosa Field – 2013	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f09---cgss-2013---follow-up-review-of-reports-on-possible-subsidence-at-scott-reef-torosa-field_.pdf?sfvrsn=714284fc_2	Seabed subsidence
GMI Geomechanics Services	A Review of Analytical Compaction and Subsidence Modelling - First Order Analytical Estimates of Scott Reef Subsidence as a result of Reservoir Compaction in the Torosa Field, Browse Basin - 2012	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f04---baker-hughes-2012---a-review-of-analytical-compaction-and-subsidence-modelling_.pdf?sfvrsn=9c7bba7c_2	Seabed subsidence
Woodside	First Order Analytical Estimates of Scott Reef Subsidence as a result of Reservoir Compaction in the Torosa Field, Browse Basin – 2014	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f39---woodside-2014---first-order-analytical-estimates-of-scott-reef-subsidence-as-a-result-of-reservoir-compaction-in-the-torosa-field_-browse-basin_.pdf?sfvrsn=c309fb66_2	Seabed subsidence
DHI Water & Environment	Browse Environmental Modelling – Upstream EIS Wastewater Modelling - 2011	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f11---dhi-2011a---browse-environmental-modelling-upstream-eis-wastewater-modelling_.pdf?sfvrsn=6311c9a8_2	Produced water discharge Cooling water discharge
	Browse Environmental Modelling - Upstream EIS Sediment Transport Modelling of Drill Cuttings - 2010	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f12---dhi-2011b---browse-environmental-modelling-upstream-eis-sediment-transport-modelling-of-drill-cuttings_.pdf?sfvrsn=fbc999c4_2	Drill cuttings discharge
	Browse FLNG Development - Wastewater Dispersion Modelling - 2014	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f26---guinea-2010---long-term-monitoring-of-the-marine-turtles-of-scott-reef-february-2010_.pdf?sfvrsn=2339899b_2	Produced water discharge Cooling water discharge
ERM	Browse Upstream LNG Development: Light Impact Assessment – 2010	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f16---erm-2010---browse-upstream-lng-development-light-impact-assessment_.pdf?sfvrsn=ce2e5f40_2	Light emissions
Centre for Marine Science and Technology (CMST) (Curtin University of Technology)	Prediction of Underwater Noise Levels Associated with the Operation of FLNG Facilities in the Browse Basin - 2014	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f30---meekan-amp-radford-2010---migration-patterns-of-whale-sharks-a-summary-of-15-satellite-tag-tracks-from-2005-to-2008_.pdf?sfvrsn=f996a7e4_2	Underwater noise Emissions
	Prediction of Received Underwater Sound Levels from Torosa D and Torosa E Subsea Manifolds (Revised)	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f14---duncan-2010---prediction-of-received-underwater-sound-levels-from-torosa-d-and-torosa-e-subsea-manifolds_.pdf?sfvrsn=eb4c19e9_2	Underwater noise Emissions
JacobsSKM	Light Modelling Study - 2014	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f28---jacobs-skm-2014---light-modelling-study_.pdf?sfvrsn=7a5395f6_2	Light emissions
SKM / ERM	Torosa South-1 (TS-1) Pilot Appraisal Well, Environmental Monitoring Programme – Development of Methodologies (Part 1)	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f17---erm-amp-skm-2008---torosa-south-1-pilot-appraisal-well_-environmental-monitoring-programme-development-of-methodologies-(part-1)_.pdf?sfvrsn=58af2a1a_2	Seabed disturbance Drill cuttings Wastewater discharge Underwater noise

Organisation	Study Name	Link to Report	Aspect / Impact / Risk
			Light emissions
AIMS	AIMS Expert Opinion on Recovery Trajectories of Coral Communities at Scott Reef – 2014	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f02---aims-2014-expert-opinion-on-recovery-of-scott-reef-from-a-hydrocarbon-spill_.pdf?sfvrsn=fb882111_2	Hydrocarbon Spill
	AIMS Expert Opinion: Subsidence of Scott Reef - 2012	https://files.woodside/docs/default-source/our-business---documents-and-files/burrup-hub---documents-and-files/browse---documents-and-files/index-of-previous-browse-studies/f03---aims-2012b---expert-opinion-on-subsidence-of-scott-reef_.pdf?sfvrsn=7a0d2e36_2	Seabed subsidence

3.8.7 Summary of Workplan

Woodside has reviewed the previous technical studies in terms of relevance to the proposed Browse to NWS Project. Where emissions (in terms of location, magnitude, frequency and toxicity) are expected to be comparable to previous Development concepts, it is considered that sufficient understanding of the impacts and risks exists. Where significant differences exist to previous studies, new studies will be undertaken to inform the EIS/ERD. An overview of the current level of understanding of the potential impacts and risks as well as the workplan for each aspect is provided in **Table 12**.

Table 12 Impact and Risk Assessment Workplan

ID	Aspect	Key Aim	Assessment of Current Level of Understanding	Workplan
IMP-1	Underwater noise emissions	Understand and assess potential impacts to sensitive receptors (marine fauna) resulting from the generation of underwater noise.	Woodside has a good understanding with respect to the underwater noise generated from the proposed activities via studies undertaken for the previous Browse Development concepts. Understanding of underwater noise from construction activities (e.g VSP, drilling, seabed preparation, vessel movements) is considered sufficiently understood to inform the impact assessment for the EIS/ERD. Underwater noise associated with the physical presence of dynamically positioned MODU/vessel is also considered well understood, however to support the environmental impact assessment of this activity in the EIS/ERD, an acoustic modelling study for MODU DP activities is planned. Noise Modelling was conducted to support the FLNG EIS/ERD (Duncan 2014) where the acoustic source spectra for the FLNG facility during normal operations were based on a generic FPSO facility. It is considered that the noise assumed to be produced by the FLNG facility in the Duncan (2014) study is sufficiently representative of the Torosa FPSO facility which represents the worst-case scenario with respect to FPSO noise generation for the Proposed Action. As such, it is considered that the Duncan (2014) study is appropriate to describe the impact of noise on sensitive receptors originating on the Torosa FPSO and no further modelling of FPSO generated noise is required. Woodside modelled underwater noise generated by subsea choke valves (Duncan, 2010) within wellheads to support the FLNG EIS/ERD. This modelling was undertaken for the Torosa D (TRD) and Torosa E (TRE) subsea manifolds (i.e. located in channel between North and South Scott Reef) which is considered worst case with respect to underwater noise impacts It is considered that this modelling is representative for the proposed Browse to NWS Project and no further modelling is considered required. It is also noted that relative to the FLNG EPBC approval (2013/7079), in addition to TRE, the TRD drill centre is now planned to be installed post Ready for Start Up (RFSU). This will allow Woodside to monitor both choke noise emissions from wells outside the channel, plus pygmy blue whale presence/absence in the area prior to the installation of wells at TRD and TRE. As outlined during assessment of 2013/7079 there is potential to further mitigate choke noise for post RFSU wells if warranted. While considered unlikely to be required, driving piling is considered a planned contingent activity that will be used in the event suction piling is not feasible in any area due to geotechnical conditions. Available noise modelling of pile driving activities is not considered sufficient to support the environmental impact assessment of this activity in the EIS/ERD, and as such Browse to NWS Project specific modelling is required.	Literature review of Woodside owned and publicly available information including a review of applicable State and Commonwealth guidance and conservation plans. Implementation of a subsea piling acoustic modelling study to generate predictions of the ensonified area and ranges to acoustic thresholds and estimate acoustic exposure to pygmy blue whales and green turtles. Implementation of acoustic modelling study for MODU DP activities to generate predictions of the ensonified area and ranges to acoustic thresholds and estimate acoustic exposure to pygmy blue whales and green turtles.
IMP-2	Light emissions – MODU and FPSO including flaring	Understand and assess potential impacts to sensitive receptors (marine fauna) resulting from the generation of light emissions.	Woodside has a good understanding with respect to the light emissions generated from the proposed activities via studies undertaken for the previous Browse Development concepts. Light emissions from construction and operation activities were modelled (ERM 2010 and Jacobs 2014) as part of the two previous Browse Development concepts (JPP and FLNG). It is considered that the source light levels for the proposed FPSO facilities are similar to those previously modelled as part of the previous studies, with the overall artificial light footprint likely to be smaller due to the significantly reduced size of the facilities. Given the similarities between the previous concepts and the proposed Browse to NWS Project (with potential reduction in light emissions) it is considered that these studies adequately define the potential impacts from artificial light emissions associated with the development.	Literature review of Woodside owned and publicly available information including a review of applicable State and Commonwealth guidance and conservation plans. Use of previous modelling to inform impact assessment.
IMP-2b	Light emissions – vessels			
IMP-3a, Risk 10	Physical presence of infrastructure during construction	Understand and assess potential impacts to sensitive receptors (marine fauna, benthic habitat) resulting from the physical presence of infrastructure during construction and operations.	Woodside has a detailed understanding of the extent of temporary and permanent seabed disturbance as well as the number, frequency and location of surface facilities and support vessels. As detailed in **Table 6** Woodside has a good understanding of the seabed that is expected to be disturbed and is undertaking an environmental survey, including benthic habitat study of the BTL corridor (refer to Section 3.7.6). This information is considered sufficient to define the impacts associated with the physical presence of the infrastructure.	Literature review of Woodside owned and publicly available information to inform impact assessment including the calculation of predicted seabed disturbance.
IMP-3b, Risk 10	Physical presence of infrastructure during operations			

ID	Aspect	Key Aim	Assessment of Current Level of Understanding	Workplan
IMP-4a	Gaseous emissions - air emissions	Predict impact to local air quality as a result of gaseous emissions	Woodside has sufficient understanding of the characteristic of the Browse resource and the combustion requirements to extract, process and export the gas to accurately quantify gaseous emissions. As such no further studies are considered required. In relation to GHG assessment refer to Section 3.9. Woodside will point to and provide context for the assessment of the potential impacts of the North West Shelf Project Extension Proposal (EPBC 2018/8335) on values specifically related to the National Heritage listing on the Burrup Peninsula.	Literature review of Woodside owned and publicly available information to inform impact assessment In relation to GHG assessment refer to Section 3.9. The assessment documentation must provide details of any potential indirect impacts of the proposed action on the (Indigenous rock art) values of the Dampier Archipelago (including the Burrup Peninsula) National Heritage Place, and the extent to which these values may be impacted by the proposed action following any planned mitigations. .
IMP-4b	Gaseous emissions - GHG	In relation to GHG assessment refer to Section 3.9.		
IMP-5	Treated sewage	Understand and assess impact of the discharged of treated sewage.	Sewage generated during the Proposed Action will be treated and disposed of in accordance with MARPOL 73/78Annex IV: Sewage – (as applied in Australia under Commonwealth *Protection of the Sea (Prevention of Pollution from Ships) Act* 1983); AMSA Marine Orders - Part 96: Marine Pollution Prevention – Sewage. as applicable to vessel class. As such, no further studies are considered to be required.	Literature review of Woodside owned and publicly available information to inform impact assessment.
IMP-6, Risk 2	Treated PW and NORMs.	Understand and assess potential impacts resulting from the discharge of PW and NORMS from the FPSO, including the extent of impact based on the determination of Predicted No Effect Concentrations (PNEC) and the mixing zone.	Woodside has a good understanding of the predicted PW discharge rates and composition. However, confirmation of the dilution rate that will be achieved from the FPSO facilities and the extent of the mixing zone is required. PW discharges were modelled during the assessment of the previous Browse development concepts (DHI 2011, DHI 2014). The modelling undertaken for the FLNG EIS (DHI 2014) predicted that the PW plume would disperse to below toxicity threshold concentrations within less than 3 km from the facility. PW emissions from the FPSO facilities are expected to be broadly similar (other than MEG concentrations are likely to be pulsed at high concentrations as opposed to continuous trace concentrations). There is potential for PW volumes and discharge rates to increase during later field life to levels above predicted in the Browse FLNG EIS. Due to the increase in PW volume and discharge rates late in field life, the existing modelling can only inform the scope of the new modelling and cannot be used to inform the impact assessment. Ecotoxicology studies to determine the safe concentration of Browse PW for 99% of species protection have previously been undertaken and will be used to inform the interpretation of the PW modelling study.	Literature review of Woodside owned and publicly available information to inform impact assessment. Implementation of a PW Dispersion Modelling study to predict the fate and transport of PW discharges from the FPSO in order to determine the number of dilutions achieved from the FPSO facilities, which is required to determine an appropriate mixing zone, outside which no impacts to the receiving environment are predicted. The PW Dispersion Modelling will also be used to inform predictions of the extent, severity and persistence of environmental impacts within the defined mixing zones.
IMP-7a, Risk 3	Treated utility water – drain discharges	Understand and assess impact of the discharge of treated utility water.	Drain discharges generated during the Proposed Action will be treated and disposed of in accordance with MARPOL 73/78 Annex I, as applied in Australia under the Commonwealth *Protection of the Sea (Prevention of Pollution from Ships)* Act 1983 (Part II Prevention of pollution from oil); Marine Orders 91 (Marine pollution prevention – Oil) 2006 as applicable to vessel class; and the *Pollution of Waters by Oil and Noxious Substances Act* 1987 (WA).	Literature review of Woodside owned and publicly available information to inform impact assessment.
IMP-7b	Treated utility water – desalination brine	Understand and assess impact of the discharge of treated desalination brine.	Woodside has a good understanding of the expected desalination brine discharge rates and composition. Given the low likelihood of significant impacts occurring, no further studies are considered required.	Literature review of Woodside owned and publicly available information to inform impact assessment.
IMP-8, Risk-4	Cooling water	Understand and assess potential impacts resulting from the discharge of cooling water from the FPSO including the determination of the mixing zone.	Woodside has a good understanding of the predicted cooling water discharge rates and composition. However, confirmation of the extent of the mixing zone is required. Cooling water discharges were modelled during the assessment of the previous Browse Development concepts (DHI 2011a, DHI 2014). The modelling undertaken for the FLNG EIS (DHI, 2014) predicted that temperatures would return to with 3 degrees of ambient temperature within 190 m of the discharge point in winter and 110 m or less in summer. The modelling also predicted that residual chlorine concentrations in cooling water (0.2ppm) will reduce down-current of the discharge point to threshold concentration (0.002ppm) within 1.4 km or less in winter and within shorter distances in the transitional and summer seasons (1.3 km or less and 1.1 km or less respectively) for 95% of the time. Cooling water emissions from each of the FPSO facilities are expected to be significantly reduced compared to those assessed for Browse FLNG EIS and as such the existing modelling can only inform the scope of the new modelling and cannot be used to inform the impact assessment.	Literature review of Woodside owned and publicly available information to inform impact assessment. Implementation of a Cooling Water Dispersion Modelling study to predict the fate and transport of cooling water discharges from the FPSO in order to determine the mixing zone, outside which no impacts to the receiving environment are predicted. The Cooling Water Dispersion Modelling will also be used to inform predictions of the extent, severity and persistence of environmental impacts within the defined mixing zones
IMP-9	Putrescible organic waste	Understand and assess impact of the discharge of putrescible organic waste and the risks associated with the accidental discharge of hazardous and non-hazardous inorganic	Woodside has a good understanding of the expected organic and non-organic wastes expected to be generated during the proposed Browse to NWS Project. These wastes will be managed in accordance with legislative requirements. No further studies are	Literature review of Woodside owned and publicly available information to inform impact assessment.
IMP-10, Risk-5	Inorganic non-hazardous waste			

ID	Aspect	Key Aim	Assessment of Current Level of Understanding	Workplan
IMP-10, Risk-6	Hazardous waste - chemicals, radioactive and medical	waste.	considered required.	
IMP-12, Risk-7	Drilling cuttings and fluids	Understand and assess impact of the discharge of drill cuttings on sensitive receptors.	Woodside has a good understanding of the quantity and nature of the drill cuttings that are predicted to be generated and the drill fluids to be used. There is also a good understanding on the predicted fate of the discharges via drilling cuttings discharge modelling undertaken as part of the previous Browse Development concepts (DHI 2011b). This modelling indicated predicted that the seabed discharge of drill cuttings from top hole sections of the wells results in no sedimentation on Scott Reef coral habitats. This modelling was based on drill centres in the channel between North and South Scott reef and is considered to be representative of the worst case scenario. Drilling and completion activities required for the proposed Browse to NWS Project area expected to be broadly similar to that of the previous development concepts. As such the previous modelling is considered representative and sufficient for assessing the potential impacts.	Literature review of Woodside owned and publicly available information to inform impact assessment. Use of previous modelling to inform impact assessment.
IMP-13	Subsea control fluid	Understand and assess impact of the discharge of subsea control fluid.	Woodside has a good understanding of the quantity and nature of the subsea control fluid to be discharged. These discharges are minor, similar to that predicted for previous Browse development concepts and with a negligible impact predicted. As such further studies are not considered necessary.	Literature review of Woodside owned and publicly available information to inform impact assessment.
IMP-14	Hydrotest fluid	Understand and assess potential impacts resulting from the discharge of hydrotest fluid including the determination of the mixing zone.	Hydrotest fluid discharge modelling was not undertaken as part of the previous Browse development concepts due to the relatively small amount of hydrotest fluid that was planned to be released. Significantly larger quantities may be discharged as part of the proposed Browse to NWS Project however, due to the potential requirement to hydrotest the BTL. As such, modelling is considered required to predict the fate and transport of hydrotest discharges to inform the impact assessment.	Literature review of Woodside owned and publicly available information to inform impact assessment. Implementation of a Hydrotest Dispersion Modelling Study to predict the fate and transport of hydrotest discharges from the BTL in order to determine the number of dilutions achieved, which is required to determine an appropriate mixing zone, outside which no impacts to the receiving environment are predicted. The Hydrotest Dispersion Modelling will also be used to inform predictions of the extent, severity and persistence of environmental impacts within the defined mixing zones.
IMP-15	Atmospheric Noise	Understand and assess potential impacts resulting from Atmospheric Noise Emissions resulting from helicopter movements	Woodside has a good understanding of the noise emissions from helicopter movements and no further studies are considered necessary.	Literature review of Woodside owned and publicly available information to inform impact assessment.
Risk-1	IMS	Understand and assess the potential risks associated with the introduction of IMS.	The risk of the introduction of IMS as a result of the project will be managed in accordance with legislative requirements. No further studies are considered necessary.	Literature review of Woodside owned and publicly available information to inform impact assessment.
Risk-8	Seabed subsidence	Understand and assess the potential risks associated with seabed subsidence as a result of the extract of the Browse resource.	Woodside has modelled the magnitude of subsidence and associated horizontal movements for the Browse reservoirs as part of the previous Browse Development concepts. This analysis has been peer reviewed by Baker Hughes GMI Geomechanics Services (Baker Hughes 2012) who concluded that the method and supplied data was appropriate. The DoEE sought further independent review by CO2 Geological Storage Solutions Pty Ltd (CGSS) (CGSS 2012) who found that the report conclusions were reasonable. As such Woodside has sufficient understanding of the risks associated with seabed subsidence and no further studies are considered necessary.	Literature review of Woodside owned and publicly available information to inform impact assessment.
Risk-9	Hydrocarbon spill	Understand and assess the potential risks associated with a hydrocarbon spill.	Woodside has modelled multiple hydrocarbon spill scenario as part of the previous Browse development concepts. However, given ongoing improvements in modelling and understanding of conditions, and the addition of the BTL, a Hydrocarbon Spill Modelling study will be undertaken.	Literature review of Woodside owned and publicly available information to inform impact assessment. Implementation of a Hydrocarbon Spill Modelling study to describe the dispersion and degradation characteristics of a range of hydrocarbon spill scenarios.

3.8.8 Scope of Technical Studies informing Impact and Risk Assessment

The following technical studies will be undertaken to inform the impact and risk assessment. Where applicable the assessment will be done in consideration of the Revised Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2018 (ANZG (2018)) which provide the recommended limits to acceptable change in water quality that will continue to protect the associated environmental values.

Subsea Piling and MODU DP Acoustic Modelling

Acoustic modelling of the subsea impact pile driving operations for the mooring of the Torosa FPSO facility and of the MODU DP will be undertaken. The objective of this study is two-fold:

- to generate predictions of the ensonified area and ranges to acoustic thresholds that may result in injury to or behavioural disruption of cetaceans, turtles and fish near the construction area; and
- estimate acoustic exposure to pygmy blue whales and green turtles.

For the subsea impact pile driving operations, modelling will be undertaken for the following scenarios for a single pile type:

1. One ‘light’ subsea hammer
2. One ‘high energy’ subsea hammer

Both scenarios will be modelled at the same location using conservative assumptions from the provided information. Footprints for impact pile driving will be computed at three penetrations, and a combined footprint for the entire driving of a single pile will be computed. The modelling will assume a single pile will be driven per day.

Exposures for pygmy blue whales and inter-nesting green turtles will be assessed using a simulated animal (animat) approach. This approach will use acoustic modelling to compute three-dimensional (3-D) sound fields that vary with time, and simulated realistic movements of animats within these fields to sample the sound levels in a manner representing how real animals would experience this sound. Using the time history of the received sound levels, the number of animats exposed to levels exceeding threshold criteria will be determined and then adjusted by the number of animals in the area to estimate the potential number of animals impacted.

Produced Water Dispersion Modelling

PW dispersion modelling will be undertaken to predict the fate and transport of PW discharges from the FPSO in order to determine the number of dilutions achieved from the Browse FPSO facilities, which is required to determine an appropriate mixing zone, outside which no impacts to the receiving environment are predicted. It will also be used to inform predictions of the extent, severity and persistence of environmental impacts within the defined mixing zones.

The proposed modelling will describe the dispersion geometry (i.e. width and thickness with distance) and dilution characteristics of the discharge plume, it has been determined that hydrocarbons are the most toxic constituent of the PW discharge, with other potential contaminants such as metals present in less toxic concentrations. In addition additional production chemicals will not be continuously injected. Hence, the toxicity values used to characterise impacts to marine organisms has been derived from ecotoxicological studies conducted on Torosa condensate samples.

The modelling will take into consideration all relevant metocean parameters of the receiving environment including seasonal fluctuations as well as parameters from possible discharge scenarios (e.g. discharge location, water depth, discharge pipe diameter and orientation, and discharge volume, density, temperature and salinity). In addition, validation of the hydrodynamic model against measured data will be undertaken.

This information will be used as part of the environmental impact and risk assessment process of the EIS/ERD to determine the impacts (if any) to the receiving environment from the PW discharge and to determine the extent of the mixing zone around the Torosa FPSO discharge location (as the worst-case scenario due to the location in proximity to Scott Reef). The modelling will then also be applied to the Brecknock/Calliance FPSO facility to enable assessment of impacts from both facilities.

Cooling water dispersion modelling

Cooling water dispersion modelling will be undertaken to predict the fate and transport of cooling water discharges from the FPSO in order to determine the number of dilutions achieved from the Browse FPSO facilities, which is required to determine an appropriate mixing zone, outside which no impacts to the receiving environment are predicted. It will also be used to inform predictions of the extent, severity and persistence of environmental impacts within the defined mixing zones.

The proposed modelling will describe the dispersion geometry (i.e. width and thickness with distance) and dilution characteristics of discharge plume. This information will be used as part of the environmental risk assessment process of the EIS/ERD to determine the impacts (if any) to the receiving environment from the cooling water discharge and to determine the extent of the mixing zone around the Torosa FPSO discharge location outside which no detectable change from natural variation is predicted. The modelling will then also be applied to the Brecknock/Calliance FPSO facility to enable assessment of impacts from both facilities.

Modelling will take into consideration all relevant metocean parameters of the receiving environment including seasonal fluctuations as well as parameters from possible discharge scenarios (e.g. discharge location, water depth, discharge pipe diameter and orientation, and discharge volume, density, temperature and salinity).

Hydrotest Dispersion Modelling (BTL and Inter Field Spur Line)

Hydrotest modelling will be undertaken to predict the fate and transport of hydrotest discharges, in order to determine the number of dilutions achieved within the receiving environment. Modelling will be undertaken at all potential locations for planned discharge of hydrotest fluid from the BTL and Inter-Field Spur Line. Discharge of the hydrotest fluid from the flowlines will be discharged at the similar locations as the Inter-Field Spur line and will invoice discharge of volumes many orders of magnitude less than the spur line. As such, the potential impacts associated with the flowline hydrotest have been adequately assessed within the larger hydrotest volume.

For the purpose of modelling the BTL and Inter-Field Spur Line and the associated risk assessment, it has been assumed that the hydrotest fluid will consist of a combination of filtered inhibited seawater and biocide. The 99% species protection for biocide chemical (nominally product name Hydrosure) will be used as the threshold.

The proposed modelling will describe the dispersion geometry (i.e. width and thickness with distance) and dilution characteristics of discharge plume. This information will be used as part of the environmental risk assessment process of the EIS/ERD to determine the impacts (if any) to the receiving environment from the hydrotest discharges based on the known toxicities of the chemical additives within the hydrotest waters.

Hydrocarbon Spill Modelling

Hydrocarbon spill modelling will be undertaken to describe the dispersion and degradation characteristics of a range of hydrocarbon spill scenarios. This information will be used as part of the environmental risk assessment process of the EIS/ERD to determine the impacts (if any) to the receiving environment from hydrocarbon spills.

The credible hydrocarbon spill scenarios to be modelled are as follows:

- Hydrocarbon release caused by loss of well containment

- Hydrocarbon release due to cargo tank or condensate tanker loss of containment
- Hydrocarbon release during offtake operations
- Hydrocarbon release from fuel tanker in proximity to Rowley Shoals.

It is not proposed to model the release of dry gas from the BTL as the high temperature and low-pressure conditions would result in the released dry gas combining with water to form hydrates which would rise to the surface, decompose into methane and water. Dissolved methane would biodegrade whereas the gaseous methane will continue to rise to the sea surface and be transported away by surface winds. Water produced by the dissociation of hydrates would disperse within the water column. Due to this, the release of liquid hydrocarbons (as per the above four scenarios to be modelled) are considered the worst case credible scenarios. A detailed technical explanation and appropriately-supported evaluation of the fate and effect(s) on the environment of a release of dry gas will be included in the EIS/ERD.

It is also not proposed to model heavy fuel oil (HFO) and Marine Diesel Oil (MDO) spills from vessels. Based on the International Maritime Organisation's decision to implement a 0.50% sulphur cap on marine fuel from 2020, the assumption is being made that there will be no HFO, which have sulphur levels much higher than this cap, in use or stored onboard any of the project vessels. While MDO may be considered worse from a contaminant perspective than condensate, due to the significantly higher volumes of condensate involved in a condensate tanker loss of containment at a nearby location, this scenario is considered to be a worse case credible scenario in the vicinity of Scott Reef.

Modelling will take into consideration all relevant metocean parameters of the receiving environment including seasonal fluctuations as well as parameters from possible discharge scenarios (e.g. discharge location, water depth, discharge pipe diameter and orientation, and discharge volume, density, temperature and salinity).

Modelling will be undertaken with regard to NOPSEMA's Guidance Note on Oil pollution risk management (Rev 2, Feb 2018).

3.9 Greenhouse Gases

As requested by the Commonwealth DoEE, this chapter will summarise:

1. receptors in the environment in the Australian jurisdiction that are sensitive to an increase in greenhouse gas (GHG) content in the atmosphere - the focus should be on the most sensitive receptors, and receptors that may be sensitive to elevated GHG levels in the local airshed
2. trends in the condition of the receptors identified at point 1
3. the (direct and indirect, or Scope I–III) GHG emissions from the Proposed Action (sources and volumes, see also point 1 in Appendix A)
4. how the (total of direct plus indirect) GHG emissions from the Proposed Action could impact the receptors identified at point 1
5. mitigation and any offset measures proposed to reduce: GHG emissions from the Proposed Action; and their impacts (see also point 2 in Appendix A) - this section will include a discussion of the steps taken at the: company, Burrup Hub vision and this individual project level, to reduce GHG emissions
6. how the Scope I GHG emissions from the Proposed Action will be estimated (see point 3 in Appendix A)
7. how the Scope II and III GHG emissions from the Proposed Action will be estimated
8. the extent to which the direct and indirect GHG emissions from the Proposed Action will affect the trends in the condition of the receptors identified at point 1

9. relevant Australian and international legislation and policy in relation to the management of climate change.

Note: Without limiting what is required, the EIS/ERD must (a) identify those components of the environment in the Australian jurisdiction that are most likely to be impacted by climate change/most vulnerable to the impacts of climate and assess in detail the likely flow-on consequences of such an increase in atmospheric, air and water temperatures to those components of the environment; and (b) for all other components of the environment in the Australian jurisdiction, assess the likely impacts of climate change at a higher level (for instance, a more general discussion and/or impacts on types of ecosystems, heritage places, terrestrial habitat, marine habitat, migratory species).

3.10 Environmental Mitigation, Management and Monitoring

3.10.1 Environmental Management Framework

An environmental management framework will be described within the EIS/ERD. This will include:

- Overview of Woodside's HSE Management System Standard
- Health, Safety, Environment and Quality (HSEQ) Policy
- Standards
- Environmental Objective
- Processes for implementing, checking and acting on relevant environmental management measures as the Project is developed.

3.10.2 Management and Mitigation

As part of the EIS/ERD process, management and mitigation measures will be identified to reduce the level of impact and risk to an acceptable level in consideration of the EPBC Act, EP Act and other relevant policy instruments. This includes any practices that will reduce the impacts and risks in order to meet the identified performance criteria, any relevant legal requirements (related specifically to the impact/risk), internal company requirements, and any requirements that are identified through the stakeholder consultation process. It should be noted that further review and potential adoption of additional controls will be undertaken in subsequent phases of the project, such as during the preparation of Environment Plans (EPs) for activities under the scope of the EIS/ERD. While the overarching environmental objectives will be carried through to the EPs, controls and corresponding performance criteria will be implemented to reduce risks to as low as reasonably practicable (ALARP).

In accordance with Woodside's risk management standards and for the purpose of the draft EIS/ERD, where a risk is assessed to be low, this risk will be deemed acceptable, and no further management is required. Where the risk level is higher than low, additional management and mitigation measures are required to be considered and implemented, if the cost is not grossly disproportionate to the environmental benefit gained, to prevent or mitigate the risk to an acceptable level.

The following framework tools will be applied, as appropriate, to assist with identifying appropriate management and mitigation measures:

- Good Industry Practice – identifies further engineering control standards and guidelines which may be applied by Woodside in addition to those required to meet the legislation, codes and standards.
- Professional Judgement – uses relevant personnel with the knowledge and experience to identify alternative controls.

Using these tools, the following adaptive management framework will be used to identify appropriate management and mitigation measures for the proposed Browse to NWS Project:

- Eliminate the risk by removing the hazard.
- Substitute a hazard with a lesser one.
- Prevent a credible impact from occurring through the implementation of additional engineering control measures.
- Reduce the magnitude of a credible impact through the implementation of additional engineering control measures (e.g. solids control equipment onboard drilling rig to manage cuttings discharge).
- Mitigate the credible impact on the environment through the reduction in extent, scale, duration of impact (e.g. bunding, oil spill booms, relief well).
- Emergency response and contingency planning to facilitate recovery from the credible impact of an event.

Environmental objectives, proposed mitigation and management measures and performance criteria will be presented in the EIS/ERD.

3.10.3 Environmental Monitoring

Woodside will continue a long-term environmental monitoring program at Scott Reef, including water quality and coral health monitoring, that will be implemented prior to development at Torosa; with the results of this program used to demonstrate no long-term negative effects to Scott Reef resulting from the proposed Browse to NWS Project. The EIS/ERD will describe the objectives and scope of this long-term monitoring.

Where identified as required, additional planned monitoring will be described including the objective and scope of specific monitoring plans. These plans would subsequently be developed prior the commencement of the relevant activity and would take into consideration relevant guidance such as the Revised Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2018 (ANZG(2018)).

3.10.4 Environmental Offsets

In the event that impacts cannot be avoided or mitigated, the EIS/ERD will provide detail of the approach to be applied to offsetting impacts. It should be noted that offsets for GHG emissions are addressed separately in Section 3.9. This approach will include a commitment to develop an offsets plan that would provide details of offsets proposed to compensate for residual impacts on EPBC listed species, including the following:

- The type of offsets proposed
- The extent to which the proposed offset actions correlate to, and adequately compensate for, the impacts to EPBC listed species
- For proposed land-based offsets, the suitability of the location of proposed offset sites, including the current land tenure and method of securing and managing the offset for the life of the impact
- For non-land-based offsets, details of the proposed offset and how it will compensate for the proposal’s residual significant impacts
- The conservation gains to be achieved by the offset (for example, positive management strategies that improve the site, or how the future loss, degradation or damage of the protected matter will be averted or mitigated)

- The time it will take to achieve the proposed conservation gains
- The level of certainty that the proposed offset will be successful.

The EIS/ERD will explain how the proposed approach to applying offsets (if any) meet the principles of the Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy (2012).

3.11 Overall Conclusion

An overall conclusion as to the environmental acceptability of the Proposed Action and State waters proposal will be provided, including discussion on compliance with the principles of Ecological Sustainable Development and the objects and requirements of the EPBC Act and EP Act. This will include a qualitative assessment of the cumulative impacts on each key receptor and assess impacts on a more holistic, whole-ecosystem level, considering the potential cumulative impacts of the proposed project, and any existing and future concurrent activities, on the existing environment.

Reasons justifying undertaking the Proposed Action and State waters proposal in a manner proposed will be outlined.

The conclusion will highlight measures proposed or required by way of mitigating or managing any unavoidable impacts on the environment.

Measures proposed by way of offset and the change in residual impacts following the offset will be restated here.

3.12 Other Chapters

3.12.1 Environmental record of person(s) undertaking the Proposed Action

This chapter will outline the environmental record of the proponent including:

- details of any proceedings under Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of natural resources against:
    - the person proposing to take the action; and
    - for an action for which a person has applied for a permit, the person making the application.
- details of the Woodside's HSEQ policy and planning framework.

3.12.2 Information Sources

For information given in a draft EIS/ERD, the draft must state:

- the source of the information
- how recent the information is
- how the reliability of the information was tested
- what uncertainties (if any) are in the information.

3.12.3 References

All reference cited within the draft EIS/ERD will be listed. This will be accurate and concise and include the addresses of an internet pages used as source data.

4. PART C: STATE ESD

Proposal Name:	Proposed Browse to NWS Project
Proponent:	Woodside Energy Ltd., as Operator for and on behalf of the BJV
Assessment Number:	2191
Location:	• Approximately 425 km north of Broome, WA. • The Browse Joint Venture (BJV) holds seven petroleum retention leases. Five of the leases (WA-28-R, WA-29-R, WA-30-R, WA-31- R and WA-32-R) are located in Commonwealth waters and are governed under the Offshore Petroleum and Greenhouse Gas Storage Act 2006 (Cth) (OPGGSA). The remaining two leases (TR/5 and R2) are governed under State legislation Petroleum (Submerged Lands) Act 1982 (WA) (PSLA) and the Petroleum and Geothermal Energy Resources Act 1967 (WA) (PGERA).
Local Government Area:	Lease R2 is linked to the Shire of Broome via the Local Govt Act 1995 (WA)
Public Review Period:	Environmental Review Document – 6 weeks
EPBC Reference Number:	2018/8319

4.1 Introduction

The Environmental Protection Authority (EPA) has determined that the Browse to NWS proposal is to be assessed under Part IV of the Western Australian (WA) Environmental Protection Act 1986 (EP Act). This EISG/ESD defines the form, content, timing, and procedure of the environmental review, as required by Section 40(3) of the EP Act. Woodside Energy Ltd. (Woodside) has prepared this EISG/ESD according to the EPA’s Environmental Impact Assessment (Part IV Division 1 and 2) Procedures Manual (EPA 2018a).

4.1.1 Form

The EPA requires that the Environmental Review Document (ERD) required under Section 40 conforms with the EPA instructions on how to prepare an ERD (EPA 2018).

4.1.2 Content

The EPA requires that the ERD includes the content outlined in Sections 4.1 to 4.6 of this EISG/ESD.

4.1.3 Timing

Section 1.1.3.2 sets out the timeline for assessing the Browse to NWS proposal, as agreed between DoEE, EPA and Woodside which will be documented in a DoEE issued Client Service Charter.

4.1.4 Procedure

The EPA requires Woodside to undertake the environmental review according to the procedures in the Environmental Impact Assessment (Part IV Divisions 1 and 2) Administrative Procedures (EPA 2016a) and the Environmental Impact Assessment (Part IV Divisions 1 and 2) Procedures Manual (EPA 2018a).

4.1.5 Assessment

As described in Section 1.1.3.2, the assessment of the Proposed Action under the EPBC Act and State waters proposal under the EP Act is planned to be undertaken as a coordinated assessment between the DoEE and WA EPA. The National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) will be engaged to provide technical advice to the DoEE in relation to the assessment.

This approach includes the following:

- Simultaneous referrals under the EPBC Act and EP Act, which was completed in October 2018.
- The development of a single EISG/ESD (this document), which describes the proposed content of an Environment Impact Statement/Environmental Review Document (EIS/ERD). This ESD will be issued to DoEE and EPA for review and endorsement.
- The development of a single draft EIS/ERD document that is issued to DoEE and EPA for comment on adequacy and approval, prior to release for public comment.
- The preparation of a single final EIS/ERD document. The final EIS/ERD will be submitted to the DoEE and WA EPA for assessment and to be published.
- Decision on the acceptability of the Proposed Action and the State waters proposal.

Subsequent to a favourable decision on the acceptability of the proposed Browse to NWS Project, and prior to any development activity occurring in State waters, Environment Plans (EPs) including Oil Spill Contingency Plans (OSCP) will be developed for approval by the Department of Mines, Industry Regulation and Safety (DMIRS) in accordance with the Petroleum (Submerged Lands) (Environment) Regulations 2012.

4.2 The proposal

Refer to Section 2.2 for a description of the Proposed Action, while for the proposal relevant to State waters see Section 4.2.1.

4.2.1 Development in Western Australian State waters

The key characteristics of the proposal within State waters are described in **Table 13** and **Table 14** and shown in **Figure 1**.

Activities in State waters comprise a limited set of infrastructure and activities (**Table 13** and **Table 14**). The highest intensity of activities will likely occur during the drilling and completion activities, installation activities and future decommissioning phases; during which time, a MODU and vessel numbers of approximately ten or less may be present in the State waters. All the proposed infrastructure within State waters is subsea, with the operation of the wells to be controlled remotely from the FPSO facilities in Commonwealth waters. Outside of drilling, completion and installation periods, surface activities in State waters will comprise inspection, maintenance and repair (IMR) activities involving one or two vessels, later phase drilling and decommissioning (including well plugging and abandonment).

Proposal characteristics may change as a result of the findings of studies and investigations conducted and the application of the mitigation hierarchy by Woodside.

Table 13 Summary of the Proposal

Proposal Summary	
Proposal Title	Proposed Browse to NWS Project (State waters components)
Proponent Name	Woodside Energy Ltd, on behalf of the BJV participants
Short Description	Drilling and completion, installation, commissioning, operation, well repair and workover and decommissioning of subsea wells and associated subsea infrastructure located in Western Australian State waters, to extract hydrocarbons from the Torosa reservoir, located approximately 425 km north of Broome and approximately 290 km off the Kimberley coast.

Table 14 Location and proposed extent of physical and operational elements

Element	Description	Proposed Authorised Extent
Physical Elements		
Drilling and completion activities of up to approximately 21 wells.	Installation and physical presence of infrastructure within indicative field layout as per **Figure 1**	Approximately 20 ha of seabed.
Associated subsea infrastructure (wellheads, manifolds, flowlines, and umbilicals).		
Mooring of vessels and MODU.		
Seabed preparation and flowline stabilisation.		
Operational Elements		
Water supply (installation vessels, MODU, support vessels and supply vessels).	Water requirements sourced either from seawater (reverse osmosis plant) or loaded at port.	Limited water requirements to support drilling and completion activities, vessel and MODU water needs and potentially also for hydrotesting and decommissioning activities.
Power supply (installation vessels, MODU, support vessels and supply vessels).	Power generated on board vessels and MODU.	As required for operations and safety.
Vessel discharges (installation vessels, MODU, support vessels and supply vessels).	Discharges from vessels and MODU include treated sewage, drain waters, cooling water, sullage, putrescible organic waste and desalination brine.	Limited volumes discharged in accordance with International Convention for the Prevention of Pollution from Ships MARPOL 73/78 Annex I, as applied in Australia under the Commonwealth *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Part II Prevention of pollution from oil); Marine Orders 91 (Marine pollution prevention – Oil) 2006 as applicable to vessel class; *Pollution of Waters by Oil and Noxious Substance Act 1986.*
Drill cuttings and fluid discharges.	Disposal of drill cuttings and drilling fluids.	Approximately 800 - 900m^3 of cuttings are anticipated to be

Element	Description	Proposed Authorised Extent
		generated per well.
Produced water.	Small volumes of formation water may result during well clean-up activities by the MODU. These will be discharged directly from the MODU.	Low volumes of water that occurs naturally within the hydrocarbon-bearing geological formations.
Subsea control fluid discharge.	Discharge of control fluid at the wellheads to maintain valve functionality.	Intermittent discharge of hydraulic fluid based control fluids when valves actuated (~0.1 L).
Underwater noise emissions.	Underwater noise generated during drilling, completion and installation activities (including vessel movements on DP and vertical seismic profiling). Underwater noise generated from subsea infrastructure during operations. Underwater noise from piling activities for mooring installation for the MODU (note that this is unlikely to be required). Underwater noise from support vessel and supply vessel operations.	Noise frequencies associated with these activities are described in the Proposed Browse to NWS Development, *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act) and EP Act Environmental Referrals Supporting Document (Woodside, 2018).
Light emissions – operational lighting	Artificial light emitted by MODUs, installation vessels, and support vessels and supply vessels.	Limited to functional lighting at levels that provide a safe working environment for personnel.
Light emissions – flaring	Intermittent flaring from the FPSO facilities (located in Commonwealth waters) and MODU.	As required for operations and safety.

4.3 Preliminary key environmental factors and required work

The preliminary key environmental factors for the environmental review are:

- Benthic Communities and Habitat
- Marine Environmental Quality
- Marine Fauna
- Air Quality.

Table 15 to **Table 18** outline the objective, activities, potential impacts and risk and work required for each preliminary key environmental factor identified.

Table 15: Preliminary Key Environmental Factor and Required Work – Benthic Communities and Habitats

Benthic Habitats and Communities	
EPA Objective	To protect benthic communities and habitats so that biological diversity and ecological integrity are maintained (EPA 2016c).
Relevant Activities	• Development drilling and completions • Installation of subsea umbilicals, risers and flowlines • Operation of wells and subsea infrastructure • Decommissioning.
Potential Impacts and Risks	Refer to **Table 7** and **Table 8** for the preliminary impact and risk assessments for the proposed Browse to NWS Project. In relation to the proposal within State waters, the following impacts and potential risks are considered relevant to the Environmental Factor - Benthic Habitats and Communities: • IMP-3a Physical presence of infrastructure during construction: Seabed disturbance from seabed preparation and MODU anchors. No impact to Scott Reef is expected. • IMP-3b Physical presence of infrastructure during operations: Permanent seabed disturbance from subsea infrastructure • IMP-12 Drilling cuttings and fluids: Localised impact to deep water benthic habitats as a result of the discharge of drill cuttings. • Risk-9 Hydrocarbon spill: Long term contamination to multiple high value benthic habitats at levels above standards and on a regional scale. Considered highly unlikely to occur.
Required Work	Refer to **Table 12** for the full impact and risk assessment workplan. Refer to Section 3.8.8 for the scope of the proposed technical studies. In reference to the Environmental Factor – Benthic Habitats and Communities: • Determination of predicted temporary and permanent seabed disturbance within State waters. • Characterise the benthic habitats in the area potentially impacted using existing survey data and literature, including the preparation of habitat maps with demonstrated ground truthing for areas where proposed infrastructure will be installed on the seabed within State waters. Woodside has a good understanding of the benthic habitats expected to be disturbed within State waters and as such no further studies to characterise these benthic habitats is considered required. • Where significant benthic communities are identified in areas where infrastructure will be installed on the seabed, identify an appropriate Local Assessment Unit and assess cumulative loss of benthic communities and habitats in accordance with EPA's technical guidance (EPA 2016). • Predict the likely fate of discharged drill cuttings using existing data and modelling and assess impact on benthic habitats. Woodside has a good

Benthic Habitats and Communities	
	understanding of the quantity and nature of the drill cuttings that are predicted to be generated and the drill fluids to be used. There is also a good understanding on the predicted fate of the discharges via drilling cuttings discharge modelling undertaken as part of the previously proposed Browse Development concepts. Drilling and completion activities required for the Proposal are expected to be broadly similar to that of the previously proposed development concepts. As such the previous modelling is considered representative of the Proposal and sufficient for assessing the potential impacts. • Undertaken hydrocarbon spill modelling to describe the dispersion and degradation characteristics of a range of hydrocarbon spill scenarios to inform the risk assessment and the development of mitigation measures.
Relevant Policy and Guidance	***EPA Policy and Guidance*** • Statement of Environmental Principles, Factors and Objectives (EPA 2016b) • Environmental Factor Guideline - Benthic Communities and Habitats (EPA 2016c) • Technical Guidance - Protection of Benthic Communities and Habitats (EPA, 2016d)

Table 16: Preliminary Key Environmental Factor and Required Work – Marine Environmental Quality

Marine Environmental Quality	
EPA Objective	To maintain the quality of water, sediment, and biota so that environmental values are protected (EPA, 2016f).
Relevant Activities	• Development drilling and completions • Installation of subsea umbilicals, risers and flowlines • Operation of wells and subsea infrastructure • Decommissioning • Support activities
Potential Impacts and Risks	Refer to **Table 7** and **Table 8** for the preliminary impact and risk assessments for the proposed Browse to NWS Project. In relation to the Proposal within State waters, the following impacts and potential risks are considered relevant to the Environmental Factor – Marine Environmental Quality: • IMP-5, IMP7a&b: Vessel discharges including treated sewage, drain discharges, cooling water and desalination brine: Discharges within regulatory limits from support vessels and the MODU leading to short term, localised reduction in water quality. • IMP-12 Drilling cuttings and fluids: Localised reduction in water quality and sediment quality as a result of the discharge of drill cuttings.

Marine Environmental Quality	
	- IMP-13 Subsea control fluid: Localised reduction in water quality and sediment quality as a result of the discharge of subsea control fluids. - Risk-9 Hydrocarbon spill: Long term contamination to marine water and sediments at levels above standards and on a regional scale. Considered highly unlikely to occur.
Required Work	Refer to **Table 12** for the full impact and risk assessment workplan. Refer to Section 3.8.8 for the scope of the proposed technical studies. In reference to the Environmental Factor – Marine Environmental Quality - Characterise the marine environmental quality in the area potentially impacted using existing survey data and literature. Woodside has a good understanding of the marine environment in the State waters within the Browse Development Area via numerous available studies and as such no further studies to characterise this marine environment is considered required. - Characterise discharge type that has the potential to impact on State coastal waters (e.g. vessel and MODU discharges, drill cuttings and fluids, produced water, cooling water, hydrotest fluid, subsea control fluids) in terms of volume, frequency, composition and ecotoxicity. - Present previously undertaken modelling or revised modelling where required as described in the workplan (Section 3.8.8) and describe the dilution and fate of the discharges to determine the spatial extent of potential impacts and appropriate mixing zones. - Based on characterisation of the existing marine environment and expected discharges and modelling, develop and present spatially proposed Environmental Quality Criteria (Environmental Quality Objectives and levels of ecological protection) for State waters within the Browse Development Area. - Outline a commitment to develop and implement a Marine Environmental Quality Plan (EQP) for the State coastal waters which identifies the Environmental Values to be protected and spatially defines the Environmental Quality Objectives and levels of ecological protection that Woodside aims to achieve in State waters. - Undertaken hydrocarbon spill modelling to describe the dispersion and degradation characteristics of a range of hydrocarbon spill scenarios to inform the risk assessment and the development of mitigation measures.
Relevant Policy and Guidance	***EPA Policy and Guidance*** - Statement of Environmental Principles, Factors and Objectives (EPA 2016c) - Environmental Factor Guideline – Marine Environmental Quality (EPA 2016e) - Technical Guidance – Protecting the Quality of Western Australia's Marine Environment (EPA 2016f)

Marine Environmental Quality	
	Other Policy and Guidance • Revised Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2018 (ANZG (2018)

Table 17: Preliminary Key Environmental Factor and Required Work – Marine Fauna

Marine Fauna	
EPA Objective	To protect marine fauna so that biological diversity and ecological integrity are maintained (EPA, 2016f)
Relevant Activities	• Development drilling and completions • Installation of subsea umbilicals, risers and flowlines • Operation of wells and subsea infrastructure • Decommissioning • Support activities and helicopters
Potential Impacts and Risks	Refer to **Table 7** and **Table 8** for the preliminary impact and risk assessments for the proposed Browse to NWS Project. In relation to the proposal within State waters, the following impacts and potential risks are considered relevant to the Environmental Factor – Marine Fauna: • IMP-1 Underwater noise emissions: Impacts to sensitive marine fauna from noise emissions during drilling and completion of the wells, wellhead operations, piling and routine vessel and aviation operations • IMP-2 Light emissions: Impacts (attraction/repulsion, disorientation) on sensitive marine fauna as a result of light emissions from the MODU and support vessels • IMP-3a Physical presence of infrastructure during construction: Impacts to marine fauna as a result of unintentional interaction with support vessels. • IMP-3b Physical presence of infrastructure during operations: Impacts to marine fauna as a result of unintentional interaction with support vessels • IMP-12 Drilling cuttings and fluids: Localised reduction in water quality and sediment quality as a result of the discharge of drill cuttings and fluids with subsequent impacts to marine fauna. • IMP-15 Atmospheric Noise: Atmospheric noise generated by helicopter movements between the mainland and project area. • Risk-9 Hydrocarbon spill: Large scale mortality and injury to marine fauna on a regional scale. Considered highly unlikely to occur.
Required Work	Refer to **Table 12** for the full impact and risk assessment workplan. Refer to Section 3.8.8 for the scope of the proposed technical studies. In reference to the Environmental Factor – Marine Fauna: • Characterise the marine fauna in the area potentially impacted using

Marine Fauna	
	existing survey data and literature. Woodside generally has a good understanding of marine mammals that may occur in the Browse Development Area via a large number of surveys undertaken in relation to the previously proposed Browse Development concepts which have included habitat association surveys, long term sea noise logger deployment, aerial and vessel surveys and satellite tagging. • Characterise the predicted underwater noise emissions and potential impacts using existing and new modelling studies. • Characterise the predicted light emissions and potential impacts using existing modelling studies. Light modelling undertaken to support the FLNG EIS is considered representative of the Proposal facilities and as such no further modelling is considered necessary. • Predict the likely fate of discharged drill cuttings using existing data and modelling and assess impact on marine fauna. • Undertake a literature review on the impacts of electromagnetic emissions on marine fauna and utilise estimated direct electrical heating power demand to assess impacts. • Undertaken hydrocarbon spill modelling to describe the dispersion and degradation characteristics of a range of hydrocarbon spill scenarios to inform the risk assessment and the development of mitigation measures. This includes the modelling of a condensate spill which will be used to assess the risk to Scott Reef that such a spill would present (refer to Section 3.8.8).
Relevant Policy and Guidance	***EPA Policy and Guidance*** • Statement of Environmental Principles, Factors and Objectives (EPA 2016b) • Environmental Factor Guideline – Marine Environmental Quality (EPA 2016e) • Technical Guidance – Protecting the Quality of Western Australia's Marine Environment (EPA 2016f). ***Other Policy and Guidance*** • EPBC Act Policy Statement 2.1 – Interaction between Offshore Seismic Exploration and Whales (DEWHA 2008) • Conservation Management Plan for the Blue Whale - A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999 (DoE 2015) • Conservation advice *Anous tenuirostris melanops* Australian lesser noddy (Threatened Species Scientific Committee 2015a) • Approved Conservation Advice for *Megaptera novaeangliae* (humpback whale) (Threatened Species Scientific Committee 2015b) • Recovery plan for marine turtles in Australia (Commonwealth of Australia

Marine Fauna	
	2017) - Conservation advice Rhincodon typus whale shark (Threatened Species Scientific Committee, 2015c) - Whale shark (*Rhyncodon typus*) recovery plan 2005- 2010 (DEH, 2005)

Table 18: Preliminary Key Environmental Factor and Required Work – Air Quality

Air Quality	
EPA Objective	To maintain air quality and minimise emissions so that environmental values are protected (EPA 2016i).
Relevant Activities	- Development drilling and completions - Installation of subsea umbilicals, risers and flowlines - Decommissioning - Support activities and helicopters.
Potential Impacts and Risks	Refer to **Table 7** and **Table 8** for the preliminary impact and risk assessments for the proposed Browse to NWS Project. In relation to the proposal within State waters, the following impacts and potential risks are considered relevant to the Environmental Factor – Air Quality including GHG emissions in State waters: - IMP-4a Gaseous emissions - Air Emissions: Impacts to local air quality
Required Work	Refer to **Table 12** for the full impact and risk assessment workplan. Refer to Section 3.8.8 for the scope of the proposed technical studies. In reference to the Environmental Factor – Air Quality: - Woodside has sufficient understanding of the characteristic of the Browse resource and the combustion requirements to extract, process and export the gas to accurately quantify gaseous. As such no further studies are considered required.
Relevant Policy and Guidance	***EPA Policy and Guidance*** - Statement of Environmental Principles, Factors and Objectives (EPA 2016c) - Environmental Factor Guideline: Air Quality (EPA 2016b) ***Other Policy and Guidance*** - Air Quality Modelling Guidance Notes 2006 (DoE 2006)

4.4 Other environmental factors or matters

No other environmental factors or matters were identified as being relevant to the Browse to State waters proposal.

Note: Woodside is aware that other factors or matters may be identified during the course of the environmental review that were not apparent when this EISG/ESD was prepared. If this situation arises, Woodside will consult with the EPA to determine whether these factors and/or matters are to be addressed in the EIS/ERD and if so, to what extent.

4.5 Stakeholder consultation

Woodside will consult with stakeholders who are affected by, or are interested in, the proposed Browse to NWS Project. These stakeholders include decision-making authorities, other relevant government agencies and authorities (local, state, and Commonwealth), the local community, local indigenous groups, academics, research authorities and environmental non-government organisations. The EIS/ERD will describe the consultation method adopted, existing stakeholder forums and skills and techniques used to ensure effective communication of the nature and detail of the State waters proposal. This will include the means used to identify concerns and to gauge and progress mitigation strategies.

Stakeholder consultation will include consultation with Department of Primary Industries and Regional Development in respect to the introduction of marine pests (IMPs) to ensure that the potential risk of IMPs to State waters is adequately assessed and managed.

The assessment documentation must provide details of the potential indirect impacts of the proposed action on the (Indigenous rock art) values of the Dampier Archipelago (including the Burrup Peninsula) National Heritage Place, and the extent to which these values may potentially be impacted by the proposed action following any planned mitigations.

Woodside will document all relevant stakeholder consultation information in the EIS/ERD.

4.6 Decision-making authorities

The EPA has identified the decision-making authorities (listed in **Table 19**) for the proposal. Additional decision-making authorities may be identified during the assessment.

Table 19: Decision-making Authorities

Decision-making Authority	Relevant Western Australian Legislation
Minister for Mines and Petroleum	*Petroleum (Submerged Lands) Act 1982*
Chief Executive Officer, Department of Water and Environmental Regulation	*Environmental Protection Act 1986*
Chief Dangerous Goods Officer, Department of Mines, Industry Regulation and Safety	*Dangerous Goods Safety Act 2004*

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6. FIGURES

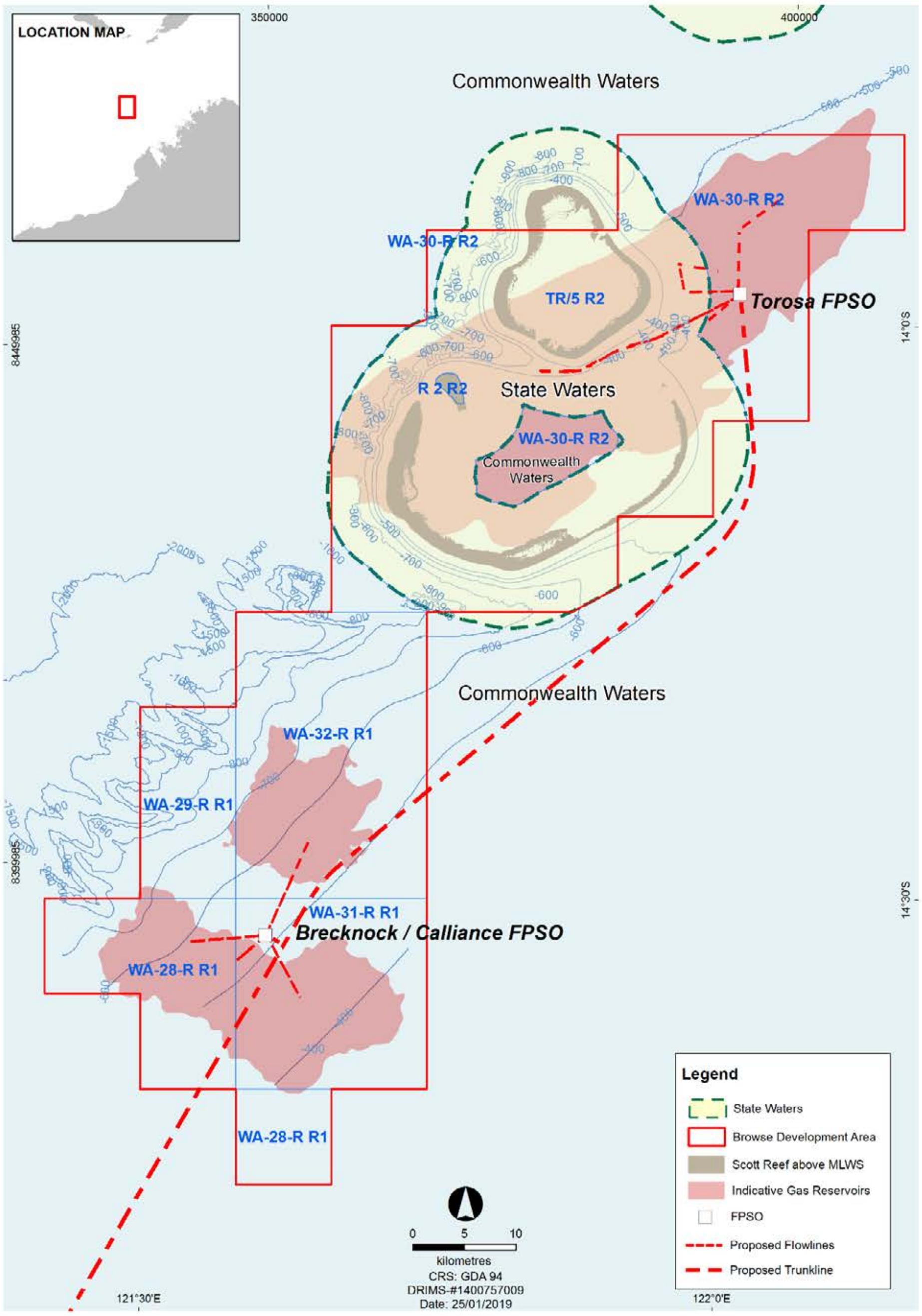

Figure 1 Proposed Browse Development Area

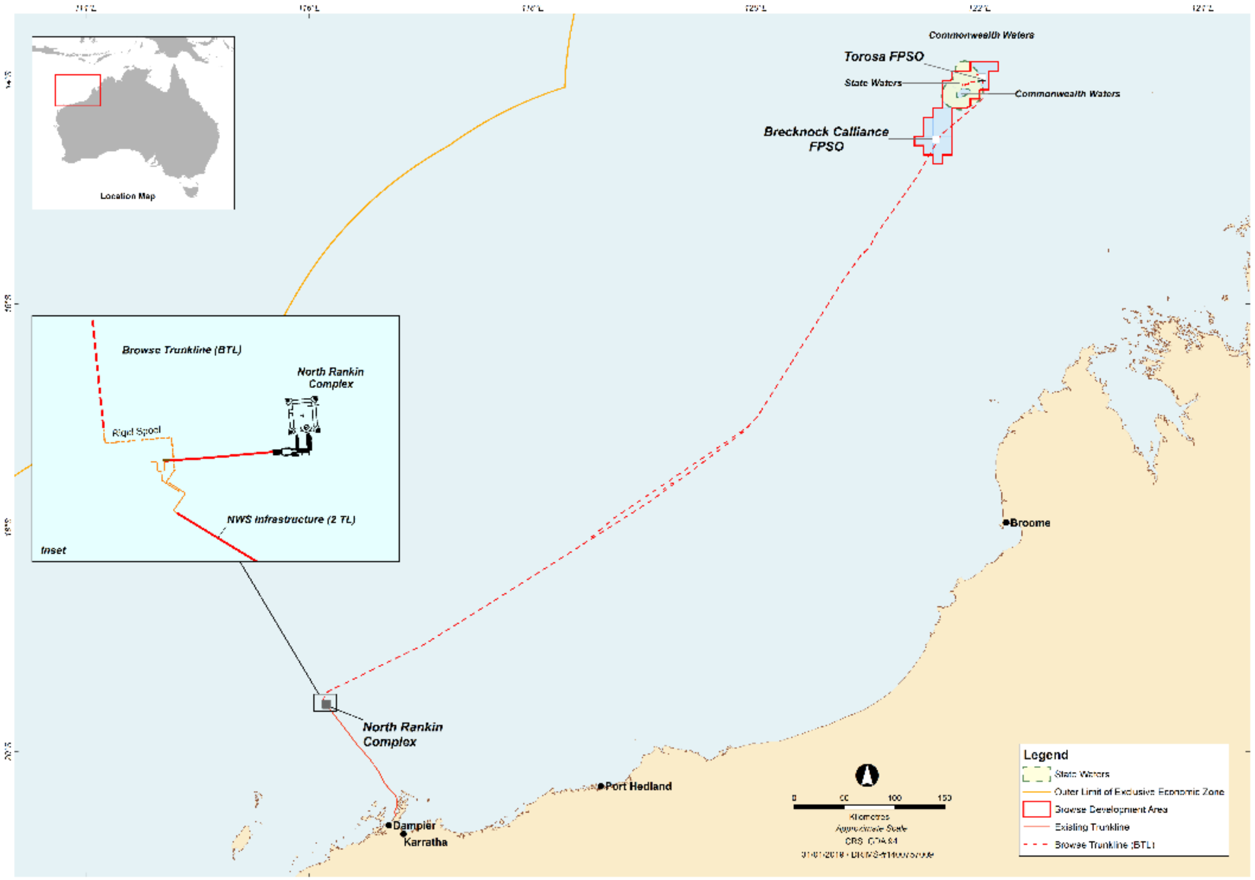

Figure 2 Indicative Browse Trunkline (BTL) route. Note alternative routes mid BTL are being assessed.

7. APPENDIX A – COMMONWEALTH GUIDANCE FOR GREENHOUSE GAS EMISSIONS

The proponent is required to provide transparent and accurate information to support decision making. This document is intended to assist the proponent to structure the discussion of the greenhouse implications of their development proposal.

To aid assessment of greenhouse gas (GHG) emissions resulting from the Browse to NWS Project, the following information is required:

1. Inventory of annual emissions

Provide data on estimated maximum annual emissions of the greenhouse gases defined in the *National Greenhouse and Energy Reporting Act 2007* (Cth): from within the development area; and, to the extent it can be predicted, from elsewhere as it is transported, processed (liquefied) and combusted, in Australia or overseas.

The inventory should include: an estimate of emissions on a gas by gas basis; a summary table of emissions on a gas by gas basis; a summary table listing emissions on a carbon dioxide equivalent basis; and a table which includes gross emissions, emission reduction due to both offsets and mitigation, and net emissions.

As far as is practicable an inventory of cumulative emissions should be included with regards to known potential future expansions or developments by Woodside and other proponents in the vicinity of the development.

In addition, estimates of emissions per year over the life of the project (in addition to the existing requirement around maximum emissions) and estimate of emissions intensity of production (ie emissions divided by production) over the life of the project should be provided.

2. Mitigation

The proponent must include a full description of mitigation measures, including analysis of a full range of alternatives to the proposed project. This should include methods by which GHG emissions could be mitigated, including:

a) analysis of the likely GHG reductions as a result of mitigation efforts to the same level of detail and approach as described in the ‘Inventory of annual emissions’ above;

b) analysis of costs, both financial and output related, of mitigation; and

c) identification of any relevant voluntary partnerships between government and the proponent, and their links to mitigation.

3. Method

The proponent must identify, in a transparent manner, the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* method used in making the estimate. If no methodology exists, a methodology reflecting the principles of the NGER will be developed and agreed by the proponent and the Department.

4. Supporting Data

The following supporting data must be provided:

a) the proponent must provide details on the emission factors used and activity data used, and

b) the project’s emission factors and activity data need to be compared with similar projects, including both Australian and international best practice. This analysis should include projects that use alternative fuel sources, processes, and technologies.


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CHAPTER 10, APPENDIX B

PROPOSED BROWSE TO NWS PROJECT STATE ERD

STATE ERD

1. PREAMBLE

This State Environmental Review Document (ERD) is an addendum to the draft Environmental Impact Statement (EIS)/ERD for the proposed Browse to North West Shelf (NWS) Project and has been prepared to provide proposed details and assessment conclusions specific to the State components of the proposed Browse to NWS Project (Proposal). The majority of the proposed Browse to NWS Project is located outside State jurisdiction. Most notably, the Floating Production Storage and Offloading facilities (FPSOs) and the entire length of the Browse Trunkline (BTL) are located in Commonwealth waters. However, a portion of the subsea wells and gathering system for the Torosa FPSO extend into State waters.

The draft EIS/ERD provides a 'whole of project' assessment as per the approved EIS Guidelines/ Environmental Scoping Document (EISG/ESD). This document has been prepared to further assist readers of the draft EIS/ERD to clearly identify the activities, aspects, receptors, predicted impacts and potential risks that are applicable to the assessment of the State aspects of the Proposal under the *WA Environmental Protection Act 1986* only.

This State ERD focuses on State aspects of the Proposal and therefore does not repeat all information on the proposed Browse to NWS Project. This State ERD references the reader back to the draft EIS/ERD where relevant. As such, this State ERD is to be read in conjunction with the draft EIS/ERD. It should be noted that, unless stated otherwise, where content within the draft EIS/ERD is referenced within this State ERD, content in the draft EIS/ERD applies equally to State and Commonwealth jurisdictions.

2. INVITATION TO MAKE A SUBMISSION

The Western Australian (WA) Environmental Protection Authority (EPA) invites people to make a submission on the environmental review for the proposed Browse to NWS Project (Proposal).

Woodside Energy Ltd, as operator for and on behalf of the Browse Joint Venture, proposes to develop and operate the proposed Browse to NWS Project. This Environmental Review Document (ERD) has been prepared in accordance with the EPA's Procedures Manual (Part IV Divisions 1 and 2). The ERD is the report through which the proponent describes the Proposal, assesses and documents its likely effects on the environment.

The ERD is available for a public review period of 8 weeks from 18 December 2019, closing on 12 February 2020.

Information on the Proposal from the public may assist the EPA to prepare an assessment report in which it will make recommendations on the Proposal to the Minister for Environment.

Why write a submission?

The EPA seeks information that will inform the EPA's consideration of the likely effect of the Proposal, if implemented, on the environment. This may include relevant new information that is not in the ERD, such as alternative courses of action or approaches.

In preparing its assessment report for the Minister for Environment, the EPA will consider the information in submissions, the proponent's responses and other relevant information.

Submissions will be treated as public documents unless provided and received in confidence, subject to the requirements of the *Freedom of Information Act 1992* (WA).

Why not join a group?

It may be worthwhile joining a group or other groups interested in making a submission on similar issues. Joint submissions may help to reduce the workload for an individual or group. If you form a small group (up to 10 people) please indicate all the names of the participants. If your group is larger, please indicate how many people your submission represents.

Developing a submission

You may agree or disagree with, or comment on information in the ERD.

When making comments on specific elements in the ERD:

+ clearly state your point of view and give reasons for your conclusions
+ reference the source of your information, where applicable
+ suggest alternatives to improve the outcomes on the environment.

What to include in your submission

Include the following in your submission to make it easier for the EPA to consider your submission:

- your contact details – name and address
- date of your submission
- whether you want your contact details to be confidential
- summary of your submission, if your submission is long
- list points so that issues raised are clear, preferably by environmental factor
- refer each point to the page, section and, if possible, paragraph of the ERD
- attach any reference material, if applicable. Make sure your information is accurate.

The closing date for public submissions is: 12 February 2020

The EPA prefers submissions to be made electronically via the EPA's Consultation Hub at https://consultation.epa.wa.gov.au

Alternatively, submissions can be:

- posted to: Chairman, Environmental Protection Authority, Locked Bag 10, Joondalup DC WA 6919, or
- delivered to: The Environmental Protection Authority, 8 Division Terrace, Joondalup WA 6027.

If you have any questions on how to make a submission, please contact the EPA Services at the Department of Water and Environmental Regulation (DWER) on (08) 6364 7000.

3. SCOPING CHECKLIST

Table 3-1 presents the completed scoping checklist which identifies the required work (as per the approved Environmental Scoping Document (ESD)) and reference to the location in the draft EIS/ERD and this State ERD where the requirement has been met.

Table 3-1 Scoping Checklist

Task No.	Required Work	Section and Page No.
Benthic Communities and Habitats		
1.	Determination of predicted temporary and permanent seabed disturbance within State waters.	Section 8.3.4.2 (pg. 915); Section 6.3.1 of the draft EIS/ERD
2.	Characterise the benthic habitats in the area potentially impacted using existing survey data and literature, including the preparation of habitat maps with demonstrated ground truthing for areas where proposed infrastructure will be installed on the seabed within State waters. Woodside has a good understanding of the benthic habitats expected to be disturbed within State waters and, as such, no further studies to characterise these benthic habitats is considered required.	Section 8.3.3 (pg. 912); Section 5.3.1 of the draft EIS/ERD
3.	Where significant benthic communities are identified in areas where infrastructure will be installed on the seabed, identify an appropriate Local Assessment Unit and assess cumulative loss of benthic communities and habitats in accordance with EPA's technical guidance.	Section 8.3.7 (pg. 922)

Task No.	Required Work	Section and Page No.
4.	Predict the likely fate of discharged drill cuttings using existing data and modelling and assess impact on benthic habitats. Woodside has a good understanding of the quantity and nature of the drill cuttings that are predicted to be generated and the drill fluids to be used. There is also a good understanding on the predicted fate of the discharges via drilling cuttings discharge modelling undertaken as part of the previously proposed Browse Development concepts. Drilling and completion activities required for the Proposal are expected to be broadly similar to that of the previously proposed development concepts. As such, the previous modelling is considered representative of the Proposal and sufficient for assessing the potential impacts.	Section 8.3.4.9 (pg. 917); Section 6.3.15 of the draft EIS/ERD
5.	Undertake hydrocarbon spill modelling to describe the dispersion and degradation characteristics of a range of hydrocarbon spill scenarios to inform the risk assessment and the development of mitigation measures.	Section 8.3.4.15 (pg. 920); Section 6.3.21 of the draft EIS/ERD
Marine Environmental Quality		
6.	Characterise the marine environmental quality in the area potentially impacted using existing survey data and literature. Woodside has a good understanding of the marine environment in the State waters within the Browse Development Area via numerous available studies and, as such, no further studies to characterise this marine environment is considered required.	Section 8.2.3 (pg. 892); Sections 5.2.9, 5.2.10, 5.3.1, 5.3.2, 5.3.3.3 and 5.4.2.2 of the draft EIS/ERD
7.	Characterise discharge type that has the potential to impact on State waters (e.g. vessel and MODU discharges, drill cuttings and fluids, produced water, cooling water, hydrotest fluid, subsea control fluids) in terms of volume, frequency, composition and ecotoxicity.	Section 8.2.4 (pg. 892); Sections 6.3.9, 6.3.10, 6.3.11, 6.3.12, 6.3.13, 6.3.15, 6.3.16, 6.3.17 of the draft EIS/ERD
8.	Present previously undertaken modelling or revised modelling where required as described in the workplan (Section 3.8.8 of the EISG/ESD) and describe the dilution and fate of the discharges to determine the spatial extent of potential impacts and appropriate mixing zones.	Section 8.2.4 (pg. 892); Sections 6.3.12, 6.3.13, 6.3.15, 6.3.17 of the draft EIS/ERD
9.	Based on characterisation of the existing marine environment and expected discharges and modelling, develop and present spatially proposed Environmental Quality Criteria (Environmental Quality Objectives and levels of ecological protection) for State waters within the Browse Development Area.	Section 8.2.6 (pg. 906);
10.	Outline a commitment to develop and implement a Marine Environmental Quality Management Plan (EQMP) for the State waters which identifies the Environmental Values to be protected and spatially defines the Environmental Quality Objectives and levels of ecological protection that Woodside aims to achieve in State waters.	Section 8.2.6 (pg.906);
11.	Undertake hydrocarbon spill modelling to describe the dispersion and degradation characteristics of a range of hydrocarbon spill scenarios to inform the risk assessment and the development of mitigation measures.	Section 8.3.4.15 (pg. 920); Section 6.3.21 of the draft EIS/ERD

Task No.	Required Work	Section and Page No.
Marine Fauna		
12.	Characterise the marine fauna in the area potentially impacted using existing survey data and literature. Woodside generally has a good understanding of marine mammals that may occur in the Browse Development Area via a large number of surveys undertaken in relation to the previously proposed Browse Development concepts which have included habitat association surveys, long-term sea noise logger deployment, aerial and vessel surveys and satellite tagging.	**Section 8.4.3** (pg. 924); **Section 5.3.2** of the draft EIS/ERD
13.	Characterise the predicted underwater noise emissions and potential impacts using existing and new modelling studies.	**Section 8.4.4.6** (pg. 933); **Section 6.3.8** of the draft EIS/ERD
14.	Characterise the predicted light emissions and potential impacts using existing modelling studies. Light modelling undertaken to support the FLNG draft EIS (EPBC 2013/7079 is considered representative of the Proposal facilities and, as such, no further modelling is considered necessary.	**Section 8.4.4.2** (pg. 928); **Section 6.3.3** of the draft EIS/ERD
15.	Predict the likely fate of discharged drill cuttings using existing data and modelling and assess impact on marine fauna.	**Section 8.4.4.11** (pg. 935); **Section 6.3.15** of the draft EIS/ERD
16.	Undertake a literature review on the impacts of electromagnetic emissions on marine fauna and utilise estimated direct electrical heating power demand to assess impacts.	**Section 8.4.4.3** (pg. 931)
17.	Undertake hydrocarbon spill modelling to describe the dispersion and degradation characteristics of a range of hydrocarbon spill scenarios to inform the risk assessment and the development of mitigation measures. This includes the modelling of a condensate spill which will be used to assess the risk to Scott Reef that such a spill would present.	**Section 8.4.4.18** (pg. 940); **Section 6.3.21** of the draft EIS/ERD.
Air Quality		
18.	Woodside has sufficient understanding of the characteristics of the Browse resource and the combustion requirements to extract, process and export the gas to accurately quantify gaseous emissions. As such, no further studies are considered required.	**Section 8.5** (pg. 942); **Section 6.3.5**, **6.3.6** and **Chapter 7** of the draft EIS/ERD.

4. INTRODUCTION

This State ERD is an addendum to the draft EIS/ERD for the proposed Browse to NWS Project to satisfy the requirements of the:

- Environmental Impact Assessment (Part IV Divisions 1 and 2) Administrative Procedures 2016 (EPA, 2016)
- EPA's Instructions on how to prepare an Environmental Review Document (EPA, 2018a).

It has been prepared to assist the reader of the draft EIS/ERD to clearly identify the activities, aspects, receptors, predicted impacts and potential risks that are applicable to the assessment of the Proposal under the WA *Environmental Protection Act 1986* only.

The scope of the Proposal that is the subject of this State ERD is limited to the proposed activities within the State Proposal Area (**Section 5.3.1**) and vessel and helicopter movements occurring within State waters between the State Proposal Area and the potential supply chain and logistics support locations.

4.1 Proponent

Please refer to **Section 2.3** of the draft EIS/ERD for proponent details.

4.2 Environmental Impact Assessment Process

Please refer to **Section 2.9** of the draft EIS/ERD for the assessment process for the proposed Browse to NWS Project, including the Proposal.

4.3 Other Approvals and Regulation

4.3.1 Titles

The Browse Joint Venture (BJV) holds seven petroleum retention leases. Five of the leases (WA 28 R, WA-29-R, WA-30-R, WA-31-R and WA-32-R) are located in Commonwealth waters and are governed under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cth) (OPGGSA). The remaining two leases (TR/5 and R2) are governed under State legislation, the *Petroleum (Submerged Lands) Act 1982* (WA) (PSLA) and the *Petroleum and Geothermal Energy Resources Act 1967* (WA).

4.3.2 Decision Making Authorities

The decision making authorities for the Proposal are listed in **Table 4-1.**

Table 4-1 Decision Making Authorities

Decision Making Authority	Relevant Western Australian Legislation
Minister for Mines and Petroleum	*Petroleum (Submerged Lands) Act* 1982 and the *Petroleum and Geothermal Energy Resources Act* 1967 (WA)
Chief Executive Officer, Department of Water and Environmental Regulation	*Environmental Protection Act* 1986
Chief Dangerous Goods Officer, Department of Mines, Industry Regulation and Safety	*Dangerous Goods Safety Act* 2004

4.3.3 Other Approvals

Table 4-2 summarises the other approvals and regulations that apply to the Proposal.

Table 4-2 Other Approvals

Proposed Activities	Land tenure/access	Type of approval	Legislation regulating the activity
Subsea infrastructure development and operation	Petroleum titles	Environment Plans and Oil Spill Contingency Plans	*Petroleum (Submerged Lands) Act 1982* (WA) and associated regulations

5. THE PROPOSAL

5.1 Background

The Proposal was referred to the EPA under the *Environmental Protection Act* 1986 (EP Act) in October 2018. On 22 January 2019, the EPA determined the Proposal required assessment under Section 29 of the EP Act and set a Public Environmental Review (PER) level of assessment. The determination identified these EPA Environmental Factors as being relevant for the Proposal:

- Marine Environmental Quality
- Benthic Communities and Habitats
- Marine Fauna
- Air Quality.

The draft EIS/ERD conforms with the EIS Guidelines/ Environmental Scoping Document (EISG/ESD) approved by the DoEE on 5 July 2019 and EPA on 4 July 2019, respectively (**Chapter 10, Appendix A** of the draft EIS/ ERD). The EISG/ESD was made publicly available on the 8 July 2019.

The proposal is similar to the previously referred 'Torosa Subsea Development Proposal' that resulted in a 'Not Assessed – Public Advice Given' decision by the EPA in 2015 (CMS14397).

The proposed Browse to NWS Project continues to be subject to detailed design and refinement. Key modifications that have occurred since the referral of the Proposal and approval of the EISG/ESD include:

- an increase in the number of wells within State waters from up to approximately 21 to up to approximately 24
- a minor increase in seabed infrastructure related to the higher well count and design refinement.

Refer to **Chapter 2** of the draft EIS/ERD for an overview of the proposed Browse to NWS Project and background information, including details of the assessment process (**Section 2.9** of the draft EIS/ERD), the Browse resources, the proponent, the project objectives, current status and relationship with other developments.

5.2 Justification

Please refer to **Section 2.8** of the draft EIS/ERD for the development justification.

5.3 Proposal Description

This section provides an overview of the State components of the Proposed Browse to NWS Project Proposal. A full description of the proposed Browse to NWS Project is provided in **Chapter 3** of the draft EIS/ERD.

5.3.1 State Proposal Area

As described in **Chapter 2** of the draft EIS/ERD, the overall Project Area (encompassing both State and Commonwealth components) comprises:

- the proposed Browse Development Area (in which the Brecknock, Calliance, and Torosa fields, the FPSO facilities and the subsea production systems, including wells, will be located) (**Figure 2-1** of the draft EIS/ERD)
- the pipeline corridor within which the proposed BTL and inter-field spur line will be located (**Figure 2-2** of the draft EIS/ERD).

The State Proposal Area, which is the subject of the assessment under the EP Act, is located within the Browse Development Area and comprises all areas above the low water line (based on mean low water springs (MLWS)) and all waters within 3 nm of the low water line, as shown in **Figure 5-1**.

It should be noted that, as detailed in **Chapter 4**, the scope of this State ERD includes vessel and helicopter movements occurring within State waters outside of the State Proposal Area.

5.3.2 Overview

Activities in the State Proposal Area comprise a small subset of infrastructure and activities of the proposed Browse to NWS Project. Within State jurisdiction, activities include the development of up to an estimated 24 wells and associated subsea infrastructure targeting the hydrocarbon resources within the Torosa reservoir. The remaining facilities and infrastructure will be located in Commonwealth waters and are outside the scope of this State ERD. Extracted hydrocarbons will be transferred via subsea infrastructure, including Christmas trees, manifolds and flowlines, to the Torosa FPSO facility, located in Commonwealth waters.

The highest intensity of activities within the State Proposal Area is likely to occur during the drilling and completion activities, installation activities and future decommissioning phases. During this time, a mobile offshore drilling unit (MODU) and approximately ten vessels may be present. As all permanent infrastructure within the State Proposal Area is subsea, the operation of the wells will be controlled remotely via the FPSO facilities that are located in Commonwealth waters. Outside of drilling and completion and installation periods, surface activities in the State Proposal Area will comprise periodic inspection, maintenance and repair activities involving one or two vessels and later phase well construction and decommissioning (including well plug and abandonment). **Table 5-1** provides a summary of the Proposal.

Table 5-1 Summary of the Proposal

Proposal Summary	
Proposal Title	Proposed Browse to NWS Project (State component)
Proponent Name	Woodside Energy Ltd, as Operator for and on behalf of the Browse Joint Venture
Short Description	Drilling and completion, subsea installation, commissioning, operation, inspection, maintenance and repair and decommissioning of subsea wells and associated subsea infrastructure located in Western Australian State waters, to extract hydrocarbons from the Torosa reservoir, located approximately 425 km north of Broome and approximately 290 km off the Kimberley coast.

Table 5-2 Location and proposed extent of physical and operational elements of the Proposal

Element	**Description**	**Proposed Authorised Extent**
Physical Elements		
Drilling and completion activities of up to approximately 24 wells	Installation and physical presence of infrastructure within indicative field layout as per **Figure 5-1**.	Approximately 0.31 km^2 of direct seabed disturbance (including 25% contingency).
Associated subsea infrastructure (Christmas trees, manifolds, flowlines, and umbilicals)		
Temporary mooring of MODU		
Seabed preparation and flowline stabilisation		
Operational Elements		
Water supply (installation vessels, Inspection, Maintenance and Repair (IMR) vessels, MODUs and project vessels)	Water requirements sourced either from seawater (reverse osmosis plant) or loaded at port.	Limited water requirements to support drilling and completion activities, subsea installation activities (e.g. potential hydrotest), vessel and MODU water needs and potentially also for decommissioning activities.
Power supply (installation vessels, IMR vessels, MODUs and project vessels)	Power generated on board vessels and MODU.	As required for operations and safety.
Vessel discharges (installation vessels, IMR vessels, MODU, and project vessels).	Discharges from vessels and MODU include treated sewage, drain waters, cooling water, sullage, putrescible organic waste and desalination brine.	Limited volumes discharged in accordance with International Convention for the Prevention of Pollution from Ships MARPOL 73/78 Annex I, as applied in Australia under the Commonwealth *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Part II Prevention of pollution from oil); Marine Orders 91 (Marine pollution prevention – Oil) 2014 as applicable to vessel class; *Pollution of Waters by Oil and Noxious Substance Act 1986.*
Drill cuttings and fluid discharges	Drill cuttings and drilling fluids.	Approximately 850 m^3 of cuttings per well, with up to approximately 24 wells to be developed in the State Proposal Area. Approximately 100-130 m^3 well discharge fluid per well during well unloading.

Element	Description	Proposed Authorised Extent
Hydrotest fluid discharges	Hydrotest fluids discharged at the seabed during integrity testing of the subsea infrastructure.	Oneoff discharges of up to approximately 950 m^3 of hydrotest fluid for the TRE flowline and up to approximately 250 m^3 at the TRF flowline.
Produced water	Low volumes of water that occurs naturally within the hydrocarbon-bearing geological formations.	Small volumes of formation water may result during well unloading activities by the MODU. These will be discharged directly from the MODU.
Subsea control fluid discharge	Control fluid discharged at the Christmas trees to maintain valve functionality.	Intermittent discharge of waterbased hydraulic control fluid when subsea valves are actuated (~0.1 L). Maximum volume of control fluid that will be released to the marine environment per manifold is 1,900 L per year of water based fluid containing approximately ~3% active ingredient (40–68 L of control fluid additive).
Underwater noise emissions	Underwater noise: + generated during drilling, completion and installation activities (including vessel movements using Dynamic Positioning (DP), vertical seismic profiling (VSP) and distributed acoustic sensing (DAS) + generated from subsea infrastructure during operations + from piling activities for mooring installation for the MODU (note that this is unlikely to be required) + from installation vessels, IMR vessels, MODUs and project vessels + from helicopter movements from the MODU + from IMR activities.	Noise related behavioural disturbance radius of up to approximately 10.5 km around drilling and installation activities. Noise related behavioural disturbance radius of up to approximately 500 m around subsea infrastructure during operations.
Light emissions – operational lighting	Artificial light emitted by installation vessels, IMR vessels, MODUs and project vessels.	Limited to functional lighting at levels that provide a safe working environment for personnel.
Light emissions – flaring	Intermittent flaring from the MODU during well unloading. This occurs only during well installation or intervention for repairs.	
Air emissions – offshore activities	Air emissions resulting from power generation on project vessels and MODU.	

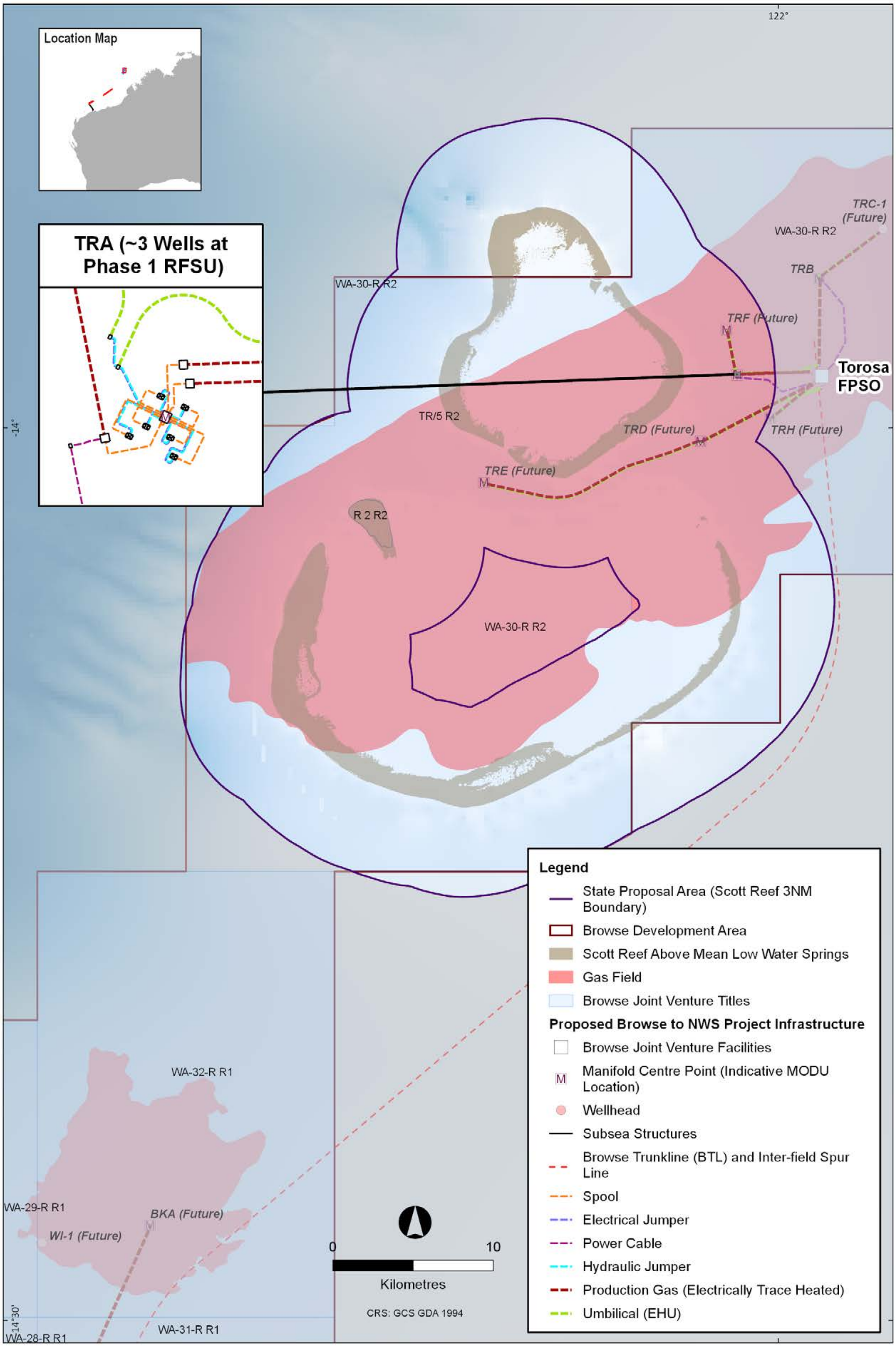

Figure 5-1 State Proposal Area

5.3.3 Project Infrastructure

Project infrastructure within the State Proposal Area is proposed to comprise the following:

- 24 production wells
- subsea infrastructure
- temporary moorings for MODU anchoring.

It should be noted that the BTL, inter-field spur line and FPSO facilities will be located entirely in Commonwealth waters.

Production wells
It is anticipated the proposed Browse to NWS Project will require drilling and completion of up to 24 production wells in State waters at the Torosa reservoir over the life of the proposed Browse to NWS Project. This includes the drilling and completion of approximately three wells at the TRA drill centre for Phase 1 Ready for Start Up (RFSU). The remaining 30 production wells of the Browse to NWS Project will be located in Commonwealth waters (including five at the Torosa reservoir and 25 at the Brecknock and Calliance reservoirs).

A wellhead will be installed at the top of each well. The wellhead will hold the production well casing and will enable installation of the Christmas tree, complete with well control facilities. Christmas trees are steel structures with various valves and are used to:

- control production, whereby hydraulically controlled valves on the Christmas trees are used to control flow rates and provide a well shut-off mechanism
- manage chemical injection.

Surface controlled subsurface safety valves will be installed in the wells.

To optimise the layout of the subsea infrastructure, production wells will be arranged around drill centres (a cluster of wells around a central manifold) with up to four drill centres located within the State Proposal Area. Only one drill centre (TRA) will be installed in the State Proposal Area prior to start-up of the Torosa FPSO Facility – the residual will be installed in later years. The number and location of these wells and drill centres will depend on reservoir target areas, seabed bathymetry and features to optimise reservoir recovery. A notional field layout is provided in Figure 5-1.

Subsea infrastructure
The wells at each drill centre will be connected to manifolds by well jumpers (a specially-designed piece of pipe used to transport production fluid between components of the subsea infrastructure) to allow reservoir fluids to be carried from the wells to the manifolds. The manifolds will connect the wells to corrosion resistant alloy clad (or lined) flowlines that will be routed back to the FPSOs, located in Commonwealth waters. An example of subsea infrastructure for illustrative purposes is provided in Figure 3-1 of the draft EIS/ERD.

Subsea infrastructure will be powered, monitored and controlled from the FPSO facilities using a network of electro-hydraulic control umbilicals and subsea distribution units. Each drill centre will be serviced by an electro-hydraulic umbilical, which will follow a similar alignment as the infield flowlines. Some umbilicals may be integrated within the production flowline bundle. Umbilicals will also be tied back to the FPSO facilities (in Commonwealth waters) using a system of flexible risers.

Other subsea infrastructure may include pile installation and temporary mooring lines for MODU anchoring.

5.3.4 Development Activities

Development activities within the State Proposal Area will include:

- pile installation
- development drilling and completions
- subsea umbilicals, risers and flowlines (SURF) installation and commissioning.

Pile installation
Pile installation may be required within State waters for temporary mooring of the MODUs. Data from the surveys undertaken by Woodside in 2014 has been analysed and demonstrates suction piling for moorings is feasible and will be the most likely option for pile installation.

Suction piles are installed by gently lowering the pile onto the seabed and using gravity to lower the pile into the soft substrate. Installation is completed by pumping out the entrapped water inside the pile, with the resulting differential pressure driving the pile into the seabed.

Should alternate piling methods be selected, options include drilling and cementing or impact piling, which involves the application of force to drive the pile into the seabed.

Development drilling and completions

The proposed Browse to NWS Project will require the drilling of up to 24 production wells within State waters. It is anticipated the drilling and completion activities will be completed in multiple phases. The first phase will be drilling and completion of approximately three wells at the TRA drill centre to achieve RFSU, with subsequent phases of drilling and completion of additional wells undertaken over the life of the Proposal to optimise reservoir recovery (Figure 5-1). The drilling and completions process will not differ between wells in State and Commonwealth waters and is described in detail in Section 3.7.2 of the draft EIS/ERD.

Subsea Umbilicals, Risers and Flowlines (SURF) installation and commissioning

The process for the installation and commissioning of the SURF infrastructure, including site preparation, is described in detail in Section 3.7.3 of the draft EIS/ERD.

5.3.5 Operations

Activities within the State Proposal Area during operations will be limited to:

- hydrocarbon extraction
- inspection, maintenance and repair (IMR) activities.

Hydrocarbon extraction

During operations, hydrocarbons extracted from the reservoirs will flow via the Christmas trees and manifolds through the flowlines and risers to the FPSO facilities in Commonwealth waters. The flow rate of hydrocarbons will be controlled by subsea choke valves at the Christmas trees. Subsea hydraulic control fluids will be used to operate subsea valves. Hydrocarbon extraction including the potential use of distributed acoustic sensing (DAS) surveys is described in Section 3.7.6.1 of the draft EIS/ERD. Note that processing of the gas and condensate on the FPSO facilities and subsequent condensate offload and gas export will occur in Commonwealth waters.

Inspection, maintenance and repair (IMR)

The subsea infrastructure will be designed to require only minor degrees of intervention. Inspection and maintenance will be undertaken to ensure the integrity of the infrastructure and identify any problems before they present a risk of loss of containment. Intervention may be required to repair identified problems. A detailed description of the planned IMR activities is provided in Section 3.7.7 of the draft EIS/ERD.

5.3.6 Decommissioning

At the end of the proposed Browse to NWS Project life, the infrastructure will be decommissioned in accordance with good oilfield practice and relevant legislation and practice at the time. This is likely to include well suspension, plugging and abandoning wells and removing the subsea infrastructure. All infrastructure installed above the seabed will be designed to allow removal.

Given the expected life of the project, the decommissioning of the proposed Browse to NWS Project is not likely for many years. Given the possible improvements in technology that may occur between now and the time of decommissioning, it is not possible to fully scope the decommissioning strategy that will be employed at that time however all infrastructure above the seabed has been designed to allow removal. The strategy demonstrated through activity-specific Environment Plans will be developed in consultation with the EPA and other stakeholders closer to the time (Table 4-2).

5.3.7 Support Activities and Infrastructure

5.3.7.1 Logistics support

The proposed Browse to NWS Project will require supply chain and logistics support during construction and operations, as described in Section 3.7.9 of the draft EIS/ERD.

Requirements for supply chain and logistics support for the proposed Browse to NWS Project may include:

- port access for supply and support vessels to transfer people, equipment, materials and waste to and from the Project Area
- airport access for fixed-wing aircraft and helicopters to transfer people and supplies to and from the Project Area
- search and rescue capabilities
- onshore support for receiving, storing, and distributing materials and equipment.

The proposed Browse to NWS Project is not dependent on the development of new onshore supporting infrastructure to proceed. Supply chain and logistics support locations that have existing services and infrastructure for ongoing regular support over the whole life of the proposed Browse to NWS Project are being considered, with the assessment and selection focused on using supply chain services and infrastructure within WA.

Potential supply chain and logistics support locations in Australia include:

- Broome
- Djarindjin
- Dampier/Karratha
- Exmouth
- Perth.

Facilities in Broome include the Port of Broome, which is the main deep water port servicing the Kimberley region. The port supports livestock export, offshore oil and gas, supply vessels, pearling, fishing charter boats, cruise liners and is the main fuel and container receiving point for the Kimberley. Facilities at the port include an outer berth, two inner berths, fuel and potable water distribution facilities, a laydown area, lighting suitable for night work and a slipway. Other facilities include the Broome International Airport which is located in Broome and includes a runway for fixed wing operations and a heliport which opened in 2008. A helipad is also available on site with space for four larger helicopters and 10 additional helicopter parking positions are available near the airport.

The King Bay Supply Base is located in the Port of Dampier and is operated by Woodside (Woodside 2014). The facility is suitable for a wide range of vessels varying in size and configuration such as harbour tugs, supply vessels, crew and utility vessels and transportation/heavy lift vessels.

Facilities in Djarindjin include a fixed and rotary wing aviation base which supports existing offshore oil and gas facility crew change operations.

As the proposed Browse to NWS Project will be using existing supply and logistics services and infrastructure which are managed by third parties, such services and infrastructure are not considered further as part of this assessment. The scope of this assessment is limited to vessel and helicopter movements between the State Project Area and the potential supply chain and logistics support locations. Any activity at supply chain and logistics support locations is outside the scope of this assessment.

In addition, there may be a requirement to conduct short term, discrete logistical support activities from time to time at various port and airport locations along the coast of WA, Australia and internationally to support activities throughout the life of the proposed Browse to NWS Project. These activities are likely to be consistent with general shipping activities.

5.3.7.2 Project vessels and helicopters

The drilling and completion, subsea installation and commissioning phases will be supported by project vessels including barges, tugs, survey vessels, supply vessels and installation vessels.

During the operations phase, vessel presence in the State Proposal Area will primarily be limited to IMR activities and environmental monitoring purposes.

Personnel transfer to offshore facilities from Broome will be either via helicopter or vessel. If helicopters are used, it is anticipated that up to five personnel transfers a week per FPSO facility will be required during normal operations. Helicopters will not enter the State Proposal Ara under normal operations, however they will traverse State Waters near the mainland.

Fast crew transfer vessels (FCTVs) may be used for crew transfer. These crew transfer vessels are capable of travelling at 50 – 55 knots. It is anticipated one transfer per day will occur during normal operations, with additional transfers during shut downs and major maintenance. FCTVs will not enter the State Proposal Area around Scott Reef under normal operations. They will traverse coastal State waters near the logistical base.

Vessel requirements during the decommissioning phase are unknown at this stage as decommissioning plans have not been finalised. However, it can be expected decommissioning may use similar vessels to those engaged for installation activities.

5.4 Local and Regional Context

The local context for the proposed Browse to NWS Project is provided in **Chapter 5** of the draft EIS/ERD. Specifically, values relating to the State Proposal Area include the following:

- the Scott Reef Nature Reserve (**Section 5.3.3.3** of the draft EIS/ERD)
- the Seringapatam Reef and Commonwealth waters in the Scott Reef Complex and the Continental Slope Demersal Fish Communities KEFs, which overlap the State Proposal Area (**Section 5.3.3.1** of the draft EIS/ERD)

- Biological Important Areas (BIAs) (green turtle, hawksbill turtle, little tern, pygmy blue whale; Section 5.3.2.2 of the draft EIS/ERD) and habitat critical to the survival of a species (green turtle; Section 5.3.2.3)
- Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) Listed species (Section 5.3.2.1 and Section 5.3.2.4 of the draft EIS/ERD)
- socio-economic values including commercial, traditional and recreational fishers (Sections 5.4.2.2 and Section 5.4.2.3 of the draft EIS/ERD) and scientific research (Section 5.4.2.7 of the draft EIS/ERD).

Regional context and values relevant to the proposed Browse to NWS Project, such as Commonwealth Managed Fisheries and State and Australian Marine Parks (AMPs), are also detailed in Chapter 5 of the draft EIS/ERD.

6. STAKEHOLDER ENGAGEMENT

6.1 Key Stakeholders

Refer to Table 4-1 in Section 4.3 of the draft EIS/ERD for a list of the identified stakeholders in relation to the proposed Browse to NWS Project.

6.2 Stakeholder Engagement Process

Refer to Chapter 4 of the draft EIS/ERD for an overview of the stakeholder engagement process, including historical stakeholder engagement relating to the development of the Browse resource, stakeholder engagement undertaken specific to the proposed Browse to NWS Project and planned ongoing stakeholder engagement.

6.3 Stakeholder Consultation

Refer to Table 4-2 in Section 4.3 of the draft EIS/ERD for an outline of engagements undertaken in relation to the proposed Browse to NWS Project following the referral of the proposed Browse to NWS Project in October 2018.

7. IDENTIFYING IMPACTS AND RISKS

The environmental impact and risk assessment process undertaken in relation to the proposed Browse to NWS Project is described in Section 6.2.3 of the draft EIS/ERD. This process included the identification of impacts and risks as well as associated receptor groups, as presented in Table 6-2, which shows the project wide aspect-receptor relationships. To inform the assessment in relation to the EPA's environmental objectives, the aspect-receptor relationships specific to activities occurring within the State jurisdiction have been identified and are shown in Table 7-1. Within Table 7-1, aspects that present a potential impact from a planned activity are identified with an 'I'. Where the aspect presents a risk from an unplanned event or incident they are identified with an 'R". Where both an impact and a risk apply, this is identified by 'I/R'. As application of the EPA Factors inherently result in overlap between aspects some repetition is necessary. This has been minimised wherever possible by subdividing aspects between Factors and cross referencing to the draft EIS/ERD.

Table 7-1 Aspect-Receptor Relationship of the State Proposal

Key			
■	Detailed impact/risk assessment	□	Impact/risk considered
I	Impact	R	Risk

Aspects	Impact/Risk	Sediment Quality	Water Quality	Air Quality	Ambient Light	Ambient Noise	Plankton Communities	Deepwater Benthic Communities and Habitats (>75 m depth)	Shallow Water Benthic Communities and Habitats (<75 m depth)	Coastal Habitats	Seabirds and Migratory Shorebirds	Fish	Marine Mammals	Marine Reptiles	State Marine Parks & Nature Reserves	State Managed Fisheries
EPA Environmental Factors																
Marine Environmental Quality		✓	✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Benthic Communities and Habitats							✓	✓	✓					✓		
Marine Fauna						✓				✓	✓	✓	✓		✓	
Air Quality			✓													
Planned																
Physical Presence: Seabed Disturbance	Change in water quality		I/R					I/R	R							
	Change in sediment quality	I/R						I/R	I/R							
	Change in habitat							I/R	I/R							
	Injury or mortality to fauna						I/R	I/R	I/R							
Physical Presence: Disturbance to Other Users	Changes to the functions, interests or activities of other users															I
Physical Presence: Light	Change in ambient light				I											
	Change in fauna behaviour						I		I		I	I		I	I	
	Injury or mortality to fauna													I		
	Changes to the functions, interests or activities of other users															I
Physical Presence: Electromagnetic Emissions	Change in fauna behaviour											I	I	I		

Aspects	Impact/Risk	Sediment Quality	Water Quality	Air Quality	Ambient Light	Ambient Noise	Plankton Communities	Deepwater Benthic Communities and Habitats (>75 m depth)	Shallow Water Benthic Communities and Habitats (<75 m depth)	Coastal Habitats	Seabirds and Migratory Shorebirds	Fish	Marine Mammals	Marine Reptiles	State Marine Parks & Nature Reserves	State Managed Fisheries
Atmospheric Emissions: Offshore Activities	Change in air quality			I												
	Injury or mortality to fauna										I					
Atmospheric Emissions: Third Party Processing of Browse Gas	Change in air quality			I												
Atmospheric Noise Emissions	Change in ambient noise					I										
	Change in fauna behaviour										I	I	I	I	I	
Underwater Noise Emissions	Change in ambient noise					I/R										
	Change in fauna behaviour						I/R					I/R	I/R	I/R	I/R	
	Injury or mortality to fauna							I/R	I/R			I/R	I/R	I/R	I/R	
	Changes to the functions, interests or activities of other users															I/R
Marine Discharges: Sewage and Sullage	Change in water quality		I/R					I/R	I/R							
	Change in fauna behaviour						I/R									
	Injury or mortality to fauna											I/R	I/R	I/R		
	Changes to the functions, interests or activities of other users															I/R
Marine Discharges: Treated Utility Water, Chemical and Deck Drainage	Change in water quality		I/R					I/R	I/R							
	Injury or mortality to fauna						I/R					I/R	I/R	I/R		
	Changes to the functions, interests or activities of other users															I/R
Marine Discharges: Putrescible Waste	Change in water quality		I					I	I							
	Change in fauna behaviour						I				I	I	I	I		
	Changes to the functions, interests or activities of other users															I

Aspects	Impact/Risk	Sediment Quality	Water Quality	Air Quality	Ambient Light	Ambient Noise	Plankton Communities	Deepwater Benthic Communities and Habitats (>75 m depth)	Shallow Water Benthic Communities and Habitats (<75 m depth)	Coastal Habitats	Seabirds and Migratory Shorebirds	Fish	Marine Mammals	Marine Reptiles	State Marine Parks & Nature Reserves	State Managed Fisheries
Marine Discharges: Produced water	Change in water quality		I/R					I/R							I/R	
	Change in sediment quality	I/R														
	Injury or mortality to fauna						I/R					I/R	I/R	I/R	I/R	
	Changes to the functions, interests or activities of other users															I/R
Marine Discharges: Cooling Water	Change in water quality		I/R					I/R	I/R						I/R	
	Injury or mortality to fauna						I/R					I/R	I/R	I/R		
	Changes to the functions, interests or activities of other users															I/R
Marine Discharges: Drilling and completions discharges	Change in water quality		I/R													
	Change in sediment quality	I/R														
	Injury or mortality to fauna						I/R	I/R	I/R			I/R	I/R	I/R		
	Change in habitat							I/R	I/R							
	Changes to the functions, interests or activities of other users															I/R
Marine Discharges: Subsea control fluids	Change in water quality		I/R					I/R	R							
	Change in sediment quality	I/R														
	Injury or mortality to fauna						I/R					I/R	I/R	I/R		
	Changes to the functions, interests or activities of other users															I/R

Aspects	Impact/Risk	Sediment Quality	Water Quality	Air Quality	Ambient Light	Ambient Noise	Plankton Communities	Deepwater Benthic Communities and Habitats (>75 m depth)	Shallow Water Benthic Communities and Habitats (<75 m depth)	Coastal Habitats	Seabirds and Migratory Shorebirds	Fish	Marine Mammals	Marine Reptiles	State Marine Parks & Nature Reserves	State Managed Fisheries
Marine Discharges: Hydrotest Fluid	Change in water quality		I					I	I							
	Change in sediment quality	I						I								
	Injury or mortality to fauna						I	I				I	I	I		
	Changes to the functions, interests or activities of other users															I
Production Activities: Seabed Subsidence	Change in habitat							I	I		I			I	I	
Marine Discharges: Hazardous and Non-Hazardous Inorganic Waste	Change in water quality		R						R							
	Change in sediment quality	R														
	Injury or mortality to fauna						R	R			R	R	R	R	R	
	Changes to the functions, interests or activities of other users															R
Unplanned Vessel Interactions with Fauna	Injury or mortality to fauna											R	R	R		
Physical Presences (Unplanned): Invasive Marine Species	Change in ecosystem dynamics							R	R			R			R	
	Changes to the functions, interests or activities of other users															R
Unplanned Hydrocarbon Releases	Change in water quality		R					I	I						R	
	Change in sediment quality	R								R					R	
	Injury or mortality to fauna						R	R			R	R	R	R		R
	Changes to the functions, interests or activities of other users															R

8. ENVIRONMENTAL PRINCIPLES AND FACTORS

8.1 Principles

Consideration of the Proposal in relation to the Environmental Protection Principles and objects of the EP Act are presented in Table 8-1.

Table 8-1: Consideration of Environmental Protection Principles

Principle	Consideration
The precautionary principle Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In application of this precautionary principle, decisions should be guided by: a. careful evaluation to avoid, where practicable, serious or irreversible damage to the environment; and b. an assessment of the risk-weighted consequences of various options.	Credible and defensible science has been at the core of the environmental assessment of the proposed Browse to NWS Project. This science is underpinned by over 25 years of studies and research at Scott Reef in partnership with the Australian Institute of Marine Science (AIMS). This scientific knowledge has been incorporated into the selection of the concept for the proposed Browse to NWS Project, as well as into design during the concept definition phase. Scientific knowledge will continue to be a key input into the detailed engineering phase and the implementation of the environmental mitigation, management and monitoring programs. Studies completed were determined to be adequate for the purposes of impact assessment and management planning purposes based on the lack of significantly altered regional cumulative impacts since collection, ability to extrapolate population trends using existing literature, and conservative interpretation of available data where applied. The existing baseline data will be updated by targeted monitoring programs to verify impact predictions and inform adaptive management approaches at relevant times throughout the project life cycle. Woodside has committed to the continuation of the Scott Reef longterm monitoring program to monitor the functionality and status of the reef system throughout the full lifecycle of the proposed Browse to NWS Project. As described in the Chapter 6 of the draft EIS/ERD, serious or irreversible damage to the environment associated with the Proposal is not predicted to occur. The ongoing integrity of all ecological and socio-economic values of the Scott Reef system is central to the considerations of the State Proposal Area. Serious or irreversible damage to the environmental value of the Scott Reef system will be avoided by locating the FPSO facilities, BTL and interfield spur line well away from Scott Reef (outside of State waters) and by locating the subsea infrastructure within the State Proposal Area in deep waters, well away from Scott Reef shallow water habitat. No activities related to petroleum recovery are planned to occur on Scott Reef (<75 m water depth). The assessment presented here and in the draft EIS/ERD was conducted based on environmental objectives defined by Woodside, in accordance with relevant legislative requirements, corporate standards, benchmarking and industry best practice. Where relevant, additional management and mitigation measures have been identified for implementation to reduce the level of risk associated with aspects of the Proposal. These proposed management and mitigation measures have been developed using Woodside's adaptive management framework (Eliminate/Substitute/Prevent/Reduce/Mitigate). The adaptive management approach encompasses a range of measures to address uncertainties over environmental impacts and ensure that the EPA's environmental objectives are met. As such, it is considered this environmental protection principle has been and will continue to be met.

Principle	Consideration
The principle of intergenerational equity The present generation should ensure that the health, diversity, and productivity of the environment is maintained and enhanced for the benefit of future generations.	As described above, serious or irreversible damage to the environment is not predicted to occur as a result of the Proposal. In addition, environmental risks have been reduced to an acceptable level with the likelihood of impacts occurring as a result of unplanned events or incidents considered highly unlikely to remote. It is considered maintenance of the health, diversity and productivity of the environment will not be adversely impacted by the Proposal and access to the Scott Reef natural environment for future generations will be maintained. As such, it is considered this environmental protection principle has been and will continue to be met.
Principles relating to improved valuation, pricing, and incentive mechanisms 1. Environmental factors should be included in the valuation of assets and services. 2. The polluter pays principles – those who generate pollution and waste should bear the cost of containment, avoidance, and abatement. 3. The users of goods and services should pay prices based on the full lifecycle costs of providing goods and services, including the use of natural resources and assets and the ultimate disposal of any waste. 4. Environmental goals, having been established, should be pursued in the most cost-effective way, by establishing incentive structures, including market mechanisms, which enable those best placed to maximise benefits and/or minimise costs to develop their own solutions and responses to environmental problems.	In line with Woodside's HSEQ Policy, Woodside has drawn from its operating experience in Australian offshore environments and its knowledge of the existing environment of the State Proposal Area to identify a range of design features and management measures to prevent or mitigate impacts to the environment. The selection of these measures for implementation included the following key aspects: + In line with its corporate policies and procedures, Woodside will use valuation, pricing and incentive mechanisms during procurements associated with the proposed Browse to NWS Project with the aim of balancing economic and HSE outcomes. + Net environmental benefits will be compared against a range of alternative measures. + Costs involved with the implementation of management measures at various stages of the lifecycle of the Proposal will and have been compared. + Key environmental objectives will be established, to maximise environmental benefits in a cost-effective way. As such, it is considered that this environmental protection principle has been and will continue to be met.

Principle	Consideration
The principle of the conservation of biological diversity and ecological integrity Conservation of biological diversity and ecological integrity should be a fundamental consideration.	As part of the development of the State ERD, management and mitigation measures have been identified to reduce the level of risk for each of the environmental aspects associated with the Proposal. These proposed measures have been developed using Woodside's adaptive management framework (Eliminate/Substitute/Prevent/Reduce/Mitigate), with the overall objective to conduct activities associated with the proposed Browse to NWS Project in a manner which does not affect Ecological Sustainable Development outcomes. This includes the principles of the EP Act, including the principle of 'biological diversity and ecological integrity'. Woodside has developed a range of design features, as well as management and mitigation measures to avoid impacts to Scott Reef (refer to **Section 8**). These have been developed in consideration of the environment of Scott Reef. In addition, Woodside has committed to the continuation of the Scott Reef long-term monitoring program to monitor the functionality and status of the reef system, throughout the full lifecycle of the proposed Browse to NWS Project. As such, it is considered this environmental protection principle has been and will continue to be met.
The principle of waste minimisation All reasonable and practicable measures should be taken to minimise the generation of waste and its discharge into the environment.	Woodside is committed to managing its activities to reduce the adverse effects on the environment while balancing economic and social needs of sustainable development. A key principle of Woodside's HSEQ Policy is to use energy, water and other resources efficiently and reduce greenhouse gas (GHG) emissions and waste. This principle is reflected in the various design features and waste management measures to be implemented by Woodside. In the development of its management approach for the Proposal, Woodside has specifically focused on reduction at source and efficiency maximisation for emissions and discharges to the environment, as follows: + There will be no routine discharge of non-hazardous solid waste at sea. + Chemicals that may be operationally released or discharged to the marine environment will be subject to Woodside's chemical selection and assessment process and approved prior to use. + The flowline length and subsea infrastructure installation schedule will be optimised to reduce the volume of hydrotest fluid discharged. + There will be no discharge of untreated sewage within three nautical miles (nm) of Scott Reef. + The number of wells has been, and will continue to be, optimised to meet hydrocarbon recovery objectives and operational requirements and thereby reduce unnecessary use of drilling fluids and generation of drill cuttings. Solids control equipment will be available on board the MODU to reduce the amount of residual drill fluids on cuttings prior to discharge. Drill cuttings will be tested to confirm that the average oil on cuttings for the entire well (sections using non water based fluids (NWBFs)) will not exceed 6.9% by wet weight. + Dry commissioning is being pursued for the BTL + A hybrid subsea control system has been designed to return fluids to the FPSO for reuse during normal operations. Woodside has set performance criteria to be monitored as part of the Proposal to ensure the effective management of waste. As such, it is considered this environmental protection principle has been, and will continue to be, met.

8.2 Key Environmental Factor – Marine Environmental Quality

8.2.1 EPA Objective

The EPA objective for marine environmental quality is *"to maintain the quality of water, sediment and biota so that environmental values are protected"* (EPA, 2016a).

The EPA Environmental Factor Guideline for Marine Environmental Quality defines the term 'environmental quality' as "the level of contaminants in water, sediments or biota or to changes in the physical or chemical properties of waters and sediments relative to a natural state. It does not include noise pollution, which is dealt with separately under the marine fauna factor." (EPA, 2016a).

8.2.2 Policy and Guidance

The following policy and guidance have been considered in relation to the EPA environmental factor - marine environmental quality.

+ EPA Policy and Guidance
+ Statement of Environmental Principles, Factors and Objectives (EPA, 2016b)
+ Environmental Factor Guideline – Marine Environmental Quality (EPA, 2016a)
+ Technical Guidance – Protecting the Quality of Western Australia's Marine Environment (EPA, 2016c).

Other Policy and Guidance

+ Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018).

8.2.3 Receiving Environment

The characteristics of the marine environment of the Browse Development Area are described in detail in Chapter 5 of the draft EIS/ERD.

Water quality and seabed sediment quality in the deep waters (below the 75 m bathymetric contour) within the State Proposal Area are well aligned with that of the broader Browse Development Area and typical of a pristine tropical offshore environment reflective of the anthropogenically undisturbed waters of the region.

The findings of three surveys have been used to characterise water quality in the State Proposal Area (Brinkman et al., 2009; Gardline Marine Services Pty Ltd, 2009a; URS Australia Pty Ltd, 2007) as described in Section 5.2.9 of the draft EIS/ERD.

These studies have also been used to characterise the deepwater seabed sediments within the Browse Development Area, as described in Section 5.2.10 of the draft EIS/ERD. These surveys found no evidence of hydrocarbons within the sediment in the Browse Development Area, generally low levels of metals (majority below guideline levels), and nutrient levels well within the normal baseline values expected for carbonate-dominated sediments in remote tropical settings.

Biota associated with the deepwater seabed habitats within the Browse Development Area are described in Section 5.3.1 (ecological communities) and Section 5.3.2 (fauna) of the draft EIS/ERD. Planktonic communities within the open waters of the State Proposal Area are expected to be consistent with the remainder of the Browse Development Area. A description of the shallow water benthic habitats associated with the Scott Reef system (above the 75 m bathymetric contour) is provided in Section 8.3.3. A description of the marine fauna found in the State Proposal Area is provide in Section 8.4.3. As described in Section 6 of the draft EIS/ERD, for the purposed of this State ERD, Scott Reef is considered as the area above the 75 m bathymetric contour within the 3 nm State waters boundary.

State marine parks and nature reserves are described in Section 5.3.3.3 of the draft EIS/ERD. State managed fisheries are described in Section 5.4.2.2 of the draft EIS/ERD.

8.2.4 Potential Impacts

8.2.4.1 Summary of identified impacts and risks

Table 8-2 summarises the sources of potential impact to marine environmental quality in the State Proposal Area from the Proposal. Table 8-2 is followed by a detailed description of the potential direct, indirect and cumulative impacts. An assessment of the significance of these impacts on marine environmental quality and a conclusion on the acceptability of the impacts in relation to the EPA environmental objective is presented in Section 8.2.5. It should be noted that a discussion of the impacts from the predicted activities on marine fauna and benthic 'biota' as a component of marine environmental quality is presented in Sections 8.2 and Section 8.4.

Table 8-2 Sources of Potential Impact to Marine Environmental Quality from the Proposal

Aspect	Proposal Phase[1]					Source (in State jurisdiction)
	Dr	I	C	O	De	
Planned (routine and non-routine activities)						
Physical presence: light emissions	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating in the State Proposal Area Intermittent flaring from the MODU
Physical presence: seabed disturbance and disturbance to other users	✓	✓		✓	✓	Development of the production wells Installation of subsea infrastructure Wet storage of infrastructure prior to installation MODU anchors IMR activities
Marine discharges: sewage and sullage	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating in the State Proposal Area
Marine discharges: treated utility water, chemical and deck drainage	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating in the State Proposal Area
Marine discharges: produced water	✓					MODU during well unloading activities
Marine discharges: cooling water	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating in the State Proposal Area
Marine discharges: drilling or completions discharges	✓					MODU during drilling activities
Marine discharges: subsea control fluids	✓	✓		✓	✓	Subsea infrastructure BOP during drilling Remotely Operated Vessels (ROVs)
Marine discharges: hydrotest fluid	✓	✓	✓	✓		Temporary production system on MODU Integrity testing of subsea infrastructure
Unplanned events and incidents						
Marine discharges: hazardous and non-hazardous inorganic waste	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating in the State Proposal Area
Unplanned hydrocarbon releases	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating in the State Proposal Area Subsea infrastructure

[1] *Dr = Drilling; I = Installation; C = Commissioning; O = Operation; De = Decommissioning*

8.2.4.2 Physical presence: seabed disturbance

As described in **Section 6.3.1.6** of the draft EIS/ERD, seabed disturbance as a result of the installation of subsea infrastructure (including pre-lay activities, placement and post lay rectification of infrastructure), wet storage (which involves temporarily placing equipment on the seabed), anchoring of the MODU and IMR activities within the State Proposal Area is expected to be approximately 4.15 km^2 in area of which 0.31 km^2 will constitute direct disturbance resulting in permanent impact. The 3.84 km^2 balance is the result of indirect disturbance and is considered reversible. Seabed disturbance is likely to result in temporary and localised displacement of naturally-occurring sediments for the duration of the activity (ranging in the order of minutes to a few hours) and limited to the immediate disturbance area. This is likely to result in increases in turbidity levels at the seabed that will quickly disperse in the oceanic marine environment due to prevailing hydrodynamic conditions. As such, any reduction in water quality will be temporary (ranging in the order of minutes to a few hours) and will be limited to the water column immediately surrounding the disturbance area. The sediments that may be displaced are naturally occurring and, based on baseline surveys as described in **Section 5.2.10** of the draft EIS/ERD, do not contain any contaminants of concern. Due to the temporary and localised nature of changes in water quality, impacts to plankton are negligible.

Further, the small volumes of sediment mobilised, the water depth at which the seabed disturbance will occur, and the dynamic nature of the marine environment means that it is highly unlikely that any mobilised sediments will deposit on Scott Reef shallow water benthic habitats (<75 m water depth).

Given this, turbidity and associated sedimentation generated by seabed disturbances is not expected to result in any lasting change to the physical or chemical properties of water or sediments; or result in any lasting adverse impact to biota. As such minor impacts are expected to deep-water benthic communities and habitats (>75m water depth) are predicted. No impacts to Scott Reef shallow water benthic communities and habitats (<75 m water depth) located well away from the closest proposed location of the subsea infrastructure are predicted.

8.2.4.3 Physical presence: light

Potential impacts to plankton from light emissions are described in **Section 6.3.3** of the draft EIS/ERD.

Zooplankton often display diurnal vertical movements (Leach and Johnsen, 2003) within the ocean, migrating to surface waters at night to feed. Artificial light has, therefore, the potential to reduce the amplitude of their migration if lighting levels are sufficiently high at night (Moore et al., 2000). Artificial light emissions can influence the migration of zooplankton from deepwater to the surface, thereby affecting the food supply of nocturnal plankton-feeders. Alternatively, as most studies have demonstrated, the illumination of marine waters at night has the effect of increasing feeding opportunities for predators due to better visualisation of prey rather than resulting in potential plankton density reduction, however, these effects are expected to be highly localised and given the high turnover rate of plankton populations (ITOF, 2011) in open oceanic water there will be no lasting impact.

It is likely that plankton in the immediate vicinity of the FPSO facilities, MODU and project vessels that are within the light spill area (within hundreds of metres) will be impacted by light, based on the light emissions modelling. Given the highly localised effects of light emissions from the FPSO facilities, MODU and vessels associated with the proposed Browse to NWS Project, the proportion of the plankton population affected and the high turnover and recovery of plankton populations, no discernible impact on plankton communities at a population level is expected.

8.2.4.4 Marine discharges: sewage and sullage

A detailed description of the planned discharge of sewage and sullage and an assessment of the potential impacts and risks associated with the discharge are provided in **Section 6.3.9** of the draft EIS/ERD.

There are no planned discharges of untreated sewage or sullage within the State Proposal Area; however, discharges of treated sewage and sullage from project vessels, installation vessels and the MODU within the State Proposal Area will occur. These discharges will be primarily related to drilling activities and installation of the subsea infrastructure, with no permanent vessel presence in the State Proposal Area during operations. Under normal operating conditions, drilling and vessel activity (and associated marine discharges) will be limited to the deep waters in close proximity to the location of the proposed development wells and subsea infrastructure. Drilling activities are expected to take 2-3 months per well, with up to 24 wells in the State Proposal Area. It must be noted that all 24 wells will not be drilled in a continuous sequence. Approximately 3 wells will be installed at RFSU at the TRA drill centre, then remaining wells will in installed over subsequent years.

A review of current petroleum activities shows that vessels and MODUs typically generate around 5–15 m^3 of waste water (consisting of sewage and sullage) per day (NERA, 2017). Using a rate of 0.375 m^3/person/day as a guide (NERA, 2017), installation vessels may discharge approximately 22.5 m^3/day, based on 60 persons aboard.

The discharge of treated sewage and sullage has the potential to result in the temporary (minutes to hours) and localised (tens of metres) reduction in water quality via eutrophication as a result of increased nutrient levels (e.g. ammonia, nitrite, nitrate and orthophosphate). This has the potential to cause adverse changes to the ecosystem, such as increased growth of primary producers (e.g. phytoplankton) which can deplete oxygen in the water column and result in changes in biological processes.

Sewage and sullage may also include some particulate matter which can cause an increase in the turbidity of the receiving waters close to the point of discharge. Discharges will disperse and dilute rapidly, with concentrations of wastes significantly dropping with distance from the discharge point. Several studies have quantified the high levels of dilution, including Loehr et al. (2006). A study by the US EPA (2002) found that discharge plumes behind cruise ships moving at between 9.1 and 17.4 knots are diluted by a factor of between 200,000:1 and 640,000:1. The discharges and level of effluent dilution in the studies did not present significant localised toxicity impacts to marine biota from any changes in water quality.

As described in **Section 6.3.9** of the draft EIS/ERD, monitoring of sewage and sullage discharge during the drilling campaign for the Torosa-6 well in 2008 determined discharges were rapidly diluted in the upper (less than 10 m) water layer to 1% of their original concentration within 50 m, with no elevations above background in nutrients or metals recorded at any sampling station (ERM and SKM, 2008). As such, changes to the physical and chemical properties of the marine water will be temporary and highly localised. No change to the physical or chemical properties of sediments are expected due to the depth of the water where treated sewage and sullage would be discharged.

Although organic materials from the discharges will likely exert biological oxygen demand on the receiving waters, this is unlikely to reach levels below background ambient dissolved oxygen concentrations. Similarly, while the nutrient inputs from discharged effluent will rapidly be taken up by phytoplankton, pronounced increases in productivity as evidenced by increased chlorophyll a concentration are not expected. This is largely due to the assimilative capacity of the open ocean, with any potential additive nutrients not expected to accumulate in the vicinity of the discharge location. As such no lasting impacts to planktonic communities are expected.

Given the relatively small volume of treated sewage and sullage to be discharged, the distance from the discharge to Scott Reef and the expected rapid dilution of the discharge, the temporary and highly localised changes to water quality are not expected to have any impacts to biota or the environmental values of the Scott Reef system.

Though unlikely, discharges of sewage and sullage at levels significantly above the discharge specifications may result from human error or equipment failure. This would potentially result in a larger area being impacted (a temporary larger mixing zone), although the plume would still be expected to rapidly disperse. The subsequent temporary (i.e. limited to the duration of the unplanned discharge) and localised reduction in water quality would be unlikely to lead to subsequent impacts to deepwater receptors due to the depth of water; or to the Scott Reef system due to the distance from where the discharges would occur.

8.2.4.5 Marine discharges: treated utility water, chemical and deck drainage

A detailed description of the planned discharge of treated utility water, chemical and deck drainage and an assessment of the potential impacts and risks associated with the discharges is provided in **Section 6.3.10** of the draft EIS/ERD.

Within the State Proposal Area, treated utility water, chemical and deck drainage will be limited to deck drainage, treated bilge water and desalination brine from project vessels, installation vessels and the MODU. As described in **Section 6.3.10** of the draft EIS/ERD, potentially contaminated deck drainage discharges would occur from the MODU during periods of heavy rain, with potentially contaminated drainage routed to slops tanks for treatment prior to discharge. Bilge water from within machinery spaces will be captured separately in a bilge tank for treatment.

As described in **Section 6.3.10** of the draft EIS/ERD, an oil-in-water separator will be available onboard the MODU and vessels (as applicable to vessel class), which will be maintained and operated so that bilge water is treated to reduce hydrocarbon concentrations below 15 ppm in accordance with MARPOL 73/78 Annex. Under normal operating conditions, drilling and vessel activity (and associated marine discharges) will be limited to the deep waters in proximity to the location of the proposed development wells and subsea infrastructure.

Considering the composition of the drain discharges (i.e. small quantities of hydrocarbons and detergents) and assimilative capacity of the receiving environment, it is expected that drain discharges will rapidly dilute within the surrounding waters. As such, these discharges will result in temporary (lasting a few minutes) change to water quality in the immediate vicinity of the discharge. Given the water depth (>300 m) and distance to Scott Reef from where these discharges would occur, this change to water quality is not expected to have any impacts to sediment, biota or the environmental values of the Scott Reef system.

Desalination brine discharge is expected to be 20 to 50% more saline than the intake seawater (depending on the desalination process used) and therefore only a small number of dilutions will be required to achieve ambient salinity levels. Studies undertaken by the US EPA (Frick et al., 2001) determined that brine discharges from the surface dilute 40–fold approximately 4 m from the source. This modelling can be used as an indicator for predicting horizontal attenuation and diffusion of brine discharges. Given the proposed discharge volumes from the FPSO facilities (21.5 m^3/hr), which is the largest source of such discharges, dilution to ambient levels is likely to be achieved within a very short distance from the discharge point (<100 m). Therefore, owing to the likely high number of dilutions achieved following discharge from the proposed sources (i.e. FPSO, vessels and MODU), elevated salinity levels (above ambient) will be highly localised at the discharge point and unlikely to have a perceptible effect on ambient salinity concentrations in the water column.

Though unlikely, unplanned discharges resulting from human error or equipment failure on project vessels or the MODU may occur. This would potentially result in a larger area being impacted (a temporary larger mixing zone), although the plume would still be expected to rapidly disperse. The subsequent temporary (i.e. limited to the duration of the unplanned discharge) and localised reduction in water quality would be unlikely to lead to subsequent impacts to deepwater receptors due to the depth of water; or to Scott Reef system due to the distance from where the discharges would occur.

8.2.4.6 Marine discharges: produced water

A detailed description of the planned discharge of produced water (PW) and an assessment of the potential impacts and risks associated with the discharge of PW is provided in Section 6.3.12 of the draft EIS/ERD.

Low levels of PW may be discharged from the MODU at the well locations, including within deep water areas of the State Proposal Area during well unloading. This PW would be condensed water generated in the hydrocarbon gas stream during well unloading and would be discharged as part of the discharge of well clean up fluids, which would include drilling fluids (addressed below). The PW component of the discharge will constitute a very small proportion of the discharge stream, with the discharge dominated by suspension fluids and associated PW generally limited to small volumes of condensed water. Well unloading is anticipated to take 1-2 days per well (i.e. the amount of time that the well is flowing). The PW component of the discharge may contain inorganic salts from geological formations, dissolved organic compounds, dissolved gases (including H_2S and CO_2), dissolved and dispersed hydrocarbons, metals and low levels of Naturally Occurring Radioactive Material (NORMs).

Given the PW component is a fraction of the overall discharge during well unloading, this discharge is addressed below under drill cuttings and fluids.

8.2.4.7 Marine discharges: cooling water

A detailed description of the planned discharge of cooling water and an assessment of the potential impacts and risks associated with the discharge is provided in Section 6.3.13 of the draft EIS/ERD.

Cooling water discharge from project vessels and the MODU at the well locations may impact marine environmental quality due to thermal impacts (increased water temperature) and toxicity impacts relating to the residual chlorine concentration within the cooling water discharge.

Relatively low levels of cooling water will be discharged from project vessels and the MODU (approximately 50 m^3/day depending on vessel size). Under normal operating conditions, drilling and vessel activity (and associated marine discharges) will be limited to the deep waters near the location of the proposed development wells and subsea infrastructure.

To put this discharge volume in context, the FPSO facilities are expected to discharge up to approximately 720,000 m^3/day (discharge to Commonwealth waters). Modelling undertaken of the FPSO facilities cooling water discharge indicated a rapid dilution would be expected (Section 6.3.13 of the draft EIS/ERD). Given the markedly smaller discharge volumes from the vessels and MODU, these small volumes are expected to rapidly disperse and dilute (within tens of metres) with impacts expected to be a highly localised change in water quality. This reduction in water quality would be primarily limited to the construction phase, with vessel activities in the State Proposal Area during operations primarily limited to intermittent IMR activities. Due to the distance of proposed cooling water discharge to Scott Reef, the reduction in water quality is not expected to have any impacts to sediment, biota or the environmental values of the Scott Reef system.

8.2.4.8 Marine discharges: drilling or completions discharges

A detailed description of the planned discharge associated with the drilling activities and an assessment of the potential impacts and risks associated with the discharge are provided in Section 6.3.15 of the draft EIS/ERD. The impact assessment in the draft EIS/ERD focuses largely on activities in the State Proposal area however they are repeated here in order to provide a standalone assessment of impacts within State jurisdiction.

Development drilling activities within the State Proposal Area associated with the proposed Browse to NWS Project involve the drilling and completion of up to 24 wells. Drilling of production wells will generate drill cuttings, require cementing of the casing, and require the use of a range of fluids, that may be discharged to the marine environment, typically at the seabed and at or near the sea surface depending on the hole section.

During the life of the proposed Browse to NWS Project, well components will require maintenance, repair or replacement. This will require well intervention activities which generally occur within the wellbore and may include but not limited to well logging activities (slickline, wireline, coil tubing), well testing and flowback; and well workovers. Relevant discharge types generated from these activities may include subsea control fluid (control of subsea tree) (refer to Section 6.3.16 of the draft EIS/ERD), completions fluids and well annular fluids.

In addition, well abandonment activities can result in discharges to the marine environment including but not limited to installation and pressure testing of the blow out preventer (BOP), cutting/perforation of casing or production tubing; and installation of permanent reservoir and surface barrier (cementing). Relevant discharge types generated from these activities may include subsea control fluids (refer to Section 6.3.16 of the draft EIS/ERD), well annular fluids and cement.

Drilling and completion activities required for the proposed Browse to NWS Project are expected to be broadly similar to that of the previous development concepts (Section 2.7.1 of the draft EIS/ERD).

Drill cuttings

Drilling generates drill cuttings due to the breakup of solid material from within the borehole. The resultant drill cuttings are basically rock particles of various shapes, with sizes typically ranging from very fine to very coarse. Cuttings generated during drilling of the top-hole sections are typically discharged to the seabed at the well site.

Once the top-hole sections are complete, installation of the riser and BOP provides a conduit back to the MODU, forming a closed circulating system. The bottom hole sections will be drilled with a marine riser in place that enables cuttings and drilling fluids to be circulated back to the MODU, where the cuttings are separated from the drilling fluids by the solids control equipment (SCE). The SCE comprises equipment such as shale shakers, cuttings dryer(s) and centrifuges. The SCE uses shale shakers to remove coarse cuttings from the drilling fluid. The recovered fluids from the cuttings may then be directed to centrifuges, which are used to remove fine solids (4.5 to 6 µm). The cuttings are usually discharged below the water line and the fluid is recirculated into the fluid system.

The drilling fluid retained on cuttings is determined by the SCE and typically, treated water based fluid (WBF) cuttings may retain 5 to 25% of the drilling fluid after passage through SCE (Neff, 2005) and treated cuttings when drilling with non water based fluid (NWBF) may retain 5 to 15% of the drilling fluid (Neff et al., 2000). The cuttings with retained NWBF will also pass through a cuttings dryer and associated SCE, to reduce the average oil on cuttings to 6.9% wt/wt or less on wet cuttings, prior to discharge.

The fate and dispersion of the cuttings once discharged into the marine environment is determined by particle size and the density of the unrecoverable fluids. The larger cuttings particles will drop out of suspension and deposit in close proximity to the well site (tens of metres) with potential for localised spreading downstream. In contrast, the finer particles will remain in suspension and be transported away from the well site, rapidly diluting and eventually depositing over a widespread area (hundreds of metres) downstream of the well site.

Drill cuttings and unrecoverable fluids are discharged at the seabed at the well site for the top-hole sections drilled riser-less (no closed loop with the MODU). This results in a localised area of sediment deposition (known as a cuttings pile) in close proximity to the well site. The spread of cuttings and associated water based fluids is expected to be up to 50-200 m downstream from the discharge location based on a review of seven studies summarised by International Association of Oil and Gas Producers (IOGP, 2016). Drill cuttings and retained NWBF (<6.9% OOC) released at or below the surface after treatment on the MODU for the bottom-hole well sections are generally dispersed and settle within a seabed area confined to a maximum of 500 m distance of the discharge point (IOGP, 2016).

Drilling fluids

Drilling fluids (also termed drilling muds) serve many purposes including maintaining borehole stability and hydrostatic pressure, reducing friction and cleaning/cooling of the drill bit, in addition to acting as a medium to carry cuttings from the well bore and return them to the surface at seabed or on the MODU. Drilling fluids are either mixed on the MODU or received pre-mixed, then stored and maintained in a series of mud pits aboard the MODU or a suitable vessel. There are two main types of drilling fluids, including water based fluids (WBF) and non-water based fluids (NWBF).

Water based drilling fluids

The proposed Browse to NWS Project will use WBF as the preferred option. WBF consists mainly of seawater with the addition of chemical and mineral additives to aid in its function. Drilling additives typically used may include chlorides (e.g. sodium, potassium), bentonite (clay), cellulose polymers, guar gum, barite or calcium carbonate. These additives are either completely inert in the marine environment, naturally occurring benign materials, or readily biodegradable organic polymers with a very fast rate of biodegradation in the marine environment.

WBF will be discharged to the marine environment at the location of the well being drilled under the following scenarios:

- at the seabed when drilling the top-hole (riser less) sections
- below sea surface as fluid remaining on drill cuttings, after passing through SCE (bottom-hole sections, drilled with riser in place)
- from the mud pits via a discharge pipe below the sea surface, If WBF cannot be re-used due to bacterial deterioration or does not meet required drilling fluid properties, it may be discharged to the marine environment using seawater flushing. WBF may not be able to be reused between drilling sections due to the drilling sequence, technical requirements of the fluid (i.e. no tolerance for deterioration of fluid during storage) and maintenance of productivity/injectivity. Unused or spent WBFs may be disposed from the MODU as a bulk discharge (defined as a discrete discharge of large quantities) at the end of each well section.

Additional products such as barite and bentonite may be discharged in bulk/single discharge at the end of the activity if they cannot be reused or taken back to shore. Use and discharge of all chemicals will be performed in line with Woodside's internal guidelines. Discharge may be in the form of dry bulk or as a slurry; however, discharges will not be contaminated with hydrocarbons. Planned bulk discharges at wells within the State Proposal Area will be managed as described in the **Management approach - Torosa wells in the State Proposal Area** section below.

Non water based drilling fluids

Non-water-based fluids (NWBF) refers to drill fluids that are hydrocarbon rather than water based fluid. NWBF may be used to manage well stability to safe levels based on the offset history, geohazards assessment and borehole stability studies. Like a WBF system, a range of standard solid and liquid additives may be added to alter specific fluid properties for each section of the well, dependent on the conditions encountered while drilling. NWBFs will be selected in accordance with Woodside's chemical selection and assessment process on the basis of lowest health, safety and environmental risks while meeting operational requirements.

During drilling operations, the NWBF (like WBF) are pumped by high pressure pumps down the drill string and out through the drill bit, returning via the annulus between the drill string and the casing of the well bore, and back to the MODU via the riser. Discharge scenarios are much the same as that described for WBF, however NWBF will not be used for top-hole section drilling (riserless); therefore, no direct seabed discharge of NWBF will occur.

The NWBF that cannot be re-used (i.e. do not meet required drilling fluid properties or are mixed in excess of required volumes) are recovered from the mud pits and returned to the shore base for onshore processing for recycling and/or disposal. The mud pits and associated equipment/ infrastructure are cleaned when NWBF is no longer required, with wash water discharged with mud pit washings, or returned to shore for disposal if discharge criteria cannot be achieved.

There are typically a number of mud pits (tanks) on the MODU that provide a capacity to mix, maintain and store fluids required for drilling activities. The mud pits form part of the drilling fluid circulating system. The mud pits, any supply vessel storage tanks carrying WBF or NWBF, and associated equipment/infrastructure are cleaned out during and at the end of drilling and completions operations. Mud pit wash residue is operationally discharged from the MODU with less than 1% oil contamination by volume. Where the mud pit residue exceeds 1% by volume, the residue will be retained and disposed onshore.

Drilling fluids toxicity

Components of the WBF system have a low toxicity. Bentonite and guar gum are listed as 'E' category fluids under the OCNS and is included on the Oslo Paris (OSPAR) Commission PLONOR (chemicals that 'pose little or no risk to the environment') list (OSPAR, 2019). They may, however, cause physical damage to benthic organisms by abrasion or clogging, or through changes in sediment texture that can inhibit the settlement of planktonic larvae, such as polychaete and mollusc early life stages (Swan et al., 1994). However, these impacts are not expected to be significant due to the rapid biodegradation and dispersion of WBFs (Terrens et al., 1998).

NWBF may contain a range of synthetic hydrocarbons, such as paraffins and olefins; however, such additives are designed to be low in toxicity and biodegradable, as well as not being readily bioavailable or likely to bioaccumulate amongst the deepwater benthic biota that live within the seabed (infauna) or on the seabed (epifauna). However, it is noted that microbial biodegradation can result in oxygen reduction within sediments. Nedwed et al. (2006) however, found that depth is an important factor for residual concentrations of NWBF once they reach the seabed, suggesting that loss of base fluid during settling acted to significantly reduce chemical effects from discharges. It is also noted that NWBF cuttings tend to clump and settle to the seabed rapidly adding to the cuttings pile in proximity to the well site. The Nedwed et al. (2006) study concluded that NWBF discharged in deep water caused very limited environmental impacts (from analysis of differences in benthic fauna between pre- and post-drilling samples).

Cement

Once each of the top-hole sections are drilled, casing is installed in the wellbore and secured in place by pumping cement into the annular space and may involve a discharge of excess cement at the seabed (~80 m^3/well). Wherever possible, the cement line flush volumes are included in the planned cement jobs. When a job is completed, the cement unit is cleaned, and the residual cement discharged overboard. The discharge volumes of residual cement products are approximately 1 m^3.

At the commencement of the drilling campaign there may be a requirement to run a cement unit test to test the functionality of the cement unit and the cement bulk delivery system prior to performing an actual cement job. This test would result in a small volume of approximately 10 m^3 of cement slurry being discharged at surface to sea. The slurry is usually a mix of cement and water however may sometimes contain stabilisers or chemical additives. Excess cement (dry bulk) after well operations are completed, will be held onboard and used for subsequent wells, provided to the next operator at the end of the program, or discharged to the marine environment. Planned bulk discharges at wells within the State Proposal Area will be managed as described in the **Management approach - Torosa wells in the State Proposal Area** section below.

Completion fluids

Completion fluids are usually brines (i.e. a mixture of seawater or formation water) with additives that can include chlorides (often sodium, potassium or calcium), bromides, hydrate inhibitor (MEG), biocide and/or oxygen scavenger. They are designed to have the proper density and flow characteristics to be compatible with the reservoir formation. Completion fluids may also include solids-free fluid, gravel pack carrier fluid and loss circulation material. Completion fluids are used during wellbore clean-up, while running completions, and may be returned to surface during well unload activities. Most of the gravel pack carrier fluid is bulk discharged.

Wellbore and casing clean-up are required at various stages of the operations to ensure the contents of the well are free of contaminants before the next stage of well construction. A chemical wellbore cleanout fluid train may be used to remove residual fluids (including NWBF, if used) from the wellbore. The wellbore cleanout fluid is usually brine (similar to completion fluid) that can include several chemicals, such as biocide and surfactant. During the wellbore clean-out process, fluids are circulated back to the MODU, and, if required, analysed before they are discharged overboard. Discharge volume would be ~400 m^3 (based on the designs of the proposed production wells).

A brine of adequate density to control formation pressure may also be used during well suspension or well abandonment.

Well unload

During well unloading activities, all completion and reservoir fluids will be flared or discharged to the environment. The base oil column, completion fluid, some drilling fluid remnants, hydrocarbons and produced/condensed water will be measured, handled, separated, treated for overboard discharge (non-hydrocarbon) and flared/burned (hydrocarbon) through the temporary production system on the MODU.

The well test water treatment package will be used to treat produced/reservoir water before discharge. Prior to discharging, the fluids are cycled through an oilbond filtration system and gauge tank. Water filtration is standard practice for well unloading operations.

Discharges will occur during well unloading to a MODU or suitable vessel. These discharges will constitute leftover drilling fluids, completion fluids and small amounts of produced water (PW; refer to **Section 8.2.4.6**) Well unloading is anticipated to take 1-2 days per well, and discharge of fluids during this time has been indicatively estimated at approximately 100 m^3 to 130 m^3 per well.

Well annular fluids

Annular fluids fall within the category of completion fluids and refer to the fluids that remain in the annular spaces between the casing and previous casing strings or formation. It may consist of weighted drilling fluid and cement-contaminated mud, seawater, barite, cement, polymer, and may include small amounts of hydrocarbon. For the proposed Browse to NWS Project, the reference case annular fluid is base oil with no additivities apart from a demulsifier.

If a well is underperforming, or surveillance indicates debris is contained within the well, the contents of the wellbore may be flowed to a MODU. This displaces the well fluids (i.e. suspension/completion fluids). These are discharged overboard, as potential gas content makes it too dangerous for personnel to filter or treat them.

WBF used during riserless drilling will be released to the marine environment when the well head is removed during abandonment. Upon wellhead removal, small volumes (~ 1 m^3) of fluid exchange between the annular spaces and the ocean may occur. The exchange will not be instantaneous as the annular spaces are small and the fluids are typically heavier than seawater, however, as the fluids are released it is expected that they will be rapidly diluted within metres of the release location.

Overview of drill cuttings and drilling fluids

An indicative well profile is shown in **Table 8-3**. During drilling of the top-hole well sections drill cuttings (~ 625 m^3) and drilling fluids (~ 1,095 m^3) based on a typical well profile are generated and will be released from the well directly onto the seabed. During drilling of the bottom-hole well sections, drill cuttings (~ 225 m^3) and drilling fluids (~ 1,020 m^3) based on a typical well profile are generated and may be discharged at or below the sea surface.

Table 8-3 Indicative cuttings volumes and fluid type for a typical Browse well

Indicative well section diameter	Indicative Drill Length (m)	Indicative Cuttings Volume (m^3)	Indicative Fluids Volume (m^3)	Indicative Fluid Type
42”	100	89 m^3	427	Seawater with bentonite sweeps
26”	440	151 m^3	1327	Seawater with bentonite sweeps
16”	2970	385 m^3	965	Weighted Gel (Bentonite) WBF
12 ¼	2799	213 m^3	925	WBF or NWBF
9 ⅞	243	12 m3^3	790	WBF or NWBF
Total per well	**6,552 m**	**850 m^3**	**4,435 m^3**	

Contingent drilling activities include well side-track and well respud. If either of these activities are required, they will result in additional volumes of drilling discharges equal to the re-drilled sections of the well. The impacts of these unlikely scenarios are broadly covered by the base case impact assessment considerations.

It should be noted that the detailed impact evaluation with modelling is based on the primary drilling discharges (cuttings and residual fluids) due to the nature, scale and duration of the discharge compared to other sources (e.g. completion fluids). These results have been used to support impact and risk assessment and in the determination of acceptability in the context of the receiving environment and relevant receptors.

Modelling
Modelling of surface discharge of drill cuttings was undertaken for the previous development concepts and is presented in **Section 6.3.15.3** of the draft EIS/ERD.

The modelling indicated that, at all three drill centre locations, the sea surface discharge of drill cuttings from bottom hole sections of wells resulted in incursions of sediment plumes and associated increased deposition at some parts of North and South Scott Reef including within the lagoons. As a result, Woodside has committed to manage drilling discharges (in particular bottom hole discharges) at drill centre locations in the State Proposal Area (i.e. TRA, TRD, TRE and TRF) in such a manner to avoid impacts to Scott Reef shallow water benthic communities and habitats (<75 m water depth). This management approach is further described in **Section 8.2.6**.

In contrast, the seabed discharge of drill cuttings from top-hole well sections may result in sediment plumes and associated deposition of sediment to the surrounding seabed and was confined to the deeper layers of the water column with no contact with deeper water or shallow water coral habitats at Scott Reef. As outlined in **Section 5.2.5.7**, while there is some evidence of localised intrusions of cooler water around the western and eastern entrances to the channel between North and South Scott Reef during spring tides, there is no evidence of persistent upwelling or downwelling currents around Scott Reef (Green et al., 2019) and therefore, no transport mechanisms to mobilise drill cuttings from deep waters to the shallower waters of the reef system. As such, given the location of the drill centres in deep water, which experience strong surface and subsurface currents, drill cuttings and fluid discharge disposal at seabed would be expected to settle rapidly. Therefore, any reduction in water quality such as elevated TSS is expected to occur in a localised area around the drill centre and will be temporary in nature.

To further inform the impact assessment, for the seabed discharge of drill cuttings generated from the top-hole sections of the wells, the modelling results indicated that at the:

- previously proposed TRE drill centre location (water depths of 360 m):
  - Sediment plume predominantly extended westward, driven by the stronger ebb tide, with some eastward extension during the flood tide (**Figure 6-34** of the draft EIS/ERD).
  - Cuttings sedimentation would be limited to the deep seabed and water layers of the channel, with no sedimentation on Scott Reef shallow water benthic communities and habitats (<75 m water depth) including in the lagoons of North and deeper water coral habitat of South Scott Reef.
  - Maximum net sediment deposition over the duration of the 12-month drilling program is estimated at approximately 46 cm at the previously proposed TRE drill centre location (**Figure 6-34** of the draft EIS/ERD).

- previously proposed TRD drill centre location (water depths of 400 m):
    - Sediment plume confined to the deepwater layers of the water column (Figure 6-41 of the draft EIS/ERD).
    - Modelling did not predict elevated suspended sediment concentrations or net sedimentation at Scott Reef Scott Reef shallow water benthic communities and habitats (<75 m water depth) including in the lagoons of North and deeper water coral habitat of South Scott Reef.
    - Net sediment deposition over the duration of the drilling program is approximately 35 cm at the previously proposed TRD drill centre location (**Figure 6-35** of the draft EIS/ERD).
- previously proposed TRA/TRB drill centre location (water depths of 460 m):
    - Sediment plume confined to the deep-water layers and was not expected to reach Scott Reef Scott Reef shallow water benthic communities and habitats (<75 m water depth) including in the lagoons of North and deeper water coral habitat of South Scott Reef (**Figure 6-36** of the draft EIS/ERD)).
    - Sedimentation was predicted to extend eastwards of Scott Reef, influenced by the north-west south-east tidally-induced currents.
    - Net sediment deposition at seabed over the duration of the drilling program is approximately 21 cm at the previously proposed TRA/TRB drill centre location **Figure 6-42** of the draft EIS/ESD).

Maximum suspended sediment concentrations in the water column in the vicinity of the release points (near the seabed) was predicted to reach 1250 mg/L at TRE, 1530 mg/L at TRD and 2500 mg/L at the previously proposed TRA/TRB drill centre location.

Management approach - Torosa wells in the State Proposal Area

Modelling indicated that the sea surface discharge of drill cuttings from the bottom-hole sections generated at the previously proposed TRE and TRD drill centre locations would potentially result in incursions of sediment plumes and associated increased sedimentation to portions of North and South Scott Reef including within the lagoons.

Given the potential sensitivities of Scott Reef shallow water benthic habitat (<75 m bathymetry) to sedimentation from drilling discharges, Woodside has committed to managing the drilling discharges (in particular, bottom-hole section discharges) at drill centre locations in the State Proposal Area (i.e. TRA, TRD, TRE and TRF) in such a manner to avoid potential impacts to Scott Reef shallow water benthic communities and habitats (<75 m water depth). This approach is as follows:

1. For each identified drill centre, drilling discharge modelling will be completed using final design data to assess the dispersion and fate of drill cuttings, residual drilling fluids on cuttings, as well as bulk discharge (collectively referred to as drilling or completions discharges). This information will be provided in the relevant Environment Plan.
    a. Where modelling can demonstrate that the discharge techniques and operational parameters (e.g. depth, rate and duration) are such that no impact to Scott Reef shallow water benthic communities and habitats (<75 m water depth) are predicted, drilling will be undertaken accordingly.
    b. For those scenarios where modelling suggests impact to Scott Reef shallow water benthic communities and habitats (<75 m water depth) may occur, alternative drilling discharge techniques and operational parameters (e.g. depth, rate and duration) will be assessed and selected to avoid potential impacts.
2. Where bottom-hole section drilling discharges are planned to be undertaken at the specified drill centre locations based on outcomes from the drilling discharge modelling, monitoring at discharge source will be undertaken to verify the model predictions and ensure they are appropriately conservative.
3. For those scenarios where modelling predicts impact to Scott Reef shallow water benthic communities and habitats (<75 m water depth), and no alternative discharge techniques and operational parameters are available, then the relevant drilling or completions discharges predicted to cause the impact will be transported to a suitable location (e.g. at a sufficient distance from the reef or onshore) for disposal.
4. For those scenarios where verification monitoring at the discharge point indicates a potential impact to Scott Reef shallow water benthic communities and habitats (<75 m water depth), then the management of drilling or completions discharges (as predicted to cause the impact) will be addressed by transportation to a suitable location (e.g. at a sufficient distance from Scott Reef or onshore) for disposal.

These management objectives are supported by a range of both feasible and industry proven management measures.

Assessment

The impacts of drilling or completion discharges on water and sediment properties, and benthic communities are well documented. The United Kingdom Offshore Operators Association (UKOOA) sponsored an extensive initiative to assess the issue of cuttings piles in the North Sea from operations between 1970 and 2000 (Danielsson et al., 2005). More recently, the International Association of Oil and Gas Producers (IOGP) published a report which reviews scientific literature on the fate and effects of ocean discharge of drill cuttings and associated drilling fluids from offshore oil and gas operations (IOGP, 2016). Drill cuttings have been studied specifically on the NWS of Australia (Oliver and Fisher, 1999; SKM, 2007). The effects of turbidity and sediment deposition on sensitive ecological receptors such as corals have also been the subject of many peer-reviewed studies (e.g. Fabricius, 2005).

Drilling or completions discharges have the potential to impact the marine environment through:

- temporary increase in TSS in the water column
- attenuation of light penetration as an indirect consequence of the elevation of TSS and the rate of sedimentation
- sediment deposition to the seabed leading to the alteration of the physio-chemical composition of sediments, and burial and potential smothering effects to sessile benthic biota
- potential contamination and toxicity effects to benthic and in-water biota from drilling fluids.

It should be noted that the following assessment is restricted to potential impacts to deepwater habitats around Scott Reef, given Woodside's commitment (see Section 8.2.6) to not undertake sea surface discharge from the bottom-hole sections that could potentially affect Scott Reef shallow water benthic habitats (<75 m water depth).

Change in sediment quality

Cuttings discharged at the seabed will result in localised cuttings piles on the seabed surrounding the wellhead, with a greater spread of cuttings expected to occur down current from the well site. Sediment quality can be impacted by drilling or completions discharges as the drill cuttings alter the particle size distribution and physico-chemical composition of sediments and from the introduction of contaminants (e.g. hydrocarbons and metals) from drilling fluids. This in turn can have an impact on benthic communities through sediment deposition causing burial and smothering, or toxicity effects from drilling fluids.

The modelling indicates that sediment deposition would potentially occur to a distance in the order of a couple of hundred metres from each well location (in the direction of the prevailing current). This assessment aligns with several studies which indicate that the spread of cuttings can be expected to be up to about 150 m from the discharge location (IOGP, 2016).

Change in water quality

The discharge of drill cuttings and unrecoverable fluids is expected to increase turbidity and TSS levels in the water column. Drilling or completions discharges are generally intermittent and of short duration during the drilling of a well. Nelson et al (2016) identified <10 mg/L as no effect or sub lethal minimal effect concentration, with Boesch and Rabalais (1987) demonstrating that surface discharges are likely to be confined to within 350 m - 1,500 m downstream from the discharge location.

The modelling (Section 6.3.15.3 of the draft EIS/ERD) indicates that both seabed and surface drilling discharges would result in impacts to water quality as a result of elevations in TSS and the introduction of low toxicity contaminants. This reduction in water quality will be temporary (i.e. limited to the duration of the activity, restricted to deep water (for Torosa drill centres in the State Proposal Area) and subject to rapid dispersion and dilution by prevailing currents, due to the open oceanic waters of the State Proposal Area.

Overall, given the predicted rapid dispersion of suspended sediments within the open ocean environment of the State Proposal Area, the short period of intermittent discharge and the generally low concentration of TSS within tens of metres of the discharge, any change in water quality and sediment associated with drill cutting discharge are expected to be temporary with a slight effect and with no long-term reduction in the environmental values of the State Proposal Area. In addition, the implementation of the proposed management approach for the proposed Torosa drill centres should ensure that impacts to Scott Reef shallow water benthic habitats (<75 m depth) are avoided.

Further discussion on the potential impacts to benthic habitats from drill cuttings discharge is presented in Section 8.3.5.

8.2.4.9 Marine discharges: subsea control fluids

A detailed description of the proposed discharge of subsea control fluids and an assessment of the potential impacts associated with the discharge is provided in Section 6.3.16 of the draft EIS/ERD.

The subsea hydraulic control system will have high pressure (HP) and low pressure (LP) circuits. The HP system will operate the downhole safety valve and the LP system will operate all other subsea valves. An open loop subsea control system will be adopted for the HP control systems, whereby the control fluid is pressurised on the FPSO facilities by the hydraulic accumulators and delivered to subsea valves via umbilicals. For the LP control system, a hybrid solution will be used.

The open loop HP hydraulic system will discharge a small amount (0.1 L) at the Christmas tree when testing or operating the downhole safety valve. The release will be at the wellhead subsea control module, typically at 350 m water depth or greater. The hybrid LP hydraulic system will utilise a contingency injection line in the umbilical in order to achieve a closed loop configuration. This hybrid system has no planned discharges and will only release hydraulic fluid if the system leaks or the contingency injection line is required due to failure of the primary injection line.

Control fluids are sourced from proprietary suppliers and are composed of low toxicity, water-based fluids. The specific control fluid has not yet been selected; however, such fluids are typically waterbased with additives such as monoethylene glycol (MEG) (usually about 40% of the total volume), lubricants, corrosion inhibitors, biocides and surfactants.

During drilling activities, control fluids will be discharged during function and pressure testing of the BOP control system. The maximum volume of control fluid that will be released to the marine environment per manifold is 1,900 L per year of water-based fluid containing ~3% active ingredient (40–68 L of control fluid additive).

Given the small volumes and solubility of the proposed water-based discharges, it is anticipated the fluids would be rapidly diluted (within tens of metres) in the prevailing currents adjacent to the discharge location on the seabed. Hence, the intermittent discharge of small volumes of subsea control fluid may result in a reduction in water quality that will be temporary (limited to the duration of the activity), restricted to deep water; and subject to rapid dispersion and dilution by prevailing currents due to the open oceanic waters of the State Proposal Area.

Due to the expected rapid dispersion and dilution by prevailing currents, and fact that discharged subsea fluid is not predicted to accumulate in sediments, no lasting change to sediment quality is predicted.

Given the minimum water depth at potential discharge locations (greater than 350 m), and the expected rapid dispersion and dilution by prevailing currents, exposure of plankton to the discharge is predicted to be negligible. In addition, the wide spread nature and rapid turn-over of plankton populations leading to relatively quick recovery times, ensures that any impact on local communities would be expected to recover relatively quickly (within weeks or months) (ITOPF, 2011).

Given this and the sparse nature of the deepwater benthic habitats in the State Proposal Area, no impacts to biota are predicted. Further, given the distance from the subsea infrastructure to Scott Reef and the depth of the discharge, this reduction in water quality is not expected to result in any lasting impacts to the environmental values of the State Proposal Area, including the Scott Reef system.

8.2.4.10 Marine discharges: hydrotest fluid

Hydrotest fluids are used for two distinct purposes; testing of the integrity of the flowlines and for preservation of the flowlines prior to the introduction of reservoir fluids. Hydrotest fluids may consist of a combination of seawater, biocides, corrosion inhibitors, oxygen scavenger, MEG and fluorescent dye.

The period of time the hydrotest fluid is left within the infrastructure as a preservation fluid will depend on the type of fluid selected and the proposed Browse to NWS Project schedule for construction and installation activities. It may be necessary to discharge and replace the hydrotest fluid if it is not providing an effective mitigation against integrity threats.

For the SURF infrastructure, the flowline and riser hydrotest fluid will most likely be returned to the FPSO facility and then discharged to sea in Commonwealth waters. However, discharge may occur in deep water at the manifolds or riser base FLETS for rigid flowlines.

For flowlines where the manifold is in the State Proposal Area, discharge will occur at the FPSO location (either from the FPSO or from the riser base FLETS) in order to maximise distance of the discharge from Scott Reef. However, for flowlines which are terminated at both ends within the State Proposal Area (specifically for TRE and TRF manifolds only), discharge of flowline hydrotest fluid in the State Proposal Area may be unavoidable. Given that the TRE and TRF manifolds are daisy-chain connected to other manifolds in the State Proposal Area and are not part of Torosa Phase 1 RFSU equipment, future engineering will consider the viability of alternatives to flowline hydrotest fluid discharge in the State Proposal Area, which will be described in a future Environment Plans. Minor hydrotest discharges associated with smaller pieces of subsea equipment may also occur in situ.

For the SURF flowlines (including those in the State Proposal Area), hydrotest fluids may consist of chemically treated seawater or a MEG/water mixture. The combination of constituents for the SURF flowlines are dependent on the flowline material type and on the period of preservation required.[1]

Hydrotest fluid volumes being discharged to the marine environment will vary depending on the flowline section to be tested. Volumes are estimated to be up to approximately 950 m^3 of hydrotest fluid for the TRE flowline and up to approximately 250 m^3 for TRF flowline. A subsea flowline hydrotest discharge is likely to take less than a day to complete. These discharges will occur for each piece of infrastructure during pre-commissioning.

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[1] *While the majority of subsea infrastructure will be flooded with hydrotest fluid post installation, some components will be pre-flooded with hydrotest fluid prior to installation.*

Previous modelling of SURF infrastructure

The size of the mixing zone associated with a hydrotest discharge from flowlines is dependent on the discharge characteristics (e.g. rate, volume, density etc.) and prevailing hydrodynamics. Woodside has previously performed hydrotest modelling for a range of discharge rates (4.8 m^3/min, 3.7 m^3/min, 1.85 m^3/min and 1.5 m^3/min), in water depths ranging from 130 m to 830 m on the North West Shelf, which is considered appropriate to support the impact assessment, in recognition that further hydrotest modelling will be completed to support the relevant Environment Plan.

The nearfield dispersion modelling indicated that due to the momentum of the discharges a turbulent mixing zone is created in the immediate vicinity of the discharge points. Following this initial mixing, the negatively-buoyant plumes are predicted to travel laterally in the water column and remain close to the seabed.

The far-field dispersion modelling indicated that based on an in-pipe chemical concentration of 600 ppm, the plume would achieve 600 dilutions to dilute to below 1 ppm (based on LC50 over 96 hours) in proximity to the discharge location, ranging at a distance from 50 m (130 m water depth; 1.5 m^3/min; summer; 95th percentile) to 300 m (844 m water depth; 4.8 m^3/min; summer; 95th percentile) downstream of the discharge point. Given the negative buoyancy of the plume, bathymetry of the location (steep reef slopes surrounding the discharge location), and lack of upwelling processes from the depth of discharge, regardless of the size of the mixing zone the zone of influence will remain restricted to depth and avoid Scott Reef shallow water benthic habitat (<75 m bathymetry).

While the modelling for the planned dewatering discharges are not directly comparable with regards to depth of discharge, the typical density and nearfield mixing profile near the seabed provides a good indication that potential impacts to benthic communities, fish or pelagic invertebrates would be limited and restricted to the deepwater location where the SURF infrastructure is located. Noting the results presented are also conservative as they assume that no processes other than dilution would reduce the source concentrations over time, and therefore can be considered as conservative outcomes.

MODU

The temporary production system on the MODU will be hydrotested for well unloading activities. This will be conducted using hydrotest fluids, whereby the temporary production system on the MODU flowlines will be pressurised with fluids and the pressure will be monitored to detect leaks, prior to discharge of the hydrotest fluids.

Contingency discharge

Contingency discharge of hydrotest fluids during construction (e.g. buckling and leaking of the flowline during installation) are possible but are a contingent planned activity to be undertaken due to an unplanned event. The requirement for contingency discharge is determined by the technical design specifications and performance criteria of the subsea infrastructure. Should these be compromised (i.e. failed welding joint) various repair strategies will be assessed and a decision made should the contingency be required. The volume of hydrotest fluid that would be discharged in the event of a wet buckle depends on the location, extent and repair method. The planned hydrotest discharge would not occur at the same time as contingency discharge. As such, it is considered that the impacts relating to this contingency activity (as a worst case) are consistent with the below assessment and no cumulative impacts would occur.

Hydrotest fluid toxicity

Due to the proposed chemical additives with the hydrotest fluid (i.e. biocides, corrosion inhibitors, oxygen scavenger, fluorescent dyes and MEG), the discharges have the potential to impact sensitive receptors within the discharge area of influence, primarily through toxicological effects ranging from the inhibition of key biological processes (e.g. reproduction) to mortality. In considering the potential impacts to receptors it should be noted that the activity is planned during commissioning, with no ongoing discharge of hydrotest fluids during the normal operations.

MEG, which may be used in the SURF flowlines, is commonly used as a hydrate inhibitor within oil and gas developments. The chemical itself is clear and colourless, with a low volatility and miscible with water; however, no hydrolysis of the compound is expected in surface waters (WHO, 2000). MEG is listed as ‘E’ category fluids under the Offshore Chemical Notification Scheme (OCNS) and are listed on the Oslo Paris Commission (OSPAR) PLONOR (‘pose little or no risk to the environment’) list. In addition, the compound has little or no capacity to bind to particulates and will be mobile in soil (WHO, 2000). Rapid degradation has been reported in surface waters, with a generally low toxicity to aquatic organisms. Direct toxicity testing of neat MEG, on eight, mainly tropical species, representing seven taxonomic groups, established the lowest no observable effect concentration (NOEC) for sea urchin fertilisation of 130 mg/L (Jacobs, 2019). While MEG may result in highly localised, temporary and minor change in water quality in the immediate vicinity of the discharge point, it will dilute rapidly below levels that could cause impacts to marine biota.

Fluorescein dye is typically selected for use as a leak detection dye due to its low toxicity, availability, low cost, water solubility and stability, and ease of detection. In addition, rapid breakdown of fluorescein dye following exposure to sunlight suggests that concentrations likely to be encountered by organisms in the receiving environment would be low (Walthall and Stark, 1999). During discharge the dye may result in a temporary localised discoloration in the immediate vicinity of the discharge point on the seabed; however, as the dye is water soluble, it will rapidly dilute in the marine environment with no anticipated toxicity effects on marine organisms.

Due to the addition of oxygen scavengers within the hydrotest fluid, the discharge will have a lower dissolved oxygen level than the surrounding seawater. However, oxygen levels are anticipated to rapidly achieve background levels soon after discharge with any impacts on the surrounding waters expected to be temporary and highly localised. In addition, as the hydrotest fluid is planned to remain inside the pipelines and infrastructure for several months, the toxicity of residual chemicals will be markedly reduced over time, through natural decay and degradation, further reducing the potential impacts associated with the discharge.

Assessment of impacts

The presence of chemical additives in discharged hydrotest fluids is expected to result in a temporary decline in water quality around the discharge locations. For the SURF discharges, the plume is expected to travel in close proximity to the seabed which means the temporary change in water quality will be restricted to deep waters. As outlined in the draft EIS/ERD **Section 5.2.5.7**, while there is some evidence of localised intrusions of cooler water around the western and eastern entrances to the channel between North and South Scott Reef during spring tides, there is no evidence of persistent upwelling or downwelling currents around Scott Reef (Green et al., 2019b). Hence, the discharge would be subject to rapid dispersion and dilution by prevailing currents, due to the open oceanic waters of the Project Area. In addition, the low toxicity hydrotest fluids will degrade and decay once released. As such no lasting effect on water quality is predicted.

8.2.4.11 Unplanned marine discharges: hazardous and non-hazardous inorganic waste

A detailed assessment of the potential risks associated with the unplanned discharge of hazardous and non-hazardous inorganic wastes is provided in **Section 6.3.14** of the draft EIS/ERD.

There is no planned discharge of hazardous or non-hazardous inorganic waste within the State Proposal Area and, as such, no impact to marine environmental quality is expected from such discharge. As described in **Section 6.3.14** of the draft EIS/ERD, however, an unplanned loss of hazardous and non-hazardous inorganic waste during transfer, handling and storage may be caused by human error, equipment or poor weather conditions, resulting in an accidental release of waste to the State Proposal Area.

In the event of an accidental discharge to the marine environment, discharged materials in liquid or sludge form would be subject to rapid dispersion and dilution by prevailing currents, due to the open oceanic waters of the State Proposal Area. Given the typically small volumes and temporary duration of accidental discharge events, these would result in a temporary and highly localised reduction in water quality. Under normal operating conditions, drilling and vessel activity will be limited to the deep waters in proximity to the location of the proposed development wells and subsea infrastructure so any accidental discharge to the marine environment is unlikely to impact the Scott Reef system.

8.2.4.12 Unplanned hydrocarbon releases

A detailed assessment of the potential risks associated with unplanned hydrocarbon releases is provided in **Section 6.3.21** of the draft EIS/ERD. Quantitative hydrocarbon spill modelling of various worst-case hydrocarbon release scenarios is presented in **Section 6.3.21.3** of the draft EIS/ERD. This included modelling of a loss of well integrity scenario at the TRA-C well (Scenario 1), which represents the worst-case scenario for activities within the State Proposal Area. The summarised result of the modelling of Scenario 1 are presented in **Table 6-158** and **Figure 6-51** of the draft EIS/ERD.

Based on the outcomes of quantitative spill modelling, hydrocarbon spills resulting from the proposed Browse to NWS Project have the potential to significantly impact regional water and sediment quality including within the State Proposal Area. However, the occurrence of hydrocarbon spills is considered highly unlikely and the extent of impacts would depend on the exposure concentration, duration and degree of weathering of the hydrocarbons.

8.2.4.13 Cumulative impacts

Given the distance of the State Proposal Area from other operating developments in the region, it is not considered credible that cumulative impacts from the proposed Browse to NWS Project (or the Proposal) and other developments will occur.

With respect to the Commonwealth waters component of the proposed Browse to NWS Project, other than potentially hydrotest discharges, it is not expected that planned marine discharges to Commonwealth waters will contribute to impacts on marine environmental quality within the State Proposal Area (**Chapter 6** of the draft EIS/ERD). Operational discharges (i.e. PW and cooling water) from the FPSO will be managed in Commonwealth waters to ensure the defined threshold values (e.g. 99% species protection or no effect concentrations) at the State waters 3 nm boundary are met 95% of the time, based on dispersion modelling results.

While not considered the base-case, the potential discharged of hydrotest fluids from the BTL at the Torosa pipeline end terminal (Section 6.3.17 of the draft EIS/ERD) may result in a temporary reduction in water quality within the State Proposal Area. Modelling (Section 6.3.17.3 of the draft EIS/ERD) indicates this would be restricted to deep waters surrounding the pipeline end terminal (>400 m depth). Given this, and the fact this discharge would be a one-off event that would occur prior to the commencement of operations, the discharge of hydrotest fluid from the BTL at the Torosa PLET would not be expected to contribute significantly to cumulative impacts to marine environmental quality within the State Proposal Area.

8.2.5 Assessment of Impacts

Reductions in water quality and sediment quality are predicted to occur in the State Proposal Area as a result of increased turbidity and the introduction of contaminants via marine discharges. These impacts are predicted to arise primarily from the discharge of drill cuttings and fluids during development drilling, with less significant impacts predicted to occur throughout the duration of the proposed Browse to NWS Project activities (e.g. through subsea discharges from the subsea infrastructure).

There is a large body of knowledge indicating a discharge of cuttings with adhered fluids dilutes rapidly. These studies have found that that within 100 m of the discharge point, a drilling cuttings and fluid plume released at the surface will have diluted by a factor of at least 10,000, while J.M. Neff (2005) stated that in well-mixed oceans waters (as is likely to be the case within the drilling area), drilling fluid was diluted by more than 100-fold within 10 m of the discharge.

The majority of planned marine discharges would be subject to rapid dispersion and dilution by prevailing currents, due to the open oceanic waters of the State Proposal Area. As such, reductions in water and sediment quality would be temporary and highly localised, with no subsequent impact to marine biota predicted. The exception to this would be the discharge of drill cuttings that would result in the smothering of benthic biota in the immediate vicinity (within a distance in the order of 200 m) of the drilling locations.

Given the proposed location of the wells and subsea infrastructure will be in deep waters (>300 m), away from Scott Reef and that under normal operating conditions the drilling and vessel activity will be limited to the immediate vicinity of the subsea infrastructure, it is considered unlikely that marine discharges will impact Scott Reef shallow water benthic communities and habitats (<75 m water depth). In accordance with the precautionary principle, however, given the potential sensitivities of Scott Reef benthic communities and habitats to sedimentation from surface drill cuttings discharges, Woodside has committed to managing the discharges of drill cuttings and fluids at TRA, TRD, TRE and TRF drill centre locations in such a manner that impacts to Scott Reef shallow water benthic communities and habitats (<75 m water depth) are avoided. Section 8.2.6 outlines a range of proven mitigation measures capable of achieving this outcome.

In summary, given the low toxicity of the discharges, the localised scale and temporary nature of potential changes to water and sediment quality, these changes are not expected to result in any subsequent impacts to biota or the environmental values of the Scott Reef system. Impacts will be largely confined to the benign deep-water seabed between North and South Scott Reef. No long-term change in water or sediment quality or last adverse impacts to biota is expected to occur and aside from the drill cuttings accumulation in the immediate vicinity of the wells, no lasting changes to the physical or chemical properties of waters and sediments relative to a natural state are predicted.

Given no lasting impacts are expected to water quality or biota, no subsequent impact to State managed fisheries are expected. In addition, the localised and temporary nature of the predicted reduction in water and sediment quality mean that no impacts to State marine parks (the closest being over 400 km from the State Proposal Area) are anticipated to occur. As no impacts to the Scott Reef system are expected, no impacts are expected to the Scott Reef Nature Reserve.

Given the minimal extent and magnitude of changes to marine environmental quality within the State Proposal Area as a result of the proposed Browse to NWS Project (or Proposal), impacts are expected to be consistent with the EPA objective for the environmental factor - marine environmental quality.

8.2.6 Mitigation

Chapter 8 of the draft EIS/ERD presents the overarching HSE management approach Woodside will implement for the proposed Browse to NWS Project.

Environmental Quality Management Plan

As recommended in the WA EPA Technical Guidance – Protecting the Quality of Western Australia's Marine Environment (EPA, 2016c), an Environmental Quality Management Plan (EQMP) will be prepared and implemented for the Proposal. The EQMP will only apply to the State Proposal Area. The EQMP will be developed using the principles and approaches outlined in the EPA's technical guidance.

The EPA's technical guidance outlines the following elements within an Environmental Quality Management Framework (EPA, 2016c):

- **Environmental Values (EVs):** These are values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health and which require protection from the effects of pollution, waste discharges and deposits.

- **Environmental Quality Objectives (EQOs):** These are high level management objectives that describe what must be achieved to protect each EV.
- **Levels of Ecological Protection (LEPs):** Four levels of ecological protection (LEPs) are provided for the EQO maintenance of ecosystem integrity so that areas identified as important for conservation and biodiversity protection can be maintained in their natural state while recognising that in other parts of the marine environment there are societal uses that may preclude a high level of ecological protection from being achieved (e.g. port operations or use of marine waters for waste disposal). LEPs are not defined by current condition but are intended to represent long-term objectives for environmental quality.
- **Environmental Quality Criteria (EQC):** These represent scientifically based limits of acceptable change to a measurable environmental quality indicator that is important for the protection of the associated EV. EQC are divided into relatively simple and easy to measure environmental quality guidelines (EQGs) and more robust environmental quality standards (EQSs).

Environmental Values, EQOs and LEPs for the State Proposal Area component of the proposed Browse to NWS Project have been identified as part of the development of the draft EIS/ERD. When determining the proposed LEPs, consideration has been given to potential impacts to marine environmental quality during construction, commissioning and operations, and the planned staged development of the proposed Browse to NWS Project, where construction and commissioning activities such as drilling and completions of future drill centres may occur simultaneously with operations. As such, separate LEPs have been proposed for construction activities (including commissioning) and for operations. The following LEPs are proposed:

Construction activities

- Moderate LEP – Moderate LEPs are proposed for all areas within a 1,000 m radius of each drill centre and 500 m around all subsea infrastructure. A moderate LEP has been proposed in this area given the predicted deposition of drill cuttings above ecological thresholds for a radius in the order of a couple of hundred meters from each well, the discharge of cement for a radius of approximately 50 m from each well; the installation of the subsea infrastructure (including seabed preparation); and one-off hydrotest fluid discharge from the flowlines.
- High LEP - A high LEP is proposed for the deep waters of the State Proposal Area where the subsea infrastructure will be located (except where designated a moderate LEP). A high LEP is also proposed along the eastern edge of the State Proposal Area where there is potential for one off hydrotest discharge from the BTL (in Commonwealth waters) to temporarily incur into the State Proposal Area. Seabed disturbance may occur from anchoring within the high LEP.
- Maximum LEP - A maximum LEP is proposed for all other areas within the State Proposal Area. This includes all Scott Reef shallow water benthic communities and habitats (<75 m water depth).

Operations

- Moderate LEP – Moderate LEPs are proposed for all areas within a 1,000 m radius of each drill centre. A moderate LEP has been proposed in these areas given the predicted deposition of drill cuttings and cement during construction, as well as the physical presence of the wells and manifolds and subsea fluid discharge from the wells during operations.
- High LEP - A high LEP is proposed for the deep waters of the State Proposal Area where the subsea infrastructure will be located (except where designated a moderate LEP).
- Maximum LEP - A maximum LEP is proposed for all other areas within the State Proposal Area. This includes all Scott Reef shallow water benthic communities and habitats (<75 m water depth).

The Proposed LEPs are shown in Figure 8-1 and Figure 8-2.

The limits of acceptable change for each of the LEPs are detailed in Table 8-4.

Table 8-4 Limits of Acceptable Change to State Proposal Area Marine Environmental Quality

Key elements	Limits of acceptable change	Maximum LEP	High LEP	Moderate LEP
Ecosystem processes (e.g. primary production, nutrients cycles, food chains)	Ecosystem processes are maintained within the limits of natural variation (no detectable change)	✓	✓	
	Small changes in rates, but not types of ecosystem processes			✓
Biodiversity (e.g. variety and types of naturally occurring marine life)	Biodiversity as measured on both local and regional scales remains at natural levels (no detectable change)	✓	✓	✓
Abundance and biomass of marine life (e.g. number or density of individual animals, the total weight of plants)	Abundances and biomasses of marine life vary within natural limits (no detectable change)	✓	✓	
	Small changes in abundances and/or biomasses of marine life			✓
The quality of water, biota and sediment (e.g. types and levels of contaminants such as heavy metals, dissolved oxygen content, water clarity)	Levels of contaminants and other measures of quality remain within limits of natural variation (no detectable changes)	✓		
	Small detectable changes beyond limits of natural variation but no resultant effect on biota		✓	
	Moderate changes beyond limits of natural variation but not to exceed specified criteria			✓

The purpose of the EQMP will be to detail how the EQO outlined in Table 8-4 will be met, including planned management, monitoring and reporting. In accordance with the EPA's technical guidance (EPA, 2016) the EQMP will include:

- a description of the system to be monitored
- the pressures or threats to environmental quality
- an objective outlining the reason for monitoring and management
- duration of the monitoring program
- the indicators to be measured with a rationale for their use
- monitoring/sampling methodology and rationale (including site locations, frequency, depth, equipment, etc.)
- analytical methods and limits of reporting for samples
- clear, measurable and auditable EQC for each indicator and the statistical methods for interpreting monitoring data against the EQC
- the actions triggered when an EQG is exceeded
- management responses triggered when an EQS is exceeded
- reporting mechanisms and timing.

Specific proposed measures to mitigate and manage unavoidable impacts from planned activities and reduce the environmental risk associated with unplanned events and incidents are presented in Chapter 6 of this draft EIS/ERD and these will be incorporated into the EQMP where relevant. Measures presented in the draft EIS/ERD will also be incorporated into activity-specific Environment Plans to be submitted for acceptance by DMIRS prior to the activity commencing within the State Proposal Area.

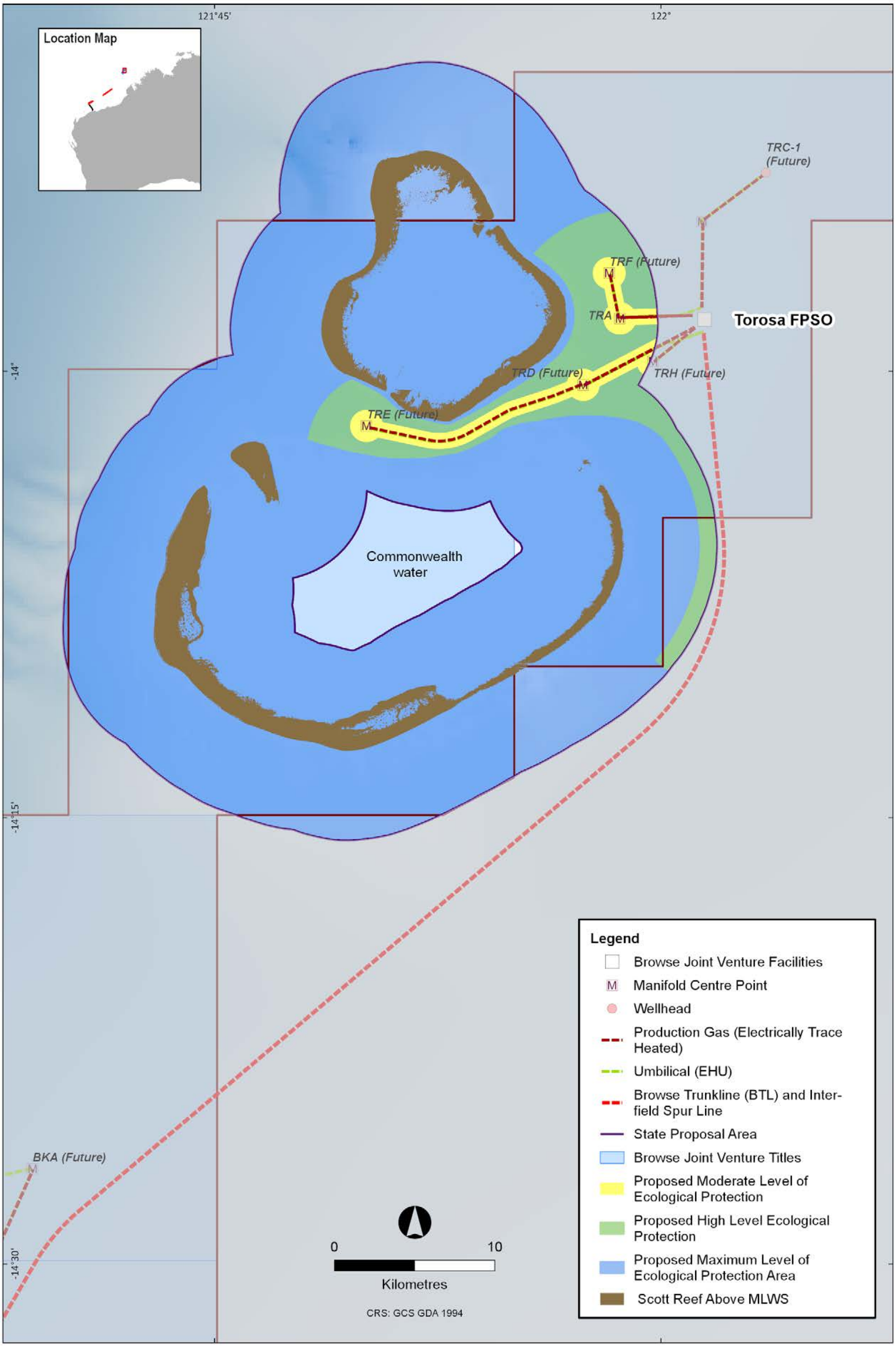

Figure 8-1 Proposed State Proposal Area Levels of Ecological Protection (LEPs) – Construction activities

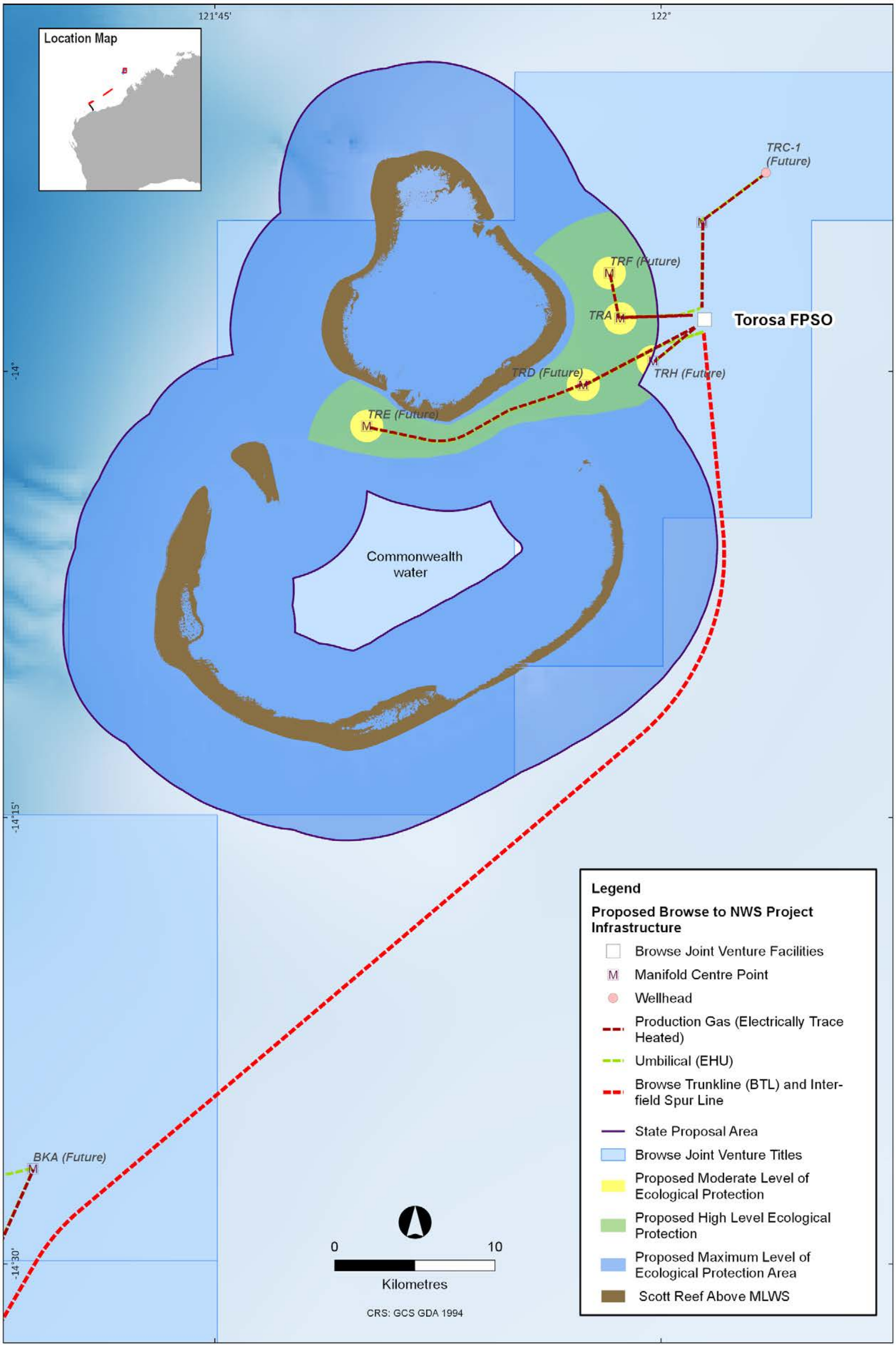

Figure 8-2 Proposed State Proposal Area Levels of Ecological Protection (LEPs) – Operations

8.2.7 Predicted Outcome

Impacts to marine environmental quality within the State Proposal Area have been reduced by locating the FPSO facilities, BTL and inter-field spur line outside the State Proposal Area and siting infrastructure within the State Proposal Area in deep waters off Scott Reef.

Impacts will be further reduced by implementing mitigation and management measures, the majority of which are standard maritime and offshore oil and gas industry practice. However, given the potential sensitivities of Scott Reef shallow water benthic communities and habitats to sedimentation from drilling discharges, Woodside has committed to managing the drilling discharges (in particular bottom hole discharges) at drill centre locations in the State Proposal Area (i.e. TRA, TRD, TRE and TRF) in such a manner that avoids impacts to Scott Reef shallow water benthic communities and habitats (<75 m water depth) (refer to **Section 8.2.6**). Implementation of this management approach will be assured through activity specific Environment Plan(s) under Petroleum Legislation.

Taking proposed mitigation and management measures into account and considering the limited scope and scale of the Proposal (with no permanent surface facility or vessel presence in the State Proposal Area) plus the overall phasing of Proposal, impacts to water quality, sediments and biota as a result of the Proposal are not predicted to result in any reduction of the environmental values of the Scott Reef shallow water benthic communities and habitats (<75m water depth).

As described in **Section 8.2.6**, it is expected a maximum LEP will be achieved in the majority of the State Proposal Area during construction and operations. A high LEP will be achieved for the deep waters of the State Proposal Area where subsea infrastructure will be located, except where a moderate LEP is proposed within a 1000 m radius of each drill centre during construction and operations; and 500 m around subsea infrastructure during construction. Further, an area of moderate LEP is proposed during construction where the potential discharge of hydrotest fluid from the BTL (in Commonwealth waters), may incur into the State Proposal Area. An EQMP will be prepared and implemented to achieve this outcome.

The EPA Technical Guidance for Protecting the Quality of Western Australia's Marine Environment (EPA, 2016c) states that the objective for LEPs are:

- A maximum level of ecological protection would require activities to be managed so that there were no changes beyond natural variation in ecosystem processes, biodiversity, abundance and biomass of marine life or in the quality of water, sediment and biota.
- The objective for a high level of ecological protection is to allow for small measurable changes in the quality of water, sediment and biota, but not to a level that changes ecosystem processes, biodiversity or abundance and biomass of marine life beyond the limits of natural variation.
- A moderate level of ecological protection may be applied to relatively small areas within inner ports and adjacent to heavy industrial premises where waste discharges from current and/or historical activities may have compromised a high level of ecological protection.

Given the majority of the State Proposal Area will be maintained at a maximum or high LEP and the moderate LEP portion corresponding with deep water benign seabed, it is expected that the WA EPA environmental objective *"To maintain the quality of water, sediment and biota so that environmental values are protected"* will be achieved for the Proposal; and the predicted impacts on marine environmental quality within the State Proposal Area are considered **Acceptable**.

8.3 Key Environmental Factor – Benthic Communities and Habitat

8.3.1 EPA Objective

The EPA objective for benthic communities and habitat is *"to protect benthic communities and habitats so that biological diversity and ecological integrity are maintained"* (EPA, 2016c).

8.3.2 Policy and Guidance

The following policy and guidance have been considered in relation to the EPA environmental factor - benthic communities and habitats.

EPA Policy and Guidance

- Statement of Environmental Principles, Factors and Objectives (EPA, 2016b)
- WA EPA Environmental Factor Guideline - Benthic Communities and Habitats (EPA, 2016b)
- WA EPA Technical Guidance - Protection of Benthic Communities and Habitats (EPA, 2016c)
- Technical Guidance - Protecting the Quality of Western Australia's Marine Environment (EPA, 2016c).

Other Policy and Guidance

Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018).

8.3.3 Receiving Environment

The characteristics of the marine environment of the Browse Development Area are described in detail in **Chapter 5** of the draft EIS/ERD. The benthic communities and habitats within the State Proposal Area can broadly be delineated into two areas, Scott Reef benthic communities and habitats and the deepwater benthic communities and habitats. As described in **Chapter 6** of the draft EIS/ERD, for the purpose of the environmental impact and risk assessment undertaken for the proposed Browse to NWS Project, Scott Reef is considered as the area above the 75 m bathymetric contour within the 3 nm State waters boundary. The deepwater communities are defined as those communities below the 75 m bathymetric contour and make up the remainder of the State Proposal Area. It should be noted that, as shown in **Figure 5-1**, all proposed subsea infrastructure will be located within the deepwater habitats away from Scott Reef. As such, no direct disturbance of the Scott Reef benthic communities and habitats will occur, with disturbance limited to the deepwater habitats of the State Proposal Area.

Scott Reef habitats and communities

The Scott Reef system consists of two shelf atolls, North Scott Reef and South Scott Reef, separated by a deep channel. The Scott Reef system is characterised by extensive benthic primary producer habitat (i.e. corals, seagrass, macroalage and filter feeders). At least 14 distinct benthic habitat types have been defined that can broadly be grouped into shallow water habitats (<30 m), deep lagoonal habitats (between 30-70 m) and deepwater slope habitats (70-500 m) (**Figure 8-3**). The shallow water habitats occupy 170.5 km^2 and 147.1 km^2 at the South and North Scott Reef, respectively, and include reef crests, flats and slopes, patch reefs and the shallow water lagoons. These habitats support more diverse coral communities than deeper waters; however, they are more susceptible to natural impacts such as thermally induced coral bleaching and cyclone damage. The deepwater lagoonal habitats of South Reef are extensive, covering approximately 289 km^2.

The Scott Reef system is largely unaffected by many of the anthropogenic stressors that affect coral reefs close to the coast, due to its isolation, distance from shore and the absence of human settlement. However, the reef and its benthic communities and habitats are not without exposure to physical disturbances and pressures including tropical cyclones, anomalous sea surface temperatures and disease.

Section 5.3.2.2 of the draft EIS/ERD provides further details on the status of the benthic communities and habitats within the Scott Reef system.

Deepwater habitats and communities

The deepwater benthic habitats of the State Proposal Area are consistent with the remainder of the Browse Development Area. Survey findings for the benthic communities inhabiting the predominantly soft sediments of the deep water benthic habitats where the subsea infrastructure will be installed demonstrated that these areas were characterised by fine sediments with infaunal polychaetes dominant and sparsely distributed epifauna observed (i.e. bryozoans, brittlestars, basketstars and sea anemones) (Gardline Marine Services Pty Ltd, 2009b). **Section 5.3.2.1** of the draft EIS/ERD provides further details of these communities and habitats.

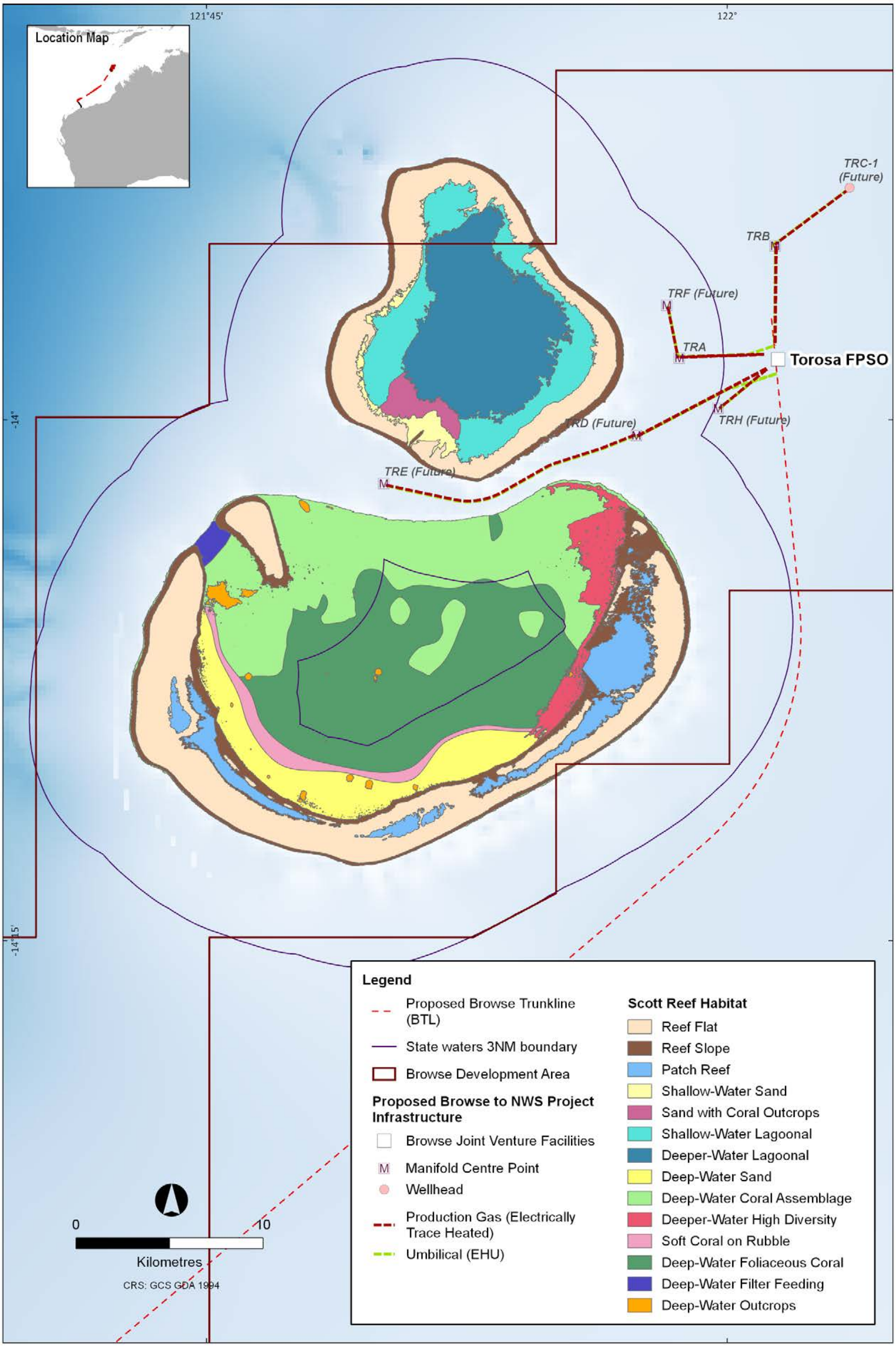

Figure 8-3 Scott Reef Habitat Map (Smith et al., 2006)

8.3.4 Potential Impacts

8.3.4.1 Summary of Identified Impacts and Risks

Table 8-5 summarises the sources of potential impact to benthic communities and habitats arising from the Proposal. Table 8-5 is followed by a detailed description of the potential direct, indirect and cumulative impacts. An assessment of the significance of these impacts on benthic communities and habitats and a conclusion on the acceptability of the impacts in relation to the EPA environmental objective is presented in Section 8.3.5.

Table 8-5: Sources of Potential Impact to Benthic Communities and Habitats from the Proposal

Aspect	Proposal Phase[1]					Source (in State jurisdiction
	Dr	I	C	O	De	
Planned (routine and non-routine activities)						
Physical presence: light emissions	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating in the State Proposal Area Intermittent flaring from the MODU
Physical presence: seabed disturbance and disturbance to other users	✓	✓		✓	✓	Development of the production wells Installation of subsea infrastructure Wet storage of infrastructure prior to installation MODU anchors IMR activities
Underwater noise	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating in the State Proposal Area VSP/DAS during well development Piling for MODU anchor installation (if required) Seabed preparation Helicopter movements
Marine discharges: sewage and sullage	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating in the State Proposal Area
Marine discharges: treated utility water, chemical and deck drainage	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating in the State Proposal Area
Marine discharges: produced water	✓					MODU during well unloading activities
Marine discharges: cooling water	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating in the State Proposal Area
Marine discharges: drilling and completion discharges	✓					MODU during drilling activities
Marine discharges: subsea control fluids	✓	✓	✓	✓	✓	Subsea infrastructure BOP during drilling ROVs
Marine discharges: hydrotest fluid	✓	✓	✓	✓		Temporary production system on MODU Integrity testing of subsea infrastructure
Production Activities: Seabed Subsidence				✓		Extraction of reservoir fluids
Unplanned events and incidents						
Marine discharges: hazardous and non-hazardous waste inorganic waste	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating in the State Proposal Area

Aspect	Proposal Phase[1]					Source (in State jurisdiction
	Dr	I	C	O	De	
Unplanned hydrocarbon releases	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating in the State Proposal Area Subsea infrastructure
Physical Presences (Unplanned): Invasive Marine Species	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating in the State Proposal Area

1 Dr = Drilling; I = Installation; C = Commissioning; O = Operation; De = Decommissioning

8.3.4.2 Physical presence: seabed disturbance

Where present, benthic epifaunal and infaunal communities in the deep waters of the State Proposal Area will be impacted by the temporary and permanent installation of physical infrastructure on the seabed, resulting in modification of habitats, smothering of biota and temporary reductions in water quality from sediment re-suspension and sedimentation. Due to the distance of the proposed subsea infrastructure to Scott Reef, no impacts to the environmental values of the Scott Reef system will occur as a result of seabed disturbance.

A detailed description of the planned seabed disturbance and an assessment of the potential impacts associated with seabed disturbance is provided in **Section 6.3.1** of the draft EIS/ERD.

The WA EPA Technical Guidance - Protection of Benthic Communities and Habitats provides the following definitions with respect to impacts to benthic communities and habitats (EPA, 2016c):

+ Permanent loss refers to direct removal or destruction of benthic communities and/or their habitats. Permanent loss of benthic communities and their associated habitats would commonly be associated with activities such as excavation or burial. In almost all cases these activities directly modify the benthic community and its habitat so significantly that the impacted community would not recover to the pre-impact state.
+ 'Serious damage' means damage to benthic communities and/or their habitats that is effectively irreversible or where any recovery, if possible, would be unlikely to occur for at least 5 years. Serious damage is most often associated with indirect effects of development activities such as alteration of natural groundwater hydrology (e.g. leading to impacts on dependent mangroves) or chronically elevated suspended sediment levels in the water column (e.g. leading to reduced benthic light and impacts on dependent seagrass or coral communities).
+ 'Reversible impacts or loss' refer to the situation where impacts or losses of benthic communities occur, but there is confidence that the community, and the ecological services it provides, will fully recover within five years.

Seabed disturbance in the State Proposal Area is expected to be approximately 4.15km^2 and will be limited to deep water habitats and communities. No disturbance of the Scott Reef shallow water benthic communities and habitats (<75 m water depth) is planned. **Table 8-6** provides an overview of the extent of seabed disturbance in the State Proposal Area. Note that these disturbance estimates include indirect disturbance from drilling discharges which are address in **Section 8.3.4.9**.

This disturbance will result in the permanent loss of up to 0.31km^2 (including 25% contingency) of deepwater habitat for the development of the wells and installation of subsea infrastructure. This is the area lost directly due to the infrastructure footprint. It should be noted that this permanent loss may be partially compensated by the creation of artificial hard substrate habitat (i.e. subsea infrastructure) which may be colonised by epifaunal organisms.

The contingency includes allowance for temporary wet storage during construction, pre lay and post lay of subsea infrastructure activities, allowance for a broader well radius for potential cementing and sedimentation, and other disturbance associated with MODU piling/anchoring (if required).The remaining 3.84 km^2 (including 25% contingency) of seabed disturbance will result from temporary indirect impact associated with wet storage of temporary infrastructure and the installation of subsea infrastructure. This will result in reversible loss of deepwater benthic habitat, with benthic biota expected to recolonise the area once the permanent infrastructure is installed and the temporary infrastructure is removed. Studies indicate that benthic infauna and epifauna recover relatively quickly, with substantial recovery in deepwater benthic communities within three to ten years (Jones et al., 2012).

Given the relatively sparse nature of the deep water benthic communities and habitats of the area to be disturbed (**Section 5.3.1.2** of the draft EIS/ERD), the small area of permanent disturbance (relative to the total area of similar habitat available regionally); and expected recolonisation of the seabed with similar benthic biota after the removal of temporary infrastructure, seabed disturbance within the deep waters of the Project Area is not predicted to impact biological diversity or ecological integrity.

Table 8-6 Indicative extent of seabed disturbance within the State Proposal Area

	Description	No.	Direct Disturbance (km²) (Permanent Loss)	Indirect Disturbance (km²) (Reversible Loss)	Total (km²)
Drilling and Completions					
Wells	Torosa	24	0.19	2.83	3.02
SURF Footprint					
Flowline network	Torosa	1	0.06	0.24	0.30
Total Expected			**0.25**	**3.07**	**3.32**
Contingency (25%)			0.06	0.77	0.83
Total (including Contingency)			**0.31**	**3.84**	**4.15**

Basis:

1. *Wells have a direct impact radius of 50 m and a total radius of 200 m.*
2. *Flowlines have a 2 m corridor direct impact and a 10 m corridor total impact.*

This estimate includes subsea disturbance from all major infrastructure sources. The contingency includes allowance for temporary wet storage during construction, pre lay and post lay of subsea infrastructure activities, allowance for a broader well radius for potential cementing and sedimentation, and other disturbance associated with piling/anchoring (if required)

8.3.4.3 Physical presence: light

Potential impacts to shallow benthic communities and habitats (i.e. corals) from light emissions are described in **Section 6.3.3** of the draft EIS/ERD. Theoretically, there is the potential for impacts to shallow water coral communities from light emissions from the MODU and vessels within the State Proposal Area, with coral colonies particularly sensitive to changes in ambient environmental conditions, with natural factors such as nocturnal moonlight cycles and daily light/dark cycles providing cues for reproduction (i.e. spawning) (Harrison and Wallace, 1990).

Light modelling results (**Section 6.3.3** of the draft EIS/ERD) indicate that Scott Reef is expected to receive light emission levels of less than 0.01 Lux from the MODU operating in the channel between North Scott Reef and South Scott Reef. Such light levels are less than a comparable full moon and therefore it is not considered that light emissions from the MODU or vessels associated with the proposed activities within the State Proposal Area will be of sufficient intensity to affect coral reproduction or spawning events. In addition, no permanent surface facilities to emit light will be present in the State Proposal Area during operations.

8.3.4.4 Underwater noise

Potential impacts to shallow benthic communities and habitats (i.e. corals) from underwater noise emissions are described in **Section 6.3.8** of the draft EIS/ERD. As discussed in **Section 6.3.8.3** of the draft EIS/ERD, Woodside's Maxima Study on seismic noise on Scott Reef estimated that corals would require received levels of PK-PK exceeding 260 dB re 1 μPa (SPL) to induce injury (Hastings, 2010). The modelling indicates that sound levels reaching Scott Reef from the proposed activities do not reach these levels and as such no impact to corals from underwater noise resulting from the proposed activities is predicted to occur. Likewise modelling of the VSP activities indicates that the sound level associated with no effect (Heyward et al., 2018) was not reached. As such, no impacts to corals are expected to occur.

8.3.4.5 Marine discharges: sewage and sullage

An assessment of the potential impact on marine environmental quality from the discharge of sewage and sullage from project vessels and the MODU is presented in **Section 8.2.4**. This assessment concluded that changes to the physical and chemical properties of the marine water would be temporary and highly localised (discharge diluted to 1% of its original concentration with 50 m). No change to the physical or chemical properties of sediments are expected due to the depth of the water where treated sewage and sullage would be discharged.

Given the water depth at the discharge locations (>300 m), it is not predicted that the this change in water quality will affect the deepwater benthic habitats of the State Proposal Area. Given the distance from the discharge to Scott Reef and rapid dispersion predicted (refer to **Section 8.2.4.4**), no effect on Scott Reef benthic communities and habitats is expected to result from the discharge of treated sewage and sullage in the State Proposal Area.

8.3.4.6 Marine discharges: treated utility water, chemical and deck drainage

An assessment of the potential impact on marine environmental quality from the discharge of treated utility water, chemical and deck drainage from project vessels, installation vessels and the MODU is presented in Section 8.2.4. This assessment concluded that treated utility water, chemical and deck discharges would result in temporary change in water quality in the immediate vicinity of the discharge. Given the water depth at the discharge location (>300 m) and distance to Scott Reef from where these discharges would occur, this temporary and highly localised change to water quality is not expected to have any impacts to either the deepwater benthic communities and habitats of the State Proposal Area or the benthic communities and habitats associated with Scott Reef.

8.3.4.7 Marine discharges: produced water

As detailed in Section 8.2.4, given the small percentage that the PW component makes of the overall discharge from the MODU during well unloading, this discharge is addressed as part of the assessment of discharges during drill cuttings and fluids.

8.3.4.8 Marine discharges: cooling water

An assessment of the potential impact on marine environmental quality from the discharge of cooling water from project vessels, installation vessels and the MODU is presented in Section 8.2.4. This assessment concluded that cooling water discharges would result in temporary change in water quality in the immediate vicinity of the discharge. Given the water depth at the discharge location (>300 m) and distance to Scott Reef from where these discharges would occur, this temporary and highly localised change to water quality is not expected to have any impacts to either the deepwater benthic communities and habitats of the State Proposal Area or the benthic communities and habitats associated with Scott Reef.

8.3.4.9 Marine discharges: drilling and completions discharges

A detailed description of the planned discharge of drill cuttings and fluids is provided in Section 8.2.4.8. Section 8.2.4.8 focuses largely on the water quality and sedimentation aspects of this impact whereas this section focuses largely on benthic fauna impacts associated with the aspect.

Change in water quality

The assessment of the potential impact on marine environmental quality (water quality, sediments and biota) from the discharge of drill cuttings and fluids from the MODU during drilling and completions activities presented in Section 8.2.4 concluded that change in to water quality (through elevated TSS and the introduction of contaminants) would be temporary and localised with no subsequent impacts to biota predicted.

Cement discharge

Once each of the top hole sections are drilled, casing will be inserted into the wellbore and secured in place by pumping cement into the annular space back to approximately 300 m above the casing shoe, which may involve a discharge of excess cement at the seabed (~80 m^3/well). Overspill of cement will permanently alter physical sediment properties immediately adjacent to the well (within <50 m). The potential disturbance area is 0.8 ha per well; giving a total potential disturbance footprint of 0.19km^2 within the State Proposal Area. This will result in the permanent loss of the benthic communities and habitats in the disturbance area.

Sediment deposition

Following the discharge of drill cuttings and fluids, the coarser fractions (sand and gravel-sized particles), will rapidly settle to the seabed. Where cuttings are discharged to the seabed, a cuttings pile will develop immediately around the well site. The nature and size of the pile will depend on a number of factors including particle size of the cuttings, tidal and current forces and water depth. Discharge of cuttings at the surface will result in a sediment plume with the dispersion and settlement of cuttings dependent on the particle sizes of cuttings, water depth, as well as the prevailing wind, tidal influence and current directions.

Potential impacts are expected to be confined to sessile biota such as sediment burrowing infauna and epifauna where present in or on the seabed in immediate proximity to the well location. Ecological impacts to such biota are predicted when sediment deposition is equal to or greater than 6.5 mm (in thickness) (IOGP, 2016). Modelling (Section 6.3.15.3 of the draft EIS/ERD) indicated that such deposition would potentially occur out from the well location to approximately 200 m (following the direction of the prevailing current). This aligns with (IOGP, 2016) review of seven studies, which indicated that the spread of drill cuttings and WBFs is expected to be up to about 150 m from the discharge location. It should also be noted that sedimentation was modelled concurrently for multiple wells at the drill centres, resulting in a likely overestimation of net sedimentation given that in reality wells will be drilled sequentially and therefore further dispersion of deposited sediments will occur in between individual well drilling activities.

This deposition may result in the reversible loss in the order of 0.12 km^2 of deepwater benthic habitat per well based on an assumption of an expected spread radius of 150 m from each well (in addition to the irreversible loss of 50 m associated with cement – described above). Balcom et al., (2012) concluded that impacts associated with the discharge of cuttings and NWBFs are minimal, with impacts highly localised to the area of the discharge. Changes to benthic communities are normally not severe. Organic enrichment can occur leading to anoxic conditions in the surface sediments and a loss of infauna species that have a low tolerance to low oxygen concentrations, and to a lesser extent chemical toxicity near the well location. These impacts are highly localised with short-term recovery that may include changes in community composition with the replacement of infauna species that are hypoxia-tolerant (IOGP et al., 2016).

Recovery of affected benthic infauna, epifauna and demersal communities is expected to occur quickly, given the short duration of sediment deposition and the widely represented benthic and demersal community composition. Jones et al., (2012) compared pre and post-drilling ROV surveys and documented physical smothering effects from WBM cuttings within 100 m of the well. Outside the area of smothering, fine sediment was visible on the seafloor up to at least 250 m from the well. After three years, there was significant removal of cuttings, particularly in the areas with relatively low initial deposition (Jones et al., 2012). The area impacted by complete cuttings cover had reduced from 90 m to 40 m from the drilling location, and faunal density within 100 m of the well had increased considerably and was no longer significantly different from conditions further away. As such, the impacts to the deepwater benthic habitats are considered reversible, with benthic biota are expected to recolonise the area rapidly on completion of the drill cuttings discharge at each well.

Based on the modelling (**Section 6.3.15.2** of the draft EIS/ERD), the sedimentation footprint associated with discharge of drilling or completions discharges at the seabed, indicates that away from the immediate area around the well (i.e. 50 m radius associated with the permanent impact from well casing cement overspill), sedimentation over the course of the drilling program would be low, equating to a thin veneer of settled drilling discharges away from the immediate deposition area around the well (in the order of 200 m from the well) which will likely be naturally reworked into surficial sediment through processes including bioturbation (US EPA, 2002). Ecological impacts in these areas are not expected for mobile benthic fauna such as crabs and shrimps or pelagic and demersal fish, given their mobility (IOGP, 2016).

These impacts are considered reversible, with benthic biota expected to recolonise once the cause of the temporary disturbance is removed. Studies indicate that benthic infauna and epifauna recover relatively quickly, with substantial recovery in deep water benthic communities within three to ten years (Jones et al., 2012). IOGP (2016) found that recovery of the benthic communities generally occurred by the recruitment of new colonising organisms and migration from undisturbed sediments, with recovery beginning shortly after the completion of drilling and well underway within a year.

The assessment of the potential impact on marine environmental quality (water quality, sediments and biota) from the discharge of drill cuttings and fluids from the MODU during drilling and completions activities presented in **Section 8.2.4** concluded that change in to water quality (through elevated TSS and the introduction of contaminants) would be temporary and localised with no subsequent impacts to biota predicted.

Summary

In summary, likely impacts to benthic communities and habitats from drill cuttings and fluids discharge and cement discharge will be restricted to the localised burial of deepwater benthic habitats and likely changes to sediment quality within the immediate vicinity each well (in the order of 200 m). However, outside this area, little to no impact to the deepwater benthic communities and habitats is expected. The proposed further modelling, assessment and selection of management measures for TRA, TRD, TRE and TRF drill centres described above will inform the drill cuttings disposal method to ensure impacts to Scott Reef benthic communities and habitats are avoided.

Overall, the localised smothering of biota associated the deepwater habitats that are well represented both in the State Proposal Area and regionally is not expected to reduce biological diversity and ecological integrity within the State Proposal Area.

8.3.4.10 Marine discharges: subsea control fluids

An assessment of the potential impact on marine environmental quality from the discharge of subsea control fluids during operation of the subsea infrastructure is presented in **Section 8.2.4**. This assessment concluded that the intermittent discharge of small volumes of subsea control fluid may result in a reduction in water quality that would be temporary (limited to the duration of the activity), restricted to deepwater (i.e. not affecting Scott Reef benthic communities or habitats) and subject to rapid dispersion and dilution by prevailing currents, due to the open oceanic waters of the State Proposal Area. While benthic biota associated with the deepwater habitats of the State Proposal Area may come into contact with these discharges, given that the discharges will disperse rapidly close to the discharge point and that any contact with the discharge with benthic biota will be of extremely short duration, it is not considered credible that toxic affects to benthic biota will occur as a result of the discharge of subsea fluids within the State Proposal Area.

8.3.4.11 Marine discharges: hydrotest fluid

A description and assessment of the potential impact on marine environmental quality from the discharge of hydrotest fluid during integrity testing of the subsea infrastructure and the temporary production system on the MODU is presented in **Section 8.2.4**. This assessment concluded that given the low volume of hydrotest fluid to be discharged, the low toxicity of the fluid, and the water depth at which the discharge will occur, hydrotest discharges within the State Proposal Area would be not expected to result in any lasting impacts to biota. As such, while modelling (Section 6.3.17 of the draft EIS/ERD) predicts that the plume would travel in close proximity to the seabed and therefore may result in localised and temporary decline in sediment quality, no lasting effect to the deepwater habitats are predicted.

As described in Section 8.2.4.10, previous modelling of hydrotest fluid discharge from SURF infrastructure has been used to inform this impact assessment. From this modelling it is concluded that given the negative buoyancy of the plume, bathymetry of the location (steep reef slopes surrounding the discharge location), and lack of upwelling processes from the depth of discharge, regardless of the size of the mixing zone the zone of influence will remain restricted to depth and avoid Scott Reef shallow water benthic habitat (<75 m bathymetry).

8.3.4.12 Production Activities: Seabed Subsidence

A detailed description of the subsea subsidence that may manifest as a result of production activities and an assessment of the potential impacts that may result is provided in Section 6.3.20 of the draft EIS/ERD. This includes peer reviewed modelling (Section 6.3.20.3 of the draft EIS/ERD) which provides a high level of confidence that any production-related subsidence at Scott Reef would be in the order of less than 10 cm over field life.

As described in Section 6.3.20 of the draft EIS/ERD, AIMS (2012) assessed the impact of net sea level rise (from subsidence and climate change induced sea level rise) and its predicted impacts on reef flat habitat (0 to 5 m depth), shallow water coral habitats (5 to 30 m), deepwater coral habitat (30 to 70 m) and Sandy Islet, for three scenarios (worse case, intermediate case and best case).

Overall, the study concluded that minor seabed subsidence over the life of the Torosa reservoir affecting a part of Scott Reef and Sandy Islet would not significantly contribute to sea level changes and associated impacts. As such, no reduction in biological diversity or ecological integrity within the State Proposal Area is predicted to occur as a result of seabed subsidence. Subsidence will be monitored throughout the life of the Project as detailed in Section 6.3.20 of the draft EIS/ERD.

8.3.4.13 Unplanned marine discharges: hazardous and non-hazardous inorganic waste

A description and assessment of the potential impact on marine environmental quality from unplanned discharge of hazardous and non-hazardous inorganic wastes is presented in Section 8.2.4. This assessment concluded that in the unlikely event of an unplanned discharge, discharged materials in liquid or sludge form would be subject to rapid dispersion and dilution by prevailing currents, due to the open oceanic waters of the State Proposal Area. This would result in a temporary and highly localised change in water quality that would be highly unlikely to impact the deepwater benthic habitats of the State Proposal Area. Accidentally discharged non-buoyant waste would have the potential to sink to the seabed and impact epifauna, however, given the sparse nature of deepwater habitats that are well represented both in the State Proposal Area and regionally, any impacts are highly unlikely to reduce biodiversity or ecological integrity within the State Proposal Area.

Under normal operating conditions, drilling and vessel activity will be limited to the deep waters in proximity to the location of the proposed development wells and subsea infrastructure away from Scott Reef so any accidental discharge to the marine environment is highly unlikely to impact the Scott Reef benthic communities and habitats.

8.3.4.14 Physical presences (unplanned): invasive marine species (IMS)

Non-indigenous Marine Species (NIMS) are species which are translocated into a recipient environment where they are not historically found. Invasive marine species are NIMS that are translocated into a marine environment where they have the potential to establish and disrupt the natural balance of marine ecosystems.

Not all NIMS that are translocated to a receiving location will survive through to establishment and only a subset of these species that become established will impact on social/cultural, human health, economic and/or environmental values are considered IMS (Wells, 2018).

IMS can be introduced through a variety of natural and human mediated vectors. The key pathways for introduction of IMS to the State Proposal Area is within biofouling on external surfaces of vessels and within internal niche areas and systems, and through vessel's ballast water. The vectors for translocation are via project vessels and MODU(s).

A detailed assessment of the potential risks associated with unplanned introduction of IMS is provided in Section 6.3.21 of the draft EIS/ERD. This includes an overview of the potential pathways of introduction, the process of the establishment of an IMS, an assessment of project specific pathways of IMS introduction and potential impact to ecosystem dynamics that could occur as a result of the introduction and establishment of an IMS.

The majority of the State Proposal Area consists of deep offshore open waters, away from shallow habitats, that are not conducive to the settlement and establishment of IMS, due to the lack of benthic light (required to support the photosynthetic processes required for many NIMS) or suitable hard substrates to allow attachment and growth.

The primary receptors with respect to IMS in the State Proposal Area are shallow-water marine habitats, species and ecosystem function at Scott Reef. Shallow water marine habitats, such as coral reefs, are considered susceptible to the introduction and subsequent establishment of IMS due to the availability of light and complex habitats. IMS introduced to shallow water marine habitats are, therefore, much more likely to successfully establish than those introduced to deep oceanic waters.

Shallow water benthic habitats, such as coral reefs, are considered susceptible to the introduction and subsequent establishment of IMS due to the availability of light and available substrate for establishment. IMS introduced into shallow water marine habitats are, therefore, much more likely to successfully establish than those introduced to deep oceanic waters (i.e. the deepwater habitat of the reef system).

Sites subject to existing disturbance such as Scott Reef are also considered to be more susceptible to IMS. This includes artificial structures (e.g. the two shipwrecks at Scott Reef; **Section 5.4.3.2** of the draft EIS/ERD), sites effected by coral bleaching and/or extreme weather events (as described for Scott Reef in **Section 5.3.1.3** of the draft EIS/ERD), and those areas impacted by tourism or fishing (e.g. tourism and Indonesian fishers at Scott Reef). The cumulative pressure of these disturbances may lead to weakened ecosystem function and reduced resilience to external pressures such as IMS. An IMS surveillance program at Scott Reef is proposed to be undertaken, with a survey completed prior to the commencement of the proposed Browse to NWS Project activities in the State Proposal Area to verify baseline condition, and periodic surveys over the life of the proposed Browse to NWS Project.

As described in **Table 6-146** of the draft EIS/ERD, given this sensitivity and the regional significance of Scott Reef, the consequence of the introduction and successful establishment of an IMS has been determined to represent a consequence level of Major due to the potential for regionally significant impacts to high value habitat. However, given the legislative and Woodside management controls in place to prevent translocation and establishment of IMS in the Project Area it is considered that the likelihood that IMS would be introduced, establish a self-sustaining population and cause environmental impacts to sensitive ecological communities within the vicinity of Project Area, including the State Proposal Area (e.g. Scott Reef) is remote.

8.3.4.15 Unplanned hydrocarbon releases

A detailed assessment of the potential risks associated with unplanned hydrocarbon releases is provided in **Section 6.3.21** of the draft EIS/ERD. Quantitative hydrocarbon spill modelling of various worst-case hydrocarbon release scenarios is presented in **Section 6.3.21.3** of the draft EIS/ERD. This included modelling of a loss of well integrity scenario at the TRA-C well (Scenario 1) which represents the worst case impacts to Scott Reef. The summarised result of the modelling of Scenario 1 are presented in **Table 6-158** and **Figure 6-51** of the draft EIS/ERD.

Based on the outcomes of quantitative spill modelling, hydrocarbon spills resulting from the Proposal have the potential to significantly impact shallow benthic communities and habitats within the State Proposal Area. However, given existing legislative and management controls the occurrence of hydrocarbon spills is considered highly unlikely.

8.3.4.16 Cumulative impacts

Given the distance of the State Proposal Area from other operating developments in the region, it is not considered credible cumulative impacts from the proposed Browse to NWS Project (or the Proposal) and other developments will occur.

With respect to the Commonwealth waters component of the proposed Browse to NWS Project, other than potentially hydrotest discharges (discussed below), it is not expected that planned marine discharges to Commonwealth waters would contribute to cumulative impacts on benthic communities and habitats within the State Proposal Area. Operational discharges (i.e. produced water and cooling water) from the FPSO facilities (in Commonwealth waters) have been designed and will be managed to ensure the defined threshold values (e.g. 99% species protection or no effect concentrations) at the State waters boundary are met (95% of the time based on dispersion modelling results).

While not considered the base-case, the potential discharge of hydrotest fluids from the BTL at the Torosa pipeline end terminal (**Section 6.3.17** of the draft EIS/ERD), may result in a temporary reduction in water quality within the State Proposal Area and thus a potential impact on adjacent benthic communities and habitats. The modelling results (**Section 6.3.17.3** of the draft EIS/ERD) indicate this would be restricted to deep waters surrounding the pipeline end terminal (461 m depth) and therefore impacts would be restricted to a small proportion of sparsely distributed epifauna. Given this, and the fact this discharge would be a one-off event that would occur prior to the commencement of operations, the discharge of hydrotest fluid from the BTL at the Torosa pipeline end terminal would not be expected to contribute significantly to cumulative impacts to benthic communities and habitats within the State Proposal Area.

8.3.5 Assessment of Impacts

The assessment of the predicted impacts to benthic communities and habitats in the State Proposal Area (i.e. deepwater habitats and Scott Reef habitats) demonstrates predominately temporary and minor impacts to the deepwater habitats on a localised scale associated with some of the proposed activities. Such impacts are associated with the direct disturbance resulting from the installation of the subsea infrastructure and the discharge of drill cuttings and fluids during development drilling.

Given the proposed location of the wells and subsea infrastructure will be in deep waters (>300 m), away from Scott Reef and that under normal operating conditions the drilling and vessel activity will be limited to the immediate vicinity of the subsea infrastructure, it is considered unlikely that marine discharges will impact Scott Reef shallow water benthic communities and habitats (<75 m water depth). Given the potential sensitivities of Scott Reef benthic communities and habitats to sedimentation from surface drill cuttings discharges, Woodside has committed to managing the discharges of drill cuttings and fluids at TRA, TRD, TRE and TRF drill centre locations using established and proven techniques such that impacts to Scott Reef shallow water benthic communities and habitats (<75 m water depth) are avoided.

In summary, given the localised scale and temporary nature of potential impacts to deepwater benthic communities and habitats, and no predicted impact to Scott Reef benthic communities and habitats, there is not expected to be any reduction in diversity or ecological integrity within the State Proposal Area.

In addition, the localised and temporary nature of the predicted sediment deposition mean that no impacts to benthic communities and habitats associated with State marine parks (the closest being over 400 km from the State Proposal Area) are expected to occur.

Given the above, impacts to benthic communities and habitats within the State Proposal Area as a result of the proposed Browse to NWS Project (or the Proposal) are expected to be consistent with the EPA objective for the environmental factor – benthic communities and habitats.

8.3.6 Mitigation

Level of Ecological Protection

As described in **Section 8.2.6**, and EMQP will be prepared and implemented to achieve the proposed LEPs (**Figure 8-1** and **Figure 8-2**). With the implementation of the EMQP, it is expected a maximum LEP will be achieved in the majority of the State Proposal Area, including all Scott Reef shallow water benthic communities and habitats (<75 m water depth) during construction and operations. A high LEP will be achieved for the deep waters of the State Proposal Area where subsea infrastructure will be located, except where a moderate LEP is proposed within a 1000 m radius of each drill centre during construction and operations; and 500 m around subsea infrastructure during construction. Further, an area of moderate LEP is proposed during construction where the potential discharge of hydrotest fluid from the BTL (in Commonwealth waters), may incur into the State Proposal Area.

Specific proposed measures to mitigate and manage unavoidable impacts from planned activities and reduce the environmental risk associated with unplanned events and incidents are presented in **Chapter 6** of the draft EIS/ERD and these will be incorporated into the EQMP where relevant. Measures presented in the draft EIS/ERD will also be incorporated into activity specific Environment Plans to be submitted for acceptance by DMIRS prior to the activity commencing within the State Proposal Area.

Drilling discharge management

As detailed in **Section 8.2.4.8**, modelling indicated that the sea surface discharge of drill cuttings from the bottom-hole sections generated at the previously proposed TRE and TRD drill centre locations would potentially result in incursions of sediment plumes and associated increased sedimentation to portions of North and South Scott Reef including within the lagoons.

Given the potential sensitivities of Scott Reef shallow water benthic communities and habitats to sedimentation from drilling discharges, Woodside has committed to managing the drilling discharges (in particular bottom hole discharges) using established and proven techniques (e.g. disposal at alternative locations if necessary) at drill centre locations in the State Proposal Area (i.e. TRA, TRD, TRE and TRF) in such a manner that avoids impacts to Scott Reef shallow water benthic communities and habitats (<75 m water depth). This approach is outlined in **Section 8.2.6**.

8.3.7 Predicted Outcome

Cumulative loss assessment

WA EPA Technical Guidance - Protection of Benthic Communities and Habitats, requires the establishment of a local assessment units (LAUs) to establishes the spatial context for the calculation and assessment of recoverable impacts and cumulative losses (EPA, 2016c).

The following five LAU representing the broad benthic community and habitat types are proposed for the State Proposal Area.

- Scott Reef south lagoon deepwater coral habitats
- Scott Reef north deepwater sediment habitat
- Scott Reef south deepwater sediment habitat
- Scott Reef north shallow water benthic communities and habitats
- Scott Reef south shallow water benthic communities and habitats.

As per the EPA technical guidance *"Calculating cumulative losses relies on three fundamental pieces of information – 1) estimates of the areas of benthic communities and their habitats present before European habitation, 2) estimates of the extent of historic and approved losses, and 3) predictions of the additional losses associated with the current proposal (EPA, 2016c)."* In this regard:

- Original spatial extent is considered to be the entire spatial extent of the two above defined broad habitat types.
- No historical losses have been recorded. While Woodside has drilled seven previous wells within the State Proposed Area, impacts from the associated drill cuttings discharge are considered reversable (as described in Section 8.3.4.9), with benthic biota expected to have recolonised the area once drilling is completed.
- Proposed extent of permanent loss (0.31km^2) from proposal has been estimated based on the planned seabed disturbance for the installation of subsea infrastructure.
- Up to 3.84 km^2 of reversible loss may occur as a result of indirect impact from subsea infrastructure. Reversible loss is not included in the cumulative loss estimates.

Table 8-7 summarises the cumulative benthic communities and habitat loss estimates for the State waters around Scott Reef LAU.

Table 8-7 Cumulative permanent benthic communities and habitat loss assessment for State waters around Scott Reef LAU

Benthic communities and habitat type	Original spatial extent (pre-European habitation)	Historic and approved losses	Current % remaining	Proposed extent of permanent loss from proposal	Spatial extend of cumulative loss	% remaining after proposal
Scott Reef south lagoon deepwater coral habitats	213.47 km^2	0 km^2	100%	0 km^2	0 ha	100%
Scott Reef north deepwater sediment habitat	311.26 km^2	0 km^2	100%	0.31 km^2	0.31 km^2	99.90 %
Scott Reef south deepwater sediment habitat	379.16 km^2	0 km^2	100%	0 km^2	0 km^2	100%
Scott Reef north shallow water benthic communities and habitats	179.51 km^2	0 km^2	100%	0 km^2	0 km^2	100%
Scott Reef south shallow water benthic communities and habitats	147.14 km^2	0 km^2	100%	0 km^2	0 km^2	100%

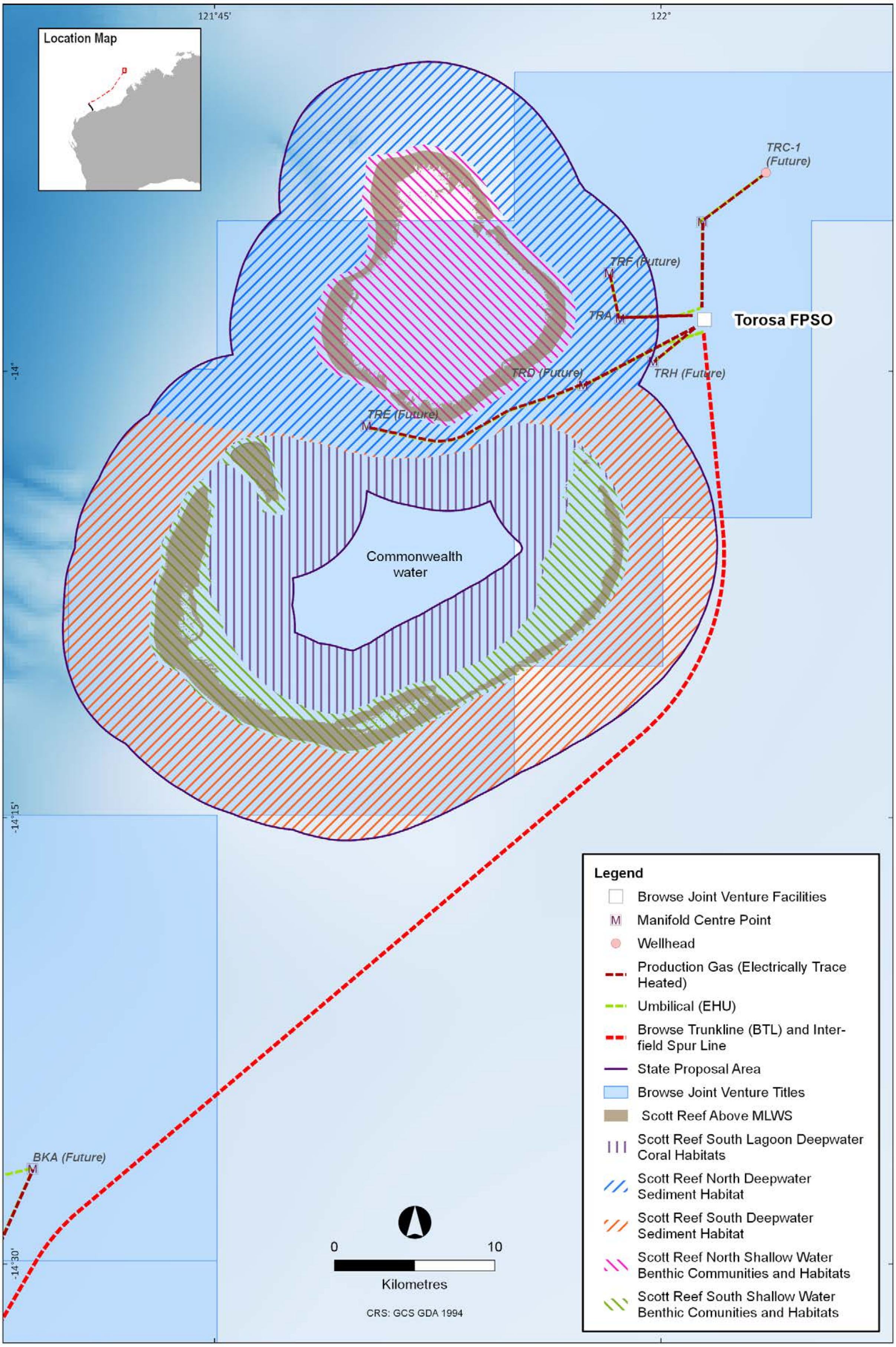

Figure 8-4 Proposed State Proposal Area Local Assessment Units

Summary

Impacts to benthic communities and habitats within the State Proposal Area have been reduced by locating the FPSO facilities, BTL and inter-field spur line outside of the State Proposal Area, and siting infrastructure within the State Proposal Area in deep waters off Scott Reef. This will result in any impacts being restricted to the deepwater benthic habitats, with no impacts to Scott Reef benthic communities or habitats.

Impacts will be further reduced by implementing mitigation and management measures, the majority of which are standard maritime and offshore oil and gas industry practice. However, given the potential sensitivities of Scott Reef shallow water benthic communities and habitats to sedimentation from drilling discharges, Woodside has committed to managing the drilling discharges (in particular bottom hole discharges) at drill centre locations in the State Proposal Area (i.e. TRA, TRD, TRE and TRF) in such a manner to avoid impacts to Scott Reef shallow water benthic communities and habitats (<75 m water depth) (refer to **Section 8.2.6**). Implementation of this management approach will be assured through activity specific Environment Plan(s) under Petroleum Legislation.

Given cumulative losses (historical plus proposed) of benthic communities and habitats will be limited to a small portion that are well represented both in the State Proposal Area and regionally (approximately 0.11% of Scott Reef north deepwater sediment habitat LAU with no losses in any of the other four proposed LUA), the Proposal is not predicted to result in any reduction of biological diversity and ecological integrity within the State Proposal Area.

As such, the WA EPA environmental objective *"to protect benthic communities and habitats so that biological diversity and ecological integrity are maintained"* will be achieved for the Proposal; and the predicted impacts on benthic communities and habitats within the State Proposal Area are considered **Acceptable**.

8.4 Key Environmental Factor – Marine Fauna

8.4.1 EPA Objective

The EPA objective for marine fauna is *"To protect marine fauna so that biological diversity and ecological integrity are maintained"* (EPA, 2016b).

8.4.2 Policy and Guidance

The following policy and guidance have been considered in relation to the EPA environmental factor - marine fauna:

EPA Policy and Guidance

+ Statement of Environmental Principles, Factors and Objectives (EPA, 2016b)
+ Environmental Factor Guideline – Marine Fauna (EPA, 2016b).

Other Policy and Guidance

+ *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) Policy Statement 2.1 – Interaction between Offshore Seismic Exploration and Whales (Department of the Environment, Water, Heritage and the Arts, 2008)
+ Conservation Management Plan for the Blue Whale - A Recovery Plan under the EPBC Act (Commonwealth of Australia, 2015a)
+ Conservation advice *Anous tenuirostris melanops* Australian lesser noddy (Threatened Species Scientific Committee, 2015a)
+ Approved Conservation Advice for *Megaptera novaeangliae* (humpback whale) (Threatened Species Scientific Committee, 2015b)
+ Recovery plan for marine turtles in Australia (Commonwealth of Australia, 2017a)
+ Conservation advice *Rhincodon typus* whale shark (DEWHA, 2015c).

8.4.3 Receiving Environment

Marine fauna that may occur within the Browse Development Area are described in detail in **Chapter 5** of the draft EIS/ERD. Marine fauna that may occur in the State Proposal Area are summarised below, with cross references to specific sections of **Chapter 5** of the draft EIS/ERD provided for further detail.

Seabirds and migratory shorebirds

Seabirds birds have been observed in low numbers at Scott Reef, as described in **Section 5.3.2.4.1** of the draft EIS/ERD. Sandy Islet (the only permanently emergent land mass at Scott Reef) may be used by nesting seabirds and is known to provide roosting habitat for low numbers of individuals but it is not large enough to support large numbers of seabirds at any one time. Scott Reef is recognised as part of a resting Biologically Important Area (BIA) for the little tern (*Sternula albifrons*) (**Section 5.3.2.2** of the draft EIS/ERD). This species is widely distributed within Australia and is expected to occur within the State Proposal Area.

Migratory shorebirds may also use Scott Reef as a staging ground during migrations, for nesting and roosting and have occasionally been observed in very low numbers, as detailed in **Section 5.3.2.4.2** of the draft EIS/ERD.

Marine mammals

Marine mammals have wide distributions that are associated primarily with seasonal feeding and migration patterns that are linked to their reproductive cycles. A number of marine mammal species have been identified as potentially occurring within the wider Project Area, as described in **Section 5.3.2.5** of the draft EIS/ERD. A number of surveys have been undertaken in recent years to establish baseline data for marine mammals, primarily humpback whales and pygmy blue whales, within proximity of the Browse Development Area, including the State Proposal Area. These are summarised in **Section 5.3.2.5** of the draft EIS/ERD. The species discussed below are considered likely to occur within the State Proposal Area.

- Humpback whale - the humpback whale (*Megaptera novaengliae*) is listed under the EPBC Act as Vulnerable, Migratory and Marine, and as Conservation Dependant under the *Biodiversity Conservation Act* (BC Act). This species has a wide global distribution and displays migratory behaviours, as described in **Section 5.3.2.5.1** of the draft EIS/ERD. Recent studies have indicated that this species travels less than 46 km from the coastline and within waters less than 50 m deep (RPS Environment and Planning, 2010b; 2012). Sightings have, however, been recorded around Scott Reef. There are no known BIAs for this species within the State Proposal Area and only low numbers of humpback whales are expected to be present in the area.

  There are also key calving areas for the humpback whale between Broome and the northern end of Camden Sound, as described in **Section 5.3.2.5** of the draft EIS/ERD. Additionally, there is a migration BIA for the species (**Section 5.3.2.2** of the draft EIS/ERD) which encompasses State waters around Broome.

- Pygmy blue whale - the pygmy blue whale (*Balaenoptera musculus*) subspecies is listed under the EPBC Act as Endangered, Migratory and Marine, and as Endangered under the BC Act. As described in **Section 5.3.2.5.2** of the draft EIS/ERD, this migratory subspecies is widely distributed from Indonesia to the south west of Australian and east along the Great Australian Bight to the Bass Straight. Noise logger data and historic observations have recorded this species within the waters of and surrounding Scott Reef, including the channel between North and South Scott Reef (McCauley, 2011). A possible foraging area has been documented at Scott Reef (although individuals have not been directly observed feeding) and the reef is recognised as part of a foraging BIA for this species in the Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015b) (**Section 5.3.2.2** of the draft EIS/ERD). Migration and distribution BIAs for this species also encompass the State Proposal Area (**Section 5.3.2.2** of the draft EIS/ERD). The distribution BIA for the pygmy blue whale also encompasses State waters at Broome.

  Given the historical observations (Blue Planet Marine, 2019) and noise logger data (McCauley, 2011), it is expected that pygmy blue whales will occur in low numbers within the Browse Development Area, particularly within and around the waters of Scott Reef. It is acknowledged that pygmy blue whales have been recorded in the channel between North and South Scott Reef and they may forage opportunistically in and around Scott Reef during their migration to and from recognised aggregation areas.

- Bryde's whale - the Bryde's whale (*Balaenoptera edeni*) is listed under the EPBC Act as Migratory. The species is not listed under the BC Act. As described in **Section 5.3.2.5** of the draft EIS/ERD, noise loggers were deployed in and around Scott Reef from 2006 to 2009 and this species was found to be present in low numbers throughout the year. Data indicated this species was typically present as individuals, with occasional calls from multiple whales.

  Bryde's whales are subsequently expected to occur in low numbers within the State Proposal Area.

- Spinner dolphin - the spinner dolphin (*Stenella longirostris*) is a listed Cetacean under the EPBC Act and Priority 4 under the BC Act. This species is known from both oceanic and coastal habitats and has been recorded near Scott Reef in 2008 and 2009, as described in **Section 5.3.2.5** of the draft EIS/ERD. This species is likely to be found in or within the vicinity of the State Proposal Area.

Marine turtles

Marine turtles may occur within the Project Area, as described in **Section 5.3.2.6** of the draft EIS/ERD. As marine turtles are highly migratory it is possible that all six marine turtle species may occur within the State Proposal Area. The green turtle (described in **Section 5.3.2.6** of the draft EIS/ERD) and hawksbill turtle (described in **Section 5.3.2.6** of the draft EIS/ERD) are considered most likely to occur within the State Proposal Area as these species are known to nest at Sandy Islet. Both species are listed as Vulnerable under the EP Act and the EPBC Act. The internesting, nesting and post-nesting migratory behaviour of the green turtle at Scott Reef and surrounds has been studied in some detail and is summarised in **Section 5.3.2.6** of the draft EIS/ERD.

There are nesting/internesting BIAs for the green and hawksbill turtle at Scott Reef (described in Section 5.3.2.2 of the draft EIS/ERD) due to nesting habitat on Sandy Islet. While green turtles are known to nest each season at this location in low numbers, only one hawksbill turtle has been recorded nesting at this location. Habitat Critical to the Survival of a Species has also been designated for the green turtle at Scott Reef (Section 5.3.2.3 of the draft EIS/ERD), in order to preserve the genetic stock of the nesting population associated with these locations.

Sea snakes

Comprehensive surveys of sea snakes were undertaken at Scott Reef in February, September and November of 2006. A number of sea snake species were identified as part of these surveys (listed in Section 5.3.2.7 of the draft EIS/ERD). Sea snakes were typically associated with complex reef habitats and survey results indicated that these individuals were likely residential to Scott Reef. Sea snakes are expected to occur within the State Proposal Area.

Fish

Demersal and pelagic fish communities and species that may occur within the Project Area are listed and described in Section 5.3.2.8 of the draft EIS/ERD. Surveys of shallow water fish communities were undertaken at Scott Reef in 2006. The overall composition of fish fauna at Scott Reef was found to be generally similar to oceanic reefs in the tropical Indo-west Pacific, with a stronger affinity to the islands of eastern Indonesia than to the adjacent Australian mainland. Studies were also undertaken using Baited Remoted Underwater Video Systems (BRUVs) in the deeper waters of South Scott Reef lagoon and found herbivorous and coral feeding species to be widespread.

Species of sharks and rays identified as potentially occurring within the Project Area include the whale shark, shortfin mako, longfin mako, green sawfish and largetooth sawfish. There are no BIAs or known important habitat for these species within the State Proposal Area. The whale shark is a widely distributed migratory species and may occur within the vicinity of Scott Reef whilst undertaking migratory movements. The shortfin and longfin mako are widely oceanic species and, subsequently may occur within the vicinity of the State Proposal Area. The green and largetooth sawfish are not considered likely to occur within the State Proposal Area as they exhibit a preference for/reliance on inshore, shallow, sandy/muddy bottomed and estuarine habitats.

8.4.4 Potential Impacts

8.4.4.1 Summary of identified impacts and risks

Table 8-8 summarises the sources of potential impact to marine fauna from the Proposal. Table 8-8 is followed by a detailed description of the potential direct, indirect and cumulative impacts. An assessment of the significance of these impacts on marine environmental quality and a conclusion on the acceptability of the impacts in relation to the EPA environmental objective is presented in Section 8.4.5.

Table 8-8 Sources of Potential Impact to Marine Fauna from the Proposal

Aspect	Proposal Phase[1]					Source (in State jurisdiction)
	Dr	I	C	O	De	
Planned (routine and non-routine activities)						
Physical presence: light emissions	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating in the State Proposal Area Intermittent flaring from the MODU
Physical presence: electromagnetic emissions				✓		Subsea infrastructure
Atmospheric emissions: offshore activities	✓	✓	✓	✓	✓	Power generation on project vessels and the MODU Intermittent flaring from the MODU Venting of gas from the MODU (during well kick)

Aspect	Proposal Phase[1]					Source (in State jurisdiction)
	Dr	I	C	O	De	
Atmospheric noise	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating in the State Proposal Area Intermittent flaring from the MODU Helicopters movements Piling for MODU mooring installation (if required)
Underwater noise	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating in the State Proposal Area VSP/DAS during well development Piling for MODU mooring installation (if required) Wellhead operation Seabed preparation Helicopter movements
Marine discharges: sewage and sullage	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating in the State Proposal Area
Marine discharges: treated utility water, chemical and deck drainage	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating in the State Proposal Area
Marine discharges: produced water	✓					MODU during well unloading activities
Marine discharges: cooling water	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating in the State Proposal Area
Marine discharges: drilling and completions discharges	✓					MODU during drilling activities
Marine discharges: subsea control fluids	✓	✓		✓	✓	Subsea infrastructure during operations BOP during drilling ROVs
Marine discharges: hydrotest fluid	✓	✓	✓	✓		Temporary production system on MODU Integrity testing of subsea infrastructure
Production Activities: Seabed Subsidence				✓		Extraction of reservoir fluids
Unplanned events and incidents						
Marine discharges: hazardous and non-hazardous waste inorganic waste	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating in the State Proposal Area
Physical Presence (unplanned): Vessel Interactions with Fauna	✓	✓	✓	✓	✓	Project vessels and installation vessels operating in the State Proposal Area
Physical Presences (unplanned): Invasive Marine Species	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating in the State Proposal Area
Unplanned hydrocarbon releases	✓	✓	✓	✓	✓	Project vessels, installation vessels and MODU operating the State Proposal Area Subsea infrastructure

[1] *Dr = Drilling; I = Installation; C = Commissioning; O = Operation; De = Decommissioning*

8.4.4.2 Physical presence: light

Modelling

A detailed description of the planned light emissions and an assessment of the potential impacts associated with these emissions is provided in **Section 6.3.3** of the draft EIS/ERD.

Light emissions within the State Proposal Area will occur as a result of operational and navigational lighting on project vessels, installation vessels and the MODU; as well as intermittent flaring on the MODU during well unloading. Light emissions in the State Proposal Area will occur only during the construction phase, contingency drilling and completion activities and during infrequent IMR activities. There will be no regular sources of light emissions in the State Proposal Area during routine operations.

To further understand the effects of light emissions on sensitive receptors (particularly green turtles), a line of sight assessment and a light density (luminous flux density) modelling study were conducted as part of the approved Browse FLNG Development EIS developed in 2014. Although the MODU for drilling is yet to be confirmed and different MODUs are likely to be used throughout the Browse field life, light levels associated with drill rig lighting are expected to be comparable to that studied. It is considered that these studies adequately define the potential impacts from artificial light emissions associated with the proposed Browse to NWS Project. Given the similar nature of the Proposal and the previously considered Torosa Subsea Development, the modelling undertaken previously is considered appropriate to inform the impact assessment of the Proposal. The results of these studies are summarised in **Section 6.3.3.3** of the draft EIS/ERD.

Due to the proximity of the TRE drill centre to Scott Reef, it was predicted direct light emitted from a drill rig at this location would be visible to some extent from all areas of Scott Reef, including Sandy Islet (approximately 7 km distant) (**Figure 6-5** of the draft EIS/ERD). However, based on the light density modelling, the maximum predicted light density levels from a drill rig at TRE reaching Sandy Islet are lower than 0.01 Lux, which is comparable to light levels between a moonless clear night sky and a quarter moon.

Light emissions from project vessels were not included in the line of sight assessment and light density modelling due to the temporary and transient nature of vessel movements.

Seabirds and migratory shorebirds

As described in **Section 6.3.3** of the draft EIS/ERD, seabirds and migratory shorebirds at Scott Reef may be affected by light emissions from project vessels and the MODU operating in the State Proposal Area. It should be noted, however, that the area does not represent a significant aggregation, nesting or roosting area.

The exact mechanism for navigation of migratory birds is not clear, however, it is widely thought that they use a mixture of natural cues, including the earth's magnetic field, solar and celestial orientation and polarised light patterns to determine their migratory pathway (Weindler and Liepa, 1999; Wiltschko and Wiltschko, 2001). Therefore, there is a risk that artificial light sources along migratory pathways may alter natural patterns, specifically in the absence of terrestrial landmarks (i.e. within offshore).

Studies have demonstrated that light from offshore facilities may attract migrating birds, with species that migrate during the night more likely to be affected (Marquenie et al., 2008; Verheijen, 1985). Birds may either be attracted by the light source itself or indirectly as lighted structures in marine environments tend to attract marine life at all trophic levels, creating food sources and shelter for seabirds. In some cases, sources of artificial light may provide enhanced capability for seabirds to forage at night (Verheijen, 1985). Studies in the North Sea indicated that migratory birds may be attracted to lights on offshore platforms when travelling within a radius of 3 to 5 km from the light source. Outside this area their migratory paths were not likely to be affected (Marquenie et al., 2008).

Additionally, artificial lighting may interfere with a bird's internal magnetic compass. It is thought that migratory birds require light from the blue-green part of the spectrum for magnetic compass orientation (Muheim et al., 2002; Wiltschko and Wiltschko, 2001, 1995) whereas red light, the long-wavelength component of light, is more likely to disrupt magnetic compass orientation.

Light from the MODU is unlikely to attract a significant number of such seabirds or shorebirds as activities are proposed to be located a considerable distance from known key aggregation areas such as Ashmore Reef (230 km), Roebuck Bay (370 km) and Eighty Mile Beach (500 km). Given a relatively small number of transiting birds are expected to pass in the vicinity of the Proposal Area, behavioural effects such as disorientation and/or attraction are expected to be minor. Similarly, birds roosting at night on Sandy Islet are unlikely to be disturbed given the low level of artificial light (less than 0.01 Lux) that would be received at Sandy Islet from the MODU.

Red light (the long-wavelength component of light) is more likely to disrupt the magnetic compass orientation of migratory birds. The expected spectral signature of light emissions from the MODU is between 530 to 620 nm (based on measurements of the drill rig during drilling of the TS-1 pilot appraisal well), with the red part of the spectrum outside of these ranges. Therefore, it is not expected that bird species magnetic compass orientation will be disrupted.

Fish
As described in Section 6.3.3 of the draft EIS/ERD, the waters of the State Proposal Area host a rich diversity of fish species, including demersal and pelagic fish. The attraction of fish to artificial light is a well know phenomenon and is likely to be associated with the increased availability of planktonic prey on the surface at night (due to vertical migration of zooplankton) and the increased prey detection abilities provided by the light (Marchesan et al., 2005). The response of fish to artificial light has been shown to differ depending on species and changes in behaviour due to the light regime potentially pose an increased risk of predation through changes to natural night time distribution (Marchesan et al., 2005; Nightingale and Simenstad, 2001). Artificial light may also exclude nocturnal foragers/predators from an area, allowing diurnal species to benefit from increased access to resources. Credible impacts from light emissions from the MODU and project vessels associated with the Proposal are expected to be restricted to localised fish attraction.

The whale shark is the only threatened fish species that is likely to occur within the State Proposal Area, albeit infrequently and in low numbers (refer to Section 5.3.2.8 of the draft EIS/ERD). Impacts from light emissions are not documented for this species, although this has been identified as an area for further research within the latest conservation advice for this species (Threatened Species Scientific Committee, 2015c). Given the low numbers and infrequent nature of whale shark presence in the State Proposal Area, it is considered highly unlikely that adverse impacts will occur to the small number of individual whale sharks that may encounter elevated, localised light emissions around the MODU and vessels. Occasional and temporary behavioural changes such as utilising attractant aggregations of food sources (such as zooplankton) for opportunistic feeding is known to occur around offshore facilities and may occur for the proposed Browse to NWS Project.

Marine turtles
Specific behavioural response to artificial light emissions by marine turtles relates to altered nocturnal behaviours (as described by Witherington and Martin (1996) and include:

- disorientation: loss of orientation, being unable to maintain constant directional movement
- misorientation: orientation in the wrong direction, for hatchling marine turtles on the beach, travel in any direction other than the general vicinity of the ocean.

There are many variables that influence the range and severity of potential impacts of light emissions on the behaviour of marine turtles including:

- turtle vision
- life stage (adult and hatchling).

Exposure of marine turtles to artificial light can result in changes to their natural behaviour, in particular with regards to nesting (Commonwealth of Australia, 2019). Sandy Islet (nesting habitat) and a 20 km interesting buffer of the surrounding waters are recognised as habitat critical to the survival of green turtles for the Scott Reef-Browse Island genetic stock in the Recovery Plan for Australian Marine Turtles 2017-2027 (Commonwealth of Australia, 2017a) (Figure 5-29 of the draft EIS/ERD). In addition, a BIA exists for internesting green and hawksbill turtles around Sandy Islet (Commonwealth of Australia, 2017a). Green turtles predominately nest at Sandy Islet between November and February and internesting turtles have been observed to aggregate primarily in an area to the south west of Sandy Islet. Only one hawksbill turtle has been recorded nesting at Sandy Islet (Section 5.3.2.5.2 of the draft EIS/ERD).

The Recovery Plan for Marine Turtles in Australia (2017-2027) identifies light pollution as a moderate risk to the Scott Reef-Browse Island green turtle genetic stock and a high risk to the WA hawksbill turtle population (Commonwealth of Australia, 2017a). The long-term recovery objective for marine turtles is to minimise anthropogenic threats to allow for the conservation status of marine turtles to improve so that they can be removed from the EPBC Act threatened species list.

The National Light Pollution Guidelines for Wildlife Including Marine Turtles, Seabirds and Migratory Shorebirds (Commonwealth of Australia, 2019) further discuss impacts and management of artificial light in relation to marine turtles.

Female adult marine turtles spend most of their lives in open ocean environments, however, female turtles return to natal beaches to nest and lay eggs, predominantly at night. There is significant evidence that indicates artificial lighting on or near nesting beaches may disrupt adult female turtle nesting behaviour (Commonwealth of Australia, 2019; Salmon, 2005; Salmon et al., 1992). Artificial lighting may affect the location that turtles emerge on the beach, the success of nest construction, whether nesting is abandoned and even the seaward return of adults (Salmon, 2005 and Salmon et al., 1992). It was found that turtles deterred from typical nesting beaches due to artificial lighting re-emerged onto alternate beaches outside of their typical range at increasingly distant and inappropriate nesting locations (Witherington and Martin, 2000, 1996). The selection of suboptimal nesting habitat may contribute to a reduction in the success of egg deposition and hatchling production (Witherington and Martin, 2000). There is no indication whether, under natural conditions, the full moon affects rates of female adults landing on a beach to nest. Nor is there any information available in the published literature that suggests adult turtles are affected by light during foraging activity (Pendoley, 2000).

Hatchlings have a strong tendency to orient themselves to the brightest light source, which under natural conditions is the seaward horizon (in natural circumstances derived from the moon for most of the month) rather than the darker silhouetted landward horizon (Limpus, 2006). The light glow created by artificial lighting may, therefore, cause hatchlings to be attracted to this light source rather than to the water (Witherington and Martin, 2000, 1996). Hatchlings which are disoriented or mis-oriented by artificial lights often do not find the sea promptly, this may lead to predation or exhaustion. Once in the ocean, little is known of the extent to which hatchlings still use vision over wave direction and the earth's magnetic field for orientation (Lohmann, 1992). Hatchlings swimming out to sea from the beach, however, may be attracted to light emissions from offshore structures or vessels, making them more susceptible to predation or vessel strike after they enter the water (Thums et al., 2016). Wilson et al. (2018) found that light emissions disrupted the dispersal of hatchlings and hatchlings become disoriented in nearshore environments.

The wavelength at which adult and hatchling turtles can sense light is important in determining their corresponding attraction and sensitivity to light emissions. Studies suggest that marine turtles are most sensitive to short-wavelength light in the near-ultraviolet to yellow region of the visible spectrum, from approximately 340 to 700 nm (Witherington and Martin, 2000). Studies on hatchling orientation, relative to spectrally controlled light sources, indicate that although the wavelength at which hatchlings can sense light varies between species, all turtle species are more sensitive to light in the blue and ultraviolet (UV) end of the spectrum. The most disruptive wavelengths to hatchlings are in the 300 to 500 nm range (Witherington, 1997). Light spill effects are not known to vary for different turtle species, however, green turtles are known to be attracted to light of lower wavelengths (<600 nm), with a preference for blue light (400 – 450 nm). The light intensity measurements and modelling predictions accounted for the full wavelength spectrum detected by marine turtles (340 to 700 nm) (ERM and SKM, 2008).

Based on lighting data from the drill rig, approximately 60% of the total light wavelength transmission is within the sensitive wavelength range for turtle hatchlings (300 to 500 nm) (ERM, 2010), with most common artificial light sources, such as fluorescent, generating light within these wavelengths (Witherington and Martin, 2000; Witherington, 1997). Given light intensity attenuated to 0.1 Lux at distances of 1.2 km from the studied drilling rig, given the distance of the TRE drill centre location from Sandy Islet it is only in the nearfield light spill that may impact adult breeding turtles on the water.

Based on the measured attenuation of light density and wavelengths from a drill rig at Scott Reef (ERM and SKM, 2008) and the predicted light levels modelled (ERM and SKM, 2008; Jacobs and SKM, 2014), light levels expected are below detection levels or so low (0.1 Lux) that no disturbance to nesting behaviour of adult female marine turtles is predicted at Sandy Islet. It should also be noted that drilling at TRE (the closet light source to Sandy Islet) is a temporary activity, with the MODU only likely to be in that location during the development drilling activities. Flaring from the MODU is not predicted to lead to impacts given its temporary nature (will only occur during well unloading activities and be of 1-2 days duration per well)

Impact of light spill around MODU on marine turtles

Historical studies have reported that due to turtle hatchlings' vision being limited in water, other more dominant navigational cues take over (Amos, 2014; Lohmann and Lohmann, 1992) such as surface currents (Frick, 1976; Liew and Heng Chan, 1992; Okuyama et al., 2009; Salmon and Wyneken, 1987; Witherington, 1995). However, more recent studies (Limpus et al., 2003; Thums et al., 2016) have demonstrated that offshore lights have the ability to attract in-water dispersing hatchlings, causing them to linger around the light source at sea. Additionally, Whelan and Wyneken (2007) and Harewood and Horrocks (2008) reported that artificial lights onshore, can slow down hatchlings' in-water dispersal. Harewood and Horrocks (2008) also demonstrated in this study, that hatchling turtles released from dark beaches, were attracted by artificial lights from neighbouring beaches that were only visible after the hatchlings were a substantial distance from shore. Perhaps more importantly, this study reported that a number of the unsuccessful hatchlings (unsuccessful, meaning hatchlings which did not correctly orientate themselves in a seaward position from the beach) stayed within 10 m of shore and travelled parallel to the shoreline, orientating towards the lighted headlands. Harewood and Horrocks (2008) concluded that artificial lights may override the effects of wave cues in low wave energy environments.

Similarly, Truscott et al. (2017) reported that artificial light sources can attract hatchlings back to shore. More recently, Wilson et al. (2018) confirmed that in the presence of artificial light, surface currents had little effect on the bearing of hatchling swimming, with 88% of individuals' trajectories tracked, orientated towards the experimental artificial lighting. Additionally, this study showed that under ambient conditions, ocean currents affected the bearing of hatchlings as they left the shore; however, when light was present, this effect was diminished, showing that the turtles actively swam against currents in their attempts to move towards light. Hatchling behaviour onshore is not expected to be impacted given the distance of Sandy Islet to TRE and the islet's height above sea level (maximum on west side of 5 m). Hatchling emergence and sea entry were assessed for potential impact from MODU lighting. It was concluded that hatchlings being drawn to MODU lighting thereby increasing vulnerability to predation were considered unlikely, given the distance of Sandy Islet from all drill centre locations and short travel distance to water regardless of direction.

As surface currents within the Scott Reef channel are known to be strong (averaging approximately 0.5 knots with speeds up to and exceeding two knots), it is unlikely that hatchlings will have the ability to linger and come within the light spill area in the vicinity of a MODU operating in the channel as a result of the artificial light acting as an attractant.

Therefore, artificial lighting associated with the MODU and proposed facilities, may theoretically have the potential to override and disorientate natural hatchling cues, potentially attracting individuals towards the structure. However, the results from the line of sight assessment undertaken as part of the previously proposed FLNG Development concept (ERM, 2010; Jacobs and SKM, 2014), demonstrate that the maximum predicted direct light levels reaching Sandy Islet from a MODU at the TRE drill centre (approximately 7 km away, **Figure 6-5** of the draft EIS/ERD) are less than 0.1 Lux.

For context, the predicted light intensity at this level of light is comparable to the light level between a moonless clear night sky and a quarter moon. Therefore, this level of light is not expected to be of an intensity (and associated wavelength frequency) to alter hatchling behaviour (attraction or mis-orientation of hatchlings leaving nesting sites on Sandy Islet). In addition, spectral analysis of light emissions from a flare at Thevenard Island (Pendoley 2000) determined that this light source does not contain a high proportion of light wavelengths within the range that is most disruptive to turtle hatchlings (300 to 500 nm). Therefore, no adverse impacts to hatchlings from artificial light are anticipated, despite the fact that some studies have demonstrated the theoretical potential for misorientation to some individuals.

Adult turtles passing through the Project Area may temporarily alter their normal behaviour whilst attracted to the light spill from the offshore facilities. Light spill of at least 0.1 Lux (i.e. at least quarter moon light intensity levels) is likely to extend 1.2 km radially from the MODU. While the light spill area overlaps with the internesting habitat for green turtles, it is not anticipated that large number of individuals will be present within this area given the preference to internest to the southwest of Sandy Islet and, therefore, will not be subject to behavioural impacts.

In addition, given the wide migratory distribution of adult turtles outside of nesting season (i.e. several hundred kilometres) and their low-density presence within the Project Area, the zone of influence and subsequent attraction from direct lighting is expected to be relatively minor in comparison to their migratory area, resulting in only a temporary disruption to a small portion of the adult turtle population. In addition, due to the limited range of any lighting impacts, it is not deemed that the predicted lighting impacts will adversely affect habitat critical to the survival of green turtles and is, therefore, not inconsistent with the recovery objectives outlined within the Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a).

8.4.4.3 Physical presence: electromagnetic emissions

EMF will be generated within the State Proposal Area as a result of active heating of the subsea flowlines and power cables. The use of active heating technology in the design of the subsea system minimises the volume of Mono-ethylene Glycol (MEG) required to prevent hydrate formation. Active heating occurs using electricity and will be used in the infield flowlines and risers carrying the reservoir fluids from the subsea manifolds to the FPSOs. Active heating will prevent blockages in the flowlines which can occur when fluids cool causing hydrates and waxes to solidify. Active heating is not expected to be required continuously. While the flowlines are producing, active heating is not required, instead only being turned on for hydrate management when the flowline is not producing after a short period. Active heating remains on until the flowline recommences production and warms up. The other source of EMF will be the subsea power cables that distribute power generated at the FPSO to subsea infrastructure.

Further details of the potential electromagnetic emissions resulting from the proposed Browse to NWS Project is provided in **Section 6.3.4** of the draft EIS/ERD.

Fish

It is well established that many organisms including elasmobranchs and some bony fish, can detect both natural and anthropogenic EMFs, which many species use for directional movement, foraging and migration. However, the mechanism or mechanisms by which animals can exploit these fields is not fully understood. Some species may sense magnetic fields directly through biogenic magnetite crystals that reorient as the animal moves to maintain alignment with geomagnetic field lines (e.g., (Kirschvink et al., 2001)). Alternatively, the movement of seawater through magnetic fields (e.g. via current or tidal flow) induces localized electric fields that, although small (0.05-0.5 uV/cm), may be detectable by certain species (Kalmijn, 1982).

A wide range of studies have quantified the effects of EMFs on the behaviour and physiology of fish species (Gill et al., 2005; Normandeau et al., 2011; Walker, 2001). EMF produced from anthropogenic sources within the range of detection by electroreceptors have the potential to impact these species through alteration of their behaviour (attraction or repulsion) or disorientation, leading to interference in migration and movement patterns (Gill et al., 2005; Gill and Taylor, 2005). As electric fields diminish in strength with increasing distance from the source, elasmobranchs are likely to be initially attracted to the electric field, but as the individual approaches and the electric field strength increases there will be a point where the animal will turn and swim away. Gill and Taylor (2005) observed the repulsion of elasmobranchs from electric fields >10 µV/cm (Gill and Taylor, 2005). Therefore, when considering the result of the modelling presented in the draft EIS/ERD it is likely that fish may be repulsed by the electric field from the DEH system within a least 75m of the source. However, such impacts are predicted to be behavioural only with no physical impacts likely as a result of the likely avoidance of the source (Walker, 2001).

Marine turtles

Marine turtles are able to detect magnetic fields and note electric fields; however, they do not appear to be as sensitive to magnetic fields as elasmobranchs (Courtillotl et al., 1997; Normandeau et al., 2011; Walker, 2001) and furthermore the potential for behavioural disturbance or displacement is considered low as they are unlikely to be in proximity to the sources of EMF given the depth of water (>400 m) that the subsea infrastructure will be installed in.

Marine mammals

Marine mammals have been observed to be affected to varying degrees by magnetic fields but not electric fields (Fisher and Slater, 2010). Whales and dolphins appear to rely on geomagnetic contours for navigation, and magnetic fields generated by cables may result in disorientation and disruption to navigation and therefore negatively affect migratory behaviour (Meißner et al., 2006). However, the magnetic field strength emitted from the active heating of the flowlines will be indistinguishable from the earth's field beyond 1 m from the source (Table 6-28 of the draft EIS/ERD). In addition, given the depth of water (>400 m) that the majority of the EMF will be in, the significance level is predicted to be slight as it is not anticipated that marine mammals will be in close enough proximity to the source to elicit any lasting effects.

Summary

In summary, EMF can be detected at various levels of sensitivity by a number of marine fauna, with some behaviour responses evident from studies outlined above. However, EMF associated with DEH of the flowlines and risers are predicted to attenuate rapidly from the source, with the magnetic field predicted to be below the earth's natural geomagnetic level within 1 m and the electric field predicted to dissipate to 46 µV/cm within 75 m (Table 6-28 of the draft EIS/ERD). Given the depth of water (>400 m) that the majority of the EMF will be in and the predicted attenuation distances of the electric and magnetic fields, impacts on marine fauna are not predicted to be significant. If marine fauna are temporarily within the area of influence of EMF, effects are expected to be limited to short-term behavioural impacts.

8.4.4.4 Atmospheric emissions: offshore activities

Potential impacts relating the EPA Environmental Factor – Air Quality are addressed in Section 8.5. This assessment concluded that given the low emissions levels it is not anticipated emissions from the Proposal will result in lasting adverse impacts to air quality in the State Proposal Area.

Atmospheric emissions can cause direct impacts to fauna if they are present in the immediate vicinity of significant releases. Birds, for example, have been shown to suffer respiratory distress and illness when subjected to extended duration exposure to air pollutants (Sanderfoot and Holloway, 2017). Given that no lasting adverse impacts to air quality are predicted, it is highly unlikely that seabirds or migratory shorebirds will be exposed to air pollutants for an extended duration of time. As such, adverse impacts to seabirds or migratory shorebirds as a result of atmospheric emission are not predicted.

8.4.4.5 Atmospheric noise

Atmospheric noise emissions are expected to be generated in the State Proposal Area as a result of helicopter flyover during crew transfer, MODU flaring, pile driving and the operation of project vessels and the MODU. Predicted atmospheric noise levels and potential impacts relating to the proposed Browse to NWS Project are described in Section 6.3.7 of the draft EIS/ERD, which concluded that potential impacts to marine fauna from atmospheric noise emissions are expected to be limited to temporary behavioural responses.

Potential behavioural impacts for fauna that are present on the surface during a helicopter flyover (either in State waters near Broome during crew transfer, or in the State Proposal Area near the MODU during crew transfer) may include temporary 'startle' responses (e.g. diving). Such responses typically occur at relatively short ranges (tens of metres) (Hazel et al., 2007) and behavioural impacts during a typical helicopter flight are highly unlikely due to the altitude and distance between the helicopter and the potential receptor.

Atmospheric noise emissions from flaring on the MODU during well unloading will be intermittent and short in duration and are not expected to result in impacts to fauna beyond avoidance behaviour of individual fauna near the MODU at the time of flaring.

Some atmospheric noise emissions will occur during pile driving (if pile driving is required for the MODU mooring during the construction phase) and from project vessels and the MODU (particularly while on DP). The atmospheric noise emissions associated with these sources are expected to be relatively minor and are not expected to result in impacts to fauna beyond avoidance behaviour of individual fauna.

Seabirds and migratory shorebirds

Seabirds and migratory shorebirds may be affected by atmospheric noise emissions from helicopters transiting between Broome Heliport and the Browse Development Area. In particular, bird species present around Roebuck Bay and Cable Beach (<1 km from the Broome Heliport) and roosting birds at Scott Reef may be affected. Anthropogenic disturbance is identified in the Wildlife Conservation Plan for Migratory Shorebirds as a threat to the conservation of migratory shorebirds (Commonwealth of Australia, 2015c).

Given the high visibility and noise levels associated with helicopter movements, bird species are expected to actively avoid interaction. Any disturbance from helicopters in transit will be of limited duration as they pass by.

Impacts to bird species in the area surrounding Broome are expected to be negligible as helicopters passing by bird aggregation areas will be at significant altitude.

Impacts to bird species at Scott Reef are also expected to be negligible given the area does not represent a significant aggregation, nesting or roosting area for seabirds and migratory shorebirds; and flight paths will actively avoid roosting areas (Sandy Islet).

Bird species along the remainder of the flight path are expected to occur in low numbers. Given the altitude the helicopters will be flying at, impacts are not considered credible.

Cetaceans, marine turtles and fish

Underwater noise monitoring by McCauley (2008) at Scott Reef during a drilling program in 2008 demonstrated that noise emissions from helicopters operating from the MODU were not detectable at a noise logger set 4.6 km away (McCauley, 2008). Given this, and the typical characteristics of helicopter flights from Broome Heliport to the Project Area (i.e. duration, frequency, altitude and air speed), the predicted environmental impact of helicopter generated atmospheric levels that may result in behavioural disturbance to cetaceans, marine turtles and fish is not expected to have any lasting effect.

8.4.4.6 Underwater noise

Key underwater noise emissions that may occur within the State Proposal Area may include pile driving for mooring of the MODU, the MODU on DP, VSP and DAS and the operation of the wellhead. Other noise sources such as vessel operation, helicopter movements and seabed preparation are expected to be minor in comparison and are not considered further here. A detailed assessment of the potential impacts to marine fauna resulting from underwater noise emissions relating to the proposed Browse to NWS Project is presented in Section 6.3.8 of the draft EIS/ERD.

Modelling

Underwater noise emissions in the State Proposal Area are likely to be greatest during drilling, installation and decommissioning phases when activities such as pile driving may be occurring and vessel activity within the State Proposal Area is at its highest. Nevertheless, given the overall scale of the Proposal and activity phasing, noise emissions during these phases are expected to be limited and of relatively short duration. The results of the underwater noise modelling undertaken for the proposed Browse to NWS Project, including simulated animal movement and exposure modelling, are presented in **Section 6.3.8.3** of the draft EIS/ERD. The representative modelling undertaken for activities represent the State Proposal Area include driven piling modelling, the MODU on DP, well VSP and wellhead noise modelling. Modelling for MODU piling noise was based on results for the larger FPSO anchor piles using the IHC S-600 hammer. These estimated ranges of potential impact are considered a representative analogue for potential pile driving for mooring of the MODU, due to the expected smaller diameter and reduced loading requirements of the MODU mooring piles.

Marine mammals

The assessment presented in **Section 6.3.8** of the draft EIS/ERD concluded that predicted underwater noise emissions associated with key activities within the State Proposal Area may result in localised avoidance and/or behavioural disturbance of marine mammals within the vicinity of the proposed activities. Humpback and pygmy blue whales are known to occur within the State Proposal Area during their annual migrations, however, studies indicate these species occur in relatively low numbers within the area.

Injury/Mortality

As discussed in **Section 6.3.8.3** of the draft EIS/ERD, acoustic modelling of piling activities at Torosa (which incorporates animal behaviour and exposure), indicates that with exclusion zones in place, exposures to sounds levels where permanent injury could occur for pygmy blue whales is reduced to zero. Modelling also indicates that for other activities including the MODU on DP, it is highly unlikely that marine mammals would be exposed to underwater noise levels where injury would occur and as such injury or mortality to marine fauna is not expected.

Behavioural impacts

Modelling of the FPSO anchor piling activities estimated that only 0.32 migrating individual pygmy blue whales and 0.43 foraging pygmy blue whale individuals would exposed to behavioural response per pile. These estimates are based on the larger FPSO piles and does not include industry standard pre-start observations or soft starts and, as such, the actual number of individuals for MODU piling is likely to be less. Impacts are expected to be limited to temporary avoidance behaviour for the duration of the piling.

Modelling indicates that behavioural impacts may result from the MODU DP to a distance of 10.5 km. As with the piling noise, these impacts are expected to be limited to temporary avoidance behaviour and would only occur during MODU activities (in the order of 75 days per well).

Noise levels predicted from well evaluation using VSP demonstrate that potential behaviour impacts may occur within 1.6-1.7 km from the well; however, these would be limited to a very short duration as this type of activity will only occur for up to 10 hours per well.

Underwater noise levels from subsea wellheads will likely fall below the 120 dB re 1 µPa (SPL) cetacean behavioural response threshold within approximately 500 m of the wellheads at the TRD and TRE drill centres and are not predicted to reach the top 100 m of the water column, even directly above the wellheads. Potential impacts to whales and other cetaceans from increased noise levels in the vicinity of the wellheads are therefore expected to be minor and highly localised and are not expected to deter passage through Scott Reef Channel.

Potential impacts to whales and other cetaceans from increased noise levels in the vicinity of the wellheads are, therefore, expected to be localised and are not expected to cause significant impact at a population level.

Given the above, impacts to marine mammals resulting from underwater noise emissions are expected to be limited to occasional temporary behavioural/avoidance impacts to a relatively low numbers of transient marine mammals expected to seasonally occur within the State Proposal Area.

Marine turtles

A detailed assessment of the potential impacts to marine turtles resulting from underwater noise emissions relating to the proposed Browse to NWS Project is presented in **Section 6.3.8** of the draft EIS/ERD.

The underwater noise and animal exposure modelling (**Section 6.3.8.3** of the draft EIS/ERD) shows when representative animal movement and behaviour for both migratory and internesting turtles is incorporated into the impact piling propagation model for piling at the Torosa location in the State Proposal Area, no individual turtles would be exposed to injury levels. Additionally, when incorporating representative migratory green turtle animal movement and behaviour, the 95th percentile exposure ranges to the recoverable auditory fatigue (TTS) threshold are approximately 1.65 km for the IHC S-600 hammer. It should be noted these results do not incorporate incorporated potential shutdowns and soft starts.

Further, the modelling shows for other key activities the turtle injury PTS threshold is either not reached, or only extends a distance in the order of 130 m. Given these results do not incorporate animal movement and behaviour is based on the assumption the marine turtle is stationary within this distance for a 24 hour period (which is highly unlikely to occur), it is considered highly unlikely marine turtles will be exposed to underwater noise levels above the PTS threshold as a result of activities associated with the Proposal.

Modelling also indicates that the recoverable TTS threshold for marine turtles extends in the order of 50 – 160 m for other modelled activities, including the MODU on DP and VSP. It should be noted again that these results do not incorporate animal movement and behaviour and based on the assumption the marine turtle is stationary within this distance for the duration of VSP or 24 hour period for continuous sources (which is highly unlikely to occur). Given this, the planned mitigation measures (including exclusion zones and shut downs), the small exposure area, the temporary nature of the piling activities and the likely avoidance behaviour of marine turtles, it is considered that these impacts will be limited to behavioural (avoidance) impacts and would not result in any lasting effect. Given the temporary nature of the piling and drilling activities, these behavioural impacts are not expected to result in any reduction in nesting success or long terms impacts to internesting or migrating marine turtles in the State Proposal Area.

Fish

The modelling indicates that for the most sensitive fish groups (fish with swim bladder involved in hearing) sounds levels from the piling activities could exceed mortality levels within 200-210 m of the noise source. For fish species, including sharks, sound levels exceeding the recoverable TTS threshold are predicted to within in the order of 9 km at Torosa, assuming fish are stationary and do not avoid the sound source. Given the mobility of fish species and the likely avoidance behaviour, it is considered unlikely that such an exposure would occur.

For the other modelled activities, including the MODU on DP and VSP activities, the modelling indicates that fish would not be exposed to sound levels that could cause permanent injury or mortality. Recoverable injury to some fish species could occur, but only if the animals were in very close proximity to the sound sources (within a planar distance of 60 m) for a 48-hour period. As discussed above, this is considered highly improbable. Temporary impairment due to TTS could occur at similar short distances if fish remain at the same point within the sound field for long periods of time (12 hours), which is also considered highly improbable.

As such, it is considered that any impacts to fish from underwater noise emissions will be limited to temporary avoidance behaviour.

Sea snakes

As discussed in **Section 6.3.8** of the draft EIS/ERD, there is limited information available on hearing in sea snakes, but they are known to be capable of detecting pressure changes (Mick Guinea pers. comm.). Due to this and the fact that quantifiable distances for assessing impacts from continuous sounds only exist for fish, fish have been used as a surrogate for this assessment. As discussed, any impacts to fish from underwater noise emissions will be limited to temporary avoidance behaviour.

8.4.4.7 Marine discharges: sewage and sullage

An assessment of the potential impact on marine environmental quality from the discharge of sewage and sullage from project vessels, installation vessels and the MODU is presented in **Section 8.2.4**. This assessment concluded that changes to the physical and chemical properties of the marine water will be temporary and highly localised (discharge diluted to 1% of its original concentration with 50 m). Given the relatively small volume of treated sewage and sullage to be discharged and the expected rapid dilution of the discharge, the temporary and highly localised changes to water quality are not expected to have any lasting impacts to marine fauna within the State Proposal Area.

8.4.4.8 Marine discharges: treated utility water, chemical and deck drainage

An assessment of the potential impact on marine environmental quality from the discharge of treated utility water, chemical and deck drainage from project vessels, installation vessels and the MODU is presented in **Section 8.2.4**. This assessment concluded that treated utility water, chemical and deck discharges would result in temporary change water quality in the immediate vicinity of the discharge. Marine fauna such as fish, marine mammals and marine turtles may come into contact with these discharges. However, the discharges are expected to be rapidly diluted in the prevailing currents. Given this, the small volume of any discharge and the short, intermittent nature of these discharges, any contact with the discharge with marine fauna would be of extremely short duration. As such, it is not considered credible that toxic affects to marine fauna will occur as a result of the discharge of treated utility water, chemical and deck drainage within the State Proposal Area.

8.4.4.9 Marine discharges: produced water

As detailed in **Section 8.2.4**, given the small percentage that the PW component makes of the overall discharge from the MODU during well unloading, this discharge is addressed as part of the assessment of discharges during drill cuttings and fluids.

8.4.4.10 Marine discharges: cooling water

An assessment of the potential impact on marine environmental quality from the discharge of cooling water from project vessels, installation vessels and the MODU is presented in **Section 8.2.4**. This assessment concluded that cooling water discharges would result in temporary changes in water quality in the immediate vicinity of the discharge. While marine fauna such as fish, marine mammals and marine turtles may come into contact with these discharges, given that the discharges will disperse rapidly close to the discharge point and that any contact with the discharge with marine fauna will be of extremely short duration, it is not considered credible that toxic affects to marine fauna will occur as a result of the discharge of cooling water within the State Proposal Area.

8.4.4.11 Marine discharges: drill cuttings and fluids

An assessment of the potential impact on marine environmental quality from the discharge of drill cuttings and fluids from the MODU during drilling activities is presented in **Section 8.2.4**. This assessment concluded that change in to water quality (through elevated TSS and the introduction of contaminants) would be temporary and localised with no subsequent impacts to biota predicted.

This reduction in water quality would be temporary (limited to the duration of the activity) and subject to rapid dispersion and dilution by prevailing currents, due to the open oceanic waters of the State Proposal Area. There is a large body of knowledge indicating a discharge of cuttings with adhered fluids dilutes rapidly. These studies found that that within 100 m of the discharge point, a drilling cuttings and fluid plume released at the surface diluted by a factor of at least 10,000, while J.M. Neff (2005) stated that, in well-mixed oceans waters (as is likely to be the case within the drilling area), drilling fluid was diluted by more than 100-fold within 10 m of the discharge. While marine fauna such as fish, marine mammals and marine turtles may come into contact with these discharges, given that the discharges will disperse rapidly close to the discharge point and that any contact with the discharge with mobile marine fauna will be of extremely short duration, it is not considered credible that toxic affects to marine fauna will occur as a result of changes in water quality resulting from the discharge of drilling cuttings and fluids within the State Proposal Area.

The assessment presented in **Section 8.2.4** also found that impacts to benthic biota from sedimentation (discharged drill cuttings and fluids depositing on the seabed) are expected to be confined to sessile biota, such as sediment burrowing infauna and epifauna, where present in or on the seabed in immediate proximity to the well location (in the order of 200 m from each well). Away from this immediate area, sedimentation over the course of the drilling program would be low, equating to a thin veneer of settled drill cuttings which would likely be naturally reworked into surficial sediment through processes such as bioturbation (US EPA (2002). Ecological impacts are not expected for mobile benthic fauna such as crabs and shrimps or pelagic and demersal fish, given their mobility (IOGP, 2016).

As detailed in **Section 8.2.4.8**, modelling indicated that the sea surface discharge of drill cuttings from the bottom-hole sections generated at the previously proposed TRE and TRD drill centre locations would potentially result in incursions of sediment plumes and associated increased sedimentation to portions of North and South Scott Reef including within the lagoons.

Given the potential sensitivities of Scott Reef shallow water benthic communities and habitats (and associated marine fauna) to sedimentation from drilling discharges, Woodside has committed to managing the drilling discharges (in particular bottom hole discharges) at drill centre locations in the State Proposal Area (i.e. TRA, TRD, TRE and TRF) in such a manner to avoid impacts to Scott Reef shallow water benthic communities and habitats (<75 m water depth). This approach is outlined in **Section 8.2.6**.

Given that impacts to marine fauna will be limited to highly localised smothering of biota associated the deepwater habitats that are well represented both in the State Proposal Area and regionally, is not predicted to result in any reduction of biological diversity and ecological integrity at local and regional scales will occur.

8.4.4.12 Marine discharges: subsea control fluids

An assessment of the potential impact on marine environmental quality from the discharge of subsea control fluids during operation of the subsea infrastructure is presented in **Section 8.2.4**. This assessment concluded that the intermittent discharge of small volumes of subsea control fluid may result in a temporary reduction in water quality (limited to the duration of the activity), restricted to deep water and subject to rapid dispersion and dilution by prevailing currents, due to the open oceanic waters of the State Proposal Area.

Given the volume of the discharges and the location (at the seabed in water depths exceeding 300 m), it is not considered credible that impacts to marine fauna will occur as a result of the discharge of subsea control fluids within the State Proposal Area.

8.4.4.13 Marine discharges: hydrotest fluid

A description and assessment of the potential impact on marine environmental quality from the discharge of hydrotest fluid during integrity testing of the subsea infrastructure and the temporary production system on the MODU is presented in **Section 8.2.4**. Modelling (**Section 6.3.17.3** of the draft EIS/ERD) indicates that the hydrotest plume would be expected to travel in close proximity to the seabed at depths greater than 300 m. As such, fauna exposed to the discharge plume would be limited to pelagic fish and benthic biota in the deep waters of the State Proposal Area. The assessment presented in **Section 8.2.4** concluded that given the low volume of hydrotest fluid to be discharged, the low toxicity of the fluid, and the water depth at which the discharge would occur, hydrotest discharges within the State Proposal Area are not expected to result in any lasting impacts to benthic biota.

Impacts to pelagic fish from the discharge of hydrotest fluid is expected to be highly localised. Highly motile fish and other marine fauna have the capacity to adapt their behaviour in response to changes in environmental conditions and can be expected to move away from the discharge if exposed. The depth of the plume will also limit the number of fish that may potentially be affected.

Given the above, it is not expected that hydrotest fluid discharge in the State Proposal Area will result in a reduction in biological diversity or ecological integrity.

8.4.4.14 Unplanned marine discharges: hazardous and non-hazardous waste inorganic waste

A description and assessment of the potential impact on marine environmental quality from unplanned discharge of hazardous and non-hazardous inorganic wastes is presented in **Section 8.2.4**. This assessment concluded that in the unlikely event of an unplanned discharge, discharged materials in liquid or sludge form would be subject to rapid dispersion and dilution by prevailing currents, due to the open oceanic waters of the State Proposal Area. This would result in a temporary and highly localised change in water quality. Given this, it is not considered credible marine fauna will be exposed to sufficient concentrations or durations of the discharge constituents to elicit a toxic response.

Accidentally discharged non-buoyant waste has the potential to sink to the seabed and impact epifauna, however, given the sparse nature of deepwater habitats that are well represented both in the State Proposal Area and regionally, any impacts are highly unlikely to reduce biodiversity or ecological integrity within the State Proposal Area.

8.4.4.15 Physical presence (unplanned): vessel interactions with fauna

Vessel movements during all phases of the Proposal have the potential to cause injury or mortality to marine fauna as a result of accidental collisions (**Section 6.3.18** of the draft EIS/ERD). These movements include within the State Proposal Area, and within State coastal waters near the potential logistics supply bases (for example, FCTVs transiting between Broome and the FPSO facilities).

The type and number of vessels in the Project Area (and transiting to and from the Project Area) at any one time, and the duration of presence, will differ depending on the project phase. Vessel presence is expected to be greatest for short term project phases (e.g. drilling and completions, subsea installation including BTL, and commissioning), with the longer-term operational phase requiring fewer vessels.

In addition, in the instance flowlines are installed as towed bundles up to 10 km in length, the movement of these towed bundles have the potential to result in accidental collisions due to their length and limitations in manoeuvrability. Although it is noted that there will be far fewer movements of towed bundles (when compared with traditional installation techniques such as pipelay vessels) which are only required during construction. Towed bundle movements will occur at a significantly slower speed than regular vessel movements.

Vessel speed has been demonstrated as a key factor in collisions with marine fauna (Commonwealth of Australia, 2017b; Laist et al., 2001). Large (>80 m), fast moving vessels pose the highest risk, collisions are difficult to avoid as the vessels are potentially not able to slow down or evade marine fauna upon sighting (Laist et al., 2001). All project vessels will not travel at speeds greater than 12 knots with the State Proposal Area, or 6 knots in the Scott Reef channel, which will reduce the risk of accidental collisions (Laist et al., 2001).

Fast Crew Transfer Vessel (FCTV)

Fast crew transfer vessels (FCTVs) may be used for crew transfer. These FCTVs are capable of travelling at 50 – 55 knots. It is anticipated that one transfer per day would occur during normal operations, with additional transfers during shut downs and major maintenance. FCTVs will not travel at speeds in excess of 12 knots in the State Proposal Area.

If a FCTV is utilised, Woodside would select a FCTV design which inherently minimises the risk of unplanned interaction with marine fauna. The vessel has no propeller, has a shallow draught (<1 m) and can rapidly slow down, for example reaching dead stop within approximately 150 m from a cruising speed of 30 knots.

Figure 6-46 of the draft EIS/ERD provides an indicative route from Broome to the Browse Development Area. Recognising that interactions are most likely to coincide with increased fauna presence particularly within BIAs, consideration has been given to control measures beyond standard practice to specifically manage the risk of vessel strike within sensitive areas at sensitive times. The Proposed Management Approach for the FCTV is outlined in detail in Section 6.3.18.2 of the draft EIS/ERD.

Fauna that are highly unlikely to co-occur with project vessels

Fish

As described in Section 6.3.18 of the draft EIS/ERD, in the context of unplanned vessel collisions with fauna, the type of fish most likely to be impacted are larger pelagic species, particularly large sharks. Whale sharks are at particular risk due to their slow swimming behaviour and propensity to spend significant portions of time at the surface. Studies have indicated that whale sharks spend approximately 25% of their time less than 2 m from the surface and greater than 40% in the upper 15 m of the water column (Gleiss et al., 2013; Wilson et al., 2006). Conservation advice for the whale shark (Threatened Species Scientific Committee, 2015f) identifies vessel strike from large vessels as a key threat. However, based on the available information, it is expected that while whale sharks may occur within the Project Area, they are likely to occur in low numbers and as vagrant individuals (Meekan and Radford, 2010; Wilson et al., 2006). Whale sharks are not expected to occur in State waters near the potential logistic base locations. As such, it is considered highly unlikely that a vessel strike on a whale shark will occur in these areas. Given this, and the proposed vessel speed restrictions, it is considered highly unlikely that a vessel strike on a whale shark will occur.

Other fish are thought to be generally less vulnerable to vessel strike due to size, natural flee responses and preferred habitat use. Smaller fish may be at risk of mortality through being caught in vessel thrusters during station keeping operations. However, the noise emissions generated by the operation of dynamic positioning thrusters will generally deter fish from the vicinity of these operations.

Marine mammals – cetaceans (other than humpback whales)

As described in Section 6.3.18 of the draft EIS/ERD, large whales are more vulnerable to vessel collisions, particularly those species whose behaviour includes extended surface ‘milling’ time (Laist et al., 2001) and which demonstrate a lack of avoidance behaviour to approaching vessels (Nowacek et al., 2004). Cetacean calves and juveniles also have a higher risk of impact (Stevick, 1999), possibly due to less frequent and shorter dives (Szabo and Duffus, 2008).

Pygmy blue whales demonstrate limited behavioural responses to avoiding vessel collisions, with some undertaking slow shallow dives; however, active flee responses from vessels have not been observed (McKenna et al., 2015). While it is acknowledged that pygmy blue whales are vulnerable to vessel collisions, they are not expected to occur in high densities within the State Proposal Area or within State waters along the route that vessels will traverse when transiting to and from the Project Area. It is noted that the Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015a) documents a possible foraging area within the vicinity of the Scott Reef. The plan also recognises vessel disturbance as a key threat to blue whales.

However, while studies indicate that pygmy blue whales pass through the Scott Reef area and that this area represents a potential foraging area for the species (as outlined in Conservation Management Plan for the Blue Whale (Commonwealth of Australia, 2015c)), multiple surveys, have failed to observe significant numbers of individuals present or evidence of foraging.

Therefore, co-occurrence of project vessels with pygmy blue whales is considered to be highly unlikely.

With respect to the other large cetacean species that may occur in the State Proposal Area, neither the Bryde's whale, sei whale or fin whale are expected to occur in large numbers in the State Proposal Area or in the State waters along the route project vessels would take when transiting to and from the Project Area.

Although spinner dolphins are very agile in the water and often display positive behaviours to the presence of vessels (e.g. bow-riding), there are a significant numbers of recorded vessel collisions with dolphins across Australia (DoEE, 2017). However, it is likely that the majority of such occurrences occur within more confined coastal areas subject to high vessel-traffic, significantly increasing the chance of vessel collision. It is thought that the risk of collision within deeper offshore waters with less vessel traffic, is significantly reduced (DoEE, 2017).

Given the low likelihood of co-occurrence of vessels with these species and the proposed speed restrictions within sensitive areas at sensitive times (**Table 6-139** of the draft EIS/ERD), the likelihood of vessel interaction with these species resulting in injury or mortality to fauna is considered highly unlikely, with the subsequent risk rated as low.

Fauna that may co-occur with project vessels

Humpback whales

As described in **Section 6.3.18** of the draft EIS/ERD, considering the densities, distributions and migratory pathways of the key marine fauna within the Project Area, humpback whales are considered to be the main species at risk from vessel interactions related to the proposed project activities, and in particular the possible use of FCTVs to transfer personnel from Broome to the offshore facilities during operations. A comprehensive review of ship strikes on large whales by Jensen and Silber (2004) revealed that humpback whales were the second highest reported species struck (44 records).

During their annual migration, humpback whales occur in relatively high densities between the Project Area and the Western Australian coast, include State waters adjacent to the mainland, which represents a migratory BIA for the species (see **Section 5.3** of the draft EIS/ERD for a detailed discussion on humpback whale distribution). Project vessels including FCTVs will traverse this BIA during transit from logistic bases (in Broome and Dampier) and the Project Area (**Figure 6-46** of the draft EIS/ERD). The risk of collision is likely to be higher during the southern migration given the broader migratory corridor and the presence of cow and calf pairs travelling at slower speeds with a higher proportion of time spent at the surface (Bejder et al., 2019; Zoidis and Lomac-MacNair, 2017). Vessel disturbance and strike is identified as a threat to humpback whales within the Conservation advice *Megaptera novaeangliae*, Humpback Whale (Threatened Species Scientific Committee, 2015e).

Given this risk to high value fauna, Woodside has developed a mitigation measures to reduce the likelihood and severity of potential vessel collision with humpback whales. These measures have been developed in consideration of the National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna (Commonwealth of Australia, 2017b).

While research into these potential methods to reduce the risk of vessel collisions is limited in the existing scientific literature, a key action of the National Strategy for Reducing Vessel Strike is to identify and adopt best-practice mitigation measures and emerging technologies and encourage the development of new mitigation measures. It is therefore considered emerging technologies may offer an equivalent reduction in risk to speed reductions and may in future eliminate the need for speed reductions in sensitive areas at sensitive times.

The proposed management approach (outlined in **Section 6.3.18** of the draft EIS/ERD) including engineering controls and speed restrictions, is considered sufficient to manage the risk of unplanned vessel interaction with humpback whales.

Dugongs

As described in **Section 5.3.2.5** of the draft EIS/ERD, dugongs are known to inhabit the coastal regions of the Dampier Peninsula, with high concentrations noted at Roebuck Bay adjacent to Broome (RPS, 2010). Dugongs typically spend the majority of their time submerged, surfacing on average every 1-4 minutes (Anderson and Birtles, 1978; (De longh et al., 1997; and Cox, 2002) and typically spending less than 5% of the time resting on the surface (Hodgson, 2004). Because of their size, dugongs are susceptible to injury or mortality resulting from interaction with vessels, particularly when they rise to the surface to breathe, rest or forage in shallow waters. One of the primary responses of dugongs to approaching vessels is to move towards deeper water (Hodgson, 2004).

Similarly, dugongs are susceptible to injury or mortality resulting from interaction with vessels, particularly when they rise to the surface to breathe, rest or forage in shallow coastal waters as opposed to deeper offshore waters.

The proposed management approach (outlined in **Section 6.3.18.2** of the draft EIS/ERD) including engineering controls and speed restrictions, is considered sufficient to manage the risk of unplanned vessel interaction with dugongs, particularly given the likely lower densities of individuals within the proposed FCTV route and the minimal overlap between the proposed route and dugong foraging BIA.

Turtles

Turtles that are known to occur in the North West Marine Region are described in **Section 5.3.2.6** of the draft EIS/ERD). The Recovery Plan for Marine Turtles in Australia (2017-2027) (Commonwealth of Australia, 2017a) recognises vessel strikes as a moderate threat to the Scott Reef – Browse Island green turtle genetic stock. It also defines the area around Scott Reef as habitat critical to the survival of green turtles, and the area around the Lacepede Islands as an important nesting location for green turtles and flatback turtles.

Turtles may be particularly vulnerable to vessel strike while surfacing to rest or breathe. However, it has been reported that turtles spend a comparatively limited amount of time (3–6%) at the surface, with dives lasting between 15 and 60 minutes in general (Milton and Lutz, 2003). Turtles have been observed to avoid approaching vessels by moving away from the vessel's track (Hazel et al., 2007). Hazel et al. (2007) suggest that this avoidance behaviour is based primarily on visual cues (although the authors acknowledge vessel noise is within range of turtle hearing), and the success of this behaviour in avoiding a vessel strike largely depends on the speed of the approaching vessel and the prevailing water clarity. It's also likely that the propagation characteristics of underwater noise, particularly in high-use areas, would make it difficult for turtles to determine the direction of an oncoming vessel to elicit an appropriate flee response (Hazel et al., 2007). In the event of a collision, a turtle's carapace provides a level of protection from serious injury, although the type and severity of the injuries would depend on the force of the collision and structure and size of the vessel.

Turtles generally aggregate in shallow coastal areas adjacent to nesting beaches or in areas where sufficient food is available. Therefore, vessel interactions with turtles will be primarily restricted to coastal areas and in proximity to offshore nesting beaches (e.g. Scott Reef) where vessel movements would be limited, significantly reducing the likelihood of vessel collision.

The proposed management approach (outlined in **Section 6.3.18** of the draft EIS/ERD), including engineering controls and speed restrictions, is sufficient to manage the risk of unplanned vessel interaction with marine turtles.

8.4.4.16 Production activities: seabed subsidence

A detailed description of the subsea subsidence that may manifest as a result of production activities and as an assessment of the potential impacts that may result is provided in **Section 6.3.20** of the draft EIS/ERD. This includes peer reviewed modelling (**Section 6.3.20.3** of the draft EIS/ERD) which estimated that the average vertical seafloor movement is a total of approximately 5.4 cm (range 2.6 – 8.9 cm) over 40 years based on modelling; this is equivalent to 0.06-0.22 cm/year.

AIMS, (2012) assessed the impact of net sea level rise (from subsidence and climate change induced sea level rise) and its predicted impacts on reef flat habitat (0 to 5 m depth), shallow water coral habitats (5 to 30 m), deepwater coral habitat (30 to 70 m) and Sandy Islet, for three scenarios (worse case, intermediate case and best case).

Overall the study concluded that minor seabed subsidence over the life of the Torosa reservoir affecting a part of Scott Reef and Sandy Islet is not predicted to significantly contribute to sea level changes and predicted associated impacts.

Seabed subsidence has the potential to impact marine fauna by reducing the available land which comprises Sandy Islet. A reduction in the area of Sandy Islet could impact marine turtles, which use the landform for nesting, by reducing available or suitable nesting locations, which could impact nesting success rates. Scott Reef and Sandy Islet have experienced considerable natural variability in sea level over different time scales. For example, the tidal regime at Scott Reef is semi-diurnal with a maximum daily range of approximately 4 m. Similarly, sea levels can temporarily vary by tens of centimetres in response to large-scale oceanographic and atmospheric processes, such as the passage of mesoscale ocean eddies and inverse barometer effects with the passing of cyclonic and anticyclonic pressure systems. During El Nino years, up to 20 to 30 cm increases in sea levels occurred from the eastern Pacific Ocean to the eastern Indian ocean. Satellite data (ToPEX/Poseidon) from 1992 to 2009 showed intra and inter-annual sea level variability in the vicinity of Scott Reef to be from 30 cm below to 40 cm above MSL (Cooper et al., 2010). Given the natural variability in sea level at Scott Reef described above, nesting turtles (primarily green turtles) demonstrate the ability to cope with variability in the sea level at Sandy Islet.

The AIMS (2012) study concluded that with worst-case net sea level rises there is potential for wave action at high tide to reduce the height of the islet. This could affect the stability of Sandy Islet due to erosional processes associated with increased wave height, and thus impact on the availability of turtle nesting habitat. These impacts would still occur in the absence of subsidence, albeit over a slightly longer time period, with the most important factor influencing the persistence of the islet being the frequency of Category five cyclones. The study concluded for the worst-case scenario, given the highly variable nature of sea level rise, cyclone occurrence and sediment dynamics, that it is not possible to reliably predict the timing or just how much earlier any major changes to Sandy Islet might occur. The AIMS (2012) study concluded impact to Sandy Islet from the intermediate and bestcase scenarios would be negligible.

Given the above, no change is predicted in terms of available turtle nesting locations or nesting success as a result of seabed subsidence.

Likewise, no material reduction in the land available for seabirds that may roost on Sandy Islet is expected.

8.4.4.17 Physical presences (unplanned): invasive marine species (IMS)

A detailed assessment of the potential risks associated with unplanned introduction of IMS is provided in **Section 6.3.17** of the draft EIS/ERD.

While the primary receptors with respect to IMS within the State Proposal Area are the benthic communities and habitats of the Scott Reef system (refer to **Section 8.3.4.14**), once an IMS is established, it has the potential to impact on native species diversity and abundance in a variety of ways which may result in changes to ecosystem dynamics. This can occur via competition for or reduction of natural resources, predation, changes to nutrient cycling processes, habitat change and the spread of disease.

As described in **Section 6.3.17** of the draft EIS/ERD, given the existing legislative and management controls in place to prevent translocation and establishment of IMS within State waters, it is considered that the likelihood of IMS being introduced, establish a self-sustaining population and subsequently cause environmental impacts to the ecological communities within Scott Reef is remote and, as such, biological diversity and ecological integrity will be maintained.

8.4.4.18 Unplanned hydrocarbon releases

A detailed assessment of the potential risks associated with unplanned hydrocarbon releases is provided in **Section 6.3.19** of the draft EIS/ERD. Quantitative hydrocarbon spill modelling of various worst-case hydrocarbon release scenarios is presented in **Section 6.3.21.3** of the draft EIS/ERD. This included modelling of a loss of well integrity scenario at the TRA-C well (Scenario 1) which represents the worst case impacts to Scott Reef. The results of the modelling of Scenario 1 are summarised in **Table 6-158** and **Figure 6-51** of the draft EIS/ERD.

Based on the outcomes of quantitative spill modelling, hydrocarbon spills resulting from the proposed Browse to NWS Project have the potential to significantly impact marine fauna within the State Proposal Area and other State waters in the region such as at Rowley Shoals and the Kimberly coastline. Potential impacts to marine fauna exposed to hydrocarbons are described in **Section 6.3.21** of the draft EIS/ERD. Given the existing legislative and management controls, the occurrence of hydrocarbon spills is considered highly unlikely.

8.4.4.19 Cumulative impacts

Given the distance of the State Proposal Area from other operating developments in the region, it is not considered credible that cumulative impacts from the proposed Browse to NWS Project and other development will occur.

Cumulative impacts to marine fauna from exposure to multiple aspects resulting from the proposed Browse to NWS Project (both State and Commonwealth Waters components) are discussed in **Section 9.2.2** of the draft EIS/ERD. The following provides an assessment of the potential cumulative impacts to marine fauna located in the State Proposal Area.

Seabirds and migratory shorebirds

Atmospheric noise from helicopters and flaring from the MODU, and light emissions from vessels and the MODU, may have slight and temporary behavioural impacts on seabirds and migratory shorebirds. The low magnitude of these light impacts and the infrequent nature of the noise emissions means that exposure to multiple impact sources is unlikely, with cumulative impact to seabirds and migratory shorebirds expected to be limited to slight and temporary behavioural changes.

Fish

With respect to the Commonwealth waters component of the proposed Browse to NWS Project, it is not expected that planned marine discharges to Commonwealth waters will contribute to impacts on marine fauna within the State Proposal Area (**Chapter 6** of the draft EIS/ERD). Operational discharges (i.e. PW and cooling water) from the FPSO will be managed in Commonwealth waters to ensure the defined threshold values (e.g. 99% species protection or no effect concentrations) at the State waters 3 nm boundary are met 95% of the time based on dispersion modelling results.

Operational discharges within the State Proposal Area from project vessels and the MODU (such as cooling water and PW) are predicted to rapidly disperse and dilute within the receiving environment and therefore impacts to fish, if any, will be limited to a localised area within the associated mixing zone. In addition, the relatively low toxicity of these discharges, and short exposure time, means that a toxic response by fish is considered unlikely.

Likewise, modelling has indicated impacts to fish (including whale sharks) from underwater noise emissions are expected to be limited to behavioural impacts.

Given no lasting impacts to fish from marine discharges are predicted and impacts from underwater noise emissions are expected to be limited to behavioural impacts, cumulative impacts on fish as a result of the Proposal are not expected.

Marine mammals
The primary source of potential impacts to marine mammals such as pygmy blue whales in the State Proposal Area is from underwater noise emissions during construction (e.g. piling, VSP and DAS, and MODU on DP) and operations (e.g. subsea infrastructure operations). As described in **Section 6.3.8** of the draft EIS/ERD, modelling has indicated that although no injury or mortality to cetaceans is predicted to occur, there is potential for some degree of behavioural disturbance to cetaceans as a result of underwater noise emissions resulting from activities in the State Proposal Area. Potential impacts to whales and other cetaceans from increased noise levels in the vicinity of the wellheads are expected to be limited to behavioural/avoidance impacts to a relatively low numbers of transient marine mammals expected to seasonally occur within the State Proposal Area which is not recognised as habitat key to any life cycle stage (breeding, calving) or marked aggregations for marine mammals.

No other aspect is predicted to have any lasting effect on marine mammals and, as such, cumulative impact from multiple aspects is not expected.

Marine reptiles
The primary sources of potential impacts to marine turtles are artificial light emissions from the MODU and underwater noise emissions resulting from potential pile driving activities, drilling and the MODU DP.

As described above, it is considered that these impacts can be managed to an acceptable level through the implementation of mitigation measures. Cumulative impacts may occur as a result of simultaneous exposure to these sources. For example, nesting turtles or hatchlings attracted by light emissions from the MODU would subsequently be exposed to noise emissions from the MODU (e.g. DP noise). These cumulative impacts would be limited to behavioural responses for a small number of adult marine turtles.

Cumulative impacts to marine turtles may also occur as a result of attraction resulting from light emissions and concurrent exposure to other temporary, higher intensity noise emissions such as pile driving and VSP noise emissions. However, with the implementation of a proposed 500 m shut down zone during pile driving and VSP operations, as well as pre-start up visual observations, soft starts, operational, and shut-down procedures; cumulative impacts resulting from light and noise emission from pilling and VSP operations are not expected to occur.

Cumulative impacts could also occur as a result of non-simultaneous exposure to light and noise emissions. For example, decreased nesting success as a result of behavioural impacts from noise emissions (i.e. females avoiding nesting habitat at Sandy Islet) combined with decreased hatchling survival rates due to disorientation from light emissions would have a combined impact on the overall population success of green turtles. However, as described above, light and noise emissions are not expected to significantly impact the breeding cycle of marine turtles at Sandy Islet (predominately green turtles) and given the temporary nature of pile driving activities and the MODU's presence at a single location, no cumulative impacts on the nesting success or hatchling survival rates are expected as a result of the Proposal.

Potential impacts may also potentially occur to sea snakes as a result of marine discharges and underwater noise emissions resulting from the proposed Browse to NWS Project. As described in **Section 8.2.4**, impacts to water quality will be temporary and localised and impacts to sea snakes from noise emissions are expected to be limited to slight behavioural/avoidance impacts. As such, no cumulative impacts to sea snakes from the Proposal are predicted.

8.4.5 Assessment of Impacts

With the implementation of management measures such as shut down zones during activities such as piling and VSP, impacts to marine fauna are predicted to be restricted to temporary and localised behavioural impacts to a small number of individual seabirds and migratory shorebird, cetaceans, fish and marine turtles, primarily resulting from underwater noise and light emissions. These emissions will potentially occur from piling activities, VSP, project vessels and the MODU operating in the State Proposal Area, primarily during the construction phase of the project. There is no proposed permanent vessel or facilities presence in the State Proposal Area.

These behavioural impacts are not expected to impact foraging or nesting success and are not expected to reduce biological diversity or ecological integrity.

There is a risk of injury or mortality to a small number of individual animals resulting from collision with project vessels, particularly FCTVs. As described above, however, an adaptive management strategy will be implemented to ensure the risk of vessel strike is not significantly increased above the risk presented by existing marine traffic.

8.4.6 Mitigation

Chapter 8 of the draft EIS/ERD presents the overarching HSE management approach Woodside will implement for the proposed Browse to NWS Project.

Specific proposed measures to mitigate and manage unavoidable impacts from planned activities and reduce the environmental risk associated with unplanned events and incidents are presented in **Chapter 6** of the draft EIS/ERD.

Note that the measures presented in this draft EIS/ERD will be incorporated into activity-specific Environment Plans to be submitted for acceptance by DMIRS prior to the activity commencing within the State Proposal Area.

8.4.7 Predicted Outcome

Taking proposed mitigation and management measures into account; and considering the limited scope and scale of the Proposal (with no permanent facility or vessel presence) and the overall phasing of Proposal development, impacts to marine fauna within the State Proposal Area as a result of the proposed Browse to NWS Project are expected to be limited to temporary behavioural impacts to a small number of individual fauna.

Potential impacts to marine fauna that use the shallow water and emergent habitats of Scott Reef will be reduced by locating the FPSO facilities, BTL and inter-field spur line outside of the State Proposal Area and siting infrastructure within the State Proposal Area in deep waters off Scott Reef. As the State Proposal Area is not known to provide significant aggregation areas for birds or marine mammals, any impacts associated with Proposal activities on fauna are likely to be limited to transient individuals. Similarly, given the small scale of Proposal activities in the State Proposal Area, the temporary nature of the surface activities (restricted to the construction phase and intermittent IMR activities) and the distance from nesting and internesting sites for marine turtles, only a small portion of the turtle nesting population could be temporarily disturbed with no adverse impact on nesting success or hatchling survival rates predicted.

Impacts will be further reduced via the implementation of mitigation and management measures, the majority of which are standard maritime and offshore oil and gas industry practice. Implementation of these mitigation and management measures to ensure impacts are acceptable and ALARP will be assured through activity specific Environment Plans under other regulatory processes.

As such, the WA EPA environmental objective *"To protect marine fauna so that biological diversity and ecological integrity are maintained"* will be achieved for the proposed Browse to NWS Project; and the predicted impacts on marine fauna within the State Proposal Area are considered **Acceptable**.

8.5 Key Environmental Factor – Air Quality

8.5.1 EPA Objective

The EPA objective for air quality is *"To maintain air quality and minimise emissions so that environmental values are protected"* (EPA, 2016e).

8.5.2 Policy and Guidance

The following policy and guidance have been considered in relation to the EPA environmental factor - air quality.

EPA Policy and Guidance

- Statement of Environmental Principles, Factors and Objectives (EPA, 2016b)
- Environmental Factor Guideline – Air Quality (EPA, 2016e).

The Western Australia Government released a GHG Emissions Policy for Major Projects on 28 August 2019. The Policy includes an aspirational target of net zero GHG emissions by 2050. The Minister for Environment will consider how the Policy relates to major proposals assessed under Part IV of the EP Act (Government of Western Australia, 2019).

Public consultation on the WA EPA's draft Environmental Factor Guideline and Technical Guidance relating specifically to GHG emissions closed on 2 September 2019.

8.5.2.1 Receiving Environment

Air quality within the State Proposal Area is described in detail in **Chapter 5** of the draft EIS/ERD. The State Proposal Area is located approximately 260 km the WA coastline and is thus remote from urban and/or industrial air pollutants. Given this, air quality at the State Proposal Area is expected to be of high quality. Air quality of the receiving environment in relation to the atmospheric emissions resulting from the third party processing of Browse gas are described within the ERD associated with the North West Shelf Project Extension Proposal (EPA 2186, EPBC 2018/8335).

8.5.3 Potential Impacts

Summary of identified impacts and risks

Table 8-9 summarises the sources of potential impact to air quality from the Proposal. **Table 8-9** is followed by a detailed description of the potential direct, indirect and cumulative impacts. An assessment of the significance of these impacts on air quality and a conclusion on the acceptability of the impacts in relation to the EPA environmental objective is presented in **Section 8.5.4**.

Table 8-9 Sources of Potential Impact to Air Quality from the Proposal

Aspect	Proposal Phase[1]					Source (in State jurisdiction)
	Dr	I	C	O	De	
Planned (routine and non-routine activities)						
Atmospheric emissions: offshore activities	✓	✓	✓	✓	✓	Power generation on project vessels and the MODU. Intermittent flaring from the MODU Venting of gas from the MODU (during well kick)
Atmospheric emissions: third party processing of Browse gas			✓	✓		Emissions anticipated to result from third party processing of Browse gas

1 Dr = Drilling; I = Installation; C = Commissioning; O = Operation; De = Decommissioning

Atmospheric emissions: offshore activities
Atmospheric emissions will occur from activities within the State Proposal Area. Sources will include the combustion of fuel for power generation, intermittent flaring from the MODU during drilling and completions and the venting of reservoir gas in the event of a well kick (where there is an influx of gas into the wellbore while drilling). These emissions will occur mainly during the construction phase, with emissions during operations limited to vessel emissions during infrequent IMR activities. Atmospheric emissions generated may include carbon monoxide (CO), oxides of nitrogen (NOx), sulphur dioxide (SO_2), particulate matter less than 10 microns (PM10), mercury and non-methane volatile organic compounds (VOCs), such as BTEX (benzene, toluene, ethylbenzene and xylenes).

A detailed description of the planned atmospheric emissions (non GHG) from the offshore activities associated with the proposed Browse to NWS Project is provided in Section 6.3.5 of the draft EIS/ERD, which concluded that no material impact to local air quality or sensitive receptors would occur. Given the majority of emissions from the proposed Browse to NWS Project will occur during operations from the FPSO facilities in Commonwealth waters, the emissions planned within the State Proposal Area represent a small portion of the planned emissions. As such, it can be concluded impacts to air quality and sensitive receptors from these emissions are likely to negligible.

GHG emissions expected to occur within State jurisdiction are described in Section 7.4.4 of the draft EIS/ERD. GHG emissions occurring within State jurisdiction associated with the proposed Browse to NWS Project relate to activities in the State Proposal Area associated with the Torosa field. Total installation emissions across the life of the proposed Browse to NWS Project occurring within the State Proposal Area are estimated to be ~0.4 MT CO2-e (total over field life).

Atmospheric emissions: third party processing of Browse gas
The assessment of any potential impacts on the national heritage values, including aboriginal heritage values, of the listed National Heritage Place on the Dampier Archipelago that may be associated with the onshore processing of the Browse gas by the NWS JV, is addressed within the ERD associated with the North West Shelf Project Extension Proposal (EPA 2186, EPBC 2018/8335).

As described in Section 7.4.4 of the draft EIS/ERD, downstream GHG emissions have been apportioned based on the proportion of NWS processing plant capacity that Browse gas utilises, relative to the GHG footprint currently approved for the facility as per Ministerial Statement 536. Table 7-5 in Section 7.4.4 of the draft EIS/ERD details the reservoir emissions estimated to occur in each jurisdiction under the range of expected export gas specification outcomes. This is dependent on the outcome of final commercial arrangements between the Browse JV and NWS JV.

8.5.4 Assessment of Impacts

Air quality
While a slight reduction in air quality on a local scale will occur for the duration of the activities, given the low emissions levels and the very low background levels of contaminants, it is not anticipated emissions from the Proposal will have a lasting impact on air quality within the State Proposal Area.

8.5.5 Mitigation

Chapter 8 of the draft EIS/ERD presents the overarching HSE management approach Woodside will implement for the proposed Browse to NWS Project. Specific proposed measures to mitigate and manage air quality impacts from planned activities and reduce the environmental risk associated with unplanned events and incidents are presented in Chapter 6 of the draft EIS/ERD. Note the measures presented in this draft EIS/ERD will be incorporated into activity-specific Environment Plans to be submitted for acceptance by DMIRS prior to the activity commencing within the State Proposal Area.

Specific measures to manage and mitigate GHG emissions are presented in Section 7.7 of the draft EIS/ERD. The proposed Browse to NWS Project has proposed a GHG Abatement Plan to continuously review mechanisms to mitigate and manage GHG emissions and compliance with NGER/SGM baseline requirements through use of offsets, at this stage anticipated to be in the form of Australian Carbon Credit Units (ACCUs).

8.5.6 Predicted Outcome

Given the low emissions levels and distance of the emissions sources from the nearest sensitive environmental receptors, it is not anticipated emissions from the Proposal will have an impact on any sensitive receptors. The Proposal is expected to result in a localised, temporary and negligible reduction in air quality in the immediate vicinity of the release point with overall contributions to the atmosphere not expected to be significant. No impact to the environmental values of the State Proposal Area are expected.

As such, the WA EPA environmental objective *"To maintain air quality and minimise emissions so that environmental values are protected"* will be achieved for the Proposal; and the predicted impacts on air quality within the State Proposal Area around Scott Reef are considered **Acceptable**.

9. OTHER ENVIRONMENTAL FACTORS OR MATTERS

No other environmental factors or matters against the environmental objectives/s have been identified in the ESD and/or during stakeholder engagement.

10. MATTERS OF NATIONAL ENVIRONMENTAL SIGNIFICANCE

As detailed in Section 2.9 of the draft EIS/ERD (and Section 5.1), the proposed Browse to NWS Project was referred to the DoEE under the EPBC Act in October 2018 and subsequently determined to be a controlled action. The following Matters of National Environmental Significance (MNES) were identified as controlled action provisions for the proposed Browse to NWS Project:

- National heritage values of a National Heritage Place
- Listed threatened species and communities
- Listed migratory species
- the Commonwealth marine area, the protected matter being the environment generally.

Chapter 5 of the draft EIS/ERD summarises the specific MNES/existing environmental values identified as relevant to the proposed Browse to NWS Project. Potential impacts to these MNES (e.g. atmospheric emissions, marine discharges), and an assessment of the level of significance of these impacts to MNES are detailed in Chapter 6 and Chapter 9 of the draft EIS/ERD respectively. Proposed mitigation and management of these impacts are outlined within the respective impact and risk assessment for each aspect in Chapter 6 of the draft EIS/ERD.

WA State Legislation and policy relevant to the MNES listed above are detailed in Section 2.11.4 and Section 2.11.5 of the draft EIS/ERD, including the EP Act and BC Act.

In the event impacts to MNES cannot be avoided or mitigated to an acceptable level, an environmental offset plan will be developed, as described in Chapter 8 of the draft EIS/ERD. This excludes GHG emissions offsets, which have been considered separately in Chapter 7 of the draft EIS/ERD.

11. HOLISTIC IMPACT ASSESSMENT

An assessment of the Proposal against the relevant WA EPA's Environmental Objectives (as determined by the WA EPA) is provided in **Section 9.5** of the draft EIS/ERD.

This section assesses holistically the potential impacts of the Proposal on the whole environment. In accordance with 'Instructions on how to prepare an environmental review document' (EPA, 2018a) this section describes the connections and interactions between the environmental factors relevant to the Proposal and discusses the predicted outcomes of the Proposal in relation to the environmental principles and the EPA's environmental objectives.

The receiving environment relevant to the Proposal is characterised by relatively pristine offshore environment, largely unaffected by anthropogenic sources and of high marine and air quality. The Proposal's activities have the potential to affect various elements of the environment (as defined by the EPA's environmental factors). Where the receiving environment of environmental factors overlaps, the draft EIS/ERD has considered the receiving environment from the perspective of each relevant environmental factor.

The air quality and marine fauna environmental factors overlap in relation to potential impacts to seabirds and migratory shorebirds. However, as described in **Section 8.4.4**, no lasting effect on seabirds and migratory shorebirds from air emissions is predicted.

Significant overlaps exist between the other relevant factors (marine environmental quality, benthic communities and habits; and marine fauna), where impacts to components of one or more of these factors would potentially impact the other factors. For example, changes to marine environmental quality (e.g. water quality reduction) would potentially impact benthic communities and habitats (e.g. Scott Reef corals) and marine fauna (e.g. green turtles). This is one of the primary drivers in the setting of a level of ecological protection (no detectable change from natural background) for all of Scott Reef (<75 m water depth) and a high level of ecological protection (99% species protection) for the majority of the remainder of the State Proposal Area during steady state operations.

As described in **Section 8.2.6**, it is expected a maximum LEP will be achieved in the majority of the State Proposal Area during construction and operations. A high LEP will be achieved for the deep waters of the State Proposal Area where subsea infrastructure will be located, except where a moderate LEP is proposed within a 1000 m radius of each drill centre during construction and operations; and 500 m around subsea infrastructure during construction. Further, an area of moderate LEP is proposed during construction where the potential discharge of hydrotest fluid from the BTL (in Commonwealth waters), may incur into the State Proposal Area. An EQMP will be prepared and implemented to achieve this outcome.

No disturbance to Scott Reef shallow water benthic communities and habitats (<75 m water depth) will occur, with impacts to benthic habitats limited to the disturbance of approximately 4.15 km^2 (0.31 km^2 permanent and 3.84 km^2 reversible loss) of deepwater habitats that are well represented both in the State Proposal Area and regionally. Feasible mitigation measures (e.g. discharge at depth and/or skip and ship) exist to achieve the stated objective of avoiding impact on Scott Reef coral habitat. Impacts to other fauna such as seabirds and migratory shorebird, fish, marine mammals and marine turtles from marine discharges, light emissions and noise emissions are expected to be restricted to temporary behavioral impacts such as avoidance or attraction.

As such, in consideration of the interconnection between these environmental factors, and the detailed environmental assessment undertaken in the draft EIS/ERD, it is expected the environmental values of the State Proposal Area including marine environmental quality, biological diversity and ecological integrity, and air quality will be maintained, and the Proposal is **Acceptable**.

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CHAPTER 10, APPENDIX C

PROTECTED MATTER SEARCH TOOL REPORT

Woodside

Contents

Chapter 10 C.1 PMST Browse Development Area

Australian Government
Department of the Environment and Energy

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

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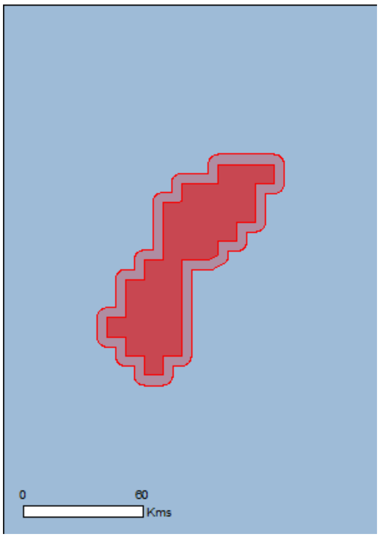

This map may contain data which are ©Commonwealth of Australia (Geoscience Australia), ©PSMA 2010

Coordinates
Buffer: 5.0Km

Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	1
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	19
Listed Migratory Species:	37

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	None
Commonwealth Heritage Places:	1
Listed Marine Species:	67
Whales and Other Cetaceans:	25
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	None
Regional Forest Agreements:	None
Invasive Species:	None
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	2

Details

Matters of National Environmental Significance

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside the Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Name
EEZ and Territorial Sea

Marine Regions [Resource Information]

If you are planning to undertake action in an area in or close to the Commonwealth Marine Area, and a marine bioregional plan has been prepared for the Commonwealth Marine Area in that area, the marine bioregional plan may inform your decision as to whether to refer your proposed action under the EPBC Act.

Name
North-west

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat likely to occur

Name	Status	Type of Presence within area
Reptiles		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Sharks		
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Glyphis garricki Northern River Shark, New Guinea River Shark [82454]	Endangered	Species or species habitat may occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Sternula albifrons Little Tern [82849]		Congregation or aggregation known to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat known to occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Orcaella heinsohni Australian Snubfin Dolphin [81322]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat may occur within area
Migratory Terrestrial Species		
Cecropis daurica Red-rumped Swallow [80610]		Species or species habitat may occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Commonwealth Heritage Places

[Resource Information]

Name	State	Status
Natural		
Scott Reef and Surrounds - Commonwealth Area	EXT	Listed place

Listed Marine Species

[Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area

Name	Threatened	Type of Presence
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Hirundo daurica Red-rumped Swallow [59480]		Species or species habitat may occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Sterna albifrons Little Tern [813]		Congregation or aggregation known to occur within area
Fish		
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Corythoichthys intestinalis Australian Messmate Pipefish, Banded Pipefish [66202]		Species or species habitat may occur within area
Corythoichthys schultzi Schultz's Pipefish [66205]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus dunckeri Red-hair Pipefish, Duncker's Pipefish [66220]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus fuscus Dusky Seasnake [1119]		Species or species habitat known to occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Name	Threatened	Type of Presence
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Hydrophis coggeri Slender-necked Seasnake [25925]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [1111]		Species or species habitat may occur within area
Lapemis hardwickii Spine-bellied Seasnake [1113]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans [Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species

Name	Status	Type of Presence
		habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia simus Dwarf Sperm Whale [58]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat likely to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Orcaella brevirostris Irrawaddy Dolphin [45]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat may occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within

Name	Status	Type of Presence
		area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Extra Information

Key Ecological Features (Marine)

[Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Continental Slope Demersal Fish Communities	North-west
Seringapatam Reef and Commonwealth waters in	North-west

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-14.581948 121.50126,-14.581949 121.41793,-14.498615 121.41793,-14.498615 121.50126,-14.331948 121.50126,-14.331947 121.58459,-14.248613 121.58459,-14.248613 121.66793,-13.998612 121.66793,-13.998612 121.73711,-13.99273 121.75126,-13.915278 121.75126,-13.915277 121.91792,-13.831943 121.91792,-13.831942 122.16792,-13.915275 122.16792,-13.915276 122.08459,-14.081943 122.08459,-14.081943 122.00126,-14.165277 122.00126,-14.165277 121.91793,-14.227459 121.91793,-14.248612 121.87802,-14.248612 121.75126,-14.66528 121.75126,-14.66528 121.66793,-14.748614 121.66793,-14.748615 121.5846,-14.665281 121.5846,-14.665281 121.50126,-14.581948 121.50126

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Chapter 10 C.2 PMST Browse Trunkline Route

Australian Government
Department of the Environment and Energy

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 18/03/19 18:57:07

This map may contain data which are ©Commonwealth of Australia (Geoscience Australia), ©PSMA 2010

Coordinates
Buffer: 5.0Km

Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	1
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	20
Listed Migratory Species:	38

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	73
Whales and Other Cetaceans:	25
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	3

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	None
Regional Forest Agreements:	None
Invasive Species:	None
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	4

Details

Matters of National Environmental Significance

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside the Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Name
EEZ and Territorial Sea

Marine Regions [Resource Information]

If you are planning to undertake action in an area in or close to the Commonwealth Marine Area, and a marine bioregional plan has been prepared for the Commonwealth Marine Area in that area, the marine bioregional plan may inform your decision as to whether to refer your proposed action under the EPBC Act.

Name
North-west

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur

Name	Status	Type of Presence
		within area
Reptiles		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Sharks		
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Glyphis garricki Northern River Shark, New Guinea River Shark [82454]	Endangered	Species or species habitat may occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Foraging, feeding or related behaviour likely to occur within area

Name	Threatened	Type of Presence
Sternula albifrons Little Tern [82849]		Congregation or aggregation known to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat known to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat known to occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area

Name	Threatened	Type of Presence
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat may occur within area
Migratory Terrestrial Species		
Cecropis daurica Red-rumped Swallow [80610]		Species or species habitat may occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat may occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species		[Resource Information]
* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.		
Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Hirundo daurica Red-rumped Swallow [59480]		Species or species habitat may occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat may occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Phaethon lepturus White-tailed Tropicbird [1014]		Foraging, feeding or related behaviour likely to occur within area
Sterna albifrons Little Tern [813]		Congregation or aggregation known to occur within area
Fish		
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Corythoichthys intestinalis Australian Messmate Pipefish, Banded Pipefish [66202]		Species or species habitat may occur within area
Corythoichthys schultzi Schultz's Pipefish [66205]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus dunckeri Red-hair Pipefish, Duncker's Pipefish [66220]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus fuscus Dusky Seasnake [1119]		Species or species habitat known to occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Hydrophis coggeri Slender-necked Seasnake [25925]		Species or species habitat may occur within area
Hydrophis czeblukovi Fine-spined Seasnake [59233]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis mcdowelli null [25926]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [1111]		Species or species habitat may occur within area
Lapemis hardwickii Spine-bellied Seasnake [1113]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans [Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia simus Dwarf Sperm Whale [58]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species

Name	Status	Type of Presence
		habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat may occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks

[Resource Information]

Name	Label
Argo-Rowley Terrace	Multiple Use Zone (IUCN VI)
Kimberley	Multiple Use Zone (IUCN VI)
Mermaid Reef	National Park Zone (IUCN II)

Extra Information

Key Ecological Features (Marine)

[Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Ancient coastline at 125 m depth contour	North-west
Continental Slope Demersal Fish Communities	North-west

Name	Region
Mermaid Reef and Commonwealth waters	North-west
Seringapatam Reef and Commonwealth waters in	North-west

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-19.583 116.133,-19.539 116.129,-19.502 116.137,-19.472 116.159,-19.462 116.173,-19.247 116.609,-19.036 117.039,-18.15 118.437,-17.757 119.058,-17.706 119.128,-17.309 119.664,-17.146 119.879,-16.987 120.026,-15.576 120.93,-15.369 121.079,-14.865 121.439,-14.483 121.66,-14.158 122.026,-13.98 122.026

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Chapter 10 C.3 PMST EMBA

Australian Government

Department of the Environment and Energy

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

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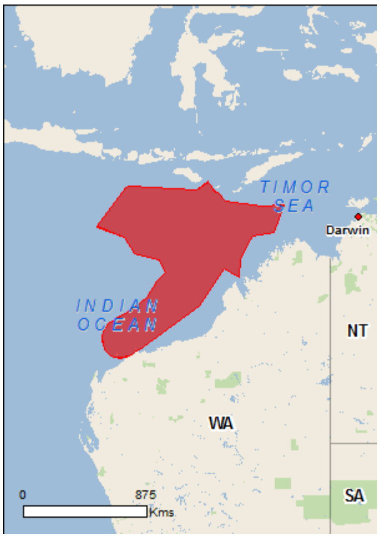

This map may contain data which are ©Commonwealth of Australia (Geoscience Australia), ©PSMA 2010

Coordinates

Buffer: 1.0Km

Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	2
Wetlands of International Importance:	1
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	2
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	44
Listed Migratory Species:	64

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	1
Commonwealth Heritage Places:	3
Listed Marine Species:	118
Whales and Other Cetaceans:	32
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	14

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	15
Regional Forest Agreements:	None
Invasive Species:	13
Nationally Important Wetlands:	2
Key Ecological Features (Marine)	8

Details

Matters of National Environmental Significance

National Heritage Properties [Resource Information]

Name	State	Status
Natural		
The West Kimberley	WA	Listed place
Indigenous		
Dampier Archipelago (including Burrup Peninsula)	WA	Listed place

Wetlands of International Importance (Ramsar) [Resource Information]

Name	Proximity
Ashmore reef national nature reserve	Within Ramsar site

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside the Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Name
EEZ and Territorial Sea
Extended Continental Shelf

Marine Regions [Resource Information]

If you are planning to undertake action in an area in or close to the Commonwealth Marine Area, and a marine bioregional plan has been prepared for the Commonwealth Marine Area in that area, the marine bioregional plan may inform your decision as to whether to refer your proposed action under the EPBC Act.

Name
North-west

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Limosa lapponica baueri Bar-tailed Godwit (baueri), Western Alaskan Bar-tailed Godwit [86380]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Bar-tailed Godwit (menzbieri) [86432]	Critically Endangered	Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Malurus leucopterus edouardi White-winged Fairy-wren (Barrow Island), Barrow Island Black-and-white Fairy-wren [26194]	Vulnerable	Species or species habitat likely to occur

Name	Status	Type of Presence
		within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Pezoporus occidentalis Night Parrot [59350]	Endangered	Species or species habitat may occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Breeding known to occur within area
Fish		
Milyeringa veritas Blind Gudgeon [66676]	Vulnerable	Species or species habitat may occur within area
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Bettongia lesueur Barrow and Boodie Islands subspecies Boodie, Burrowing Bettong (Barrow and Boodie Islands) [88021]	Vulnerable	Species or species habitat known to occur within area
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat known to occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat may occur within area
Isoodon auratus barrowensis Golden Bandicoot (Barrow Island) [66666]	Vulnerable	Species or species habitat known to occur within area
Lagorchestes conspicillatus conspicillatus Spectacled Hare-wallaby (Barrow Island) [66661]	Vulnerable	Species or species habitat known to occur within area
Lagorchestes hirsutus Central Australian subspecies Mala, Rufous Hare-Wallaby (Central Australia) [88019]	Endangered	Translocated population known to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Osphranter robustus isabellinus Barrow Island Wallaroo, Barrow Island Euro [89262]	Vulnerable	Species or species habitat likely to occur within area

Name	Status	Type of Presence
Petrogale lateralis lateralis		
Black-flanked Rock-wallaby, Moororong, Black-footed Rock Wallaby [66647]	Endangered	Species or species habitat known to occur within area
Rhinonicteris aurantia (Pilbara form)		
Pilbara Leaf-nosed Bat [82790]	Vulnerable	Species or species habitat known to occur within area
Reptiles		
Aipysurus apraefrontalis		
Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus foliosquama		
Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to occur within area
Caretta caretta		
Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas		
Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Ctenotus zastictus		
Hamelin Ctenotus [25570]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Eretmochelys imbricata		
Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Lepidochelys olivacea		
Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Species or species habitat known to occur within area
Liasis olivaceus barroni		
Olive Python (Pilbara subspecies) [66699]	Vulnerable	Species or species habitat known to occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Sharks		
Carcharias taurus (west coast population)		
Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat known to occur within area
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Glyphis garricki		
Northern River Shark, New Guinea River Shark [82454]	Endangered	Species or species habitat may occur within area
Pristis clavata		
Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Listed Migratory Species		[Resource Information]
* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.		
Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Breeding known to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardenna pacifica Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Breeding known to occur within area
Hydroprogne caspia Caspian Tern [808]		Breeding known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Breeding known to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons Little Tern [82849]		Congregation or aggregation known to occur within area
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Sula sula Red-footed Booby [1023]		Breeding known to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat known to occur within area
Balaena glacialis australis Southern Right Whale [75529]	Endangered*	Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area

Name	Threatened	Type of Presence
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Dugong dugon Dugong [28]		Breeding known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Species or species habitat known to occur within area
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat known to occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcaella heinsohni Australian Snubfin Dolphin [81322]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Breeding known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Migratory Terrestrial Species		
Cecropis daurica Red-rumped Swallow [80610]		Species or species habitat may occur within area
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area
Migratory Wetlands Species		
Acrocephalus orientalis Oriental Reed-Warbler [59570]		Species or species habitat known to occur within area
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Thalasseus bergii Crested Tern [83000]		Breeding known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Land

[Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Name
Commonwealth Land -

Commonwealth Heritage Places

[Resource Information]

Name	State	Status
Natural		
Ashmore Reef National Nature Reserve	EXT	Listed place
Mermaid Reef - Rowley Shoals	WA	Listed place
Scott Reef and Surrounds - Commonwealth Area	EXT	Listed place

Listed Marine Species

[Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Acrocephalus orientalis Oriental Reed-Warbler [59570]		Species or species habitat known to occur within area
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous minutus Black Noddy [824]		Breeding known to occur within area
Anous stolidus Common Noddy [825]		Breeding known to occur within area
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat known to occur within area
Ardea ibis Cattle Egret [59542]		Species or species

Name	Threatened	Type of Presence
		habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
Chrysococcyx osculans Black-eared Cuckoo [705]		Species or species habitat likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Breeding known to occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Hirundo daurica Red-rumped Swallow [59480]		Species or species habitat may occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area
Larus novaehollandiae Silver Gull [810]		Breeding known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to occur within area
Motacilla flava Yellow Wagtail [644]		Species or species

Name	Threatened	Type of Presence
		habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Breeding known to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Puffinus pacificus Wedge-tailed Shearwater [1027]		Breeding known to occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat may occur within area
Sterna albifrons Little Tern [813]		Congregation or aggregation known to occur within area
Sterna anaethetus Bridled Tern [814]		Breeding known to occur within area
Sterna bengalensis Lesser Crested Tern [815]		Breeding known to occur within area
Sterna bergii Crested Tern [816]		Breeding known to occur within area
Sterna caspia Caspian Tern [59467]		Breeding known to occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sterna fuscata Sooty Tern [794]		Breeding known to occur within area
Sterna nereis Fairy Tern [796]		Breeding known to occur within area
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Sula sula Red-footed Booby [1023]		Breeding known to occur within area
Thinornis rubricollis Hooded Plover [59510]		Species or species habitat known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area
Fish		
Acentronura larsonae Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys latispinosus Muiron Island Pipefish [66196]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Corythoichthys intestinalis Australian Messmate Pipefish, Banded Pipefish [66202]		Species or species habitat may occur within area
Corythoichthys schultzi Schultz's Pipefish [66205]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Doryrhamphus multiannulatus Many-banded Pipefish [66717]		Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area
Festucalex scalaris Ladder Pipefish [66216]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus dunckeri Red-hair Pipefish, Duncker's Pipefish [66220]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Phoxocampus belcheri Black Rock Pipefish [66719]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammals		
Dugong dugon Dugong [28]		Breeding known to occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus fuscus Dusky Seasnake [1119]		Species or species habitat known to occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Aipysurus tenuis Brown-lined Seasnake [1121]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Enhydrina schistosa Beaked Seasnake [1126]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis atriceps Black-headed Seasnake [1101]		Species or species habitat may occur within area
Hydrophis coggeri Slender-necked Seasnake [25925]		Species or species habitat may occur within area
Hydrophis czeblukovi Fine-spined Seasnake [59233]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis mcdowelli null [25926]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [1111]		Species or species habitat may occur within area
Lapemis hardwickii Spine-bellied Seasnake [1113]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans

[Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area

Name	Status	Type of Presence
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Indopacetus pacificus Longman's Beaked Whale [72]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia simus Dwarf Sperm Whale [58]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area
Orcaella brevirostris Irrawaddy Dolphin [45]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within

Name	Status	Type of Presence
		area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Breeding known to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks [Resource Information]

Name	Label
Argo-Rowley Terrace	Multiple Use Zone (IUCN VI)
Argo-Rowley Terrace	National Park Zone (IUCN II)
Argo-Rowley Terrace	Special Purpose Zone (Trawl) (IUCN VI)
Ashmore Reef	Recreational Use Zone (IUCN IV)
Ashmore Reef	Sanctuary Zone (IUCN Ia)
Cartier Island	Sanctuary Zone (IUCN Ia)
Dampier	Habitat Protection Zone (IUCN IV)
Dampier	Multiple Use Zone (IUCN VI)
Dampier	National Park Zone (IUCN II)
Kimberley	Habitat Protection Zone (IUCN IV)
Kimberley	Multiple Use Zone (IUCN VI)
Kimberley	National Park Zone (IUCN II)
Mermaid Reef	National Park Zone (IUCN II)
Montebello	Multiple Use Zone (IUCN VI)

Extra Information

State and Territory Reserves

[Resource Information]

Name	State
Adele Island	WA
Barrow Island	WA
Boodie, Double Middle Islands	WA
Browse Island	WA
Lowendal Islands	WA
Montebello Islands	WA
Unnamed WA36909	WA
Unnamed WA36910	WA
Unnamed WA36913	WA
Unnamed WA36915	WA
Unnamed WA40828	WA
Unnamed WA40877	WA
Unnamed WA41080	WA
Unnamed WA41775	WA
Unnamed WA44673	WA

Invasive Species

[Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Mammals		
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Rattus exulans Pacific Rat, Polynesian Rat [79]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Vulpes vulpes Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Cenchrus ciliaris Buffel-grass, Black Buffel-grass [20213]		Species or species habitat likely to occur within area
Jatropha gossypifolia Cotton-leaved Physic-Nut, Bellyache Bush, Cotton-leaf Physic Nut, Cotton-leaf Jatropha, Black Physic Nut [7507]		Species or species habitat likely to occur within area
Opuntia spp. Prickly Pears [82753]		Species or species habitat likely to occur within area

Name	Status	Type of Presence
Parkinsonia aculeata		
Parkinsonia, Jerusalem Thorn, Jelly Bean Tree, Horse Bean [12301]		Species or species habitat likely to occur within area
Prosopis spp.		
Mesquite, Algaroba [68407]		Species or species habitat likely to occur within area
Reptiles		
Ramphotyphlops braminus		
Flowerpot Blind Snake, Brahminy Blind Snake, Cacing Besi [1258]		Species or species habitat likely to occur within area

Nationally Important Wetlands

[Resource Information]

Name	State
Ashmore Reef	EXT
Mermaid Reef	EXT

Key Ecological Features (Marine)

[Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Ancient coastline at 125 m depth contour	North-west
Ashmore Reef and Cartier Island and surrounding	North-west
Canyons linking the Argo Abyssal Plain with the	North-west
Carbonate bank and terrace system of the Sahul	North-west
Continental Slope Demersal Fish Communities	North-west
Glomar Shoals	North-west
Mermaid Reef and Commonwealth waters	North-west
Seringapatam Reef and Commonwealth waters in	North-west

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-10.72757 120.4293,-10.19343 121.1663,-10.43254 121.3932,-10.56299 121.4444,-10.62183 121.4776,-10.65196 121.4951,-10.68166 121.5132,-10.69622 121.5227,-10.7105 121.5325,-10.72402 121.5425,-10.73724 121.5529,-10.76298 121.5746,-10.78787 121.5973,-10.79995 121.6089,-10.81169 121.6209,-10.823 121.6332,-10.83376 121.6459,-10.8367 121.6498,-10.88058 121.717,-10.88768 121.7764,-10.96269 121.8961,-11.38865 122.3002,-11.6862 124.5754,-11.61034 126.0347,-13.33985 125.3824,-13.54459 124.0767,-14.19068 123.6584,-15.07674 123.2374,-16.13121 123.1809,-15.61734 122.2045,-17.9044 120.633,-20.51458 116.7925,-20.51815 116.7381,-20.86655 116.1585,-20.93041 116.0111,-20.97548 115.8509,-20.99884 115.6827,-20.9996 115.5206,-20.97892 115.3579,-20.93689 115.1992,-20.87753 115.055,-20.79457 114.9117,-20.72521 114.8195,-20.64997 114.7377,-20.5629 114.6606,-20.46445 114.5906,-20.3682 114.5367,-20.25978 114.4904,-20.1523 114.4578,-20.04637 114.4376,-19.87308 114.422,-19.77535 114.42,-19.65889 114.4296,-19.54368 114.4522,-19.42472 114.4903,-19.31508 114.5398,-19.20626 114.6048,-19.10676 114.6808,-18.9789 114.8097,-18.87113 114.96,-18.51927 115.5542,-18.50949 115.5708,-18.48534 115.6207,-18.40199 115.7518,-18.33682 115.8941,-17.34141 117.3,-16.3512 117.8932,-15.85248 118.4494,-15.02616 118.0597,-14.67767 116.4879,-13.66786 115.8281,-12.99872 114.0832,-10.52483 115.9443,-10.47602 116.2651,-10.73517 120.4073,-10.72757 120.4293

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Chapter 10 C.4 PMST Exmouth Gulf

Australian Government
Department of the Environment and Energy

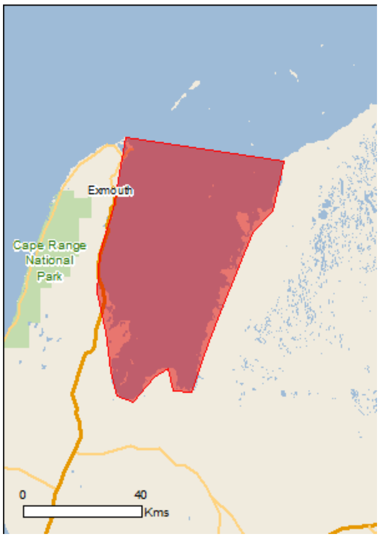
EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

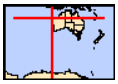
Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 16/07/19 09:55:21



This map may contain data which are ©Commonwealth of Australia (Geoscience Australia), ©PSMA 2010

Coordinates
Buffer: 1.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	1
National Heritage Places:	1
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	29
Listed Migratory Species:	42

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	5
Commonwealth Heritage Places:	None
Listed Marine Species:	79
Whales and Other Cetaceans:	13
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	9
Regional Forest Agreements:	None
Invasive Species:	15
Nationally Important Wetlands:	2
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

World Heritage Properties

[Resource Information]

Name	State	Status
The Ningaloo Coast	WA	Declared property

National Heritage Properties

[Resource Information]

Name	State	Status
Natural		
The Ningaloo Coast	WA	Listed place

Listed Threatened Species

[Resource Information]

Name	Status	Type of Presence
Birds		
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Limosa lapponica baueri Bar-tailed Godwit (baueri), Western Alaskan Bar-tailed Godwit [86380]	Vulnerable	Species or species habitat may occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Bar-tailed Godwit (menzbieri) [86432]	Critically Endangered	Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pezoporus occidentalis Night Parrot [59350]	Endangered	Species or species habitat may occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Breeding likely to occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Fish		
Milyeringa veritas Blind Gudgeon [66676]	Vulnerable	Species or species habitat known to occur within area
Ophisternon candidum Blind Cave Eel [66678]	Vulnerable	Species or species habitat known to occur within area

Name	Status	Type of Presence
Mammals		
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat likely to occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Congregation or aggregation known to occur within area
Petrogale lateralis lateralis Black-flanked Rock-wallaby, Moororong, Black-footed Rock Wallaby [66647]	Endangered	Species or species habitat known to occur within area
Pseudomys fieldi Shark Bay Mouse, Djoongari, Alice Springs Mouse [113]	Vulnerable	Species or species habitat likely to occur within area
Rhinonicteris aurantia (Pilbara form) Pilbara Leaf-nosed Bat [82790]	Vulnerable	Species or species habitat may occur within area
Reptiles		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Sharks		
Carcharias taurus (west coast population) Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat known to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardenna carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Species or species habitat likely to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Hydroprogne caspia Caspian Tern [808]		Breeding known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat likely to occur within area
Balaena glacialis australis Southern Right Whale [75529]	Endangered*	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Dugong dugon Dugong [28]		Breeding known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area

Name	Threatened	Type of Presence
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat known to occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat known to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Congregation or aggregation known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Migratory Terrestrial Species		
Hirundo rustica Barn Swallow [662]		Species or species habitat may occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Land [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Name
Commonwealth Land -
Defence - EXMOUTH ADMIN & HF TRANSMITTING
Defence - EXMOUTH VLF TRANSMITTER STATION
Defence - LEARMONTH - RAAF BASE
Defence - LEARMONTH TRANSMITTING STATION

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat known to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
Chrysococcyx osculans Black-eared Cuckoo [705]		Species or species habitat known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat may occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [1043]		Species or species habitat likely to occur within area
Sterna caspia Caspian Tern [59467]		Breeding known to occur within area
Sterna fuscata Sooty Tern [794]		Breeding known to occur

Name	Threatened	Type of Presence
		within area
Sterna nereis Fairy Tern [796]		Breeding known to occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area
Fish		
Acentronura larsonae Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within area
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys latispinosus Muiron Island Pipefish [66196]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Doryrhamphus multiannulatus Many-banded Pipefish [66717]		Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area
Festucalex scalaris Ladder Pipefish [66216]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Phoxocampus belcheri Black Rock Pipefish [66719]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammals		
Dugong dugon Dugong [28]		Breeding known to occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [1111]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans

[Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area

Name	Status	Type of Presence
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Congregation or aggregation known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat known to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area

Extra Information

State and Territory Reserves

[Resource Information]

Name	State
Bundegi Coastal Park	WA
Burnside And Simpson Island	WA
Giralia	WA
Gnandaroo Island	WA
Rocky Island	WA
Tent Island	WA
Victor Island	WA
Whitmore,Roberts,Doole Islands And Sandalwood Landing	WA
Y Island	WA

Invasive Species

[Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Mammals		
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area
Capra hircus Goat [2]		Species or species habitat likely to occur within area
Equus asinus Donkey, Ass [4]		Species or species habitat likely to occur within area
Equus caballus Horse [5]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Vulpes vulpes Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Cenchrus ciliaris Buffel-grass, Black Buffel-grass [20213]		Species or species habitat likely to occur within area
Parkinsonia aculeata Parkinsonia, Jerusalem Thorn, Jelly Bean Tree, Horse Bean [12301]		Species or species habitat likely to occur within area
Prosopis spp. Mesquite, Algaroba [68407]		Species or species habitat likely to occur within area
Reptiles		
Hemidactylus frenatus Asian House Gecko [1708]		Species or species habitat likely to occur within area
Ramphotyphlops braminus Flowerpot Blind Snake, Brahminy Blind Snake, Cacing Besi [1258]		Species or species habitat may occur within area

Nationally Important Wetlands

[Resource Information]

Name	State
Cape Range Subterranean Waterways	WA
Exmouth Gulf East	WA

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-21.78629 114.16425,-21.85037 114.64648,-21.99407 114.61211,-22.052083 114.550381,-22.26055 114.45991,-22.35743 114.4182,-22.50269 114.36582,-22.49732 114.30945,-22.43685 114.29314,-22.46177 114.25,-22.52883 114.18754,-22.51184 114.1379,-22.44411 114.11747,-22.33451 114.10353,-22.22184 114.07659,-22.11393 114.0827,-21.98585 114.12735,-21.78629 114.16425

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Chapter 10 C.5 PSMT Port of Broome

Australian Government
Department of the Environment and Energy

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

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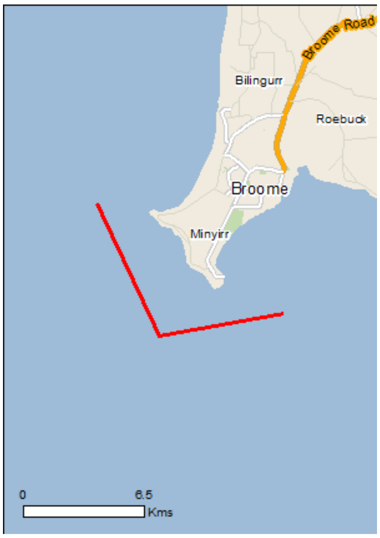

This map may contain data which are ©Commonwealth of Australia (Geoscience Australia), ©PSMA 2010

Coordinates
Buffer: 10.0Km

Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	1
Wetlands of International Importance:	1
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	1
Listed Threatened Ecological Communities:	1
Listed Threatened Species:	31
Listed Migratory Species:	65

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	2
Commonwealth Heritage Places:	None
Listed Marine Species:	104
Whales and Other Cetaceans:	12
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	1

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	3
Regional Forest Agreements:	None
Invasive Species:	12
Nationally Important Wetlands:	1
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

National Heritage Properties [Resource Information]

Name	State	Status
Natural		
The West Kimberley	WA	Listed place

Wetlands of International Importance (Ramsar) [Resource Information]

Name	Proximity
Roebuck bay	Within Ramsar site

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside the Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Name
EEZ and Territorial Sea

Marine Regions [Resource Information]

If you are planning to undertake action in an area in or close to the Commonwealth Marine Area, and a marine bioregional plan has been prepared for the Commonwealth Marine Area in that area, the marine bioregional plan may inform your decision as to whether to refer your proposed action under the EPBC Act.

Name
North-west

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Name	Status	Type of Presence
Monsoon vine thickets on the coastal sand dunes of Dampier Peninsula	Endangered	Community likely to occur within area

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Roosting known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Erythrura gouldiae Gouldian Finch [413]	Endangered	Species or species habitat may occur within area

Name	Status	Type of Presence
Limosa lapponica baueri Bar-tailed Godwit (baueri), Western Alaskan Bar-tailed Godwit [86380]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Bar-tailed Godwit (menzbieri) [86432]	Critically Endangered	Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Polytelis alexandrae Princess Parrot, Alexandra's Parrot [758]	Vulnerable	Species or species habitat likely to occur within area
Rostratula australis Australian Painted-snipe, Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area
Tyto novaehollandiae kimberli Masked Owl (northern) [26048]	Vulnerable	Species or species habitat may occur within area
Mammals		
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Macrotis lagotis Greater Bilby [282]	Vulnerable	Species or species habitat known to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Saccolaimus saccolaimus nudicluniatus Bare-rumped Sheath-tailed Bat, Bare-rumped Sheathtail Bat [66889]	Vulnerable	Species or species habitat likely to occur within area
Xeromys myoides Water Mouse, False Water Rat, Yirrkoo [66]	Vulnerable	Species or species habitat may occur within area
Plants		
Keraudrenia exastia Fringed Keraudrenia [66301]	Critically Endangered	Species or species habitat known to occur within area
Reptiles		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Ctenotus angusticeps Northwestern Coastal Ctenotus, Airlie Island Ctenotus [25937]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area

Name	Status	Type of Presence
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Sharks		
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat known to occur within area
Sternula albifrons Little Tern [82849]		Breeding known to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area

Name	Threatened	Type of Presence
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Dugong dugon Dugong [28]		Foraging, feeding or related behaviour known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding likely to occur within area
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat may occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcaella heinsohni Australian Snubfin Dolphin [81322]		Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Breeding known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Migratory Terrestrial Species		
Cecropis daurica Red-rumped Swallow [80610]		Species or species habitat known to occur within area
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species

Name	Threatened	Type of Presence
		habitat known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius bicinctus Double-banded Plover [895]		Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Roosting known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Roosting known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Glareola maldivarum Oriental Pratincole [840]		Roosting known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Roosting known to occur

Name	Threatened	Type of Presence
		within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting known to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Tringa brevipes Grey-tailed Tattler [851]		Roosting known to occur within area
Tringa glareola Wood Sandpiper [829]		Roosting known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area
Tringa totanus Common Redshank, Redshank [835]		Roosting known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Land [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Name
Commonwealth Land - Defence - BROOME TRAINING DEPOT

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur

Name	Threatened	Type of Presence
		within area
Anseranas semipalmata Magpie Goose [978]		Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat known to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Charadrius bicinctus Double-banded Plover [895]		Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Roosting known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Charadrius ruficapillus Red-capped Plover [881]		Roosting known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Roosting known to occur within area
Chrysococcyx osculans Black-eared Cuckoo [705]		Species or species habitat known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area

Name	Threatened	Type of Presence
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Glareola maldivarum Oriental Pratincole [840]		Roosting known to occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Heteroscelus brevipes Grey-tailed Tattler [59311]		Roosting known to occur within area
Himantopus himantopus Pied Stilt, Black-winged Stilt [870]		Roosting known to occur within area
Hirundo daurica Red-rumped Swallow [59480]		Species or species habitat known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Roosting known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting known to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area

Name	Threatened	Type of Presence
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Recurvirostra novaehollandiae Red-necked Avocet [871]		Roosting known to occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat likely to occur within area
Sterna albifrons Little Tern [813]		Breeding known to occur within area
Tringa glareola Wood Sandpiper [829]		Roosting known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area
Tringa totanus Common Redshank, Redshank [835]		Roosting known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area
Fish		
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammals		
Dugong dugon Dugong [28]		Foraging, feeding or related behaviour known to occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Aipysurus tenuis Brown-lined Seasnake [1121]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Crocodylus johnstoni Freshwater Crocodile, Johnston's Crocodile, Johnston's River Crocodile [1773]		Species or species habitat may occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding likely to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis mcdowelli null [25926]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [1111]		Species or species habitat may occur within area
Lapemis hardwickii Spine-bellied Seasnake [1113]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans [Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Orcaella brevirostris Irrawaddy Dolphin [45]		Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Breeding known to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area

Australian Marine Parks [Resource Information]

Name	Label
Roebuck	Multiple Use Zone (IUCN VI)

Extra Information

State and Territory Reserves [Resource Information]

Name	State
Unnamed WA51105	WA
Unnamed WA51497	WA
Unnamed WA51617	WA

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Sturnus vulgaris Common Starling [389]		Species or species habitat likely to occur within area
Frogs		
Rhinella marina Cane Toad [83218]		Species or species habitat may occur within area
Mammals		
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Plants		
Cenchrus ciliaris Buffel-grass, Black Buffel-grass [20213]		Species or species habitat likely to occur within area
Dolichandra unguis-cati Cat's Claw Vine, Yellow Trumpet Vine, Cat's Claw		Species or species

Name	Status	Type of Presence
Creeper, Funnel Creeper [85119]		habitat likely to occur within area
Jatropha gossypifolia		
Cotton-leaved Physic-Nut, Bellyache Bush, Cotton-leaf Physic Nut, Cotton-leaf Jatropha, Black Physic Nut [7507]		Species or species habitat likely to occur within area
Reptiles		
Hemidactylus frenatus		
Asian House Gecko [1708]		Species or species habitat likely to occur within area
Ramphotyphlops braminus		
Flowerpot Blind Snake, Brahminy Blind Snake, Cacing Besi [1258]		Species or species habitat known to occur within area

Nationally Important Wetlands

[Resource Information]

Name	State
Roebuck Bay	WA

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-17.97 122.15,-18.03 122.18,-18.02 122.24

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Chapter 10 C.6 PSMT Port of Dampier

Australian Government
Department of the Environment and Energy

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

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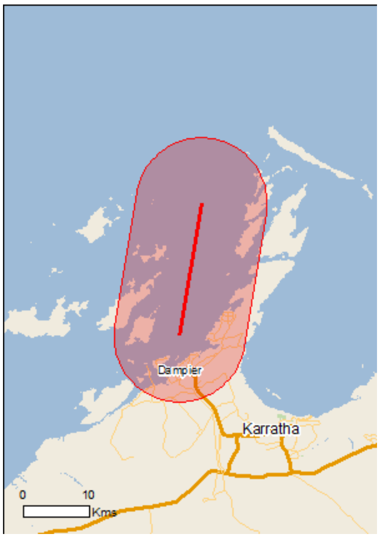

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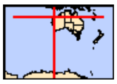
Coordinates
Buffer: 10.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	1
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	31
Listed Migratory Species:	60

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	1
Commonwealth Heritage Places:	None
Listed Marine Species:	103
Whales and Other Cetaceans:	12
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	5
Regional Forest Agreements:	None
Invasive Species:	17
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

National Heritage Properties		[Resource Information]
Name	State	Status
Indigenous		
Dampier Archipelago (including Burrup Peninsula)	WA	Listed place

Listed Threatened Species		[Resource Information]
Name	Status	Type of Presence
Birds		
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Species or species habitat known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Species or species habitat known to occur within area
Limosa lapponica baueri Bar-tailed Godwit (baueri), Western Alaskan Bar-tailed Godwit [86380]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Bar-tailed Godwit (menzbieri) [86432]	Critically Endangered	Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pezoporus occidentalis Night Parrot [59350]	Endangered	Species or species habitat may occur within area
Rostratula australis Australian Painted-snipe, Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Breeding known to occur within area

Name	Status	Type of Presence
Mammals		
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat known to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat likely to occur within area
Macrotis lagotis Greater Bilby [282]	Vulnerable	Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Rhinonicteris aurantia (Pilbara form) Pilbara Leaf-nosed Bat [82790]	Vulnerable	Species or species habitat may occur within area
Reptiles		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Ctenotus angusticeps Northwestern Coastal Ctenotus, Airlie Island Ctenotus [25937]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Liasis olivaceus barroni Olive Python (Pilbara subspecies) [66699]	Vulnerable	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Sharks		
Carcharias taurus (west coast population) Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species

Name	Status	Type of Presence
		habitat may occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardenna pacifica Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Hydroprogne caspia Caspian Tern [808]		Breeding known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area
Sterna dougallii Roseate Tern [817]		Breeding likely to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Dugong dugon Dugong [28]		Species or species habitat known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area

Name	Threatened	Type of Presence
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat known to occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Migratory Terrestrial Species		
Hirundo rustica Barn Swallow [662]		Species or species habitat may occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Species or species habitat known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris alba Sanderling [875]		Species or species habitat known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area

Name	Threatened	Type of Presence
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Calidris ruficollis Red-necked Stint [860]		Species or species habitat known to occur within area
Calidris subminuta Long-toed Stint [861]		Species or species habitat known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Species or species habitat known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Species or species habitat known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat known to occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius phaeopus Whimbrel [849]		Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Phalaropus lobatus Red-necked Phalarope [838]		Species or species habitat known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Species or species habitat known to occur within area
Pluvialis squatarola Grey Plover [865]		Species or species habitat known to occur within area
Thalasseus bergii Crested Tern [83000]		Breeding known to occur

Name	Threatened	Type of Presence within area
Tringa brevipes Grey-tailed Tattler [851]		Species or species habitat known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Species or species habitat known to occur within area
Tringa totanus Common Redshank, Redshank [835]		Species or species habitat known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Species or species habitat known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Land [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Name
Commonwealth Land -

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat likely to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Arenaria interpres Ruddy Turnstone [872]		Species or species habitat known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris alba Sanderling [875]		Species or species habitat known to occur within area

Name	Threatened	Type of Presence
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Calidris ruficollis Red-necked Stint [860]		Species or species habitat known to occur within area
Calidris subminuta Long-toed Stint [861]		Species or species habitat known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Species or species habitat known to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Species or species habitat known to occur within area
Charadrius ruficapillus Red-capped Plover [881]		Species or species habitat known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat known to occur within area
Chrysococcyx osculans Black-eared Cuckoo [705]		Species or species habitat likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat known to occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Breeding known to occur within area
Heteroscelus brevipes Grey-tailed Tattler [59311]		Species or species habitat known to occur within area
Himantopus himantopus Pied Stilt, Black-winged Stilt [870]		Species or species habitat known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat may occur within area
Larus novaehollandiae Silver Gull [810]		Breeding known to occur

Name	Threatened	Type of Presence
		within area
Limicola falcinellus Broad-billed Sandpiper [842]		Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Species or species habitat known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius phaeopus Whimbrel [849]		Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Phalaropus lobatus Red-necked Phalarope [838]		Species or species habitat known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Species or species habitat known to occur within area
Pluvialis squatarola Grey Plover [865]		Species or species habitat known to occur within area
Puffinus pacificus Wedge-tailed Shearwater [1027]		Breeding known to occur within area
Recurvirostra novaehollandiae Red-necked Avocet [871]		Species or species habitat known to occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat may occur within area
Sterna anaethetus Bridled Tern [814]		Breeding known to occur within area
Sterna bergii Crested Tern [816]		Breeding known to occur within area
Sterna caspia Caspian Tern [59467]		Breeding known to occur within area

Name	Threatened	Type of Presence
Sterna dougallii Roseate Tern [817]		Breeding likely to occur within area
Sterna fuscata Sooty Tern [794]		Breeding known to occur within area
Sterna nereis Fairy Tern [796]		Breeding known to occur within area
Stiltia isabella Australian Pratincole [818]		Species or species habitat known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Species or species habitat known to occur within area
Tringa totanus Common Redshank, Redshank [835]		Species or species habitat known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Species or species habitat known to occur within area
Fish		
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area
Festucalex scalaris Ladder Pipefish [66216]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammals		
Dugong dugon Dugong [28]		Species or species habitat known to occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species

Name	Threatened	Type of Presence
		habitat likely to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Aipysurus tenuis Brown-lined Seasnake [1121]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis czeblukovi Fine-spined Seasnake [59233]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis mcdowelli null [25926]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [1111]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area

Name	Threatened	Type of Presence
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans

[Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat known to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area

Extra Information

State and Territory Reserves

[Resource Information]

Name	State
Murujuga	WA
Unnamed WA36907	WA
Unnamed WA36909	WA
Unnamed WA36910	WA
Unnamed WA36915	WA

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Passer domesticus House Sparrow [405]		Species or species habitat likely to occur within area
Passer montanus Eurasian Tree Sparrow [406]		Species or species habitat likely to occur within area
Mammals		
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area
Equus caballus Horse [5]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Vulpes vulpes Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Cenchrus ciliaris Buffel-grass, Black Buffel-grass [20213]		Species or species habitat likely to occur within area
Jatropha gossypifolia Cotton-leaved Physic-Nut, Bellyache Bush, Cotton-leaf Physic Nut, Cotton-leaf Jatropha, Black Physic Nut [7507]		Species or species habitat likely to occur within area
Opuntia spp. Prickly Pears [82753]		Species or species habitat likely to occur within area
Parkinsonia aculeata Parkinsonia, Jerusalem Thorn, Jelly Bean Tree, Horse Bean [12301]		Species or species habitat likely to occur within area
Prosopis spp. Mesquite, Algaroba [68407]		Species or species habitat likely to occur within area
Reptiles		
Hemidactylus frenatus Asian House Gecko [1708]		Species or species

Name	Status	Type of Presence
		habitat likely to occur within area
Ramphotyphlops braminus		
Flowerpot Blind Snake, Brahminy Blind Snake, Cacing Besi [1258]		Species or species habitat likely to occur within area

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-20.62 116.71,-20.45 116.74

Acknowledgements

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-Office of Environment and Heritage, New South Wales
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-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Chapter 10 C.7 Species identified in PMST not considered likely to occur within Project Area

Species identified by the PMST as potentially occurring within the Project Area, but which are not considered likely to occur within the Project Area and/or be impacted by Project Activities and were, therefore, excluded from discussion. Justification of this decision is provided here.

Species	EPBC Act Listing	Status under BC Act	Justification
Birds			
***Assessment**: The following migratory shorebird species utilise sites along the WA coastline (e.g. 80 Mile Beach, Roebuck Bay and Ashmore Reef). They do not have key sites within the Project Area and are not expected to occur within the Project Area, other than as migratory vagrants.*			
Red knot (*Calidris canutus*)	Endangered, Migratory (Wetland), Marine	Endangered	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.
Curlew sandpiper (*Calidris ferruginea*)	Critically Endangered, Migratory (Wetland), Marine	Critically Endangered	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.
Eastern curlew (*Numenius madagascariensis*)	Critically Endangered, Migratory (Wetland), Marine	Critically Endangered	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.
Sharp-tailed sandpiper (*Calidris acuminate*)	Migratory (Wetland), Marine	Migratory	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.
***Assessment**: The following species do not have key sites within the Project Area, however, as these species are migratory, they may be present as vagrants within the Project Area.*			
Greater frigatebird (*Fregata minor)*	Migratory (Marine), Marine	Migratory	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.
Pectoral sandpiper (*Calidris melanotos*)	Migratory (Wetland), Marine	Migratory	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.
Grey wagtail (*Motacilla cinereal*)	Migratory (Terrestrial), Marine	Migratory	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.
Yellow wagtail (*Motacilla flava*)	Migratory (Terrestrial), Marine	Migratory	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.
Red-rumped swallow (*Cecropis daurica*)	Migratory (Terrestrial), Marine	Migratory	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.

Species	EPBC Act Listing	Status under BC Act	Justification
Marine Mammals			
Killer whale (*Orcinus orca*)	Migratory (Marine)	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment:** The killer whale is the largest member of the dolphin family and is widespread from polar to equatorial regions of all oceans. This species has been recorded for waters all states of Australia (Bannister et al., 1996), with concentrations reported around Tasmania and frequent sightings in South Australia and Victoria. Killer whales appear to be more common in cold, deep waters; however, they have been observed along the continental slope and shelf (Bannister et al., 1996), as well as in shallow coastal areas of WA (RPS, 2011). Killer whales are not well surveyed in Australian waters, with the exception of the Antarctic where whale surveys have been conducted and off Macquarie Island in the southwest Pacific Ocean. There are no documented areas of aggregation or important habitat for killer whales within the Browse Development Area (including Scott Reef) or along the proposed BTL route. Given the wide distribution of killer whales, it is possible that they may occur in the Project Area while travelling within the wider NWMR. .
Pygmy killer whale (*Feresa attenuata*)	Cetacean	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment:** There are a limited number of recordings for this species within Australia; a number of records are in relation to strandings with three mass stranding events in and around Augusta (WA) since 1986. Records indicate this species is distributed widely throughout Australia, typically in deep offshore waters. There is no known key habitat within the Project Area for this cetacean species and it is not expected to be present in large numbers within the Project Area.
False killer whale (*Pseudorca crassidens*)	Cetacean	N/A	**SPRAT Distribution Map**: Species or species habitat *likely* to occur within Project Area. **Assessment:** The false killer whale is considered to be widespread globally in tropical and warm temperate waters,

Species	EPBC Act Listing	Status under BC Act	Justification
			including throughout Australian oceanic waters. Though sometimes sighted closer to the coast in areas with cooler water, this species is typically oceanic in distribution and sighted away from land (Australian Museum, 2019; DEC, 2011). The false killer whale is known to form groups in excess of 100 individuals with strong social cohesion (DEC, 2011). Two mass stranding events for this species have occurred in southern WA in Augusta (1986 and 1988; DEC, 2011). The false killer whale's distribution has largely been surmised from stranding events and incidental sightings. A NT study found by satellite tracking of four individuals indicated, regular use of both coastal and pelagic waters of the Arafura and Timor Seas. Globally, however, the species is listed as Data Deficient by the IUCN and no population estimates or categorised habitat preferences are available for this species. There are no known key habitats for this species within the Project Area and survey efforts to date encompassing the Project Area have recorded this species. This species is not expected to occur in large numbers within the Project Area.
Short-finned pilot whale (*Globicephala macrorhynchus*)	Cetacean	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment:** The short-finned pilot whale has a widespread distribution throughout Australia in tropical and warm-temperate waters. There is a paucity of records for this species within Australian waters, with limited incidental sightings and only a few stranding events around Australia to provide records of possible distribution. This species is still hunted in Japan. No key habitats have been identified within the Project Area. This species is not expected to occur in large numbers within the Project Area.
Sperm whale (*Physeter macrocephalus*)	Migratory (Marine)	Vulnerable	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment:** The sperm whale is the largest of the toothed whales. The species is distributed globally in deep waters off continental shelves and sometimes near

Species	EPBC Act Listing	Status under BC Act	Justification
			shelf edges (Bannister et al., 1996). Sperm whales have been recorded in all Australian state waters and are known to migrate northward in winter and southwards in summer (Bannister et al., 1996). They tend to inhabit offshore areas with a water depth greater than 600 m and are uncommon in waters less than 300 m deep (National Marine Fisheries Service, 2006). Sperm whales, like other toothed whales, live in groups of up to 50 individuals, although male sperm whales are sometimes solitary in high latitudes (above 40°). In WA sperm whales have two BIAs recognised for foraging activities; these are located west of Rottnest Island and along the southern WA coastline between Cape Leeuwin and Esperance (more than 1,000 km from the Project Area). In deep water off the North West Cape sperm whales have been sighted in pod sizes of up to six animals between February and April from two separate surveys, in 2010 and 2017 (EPI Group, 2017; RPS, 2011). Based on the available information, it is considered unlikely that the sperm whale will be present in large numbers within the project area; however, transient individuals may occur especially in the areas of greatest water depth which occur off the west side of Scott Reef in the Browse Development Area.
Pygmy sperm whale (Kogia breviceps)	Cetacean	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment:** This species typically occurs in warmer oceanic waters and has been recorded in all Australian States. There are no known key habitats within the Project Area. This species is, therefore, not expected to occur in large numbers within the Project Area.
Dwarf sperm whale (*Kogia simus*)	Cetacean	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment:** This species typically occurs in warmer oceanic waters. There are no known key habitats within the Project Area. This species is, therefore, not

Species	EPBC Act Listing	Status under BC Act	Justification
			expected to occur in large numbers within the Project Area.
Blainville's beaked whale (*Mesoplodon densirostris*	Cetacean	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment:** Blainville's beaked whales are considered to have an oceanic and global distribution, occurring in low to mid latitudes in all oceans and both hemispheres, and preferring tropical and warm temperate waters (Mead, 1989). There are no estimates of population size either globally or in Australia but the species appears to be one of the more widespread and common beaked whales (Pitman, 2002). Their preferred habitat appears to be in tropical oceanic regions, in waters ranging from 700 m to 100 m deep, but are often recorded adjacent to much deeper waters of 5000 m (Bannister et al., 1996). Historically it was thought that Blainville's beaked whales avoided coasts, however, a study suggested that this species are the most commonly seen beaked whales in the shallower waters around tropical oceanic islands (Culik, 2011). It is likely that such habitats are utilised by beaked whales along much of Australia's extensive coastline (Ross, 2006). There are no key habitat known within the Project Area. Given this species wide distribution it is not expected to occur in large numbers within the Project Area.
Cuvier's beaked whale (*Ziphius cavirostris*)	Cetacean	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment:** Cuvier's beaked whales may have the most extensive range and be one of the most abundant of any beaked whale species (Culik, 2011). The species has a worldwide distribution in all temperate and tropical waters and is only absent from the polar waters in each hemisphere. In Australian waters, Cuviers beaked whale is known from 31 strandings, mostly from January to July, suggesting some seasonality to occurrence (Ross, 2006). Records of this species are from all States and Territories. Whaling records from Japan indicate that Cuvier's beaked

Species	EPBC Act Listing	Status under BC Act	Justification
			whales are most commonly found in waters deeper than 1,000 m. They are considered an oceanic species and are rarely found close to mainland shores, except in submarine canyons or in areas where the continental shelf is narrow and coastal waters are deep. Similar to the Blainville's beaked whale this species may utilise shelf-edge habitats along much of Australia's extensive coastline. There are no known key habitat within Australian waters and the species is not expected to occur in large numbers within the Project Area.
Melon-headed whale (*Peponocephala electra*)	Cetacean	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment:** Records for this species are largely from mass stranding events in the NT, NSW and QLD. There are no known key habitat within the Project Area for this species and it is not expected to occur within the Project Area.
Australian snubfin dolphin (*Orcaella heinsohni*)	Migratory (Marine)	Priority 4	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment:** This species occurs along the Australian coastline, typically in shallow waters, including north of Broome within WA. No key habitat have been identified within or in proximity to the Project Area and this species is not expected to occur within the Project Area.
Irrawaddy dolphin (*Orcaella brevirostris*)	Cetacean, Migratory (Marine)	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment:** This species is known to occur north of Broome within WA, typically in shallow coastal waters. There are no known key habitat within the Project Area. The species, is therefore, not expected to occur in large numbers within the Project Area.
Striped dolphin (*Stenella coeruleoalba*)	Cetacean	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment**: There is a sparsity of records within Australia and the species is not thought to be common in Australian waters. There are no known key habitat within the Project Area and the species is

Species	EPBC Act Listing	Status under BC Act	Justification
			not expected to occur within the Project Area.
Rough-toothed dolphin (*Steno bredanensis*)	Cetacean	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment**: Within WA this species was recorded at Barrow Island, south of the Project Area, when three individuals were stranded in 1971. There are no known key habitat within the Project Area or in WA waters. The species is not expected to occur in large numbers within the Project Area.
Bottlenose dolphin (*Tursiops truncatus*)	Cetacean	N/A	**SPRAT Distribution Map**: Species or species habitat *likely* to occur within Project Area. **Assessment:** This species is distributed widely throughout offshore, coastal and estuarine waters in Australia. There are no known key habitat within the Project Area, however, due to its wide distribution it may occur within the Project Area.
Spotted bottlenose dolphin (Arafura/Timor Sea populations) *(Tursiops aduncus - Arafura/Timor Sea populations)*	Cetacean, Migratory (Marine)	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment**: This species distribution extends south from the Timor and Arafura Seas to approximately Coral Bay (WA). It inhabits both inshore and offshore habitats and may occur within the Project Area.
Spotted Bottlenose Dolphin (*Tursiops aduncus*)	Cetacean	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment**: This species is widely distributed throughout Australian waters, with a preference for nearshore habitats. Due to its widespread distribution it may occur within the Project Area.
Oceanic Dolphin Species *Assessment: There is a paucity of records for these oceanic dolphin species, largely due to their offshore existence, meaning that population numbers, seasonal behaviours/movements (if any) and key habitat of aggregation/importance are unknown. Distribution within Australia is largely ascertained from incidental sightings and/or stranding events.* *As these species do not have key habitats identified within WA waters, and as they are described as having widespread distributions, large numbers of these species are not expected to occur within the Project Area; rather, only low numbers of individuals may transit the area. Additional species specific information is provided below.*			

Species	EPBC Act Listing	Status under BC Act	Justification
Common dolphin (*Delphinus delphis*)	Cetacean	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment**: This species typically occurs in the offshore waters of all Australian States and Territories. There are two primary groupings of this species; in the southern south-eastern Indian Ocean and the Tasman Sea. These locations are a significant distance from the Project Area. There are no known key habitats within the Project Area and this species is not expected to occur within the Project Area.
Risso's dolphin (*Grampus griseus*)	Cetacean	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment:** Typically considered to occur in oceanic waters, although in shore sightings recorded. The species has a widespread distribution throughout Australia, although there is a paucity of records meaning that estimates of population numbers is not possible. Records of incidental sightings vary in water depths from 180 to 1,500 m. The only residential population thought to be at Fraser Island (Qld). No key habitat have been identified within the Project Area. Therefore, not expected to occur in large numbers within the Project Area.
Fraser's dolphin (*Lagenodelphis hosei*)	Cetacean	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment:** Within Australia, this species is known to occur north of 30°S and in waters deeper than 1,000 m. Globally the species is considered pantropical and to occur between 30°N and 30°S, with sightings outside of these latitudes considered to be vagrants. There are no known key habitat within the Project Area. This species is not expected to occur in large numbers within the Project Area.
Spotted dolphin (*Stenella attenuate*)	Cetacean	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment**: Within Australian waters, this species has been recorded off the NT,

Species	EPBC Act Listing	Status under BC Act	Justification
			WA, Qld and NSW. The species typically inhabits waters of depths greater than 200 m, although it is known to occur on the continental shelf. The species is considered to be common, although there are no reliable estimates of population numbers within Australia. Globally, this species has been killed for food, bait and by tuna fishers between the 1950s and 1980s. There are no known key habitat within the Project Area. This species is, therefore, not expected to occur in large numbers within the Project Area.
Marine Reptiles			
Assessment: *The following sea snake species were recorded at Scott Reef by (URS Australia Pty Ltd, 2006b, 2007). Whilst these species were recorded within the Project Area, their preference for and reliance on shallow reef habitats makes it unlikely that they will be impacted by Project infrastructure or activities. Notably, these species are thought to be resident at Scott Reef and to not undertaken migrations to/from the reef; it is subsequently unlikely that they will interact with Project vessels in deeper waters near to the reef.*			
Horned seasnake *(Acalyptophis peronii*)	Marine	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.
Dubois' seasnake *(Aipysurus duboisii*)	Marine	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.
Olive seasnake (*Aipysurus laevis*)	Marine	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.
Turtle-headed seasnake (*Emydocephalus annulatus*)	Marine	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.
Slender-necked seasnake (*Hydrophis coggeri*)	Marine	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.
Dusky seasnake (*Aipysurus fuscus*)	Marine	N/A	**SPRAT Distribution Map**: Species or species habitat *likely* to occur within Project Area.
Assessment: *The following sea snakes were not recorded at Scott Reef despite comprehensive survey effort by URS Australia Pty Ltd (2006b, 2007). As Scott Reef is the only shallow reef habitat within the Project Area these species are only expected to occur with the Project Area as vagrants, if at all.*			

Species	**EPBC Act Listing**	**Status under BC Act**	**Justification**
Short-nosed seasnake (*Aipysurus apraefrontalis*)	Critically Endangered, Marine	Critically Endangered	**SPRAT Distribution Map**: Species or species habitat *likely* to occur within Project Area**.**
Stokes' seasnake (*Astrotia stokesii*)	Marine	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.
Spectacled seasnake (*Disteira kingii*)	Marine	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.
Olive-headed seasnake (*Disteira major*)	Marine	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.
Elegant seasnake (*Hydrophis elegans*)	Marine	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.
Spotted seasnake (*Hydrophis ornatus*)	Marine	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.
Spine-bellied seasnake (*Lapemis curtus*)	Marine	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.
North-western mangrove seasnake (*Ephalophis greyi*)	Marine	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.
Fine-spined seasnake (*Leioselasma czeblukovi*)	Marine	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.
Small-headed seasnake (*Hydrophis macdowelli*)	Marine	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area.
Yellow-bellied seasnake (*Pelamis platurus*)	Marine	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment**: This species is distributed widely throughout Australian waters, typically exhibiting a preference for warmer waters. This species is known to frequent waters some kilometres from coastlines. There are no known key sites for this species within the Project Area; however given its broad distribution it may occur within the Project Area.

Species	EPBC Act Listing	Status under BC Act	Justification
Fish			
White shark (*Carcharodon carcharias*)	Vulnerable, Migratory (Marine)	Vulnerable	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment**: This species is widely distributed in Australian waters and, therefore, may occur within the Project Area. There are no known key sites for this species within the Project Area and the species is not expected to interact with the Project infrastructure or activities.
Northern river shark (*Glyphis garricki*)	Endangered	Priority 1	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment**: Distributed across the northern WA and NT coastal areas, this species lives between both freshwater and seawater habitats, particularly rivers, intertidal and inshore habitats and estuarine systems. The species has also been recorded in waters further offshore, however, the extent to which this occurs is uncertain. Therefore, this species is not expected to occur within the Project Area.
Reef manta ray (*Mobula alfredi*)	Migratory (Marine)	N/A	**SPRAT Distribution Map**: Species or species habitat *likely* to occur within Project Area. **Assessment**: This species may occur in low numbers within the Project Area and is not expected to interact with Project vessels or infrastructure. There are no known key sites for this species within the Project Area.
Giant manta ray (*Mobula birostris*)	Migratory (Marine)	N/A	**SPRAT Distribution Map**: Species or species habitat *likely* to occur within Project Area. **Assessment**: This species may occur in low numbers within the Project Area and is not expected to interact with Project vessels or infrastructure. There are no known key sites for this species within the Project Area.
Narrow sawfish (*Anoxypristis cuspidate*)	Migratory (Marine)	N/A	**SPRAT Distribution Map**: Species or species habitat *may* occur within Project Area. **Assessment**: This species is not expected to occur within the Project Area due to the species' preference for shallow coastal habitats.

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CHAPTER 10, APPENDIX D

TECHNICAL STUDIES

Woodside

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Chapter 10 D.1 Advisian BTL Environmental Survey Report

NEPTUNE MARINE SERVICES

BROWSE TO NWS PROJECT

TRUNKLINE ROUTE SURVEYS 2019

ENVIRONMENTAL SURVEY REPORT (VOLUME 5D)

REVISION: 4

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DOCUMENT CONTROL

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A	For client review	Advisian	D. Hawkes	15/07/2019
0	Address client comments RevA	Advisian	D. Hawkes	25/07/2019
1	Address client comments Rev0	Advisian	D. Hawkes	29/08/2019
2	Address client comments Rev1	Advisian	D. Hawkes	06/09/2019
N/A	Benthic Infauna Report (Addendum to Env Report)	Advisian	D. Hawkes	27/09/2019
3	Combined Environment and Benthic Infauna Reports	Advisian	P. Wells	04/10/2019
4	Address client comments Rev3	Advisian	D. Hawkes	30/10/2019

Browse to NWS Project Environmental Survey

Environmental Survey Report

Neptune

29 October 2019

401012-02648-00-EN-REP-0001

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Appendix D	Field Sheets
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Appendix F	Laboratory Reports
Appendix G	Water Quality Data QA
Appendix H	Sediment Data QA
Appendix I	Photo Plates of Seabed Imagery
Appendix J	Benthic Habitat Classifications
Appendix K	Physical Water Quality Data

1 Introduction

In September 2018, the BJV selected the Browse to North West Shelf (NWS) development concept to progress into the concept definition phase.

Woodside Energy Limited (Woodside) has contracted Neptune Geomatics Pty Ltd (Neptune) to undertake two phases for the Browse to NWS Project.

The Browse to NWS Project is required to confirm a nominal pipeline route corridor is suitable and collect detailed data for engineering design purposes. The MV Outer Limit (Outer Limit) is the dedicated vessel for the Neptune scope of work, supplied by Offshore Unlimited.

The Browse to NWS Project comprises two field work phases, each containing discrete work packages, being:

1. Reconnaissance Phase:
   - Work Package 1 – Reconnaissance Survey.
2. Primary Survey Phase:
   - Work Package 3 – Geophysical Survey
   - Work Package 4 – Geotechnical Investigation
   - Work Package 5 – Environment Survey.

1.1 Survey Objectives

Neptune has engaged Advisian to support the delivery of Work Package 5 – Environment Survey. This report presents the results of the Environment Survey, including benthic habitat map validation (seabed imagery), sediment quality and water column physico-chemical properties. The objectives of the Environmental Survey were to survey strategically identified locations along the proposed Browse Trunkline (BTL) route, including areas where the BTL would intersect with Key Ecological Features (KEFs) and Australian Marine Parks (AMPs) to:

- confirm the environmental characteristics (physical and biological attributes) of habitat types selected from the geophysical data, including identification and semi qualitative descriptions of seabed habitat types and their general distribution (plus documentation of sensitive receptor types, if encountered)
- collect and record baseline water and seabed samples to present the physico-chemical characteristics and quality.

2 Survey Design and Sampling Rationale

2.1 Review of Existing Data

Advisian evaluated the supplied bathymetry and backscatter data acquired during Work Package 1 (Neptune, 2018) to identify areas of potential interest, including areas that demonstrate high reflectivity associated with harder substrates. Swath bathymetry was acquired between 28 October 2018 and 16 November 2018 using a Kongsberg EM710 Multibeam Echo Sounder (MBES). Data logged by Kongsberg SIS was imported to CARIS HIPS, where it was examined, processed and reduced to final soundings. In addition, seabed intensity data (backscatter) was processed within HIPS. Surfaces were created from the final soundings and exported to ESRI ASCII format, while backscatter data was exported to GeoTIFF format. The geophysical data was interpreted based on a visual assessment of the geomorphic features on the seabed, using the bathymetry and backscatter data collected during the geophysical survey.

A preliminary seabed habitat map was produced based on the interpretation of the MBES and a standardised classification scheme for substrate and features, which was the Collaborative and Annotation Tools for Analysis of Marine Imagery and Video (CATAMI) (Table 2-1). Each standardised label was also assigned a CAAB (Codes for Australian Aquatic Biota) 'code' (Table 2-2).

The preliminary seabed habitat map (Appendix A) was used as the basis to strategically identify survey locations overlaid with the intersection of the BTL route with AMPs and KEFs.

Table 2-1: Attribute table (final substrate descriptor using CATAMI classification)

Descriptor	Bathymetry	Slope/Topographic Position	Relative Backscatter
Find sand/mud	Smooth (no discernible features beyond acquisition artefacts at 5 m gridding), or with identifiable, regular ripples or dunes	Even, typically less than 5°	Low (dark); no discernible features at 1 m gridding
Coarse (sand-gravel)	Smooth (no discernible features beyond acquisition artefacts at 5 m gridding), or with identifiable, regular ripples or dunes	Even, typically less than 5°	High (light); no discernible features at 1 m gridding
Rock veneer	Uneven, rugged and irregular features	Variable, typically less than 5°, topographic high	Varied; mostly high
Rock veneer (superimposed ripples)	Uneven, rugged and irregular features. Various irregular ripple or dune types may be present	Variable, typically less than 5°	Varied, mostly high; finer scale ripple/dune features may be evident
Isolated dune (e.g. ribbon, stringers)	Bathymetric feature, smooth	Variable, may have steep sides	Varies depending on incidence angle
Sloped Terrain (Scarp, Scour)	Bathymetric feature, smooth	Typically greater than 5°, may have steep sides	Varies depending on incidence angle
Ripples (Small, Medium 2D or 3D, Irregular)	May be visible bathymetric features, or may only occur in backscatter if small	Varied, wavelength and amplitude measured in profile (Ashley, 1990)	Varies depending on incidence angle; typically low
Waves (Medium, Large, Very Large 2D or 3D, Irregular)	Bathymetric features measurable in profile	Varied, wavelength and amplitude measured in profile (Ashley, 1990)	Varies depending on incidence angle
Mound (Rock or Rock Veneer)	Bathymetric features measurable in profile; isolated, sharp edged feature	Varied, up to 90°	Varies depending on incidence angle; typically very high
Depression (Scour or Pockmark)	Bathymetric features measurable in profile	Varied, up to 90°	Varies depending on incidence angle

Table 2-2: Classification table – feature descriptors (using the decision tree)

S1	S2	S3	R1	R2	B1	B2	B3
Consolidated/ Hard (CAAB 82 001001)	**Fine sand/ mud** (CAAB 82 001015 + 82 001016 Undiff.)	**Veneer**	**Flat** (CAAB 82 003001)	**Low** <1 m (CAAB 82 003003)	**None** (CAAB 82 002001)	**Ripples** <10 cm (CAAB 82 002003)	<10 m **Small***
Unconsolidated/ Soft (CAAB 82 001005)	**Coarse sand** (CAAB 82 001014)	**Rock** (CAAB 82 001002)	**Low/ Mod** (CAAB 82 003002)	**Mod** 1 to 3 m (CAAB 82 003004)	**2D** (CAAB 82 002002)	**Waves** >10 cm (CAAB 82 002004)	10-50 m **Med***
	Pebble/ gravel (CAAB 82 001006)		**High** (CAAB 82 003005)	**HIGH** >3 m (CAAB 82 003006)	**3D** (CAAB 82 002006)	**Large Waves*** >0.75 m	50-100 m **Large***
				Wall (CAAB 82 003007)	**Other**	**Very Large Waves*** >5 m	>100 m **Very Large***
						Irregular*	

Derived from Ashley, 1990.

2.2 Sampling Rationale

The sampling rationale was agreed in a Sampling and Analysis Plan (SAP) (Advisian, 2019) prior to survey mobilisation and is summarised in this section.

Sampling sites were selected to provide data to document the existing environment of the proposed BTL (Table 2-4), including habitat types and features across the depth profile and geographical coverage of the BTL route, using the preliminary habitat map (Appendix A) as a basis to determine an appropriate sampling approach.

The proposed BTL route options include passage through designated areas described in Table 2-3. These designated areas were overlaid on the geophysical data and a range of substrata and seabed bedforms selected within each area (Table 2-4). Areas of sparse data and spatial coverage of the BTL route were also considered to design the survey and select sampling sites.

Additional rationale for selecting sampling sites is provided in Appendix B. The sample sites relative to the KEFs and AMPs are presented in Figure 2-1 and Figure 2-2.

Table 2-3: Environmental and conservation values of AMPs and KEFs that intersect the proposed pipeline route

Area of Environmental Importance	Environmental Values
Argo-Rowley Terrace (Multiple Use Zone, IUCN VI)	Marine Park provides protection for the communities and habitats of the deeper offshore waters of the region in depth ranges from 22 to 5000 m. Marine Park provides connectivity between the Mermaid Reef Marine Park/WA Rowley Shoals Marine Park and the deeper waters of the region. Adjacent to important foraging and pupping areas for sawfish and important nesting sites for green turtles (Director of National Parks, 2018).
Kimberley Marine Parks (Multiple Use Zone, IUCN VI)	Marine Park provides protection for the communities and habitats of waters offshore of the Kimberley coastline ranging in depth from less than 15 to 800 m. Important foraging areas for migratory seabirds, migratory dugongs, dolphins and threatened and migratory marine turtles. Important migration pathway and nursery areas for the protected humpback whale (Director of National Parks, 2018).
Continental Slope Demersal Fish Communities KEF	This KEF represents the diversity of demersal fish assemblages on the continental slope in the Timor Province, the North-west Transition and the North-west Province which is high compared to elsewhere along the continental slope (Commonwealth of Australia, 2012).
Ancient Coastline at 125 m Depth Contour KEF	Parts of the ancient coastline, particularly where it exists as a rocky escarpment, are thought to provide biologically important habitats in areas otherwise dominated by soft sediments (Commonwealth of Australia, 2012).
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF	Mermaid Reef and the Commonwealth waters surrounding the Rowley Shoals are recognised as areas of enhanced productivity and high species richness, facilitated by the breaking of internal waves in the waters surrounding the reefs. This results in the mixing and re-suspension of nutrients from water depths of 500 to 700 m into the photic zone. Migratory pelagic species are present due to the steep changes in slope, such as dolphins, tuna, billfish and sharks (Commonwealth of Australia, 2012).
Seringapatam Reef and Commonwealth waters in the Scott Reef Complex KEF	Seringapatam Reef and the Commonwealth waters in the Scott Reef complex are regionally important as they support diverse aggregations of marine life, high primary productivity and high species richness (Commonwealth of Australia, 2012).

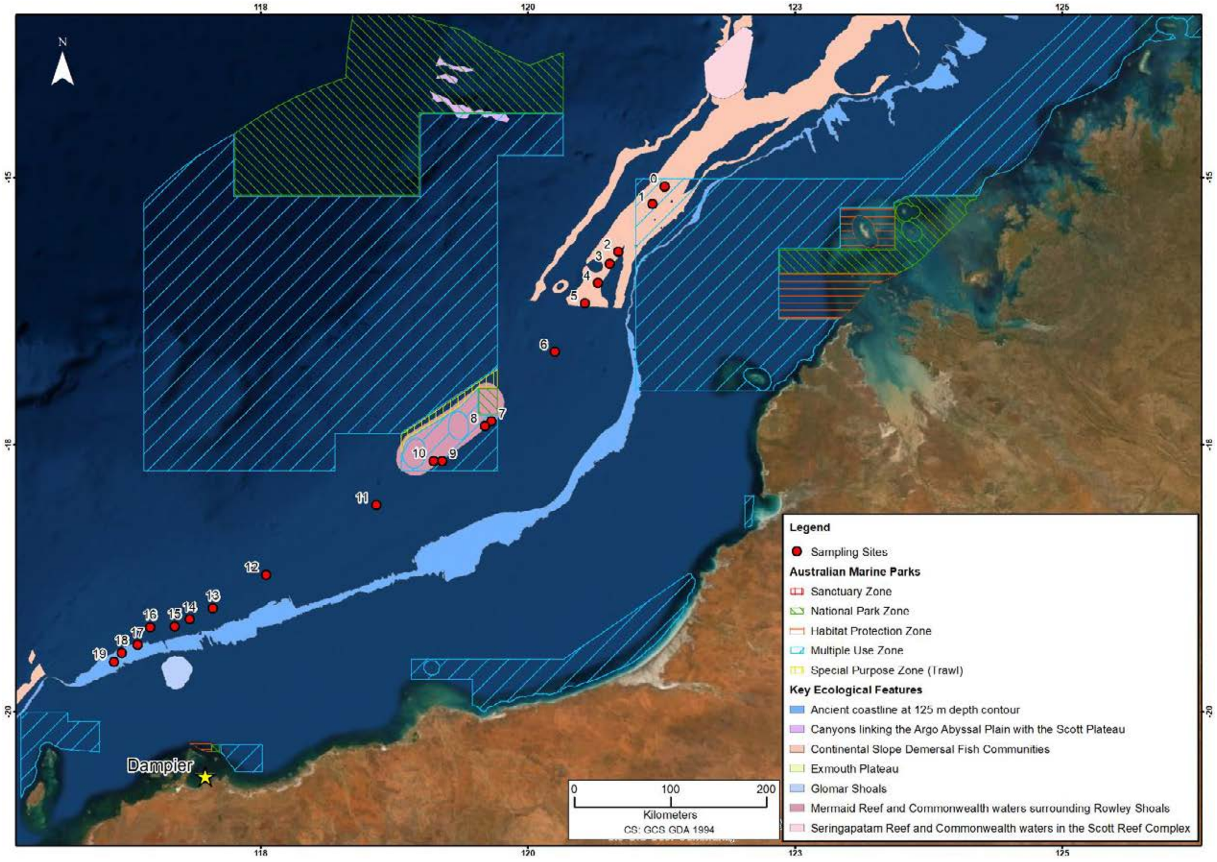

Figure 2-1: BTL survey sites with respect to the AMPs and KEFs

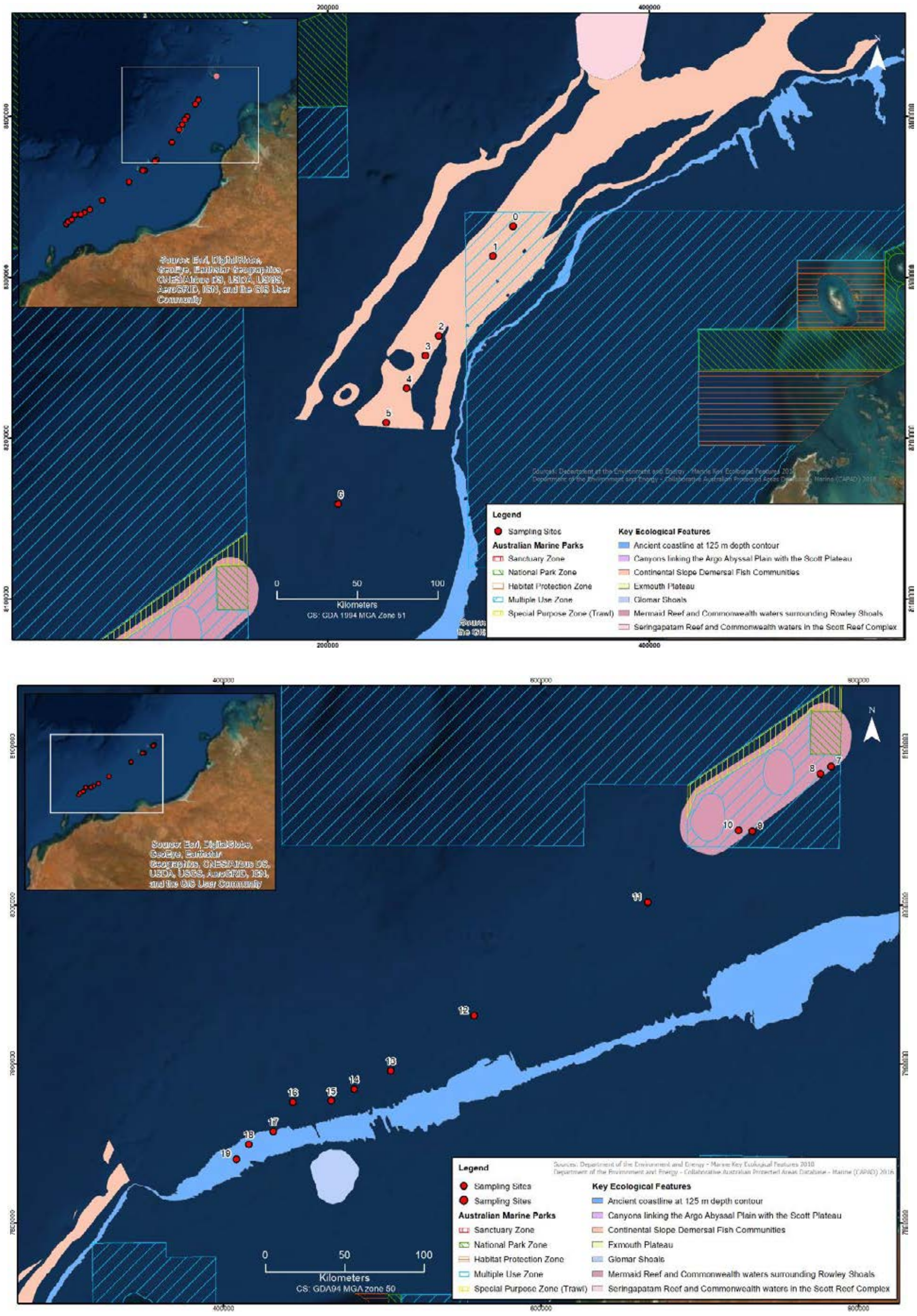

Figure 2-2: Sampling sites

Sources: Department of the Environment and Energy - Marine Key Ecological Features 2018
Department of the Environment and Energy - Collaborative Australian Protected Areas Database - Marine (CAPAD) 2016

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Table 2-4: Summary of sampling conducted at each site

Site No.	Approximate Depth (m)	AMP/KEF	Preliminary Habitat Description	Water Quality Sampling	Sediment Quality Sampling	Drop Camera Survey
0	375	Kimberley Marine Park and Continental Slope Demersal Fish KEF	Coarse sand	Y	Y	Y
1	345	Kimberley Marine Park and Continental Slope Demersal Fish KEF	Fine sand-mud	Y	Y	Y
2	335	Continental Slope Demersal Fish KEF	Large 2D ripples	Y	Y	Y
3	352	Continental Slope Demersal Fish KEF	Fine sand-mud	Y	Y	Y
4	350	Continental Slope Demersal Fish KEF	Fine sand-mud	Y	Y	Y
5	377	Continental Slope Demersal Fish KEF	Fine sand-mud	Y	Y	Y
6	430	None	Coarse sand	Y	Y	Y
7	375	Argo-Rowley Terrace Marine Park and Mermaid Reef KEF	Medium 2D ripples	Y	Y	Y
8	372	Argo-Rowley Terrace Marine Park and Mermaid Reef KEF	Coarse sand	Y	Y	Y
9	322	Argo-Rowley Terrace Marine Park and Mermaid Reef KEF	Medium 2D sand waves	Y	Y	Y
10	329	Argo-Rowley Terrace Marine Park	Coarse sand	Y	Y	Y
11	260	None	Coarse sand	Y	Y	Y
12	260	None	Coarse sand	Y	Y	Y
13	260	None	Sloped terrain scarp	Y	Y	Y
14	220	None	Irregular 2D ripples	Y	Y	Y
15	182	None	Mound	Y	N	Y
16	190	None	Irregular 3D ripples	Y	Y	Y
17	130	Ancient Coastline at 125 m Depth Contour KEF	Fine sand-mud	Y	Y	Y

Site No.	Approximate Depth (m)	AMP/KEF	Preliminary Habitat Description	Water Quality Sampling	Sediment Quality Sampling	Drop Camera Survey
18	126	Ancient Coastline at 125 m Depth Contour KEF	Coarse sand	Y	Y	Y
19	120	Ancient Coastline at 125 m Depth Contour KEF	Fine sand-mud	Y	Y	Y

3 Sampling Methodology

3.1 Survey Timing

The survey was completed between 9 March and 10 June 2019. Over this period, the survey vessel was required to seek safe anchorage on a number of occasions to avoid adverse weather, including during the passage of Tropical Cyclone Veronica in late March. Survey events are summarised in Appendix C.

3.2 Benthic Habitat (Seabed Imagery)

3.2.1 Camera System

Seabed imagery was captured using the STR Sea Spyder Drop Camera System, capable of working at depths of up to 1000 m. The system was configured and integrated to the survey vessel during project mobilisation, before leaving the port.

The camera system provided live standard definition footage to the surface, allowing the operator to view the seabed footage in real time. The lighting and flash system were aligned to provide clear video and digital stills. A high-resolution digital camera was used to capture still images of the seabed and any benthic communities of interest. Additionally, an autonomous high definition video camera was mounted to the frame to collect high definition video. A scaling laser system was also configured with the camera spread to ensure it was visible in the telemetered video footage and still images.

Geographical positioning data was recorded using an Ultra-Short Base Line (USBL) system, with a beacon mounted above the camera frame. Time stamps on all cameras were synced with the timing on the USBL system, ensuring all footage was georeferenced. The positioning system and data management was supplied and operated by Neptune.

3.2.2 Survey Methodology

At each site, the camera was lowered to about 1 m above the seabed. Camera heights were controlled from the coaxial winch. Typically, the camera would be landed on the seafloor to obtain clear images and then raised about 1 m while the vessel drifted or motored a short distance away (less than 20 m) to increase spatial coverage. Once camera movement stabilised, the camera was lowered back to the seafloor and additional images were collected. Spatial coverage depended on several factors including the rate of drift, subsea currents and surface wave action (heave). A minimum of ten minutes of video footage was collected at each site.

3.2.3 Image Assessment

Video footage was described in seabed logs onboard the vessel and qualitatively classified using the CATAMI classification scheme. All footage was reviewed upon completing the survey and benthic classifications were checked. Broader scale seabed features (large sand waves, isolated mounds) were hard to identify from the seabed imagery, given the limited field of view of the drop camera system. Discrepancies between the preliminary habitat map and the observed seabed features may result from these scale differences. For example, seabed imagery may be classified as 2D ripples but these may be superimposed on the surface of larger sandwave features.

3.3 Water Quality

The water column along the BTL was characterised by implementing the following methods.

3.3.1 Water Profiling

Baseline water quality data was collected over the entire water column at each site. Vertical profiles to full ocean depth were taken using a calibrated Seabird Electronics (SBE) 19plus current, temperature and depth profiler (CTD) with integrated WET Labs fluorometers to measure turbidity. Data was logged while deploying and retrieving the CTD.

The SBE 19plus CTD profiler was equipped with sensors to measure:

- depth (pressure)
- conductivity
- temperature
- pH
- dissolved oxygen (DO)
- turbidity
- fluorescence.

3.3.2 Water Quality Sampling

Water quality samples were collected at three depths:

1. from near sea-bed
2. mid water column
3. sub-surface.

Water quality sampling was completed by lowering Niskin bottles to the designated depths where they were triggered for collection. Once retrieved on deck, the water collections were transferred into labelled sample bottles for the required analyses. Water samples were collected concurrently with the CTD deployments. Water samples were analysed for:

- Nutrients (TN, TP)
- Ammonia (NH4)
- Nitrate and Nitrite (NO_3/NO_2)
- Total Recoverable Hydrocarbons (TRH)
- Polycyclic Aromatic Hydrocarbons (PAH) (only tested for when TRH were above detection limits)
- Trace Metals (Al, As, Ba, Cd, Cr, Cu, Co, Fe, Hg, Ni, Pb, Sn, V, Zn).

3.3.3 Laboratory Analysis

Water quality was analysed at ALS, a National Association of Testing Authorities (NATA[1]) accredited laboratory. ALS analysed the required laboratory blanks and duplicates and tested standards and splits in accordance with NATA requirements.

The laboratory methods and analytical limits of reporting (LoRs) for the required water quality analysis is summarised in Table 3-1.

Table 3-1: Water quality analysis methodology and limits of reporting

Parameter	Method Reference	LoR (µg/L) (or as indicated)
TRH/BTEX/PAH	GC/FID, P&T/HS/MS GC/MS – SIM	TRH: 20 to 100 µg/L BTEX: 1 to 5 µg/L PAH: 0.5 to 2 µg/L
TRH (C11-C40), PAHs- only where TRH is detected	GC/FID, P&T/HS/MS GC/MS – SIM	TPH:20 to 100 µg/L BTEX:1 to 5 µg/L PAH: 0.5 to 2 µg/L
Ultra trace metals (Al, As, Ba, Be, Cd, Co, Cu, Fe, Pb, Hg, Mn, Ni, Ag, Sb, Sn and Zn)	APHA 3125B ORC/ICP/MS	0.00002 to 0.005
Ammonium calculated from ammonia (saline water method), temperature and pH	APHA 4500-NH3 G	0.005 mg/L
Ultra trace Nitrite and Nitrate	APHA 4500-NO3 I, APHA 4500-NO2 B	0.002 mg/L
Ultra trace Nitrogen (Total) and Phosphorus (Total)	APHA 4500-P J	0.005 to 0.050 mg/L

3.4 Sediment Quality

Baseline sediment quality was analysed to provide information on seabed particle size and to determine ambient concentrations of metals and hydrocarbons in the seabed sediments. The box corer (0.5 m × 0.5 m × 0.5 m) was constructed of stainless steel to prevent sample contamination and was supplied and operated by Neptune. Samples were photographed and processed directly on recovery. Sediment samples retained for quality analysis were handled in accordance with standard sampling protocols as required by NATA-accredited laboratories. Sample transport to the laboratories was documented under the appropriate chain of custody (CoC) documentation.

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[1] The National Association of Testing Authorities, Australia (NATA) is Australia's national accreditation body for the accreditation of laboratories, inspection bodies, calibration services, producers of certified reference materials and proficiency testing scheme providers throughout Australia.

Sediment samples were analysed for:

- Trace Metals (Al, Ba, Cd, Cr, Cu, Fe, Hg, Ni, Pb, Sn, V, Zn)
- Organics (BTEX, TPH and PAH)
- Nutrients – Nitrate and Nitrite (NO3/NO2)
- Total Organic Carbon (TOC)
- Total Carbon (as a proportion of calcium carbonate)
- Particle Size Distribution (PSD).

3.4.1 Laboratory Analysis

All sediment quality was tested at ALS, a NATA-accredited laboratory. ALS analysed the required laboratory blanks and duplicates and tested standards and splits in accordance with NATA requirements.

The laboratory methods and analytical LoRs for the required sediment quality analysis are summarised in Table 3-2.

Table 3-2: Sediment quality analysis methodology and limits of reporting

Parameter	Method Reference	LoR (mg/kg) (or as indicated)
PSD	AS 1289 3.6.3-2003, AS 1289.3.5.1-2006	1 %
TPH	USEPA 8260B/8270D	3-5
PAHs	USEPA 8270	0.004 to 0.005
BTEX (Benzene, Toluene, Ethyl Benzene and Xylenes)	USEPA 8260B	BTEX: 0.2 to 0.5
TOC	ALs-In-house	0.02%
TC	ALS-in house	0.02%
Mercury: Total-Low level	APHA 3112 Hg-B	0.01
Trace metals: Al, Cd, Cr, Cu, Ni, Pb, V, Zn	USEPA 6020	0.1 to 2
Total Metals in Sediments: Fe, Al	USEPA 6010	50
Metals ICPMS: Ba, Sn (includes digestion)	USEPA 6020 ICP/MS	0.1
Ammonia, Nitrate, Nitrite, NOx, TKN, Total Nitrogen, Total Phosphorus	APHA 4500-NH3 B/G/H, APHA 4500-NO3 F, Thermo Scientific Method D08727 and NEMI (National Environmental Method Index) Method ID: 9171, APHA 4500-NO3 B, APHA 4500-Norg D, APHA 4500-Norg/NO3, APHA 4500-P B&H	0.1 to 20 mg/kg

3.5 Benthic Infauna

3.5.1 Sampling Sites and Characteristics

Benthic infauna sampling was attempted at 20 sampling sites as shown Figure 2-1 and Figure 2-2.

Samples could not be obtained for various reasons from three sites; Site 4, Site 9 and Site 11. At Site 15, only shell material (but no soft sediment) was obtained, likely due to consolidated substrate in this area. This shell material was sent for infauna analysis.

Field sheets were completed onsite providing the following information; date, time, location, sample ID, latitude/longitude, water depth, sample collector, type of sample, sea state, conditions (weather, sea state, wind speed, shipping traffic), sediment description and any other general comments. These are included in Appendix D.

Sampling sites were characterised in relation to their depth, sediment particle size distribution (PSD) (with no PSD data available for Site 15) and location in relation to designated areas (i.e. whether they occurred within an Australian Marine Park (and Marine Park Zone if so) or an area identified as a Key Ecological Feature (KEF)). Sediment PSD, Marine Park, Marine Park Zone and Key Ecological Features (KEFs) were all included as factors within the ensuing multivariate analysis (refer to Section 2.6).

A summary of all infauna sampling site characteristics are shown in Table 3-3.

Table 3-3 Infauna sampling site characteristics

Site	Sample Volume (L)*	Depth (m)	Sediment PSD	Marine Park	Marine Park Zone	Key Ecological Features (KEFs)
0	60	376	Refer to PSD data	Kimberly Marine Park	Multiple Use	Continental Slope Demersal Fish KEF
1	36	346	Refer to PSD data	Kimberly Marine Park	Multiple Use	Continental Slope Demersal Fish KEF
2	42	336	Refer to PSD data	No	No	Continental Slope Demersal Fish KEF
3	40	351	Refer to PSD data	No	No	Continental Slope Demersal Fish KEF
5	121	378	Refer to PSD data	No	No	Continental Slope Demersal Fish KEF
6	36	428	Refer to PSD data	No	No	No
7	72	377	Refer to PSD data	Argo-Rowley Terrace Marine Park	Multiple Use	Mermaid Reef KEF
8	68	371	Refer to PSD data	Argo-Rowley Terrace Marine Park	Multiple Use	Mermaid Reef KEF
10	40	329	Refer to PSD data	Argo-Rowley Terrace Marine Park	Multiple Use	Mermaid Reef KEF
12	72.5	265	Refer to PSD data	No	No	No
13	75	261	Refer to PSD data	No	No	No
14	32.5	224	Refer to PSD data	No	No	No
15	0	188	Refer to PSD data	No	No	No
16	45	196	Refer to PSD data	No	No	No
17	50	132	Refer to PSD data	No	No	Ancient Coastline at 125m KEF
18	32.5	130	Refer to PSD data	No	No	Ancient Coastline at 125m KEF
19	32.5	125	Refer to PSD data	No	No	Ancient Coastline at 125m KEF

* the sample volume (L) refers to the total volume of material collected at each site for the infauna analysis, as provided in field data sheets – the original sample volume in L was later standardised to 0.1m3 for each site for statistical analysis.

3.5.2 Sample Collection and Processing

Benthic infauna samples were collected using the same box corer (0.5 m × 0.5 m × 0.5 m = 0.125 m^3) as was used for the sediment collection and followed the method of sampling outlined for marine sediments (Section 3.4). The sediment sample used for benthic infauna analysis comprised the sediment which remained after the required volume had been taken for all other sediment characterisation analysis.

Once retrieved and on the boat, each sediment sample was sieved using an Endecott sieve with a

1 mm mesh size. After sieving the sediment, the remaining contents were transferred into buckets and samples were preserved in a ~10% borax buffered formalin solution.

Total sample volume (i.e. the volume of material sieved) varied significantly between sites, ranging from 32.5 L – 121 L. This was dependent on the total volume of material obtained from each site, the amount of sample required for sediment characteristation and operational restrictions during sampling (e.g. time available). Varying numbers of buckets were submitted to the laboratory for each site dependent on the sample volume, with this data subsequently combined for each individual site.

3.5.3 Sample Transport

Sample transport to the analytical laboratory was documented under the appropriate chain of custody (CoC) protocols.

3.5.4 Infauna Identification

All samples were identified by Aquen (Aquatic and Environmental Consulting) to family level. This level of identification has been proven to be adequate in determining the effects of anthropogenic influences on the marine environment, in particular, for infauna communities (e.g. Warwick, 1988, Chapman 1998, Underwood et al. 2003).

3.5.5 Data Analysis

3.5.5.1 Data Investigation

The total abundance of each infauna taxa (family level) identified was recorded for each site. As the original pre-sieve sample volume was not consistent between sites, the original infauna abundance data for each site was standardised to a sample volume of 0.1 m3 (100 L). Standardisation of infauna abundance data was necessary to allow for meaningful comparisons of data between sites. Richness data (i.e. the number of different taxa in a sample) was not standardised to 0.1 m3 as it is not possible to allude to the existence of additional taxa and so richness values for each site remained unchanged. The raw and standardised abundance data are provided in Appendix E.

Abundance, Richness and Diversity

Infauna abundance, richness and diversity were calculated for each site based on the standardised infauna abundance data.

A brief definition of each of these indices is provided below:

- Abundance: Relates to how common or rare taxa are relative to other taxa in a defined location or community. For the purposes of this report, total abundance = the total number of individuals at a given site.
- Richness: A measure related to the total number of different taxa present within a sample (for the purposes of this report taxa richness was determined for each site).
- Diversity: Diversity accounts for the number of taxa and the evenness of taxa, giving a measure of the biodiversity and complexity of a population. Taxa diversity consists of two components, taxa richness and taxa evenness. Taxa richness is a simple count of taxa, whereas taxa evenness quantifies how equal the abundances of the taxa are. The Shannon diversity index was used as the measure of diversity.

Family level abundance, taxa richness and Shannon diversity for each site were tabulated and presented graphically to compare these indices between sites.

The abundance and richness of all infauna Phylum identified in this study (for all sites combined) were also tabulated and presented graphically.

3.5.5.2 Multivariate Analysis

Multivariate analysis was undertaken to determine whether there were any differences in infauna assemblages between sites and whether these could be related to Factors such as depth, PSD or location within a designated area (MPA or KEF). All multivariate analyses were undertaken in PRIMER 7 with the PERMANOVA add on (Anderson et al. 2008).

3.5.5.3 Data Transformation

For multivariate analyses, the data first needed to be transformed to achieve similar distribution among datasets. The infauna abundance dataset was transformed using a square root transformation which is typical for this type of biological data and useful for low values of ecological abundance data.

3.5.5.4 Shade Plots

Shade plots were used as an alternative visual tool to assess the relative abundance of infauna families by site. These plots provided clear visual representation of the different families occurring at each site and their relative abundance as indicated by varying degrees of shading.

3.5.5.5 Resemblance Matrix

The transformed dataset was then used to make a resemblance matrix using the Bray Curtis similarity metric, which is robust to ecological data measured on different scales and with a high proportion of 'low' or absent species. A resemblance matrix is a matrix of scores which represents the similarity between each pairwise comparison of data points.

3.5.5.6 Multidimensional Scaling

The resemblance matrix was used to generate multi-dimensional scaling (MDS) plots. MDS plots are visual representations of the similarity matrix; where points that are closer together on the plot are more like each other than those further apart. Goodness of fit (stress) was assessed using Kruskal's stress formula and compared to maximum values (stress should be less than 0.2) as recommended by Sturrock and Rocha (2000).

MDS plots can be overlaid by different Factors, whereby the points on the graph which represent the similarity matrix are in the same position but are coloured according to the different Factors. The various Factors of interest which were overlaid on the MDS plots to further investigate any patterns seen included:

- Site: 0 - 19 (site 15 was excluded from multivariate analysis as no infauna were recorded).
- Depth: Depths from 100 m – 450 m were divided into 50 m class categories for categorical comparison.
- Marine Park: Kimberly Marine Park, Argo-Rowley Terrace Marine Park or N/A.
- Marine Park Zone: Multiple Use or N/A.

- Key Ecological Features: Continental Slope Demersal Fish KEF, Mermaid Reef KEF, Ancient Coastline at 125m KEF or N/A.
- Sediment Particle Size: i.e. Percentage Clay (<2 µm), Percentage Silt (2-60 µm) and Percentage Cobbles (>6 cm). This was undertaken as infauna assemblages can vary significantly with varying sediment particle sizes. MDS plots need to be grouped by categorical factors. As sediment size is continuous data, the percentage of various sediment classes were divided into 5% class categories to allow comparison by MDS.

3.6 Quality Control

3.6.1 Field QA/QC

The following quality assurance/control (QA/QC) measures were implemented during sampling:

- Sample containers were sourced from the laboratory.
- Prior to use, any evidence of or sources of contamination was cleaned or either removed from the vessel or covered to prevent contamination.
- Disposable, powder-free gloves were used for handling samples and changed after each sample.
- Equipment was decontaminated between collecting each sample.
- Field duplicates for water and sediment samples were obtained at 10% of sites (two sites).
- Field replicates for water and sediment samples were obtained at 10% of sites (two sites).

CoC forms accompanied samples and each stage of handling was recorded. The following actions were performed daily to minimise the chance of missing or misplacing a subsample:

- All pre-labelled sample containers were filled at each site.
- A sample matrix record was updated with confirmation of sites visited, and containers filled as samples were being collected.
- During each shift, the notes on the sample matrix, field book and photographs were compared against the total number of containers stored from that shift before populating the CoC form.

3.6.2 Sub Sampling

Water and sediment were sampled at a location on the vessel deck that was free from potential contamination. All sub sampling was completed in a clean area, away from any exhaust fumes or discharge locations.

Upon recovery, samples were directly subsampled or placed into the relevant sample containers or a designated and decontaminated intermediate container before further processing (e.g. filtration).

3.6.3 Sample Containers

ALS provided sampling containers and information relating to holding times and on-board storage requirements to ensure adequate sample volumes were collected.

3.6.4 Sample Naming Conventions

Each sample had a unique reference code. The reference code was used on sample labels, reports and CoC documentation. The sample reference code was written on the labels of each sample using permanent marker. Also noted were the:

- project number
- date and time
- name or initial of the person conducting the sampling.

Containers were pre-labelled where possible before commencing sampling.

3.6.5 Sample Storage and Preservation Requirements

Water and sediment quality samples designated for laboratory analysis were collected in cleaned and decontaminated laboratory-supplied glass jars. Glass containers were filled completely with sample.

Samples that required chilling or freezing were refrigerated while onboard the vessel in a designated refrigerator/freezer. Once back at port, samples were packed in sealed plastic coolers (eskies) with ice bricks before being hand carried off the vessel to transport vehicles.

3.6.6 Laboratory QA/QC

The integrity of the samples was assured using CoC documentation. Samples were always chilled using ice blocks and refrigerated between field collection and delivery to the laboratory.

As part of NATA requirements, laboratory analysis included quality control of samples, including duplicate samples (the same sample analysed more than once), blanks (containing no levels of the analytes to be analysed) and spiked samples (containing known additions of the analytes to appropriate matrices). The laboratory QA/QC report is also presented with the laboratory results in Appendix F. Field QA/QC checks are presented in Appendix G and Appendix H.

4 Results

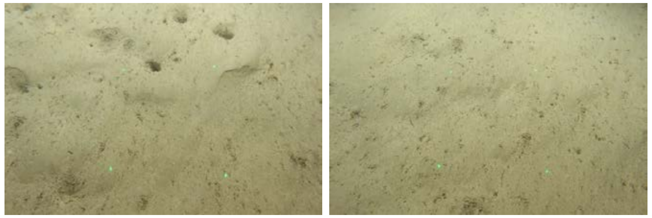
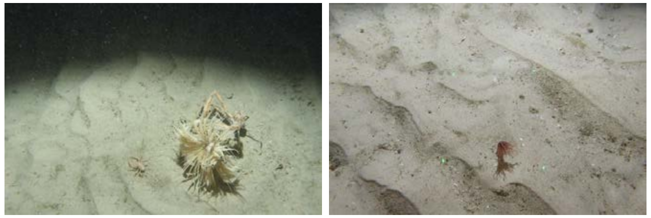
4.1 Benthic Habitat Assessment (Seabed Imagery)

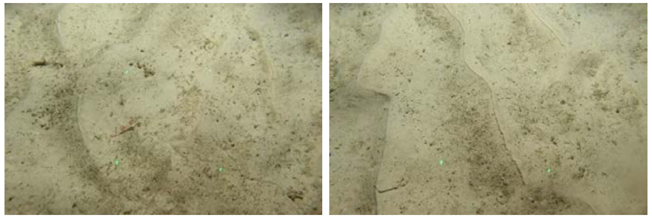
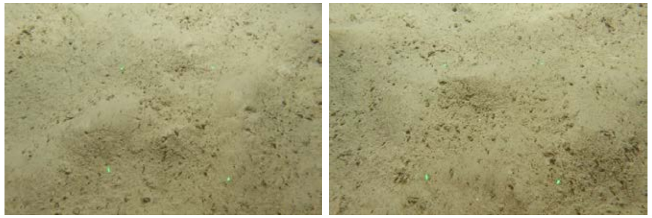
Seabed imagery was collected at all 20 sampling sites, with depths ranging from 119 to 432 m, identified in the SAP (Advisian, 2019). Substrates described at these sites were typically aligned with the preliminary habitat map (Appendix A), developed from the geophysical data. Variations between the preliminary habitat map and field data are likely a result of scale differences. Larger seabed bedforms are unlikely to be distinguished from the seabed imagery, given the field of view of the camera system. For example, ripples or waves may be identified from the camera footage; however, the identified waves/ripples may be superimposed on larger bedforms such as sand waves.

Seabed imagery was collected over a duration of approximately 10 minutes at each site, during this time the vessel remained generally static to provide a stable and safe platform for operation of the drop camera system. Resulting spatial coverage of the habitat observed in the imagery is therefore limited, and interpolation of the presence of epifauna from the geophysical data is also not possible as the approach was intended to capture data on bedform and substrate over a large area. There is no evidence to suggest that the habitat observed in the imagery is not homogenous as no boundaries were observed in the imagery and the boundaries developed in the preliminary habitat map are considered reliable (Appendix A). Confirmation of substrates defined in the preliminary habitat map can allow some inferences to the presence of epifauna beyond the scale of seabed image acquisition though this would be assumed and should be considered with caution without additional ground truthing data. Benthic habitat observed in seabed imagery did not appear to have any association with depth, nor were there discernible associations between designated management zones (AMPs or KEFs) and habitats observed.

Habitat types were relatively homogenous at each sampling site and typically consisted of Sandy seabed sediments with varying proportions of Silt and Clay, except for Site 15, which consisted of consolidated rubble. Bioturbation (disturbance of sedimentary deposits by living organisms) was evident to varying degrees between sites and was a frequent observation, since the substrate at most sites was unconsolidated soft sand or mud. Where epifauna (fauna that inhabit the seabed) was observed, it was in very low abundance, usually occurring as solitary individuals including crustaceans, various cnidarians (solitary anemones and hydroids), echinoderms (sea stars and brittle stars) and small bony fishes. Table 4-1 presents a summary of seabed imagery observations, habitat classifications and example images from each site. Photo plates, which present additional representative seabed images, are presented in Appendix I. Qualitative benthic habitat classifications are presented in Appendix J.

Table 4-1: Seabed imagery observations and summary of habitat classifications

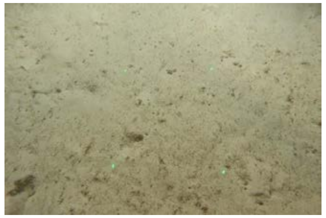
Site Number	Approximate Depth (m)	AMP/KEF	Classification from Preliminary Habitat Map	Observed Habitat	General Comments	Example Images (laser scale = 18 cm (l) x 23 cm (h)
0	375	Kimberley Marine Park and Continental Slope Demersal Fish KEF	Coarse sand	Sediments were classified as soft fine sand/mud from the seabed imagery; the sediment sample collected at Site 0 was classified as silt with sand and clay from the PSD data. The only epibenthic fauna observed at Site 0 was a solitary prawn, though some bioturbation was evident indicating presence of some infauna.	The sediments at the sampling site were noted to be finer than predicted from the geophysical data.	
1	354	Kimberley Marine Park and Continental Slope Demersal Fish KEF	Fine sand-mud	The sediments were classified as soft fine sand/mud from the seabed imagery; the sediment sample collected at Site 1 was classified as sand with some silt and clay from the PSD data. Epifauna observed in the seabed imagery were in low abundance and included a single bony fish, a lobster and solitary stalked anemone.	The habitat map is considered to accurately represent the seabed at this site.	
2	335	Continental Slope Demersal Fish KEF	Large 2D ripples	The sediments were classified as coarse sand with 3D small waves/ripples from the seabed imagery; the sediment sample collected at Site 2 was classified as sand with some silt and clay from the PSD data. Epifauna observed in the seabed imagery included occasional crabs, crinoids and solitary anemones.	There is some minor variation between the habitat map and field data in the description of the complexity of the ripples (2D.v. 3D).	
3	352	Continental Slope Demersal Fish KEF	Fine sand-mud	The sediments were classified as coarse sand from the seabed imagery; the sediment sample collected at Site 3 was classified as Sand with some silt and clay from the PSD data. Epifauna observed in seabed imagery included an occasional solitary sea pen, lobster, crinoids and hydroid.	The habitat map is considered to accurately represent the seabed at this site.	

Site Number	Approximate Depth (m)	AMP/KEF	Classification from Preliminary Habitat Map	Observed Habitat	General Comments	Example Images (laser scale = 18 cm (l) x 23 cm (h)
4	350	Continental Slope Demersal Fish KEF	Fine sand-mud	The sediments were classified as soft fine Sand/Mud from the seabed imagery; the sediment sample collected at Site 4 was classified as sand with some clay from the PSD data. Very low numbers of epifauna were observed in seabed imagery and included an occasional solitary ascidian and crustacean.	The habitat map is considered to accurately represent the seabed at this site.	
5	377	Continental Slope Demersal Fish KEF	Fine sand-mud	The sediments were classified as soft fine Sand/Mud from the seabed imagery; the sediment sample collected at Site 5 was classified as silt with some sand and clay from the PSD data. No evidence of benthic fauna was observed from the seabed imagery at Site 5.	The habitat map is considered to accurately represent the seabed at this site.	
6	430	None	Coarse sand	The sediments were classified as coarse sand from the seabed imagery; the sediment sample collected at Site 6 was classified as sand with some clay from the PSD data. Epifauna observed in seabed imagery included a solitary crustacean (lobster) and echinoderm (sea star).	The habitat map is considered to accurately represent the seabed at this site.	
7	375	Argo-Rowley Terrace Marine Park and Mermaid Reef KEF	Medium 2D ripples	The sediments were classified as coarse sand from the seabed imagery with 3D ripples/waves; the sediment sample collected at Site 7 was classified as predominantly sand from the PSD data. Epifauna observed in seabed imagery included a solitary bony fish and echinoderm (sea star).	The habitat map is considered to accurately represent the seabed at this site.	

Site Number	Approximate Depth (m)	AMP/KEF	Classification from Preliminary Habitat Map	Observed Habitat	General Comments	Example Images (laser scale = 18 cm (l) x 23 cm (h)
8	372	Argo-Rowley Terrace Marine Park and Mermaid Reef KEF	Coarse sand	The sediments were classified as coarse sand from the seabed imagery; the sediment sample collected at Site 8 was classified as predominantly sand with some clay from the PSD data. A higher abundance of bony fishes was observed at Site 8 when compared with other sites, but there is no evidence from seabed imagery or geophysical data that the seabed habitat is significantly different from other sites or would support higher abundance of fishes compared with other sites.	The habitat map is considered to accurately represent the seabed at this site.	
9	322	Argo-Rowley Terrace Marine Park and Mermaid Reef KEF	Medium 2D sand waves	The sediments were classified as coarse Sand from the seabed imagery; the sediment sample collected at Site 9 was classified as predominantly sand from the PSD data. Epifauna observed in seabed imagery included a low abundance of crustaceans (lobsters), occurring mostly as solitary individuals.	It is hard to detect broader scale bathymetric changes from the drop camera system and the 3D ripples apparent in the seabed imagery may exist on top of larger sand wave bedforms predicted in the preliminary habitat map. The habitat map is considered to accurately represent the seabed at this site.	
10	329	Argo-Rowley Terrace Marine Park	Coarse sand	The sediments were classified as fine sand/mud from the seabed imagery; the sediment sample collected at Site 10 was classified as sand with some silt and clay from the PSD data. A higher abundance of bony fishes was observed at Site 10 when compared with other sites, but there is no evidence from seabed imagery or geophysical data that the seabed habitat is significantly different from other sites or would support higher abundance of fishes compared with other sites.	The habitat map is considered to accurately represent the seabed at this site.	

Site Number	Approximate Depth (m)	AMP/KEF	Classification from Preliminary Habitat Map	Observed Habitat	General Comments	Example Images (laser scale = 18 cm (l) x 23 cm (h)
11	260	None	Coarse sand	The sediments were classified as coarse sand from the seabed imagery; the sediment sample collected at Site 11 was classified as sand with some clay from the PSD data. Epifauna observed in seabed imagery included an occasional solitary cnidarian (sea pen/whip) and solitary bony fish, though abundance was very low.	The site site was selected as the pipeline intersects an area of potentially harder substrate with a potential for increased species richness. Evidence of harder substrate and increased species richness was not observed at this site in the imagery or PSD data. Given the preliminary classification of course sand, the habitat map is considered to accurately represent the seabed at this site.	
12	260	None	Coarse sand – some areas of softer sediments were also identified near the sampling site	The sediments were classified as fine sand/mud from the seabed imagery; the sediment sample collected at Site 12 was classified as silt with some sand and clay from the PSD data. Bioturbation at Site 12 was observed to be more prevalent, with more variation in hole size than other sites. Epifauna observed included low abundance of crustaceans (lobsters).	Imagery and PSD suggest that the sediments sampled aligned with the softer sediments indicated on the preliminary habitat map to be in the vicinity of the site and the habitat map is considered suitable at this site.	
13	260	None	Sloped terrain scarp	The sediments were classified as coarse sand from the seabed imagery; the sediment sample collected at Site 13 was classified as sand with some silt and clay from the PSD data. Epifauna observed in seabed imagery included a solitary sponge and bivalve. A small number of track marks were also observed.	The seabed at Site 13 was predicted to consist of more complex seabed features in an area of sloped terrain/scarp from the preliminary habitat map. Though no evidence of this was observed in the imagery or PSD data. Note: Broader scale geological features (greater than 10 metres) such as scarps may be difficult to detect from drop camera surveys of areas where the field of view is in the range of 1 to 10 metres.	

Site Number	Approximate Depth (m)	AMP/KEF	Classification from Preliminary Habitat Map	Observed Habitat	General Comments	Example Images (laser scale = 18 cm (l) x 23 cm (h)
14	220	None	Irregular 2D ripples	The sediments were classified as fine sand/mud from the seabed imagery; the sediment sample collected at Site 14 was classified as clay with some silt and sand from the PSD data. Sediment colour was observed to be more variable than at other sites, apparently associated with bioturbation, which was evident at Site 14.	Site 14 was selected to provide coverage of differing bedform types along the pipeline route. The seabed was relatively flat with some very small 2D ripples and notably finer sediments compared with other sections of the pipeline route. The area of irregular 2D ripples is intersected by areas of fine sand/mud on the habitat map and the habitat map is considered accurate for this site.	
15	182	None	Mound	The sediments were classified as biogenic rubble (rubble that is comprised of remnants of biological origin, such as coral skeletons) with a low to moderate seabed relief from the seabed imagery. Two sediment samples were attempted at Site 15, with refusal (no material able to be recovered) both times suggesting a hard seabed. The species diversity at this site was noted to be higher in comparison to other sites, with more small crustaceans observed to be residing in the habitat provided by the rubble. Larger schooling bony fishes (possibly Amberjack) were also observed in imagery at this site.	The consolidated rubble observed from the seabed imagery is harder in comparison with other sites along the pipeline route. Determining the seabed bedform classification as a mound is difficult from the seabed imagery given the fine scale field of view of the drop camera.	
16	190	None	Irregular 3D ripples	The sediments were classified as coarse sand from the seabed imagery; the sediment sample collected at Site 16 was classified as sand with some clay and silt from the PSD data. Irregular 3D ripples are also apparent from the seabed imagery. A small number of solitary echinoderms and crustaceans were observed in the seabed imagery at Site 16.	The habitat map is considered to accurately represent the seabed at this site.	

Site Number	Approximate Depth (m)	AMP/KEF	Classification from Preliminary Habitat Map	Observed Habitat	General Comments	Example Images (laser scale = 18 cm (l) x 23 cm (h)
17	130	Ancient Coastline at 125 m Depth Contour KEF	Fine sand-mud	The sediments were classified as fine sand/mud from the seabed imagery; the sediment sample collected at Site 17 was classified as sand with some silt and clay from the PSD data. Relatively high levels of bioturbation of various sizes were observed in seabed imagery at Site 17. Some individual bony fishes were also observed here.	The habitat map is considered to accurately represent the seabed at this site.	 
18	126	Ancient Coastline at 125 m Depth Contour KEF	Coarse sand	The sediments were classified as fine sand/mud from the seabed imagery; the sediment sample collected at Site 18 was classified as predominantly sand from the PSD data. Epifauna observed in seabed imagery included an few small solitary bony fishes.	The habitat map is considered to accurately represent the seabed at this site.	 
19	120	Ancient Coastline at 125 m Depth Contour KEF	Fine sand-mud	The sediments were classified as fine sand/mud from the seabed imagery; the sediment sample collected at Site 18 was classified as sand with some clay from the PSD data. There was no epifauna observed in seabed imagery at Site 19. Bioturbation was observed to be relatively high compared to most other sites.	The habitat map is considered to accurately represent the seabed at this site.	 

4.2 Physico-Chemical Characteristic (Water Quality)

A total of 22 water column profiles were recorded from 20 survey sites. The shallowest site was Site 19, with a depth of 120 m; the deepest site was Site 6, with a depth of 432 m. Water column profiles for all sites are presented in Sections 4.2.1 to 4.2.7 and for individual sites in Appendix K.

4.2.1 Temperature

Figure 4-1 shows the temperature profile of all sampling sites; individual site profiles are presented in Appendix K. Water temperatures ranged from 9.3 to 30.7 °C and were highest, and most stable, in the upper surface waters down to 50 m. Between 50 and 200 m depth, the gradient in temperature decrease is the steepest, with about 5 °C decrease with every 50 m of depth. Where data was collected at sites deeper than 200 m, temperature continued to reduce as depth increased, though the rate of change decreased. The lowest water temperatures were recorded at the deepest sites profiled.

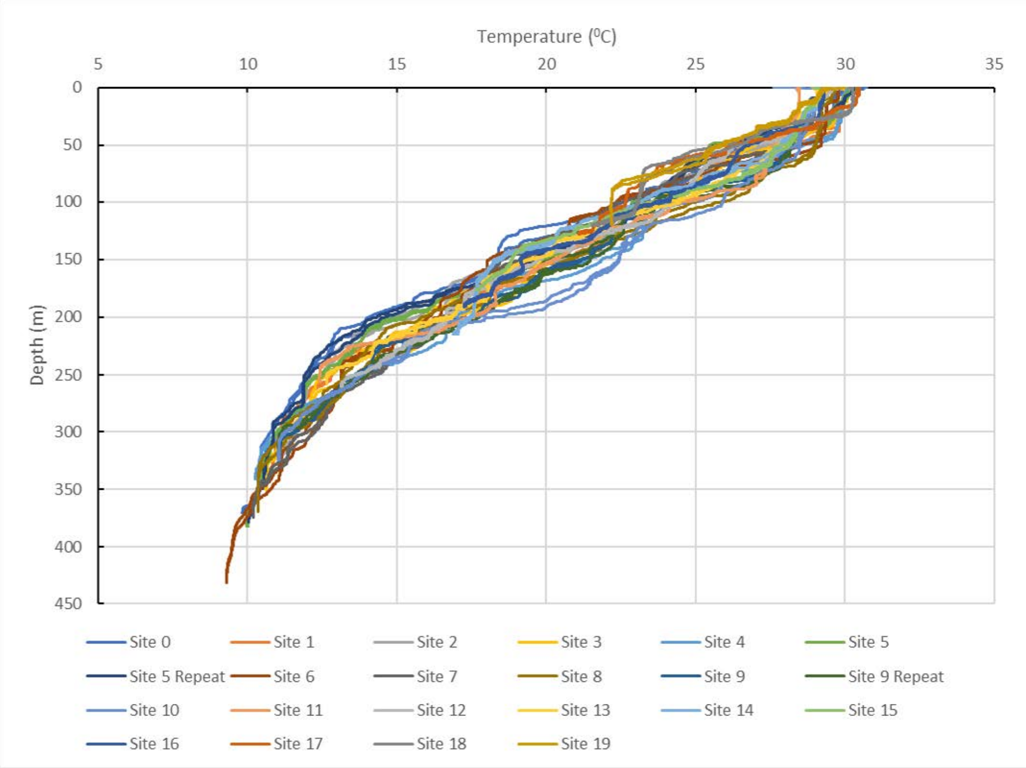


Figure 4-1: Temperature (°C) depth (m) profile at all sampling sites

4.2.2 Conductivity

Figure 4-2 shows the conductivity profile of all sampling sites; individual site profiles are presented in Appendix K.The conductivity ranged from 32.27 to 58.73 mS/cm. Conductivity values recorded displayed a similar trend to water temperature and were most stable in the upper surface waters, down to about 50 m. Between 50 and 200 m depth, the gradient of decline is steepest. The reduction in conductivity continued to decline with depth beyond 200 m, though the rate of change decreased beyond 200 m. The lowest conductivity values recorded were associated with the deepest sites profiled.

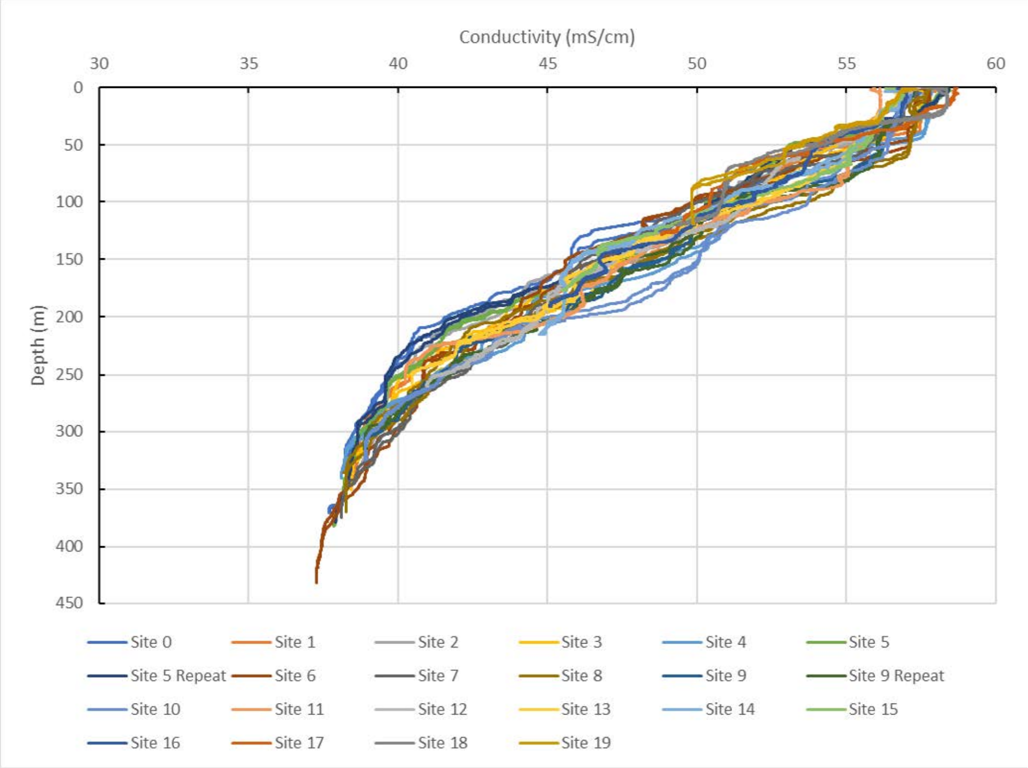


Figure 4-2: Conductivity (mS/cm) depth (m) profile at all sampling sites

4.2.3 Salinity

Figure 4-3 shows the salinity profile of all sampling sites, individual site profiles are presented in Appendix K. Salinity ranged from 34.20 to 35.09 PSU and remained relatively constant between this range throughout the depth profile (Figure 4-3).

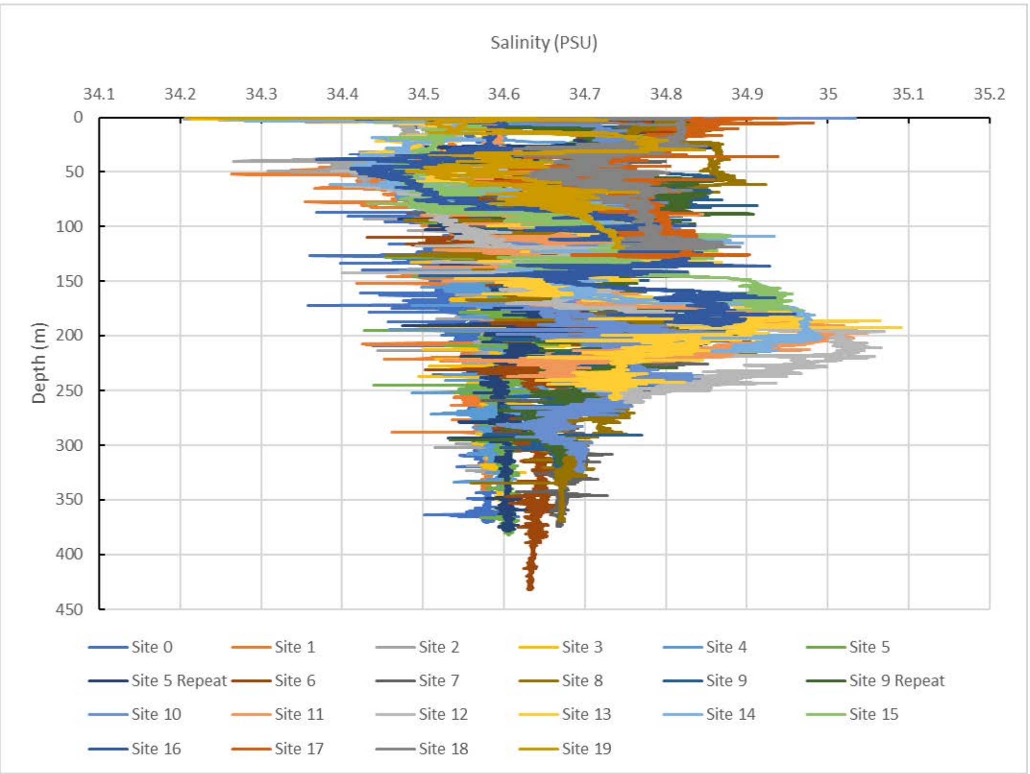


Figure 4-3: Salinity (PSU) depth (m) profile at all sampling sites

4.2.4 Turbidity

Figure 4-4 shows the turbidity profile of all sampling sites; individual site profiles are presented in Appendix K. Any recorded negative values have been corrected to 0. The measurement of negative NTU values is attributable to water that is clearer than the calibration fluid (Letterman et al., 2004). The range of turbidity varied from 0 to 2.35 NTU. Turbidity from each site displayed consistent readings throughout the water column. Sites 4, 5, 5 Repeat, 8 and 19 were around the range of 0 NTU. Sites 0, 1, 11, 13, 15 and 16 varied between 0.5 and 1.0 NTU. Sites 3, 6, 7, 9, 9 Repeat, 10, 14 and 17 were between 1 to 1.5 NTU. Site 2 was around the range of 1.8 and Sites 12 and 18 had the highest NTU, with values between 2.1 to 2.4 (Figure 4-4). The passage of tropical cyclone Veronica did not affect turbidity values.

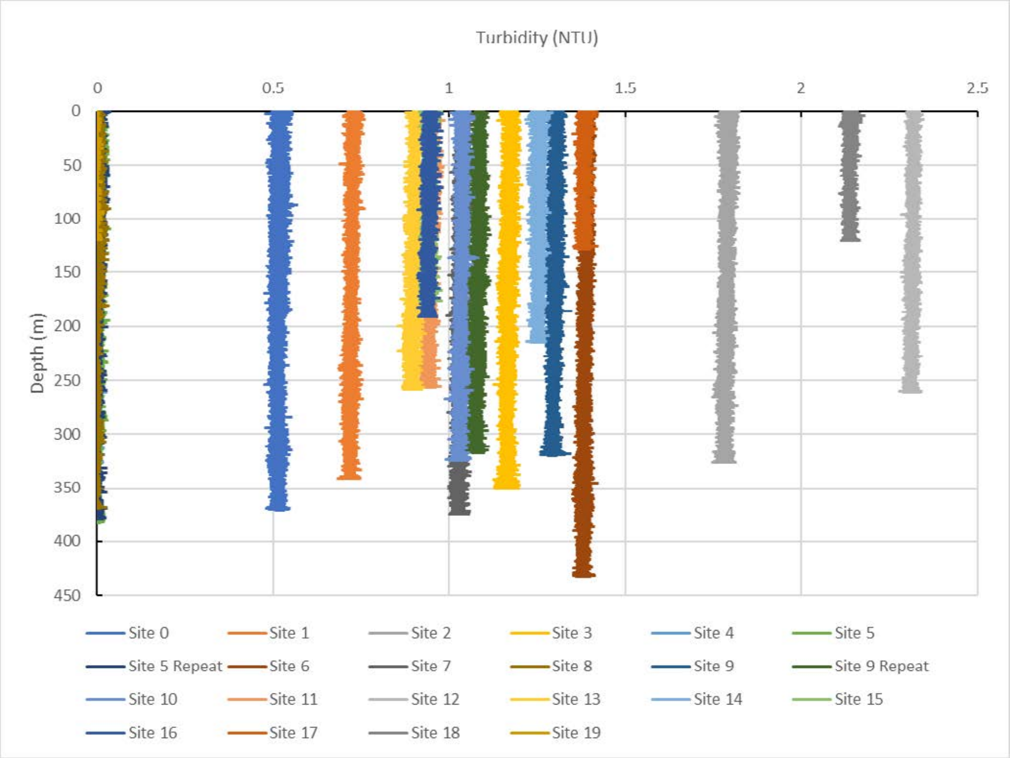


Figure 4-4: Turbidity (NTU) depth (m) profile at all sampling sites

4.2.5 Dissolved Oxygen

Only profile data from the instrument recovery (i.e. from the sea floor to the surface) was collated in Figure 4-5. The range of oxygen (%Sat) recorded was from 26% to 79%. There was a general trend of decreased saturation with depth. Dissolved oxygen values at Sites 13, 14, 15, 16 and 19 were significantly lower in comparison with other sites. The data from these sites is considered erroneous and is not presented.

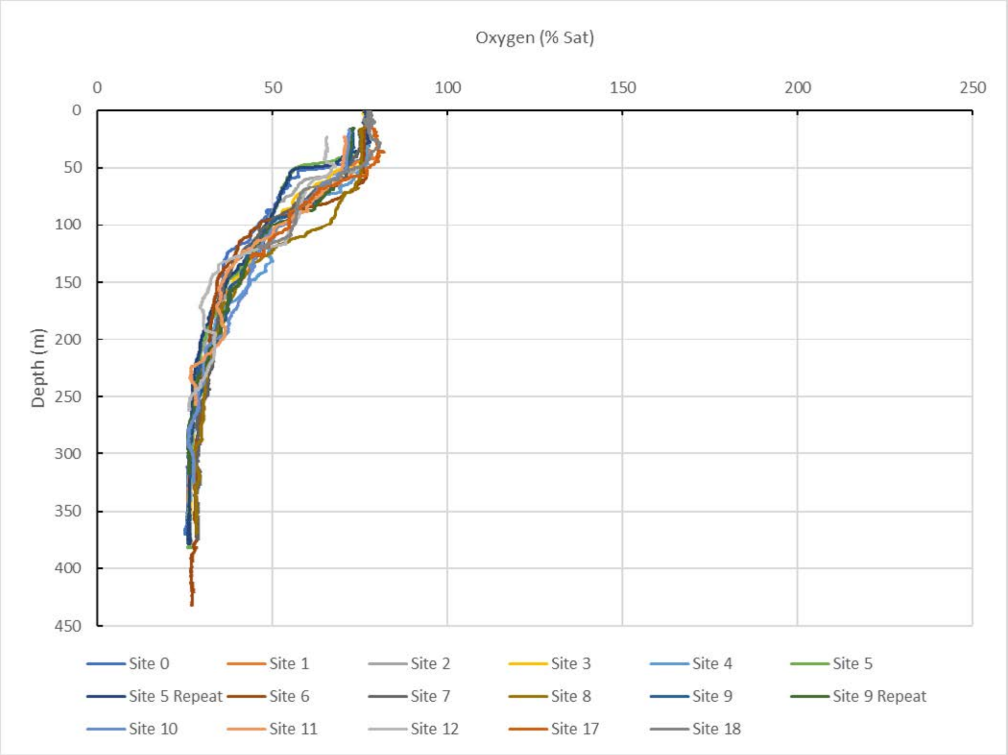


Figure 4-5: Oxygen (% Sat) depth (m) profile at all sampling sites

4.2.6 pH

Only the profile data from the instrument retrieval (i.e. from the sea floor to surface) was plotted in Figure 4-6. The range of pH was between 8.47 to 8.97. pH was observed to decrease with depth (Figure 4-6).

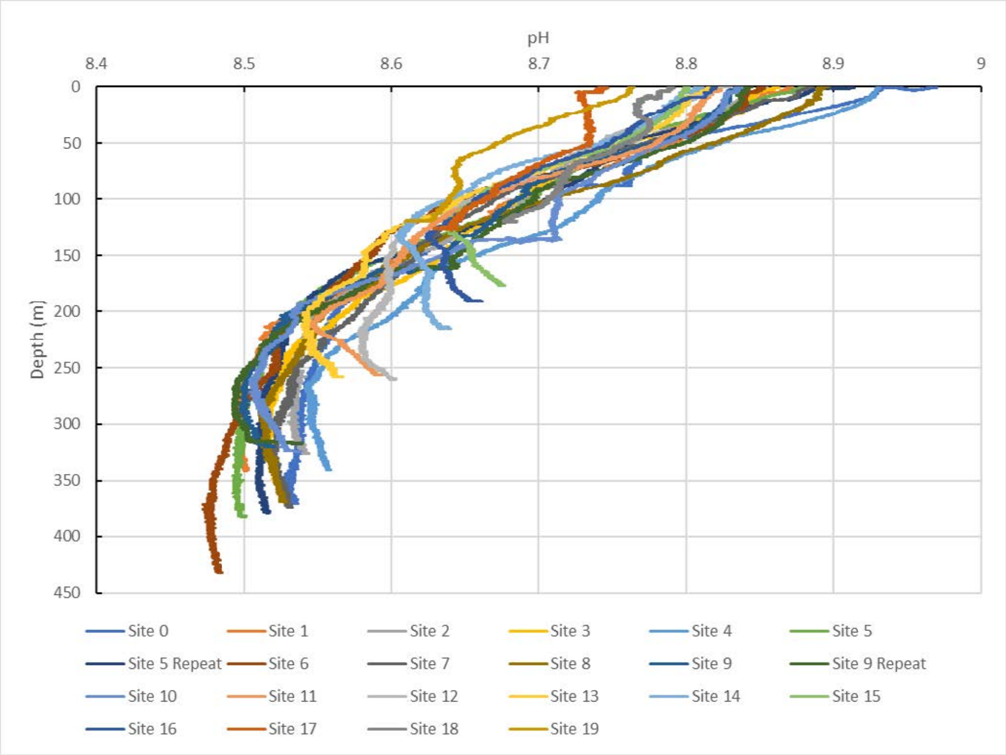


Figure 4-6: pH depth (m) profile at all sampling sites

4.2.7 Fluorescence

At all sites, there was a general trend of increasing fluorescence with depth (Figure 4-7), which is expected to be a result of nutrient levels increasing with depth (Section 4.2.10).

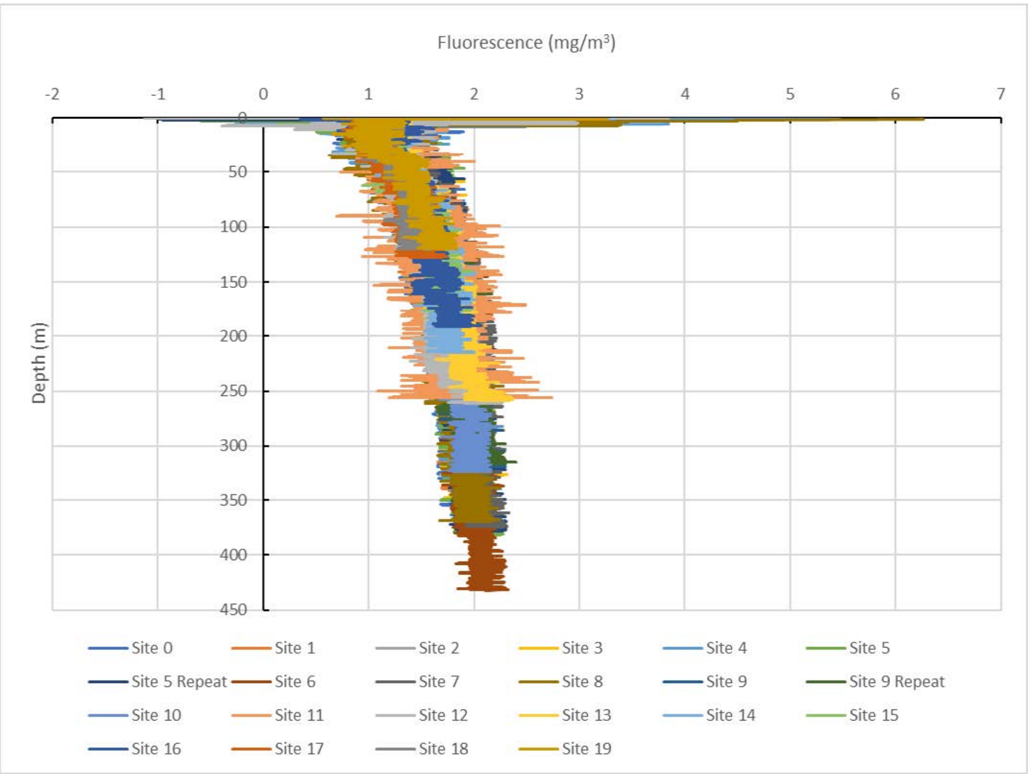


Figure 4-7: Fluorescence (mg/m^3) depth (m) profile at all sampling sites

4.2.8 Trace Metals

A summary of the results from water samples collected at mid, surface and near bottom from the 20 survey sites is presented in Sections 4.2.8.1 to 4.2.10.4. Total metals concentrations were below the ANZECC 99% species protection level at most sampling sites, except for Copper in the surface samples at Sites 2 and 8. The remaining trace metals concentrations were all below the ANZECC/ARMACANZ (2000) 99% trigger level for marine water.

4.2.8.1 Aluminium

There is no trigger level for aluminium in marine water in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) or the ANZECC/ARMACANZ (2000) guidelines. The aluminium concentration ranged from less than 5 to 19 µg/L (Figure 4-8). Most sites were below the LoR except for Site 0 (all depths) and the mid water sample at Site 18.

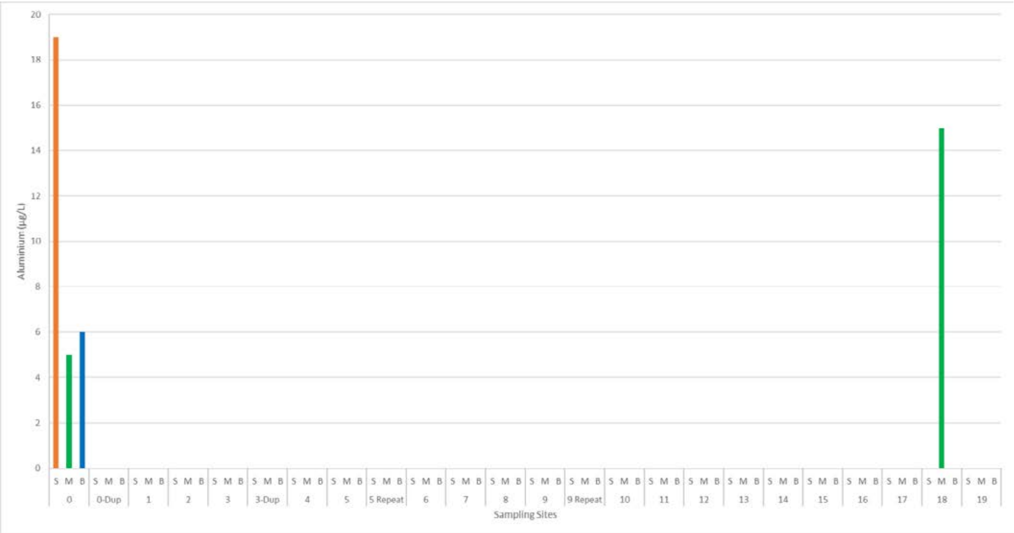


Figure 4-8: Aluminum concentration (µg/L) in marine water of all sampling sites to their relevant depth (Surface (S), Mid (M) and Bottom (B))

4.2.8.2 Arsenic

There is no trigger level for arsenic in marine water in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) or the ANZECC/ARMACANZ (2000) guidelines. The arsenic concentration ranged from 1.4 to 2.1 µg/L, with minimal variation between sites and depths (Figure 4-9). The maximum concentration was observed in the bottom depth of Sites 1, 8, 12 and 13. The minimum concentration was observed in surface depth of Site 15. Arsenic concentrations are significantly lower than those detected in other regional baseline surveys (Gardline, 2009)

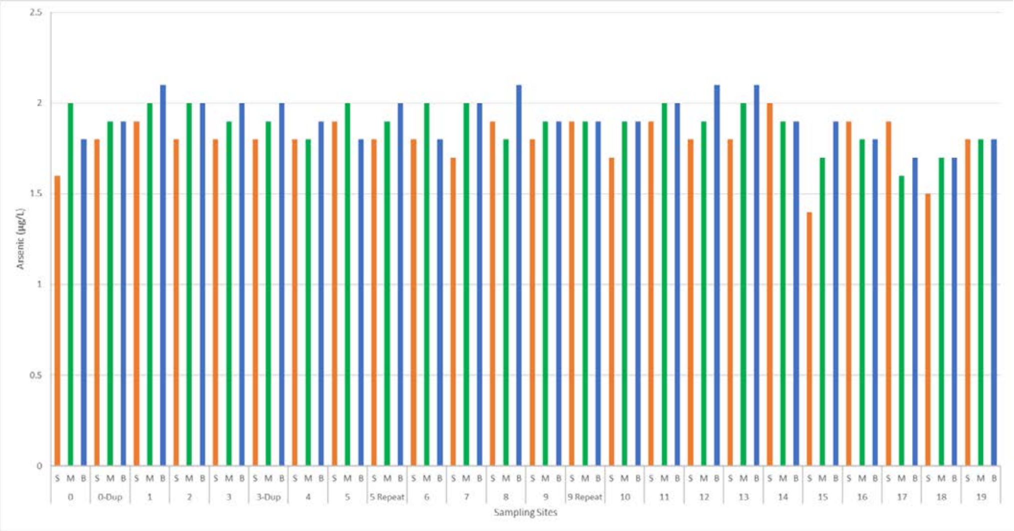


Figure 4-9: Arsenic concentration (µg/L) in marine water of all sampling sites to their relevant depth (Surface (S), Mid (M) and Bottom (B))

4.2.8.3 Barium

There is no trigger level for barium in marine water in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) or the ANZECC/ARMACANZ (2000) guidelines. The barium concentration ranged from 5 to 18 µg/L (Figure 4-10). Slight variation was observed between sites with no apparent spatial trends. While there is no guideline value for Barium it is commonly associated with drilling muds and may become present in the water column through the resuspension of these muds, however much higher levels of Barium and strong stratification between bottom and mid samples would be expected from any anthropogenic contamination.

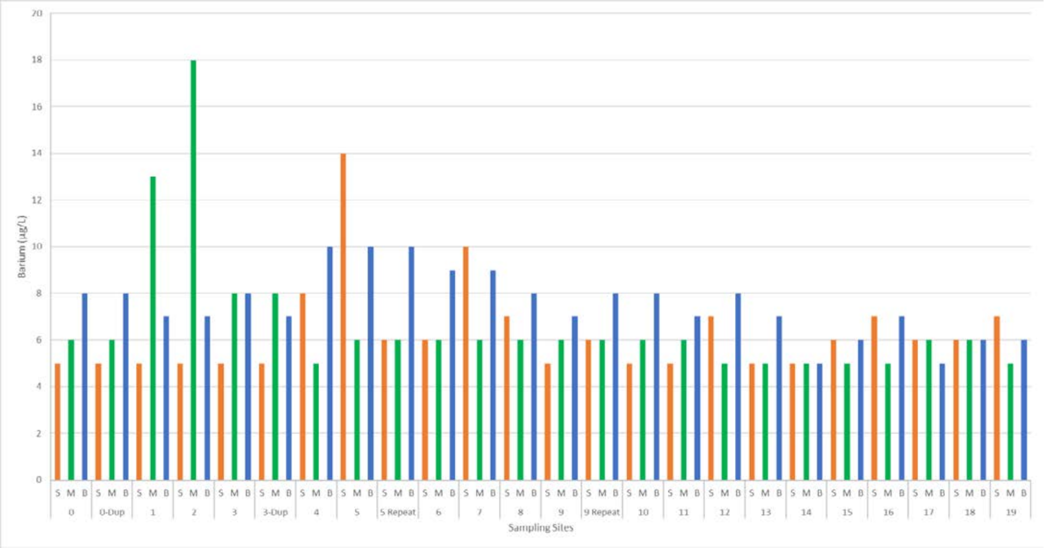


Figure 4-10: Barium concentration (µg/L) in marine water of all sampling sites to their relevant depth (Surface (S), Mid (M) and Bottom (B))

4.2.8.4 Cadmium

All results for Cadmium were below the LoR.

4.2.8.5 Chromium

Chromium concentrations for all sampling sites are below the 99% level of species protection default guideline value (DGV) for Chromium III in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) (7.7 µg/L) (Figure 4-11). The concentration ranged from less than 0.5 to 1.9 µg/kg.

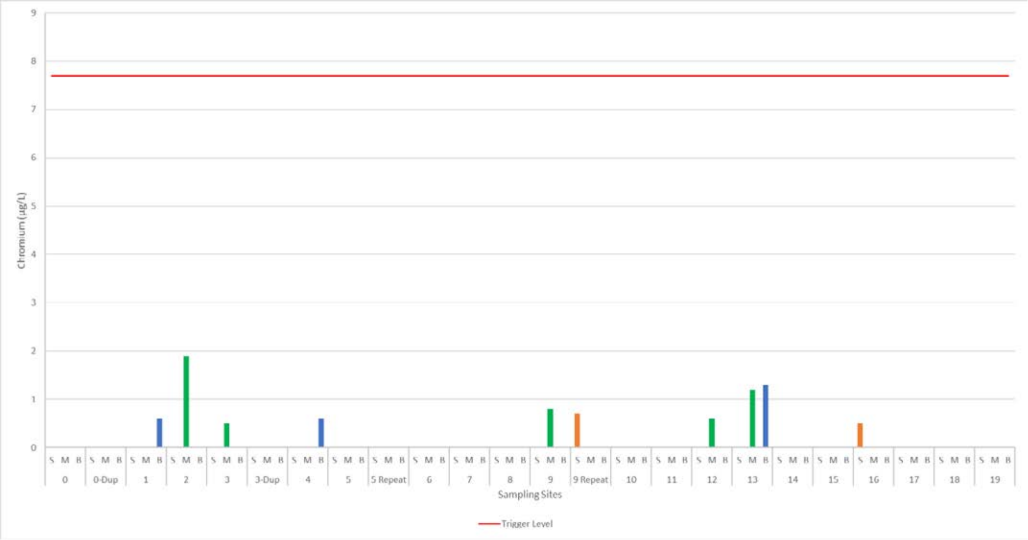


Figure 4-11: Chromium concentration (µg/L) in marine water of all sampling sites to their relevant depth (Surface (S), Mid (M) and Bottom (B))

4.2.8.6 Copper

Copper concentration for most sampling sites are below the 99% level of species protection DGV for copper in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) (0.3 µg/L), except at Sites 2 and 8 (Figure 4-12). The concentrations ranged from less than 0.2 to 0.7 µg/kg.

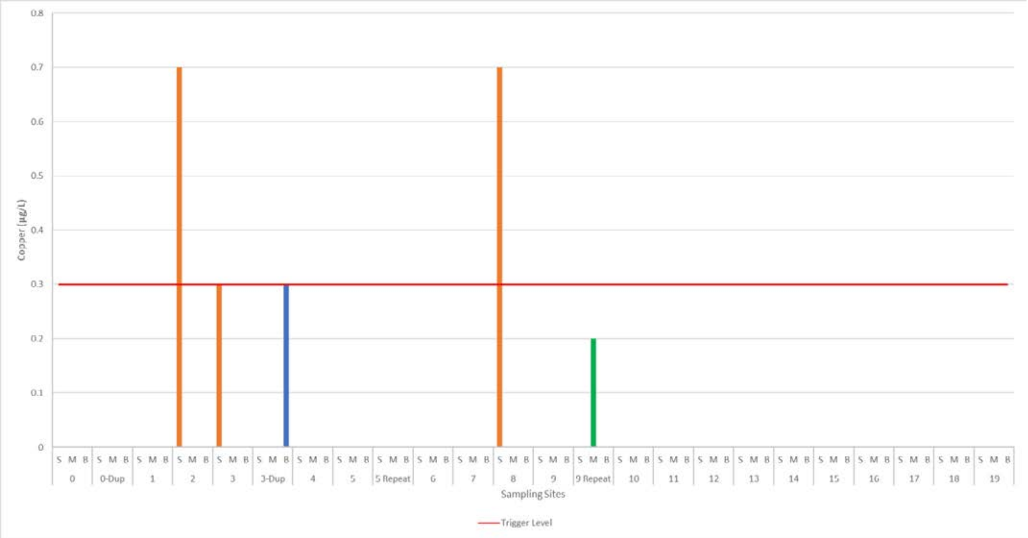


Figure 4-12: Copper concentration (µg/L) in marine water of all sampling sites to their relevant depth (Surface (S), Mid (M) and Bottom (B))

4.2.8.7 Cobalt

Cobalt concentrations for all sampling sites are below the LoR of less than 0.05 µg/L.

4.2.8.8 Iron

There is no trigger level for iron in marine water in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) or the ANZECC/ARMACANZ (2000) guidelines. The iron concentration ranged from less than 5 (LoR) to 18 µg/L (Figure 4-13). Slight variation was observed between sites, with no apparent spatial trends.

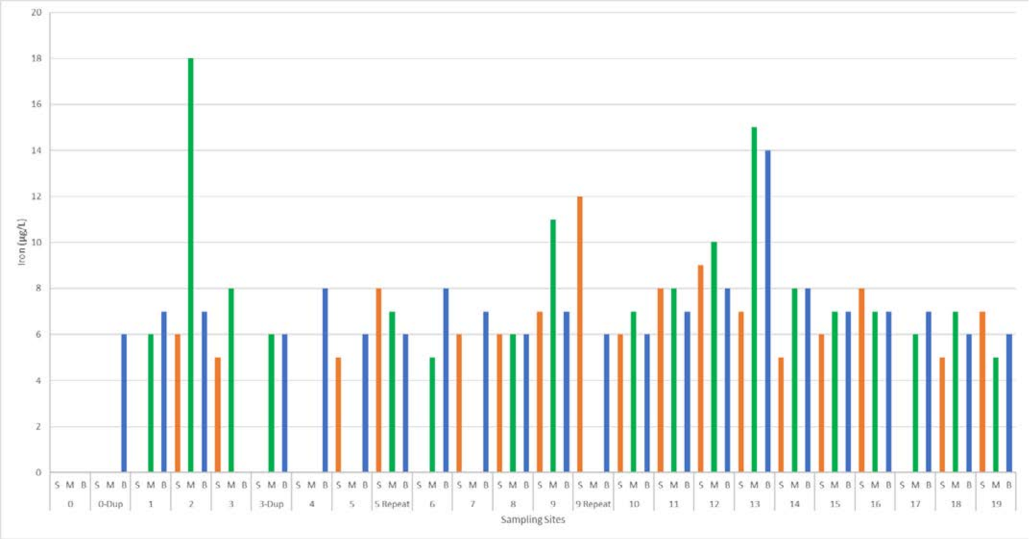


Figure 4-13: Iron concentration (µg/L) in marine water of all sampling sites to their relevant depth (Surface (S), Mid (M) and Bottom (B))

4.2.8.9 Mercury

Mercury concentrations for all sampling sites are below the LoR.

4.2.8.10 Nickel

Nickel concentrations for all sampling sites are below the LoR.

4.2.8.11 Lead

Lead concentrations for all sampling sites are below the 99% level of species protection DGV for lead in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) (2.2 µg/L) (Figure 4-14). The concentration ranged from less than 0.2 (LoR) to 0.5 µg/l.

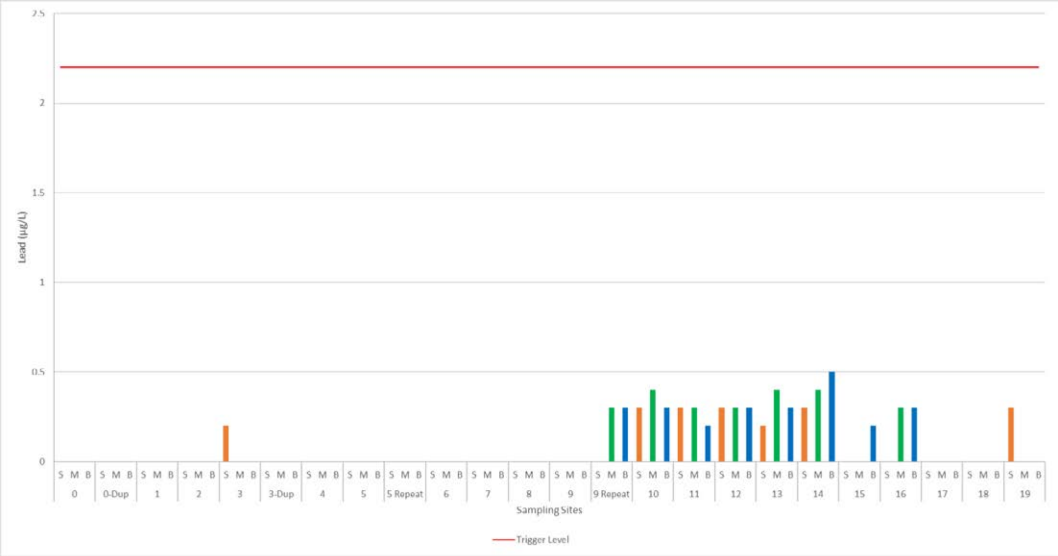


Figure 4-14: Lead concentration (µg/L) in marine water of all sampling sites to their relevant depth (Surface (S), Mid (M) and Bottom (B))

4.2.8.12 Tin

There is no trigger level for tin in marine water and all results were below the LoR of less than 5 µg/L.

4.2.8.13 Vanadium

Vanadium concentration of all sampling sites is below the 99% level of species protection DGV for vanadium in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) (50 µg/L) (Figure 4-15). The concentration ranged from 0.8 to 5.8 µg/L, with minimal variation observed between sites.

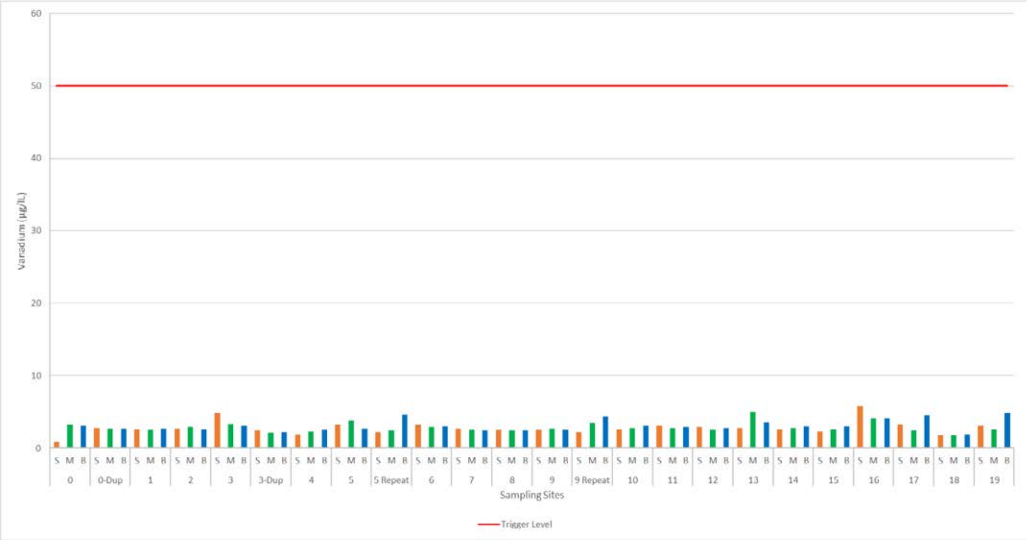


Figure 4-15: Vanadium concentration (µg/L) in marine water of all sampling sites to their relevant depth (Surface (S), Mid (M) and Bottom (B))

4.2.8.14 Zinc

Zinc concentration for all sampling sites is below the LoR of less than 5 µg/L.

4.2.9 Hydrocarbons TPH, TRH and PAH

All concentrations of TPH, TRH and PAHs were below the LoR.

4.2.10 Nutrients

Nutrients increased with depth at all sites and were generally below ANZECC trigger values for slightly disturbed ecosystems in tropical Australia (ANZECC/ARMCANZ, 2000) and, where available, the DGVs for the 99% level of species protection from the Australian & New Zealand Guidelines for Fresh and Marine Water Quality (2018).

4.2.10.1 TN

Nitrogen concentrations increased with depth at all sites. Surface waters were all below the LoR or trigger level for total nitrogen in offshore (tropical) marine environments (refer to table 3.3.4 of ANZECC/ARCANZ, 2000) of 0.1 mg/L.

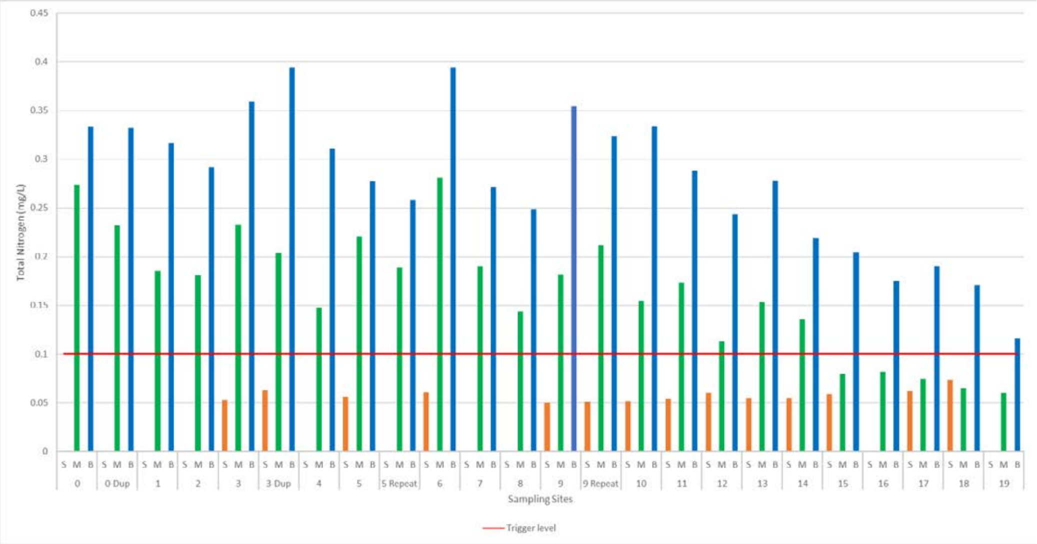


Figure 4-16: Total nitrogen concentration (mg/L) in marine water of all sampling sites to their relevant depth (Surface (S), Mid (M) and Bottom (B))

4.2.10.2 TP

Total Phosphorus concentrations increased with depth at all sites. All surface samples were slightly above the trigger level for total phosphorus in offshore (tropical) marine environments of 10 µg/L (refer to table 3.3.4 of ANZECC/ARMCANZ, 2000) (Figure 4-17).

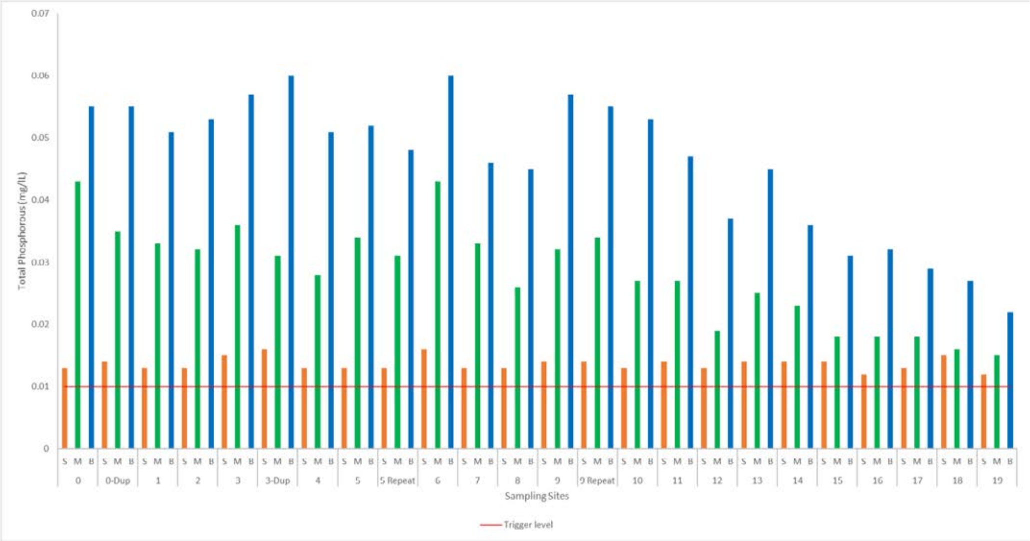


Figure 4-17: Total phosphorous (mg/L) in marine water of all sampling sites to their relevant depth (Surface (S), Mid (M) and Bottom (B))

4.2.10.3 Nitrite and Nitrate

There is no trigger level for individual nitrite and nitrate in marine water. Concentrations ranged from 0.002 to 0.344 mg/L, with concentration increasing with depth. Concentrations are similar to those observed in other regional marine baseline surveys (Gardline, 2009).

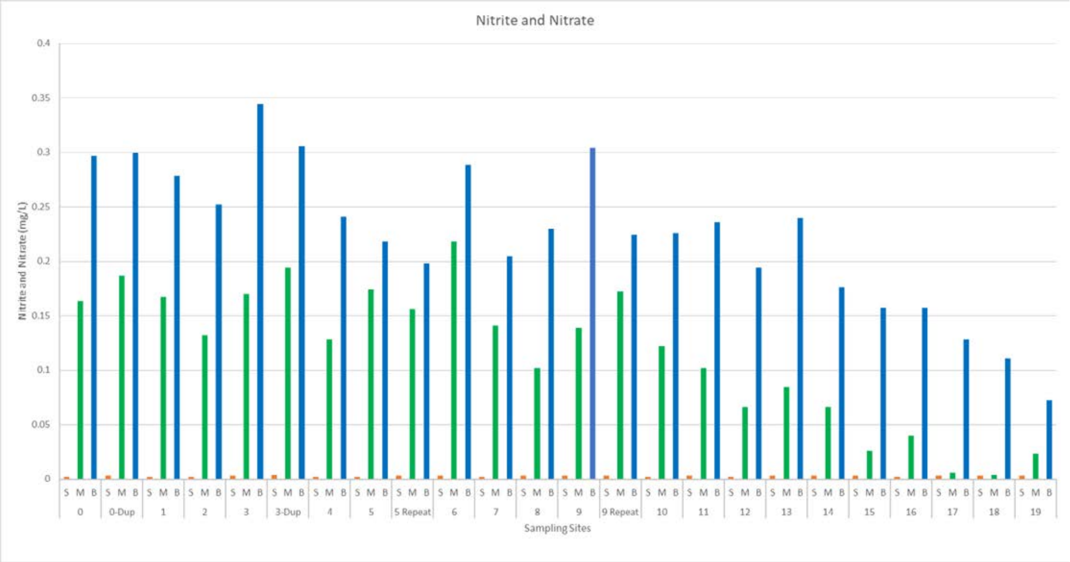


Figure 4-18: Nitrite and nitrate (mg/L) in marine water of all sampling sites to their relevant depth (Surface (S), Mid (M) and Bottom (B))

4.2.10.4 NH4

All NH4 concentrations were observed to be below the 99% level of species protection DGV for ammonia in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) (0.5 mg/L) (Figure 4-19). The concentration ranged from 0.007 to 0.261 mg/L.

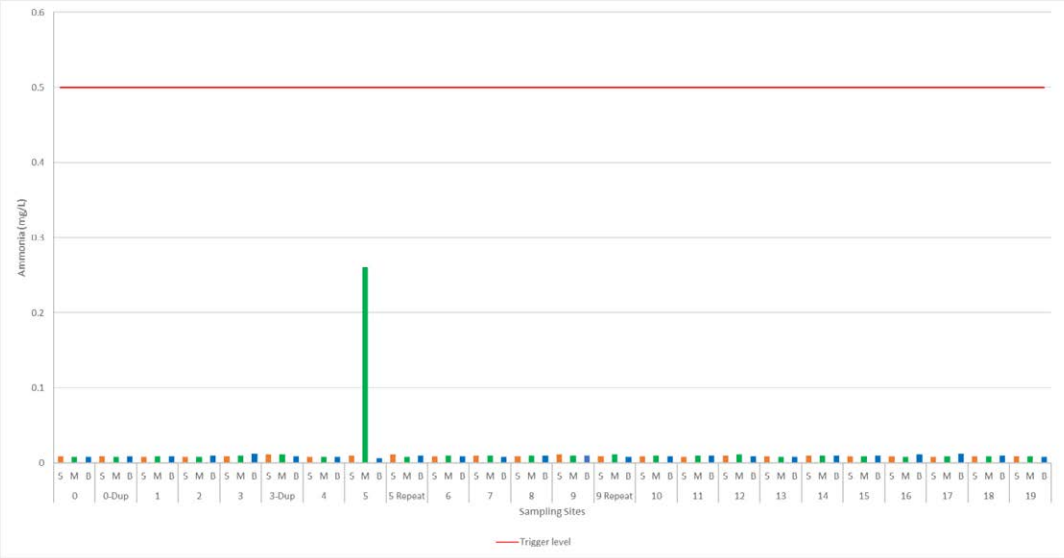


Figure 4-19: Ammonia concentration (µg/L) in marine water of all sampling sites to their relevant depth (Surface (S), Mid (M) and Bottom (B))

4.3 Sediment Quality

4.3.1 Trace Metals

4.3.1.1 Aluminium

There is no DGV in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) or an Interim Sediment Quality Guideline (ISQG) in ANZECC/ARMCANZ (2000) for aluminium in sediments. The aluminium concentration ranged from 600 to 4620 mg/kg, with variation between sites (Figure 4-20). The maximum concentration occurred at Site 0 and minimum concentration at Site 16. Though no DGV exist for aluminium, concentrations were much lower than values estimated to be naturally occurring in Pilbara coastal sediments (DEC, 2006).

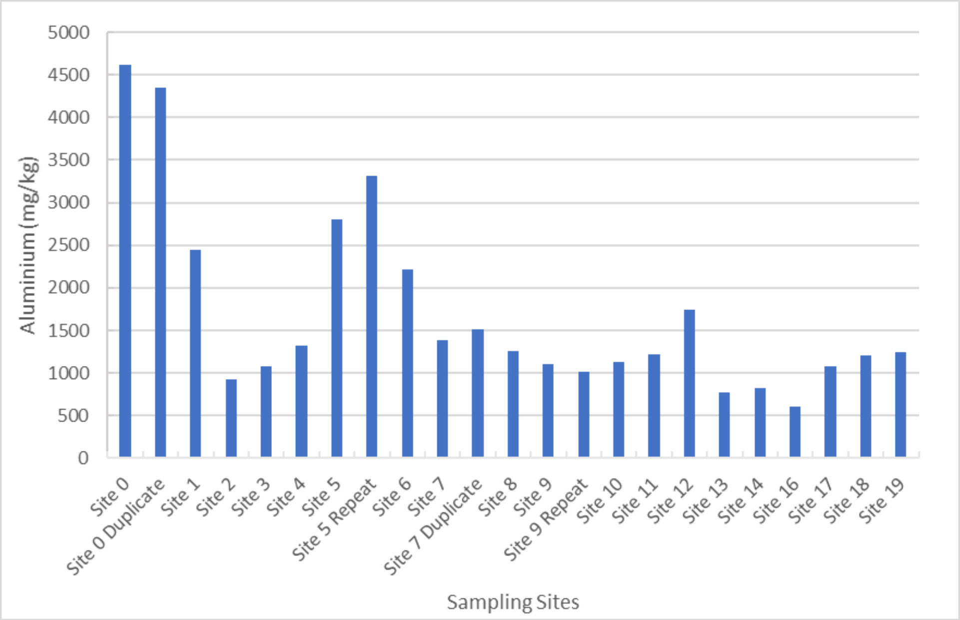


Figure 4-20: Aluminum concentration (mg/kg) in sediment samples for all sites

4.3.1.2 Barium

There is no DGV in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) or an ISQG in ANZECC/ARMCANZ (2000) for barium in sediments. The barium concentration ranged from 7.9 to 46 mg/kg, with some variation between sites (Figure 4-21). The maximum concentration occurred at Site 5 Repeat and minimum concentration at Site 9 Repeat.

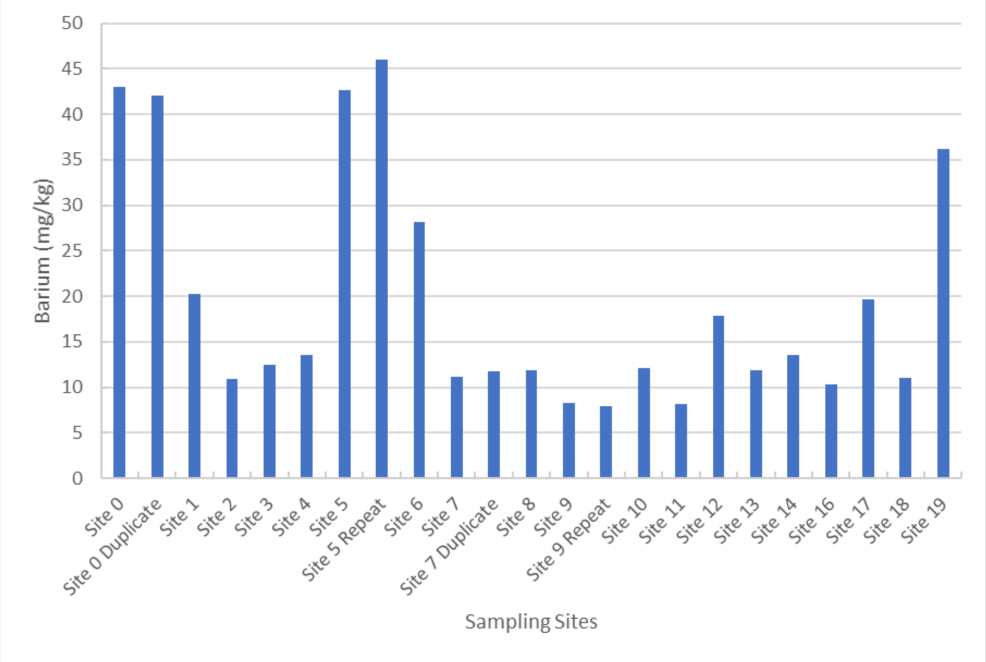


Figure 4-21: Barium concentration (mg/kg) in sediment samples for all sites

4.3.1.3 Cadmium

Cadmium concentration for all sampling sites is below the DGV for sediment quality in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) (1.5 mg/kg) (Figure 4-22). The concentration ranged from 0.1 to 0.2 mg/kg, showing minimal variation between sites.

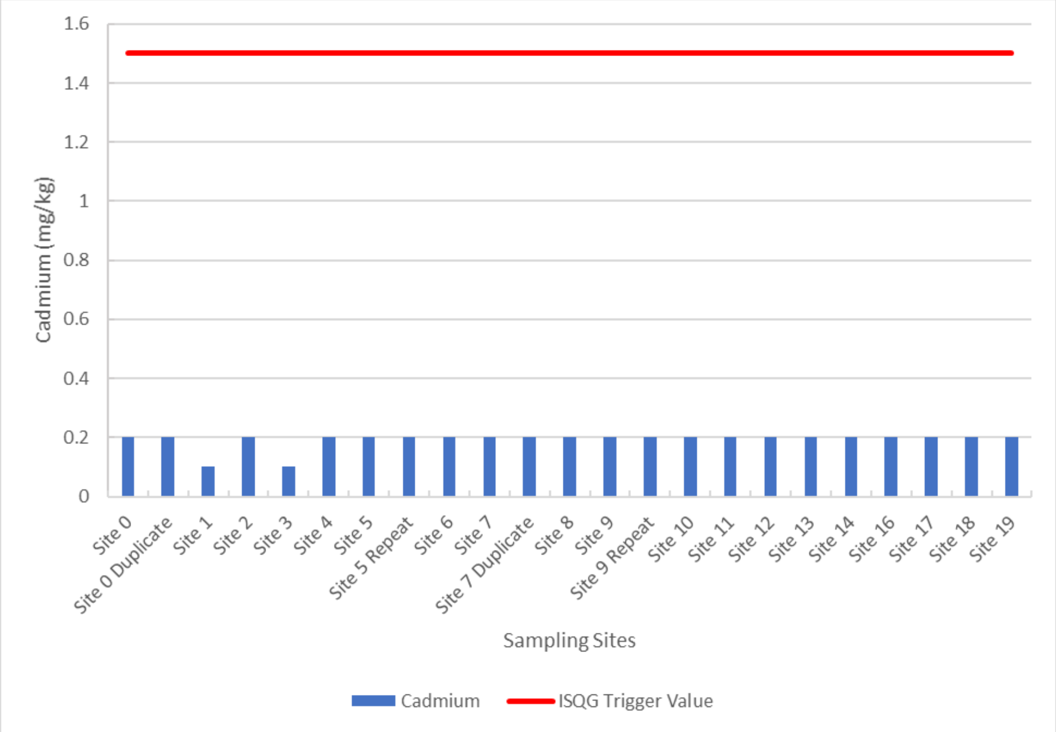


Figure 4-22: Cadmium concentration (mg/kg) in sediment samples for all sites

4.3.1.4 Chromium

Chromium concentration for all sampling sites is below the DGV for sediment quality in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) (80 mg/kg) (Figure 4-23). The concentration ranged from 6.2 to 15.7 mg/kg, showing minimal variation between sites.

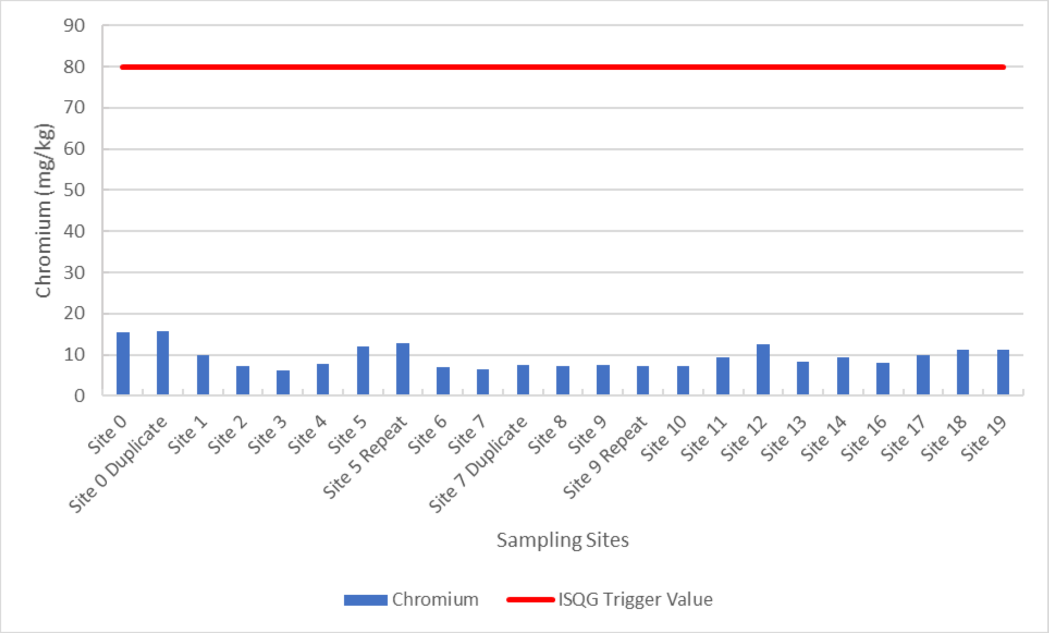


Figure 4-23: Chromium concentration (mg/kg) in sediment samples for all sites

4.3.1.5 Copper

Copper concentration for all sampling sites is below the DGV for sediment quality in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) (65 mg/kg) (Figure 4-24). The concentration ranged from 2.3 to 11.4 mg/kg, showing slight variation between sites.

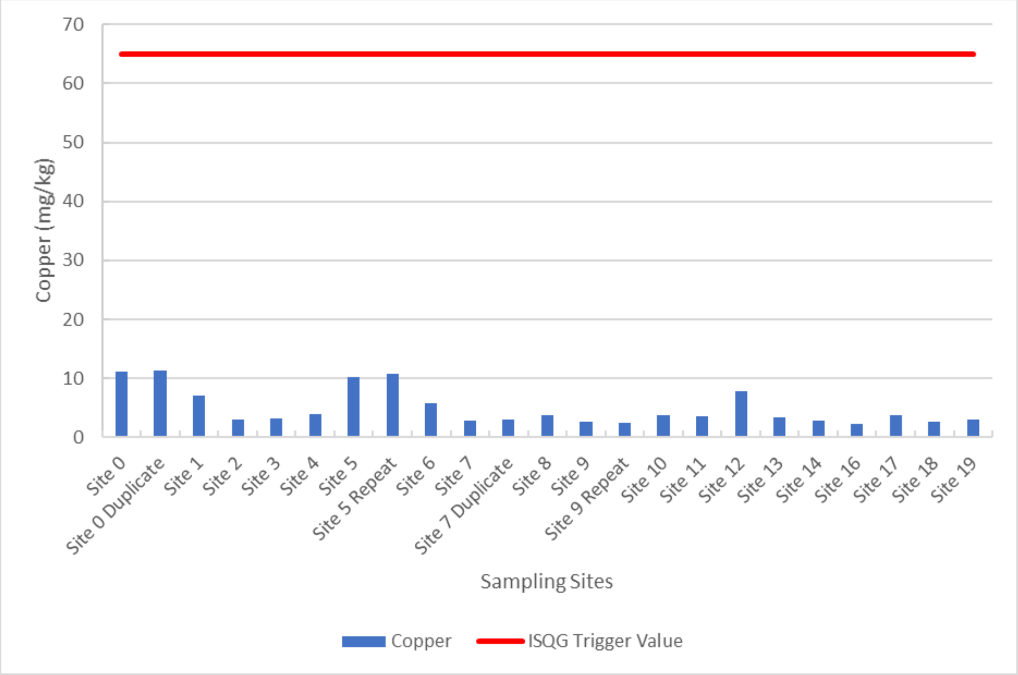


Figure 4-24: Copper concentration (mg/kg) in sediment samples for all sites

4.3.1.6 Iron

There is no DGV in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) or an ISQG in ANZECC/ARMCANZ (2000) for iron in sediments. The iron concentration ranged from 1160 to 5290 mg/kg, with variation between sites (Figure 4-25). Though no DGV exist for iron, concentrations were much lower than values estimated to be naturally occurring in Pilbara coastal sediments (DEC, 2006).

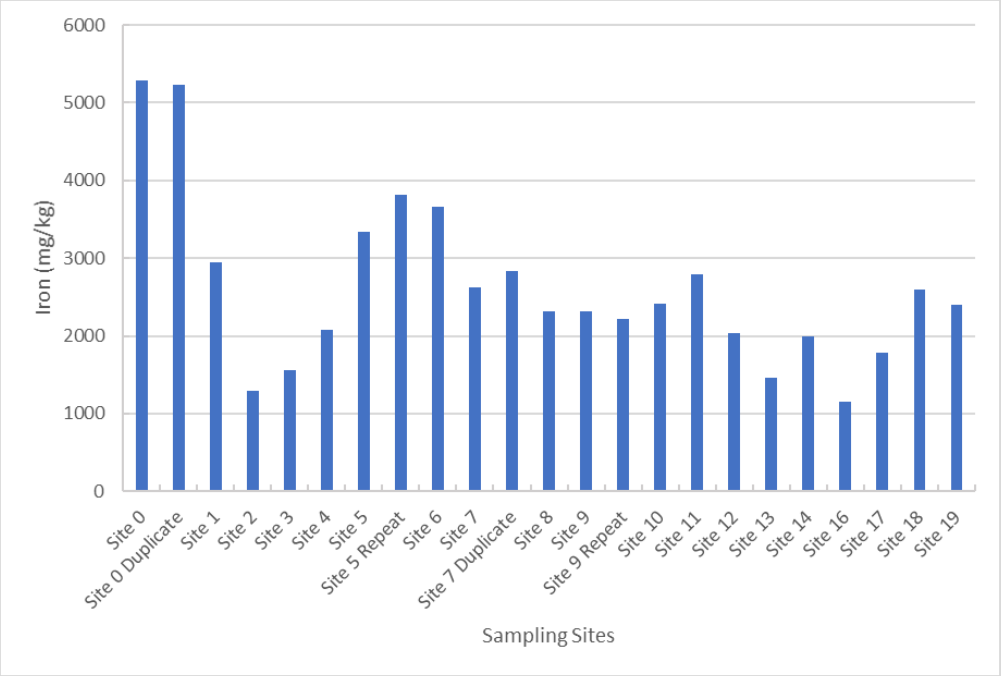


Figure 4-25: Iron concentration (mg/kg) in sediment samples for all sites

4.3.1.7 *Lead*

Lead concentration for all sampling sites is below the DGV for sediment quality in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) (50 mg/kg) (Figure 4-26). The concentration ranged from less than 1 to 11.3 mg/kg, showing minimal variation between sites except for Site 6, which had the maximum concentration. The minimum concentration was observed at Sites 3, 14 and 16.

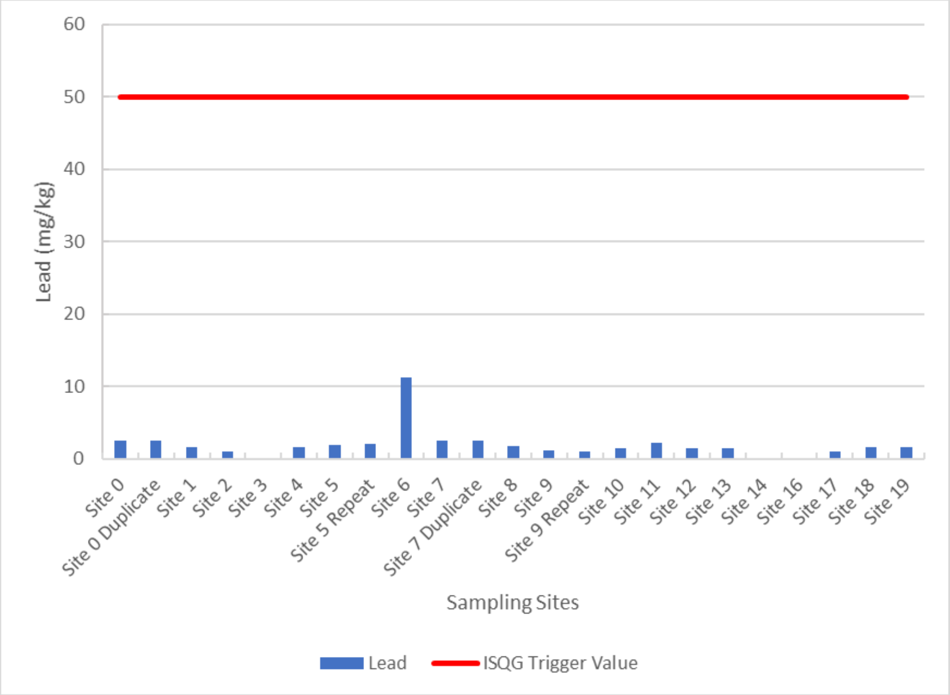


Figure 4-26: Lead concentration (mg/kg) in sediment samples for all sites

4.3.1.8 Mercury

Mercury concentration for all sampling sites is below the DGV for sediment quality in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) (0.15 mg/kg) (Figure 4-27). The concentration ranged from less than 0.01 to 0.03 mg/kg, showing minimal variation between sites.

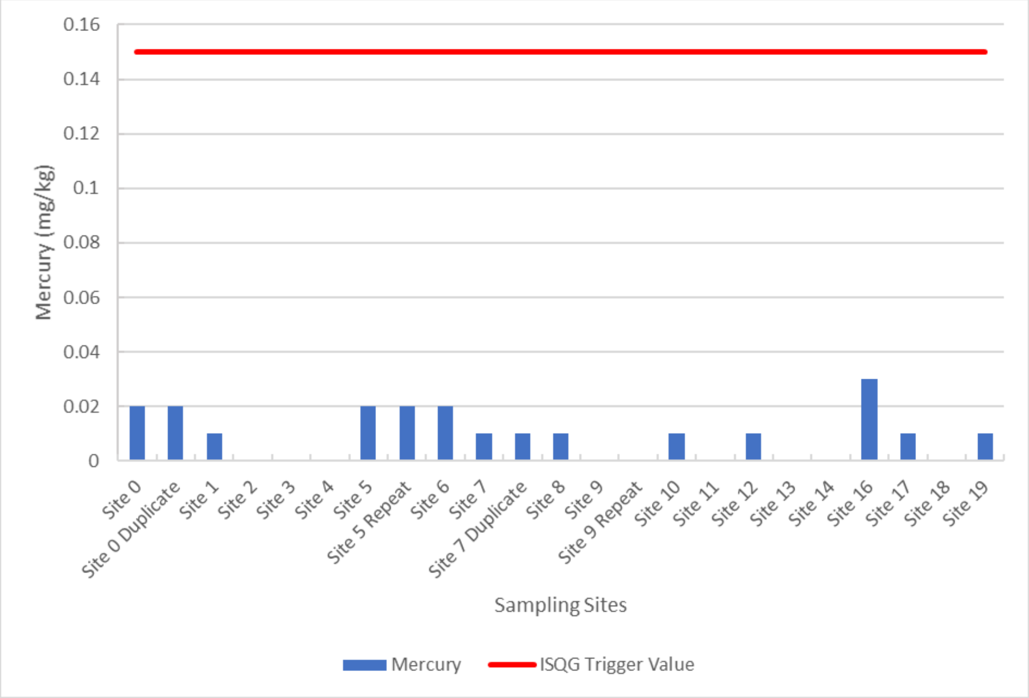


Figure 4-27: Mercury concentration (mg/kg) in sediment samples for all sites

4.3.1.9 Nickel

Nickel concentration for all sampling sites is below the DGV for sediment quality in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) (21 mg/kg) except for Site 6, with the maximum concentration of 43.1 mg/kg (Figure 4-28). The concentration ranged from 3.4 to 43.1 mg/kg. Besides Site 6, minimal variation was observed between sites.

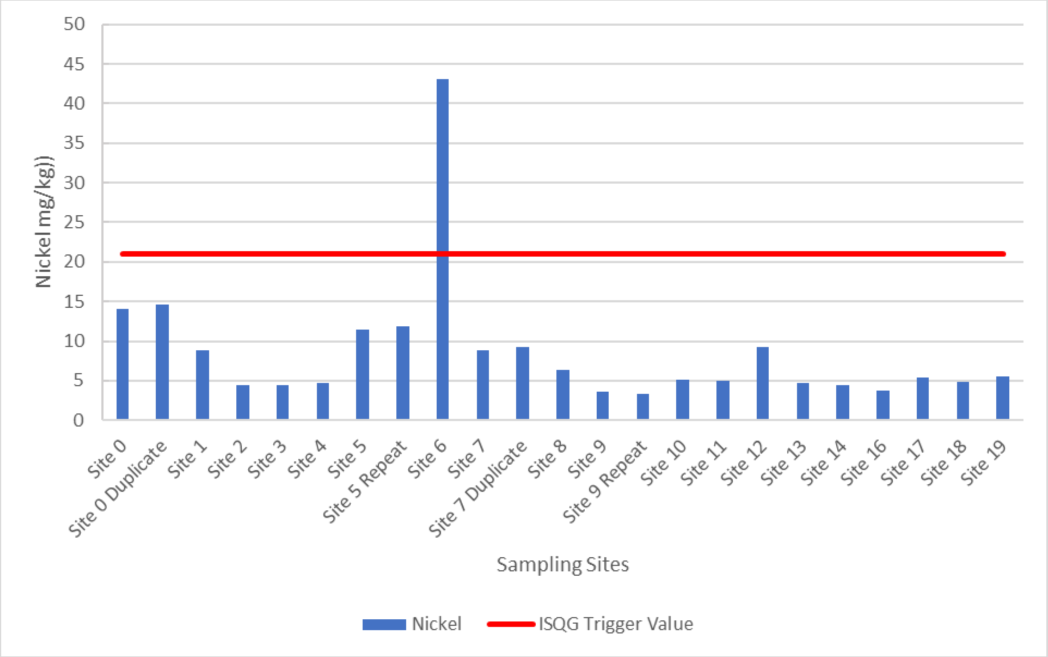


Figure 4-28: Nickel concentration (mg/kg) in sediment samples for all sites

4.3.1.10 Tin

There is no DGV in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) or an ISQG in ANZECC/ARMCANZ (2000) for tin in sediments. The tin concentration ranged from less than 0.1 to 0.4 mg/kg, with minimal variation between sites (Figure 4-29).

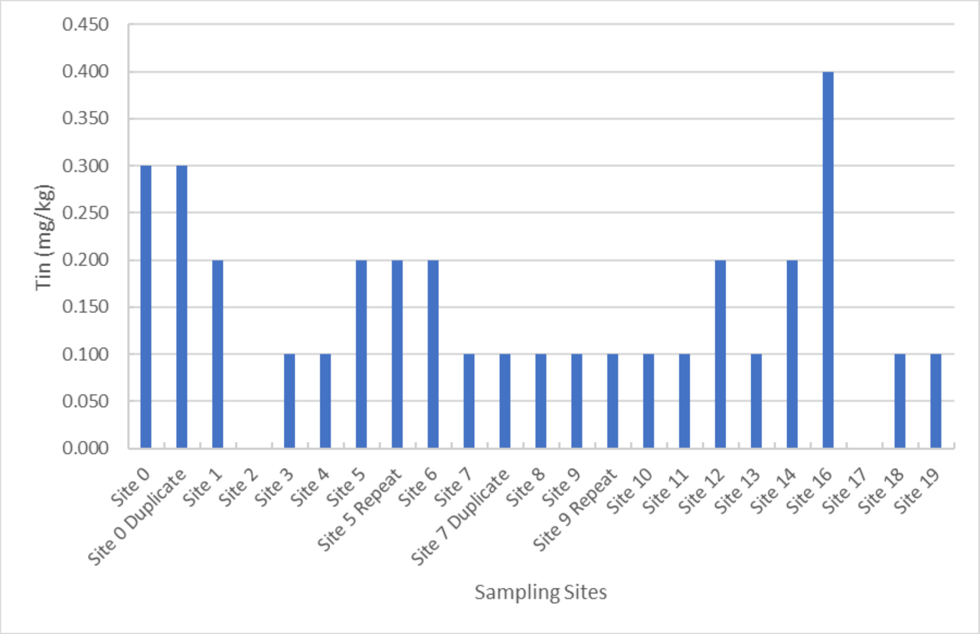


Figure 4-29: Tin concentration (mg/kg) in sediment samples for all sites

4.3.1.11 Vanadium

There is no DGV in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) or an ISQG in ANZECC/ARMCANZ (2000) for vanadium in sediments. The vanadium concentration ranged from 2.5 to 10.6 mg/kg, with variation between sites (Figure 4-30).

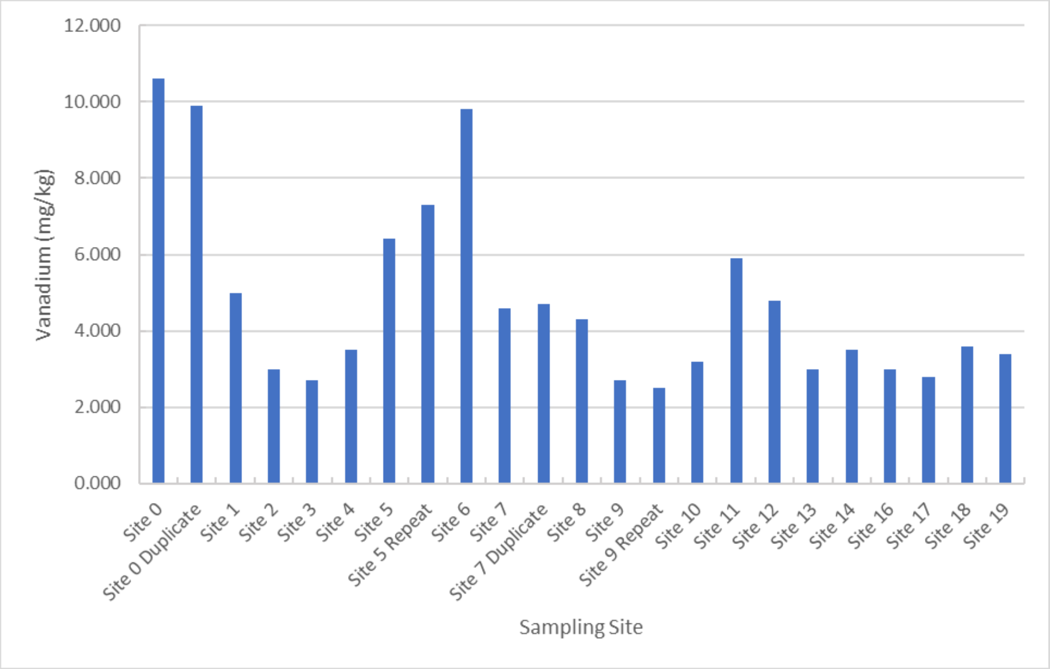


Figure 4-30: Vanadium concentration (mg/kg) in sediment samples for all sites

4.3.1.12 Zinc

Zinc concentration for all sampling sites is below the DGV for sediment quality in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) (200 mg/kg) (Figure 4-31). The concentration ranged from 7.2 to 25.8 mg/kg, with slight variation observed between sites.

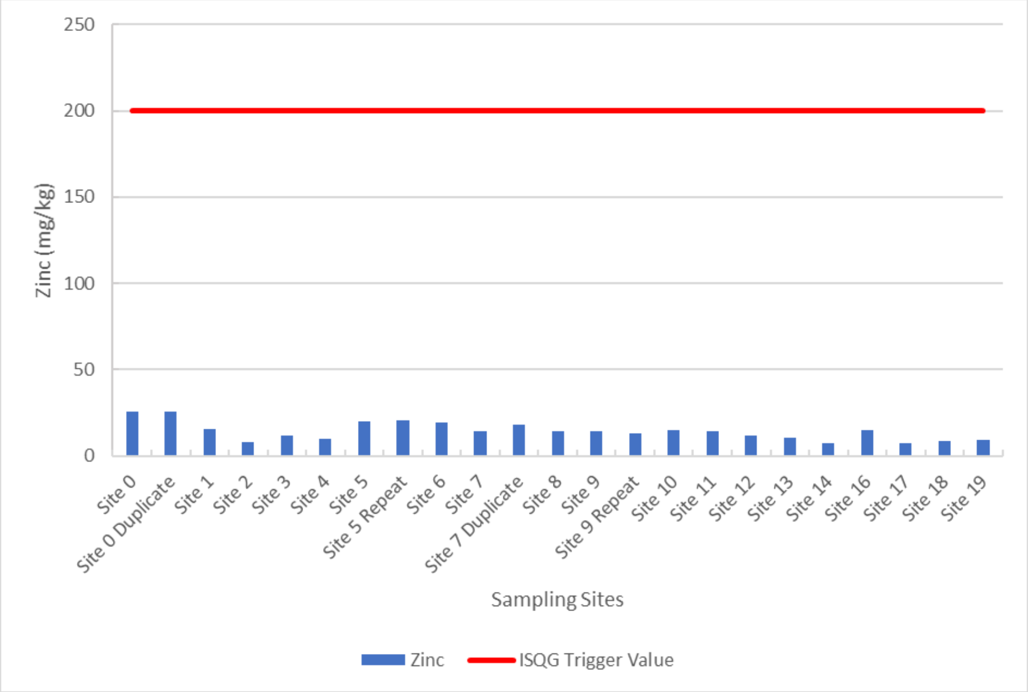


Figure 4-31: Zinc concentration (mg/kg) in sediment samples for all sites

4.3.2 Hydrocarbons

4.3.2.1 BTEX

All results for BTEX were below the LoR.

4.3.2.2 TPHs

TPH concentrations for most sampling sites are below the LoR. Sites 5 and 11 are above the LoR but well below the DGV for sediment quality in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) (280 mg/kg). The TPH concentration ranged from less than 3 to 18 mg/kg. Almost all sites were below the LoR of 3 mg/kg, except for Sites 5 and 11 (Figure 4-32).

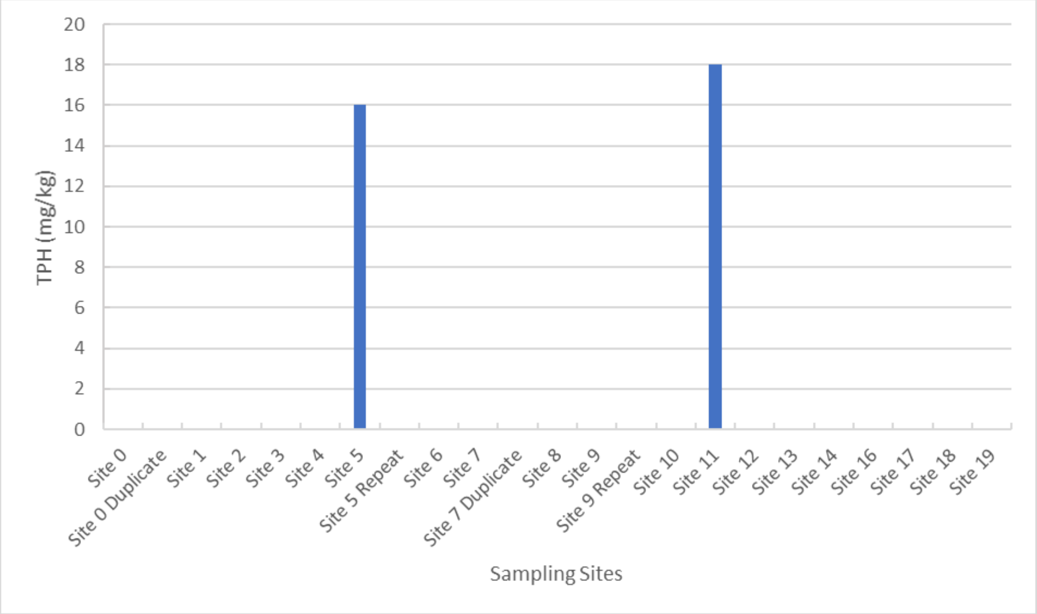


Figure 4-32: TPH concentration in sediment samples for all sites (mg/kg)

4.3.2.3 PAHs

The sum of PAH concentration for all sampling sites is below the DGV for sediment quality in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) (10 mg/kg) (Figure 4-33). The concentration ranged from 4 to 139 µg/kg, with variation observed in Sites 0 Duplicate and 5, with 99 and 139 µg/kg respectively.

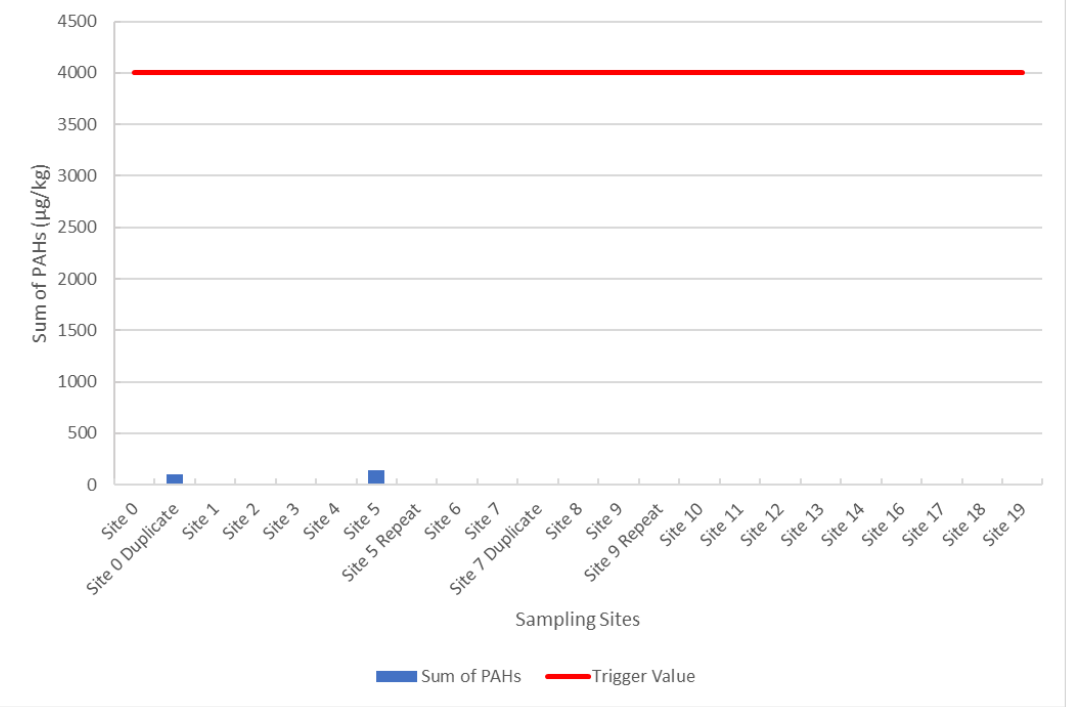


Figure 4-33: Sum of PAHs concentration in sediment samples for all sites (µg/kg)

4.3.3 Nutrients

4.3.3.1 Nitrate

There is no DGV in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) or an ISQG in ANZECC/ARMCANZ (2000) for nitrate in sediments. The nitrate concentration ranged from 0.1 to 1.3 mg/kg, with slight variation between sites (Figure 4-34).

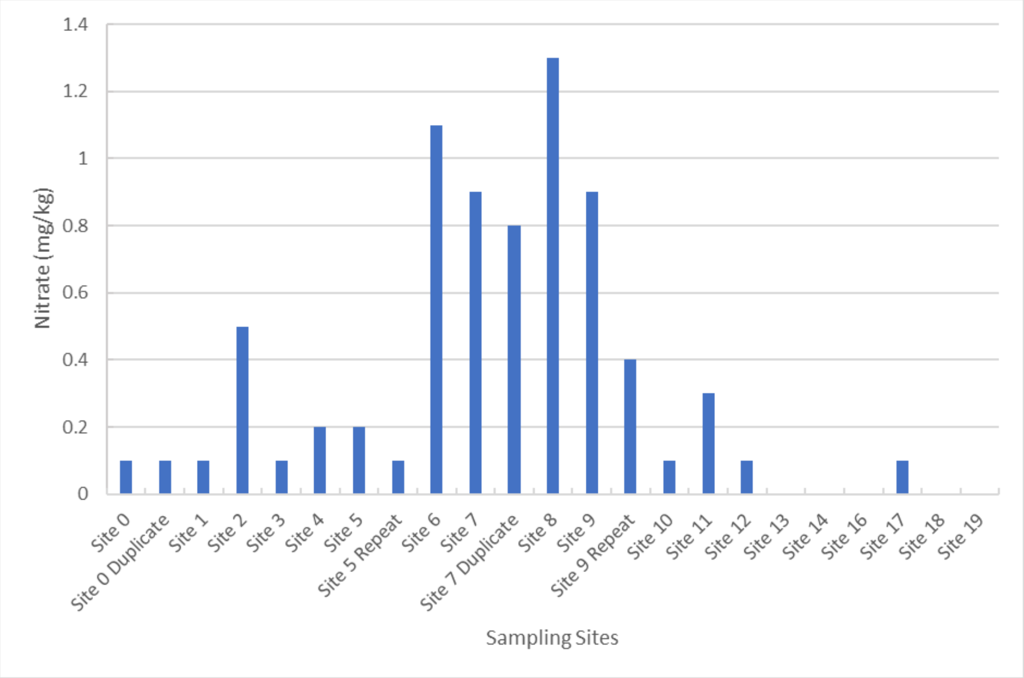


Figure 4-34: Nitrate concentration in sediment samples for all sites (mg/kg)

4.3.3.2 Nitrite

There is no DGV in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) or an ISQG in ANZECC/ARMCANZ (2000) for nitrite in sediments. All concentrations were below the LoR of 0.1 mg/kg.

4.3.4 Total Organic Carbon

Slight variation of TOC was observed between sites; concentrations ranged from 0.13 to 0.84% (Figure 4-35).

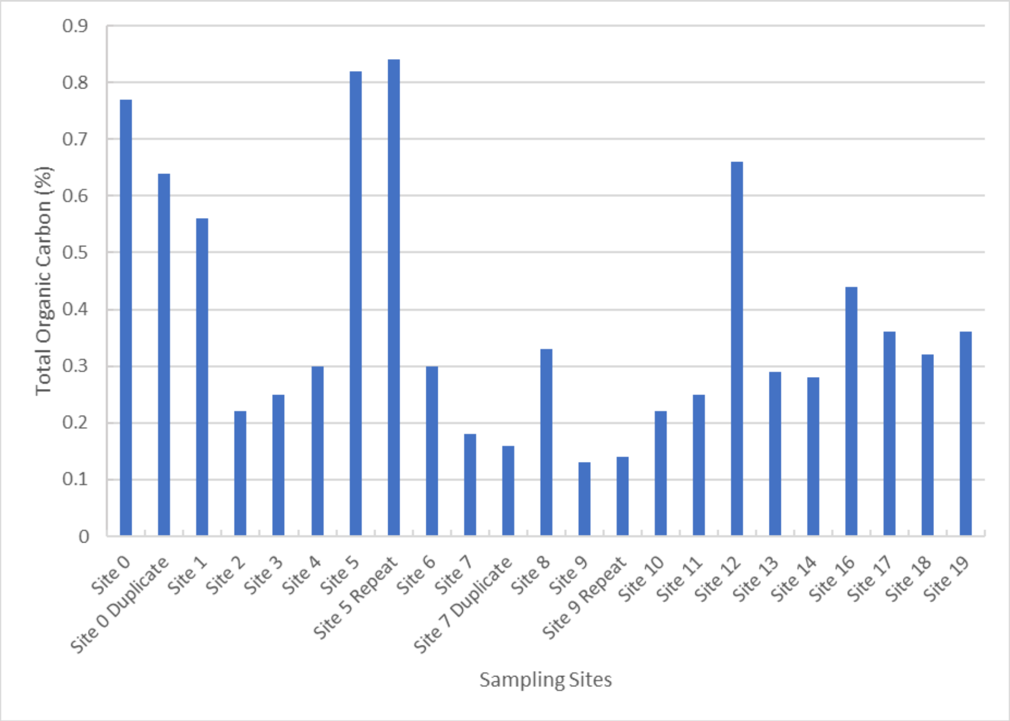


Figure 4-35: Total organic carbon concentration in sediment samples for all sites (%)

4.3.5 Total Carbon

Slight variations of total carbon were observed between sites; concentrations ranged from 9.65 to 12.1% (Figure 4-36).

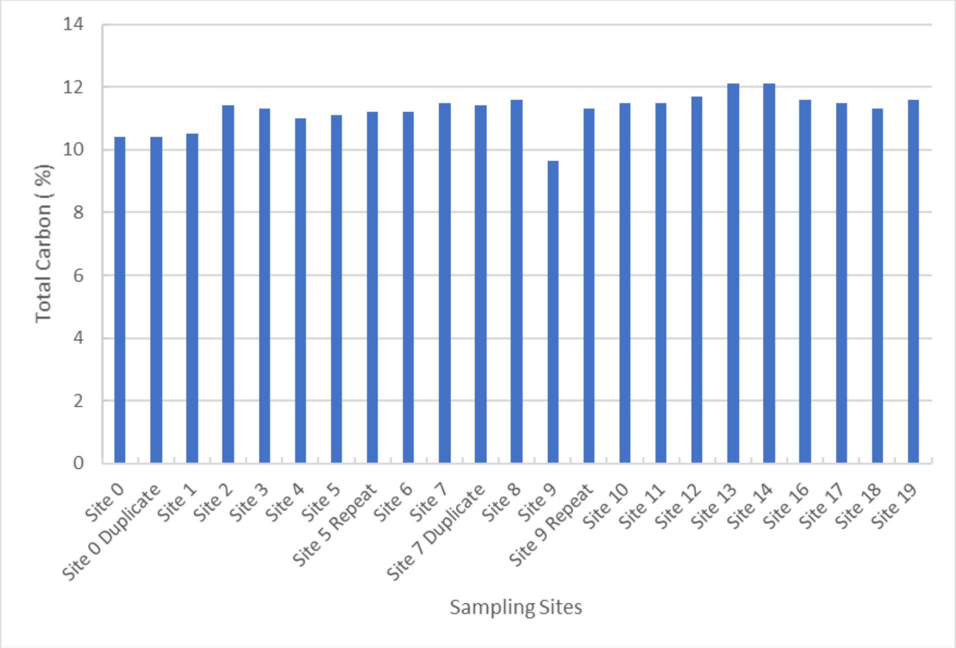


Figure 4-36: Total carbon concentration in sediment samples for all sites (%)

4.3.6 Particle Size Distribution

Sediments were typical of the North West Shelf and were dominated by Sand, with varying proportions of silt and clay along the proposed pipeline route. After multiple attempts and continued sampling refusal, likely due to consolidated substrate, sediment was unable to be recovered at Site 15.

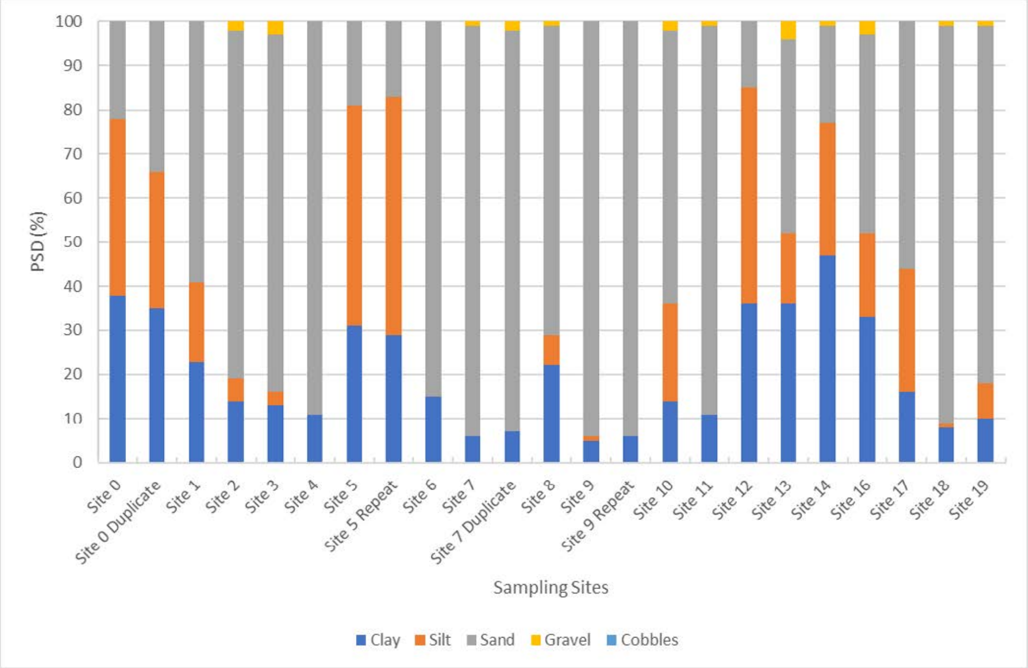


Figure 4-37: Particle size distribution for all sites

4.4 Infauna Results

4.4.1 Data Investigation

4.4.1.1 Abundance, Richness and Diversity

A summary of the abundance, richness and diversity data for each site, based on the standardised infauna abundance data is provided in Table 4-2and Appendix E. Table 4-2 also shows the depth for each site and whether the site was located in a MPA or KEF for ease of reference.

A total abundance of 293 individuals (ranging from 0 to 57 individuals per site), with a total taxa richness of 47 families (ranging from 0 to 14 families per site) were recorded during the infauna survey (see Table 4-2and Appendix E). Considering that 17 sites were sampled, these numbers are considered to be very low. Taxa diversity was also low at all sites and Shannon diversity ranged from 0 to 2.4 per site.

Table 4-2 Infauna abundance, richness and diversity at each site (based on standardised volume of 0.1 m^3)

Site	0	1	2	3	5	6	7	8	10	12	13	14	15	16	17	18	19
Total Abundance	8	14	5	30	3	6	1	8	3	22	57	37	0	31	28	15	25
Taxa Richness*	3	5	2	9	4	2	1	3	1	8	14	3	0	10	11	4	7
Taxa Diversity **	1.0	1.6	0.7	2.1	1.4	0.7	0	1.1	0	2	1.9	0.9	0	2.2	2.3	1.3	1.9
Depth (m)	376	346	336	351	378	428	377	371	329	265	261	224	188	196	132	130	125
Marine Park	■	■					■	■	■								
KEF	■	■	■	■	■		■	■	■							■	■

* Richness data cannot be standardised and is per original volume

**Shannon diversity is displayed to 2 decimal places.

A summary of the abundance and richness of individual infauna phylum identified during the infauna survey is presented in Table 4-3. Annelida were the most abundant phylum (142 individuals recorded over all sites) and also contained the most families (21 families identified within this phylum). Arthropoda were the next most abundant phylum (with 89 individuals) and richness for this group was also higher than most (16 families). The total abundance of Echinodermata (22 individuals over 17 sites) and Sipuncula (35 individuals over 17 sites) were low but considerably higher than all other taxa identified with abundances ranging from just one to three individuals over 17 sampling sites. Total richness for all phylum apart from Annelida and Arthropoda were also low and ranged from just one to four families being identified.

Table 4-3 Abundance and richness of each infauna phylum identified

Phylum	Total Infauna Abundance	Total Taxa (Family) Richness
Annelida	142	21
Arthropoda	89	16
Chordata	3	2
Echinodermata	22	4
Mollusca	1	1
Nemertia	1	1
Sipuncula	35	2
Total	**293**	**47**

Figure 4-38 to Figure 4-40 show the total abundance, taxa richness and Shannon diversity at each site. As there was no spatial or temporal replication of samples within sites, no estimation of error can be provided.

Total infauna abundance was highest at Site 13 (57 individuals) and taxa richness was also highest at this site. Site 13 is located in water depths of 261 m and is not located within an AMP or KEF. Sites 3, 14, 16, 17 and 19 also had relatively high abundance (compared to that at many other sampling sites) ranging from 25 to 37 individuals (Figure 4-38). Depths at these five sites were extremely variable and ranged from 125 m to 351 m. Three of these sites were located within a KEF and none in an AMP. No infauna was recorded from the shell material submitted for Site 15. Abundance was very low, below 10 individuals, at Sites 0, 2, 5, 6, 7, 8 and 10. Water depth at these sites was typically much deeper, ranging from 329 to 428 m. Four of these sites were located within an AMP and six within a KEF.

The patterns seen for taxa richness tended to mirror the infauna abundance patterns (i.e. sites with higher abundance tended to have a higher taxa richness) (Figure 4-39). The same was true for infauna diversity, which generally mirrored patterns in abundance and richness (Figure 4-40).

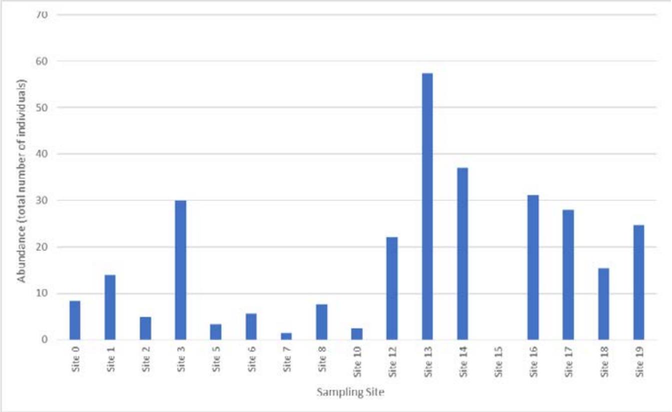


Figure 4-38 Infauna abundance (total number of individuals recorded) at each sampling site

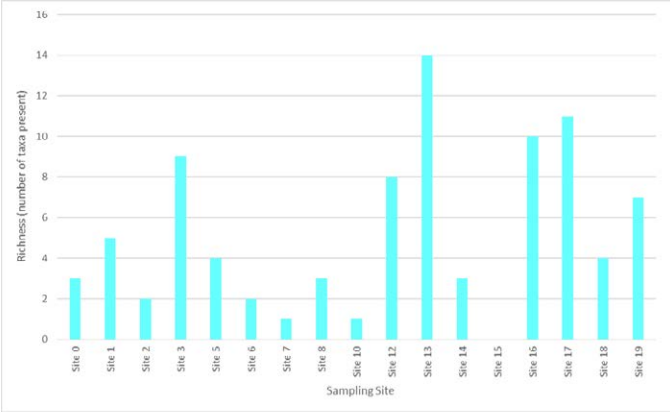


Figure 4-39 Infauna richness (total number of taxa recorded) at each sampling site

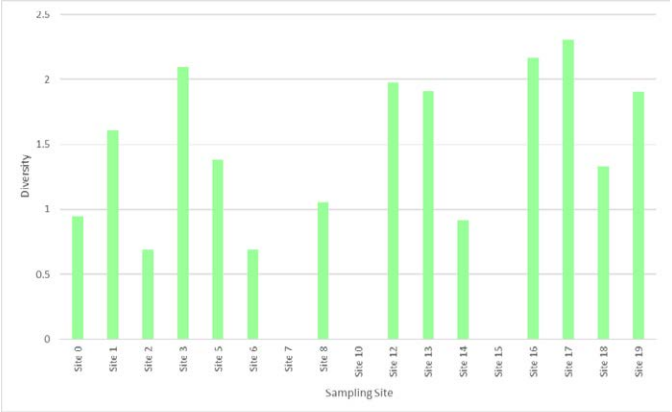


Figure 4-40 Infauna diversity (Shannon Diversity Index) at each sampling site

4.4.1.2 Multivariate Analysis

Sediment Characteristics

Sediment particle size distribution has been described in Section 4.3.6. Particle size distribution is variable between sites with the following noted in relation to smaller size classes.

- Sites 0, 5, 12 and 14 have lower proportions of sand and higher proportions of silt in comparison to all other sites.
- Sites 6, 7 and 18 have no, or very little, silt.
- Sites 0, 5, 12, 13, 14 and 16 have the highest proportions of clay.
- No PSD analysis was undertaken for Site 15.

Shade Plot

The shade plot below (Figure 4-41) lists the 25 most important infauna taxa present and shows their relative abundance (darker shading = more abundant), grouped by site. The plot is more useful as a baseline list of which infauna families are present, as there is too low an abundance and diversity to be able to interpret discernible patterns between sites.

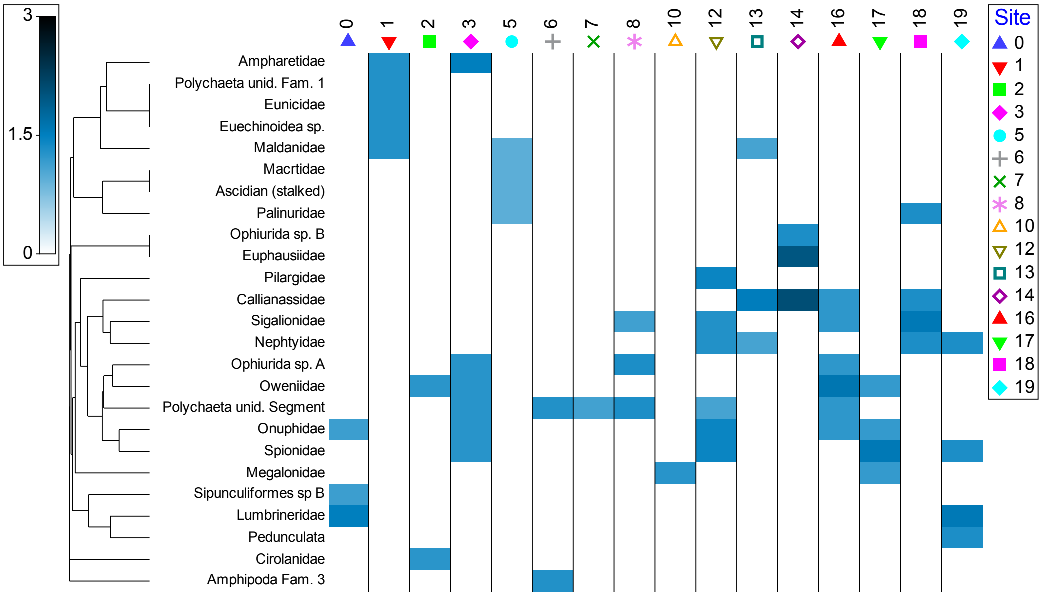


Figure 4-41 Shade plot showing the distribution of infauna families by site

Multi-dimensional Scaling

Multi-dimensional scaling (nMDS) plots of the fourth square root transformed infauna abundance data and displayed by various factors are shown in Figure 4-42 to Figure 4-49. In MDS plots, sites which are more similar to each other are grouped more closely together. A 2D stress level of 0.06 shows that the nMDS plots are a good representation of the underlying data. In general, no strong or definitive grouping of any sites based on the eight factors analysed by MDS were seen, indicating variation amongst the individual sites, however, the low infauna abundance and sampling approach should be acknowledged when interpreting the MDS plots. A summary of the patterns shown in the nMDS plots when displayed by the various factors is outlined in Table 4-4.

Table 4-4 Summary of patterns seen in MDS plots

Displayed by Factor	Figure	Potential Patterns
Site	Figure 4-42	Sites 6 and 7 were more similar to each other but there were no other discernible patterns seen between sites. Sites located closer together spatially were not necessarily similar to each other in terms of their infauna assemblages.
Depth	Figure 4-43	There was a slight tendency sites with depths below 250 m to occur more closely together, in comparison to sites located at depths between 250 m and 450 m. However, no strong patterns were detected between depth.
Marine Park	Figure 4-44	There was a slight grouping of sites that were located within the Kimberly Marine Park, the Argo-Rowley Terrace Marine Park (2 of 3 sites only) and those sites not located in a Marine Park. As all Marine Park Zones were classed as Multiple Use, no further information was gained from this Factor.
Marine Park Zone	Figure 4-45	
Key Ecological Features	Figure 4-46	No discernible patterns were seen between sites whether they were in an area defined as a KEF or not.
% Clay	Figure 4-47	There was a slight grouping of sites with a lower % of clay (6-20%) in comparison to sites with higher % of clay (21-50%).
% Silt	Figure 4-48	There was a slight grouping of sites with lower % of silt (6-10%).
% Sand	Figure 4-49	No discernible patterns could be seen.

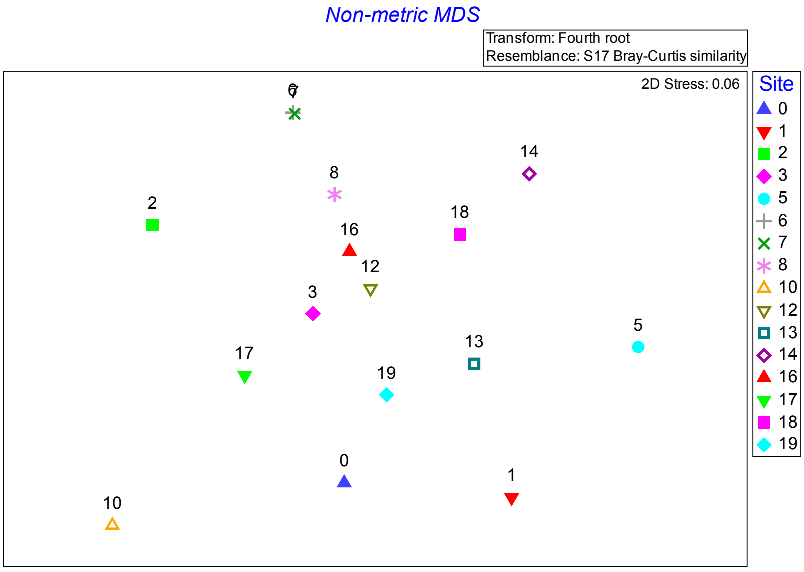


Figure 4-42 n-MDS plot of fourth square root transformed infauna abundance data displayed by 'Site'

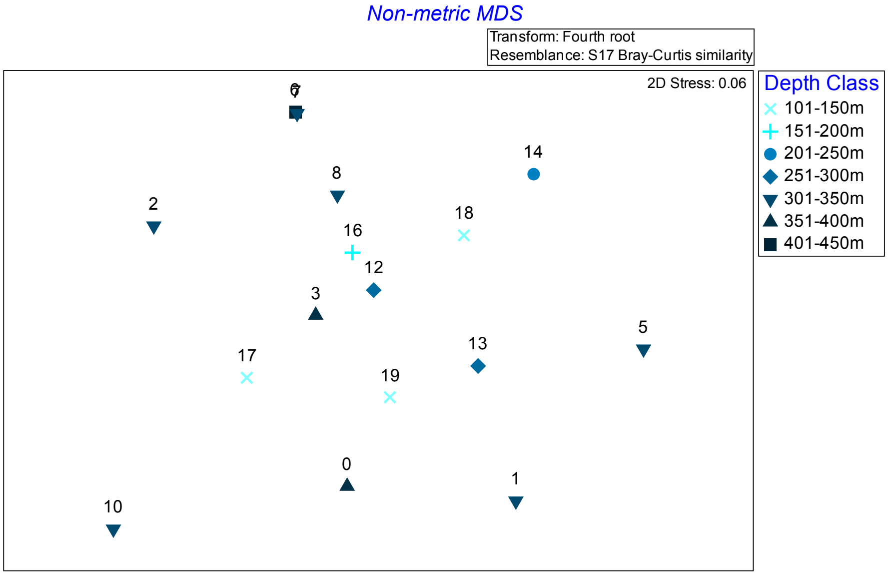


Figure 4-43 n-MDS plot of fourth square root transformed infauna abundance displayed by 'Depth'

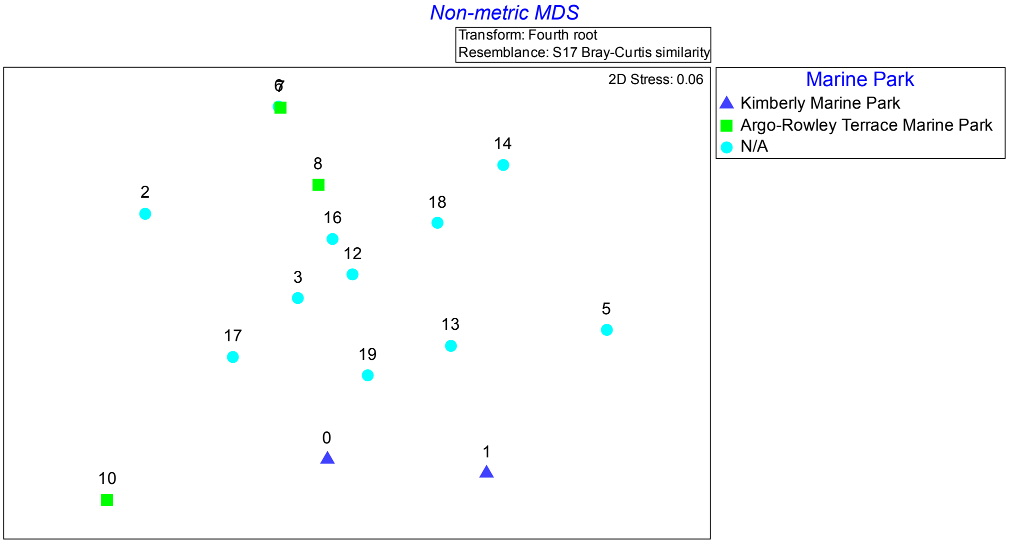


Figure 4-44 n-MDS plot of fourth square root transformed infauna abundance data displayed by 'Marine Park'

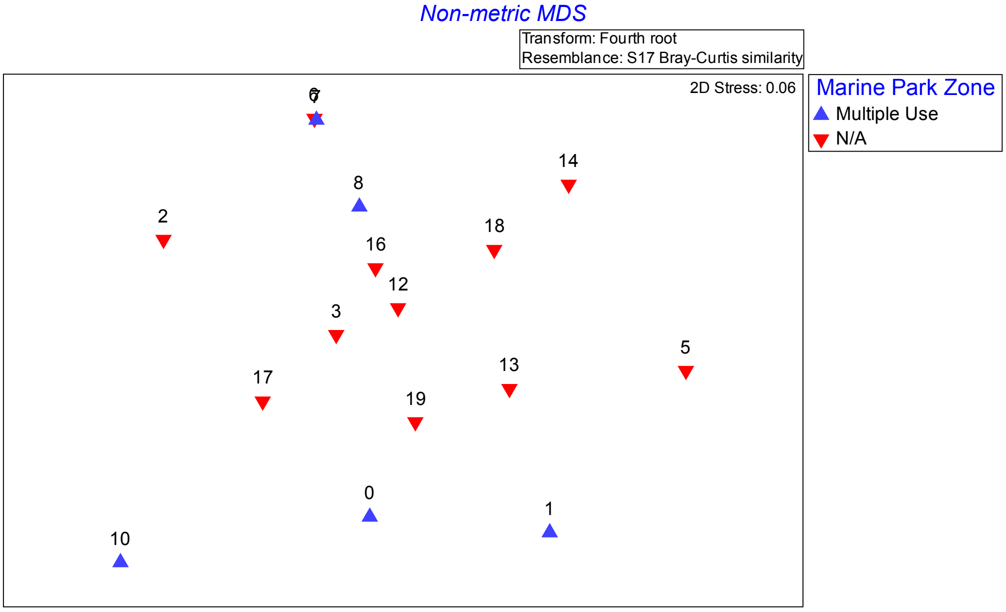


Figure 4-45 n-MDS plot of fourth square root transformed infauna abundance data displayed by 'Marine Park Zone'

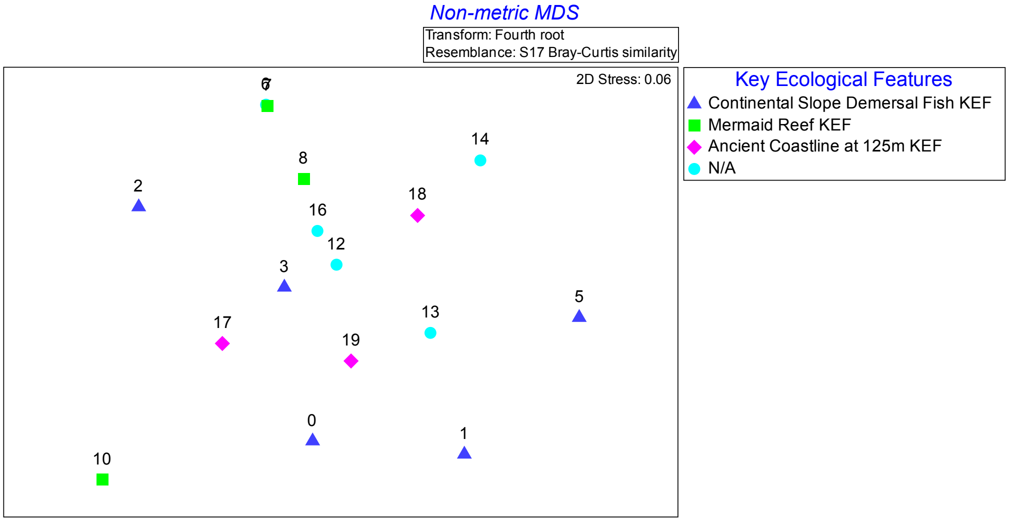


Figure 4-46 n-MDS plot of fourth square root transformed infauna abundance data displayed by 'Key Ecological Features'

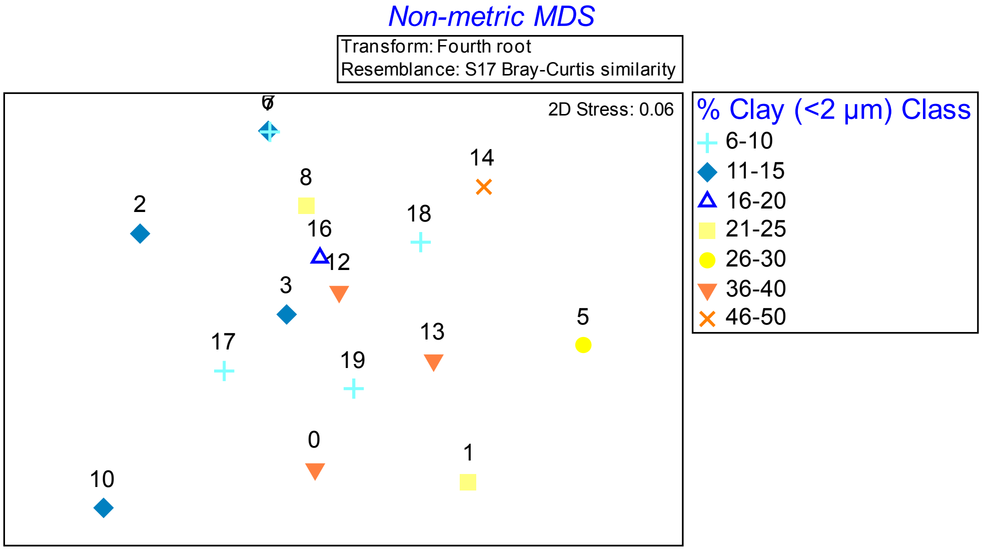


Figure 4-47 n-MDS plot of fourth square root transformed infauna abundance data displayed by '% Clay'

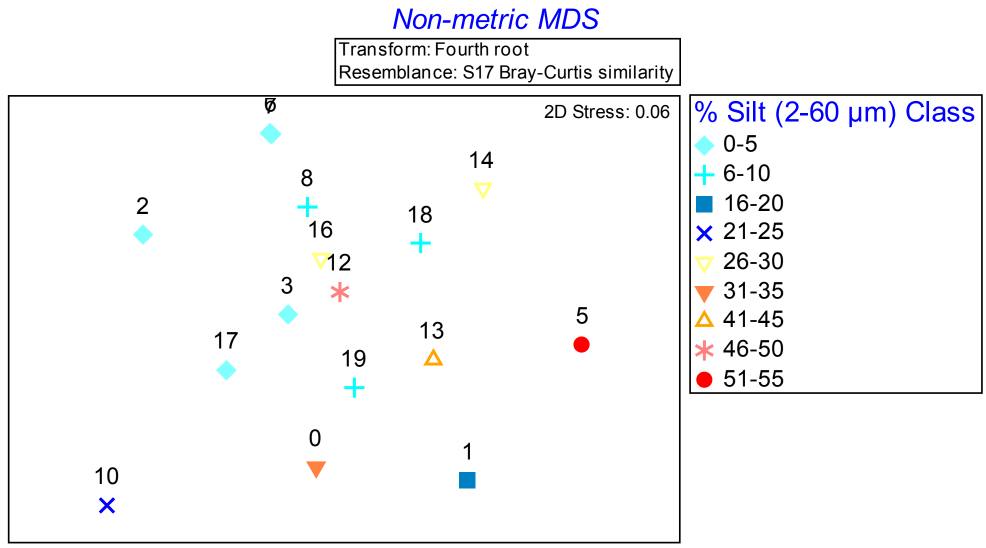


Figure 4-48 n-MDS plot of fourth square root transformed infauna abundance data displayed by '% Silt'

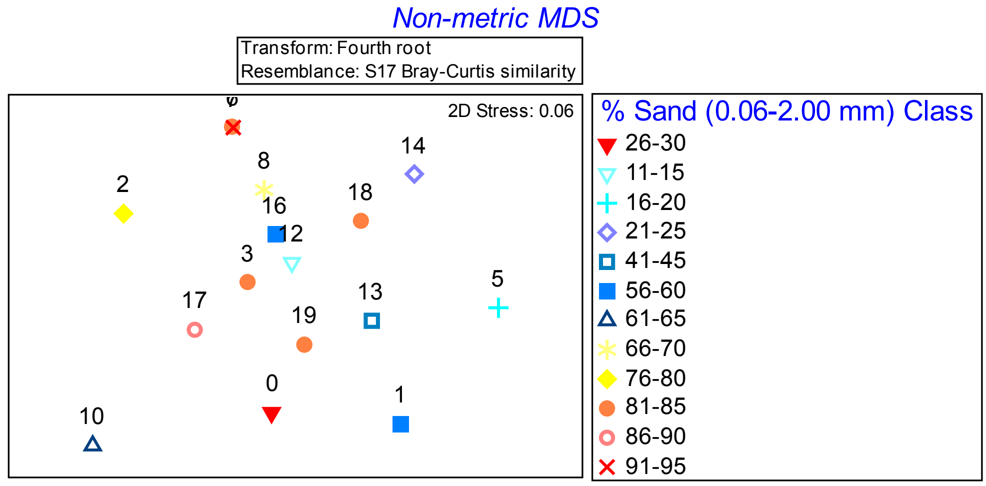


Figure 4-49 n-MDS plot of fourth square root transformed infauna abundance displayed by '% Sand'

5 Discussion

Sample sites were selected from the preliminary habitat map that represented both the expected seabed substrate and bedform type along the pipeline route, but also at sites with predicted more complex seabed features (mounds, scarps, harder substrates). Sample sites were also strategically located within areas where the proposed pipeline route intersects with AMPs or KEFs to determine if the environmental values associated with these areas are present or absent along the pipeline route.

Seabed imagery collected along the pipeline route is generally aligned with the interpretation of the geophysical data in the preliminary habitat map. The geophysical data is considered a good predictor of seabed substrate type and bedform. Differences between the interpretation of the geophysical data, the seabed imagery and sediment samples may be a result of scale differences. Larger bedforms such as sand waves are hard to accurately detect from the seabed imagery, with a field of view generally less than 5 m. This may result in the classification of waves/ripples superimposed on the larger bedform. Additionally, the gridding size of the bathymetry data (5 m) means smaller features (ripples) were only identifiable in the backscatter data when constructing the preliminary habitat map. The ability to detect these smaller features from the backscatter data depends on the scale of the features and the incidence angle, resulting in some minor discrepancies between the preliminary habitat map and the observations of smaller seabed features.

Sample sites (0 and 1) in the Kimberley Marine Park Multiple Use Zone did not identify any important foraging areas. The seabed was consistent with that expected on the North West Shelf. Sample sites (0, 1, 2, 3, 4 and 5) in the Continental Slope Demersal Fish Communities KEF did not identify an increase in the presence or diversity of demersal fishes. However, some species may have been disturbed by the presence of the camera system. Sample sites (7, 8, 9 and 10) in the Argo-Rowley Terrace AMP and Mermaid Reef and Commonwealth waters surrounding the Rowley Shoals KEF (Multiple Use Zone) did not identify any complex seabed features, increased species richness or resuspension of nutrients into the photic zone. Sample sites (17, 18 and 19) in the Ancient Coastline at 125 m Depth Contour KEF consisted of sand with varying proportions of silt and clay, with no evidence of rocky escarpments or harder seabed substrates.

The consolidated rubble identified at Sites 15 and 16 is in an area of more complex seabed features (scarps, mounds and scours) identified from the geophysical data. This was the only area identified from the field data containing harder seabed substrates along the proposed pipeline route. This harder substrate does not appear to support populations of epibenthic communities, with only solitary individuals identified from the seabed imagery. The geophysical data also suggests these areas of harder consolidated rubble are likely spatially confined (less than 1 km).

The dominant habitat type identified along the proposed pipeline route was unconsolidated soft sand, supporting various benthic infauna as evidenced by the observation of bioturbation and tracks at many sites. There was no discernable association between particular habitat types and geographical location or depth along the proposed pipeline route and given the absence of observations of habitat boundaries at sampling sites, habitat features outlined in the preliminary habitat map are considered to be accurate.

Results of water profiling and sampling indicate that the sites sampled were representative of the north-west offshore oceanic environment. Most of the physico-chemical characteristics of the water column were consistent between sites. Surface waters were generally well mixed to about 30 m at most sites; there is no apparent anthropogenic contamination of the waters along the proposed pipeline route, with most concentrations of potential contaminants below the 99% level of species protection DGVs from the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018). The exception to this was the nutrient analyses (for TN and TP, NH_4, nitrite and nitrate), which were above the default guideline value for offshore waters at many of the sample locations (as per table 3.3.4 of ANZECC, 2000). Samples were unable to be delivered to the laboratory within the recommended holding times for nutrient analyses, due to the logistical nature of the survey. While it is possible the breach of recommended holding times may have affected nutrient results, there does not appear to be any obvious association between samples that exceeded holding times and elevations beyond guideline values.

Sediment quality results were below the DGV for sediment quality in the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (2018) at most sites, except nickel at Site 6. While nickel concentrations are known to occur naturally beyond DGV in Pilbara regional waters (Stoddart et al., 2019), the elevated results from Site 6 are anomalous in the context of the proposed pipeline route. They may be caused by an anthropogenic source, possibly occurring while collecting samples. Where DGV are absent and concentrations of trace metals in sediments were able to be compared to other regional surveys (Gardline, 2009), or estimated natural background levels (DEC, 2006), the results from this survey were substantially lower. Given the low incidence of elevated concentration of contaminants over the extent of the proposed BTL, sediments are considered free from any anthropogenic contamination and are typical of open ocean environments off the west coast of Australia.

Benthic infauna abundance, taxa richness and diversity, as measured for individual sites, was low. The general patterns (but not values) between sites for infauna abundance, taxa richness and diversity were similar. The most abundant Phylum recorded during the survey were Annelida, with this Phylum also being the most taxa rich. Arthropoda were also relatively abundant and richness for this group was also higher than most others. The total abundance of the Phylum Echinodermata and Phylum Sipuncula were also relatively high.

There was considerable variability in infauna abundance, richness and diversity between sites. Multidimensional scaling showed the following patters:

- There was no grouping between sites with one exception being sites 6 and 7 which were very similar. Sites located closer together spatially were not necessarily similar to each other in terms of their infauna assemblages.
- There was a slight tendency for infauna assemblages at sites with depths below 250 m to occur more closely together (i.e. showing more similarity) in comparison to sites located at depths between 250 m and 450 m. However, no strong patterns in assemblages were detected for the factor depth. Initial data investigation showed that the sites with the highest infauna abundances occurred at depths ranging from 125 m to 351 m.
- When infauna assemblages were analysed according to sediment types (clay, silt and sand), there was a slight grouping of sites with a lower % of clay (6-20%) in comparison to sites with higher % of clay (21-50%). There was also a slight grouping of sites with lower % of silt (6-10%). However, no discernible patterns could be seen for % sand.
- When infauna assemblages were assessed in terms of their presence within an AMP, there was a slight grouping of sites that were located within the Kimberly Marine Park, sites in the Argo-Rowley Terrace Marine Park (2 of 3 sites only) and those sites not located in an AMP. Interestingly, sites with the highest abundance (and typically richness) were located outside of the AMPs. Four of the seven sites with the lowest infauna abundance (<10 individuals) and

richness occurred within AMPs (two in the Kimberly Marine Park and two in the Argo-Rowley Terrace Marine Park).

- No discernible patterns in infauna assemblages were detected between sites whether they were located in an area defined as a KEF or not. For example, three of the six sites with the highest infauna abundance (and typically corresponding richness) occurred in KEFs (one in the Continental Slope Demersal Fish KEF and two in the Ancient Coastline at 125m KEF). However, six of the seven sites with the lowest infauna abundance (< 10 individuals) and richness also occurred within a KEF (three in the Continental Slope Demersal Fish KEF and three in the Mermaid Reef KEF).

Most infauna sampling was undertaken in areas of unconsolidated soft sediment apart from Site 15 and 16 which were located in areas of more complex and consolidated habitat. The shell rubble collected from Site 15 did not contain infauna. However, soft sediment was able to be collected from Site 16, which was reported as being of a similar nature, and this site had relatively high infauna abundance and richness. The geophysical data suggests these areas of harder consolidated rubble are likely spatially confined (less than 1 km), which could account for soft sediment being able to be collected at Site 16 but not at Site 15.

The infauna investigation did not show any consistent differences in patterns of abundance, richness or diversity between sites with differing depths, or located within AMPs and/or KEFs. The statistical analysis undertaken for the current investigation is characterised by low abundance, richness and diversity of infauna assemblages. This feature is likely to be related to the depth of samples, as generally species diversity and richness are known to decrease with increasing depth, due to reduced sunlight and other optimum conditions for the productivity of infauna (Duxbury et al. 2003; Kropp et al. 2003).

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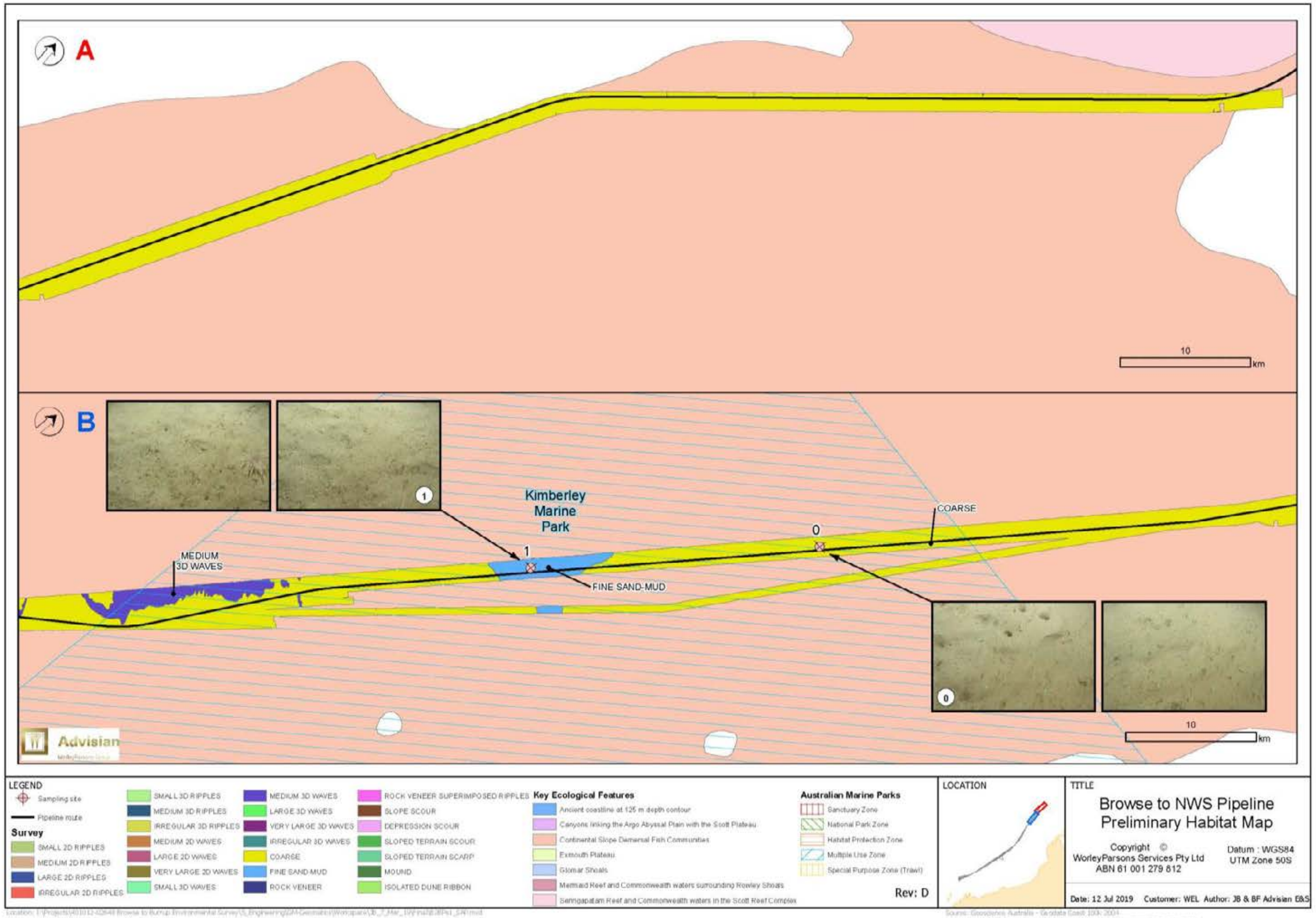
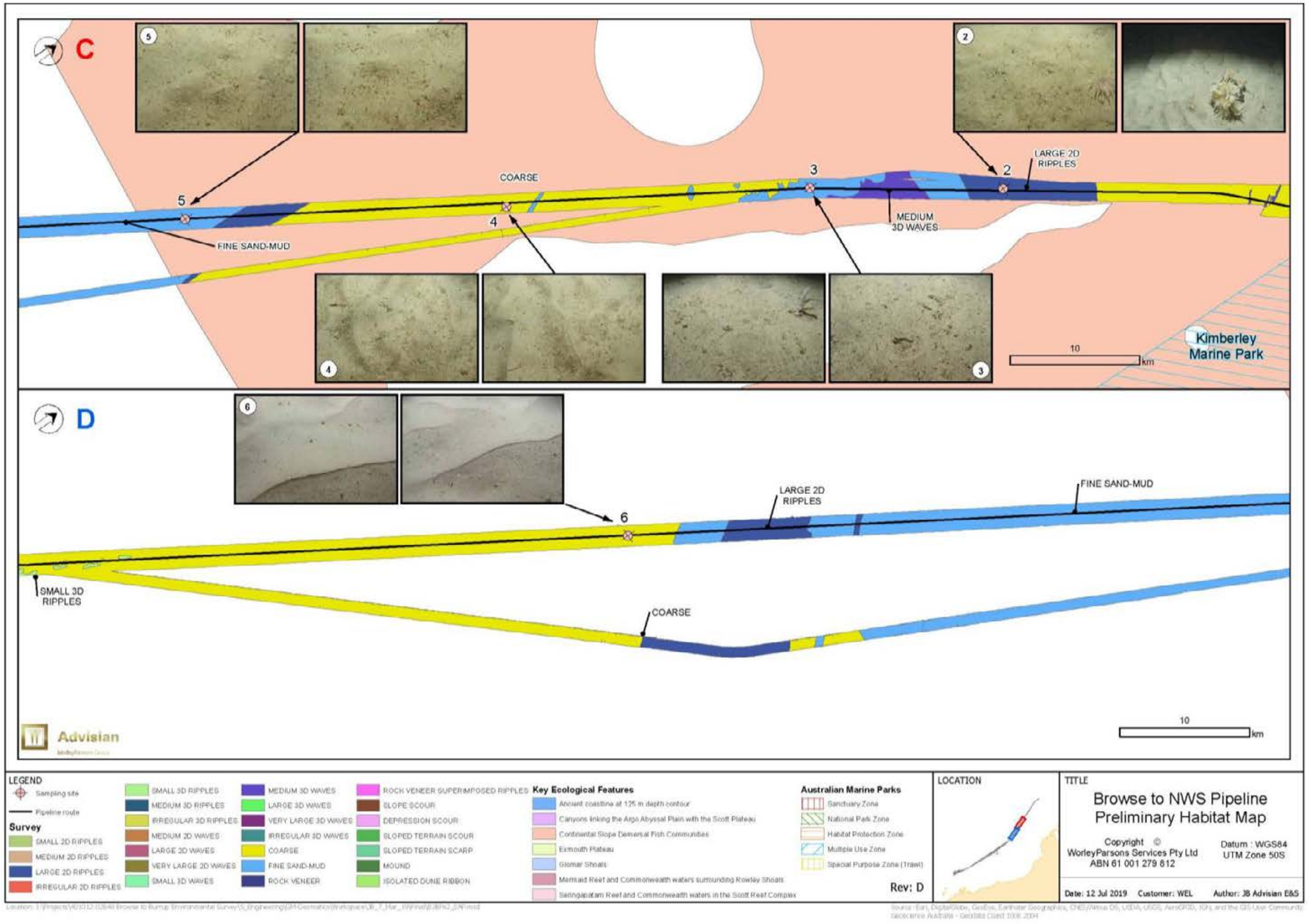
Appendix A
Habitat Map



Source: Geoscience Australia - Geodata Coast 100k 2004
Department of the Environment and Energy - Marine Key Ecological Features 2018
Department of the Environment and Energy - Collaborative Australian Protected Areas Database - Marine (CAPAD) 2016



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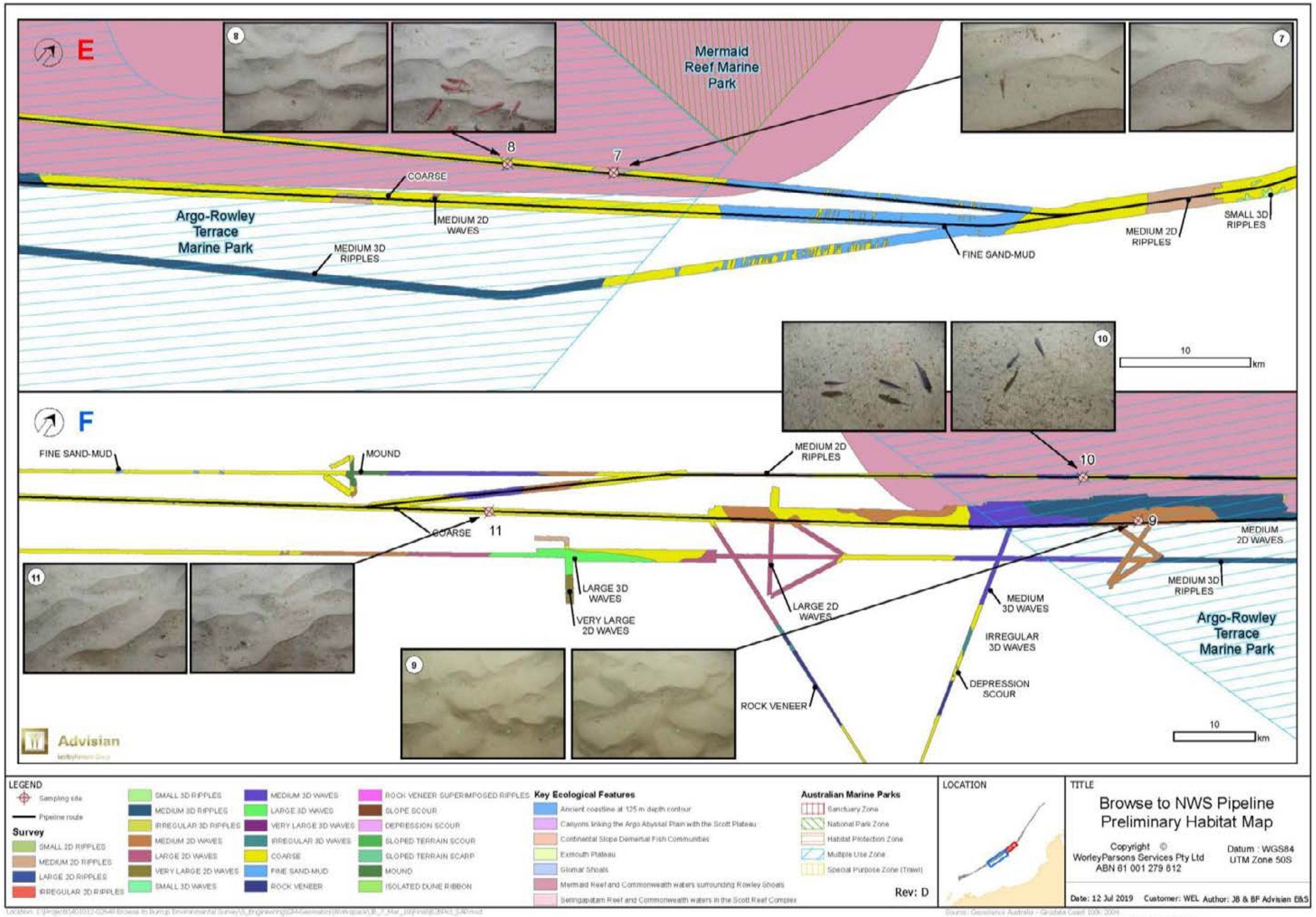

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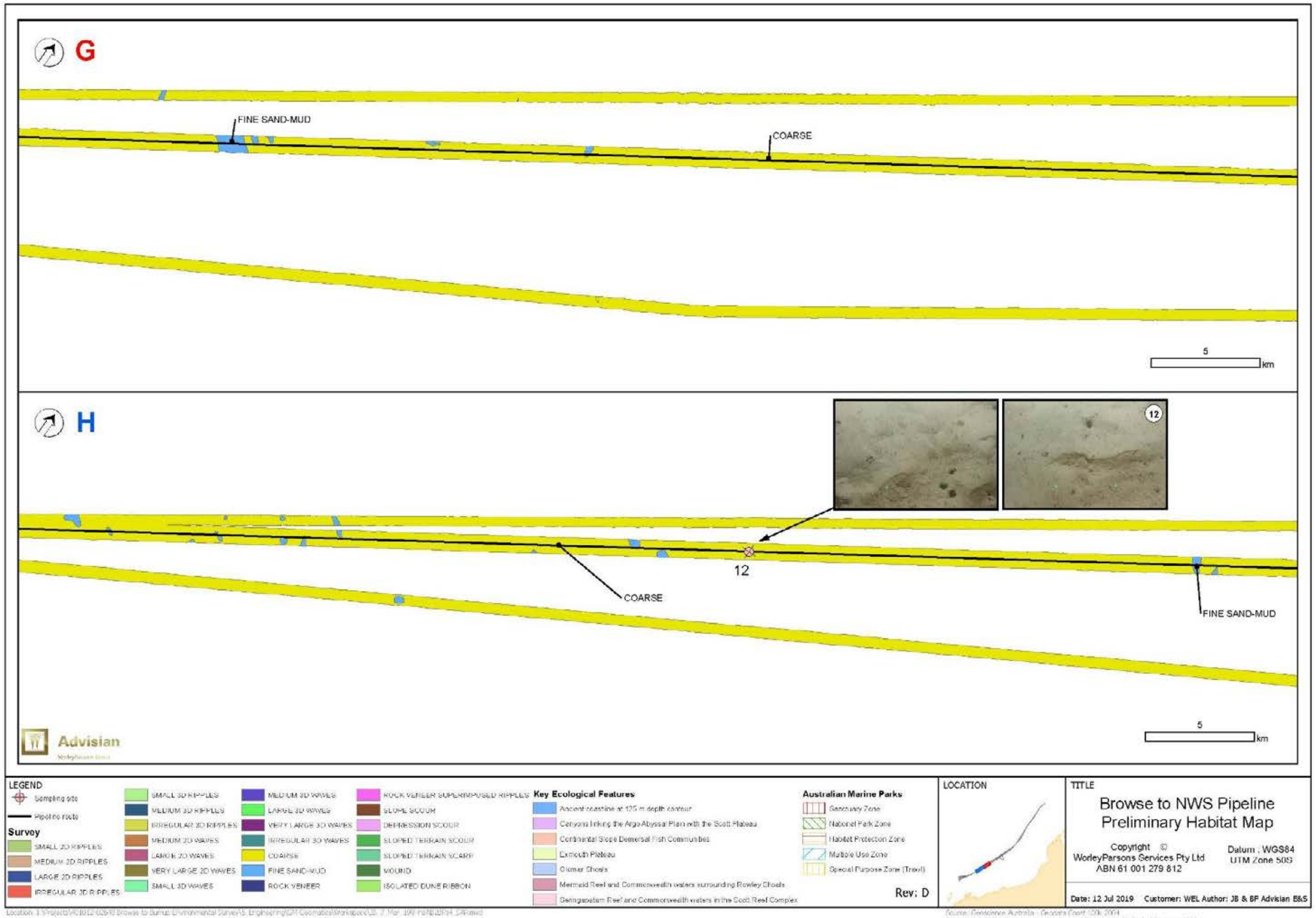

TITLE

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Preliminary Habitat Map

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UTM Zone 50S

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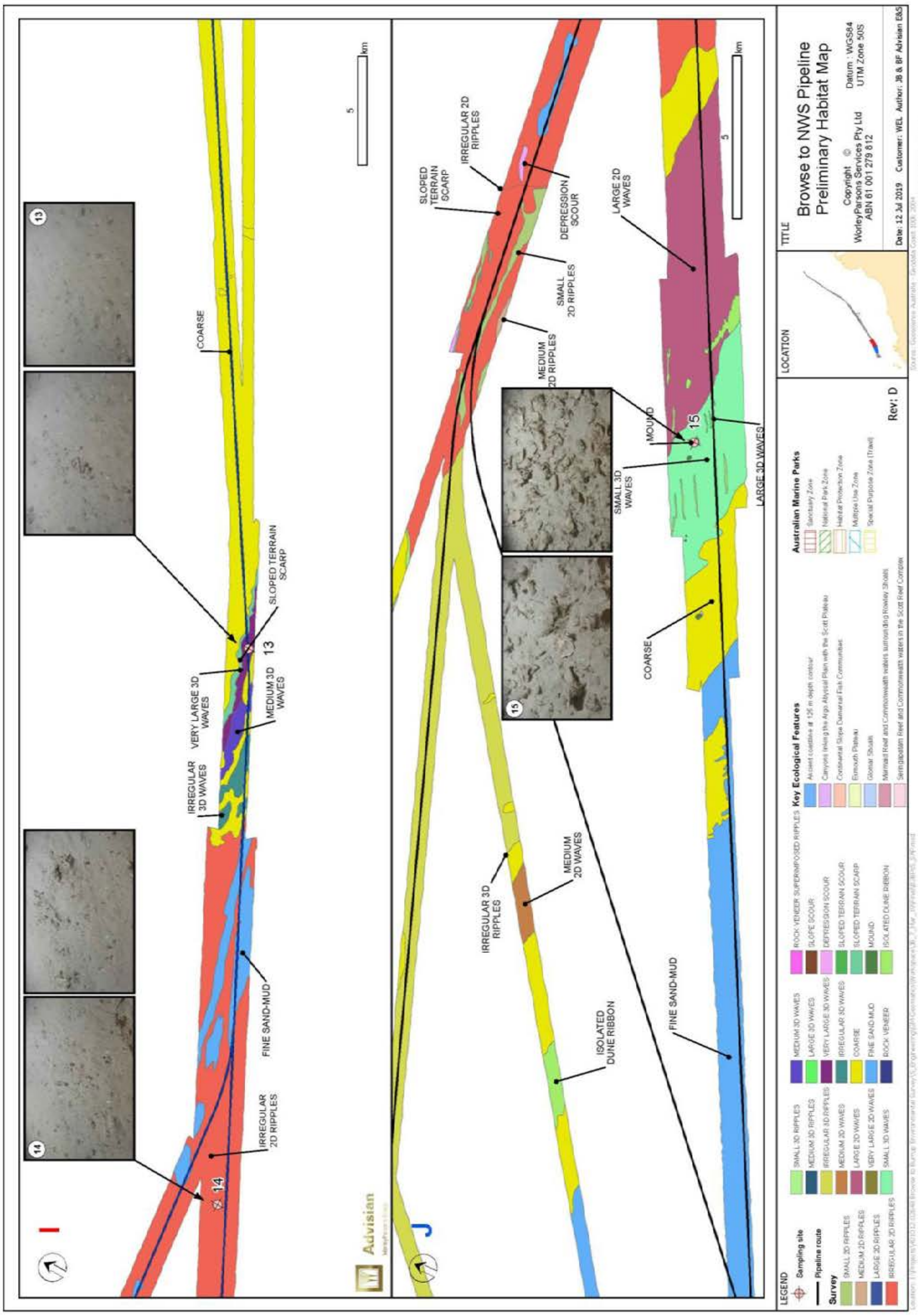
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Key Ecological Features
Ancient coastline at 125 m depth contour
Canyons linking the Argo Abyssal Plain with the Scott Plateau
Continental Slope Demersal Fish Communities
Exmouth Plateau
Glomar Shoals
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals
Seringapatam Reef and Commonwealth waters in the Scott Reef Complex
Australian Marine Parks
Sanctuary Zone
National Park Zone
Habitat Protection Zone
Multiple Use Zone
Special Purpose Zone (Trawl)
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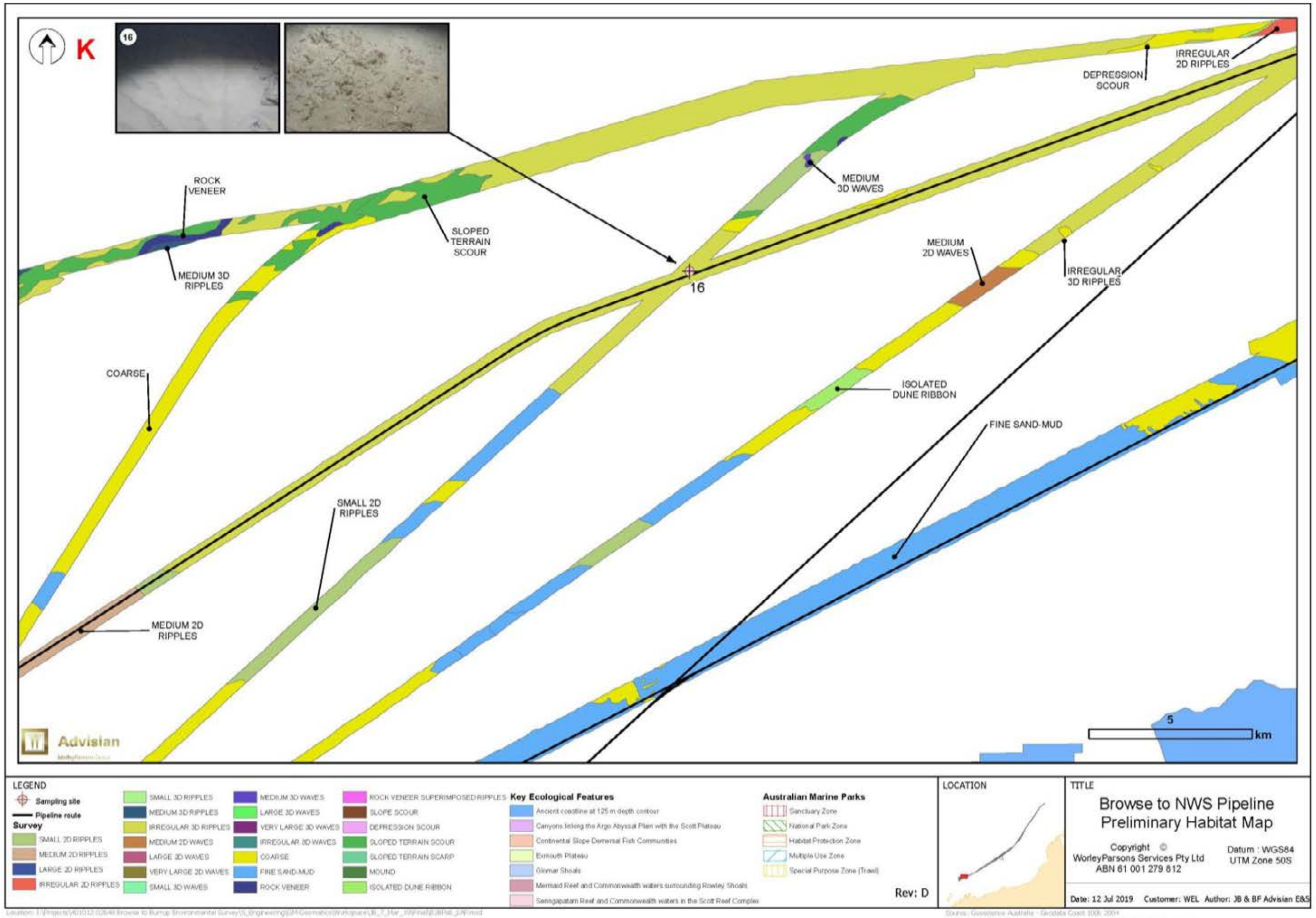

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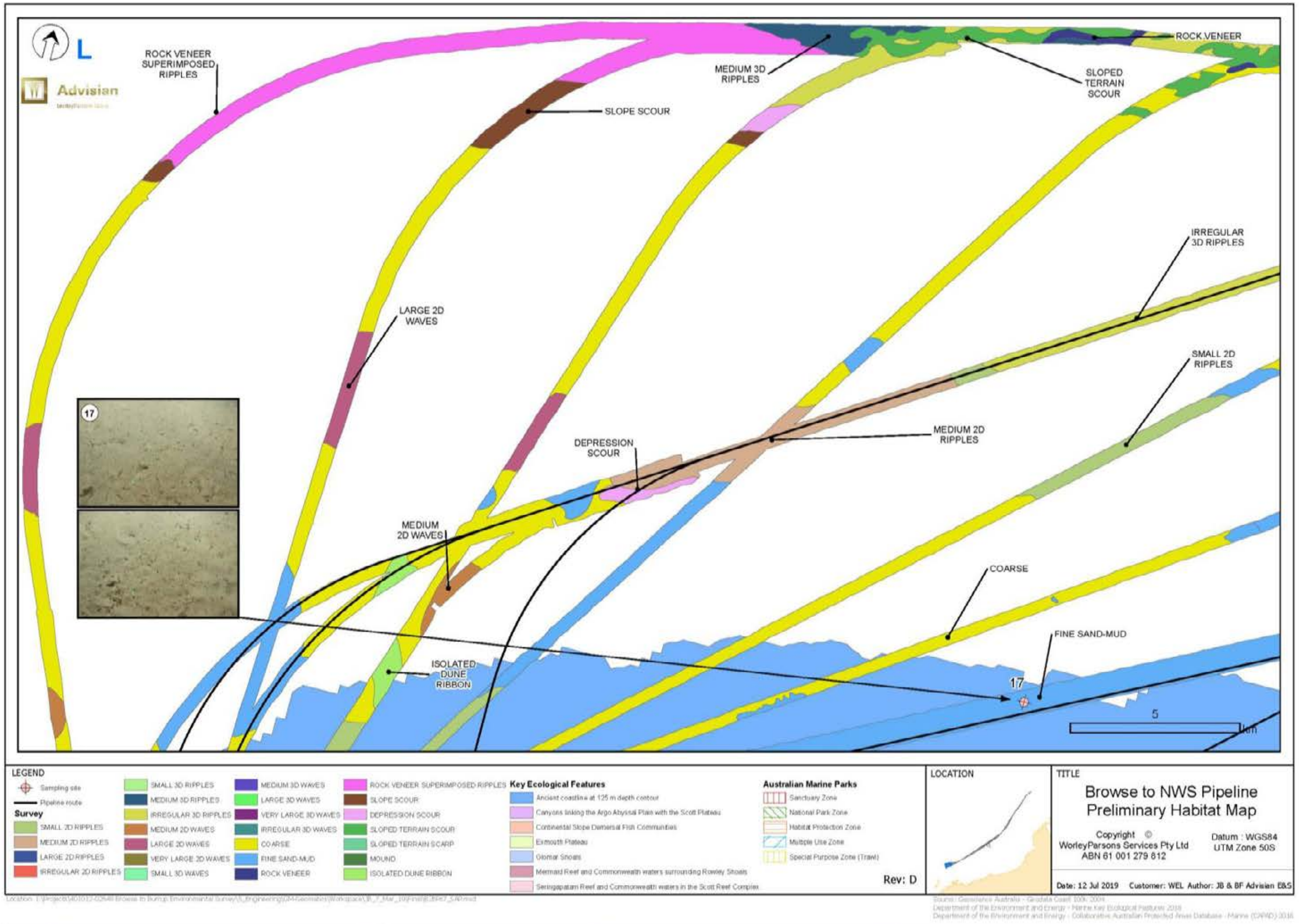
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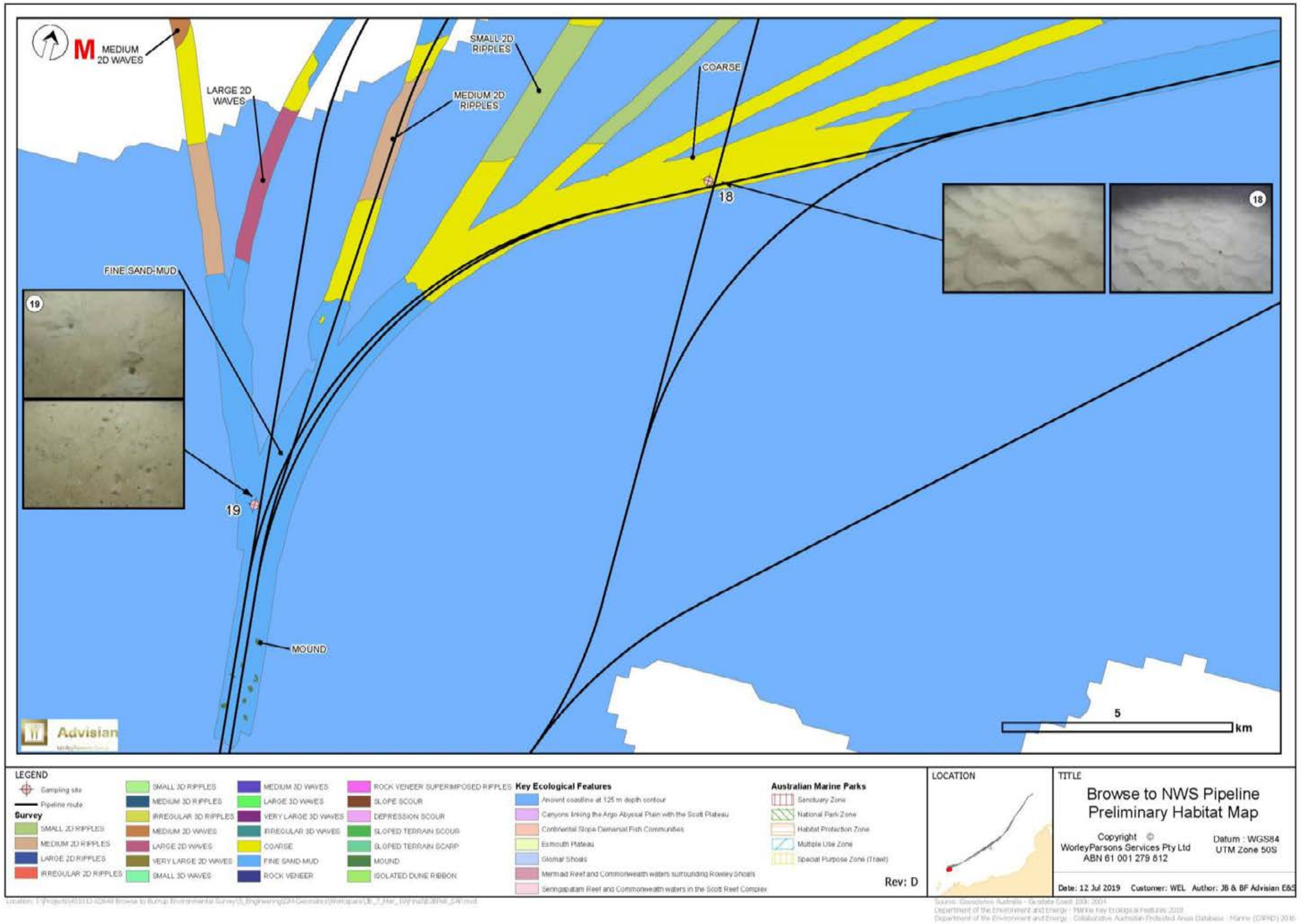

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Appendix B
Sampling Design Rationale

Sample Priority	Sample Site	Seabed Substrate	KEF or Marine Park	Reason for Site Selection	Depth (m)	Field Duplicate (FD)/Field Replicate (FR)	X Coordinate (Sample Site 0-6 = GDA Z51, 7-19 GDA Z50)	X Coordinate (Sample Site 0-6 = GDA Z51, 7-19 GDA Z50)
1	0	Coarse sand	KEF and AMP	Continental Slope Demersal Fish Communities KEF Kimberley Marine Park Spatial representation of the pipeline route and KEF	378	FD	315118.180	8331763.044
1	1	Fine sand-mud	KEF AMP	Continental Slope Demersal Fish Communities KEF Kimberley Marine Park Spatial representation of the pipeline route and KEF	349		302648.480	8313408.635
2	2	Large 2D Ripples	KEF	Continental Slope Demersal Fish Communities Ensure different seabed type in KEF is sampled	339		268950.462	8263767.183
2	3	Fine sand-mud	KEF	Continental Slope Demersal Fish Communities KEF Ensure different seabed type in KEF is sampled	356	FD	260738.068	8251358.479

Sample Priority	Sample Site	Seabed Substrate	KEF or Marine Park	Reason for Site Selection	Depth (m)	Field Duplicate (FD)/Field Replicate (FR)	X Coordinate (Sample Site 0-6 = GDA Z51, 7-19 GDA Z50)	X Coordinate (Sample Site 0-6 = GDA Z51, 7-19 GDA Z50)
2	4	Coarse sand	KEF	Continental Slope Demersal Fish Communities KEF	348		249088.284	8231056.756
2	5	Fine sand-mud	KEF	Continental Slope Demersal Fish Communities KEF	382	FR	236292.133	8209858.855
2	6	Coarse sand	KEF	Spatial coverage of pipeline route	434		206509.023	8159291.802
1	7	Medium 2D ripples	AMP KEF	Site is within Argo-Rowley Terrace Marine Park Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF	377		782643.073	8087374.895
1	8	Coarse sand	AMP KEF	Argo-Rowley Terrace Marine Park Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF	373		775964.986	8082667.771

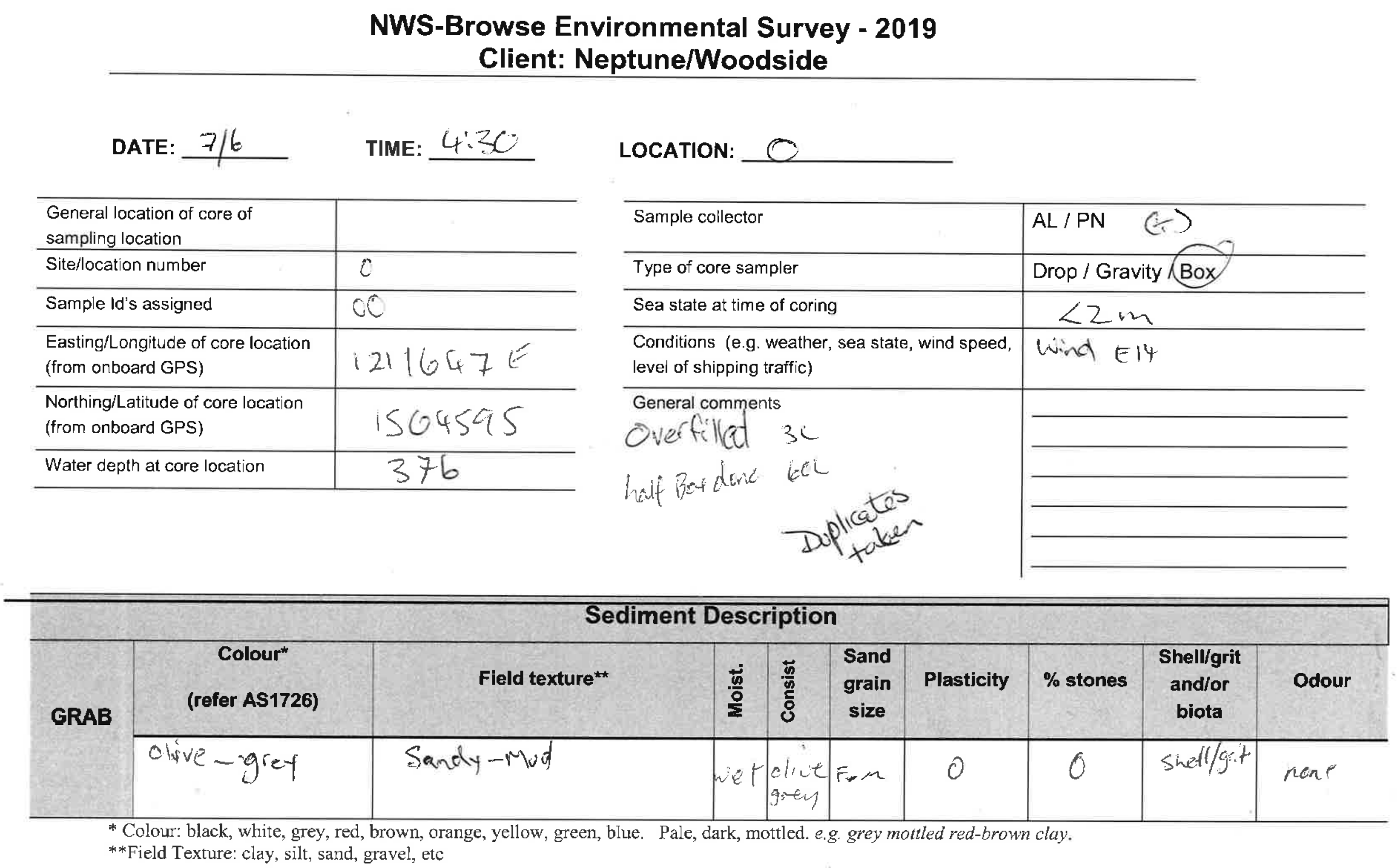
Sample Priority	Sample Site	Seabed Substrate	KEF or Marine Park	Reason for Site Selection	Depth (m)	Field Duplicate (FD)/Field Replicate (FR)	X Coordinate (Sample Site 0-6 = GDA Z51, 7-19 GDA Z50)	X Coordinate (Sample Site 0-6 = GDA Z51, 7-19 GDA Z50)
1	9	Medium 2D sand waves	AMP KEF	Argo-Rowley Terrace Marine Park Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF	328	FR	733024.695	8046668.013
1	10	Coarse sand	AMP KEF	Argo-Rowley Terrace Marine Park Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF	331		724509.125	8047096.470
3	11	Coarse sand		Potential site for hard substrate Potential for Increased species richness	267		667109.278	8001846.750
3	12	Coarse sand		Spatial coverage of pipeline route	268		557905.909	7930336.135
2	13	Sloped terrain scarp		Area of more complex seabed features	267		505237.135	7895811.563
3	14	Irregular 2D ripples		Coverage of variation of seabed substrate across the pipeline route	225		482387.779	7884252.744

Sample Priority	Sample Site	Seabed Substrate	KEF or Marine Park	Reason for Site Selection	Depth (m)	Field Duplicate (FD)/Field Replicate (FR)	X Coordinate (Sample Site 0-6 = GDA Z51, 7-19 GDA Z50)	X Coordinate (Sample Site 0-6 = GDA Z51, 7-19 GDA Z50)
2	15	Mound		Area of more complex seabed features	189		467787.611	7876922.289
3	16	Irregular 3D Ripples		Coverage of variation of seabed substrate across the pipeline route	197		443720.798	7876108.698
2	17	Fine sand-mud	KEF	Ancient Coastline at 125 m Depth Contour KEF	136		431325.375	7857652.669
2	18	Coarse sand	KEF	Area of more complex seabed features	131		415897.490	7849425.434
2	19	Fine sand-mud	KEF	Coverage of seabed substrate types within the Ancient Coastline at 125 m Depth Contour KEF	128		408199.977	7840088.869

Appendix C Survey Events

Dates	Sampling/Survey Events	Sites
9-Mar-19 to 12-Mar-19	Vessel mobilisation in Exmouth	NA
13-Mar-19	Drill and survey test	NA
14-Mar-19 to 15-Mar-19	Drop camera survey	18, 17 and 16
16-Mar-19	CPTs	NA
17-Mar-19	CPT and water quality sampling	17 and 18
18-Mar-19 to 19-Mar-19	Transit to Dampier and winch repair	NA
20-Mar-19 to 31-Mar-19	On standby while tropical cyclone Veronica passes	NA
1-Apr-19	Transit to sampling site	NA
2-Apr-19 to 5-Apr-19	Drop camera and water quality sampling	14, 15, 16 and 19
7-Apr-19 to 10-Apr-19	Servicing and crew change in Exmouth	NA
11-Apr-19 to 2-May-19	CPTs and crew change in Broome	NA
3-May-19 to 14-May-19	Piston coring, weather standby	NA
15-May-19 to 19-May-19	Sediment sampling	12, 19, 16, 17 and 18
20-May-19 to 21-May-19	Transit to Exmouth and IMS inspection	NA
22-May-19	Piston coring	NA
23-May-19	Sediment sampling	11, 13 and 14
24-May-19 to 6-Jun-19	Piston coring, weather standby and crew change in Broome	NA
7-Jun-19 to 10-Jun-19	Sediment sampling	0, 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10

Appendix D Field Sheets



NWS-Browse Environmental Survey - 2019
Client: Neptune/Woodside

DATE: 7/6

TIME: 4:30

LOCATION: C

General location of core of sampling location	
Site/location number	C
Sample Id's assigned	CC
Easting/Longitude of core location (from onboard GPS)	1211647 E
Northing/Latitude of core location (from onboard GPS)	1504595
Water depth at core location	376

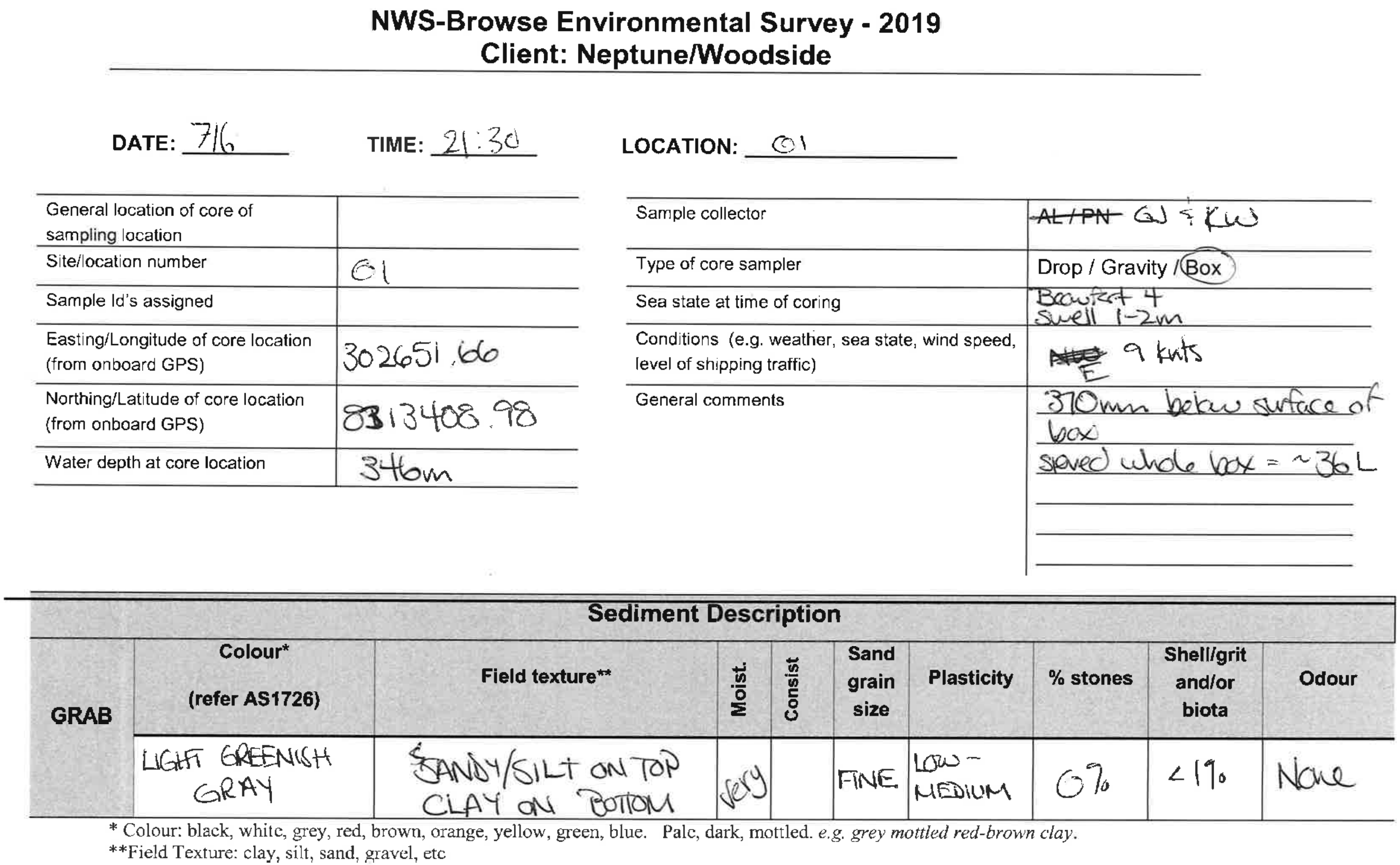
Sample collector	AL / PN (G)
Type of core sampler	Drop / Gravity / [✓ Box]
Sea state at time of coring	<2m
Conditions (e.g. weather, sea state, wind speed, level of shipping traffic)	Wind E14
General comments Overfilled 3L half Box done 6L Duplicates taken	

Sediment Description

GRAB	Colour* (refer AS1726)	Field texture**	Moist.	Consist	Sand grain size	Plasticity	% stones	Shell/grit and/or biota	Odour
	olive-grey	Sandy-Mud	wet	olive grey	Fine	0	0	shell/grit	none

* Colour: black, white, grey, red, brown, orange, yellow, green, blue. Pale, dark, mottled. *e.g. grey mottled red-brown clay.*

**Field Texture: clay, silt, sand, gravel, etc



NWS-Browse Environmental Survey - 2019
Client: Neptune/Woodside

DATE: 7/6 TIME: 21:30 LOCATION: G1

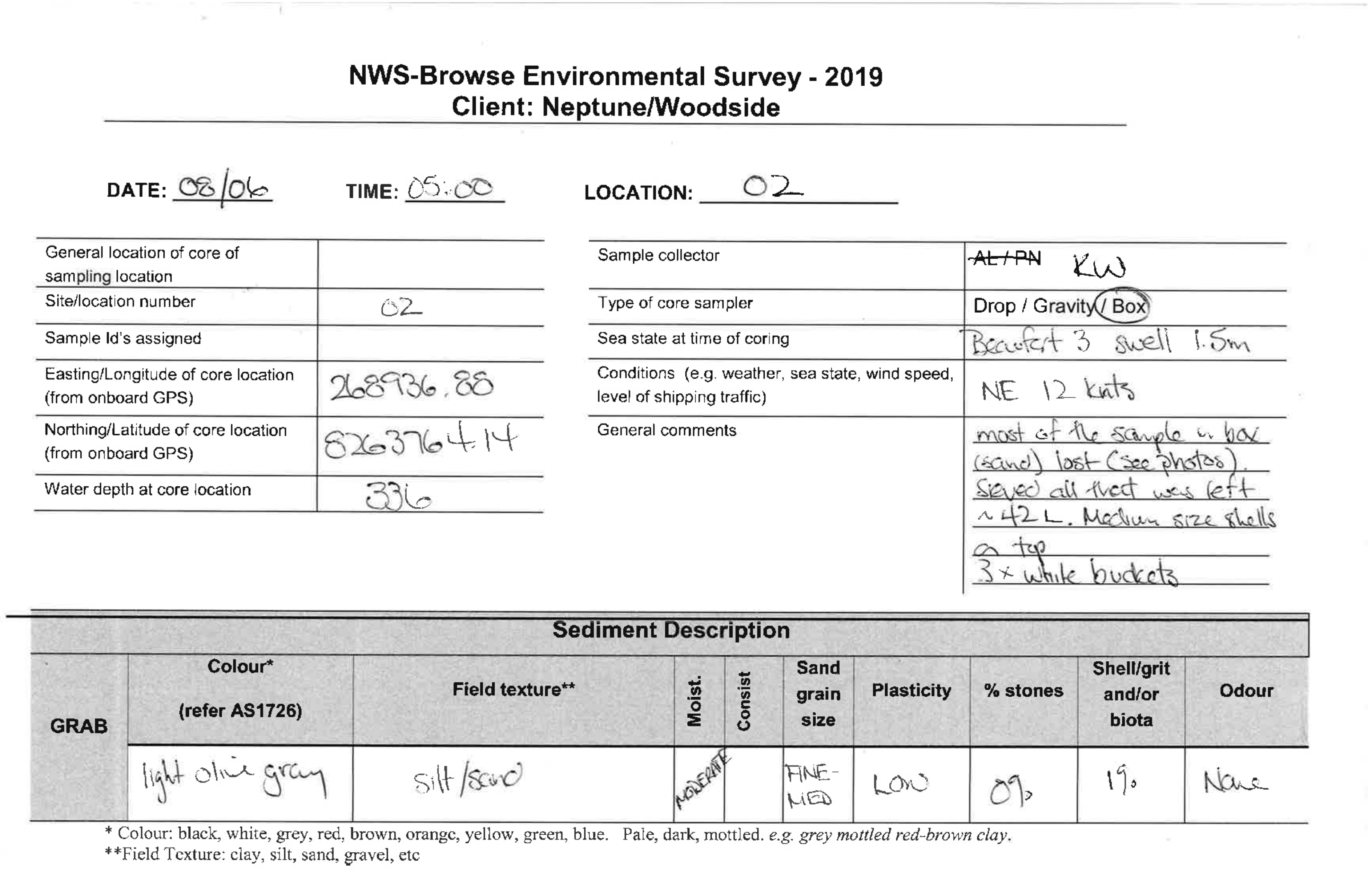
General location of core of sampling location	
Site/location number	G1
Sample Id's assigned	
Easting/Longitude of core location (from onboard GPS)	302651.66
Northing/Latitude of core location (from onboard GPS)	8313408.98
Water depth at core location	346m

Sample collector	~~AL / PN~~ GJ & KW
Type of core sampler	Drop / Gravity / [✓ Box]
Sea state at time of coring	Beaufort 4 Swell 1-2m
Conditions (e.g. weather, sea state, wind speed, level of shipping traffic)	E 9 knts
General comments	370mm below surface of box sieved whole box = ~36L

Sediment Description

GRAB	Colour* (refer AS1726)	Field texture**	Moist.	Consist	Sand grain size	Plasticity	% stones	Shell/grit and/or biota	Odour
	LIGHT GREENISH GRAY	SANDY/SILT ON TOP CLAY ON BOTTOM	very		FINE	LOW – MEDIUM	0%	<1%	None

* Colour: black, white, grey, red, brown, orange, yellow, green, blue. Pale, dark, mottled. *e.g. grey mottled red-brown clay.*
**Field Texture: clay, silt, sand, gravel, etc



NWS-Browse Environmental Survey - 2019
Client: Neptune/Woodside

DATE: 08/06 **TIME:** 05:00 **LOCATION:** 02

General location of core of sampling location	
Site/location number	02
Sample Id's assigned	
Easting/Longitude of core location (from onboard GPS)	268936.88
Northing/Latitude of core location (from onboard GPS)	8263764.14
Water depth at core location	336

Sample collector	~~AL / PN~~ KW
Type of core sampler	Drop / Gravity [✓ Box]
Sea state at time of coring	Beaufort 3 swell 1.5m
Conditions (e.g. weather, sea state, wind speed, level of shipping traffic)	NE 12 knts
General comments	most of the sample in box (sand) lost (see photos). Sieved all that was left ~42L. Medium size shells on top 3 × white buckets

Sediment Description

GRAB	Colour* (refer AS1726)	Field texture**	Moist.	Consist	Sand grain size	Plasticity	% stones	Shell/grit and/or biota	Odour
	light olive gray	silt/sand	MODERATE		FINE-MED	LOW	0%	1%	None

* Colour: black, white, grey, red, brown, orange, yellow, green, blue. Pale, dark, mottled. *e.g. grey mottled red-brown clay.*
**Field Texture: clay, silt, sand, gravel, etc

NWS-Browse Environmental Survey - 2019
Client: Neptune/Woodside

DATE: 08/06 **TIME:** 07:50 **LOCATION:** 03

General location of core of sampling location	
Site/location number	03
Sample Id's assigned	
Easting/Longitude of core location (from onboard GPS)	260137.42 E
Northing/Latitude of core location (from onboard GPS)	8251361. 25N
Water depth at core location	351m

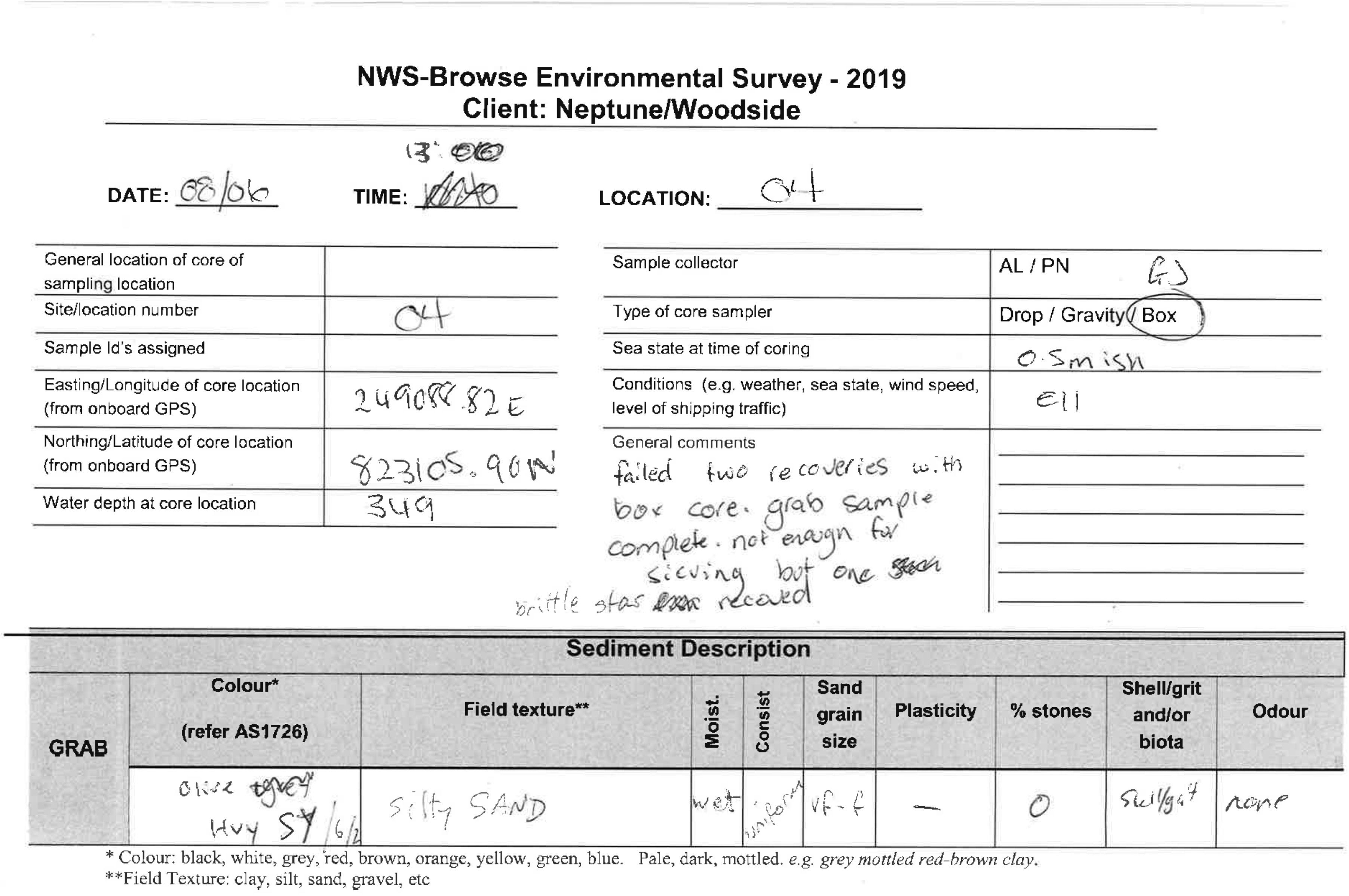
Sample collector	~~AL/PN~~ KW
Type of core sampler	Drop / Gravity [✓ Box]
Sea state at time of coring	Beaufort 3 swell 1.5m
Conditions (e.g. weather, sea state, wind speed, level of shipping traffic)	NE 11 Knts
General comments	water on top of sample when came to surface - siphoned off. One live brittle star ~~3~~ 220mm from top of bucket. Sieved 1/2 ≈ 40L 5× white buckets

Sediment Description

GRAB	Colour* (refer AS1726)	Field texture**	Moist.	Consist	Sand grain size	Plasticity	% stones	Shell/grit and/or biota	Odour
	Light olive grey	Silt (some clay near bottom)	Very		FINE-MODERATE	Low	0%	1%	None

* Colour: black, white, grey, red, brown, orange, yellow, green, blue. Pale, dark, mottled. *e.g. grey mottled red-brown clay.*

**Field Texture: clay, silt, sand, gravel, etc



NWS-Browse Environmental Survey - 2019
Client: Neptune/Woodside

DATE: 08/06 TIME: 13:00 LOCATION: 04

General location of core of sampling location	
Site/location number	04
Sample Id's assigned	
Easting/Longitude of core location (from onboard GPS)	249088.82 E
Northing/Latitude of core location (from onboard GPS)	823105.90N
Water depth at core location	349

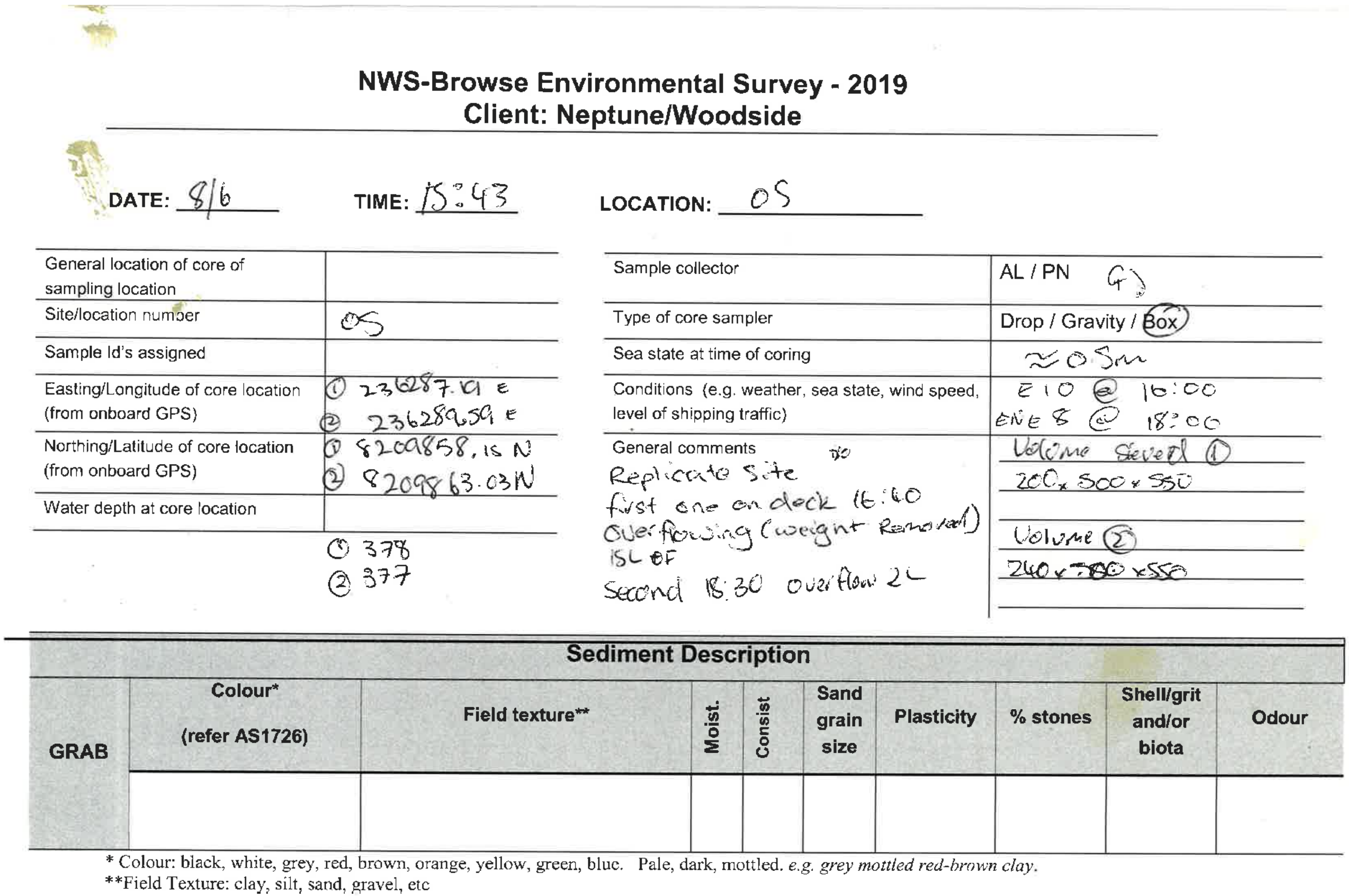
Sample collector	AL / PN GJ
Type of core sampler	Drop / Gravity / [✓ Box]
Sea state at time of coring	0.5m ish
Conditions (e.g. weather, sea state, wind speed, level of shipping traffic)	Ell
General comments	

failed two recoveries with box core. grab sample complete. not enough for sieving but one brittle star recoved

Sediment Description

GRAB	Colour* (refer AS1726)	Field texture**	Moist.	Consist	Sand grain size	Plasticity	% stones	Shell/grit and/or biota	Odour
	olive grey Hvy 5Y 6/2	silty SAND	wet	uniform	vf-f	–	0	Shell/grit	none

* Colour: black, white, grey, red, brown, orange, yellow, green, blue. Pale, dark, mottled. *e.g. grey mottled red-brown clay.*
**Field Texture: clay, silt, sand, gravel, etc



NWS-Browse Environmental Survey - 2019
Client: Neptune/Woodside

DATE: 8/6 TIME: 15:43 LOCATION: 05

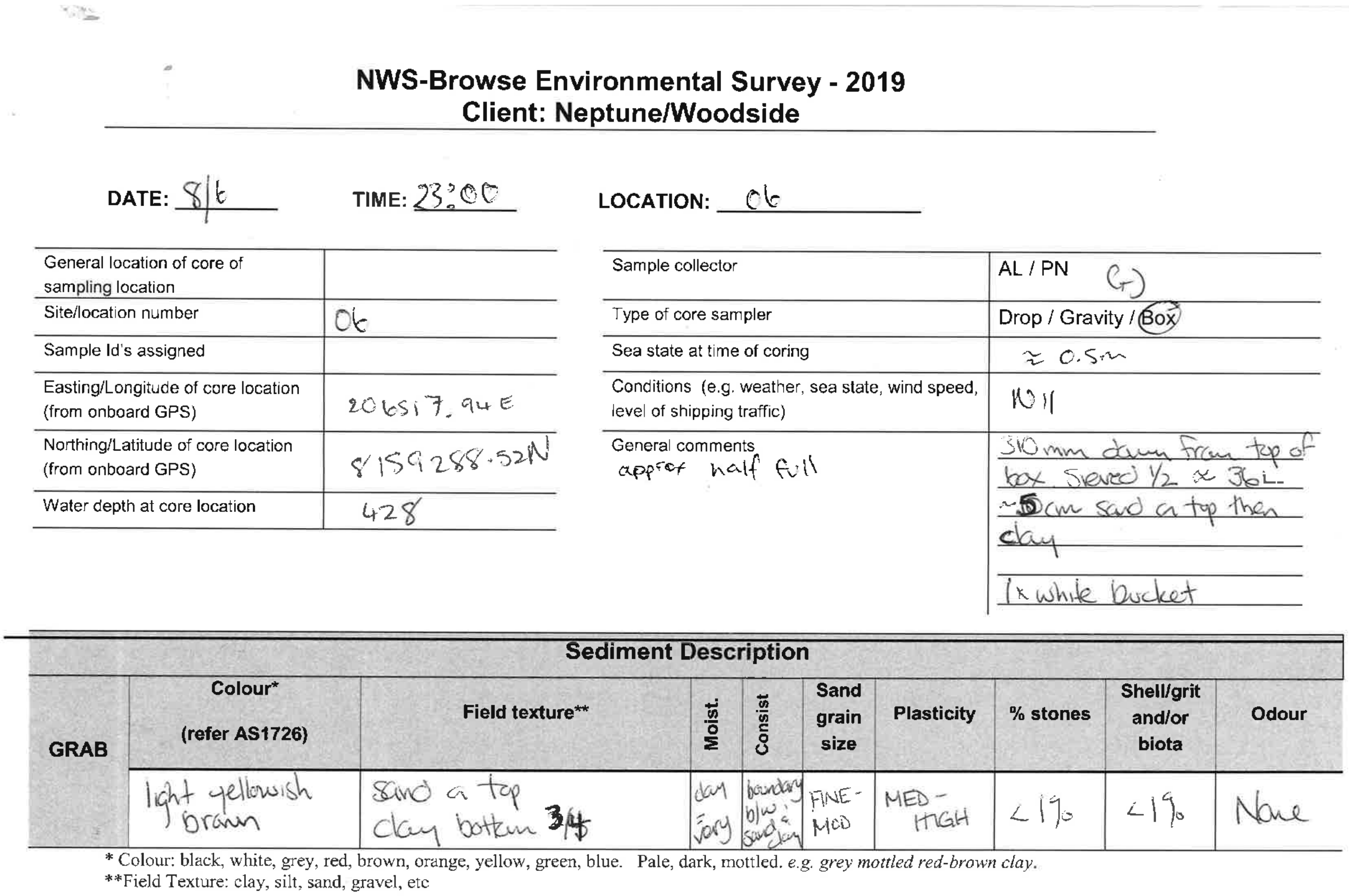
General location of core of sampling location	
Site/location number	05
Sample Id's assigned	
Easting/Longitude of core location (from onboard GPS)	① 236287.19 E ② 236289.59 E
Northing/Latitude of core location (from onboard GPS)	① 8209858.15 N ② 8209863.03N
Water depth at core location	
	① 378 ② 377

Sample collector	AL / PN GJ
Type of core sampler	Drop / Gravity / [✓ Box]
Sea state at time of coring	≈ 0.5m
Conditions (e.g. weather, sea state, wind speed, level of shipping traffic)	E 10 @ 16:00 ENE 8 @ 18:00
General comments Replicate Site first one on deck 16:40 Overflowing (weight Removed) 15L OF Second 18:30 overflow 2L	Volume Sieved ① 200 x 500 x 550 Volume ② 240 x 380 x 550

Sediment Description

GRAB	Colour* (refer AS1726)	Field texture**	Moist.	Consist	Sand grain size	Plasticity	% stones	Shell/grit and/or biota	Odour

* Colour: black, white, grey, red, brown, orange, yellow, green, blue. Pale, dark, mottled. *e.g. grey mottled red-brown clay.*
**Field Texture: clay, silt, sand, gravel, etc



NWS-Browse Environmental Survey - 2019
Client: Neptune/Woodside

DATE: 8/6 TIME: 23:00 LOCATION: 06

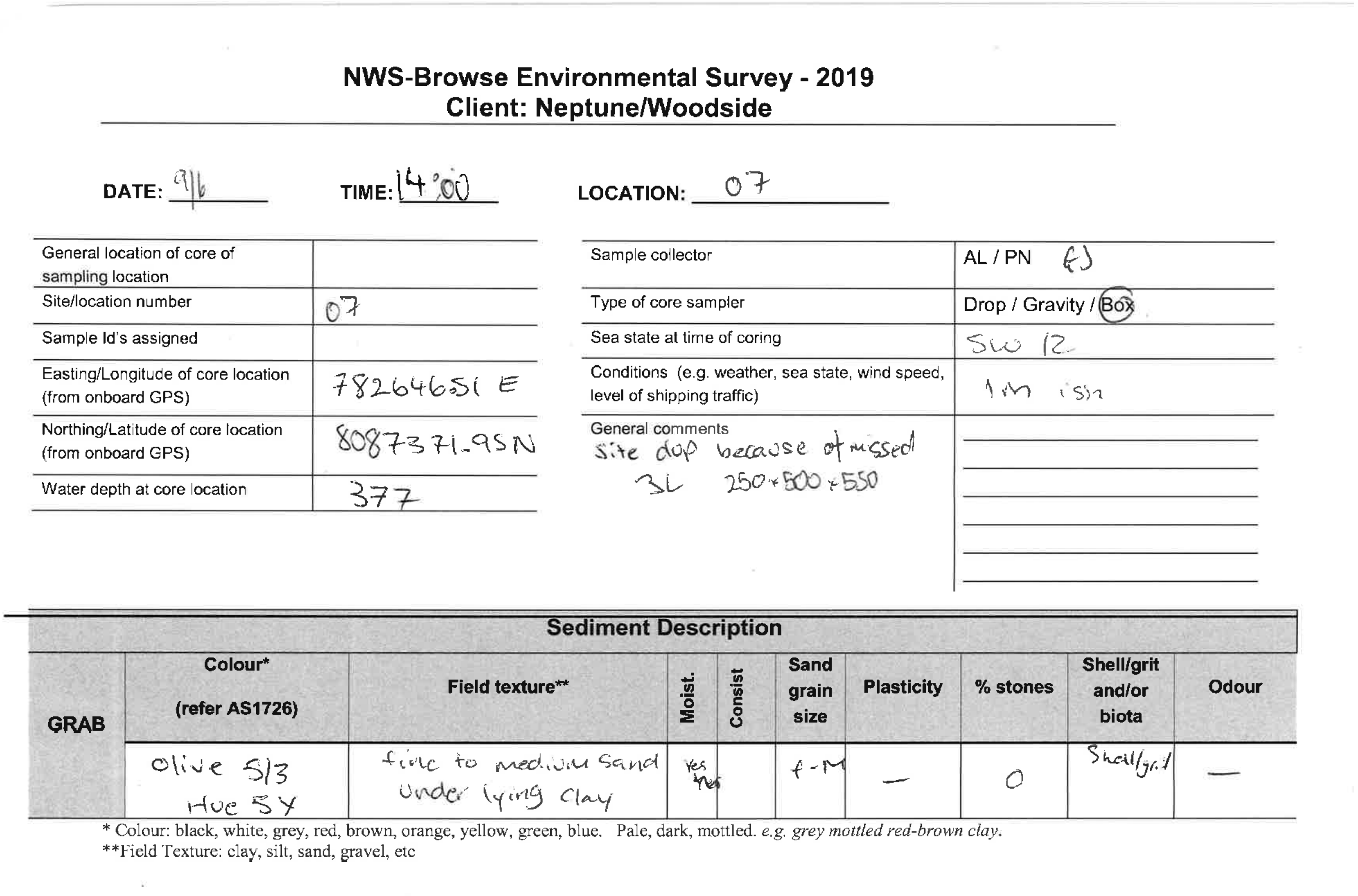
General location of core of sampling location	
Site/location number	06
Sample Id's assigned	
Easting/Longitude of core location (from onboard GPS)	206517.94E
Northing/Latitude of core location (from onboard GPS)	8159288.52N
Water depth at core location	428

Sample collector	AL / PN (G)
Type of core sampler	Drop / Gravity / [✓ Box]
Sea state at time of coring	≈ 0.5m
Conditions (e.g. weather, sea state, wind speed, level of shipping traffic)	10 11
General comments approx half full	310mm down from top of box. Sieved 1/2 ≈ 36L. ~5cm sand @ top then clay 1x white bucket

Sediment Description

GRAB	Colour* (refer AS1726)	Field texture**	Moist.	Consist	Sand grain size	Plasticity	% stones	Shell/grit and/or biota	Odour
	light yellowish brown	sand @ top clay bottom 3/4	clay = very	boundary b/w sand & clay	FINE-MED	MED-HIGH	<1%	<1%	None

* Colour: black, white, grey, red, brown, orange, yellow, green, blue. Pale, dark, mottled. *e.g. grey mottled red-brown clay.*
**Field Texture: clay, silt, sand, gravel, etc



NWS-Browse Environmental Survey - 2019
Client: Neptune/Woodside

DATE: 9/6
TIME: 14:00
LOCATION: 07

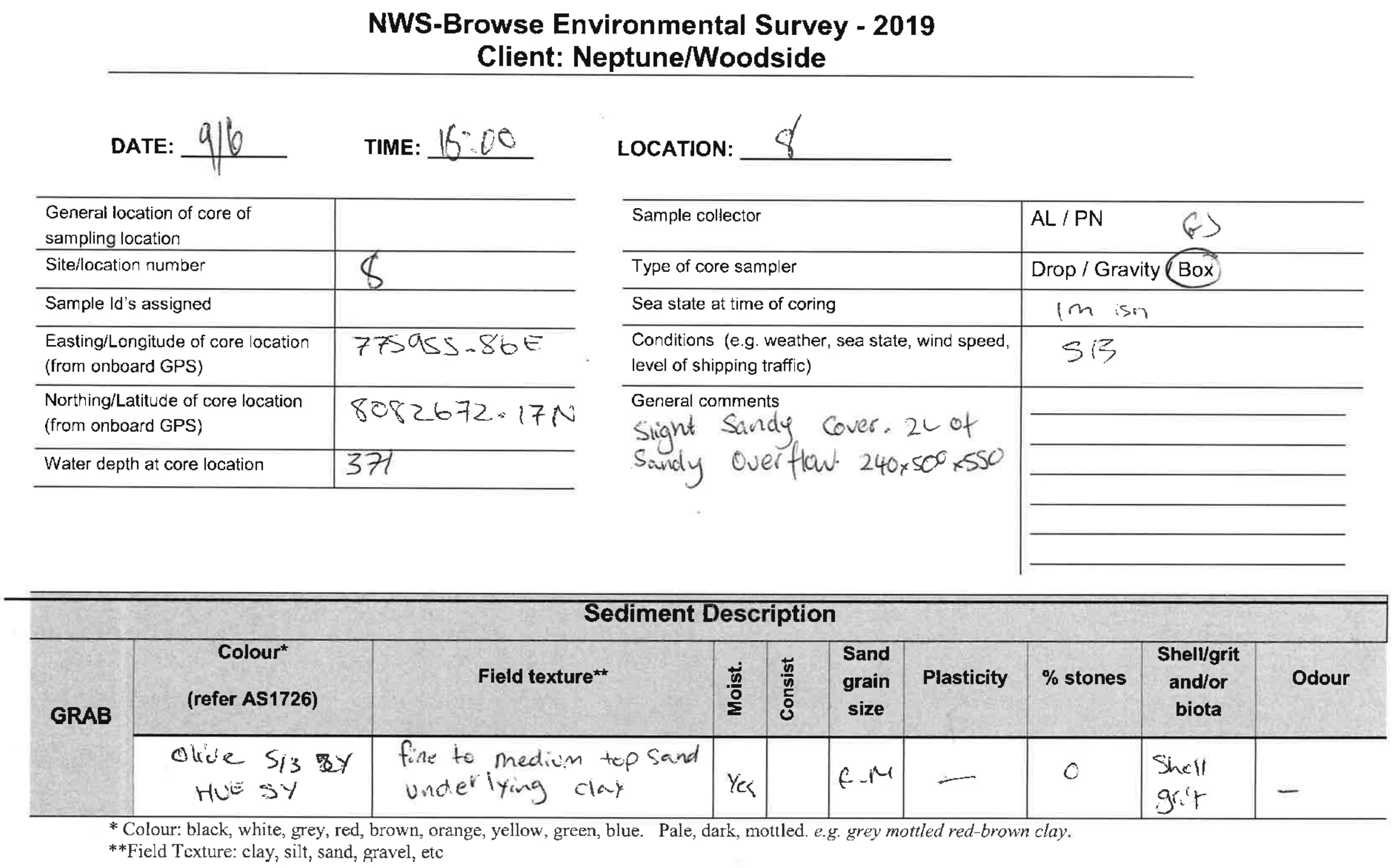
General location of core of sampling location	
Site/location number	07
Sample Id's assigned	
Easting/Longitude of core location (from onboard GPS)	782646.51 E
Northing/Latitude of core location (from onboard GPS)	8087371.95 N
Water depth at core location	377

Sample collector	AL / PN EJ
Type of core sampler	Drop / Gravity / [✓ Box]
Sea state at time of coring	SW 12
Conditions (e.g. weather, sea state, wind speed, level of shipping traffic)	1m ish
General comments Site dop because of missed 3L 250 + 500 + 550	

Sediment Description

GRAB	Colour* (refer AS1726)	Field texture**	Moist.	Consist	Sand grain size	Plasticity	% stones	Shell/grit and/or biota	Odour
	olive 5/3 Hue 5Y	fine to medium sand under lying clay	Yes Yes		f - M	–	0	Shell/grit	–

* Colour: black, white, grey, red, brown, orange, yellow, green, blue. Pale, dark, mottled. *e.g. grey mottled red-brown clay.*
**Field Texture: clay, silt, sand, gravel, etc



NWS-Browse Environmental Survey - 2019
Client: Neptune/Woodside

DATE: 9/6 TIME: 15:00 LOCATION: 8

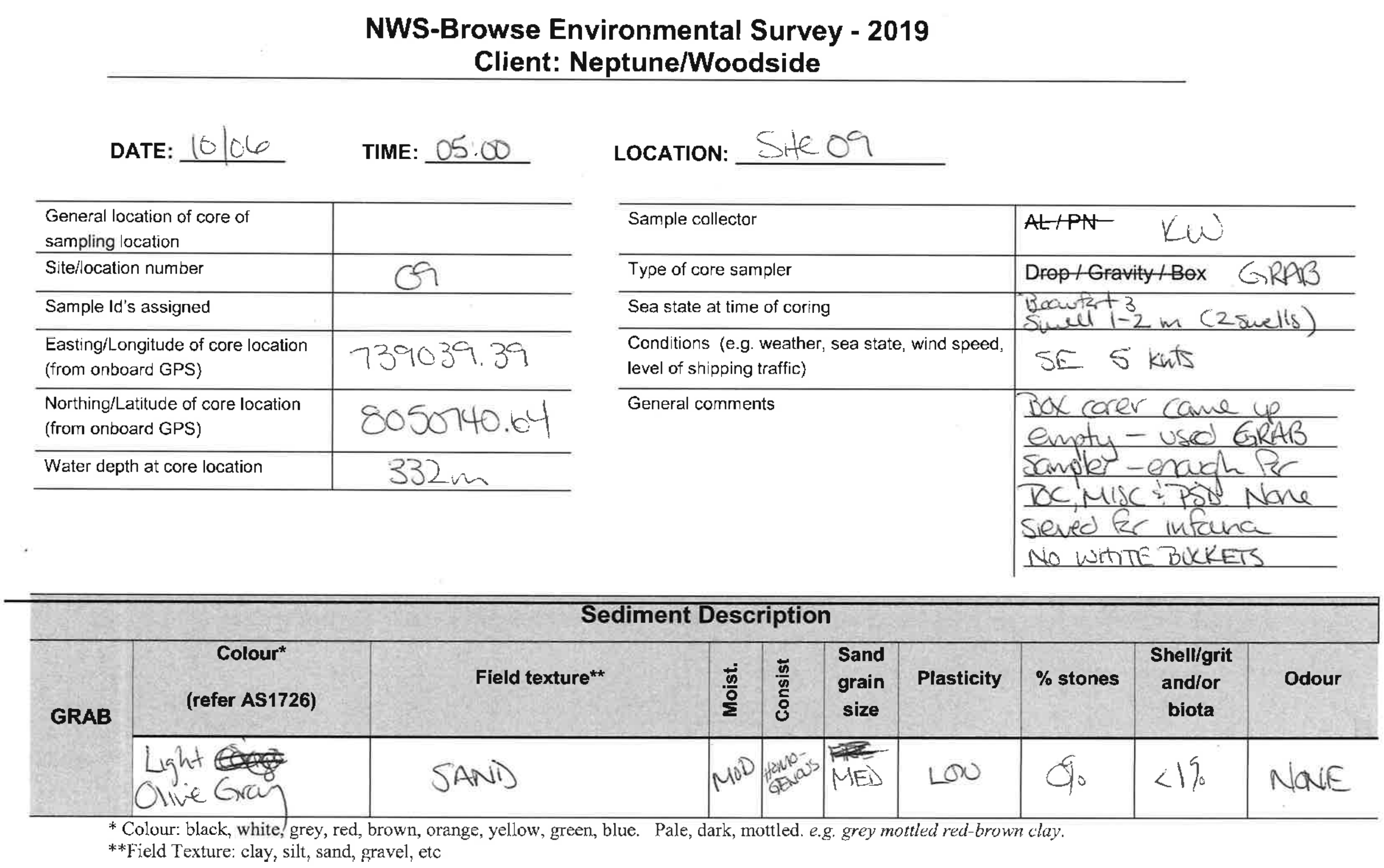
General location of core of sampling location	
Site/location number	8
Sample Id's assigned	
Easting/Longitude of core location (from onboard GPS)	775955.86E
Northing/Latitude of core location (from onboard GPS)	8082672.17N
Water depth at core location	371

Sample collector	AL / PN GJ
Type of core sampler	Drop / Gravity [✓ Box]
Sea state at time of coring	1m 5s
Conditions (e.g. weather, sea state, wind speed, level of shipping traffic)	5/3
General comments Slight Sandy Cover. 2L of Sandy overflow 240x500x550	

Sediment Description

GRAB	Colour* (refer AS1726)	Field texture**	Moist.	Consist	Sand grain size	Plasticity	% stones	Shell/grit and/or biota	Odour
	Olive 5/3 5Y HUE 5Y	fine to medium top Sand underlying clay	Yes		F-M	–	0	Shell grit	–

* Colour: black, white, grey, red, brown, orange, yellow, green, blue. Pale, dark, mottled. *e.g. grey mottled red-brown clay.*
**Field Texture: clay, silt, sand, gravel, etc



NWS-Browse Environmental Survey - 2019
Client: Neptune/Woodside

DATE: 10/06 TIME: 05:00 LOCATION: Site 09

General location of core of sampling location	
Site/location number	09
Sample Id's assigned	
Easting/Longitude of core location (from onboard GPS)	739039.39
Northing/Latitude of core location (from onboard GPS)	8050740.64
Water depth at core location	332m

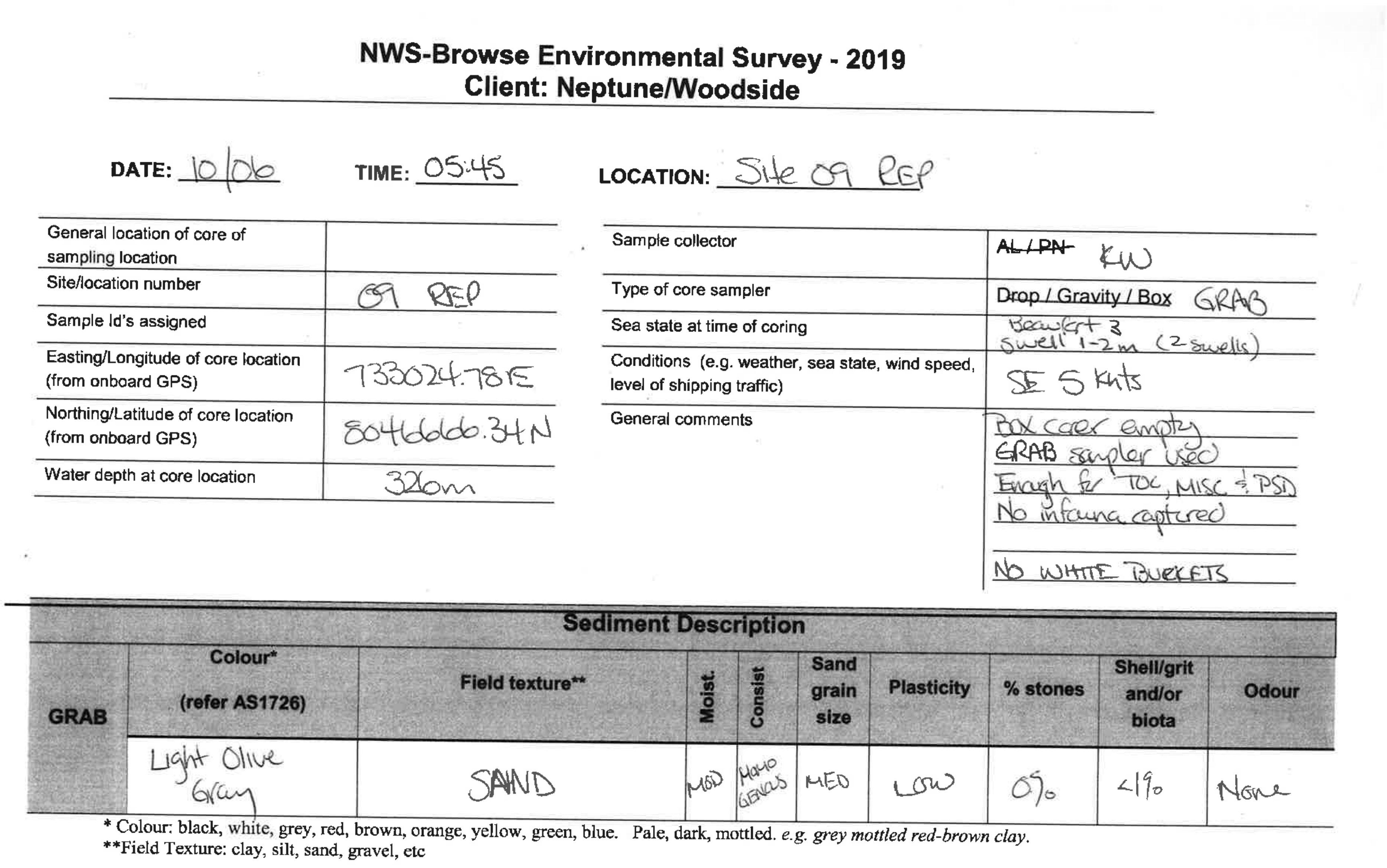
Sample collector	~~AL / PN~~ KW
Type of core sampler	~~Drop / Gravity / Box~~ GRAB
Sea state at time of coring	Beaufort 3 Swell 1-2 m (2 swells)
Conditions (e.g. weather, sea state, wind speed, level of shipping traffic)	SE 5 knts
General comments	Box corer came up empty – used GRAB sampler – enough for TOC, MISC & PSD. None sieved for infauna NO WHITE BUCKETS

Sediment Description

GRAB	Colour* (refer AS1726)	Field texture**	Moist.	Consist	Sand grain size	Plasticity	% stones	Shell/grit and/or biota	Odour
	Light ~~[illegible]~~ Olive Gray	SAND	MOD	HOMOGENOUS	~~FINE~~ MED	LOW	0%	<1%	NONE

* Colour: black, white, grey, red, brown, orange, yellow, green, blue. Pale, dark, mottled. *e.g. grey mottled red-brown clay.*

**Field Texture: clay, silt, sand, gravel, etc



NWS-Browse Environmental Survey - 2019
Client: Neptune/Woodside

DATE: 10/06 **TIME:** 05:45 **LOCATION:** Site 09 REP

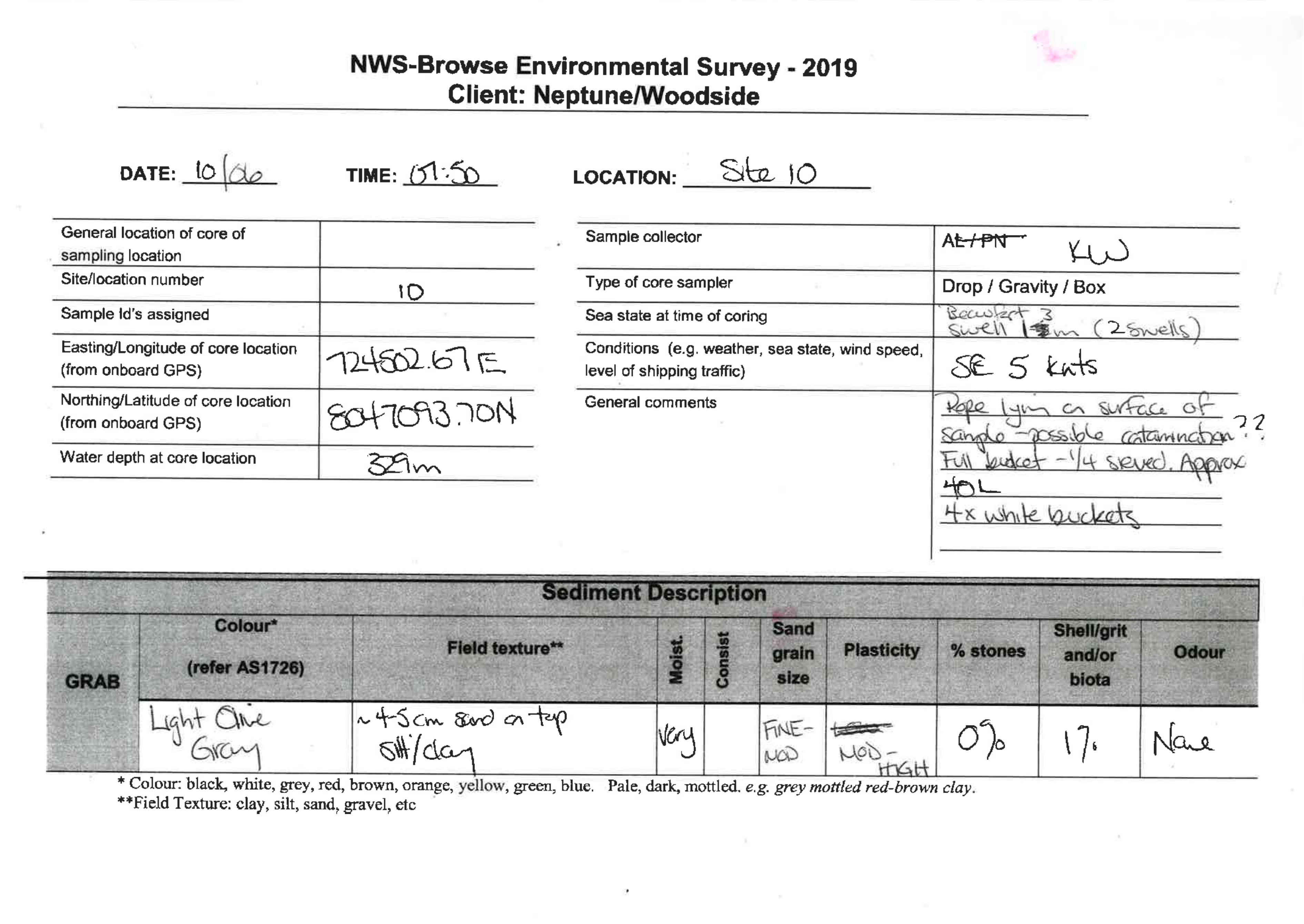
General location of core of sampling location	
Site/location number	09 REP
Sample Id's assigned	
Easting/Longitude of core location (from onboard GPS)	733024.78E
Northing/Latitude of core location (from onboard GPS)	8046666.34N
Water depth at core location	326m

Sample collector	~~AL / PN~~ KW
Type of core sampler	Drop / Gravity / Box GRAB
Sea state at time of coring	Beaufort 3 Swell 1-2m (2 swells)
Conditions (e.g. weather, sea state, wind speed, level of shipping traffic)	SE 5 knts
General comments	Box corer empty GRAB sampler used Enough for TOC, MISC & PSD No infauna captured No WHITE BUCKETS

Sediment Description

	Colour* (refer AS1726)	Field texture**	Moist.	Consist	Sand grain size	Plasticity	% stones	Shell/grit and/or biota	Odour
GRAB	Light Olive Gray	SAND	MOD	HOMOGENOUS	MED	LOW	0%	<1%	None

* Colour: black, white, grey, red, brown, orange, yellow, green, blue. Pale, dark, mottled. *e.g. grey mottled red-brown clay.*
**Field Texture: clay, silt, sand, gravel, etc



NWS-Browse Environmental Survey - 2019
Client: Neptune/Woodside

DATE: 10/06 TIME: 07:50 LOCATION: Site 10

General location of core of sampling location	
Site/location number	10
Sample Id's assigned	
Easting/Longitude of core location (from onboard GPS)	724502.67E
Northing/Latitude of core location (from onboard GPS)	8047093.70N
Water depth at core location	329m

Sample collector	~~AL / PN~~ KW
Type of core sampler	Drop / Gravity / Box
Sea state at time of coring	Beaufort 3 Swell 1m (2 swells)
Conditions (e.g. weather, sea state, wind speed, level of shipping traffic)	SE 5 knts
General comments	Rope lying on surface of sample - possible contamination ?? Full bucket - 1/4 sieved. Approx 40L 4x white buckets

Sediment Description

GRAB	Colour* (refer AS1726)	Field texture**	Moist.	Consist	Sand grain size	Plasticity	% stones	Shell/grit and/or biota	Odour
	Light Olive Gray	~4-5cm sand on top silt/clay	Very		FINE-MOD	~~[illegible]~~ MOD-HIGH	0%	1%	None

* Colour: black, white, grey, red, brown, orange, yellow, green, blue. Pale, dark, mottled. e.g. *grey mottled red-brown clay.*

**Field Texture: clay, silt, sand, gravel, etc

NWS-Browse Environmental Survey - 2019
Client: Neptune/Woodside

DATE: 9 23/5 **TIME:** 21:09 **LOCATION:** 11

General location of core of sampling location	
Site/location number	11
Sample Id's assigned	
Easting/Longitude of core location (from onboard GPS)	E 667115.75
Northing/Latitude of core location (from onboard GPS)	N 8001851.07
Water depth at core location	266m

Sample collector	AL / PN GJ
Type of core sampler	Drop / Gravity / Box / Grab
Sea state at time of coring	<1m
Conditions (e.g. weather, sea state, wind speed, level of shipping traffic)	E 5kr
General comments This grab sample is a re-attempt after failed Box sample. no sieving conducted	

Sediment Description

GRAB	Colour* (refer AS1726)	Field texture**	Moist.	Consist	Sand grain size	Plasticity	% stones	Shell/grit and/or biota	Odour
	5Y-5/3 Olive grey				Bit Fine Silty Sand	none	–	abundent Shell grit	none

* Colour: black, white, grey, red, brown, orange, yellow, green, blue. Pale, dark, mottled. *e.g. grey mottled red-brown clay.*

**Field Texture: clay, silt, sand, gravel, etc

NWS-Browse Environmental Survey - 2019
Client: Neptune/Woodside

DATE: 14/5/19 **TIME:** 0215 **LOCATION:** 11

General location of core of sampling location	
Site/location number	
Sample Id's assigned	
Easting/Longitude of core location (from onboard GPS)	667092.0
Northing/Latitude of core location (from onboard GPS)	8001852.0
Water depth at core location	260

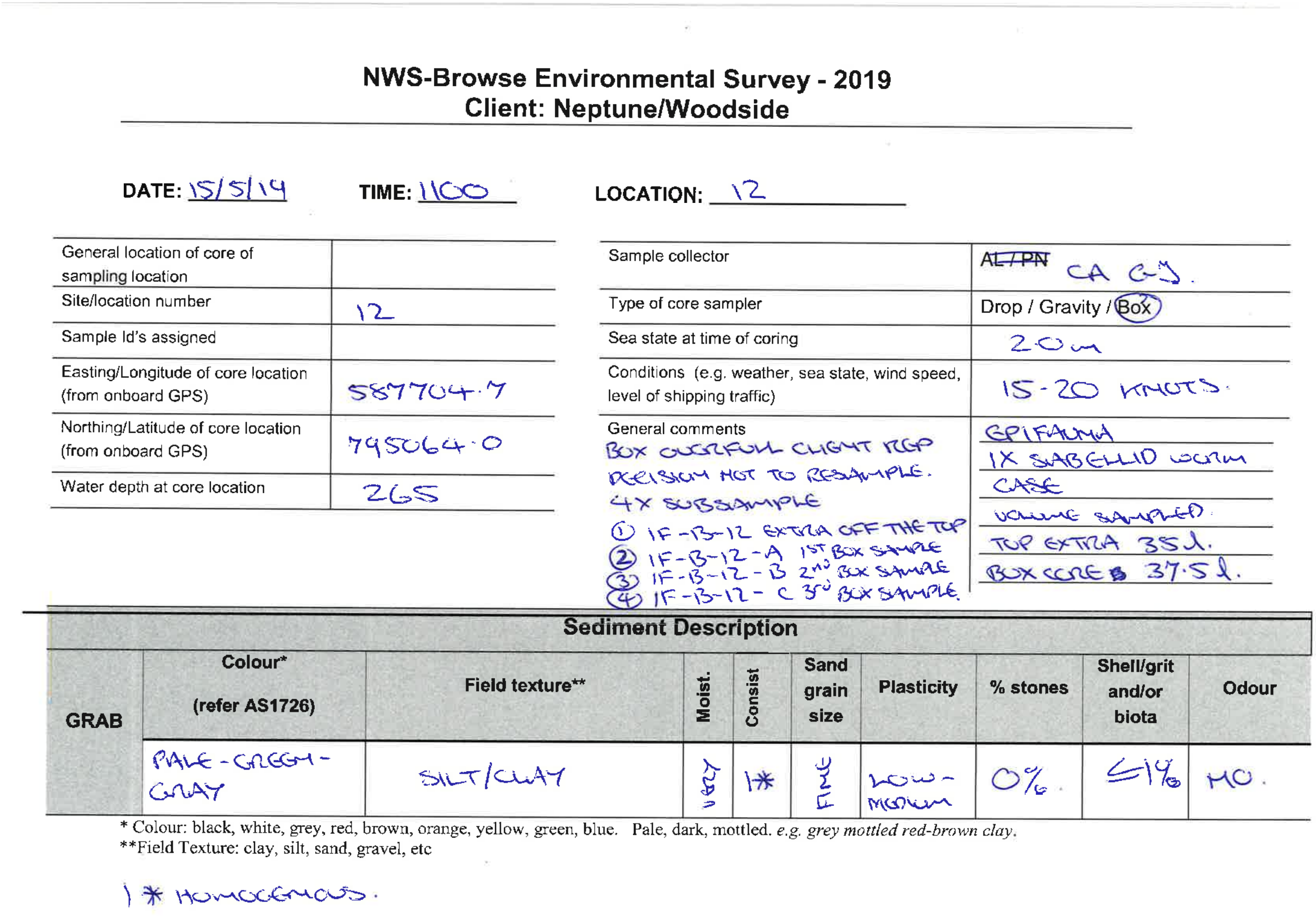
Sample collector	~~AL / PN~~ CA + G.J.
Type of core sampler	Drop / Gravity / [✓ Box]
Sea state at time of coring	≤ 2m
Conditions (e.g. weather, sea state, wind speed, level of shipping traffic)	≤ 2m 14KNOTS.
General comments	

NO SAMPLE RECOVERED.
CLIENT REP (M. VASARHMI)
DECISION NOT TO REPEAT.
AND NO ALTERNATIVE
GRAB SAMPLER ON BOARD.

Sediment Description

GRAB	Colour* (refer AS1726)	Field texture**	Moist.	Consist	Sand grain size	Plasticity	% stones	Shell/grit and/or biota	Odour

* Colour: black, white, grey, red, brown, orange, yellow, green, blue. Pale, dark, mottled. *e.g. grey mottled red-brown clay.*
**Field Texture: clay, silt, sand, gravel, etc



NWS-Browse Environmental Survey - 2019
Client: Neptune/Woodside

DATE: 15/5/19 TIME: 1100 LOCATION: 12

General location of core of sampling location	
Site/location number	12
Sample Id's assigned	
Easting/Longitude of core location (from onboard GPS)	587704.7
Northing/Latitude of core location (from onboard GPS)	795064.0
Water depth at core location	265

Sample collector	~~AL / PN~~ CA GJ.
Type of core sampler	Drop / Gravity / [✓ Box]
Sea state at time of coring	2.0 m
Conditions (e.g. weather, sea state, wind speed, level of shipping traffic)	15-20 KNOTS.
General comments BOX OVERFULL CLIENT REP DECISION NOT TO RESAMPLE. 4X SUBSAMPLE ① IF-B-12 EXTRA OFF THE TOP ② IF-B-12-A 1ST BOX SAMPLE ③ IF-B-12-B 2ND BOX SAMPLE ④ IF-B-12-C 3RD BOX SAMPLE.	EPIFAUNA 1X SABELLID WORM CASE VOLUME SAMPLED. TOP EXTRA 35 l. BOX CORE 37.5 l.

Sediment Description

GRAB	Colour* (refer AS1726)	Field texture**	Moist.	Consist	Sand grain size	Plasticity	% stones	Shell/grit and/or biota	Odour
	PALE-GREEN-GRAY	SILT/CLAY	VERY	1*	FINE	LOW-MEDIUM	0%.	≤1%	NO.

* Colour: black, white, grey, red, brown, orange, yellow, green, blue. Pale, dark, mottled. *e.g. grey mottled red-brown clay.*
**Field Texture: clay, silt, sand, gravel, etc

1* HOMOGENOUS.

NWS-Browse Environmental Survey - 2019
Client: Neptune/Woodside

DATE: 23/05/19 TIME: 08:25 LOCATION: 13

General location of core of sampling location	
Site/location number	13
Sample Id's assigned	
Easting/Longitude of core location (from onboard GPS)	505242.20
Northing/Latitude of core location (from onboard GPS)	7895813.68
Water depth at core location	261m

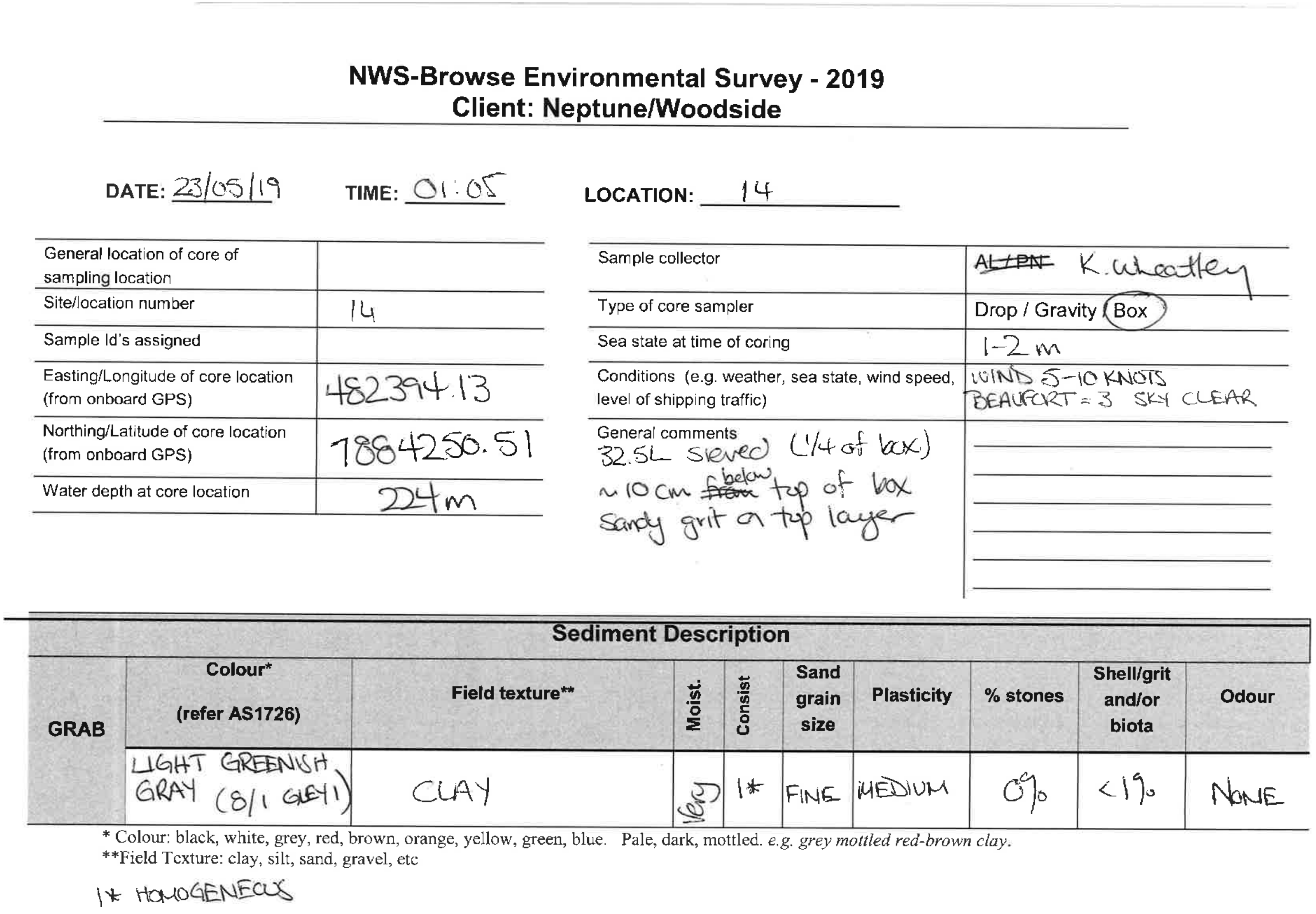
Sample collector	~~AL / PN~~ K. WHEATLEY
Type of core sampler	Drop / Gravity / [✓ Box]
Sea state at time of coring	1-2m
Conditions (e.g. weather, sea state, wind speed, level of shipping traffic)	10-15 knots Clear skies Beaufort = 4 3/8 oktas
General comments ~20cm below top of box ~75L sieved	+hermit crabs on top worm tubes, single polyp coral

Sediment Description

GRAB	Colour* (refer AS1726)	Field texture**	Moist.	Consist	Sand grain size	Plasticity	% stones	Shell/grit and/or biota	Odour
	LIGHT GREENISH GRAY (8/1 GLEY1)	clay/silt	VERY	loose on top homogeneous further down	FINE	LOW	0	1-2% all present	sulphur odour when box brought on surface

* Colour: black, white, grey, red, brown, orange, yellow, green, blue. Pale, dark, mottled. *e.g. grey mottled red-brown clay.*

**Field Texture: clay, silt, sand, gravel, etc



NWS-Browse Environmental Survey - 2019
Client: Neptune/Woodside

DATE: 23/05/19 TIME: 01:05 LOCATION: 14

General location of core of sampling location	
Site/location number	14
Sample Id's assigned	
Easting/Longitude of core location (from onboard GPS)	482394.13
Northing/Latitude of core location (from onboard GPS)	7884250.51
Water depth at core location	224m

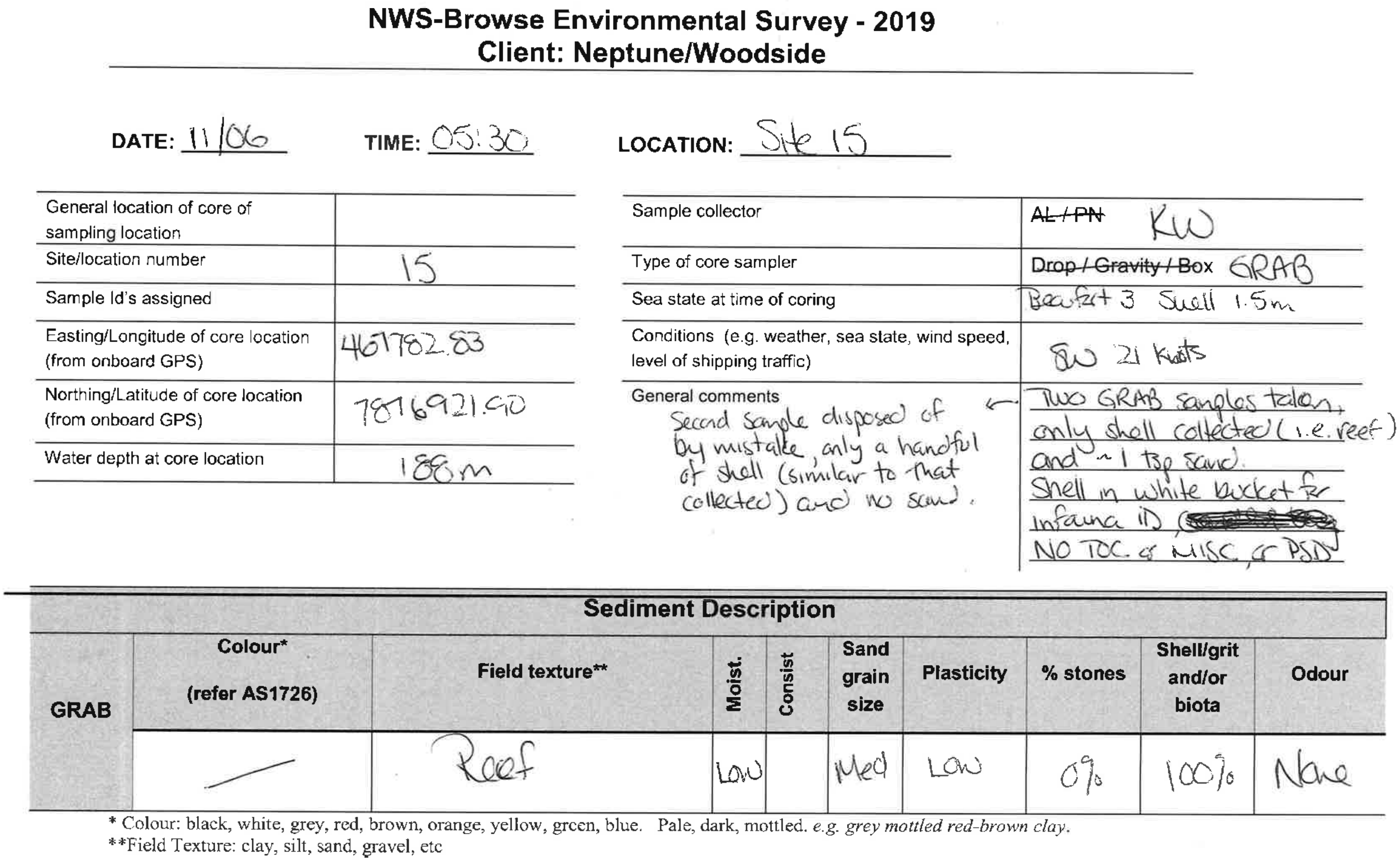
Sample collector	~~AL/PN~~ K. Wheatley
Type of core sampler	Drop / Gravity / [✓ Box]
Sea state at time of coring	1-2 m
Conditions (e.g. weather, sea state, wind speed, level of shipping traffic)	WIND 5-10 KNOTS BEAUFORT = 3 SKY CLEAR
General comments 32.5L Sieved (1/4 of box) ~10 cm ~~from~~ below top of box Sandy grit on top layer	

Sediment Description

GRAB	Colour* (refer AS1726)	Field texture**	Moist.	Consist	Sand grain size	Plasticity	% stones	Shell/grit and/or biota	Odour
	LIGHT GREENISH GRAY (8/1 GLEY1)	CLAY	Very	1*	FINE	MEDIUM	0%	<1%	NONE

* Colour: black, white, grey, red, brown, orange, yellow, green, blue. Pale, dark, mottled. *e.g. grey mottled red-brown clay.*
**Field Texture: clay, silt, sand, gravel, etc

1* HOMOGENEOUS



NWS-Browse Environmental Survey - 2019
Client: Neptune/Woodside

DATE: 11/06 TIME: 05:30 LOCATION: Site 15

General location of core of sampling location	
Site/location number	15
Sample Id's assigned	
Easting/Longitude of core location (from onboard GPS)	461782.83
Northing/Latitude of core location (from onboard GPS)	7876921.90
Water depth at core location	188m

Sample collector	~~AL / PN~~ KW
Type of core sampler	~~Drop / Gravity / Box~~ GRAB
Sea state at time of coring	Beaufort 3 Swell 1.5m
Conditions (e.g. weather, sea state, wind speed, level of shipping traffic)	SW 21 Knots
General comments Second sample disposed of by mistake, only a handful of shell (similar to that collected) and no sand. ←	Two GRAB samples taken, only shell collected (i.e. reef) and ~1 tsp sand. Shell in white bucket for infauna iD ([redacted] NO TOC or MISC or PSD

Sediment Description

GRAB	Colour* (refer AS1726)	Field texture**	Moist.	Consist	Sand grain size	Plasticity	% stones	Shell/grit and/or biota	Odour
	—	Reef	Low		Med	Low	0%	100%	None

* Colour: black, white, grey, red, brown, orange, yellow, green, blue. Pale, dark, mottled. *e.g. grey mottled red-brown clay.*

**Field Texture: clay, silt, sand, gravel, etc

NWS-Browse Environmental Survey - 2019
Client: Neptune/Woodside

DATE: 19-5-19 **TIME:** 0930 **LOCATION:** 16

General location of core of sampling location	
Site/location number	16
Sample Id's assigned	
Easting/Longitude of core location (from onboard GPS)	443729.13
Northing/Latitude of core location (from onboard GPS)	7876108.24
Water depth at core location	196m

Sample collector	~~AL / PN~~ C. ASTBURY
Type of core sampler	Drop / Gravity / [✓ Box]
Sea state at time of coring	1m
Conditions (e.g. weather, sea state, wind speed, level of shipping traffic)	5-10 KNOTS.
General comments BOX CORER FULL BY ≃ 3–5cm NO OBVIOUS LIVE EPIFAUNA SURFACE PARTIALLY WASHED OUT COURSE SAND GRIT LAYER LEFT ON SURFACE. REMAINING BOX CORE CONTENT CLAY.	SAMPLES 1F-B-16 = EXTRA ON TOP OF BOX CORE 7.5 l SIEVED 1F-B-16 A+B = BOX CORE SAMPLE 37.5 l SIEVED. TOTAL = 45 l.

Sediment Description

GRAB	Colour* (refer AS1726)	Field texture**	Moist.	Consist	Sand grain size	Plasticity	% stones	Shell/grit and/or biota	Odour
	LIGHT BROWN ORANGE	CLAY 100%	VERY	1*	FINE	LOW MEDIUM	0%	<1%	NO

* Colour: black, white, grey, red, brown, orange, yellow, green, blue. Pale, dark, mottled. *e.g. grey mottled red-brown clay.*

**Field Texture: clay, silt, sand, gravel, etc

1* HOMOGENEOUS

NWS-Browse Environmental Survey - 2019
Client: Neptune/Woodside

DATE: 19/5

TIME: 6:00
FINISHED 0830

LOCATION: 17

General location of core of sampling location	
Site/location number	17
Sample Id's assigned	
Easting/Longitude of core location (from onboard GPS)	431330.16
Northing/Latitude of core location (from onboard GPS)	7857650.11
Water depth at core location	132

SIEVED A 1/4 BOX IN AGREEMENT WITH CLIENT REP SO WE CAN GET AN ADDITIONAL SITE DONE BEFORE DEPARTING.

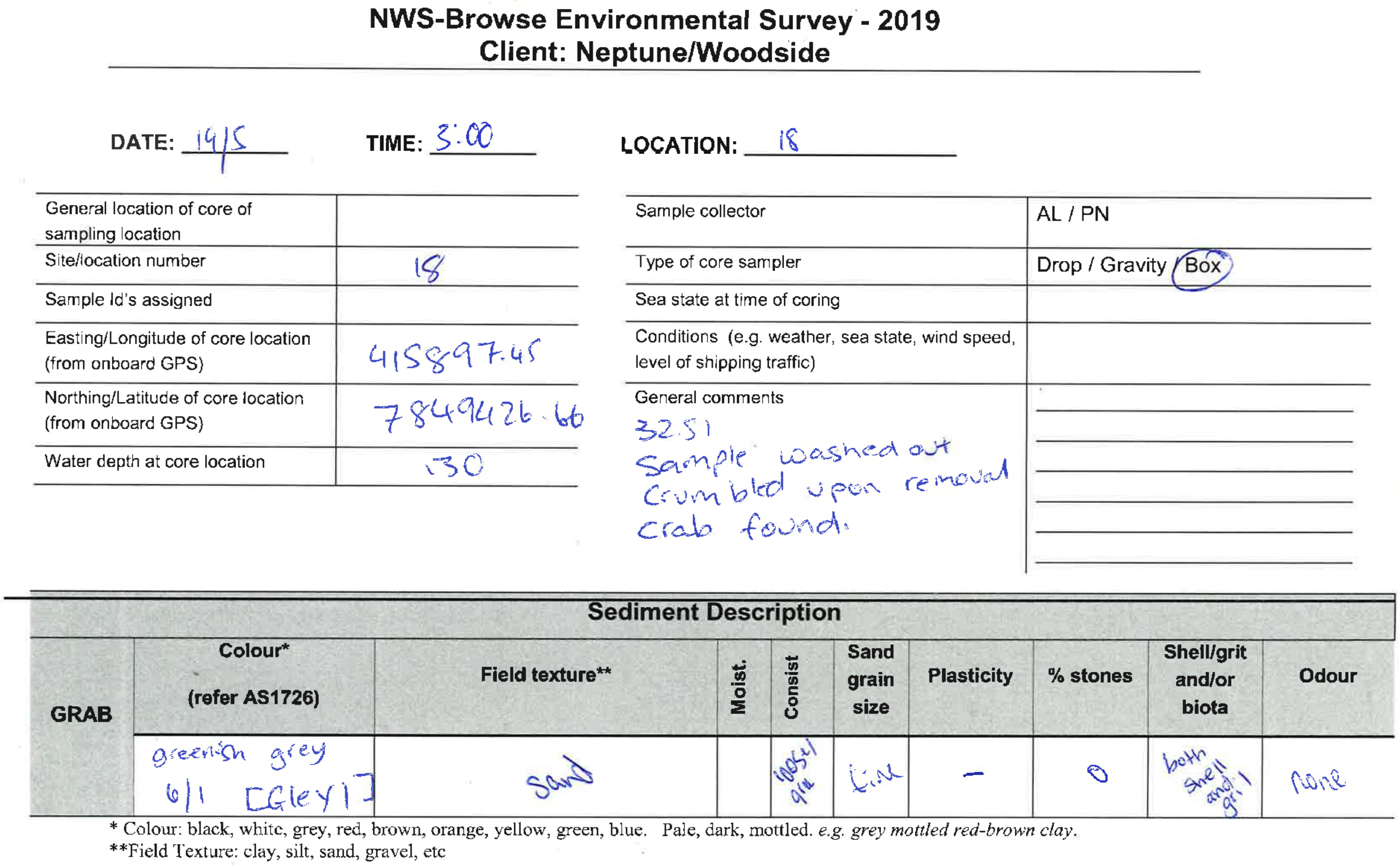
Sample collector	AL / PN GS + CA.
Type of core sampler	Drop / Gravity / [✓ Box]
Sea state at time of coring	
Conditions (e.g. weather, sea state, wind speed, level of shipping traffic)	<2m (calm) NE 3
General comments Box overflow overflow volume 6.6L 50 l SIEVED. EASIER TO SIEVE.	SAMPLE 1F-B-17.

Sediment Description

GRAB	Colour* (refer AS1726)	Field texture**	Moist.	Consist	Sand grain size	Plasticity	% stones	Shell/grit and/or biota	Odour
	LIGHT BROWN	SAND/CLAY	VERY	*1	FINE	LOW -MEDIUM	0%	<1%	NO.

* Colour: black, white, grey, red, brown, orange, yellow, green, blue. Pale, dark, mottled. *e.g. grey mottled red-brown clay.*
**Field Texture: clay, silt, sand, gravel, etc

*1 HOMOGENOUS



NWS-Browse Environmental Survey - 2019
Client: Neptune/Woodside

DATE: 19/5 TIME: 3:00 LOCATION: 18

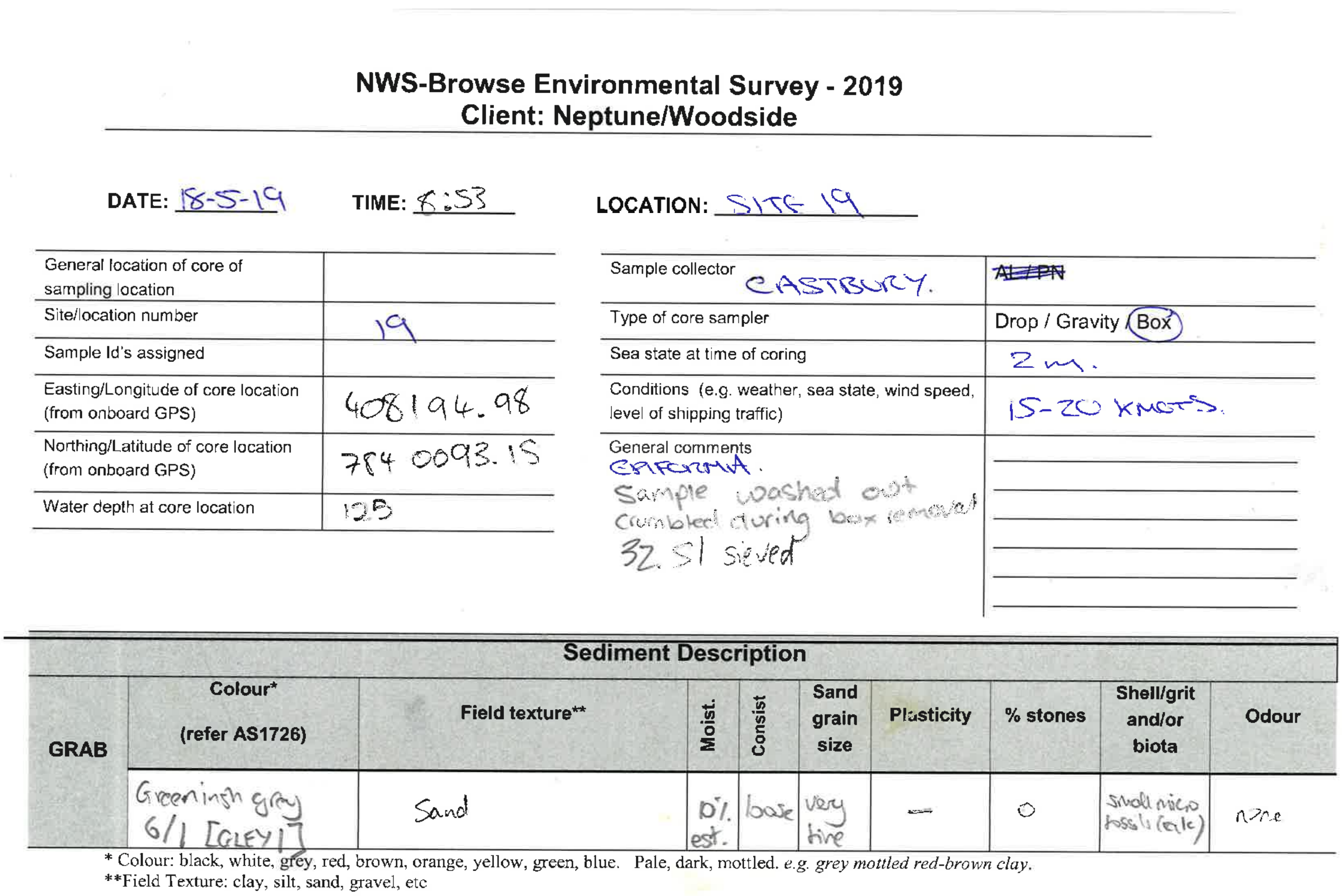
General location of core of sampling location	
Site/location number	18
Sample Id's assigned	
Easting/Longitude of core location (from onboard GPS)	415897.45
Northing/Latitude of core location (from onboard GPS)	7849426.66
Water depth at core location	130

Sample collector	AL / PN
Type of core sampler	Drop / Gravity / [✓ Box]
Sea state at time of coring	
Conditions (e.g. weather, sea state, wind speed, level of shipping traffic)	
General comments 32.51 Sample washed out Crumbled upon removal Crab found.	

Sediment Description

GRAB	Colour* (refer AS1726)	Field texture**	Moist.	Consist	Sand grain size	Plasticity	% stones	Shell/grit and/or biota	Odour
	greenish grey 6/1 [Gley 1]	Sand		loose/ gra	fine	–	0	both shell and grit	none

* Colour: black, white, grey, red, brown, orange, yellow, green, blue. Pale, dark, mottled. *e.g. grey mottled red-brown clay.*
**Field Texture: clay, silt, sand, gravel, etc



NWS-Browse Environmental Survey - 2019
Client: Neptune/Woodside

DATE: 18-5-19 TIME: 8:53 LOCATION: SITE 19

General location of core of sampling location	
Site/location number	19
Sample Id's assigned	
Easting/Longitude of core location (from onboard GPS)	408194.98
Northing/Latitude of core location (from onboard GPS)	784 0093.15
Water depth at core location	125

Sample collector CASTBURY.	~~AL/PN~~
Type of core sampler	Drop / Gravity / [✓ Box]
Sea state at time of coring	2 m.
Conditions (e.g. weather, sea state, wind speed, level of shipping traffic)	15-20 KNOTS.
General comments EPIFAUNA. Sample washed out crumbled during box removal 32.5 l sieved	

Sediment Description									
GRAB	Colour* (refer AS1726)	Field texture**	Moist.	Consist	Sand grain size	Plasticity	% stones	Shell/grit and/or biota	Odour
	Greeninsh gray 6/1 [GLEY1]	Sand	10% est.	loose	very fine	—	0	small micro fossils (calc)	none

* Colour: black, white, grey, red, brown, orange, yellow, green, blue. Pale, dark, mottled. *e.g. grey mottled red-brown clay.*

**Field Texture: clay, silt, sand, gravel, etc

Appendix E Infauna Abundance Data (Raw and Standardised)

Raw and Standardised Benthic Infauna Data 2019

Raw abundance data (as per total sample volume sieved)							Site	0	1	2	3	5	6	7	8	10	12	13	14	15	16	17	18	19	Total
Phylum	Subphylum	Class	Subclass	Order	Suborder (so) / Superfamily (sf)	Family / Other Taxa	Common Name																		
Annelida	undifferentiated	Polychaeta	Palpata	Aciculata	Eunicida	Cirratulidae	Spagetti worms															1			**1**
Annelida	undifferentiated	Polychaeta	Palpata	Aciculata	Eunicida	Dorveliidae	Dorveliid worms				1														**1**
Annelida	undifferentiated	Polychaeta	Palpata	Aciculata	Eunicida	Eunicidae	Eunicid worms		1																**1**
Annelida	undifferentiated	Polychaeta	Palpata	Aciculata	Eunicida	Lumbrineridae	Lumbrinerid worms	3																2	**5**
Annelida	undifferentiated	Polychaeta	Palpata	Aciculata	Eunicida	Onuphidae	Onuphid worms	1			1						3				1	1			**7**
Annelida	undifferentiated	Polychaeta	Palpata	Aciculata	Phyllodocida	Acoetidae	Acoetid worms											1							**1**
Annelida	undifferentiated	Polychaeta	Palpata	Aciculata	Phyllodocida	Nephtyidae	Nephtyid worms										2	1					1	1	**5**
Annelida	undifferentiated	Polychaeta	Palpata	Aciculata	Phyllodocida	Pilargidae	Pilargid worms										3								**3**
Annelida	undifferentiated	Polychaeta	Palpata	Aciculata	Phyllodocida	Sigalionidae	Sigalionid worms								1		2				1		2		**6**
Annelida	undifferentiated	Polychaeta	Palpata	Canalipalpata	Sabellida	Oweniidae	Oweniid worms			1	1										3	1			**6**
Annelida	undifferentiated	Polychaeta	Palpata	Canalipalpata	Spionida	Megalonidae	Megalonid worms									1						1			**2**
Annelida	undifferentiated	Polychaeta	Palpata	Canalipalpata	Spionida	Poecilochaetidae	Poecilochaetid worms											1							**1**
Annelida	undifferentiated	Polychaeta	Palpata	Canalipalpata	Spionida	Spionidae	Spionid worms				1						3					3		1	**8**
Annelida	undifferentiated	Polychaeta	Palpata	Canalipalpata	Terebellida	Ampharetidae	Ampharetid worms		1		2														**3**
Annelida	undifferentiated	Polychaeta	Palpata	Canalipalpata	Terebellida	Flabelligeridae	Flabelligerid worms											1			1				**2**
Annelida	undifferentiated	Polychaeta	Palpata	Canalipalpata	Terebellida	Sternaspidae	Sternaspid worms															2			**2**
Annelida	undifferentiated	Polychaeta	Palpata	Canalipalpata	Terebellida	Terrebellidae	Terebellid worms				3							1							**4**
Annelida	undifferentiated	Polychaeta	Palpata	Canalipalpata	Terebellida	Trichobranchidae	Trichobranchid worms															1			**1**
Annelida	undifferentiated	Polychaeta	Scolecida	Scolecida	Scolecida	Maldanidae	Bamboo worms		1			1						1							**3**
Annelida	undifferentiated	Polychaeta	undifferentiated	undifferentiated	undifferentiated	Polychaeta unid. Segment	Polychaet worms				1		1	1	2		1				1				**7**
Annelida	undifferentiated	Polychaeta	undifferentiated	undifferentiated	undifferentiated	Polychaeta unid. Fam. 1	Polychaet worms		1																**1**
Arthropoda	Chelicerata	Pycnogonida	undifferentiated	undifferentiated	undifferentiated	Pycnogonida sp.	Sea spiders															1			**1**
Arthropoda	Crustacea	Hexanauplia	undifferentiated	Pedunculata	undifferentiated	Pedunculata	Goose barnacles																	1	**1**
Arthropoda	Crustacea	Malocostraca	Eumalocostraca	Amphipoda	So: Gammaridea	Amphipoda Fam. 1	Amphipods														3				**3**
Arthropoda	Crustacea	Malocostraca	Eumalocostraca	Amphipoda	So: Gammaridea	Amphipoda Fam. 2	Amphipods														1				**1**
Arthropoda	Crustacea	Malocostraca	Eumalocostraca	Amphipoda	So: Gammaridea	Amphipoda Fam. 3	Amphipods						1												**1**
Arthropoda	Crustacea	Malocostraca	Eumalocostraca	Amphipoda	So: Gammaridea	Amphipoda Fam. 4	Amphipods											1							**1**
Arthropoda	Crustacea	Malocostraca	Eumalocostraca	Amphipoda	undifferentiated	Corophiida	Corophiid amphipods											1							**1**
Arthropoda	Crustacea	Malocostraca	Eumalocostraca	Isopoda	So. Anthuridea	Anthuridae	Anthurid isopods															1			**1**
Arthropoda	Crustacea	Malocostraca	Eumalocostraca	Isopoda	So: Cymothoida	Cirolanidae	Cirolanid isopods			1															**1**
Arthropoda	Crustacea	Malocostraca	Peracarida	Tanaidacea	undifferentiated	Apseudidae	Apseudid tanaids											2				1		1	**4**
Arthropoda	Crustacea	Malocostraca	undifferentiated	Decapoda	undifferentiated	Alpheidae	Snapping shrimp															1			**1**
Arthropoda	Crustacea	Malocostraca	undifferentiated	Decapoda	undifferentiated	Callianassidae	Ghost shrimps											4	6		1		1		**12**
Arthropoda	Crustacea	Malocostraca	undifferentiated	Decapoda	undifferentiated	Diogenidae	Hermit crabs											4							**4**
Arthropoda	Crustacea	Malocostraca	undifferentiated	Decapoda	undifferentiated	Mysidae	Mysids											1							**1**
Arthropoda	Crustacea	Malocostraca	undifferentiated	Decapoda	undifferentiated	Euphausiidae	Pacific krill												5						**5**
Arthropoda	Crustacea	Malocostraca	undifferentiated	Decapoda	undifferentiated	Palinuridae	Oriental spear lobster					1											1		**2**
Chordata	Tunicata	undifferentiated	undifferentiated	undifferentiated	undifferentiated	Tunicata sp.	Sea squirts with sand														1				**1**
Chordata	Tunicata	undifferentiated	undifferentiated	undifferentiated	undifferentiated	Ascidian (stalked)	Stalked Ascidian					1													**1**
Echinodermata	Asterozoa	Stelleroidea	Ophiuroidea	Ophiurida	undifferentiated	Ophionereididae	Ophionereid brittle stars										1	3						1	**5**
Echinodermata	Asterozoa	Stelleroidea	Ophiuroidea	Ophiurida	undifferentiated	Ophiurida sp. A	Brittle stars				1				2						1				**4**
Echinodermata	Asterozoa	Stelleroidea	Ophiuroidea	Ophiurida	undifferentiated	Ophiurida sp. B	Brittle stars												1						**1**
Echinodermata	Echinozoa	Echinoidea	Euechinoidea	undifferentiated	undifferentiated	Euechinoidea sp.	Sea Urchin		1																**1**
Mollusca	Diasoma	Bivalvia	Heterodonta	undifferentiated	Sf. Mactroidea	Mactridae	Mactrid clams					1													**1**
Nemertia	Nemertia	Enopla	undifferentiated	Hoplonemertea	undifferentiated	Hoplonemertea spp	Ribbon worms										1								**1**
Sipuncula	undifferentiated	Sipunculidea	undifferentiated	Sipunculiformes	undifferentiated	Sipunculiformes sp A	Peanut worms				1							21						1	**23**
Sipuncula	undifferentiated	Sipunculidea	undifferentiated	Sipunculiformes	undifferentiated	Sipunculiformes sp B	Peanut worms	1																	**1**
							Total Abundance	**5**	**5**	**2**	**12**	**4**	**2**	**1**	**5**	**1**	**16**	**43**	**12**	**0**	**14**	**14**	**5**	**8**	
							Taxa Richness	**3**	**5**	**2**	**9**	**4**	**2**	**1**	**3**	**1**	**8**	**14**	**3**	**0**	**10**	**11**	**4**	**7**	

Abundance data standardised to volume of 0.1m3 (100L)							Site	0	1	2	3	5	6	7	8	10	12	13	14	15	16	17	18	19	Total
Phylum	**Subphylum**	**Class**	**Subclass**	**Order**	**Suborder (so) / Superfamily (sf)**	**Family / Other Taxa**	**Common Name**																		
Annelida	undifferentiated	Polychaeta	Palpata	Aciculata	Eunicida	Cirratulidae	Spagetti worms															2			**2**
Annelida	undifferentiated	Polychaeta	Palpata	Aciculata	Eunicida	Dorveliidae	Dorveliid worms				3														**3**
Annelida	undifferentiated	Polychaeta	Palpata	Aciculata	Eunicida	Eunicidae	Eunicid worms		3																**3**
Annelida	undifferentiated	Polychaeta	Palpata	Aciculata	Eunicida	Lumbrineridae	Lumbrinerid worms	5																6	**11**
Annelida	undifferentiated	Polychaeta	Palpata	Aciculata	Eunicida	Onuphidae	Onuphid worms	2			3						4				2	2			**13**
Annelida	undifferentiated	Polychaeta	Palpata	Aciculata	Phyllodocida	Acoetidae	Acoetid worms											1							**1**
Annelida	undifferentiated	Polychaeta	Palpata	Aciculata	Phyllodocida	Nephtyidae	Nephtyid worms										3	1					4	4	**1**
Annelida	undifferentiated	Polychaeta	Palpata	Aciculata	Phyllodocida	Pilargidae	Pilargid worms										4								**4**
Annelida	undifferentiated	Polychaeta	Palpata	Aciculata	Phyllodocida	Sigalionidae	Sigalionid worms								2		3				2		6		**13**
Annelida	undifferentiated	Polychaeta	Palpata	Canalipalpata	Sabellida	Oweniidae	Oweniid worms			2	3										7	2			**14**
Annelida	undifferentiated	Polychaeta	Palpata	Canalipalpata	Spionida	Megalonidae	Megalonid worms									3						2			**5**
Annelida	undifferentiated	Polychaeta	Palpata	Canalipalpata	Spionida	Poecilochaetidae	Poecilochaetid worms											1							**1**
Annelida	undifferentiated	Polychaeta	Palpata	Canalipalpata	Spionida	Spionidae	Spionid worms				3						4					6		4	**16**
Annelida	undifferentiated	Polychaeta	Palpata	Canalipalpata	Terebellida	Ampharetidae	Ampharetid worms		3		5														**8**
Annelida	undifferentiated	Polychaeta	Palpata	Canalipalpata	Terebellida	Flabelligeridae	Flabelligerid worms											1			2				**4**
Annelida	undifferentiated	Polychaeta	Palpata	Canalipalpata	Terebellida	Sternaspidae	Sternaspid worms															4			**4**
Annelida	undifferentiated	Polychaeta	Palpata	Canalipalpata	Terebellida	Terrebellidae	Terebellid worms				8							1							**9**
Annelida	undifferentiated	Polychaeta	Palpata	Canalipalpata	Terebellida	Trichobranchidae	Trichobranchid worms															2			**2**
Annelida	undifferentiated	Polychaeta	Scolecida	Scolecida	Scolecida	Maldanidae	Bamboo worms		3			1						1							**5**
Annelida	undifferentiated	Polychaeta	undifferentiated	undifferentiated	undifferentiated	Polychaeta unid. Segment	Polychaet worms				3		3	1	3		1				2				**13**
Annelida	undifferentiated	Polychaeta	undifferentiated	undifferentiated	undifferentiated	Polychaeta unid. Fam. 1	Polychaet worms		3																**3**
Arthropoda	Chelicerata	Pycnogonida	undifferentiated	undifferentiated	undifferentiated	Pycnogonida sp.	Sea spiders															2			**2**
Arthropoda	Crustacea	Hexanauplia	undifferentiated	Pedunculata	undifferentiated	Pedunculata	Goose barnacles																	4	**4**
Arthropoda	Crustacea	Malocostraca	Eumalocostraca	Amphipoda	So: Gammaridea	Amphipoda Fam. 1	Amphipods														7				**7**
Arthropoda	Crustacea	Malocostraca	Eumalocostraca	Amphipoda	So: Gammaridea	Amphipoda Fam. 2	Amphipods														2				**2**
Arthropoda	Crustacea	Malocostraca	Eumalocostraca	Amphipoda	So: Gammaridea	Amphipoda Fam. 3	Amphipods						3												**3**
Arthropoda	Crustacea	Malocostraca	Eumalocostraca	Amphipoda	So: Gammaridea	Amphipoda Fam. 4	Amphipods											1							**1**
Arthropoda	Crustacea	Malocostraca	Eumalocostraca	Amphipoda	undifferentiated	Corophiida	Corophiid amphipods											1							**1**
Arthropoda	Crustacea	Malocostraca	Eumalocostraca	Isopoda	So. Anthuridea	Anthuridae	Anthurid isopods															2			**2**
Arthropoda	Crustacea	Malocostraca	Eumalocostraca	Isopoda	So: Cymothoida	Cirolanidae	Cirolanid isopods			2															**2**
Arthropoda	Crustacea	Malocostraca	Peracarida	Tanaidacea	undifferentiated	Apseudidae	Apseudid tanaids											3				2		4	**8**
Arthropoda	Crustacea	Malocostraca	undifferentiated	Decapoda	undifferentiated	Alpheidae	Snapping shrimp															2			**2**
Arthropoda	Crustacea	Malocostraca	undifferentiated	Decapoda	undifferentiated	Callianassidae	Ghost shrimps											5	18		2		4		**30**
Arthropoda	Crustacea	Malocostraca	undifferentiated	Decapoda	undifferentiated	Diogenidae	Hermit crabs											5							**5**
Arthropoda	Crustacea	Malocostraca	undifferentiated	Decapoda	undifferentiated	Mysidae	Mysids											1							**1**
Arthropoda	Crustacea	Malocostraca	undifferentiated	Decapoda	undifferentiated	Euphausiidae	Pacific krill												15						**15**
Arthropoda	Crustacea	Malocostraca	undifferentiated	Decapoda	undifferentiated	Palinuridae	Oriental spear lobster					1											4		**4**
Chordata	Tunicata	undifferentiated	undifferentiated	undifferentiated	undifferentiated	Tunicata sp.	Sea squirts with sand														2				**2**
Chordata	Tunicata	undifferentiated	undifferentiated	undifferentiated	undifferentiated	Ascidian (stalked)	Stalked Ascidian					1													**1**
Echinodermata	Asterozoa	Stelleroidea	Ophiuroidea	Ophiurida	undifferentiated	Ophionereididae	Ophionereid brittle stars										1	4						4	**8**
Echinodermata	Asterozoa	Stelleroidea	Ophiuroidea	Ophiurida	undifferentiated	Ophiurida sp. A	Brittle stars				3				3						2				**8**
Echinodermata	Asterozoa	Stelleroidea	Ophiuroidea	Ophiurida	undifferentiated	Ophiurida sp. B	Brittle stars												4						**4**
Echinodermata	Echinozoa	Echinoidea	Euechinoidea	undifferentiated	undifferentiated	Euechinoidea sp.	Sea Urchin		3																**3**
Mollusca	Diasoma	Bivalvia	Heterodonta	undifferentiated	Sf. Mactroidea	Mactridae	Mactrid clams					1													**1**
Nemertia	Nemertia	Enopla	undifferentiated	Hoplonemertea	undifferentiated	Hoplonemertea spp	Ribbon worms										1								**1**
Sipuncula	undifferentiated	Sipunculidea	undifferentiated	Sipunculiformes	undifferentiated	Sipunculiformes sp A	Peanut worms				3							28						4	**34**
Sipuncula	undifferentiated	Sipunculidea	undifferentiated	Sipunculiformes	undifferentiated	Sipunculiformes sp B	Peanut worms	2																	**2**
							Total Abundance	**8**	**14**	**5**	**30**	**3**	**6**	**1**	**8**	**3**	**22**	**57**	**38**	**0**	**31**	**28**	**17**	**29**	
							Taxa Richness	**3**	**5**	**2**	**9**	**4**	**2**	**1**	**3**	**1**	**8**	**14**	**3**	**0**	**10**	**11**	**4**	**7**	

Appendix F Laboratory Reports

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order : **EP1902492**
Amendment : **1**
Client : **WorleyParsons Services Pty Ltd**
Contact : MR PAUL NICHOLS
Address : LEVEL 4, 600 MURRAY STREET
WEST PERTH WA, AUSTRALIA 6005
Telephone : +61 08 9278 8111
Project : 401012-02648
Order number : 401012-02648
C-O-C number : ----
Sampler : Brendan Hirniak
Site : ----
Quote number : EP/618/18 V2
No. of samples received : 6
No. of samples analysed : 6

Page : 1 of 9
Laboratory : Environmental Division Perth
Contact : Marnie Thomsett
Address : 26 Rigali Way Wangara WA Australia 6065
Telephone : 08 9406 1311
Date Samples Received : 19-Mar-2019 08:00
Date Analysis Commenced : 20-Mar-2019
Issue Date : 01-Apr-2019 12:14

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Canhuang Ke	Inorganics Supervisor	Perth Inorganics, Wangara, WA
David Viner	SENIOR LAB TECH	Perth Organics, Wangara, WA
Efua Wilson	Metals Chemist	Perth Inorganics, Wangara, WA
Ivan Taylor	Analyst	Sydney Inorganics, Smithfield, NSW
Mark Kinnin	Laboratory Technician	Perth Inorganics, Wangara, WA

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Work Order : EP1902492 Amendment 1
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EG093 conducted by ALS Sydney, NATA accreditation no. 825, site no 10911.
- Benzo(a)pyrene Toxicity Equivalent Quotient (TEQ) per the NEPM (2013) is the sum total of the concentration of the eight carcinogenic PAHs multiplied by their Toxicity Equivalence Factor (TEF) relative to Benzo(a)pyrene. TEF values are provided in brackets as follows: Benz(a)anthracene (0.1), Chrysene (0.01), Benzo(b+j) & Benzo(k)fluoranthene (0.1), Benzo(a)pyrene (1.0), Indeno(1.2.3.cd)pyrene (0.1), Dibenz(a.h)anthracene (1.0), Benzo(g.h.i)perylene (0.01). Less than LOR results for 'TEQ Zero' are treated as zero.
- Amendment (01/04/2019): This report has been amended as a result of a change to the client office. All analysis results are as per the previous report.

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Work Order : EP1902492 Amendment 1
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	W-B-17	W-S-17	W-M-17	W-B-18	W-S-18
			Client sampling date / time	17-Mar-2019 23:35	18-Mar-2019 00:15	17-Mar-2019 23:55	18-Mar-2019 03:30	18-Mar-2019 04:05
				EP1902492-001	**EP1902492-002**	**EP1902492-003**	**EP1902492-004**	**EP1902492-005**
				Result	Result	Result	Result	Result
EG035T: Total Mercury by FIMS								
Mercury	7439-97-6	0.00004	mg/L	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L	**1.7**	**1.9**	**1.6**	**1.7**	**1.5**
Barium	7440-39-3	1	µg/L	**5**	**6**	**6**	**6**	**6**
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Iron	7439-89-6	5	µg/L	**7**	<5	**6**	**6**	**5**
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Tin	7440-31-5	5	µg/L	<5	<5	<5	<5	<5
Vanadium	7440-62-2	0.5	µg/L	**4.5**	**3.3**	**2.4**	**1.9**	**1.8**
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
EK255A-NH4: Ammonium								
Ammonium as N	14798-03-9_N	0.005	mg/L	**0.012**	**0.008**	**0.009**	**0.010**	**0.009**
EK257A: Nitrite								
Nitrite as N	14797-65-0	0.002	mg/L	**0.004**	<0.002	<0.002	**0.004**	**0.003**
EK258A: Nitrate								
Nitrate as N	14797-55-8	0.002	mg/L	**0.124**	**0.003**	**0.006**	**0.107**	<0.002
EK259A: Nitrite and Nitrate (NOx)								
Nitrite + Nitrate as N	----	0.002	mg/L	**0.128**	**0.003**	**0.006**	**0.111**	**0.003**
EK262A: Total Nitrogen								
Total Nitrogen as N	----	0.050	mg/L	**0.190**	**0.062**	**0.075**	**0.171**	**0.073**
EK267A: Total Phosphorus (Persulfate Digestion)								
Total Phosphorus as P	----	0.005	mg/L	**0.029**	**0.013**	**0.018**	**0.027**	**0.015**
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthene	83-32-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluorene	86-73-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Phenanthrene	85-01-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

			Client sample ID	**W-B-17**	**W-S-17**	**W-M-17**	**W-B-18**	**W-S-18**
			Client sampling date / time	17-Mar-2019 23:35	18-Mar-2019 00:15	17-Mar-2019 23:55	18-Mar-2019 03:30	18-Mar-2019 04:05
Compound	*CAS Number*	*LOR*	*Unit*	**EP1902492-001**	**EP1902492-002**	**EP1902492-003**	**EP1902492-004**	**EP1902492-005**
				Result	Result	Result	Result	Result
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
Anthracene	120-12-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluoranthene	206-44-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Pyrene	129-00-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Chrysene	218-01-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
^ **Benzo(a)pyrene TEQ (zero)**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Client sample ID				**W-B-17**	**W-S-17**	**W-M-17**	**W-B-18**	**W-S-18**
Client sampling date / time				17-Mar-2019 23:35	18-Mar-2019 00:15	17-Mar-2019 23:55	18-Mar-2019 03:30	18-Mar-2019 04:05
Compound	*CAS Number*	*LOR*	*Unit*	**EP1902492-001**	**EP1902492-002**	**EP1902492-003**	**EP1902492-004**	**EP1902492-005**
				Result	Result	Result	Result	Result
EP080: BTEXN - Continued								
^ Total Xylenes	----	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	1.0	%	**12.6**	**15.5**	**14.4**	**19.1**	**17.7**
2-Chlorophenol-D4	93951-73-6	1.0	%	**31.0**	**35.0**	**32.9**	**44.6**	**40.8**
2.4.6-Tribromophenol	118-79-6	1.0	%	**39.9**	**38.4**	**30.8**	**50.0**	**39.8**
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	1.0	%	**36.0**	**35.6**	**35.8**	**45.6**	**40.8**
Anthracene-d10	1719-06-8	1.0	%	**52.8**	**58.3**	**48.1**	**73.0**	**63.6**
4-Terphenyl-d14	1718-51-0	1.0	%	**58.0**	**59.0**	**49.6**	**65.7**	**59.6**
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**94.2**	**86.1**	**90.6**	**92.0**	**91.2**
Toluene-D8	2037-26-5	2	%	**95.3**	**97.0**	**95.8**	**96.3**	**96.7**
4-Bromofluorobenzene	460-00-4	2	%	**99.1**	**94.8**	**99.0**	**100.0**	**97.3**

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Client	: WorleyParsons Services Pty Ltd
Project	: 401012-02648

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER)**			*Client sample ID*	**W-M-18**	**----**	**----**	**----**	**----**
			Client sampling date / time	17-Mar-2019 03:45	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP1902492-006**	**--------**	**--------**	**--------**	**--------**
				Result	----	----	----	----
EG035T: Total Mercury by FIMS								
Mercury	7439-97-6	0.00004	mg/L	<0.00004	----	----	----	----
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	**15**	----	----	----	----
Arsenic	7440-38-2	0.5	µg/L	**1.7**	----	----	----	----
Barium	7440-39-3	1	µg/L	**6**	----	----	----	----
Cadmium	7440-43-9	0.2	µg/L	<0.2	----	----	----	----
Chromium	7440-47-3	0.5	µg/L	<0.5	----	----	----	----
Iron	7439-89-6	5	µg/L	**7**	----	----	----	----
Lead	7439-92-1	0.2	µg/L	<0.2	----	----	----	----
Nickel	7440-02-0	0.5	µg/L	<0.5	----	----	----	----
Tin	7440-31-5	5	µg/L	<5	----	----	----	----
Vanadium	7440-62-2	0.5	µg/L	**1.8**	----	----	----	----
Zinc	7440-66-6	5	µg/L	<5	----	----	----	----
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	----	----	----	----
Copper	7440-50-8	0.2	µg/L	<0.2	----	----	----	----
EK255A-NH4: Ammonium								
Ammonium as N	14798-03-9_N	0.005	mg/L	**0.009**	----	----	----	----
EK257A: Nitrite								
Nitrite as N	14797-65-0	0.002	mg/L	**0.002**	----	----	----	----
EK258A: Nitrate								
Nitrate as N	14797-55-8	0.002	mg/L	**0.002**	----	----	----	----
EK259A: Nitrite and Nitrate (NOx)								
Nitrite + Nitrate as N	----	0.002	mg/L	**0.004**	----	----	----	----
EK262A: Total Nitrogen								
Total Nitrogen as N	----	0.050	mg/L	**0.065**	----	----	----	----
EK267A: Total Phosphorus (Persulfate Digestion)								
Total Phosphorus as P	----	0.005	mg/L	**0.016**	----	----	----	----
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	----	----	----	----
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	----	----	----	----
Acenaphthene	83-32-9	1.0	µg/L	<1.0	----	----	----	----
Fluorene	86-73-7	1.0	µg/L	<1.0	----	----	----	----
Phenanthrene	85-01-8	1.0	µg/L	<1.0	----	----	----	----

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Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

			Client sample ID	**W-M-18**	----	----	----	----
			Client sampling date / time	17-Mar-2019 03:45	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP1902492-006**	--------	--------	--------	--------
				Result	----	----	----	----
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
Anthracene	120-12-7	1.0	µg/L	<1.0	----	----	----	----
Fluoranthene	206-44-0	1.0	µg/L	<1.0	----	----	----	----
Pyrene	129-00-0	1.0	µg/L	<1.0	----	----	----	----
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	----	----	----	----
Chrysene	218-01-9	1.0	µg/L	<1.0	----	----	----	----
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L	<1.0	----	----	----	----
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	----	----	----	----
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	----	----	----	----
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	----	----	----	----
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	----	----	----	----
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	----	----	----	----
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	<0.5	----	----	----	----
^ **Benzo(a)pyrene TEQ (zero)**	----	0.5	µg/L	<0.5	----	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	----	----	----	----
C10 - C14 Fraction	----	50	µg/L	<50	----	----	----	----
C15 - C28 Fraction	----	100	µg/L	<100	----	----	----	----
C29 - C36 Fraction	----	50	µg/L	<50	----	----	----	----
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	----	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	----	----	----	----
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	----	----	----	----
>C10 - C16 Fraction	----	100	µg/L	<100	----	----	----	----
>C16 - C34 Fraction	----	100	µg/L	<100	----	----	----	----
>C34 - C40 Fraction	----	100	µg/L	<100	----	----	----	----
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	----	----	----	----
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	----	----	----	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	----	----	----	----
Toluene	108-88-3	2	µg/L	<2	----	----	----	----
Ethylbenzene	100-41-4	2	µg/L	<2	----	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	----	----	----	----
ortho-Xylene	95-47-6	2	µg/L	<2	----	----	----	----

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

			Client sample ID	**W-M-18**	**----**	**----**	**----**	**----**
			Client sampling date / time	17-Mar-2019 03:45	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP1902492-006**	**--------**	**--------**	**--------**	**--------**
				Result	----	----	----	----
EP080: BTEXN - Continued								
^ **Total Xylenes**	----	2	µg/L	<2	----	----	----	----
^ **Sum of BTEX**	----	1	µg/L	<1	----	----	----	----
Naphthalene	91-20-3	5	µg/L	<5	----	----	----	----
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	1.0	%	**17.6**	----	----	----	----
2-Chlorophenol-D4	93951-73-6	1.0	%	**39.4**	----	----	----	----
2.4.6-Tribromophenol	118-79-6	1.0	%	**43.9**	----	----	----	----
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	1.0	%	**48.3**	----	----	----	----
Anthracene-d10	1719-06-8	1.0	%	**69.0**	----	----	----	----
4-Terphenyl-d14	1718-51-0	1.0	%	**64.5**	----	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**85.9**	----	----	----	----
Toluene-D8	2037-26-5	2	%	**96.9**	----	----	----	----
4-Bromofluorobenzene	460-00-4	2	%	**93.9**	----	----	----	----

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Surrogate Control Limits

Sub-Matrix: **WATER**

Compound	CAS Number	Recovery Limits (%)	
		Low	High
EP075(SIM)S: Phenolic Compound Surrogates			
Phenol-d6	13127-88-3	10	67
2-Chlorophenol-D4	93951-73-6	29	120
2.4.6-Tribromophenol	118-79-6	10	131
EP075(SIM)T: PAH Surrogates			
2-Fluorobiphenyl	321-60-8	34	131
Anthracene-d10	1719-06-8	43	127
4-Terphenyl-d14	1718-51-0	41	142
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	61	141
Toluene-D8	2037-26-5	73	126
4-Bromofluorobenzene	460-00-4	60	125

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order : **EP1903253**
Client : **WorleyParsons Services Pty Ltd**
Contact : MR PAUL NICHOLS
Address : LEVEL 4, 600 MURRAY STREET
WEST PERTH WA, AUSTRALIA 6005
Telephone : +61 08 9278 8111
Project : 401012-02648
Order number : 401012-02648
C-O-C number : ----
Sampler : Brendan Hirniak, Craig Astbury
Site : ----
Quote number : EP/618/18 V2
No. of samples received : 66
No. of samples analysed : 66

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Laboratory : Environmental Division Perth
Contact : Marnie Thomsett
Address : 26 Rigali Way Wangara WA Australia 6065
Telephone : 08 9406 1311
Date Samples Received : 08-Apr-2019 14:40
Date Analysis Commenced : 09-Apr-2019
Issue Date : 24-Apr-2019 11:46

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Canhuang Ke	Inorganics Supervisor	Perth Inorganics, Wangara, WA
Celine Conceicao	Senior Spectroscopist	Sydney Inorganics, Smithfield, NSW
David Viner	SENIOR LAB TECH	Perth Organics, Wangara, WA
Mark Kinnin	Laboratory Technician	Perth Inorganics, Wangara, WA

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- ORC Metals analysis conducted by ALS Sydney, NATA accreditation no. 825, site no 10911.
- Benzo(a)pyrene Toxicity Equivalent Quotient (TEQ) per the NEPM (2013) is the sum total of the concentration of the eight carcinogenic PAHs multiplied by their Toxicity Equivalence Factor (TEF) relative to Benzo(a)pyrene. TEF values are provided in brackets as follows: Benz(a)anthracene (0.1), Chrysene (0.01), Benzo(b+j) & Benzo(k)fluoranthene (0.1), Benzo(a)pyrene (1.0), Indeno(1.2.3.cd)pyrene (0.1), Dibenz(a.h)anthracene (1.0), Benzo(g.h.i)perylene (0.01). Less than LOR results for 'TEQ Zero' are treated as zero.
- EG093: Samples containing high levels of sulfate may precipitate barium under the acidic conditions of this method and may therefore bias results low.

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

			Client sample ID	**W-S-00**	**W-M-00**	**W-B-00**	**W-S-00-DUP**	**W-M-00-DUP**
			Client sampling date / time	02-Apr-2019 15:25	02-Apr-2019 15:05	02-Apr-2019 14:10	02-Apr-2019 15:25	02-Apr-2019 15:05
Compound	CAS Number	LOR	Unit	**EP1903253-001**	**EP1903253-002**	**EP1903253-003**	**EP1903253-004**	**EP1903253-005**
				Result	Result	Result	Result	Result
EG035T: Total Mercury by FIMS								
Mercury	7439-97-6	0.00004	mg/L	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	**19**	**5**	**6**	<5	<5
Arsenic	7440-38-2	0.5	µg/L	**1.6**	**2.0**	**1.8**	**1.8**	**1.9**
Barium	7440-39-3	1	µg/L	**5**	**6**	**8**	**5**	**6**
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Iron	7439-89-6	5	µg/L	<5	<5	<5	<5	<5
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Tin	7440-31-5	5	µg/L	<5	<5	<5	<5	<5
Vanadium	7440-62-2	0.5	µg/L	**0.8**	**3.2**	**3.1**	**2.8**	**2.7**
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
EK255A: Ammonia								
Ammonia as N	7664-41-7	0.005	mg/L	**0.009**	**0.008**	**0.008**	**0.009**	**0.008**
EK257A: Nitrite								
Nitrite as N	14797-65-0	0.002	mg/L	**0.002**	**0.002**	**0.003**	**0.003**	**0.003**
EK258A: Nitrate								
Nitrate as N	14797-55-8	0.002	mg/L	<0.002	**0.161**	**0.294**	<0.002	**0.184**
EK259A: Nitrite and Nitrate (NOx)								
Nitrite + Nitrate as N	----	0.002	mg/L	**0.002**	**0.163**	**0.297**	**0.003**	**0.187**
EK262A: Total Nitrogen								
Total Nitrogen as N	----	0.050	mg/L	<0.050	**0.274**	**0.333**	<0.050	**0.232**
EK267A: Total Phosphorus (Persulfate Digestion)								
Total Phosphorus as P	----	0.005	mg/L	**0.013**	**0.043**	**0.055**	**0.014**	**0.035**
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthene	83-32-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluorene	86-73-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Phenanthrene	85-01-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

			Client sample ID	W-S-00	W-M-00	W-B-00	W-S-00-DUP	W-M-00-DUP
			Client sampling date / time	02-Apr-2019 15:25	02-Apr-2019 15:05	02-Apr-2019 14:10	02-Apr-2019 15:25	02-Apr-2019 15:05
Compound	*CAS Number*	*LOR*	*Unit*	**EP1903253-001**	**EP1903253-002**	**EP1903253-003**	**EP1903253-004**	**EP1903253-005**
				Result	Result	Result	Result	Result
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
Anthracene	120-12-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluoranthene	206-44-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Pyrene	129-00-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Chrysene	218-01-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
^ **Benzo(a)pyrene TEQ (zero)**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Client sample ID				**W-S-00**	**W-M-00**	**W-B-00**	**W-S-00-DUP**	**W-M-00-DUP**
Client sampling date / time				02-Apr-2019 15:25	02-Apr-2019 15:05	02-Apr-2019 14:10	02-Apr-2019 15:25	02-Apr-2019 15:05
Compound	*CAS Number*	*LOR*	*Unit*	**EP1903253-001**	**EP1903253-002**	**EP1903253-003**	**EP1903253-004**	**EP1903253-005**
				Result	Result	Result	Result	Result
EP080: BTEXN - Continued								
^ Total Xylenes	----	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	1.0	%	**34.5**	**25.0**	**30.0**	**34.5**	**28.5**
2-Chlorophenol-D4	93951-73-6	1.0	%	**73.6**	**52.3**	**65.1**	**77.0**	**60.5**
2.4.6-Tribromophenol	118-79-6	1.0	%	**55.3**	**72.1**	**92.7**	**62.8**	**78.5**
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	1.0	%	**71.5**	**77.3**	**73.7**	**79.1**	**73.9**
Anthracene-d10	1719-06-8	1.0	%	**86.3**	**87.6**	**84.3**	**104**	**82.8**
4-Terphenyl-d14	1718-51-0	1.0	%	**84.8**	**101**	**92.3**	**101**	**91.6**
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**96.4**	**91.2**	**89.6**	**90.5**	**90.8**
Toluene-D8	2037-26-5	2	%	**97.9**	**98.7**	**98.6**	**99.6**	**98.4**
4-Bromofluorobenzene	460-00-4	2	%	**102**	**100**	**99.2**	**101**	**100**

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	W-B-00-DUP	W-S-01	W-M-01	W-B-01	W-S-02
			Client sample ID	**W-B-00-DUP**	**W-S-01**	**W-M-01**	**W-B-01**	**W-S-02**
			Client sampling date / time	02-Apr-2019 14:10	02-Apr-2019 20:30	02-Apr-2019 20:00	02-Apr-2019 19:45	03-Apr-2019 02:15
				EP1903253-006	**EP1903253-007**	**EP1903253-008**	**EP1903253-009**	**EP1903253-010**
				Result	Result	Result	Result	Result
EG035T: Total Mercury by FIMS								
Mercury	7439-97-6	0.00004	mg/L	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L	**1.9**	**1.9**	**2.0**	**2.1**	**1.8**
Barium	7440-39-3	1	µg/L	**8**	**5**	**13**	**7**	**5**
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	**0.6**	<0.5
Iron	7439-89-6	5	µg/L	**6**	<5	**6**	**7**	**6**
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Tin	7440-31-5	5	µg/L	<5	<5	<5	<5	<5
Vanadium	7440-62-2	0.5	µg/L	**2.7**	**2.6**	**2.5**	**2.7**	**2.7**
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	**0.7**
EK255A: Ammonia								
Ammonia as N	7664-41-7	0.005	mg/L	**0.009**	**0.008**	**0.009**	**0.009**	**0.008**
EK257A: Nitrite								
Nitrite as N	14797-65-0	0.002	mg/L	**0.003**	**0.002**	**0.003**	**0.003**	**0.002**
EK258A: Nitrate								
Nitrate as N	14797-55-8	0.002	mg/L	**0.297**	<0.002	**0.164**	**0.275**	<0.002
EK259A: Nitrite and Nitrate (NOx)								
Nitrite + Nitrate as N	----	0.002	mg/L	**0.300**	**0.002**	**0.167**	**0.278**	**0.002**
EK262A: Total Nitrogen								
Total Nitrogen as N	----	0.050	mg/L	**0.332**	<0.050	**0.185**	**0.316**	<0.050
EK267A: Total Phosphorus (Persulfate Digestion)								
Total Phosphorus as P	----	0.005	mg/L	**0.055**	**0.013**	**0.033**	**0.051**	**0.013**
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthene	83-32-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluorene	86-73-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Phenanthrene	85-01-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			*Client sample ID*	**W-B-00-DUP**	**W-S-01**	**W-M-01**	**W-B-01**	**W-S-02**
			Client sampling date / time	02-Apr-2019 14:10	02-Apr-2019 20:30	02-Apr-2019 20:00	02-Apr-2019 19:45	03-Apr-2019 02:15
Compound	*CAS Number*	*LOR*	*Unit*	**EP1903253-006**	**EP1903253-007**	**EP1903253-008**	**EP1903253-009**	**EP1903253-010**
				Result	Result	Result	Result	Result
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
Anthracene	120-12-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluoranthene	206-44-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Pyrene	129-00-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Chrysene	218-01-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
^ **Benzo(a)pyrene TEQ (zero)**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2

Page : 8 of 45
Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

			Client sample ID	**W-B-00-DUP**	**W-S-01**	**W-M-01**	**W-B-01**	**W-S-02**
			Client sampling date / time	02-Apr-2019 14:10	02-Apr-2019 20:30	02-Apr-2019 20:00	02-Apr-2019 19:45	03-Apr-2019 02:15
Compound	*CAS Number*	*LOR*	*Unit*	**EP1903253-006**	**EP1903253-007**	**EP1903253-008**	**EP1903253-009**	**EP1903253-010**
				Result	Result	Result	Result	Result
EP080: BTEXN - Continued								
^ **Total Xylenes**	----	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	1.0	%	**24.2**	**19.7**	**26.2**	**19.8**	**17.3**
2-Chlorophenol-D4	93951-73-6	1.0	%	**51.0**	**42.4**	**57.5**	**44.0**	**41.0**
2.4.6-Tribromophenol	118-79-6	1.0	%	**71.8**	**54.2**	**79.0**	**53.6**	**55.5**
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	1.0	%	**75.9**	**59.2**	**69.7**	**63.1**	**50.3**
Anthracene-d10	1719-06-8	1.0	%	**81.1**	**73.6**	**83.7**	**63.2**	**57.0**
4-Terphenyl-d14	1718-51-0	1.0	%	**92.1**	**84.9**	**104**	**72.5**	**62.3**
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**87.4**	**91.5**	**87.6**	**87.1**	**87.8**
Toluene-D8	2037-26-5	2	%	**97.9**	**96.4**	**97.4**	**98.4**	**99.7**
4-Bromofluorobenzene	460-00-4	2	%	**102**	**102**	**98.8**	**102**	**101**

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

			Client sample ID	**W-M-02**	**W-B-02**	**W-S-03**	**W-M-03**	**W-B-03**
			Client sampling date / time	03-Apr-2019 02:10	03-Apr-2019 02:42	03-Apr-2019 06:15	03-Apr-2019 06:05	03-Apr-2019 05:45
Compound	CAS Number	LOR	Unit	**EP1903253-011**	**EP1903253-012**	**EP1903253-013**	**EP1903253-014**	**EP1903253-015**
				Result	Result	Result	Result	Result
EG035T: Total Mercury by FIMS								
Mercury	7439-97-6	0.00004	mg/L	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L	**2.0**	**2.0**	**1.8**	**1.9**	**2.0**
Barium	7440-39-3	1	µg/L	**18**	**7**	**5**	**8**	**8**
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	**1.9**	<0.5	<0.5	**0.5**	<0.5
Iron	7439-89-6	5	µg/L	**18**	**7**	**5**	**8**	<5
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	**0.2**	<0.2	<0.2
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Tin	7440-31-5	5	µg/L	<5	<5	<5	<5	<5
Vanadium	7440-62-2	0.5	µg/L	**2.9**	**2.6**	**4.9**	**3.4**	**3.1**
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L	<0.2	<0.2	**0.3**	<0.2	<0.2
EK255A: Ammonia								
Ammonia as N	7664-41-7	0.005	mg/L	**0.008**	**0.010**	**0.009**	**0.010**	**0.012**
EK257A: Nitrite								
Nitrite as N	14797-65-0	0.002	mg/L	**0.002**	**0.003**	**0.003**	**0.003**	**0.004**
EK258A: Nitrate								
Nitrate as N	14797-55-8	0.002	mg/L	**0.130**	**0.249**	<0.002	**0.167**	**0.340**
EK259A: Nitrite and Nitrate (NOx)								
Nitrite + Nitrate as N	----	0.002	mg/L	**0.132**	**0.252**	**0.003**	**0.170**	**0.344**
EK262A: Total Nitrogen								
Total Nitrogen as N	----	0.050	mg/L	**0.181**	**0.292**	**0.053**	**0.233**	**0.359**
EK267A: Total Phosphorus (Persulfate Digestion)								
Total Phosphorus as P	----	0.005	mg/L	**0.032**	**0.053**	**0.015**	**0.036**	**0.057**
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthene	83-32-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluorene	86-73-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Phenanthrene	85-01-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

			Client sample ID	**W-M-02**	**W-B-02**	**W-S-03**	**W-M-03**	**W-B-03**
			Client sampling date / time	03-Apr-2019 02:10	03-Apr-2019 02:42	03-Apr-2019 06:15	03-Apr-2019 06:05	03-Apr-2019 05:45
Compound	*CAS Number*	*LOR*	*Unit*	**EP1903253-011**	**EP1903253-012**	**EP1903253-013**	**EP1903253-014**	**EP1903253-015**
				Result	Result	Result	Result	Result
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
Anthracene	120-12-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluoranthene	206-44-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Pyrene	129-00-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Chrysene	218-01-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
^ **Benzo(a)pyrene TEQ (zero)**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Client sample ID	**W-M-02**	**W-B-02**	**W-S-03**	**W-M-03**	**W-B-03**
			Client sampling date / time	03-Apr-2019 02:10	03-Apr-2019 02:42	03-Apr-2019 06:15	03-Apr-2019 06:05	03-Apr-2019 05:45
Compound	*CAS Number*	*LOR*	*Unit*	**EP1903253-011**	**EP1903253-012**	**EP1903253-013**	**EP1903253-014**	**EP1903253-015**
				Result	Result	Result	Result	Result
EP080: BTEXN - Continued								
^ **Total Xylenes**	----	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	1.0	%	**19.8**	**16.4**	**21.6**	**25.1**	**25.2**
2-Chlorophenol-D4	93951-73-6	1.0	%	**41.3**	**39.6**	**46.5**	**52.0**	**59.3**
2.4.6-Tribromophenol	118-79-6	1.0	%	**55.3**	**53.6**	**46.2**	**61.5**	**69.6**
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	1.0	%	**48.0**	**53.2**	**58.0**	**65.8**	**83.8**
Anthracene-d10	1719-06-8	1.0	%	**55.9**	**63.6**	**56.7**	**73.9**	**85.7**
4-Terphenyl-d14	1718-51-0	1.0	%	**64.0**	**65.0**	**73.6**	**95.7**	**92.4**
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**84.2**	**88.9**	**88.7**	**84.2**	**86.1**
Toluene-D8	2037-26-5	2	%	**98.3**	**99.7**	**99.2**	**99.6**	**100**
4-Bromofluorobenzene	460-00-4	2	%	**101**	**98.7**	**100**	**102**	**101**

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Work Order	: EP1903253
Client	: WorleyParsons Services Pty Ltd
Project	: 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	*CAS Number*	*LOR*	*Unit*	W-S-03-DUP	W-M-03-DUP	W-B-03-DUP	W-S-04	W-M-04
			Client sample ID	**W-S-03-DUP**	**W-M-03-DUP**	**W-B-03-DUP**	**W-S-04**	**W-M-04**
			Client sampling date / time	03-Apr-2019 06:15	03-Apr-2019 06:05	03-Apr-2019 05:45	03-Apr-2019 10:55	03-Apr-2019 10:45
				EP1903253-016	**EP1903253-017**	**EP1903253-018**	**EP1903253-019**	**EP1903253-020**
				Result	Result	Result	Result	Result
EG035T: Total Mercury by FIMS								
Mercury	7439-97-6	0.00004	mg/L	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L	**1.8**	**1.9**	**2.0**	**1.8**	**1.8**
Barium	7440-39-3	1	µg/L	**5**	**8**	**7**	**8**	**5**
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Iron	7439-89-6	5	µg/L	<5	**6**	**6**	<5	<5
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Tin	7440-31-5	5	µg/L	<5	<5	<5	<5	<5
Vanadium	7440-62-2	0.5	µg/L	**2.4**	**2.1**	**2.2**	**1.9**	**2.3**
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L	<0.2	<0.2	**0.3**	<0.2	<0.2
EK255A: Ammonia								
Ammonia as N	7664-41-7	0.005	mg/L	**0.011**	**0.011**	**0.009**	**0.008**	**0.008**
EK257A: Nitrite								
Nitrite as N	14797-65-0	0.002	mg/L	**0.004**	**0.004**	**0.003**	**0.002**	**0.002**
EK258A: Nitrate								
Nitrate as N	14797-55-8	0.002	mg/L	<0.002	**0.190**	**0.303**	<0.002	**0.126**
EK259A: Nitrite and Nitrate (NOx)								
Nitrite + Nitrate as N	----	0.002	mg/L	**0.004**	**0.194**	**0.306**	**0.002**	**0.128**
EK262A: Total Nitrogen								
Total Nitrogen as N	----	0.050	mg/L	**0.063**	**0.204**	**0.394**	<0.050	**0.147**
EK267A: Total Phosphorus (Persulfate Digestion)								
Total Phosphorus as P	----	0.005	mg/L	**0.016**	**0.031**	**0.060**	**0.013**	**0.028**
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthene	83-32-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluorene	86-73-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Phenanthrene	85-01-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

			Client sample ID	**W-S-03-DUP**	**W-M-03-DUP**	**W-B-03-DUP**	**W-S-04**	**W-M-04**
			Client sampling date / time	03-Apr-2019 06:15	03-Apr-2019 06:05	03-Apr-2019 05:45	03-Apr-2019 10:55	03-Apr-2019 10:45
Compound	CAS Number	LOR	Unit	**EP1903253-016**	**EP1903253-017**	**EP1903253-018**	**EP1903253-019**	**EP1903253-020**
				Result	Result	Result	Result	Result
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
Anthracene	120-12-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluoranthene	206-44-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Pyrene	129-00-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Chrysene	218-01-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
^ **Benzo(a)pyrene TEQ (zero)**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

			Client sample ID	**W-S-03-DUP**	**W-M-03-DUP**	**W-B-03-DUP**	**W-S-04**	**W-M-04**
			Client sampling date / time	03-Apr-2019 06:15	03-Apr-2019 06:05	03-Apr-2019 05:45	03-Apr-2019 10:55	03-Apr-2019 10:45
Compound	*CAS Number*	*LOR*	*Unit*	**EP1903253-016**	**EP1903253-017**	**EP1903253-018**	**EP1903253-019**	**EP1903253-020**
				Result	Result	Result	Result	Result
EP080: BTEXN - Continued								
^ Total Xylenes	----	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	1.0	%	**23.0**	**21.9**	**18.6**	**14.3**	**17.9**
2-Chlorophenol-D4	93951-73-6	1.0	%	**49.1**	**47.4**	**41.6**	**31.6**	**45.3**
2.4.6-Tribromophenol	118-79-6	1.0	%	**57.3**	**59.0**	**46.7**	**45.5**	**66.2**
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	1.0	%	**56.1**	**58.0**	**47.9**	**37.0**	**63.9**
Anthracene-d10	1719-06-8	1.0	%	**73.3**	**80.2**	**61.6**	**48.4**	**65.1**
4-Terphenyl-d14	1718-51-0	1.0	%	**60.1**	**82.1**	**91.1**	**51.7**	**71.7**
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**85.8**	**88.7**	**86.3**	**88.5**	**89.0**
Toluene-D8	2037-26-5	2	%	**99.1**	**99.5**	**101**	**98.8**	**100**
4-Bromofluorobenzene	460-00-4	2	%	**98.6**	**101**	**99.0**	**100**	**97.9**

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	W-B-04	W-S-05	W-M-05	W-B-05	W-S-05-REP
			Client sampling date / time	03-Apr-2019 10:22	03-Apr-2019 15:45	03-Apr-2019 15:35	03-Apr-2019 15:10	03-Apr-2019 16:35
				EP1903253-021	**EP1903253-022**	**EP1903253-023**	**EP1903253-024**	**EP1903253-025**
				Result	Result	Result	Result	Result
EG035T: Total Mercury by FIMS								
Mercury	7439-97-6	0.00004	mg/L	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L	**1.9**	**1.9**	**2.0**	**1.8**	**1.8**
Barium	7440-39-3	1	µg/L	**10**	**14**	**6**	**10**	**6**
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	**0.6**	<0.5	<0.5	<0.5	<0.5
Iron	7439-89-6	5	µg/L	**8**	**5**	<5	**6**	**8**
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Tin	7440-31-5	5	µg/L	<5	<5	<5	<5	<5
Vanadium	7440-62-2	0.5	µg/L	**2.5**	**3.2**	**3.8**	**2.7**	**2.2**
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
EK255A: Ammonia								
Ammonia as N	7664-41-7	0.005	mg/L	**0.008**	**0.010**	**0.261**	**0.007**	**0.011**
EK257A: Nitrite								
Nitrite as N	14797-65-0	0.002	mg/L	**0.002**	**0.002**	**0.002**	**0.002**	**0.003**
EK258A: Nitrate								
Nitrate as N	14797-55-8	0.002	mg/L	**0.239**	<0.002	**0.172**	**0.216**	<0.002
EK259A: Nitrite and Nitrate (NOx)								
Nitrite + Nitrate as N	----	0.002	mg/L	**0.241**	**0.002**	**0.174**	**0.218**	**0.003**
EK262A: Total Nitrogen								
Total Nitrogen as N	----	0.050	mg/L	**0.311**	**0.056**	**0.221**	**0.277**	<0.050
EK267A: Total Phosphorus (Persulfate Digestion)								
Total Phosphorus as P	----	0.005	mg/L	**0.051**	**0.013**	**0.034**	**0.052**	**0.013**
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthene	83-32-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluorene	86-73-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Phenanthrene	85-01-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

			Client sample ID	**W-B-04**	**W-S-05**	**W-M-05**	**W-B-05**	**W-S-05-REP**
			Client sampling date / time	03-Apr-2019 10:22	03-Apr-2019 15:45	03-Apr-2019 15:35	03-Apr-2019 15:10	03-Apr-2019 16:35
Compound	*CAS Number*	*LOR*	*Unit*	**EP1903253-021**	**EP1903253-022**	**EP1903253-023**	**EP1903253-024**	**EP1903253-025**
				Result	Result	Result	Result	Result
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
Anthracene	120-12-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluoranthene	206-44-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Pyrene	129-00-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Chrysene	218-01-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
^ **Benzo(a)pyrene TEQ (zero)**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Client sample ID	**W-B-04**	**W-S-05**	**W-M-05**	**W-B-05**	**W-S-05-REP**
			Client sampling date / time	03-Apr-2019 10:22	03-Apr-2019 15:45	03-Apr-2019 15:35	03-Apr-2019 15:10	03-Apr-2019 16:35
Compound	*CAS Number*	*LOR*	*Unit*	**EP1903253-021**	**EP1903253-022**	**EP1903253-023**	**EP1903253-024**	**EP1903253-025**
				Result	Result	Result	Result	Result
EP080: BTEXN - Continued								
^ **Total Xylenes**	----	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	1.0	%	**16.1**	**26.2**	**20.0**	**14.6**	**26.6**
2-Chlorophenol-D4	93951-73-6	1.0	%	**37.9**	**48.6**	**52.5**	**34.3**	**58.3**
2.4.6-Tribromophenol	118-79-6	1.0	%	**45.4**	**65.0**	**60.2**	**50.0**	**77.2**
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	1.0	%	**54.8**	**60.0**	**51.8**	**45.3**	**66.6**
Anthracene-d10	1719-06-8	1.0	%	**63.4**	**71.7**	**82.9**	**53.4**	**86.0**
4-Terphenyl-d14	1718-51-0	1.0	%	**75.5**	**80.1**	**103**	**58.5**	**96.7**
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**86.4**	**89.4**	**65.1**	**65.6**	**99.8**
Toluene-D8	2037-26-5	2	%	**101**	**99.7**	**108**	**114**	**101**
4-Bromofluorobenzene	460-00-4	2	%	**97.5**	**98.0**	**63.1**	**61.2**	**70.9**

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

			Client sample ID	**W-M-05-REP**	**W-B-05-REP**	**W-S-06**	**W-M-06**	**W-B-06**
			Client sampling date / time	03-Apr-2019 17:39	03-Apr-2019 17:20	04-Apr-2019 00:10	04-Apr-2019 00:05	04-Apr-2019 23:43
Compound	*CAS Number*	*LOR*	*Unit*	**EP1903253-026**	**EP1903253-027**	**EP1903253-028**	**EP1903253-029**	**EP1903253-030**
				Result	Result	Result	Result	Result
EG035T: Total Mercury by FIMS								
Mercury	7439-97-6	0.00004	mg/L	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L	**1.9**	**2.0**	**1.8**	**2.0**	**1.8**
Barium	7440-39-3	1	µg/L	**6**	**10**	**6**	**6**	**9**
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Iron	7439-89-6	5	µg/L	**7**	**6**	<5	**5**	**8**
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Tin	7440-31-5	5	µg/L	<5	<5	<5	<5	<5
Vanadium	7440-62-2	0.5	µg/L	**2.4**	**4.6**	**3.2**	**2.9**	**3.0**
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
EK255A: Ammonia								
Ammonia as N	7664-41-7	0.005	mg/L	**0.008**	**0.010**	**0.009**	**0.010**	**0.009**
EK257A: Nitrite								
Nitrite as N	14797-65-0	0.002	mg/L	**0.002**	**0.002**	**0.003**	**0.003**	**0.002**
EK258A: Nitrate								
Nitrate as N	14797-55-8	0.002	mg/L	**0.154**	**0.196**	<0.002	**0.215**	**0.286**
EK259A: Nitrite and Nitrate (NOx)								
Nitrite + Nitrate as N	----	0.002	mg/L	**0.156**	**0.198**	**0.003**	**0.218**	**0.288**
EK262A: Total Nitrogen								
Total Nitrogen as N	----	0.050	mg/L	**0.189**	**0.258**	**0.061**	**0.281**	**0.394**
EK267A: Total Phosphorus (Persulfate Digestion)								
Total Phosphorus as P	----	0.005	mg/L	**0.031**	**0.048**	**0.016**	**0.043**	**0.060**
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthene	83-32-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluorene	86-73-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Phenanthrene	85-01-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			*Client sample ID*	**W-M-05-REP**	**W-B-05-REP**	**W-S-06**	**W-M-06**	**W-B-06**
			Client sampling date / time	03-Apr-2019 17:39	03-Apr-2019 17:20	04-Apr-2019 00:10	04-Apr-2019 00:05	04-Apr-2019 23:43
Compound	*CAS Number*	*LOR*	*Unit*	**EP1903253-026**	**EP1903253-027**	**EP1903253-028**	**EP1903253-029**	**EP1903253-030**
				Result	Result	Result	Result	Result
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
Anthracene	120-12-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluoranthene	206-44-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Pyrene	129-00-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Chrysene	218-01-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
^ **Benzo(a)pyrene TEQ (zero)**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	W-M-05-REP	W-B-05-REP	W-S-06	W-M-06	W-B-06
Client sampling date / time				03-Apr-2019 17:39	03-Apr-2019 17:20	04-Apr-2019 00:10	04-Apr-2019 00:05	04-Apr-2019 23:43
				EP1903253-026	**EP1903253-027**	**EP1903253-028**	**EP1903253-029**	**EP1903253-030**
				Result	Result	Result	Result	Result
EP080: BTEXN - Continued								
^ **Total Xylenes**	----	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	1.0	%	**23.2**	**20.0**	**19.0**	**22.2**	**20.5**
2-Chlorophenol-D4	93951-73-6	1.0	%	**51.6**	**47.3**	**41.0**	**49.2**	**52.1**
2.4.6-Tribromophenol	118-79-6	1.0	%	**66.3**	**66.2**	**58.4**	**66.5**	**63.8**
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	1.0	%	**52.4**	**46.3**	**41.4**	**61.6**	**56.2**
Anthracene-d10	1719-06-8	1.0	%	**70.6**	**72.9**	**70.4**	**75.7**	**83.0**
4-Terphenyl-d14	1718-51-0	1.0	%	**78.9**	**85.4**	**83.3**	**91.5**	**102**
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**84.8**	**85.9**	**87.6**	**96.4**	**82.7**
Toluene-D8	2037-26-5	2	%	**102**	**105**	**105**	**100**	**105**
4-Bromofluorobenzene	460-00-4	2	%	**69.5**	**69.3**	**65.2**	**70.2**	**67.4**

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			*Client sample ID*	**W-S-07**	**W-M-07**	**W-B-07**	**W-S-08**	**W-M-08**
			Client sampling date / time	04-Apr-2019 08:00	04-Apr-2019 08:25	04-Apr-2019 08:40	04-Apr-2019 12:30	04-Apr-2019 12:23
Compound	*CAS Number*	*LOR*	*Unit*	**EP1903253-031**	**EP1903253-032**	**EP1903253-033**	**EP1903253-034**	**EP1903253-035**
				Result	Result	Result	Result	Result
EG035T: Total Mercury by FIMS								
Mercury	7439-97-6	0.00004	mg/L	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L	**1.7**	**2.0**	**2.0**	**1.9**	**1.8**
Barium	7440-39-3	1	µg/L	**10**	**6**	**9**	**7**	**6**
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Iron	7439-89-6	5	µg/L	**6**	<5	**7**	**6**	**6**
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Tin	7440-31-5	5	µg/L	<5	<5	<5	<5	<5
Vanadium	7440-62-2	0.5	µg/L	**2.7**	**2.5**	**2.4**	**2.5**	**2.4**
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L	<0.2	<0.2	<0.2	**0.7**	<0.2
EK255A: Ammonia								
Ammonia as N	7664-41-7	0.005	mg/L	**0.010**	**0.010**	**0.008**	**0.009**	**0.010**
EK257A: Nitrite								
Nitrite as N	14797-65-0	0.002	mg/L	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**
EK258A: Nitrate								
Nitrate as N	14797-55-8	0.002	mg/L	<0.002	**0.139**	**0.203**	<0.002	**0.100**
EK259A: Nitrite and Nitrate (NOx)								
Nitrite + Nitrate as N	----	0.002	mg/L	**0.002**	**0.141**	**0.205**	**0.003**	**0.102**
EK262A: Total Nitrogen								
Total Nitrogen as N	----	0.050	mg/L	<0.050	**0.190**	**0.271**	<0.050	**0.144**
EK267A: Total Phosphorus (Persulfate Digestion)								
Total Phosphorus as P	----	0.005	mg/L	**0.013**	**0.033**	**0.046**	**0.013**	**0.026**
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthene	83-32-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluorene	86-73-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Phenanthrene	85-01-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

			Client sample ID	**W-S-07**	**W-M-07**	**W-B-07**	**W-S-08**	**W-M-08**
			Client sampling date / time	04-Apr-2019 08:00	04-Apr-2019 08:25	04-Apr-2019 08:40	04-Apr-2019 12:30	04-Apr-2019 12:23
Compound	*CAS Number*	*LOR*	*Unit*	**EP1903253-031**	**EP1903253-032**	**EP1903253-033**	**EP1903253-034**	**EP1903253-035**
				Result	Result	Result	Result	Result
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
Anthracene	120-12-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluoranthene	206-44-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Pyrene	129-00-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Chrysene	218-01-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
^ **Benzo(a)pyrene TEQ (zero)**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

			Client sample ID	**W-S-07**	**W-M-07**	**W-B-07**	**W-S-08**	**W-M-08**
			Client sampling date / time	04-Apr-2019 08:00	04-Apr-2019 08:25	04-Apr-2019 08:40	04-Apr-2019 12:30	04-Apr-2019 12:23
Compound	*CAS Number*	*LOR*	*Unit*	**EP1903253-031**	**EP1903253-032**	**EP1903253-033**	**EP1903253-034**	**EP1903253-035**
				Result	Result	Result	Result	Result
EP080: BTEXN - Continued								
^ **Total Xylenes**	----	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	1.0	%	**19.3**	**27.9**	**27.0**	**26.7**	**18.9**
2-Chlorophenol-D4	93951-73-6	1.0	%	**40.9**	**64.0**	**59.3**	**55.6**	**41.6**
2.4.6-Tribromophenol	118-79-6	1.0	%	**68.6**	**83.2**	**97.4**	**66.2**	**66.3**
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	1.0	%	**59.4**	**62.8**	**75.3**	**64.8**	**52.3**
Anthracene-d10	1719-06-8	1.0	%	**73.1**	**85.5**	**86.0**	**78.7**	**62.8**
4-Terphenyl-d14	1718-51-0	1.0	%	**92.3**	**117**	**102**	**95.6**	**68.6**
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**96.5**	**75.2**	**74.7**	**80.8**	**95.5**
Toluene-D8	2037-26-5	2	%	**102**	**105**	**115**	**103**	**104**
4-Bromofluorobenzene	460-00-4	2	%	**69.2**	**67.3**	**61.8**	**70.6**	**68.2**

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

			Client sample ID	W-B-08	W-S-09	W-M-09	W-B-09	W-S-09-REP
			Client sampling date / time	04-Apr-2019 11:55	04-Apr-2019 19:15	04-Apr-2019 18:58	04-Apr-2019 19:08	04-Apr-2019 20:05
Compound	CAS Number	LOR	Unit	EP1903253-036	EP1903253-037	EP1903253-038	EP1903253-039	EP1903253-040
				Result	Result	Result	Result	Result
EG035T: Total Mercury by FIMS								
Mercury	7439-97-6	0.00004	mg/L	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L	**2.1**	**1.8**	**1.9**	**1.9**	**1.9**
Barium	7440-39-3	1	µg/L	**8**	**5**	**6**	**7**	**6**
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	**0.8**	<0.5	**0.7**
Iron	7439-89-6	5	µg/L	**6**	**7**	**11**	**7**	**12**
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Tin	7440-31-5	5	µg/L	<5	<5	<5	<5	<5
Vanadium	7440-62-2	0.5	µg/L	**2.4**	**2.5**	**2.7**	**2.5**	**2.2**
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
EK255A: Ammonia								
Ammonia as N	7664-41-7	0.005	mg/L	**0.010**	**0.011**	**0.010**	**0.010**	**0.009**
EK257A: Nitrite								
Nitrite as N	14797-65-0	0.002	mg/L	**0.002**	**0.003**	**0.003**	**0.003**	**0.003**
EK258A: Nitrate								
Nitrate as N	14797-55-8	0.002	mg/L	**0.228**	<0.002	**0.136**	**0.301**	<0.002
EK259A: Nitrite and Nitrate (NOx)								
Nitrite + Nitrate as N	----	0.002	mg/L	**0.230**	**0.003**	**0.139**	**0.304**	**0.003**
EK262A: Total Nitrogen								
Total Nitrogen as N	----	0.050	mg/L	**0.248**	**0.050**	**0.182**	**0.354**	**0.051**
EK267A: Total Phosphorus (Persulfate Digestion)								
Total Phosphorus as P	----	0.005	mg/L	**0.045**	**0.014**	**0.032**	**0.057**	**0.014**
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthene	83-32-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluorene	86-73-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Phenanthrene	85-01-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

			Client sample ID	**W-B-08**	**W-S-09**	**W-M-09**	**W-B-09**	**W-S-09-REP**
			Client sampling date / time	04-Apr-2019 11:55	04-Apr-2019 19:15	04-Apr-2019 18:58	04-Apr-2019 19:08	04-Apr-2019 20:05
Compound	CAS Number	LOR	Unit	**EP1903253-036**	**EP1903253-037**	**EP1903253-038**	**EP1903253-039**	**EP1903253-040**
				Result	Result	Result	Result	Result
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
Anthracene	120-12-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluoranthene	206-44-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Pyrene	129-00-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Chrysene	218-01-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
^ **Benzo(a)pyrene TEQ (zero)**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	W-B-08	W-S-09	W-M-09	W-B-09	W-S-09-REP
			Client sampling date / time	04-Apr-2019 11:55	04-Apr-2019 19:15	04-Apr-2019 18:58	04-Apr-2019 19:08	04-Apr-2019 20:05
				EP1903253-036	**EP1903253-037**	**EP1903253-038**	**EP1903253-039**	**EP1903253-040**
				Result	Result	Result	Result	Result
EP080: BTEXN - Continued								
^ Total Xylenes	----	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	1.0	%	**30.7**	**26.8**	**23.0**	**24.5**	**30.4**
2-Chlorophenol-D4	93951-73-6	1.0	%	**56.2**	**58.5**	**50.4**	**52.3**	**61.0**
2.4.6-Tribromophenol	118-79-6	1.0	%	**72.5**	**70.9**	**70.6**	**64.3**	**86.8**
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	1.0	%	**70.7**	**74.5**	**67.6**	**65.9**	**76.5**
Anthracene-d10	1719-06-8	1.0	%	**75.5**	**79.6**	**77.1**	**71.5**	**92.5**
4-Terphenyl-d14	1718-51-0	1.0	%	**83.3**	**96.5**	**91.2**	**84.7**	**106**
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**95.6**	**96.8**	**87.9**	**103**	**85.5**
Toluene-D8	2037-26-5	2	%	**103**	**99.9**	**104**	**99.2**	**107**
4-Bromofluorobenzene	460-00-4	2	%	**69.8**	**71.8**	**69.2**	**71.0**	**67.4**

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER)**

Compound	*CAS Number*	*LOR*	*Unit*	W-M-09-REP	W-B-09-REP	W-S-10	W-M-10	W-B-10
			Client sampling date / time	04-Apr-2019 19:50	04-Apr-2019 20:00	04-Apr-2019 23:35	04-Apr-2019 23:25	04-Apr-2019 23:14
				EP1903253-041	**EP1903253-042**	**EP1903253-043**	**EP1903253-044**	**EP1903253-045**
				Result	Result	Result	Result	Result
EG035T: Total Mercury by FIMS								
Mercury	7439-97-6	0.00004	mg/L	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L	**1.9**	**1.9**	**1.7**	**1.9**	**1.9**
Barium	7440-39-3	1	µg/L	**6**	**8**	**5**	**6**	**8**
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Iron	7439-89-6	5	µg/L	<5	**6**	**6**	**7**	**6**
Lead	7439-92-1	0.2	µg/L	**0.3**	**0.3**	**0.3**	**0.4**	**0.3**
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Tin	7440-31-5	5	µg/L	<5	<5	<5	<5	<5
Vanadium	7440-62-2	0.5	µg/L	**3.5**	**4.4**	**2.6**	**2.8**	**3.1**
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L	**0.2**	<0.2	<0.2	<0.2	<0.2
EK255A: Ammonia								
Ammonia as N	7664-41-7	0.005	mg/L	**0.011**	**0.008**	**0.009**	**0.010**	**0.009**
EK257A: Nitrite								
Nitrite as N	14797-65-0	0.002	mg/L	**0.004**	**0.003**	**0.002**	**0.003**	**0.003**
EK258A: Nitrate								
Nitrate as N	14797-55-8	0.002	mg/L	**0.168**	**0.221**	<0.002	**0.119**	**0.223**
EK259A: Nitrite and Nitrate (NOx)								
Nitrite + Nitrate as N	----	0.002	mg/L	**0.172**	**0.224**	**0.002**	**0.122**	**0.226**
EK262A: Total Nitrogen								
Total Nitrogen as N	----	0.050	mg/L	**0.212**	**0.324**	**0.052**	**0.155**	**0.334**
EK267A: Total Phosphorus (Persulfate Digestion)								
Total Phosphorus as P	----	0.005	mg/L	**0.034**	**0.055**	**0.013**	**0.027**	**0.053**
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthene	83-32-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluorene	86-73-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Phenanthrene	85-01-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	W-M-09-REP	W-B-09-REP	W-S-10	W-M-10	W-B-10
Client sampling date / time				04-Apr-2019 19:50	04-Apr-2019 20:00	04-Apr-2019 23:35	04-Apr-2019 23:25	04-Apr-2019 23:14
				EP1903253-041	**EP1903253-042**	**EP1903253-043**	**EP1903253-044**	**EP1903253-045**
				Result	Result	Result	Result	Result
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
Anthracene	120-12-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluoranthene	206-44-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Pyrene	129-00-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Chrysene	218-01-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
^ **Benzo(a)pyrene TEQ (zero)**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	W-M-09-REP	W-B-09-REP	W-S-10	W-M-10	W-B-10
			Client sampling date / time	04-Apr-2019 19:50	04-Apr-2019 20:00	04-Apr-2019 23:35	04-Apr-2019 23:25	04-Apr-2019 23:14
				EP1903253-041	**EP1903253-042**	**EP1903253-043**	**EP1903253-044**	**EP1903253-045**
				Result	Result	Result	Result	Result
EP080: BTEXN - Continued								
^ **Total Xylenes**	----	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	1.0	%	**23.2**	**22.2**	**20.8**	**30.9**	**29.4**
2-Chlorophenol-D4	93951-73-6	1.0	%	**49.9**	**47.5**	**44.6**	**64.0**	**61.2**
2.4.6-Tribromophenol	118-79-6	1.0	%	**56.6**	**54.6**	**45.9**	**63.3**	**64.5**
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	1.0	%	**69.6**	**55.4**	**59.2**	**72.8**	**69.5**
Anthracene-d10	1719-06-8	1.0	%	**80.7**	**78.1**	**76.6**	**85.1**	**90.5**
4-Terphenyl-d14	1718-51-0	1.0	%	**78.0**	**85.6**	**83.4**	**82.3**	**96.8**
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**89.6**	**92.6**	**84.7**	**66.0**	**81.4**
Toluene-D8	2037-26-5	2	%	**104**	**103**	**102**	**113**	**104**
4-Bromofluorobenzene	460-00-4	2	%	**69.3**	**69.6**	**67.4**	**61.2**	**86.8**

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	W-S-11	W-M-11	W-B-11	W-S-12	W-M-12
Client sampling date / time				05-Apr-2019 05:45	05-Apr-2019 05:35	05-Apr-2019 05:20	05-Apr-2019 16:00	05-Apr-2019 15:55
				EP1903253-046	**EP1903253-047**	**EP1903253-048**	**EP1903253-049**	**EP1903253-050**
				Result	Result	Result	Result	Result
EG035T: Total Mercury by FIMS								
Mercury	7439-97-6	0.00004	mg/L	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L	**1.9**	**2.0**	**2.0**	**1.8**	**1.9**
Barium	7440-39-3	1	µg/L	**5**	**6**	**7**	**7**	**5**
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	**0.6**
Iron	7439-89-6	5	µg/L	**8**	**8**	**7**	**9**	**10**
Lead	7439-92-1	0.2	µg/L	**0.3**	**0.3**	**0.2**	**0.3**	**0.3**
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Tin	7440-31-5	5	µg/L	<5	<5	<5	<5	<5
Vanadium	7440-62-2	0.5	µg/L	**3.1**	**2.8**	**2.9**	**2.9**	**2.5**
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
EK255A: Ammonia								
Ammonia as N	7664-41-7	0.005	mg/L	**0.008**	**0.010**	**0.010**	**0.010**	**0.011**
EK257A: Nitrite								
Nitrite as N	14797-65-0	0.002	mg/L	**0.002**	**0.003**	**0.003**	**0.002**	**0.003**
EK258A: Nitrate								
Nitrate as N	14797-55-8	0.002	mg/L	<0.002	**0.099**	**0.233**	<0.002	**0.063**
EK259A: Nitrite and Nitrate (NOx)								
Nitrite + Nitrate as N	----	0.002	mg/L	**0.003**	**0.102**	**0.236**	**0.002**	**0.066**
EK262A: Total Nitrogen								
Total Nitrogen as N	----	0.050	mg/L	**0.054**	**0.173**	**0.288**	**0.060**	**0.113**
EK267A: Total Phosphorus (Persulfate Digestion)								
Total Phosphorus as P	----	0.005	mg/L	**0.014**	**0.027**	**0.047**	**0.013**	**0.019**
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthene	83-32-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluorene	86-73-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Phenanthrene	85-01-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	W-S-11	W-M-11	W-B-11	W-S-12	W-M-12
Client sampling date / time				05-Apr-2019 05:45	05-Apr-2019 05:35	05-Apr-2019 05:20	05-Apr-2019 16:00	05-Apr-2019 15:55
				EP1903253-046	**EP1903253-047**	**EP1903253-048**	**EP1903253-049**	**EP1903253-050**
				Result	Result	Result	Result	Result
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
Anthracene	120-12-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluoranthene	206-44-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Pyrene	129-00-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Chrysene	218-01-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
^ **Benzo(a)pyrene TEQ (zero)**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

			Client sample ID	**W-S-11**	**W-M-11**	**W-B-11**	**W-S-12**	**W-M-12**
			Client sampling date / time	05-Apr-2019 05:45	05-Apr-2019 05:35	05-Apr-2019 05:20	05-Apr-2019 16:00	05-Apr-2019 15:55
Compound	*CAS Number*	*LOR*	*Unit*	**EP1903253-046**	**EP1903253-047**	**EP1903253-048**	**EP1903253-049**	**EP1903253-050**
				Result	Result	Result	Result	Result
EP080: BTEXN - Continued								
^ **Total Xylenes**	----	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	1.0	%	**30.0**	**26.3**	**25.2**	**27.7**	**26.3**
2-Chlorophenol-D4	93951-73-6	1.0	%	**58.6**	**47.9**	**53.8**	**52.3**	**52.1**
2.4.6-Tribromophenol	118-79-6	1.0	%	**55.3**	**51.0**	**59.8**	**59.1**	**57.7**
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	1.0	%	**73.9**	**58.6**	**75.8**	**72.4**	**72.3**
Anthracene-d10	1719-06-8	1.0	%	**87.1**	**83.4**	**87.6**	**93.4**	**86.1**
4-Terphenyl-d14	1718-51-0	1.0	%	**85.1**	**79.9**	**84.2**	**90.5**	**87.2**
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**79.4**	**89.0**	**81.4**	**89.4**	**63.8**
Toluene-D8	2037-26-5	2	%	**105**	**103**	**107**	**105**	**116**
4-Bromofluorobenzene	460-00-4	2	%	**81.1**	**81.5**	**81.0**	**79.1**	**69.7**

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			*Client sample ID*	**W-B-12**	**W-S-13**	**W-M-13**	**W-B-13**	**W-S-14**
			Client sampling date / time	05-Apr-2019 15:43	05-Apr-2019 22:05	05-Apr-2019 22:00	05-Apr-2019 21:45	06-Apr-2019 01:40
Compound	*CAS Number*	*LOR*	*Unit*	**EP1903253-051**	**EP1903253-052**	**EP1903253-053**	**EP1903253-054**	**EP1903253-055**
				Result	Result	Result	Result	Result
EG035T: Total Mercury by FIMS								
Mercury	7439-97-6	0.00004	mg/L	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L	**2.1**	**1.8**	**2.0**	**2.1**	**2.0**
Barium	7440-39-3	1	µg/L	**8**	**5**	**5**	**7**	**5**
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	**1.2**	**1.3**	<0.5
Iron	7439-89-6	5	µg/L	**8**	**7**	**15**	**14**	**5**
Lead	7439-92-1	0.2	µg/L	**0.3**	**0.2**	**0.4**	**0.3**	**0.3**
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Tin	7440-31-5	5	µg/L	<5	<5	<5	<5	<5
Vanadium	7440-62-2	0.5	µg/L	**2.8**	**2.8**	**5.0**	**3.6**	**2.6**
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
EK255A: Ammonia								
Ammonia as N	7664-41-7	0.005	mg/L	**0.009**	**0.009**	**0.008**	**0.008**	**0.010**
EK257A: Nitrite								
Nitrite as N	14797-65-0	0.002	mg/L	**0.003**	**0.003**	**0.003**	**0.003**	**0.003**
EK258A: Nitrate								
Nitrate as N	14797-55-8	0.002	mg/L	**0.191**	<0.002	**0.082**	**0.237**	<0.002
EK259A: Nitrite and Nitrate (NOx)								
Nitrite + Nitrate as N	----	0.002	mg/L	**0.194**	**0.003**	**0.085**	**0.240**	**0.003**
EK262A: Total Nitrogen								
Total Nitrogen as N	----	0.050	mg/L	**0.244**	**0.055**	**0.153**	**0.278**	**0.055**
EK267A: Total Phosphorus (Persulfate Digestion)								
Total Phosphorus as P	----	0.005	mg/L	**0.037**	**0.014**	**0.025**	**0.045**	**0.014**
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthene	83-32-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluorene	86-73-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Phenanthrene	85-01-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

			Client sample ID	**W-B-12**	**W-S-13**	**W-M-13**	**W-B-13**	**W-S-14**
			Client sampling date / time	05-Apr-2019 15:43	05-Apr-2019 22:05	05-Apr-2019 22:00	05-Apr-2019 21:45	06-Apr-2019 01:40
Compound	*CAS Number*	*LOR*	*Unit*	**EP1903253-051**	**EP1903253-052**	**EP1903253-053**	**EP1903253-054**	**EP1903253-055**
				Result	Result	Result	Result	Result
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
Anthracene	120-12-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluoranthene	206-44-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Pyrene	129-00-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Chrysene	218-01-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
^ **Benzo(a)pyrene TEQ (zero)**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			*Client sample ID*	**W-B-12**	**W-S-13**	**W-M-13**	**W-B-13**	**W-S-14**
			Client sampling date / time	05-Apr-2019 15:43	05-Apr-2019 22:05	05-Apr-2019 22:00	05-Apr-2019 21:45	06-Apr-2019 01:40
Compound	*CAS Number*	*LOR*	*Unit*	**EP1903253-051**	**EP1903253-052**	**EP1903253-053**	**EP1903253-054**	**EP1903253-055**
				Result	Result	Result	Result	Result
EP080: BTEXN - Continued								
^ **Total Xylenes**	----	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	1.0	%	**20.9**	**21.2**	**26.4**	**24.7**	**22.5**
2-Chlorophenol-D4	93951-73-6	1.0	%	**49.4**	**45.0**	**53.9**	**51.6**	**42.5**
2.4.6-Tribromophenol	118-79-6	1.0	%	**51.8**	**48.8**	**55.4**	**50.9**	**49.4**
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	1.0	%	**66.3**	**60.1**	**52.4**	**46.2**	**55.9**
Anthracene-d10	1719-06-8	1.0	%	**78.7**	**77.9**	**77.8**	**67.3**	**78.3**
4-Terphenyl-d14	1718-51-0	1.0	%	**80.7**	**85.0**	**77.2**	**65.8**	**79.7**
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**88.1**	**73.2**	**77.9**	**66.5**	**82.6**
Toluene-D8	2037-26-5	2	%	**105**	**104**	**105**	**116**	**106**
4-Bromofluorobenzene	460-00-4	2	%	**77.7**	**75.7**	**76.5**	**68.1**	**74.7**

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	*CAS Number*	*LOR*	*Unit*	W-M-14	W-B-14	W-S-15	W-M-15	W-B-15
			Client sampling date / time	06-Apr-2019 01:35	06-Apr-2019 01:15	06-Apr-2019 05:05	06-Apr-2019 04:55	06-Apr-2019 04:45
				EP1903253-056	**EP1903253-057**	**EP1903253-058**	**EP1903253-059**	**EP1903253-060**
				Result	Result	Result	Result	Result
EG035T: Total Mercury by FIMS								
Mercury	7439-97-6	0.00004	mg/L	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L	**1.9**	**1.9**	**1.4**	**1.7**	**1.9**
Barium	7440-39-3	1	µg/L	**5**	**5**	**6**	**5**	**6**
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Iron	7439-89-6	5	µg/L	**8**	**8**	**6**	**7**	**7**
Lead	7439-92-1	0.2	µg/L	**0.4**	**0.5**	<0.2	<0.2	**0.2**
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Tin	7440-31-5	5	µg/L	<5	<5	<5	<5	<5
Vanadium	7440-62-2	0.5	µg/L	**2.8**	**3.0**	**2.3**	**2.6**	**3.0**
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
EK255A: Ammonia								
Ammonia as N	7664-41-7	0.005	mg/L	**0.010**	**0.010**	**0.009**	**0.009**	**0.010**
EK257A: Nitrite								
Nitrite as N	14797-65-0	0.002	mg/L	**0.003**	**0.003**	**0.003**	**0.005**	**0.003**
EK258A: Nitrate								
Nitrate as N	14797-55-8	0.002	mg/L	**0.063**	**0.173**	<0.002	**0.021**	**0.154**
EK259A: Nitrite and Nitrate (NOx)								
Nitrite + Nitrate as N	----	0.002	mg/L	**0.066**	**0.176**	**0.003**	**0.026**	**0.157**
EK262A: Total Nitrogen								
Total Nitrogen as N	----	0.050	mg/L	**0.136**	**0.219**	**0.059**	**0.080**	**0.205**
EK267A: Total Phosphorus (Persulfate Digestion)								
Total Phosphorus as P	----	0.005	mg/L	**0.023**	**0.036**	**0.014**	**0.018**	**0.031**
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthene	83-32-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluorene	86-73-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Phenanthrene	85-01-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Client sample ID	**W-M-14**	**W-B-14**	**W-S-15**	**W-M-15**	**W-B-15**
			Client sampling date / time	06-Apr-2019 01:35	06-Apr-2019 01:15	06-Apr-2019 05:05	06-Apr-2019 04:55	06-Apr-2019 04:45
Compound	CAS Number	LOR	Unit	**EP1903253-056**	**EP1903253-057**	**EP1903253-058**	**EP1903253-059**	**EP1903253-060**
				Result	Result	Result	Result	Result
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
Anthracene	120-12-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluoranthene	206-44-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Pyrene	129-00-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Chrysene	218-01-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
^ **Benzo(a)pyrene TEQ (zero)**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER)**

			Client sample ID	W-M-14	W-B-14	W-S-15	W-M-15	W-B-15
			Client sampling date / time	06-Apr-2019 01:35	06-Apr-2019 01:15	06-Apr-2019 05:05	06-Apr-2019 04:55	06-Apr-2019 04:45
Compound	*CAS Number*	*LOR*	*Unit*	**EP1903253-056**	**EP1903253-057**	**EP1903253-058**	**EP1903253-059**	**EP1903253-060**
				Result	Result	Result	Result	Result
EP080: BTEXN - Continued								
^ Total Xylenes	----	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	1.0	%	**27.6**	**26.1**	**24.7**	**26.8**	**29.6**
2-Chlorophenol-D4	93951-73-6	1.0	%	**55.3**	**52.7**	**52.9**	**51.7**	**65.0**
2.4.6-Tribromophenol	118-79-6	1.0	%	**48.9**	**57.7**	**51.5**	**60.8**	**53.9**
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	1.0	%	**56.4**	**73.5**	**68.4**	**58.3**	**84.9**
Anthracene-d10	1719-06-8	1.0	%	**84.1**	**89.7**	**87.1**	**94.9**	**104**
4-Terphenyl-d14	1718-51-0	1.0	%	**87.2**	**89.8**	**91.5**	**105**	**110**
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**75.3**	**79.5**	**78.7**	**83.7**	**83.4**
Toluene-D8	2037-26-5	2	%	**106**	**103**	**107**	**107**	**105**
4-Bromofluorobenzene	460-00-4	2	%	**74.4**	**75.6**	**71.9**	**70.5**	**70.1**

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER)**

Compound	*CAS Number*	*LOR*	*Unit*	W-S-16	W-M-16	W-B-16	W-S-19	W-M-19
			Client sampling date / time	06-Apr-2019 08:15	06-Apr-2019 08:10	06-Apr-2019 08:00	06-Apr-2019 13:40	06-Apr-2019 01:30
				EP1903253-061	**EP1903253-062**	**EP1903253-063**	**EP1903253-064**	**EP1903253-065**
				Result	Result	Result	Result	Result
EG035T: Total Mercury by FIMS								
Mercury	7439-97-6	0.00004	mg/L	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	<5	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L	**1.9**	**1.8**	**1.8**	**1.8**	**1.8**
Barium	7440-39-3	1	µg/L	**7**	**5**	**7**	**7**	**5**
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	**0.5**	<0.5	<0.5	<0.5	<0.5
Iron	7439-89-6	5	µg/L	**8**	**7**	**7**	**7**	**5**
Lead	7439-92-1	0.2	µg/L	<0.2	**0.3**	**0.3**	**0.3**	<0.2
Nickel	7440-02-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Tin	7440-31-5	5	µg/L	<5	<5	<5	<5	<5
Vanadium	7440-62-2	0.5	µg/L	**5.8**	**4.2**	**4.2**	**3.1**	**2.6**
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	7440-50-8	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
EK255A: Ammonia								
Ammonia as N	7664-41-7	0.005	mg/L	**0.009**	**0.008**	**0.011**	**0.009**	**0.009**
EK257A: Nitrite								
Nitrite as N	14797-65-0	0.002	mg/L	**0.002**	**0.003**	**0.002**	**0.002**	**0.004**
EK258A: Nitrate								
Nitrate as N	14797-55-8	0.002	mg/L	<0.002	**0.037**	**0.155**	<0.002	**0.019**
EK259A: Nitrite and Nitrate (NOx)								
Nitrite + Nitrate as N	----	0.002	mg/L	**0.002**	**0.040**	**0.157**	**0.003**	**0.023**
EK262A: Total Nitrogen								
Total Nitrogen as N	----	0.050	mg/L	<0.050	**0.082**	**0.175**	<0.050	**0.060**
EK267A: Total Phosphorus (Persulfate Digestion)								
Total Phosphorus as P	----	0.005	mg/L	**0.012**	**0.018**	**0.032**	**0.012**	**0.015**
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthene	83-32-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluorene	86-73-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Phenanthrene	85-01-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0

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Work Order	: EP1903253
Client	: WorleyParsons Services Pty Ltd
Project	: 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

			Client sample ID	**W-S-16**	**W-M-16**	**W-B-16**	**W-S-19**	**W-M-19**
			Client sampling date / time	06-Apr-2019 08:15	06-Apr-2019 08:10	06-Apr-2019 08:00	06-Apr-2019 13:40	06-Apr-2019 01:30
Compound	*CAS Number*	*LOR*	*Unit*	**EP1903253-061**	**EP1903253-062**	**EP1903253-063**	**EP1903253-064**	**EP1903253-065**
				Result	Result	Result	Result	Result
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
Anthracene	120-12-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluoranthene	206-44-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Pyrene	129-00-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Chrysene	218-01-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
^ **Benzo(a)pyrene TEQ (zero)**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	W-S-16	W-M-16	W-B-16	W-S-19	W-M-19
			Client sampling date / time	06-Apr-2019 08:15	06-Apr-2019 08:10	06-Apr-2019 08:00	06-Apr-2019 13:40	06-Apr-2019 01:30
				EP1903253-061	**EP1903253-062**	**EP1903253-063**	**EP1903253-064**	**EP1903253-065**
				Result	Result	Result	Result	Result
EP080: BTEXN - Continued								
^ **Total Xylenes**	----	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	1.0	%	**23.9**	**23.6**	**20.7**	**22.6**	**22.7**
2-Chlorophenol-D4	93951-73-6	1.0	%	**56.8**	**54.2**	**45.9**	**50.0**	**52.4**
2.4.6-Tribromophenol	118-79-6	1.0	%	**79.3**	**73.7**	**65.4**	**67.8**	**68.8**
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	1.0	%	**74.6**	**69.4**	**58.5**	**63.9**	**70.6**
Anthracene-d10	1719-06-8	1.0	%	**83.5**	**77.2**	**73.4**	**78.4**	**76.6**
4-Terphenyl-d14	1718-51-0	1.0	%	**93.5**	**86.4**	**80.3**	**95.3**	**83.1**
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**89.6**	**87.6**	**71.2**	**92.4**	**65.4**
Toluene-D8	2037-26-5	2	%	**104**	**107**	**107**	**103**	**116**
4-Bromofluorobenzene	460-00-4	2	%	**70.0**	**71.1**	**71.3**	**72.3**	**62.8**

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
Project : 401012-02648

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

			Client sample ID	**W-B-19**	----	----	----	----
			Client sampling date / time	06-Apr-2019 13:25	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EP1903253-066**	--------	--------	--------	--------
				Result	----	----	----	----
EG035T: Total Mercury by FIMS								
Mercury	7439-97-6	0.00004	mg/L	<0.00004	----	----	----	----
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	5	µg/L	<5	----	----	----	----
Arsenic	7440-38-2	0.5	µg/L	**1.8**	----	----	----	----
Barium	7440-39-3	1	µg/L	**6**	----	----	----	----
Cadmium	7440-43-9	0.2	µg/L	<0.2	----	----	----	----
Chromium	7440-47-3	0.5	µg/L	<0.5	----	----	----	----
Iron	7439-89-6	5	µg/L	**6**	----	----	----	----
Lead	7439-92-1	0.2	µg/L	<0.2	----	----	----	----
Nickel	7440-02-0	0.5	µg/L	<0.5	----	----	----	----
Tin	7440-31-5	5	µg/L	<5	----	----	----	----
Vanadium	7440-62-2	0.5	µg/L	**4.9**	----	----	----	----
Zinc	7440-66-6	5	µg/L	<5	----	----	----	----
EG093T_LL: Total Metals in Saline Water by ORC-ICPMS								
Cobalt	7440-48-4	0.05	µg/L	<0.05	----	----	----	----
Copper	7440-50-8	0.2	µg/L	<0.2	----	----	----	----
EK255A: Ammonia								
Ammonia as N	7664-41-7	0.005	mg/L	**0.008**	----	----	----	----
EK257A: Nitrite								
Nitrite as N	14797-65-0	0.002	mg/L	**0.002**	----	----	----	----
EK258A: Nitrate								
Nitrate as N	14797-55-8	0.002	mg/L	**0.070**	----	----	----	----
EK259A: Nitrite and Nitrate (NOx)								
Nitrite + Nitrate as N	----	0.002	mg/L	**0.072**	----	----	----	----
EK262A: Total Nitrogen								
Total Nitrogen as N	----	0.050	mg/L	**0.116**	----	----	----	----
EK267A: Total Phosphorus (Persulfate Digestion)								
Total Phosphorus as P	----	0.005	mg/L	**0.022**	----	----	----	----
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	----	----	----	----
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	----	----	----	----
Acenaphthene	83-32-9	1.0	µg/L	<1.0	----	----	----	----
Fluorene	86-73-7	1.0	µg/L	<1.0	----	----	----	----
Phenanthrene	85-01-8	1.0	µg/L	<1.0	----	----	----	----

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Client : WorleyParsons Services Pty Ltd
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Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	W-B-19	----	----	----	----
Client sampling date / time				06-Apr-2019 13:25	----	----	----	----
				EP1903253-066	--------	--------	--------	--------
				Result	----	----	----	----
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
Anthracene	120-12-7	1.0	µg/L	<1.0	----	----	----	----
Fluoranthene	206-44-0	1.0	µg/L	<1.0	----	----	----	----
Pyrene	129-00-0	1.0	µg/L	<1.0	----	----	----	----
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	----	----	----	----
Chrysene	218-01-9	1.0	µg/L	<1.0	----	----	----	----
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L	<1.0	----	----	----	----
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	----	----	----	----
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	----	----	----	----
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	----	----	----	----
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	----	----	----	----
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	----	----	----	----
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	<0.5	----	----	----	----
^ **Benzo(a)pyrene TEQ (zero)**	----	0.5	µg/L	<0.5	----	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	----	----	----	----
C10 - C14 Fraction	----	50	µg/L	<50	----	----	----	----
C15 - C28 Fraction	----	100	µg/L	<100	----	----	----	----
C29 - C36 Fraction	----	50	µg/L	<50	----	----	----	----
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	----	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	----	----	----	----
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	----	----	----	----
>C10 - C16 Fraction	----	100	µg/L	<100	----	----	----	----
>C16 - C34 Fraction	----	100	µg/L	<100	----	----	----	----
>C34 - C40 Fraction	----	100	µg/L	<100	----	----	----	----
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	----	----	----	----
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	----	----	----	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	----	----	----	----
Toluene	108-88-3	2	µg/L	<2	----	----	----	----
Ethylbenzene	100-41-4	2	µg/L	<2	----	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	----	----	----	----
ortho-Xylene	95-47-6	2	µg/L	<2	----	----	----	----

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Work Order : EP1903253
Client : WorleyParsons Services Pty Ltd
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Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	W-B-19	----	----	----	----
Client sampling date / time				06-Apr-2019 13:25	----	----	----	----
				EP1903253-066	--------	--------	--------	--------
				Result	----	----	----	----
EP080: BTEXN - Continued								
^ Total Xylenes	----	2	µg/L	<2	----	----	----	----
^ Sum of BTEX	----	1	µg/L	<1	----	----	----	----
Naphthalene	91-20-3	5	µg/L	<5	----	----	----	----
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	1.0	%	**22.7**	----	----	----	----
2-Chlorophenol-D4	93951-73-6	1.0	%	**52.3**	----	----	----	----
2.4.6-Tribromophenol	118-79-6	1.0	%	**74.1**	----	----	----	----
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	1.0	%	**65.9**	----	----	----	----
Anthracene-d10	1719-06-8	1.0	%	**78.6**	----	----	----	----
4-Terphenyl-d14	1718-51-0	1.0	%	**88.5**	----	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**88.7**	----	----	----	----
Toluene-D8	2037-26-5	2	%	**103**	----	----	----	----
4-Bromofluorobenzene	460-00-4	2	%	**68.7**	----	----	----	----

Surrogate Control Limits

Sub-Matrix: **WATER**

		Recovery Limits (%)	
Compound	*CAS Number*	*Low*	*High*
EP075(SIM)S: Phenolic Compound Surrogates			
Phenol-d6	13127-88-3	10	67
2-Chlorophenol-D4	93951-73-6	29	120
2.4.6-Tribromophenol	118-79-6	10	131
EP075(SIM)T: PAH Surrogates			
2-Fluorobiphenyl	321-60-8	34	131
Anthracene-d10	1719-06-8	43	127
4-Terphenyl-d14	1718-51-0	41	142
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	61	141
Toluene-D8	2037-26-5	73	126
4-Bromofluorobenzene	460-00-4	60	125

Appendix G Water Quality Data QA

Temperature

The temperature and depth profiles of Sites 5 and 5 Repeat show a similar trend of decrease in temperature with depth.

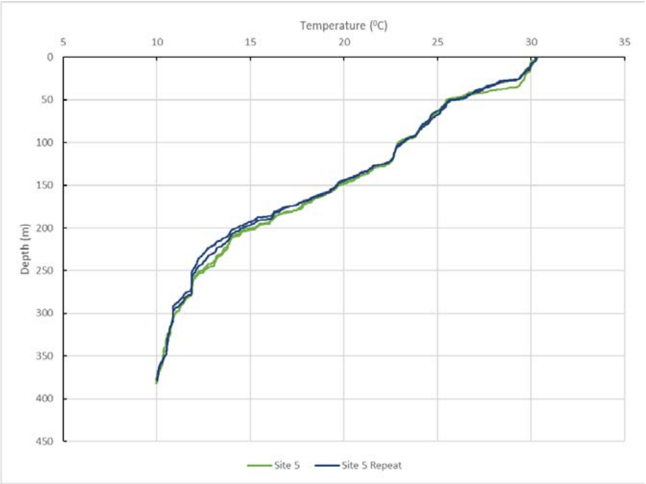

Figure E-1: Temperature (ºC) depth (m) profile at sampling Sites 5 and 5 Repeat

The temperature and depth profiles of Sites 9 and 9 Repeat show a similar trend of decrease in temperature with depth.

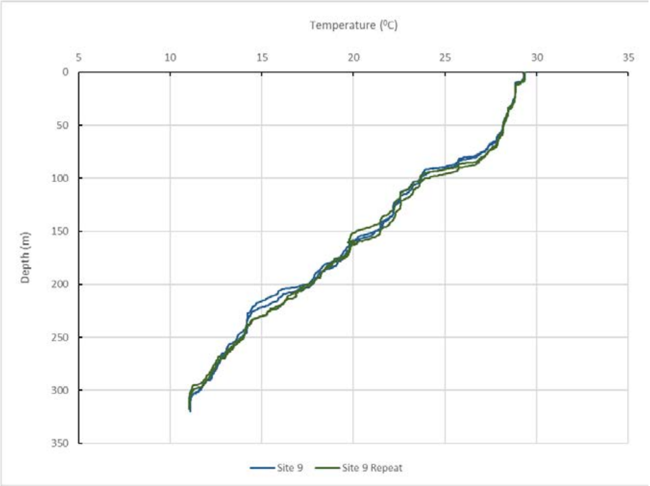

Figure E-2: Temperature (ºC) depth (m) profile at sampling Sites 9 and 9 Repeat

Conductivity

The conductivity over depth profiles of Sites 5 and 5 Repeat show a similar trend of decrease with depth; both profiles compare well.

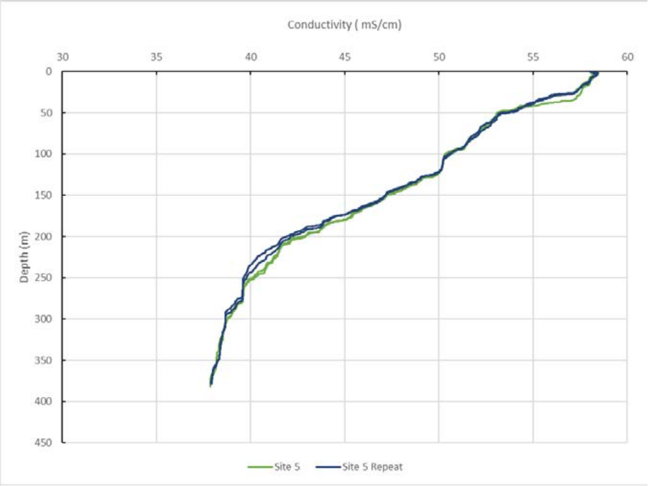

Figure E-3: Conductivity (mS/cm) depth (m) profile at sampling Sites 5 and 5 Repeat

The conductivity over depth profiles of Sites 9 and 9 Repeat show a similar trend of decrease with depth; both profiles compare well.

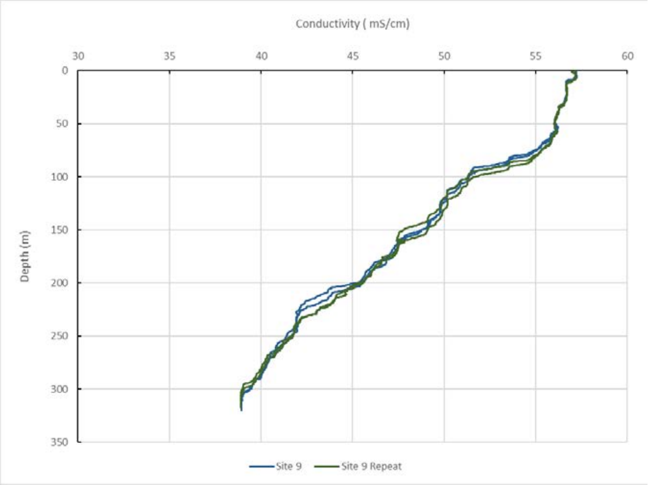

Figure E-4: Conductivity (mS/cm) depth (m) profile at sampling sites 9 and 9 Repeat

Salinity

The salinity over depth profiles for Site 5 and 5 Repeat compare well.

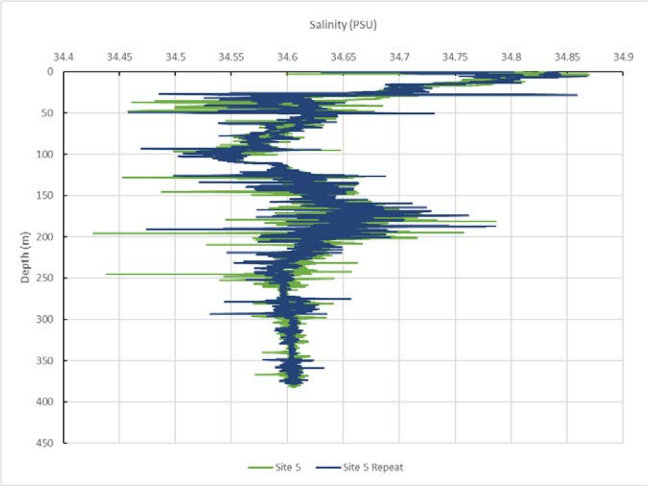

Figure E-5: Salinity (PSU) depth (m) profile at sampling Sites 5 and 5 Repeat

The salinity over depth profile for Sites 9 and 9 Repeat compare well.

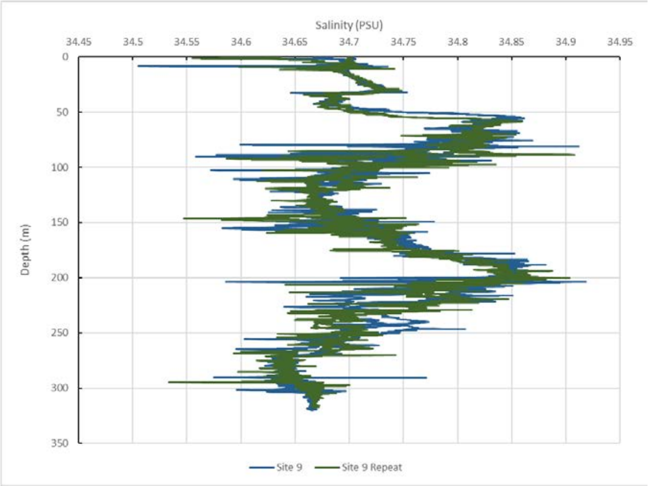

Figure E-6: Salinity (PSU) depth (m) profile at sampling Sites 9 and 9 Repeat

Turbidity

The turbidity over depth profiles for Sites 5 and 5 Repeat show a consistent trend with depth, as both profiles fluctuate around the 0 NTU range and compare well.

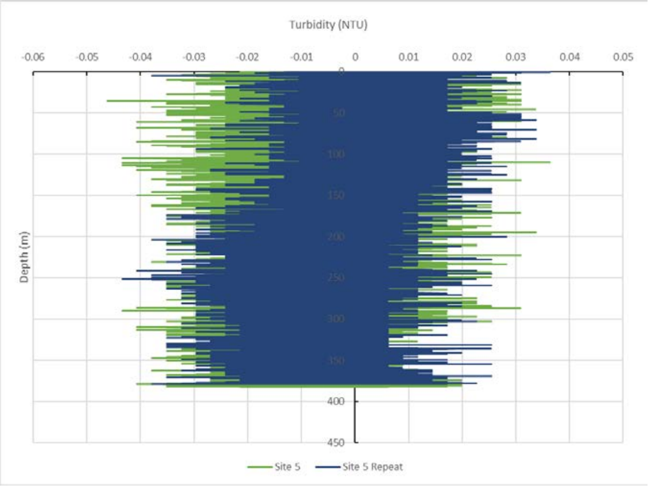

Figure E-7: Turbidity (NTU) depth (m) profile at sampling Sites 5 and 5 Repeat

The turbidity over depth profile for Sites 9 and 9 Repeat show consistent trends with depth. Site 9 is about 1.3 NTU and 9 Repeat 1.08 NTU over depth. Though these profiles appear different, the difference in NTU is negligible and they are considered to compare well.

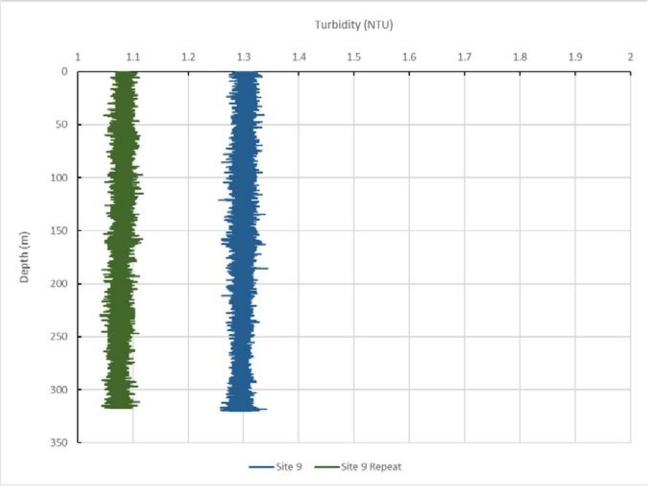

Figure E-8: Turbidity (NTU) depth (m) profile at sampling Sites 9 and 9 Repeat

Dissolved Oxygen

Both profiles for Sites 5 and 5 Repeat compare well, showing a similar trend of decrease with depth.

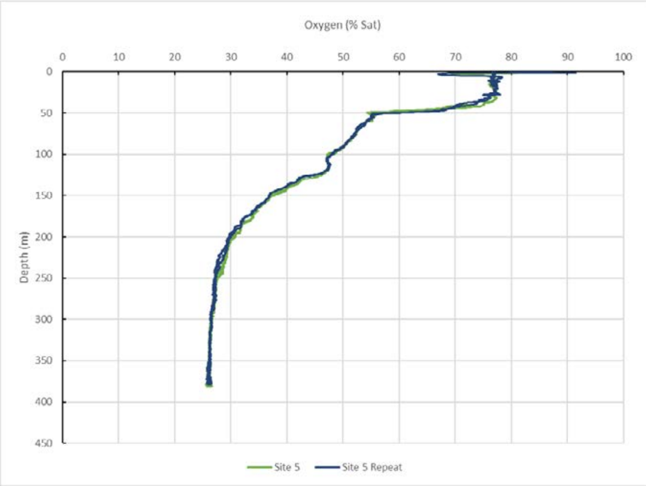

Figure E-9: Oxygen (% Sat) depth (m) profile at sampling Sites 5 and 5 Repeat

Both profiles for Sites 9 and 9 Repeat compare well, showing a similar trend of decrease with depth.

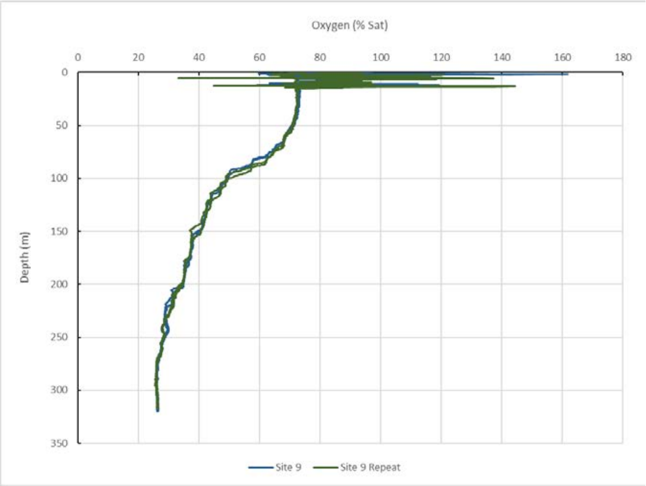

Figure E-10: Oxygen (% Sat) depth (m) profile at sampling Sites 9 and 9 Repeat

pH

The pH over depth profiles for Sites 5 and 5 Repeat show fairly similar trends, except for the initial drop from 0 to about 150 m, where Site 5 started off with a pH of 7.3 and Site 5 Repeat with a pH of 8.3.

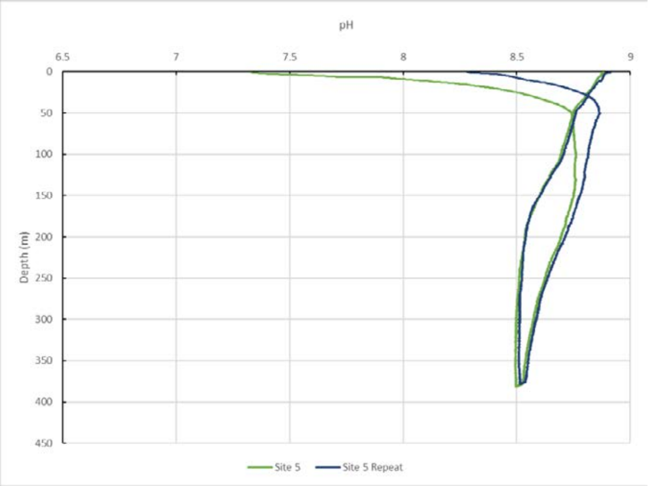

Figure E-11: pH depth (m) profile at sampling Sites 5 and 5 Repeat

The pH over depth profiles for Sites 9 and 9 Repeat show fairly similar trends, except for the initial drop from 0 to about 150 m where Site 9 started off with a pH of 7.3 and Site 9 Repeat with a pH of 8.6.

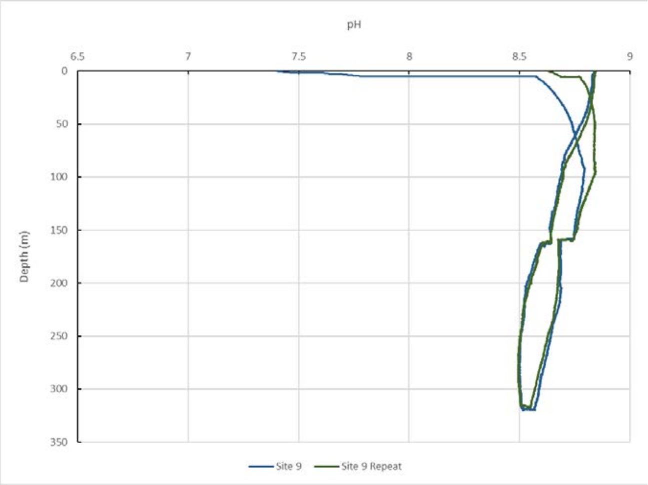

Figure E-12: pH depth (m) profile at sampling Sites 9 and 9 Repeat

Fluorescence

The fluorescence over depth profiles for Sites 5 and 5 Repeat compare well, showing a similar trend of increase with depth.

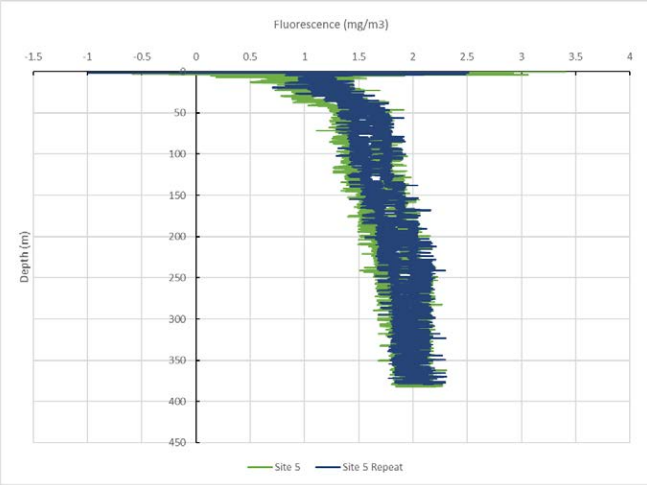

Figure E-13: Fluorescence (mg/m^3) depth (m) profile at sampling Sites 5 and 5 Repeat

The fluorescence over depth profiles for Sites 9 and 9 Repeat compare well, showing a similar trend of increase with depth.

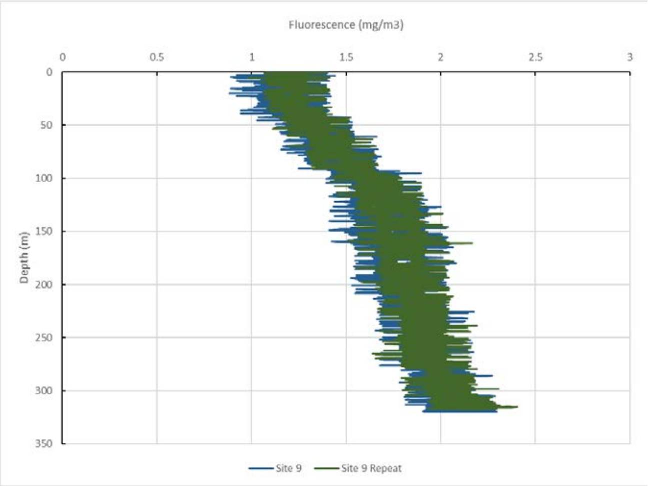

Figure E-14: Fluorescence (mg/m3) depth (m) profile at sampling sites 9 and 9 Repeat

Trace Metals

A total of 24 QA/QC samples were collected to compare with the primary samples to determine intra-lab and field variability in the data (i.e. duplicates and replicates). The derived RPD for each analysis are presented in Table E-1. In accordance with the NAGD (for all intents and purposes), the absolute value of the RPD should not be more than ±35% for duplicate and ±50% for replicate for each comparison. Values in sites that were highlighted in blue were half of their LoR for comparison of RPD. RPD highlighted in red were over their respective value.

Most of the RPD values were below the ±35 and ±50% for duplicates and replicates respectively, except:

- Aluminium for Site 0 surface, mid and bottom of 153%, 67% and 82% respectively
- Barium for Site 5 surface of 80%
- Chromium for Site 3 mid, Site 9 surface and mid of 67%, -95% and 105% respectively
- Copper for Site 3 surface, bottom and Site 9 mid of 100%, -100% and -67% respectively
- Iron for Site 0 bottom, Site 3 surface and bottom, Site 5 mid and Site 9 surface and mid of -82%, 67%, -82%, -95%, -53% and 126% respectively
- Lead for Site 3 surface and Site 9 mid of 67% and -100% respectively
- Vanadium for Site 0 surface, Site 3 surface, mid, Sites 5 and 9 bottom of -111%, 68%, 47%, -52% and -55% respectively.

Table E-1: RPD for trace metals

		Sampling Location	0	0-Dup	RPD	0	0-Dup	RPD	0	0-Dup	RPD	3	3-Dup	RPD	3	3-Dup	RPD	3	3-Dup	RPD	5	5 Repeat	RPD	5	5 Repeat	RPD	5	5 Repeat	RPD	9	9 Repeat	RPD	9	9 Repeat	RPD	9	9 Repeat	RPD
		Depth	Surface			Mid			Bottom			Surface			Mid			Bottom			Surface			Mid			Bottom			Surface			Mid			Bottom		
		Sample Type	Intralab Duplicate			Intralab Duplicate			Intralab Duplicate			Intralab Duplicate			Intralab Duplicate			Intralab Duplicate			Intralab Replicate			Intralab Replicate			Intralab Replicate			Intralab Replicate			Intralab Replicate			Intralab Replicate		
Analyte	Units	LOR																																				
Aluminium	µg/L	5	19	2.5	153%	5	2.5	67%	6	2.5	82%	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%
Arsenic	µg/L	0.5	1.6	1.8	-12%	2	1.9	5%	1.8	1.9	-5%	1.8	1.8	0%	1.9	1.9	0%	2	2	0%	1.9	1.8	5%	2	1.9	5%	1.8	2	-11%	1.8	1.9	-5%	1.9	1.9	0%	1.9	1.9	0%
Barium	µg/L	1	5	5	0%	6	6	0%	8	8	0%	5	5	0%	8	8	0%	8	7	13%	14	6	80%	6	6	0%	10	10	0%	5	6	-18%	6	6	0%	7	8	-13%
Cadmium	µg/L	0.2	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%
Chromium	µg/L	0.5	<0.5	<0.5	0%	<0.5	<0.5	0%	<0.5	<0.5	0%	<0.5	<0.5	0%	0.5	0.25	67%	<0.5	<0.5	0%	<0.5	<0.5	0%	<0.5	<0.5	0%	<0.5	<0.5	0%	0.25	0.7	-95%	0.8	0.25	105%	<0.5	<0.5	0%
Cobalt	µg/L	0.2	<0.05	<0.05	0%	<0.05	<0.05	0%	<0.05	<0.05	0%	<0.05	<0.05	0%	<0.05	<0.05	0%	<0.05	<0.05	0%	<0.05	<0.05	0%	<0.05	<0.05	0%	<0.05	<0.05	0%	<0.05	<0.05	0%	<0.05	<0.05	0%	<0.05	<0.05	0%
Copper	µg/L	0.05	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	0.3	0.1	100%	<0.2	<0.2	0%	0.1	0.3	-100%	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	0.1	0.2	-67%	<0.2	<0.2	0%
Iron	µg/L	5	<5	<5	0%	<5	<5	0%	2.5	6	-82%	5	2.5	67%	8	6	29%	2.5	6	-82%	5	8	-46%	2.5	7	-95%	6	6	0%	7	12	-53%	11	2.5	126%	7	6	15%
Mercury	µg/L	0.04	<0.04	<0.04	0%	<0.04	<0.04	0%	<0.04	<0.04	0%	<0.04	<0.04	0%	<0.04	<0.04	0%	<0.04	<0.04	0%	<0.04	<0.04	0%	<0.04	<0.04	0%	<0.04	<0.04	0%	<0.04	<0.04	0%	<0.04	<0.04	0%	<0.04	<0.04	0%
Nickel	µg/L	0.5	<0.5	<0.5	0%	<0.5	<0.5	0%	<0.5	<0.5	0%	<0.5	<0.5	0%	<0.5	<0.5	0%	<0.5	<0.5	0%	<0.5	<0.5	0%	<0.5	<0.5	0%	<0.5	<0.5	0%	<0.5	<0.5	0%	<0.5	<0.5	0%	<0.5	<0.5	0%
Lead	µg/L	0.2	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	0.2	0.1	67%	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	0.1	0.3	-100%	<0.2	0.3	0%
Tin	µg/L	5	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%
Vanadium	µg/L	0.5	0.8	2.8	-111%	3.2	2.7	17%	3.1	2.7	14%	4.9	2.4	68%	3.4	2.1	47%	3.1	2.2	34%	3.2	2.2	37%	3.8	2.4	45%	2.7	4.6	-52%	2.5	2.2	13%	2.7	3.5	-26%	2.5	4.4	-55%
Zinc	µg/L	5	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%

Nutrients, Ammonia, and Nitrite and Nitrate

As part of the field sampling program, 24 field QA/QC samples were collected for Total Nitrogen and Total Phosphorous, NH_4, and Nitrite and Nitrate analysis and comparisons to primary samples to determine intra-lab and field variability in the data (i.e. duplicate and replicate). The derived RPD for each analysis are presented in Table E-2. Most of the samples were below the ±35% and ±50% for duplicates and replicates respectively, except Sites 0 and 0 Duplicate surface sample for Nitrite and Nitrate with RPD of 40%, and Sites 5 and 5 Repeat where the mid water sample for NH4 had an RPD of 188% (highlighted in red).

Table E-2: RPD for nutrients

		Sampling Location	0	0-Dup	RPD	0	0-Dup	RPD	0	0-Dup	RPD	3	3-Dup	RPD	3	3-Dup	RPD	3	3-Dup	RPD	5	5 Repeat	RPD	5	5 Repeat	RPD	5	5 Repeat	RPD	9	9 Repeat	RPD	9	9 Repeat	RPD	9	9 Repeat	RPD
		Depth	Surface			Mid			Bottom			Surface			Mid			Bottom			Surface			Mid			Bottom			Surface			Mid			Bottom		
		Sample Type	Intralab Duplicate			Intralab Duplicate			Intralab Duplicate			Intralab Duplicate			Intralab Duplicate			Intralab Duplicate			Intralab Replicate			Intralab Replicate			Intralab Replicate			Intralab Replicate			Intralab Replicate			Intralab Replicate		
Analyte	Units	LOR																																				
Total Nitrogen	mg/L	0.05	<0.050	<0.050	0%	0.274	0.232	17%	0.333	0.332	0%	0.053	0.063	-17%	0.233	0.204	13%	0.359	0.394	-9%	0.056	<0.050	0%	0.221	0.189	16%	0.277	0.258	7%	0.050	0.051	-2%	0.182	0.212	-15%	0.354	0.324	9%
Total Phosphorous	mg/L	0.005	0.013	0.014	-7%	0.043	0.035	21%	0.055	0.055	0%	0.015	0.016	-6%	0.036	0.031	15%	0.057	0.060	-5%	0.013	0.013	0%	0.034	0.031	9%	0.052	0.048	8%	0.014	0.014	0%	0.032	0.034	-6%	0.057	0.055	4%
NH4	mg/L	0.005	0.009	0.009	0%	0.008	0.008	0%	0.008	0.009	-12%	0.009	0.011	-20%	0.010	0.011	-10%	0.012	0.009	29%	0.010	0.011	-10%	0.261	0.008	188%	0.007	0.010	-35%	0.009	0.009	0%	0.011	0.010	10%	0.008	0.009	-12%
Nitrite and Nitrate	mg/L	0.002	0.002	0.003	-40%	0.163	0.187	-14%	0.297	0.300	-1%	0.003	0.004	-29%	0.170	0.194	-13%	0.344	0.306	12%	0.002	0.003	-40%	0.174	0.156	11%	0.218	0.198	10%	0.003	0.003	0%	0.139	0.172	-21%	0.304	0.224	30%

Total Recoverable Hydrocarbons and Polycyclic Aromatic Hydrocarbons

The 24 field QA/QC samples collected for TRH and PAH analysis were all below the laboratory LoR, thus RPD for all samples is 0%.

Appendix H Sediment Data QA

A total of eight QA/QC samples were collected to compare with the primary samples to determine intra-lab and field variability in the data (i.e. duplicates and replicates). Values in sites that were highlighted in blue were half of their LoR for comparison of RPD. RPDs highlighted in red were over their respective value.

Trace Metals

The derived RPDs for trace metals are presented in Table F-1. All comparisons were below the RPD of ±35% for duplicate and ±50% for replicate

Table F-1: RPD for trace metals

		Location ID	Site 0	Site 0 Duplicate	RPD	Site 5	Site 5 Repeat	RPD	Site 7	Site 7 Duplicate	RPD	Site 9	Site 9 Repeat	RPD
Analyte	**Units**	**LoR**												
Aluminium	mg/kg	50.00	4620	4350	6%	2800	3320	-17%	1390	1510	-8%	1100	1010	9%
Barium	mg/kg	0.10	43	42	2%	42.6	46	-8%	11.2	11.8	-5%	8.3	7.9	5%
Cadmium	mg/kg	0.10	0.2	0.2	0%	0.2	0.2	0%	0.2	0.2	0%	0.2	0.2	0%
Chromium	mg/kg	1.00	15.5	15.7	-1%	12	12.8	-6%	6.5	7.4	-13%	7.6	7.3	4%
Copper	mg/kg	1.00	11.2	11.4	-2%	10.3	10.7	-4%	2.9	3.1	-7%	2.7	2.4	12%
Iron	mg/kg	50.00	5290	5230	1%	3340	3820	-13%	2620	2840	-8%	2320	2220	4%
Lead	mg/kg	1.00	2.6	2.6	0%	2	2.1	-5%	2.6	2.6	0%	1.2	1.1	9%
Mercury	mg/kg	0.01	0.02	0.02	0%	0.02	0.02	0%	0.01	0.01	0%	<0.01	<0.01	0%
Nickel	mg/kg	1.00	14.1	14.6	-3%	11.4	11.9	-4%	8.9	9.3	-4%	3.6	3.4	6%
Tin	mg/kg	0.10	0.300	0.300	0%	0.200	0.200	0%	0.100	0.100	0%	0.100	0.100	0%
Vanadium	mg/kg	2.00	10.600	9.900	7%	6.400	7.300	-13%	4.600	4.700	-2%	2.700	2.500	8%
Zinc	mg/kg	1.00	25.8	25.6	1%	19.8	20.6	-4%	14.5	17.8	-20%	14.1	13.3	6%

Hydrocarbons

The derived RPDs for hydrocarbons are presented in Table F-2. RPDs for Site 7 and Site 9 were all below ±35% for duplicate and ±50% for replicate. RPDs for Sites 0 and 5 have RPDs over ±35% and ±50% respectively for PAH and Site 5 has RPDs over ±50% for TPH as well.

Table F-2: RPD for hydrocarbons

			Location ID	Site 0	Site 0 Duplicate	RPD	Site 5	Site 5 Repeat	RPD	Site 7	Site 7 Duplicate	RPD	Site 9	Site 9 Repeat	RPD
Analytical Group	Analyte	Units	LoR												
BTEXN	Benzene	mg/kg	0.20	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%
	Toluene	mg/kg	0.20	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%
	Ethylbenzene	mg/kg	0.20	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%
	meta- & para-Xylene	mg/kg	0.20	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%
	ortho-Xylene	mg/kg	0.20	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%
	Total Xylenes	mg/kg	0.50	<0.5	<0.5	0%	<0.5	<0.5	0%	<0.5	<0.5	0%	<0.5	<0.5	0%
	Sum of BTEX	mg/kg	0.20	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%	<0.2	<0.2	0%
TPH	C6 - C9 Fraction	mg/kg	3.00	<3	<3	0%	<3	<3	0%	<3	<3	0%	<3	<3	0%
	C10 - C14 Fraction	mg/kg	3.00	<3	<3	0%	<3	<3	0%	<3	<3	0%	<3	<3	0%
	C15 - C28 Fraction	mg/kg	3.00	<3	<3	0%	8	1.5	137%	<3	<3	0%	<3	<3	0%
	C29 - C36 Fraction	mg/kg	5.00	<5	<5	0%	8	2.5	105%	<5	<5	0%	<5	<5	0%
	C10 - C36 Fraction (sum)	mg/kg	3.00	<3	<3	0%	16	1.5	166%	<3	<3	0%	<3	<3	0%
PAH	Naphthalene	µg/kg	5.00	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%
	2-Methylnaphthalene	µg/kg	5.00	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%
	Acenaphthylene	µg/kg	4.00	<5	<5	0%	<5	<5	0%	<4	<4	0%	<5	<5	0%
	Acenaphthene	µg/kg	4.00	<5	<5	0%	<5	<5	0%	<4	<4	0%	<5	<5	0%
	Fluorene	µg/kg	4.00	<5	<5	0%	<5	<5	0%	<4	<4	0%	<5	<5	0%
	Phenanthrene	µg/kg	4.00	2.5	19	-153%	7	2.5	95%	<4	<4	0%	<5	<5	0%
	Anthracene	µg/kg	4.00	<5	<5	0%	<5	<5	0%	<4	<4	0%	<5	<5	0%
	Fluoranthene	µg/kg	4.00	2.5	29	-168%	<5	<5	0%	<4	<4	0%	<5	<5	0%
	Pyrene	µg/kg	4.00	2.5	26	-165%	6	2.5	82%	<4	<4	0%	<5	<5	0%
	Benz(a)anthracene	µg/kg	4.00	2.5	10	-120%	10	2.5	120%	<4	<4	0%	<5	<5	0%
	Chrysene	µg/kg	4.00	2.5	15	-143%	11	2.5	126%	<4	<4	0%	<5	<5	0%
	Benzo(b+j)fluoranthene	µg/kg	4.00	2.5	12	-131%	7	2.5	95%	<4	<4	0%	<5	<5	0%
	Benzo(k)fluoranthene	µg/kg	4.00	<5	<5	0%	18	2.5	151%	<4	<4	0%	<5	<5	0%
	Benzo(e)pyrene	µg/kg	4.00	2.5	4	-46%	<5	<5	0%	<4	<4	0%	<5	<5	0%
	Benzo(a)pyrene	µg/kg	4.00	<5	<5	0%	<5	<5	0%	<4	<4	0%	<5	<5	0%
	Perylene	µg/kg	4.00	<5	<5	0%	<5	<5	0%	<4	<4	0%	<5	<5	0%
	Benzo(g.h.i)perylene	µg/kg	4.00	2.5	8	-105%	21	2.5	157%	<4	<4	0%	<5	<5	0%
	Dibenz(a.h)anthracene	µg/kg	4.00	<5	<5	0%	30	2.5	169%	<4	<4	0%	<5	<5	0%
	Indeno(1.2.3.cd)pyrene	µg/kg	4.00	2.5	6	-82%	29	2.5	168%	<4	<4	0%	<5	<5	0%
	Coronene	µg/kg	5.00	<5	<5	0%	<5	<5	0%	<5	<5	0%	<5	<5	0%
	Sum of PAHs	µg/kg	4.00	2.5	99	-190%	139	2.5	193%	<4	<4	0%	<5	<5	0%

Nutrients

The derived RPDs for nitrite and nitrate are presented in Table F-3. RPDs for Site 0 and Site 7 were all below ±35. RPDs for Sites 5 and 9 were over ±50%.

Table F-3: RPD for nitrite and nitrate

		Location ID	Site 0	Site 0 Duplicate	RPD	Site 5	Site 5 Repeat	RPD	Site 7	Site 7 Duplicate	RPD	Site 9	Site 9 Repeat	RPD
Analyte	Units	LoR												
Nitrite as N (Sol.)	mg/kg	0.10	<0.1	<0.1	0%	<0.1	<0.1	0%	<0.1	<0.1	0%	<0.1	<0.1	0%
Nitrate as N (Sol.)	mg/kg	0.10	0.1	0.1	0%	0.2	0.1	67%	0.9	0.8	12%	0.9	0.4	77%
Nitrite + Nitrate as N (Sol.)	mg/kg	0.10	0.1	0.1	0%	0.2	0.1	67%	0.9	0.8	12%	0.9	0.4	77%

Total Organic Carbon and Total Carbon

The derived RPDs for total organic carbon and total carbon are presented in Table F-4. No RPD values have been exceeded.

Table F-4: RPD for total organic carbon and total carbon

		Location ID	Site 0	Site 0 Duplicate	RPD	Site 5	Site 5 Repeat	RPD	Site 7	Site 7 Duplicate	RPD	Site 9	Site 9 Repeat	RPD
Analyte	Units	LoR												
Total Organic Carbon	%	0.02	0.77	0.64	18%	0.82	0.84	-2%	0.18	0.16	12%	0.13	0.14	-7%
Total Carbon	%	0.02	10.4	10.4	0%	11.1	11.2	-1%	11.5	11.4	1%	9.65	11.3	-16%

Particle Size Distribution

The derived RPDs for particle size distribution are presented in Table F-6. RPDs for Site 5 were all below ±50%. RPDs for Sites 0, 7 and 9 have PSD over ±35% and ±50% respectively; Site 0 for 75, 150, 300, 425 µm and sand of -67%, -91%, -100%, -120% and -43% respectively; Site 7 for 1180 µm and gravel of -40% and -67% respectively; and Site 9 for silt of 67%.

Table F-6: RPD for particle size distribution

		Location ID	Site 0	Site 0 Duplicate	RPD	Site 5	Site 5 Repeat	RPD	Site 7	Site 7 Duplicate	RPD	Site 9	Site 9 Repeat	RPD
Analyte	Units	LoR												
Moisture	%	0.10	57.8	57.3	1%	57.7	58.6	-2%	43.8	46.1	-5%	56.7	57.1	-1%
75µm	%	1.00	14	28	-67%	8	8	0%	92	93	-1%	93	90	3%
150µm	%	1.00	3	8	-91%	1	1	0%	82	86	-5%	80	73	9%
300µm	%	1.00	1	3	-100%	<1	<1	0%	58	66	-13%	39	33	17%
425µm	%	1.00	0.5	2	-120%	<1	<1	0%	36	44	-20%	14	12	15%
600µm	%	1.00	<1	<1	0%	<1	<1	0%	11	15	-31%	5	4	22%
1180µm	%	1.00	<1	<1	0%	<1	<1	0%	2	3	-40%	<1	<1	0%
2.36mm	%	1.00	<1	<1	0%	<1	<1	0%	<1	<1	0%	<1	<1	0%
4.75mm	%	1.00	<1	<1	0%	<1	<1	0%	<1	<1	0%	<1	<1	0%
9.5mm	%	1.00	<1	<1	0%	<1	<1	0%	<1	<1	0%	<1	<1	0%
19.0mm	%	1.00	<1	<1	0%	<1	<1	0%	<1	<1	0%	<1	<1	0%
37.5mm	%	1.00	<1	<1	0%	<1	<1	0%	<1	<1	0%	<1	<1	0%
75.0mm	%	1.00	<1	<1	0%	<1	<1	0%	<1	<1	0%	<1	<1	0%
Clay (<2 µm)	%	1.00	38	35	8%	31	29	7%	6	7	-15%	5	6	-18%
Silt (2-60 µm)	%	1.00	40	31	25%	50	54	-8%	<1	<1	0%	1	0.5	67%
Sand (0.06-2.00 mm)	%	1.00	22	34	-43%	19	17	11%	93	91	2%	94	94	0%
Gravel (>2mm)	%	1.00	<1	<1	0%	<1	<1	0%	1	2	-67%	<1	<1	0%
Cobbles (>6cm)	%	1.00	<1	<1	0%	<1	<1	0%	<1	<1	NA	<1	<1	0%

Appendix I Photo Plates of Seabed Imagery

Photo plate 1: Site 0 **Date: 2/04/2019**	**Approximate Temperature: 10.1°C** **Approximate Depth: 391.5 m** **Seabed Substrate: Coarse sand**	**Laser scale: 20 cm(l) x 24 cm(h)** **Coordinates: Z51 315111.20, 8331811.17**

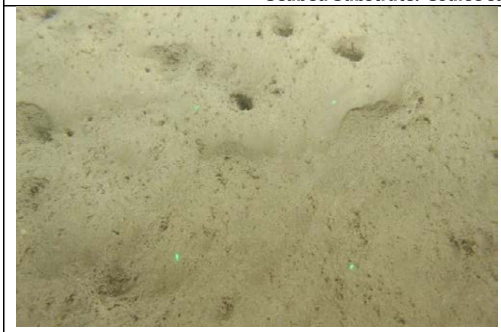
Photo 1: Bioturbation evident

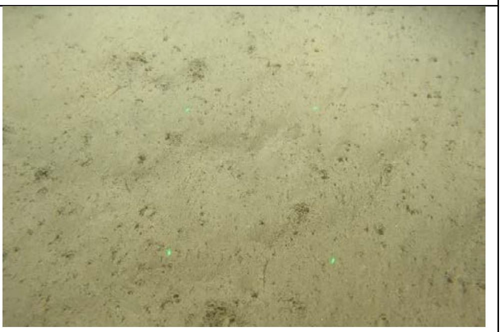
Photo 2:

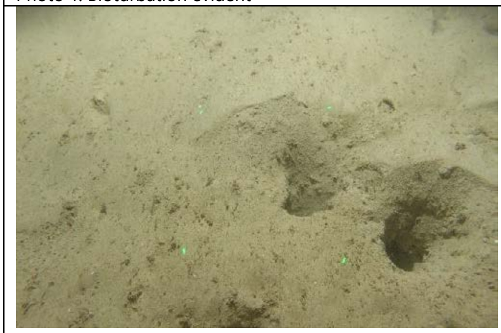
Photo 3: Bioturbation evident

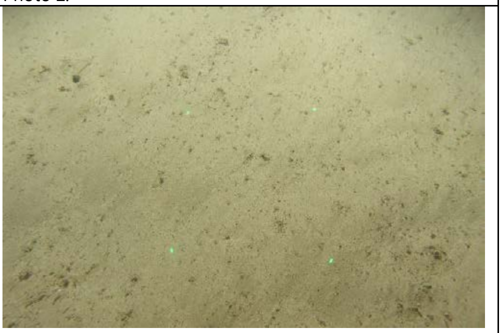
Photo 4: Small amount of bioturbation

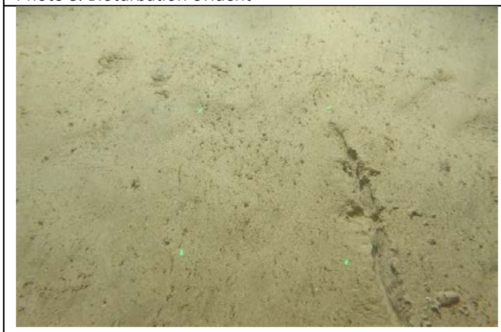
Photo 5: Track mark from camera frame

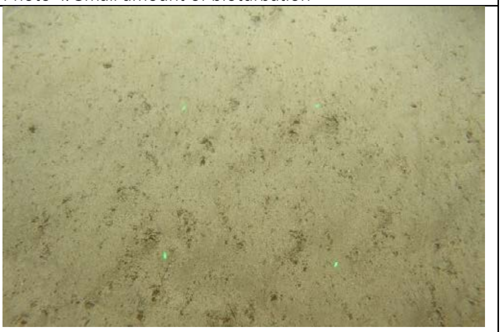
Photo 6:

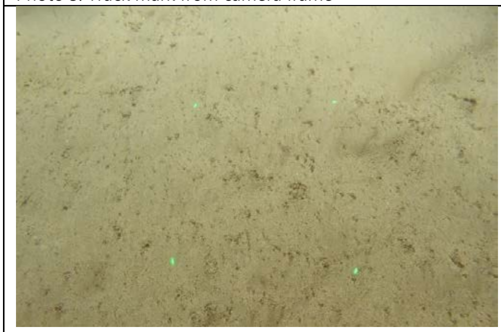
Photo 7:

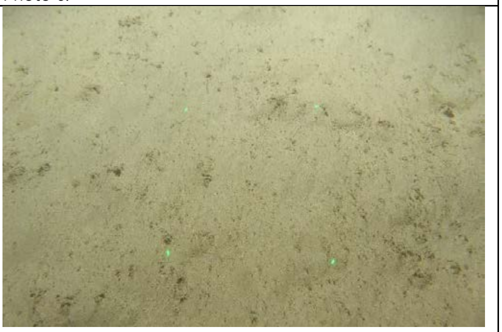
Photo 8:

Photo plate 2: Site 1 **Date: 2/04/2019**	**Approximate Temperature: 10.5°C** **Approximate Depth: 362.5 m** **Seabed Substrate: Fine sand-mud**	**Laser scale: 20 cm(l) x 24 cm(h)** **Coordinates: Z51 302674.95, 8313428.91**

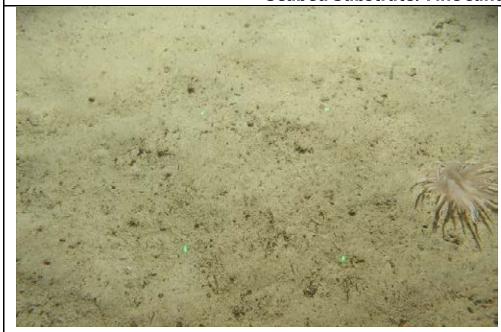
Photo 1: Solitary anemone

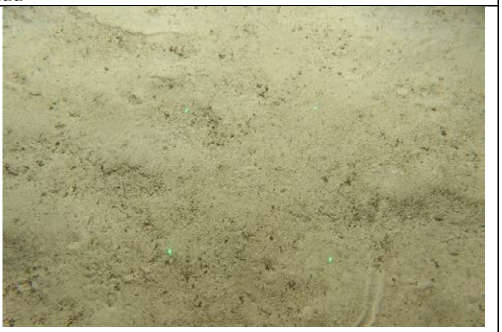
Photo 2: Small fauna tracks


Photo 3: Small fauna tracks

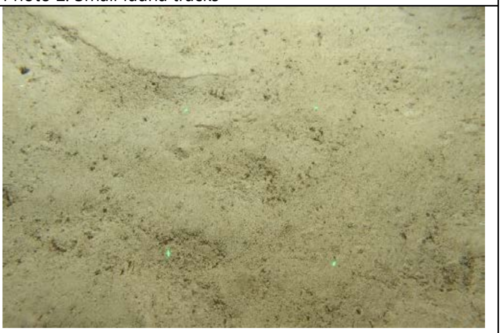
Photo 4:

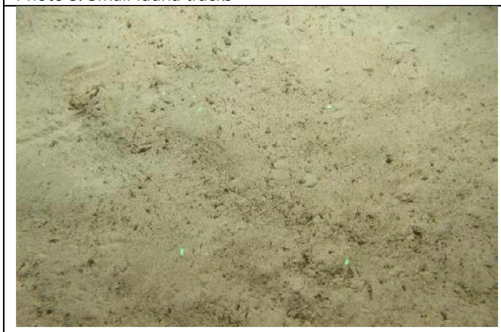
Photo 5: Small fauna tracks

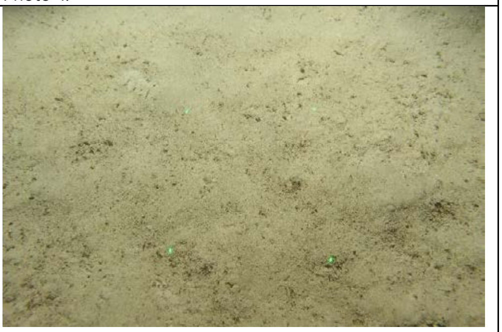
Photo 6:

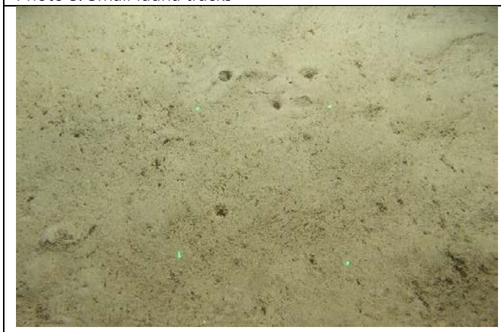
Photo 7: Bioturbation evident

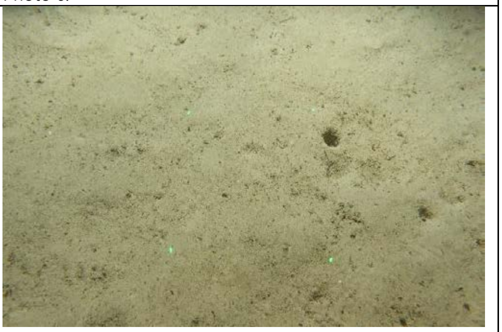
Photo 8: Bioturbation evident

Photo plate 3: Site 2 **Date: 03/04/2019**	**Approximate Temperature: 11.4 °C** **Approximate Depth: 349.5 m** **Seabed Substrate: Large 2D Ripples**	**Laser scale: 20 cm(l) x 24 cm(h)** **Coordinates: Z51 268947.84, 8263777.04**


Photo 1: Solitary anemone


Photo 2: Crustaceans (lobster & crab) around a crinoid


Photo 3: Crustacean residing in biogenic rubble


Photo 4: Coarse sand – ripples evident


Photo 5: Some shell fragments


Photo 6: Some shell fragments


Photo 7: Coarse sand – ripples evident


Photo 8: Coarse sand – ripples evident

Photo plate 4: Site 3 **Date: 03/04/2019**	**Approximate Temperature: 10.4 °C** **Approximate Depth: 368.9 m** **Seabed Substrate: Fine sand-mud**	**Laser scale: 20 cm(l) x 24 cm(h)** **Coordinates: Z51 260642.58, 8251468.57**


Photo 1: Sea pen & small crustaceans (lobster & crab)


Photo 2: Fine sand – no profile


Photo 3: Fine shell fragments on sand

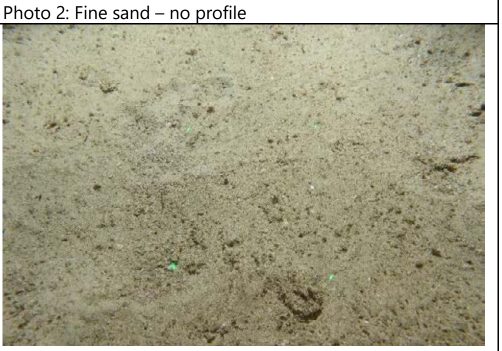
Photo 4: Fine shell fragments on sand


Photo 5: Fine shell fragments and small amount of biogenic rubble


Photo 6: Fine sand – no profile

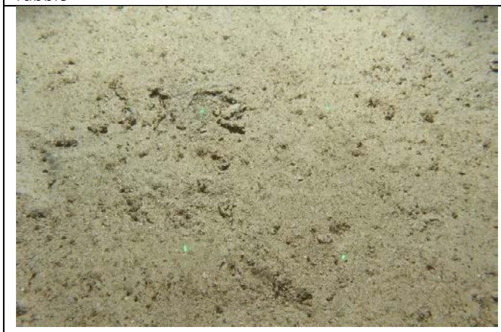
Photo 7:


Photo 8: Shell fragments & worm skeletons

Photo plate 5: Site 4
Date: 03/04/2019

Approximate Temperature: 10.3 °C
Approximate Depth: 361.9 m
Seabed Substrate: Fine sand-mud

Laser scale: 20 cm(l) x 24 cm(h)
Coordinates: Z51 249092.44, 8231100.41

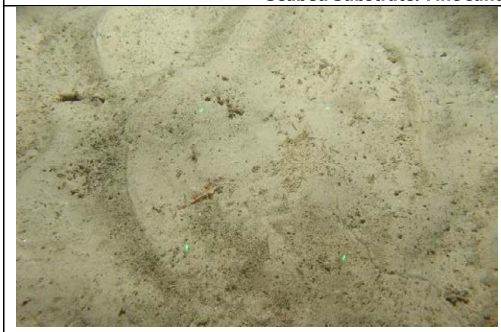

Photo 1: Soft sand and small shrimp/prawn

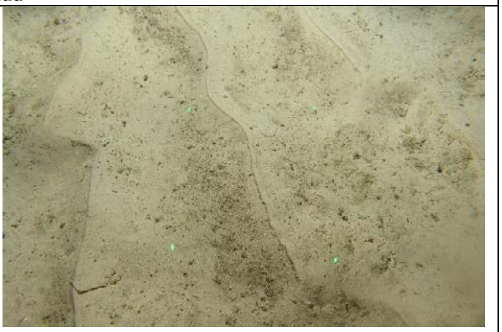

Photo 2:

Photo 3:

Photo 4: Soft sand; small hermit crab

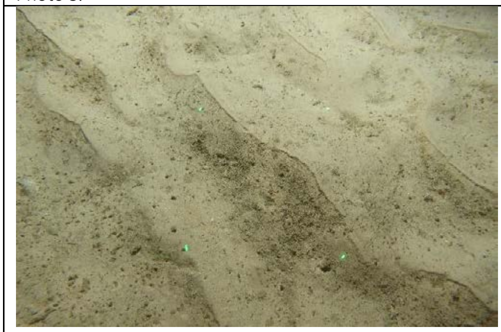

Photo 5: Soft sand; small amount of shell grit

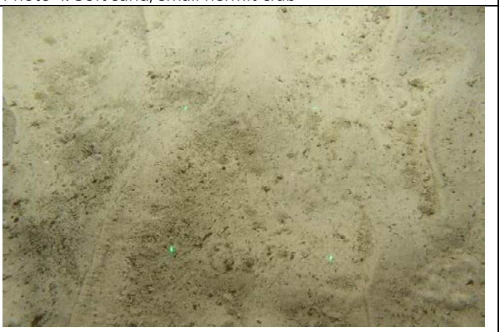

Photo 6:

Photo 7:

Photo 8: Soft sand and small shrimp/prawn

Photo plate 6: Site 5 **Date: 03/04/2019**	**Approximate Temperature: 10.1 °C** **Approximate Depth: 395.8 m** **Seabed Substrate: Fine sand-mud**	**Laser scale: 20 cm(l) x 24 cm(h)** **Coordinates: Z51 236324.53, 8209845.56**

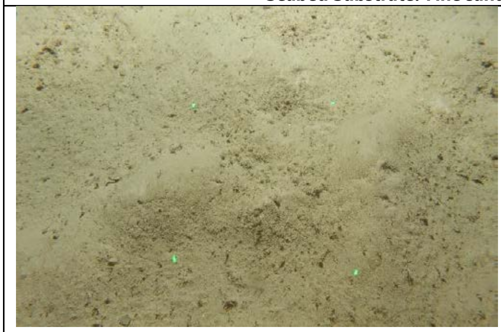
Photo 1: Soft sand/silt

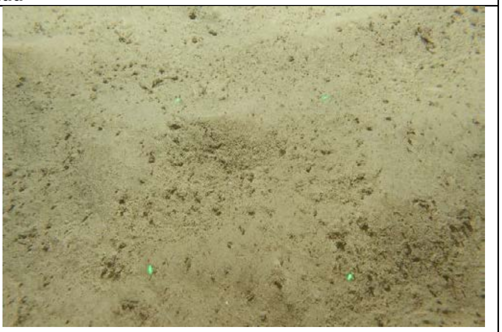
Photo 2: Soft sand/silt

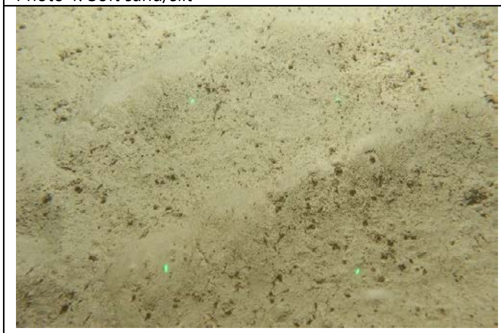
Photo 3: Soft sand/silt

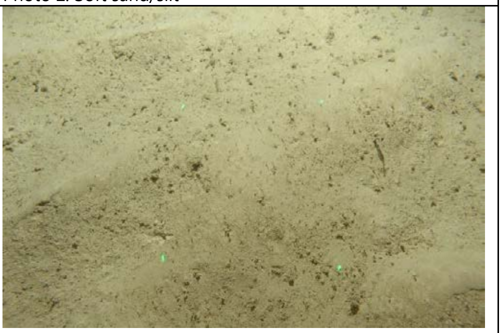
Photo 4: Soft sand/silt


Photo 5: Slight depression unknown origin

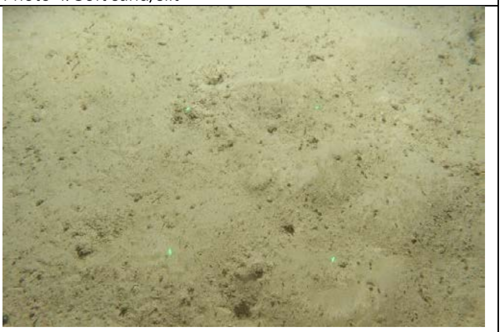
Photo 6: Soft sand/silt


Photo 7: Soft sand/silt

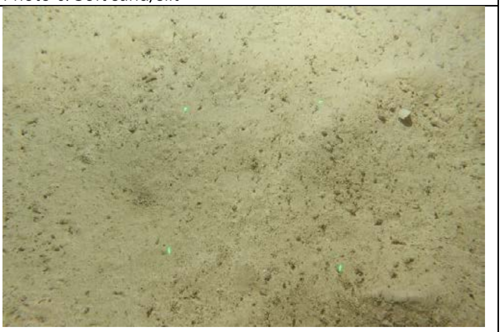
Photo 8: Soft sand/silt

Photo plate 7: Site 6 **Date: 04/04/2019**	**Approximate Temperature: no data** **Approximate Depth: 450.3 m** **Seabed Substrate: Coarse sand**	**Laser scale: 18 cm(l) x 23 cm(h)** **Coordinates: Z51 206454.54, 8159370.16**


Photo 1: Coarse sand


Photo 2: Coarse sand


Photo 3: Coarse sand


Photo 4: Coarse sand


Photo 5: Coarse sand


Photo 6: Coarse sand and some shell fragments


Photo 7: Coarse sand


Photo 8: Coarse sand

Photo plate 8: Site 7 **Date: 04/04/2019**	**Approximate Temperature: 10.2 °C** **Approximate Depth: 392.1 m** **Seabed Substrate: Medium 2D Ripples**	**Laser scale: 18 cm(l) x 23 cm(h)** **Coordinates: Z50 782707.00, 8087352.39**

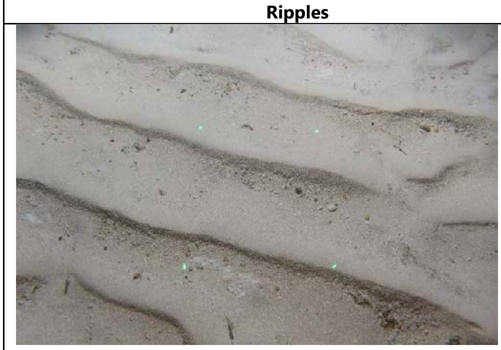
Photo 1: Coarse sand – ripples evident


Photo 2: Coarse sand – ripples evident; shell fragments


Photo 3: Solitary bony fish


Photo 4: Coarse sand – ripples evident


Photo 5: Coarse sand – ripples evident


Photo 6: Coarse sand – ripples evident


Photo 7: Coarse sand – ripples evident; shell fragments


Photo 8: Coarse sand – ripples evident; shell fragments

Photo plate 9: Site 8 **Date: 04/04/2019**	**Approximate Temperature: 10.4 °C** **Approximate Depth: 388.0 m** **Seabed Substrate: Coarse sand**	**Laser scale: 18 cm(l) x 23 cm(h)** **Coordinates: Z50 775946.27, 8082723.25**


Photo 1: Coarse sand – ripples evident


Photo 2: Schooling small bony fish


Photo 3: Schooling small bony fish


Photo 4: Coarse sand – ripples evident


Photo 5: Coarse sand – ripples evident


Photo 6: Coarse sand – ripples evident


Photo 7: Coarse sand – ripples evident


Photo 8: Coarse sand – ripples evident

Photo plate 10: Site 9 **Date: 04/04/2019**	**Approximate Temperature: 11.0 °C** **Approximate Depth: 342.5 m** **Seabed Substrate: Medium 2D Sand Waves**	**Laser scale: 18 cm(l) x 23 cm(h)** **Coordinates: Z50 733061.37, 8046631.46**

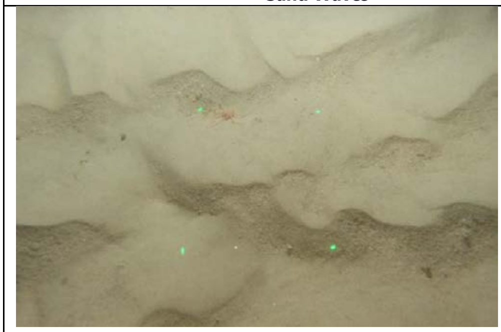
Photo 1: Coarse sand – ripples evident

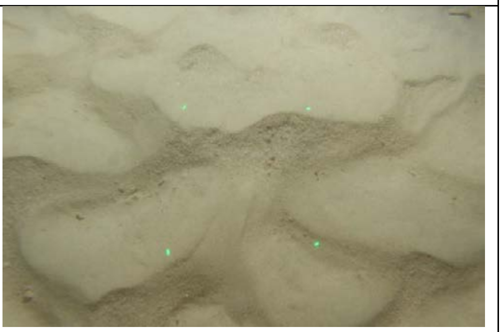
Photo 2: Coarse sand – ripples evident

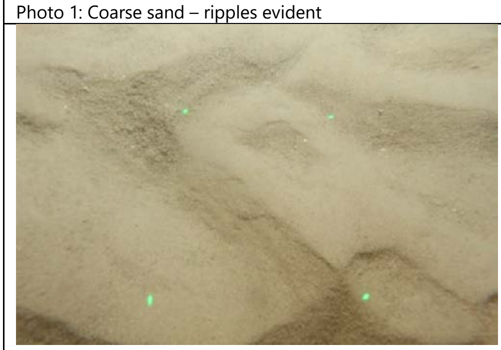
Photo 3: Coarse sand – ripples evident

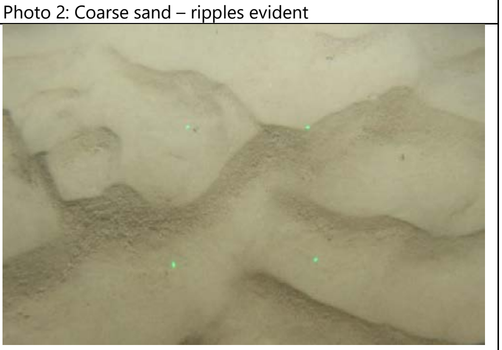
Photo 4: Coarse sand – ripples evident

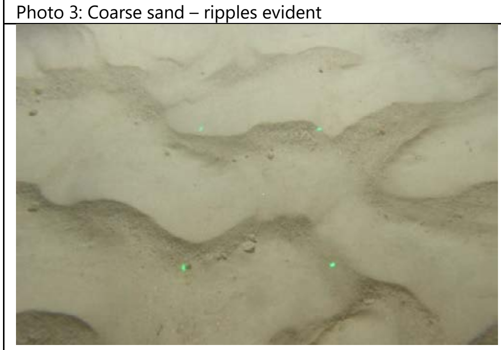
Photo 5: Coarse sand – ripples evident

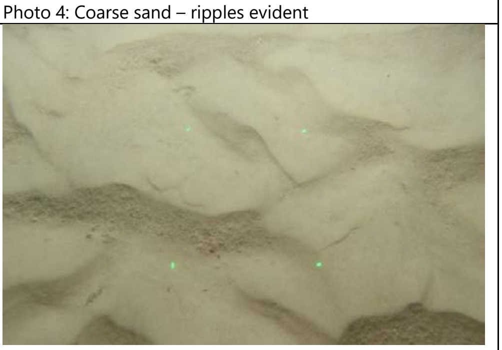
Photo 6: Coarse sand – ripples evident

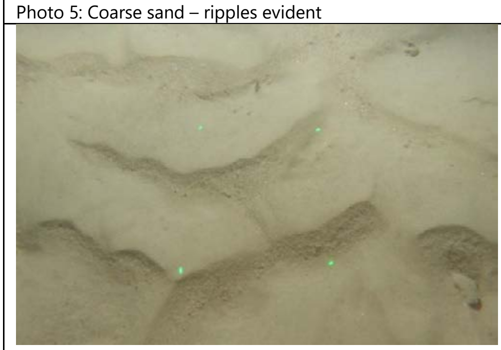
Photo 7: Coarse sand – ripples evident


Photo 8: Coarse sand – ripples evident

Photo plate 11: Site 10 **Date: 04/04/2019**	**Approximate Temperature: 11.2 °C** **Approximate Depth: 345.0 m** **Seabed Substrate: Coarse sand**	**Laser scale: 18 cm(l) x 23 cm(h)** **Coordinates: Z50 724494.40, 8047069.58**


Photo 1: Schooling small bony fish


Photo 2: Schooling small bony fish


Photo 3: Sand no profile


Photo 4: Single small bony fish


Photo 5: Schooling small bony fish


Photo 6: Schooling small bony fish


Photo 7: Single small bony fish


Photo 8: Single small bony fish

Photo plate 12: Site 11 **Date: 05/04/2019**	**Approximate Temperature: 12.4 °C** **Approximate Depth: 275.9 m** **Seabed Substrate: Coarse sand**	**Laser scale: 18 cm(l) x 23 cm(h)** **Coordinates: Z50 667105.91, 8001855.53**


Photo 1: Coarse sand with ripples; small fauna tracks


Photo 2: Coarse sand with ripples; small fauna tracks


Photo 3: Coarse sand with ripples; small fauna tracks


Photo 4: Coarse sand, small amount bioturbation


Photo 5: Coarse sand with ripples; small fauna tracks & hermit crab


Photo 6: Coarse sand with ripples; small fauna tracks


Photo 7: Coarse sand with ripples; small fauna tracks


Photo 8: Coarse sand with ripples; small fauna tracks

Photo plate 13: Site 12 **Date: 05/04/2019**	**Approximate Temperature: 13.3 °C** **Approximate Depth: 277.1 m** **Seabed Substrate: Coarse sand**	**Laser scale: 18 cm(l) x 23 cm(h)** **Coordinates: Z50 557900.67, 7930366.41**

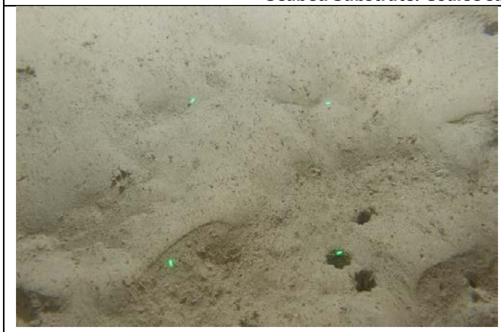
Photo 1: Bioturbation evident


Photo 2: Bioturbation & fauna tracks evident


Photo 3: Soft sand; no profile


Photo 4: Soft sand; no profile


Photo 5: Soft sand; no profile


Photo 6: Soft sand; no profile


Photo 7: Bioturbation evident


Photo 8: Bioturbation & fauna tracks evident

Photo plate 14: Site 13 **Date: 05/04/2019**	**Approximate Temperature: 12.6 °C** **Approximate Depth: 276.7 m** **Seabed Substrate: Sloped Terrain Scarp**	**Laser scale: 18 cm(l) x 23 cm(h)** **Coordinates: Z50 505303.28, 7895820.71**


Photo 1: Biogenic rubble & small fauna tracks


Photo 2: Sand; no profile; some shell fragments


Photo 3: Shell fragments & biogenic rubble


Photo 4: Shell fragments & fauna tracks


Photo 5: Shell fragments & biogenic rubble


Photo 6: Some small shells

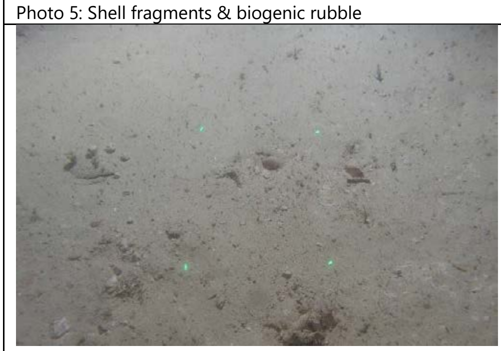
Photo 7: Shell fragments & biogenic rubble


Photo 8: Shell fragments

Photo plate 15: Site 14 **Date: 06/04/2019**	**Approximate Temperature: 16.1 °C** **Approximate Depth: 232.8 m** **Seabed Substrate: Irregular 2D Ripples**	**Laser scale: 18 cm(l) x 23 cm(h)** **Coordinates: Z50 482395.03, 7884278.20**

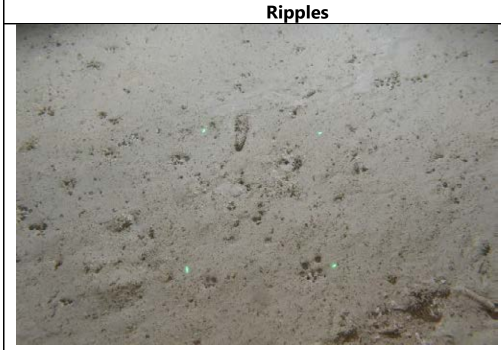
Photo 1: Fauna tracks, some rubble and small bioturbation


Photo 2: Fauna tracks, some rubble and small bioturbation


Photo 3: Drag mark from camera frame


Photo 4: Echinoderms (sea star & possible urchin); some bioturbation.


Photo 5: Bioturbation; colour change in disturbed sediments


Photo 6: Fauna tracks and bioturbation


Photo 7: Bioturbation; colour change in disturbed sediments


Photo 8: Fauna tracks and bioturbation

Photo plate 16: Site 15	**Approximate Temperature: 17.6 °C**	**Laser scale: 18 cm(l) x 23 cm(h)**
Date: 06/04/2019	**Approximate Depth: 193.8 m**	**Coordinates: Z50 467801.66, 7876933.65**
	Seabed Substrate: Mound	


Photo 1: Biogenic rubble with some hydroids present


Photo 2: Biogenic rubble; small crustaceans; small cnidarian

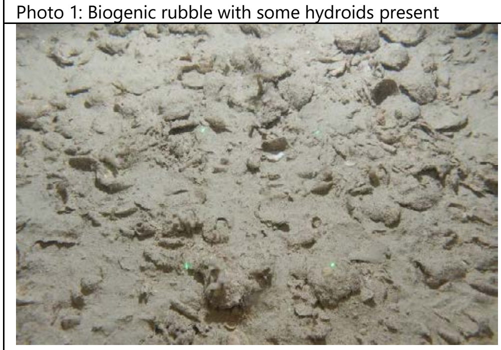
Photo 3: Solitary tube anemone; ascidians on biogenic rubble


Photo 4: Ascidians; solitary sponge and shells on bio. rubble


Photo 5: Biogenic rubble with ascidians present


Photo 6: Biogenic rubble


Photo 7: Sponge; ascidians; crustacean with bio. rubble


Photo 8: Biogenic rubble with ascidians present

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Photo plate 17: Site 16 **Date: 15/03/2019**	**Approximate Temperature: 16.2 °C** **Approximate Depth: 202.81 m** **Seabed Substrate: Irregular 3D Ripples**	**Laser scale: 18 cm(l) x 23 cm(h)** **Coordinates: Z50 443706.20, 7876121.45**

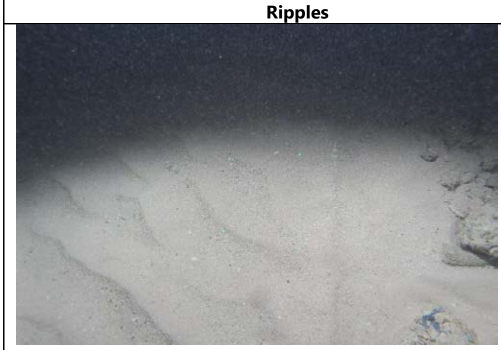


Photo 1: Coarse, rippled sand abutting


Photo 2: Echinoid (pencil urchin) & solitary sponge within biogenic rubble


Photo 3: Coarse sand & biogenic rubble


Photo 4: Coarse sand; drag mark from camera frame


Photo 5: Coarse sand – ripples evident


Photo 6: Coarse, rippled sand with biogenic rubble

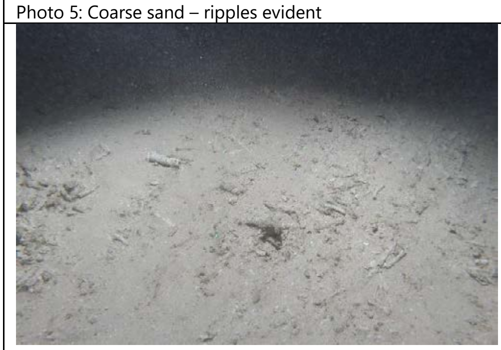


Photo 7: Coarse sand & biogenic rubble


Photo 8: Coarse, rippled sand with possible ascidian

Photo plate 18: Site 17
Date: 15/03/2019
Approximate Temperature: 20.7 °C
Approximate Depth: 140.1 m
Seabed Substrate: Fine sand-mud
Laser scale: 18 cm(l) x 23 cm(h)
Coordinates: Z50 431363.73, 7857665.61

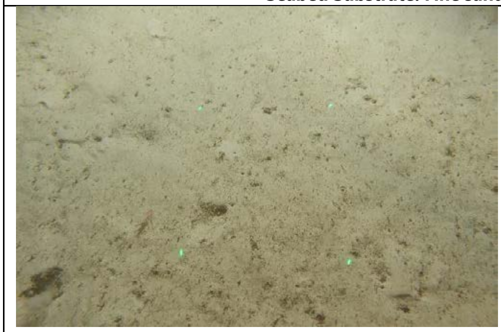


Photo 1: Bioturbation evident; solitary hydroid or soft coral

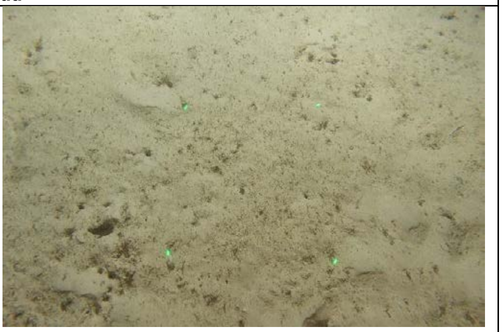


Photo 2: Single bony fish & small amount of bioturbation

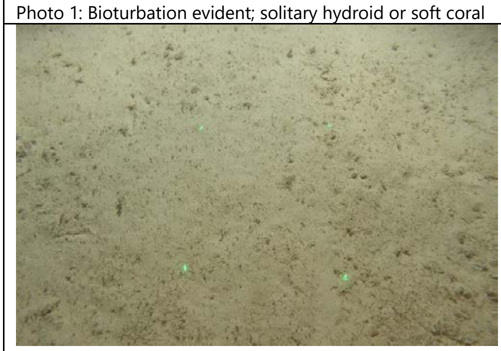


Photo 3: Fine sand


Photo 4: Single bony fish & small amount of bioturbation

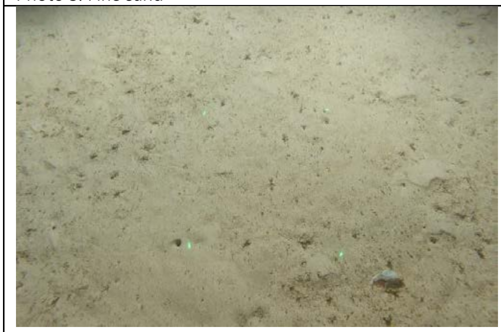


Photo 5: Single bony fish & small amount of bioturbation


Photo 6: Bioturbation evident


Photo 7: Single bony fish & small amount of bioturbation


Photo 8: Small amount of bioturbation evident

Photo plate 19: Site 18	**Approximate Temperature: 21.8 °C**	**Laser scale: 18 cm(l) x 23 cm(h)**
Date: 14/03/2019	**Approximate Depth: 134.3 m**	**Coordinates: Z50 415886.56, 7849407.51**
	Seabed Substrate: Coarse sand	


Photo 1: Solitary small bony fish; coarse, rippled sand


Photo 2: Small bony fish


Photo 3: Small bony fish


Photo 4: Small bony fish


Photo 5: Small bony fish


Photo 6: Small bony fish


Photo 7: Coarse sand – ripples evident


Photo 8: Coarse sand – ripples evident

Photo plate 20: Site 19 **Date: 06/04/2019**	**Approximate Temperature: 22.4 °C** **Approximate Depth: 131.92 m** **Seabed Substrate: Fine sand-mud**	**Laser scale: 18 cm(l) x 23 cm(h)** **Coordinates: Z50 408100.11, 7840085.65**

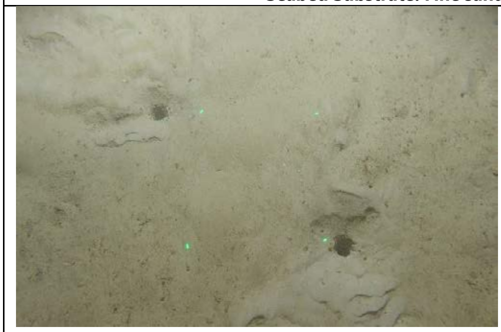


Photo 1: Bioturbation evident – larger holes

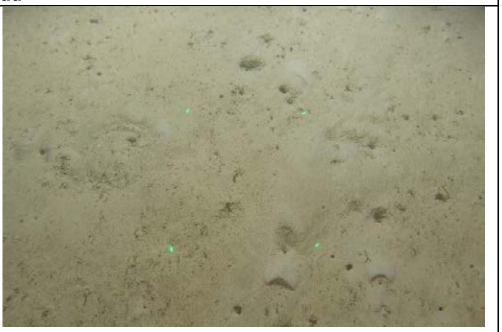


Photo 2: Bioturbation evident


Photo 3: Bioturbation evident

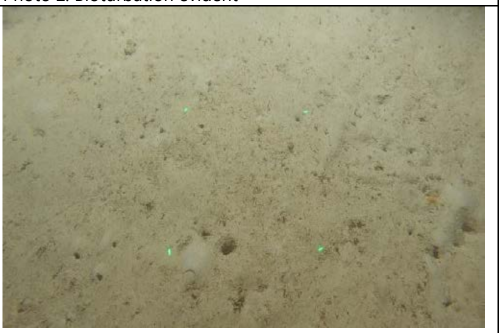


Photo 4: Bioturbation evident

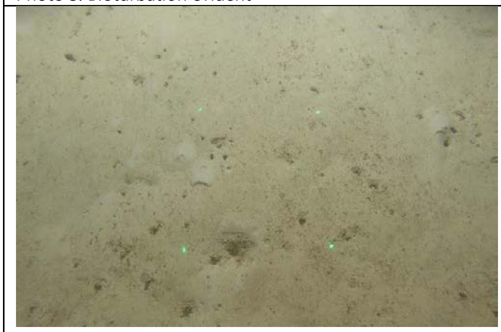


Photo 5: Bioturbation evident

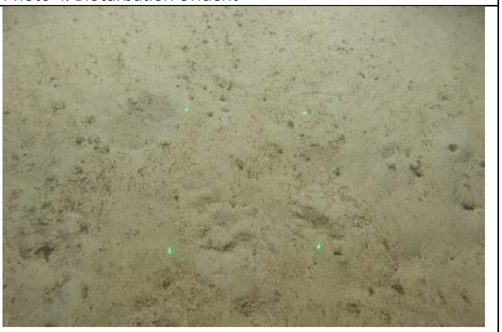


Photo 6: Bioturbation evident

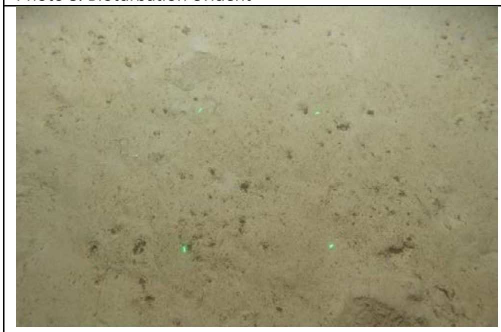


Photo 7: Bioturbation evident

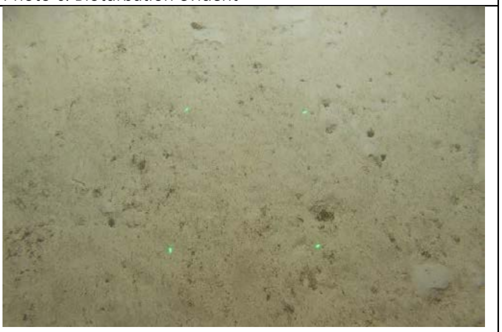


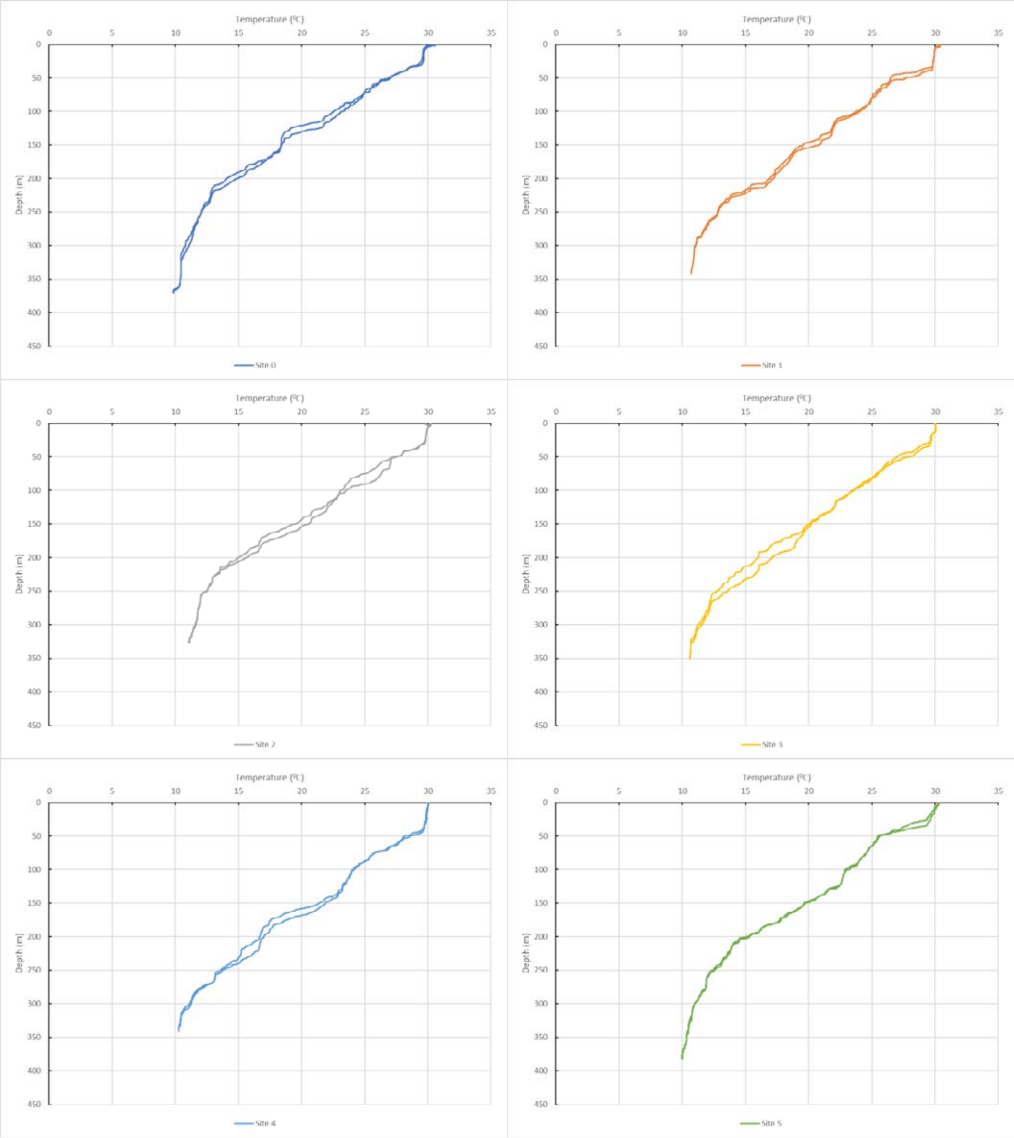
Photo 8: Bioturbation evident

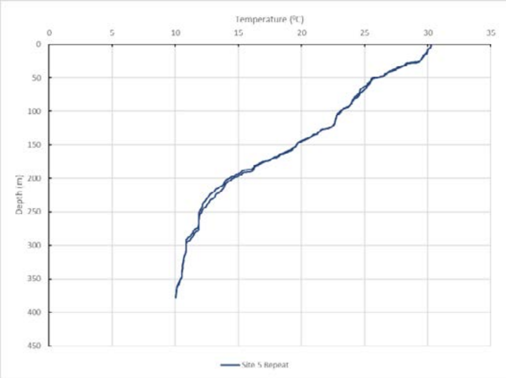
Appendix J
Benthic Habitat Classifications

Site	Physical						Biota			Change in habitat during video
	Substrate 1	Substrate 2	Relief	Bedform 1	Bedform 2	Bedform 3	1	2	3	
0	Unconsolidated	Soft: (no shell) fine sand/mud	Relief: Flat	None			Crustacea			N
1	Unconsolidated	Soft: (no shell) fine sand/mud	Relief: Flat	None	Bioturbated		Fishes	Cnidaria	Crustacea	N
2	Unconsolidated	Soft: (with shell) coarse sand	Relief: Low/moderate: Low (<1 m)	3D	Waves	Small	Cnidaria	Crustacea	Echinoderms	N
3	Unconsolidated	Soft: (with shell) coarse sand	Relief: Flat	None			Crustacea	Echinoderms	Cnidaria	N
4	Unconsolidated	Soft: (no shell) fine sand/mud	Relief: Flat	3D	Waves	Small	Ascidians	Crustacea		N
5	Unconsolidated	Soft: (no shell) fine sand/mud	Relief: Flat	3D	Waves	Small				N
6	Unconsolidated	Soft: (with shell) coarse sand	Relief: Flat	3D	Waves	Medium	Echinoderms	Crustacea		N
7	Unconsolidated	Soft: (with shell) coarse sand	Relief: Flat	3D	Waves	Medium	Fishes			N
8	Unconsolidated	Soft: (with shell) coarse sand	Relief: Flat	3D	Waves	Small	Fishes	Echinoderms		N
9	Unconsolidated	Soft: (with shell) coarse sand	Relief: Flat	3D	Waves	Small	Crustacea			N
10	Unconsolidated	Soft: (no shell) fine sand/mud	Relief: Flat	None			Fishes			N
11	Unconsolidated	Soft: (with shell) coarse sand	Relief: Flat	3D	Waves	Small	Cnidaria	Fishes		N
12	Unconsolidated	Soft: (no shell) fine sand/mud	Relief: Flat	None	Bioturbated		Crustacea	Fishes		N
13	Unconsolidated	Soft: (with shell) coarse sand	Relief: Flat	None			Molluscs	Sponges		N
14	Unconsolidated	Soft: (no shell) fine sand/mud	Relief: Flat	None	Bioturbated		Echinoderms	Fishes		N
15	Unconsolidated	Soft: Rubble biologenic	Relief: Low/moderate: Low (<1 m)	None			Crustacea	Cnidaria	Sponges	N
16	Unconsolidated	Soft: (with shell) coarse sand	Relief: Flat	None			Echinoderms	Crustacea		N
17	Unconsolidated	Soft: (no shell) fine sand/mud	Relief: Flat	None	Bioturbated		Fishes			N
18	Unconsolidated	Soft: (no shell) fine sand/mud	Relief: Low/moderate: Low (<1 m)	3D	Waves	Small				N
19	Unconsolidated	Soft: (no shell) fine sand/mud	Relief: Flat	None	Bioturbated					N

Appendix K
Physical Water Quality Data

Temperature

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400
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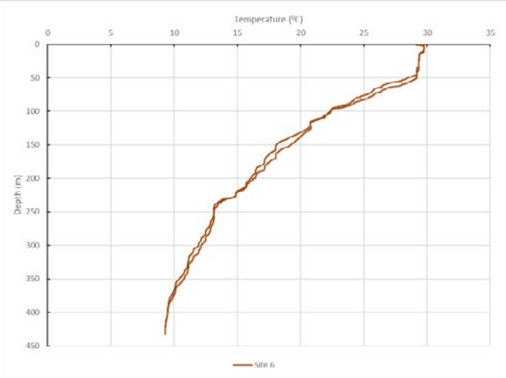
Depth (m)
Site 5 Repeat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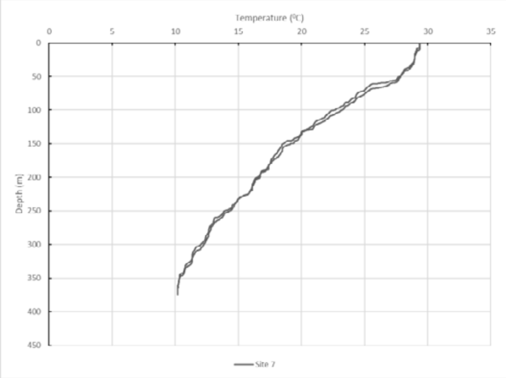
Depth (m)
Site 6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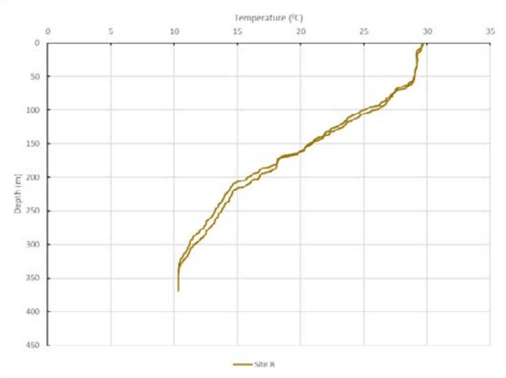
450
Depth (m)
Site 7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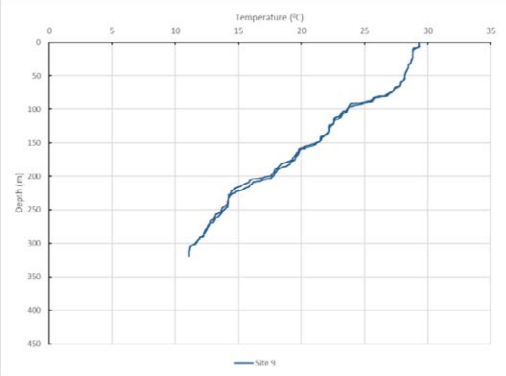
Depth (m)
Site 8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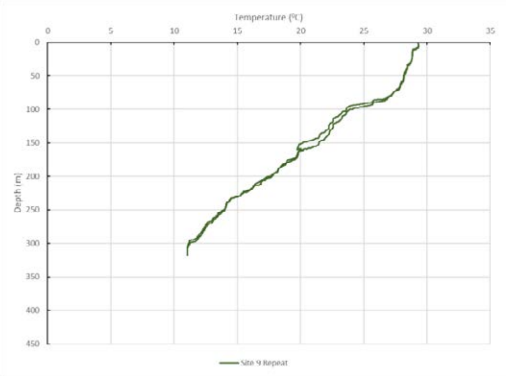
400
450
Depth (m)
Site 9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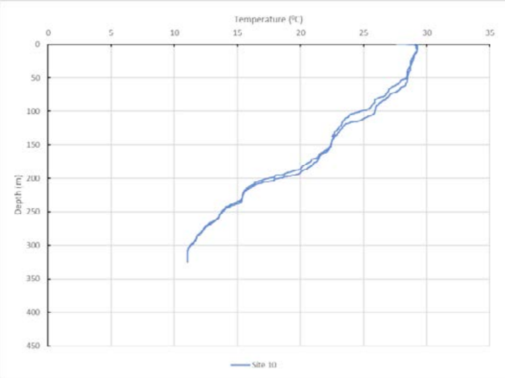
Depth (m)
Site 9 Repeat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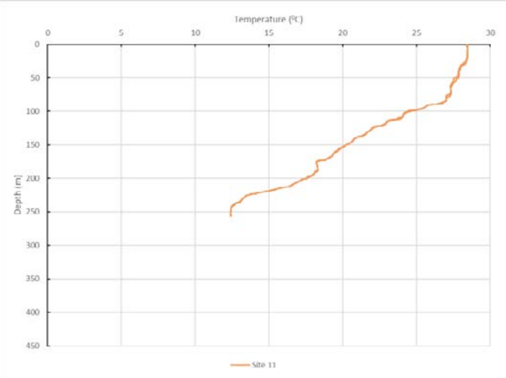
Site 10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Depth (m)
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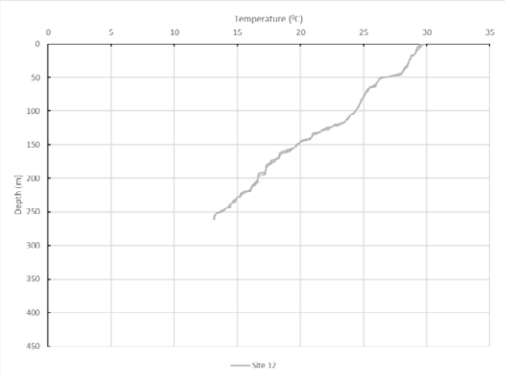
Site 11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Depth (m)
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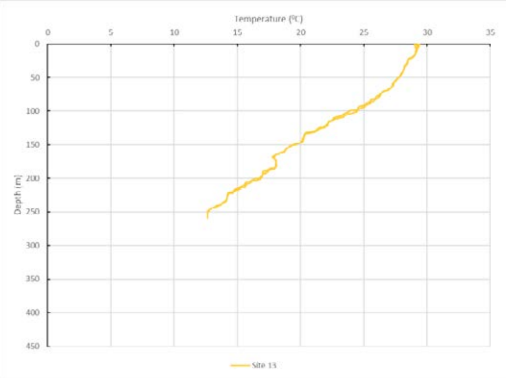
Site 12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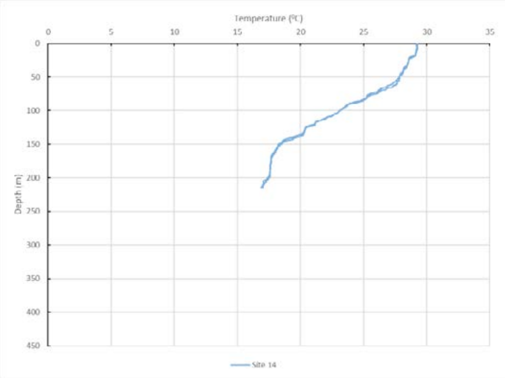
Site 13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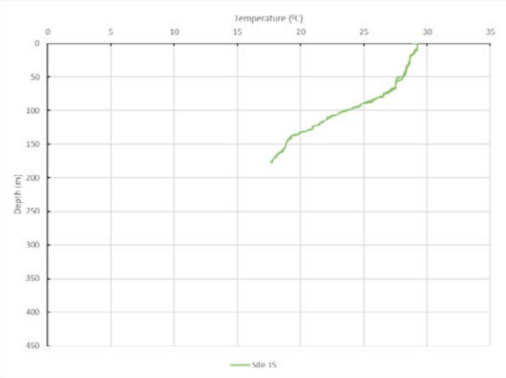
Site 14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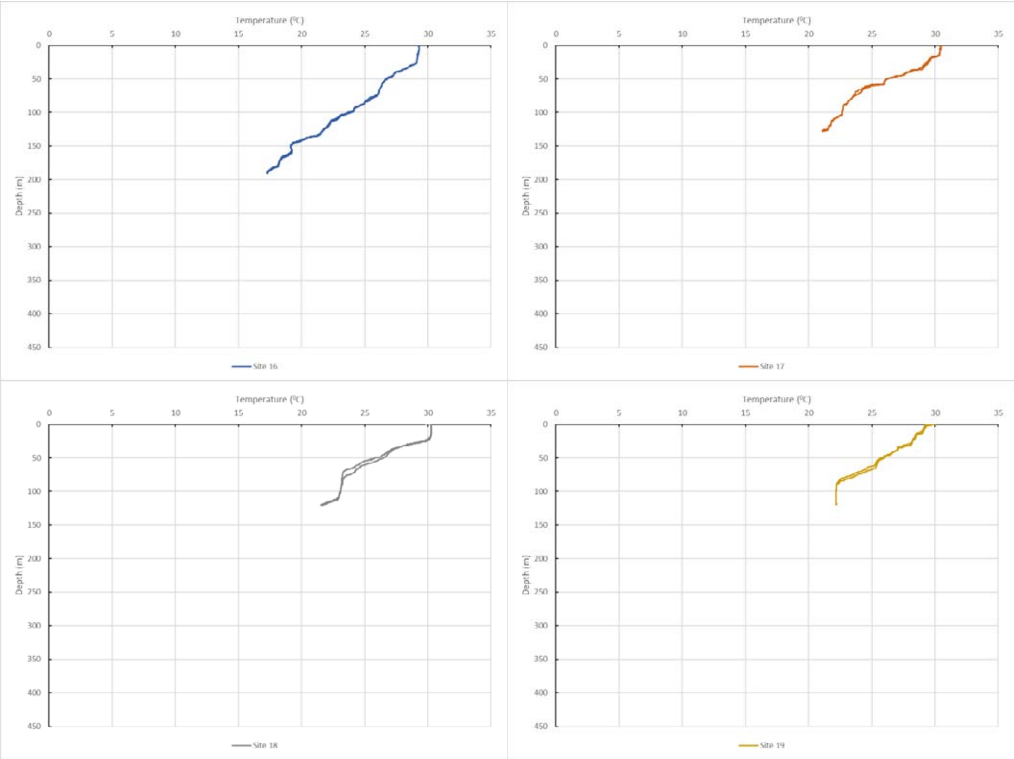
Site 15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Depth (m)
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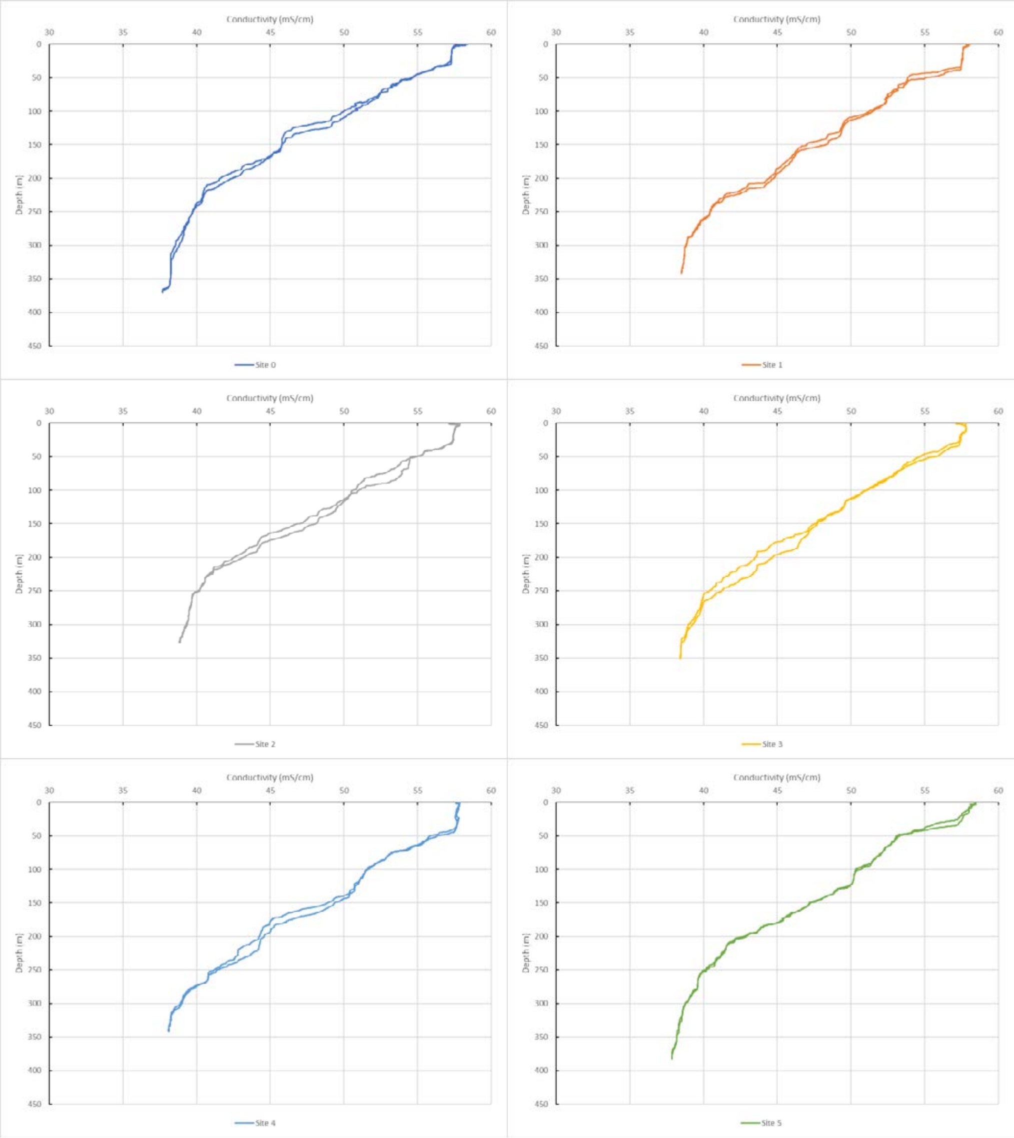
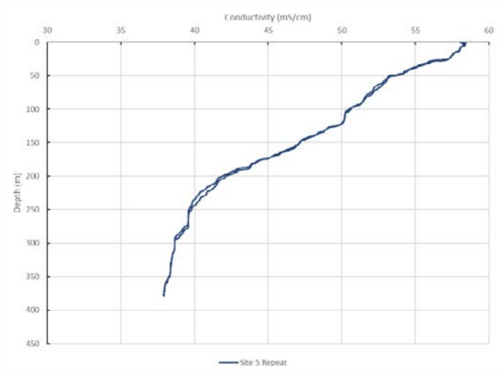
Site 16
Site 17
Site 18
Site 19

Conductivity




Conductivity (mS/cm)
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55
60
Depth (m)
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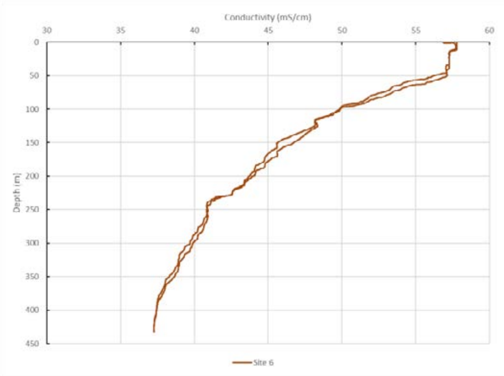
50
100
150
200
250
300
350
400
450
Site 5 Repeat


Conductivity (mS/cm)
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Depth (m)
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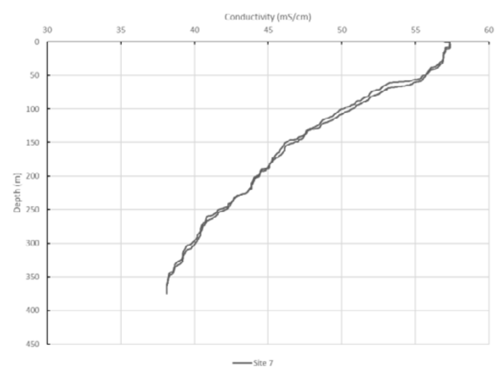
Site 6


Conductivity (mS/cm)
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Depth (m)
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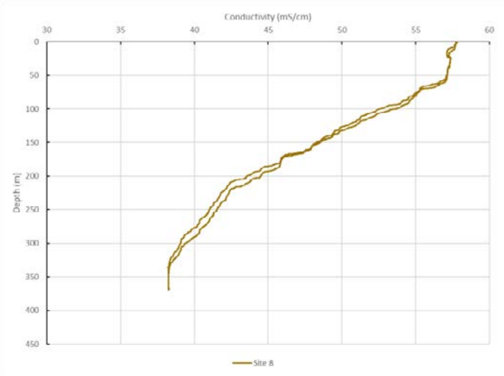
Site 7


Conductivity (mS/cm)
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Depth (m)
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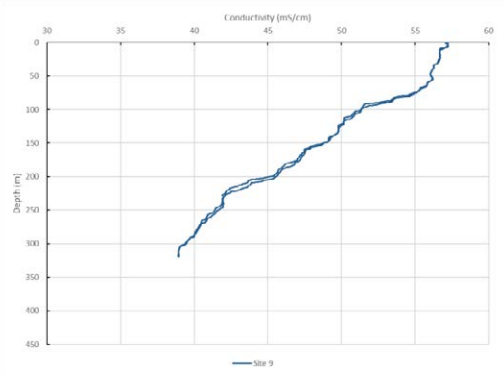
Site 8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Depth (m)
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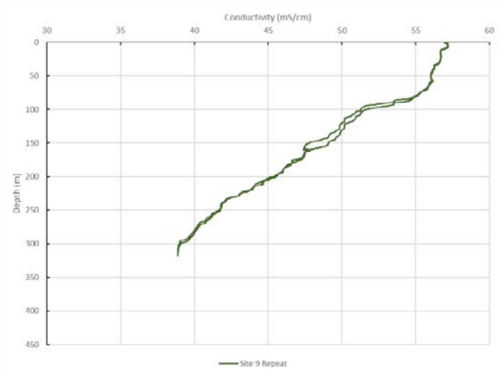
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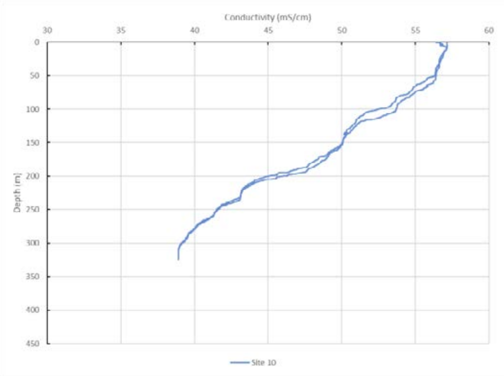
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Depth (m)
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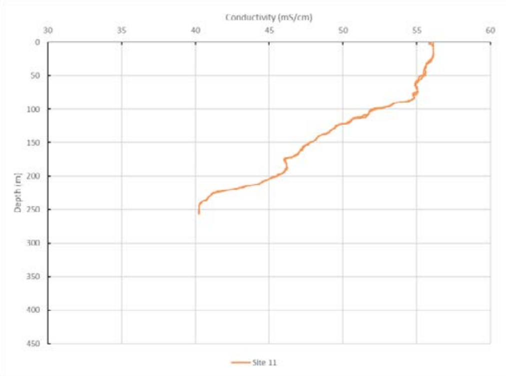
Conductivity (mS/cm)
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Depth (m)
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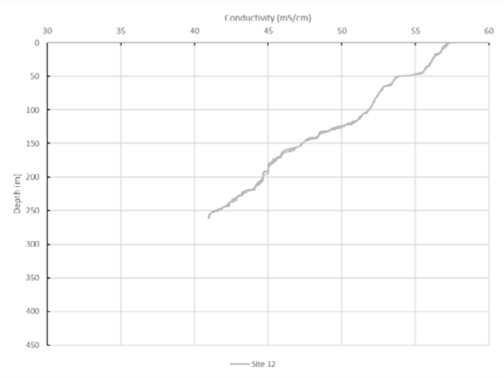
Site 11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Depth (m)
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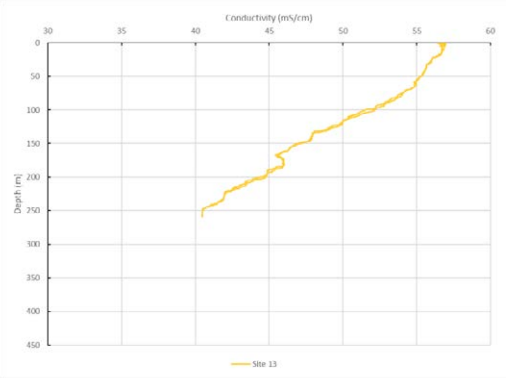
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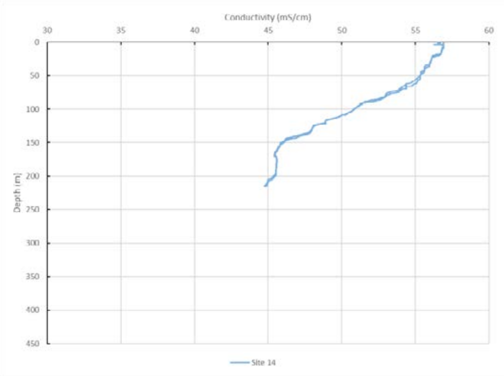
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Depth (m)
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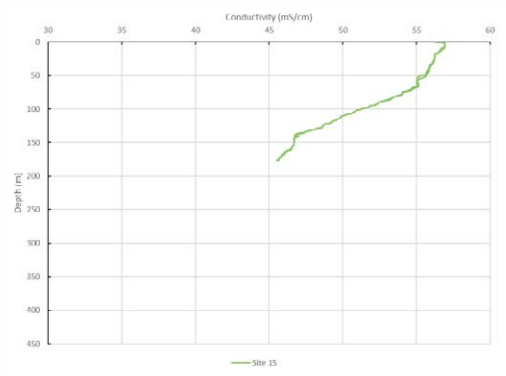
Site 14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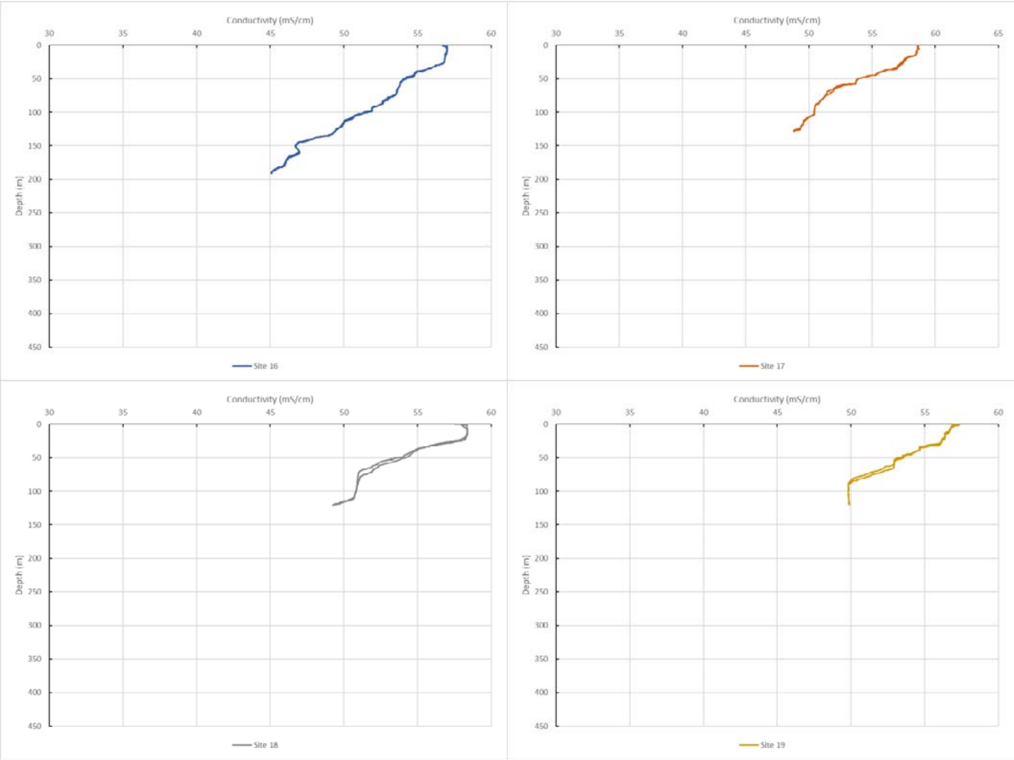
Site 15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Depth (m)
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150
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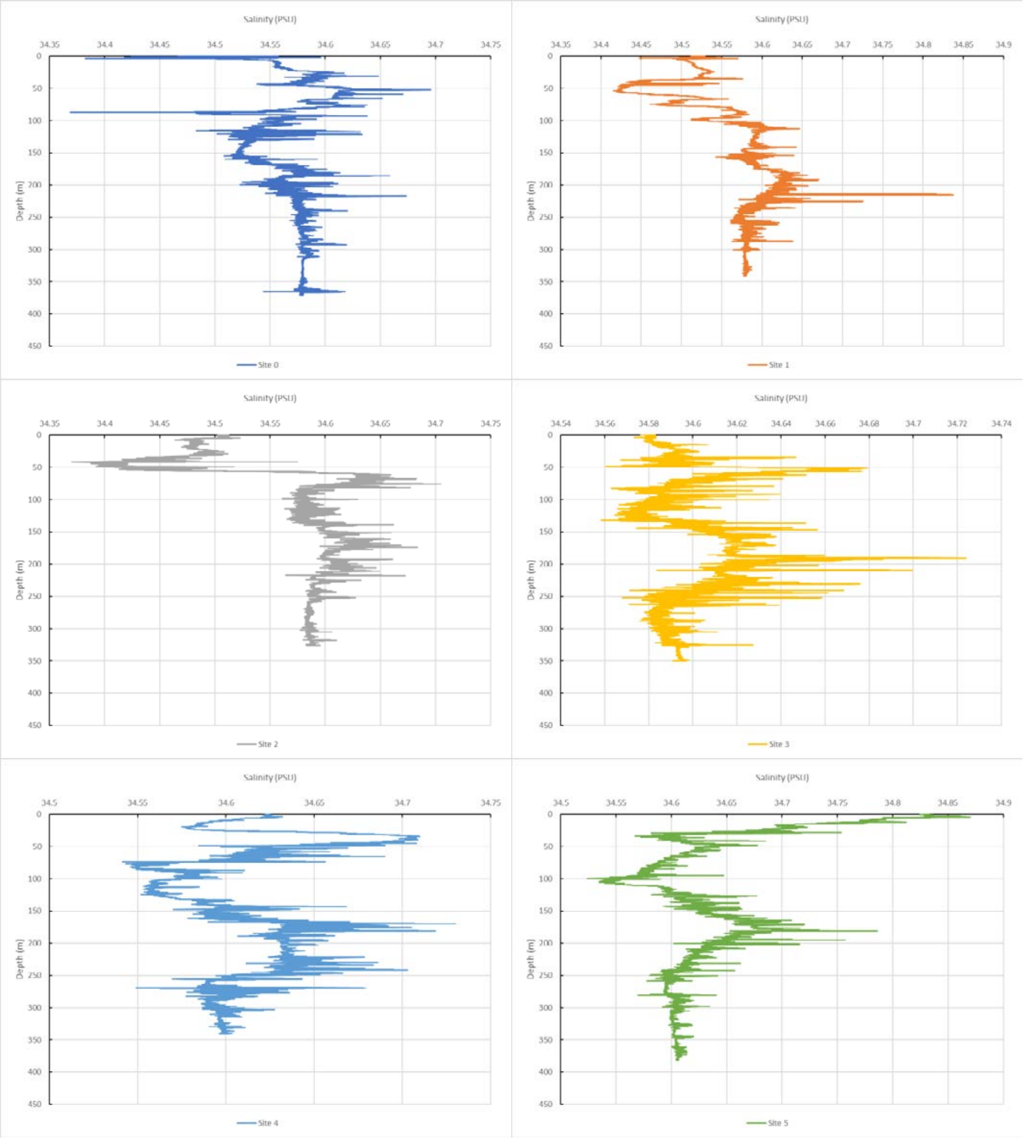
350
400
450
Site 16
Conductivity (mS/cm)
30
35
40
45
50
55
60
65
Depth (m)
Site 17
Conductivity (mS/cm)
Depth (m)
Site 18
Conductivity (mS/cm)
Depth (m)
Site 19

Salinity


Salinity (PSU)
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34.65
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Depth (m)
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50
100
150
200
250
300
350
400
450
Site 0
Salinity (PSU)
34.35
34.4
34.45
34.5
34.55
34.6
34.65
34.7
34.75
34.8
34.85
34.9
Depth (m)
Site 1
Salinity (PSU)
34.35
34.4
34.45
34.5
34.55
34.6
34.65
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Depth (m)
Site 2
Salinity (PSU)
34.54
34.56
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34.62
34.64
34.66
34.68
34.7
34.72
34.74
Depth (m)
Site 3
Salinity (PSU)
34.5
34.55
34.6
34.65
34.7
34.75
Depth (m)
Site 4
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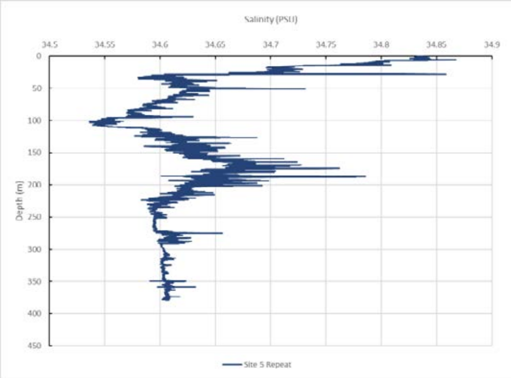
34.9
Depth (m)
Site 5


Salinity (PSU)
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34.55
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34.65
34.7
34.75
34.8
34.85
34.9
Depth (m)
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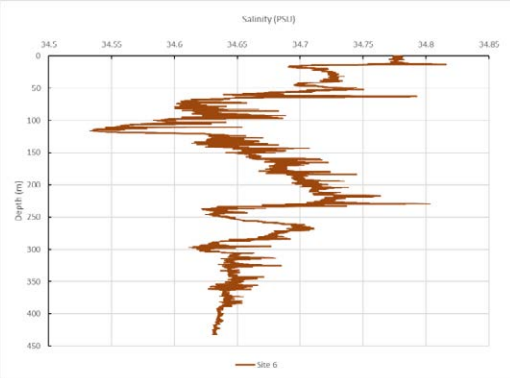
100
150
200
250
300
350
400
450
Site 5 Repeat


Salinity (PSU)
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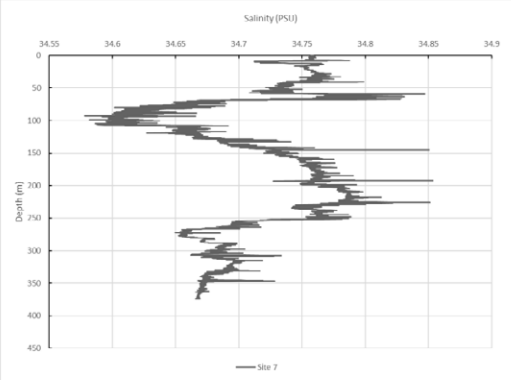
Site 6


Salinity (PSU)
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34.7
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34.9
Depth (m)
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150
200
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350
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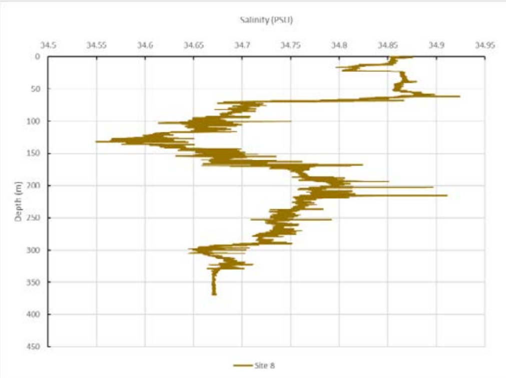
450
Site 7


Salinity (PSU)
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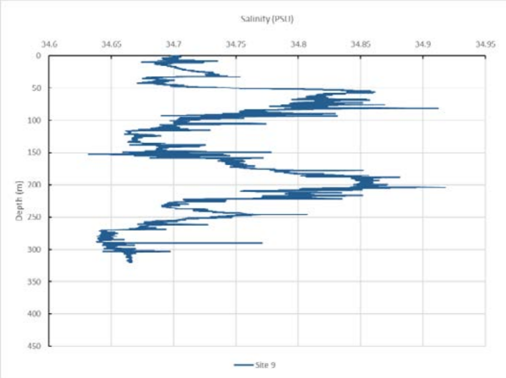
Site 8


Salinity (PSU)
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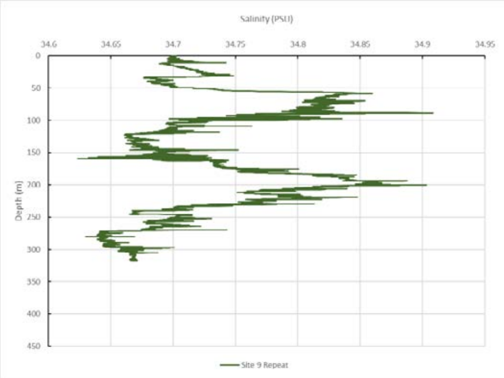
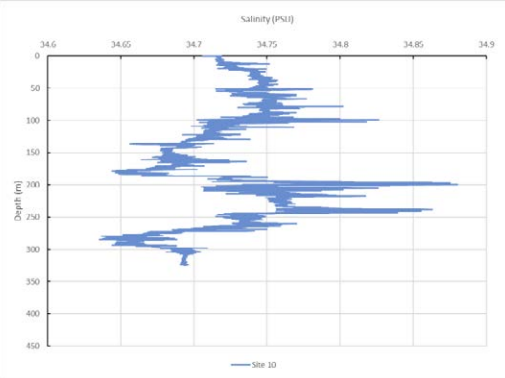
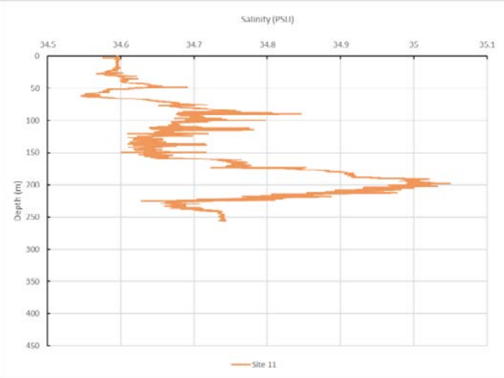
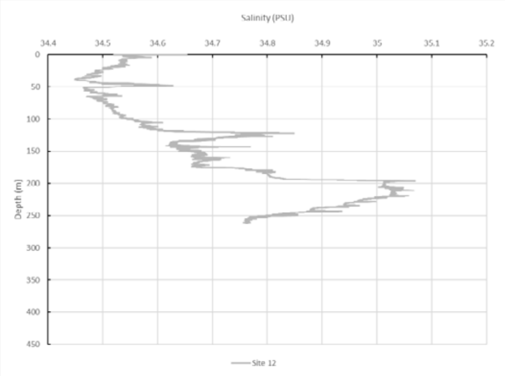
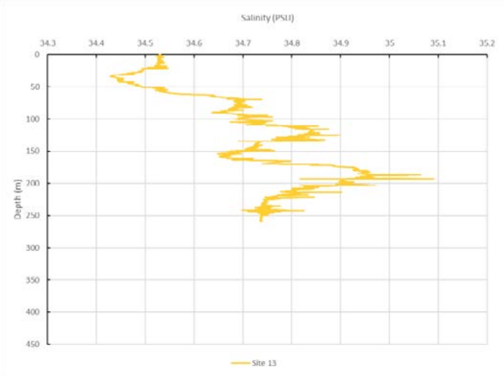
34.8
34.85
34.9
34.95
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 9

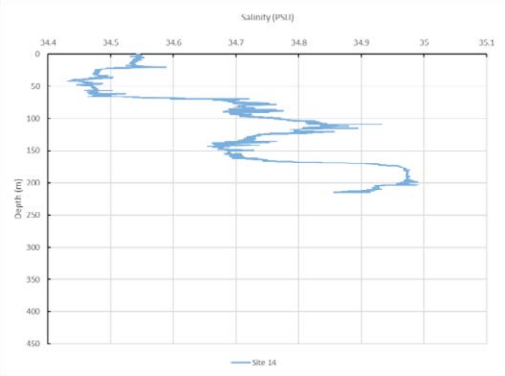

Salinity (PSU)
34.6
34.65
34.7
34.75
34.8
34.85
34.9
34.95
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 9 Repeat

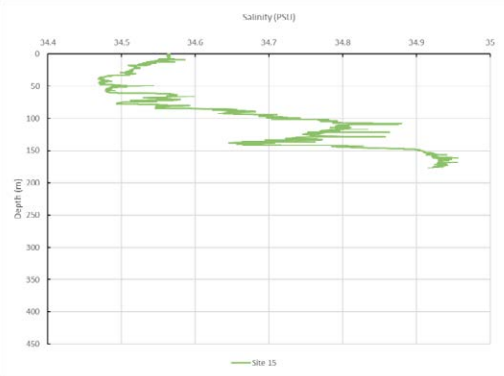

Salinity (PSU)
34.6
34.65
34.7
34.75
34.8
34.85
34.9
0
50
100
150
200
250
300
350
400
450
Depth (m)
Site 10

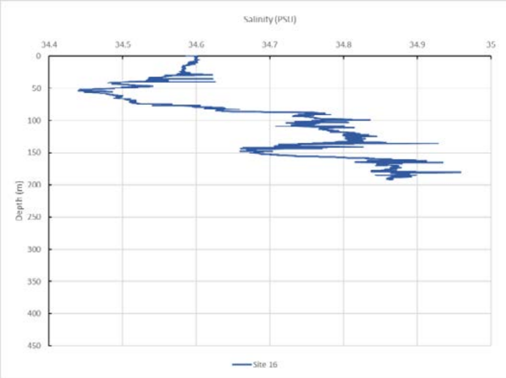

Salinity (PSU)
34.5
34.6
34.7
34.8
34.9
35
35.1
0
50
100
150
200
250
300
350
400
450
Depth (m)
Site 11

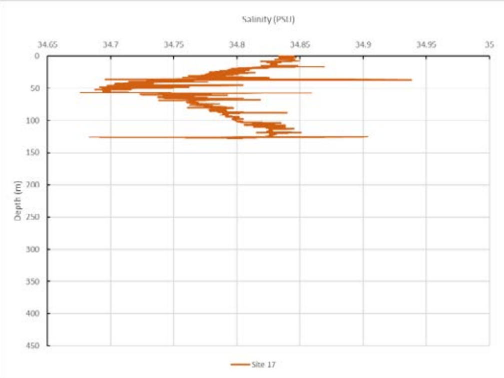

Salinity (PSU)
34.4
34.5
34.6
34.7
34.8
34.9
35
35.1
35.2
0
50
100
150
200
250
300
350
400
450
Depth (m)
Site 12

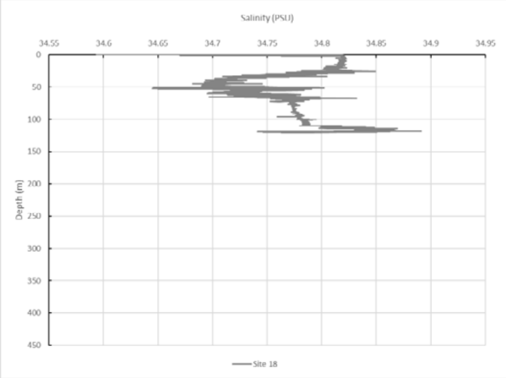

Salinity (PSU)
34.3
34.4
34.5
34.6
34.7
34.8
34.9
35
35.1
35.2
0
50
100
150
200
250
300
350
400
450
Depth (m)
Site 13

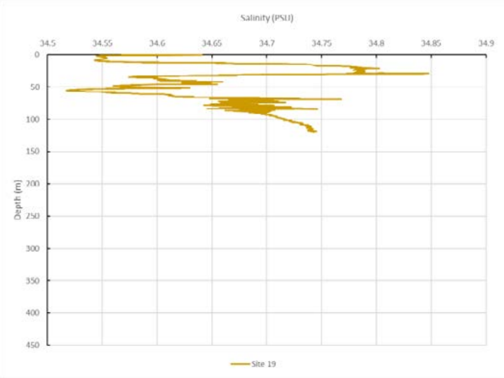

Salinity (PSU)
34.4
34.5
34.6
34.7
34.8
34.9
35
35.1
0
50
100
150
200
250
300
350
400
450
Depth (m)
Site 14


Salinity (PSU)
34.4
34.5
34.6
34.7
34.8
34.9
35
0
50
100
150
200
250
300
350
400
450
Depth (m)
Site 15

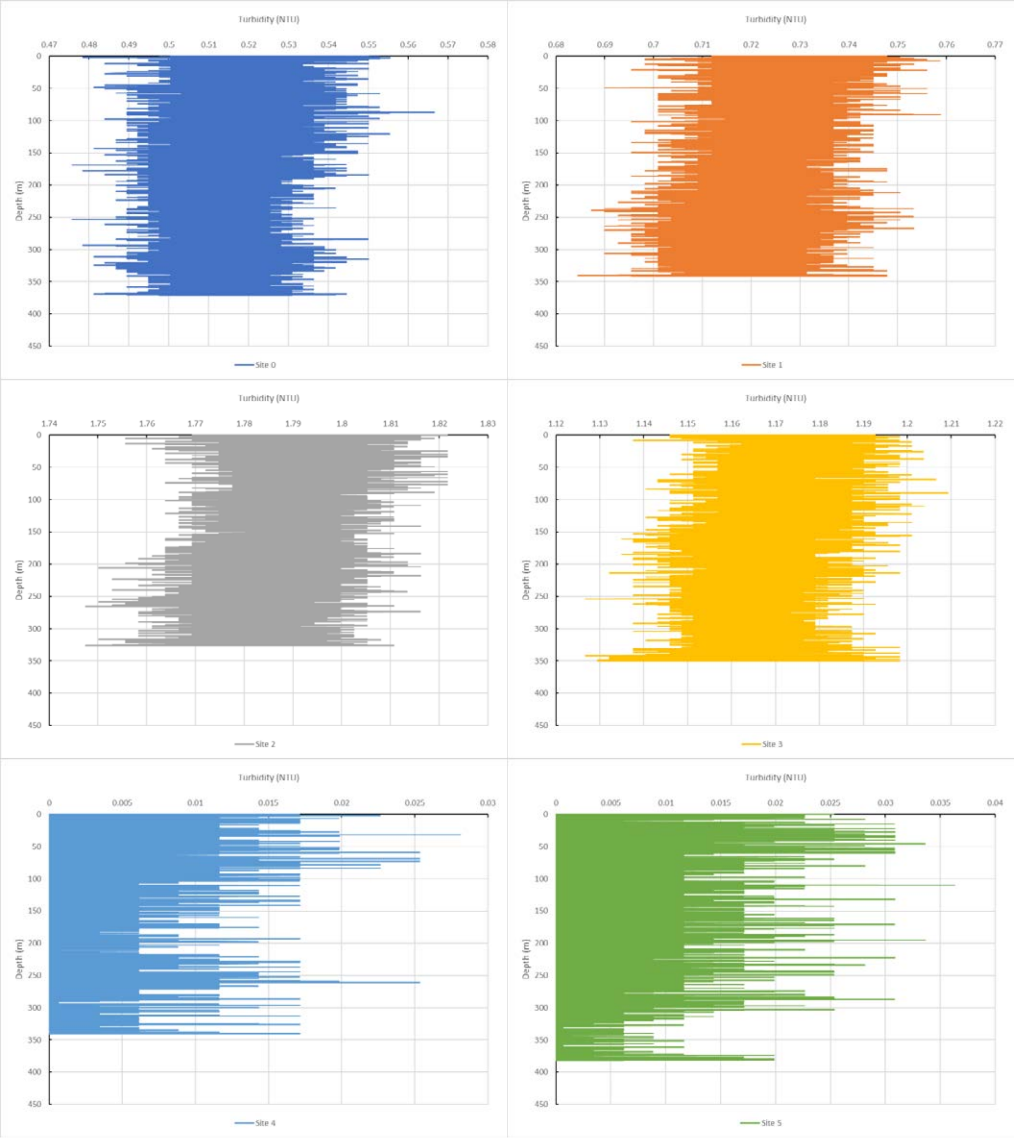

Salinity (PSU)
34.4
34.5
34.6
34.7
34.8
34.9
35
0
50
100
150
200
250
300
350
400
450
Depth (m)
Site 16

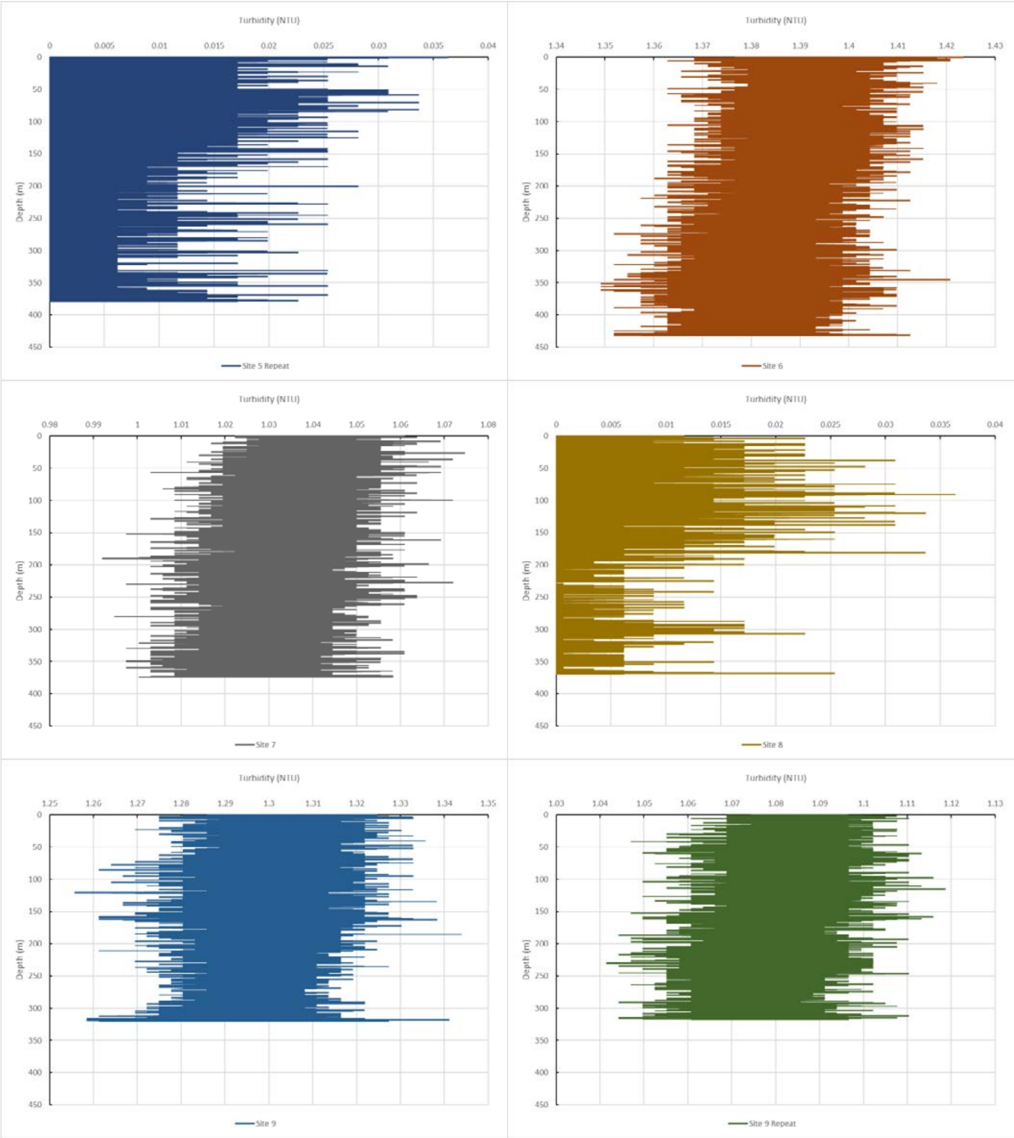

Salinity (PSU)
34.65
34.7
34.75
34.8
34.85
34.9
34.95
35
0
50
100
150
200
250
300
350
400
450
Depth (m)
Site 17

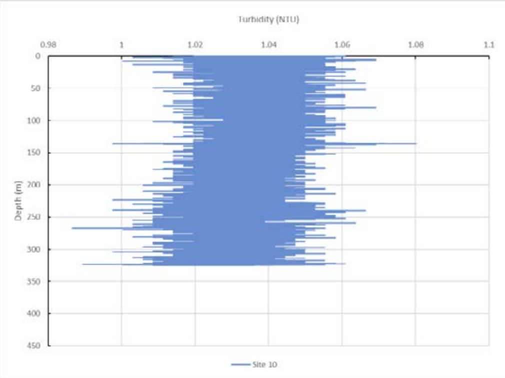

Salinity (PSU)
34.55
34.6
34.65
34.7
34.75
34.8
34.85
34.9
34.95
0
50
100
150
200
250
300
350
400
450
Depth (m)
Site 18

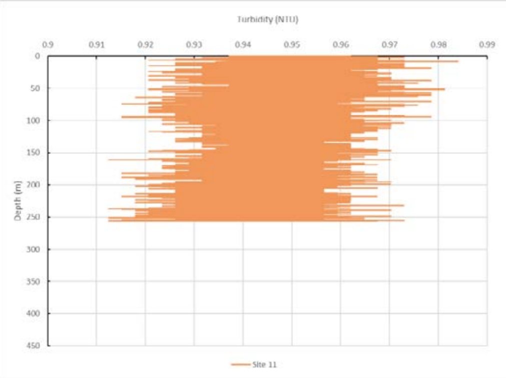

Salinity (PSU)
34.5
34.55
34.6
34.65
34.7
34.75
34.8
34.85
34.9
0
50
100
150
200
250
300
350
400
450
Depth (m)
Site 19

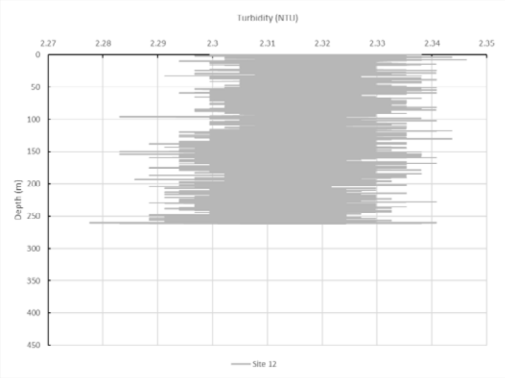
Turbidity

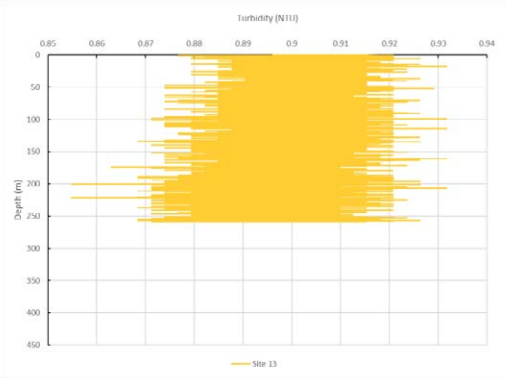

Turbidity (NTU)
0.47 0.48 0.49 0.5 0.51 0.52 0.53 0.54 0.55 0.56 0.57 0.58
Depth (m)
0 50 100 150 200 250 300 350 400 450
Site 0
Turbidity (NTU)
0.68 0.69 0.7 0.71 0.72 0.73 0.74 0.75 0.76 0.77
Depth (m)
0 50 100 150 200 250 300 350 400 450
Site 1
Turbidity (NTU)
1.74 1.75 1.76 1.77 1.78 1.79 1.8 1.81 1.82 1.83
Depth (m)
0 50 100 150 200 250 300 350 400 450
Site 2
Turbidity (NTU)
1.12 1.13 1.14 1.15 1.16 1.17 1.18 1.19 1.2 1.21 1.22
Depth (m)
0 50 100 150 200 250 300 350 400 450
Site 3
Turbidity (NTU)
0 0.005 0.01 0.015 0.02 0.025 0.03
Depth (m)
0 50 100 150 200 250 300 350 400 450
Site 4
Turbidity (NTU)
0 0.005 0.01 0.015 0.02 0.025 0.03 0.035 0.04
Depth (m)
0 50 100 150 200 250 300 350 400 450
Site 5

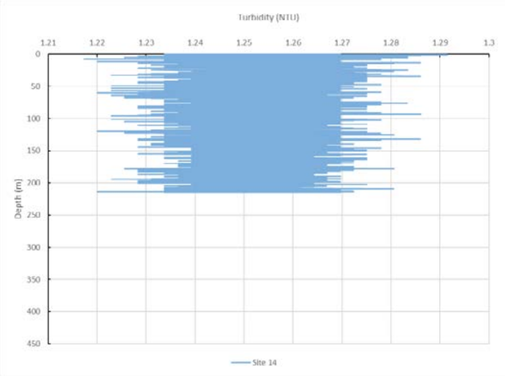

Turbidity (NTU)
0 0.005 0.01 0.015 0.02 0.025 0.03 0.035 0.04
Depth (m)
0 50 100 150 200 250 300 350 400 450
Site 5 Repeat
Turbidity (NTU)
1.34 1.35 1.36 1.37 1.38 1.39 1.4 1.41 1.42 1.43
Depth (m)
0 50 100 150 200 250 300 350 400 450
Site 6
Turbidity (NTU)
0.98 0.99 1 1.01 1.02 1.03 1.04 1.05 1.06 1.07 1.08
Depth (m)
0 50 100 150 200 250 300 350 400 450
Site 7
Turbidity (NTU)
0 0.005 0.01 0.015 0.02 0.025 0.03 0.035 0.04
Depth (m)
0 50 100 150 200 250 300 350 400 450
Site 8
Turbidity (NTU)
1.25 1.26 1.27 1.28 1.29 1.3 1.31 1.32 1.33 1.34 1.35
Depth (m)
0 50 100 150 200 250 300 350 400 450
Site 9
Turbidity (NTU)
1.03 1.04 1.05 1.06 1.07 1.08 1.09 1.1 1.11 1.12 1.13
Depth (m)
0 50 100 150 200 250 300 350 400 450
Site 9 Repeat

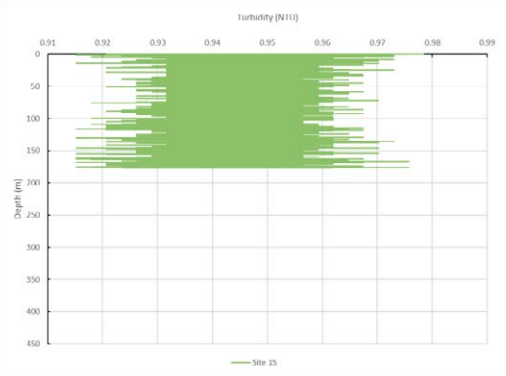

Turbidity (NTU)
0.98
1
1.02
1.04
1.06
1.08
1.1
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 10

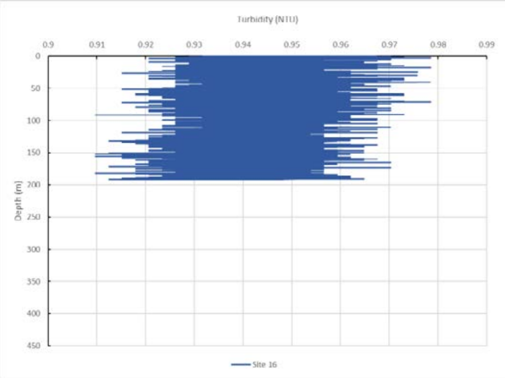

Turbidity (NTU)
0.9
0.91
0.92
0.93
0.94
0.95
0.96
0.97
0.98
0.99
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 11

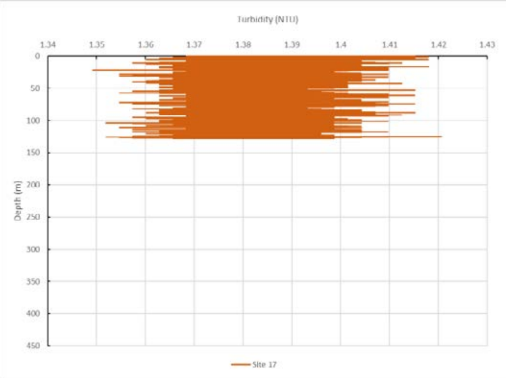

Turbidity (NTU)
2.27
2.28
2.29
2.3
2.31
2.32
2.33
2.34
2.35
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 12

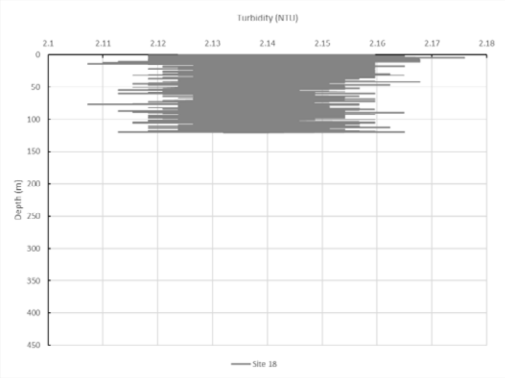

Turbidity (NTU)
0.85
0.86
0.87
0.88
0.89
0.9
0.91
0.92
0.93
0.94
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 13

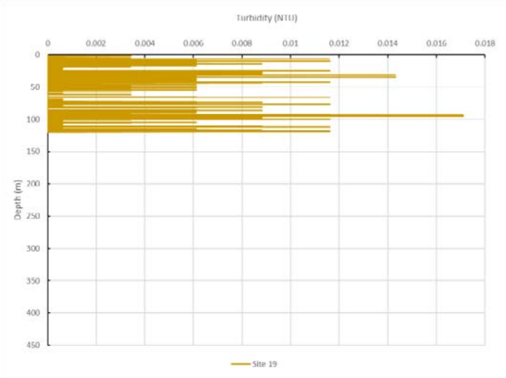

Turbidity (NTU)
1.21
1.22
1.23
1.24
1.25
1.26
1.27
1.28
1.29
1.3
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 14


Turbidity (NTU)
0.91
0.92
0.93
0.94
0.95
0.96
0.97
0.98
0.99
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 15

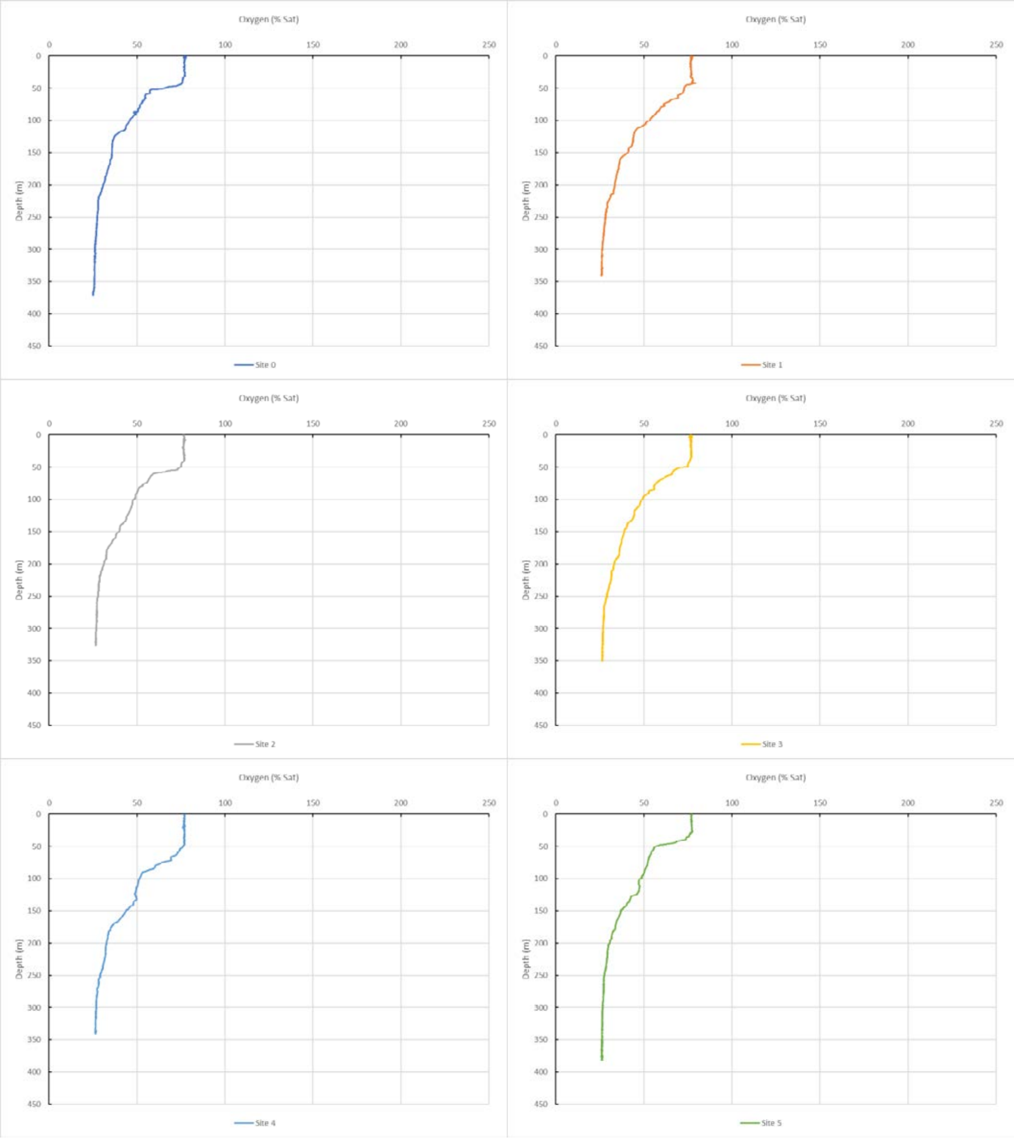

Turbidity (NTU)
0.9
0.91
0.92
0.93
0.94
0.95
0.96
0.97
0.98
0.99
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 16

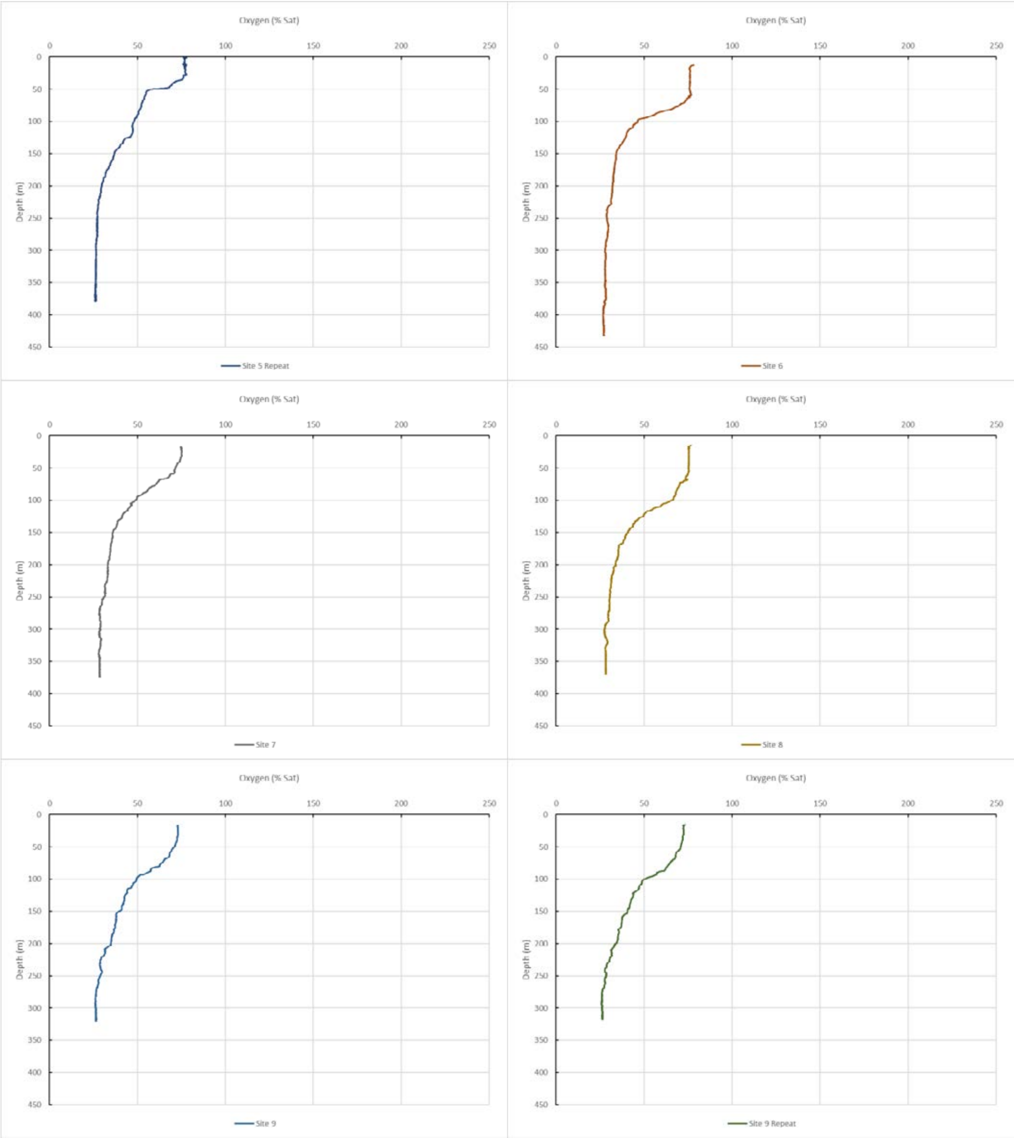

Turbidity (NTU)
1.34
1.35
1.36
1.37
1.38
1.39
1.4
1.41
1.42
1.43
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 17

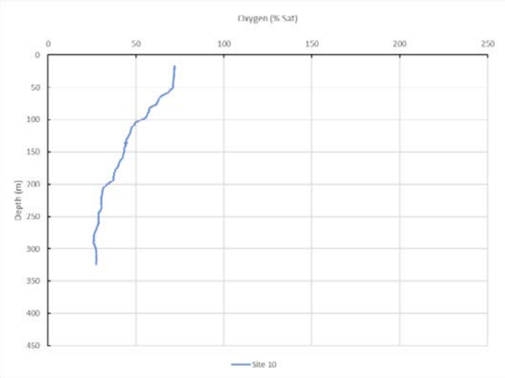

Turbidity (NTU)
2.1
2.11
2.12
2.13
2.14
2.15
2.16
2.17
2.18
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 18

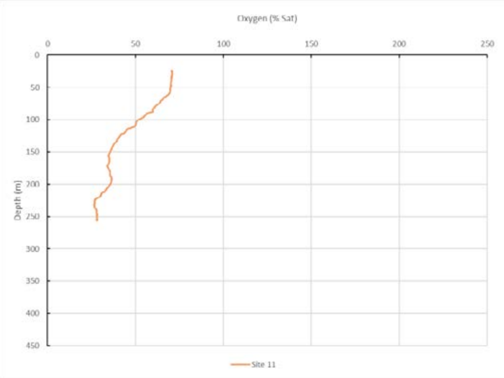

Turbidity (NTU)
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
0.018
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 19

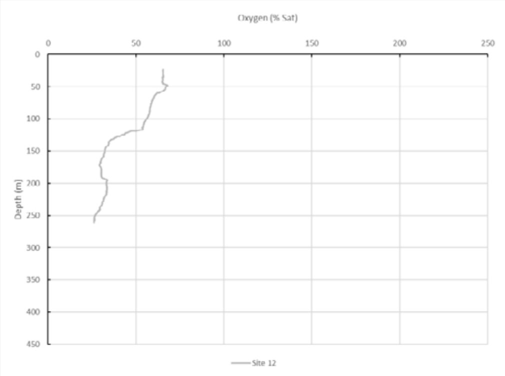
Oxygen Saturation

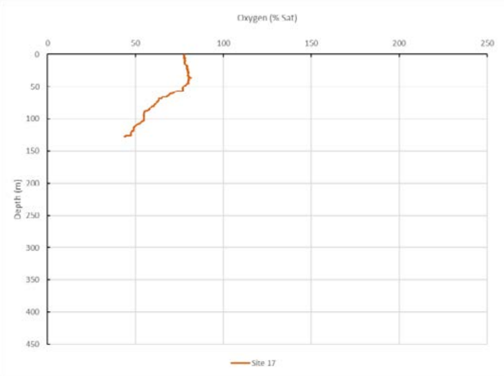


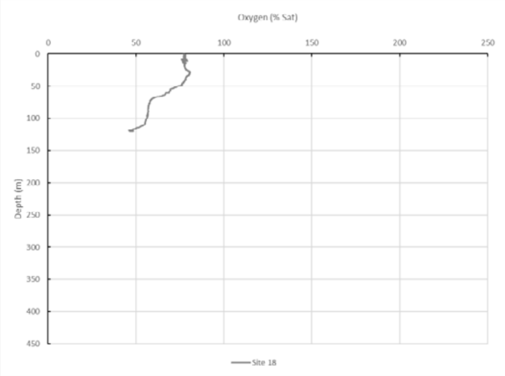

Oxygen (% Sat)
0
50
100
150
200
250
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 5 Repeat
Site 6
Site 7
Site 8
Site 9
Site 9 Repeat


Oxygen (% Sat)
0
50
100
150
200
250
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 10

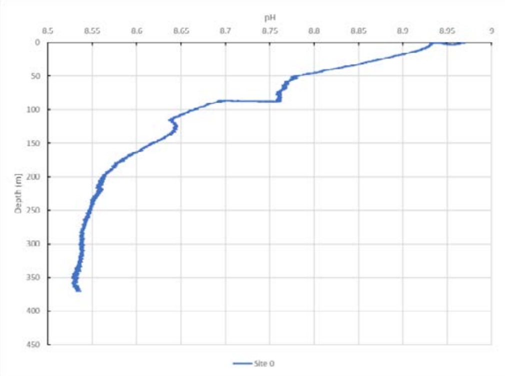

Oxygen (% Sat)
0
50
100
150
200
250
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 11

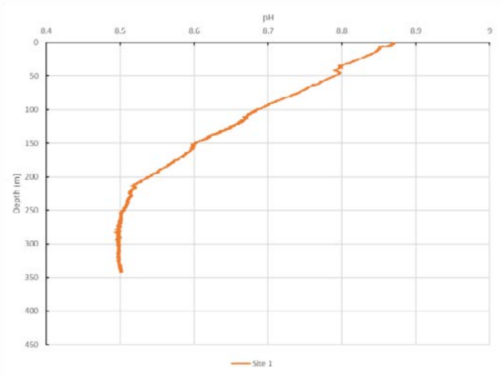

Oxygen (% Sat)
0
50
100
150
200
250
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 12

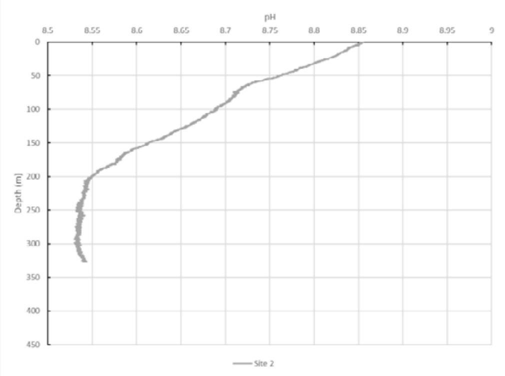

Oxygen (% Sat)
0
50
100
150
200
250
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 17

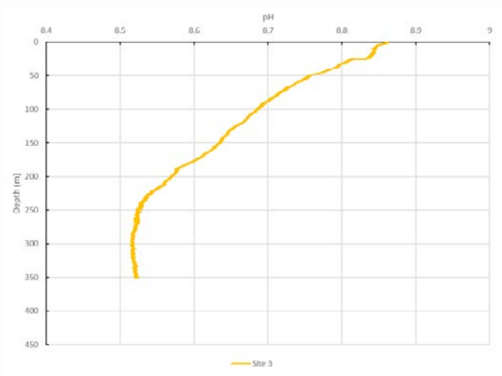

Oxygen (% Sat)
0
50
100
150
200
250
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 18

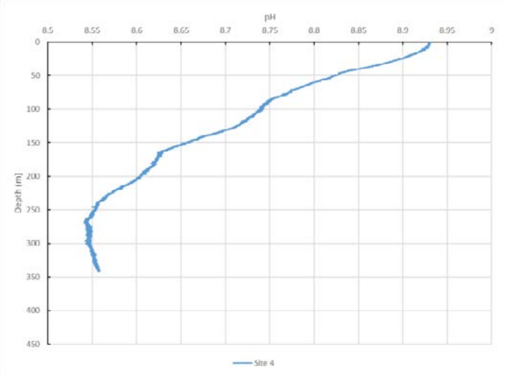
pH

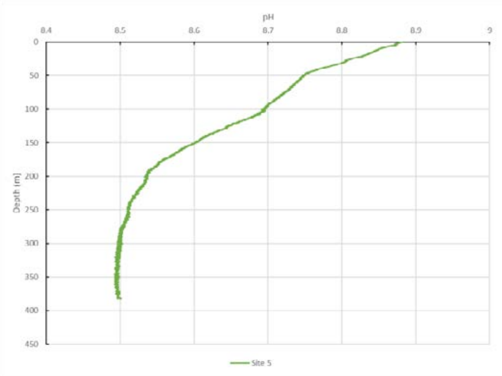

pH
8.5
8.55
8.6
8.65
8.7
8.75
8.8
8.85
8.9
8.95
9
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 0

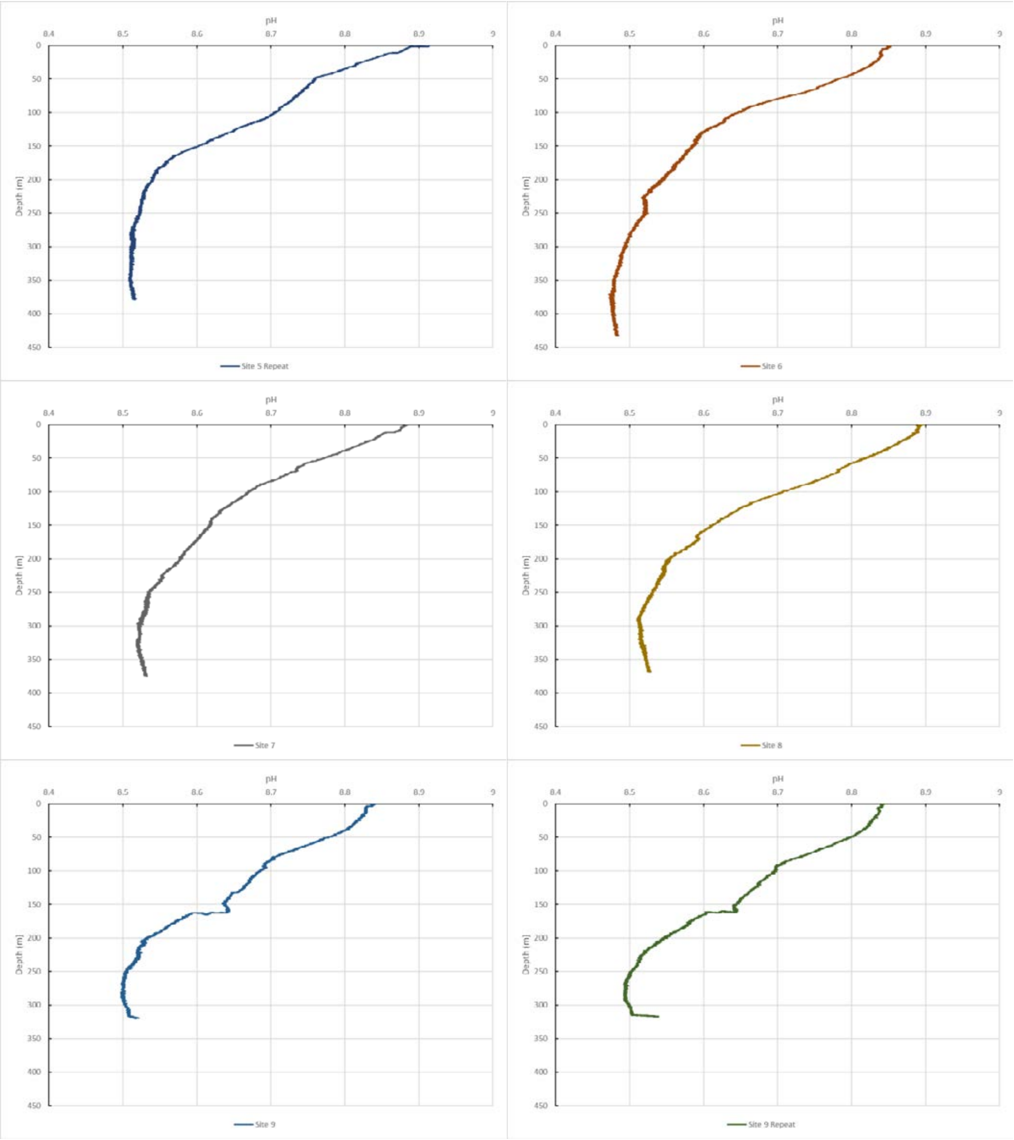

pH
8.4
8.5
8.6
8.7
8.8
8.9
9
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 1

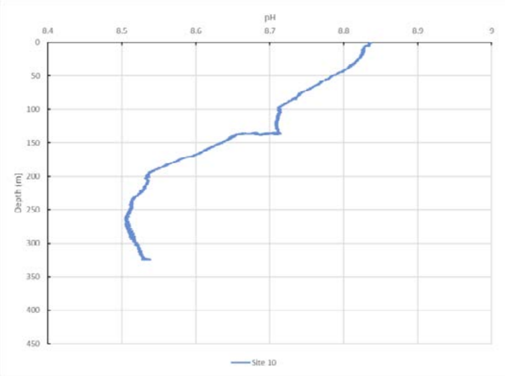

pH
8.5
8.55
8.6
8.65
8.7
8.75
8.8
8.85
8.9
8.95
9
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 2

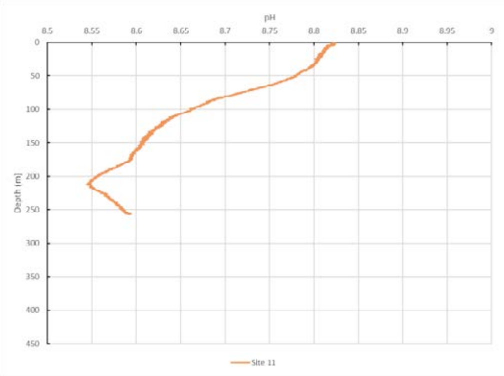

pH
8.4
8.5
8.6
8.7
8.8
8.9
9
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 3

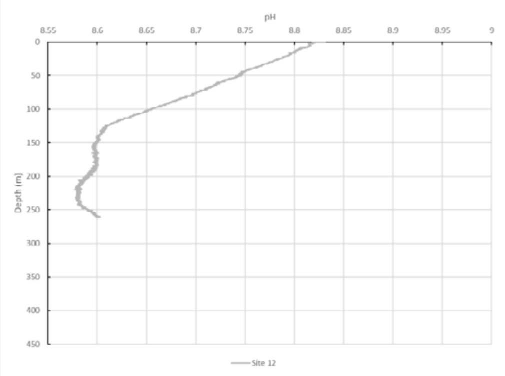

pH
8.5
8.55
8.6
8.65
8.7
8.75
8.8
8.85
8.9
8.95
9
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 4


pH
8.4
8.5
8.6
8.7
8.8
8.9
9
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 5


pH
8.4
8.5
8.6
8.7
8.8
8.9
9
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 5 Repeat
Site 6
Site 7
Site 8
Site 9
Site 9 Repeat


pH
8.4
8.5
8.6
8.7
8.8
8.9
9
0
50
100
150
200
250
300
350
400
450
Depth (m)
Site 10


pH
8.5
8.55
8.6
8.65
8.7
8.75
8.8
8.85
8.9
8.95
9
0
50
100
150
200
250
300
350
400
450
Depth (m)
Site 11


pH
8.55
8.6
8.65
8.7
8.75
8.8
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8.9
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200
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300
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400
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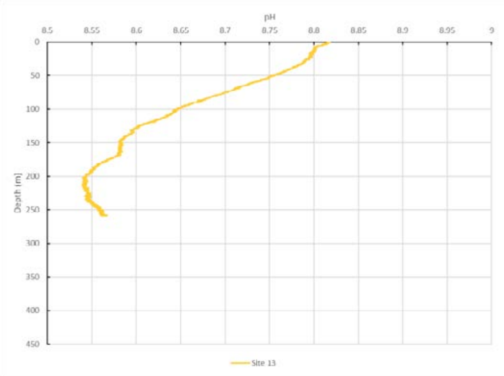
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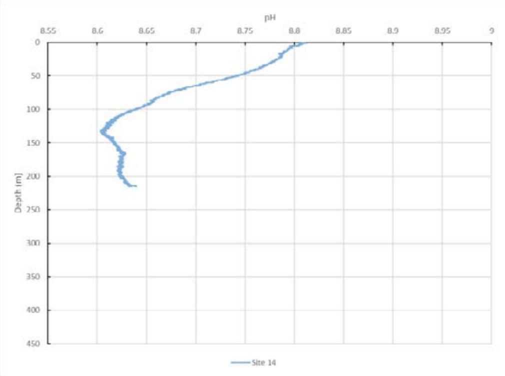
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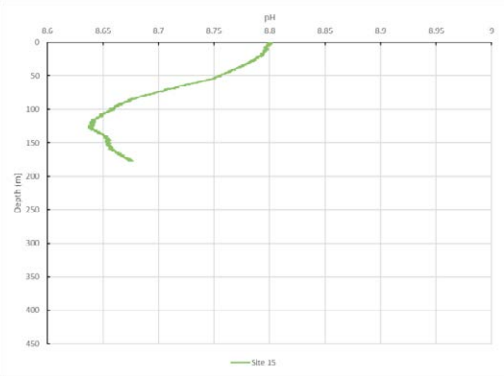
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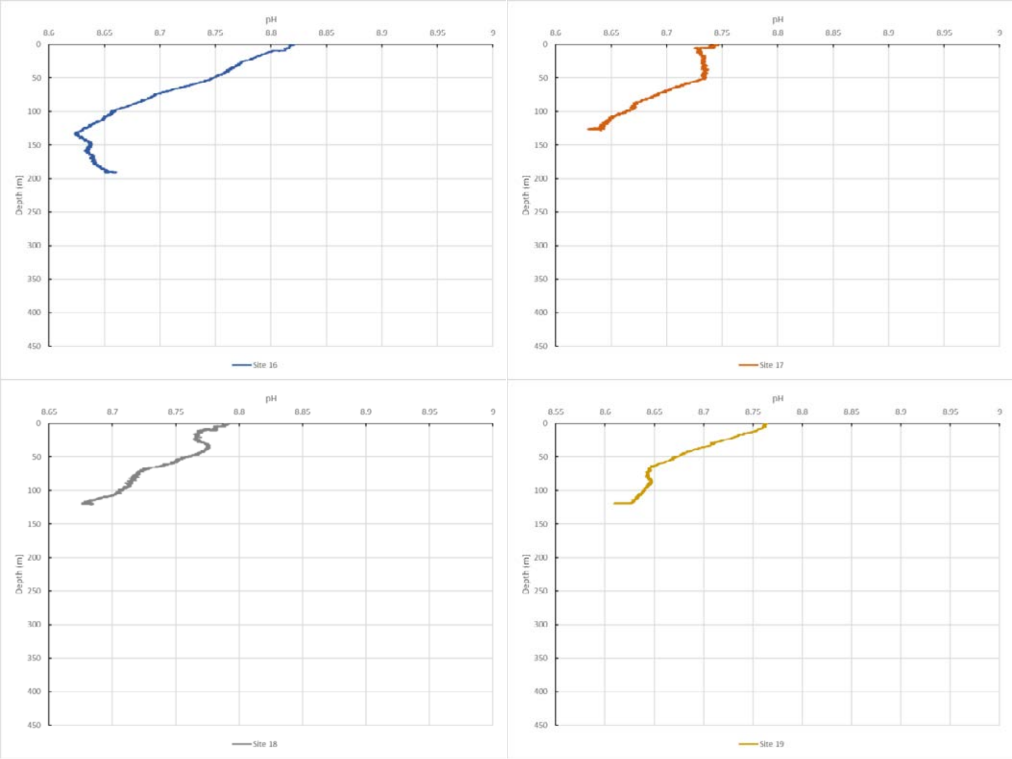
Site 15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200
250
300
350
400
450
Site 16
pH
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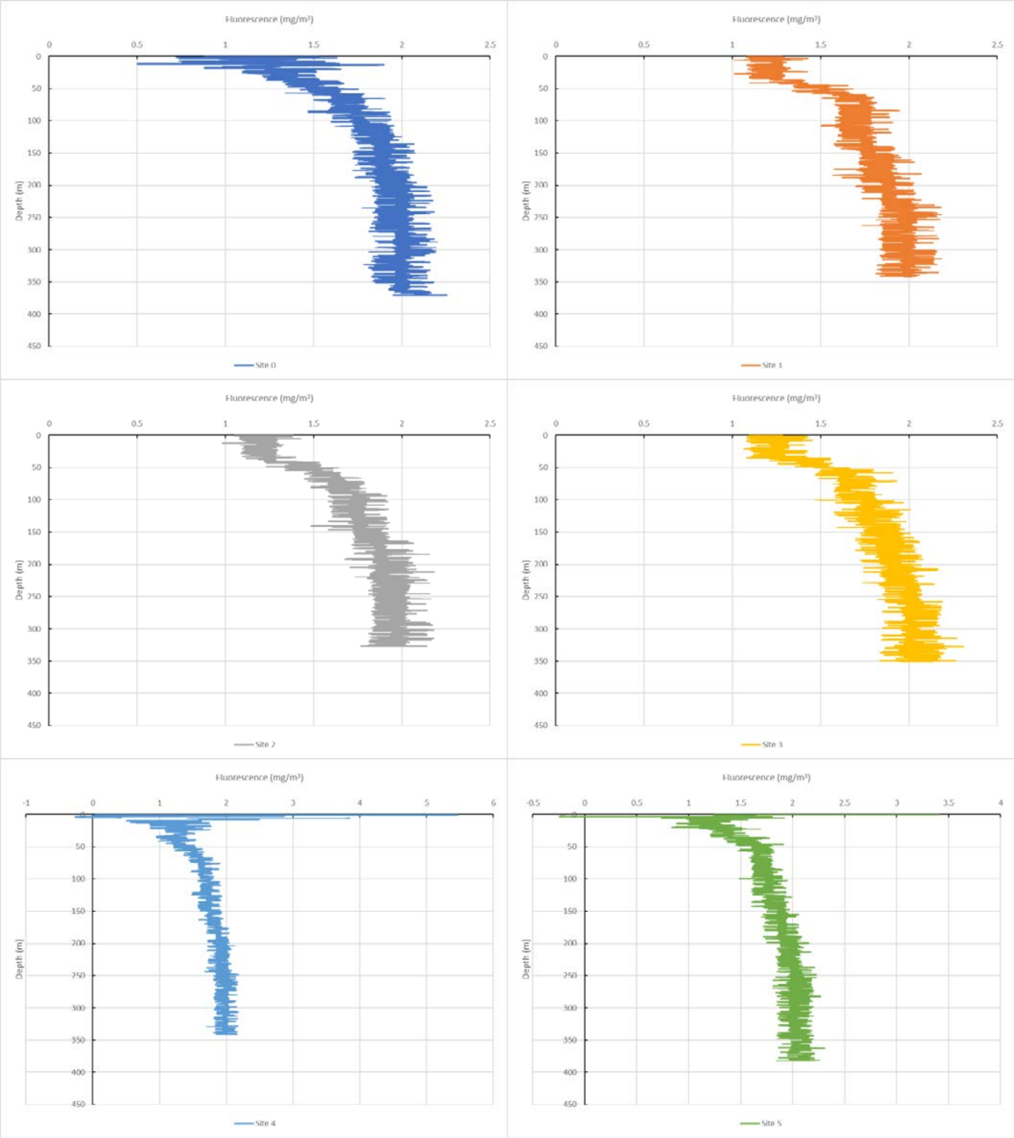
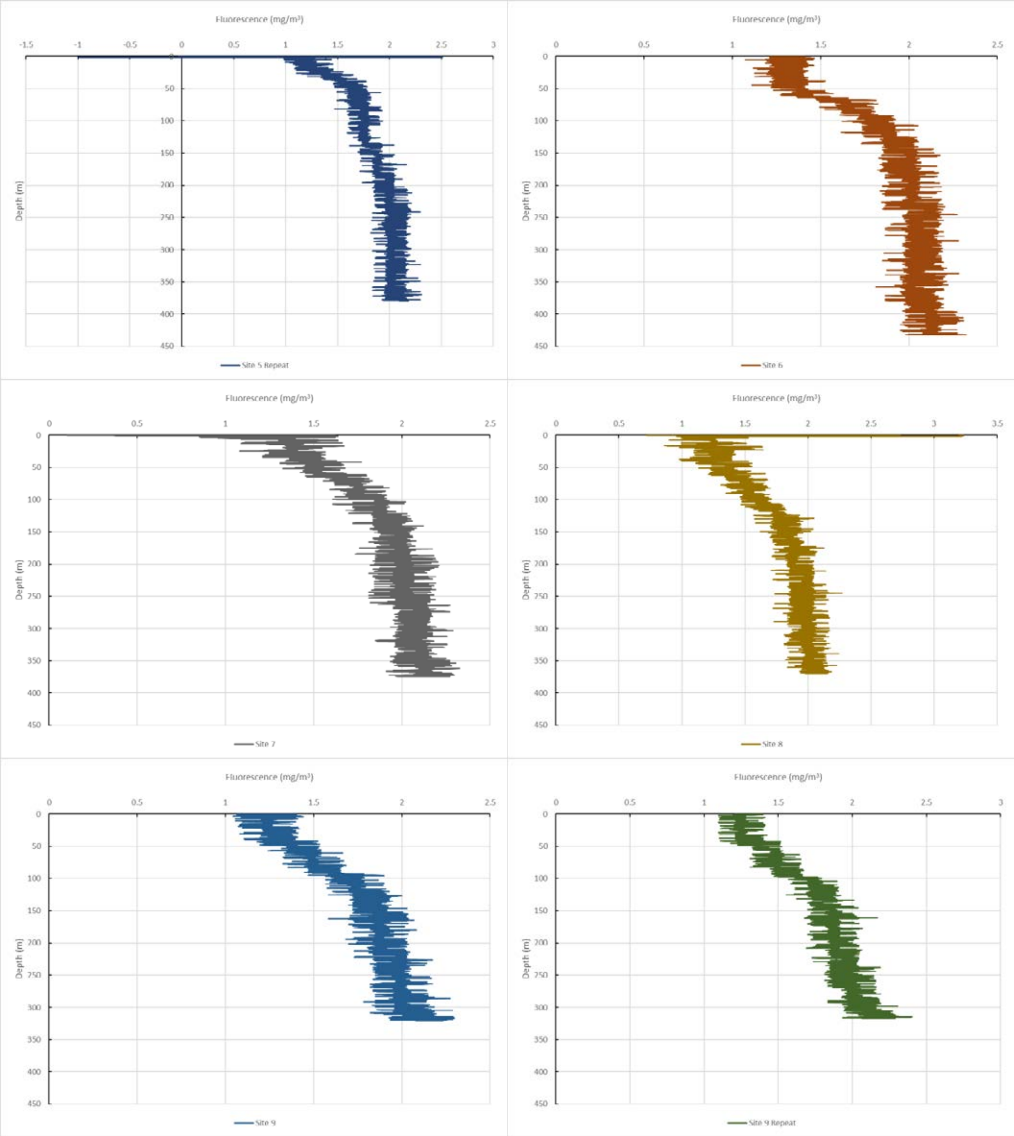
8.65
8.7
8.75
8.8
8.85
8.9
8.95
9
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 17
pH
8.65
8.7
8.75
8.8
8.85
8.9
8.95
9
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 18
pH
8.55
8.6
8.65
8.7
8.75
8.8
8.85
8.9
8.95
9
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 19

Fluorescence

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1
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2
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3
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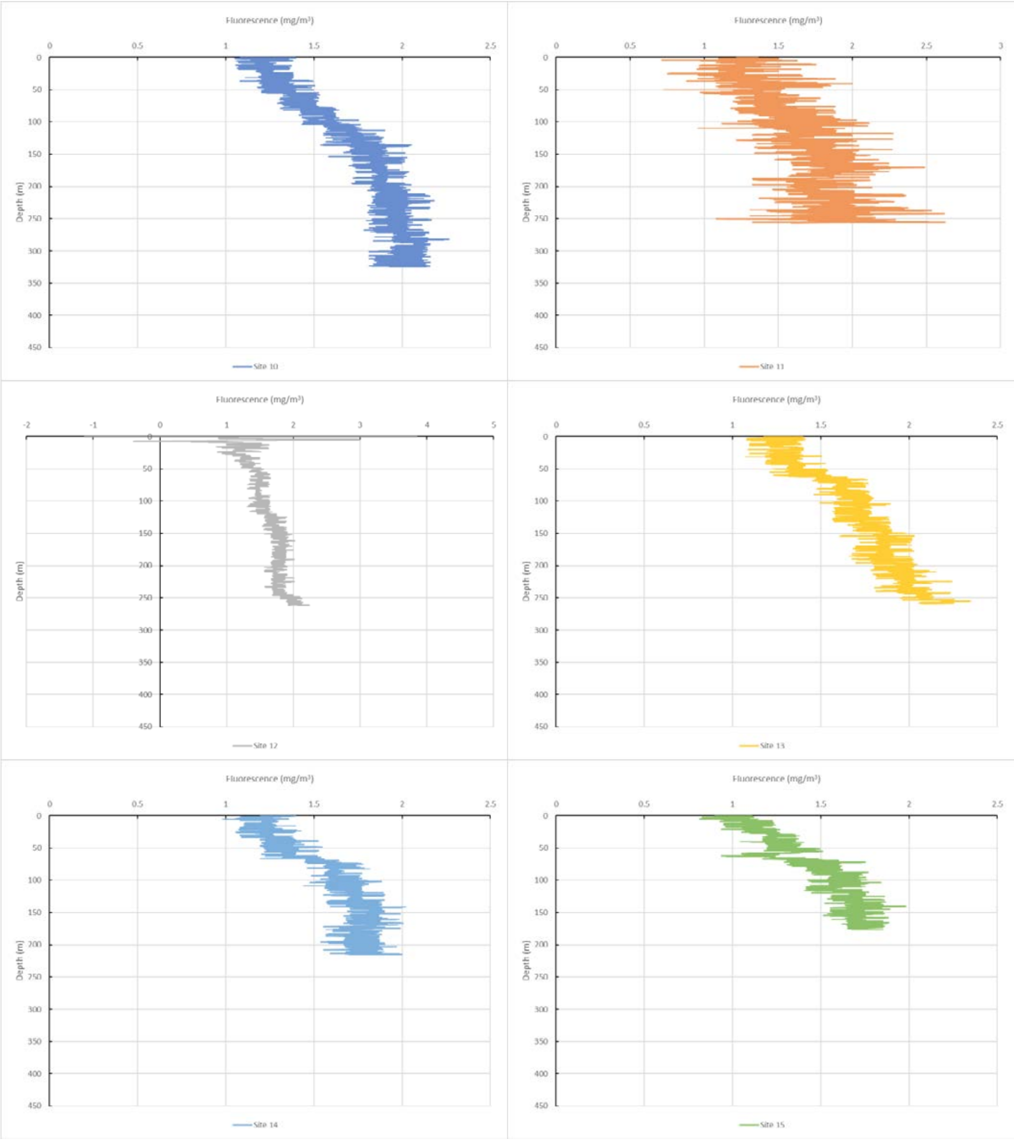
50
100
150
200
250
300
350
400
450
Site 5 Repeat
Fluorescence (mg/m³)
Depth (m)
Site 6
Fluorescence (mg/m³)
Depth (m)
Site 7
Fluorescence (mg/m³)
3.5
Depth (m)
Site 8
Fluorescence (mg/m³)
Depth (m)
Site 9
Fluorescence (mg/m³)
Depth (m)
Site 9 Repeat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2
2.5
Depth (m)
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100
150
200
250
300
350
400
450
Site 10
Fluorescence (mg/m³)
0
0.5
1
1.5
2
2.5
3
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 11
Fluorescence (mg/m³)
-2
-1
0
1
2
3
4
5
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 12
Fluorescence (mg/m³)
0
0.5
1
1.5
2
2.5
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 13
Fluorescence (mg/m³)
0
0.5
1
1.5
2
2.5
Depth (m)
0
50
100
150
200
250
300
350
400
450
Site 14
Fluorescence (mg/m³)
0
0.5
1
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2
2.5
Depth (m)
0
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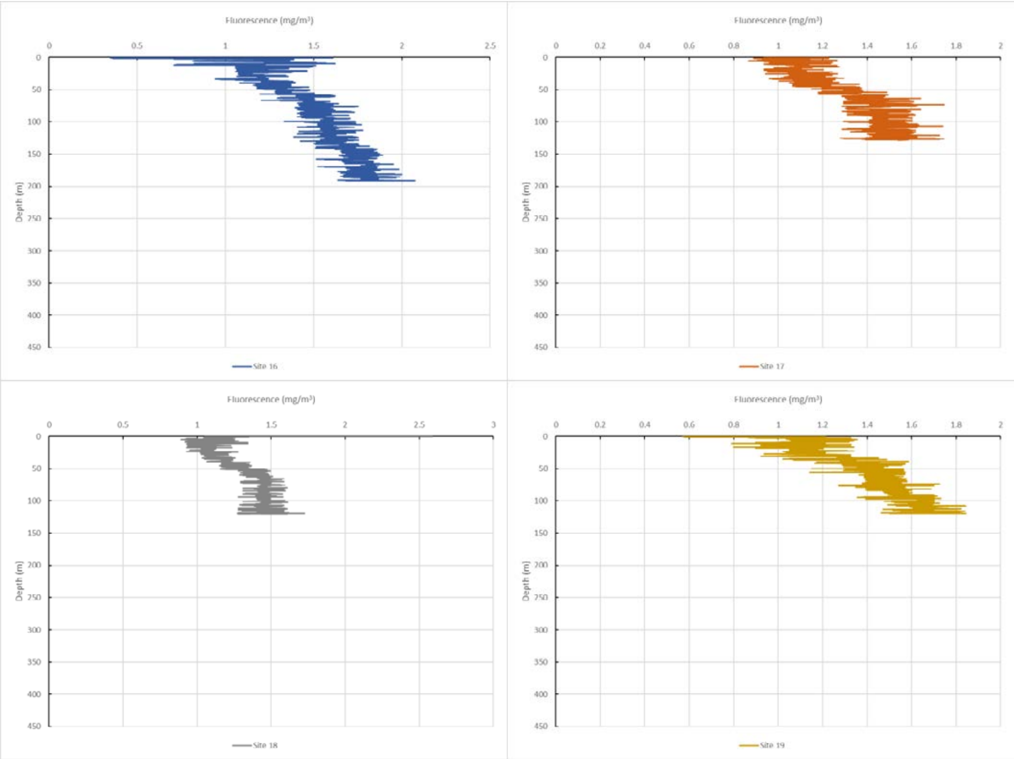
200
250
300
350
400
450
Site 15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1
1.5
2
2.5
Depth (m)
0
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100
150
200
250
300
350
400
450
Site 16
Fluorescence (mg/m³)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Depth (m)
Site 17
Fluorescence (mg/m³)
0
0.5
1
1.5
2
2.5
3
Depth (m)
Site 18
Fluorescence (mg/m³)
Depth (m)
Site 19

Chapter 10 D.2 AIMS Scott Reef and Rowley Shoals LTM 2017 report

Australian Government
Australian Institute of Marine Science

Long-term monitoring at Scott Reef and Rowley Shoals 2017: Summary Report

Authors: Gilmour J, Ryan N, Cook K, Puotinen M, Green R[1]

August 2019

PERTH

AIMS: Australia's tropical marine research agency.
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Executive Summary

Coral communities at Scott Reef and the Rowley Shoals have experienced substantial change over the history of monitoring (1994–2017). Various disturbances – mass bleaching, cyclones and moderate bleaching – and their effects on coral communities are described, with differences in impact and recovery linked to local disturbance regimes, routine environmental conditions, variation in community composition and coral life history traits.

In 2016, heat stress and coral bleaching affected reefs worldwide, including those in north-western Australia. Heat stress in the region was the highest on record, but far higher at Scott Reef (16.5° C-weeks) than at the Rowley Shoals (5.8° C-weeks). The heat stress caused mass bleaching (> 70%) across Scott Reef, but only minor (< 10%) bleaching at most locations at the Rowley Shoals.

The 2016 mass bleaching devastated coral communities at Scott Reef, which had only recently recovered from mass bleaching in 1998. Both mass bleaching events had similar impacts, reducing coral cover in shallow water habitats (< 20 m) by approximately 75% and affecting all coral taxa; there was a similar pattern of susceptibility among taxa in both events, including those that had not yet recovered from the 1998 mass bleaching. In contrast, mass bleaching has not impacted the Rowley Shoals and the 2016 bleaching did not reduce mean cover at any of its three reefs.

Over more than two decades of impact and recovery, the coral communities at Scott Reef transitioned through four states indicative of their condition. The pre-bleaching and recovery states had a higher cover (> 45%) of hard and soft corals and an abundance of different coral taxa. The mass bleaching and post-bleaching states were the more degraded, with much lower coral cover (< 22%) and the absence of vulnerable taxa (e.g. soft corals, *Acropora*, *Isopora*, Pocilloporidae), including those providing food and shelter to fishes and other reef organisms. Smaller changes in community structure at the Rowley Shoals grouped into three periods, around local impacts and rapid recovery (< 5 years) from cyclones, all of which reflected a healthy reef system.

The recovery of Scott Reef following the 1998 mass bleaching was facilitated by its healthy fish stocks, high water quality and a decade (1999–2009) with few disturbances. Given comparable impacts in 1998 and 2016, a similar timeline for recovery (10–15 years) might be expected if the future water quality, fish stocks and disturbances regime were also similar. However, from 2010 impacts from bleaching and cyclones increased, and ongoing climate change is expected to cause further increases in heat stress and cyclone intensity. Recovery of Scott Reef will not follow a similar trajectory as after the 1998 mass bleaching if severe disturbances occur more frequently (< 10 years) – meaning communities will remain in more degraded states. Global increases in the severity of heat stress and cyclones are also likely to affect the Rowley Shoals. However, since 2010 there was a consistently high (> 40%) coral cover at the Rowley Shoals and its low level of degradation makes the reef system an important benchmark for assessing the condition of other coral reefs, locally and globally.

1. Introduction

Western Australia's coral reefs span more than 12,000 km of coastline and 20 degrees of latitude, ranging from tropical to temperate climates (Veron and Marsh 1988). The most diverse reefs are in the Kimberley region of north-western Australia (McKinney 2009; Richards et al. 2014), where the oceanic reef systems of Ashmore, Scott and the Rowley Shoals sit near the edge of the continental shelf, hundreds of kilometres from the mainland and from each other. The Scott (South Reef, North Reef, Seringapatam) and Rowley Shoals (Imperieuse, Clerke, Mermaid) reef systems have high water quality and relatively low fishing pressures (Halpern et al. 2015; Zinke et al. 2018; Gilmour et al. 2019). However, traditional fishing of shark fin, *Trochus* and sea cucumber still occurs at Scott Reef (Stacey 2007), and these targeted species are all overfished (Meekan et al. 2006; Bryce 2007).

Damaging waves generated by storms and cyclones have historically been the most common acute disturbance to coral reefs in the Kimberley region. Scott Reef and the Rowley Shoals are buffeted by waves from a westerly and south-westerly direction, particularly between November and April when monsoonal storms and cyclones are common (Berry and Marsh 1986; Bowman et al. 2010; Drost et al. 2017). However, heat stress during El Niño conditions is increasingly affecting these reefs (Hughes et al. 2017; Benthuysen et al. 2018; Gilmour et al. 2019). Heat stress has caused repeated bleaching of varying severity at Ashmore Reef, Scott Reef and the Rowleys Shoals. The Rowley Shoals has so far escaped mass bleaching (Gilmour et al. 2019) and Scott Reef has been worst affected, particularly during the global bleaching events in 1998 and 2016 (Gilmour et al. 2013b; Eakin et al. 2018; Gilmour et al. 2019).

Despite the isolation of Scott Reef and the loss of 80% of its corals, communities had largely recovered from the 1998 mass bleaching within 10–15 years (McKinney 2009; Gilmour et al. 2013b). The resilience of the system was attributed to high rates of growth and survival of corals over several generations, due to high water quality and healthy fish stocks. However, not all coral taxa had recovered and there was associated variation in impacts and recovery among communities across the reef system. Changes in coral communities at both Scott Reef and the Rowley Shoals were structured by a complex regime of disturbances over more than two decades, whose effects were mediated by local environmental conditions and expressed through the life history traits of dominant coral taxa. The complexity of these processes and the degradation of the world's reefs (Hughes 1994; Knowlton 2001; Jones et al. 2004) highlight the importance of large-scale, long-term, studies that provide insights into the processes underlying their maintenance or degradation. Long-term studies are particularly important at reef systems that have escaped chronic local pressures but experienced varying levels of heat stress and coral bleaching, as climate change emerges as the most immediate threat to the future of coral reef ecosystems.

Here, we describe the changes in coral communities at Scott Reef and the Rowley Shoals over 23 years, from 1994 to 2017. We document the impacts of mass bleaching, cyclones and moderate bleaching on coral communities and attribute differences in impact and recovery to local disturbance regimes, routine environmental conditions, variation in community composition and coral life history traits. We divide changes in community structure into states of increasing disturbance and degradation, describing the corresponding reductions in coral cover and taxa that contribute most to reef structure and the maintenance of associated organisms. These processes are considered in the context of the most recent heat stress (2016) and ongoing climate change.

2. Methods

2.1 Study sites

Scott Reef is a large atoll-like reef system on the edge of the continental shelf, 270 km from the mainland of north-western Australia and 400 km from the Rowley Shoals (**Figure 1a**). The system consists of South Reef, North Reef and Seringapatam Reef. Benthic communities and habitat conditions were studied at seven locations (**Figure 1b**) in the reef-slope habitat (6 m depth at Lowest Astronomical Tide [LAT]). Outer-slope locations were on the eastern side of South Reef (Outer South East), North Reef (Outer North East) and Seringapatam Reef (Outer Seringapatam). Inner-slope locations were adjacent to the West Hook (Inner South West) and East Hook (Inner South East) at South Reef, at the lagoon at South Reef (South Lagoon), and the channel between South and North Reef (Channel). At each location, three replicate sites were surveyed during each year up to 2016. From 2016, only the first site at each location was surveyed and additional sites established in the adjacent reef crest habitat (3 m LAT), and within the lagoon at North Reef and Seringapatam Reef (SRLGA, SRLGB, NL_M23A), in response to predicted mass bleaching.

The Rowley Shoals is a group of three isolated reef atolls, 260 km from the mainland of north-western Australia (**Figure 1a**). The system consists of Imperieuse Reef, Clerke Reef and Mermaid Reef; each separated by 30–40 km. Benthic communities were surveyed at long-term monitoring locations in the outer reef-slope habitat (6 m LAT) at each reef (RS1, RS2, S3; **Figure 1c**). At each location, three replicate sites were surveyed during each year up to 2016. From 2016, only the first site at each location was surveyed. In 2013, 2016 and 2017, additional sites were established in the adjacent reef crest habitat (3 m LAT) at each reef, and in the lagoon at Mermaid (M11, M12) and Clerke (C13, C20) reefs, for comparison among habitats and in response to predicted mass bleaching in 2016. These additional lagoon sites were located at the top (edge) and base (7 to 12 m) of isolated coral outcrops (bommies). Data collection at all sites followed the standard AIMS LTM methods (Jonker et al. 2008).

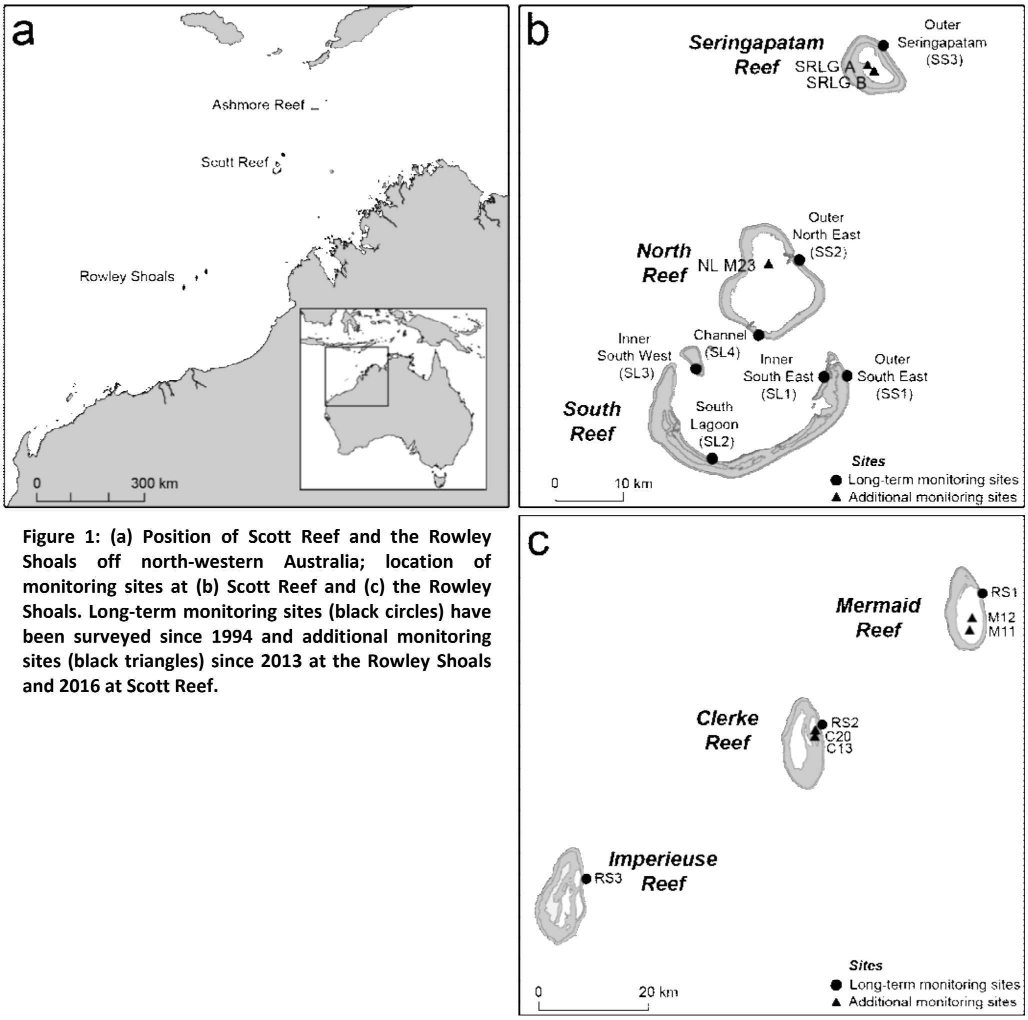

Figure 1: (a) Position of Scott Reef and the Rowley Shoals off north-western Australia; location of monitoring sites at (b) Scott Reef and (c) the Rowley Shoals. Long-term monitoring sites (black circles) have been surveyed since 1994 and additional monitoring sites (black triangles) since 2013 at the Rowley Shoals and 2016 at Scott Reef.

2.2 Benthic communities

2.2.1 Survey Methods

At each of the long-term monitoring locations (**Figure 1**), three replicate sites were separated by approximately 300 m, each consisting of 250 m of permanent transects marked at 10 m intervals. At Scott Reef, surveys were conducted annually between 1994 and 1999, and then in 2003, 2004, 2005, 2008, 2010, 2012, 2014, 2016 and 2017. In 2016, additional surveys were conducted in January, April and October 2016; before, during and after the mass bleaching. At the Rowley Shoals, surveys were conducted annually between 1995 and 1998, then in 2001, 2005, 2008, 2010, 2013, 2016 and 2017.

During each survey, a tape was laid along the permanent transect and images of the benthic community captured from a distance between 30 and 50 cm from the substrata. Images were analysed using point sampling technique and benthic groups identified to the lowest taxonomic resolution achievable by each observer (Jonker et al. 2008). These data were then divided among benthic groups according to taxa (i.e. family, genus) and growth form (encrusting, foliose, massive, branching) (**Table 1**). At Scott Reef, the six most abundant genera accounted for 80% of total hard coral cover. At the Rowley Shoals, the seven most abundant hard coral genera accounted for more than 75% percent of total hard coral cover. In instances where genera were rare (< 3% in all surveys) or difficult to distinguish, they were grouped to family or growth forms that distinguished their response to disturbances.

2.2.2 Statistical Analyses

Benthic communities were compared by multivariate analyses using the software PRIMER (Clarke and Warwick 2001). Percentage cover of each benthic group, at each site, location and year were transformed (Square root or Log + 1) to reduce the influence of dominant groups (e.g. crustose coralline algae) but to retain the major differences in community structure. Specific comparisons among communities in space or time were investigated by calculating Bray-Curtis measures of dissimilarity. Changes in community structure were illustrated using two-dimensional plots of non-metric multidimensional scaling (nMDS). The scale at which community structure varied spatially (sites) and temporally (years) was investigated using a cluster analysis and dendrograms, tested using the SIMPROF (5%) procedure in PRIMER. Over the entire survey period, there was considerable variation in community structure among the seven locations across the reef system, but little variation among the replicate sites within each location (**Appendix 1**). Consequently, data are presented at the location level throughout the Results, with associated variances derived from site replication.

2.3 Spatial and temporal variation in habitat conditions

2.3.1 Local variation in local environmental conditions at Scott Reef

Study sites within the reef slope habitat across the Scott Reef system experience different local environmental conditions. To explore the influence of local conditions on the community recovery following the 1998 mass bleaching, physical parameters predicted to have the greatest influence on community structure were quantified (**Table 2**). At the Rowley Shoals, these physical parameters have not been quantified, so equivalent comparisons cannot be made. The mean percentage cover of sand at each location was quantified along the permanent transects (250 m) during the study period (1994 to 2017) according to the AIMS LTM methods (Jonker et al. 2008). Comparative sedimentation rates were quantified using replicate ($n = 5$) sediment traps spaced at 10 m intervals along a permanent transect at each of the long-term study locations at South Reef and North Reef between July 2008 and February 2010. Sediment traps were constructed from cylindrical lengths (700 mm) of PVC tubing with an internal diameter of 110 mm, sealed at one end, and elevated above the bottom the substrata. Baffles within each trap consisted of seven 150 mm lengths of PVC tube with an internal diameter of 30 mm. Traps were changed at intervals of approximately three to four months. When recovered, the tops of the traps were sealed and the contents (sediment and water) later processed by gravimetric settling of particulate material from a known volume of water onto a pre-weighed membrane filter. Four replicate 60 ml sub-samples were measured from the trap contents and stored frozen and transported to the Particle Analysis Service Laboratory of CSIRO where samples were processed to determine particle size distributions (PSD) and the total dry weight of sediment. Mean rates of sediment accumulation (mg cm^{-2} d^{-1}) were derived for each trap location for each period of deployment and seasonal averages were calculated for these estimates. Net weight of different sediment types and mean sediment size (mean micron) were measured using up to replicate samples taken from each location. Initially, mean sediment size was grouped into nine size classes ranging from clay to coarse sand, however for our analysis these size classes are grouped into three broad categories (clay, silt and sand).

To assess variation in temperature regimes among communities (3–6 m depth) i*n situ* temperature readings were collected every 2–15 minutes using VEMCO Minilog-II-T data loggers from 2003-2017. In addition, satellite SST data and local currents were modelled to produce tidal cooling indices for communities (see Bird 2005 for details). Tidal mixing is the interaction of currents with the substratum through friction that creates bottom-up mixing, while solar heating acts to stabilise the water column (Bird 2005). Tidal cooling provides an indication of locations that are well mixed and deep enough to generate considerable surface cooling. Maps of these modelled variables were created, from which mean values were derived for each of the seven monitoring locations (1 km^2) for modelled current speed and mixing.

Adjacent to (20–40m depth) all inner-slope communities, current speed, wave height, salinity, fluorescence, turbidity and Photosynthetically Active Radiation (PAR) were quantified using Seabird SBE16 loggers with integrated Wetlabs ECO FLNTU and ECO PAR optical sensors between May 2008 and April 2009. From these data, PAR was extrapolated for each location at 9 m depth. Water column current profiles and wave heights were quantified using Nortek 600 kHz AWAC and Nortek 1MHz Aquapro Acoustic Doppler Current Profilers (ADCP) with wave capability. The current profilers were mounted adjacent to the water quality loggers at four locations and acoustically recorded vertical current velocities through the water column as five-minute averages, every 30 minutes.

All environmental data were explored and summarised as either mean or maximum averages per location per day, in addition to mean maximum current speeds and wave heights. Sediment particle size and weight, turbidity and chlorophyll were averaged at each location d^{-1} + S.E. for summer and winter seasons (**Appendix 2c**). For all environmental parameters, data were summarised in ways that best explained the spatial variation among study locations. From this initial exploration, the contribution of parameters to variation in habitat conditions among study locations was formally investigated using Principal Components Analysis (PCA) of the normalised data in the software PRIMER (Clarke and Warwick 2001). Parameter statistics that explained a low proportion of the variation among locations, and those that were highly correlated ($r > 0.9$) with another parameter that better explained variation, were excluded and the analyses repeated (**Table 2**). Of the many parameters that were initially investigated, nine remained after excluding those which explained a low proportion of variation and those highly correlated ($r > 0.9$) with another (**Appendix 2b**). The final parameters were: percentage cover of sand, cumulative wind speeds, range in water temperature, rate and composition of sedimentation, turbidity and chlorophyll concentration (fluorescence), and maximum current speed and wave height, in summer and/or winter months.

Table 1: Benthic groups used to describe coral communities at locations across Scott Reef and the Rowley Shoals. Most groups were common at most communities during one or more periods, except for groups that were most common at the South Lagoon (South Reef); and groups that characterised the Mermaid Reef community.

Benthic group	**Description**	
Non-coral		
Crustose coralline algae	Crustose coralline algae and fine turf algae, suitable for colonisation by coral recruits.	
Macroalgae + sponge	Large fleshy algae and sponges, which are rare across the reef systems, and which can exclude and outcompete coral recruits.	
Millepora	Hydrozoa within the Family Milleporidae.	
	Scott Reef	**Rowley Shoals**
Soft coral	Mostly *Sinularia* and *Lobophytum* (≈ 40%), *Sarcophyton* (≈10%), found in all communities but most common at the Channel and Inner South West.	Mostly *Lobophytum* and *Sinularia* (> 75%) found in all communities but most common at Mermaid Reef.
Hard coral		
Acropora	Including tabulate, corymbose, digitate growth forms common across Scott Reef, and arborescent and hispidose growth forms most common at the South Lagoon.	Including tabulate, corymbose, digitate and branching growth forms common across the Rowley Shoals.
Diploastrea	N/A (rare at Scott Reef).	Characteristic of Mermaid Reef.
Foliose corals	*Echinopora* (≈55%) and other foliose corals, most common at the South Lagoon community.	*Echinopora* (≈ 40%) and other foliose corals.
Isopora	*I. brueggemanni* (≈ 80%) and *I. palifera* (≈ 20%).	*I. brueggemanni* (≈ 25%) and *I. palifera* (≈ 75%).
Merulinidae	*Goniastrea, Coelastrea, Dipsastrea, Favites* and other Merulinidae species, with mostly a massive growth form. Corals from the Family Diploastreidae and the genus *Leptastrea* (Insertae Sedis) are also included in this group.	*Goniastrea, Coelastrea, Dipsastrea, Favites* and other Merulinidae species, with mostly a massive growth form. Corals from the genus *Leptastrea* (Insertae Sedis) are also included in this group.
Montipora	Mostly *Montipora* (≈75%), and other encrusting corals.	Mostly *Montipora* (> 60%), and other encrusting corals.
Pavona	N/A (rare at Scott Reef)	Including encrusting and submassive growth forms.
Pocilloporidae	*Pocillopora, Seriatopora, Stylophora.*	*Pocillopora, Seriatopora, Stylophora.*
Porites branching	Most common at the South Lagoon.	N/A (rare at Rowley Shoals).
Porites massive	Common across Scott Reef, but dominant at the Channel and Inner South West.	Common across the Rowley Shoals.

Table 2: Parameters used to characterise routine habitat conditions at locations across Scott Reef. Six parameters were quantified at all but one (Outer Seringapatam) location and an additional 9 parameters at the inner-slope locations. All data are for the long-term monitoring locations (9 m), unless stated. Summary statistics were produced for each parameter, and a reduced number used in the final analysis after removing statistics that explained a low proportion of the variation among locations, and those that were highly correlated (r > 0.9) with another parameter that better explained variation.

	Parameter	Initial estimate	Parameter revision	Final estimate
All locations	Temperature (July 06 to Oct 14)	Mean daily temperature (°C)	Excluded	
		Mean range in daily temperature (°C)	Divided among seasons; all but summer excluded	Summer range in daily temperature (°C)
	Sedimentation (May 08 to April 09)	Mean daily weight of sedimentation ($mg\ cm^{-2}\ day^{-1}$)	Divided between summer and winter months	Mean daily weight of sedimentation in summer and in winter ($mg\ cm^{-2}\ day^{-1}$)
		Mean sediment particle size (µm)	Excluded	
		Percentage composition of sediment particle sizes, for nine size classes ranging from clay to course sand (µm)	Divided between summer and winter months and size classes combined	Mean percentage of silt and clay (<63µm), sand (63-500µm) and coarse sand (>500µm), in summer and winter months
	Cover of sand (Oct 94 to Oct 10)	Cover of sand on substrata each year (%)	Averaged over all years	Mean cover of sand (%)
Inner slope locations	Current speed (Nov-May 08	Mean current speed (ms^{-1})	Excluded	
		Maximum current speed (ms^{-1})	Included	Maximum current speed (ms^{-1})
		Range in current speed (ms^{-1})	Excluded	
	Wave height (Nov-May 08)	Mean wave height (m)	Excluded	
		Maximum wave height (m)	Excluded	Maximum wave height (m)
	Fluorescence (Mar 08 to Feb 09)	Mean chlorophyll concentration (mg/m^3) at substrata adjacent to sites (25 m to 36 m depth)	Divided between summer and winter months	Mean chlorophyll concentration (mg/m^3) in summer and winter months
	Salinity (Mar 08 to Feb 09)	Mean salinity (PSU) at substrata adjacent to sites	Excluded	
		Range in mean salinity (PSU) at substrata adjacent to sites	Excluded	
	Turbidity (Mar 08 to Feb 09)	Mean turbidity (NTU) at substrata adjacent to sites (25m to 36m depth)	Divided between summer and winter months	Mean turbidity (NTU) in summer and winter months

2.3.2 Temporal variation in acute disturbances

Throughout the monitoring period, coral communities at one or more locations at Scott Reef and the Rowley Shoals experienced heat stress and coral bleaching, damaging waves generated by cyclones and storms, and an outbreak of coral disease. Heat stress was quantified by Degree Heating Weeks (DHW), extracted from NOAA Coral Reef Watch's 5km global dataset v3.1 (NOAA 2018). DHW values were extracted for pixels overlying study sites using MATLAB R2017b (http://www.mathworks.com/) and averaged for each reef. The duration of heat stress was defined as the period when DHW exceeded 4 °C-weeks. Damaging waves (both cyclonic and non-cyclonic) were identified for each monitoring site, then averaged to reef level. Hourly cyclone-generated wind speeds were reconstructed along cyclone tracks from 1985 to 2015 (McConochie et al. 2004). To account for the contribution of non-cyclonic winds to sea state, at each time step cyclone-generated winds were blended with synoptic winds (https://climatedataguide.ucar.edu/climate-data/climate-forecast-system-reanalysis-cfsr). Cyclonic winds were weighted by proximity to cyclone centres, and synoptic winds weighted by increasing distance beyond 3 radii of the cyclone eye. Following Puotinen et al. (2016), data and fetch were used to estimate whether the resulting waves were capable of damaging coral colonies, with damaging waves defined as having the top one-third of wave heights ≥ 4 m (significant wave height [H_s] ≥ 4 m). A lack of high-resolution bathymetry and reef/island mapping prevented any adjustment of localised fetch effects using custom-fit numerical wave models. However, for each cyclone from November 2010 – May 2018, wave height and direction were extracted from the nearest WaveWatch III global hindcast dataset at ~ 50 km resolution (http://polar.ncep.noaa.gov/waves/index2.shtml) (Tolman 2009) and maps of the study sites used to assess the exposure of each long-term monitoring location to damaging waves. For cyclones from January 1998 – December 2013, a finer-resolution assessment was possible using data extracted from an Australia-wide hindcast wave dataset produced by CSIRO and BOM at 11 km resolution using the WaveWatch III model.

3. Results

3.1 Scott Reef

3.1.1 Periods of impact and recovery across Scott Reef

Over 23 years, acute disturbances of varying severity impacted Scott Reef (**Figure 2**), but the system's resilience was facilitated by the lack of chronic disturbances, high water quality and abundant fish stocks. The most severe disturbances caused mean reductions in coral cover across the entire reef system and affected all coral groups, with recovery taking several years to over a decade. Moderate disturbances reduced coral cover at one or more communities, usually for a subset of coral groups, and recovery took less than a few years.

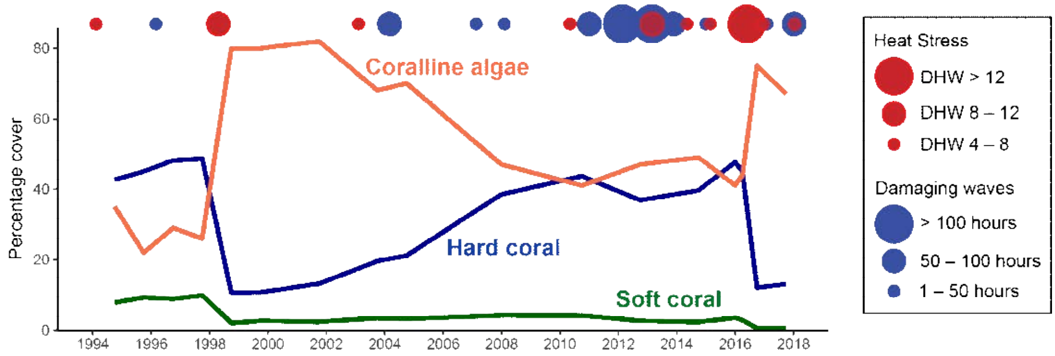

Figure 2: Over 23 years multiple acute disturbances altered community structure across Scott Reef. Disturbances were heat stress (DHW > 4 °C-weeks) and damaging waves from storms and cyclones (significant wave heights ≥ 4 m).

From 1994 to 2017, total coral cover (hard corals, soft corals, *Millepora*) across the reef system was 37%, and ranged from 12% to 61%. Reductions in cover were caused by damaging waves generated by cyclones and tropical lows, heat stress causing coral bleaching and a single outbreak of coral disease. Damaging waves (significant wave heights ≥ 4 m) impacted the reef system 13 times (**Table 3**) but affected only a few exposed communities. Heat stress (DHW > 4 °C-weeks) occurred 9 times, including three periods predicted to cause wide-spread bleaching and mortality (DHW ≥ 8 °C-weeks; **Table 3**). Mass bleaching in 1998 reduced coral cover to the lowest on record (**Figure 2**). Subsequent recovery was slowed by the local effects of cyclones and coral bleaching, but by 2010 the mean cover of hard corals had reached pre-bleaching levels; although cover of soft corals was still approximately half that prior to the 1998 mass bleaching (**Figure 2**). From 2010, heat stress and damaging waves were more frequent, but cover had increased to 51% by January 2016. Heat stress in April 2016 was the most severe on record and mass bleaching caused another large reduction in coral cover, which in 2017 was similar (14%) to that following the 1998 mass bleaching (**Figure 2**). Through the cycles of impact and recovery, benthic communities were dominated (86%) by hard corals, soft corals and coralline algae (**Figure 2**). Following the loss of corals, the available substrata were colonised by coralline algae, whereas the cover of other benthic groups (e.g. sponges, macroalgae) remained low (< 7%).

The changes in community structure across Scott Reef were driven by their exposure to two mass bleaching events and many less-severe disturbances. However, community dynamics were also mediated by the routine environmental conditions at each location and the life histories of the dominant coral taxa. The temporal dynamics grouped into five periods of impact and recovery (**Appendix 3**), which were also indicative of the condition of the reef system:

1) Pre-bleaching (1994–1997): Start of monitoring and before mass bleaching;
2) Mass bleaching (1998–2001): Up to three years after mass bleaching;
3) Post-bleaching (2002–2004): Up to six years after mass bleaching;
4) Recovery and multiple disturbances (2005–2015): Seven to fifteen years after mass bleaching;
5) Mass bleaching (2016–2017): Up to two years after mass bleaching.

3.1.2 Pre-bleaching and local environmental conditions (1994–1997)

In the absence of severe disturbances, the structure of coral communities reflected local environmental variation. Communities were distinguished by water temperatures, current speeds, exposure to winds and waves, and water quality (sedimentation, chlorophyll and turbidity) (**Appendix 2, 4, 5**). These conditions varied with proximity to the sheltered lagoon at South Reef, the deep channel between North and South Reef, and the outer eastern slope at each of the three reefs (**Figure 1, Appendix 4, 5**). Consequently, environmental conditions and community structures were most similar at the outer eastern slope locations (Outer South East, Outer North East, Outer Seringapatam), followed by the Inner South East. Communities at the Inner South West, Channel and South Lagoon locations were most unique. The South Lagoon was the most sheltered and its community distinguished by the highest cover of fragile corals, such as the foliose corals (usually *Echinopora*) and *Acropora* (particularly arborescent and hispidose forms). The Inner South West and Channel had the highest current speeds and wave heights, including those generated by seasonal storms and cyclones; they also had the highest daily temperature ranges, due to internal tides and cool water intrusions. The Inner South West and Channel communities had the highest cover of massive *Porites* and soft corals, and the lowest cover of *Acropora* and other fragile growth forms. These fundamental differences in local conditions and community structure influenced the severity of impacts from disturbances and the rates of recovery over the next two decades.

In 1996, damaging waves were generated by Cyclone Kirsty (37 hours $H_s \geq 4$ m, **Table 3**). However, from October 1994 to 1997 mean coral cover (hard corals, soft corals, *Millepora*) across the reef system increased from 53% (± 2) to 61% (± 3). There were comparable increases (7–11%) in cover at most communities, but for smaller increases at those exposed to the damaging waves (3–5% at Channel and Inner South West). Coral cover was high (45–70%) at all communities, with massive *Porites, Montipora*, soft corals, *Acropora* and *Isopora* the most common taxa (5–15%), followed by Pocilloporidae and Merulinidae (2–10%) (**Figure 3**).

Table 3: Disturbance history at Scott Reef (Oct 1994–Dec 2017). Heat stress is defined as DHW > 4 °C-weeks (yellow rows) for pixels overlying Scott Reef monitoring locations (NOAA Coral Reef Watch 2018); widespread bleaching and mortality is likely when DHW > 8 °C-weeks (orange rows). Double lines between rows indicate timing of coral monitoring surveys. Where DHW remained at its maximum ("peak date") over more than one day, the peak date given is the first day of the maximum value. Cyclone and storm events (blue rows) are defined by hours of damaging seas (H_s > 4 m). A higher number of hours at H_s > 4 m indicates greater potential for wave damage at the coral monitoring sites, assuming vulnerable colonies are present. For pre-2010 cyclones, directions of exposure are unknown and peak dates are approximate (details in Methods).

Event	Year	Peak date/s	Peak DHW	Duration	Bleaching observations; wave direction
Cyclone Kirsty	1996	9-10th Mar		37 hrs	Directions unknown
Heat stress	1998	27th Apr	9.6	90 days	Widespread bleaching and mortality
Heat stress	2003[1]	11th Feb	7.6	83 days	No known surveys, coral cover increased
Cyclone Fay	2004	19th-23rd Mar		54 hrs	E, NE
Cyclone George	2007	4-6th Mar		19 hrs	W, WNW
Cyclone Nicholas	2008	15-16th Feb		23 hrs	W, WNW
Heat stress	2010	27th Apr	7.4	82 days	Bleaching observed at some locations
Cyclone Vince	2011	11-14th Jan		87 hrs	WNW, W
Cyclone Iggy	2012	24-29th Jan		95 hrs	W, WNW
Cyclone Lua	2012	14-18th Mar		168 hrs	W, WNW
Cyclone Narelle	2013	7-11th Jan		62 hrs	W, ENE, NW, WNW
Heat stress	2013[1]	11th Feb	10.4	145 days	Bleaching observed but not quantified
Cyclone Rusty	2013	23rd-28th Feb		135 hrs	W, WNW
Cyclone Christine	2013	28-29th Dec		73 hrs	WNW
Low 05U	2014	19-20th Jan		40 hrs	WSW, W
Heat stress	2014	17th Apr	5.4	68 days	No signs of bleaching in surveys later that year
Low 05U 1	2015	7-9th Jan		48 hrs	W
Heat stress	2015[1]	10th Feb	4.5	47 days	No signs of bleaching in surveys the following year
Heat stress	2016	5th May	16.5	170 days	Widespread bleaching and mortality
Heat stress	2016[1]	21st Dec	5.9	73 days	No known surveys
Cyclone Yvette	2016	22nd-23rd Dec		61 hours	WNW, W
Low 15U	2017	6-8th Feb		39 hours	W, WNW
Heat stress	2017[2]	27th Dec	5.5	13 days	No known surveys
Low 11U	2018	29th-31st Jan		87 hours	W, WNW

[1] Heat stress conditions started in December of the previous year but are listed by the year when heat stress peaked. [2] Heat stress extended past the end of downloaded data (31st December 2017).

3.1.3 Mass bleaching (1998–2001)

In 1998, heat stress (DHW > 4 ° C-weeks) affected the reef system for 90 days, peaking at 9.6° C-weeks in late April (**Table 3**). Mass bleaching was observed in April at all shallow water habitats at all reefs to 20 m depth. Six months later, mean (± SE) hard coral cover decreased from 48% (± 7) to 10% (± 3), a relative decrease of ≈ 80% (**Figure 2**). Among the communities, the relative decreases ranged from 50 to 90% and depended on the abundance of susceptible coral groups. The relative decreases in cover were highest (> 90%) for the branching *Porites*, *Acropora*, *Millepora*, *Isopora*, and Pocilloporidae, ranged from 70 to 90% in the other coral groups, and were lowest (12–75%) in the massive *Porites* (**Figure 3**). The impact of the bleaching also varied among communities according to their environmental conditions. The Inner South West and Channel communities experience less heat stress (**Appendix 2**) and had smaller (< 60%) relative decreases in common taxa than others (> 80%) (**Figure 3, Appendix 6**). For example, the relative decreases in massive *Porites* (5–10%) and Merulinidae (30–55%) at the Inner South West and Channel were lower than at all other communities (massive *Porites* 25–75%, Merulinidae 80–97%).

The mass bleaching had homogenised the reefs, as coral taxa that had previously distinguished communities were also the most susceptible (e.g. *Isopora, Acropora,* Pocilloporidae). Three years later, there were only small increases (< 3%) in cover, due mostly to the regrowth of surviving corals (massive *Porites, Isopora,* soft corals) at communities least affected. The reefs were still characterised by taxa that had been most abundant and most resistant to heat stress, particularly the massive *Porites* and the *Montipora* and encrusting corals (**Figure 3, Appendix 6**).

3.1.4 Post-bleaching (2002–2004)

In 2003, heat stress (DHW > 4 ° C-weeks) affected the reef system for 83 days and peaked at 7.6 °C-weeks in February, followed in 2004 by damaging waves generated by Cyclone Fay (54 hours $H_s \geq 4$ m, **Table 3**). These disturbances had little obvious effect on the coral communities because the most susceptible coral taxa were still rare following the mass bleaching. The reef system had commenced a trajectory back to pre-bleaching structure, and by 2004 mean (± SE) hard coral cover had increased to 19% (± 4) (**Figure 2**). Cover ranged from 9–26% among the communities, depending on the severity of mass bleaching and exposure to Cyclone Fay. However, increases in cover were still driven by the regrowth of corals (*Isopora,* massive *Porites*, soft corals) at the communities least affected by mass bleaching, and by massive *Porites* at most communities.

3.1.5 Recovery and multiple disturbances (2005–2015)

From 2005 to 2010, damaging waves were generated by cyclones George (19 hours $H_s \geq 4$ m) in 2007 and Nicholas (23 hours $H_s \geq 4$ m) in 2008 (**Table 3**). Impacts were largely restricted to susceptible corals (e.g. *Acropora*, Pocilloporidae) at the Channel and Inner South West communities, where cover had increased by 2–12% by 2008, compared to 17–28% at the other locations (**Figure 3**). Heat stress then affected the reef system for 82 days, peaking at 7.4° C-weeks in April 2010. The resulting outbreak of disease and coral bleaching was most severe at South Lagoon, where there was a large decrease (12%) of predominantly *Acropora*. Bleaching in 2010 was also observed at the Inner South East and outer-slope communities, but caused only a small reduction in cover (5%) of Pocilloporidae at Outer Seringapatam.

More than five years after the 1998 mass bleaching, a more rapid return to pre-bleaching structure had commenced across the reef system. By 2010, mean (± SE) hard coral cover was similar (44% ± 3) to that before the mass bleaching and ranged from 35–51% among the communities. Despite the variable susceptibility and reductions in cover among taxa, most had also returned to a similar pre-bleaching cover. The exceptions were a much higher cover of *Acropora* and a much lower cover of *Millepora*, branching *Porites, Isopora* and soft corals (**Figure 3, Figure 4**). *Acropora* had returned to a similar or higher cover at all communities except for South Lagoon, where they were impacted by the recent bleaching. Branching *Porites* and *Millepora* were the most susceptible of all taxa and were previously rare at most communities, so their cover in 2010 had returned to < 20% of that before the mass bleaching (**Figure 4, Figure 5**). *Isopora* were common (10–30%) at most communities before the 1998 mass bleaching but were also among the most susceptible taxa (**Figure 5**) and returned to only 30% of pre-bleaching cover (**Figure 4**). However, local recovery of *Isopora* depended on the post-bleaching cover; where some (0.5–3%) remained, they had returned to between 50% and 130% of their pre-bleaching cover, whereas communities where no (0%) *Isopora* remained had returned to < 20% of their pre-bleaching cover (**Figure 3**). Soft corals were also common (5–20%) at most communities, were moderately susceptible, and had returned to 42% of their pre-bleaching cover (Figure 4). As with *Isopora,* the remaining cover of soft corals influenced their recovery, but in 2010 was lower than before the mass bleaching all at but one community (**Figure 3**).

Between 2010 and 2012, damaging waves were generated by cyclones Vince (87 hours $H_s \geq 4$ m), Iggy (95 hours $H_s \geq 4$ m) and Lua (168 hours $H_s \geq 4$ m), reducing mean cover across the reef system from 44% (± 3) to 36% (± 8) (**Figure 2, Table 3**). Despite causing the first reduction in mean cover since the 1998 mass bleaching, cyclone impacts were restricted to the few communities with a westerly aspect. There were large relative decreases (≈ 65%) in cover at the Channel and Inner South West, where even the most robust corals were impacted (**Figure 3**). For example, the relative decreases in cover at the Channel were 40–55% for the most robust corals (*Montipora* and encrusting corals, Merulinidae, *Porites* and massive corals), 75% for the soft corals, and > 95% for the more fragile corals (*Acropora,* Pocilloporidae). The impacts were greater than those caused by the mass bleaching in 1998 at these communities, and over the next two years small reductions (≈ 1%) in cover had continued for some groups (soft corals, Merulinidae, massive *Porites*). Although the Inner South East was less exposed to the damaging waves, the relative decreases were similar (> 90%) for the most fragile corals, but less for the soft corals (55%) and the most robust corals (5–30%); over the next two years there was a rapid increase (8%) in cover of predominantly *Acropora* and *Isopora*.

Between 2012 and 2016, damaging waves were generated by cyclones Rusty (135 hours $H_s \geq 4$ m) and Christine (73 hours $H_s \geq 4$ m) in 2013, and by tropical lows in 2014 (40 hours $H_s \geq 4$ m) and 2015 (48 hours $H_s \geq 4$ m) (**Table 3**). The Inner South West and Channel were again most exposed to the cyclone impacts. The increases in cover at these communities were largely restricted to the regrowth of massive *Porites* and soft corals following cyclone damage, and in 2015 they had the lowest cover (≈ 28%) of all communities (**Figure 3**). In 2013, the reef system was also affected by heat stress for 145 days, which peaked at 10.4° C-weeks in February (**Table 3**). The associated bleaching was largely restricted to some Pocilloporidae at the outer-slope communities, which had been sheltered from the recent cyclones. By January 2016, mean (± SE) cover across the reef system had increased to 47% (± 7) and was high (50–56%) at all communities but those worst affected by recent cyclones (**Figure 2, Figure 3**). At all communities, *Acropora* (8–15%) and *Isopora* (2–5%) had the largest increases since 2010, but cover of *Millepora*, branching *Porites*, *Isopora* and soft corals was still much lower than before the mass bleaching in 1998.

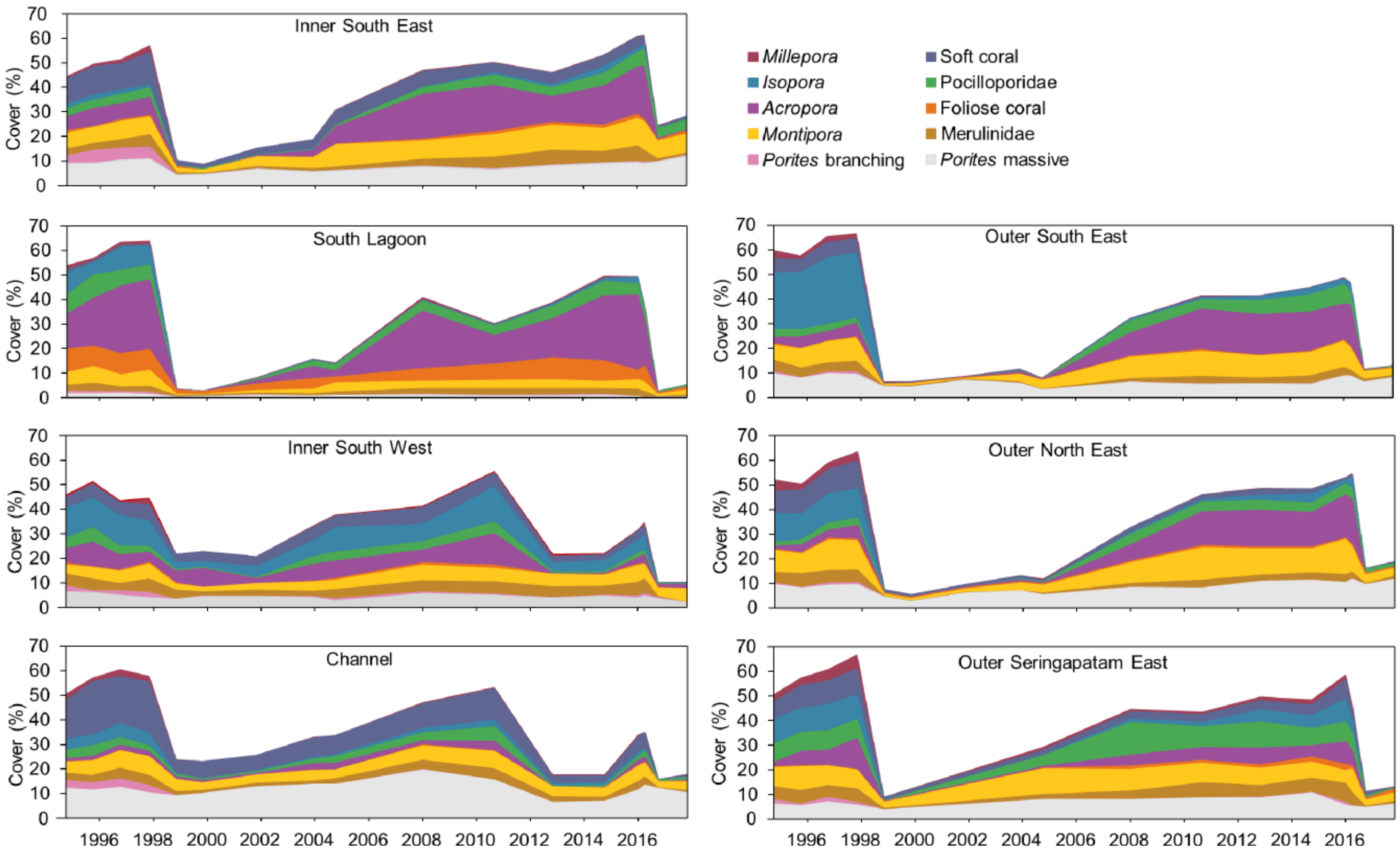

Figure 3: Temporal variation in community structure across the reef system from 1994 to 2017.

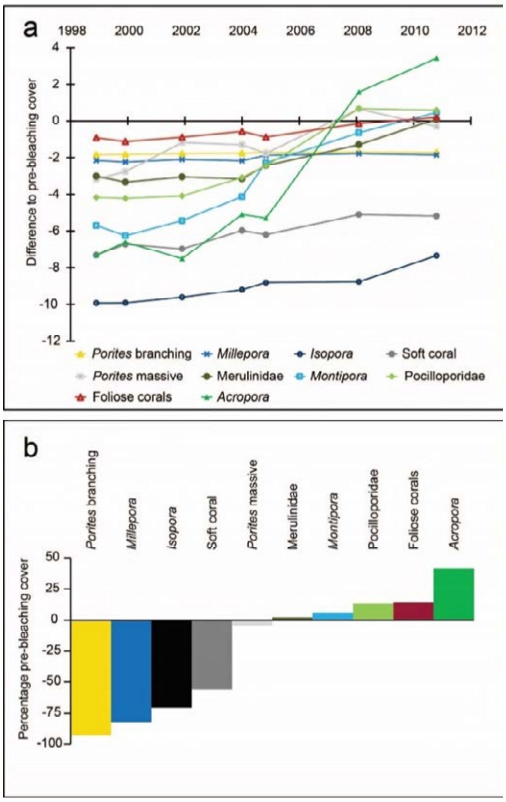

Figure 4: Recovery of coral groups following the 1998 mass bleaching. (a) Difference between mean pre-bleaching (1995 to 1997) cover at each location and in consecutive surveys to October 2010. (b) Mean percentage difference in cover between pre-bleaching years and in 2010.

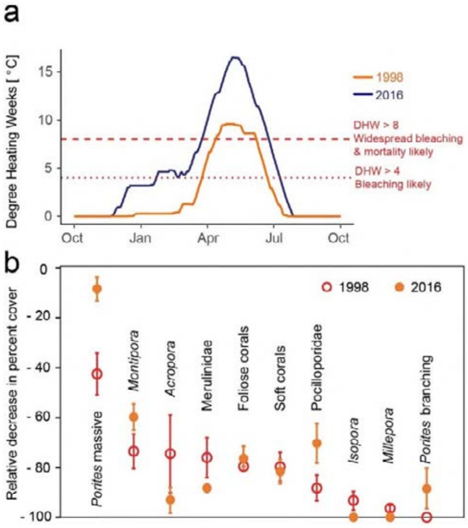

Figure 5: (a) Heat stress at Scott Reef in 1998 and 2016. Duration and maximum Degree Heating Weeks (NOAA Coral Reef Watch 2018); and (b) Susceptibility of coral groups to heat stress and mass bleaching in 1998 and 2016. Mean relative (%) decrease in cover at communities across the reef system, between approximately one year before and after each mass bleaching.

3.1.6 Mass bleaching (2016–2017)

In 2016 and 2017, three periods of heat stress (DHW > 4 °C-weeks) affected the reef system (**Table 3**). The heat stress in early 2016 was the highest on record, persisting for 170 days and peaking at 16.5° C-weeks in May (**Figure 5**). An additional 73 days of heat stress peaked at 5.9° C-weeks in December 2016, and 13 days peaked at 5.5° C-weeks in December 2017 (**Table 3**). Damaging waves were also caused by Cyclone Yvette in 2016 (61 hours $H_s \geq 4$ m) and a tropical low in 2017 (39 hours $H_s \geq 4$ m) (**Table 3**), but the heat stress in early 2016 and the resulting mass bleaching was by far the most severe disturbance.

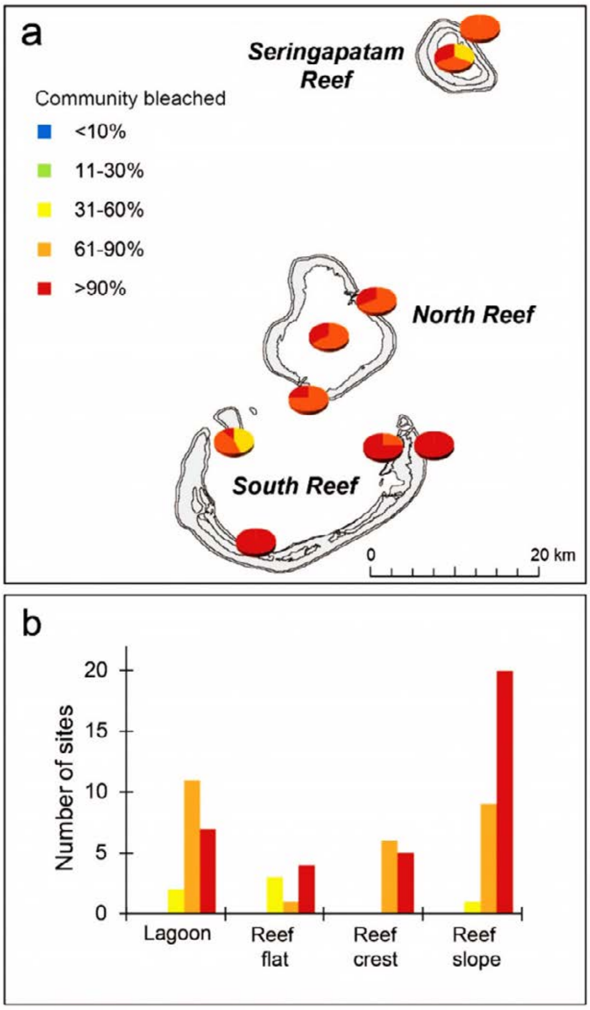

Figure 6: Percentage of bleached corals in April 2016 in communities (a) across the reef system and (b) in each habitat. Habitats are the lagoon (coral bommies and lagoon floor; 0–17m), reef flat (0–3m), reef crest (3–6m) and reef slope (6–9m). Colonies included were fully bleached or recently dead.

Mass bleaching in April 2016 was recorded at all shallow water (< 20 m depth) habitats across Scott Reef, with little variation in bleaching among locations or habitats (lagoon, reef flat, reef crest and reef slope (**Figure 6**). All 69 communities surveyed had > 30% of colonies bleached, and many (30–70%) had > 90% of corals bleached. The sites least affected were on the reef flat or in the deepest (15–20 m depth) parts of the lagoon at North Reef and Seringapatam Reef. Bleaching was observed to 30 m at the deep lagoon at South Reef, but rare at 50 m.

The bleaching estimates and the reduction in coral cover six months later (**Figure 7**) were comparable, with little variation in mortality among reefs, habitats and communities. The mean (± SE) cover of hard corals at the reef crest and reef slope had decreased from 47% (± 8) to 14% (± 5), and the soft coral from 3% (± 2) to 0.6% (± 0.3). The relative reductions in cover were similar (> 70%) at most (9 of 14) communities across the reef system, but lower (40–60%) at those worst affected by recent cyclones and exposed to the lowest heat stress. For example, at the Channel, Inner South West and Inner South East communities, there were smaller relative decreases in cover of massive *Porites* (5%) and *Montipora* (30–60%) than at the other communities (10–33% and 50–80% respectively) (**Figure 3, Appendix 6**). Among the coral groups, the relative decreases in cover were highest (> 90%) for the *Millepora*, branching *Porites, Isopora* and *Acropora*, followed by Merulinidae and soft corals (80–90%), foliose corals (mostly *Echinopora*) and Pocilloporidae (70%–80%), *Montipora* (60%) and massive *Porites* (9%) (**Figure 5; Appendix 6**).

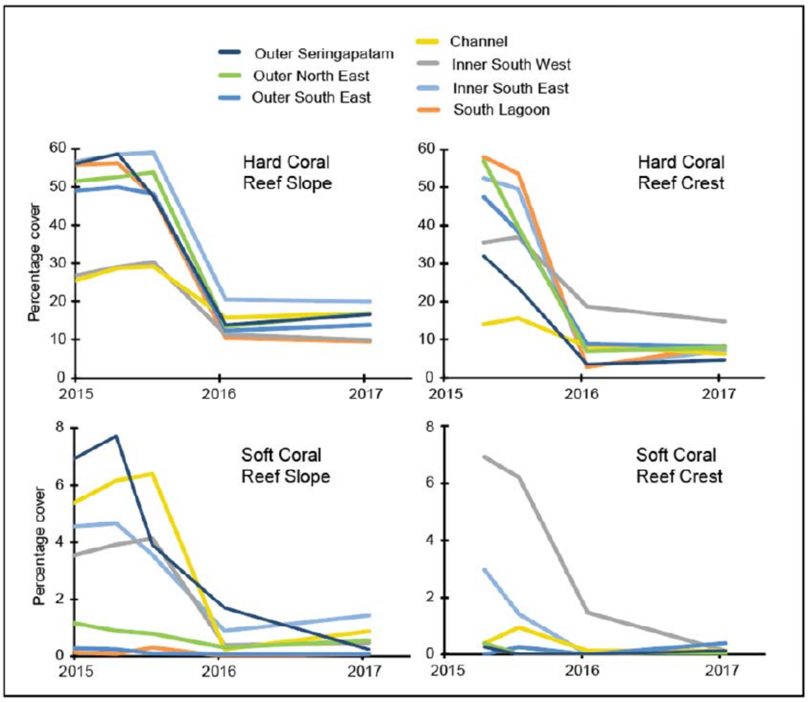

Figure 7: Changes in mean cover of hard and soft corals at reef slope (6 m) and reef crest (3 m) habitats following the 2016 mass bleaching.

3.1.7 1998 versus 2016 mass bleaching

Heat stress in 2016 lasted longer and was more severe (170 days; 16.5° C-weeks) than in 1998 (90 days; 9.6° C-weeks) (**Figure 5, Table 3**). However, the mass bleaching and mortality in 1998 and 2016 were similar in scale and severity, with mean cover across the reef system decreasing from the highest (≈ 50%) to the lowest on record (10–15%). All habitats, locations and coral groups were affected, and the loss of corals was matched by comparable increases in crustose coralline algae (**Figure 2, Figure 3, Figure 5**).

Following the mass bleaching in 1998 and 2016, the coral communities were more similar than at any other time in 23 years, and were distinguished by the loss of *Isopora*, *Acropora*, Pocilloporidae, Merulinidae, and soft corals (**Figure 5, Appendix 6**). However, the relative decreases in mean cover of some taxa were smaller following the 2016 mass bleaching than 1998. Where massive *Porites* were common (> 5% cover), their relative decreases in 2016 were smaller (10–30%) than in 1998 (30–60%), even after excluding communities recently impacted by cyclones. Similarly, in 2016 there were smaller relative decreases in *Montipora* (66%) and Pocilloporidae (62%) than in 1998 (78% and 80% respectively; **Figure 5**). However, the smaller mean reductions in cover for these taxa were mostly at the Inner South East community (**Appendix 6**), where the relative reduction in total hard coral cover was also lower (56%) in 2016 than in 1998 (79%). Among the communities, the Inner South West and Channel consistently had the lowest relative reductions (45–60%) in hard corals following both mass bleaching events, because they experienced more variable temperatures (**Appendix 2**) and had fewer susceptible taxa. For other communities, relative reductions were similar following both mass bleaching events, despite some having a much lower cover of susceptible taxa in 2016 (e.g. *Isopora*, *Millepora*).

3.1.8 Disturbance regimes, community structure and degradation

Over 23 years, Scott Reef transitioned through four general periods of impact and recovery that were indicative of the health of the reef system: healthy (pre-bleaching years, 1994 to 1997), mass bleaching (up to four years after mass bleaching in 1998 and 2016); post-bleaching (five and six years after mass bleaching) and recovery (10 to 15 years after mass bleaching). The most obvious difference between communities among the four states was the reduction in cover of hard and soft corals with increasing degradation, and the corresponding increases in crustose coralline algae (**Figure 8**).

Among the taxa, the massive *Porites*, *Montipora* and Merulinidae consistently characterised communities in all four of the states, because they were common and underwent the smallest changes in cover. However, their relative contribution to the community changed as the system transitioned from the degraded to the healthy states, indicative of the changes in communities when the return times for severe disturbances are less than a decade (**Figure 8**). As the condition of communities improved, the cover of all coral groups increased, but the most significant increases were in the *Isopora*, Pocilloporidae and particularly *Acropora*. Nonetheless, there remained some important differences between the recovery and pre-bleaching states, because the taxa most susceptible and least resilient to the mass bleaching required well over a decade to recover. This included *Millepora* and branching *Porites* that were most susceptible and were previously rare at most communities, and *Isopora* and soft corals that failed to recover at communities where they were worst affected (**Figure 3, Figure 8**).

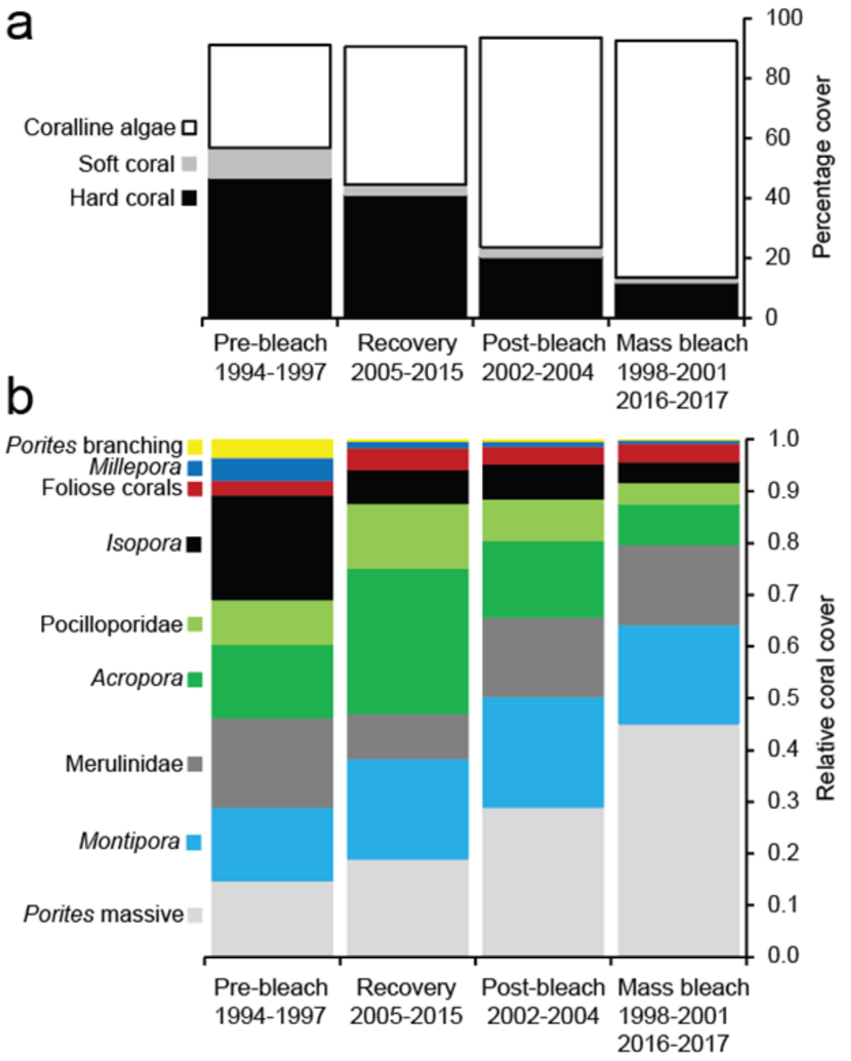

Figure 8: Community structure at Scott Reef in four states of impact and recovery, indicative of the condition of the reef system. States are: Pre-bleaching (1994-1997), Mass bleaching (1998–2001, 2016–2017), Post-bleaching (2002–2004), and recovery from mass bleaching (with local disturbances, 2005–2015); (a) percentage cover of hard corals, soft corals and coralline algae; and (b) relative cover of different coral groups, in each community stage.

3.2 Rowley Shoals

3.2.1 Periods of impact and recovery across the Rowley Shoals

Over 22 years, acute disturbances of moderate severity impacted the Rowley Shoals (**Figure 9**). Although frequent, disturbances usually reduced coral cover in only a few communities and coral taxa, and a rapid recovery was aided by the lack of chronic disturbances, high water quality and abundant fish stocks.

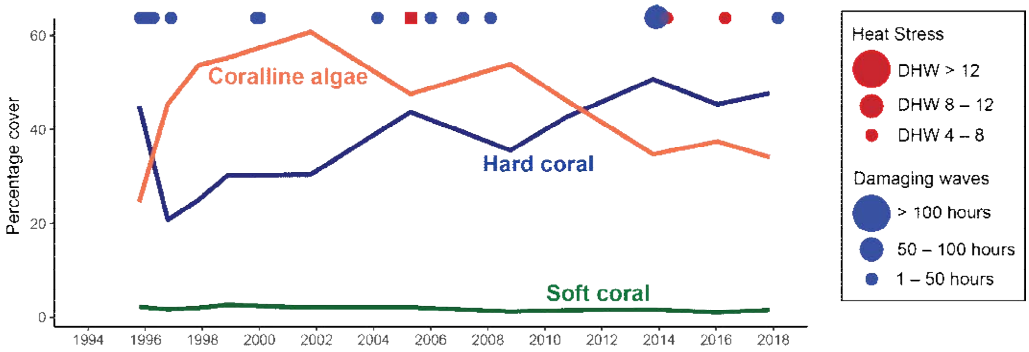

Figure 9: Over 22 years, multiple acute disturbances altered community structure across the Rowley Shoals. Disturbances were damaging waves from storms and cyclones (significant wave heights ≥ 4 m) and heat stress (DHW > 4 °C-weeks). Red square indicates observed moderate bleaching where heat stress did not exceed 4 °C-weeks.

From 1995 to 2017, mean coral cover (hard corals, soft corals, *Millepora*) across the Rowley Shoals was 45% and ranged between 28% and 58%. At least 13 cyclones produce damaging waves (**Table 4**), and eight coincided with mean reductions (up to 22%) in coral cover across the reef system (**Figure 9**). Multiple cyclones caused the largest reduction in mean coral cover, from 50% in 1995 to 28% in 1996. Between 2005 and 2008, another mean reduction in cover (from 52% to 41%) followed three cyclones and a moderate bleaching event (**Table 4**). Heat stress (DHW > 4° C-weeks) occurred three times since 1995, but not in 2005 when moderate bleaching was observed. The highest heat stress on record (5.8 °C-weeks) occurred in 2016, but caused only moderate bleaching at a few sites (**Table 4**). Severe heat stress (DHW > 8° C-weeks) and mass bleaching has not occurred at the Rowley Shoals (**Table 4**). Through cycles of impact and recovery, benthic communities were dominated (> 70%) by hard corals, soft corals and coralline algae (**Figure 9**). Following the loss of corals, available substrata were colonised by coralline algae, while the cover of other benthic groups (e.g. sponges, macroalgae) remained low. Since 1997, mean coral cover has increased through rapid cycles of impact and recovery, and has been consistently high (> 40%) since 2010 (**Figure 9**).

Changes in community structure across the reef system were driven by their local exposure to cyclones and moderate heat stress and mediated by the life histories of their dominant taxa. The temporal dynamics grouped into three periods of impact and recovery (**Appendix 7**), all of which were indicative of a healthy reef system:

1) Cyclone disturbance and decreased coral cover (1996–1997)
2) Recovery, cyclones and coral bleaching (1995, 2001, 2005)
3) Cyclones, recovery and coral bleaching (2008–2017)

Table 4: Disturbance history at the Rowley Shoals (Oct 1995–Dec 2017). Cyclone and storm events causing damaging seas (hours Hs > 4 m) are shown in blue cells. Heat stress is defined as DHW > 4 °C-weeks (yellow cells) for pixels overlying Rowley Shoals monitoring locations (NOAA Coral Reef Watch 2018). Double lines between rows indicate timing of coral monitoring surveys. Where DHW remained at its maximum ("peak date") over more than one day, the peak date given is the first day of the maximum value. A higher number of hours at $H_s > 4$ m indicates greater potential for wave damage at the coral monitoring sites, assuming vulnerable colonies are present. For pre-2010 cyclones, directions of exposure are unknown and peak dates are approximate (details in Methods).

Event	Year	Peak date/s	Peak DHW	Duration (days; hours)	Disturbance observations; wave direction
Cyclone Frank	1995	Dec		3–6 hrs	Directions unknown
Cyclone Gertie	1995	Dec		11 hrs	Directions unknown
Cyclone Jacob	1996	Feb		7 hrs	Directions unknown
Cyclone Olivia[1]	1996	Apr		9 hrs	Directions unknown
Cyclone Phil[1]	1996	Dec		10 hrs	Directions unknown
Cyclone Isla	1999	Dec		21 hrs	Directions unknown
Cyclone John	1999	Dec		30 hrs	Directions unknown
Cyclone Fay	2004	Mar		40 hrs	Directions unknown
Heat stress[2]	2005	27th Apr	2.1	–	Moderate bleaching observed
Cyclone Daryl	2006	Jan		11 hrs	Directions unknown
Cyclone George	2007	Mar		26 hrs	Directions unknown
Cyclone Nicholas	2008	Feb		47 hrs	E
Cyclone Christine	2013	Dec		62 hrs	WNW, E to SE, W
Heat stress	2014	12th Apr	5.6	71 days	No signs of recent bleaching in surveys later that year
Heat stress	2016	28th Apr	5.8	71 days	Minor bleaching
Cyclone Marcus	2018	Mar		20 hrs	NE to ENE to NNE

[1] Wave zones for cyclones Phil and Olivia did not intersect the long-term monitoring sites, but may have caused impacts given the positional uncertainty of these cyclone tracks. [2] Heat stress in 2005 did not exceed 4° C-weeks but moderate bleaching was observed.

3.2.2 Cyclone disturbances and decreased coral cover (1995–1997)

Damaging waves were generated by cyclones Frank (3–6 hours $H_s \geq 4$ m) and Gertie (11 hours $H_s \geq 4$ m) in 1995, and Jacob (7 hours $H_s \geq 4$ m) Olivia (9 hours $H_s \geq 4$ m) in 1996 (**Table 4**). The mean (± SE) cover of hard corals at Rowley Shoals decreased from 45% (± 8) in 1995 to 21% (± 4) in October 1996 (**Table 4**). However, decreases were limited to Clerke (13%) and particularly Imperieuse Reef (46%), mainly due to the loss of *Acropora* (**Figure 10**). In contrast, at Mermaid Reef hard corals had increased (7%), mainly due to *Millepora* (**Figure 10**).

Cyclone Phil generated damaging waves (10 hours $H_s \geq 4$ m) in December 1996. By 1997, cover had changed little at Clerke and Imperieuse reefs and had increased (13%) at Mermaid Reef, due mainly to encrusting corals (10%). Following the recent cyclones, *Acropora* were rare (< 2%) at all three reefs in 1997 and Merulinidae, *Millepora* and encrusting corals were most common (3–16%) (**Figure 10**).

3.2.3 Recovery, cyclones and coral bleaching (1998–2005)

Damaging waves were generated by cyclones Isla (21 hours $H_s \geq 4$ m) and John (30 hours $H_s \geq 4$ m) in December 1999 (**Table 4**). Between 1997 and 2001, the cover of hard corals had decreased (13%) at Mermaid Reef, due to the loss of Merulinidae (2%), *Diploastrea* (3%) and particularly encrusting corals (8%). In contrast, cover increased at Clerke (13%) and Imperieuse reefs (16%), due to large increases of *Acropora* (9–10%) and smaller (< 4%) increases of Pocilloporidae and massive *Porites* (≈ 4%) (**Figure 10**).

Damaging waves were generated by Cyclone Fay (40 hours $H_s \geq 4$ m) in 2004 (**Table 4**). Between 2001 and 2005, hard coral cover changed little at Mermaid Reef, but increased at Clerke (17%) and Imperieuse (24%) reefs, due to large increases (13–22%) in *Acropora* and smaller increases (< 5%) in *Isopora* and other coral groups (**Figure 10**). Coral communities in 2005 were similar at Clerke and Imperieuse reefs, with a relatively high cover of and *Acropora* (24–32%) and *Isopora* (4–5%; **Figure 10**), whereas *Acropora* were rare (< 3%) at Mermaid Reef and cover of *Diploastrea*, *Millepora*, and soft corals was higher (6–8%).

Coral bleaching was observed at all three reefs during the survey in March 2005, despite DHW not exceeding 4° C-weeks (maximum 2.1° C-weeks, **Table 4**). Moderate bleaching has been recorded on other reefs at levels of 2° C-weeks, showing that other factors influencing bleaching, such as fine-scale variability in temperatures, may not be captured by satellite sea-surface temperatures (SST) and the derived DHW metric. 10–50% of *Acropora*, Pocilloporidae, Merulinidae and *Diploastrea* colonies had bleached, but the incidence of bleaching varied among reefs. Most of the bleached corals were alive when surveys were conducted and there was little evidence of recent mortality.

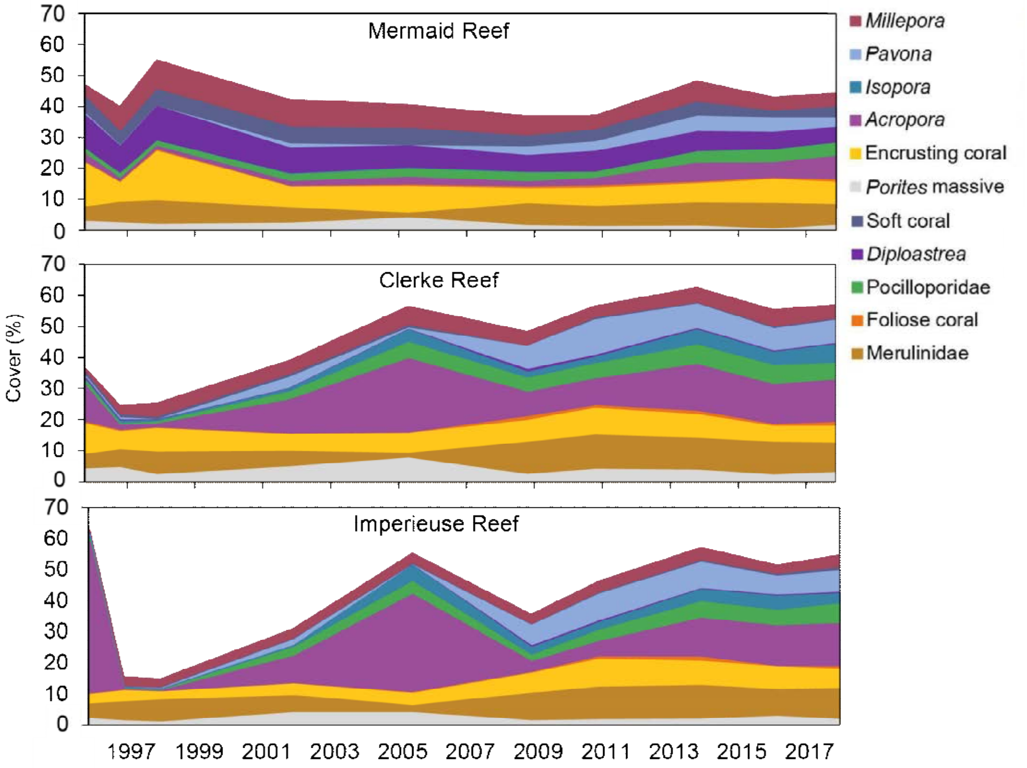

Figure 10: Temporal variation in community structure at reef slope locations at the Rowley Shoals from 1995 to 2017.

3.2.4 Cyclones, recovery and coral bleaching (2006–2017)

Damaging waves were generated by cyclones Daryl (11 hours $H_s \geq 4$ m) in 2006, George (26 hours $H_s \geq 4$ m) in 2007, and Nicholas (47 hours $H_s \geq 4$ m) in 2008 (**Table 4**). The combined effects of these cyclones and coral bleaching in 2005 (**Table 4**) caused a mean reduction in cover across the Rowley Shoals from 2005–2008. Decreases in cover of hard corals were larger at Imperieuse (20%) than at Clerke (7%) or Mermaid (3%) reefs (**Figure 10**), due to the higher abundance of susceptible corals. In particular, there were large (16–28%) decreases in *Acropora* at Imperieuse and Clerke, and small (< 5%) changes in other coral taxa at all three reefs (**Figure 10**).

Between 2008 and 2013, no cyclones affected the Rowley Shoals and hard corals increased at Mermaid (11%), Clerke (16%) and Imperieuse (22%) (**Figure 10**). *Acropora* had the largest increases in cover at all reefs (4–9%), and there were smaller increases (< 4%) in *Isopora*, Pocilloporidae and encrusting corals. (**Figure 10**). By 2013, most coral taxa had recovered from previous cyclones and coral bleaching, but for *Acropora* at Imperieuse Reef (**Appendix 7**).

Damaging waves were generated by Cyclone Christine (62 hours $H_s \geq 4$ m) in December 2013, and heat stress (DHW > 4 ° C-weeks) affected the reef system for 71 days in 2014, peaking at 5.6° C-weeks in April (**Table 4**). Between 2013 and January 2016, mean hard coral cover had decreased at Clerke (11%) and Imperieuse (5%), with the largest decreases in *Acropora* and *Montipora*. There was little change in hard coral cover at Mermaid Reef, but there were small decreases in *Millepora* and soft corals and increases in other taxa.

In 2016, heat stress affected the Rowley Shoals for 71 days, peaking at 5.8° C-weeks in late April (**Table 4**). Little (≤ 10%) or no bleaching was recorded at most reef slope and lagoon sites. However, 30% of the community had bleached at some sites in the Mermaid lagoon (**Figure 11**), particularly *Acropora*, *Montipora* and Fungiids. Despite the bleaching, mean (± SE) hard coral cover across habitats and reefs increased from 45% (± 4) in January 2016 to 48% (± 6) in 2017 (**Figure 9**). The increases in cover were largest (3–4%) at the reef slope at Clerke and Imperieuse reefs, due mainly to increases in *Acropora* (**Figure 10**). The largest decreases (4%) in cover occurred at the few sites in the Mermaid lagoon that experienced the worst bleaching (**Figure 12**), mainly due to the loss of *Acropora*. However, mean cover at the other lagoon sites, and across Mermaid Reef, had changed little by 2017 (**Figure 12**).

In 2017, the differences in reef slope communities across the Rowley Shoals were consistent with those throughout the monitoring period (**Figure 10; Appendix 7**). Reef slope communities at Imperieuse and Clerke were most similar, characterised by a higher cover of Pocilloporidae, *Isopora*, massive *Porites* and particularly *Acropora*. Hard coral cover was generally higher and more variable at Imperieuse and Clerke reefs, due mainly to changes in *Acropora*. In contrast, Mermaid Reef was distinguished by a higher cover of *Diploastrea*, *Millepora* and soft corals. Hard coral cover was usually lower and less variable at Mermaid Reef, due to the low cover of *Acropora*. Merulinidae, *Montipora* and other encrusting corals were common at all three reefs and remained relatively stable through time (**Figure 10**).

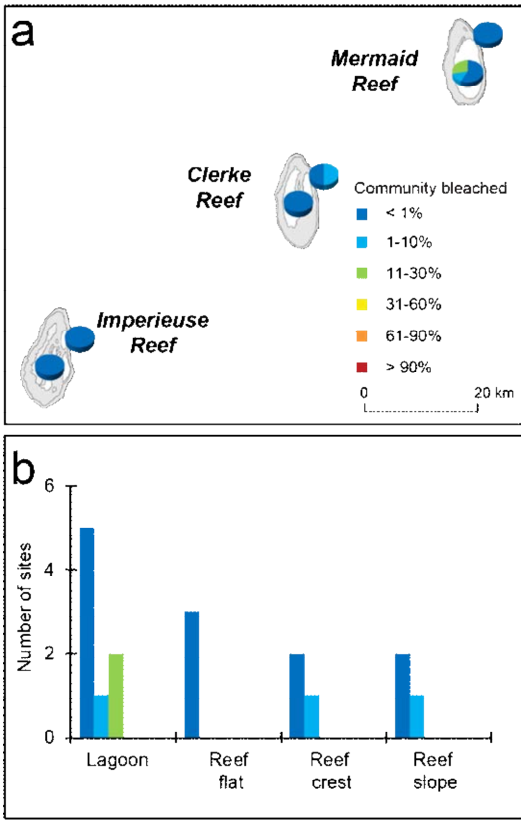

Figure 11: (a) Percentage of bleached corals in communities across the reef system in April 2016, and (b) number of sites in each habitat, using the same categories. Habitats are the lagoon (including coral bommies and lagoon floor), reef flat (0–3m), reef crest (3–6m) and reef slope (6–9m). Colonies included were fully bleached or recently dead.

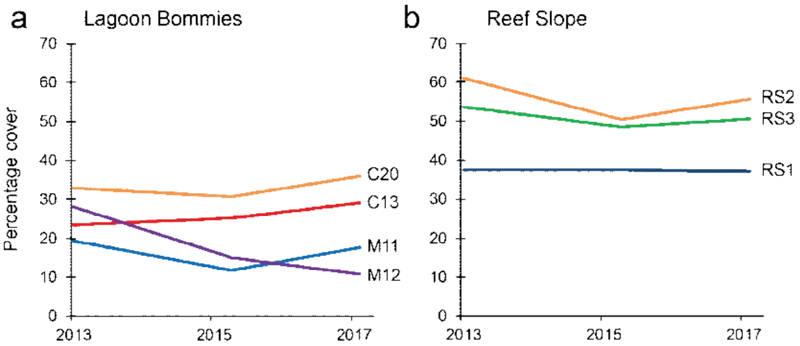

Figure 12: Hard coral cover in (a) lagoon bommie and (b) reef slope habitats at the Rowley Shoals in 2013–2017. Lagoon bommie sites were at Mermaid Reef (M11, M12) and Clerke Reef (C13, C20). Reef slope sites were at Mermaid Reef (RS1), Clerke Reef (RS2) and Imperieuse Reef (RS3).

4. Discussion

4.1 Twenty-three years of disturbances

Over 23 years, coral communities across Scott Reef underwent significant change, driven by two mass bleaching events and frequent moderate disturbances. During the same period, communities at the Rowley Shoals also changed in response to frequent moderate disturbances but did not suffer the severe and widespread impacts caused by mass bleaching. Damaging waves generated by cyclones caused mean decreases in coral cover three times at the Rowley Shoals and once at Scott Reef, but usually affected exposed communities and coral taxa with fragile growth forms. At Scott Reef, there were nine periods of heat stress, two mass bleaching events and at least two moderate bleaching events; at the Rowley Shoals, there were only two periods of heat stress and moderate bleaching events. Coral communities at Scott Reef experienced large variation in impact and recovery, with coral cover in 2017 near the lowest on record. Coral cover varied less at the Rowley Shoals and has remained high since 2014. The very different dynamics of these reef systems highlight the impacts of mass bleaching on coral reefs, and how these are mediated by local environmental conditions and coral life history traits.

4.2 Disturbances mediated by local environmental variation

Local environmental conditions play a fundamental role in structuring coral communities, even within a common habitat (Done 1982; Hughes et al. 2012; Schmidt et al. 2012; Zinke et al. 2018). Across the reef slope habitat at Scott Reef, variation in temperatures, wave energy, current speeds and water quality influenced the structure of coral communities, particularly in the absence of severe disturbances. The location on the reef and environmental conditions also mediated exposure to disturbances. For example, the Inner South West and Channel were most exposed to seasonal storms and cyclones, but are also flushed by internal waves bringing cool water from the deep (Bird 2005; Green et al. 2018; Rayson et al. 2018; Green et al. 2019). Cool water intrusions, higher current speeds and tidal mixing at the Channel and Inner South West communities reduced heat stress and bleaching in both 1998 and 2016 at Scott Reef. These localized reef hydrodynamics, singularly or in combination, have also been shown to reduce heat stress and bleaching at other reefs (Wall et al. 2015; Safaie et al. 2018; Page et al. 2019). Local reductions in heat stress and bleaching also occurred at the southern part of the Seringapatam lagoon in 2016 (**Figure 6**), following night-time cooling of water over the reef flat (Green et al. 2018). Conversely, more severe bleaching at other parts of the reef was due to the flow of warm water out of lagoons, low current speeds and limited tidal mixing. Fine-scale variation in hydrodynamics, water quality and light penetration all can influence local heat stress and the severity of coral bleaching (Nakamura and van Woesik 2001; McClanahan et al. 2007; Skirving et al. 2017; Page et al. 2019).

Local conditions also influenced the recovery of communities following severe disturbances. Reef structure and hydrodynamics determine patterns of larval connectivity among communities and rates of recruitment (Hughes et al. 1999; Becerro et al. 2006; Sato et al. 2018; Torda et al. 2018). All three atolls at the Rowley Shoals have similar shapes, which limits the dispersal of spawning and particularly brooding corals outside of each lagoon, but aids connectivity among the outer slope habitats at each reef (Thomas et al. 2019). At Scott Reef, local hydrodynamics are strongly influenced by the open lagoon at South Reef and the flow of water through the deep channel adjacent to North Reef (Green et al. 2018; Rayson et al. 2018; Green et al. 2019). The Outer South East and Channel at Scott Reef had consistently low recruitment because larvae were carried away by currents, while the Inner South East and Outer North East had the highest recruitment because larvae were concentrated by local eddies (Gilmour et al. 2013a; Rayson et al. 2018). Following larval recruitment, growth and survival of colonies were also influenced by local environmental conditions, and communities returned to their previous structure. There was no evidence of previously rare taxa becoming dominant at Scott Reef after the mass bleaching, or of major shifts in community structure towards less susceptible species. Long-term shifts in community structure on other reefs usually reflect the loss of susceptible taxa, rather than the proliferation of previously rare corals (Done et al. 2007; Hughes et al. 2018a; Torda et al. 2018; Edmunds 2019). More than a decade after the mass bleaching at Scott Reef, communities were distinguished by the loss of coral taxa whose life history traits (susceptability, growth reproduction) had made them most vulnerable to the heat stress.

4.3 Susceptibility, recovery and coral life histories

Both disturbances and routine environmental conditions structured coral communities through the life histories of their dominant taxa. At Scott Reef and Rowley Shoals, there were common patterns of susceptibility to cyclones and heat stress, with the *Acropora*, *Isopora,* Pocilloporidae generally most susceptible, and *Montipora*, Merulinidae, and massive *Porites* least susceptible. This variation in susceptibility is consistent with most other studies of coral reefs (Marshall and Baird 2000; Loya et al. 2001; McClanahan 2004; Hoey et al. 2016). However, the vulnerability of taxa depends on both their initial susceptibility (resistance) and capacity to recover (resilience) over many years (Van Woesik et al. 2011; Carturan et al. 2018). For example, when considering both the initial decreases in cover at Scott Reef following the 1998 mass bleaching and increases in cover over the following 12 years, taxa with very different life histories displayed similar levels of long-term vulnerability. Susceptible taxa recovered more rapidly while those least affected showed slower increases in cover. *Acropora* and Pocilloporidae were more susceptible to disturbances but had higher recruitment and growth rates (Harrison and Wallace 1990; Graham et al. 2011; Van Woesik et al. 2011). Their initial recovery was slow because most colonies were killed, but increased rapidly over several generations. Merulinidae, soft corals and massive *Porites* had lower susceptibility to disturbances and lower rates of sexual recruitment and growth (Harrison and Wallace 1990; Babcock 1991; Fabricius 1995; Fong and Glynn 2000; Van Woesik et al. 2011). Regrowth of injured soft corals and massive corals resulted in small initial increases in cover following cyclones and mass bleaching, but this slowed when recovery relied on recruitment.

The capacity for larval dispersal also influenced the recovery of different coral taxa following the 1998 mass bleaching. For the most susceptible taxa at the worst affected communities, recovery depended on the supply of recruits from other locations (Underwood 2009). Coral taxa with few local survivors and a low capacity for dispersal had not recovered a decade after the mass bleaching. This included the branching *Porites* and the hydrocoral *Millepora* that were already rare before the mass bleaching, and the soft corals and *Isopora* that were previously common. The slow growth of the dominant soft corals (*Sarcophyton, Lobophytum*, *Sinularia*) and their reliance on asexual replication (Fabricius 1995; Michalek-Wagner and Willis 2001; Bastidas et al. 2004) meant they remained at < 30% of pre-bleaching cover 10 years later. The recovery of *Isopora* also depended on local survivors, since their brooded larvae typically dispersed less than a few kilometres (Harrison and Wallace 1990; Underwood et al. 2009; Foster and Gilmour 2018; Thomas et al. 2019). Recovery had occurred within a decade at the two communities where the cover of *Isopora* was highest post-bleaching, but there had been little or no recovery at communities where few colonies had survived. Despite their susceptibility, broadcast spawning *Acropora* and *Pocillopora* produced many larvae that dispersed across the reef system, aiding the recovery of populations worst affected (Underwood 2009; Harrison 2011; Gilmour et al. 2013b; Thomas et al. 2019). As a result, *Acropora* were the only taxa whose cover was consistently higher at all communities more than a decade after the mass bleaching than before, with a similar transition observed on other reefs with a supply of larvae and several years without severe disturbance (Thompson and Dolman 2010; Johns et al. 2014; Torda et al. 2018). The ecological consequences of life history variation in corals is increasingly recognised (Darling et al. 2013; Done et al. 2015; Madin et al. 2016; Torda et al. 2018) and provides valuable insights into the viability of reefs through climate change. To successfully manage reefs through changing regimes of disturbance, life history variation must be considered in the context of functional importance to reefs (Darling et al. 2017) natural capacity for adaptation, and suitability for restoration efforts (Anthony 2016; McLeod et al. 2019).

4.4 Resilience of Scott Reef and the Rowley Shoals to past and future disturbance regimes

The 1998 global coral bleaching highlighted the threat of climate change to coral reefs (Hoegh-Guldberg 1999; Wilkinson 2000). Many reefs devastated in 1998 have not recovered, due to additional bleaching and local pressures (Baker et al. 2008; Sheppard et al. 2008; Graham et al. 2011; Bruno et al. 2018; MacNeil et al. 2019). Isolated reefs, including Scott Reef and the Rowley Shoals, are less exposed to local pressures (e.g. degraded water quality, pollution, depleted fish stocks), and have recovered faster, but the lack of larval connectivity with other reef systems also increases susceptibility to reef-wide reductions in population stocks (Graham et al. 2006; Sandin et al. 2008; Holbrook et al. 2018). At Scott Reef, there was a comparable decrease in coral cover and recruitment following the mass bleaching and this stock-recruitment relationship remained through the recovery period (Gilmour et al. 2013b). Recovery across the reef system relied on the surviving corals and their offspring, and not the supply of recruits from other reef systems (Underwood et al. 2009; Underwood et al. 2018). Nonetheless, high post-recruitment growth and survival was facilitated by high water quality, healthy fish stocks and a decade (1999-2009) with few disturbances (Gilmour et al. 2013b).

The heat stress in 2016 at Scott Reef was the worst on record and the mortality that followed was comparable to that in 1998, with similar variation among communities and coral groups. A recovery trajectory of 10–15 years would therefore be expected, if the future disturbance regime was also similar. However, the frequency and severity of disturbances at Scott Reef have increased since 2010, and a similar pattern is evident at many other reefs in Western Australia and around the world (Hughes et al. 2018b; Gilmour et al. 2019). With further climate change (Hoegh-Guldberg et al. 2018; Steffen et al. 2018), cyclones are expected to produce more damaging waves (Chand et al. 2017; Cheal et al. 2017; Simpkins 2018) and rising ocean temperatures (Raftery et al. 2017) are expected to increase outbreaks of coral diseases (Harvell et al. 2002; Maynard et al. 2015) and the frequency and severity of coral bleaching (Eakin et al. 2018).

Through the previous cycles of impact and recovery, the Scott Reef system transitioned through four general states indicative of the level of degradation and return times for severe disturbances. The healthier states had a much higher coral cover (> 40%) than degraded states (< 20%), but corals were replaced by crustose coralline that facilitates coral recruitment (Harrington et al. 2004). The space available for recolonization reflects the potential for the reef to recover, rather than permanently transitioning to a state in which algae or other benthic invertebrates dominate (Hoegh-Guldberg et al.

2007). Both degraded states also had a much lower cover of *Acropora, Isopora* and Pocilloporidae, which contribute most to the structure of the reef and micro-habitats used by fish and other organisms (Emslie et al. 2008; Wilson et al. 2009; Graham and Nash 2013; Darling et al. 2017; Richardson et al. 2017). These degraded states are indicative of the condition of the reef when recovery periods from severe mass bleaching are < 10 years. In contrast, at the Rowley Shoals communities maintained a healthy state through cycles of impact and rapid recovery from cyclones. Mass bleaching has not affected the reef system, but heat stress in 2016 was the highest on record and the severity of both coral bleaching and cyclones impacts are also likely to increase further at the Rowley Shoals.

The future condition of the Rowley Shoals and Scott Reef fundamentally depend on local water quality, fish stocks and regimes of disturbances, but also on local refuges from cyclones and heat stress, and the adaptive capacity of their corals. Contrasting susceptibilities and an increased understanding of the coral holobiont highlight the potential for coral adaptation to heat stress (Coles and Brown 2003; Baker et al. 2004; Maynard et al. 2008; Palumbi et al. 2014; Coles et al. 2018; DeCarlo et al. 2019). At all reefs, inferring coral adaptation to heat stress at the reef-scale is confounded by fine-scale variability, community structure, disturbance history and survey methods (percentage cover). Nonetheless, observations at the Rowley Shoals and Scott Reef suggest some adaptation to heat stress. Higher levels of heat stress at the Rowley Shoals in 2014 and 2016 caused similar or less bleaching to that in 2005. At Scott Reef, a similar level of heat stress in 2013 caused far less bleaching and mortality than in 1998, while bleaching was similar in 1998 and 2016 despite more severe heat stress in 2016. Among the coral taxa, the responses to heat stress were not consistent. For example, at Scott Reef the *Acropora* were among the worst affected by bleaching in 1998, 2010 and 2016, but not 2013; massive *Porites*, *Montipora* and Pocilloporidae had smaller relative decreases in cover in 2016 than in 1998, despite a higher level of heat stress. Other reefs also have consistent and contrasting patterns of bleaching susceptibility within and among groups (Pratchett et al. 2013; Palumbi et al. 2014; Hoey et al. 2016; McClanahan 2017; Coles et al. 2018).

Existing data for Scott Reef, the Great Barrier Reef (Hughes et al. 2017), and other reefs around the world, confirm that the current rate of adaptation by corals will not significantly reduce the likelihood of mass bleaching events in coming decades. Instead, reductions in the severity of mass bleaching at reef scales usually reflect a shift to a lower total coral cover and a higher proportion of less susceptible taxa (sliding baselines), rather than rapid and widespread adaptation (Osborne et al. 2017; Hughes et al. 2018a; Edmunds 2019). Management of Scott Reef and the Rowley Shoals must now focus on maintaining high water quality and healthy fish stocks, to aid recovery between acute disturbances (Diaz-Pulido et al. 2010; Jones et al. 2016; Johns et al. 2018; Richmond et al. 2018), and apply our emerging understanding of the reefs' natural capacity to adapt to future conditions (McLeod et al. 2019).

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6. Appendices

Appendix I

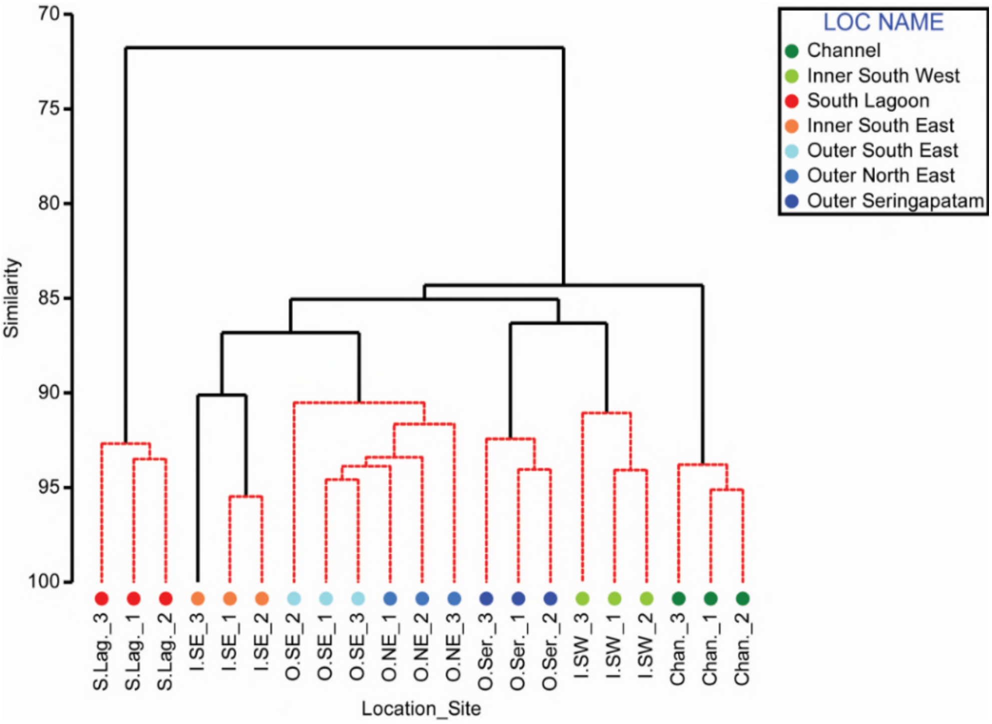

Figure A 1: Grouping of the long-term monitoring sites surveyed at the Scott Reef system over the study period 1994 – 2014 based on similarities in benthic community structure. Spatial variation in the structure of coral communities at Scott Reef (1994–2014). Replicate sites (n = 3) consistently grouped together within locations (Figure 1). Sites linked by red lines are not significantly different, according to the SIMPROF procedure at a significance level of 5%. Data are Bray Curtis similarities for Log+1 transformed percentage cover of benthic groups (Table 1).

Appendix 2

The physical parameters that best distinguished locations at Scott Reef were associated with their regimes of sedimentation, water temperatures and current speeds, winds and waves, and concentrations of chlorophyll and turbidity (**Figure A2**).

The outer-slope locations at South Reef (Outer South East) and North Reef (Outer North East) were exposed to the open ocean to the east but sheltered from monsoonal storms from the west, and had a sloping substrata with a low cover of sand; they experienced moderate variation in water temperatures, but with occasional increases in temperature at the Outer North East due to the flow of warm water out of the lagoon and over the reef flat in summer. The outer-slope locations had intermediate rates of sediment deposition spanning a range of particle sizes, moderate current velocities and exposure to moderate winds and waves from the east (**Figure A2**). Although not quantified, the routine habitat conditions at Outer Seringapatam were similar to Outer North East.

Among the inner-slope locations, habitat conditions varied according to their proximity to the sheltered lagoon in South Reef and to the western side of the deep channel between North and South Reef. The South Lagoon was by far the most sheltered, having the lowest exposure to winds and waves, the slowest current speeds, a low deposition of fine particle sizes (silt, clay) and relatively high turbidity and chlorophyll concentrations. Consequently, its community experienced moderate temperature variation and was characterised by a fragile and gently sloping substrata with a low cover of sand.

Inner South West and Channel locations were the most exposed to winds and waves generated by seasonal storms from a westerly, south-westerly direction, and had high maximum current speeds and wave heights in summer (**Figure A2a, A2c**). Both locations had a high cover of sand, a high deposition of larger particle sizes (sand, coarse sand), and a low concentration of chlorophyll and turbidity. The Inner South West and Channel both had large temperature ranges and the highest 'cooling index' of all locations (**Figure A2a, A2b**). The Channel had steep substrata, while Inner South West was comparatively flat with patchy coral outcrops. Conditions at Inner South East were a mixture of the other locations, being exposed to winds, waves and cool water through the channel from the west, while also being sheltered from the open ocean to the east.

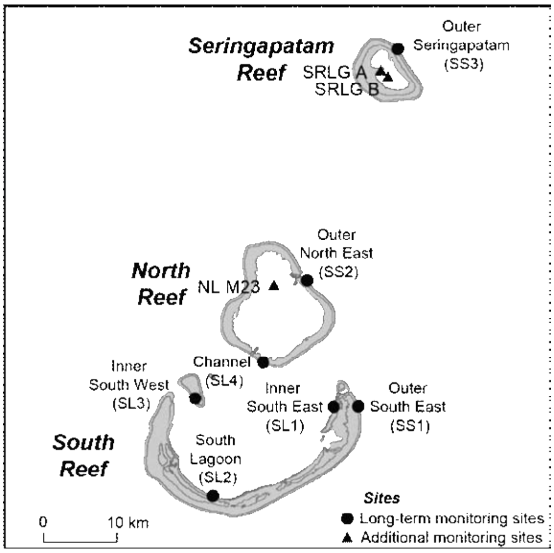

Figure A 2: (a) Location of monitoring sites at Scott Reef. Long-term monitoring sites (black circles) have been surveyed since 1994 and additional monitoring sites (black triangles) since 2016

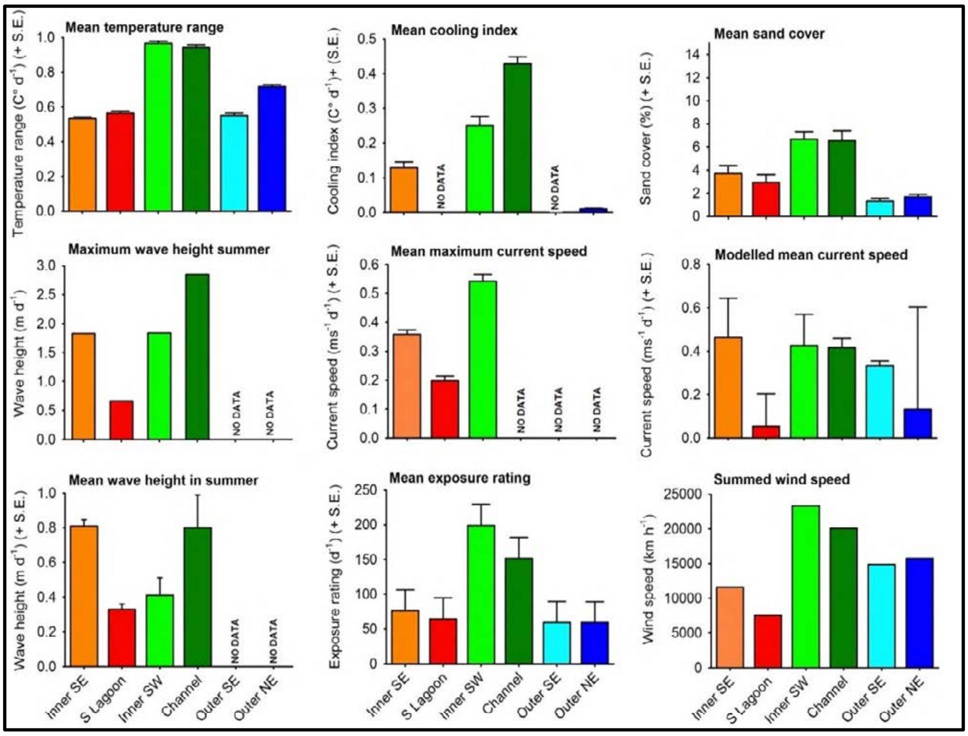

Figure A 2: (b) Physical parameters measured at the long-term monitoring locations at Scott Reef. (c) Seasonal variation in physical parameters long-term monitoring locations at Scott Reef.

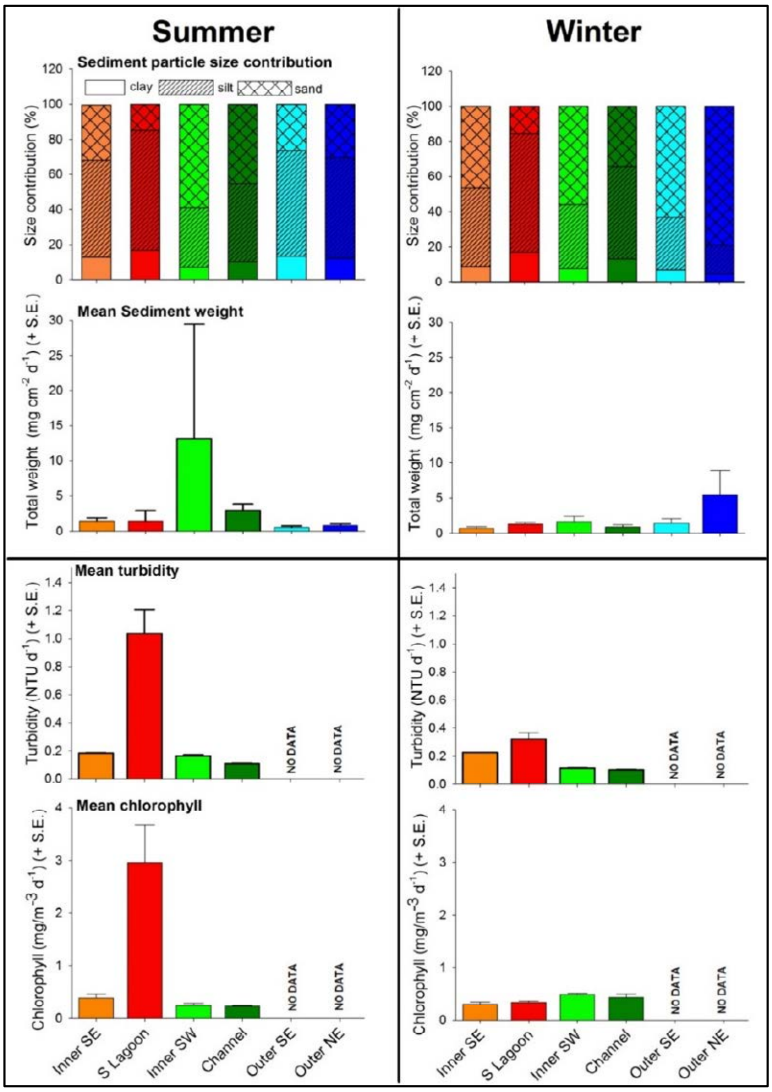

Figure A 2: (c) Seasonal variation in physical parameters long-term monitoring locations at Scott Reef.

Appendix 3

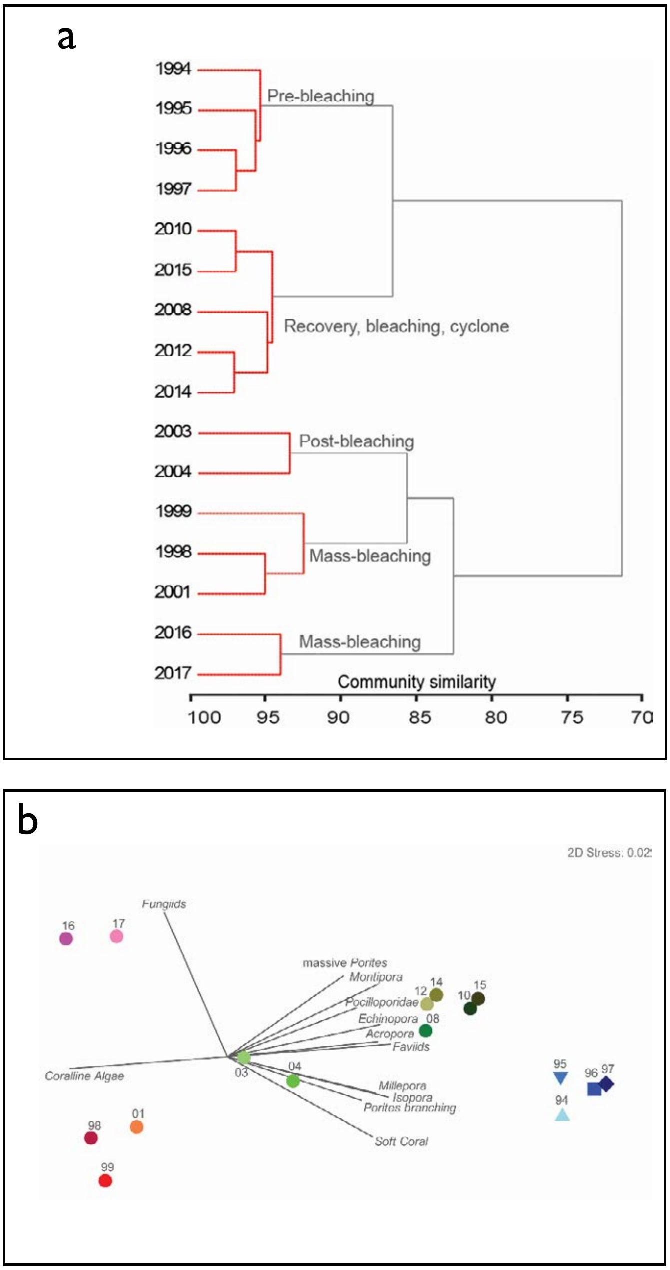

Figure A 3: Temporal variation in community structure across Scott Reef grouped into five distinct periods, according to the cycles of impact and recovery from multiple disturbances, which were indicative of the state of the reef. a) Dendrogram showing years when coral community structure varied significantly (grey lines) across Scott Reef, according to the SIMPROF procedure at a significance level of 5%. Data are Bray Curtis similarities for Log + 1 transformed percentage cover of benthic groups. (b) Grouping of coral communities among years according to their differences in structure, with vectors indicating which coral groups are most abundant during the nearest years and distinguish communities from other years. Non-metric Multidimensional Scaling of coral community structure, using Bray-Curtis similarities of percentage cover of coral groups (square root transformed) by survey year.

Appendix 4

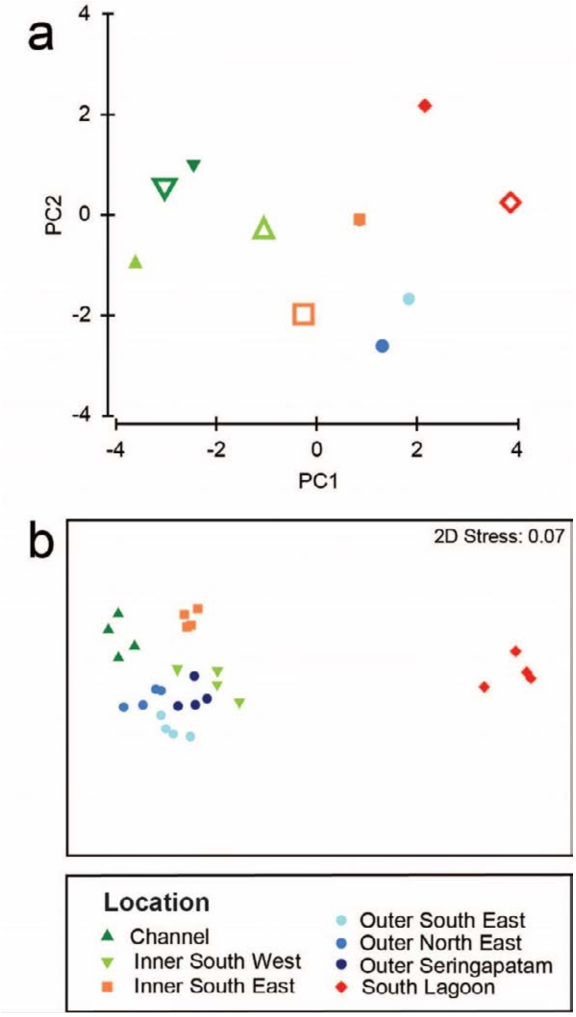

Figure A 4: Physical conditions varied among locations across Scott Reef and caused comparable variation in coral community structure. (a) Principal Coordinate Analyses showing variation in physical conditions among locations (solid symbols) at North and South Reef, and additional parameters quantified only at the inner slope locations (hollow symbols). Physical conditions and their contribution to differences among location are in Appendix 1 and Appendix 5. (b) Non-metric Multidimensional Scaling, illustrating comparable variation in coral community structure among locations, during pre-bleaching (1994-1997) when the influence of physical conditions was not confounded by severe disturbances. Data are Bray-Curtis similarities of percentage cover of coral groups (square root transformed).

Appendix 5

Table A 5: Variation in habitat conditions among locations at Scott Reef. Results of principal component analysis (PCA) of 10 variables quantified at all locations, and an additional 10 variables quantified at only the inner slope locations. Data for most parameters were first converted to daily averages and divided between summer (sum.) and winter (win.) months. More detailed parameter descriptions are in Table 2. Values indicate the strength of the correlation coefficient for each variable with the eigenvector of each PC. The first principle component (PC1) accounts for most of the variation among locations, and the contribution (positive, negative) of each parameter is ranked below each principle component.

All locations				**Inner slope locations**			
Principal Component	Eigenvalue	%Var.	Cum.%Var.	Principal Component	Eigenvalue	%Var.	Cum.%Var.
1	6.02	60.2	60.2	1	8.24	82.4	82.4
2	3.17	31.7	91.9	2	1.20	12.0	94.4
3	0.59	5.9	97.9	3	0.56	5.6	100.0
Variable	PC1	PC2	PC3	Variable	PC1	PC2	PC3
1. Sum. temp. range (ºC)	-0.377	-0.078	-0.103	1. Sum. mean current (ms^{-1})	-0.331	-0.277	-0.083
2. Cover sand (%)	-0.378	0.192	-0.074	2. Sum. max current (ms^{-1})	-0.329	-0.300	-0.073
3. Sum. silt (%)	0.39	0.152	-0.02	3. Sum. mean wave (m)	-0.259	0.383	-0.697
4. Sum. sand (%)	-0.394	-0.079	-0.25	4. Sum. max wave (m)	-0.346	-0.054	-0.114
5. Sum. course sand (%)	-0.274	-0.288	0.681	5. Sum. mean turbidity (NTU)	0.321	-0.259	-0.358
6. Win. silt (%)	-0.004	0.558	0.130	6. Win. mean turbidity (NTU)	0.326	-0.127	-0.436
7. Win. sand (%)	-0.068	-0.551	-0.038	7. Sum. mean chlorophyll (mg m^{-3})	0.318	-0.281	-0.353
8. Win. Course sand (%)	0.203	-0.454	-0.357	8. Win. mean chlorophyll (mg m^{-3})	0.296	-0.466	0.175
9. Exposure (wind, wave)	-0.401	0.038	0.210	9. Sum. salinity range (PSU)	-0.306	-0.435	-0.016
10. Cooling (temp. ºC)	-0.356	0.151	-0.517	10. Win. salinity range (PSU)	-0.322	-0.339	-0.127

Appendix 6

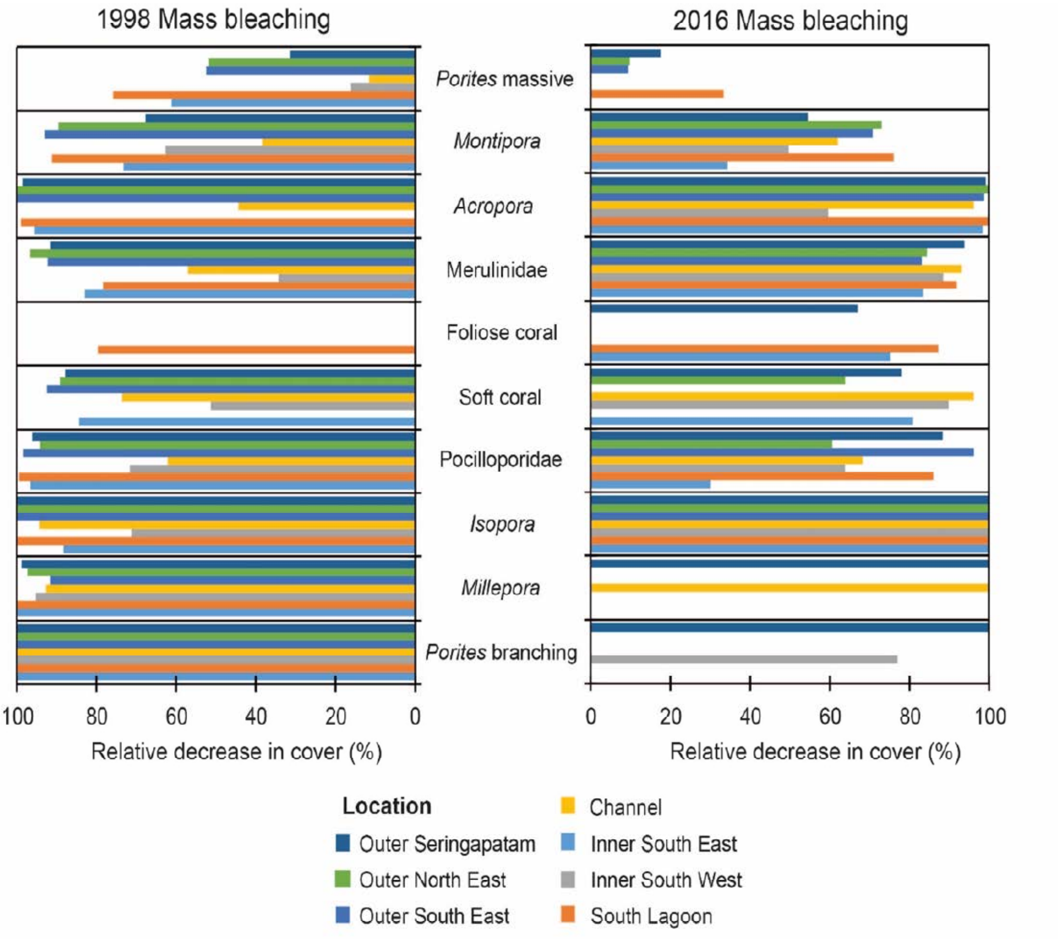

Figure A 6: The variable impact of mass bleaching in 1998 and 2016 among coral groups and locations at Scott Reef. The mean (± SE) relative decreases (%) in coral cover before (October 1997, January 2016) and after (October 1998, October 2016) mass bleaching in March/April. Coral groups and locations were included only if their mean pre-bleaching cover was > 1%, as estimates of relative change are not accurate for rare corals. Not all coral groups were common (> 1%) at all sites prior to the mass bleaching in 1998 (e.g. Foliose corals), and others were rare prior to the mass bleaching in 2016 because they had not recovered from the 1998 mass bleaching (e.g. *Porites* branching, *Millepora,* Soft Coral). Coral groups are in Table 1 and locations in Figure 1.

Appendix 7

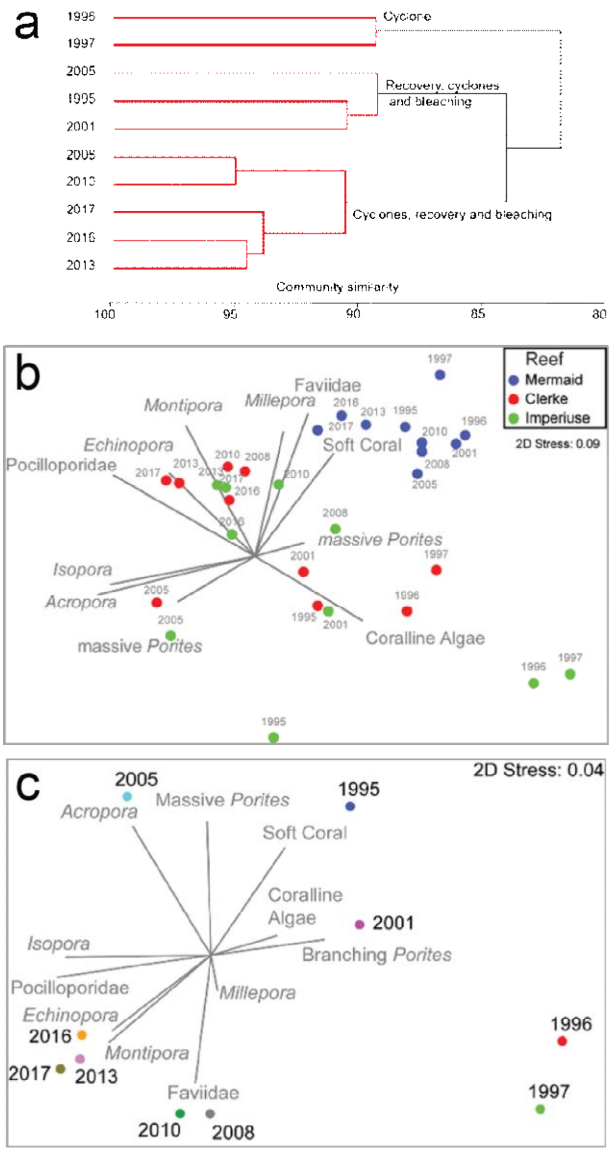

Figure A 7: Temporal variation in community structure across the Rowley Shoals grouped into three distinct periods, according to the cycles of impact and recovery from multiple disturbances. a) Dendrogram showing years when coral community structure varied significantly (black lines) across Rowley Shoals, according to the SIMPROF procedure at a significance level of 5%. Data are Bray Curtis similarities for Log + 1 transformed percentage cover of benthic groups. The grouping of coral communities among years b) at each reef, and c) averaged across all reefs, according to their differences in structure. Vectors indicate which coral groups are most abundant at the nearest reefs and/or years and distinguish communities from other reefs and/or years. Non-metric Multidimensional Scaling of coral community structure, using Bray-Curtis similarities of percentage cover of coral groups (square root transformed) by survey year.

Chapter 10 D.3 JASCO Browse to North West Shelf Noise Modelling Study

Browse to North West Shelf Project Noise Modelling Study

Assessing Marine Fauna Sound Exposures

Submitted to:
Arne De Vos
Jacobs
PO: 538, 28 May 2019

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Disclaimer:

The results presented herein are relevant within the specific context described in this report. They could be misinterpreted if not considered in the light of all the information contained in this report. Accordingly, if information from this report is used in documents released to the public or to regulatory bodies, such documents must clearly cite the original report, which shall be made readily available to the recipients in integral and unedited form.

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Tables

Executive Summary

The Browse Joint Venture (BJV) proposes to develop the Brecknock, Calliance, and Torosa fields (collectively known as the Browse resources) via the development drilling of wells and the installation of subsea production system that will supply two 1100 Million standard cubic feet per day (annual daily export average) Floating Production Storage and Offloading (FPSO) facilities. The Browse to North West Shelf (NWS) Project gas will be transported from the FPSO facilities to the existing North West Shelf (NWS) Project infrastructure via a ~900 km trunkline. Each FPSO will have a turret mooring system that will be stabilised using mooring lines secured to the seabed by piles. These piles may have to be installed using impact piling methods.

Underwater noise will be generated during the following activities considered in this modelling study:

- The installation of one subsea FPSO mooring pile per day through impact piling using either a medium or high power hammer,
- The operations of a Mobile Offshore Drilling Unit (MODU),
- Vertical Seismic Profiling (VSP) during drilling operations,
- FPSO operational noise for Torosa and Brecknock FPSO's under normal operating conditions and with Dynamic Positioning (DP) operating,
- FPSO operational noise during offtake, including the FPSO under DP, an Offshore Support Vessel (OSV) near each FPSO (presented in isolation also) and a noiseless condensate tanker, and
- Aggregate scenarios which include FPSOs under normal operating conditions (without DP), as well as offtake operations at both locations simultaneously.

The objective of the modelling study was to determine ranges to acoustic exposure thresholds representing the best available science for potential injury, temporary threshold shift (TTS), and behavioural disturbance of marine fauna including marine mammals, turtles, and fish. For pygmy blue whales and green turtles during pile driving, an additional objective of this modelling study was to predict the number of animals that may be exposed to sound levels that could result in permanent threshold shift (PTS), TTS, or behavioural disturbance.

Acoustic fields caused by pressure were modelled and are presented as sound pressure levels (SPL), zero-to-peak pressure levels (PK), and either single-impulse (i.e., per-strike, per-pulse) or accumulated sound exposure levels (SEL) as appropriate for different noise effect criteria for either continuous (vessels) or impulsive (piling and VSP) noise sources. The effects of range-dependent environmental properties on sound propagation in the study area were accounted for by the numerical models.

For pygmy blue whales and green turtles, the JASCO Animal Simulation Model Including Noise Exposure (JASMINE) was used to integrate the sound fields with species-specific behaviour. JASMINE results provide an estimate of the probability of sound exposure, which can be compared to acoustic thresholds and then scaled to estimate the number of animals expected to receive sound levels that may cause PTS, TTS or behavioural disturbance. To assist with exposure modelling, a modified Biologically Important Area (BIA) for inter-nesting green turtles and a migrating area were considered, along with the pygmy blue whale BIAs for migrating and foraging.

FPSO Anchor Pile Installation

The predicted distances to all per-strike isopleths (contours of equal sound level) are farthest from the piles at the start of piling, when most of the pile remains in the water column, and shortest at the end of piling, when most of the pile is buried in the sediment. This is despite the increased frictional resistance of sediments and stronger stress-wave reflections at the pile toe at later stages of insertion.

For exposure criteria based on SEL_{24h} metrics, the ranges must be considered in context of the duration of operations. The modelling assumed one pile will be driven per day; therefore, the corresponding sound level is denoted as SEL_{24h}; however, the estimated times for driving piles are 78.5 or 45.5 minutes (Torosa) and 80.1 or 47.4 minutes (Brecknock) for medium and high-power hammers, respectively. SEL_{24h} is a cumulative metric that reflects the dosimetric impact of noise levels within the driving period, assuming that an animal is consistently exposed to such noise levels at a fixed position. The radii that correspond to SEL_{24h} typically represent an unlikely worst-case scenario for SEL-based exposure because, more realistically, marine fauna (mammals or fish) would not stay in the same location or at the same distance from a sound source for an extended period. Therefore, a reported radius for SEL_{24h} criteria does not mean that any animal travelling within this radius from the source *will* be exposed to PTS or TTS, but rather that it *could* be exposed if it remained within that range for the entire duration of the pile driving.

Animal Movement and Exposure Modelling

To present more biologically relevant results, JASMINE was applied for pygmy blue whales and green turtles. The potential risk of acoustic exposure for these species was estimated by finding the accumulated SEL and maximum PK or SPL each simulated animal (animat) received over the duration of the simulation, using acoustic exposure thresholds representing the best available science for PTS, TTS, and behavioural disturbance. The results include the range within which 95% of the exposure exceedances occur (95th percentile ranges, P_{95}) and the projected number of individual animals exposed to sound levels above threshold values. The number of individuals was determined by scaling the number of animats exposed above threshold in the simulation using available density data and considering the relevant BIAs. The modelling considered the behaviour of pygmy blue whales while migrating and foraging, and green turtles while inter-nesting and migrating. For migratory green turtles, no density data were available, so results are presented in terms of 95th percentile ranges only. Mitigation of potential impacts through exclusion zones for pygmy blue whales and turtles (2000 and 500 m, respectively) were considered in the modelling.

Torosa Location

The number of green turtle exposures above PTS PK or PTS SEL_{24h} thresholds was zero, regardless of hammer type. The number of pygmy blue whale exposures above PTS PK was zero, and there were between 0.02 and 0.03 migrating or foraging pygmy blue whale exposures above the PTS SEL_{24h} threshold for either hammer without mitigation.

No inter-nesting green turtle animats were predicted to be exposed above threshold levels for PTS or TTS for either hammer. Densities were not available for migratory turtles; however, no turtle animats were predicted to be exposed to noise levels above PTS PK, PTS SEL_{24h}, or TTS PK thresholds. No migratory pygmy blue whales were predicted to be exposed to noise above PTS PK or TTS PK thresholds. With exclusion zones in place, exposures to injury threshold criteria for both species and both hammers were reduced to zero. TTS SEL_{24h} was still predicted to occur, with no substantial change to exposure numbers. This is because a large proportion of animats exposed above that threshold occurred at ranges greater than the exclusion zones.

The overall potential for behavioural impacts is also predicted to be low for both species. None are predicted for inter-nesting green turtles. While no real-world densities for migratory green turtles are available, the 95th percentile ranges for the most conservative case (the high power hammer and the 166 dB SPL behavioural response threshold) were between 2.54 and 4.64 km from the pile. The number of individual pygmy blue whales predicted to be exposed to noise levels exceeding the behavioural threshold was between 0.56 and 1.41 individuals, depending upon the hammer size.

Applying exclusion zones had less influence on exposures above behavioural thresholds. Ranges associated with migrating green turtles showed no substantial change, except that all animats exposed to the 175 dB SPL behavioural disturbance threshold, which were within 50 m of the pile, were removed from consideration. Therefore, the application of the exclusion zone reduced the number of animats exposed above threshold by 100%, or to zero. Both foraging and migrating pygmy blue whale exposures above the 160 dB SPL threshold, for both hammers, decreased slightly.

Brecknock Location

Results predicted that green turtles were unlikely to be exposed the noise above threshold levels for PTS, TTS, or behavioural disturbance, even without applying a 500 m exclusion zone. This is because the Brecknock pile location is more than 40 km from either the modified inter-nesting or migration area BIAs.

With no exclusion zone, pygmy blue whales were not exposed to noise levels above PTS PK or TTS PK for either hammer, exposures above the threshold for PTS SEL$_{24h}$ ranged from 0.02–0.04 for either the medium or high powered hammer, respectively. TTS SEL$_{24h}$ exposures for migrating blue whales ranged from 1.56–1.67 for either the medium or high powered hammer, respectively. The number of predicted exposures above TTS SEL$_{24h}$ threshold for foraging pygmy blue whales was much lower than for migrating pygmy blue whales because the Brecknock piling location is 10.3 km from the foraging BIA.

With the 2000 m exclusion zone in place, PTS SEL$_{24h}$ exposures reduced to zero for either hammer. The number of predicted exposures for foraging pygmy blue whales did not change as a result of applying an exclusion zone because of the large distance to the BIA.

Torosa and Brecknock Ranges to Exposure Thresholds

The analysis considered multiple effects criteria commonly used in pile driving noise assessments. Key results of the acoustic modelling are summarised below.

Marine Mammals

- United States National Marine Fisheries Service (NMFS 2014) acoustic threshold for behavioural effects in cetaceans: Pile driving impulse sounds are predicted to exceed the SPL threshold of 160 dB re 1 µPa for behavioural effects of marine mammals within 10.48 or 17.15 km (Torosa), or 7.06 or 13.97 km (Brecknock), of the pile (medium and high power hammer, respectively), are associated with the shallowest penetration of 17 m for both hammers.
- The results for the NMFS (2018) criteria applied for marine mammal PTS and TTS consider both metrics within the criteria (PK and SEL), with SEL assessed here for a single pile within a 24 h period, i.e., a single pile per day. The metric with the longest distance must be applied, and these maximum distances along with the relevant metric are summarised in Table 1.

Table 1. *Marine mammal injury and hearing sensitivity changes*: Maximum-over-depth distances (in km) from the pile to PTS and TTS thresholds (NMFS 2018).

Hearing group	PTS				TTS			
	IHC S-600		IHC S-1200		IHC S-600		IHC S-1200	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
Torosa								
LF cetaceans	5.15#	5.00#	5.35#	5.12#	26.10#	20.79#	29.46#	22.60#
MF cetaceans	<0.02†		<0.02†		0.03#		0.06#	0.06#
HF cetaceans	0.21†		0.26†		0.35†	0.30#	2.20#	2.06#
Brecknock								
LF cetaceans	4.58#	4.05#	4.62#	4.40#	23.11#	20.04#	24.75#	20.80#
MF cetaceans	<0.02†		<0.02†		<0.02†		0.05#	0.05#
HF cetaceans	0.19†		0.26†		0.36†	0.31#	2.33#	2.20#

† PK (L_{pk}; dB re 1 µPa)

Frequency weighted SEL$_{24h}$ ($L_{E,24h}$). For the SEL$_{24h}$ criteria, the model does not account for shutdowns.

Turtles

- The maximum distances to the two criteria considered in relation to turtle behaviour, behavioural response and disturbance, are associated with the shallowest penetration of 17 m for both hammers, with the maximum distances summarised in Table 2.
- The results for the Finneran et al. (2017) criteria applied for turtle PTS and TTS consider both metrics within the criteria (PK and SEL), with SEL assessed here for a single pile within a 24 h period, i.e., a single pile per day. The metric with the longest distance must be applied, and these maximum distances along with the relevant metric are summarised in Table 3.

Table 2. *Turtle behaviour*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the pile to modelled maximum-over-depth behavioural response thresholds, maximum across all three penetration depths.

SPL (L_p; dB re 1 µPa)	**IHC S-600**		**IHC S-1200**	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
Torosa				
175†	0.68	0.64	1.87	1.79
166‡	5.11	4.99	9.11	5.66
Brecknock				
175†	0.67	0.63	1.87	1.77
166‡	2.87	2.70	6.38	5.92

† Threshold for turtle behavioural response to impulsive noise (McCauley et al. 2000a, 2000b).
‡ Threshold for turtle behavioural response to impulsive noise (NSF 2011).

Table 3. *Turtle injury and hearing sensitivity changes*: Maximum-over-depth distances (in km) from the pile to turtle PTS and TTS thresholds (Finneran et al. 2017).

Hearing group	**PTS**				**TTS**			
	IHC S-600		**IHC S-1200**		**IHC S-600**		**IHC S-1200**	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
Torosa								
Turtles	0.24	0.23	0.25	0.25	4.79	2.36	5.07	4.94
Brecknock								
Turtles	0.24	0.23	0.25	0.24	2.58	2.44	2.60	2.47

All distances are associated with frequency weighted SEL$_{24h}$ ($L_{E,24h}$; dB re 1 µPa^2·s), not PK (L_{pk}; dB re 1 µPa). For the SEL$_{24h}$ criteria, the model does not account for shutdowns.

Fish, Fish Eggs, and Fish Larvae

- The modelling study assessed the ranges for quantitative criteria from Popper et al. (2014) associated with mortality and potential mortal injury and impairment (as defined in the criteria) in the following:
    - Fish without a swim bladder (also appropriate for sharks in the absence of other information)
    - Fish with a swim bladder not used for hearing
    - Fish that use their swim bladders for hearing
    - Fish eggs, and fish larvae
- The distance from pile driving at which sound levels exceeded mortality and potential mortal injury for the most sensitive fish groups from the piles was as follows for the medium or high-powered hammer, respectively:
    - Torosa, 210 or 220 m (SEL_{24h} metric),
    - Brecknock, 200 or 220 m (SEL_{24h} metric)
- Fish (including sharks) could experience TTS from the proposed pile driving activity. It is predicted that this will occur within the following distances of the pile for the medium or high-powered hammer, respectively:
    - Torosa, 9.05 or 9.15 km
    - Brecknock, 6.12 or 6.27 km

Vertical Seismic Profiling

The modelling scenarios for VSP considered a single 750 in^3 array suspended at 6 m at the MODU location at both Torosa TRD Well and Brecknock, and these scenarios assessed both individual impulses and multiple impulses within a 24 h period to determine SEL_{24h}.

The analysis considered multiple effects criteria commonly used in seismic survey noise assessments. Key results of the acoustic modelling are summarised below.

Marine mammals

- The maximum distance where the NMFS (2014) marine mammal behavioural response criterion of 160 dB re 1 µPa (SPL) could be exceeded varied between 1.6 and 1.7 km, with the distance being longer at Brecknock.
- The results for the criteria applied for marine mammal PTS, NMFS (2018), consider both metrics within the criteria (PK and SEL_{24h}), and a range of impulses within 24 h, from 1 to 150. The applicable metric from the criteria, associated with the longest distance associated with either metric, depends upon the number of impulses with the 24 h. The ranges presented are based upon no more than 150 impulses within 24 h.

  PTS and TTS are not predicted to occur in mid-frequency cetaceans. For PTS in high-frequency cetaceans, the PK metric is always associated with the longest range (68 m), while for PTS in low-frequency cetaceans, for less than 10 impulses the range is greater due to the PK metric (12 m), but otherwise the range is determined by SEL_{24h}, with the maximum distance of 200 m being associated with 150 impulses at either Torosa TRD Well or Brecknock.

  For TTS in high-frequency cetaceans the PK metric is always associated with the longest range (141 m), while for TTS in low-frequency cetaceans the range is determined by SEL_{24h}, with the maximum distance of 1.69 km for 150 impulses at Torosa TRD Well or Brecknock.

Turtles

- The VSP source is not predicted to cause PTS in turtles, as it doesn't cause either the PK or SEL_{24h} criteria from Finneran et al. (2017) to be exceeded at a distance greater than the horizontal modelling resolution (20 m) from the source.

As with marine mammals, the SEL_{24h} considers a range of impulses within 24 h, from 1 to 150. While the TTS criteria due to the PK metric isn't exceeded, depending upon the number of impulses, the TTS SEL_{24h} criteria can be exceeded at up to 160 m for 150 impulses at Torosa TRD Well or Brecknock.

- The distances at where the two criteria considered in relation to turtle behaviour, behavioural response and disturbance could be exceeded are summarised in Table 4.

Table 4. *Turtle behaviour*: Distances to behavioural response criteria for VSP.

SPL (**L_p; dB re 1 µPa**)	**R_{max} (km)**	**$R_{95\%}$ (km)**
Torosa TRD Well		
175†	0.23	0.23
166‡	0.81	0.77
Brecknock		
175†	0.23	0.23
166‡	0.72	0.69

† Threshold for turtle behavioural response to impulsive noise (McCauley et al. 2000a, 2000b).
‡ Threshold for turtle behavioural response to impulsive noise (NSF 2011).

Fish, fish eggs, and fish larvae

- This modelling study assessed the ranges for quantitative criteria based on Popper et al. (2014) and considered both PK (seafloor and water column) and SEL_{24h} metrics associated with mortality and potential mortal injury and impairment in the groups listed in the piling section
- The distance from pile driving at which sound levels exceeded mortality and potential mortal injury for the most sensitive fish groups was 40 m (PK metric).
- Sound levels at the seafloor do not exceed any of the fish criteria, and SEL_{24h} metrics for injury were not exceeded in the water column

Sponges and Coral

- To assist with assessing the potential effects on sponges and coral receptors, the PK sound level at the seafloor directly underneath the VSP source was estimated at both modelling sites. It was found that the sound level of 226 dB re 1 µPa PK, a sound level associated with no effect (Heyward et al. 2018) was not reached.

Vessel Operations

The modelled scenarios for vessels consider the following sources or scenarios:

- Two FPSO facilities 370 m long and 67 m wide, both under typical operations, with no thrusters and no offtake, only topsides equipment, and under dynamic positioning representative of typical operational loads during moderate weather conditions;
- A representative OSV, a dynamic positioning Class 2 (DP2) vessel within 700 m of each FPSO under dynamic positioning representative of typical operational loads during moderate weather conditions;
- A representative MODU that is 100 × 80 m under dynamic positioning, representative of typical operational loads during moderate weather conditions;
- FPSO operational noise during offtake, including the FPSO under DP, an Offshore Support Vessel (OSV) near each FPSO (presented in isolation also) and a noiseless condensate tanker, and
- Aggregate scenarios which include FPSOs under normal operating conditions (without DP), as well as offtake operations, at both locations simultaneously.

The analysis considered multiple effects criteria commonly used, with key results of the acoustic modelling are summarised below.

Marine mammals

- The results for the NMFS (2018) criteria applied for marine mammal PTS and TTS for vessels are assessed here for a 24 h period. The maximum distances to PTS are summarised in Table 5.
- The maximum distances to the NMFS (2014) marine mammal behavioural response criterion of 120 dB re 1 µPa (SPL) are summarised in Table 6.
- For aggregate scenarios considering both FPSO's, it was found that due to the separation between the sites, distances to PTS, TTS, and behavioural thresholds remained unaltered compared to the individual operations. This was quantified by verifying that the total aggregate area within threshold isopleth for marine mammal behavioural response to continuous noise (NMFS 2014) area equals the sum of the areas for the individual operations.

Table 5. *Marine mammal injury*: Maximum (R_{max}) horizontal distances (km) to modelled maximum-over-depth PTS thresholds from NMFS (2018) for vessel-based scenarios.

Hearing group	**Threshold for PTS, SEL_{24h} (dB re 1 µPa²·s)** [#]	**Distance R_{max} (km)**				
		MODU	OSV	FPSO on DP	FPSO without DP	FPSO offtake
Torosa						
LF cetaceans	199	0.11	0.05	0.12	-	0.12
MF cetaceans	198	-	-	<0.02	-	<0.02
HF cetaceans	173	0.15	0.07	0.28	-	0.28
Brecknock						
LF cetaceans	199	0.11	0.06	0.12	<0.02	0.12
MF cetaceans	198	-	-	<0.02	-	<0.02
HF cetaceans	173	0.15	0.07	0.28	<0.02	0.28

[#] Frequency weighted.
A dash indicates the level was not reached.
FPSO offtake includes an FPSO under DP, a noiseless condensate tanker and an OSV.

Table 6. *Marine mammal behaviour*: Summary of maximum behavioural disturbance distances for vessel-based scenarios.

SPL (L_p; dB re 1 µPa)	Distance R_{max} (km)				
	MODU	OSV	FPSO on DP	FPSO without DP	FPSO offtake
Torosa					
120†	10.50	2.25	8.77	0.57	8.89
Brecknock					
120†	8.84	2.39	8.78	0.54	8.89

† Threshold for marine mammal behavioural response to continuous noise (NMFS 2014).
FPSO offtake includes an FPSO under DP, a noiseless condensate tanker and an OSV.

Turtles

- The results for the Finneran et al. (2017) criteria applied for turtle PTS for vessel-based scenarios are assessed here for a 24 h period, and the maximum distances are summarised in Table 7.

Table 7. *Turtle injury*: Maximum-over-depth distances (in km) to PTS threshold (Finneran et al. 2017) for vessel-based scenarios.

SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Distance R_{max} (km)				
	MODU	OSV	FPSO on DP	FPSO without DP	FPSO offtake
Torosa					
220†	0.06	0.06	<0.02	-	<0.02
Brecknock					
220†	0.06	0.06	<0.02	-	<0.02

† Threshold for turtle-weighted SEL_{24h} (Finneran et al. 2017).
A dash indicates the level was not reached.
FPSO offtake includes an FPSO under DP, a noiseless condensate tanker and an OSV.

Fish

- Sound produced by the vessel operations could cause physiological effects, and recoverable injury, to some fish species, but only if the animals are in very close proximity to the sound sources–within a planar distance of 60 m, for 48 h. Temporary impairment due to TTS could occur at similar short distances if fish remain at the same point within the sound field for long periods of time (12 h). The distances are farther for the MODU, and smallest for the FPSO without DP.
- For offtake operations, recoverable injury and temporary impairment could happen if fish remain within planar distances of <20 m and 40 m, respectively, from the FPSO or the OSV thrusters.
- There is no increased risk to fish from aggregate scenarios, with ranges to thresholds from the individual sources unchanged.

1. Introduction

JASCO Applied Sciences (JASCO) performed a modelling study of underwater sound levels associated with the Browse to North West shelf (NWS) Project development of the Brecknock, Calliance, and Torosa fields (collectively known as the Browse resources) by the Browse Joint Venture (BJV). This will involve the development drilling of wells and the installation of subsea production system that will supply two 1100 Million standard cubic feet per day (annual daily export average) Floating Production Storage and Offloading (FPSO) facilities. Gas will be transported from the FPSO facilities to the existing North West Shelf (NWS) Project infrastructure via a ~900 km trunkline. Each FPSO will have a turret mooring system that will be stabilised using mooring lines secured to the seabed by piles.

The modelling study considers:

- The installation of a single subsea FPSO mooring pile per day through impact piling using either a medium or high power hammer;
- The operations of a Mobile Offshore Drilling Unit (MODU);
- Vertical Seismic Profiling (VSP) during drilling operations;
- FPSO operational noise for Torosa and Brecknock FPSO’s under normal operating conditions and with Dynamic Positioning (DP) operating;
- FPSO operational noise during offtake, including the FPSO under DP, an Offshore Support Vessel (OSV) near each FPSO (presented in isolation also) and a noiseless condensate tanker; and
- Aggregate scenarios which include FPSOs under normal operating conditions (without DP), as well as offtake operations at both locations simultaneously.

The modelling study specifically assessed distances from operations where underwater sound levels reached thresholds corresponding to various levels of impact to marine fauna. The animals considered here included marine mammals (pygmy blue whales, *Balaenoptera musculus brevicauda*), turtles, and fish (including fish eggs and larvae). Due to the variety of species considered, there are several different thresholds for evaluating effects, including: mortality, injury, temporary reduction in hearing sensitivity, and behavioural disturbance.

The modelling methodology considered source directivity and range-dependent environmental properties. Estimated underwater acoustic levels are presented as sound pressure levels (SPL, L_p), zero-to-peak pressure levels (PK, L_{pk}), and either single-impulse (i.e., per-strike) or accumulated sound exposure levels (SEL, L_E) as appropriate for different noise effect criteria for either continuous (vessels) or impulsive (piling and VSP) noise sources.

In addition to the propagation modelling, this report describes the modelled predictions of sound levels that individual animals may receive during the operations. Sound exposure distribution estimates for pygmy blue whales and green turtles (*Chelonia mydas*) to pile driving operations are determined by moving large numbers of simulated animals through a modelled time-evolving sound field, computed using specialised sound source and sound propagation models. This approach provides the most realistic prediction of the maximum expected SPL, PK, and the temporal accumulation of SEL that are considered the most relevant sound metrics for impact assessment. The most recent science in the peer-reviewed literature regarding sound propagation and animal movement modelling was used.

The geographic coordinates for the modelled sites are provided in Table 8 and an overview of the modelling area is shown in Figure 1.

Table 8. Location details for the modelled sites.

Site	Source	Latitude (S)	Longitude (E)	MGA (GDA94), Zone 51		Water depth (m)
				X (m)	*Y* (m)	
Torosa	FPSO Anchor Pile	13° 58' 16.97"	122° 00' 05.23"	392148	8455212	448
	FPSO (turret)	13° 58' 15.06"	122° 01' 28.53"	394647	8455281	463
	OSV (bow)	13° 58' 15.06"	122° 00' 50.38"	393502.3	8455276	463
Torosa TRD Well	MODU (centre)	14° 00' 26.64"	121° 57' 23.58"	387315	8451207	391
	VSP (MODU centre)					
Brecknock	FPSO Anchor Pile	14° 31' 10.31"	121° 37' 50.58"	352456	8394373	506
	FPSO (turret)	14° 31' 51.44"	121° 36' 38.47"	350305	8393096	515
	OSV (bow)	14° 31' 14.19"	121° 36' 38.55"	350300.3	8394241	515
	MODU (centre)	14° 26' 49.45"	121° 38' 52.09"	354250	8402400	467
	VSP (MODU centre)					

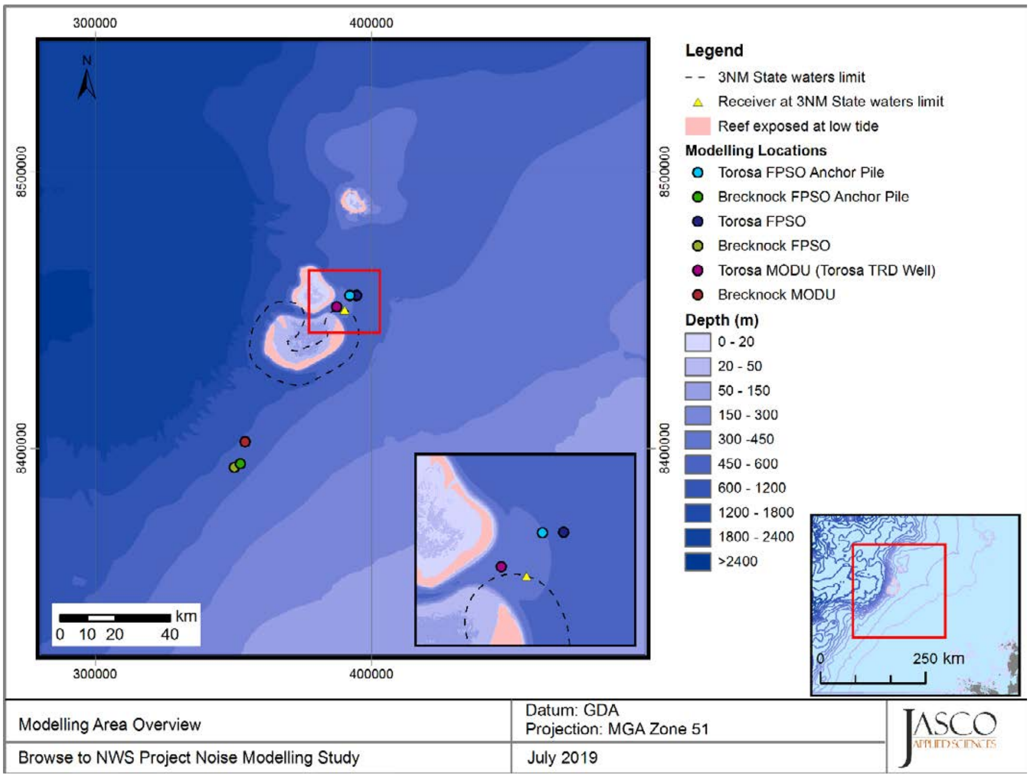

Figure 1. Overview of the modelled area and local features.

1.1. Acoustic Modelling Scenario Details

The modelling scenario for pile driving of the Torosa FPSO anchor pile (Section 3.4) considers a pile 53.25 m long, 5.5 m in diameter with 60 mm thick walls, driven a total of 51.5 m into the seabed. Two pile driving hammers were considered in this study: the IHC S-600 with 600 kJ per-strike energy and the IHC S-1200 with 1200 kJ. The modelling assumed one pile will be driven per day; therefore, while the corresponding sound level is denoted SEL_{24h}, the period of accumulation considered in the scenario is determined based upon the estimated time for driving the single pile.

The modelled scenarios for vessels (Section 3.6) consider:

- Two FPSO facilities 370 m long and 67 m wide:
    - Both under typical operations, with no thrusters and no offtake, only topsides equipment;
    - Under dynamic positioning representative of typical operational loads during moderate weather conditions;
    - Under offtake, during which the FPSO is under DP, and an OSV under DP is located 700 m behind the FPSO, and a noiseless condensate tanker is between the FPSO and the OSV; and
    - Aggregate scenarios which include FPSOs under normal operating conditions (without DP), as well as offtake operations at both locations simultaneously.
- A representative OSV, a dynamic positioning Class 2 (DP2) vessel 87.08 m long, within 700 m of each FPSO under dynamic positioning representative of typical operational loads during moderate weather conditions.
- A representative MODU that is 100 × 80 m under dynamic positioning, representative of typical operational loads during moderate weather conditions.

The modelling scenarios for VSP (Section 3.5) consider a single 750 in^3 array suspended at 6 m at the MODU location at both Torosa TRD Well and Brecknock, and these scenarios assessed both individual impulses and up to 150 impulses within a 24 h period.

Table 9. Modelled receiver location for Torosa FPSO Anchor Piling

Sound field sampling location	Latitude (S)	Longitude (E)	MGA (GDA94), Zone 51		Relevant modelled scenario	Distance from sampling location to modelled site (km)	Water depth (m)
			X (m)	*Y* (m)			
3NM State waters limit	14° 01' 02.5404"	121° 59' 03.5282"	390318	8450117	Torosa FPSO anchor pile	5.41	414

2. Noise Effect Criteria

To assess the potential impacts of a sound-producing activity, it is necessary to first establish exposure criteria (thresholds) for which sound levels may be expected to have a negative impact on animals. Whether acoustic exposure levels might injure or disturb marine fauna is an active research topic. Since 2007, several expert groups have developed SEL-based assessment approaches for evaluating auditory injury, with key works including Southall et al. (2007), Finneran and Jenkins (2012), Popper et al. (2014), and United States National Marine Fisheries Service (NMFS 2018). The number of studies that investigate the level of behavioural disturbance to marine fauna by anthropogenic sound has also increased substantially.

Several sound level metrics, such as PK, SPL, and SEL, are commonly used to evaluate noise and its effects on marine life (Appendix A). In this report, the duration of the SEL accumulation is defined differently depending on the source considering, as per the following:

- For piling: As either a “per-strike” value (i.e., integrated over the time of a single strike), or over all strikes that occur over the driving of a single pile, one pile per 24 h time period.
- For VSP: As either a “per-pulse” value (i.e., integrated over the time of a single pulse), or over all impulses that occur in a 24 h time period.
- For vessels: Integrated over a 24 h time period.

Appropriate subscripts indicate any applied frequency weighting applied (Appendix A.3). The acoustic metrics in this report reflect the updated ANSI and ISO standards for acoustic terminology, ANSI S1.1 (R2013) and ISO 18405:2017 (2017).

This study applies the following noise criteria (Sections 2.1–2.2 and Appendix A.2), chosen for their acceptance by regulatory agencies and because they represent current best available science:

1. Peak pressure levels (PK; L_{pk}) and frequency-weighted accumulated sound exposure levels (SEL; $L_{\text{E,24h}}$) from the U.S. National Oceanic and Atmospheric Administration (NOAA) Technical Guidance (NMFS 2018) for the onset of permanent threshold shift (PTS) and temporary threshold shift (TTS) in marine mammals.
2. Marine mammal behavioural threshold based on the current interim U.S. National Marine Fisheries Service (NMFS) criterion NMFS (2014) for marine mammals of 160 dB re 1 µPa and 120 dB re 1 µPa SPL (L_{p}) for impulsive and non-impulsive sound sources, respectively.
3. Sound exposure guidelines for fish, fish eggs, and larvae (Popper et al. 2014).
4. Peak pressure levels (PK; L_{pk}) and frequency-weighted accumulated sound exposure levels (SEL; $L_{\text{E,24h}}$) from Finneran et al. (2017) for the onset of permanent threshold shift (PTS) and temporary threshold shift (TTS) in turtles.
5. Turtle behavioural response threshold of 166 dB re 1 µPa SPL (L_{p}) (NSF 2011), as applied by the US NMFS, along with a sound level associated with behavioural disturbance 175 dB re 1 µPa (SPL) (McCauley et al. 2000a, 2000b).

Additionally, for comparison to published literature, for VSP only, a sound level of 226 dB re 1 µPa PK (L_{pk}), a no effect sound level, is reported for comparing to Heyward et al. (2018) for sponges and corals.

2.1. Marine Mammals

The criteria applied in this study to assess possible effects of pile driving noise and vessel noise on marine mammals are summarised in Tables 10 and 11 and detailed in Sections 2.1.1 and 2.1.2, with frequency weighting explained in Appendix A.3.

Table 10. Acoustic effects of impulsive noise on marine mammals: Unweighted SPL, SEL$_{24h}$, and PK thresholds

Hearing group	NMFS (2014)	NMFS (2018)			
	Behaviour	**PTS onset thresholds* (received level)**		**TTS onset thresholds* (received level)**	
	SPL (L_p; dB re 1 µPa)	Weighted SEL$_{24h}$ ($L_{E,24h}$; dB re 1 µPa^2·s)	PK (L_{pk}; dB re 1 µPa)	Weighted SEL$_{24h}$ ($L_{E,24h}$; dB re 1 µPa^2·s)	PK (L_{pk}; dB re 1 µPa)
LF cetaceans	160	183	219	168	213
MF cetaceans		185	230	170	224
HF cetaceans		155	202	140	196

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.
L_p denotes sound pressure level period.
$L_{pk,flat}$ denotes peak sound pressure is flat weighted or unweighted.
L_E denotes cumulative sound exposure over a 24 h period.

Table 11. Acoustic effects of continuous noise on marine mammals: Unweighted SPL and SEL$_{24h}$ thresholds.

Hearing group	NMFS (2014)	NMFS (2018)	
	Behaviour	**PTS onset thresholds (received level)**	**TTS onset thresholds (received level)**
	SPL (L_p; dB re 1 µPa)	Weighted SEL$_{24h}$ ($L_{E,24h}$; dB re 1 µPa^2·s)	Weighted SEL$_{24h}$ ($L_{E,24h}$; dB re 1 µPa^2·s)
LF cetaceans	120	199	179
MF cetaceans		198	178
HF cetaceans		173	153

L_p denotes sound pressure level period and has a reference value of 1 µPa.
L_E denotes cumulative sound exposure over a 24 h period and has a reference value of 1 µPa^{2}s.

2.1.1. Behavioural response

Numerous studies on marine mammal behavioural responses to sound exposure have not resulted in consensus in the scientific community regarding the appropriate metric for assessing behavioural reactions. However, it is recognised that the context in which the sound is received affects the nature and extent of responses to a stimulus (Southall et al. 2007, Ellison and Frankel 2012, Southall et al. 2016). Because of the complexity and variability of marine mammal behavioural responses to acoustic exposure, NMFS has not yet released technical guidance on behaviour thresholds for use in calculating animal exposures (NMFS 2018). The NMFS currently uses a step function to assess behavioural impact. A 50% probability of inducing behavioural responses at a SPL of 160 dB re 1 µPa was derived from the HESS (1999) report which, in turn, was based on the responses of migrating mysticete whales to airgun sounds (Malme et al. 1983, Malme et al. 1984). The HESS team recognised that behavioural responses to sound may occur at lower levels, but significant responses were only likely to occur above a SPL of 140 dB re 1 µPa. An extensive review of behavioural responses to sound was undertaken by Southall et al. (2007, their Appendix B). Southall et al. (2007) found varying responses for most marine mammals between a SPL of 140 and 180 dB re 1 µPa, consistent with the HESS (1999) report, but lack of convergence in the data prevented them from suggesting explicit step functions.

2.1.1.1. Impulsive noise

The absence of controls, precise measurements, appropriate metrics, and context dependency of responses (including the activity state of the animal) all contribute to the variability of the behavioural response of individuals. Therefore, unless otherwise specified, this study applied NMFS's relatively simple sound level criterion for potentially disturbing a marine mammal. For impulsive sounds, this threshold is 160 dB re 1 µPa SPL for cetaceans (NMFS 2014).

2.1.1.2. Continuous noise

The NMFS non-pulsed noise criterion was selected for this assessment because it represents the most commonly applied behavioural response criterion by regulators. The distances at which behavioural responses could occur were therefore determined to occur in areas ensonified above an unweighted SPL of 120 dB re 1 µPa (NMFS 2014).

2.1.2. Injury and hearing sensitivity changes

There are two categories of auditory threshold shifts or hearing loss: permanent threshold shift (PTS), a physical injury to an animal's hearing organs; and Temporary Threshold Shift (TTS), a temporary reduction in an animal's hearing sensitivity as the result of receptor hair cells in the cochlea becoming fatigued.

To assist in assessing the potential for effects to marine mammals, this report applies the criteria recommended by NMFS (2018), considering both PTS and TTS (Tables 10 and 11). Appendix A.2 provides more information about the NMFS (2018) criteria.

2.2. Fish, Turtles, Fish Eggs, and Fish Larvae

In 2006, the Working Group on the Effects of Sound on Fish and Turtles was formed to continue developing noise exposure criteria for fish and turtles, work begun by a NOAA panel two years earlier. The Working Group developed guidelines with specific thresholds for different levels of effects for several species groups (Popper et al. 2014). The guidelines define quantitative thresholds for three types of immediate effects:

- Mortality, including injury leading to death,
- Recoverable injury, including injuries unlikely to result in mortality, such as hair cell damage and minor haematoma, and
- TTS.

Masking and behavioural effects can be assessed qualitatively, by assessing relative risk rather than by specific sound level thresholds. However, as these depend upon activity-based subjective ranges, these effects are not addressed in this report and are included in Tables 12 and 14 for completeness only. Because the presence or absence of a swim bladder has a role in hearing, fish's susceptibility to injury from noise exposure depends on the species and the presence and possible role of a swim bladder in hearing. Thus, different thresholds were proposed for fish without a swim bladder (also appropriate for sharks and applied to whale sharks in the absence of other information), fish with a swim bladder not used for hearing, and fish that use their swim bladders for hearing. Turtles, fish eggs, and fish larvae are considered separately.

2.2.1. Impulsive noise

Impulsive noise from both piling and airguns (VSP) is assessed in this study, the relevant effects thresholds from Popper et al. (2014) are listed in Table 12. In general, whether an impulsive sound adversely effects fish behaviour depends on the species, the state of the individual exposed, and other factors.

The SEL metric integrates noise intensity over some period of exposure. Because the period of integration for regulatory assessments is not well defined for sounds that do not have a clear start or end time, or for very long-lasting exposures, an exposure evaluation time must be defined. Southall et al. (2007) defines the exposure evaluation time as the greater of 24 h or the duration of the activity. Popper et al. (2014) recommend a standard period of the duration of the activity; however, the publication also includes caveats about considering the actual exposure times if fish move. Integration times in this study for piling have been applied over the time a single pile was driven since only one pile is expected to be driven per day, while for VSP operations it is over the total number of impulses per day.

Table 12. Criteria for pile driving and seismic noise exposure for fish, adapted from Popper et al. (2014).

Type of animal	**Mortality and Potential mortal injury**	**Impairment**			**Behaviour**
		Recoverable injury	TTS	Masking	
Fish: No swim bladder (particle motion detection)	> 219 dB SEL$_{24\text{h}}$ or > 213 dB PK	> 216 dB SEL$_{24\text{h}}$ or > 213 dB PK	>> 186 dB SEL$_{24\text{h}}$	Pile driving: (N) Moderate (I, F) Low Seismic: (N, I, F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder not involved in hearing (particle motion detection)	210 dB SEL$_{24\text{h}}$ or > 207 dB PK	203 dB SEL$_{24\text{h}}$ or > 207 dB PK	>> 186 dB SEL$_{24\text{h}}$	Pile driving: (N) Moderate (I, F) Low Seismic: (N, I, F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder involved in hearing (primarily pressure detection)	207 dB SEL$_{24\text{h}}$ or > 207 dB PK	203 dB SEL$_{24\text{h}}$ or > 207 dB PK	186 dB SEL$_{24\text{h}}$	Pile driving: (N, I) High (F) Moderate Seismic: (N, I) Low (F) Moderate	(N, I) High (F) Moderate
Fish eggs and fish larvae	> 210 dB SEL$_{24\text{h}}$ or > 207 dB PK	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	Pile driving: (N) Moderate (I, F) Low Seismic: (N, I, F) Low	(N) Moderate (I, F) Low

Peak sound pressure level dB re 1 µPa; SEL$_{24\text{h}}$ dB re 1µPa^{2}·s.
All criteria are presented as sound pressure even for fish without swim bladders since no data for particle motion exist.
Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

2.2.1.1. Turtles

There is a paucity of data regarding responses of turtles to acoustic exposure, and no studies of hearing loss due to exposure to loud sounds. McCauley et al. (2000a) observed the behavioural response of caged turtles—green (*Chelonia mydas*) and loggerhead (*Caretta caretta*)—to an approaching seismic airgun. For received levels above 166 dB re 1 µPa (SPL), the turtles increased their swimming activity and above 175 dB re 1 µPa they began to behave erratically, which was interpreted as an agitated state. The 166 dB re 1 µPa level has been used as the threshold level for a behavioural disturbance response by NMFS and applied in the Arctic Programmatic Environment Impact Statement (PEIS) (NSF 2011). At that time, and in the absence of any data from which to determine the sound levels that could injure an animal, TTS or PTS onset were considered possible at an SPL of 180 dB re 1 µPa (NSF 2011). Some additional data suggest that behavioural responses occur closer to an SPL of 175 dB re 1 µPa, and TTS or PTS at even higher levels (Moein et al. 1995), but the received levels were unknown and the NSF (2011) PEIS maintained the earlier NMFS criteria levels of 180 and 166 dB re 1 µPa (SPL) for injury and behavioural response, respectively. Popper et al. (2014) suggested injury to turtles could occur for sound exposures above 207 dB re 1 µPa (PK) or above 210 dB re 1 µPa^2·s (SEL$_{24h}$). Sound levels defined by Popper et al. (2014) show that animals are very likely to exhibit a behavioural response when they are near an airgun (tens of metres), a moderate response if they encounter the source at intermediate ranges (hundreds of metres), and a low response if they are far (thousands of meters) from the airgun.

Finneran et al. (2017) presented revised thresholds for turtle injury (PTS) and TTS, considering both PK and frequency weighted SEL, which have been applied in this study, along with the NMFS criterion for behavioural response (SPL of 166 dB re 1 µPa), and a criterion for behavioural disturbance (SPL of 175 dB re 1 µPa) (Moein et al. 1995, McCauley et al. 2000a, 2000b) (Table 13).

Table 13. Acoustic effects of impulsive noise on turtles: Unweighted SPL, SEL$_{24h}$, and PK thresholds

NSF (2011)	**Moein et al. (1995), McCauley et al. (2000a), (2000b)**	**Finneran et al. (2017)**			
Behaviour		**PTS onset thresholds* (received level)**		**TTS onset thresholds* (received level)**	
SPL (L_p; dB re 1 µPa)		Weighted SEL$_{24h}$ ($L_{E,24h}$; dB re 1 µPa^2·s)	PK (L_{pk}; dB re 1 µPa)	Weighted SEL$_{24h}$ ($L_{E,24h}$; dB re 1 µPa^2·s)	PK (L_{pk}; dB re 1 µPa)
160	175	204	232	189	226

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.

L_p denotes sound pressure level period and has a reference value of 1 µPa.

$L_{pk,flat}$ denotes peak sound pressure is flat weighted or unweighted and has a reference value of 1 µPa.

L_E denotes cumulative sound exposure over a 24 h period and has a reference value of 1 µPa^{2}s.

2.2.2. Continuous noise

Table 14 lists the relevant effects thresholds from Popper et al. (2014) for shipping and continuous noise. Some evidence suggests that fish sensitive to acoustic pressure show a recoverable loss in hearing sensitivity, or injury when exposed to high levels of noise (Scholik and Yan 2002, Amoser and Ladich 2003, Smith et al. 2006); this is reflected in the SPL thresholds for fish with a swim bladder involved in hearing.

Finneran et al. (2017) presented revised thresholds for turtle injury, considering frequency weighted SEL, which have been applied in this study for vessels (Table 15).

Table 14. Criteria for vessel noise exposure for fish, adapted from Popper et al. (2014).

Type of animal	**Mortality and Potential mortal injury**	**Impairment**			**Behaviour**
		Recoverable injury	TTS	Masking	
Fish: No swim bladder (particle motion detection)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: Swim bladder not involved in hearing (particle motion detection)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: Swim bladder involved in hearing (primarily pressure detection)	(N) Low (I) Low (F) Low	170 dB SPL for 48 h	158 dB SPL for 12 h	(N) High (I) High (F) High	(N) High (I) Moderate (F) Low
Turtles	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) High (I) Moderate (F) Low
Fish eggs and fish larvae	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low	(N) Moderate (I) Moderate (F) Low

Sound pressure level dB re 1 µPa.
Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

Table 15. Acoustic effects of continuous noise on turtles, weighted SEL_{24h}, Finneran et al. (2017).

PTS onset thresholds* (received level)	**TTS onset thresholds* (received level)**
Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa2·s)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa2·s)
204	189

L_E denotes cumulative sound exposure over a 24 h period and has a reference value of 1 µPa^{2}s.

3. Methods

The operations considered in this study will take place at the Torosa and Brecknock fields, respectively, at depths 391–567 m (Appendix F.3.1). For the sites within the Torosa field, sound propagation is partially blocked in some directions by the reefs, due to a sharp decrease in water depth. Activities could take place at any time in the year. For this reason, the most conservative water sound speed profile (i.e., the profile leading to the longest acoustic propagation) was selected for modelling (Appendix F.3.2). Directly under the modelled sites, the seabed consists of silt, typical of the continental slope (Appendix F.3.3). When approaching the reefs, however, the seabed transitions from silt to sand/gravel, and then to limestone at the reefs.

This section described the methods used to characterise acoustic sources (driven piles, vessels and VSP), as well as the acoustic propagation models and frequency ranges considered for estimation of acoustic fields.

3.1. Pile driving

To predict the acoustic field around the pile driving at frequencies from 10 Hz to 1 kHz, JASCO's Pile Driving Source Model (PDSM; Appendix B) was used in conjunction with JASCO's Full Waveform Range-dependent Acoustic Model (FWRAM, Appendix E.2). In addition, a model-based extrapolation was applied to these results to extend the modelling range up to 25 kHz. Three different seafloor penetration depths were accounted for.

The SEL results for the entire pile were determined through the accumulation of energy across the entire pile driving operation, accounting for the sound fields from each strike and how the sound field changes as the pile penetrates further into the seafloor.

3.2. Vertical Seismic Profiling

The pressure signature of the individual airguns and the composite 1/3-octave-band point-source equivalent directional levels (i.e., source levels) of the 750 in^3 VSP source operated at 6 m were modelled with JASCO's Airgun Array Source Model (AASM, Appendix C.1).

Three sound propagation models were used to predict the acoustic field around the VSP source:

- Combined range-dependent parabolic equation and Gaussian beam acoustic ray-trace model (MONM-BELLHOP, 10 Hz to 25 kHz, Appendix E.3).
- Full Waveform Range-dependent Acoustic Model (FWRAM, 0.5 Hz to 1024 Hz, Appendix E.2).
- Wavenumber integration model (VSTACK, 10 Hz to 2048 Hz, Appendix E.4).

The models were used in combination to characterise the acoustic fields at short and long ranges in terms of SEL, SPL, PK, and PK-PK. Appendix E details each model. MONM was used to calculate SEL of a 360° area around each source location. VSTACK was used to calculate close range PK, PK-PK, and SEL along transects at the seafloor from the broadside direction of the seismic source. For the VSP source, FWRAM was used to calculate PK in the entire water column along four selected transects, and to obtain a conversion factor to estimate SPL from the MONM-BELLHOP SEL results.

3.3. Vessel noise (MODU, OSV, and FPSO)

JASCO's Marine Operations Noise Model (MONM-BELLHOP Appendix E.3) was used to predict the acoustic field at frequencies of 10 Hz to 63 kHz for all vessels.

For all vessels, the sound exposure level (SEL) modelling results were converted to SPL by the duration of the measurement, which is appropriate for a continuous noise source. As SEL was assessed over 24 h, the conversion to SPL was obtained by reducing the levels by $10*\log_{10}(T)$, where T is 86,400 (the number of seconds in 24 h).

3.4. Pile Driving Modelling

3.4.1. Per-strike Modelling

For impact pile driving sounds, time-domain representations of the pressure waves generated in the water are required for calculating sound pressure level (SPL), sound exposure level (SEL), and peak sound pressure level (PK). Appendix A.1 describes these sound level metrics. The following steps comprise the general approach applied in this study to model sounds from impact pile driving activities:

1. Piles driven into the sediment by impact driving are characterised as sound-radiating sources. This characterisation strongly depends on the rate and extent of pile penetration, pile dimensions, and pile driving equipment.
2. The theory of underwater sound propagation is applied to predict how sound propagates from the pile into the water column as a function of range, depth, and azimuthal direction. Propagation depends on several conditions including the frequency content of the sound, the bathymetry, the sound speed in the water column, and sediment geoacoustics (Appendix F.3 describes environmental properties such as bathymetry, sound speed profile, and geoacoustics).
3. The propagated sound field is used to compute received levels over a grid of simulated receivers, which distances to criteria thresholds and maps of ensonified areas are generated from.

To model sounds resulting from impact pile driving of cylindrical pipes, PDSM (Appendix B), a physical model of pile vibration and near-field sound radiation (MacGillivray 2014), is used in conjunction with the GRLWEAP 2010 wave equation model (GRLWEAP, Pile Dynamics 2010). JASCO modelled the IHC S-600 and IHC S-1200 impact hammers. Figure 2 shows the force at the top of the pile that is produced by GRLWEAP.

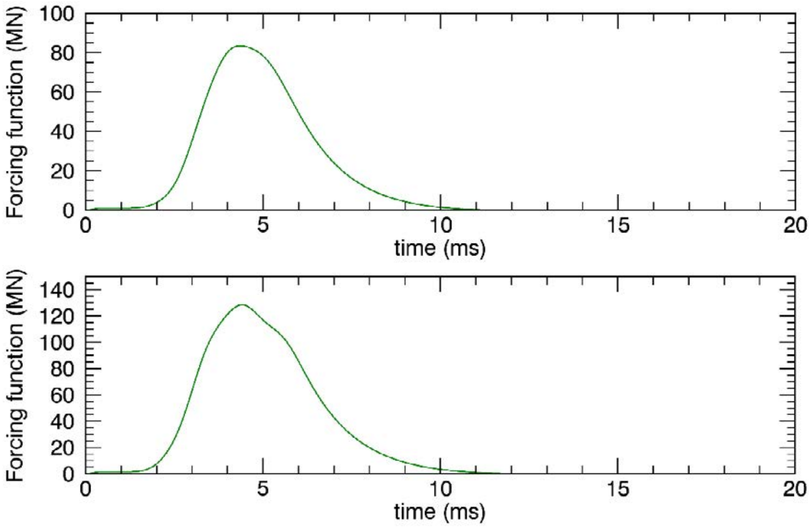

Figure 2. Force (in meganewtons) at the top of the pile corresponding to impact pile driving of a 5.5 m diameter pile, computed using the GRLWEAP 2010 wave equation model for the (top) IHC S-600 and (bottom) IHC S-1200 impact hammers.

The forcing functions (Figure 2) are used by the PDSM to obtain equivalent pile driving signatures for a vertical array of discrete point sources (Appendix B). These represent the pile as an acoustic source and account for parameters (pile type, material, size, and length), the pile driving equipment, and approximate pile penetration rate. The amplitude and phase of the point sources along the pile are computed so they collectively mimic the time-frequency characteristics of the acoustic wave at the pile wall that results from a hammer strike at the top of the pile. This approach accurately estimates spectral levels within the band 10–1000 Hz where most of the energy from impact pile driving is concentrated.

Time-domain Full Waveform Range-dependent model (FWRAM; Appendix E.2) calculates sound propagation from physically distributed impulsive sources and is valid at all distances. In the present study, received sound levels were calculated using FWRAM along transects at 28 azimuths out to 80 km from the source every 10 m, generating a total modelling area of 20000 km^2. Modelling was conducted in non-uniform azimuth increments, with a higher concentration of transects in the direction of bathymetric features of interests, such as reefs around the pile. Grids of received sound levels with 3° azimuth resolution were constructed. To this end, each 3° resolution transect was assigned the received levels corresponding to the modelled transect with the most similar bathymetry.

Source band levels at 1000 Hz were extrapolated up to 25 kHz using a 20 dB/decade decay rate to match acoustic measurements of impact pile driving of similarly sized piles (Illingworth & Rodkin 2007, Matuschek and Betke 2009).

Receiver depths are chosen to span the entire water column over the modelled areas, from 1 to 2600 m, with step size that increase with depth. To produce maps of received sound level distributions and to calculate distances to specified sound level thresholds, the maximum-over-depth level is calculated at each modelled easting and northing position within the considered region. The radial grids of maximum-over-depth levels are then resampled (by linear triangulation) to produce a regular Cartesian grid. The contours and threshold ranges are calculated from these flat Cartesian projections of the modelled acoustic fields (Appendix F.1).

3.4.2. Accumulated SEL Modelling

The modelling approach outlined in Sections 3.4.1 provides per-strike SEL for three stages of pile driving (i.e., three penetration depths). Several noise effect criteria, however, depend on accumulated SEL over many strikes (Section 2). For the purposes of modelling, one pile will be driven per day; therefore, while the corresponding sound level is denoted SEL_{24h}, the period of accumulation is determined based upon the estimated time for driving a single complete pile. Therefore, the accumulated SEL over a single pile, or the SEL_{24h}, depends on the total number of strikes.

Total driving time was estimated assuming continuous piling at a rate of approximately 0.67 strikes/second (40 strikes/minute) and 0.52 strikes/second (31 strikes/minute) for the IHC S-600 and the IHC S-1200 hammers, respectively. The number of strikes required for the driving of the pile were determined based upon a drivability assessment provided by Woodside for these two hammers operating at 95% efficiency. A summary of the total number of strikes per penetration depth and over the entire pile is provided in Tables 16 and 17.

Table 16. *Torosa*: total number of strikes and driving time. Strikes were broken down into stages corresponding to the three modelled penetrations.

Hammer	Modelled penetration (m)	Penetration range for accumulated SEL (m)	Number of strikes	Penetration rate (mm/strike)	Total number of strikes	Time for full penetration (min)
IHC S-600	17	10–24	595	19.9	3141	78.5
	31	24–38	1026	13.4		
	45	38–51.5	1520	8.0		
IHC S-1200	17	10–24	256	38.5	1412	45.5
	31	24–38	488	28.4		
	45	38–51.5	668	18.3		

Table 17. *Brecknock*: total number of strikes and driving time. Strikes were broken down into stages corresponding to the three modelled penetrations.

Hammer	Modelled penetration (m)	Penetration range for accumulated SEL (m)	Number of strikes	Penetration rate (mm/strike)	Total number of strikes	Time for full penetration (min)
IHC S-600	17	10–24	582	19.7	3203	80.0
	31	24–38	1043	12.7		
	45	38–51.5	1578	7.49		
IHC S-1200	17	10–24	264	38.0	1470	47.4
	31	24–38	497	27.0		
	45	38–51.5	709	16.9		

3.5. VSP Modelling

3.5.1. Per-pulse Modelling

To assess sound levels with MONM-BELLHOP, the sound field modelling calculated propagation losses up to distances at least 150 km from the source, with a horizontal separation of 20 m between receiver points along the modelled radials. The sound fields were modelled with a horizontal angular resolution of $\Delta\theta$ = 2.5° for a total of N = 144 radial planes. Receiver depths were chosen to span the entire water column over the modelled areas, from 2 m to a maximum of 3100 m, with step sizes that increased with depth. To supplement the MONM results, high-frequency results for propagation loss were modelled using Bellhop for frequencies from 2 to 25 kHz. The MONM and Bellhop results were combined to produce results for the full frequency range of interest.

FWRAM was run to 80 km, but along only four radials (fore and aft endfire, and port and starboard broadside) for computational efficiency, from 5 to 1024 Hz in 1 Hz steps. This was done to compute SEL-to-SPL conversions (Appendix F.2) but also to quantify water column PK and PK-PK. The horizontal range step is dependent on frequency and ranges from 50 m at lower frequencies to 10 m above 800 Hz.

The maximum modelled range for VSTACK was 1500 m and a variable receiver range increment that increased away from the source was used. The increment increased from 5 to 50 m. Received levels were computed for receivers at seafloor

3.5.2. Multiple-pulse Modelling

The VSP operation was assessed in this report by considering several potential scenarios for a maximum number of pulses per 24 h. The SEL was assessed over 24 h by adjusting the single-pulse SEL by $10 \cdot \log_{10}(N)$, where the total number of pulses N was 1, 5, 10, 15, 25, 50, 100, and 150 at each location (Torosa TRD Well and Brecknock).

3.6. Acoustic Source Parameters for MODU, OSV, and FPSO

3.6.1. Mobile Offshore Drilling Unit (MODU)

The estimates of the MODU, or semi-submersible platform, acoustic source levels and sound spectrum were based on the *Seadrill West Sirius* (Figure 3). *Seadrill West Sirius* is reportedly equipped with eight Rolls-Royce UUC 355 thrusters.

The parameters for the UUC 355 thruster are:

- 3.5 m propeller diameter,
- 177 rpm nominal propeller speed, and
- 3800 kW maximum continuous power input.

For modelling, all eight thrusters were assumed to operate at 50%. The vertical position of the thrusters was 18 m below the sea surface (draft of the rig during drilling operations). Figure 4 shows the thruster locations.

Figure 3. *Seadrill West Sirius* semi-submersible platform.

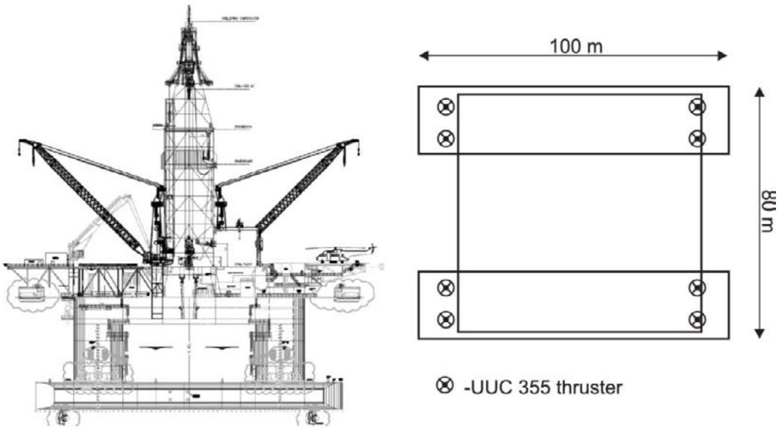

Figure 4. *Seadrill West Sirius* dimensions and thruster locations (circles).

The source levels and the sound spectrum for vessel thrusters were estimated based on the thruster specifications (diameter, revolutions-per-minute (rpm)) and the method described in Section 3.6. It is expected that the MODU at Torosa and Brecknock will operate under dynamic positioning representative of typical operational loads during moderate weather conditions. Measurements and modelling of thruster noise from the Technip *Deep Orient* (Quijano and McPherson 2018) suggest that the broadband source levels decrease when the vessel operates under mild environmental conditions compared to rough weather. Based on the monopole source levels calculated for the Technip *Deep Orient* during the measurement study, we decreased the MODU thruster levels by 5.75 dB, to account for the typical scenario with moderate environmental conditions. Figure 8 shows the MODU source levels used for this modelling, compared to measurements obtained from a similar MODU and a drillship (West Aquarius and Stena IceMAX, see Martin et al. (2019)). For additional reference, MODU thruster source levels corresponding to full capacity (i.e., rough weather) from Zykov (2016) are shown. Note that the MODU source levels correspond to the noise generated by eight thrusters operating simultaneously, while the modelling considers each thruster as an individual source.

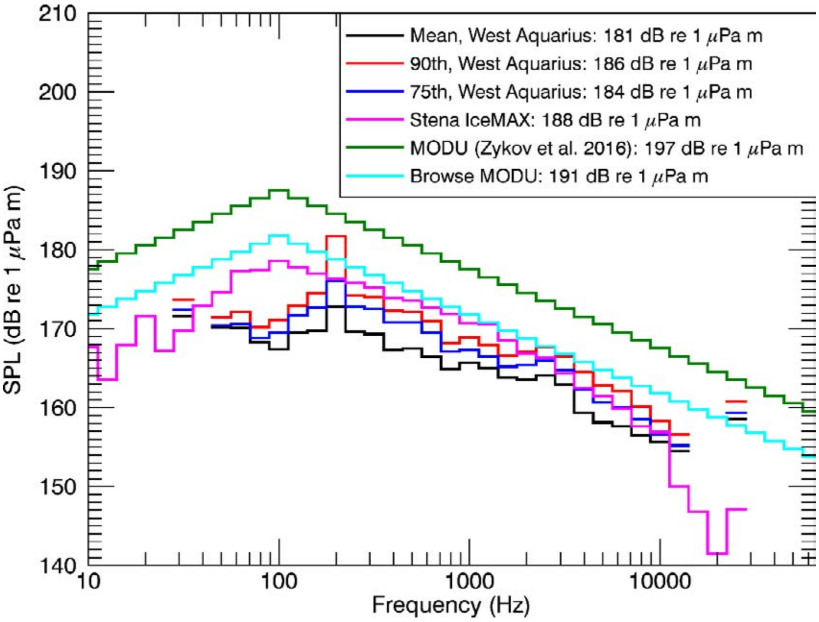

Figure 5. *MODU*: One-third-octave-band source levels. The levels assume operation of the MODU at 50% load, and account for the presence of eight thrusters. For comparison, source levels obtained from measurements of the noise generated by the West Aquarius and the Stena IceMAX (Martin et al. 2019) are provided. In addition, predicted source levels for the same MODU considered in this study under heavy operating conditions (Zykov 2016) are presented.

3.6.2. Offshore Support Vessel (OSV)

The estimates of acoustic source levels and sound spectrum for the support vessel were based on the *MMA Inscription* platform supply vessel, referred to in this report as an Offshore Support Vessel (OSV) (Figure 6). The *MMA Inscription*, of length 87.08 m, breadth of 18.8 m and maximum draft of 5.9 is equipped with two bow (main) azimuthal thrusters, one stern retractable azimuthal thruster, and one bow thruster. Since parameters such as propeller size or thruster vertical position were not available, thrusters were modelled at depth 5.9 m, equal to the draft. The bow thrusters are 2000 kW maximum continuous power input each, while the bow thruster is 910 kW maximum continuous power input. For this modelling, the stern retractable thruster was not included. Figure 7 shows the thruster locations.

Source levels for the *MMA Inscription* were obtained based on those of the Damen platform supply vessel 3300CD (length 80.08 m, breadth of 16.8 m and maximum draft of 6.9), which was used in previous studies (Zykov 2016). For the Damen 3300CD, the bow (main) thrusters are 2000 kW maximum continuous power input each, while smaller bow thrusters are 735 kW maximum continuous power input. Unlike Zykov (2016), in which thrusters were assumed to operate at full capacity, modelling in this study was conducted assuming a 25% capacity. For this reason, thrusters levels from Zykov (2016) were offset by $10*\log_{10}(0.25)$ for the main thrusters, and by $10*\log_{10}(0.25)+10*\log_{10}(910/735)$ for the bow thruster. The source levels for individual thrusters are shown in Figure 8.

Figure 6. Image of the *MMA Inscription* (MMA Offshore 2019).

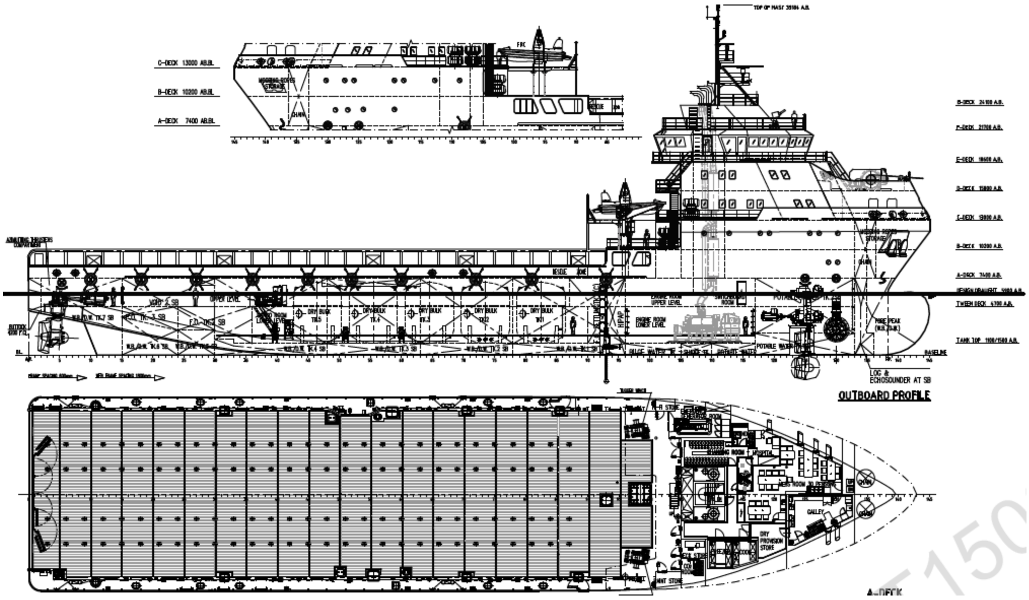

Figure 7. Nominal dimensions and thruster locations (circles) of the *MMA Inscription* (MMA Offshore 2019).

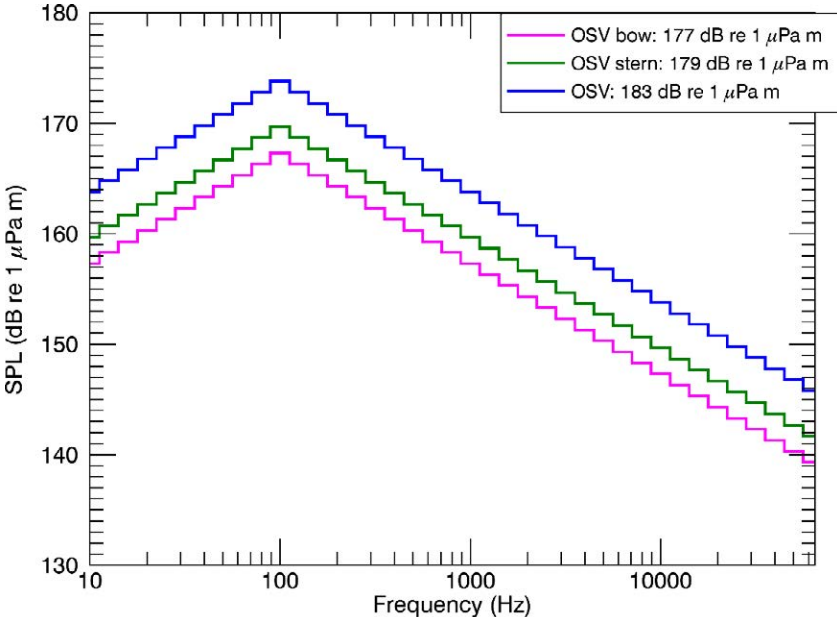

Figure 8. *OSV*: One-third-octave-band source levels of individual bow and stern thrusters. The OSV curve include the two individual stern thrusters and the bow thruster.

3.6.3. Floating Production, Storage, and Offloading (FPSO) facility

The proposed FPSO facility is a dynamically positioned production vessel approximately 370 m long and 67 m wide with a draft of 16 m. While in DP mode, it operates on two stern thrusters positioned laterally on the keel at the stern of the ship, right next to each other. Each thruster is rated at 5 MW. The vessel type and specifications are similar to the Woodside FPSO facilities *Ngujima Yin* and *Nganhurra* (with the important exception of the two thrusters rated at 2.94 MW each), from which JASCO gathered measurements in 2010 (Erbe et al. 2013). The measured spectra for these two vessels were averaged and used as a surrogate for the FPSO facility. Because the *Ngujima Yin* and *Nganhurra* were moored, they were not offloading, and the weather was calm, they were not under DP when they were measured. These averaged source levels were used in this report to model FPSO operations without DP.

To model operations that include DP, sound levels of thruster noise were added to the (non-DP) source spectrum. Sound levels for DP thruster noise were based on measurements of the dive support vessel *DSV Fu Lai* (MacGillivray 2006). The composite source spectrum (i.e., non-DP and DP components) was adjusted for the difference in total operational power level between the DSV *Fu Lai* and the FPSO facility using the following equation:

$$SL = SL_{FuLai} + 10\log\left(HP/HP_{ref}\right)\ , \qquad (1))$$

where HP_{ref} is the level of reference power. The source spectrum was additionally modified to consider the operational level of the *Fu Lai* thrusters relative to the desired operational level for the FPSO facility. Given that DP does not require full thrust, the *Fu Lai*'s thrusters only operated at between 20% and 30% of capacity when measured. To achieve a conservative estimate, FPSO facility thrusters were modelled at 50% power capacity. In addition to the adjustment in Eq.1, an offset of 10*$\log_{10}$(5/2.94) was applied to the composite source spectrum, to account for the difference in thruster power between the *Ngujima Yin* and *Nganhurra*, and the FPSO considered in this study.

The acoustic modelling source depth was determined by assuming the bottoms of the thrusters were at the draft of the vessel, but the noise from cavitation is known (Wright and Cybulski 1983) to be centralised at approximately three quarters of the propeller's height.

In the absence of information about the propeller diameters and vertical position, modelling was conducted assuming point sources at 16 m to be conservative. For modelling, it was assumed that both thrusters operated at the middle (50%) of their constant power range, at a constant speed. The thrusters are located at the stern section of the vessel; for modelling purposes, however, the source location was placed in the planar centre of the vessel to approximate a point source. Because this assessment is focused on the far-field noise from all sources on the vessel (including not just thruster noise, but also noise from ancillary equipment for power generation, etc.) the point source approximation is suitable. Figure 9 shows 1/3-octave-band source levels for the FPSO facility (with and without DP).

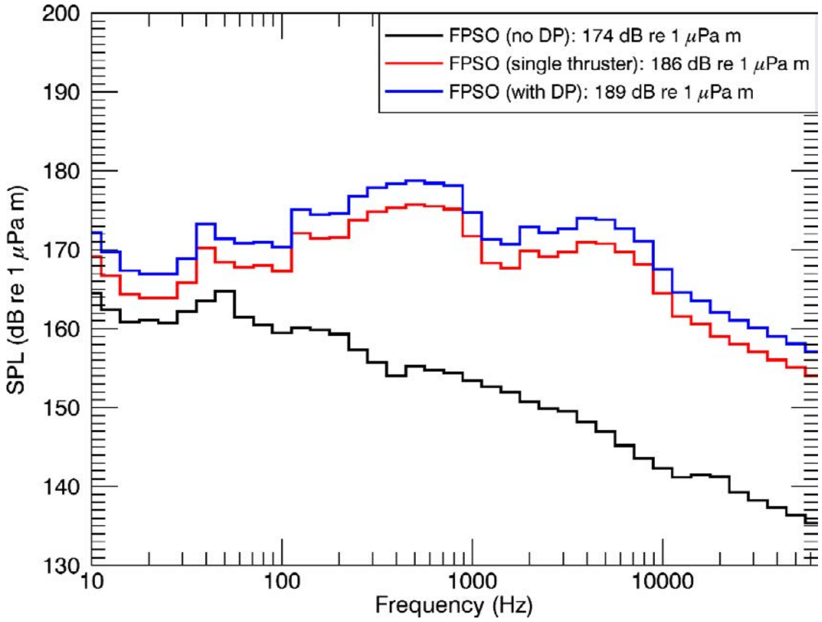

Figure 9. *FPSO*: One-third-octave-bands of modelled FPSO facility without DP, with DP (single thruster), and with DP (two thrusters).

3.6.4. FPSO Offtake

Offtake operations considered in this study consist of an FPSO on DP, a condensate tanker, and an OSV (Figure 10). The modelling scenario includes the tanker (which is considered noiseless in this study) is between the FPSO and the OSV, with the bow 80 m from the stern of the FPSO, and the OSV 700 m from the stern of the FPSO, pointing away from the FPSO. The offtake scenarios were modelled by adding the contributions from the maximum-over-depth grids computed for the individual vessels detailed in Sections 3.6.2 and 3.6.3.

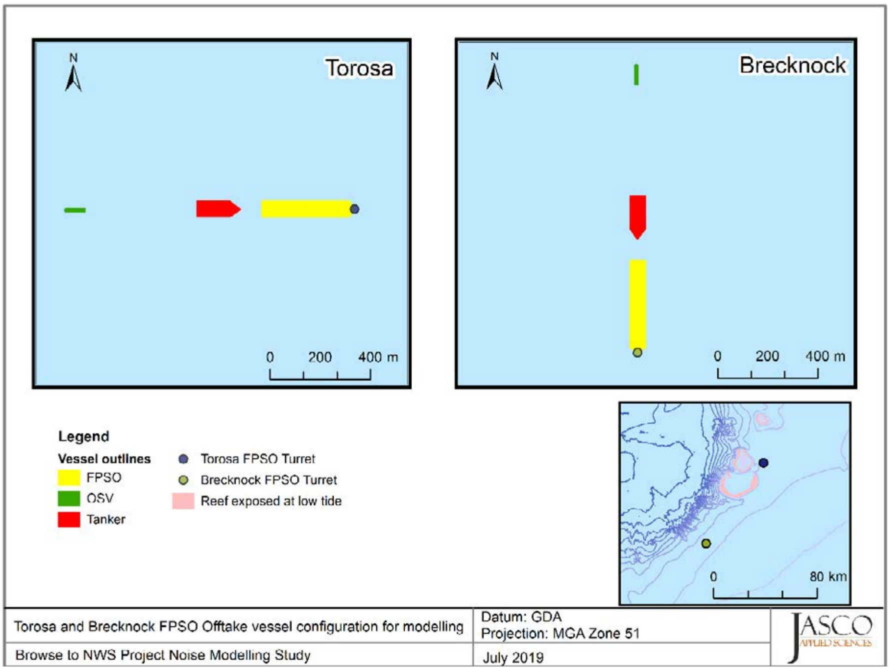

Figure 10. Torosa and Brecknock FPSO Offtake vessel configuration for modelling, showing FPSO, tanker, and OSV.

3.7. Animal Movement and Exposure Modelling

The JASCO Animal Simulation Model Including Noise Exposure (JASMINE) was used to predict the exposure of animats (virtual marine mammals) to sound arising from the pile driving. Sound exposure models like JASMINE integrate the predicted sound field with biologically meaningful movement rules for each marine mammal species (here: pygmy blue whales and green turtles) that result in an exposure history for each animat in the model. In JASMINE, the sound received by the animats is determined by the proposed pile driving activity pattern. As shown in Figure 11, animats are programmed to behave like the marine animals that may be present in the area. The parameters used for forecasting realistic behaviours (e.g., diving and foraging depth, swim speed, surface times) are determined and interpreted from marine mammal studies (e.g., tagging studies) where available, or reasonably extrapolated from related or comparable species. An individual animat's sound exposure levels are summed over a specified duration, such as 24 h or the entire simulation, to determine its total received energy, and then compared to the threshold criteria (for detailed information on JASMINE see Appendix G).

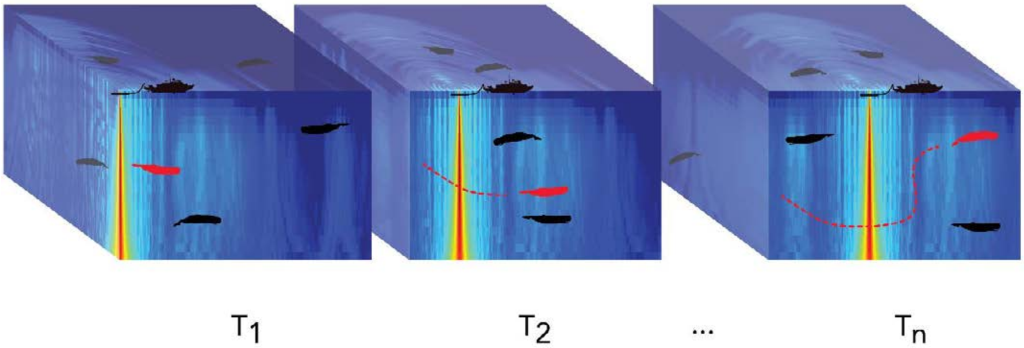

Figure 11. Cartoon of animats in a moving sound field. Example animat (red) shown moving with each time step (T_x). The acoustic exposure of each animat is determined by where it is in the sound field, and its exposure history is accumulated as the simulation steps through time.

3.7.1. Methodology

The exposure criteria for impulsive sounds (described in Section 2) were used to determine the number of animats exceeding thresholds. Model simulations were run with animat densities of 15 animats/km^2 for pygmy blue whales and 15 animats/km^2 green turtles to generate a statistically reliable probability density function for each species. To evaluate potential injury (PTS), TTS, and behavioural disturbance, exposure results were summed over the driving of a single pile (Table 16), which represents the exposure over 24 h, represented by animats described in Appendix G.

Specific areas of interest are defined for both pygmy blue whales and green turtles depending on behavioural mode (e.g., migrating, foraging, inter-nesting). Figures 12 and 14 show maps of the modified Biologically Important Areas (BIAs) for migrating and inter-nesting green turtles, while Figures 13 and 15 show the Department of Environment and Energy (DoEE) BIAs for migrating and foraging pygmy blue whales. Both of these maps also show the extents of the modelling and animat simulation area. For the final calculations, BIA areas are clipped to the extents of the simulation. To account for the difference between the animat simulation area and the BIAs, the final exposure estimates are scaled by the ratio of the clipped BIA relative to the simulation area.

The modified BIA for green turtle inter-nesting area is restricted to the 50 m contour around North and South Scott Reef, and connects between the two Reefs (Figure 12), this area was defined based upon the best available science (turtle tagging data (Guinea 2011) and external advice), and has been applied in this study instead of the DoEE defined inter-nesting BIA boundary around Scott Reef. While the simulations assume the inter-nesting green turtles are evenly distributed within the defined area of interest, the majority are concentrated on or next to Sandy Islet (Guinea 2009). The migratory area has been defined based upon tagged turtles (Guinea 2011) and the area prescribed is based upon the distance a turtle would transit within 24 h.

The animal simulation model requires detailed behavioural information on how the modelled species moves in the water column. This is detailed in Sections 3.7.2 and 3.7.3 for pygmy blue whales and green turtles, respectively.

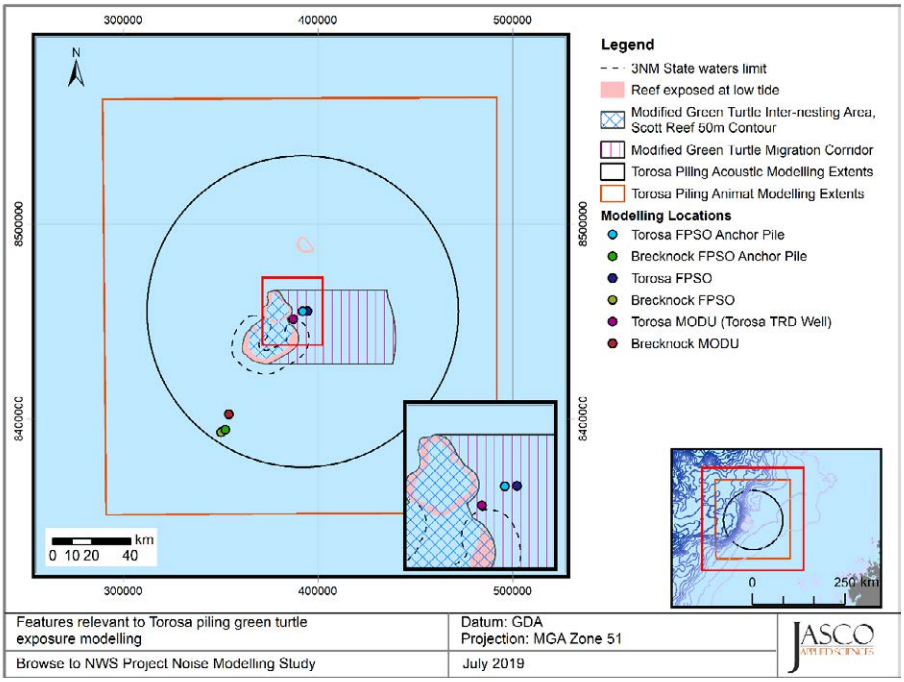

Figure 12. *Torosa:* Map of green turtle exposure modelling features, including modified BIAs for inter-nesting and migrating green turtles, along with extents for acoustic propagation modelling and animat modelling.

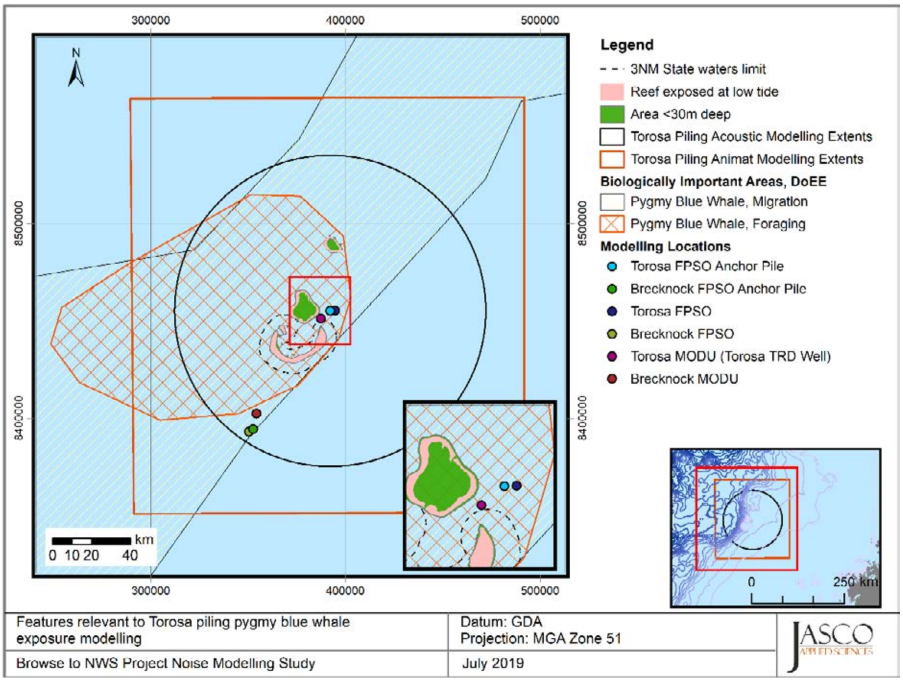

Figure 13. *Torosa*: Map of pygmy blue whale exposure modelling features, including BIAs for foraging and migrating pygmy blue whales, along with extents for acoustic propagation modelling and animat modelling.

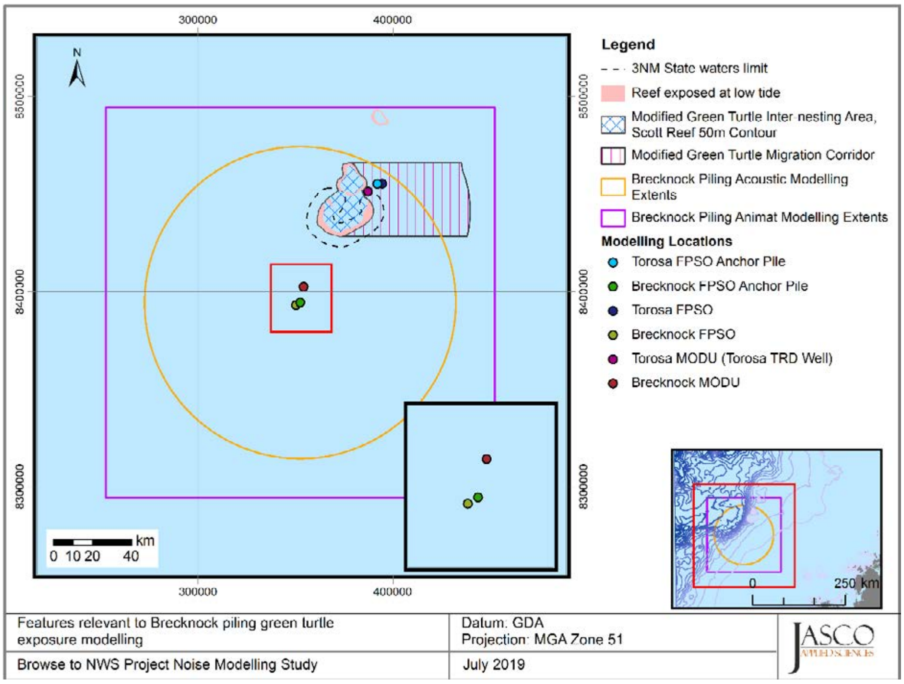

Figure 14. *Brecknock:* Map of green turtle exposure modelling features, including modified BIAs for inter-nesting and migrating green turtles, along with extents for acoustic propagation modelling and animat modelling.

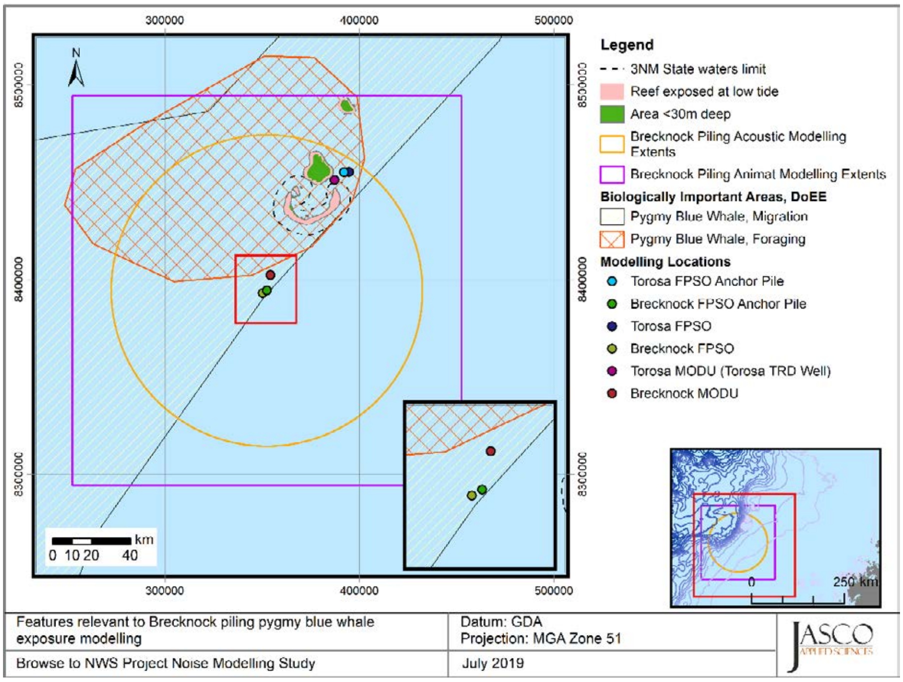

Figure 15. *Brecknock*: Map of pygmy blue whale exposure modelling features, including BIAs for foraging and migrating pygmy blue whales, along with extents for acoustic propagation modelling and animat modelling.

In the case of the inter-nesting green turtles, the pile location is approximately 7.9 km away from the closest point of the BIA. To ensure that no animats are impacted outside the relevant BIA, exposures occurring at ranges smaller than the minimum distance between the pile and the BIA were not included in the final count. This effectively reduces the simulation area by πr^2, where r = 7.9 km. Therefore, the final area-based scaling S_A is

$$S_A = \frac{BIA_{clipped}}{(A_{full} - \pi r^2)}, \quad (2)$$

where $BIA_{clipped}$ is the BIA clipped to the full animat simulation area A_{full}. Pygmy blue whales are not expected in water depths less than 30 m, so the clipped BIA is reduced by the area within the 30m depth contour (Figure 13). A summary of the BIA areas and the various inputs to exposure scaling for each of the animat modelling scenarios can be found in Table 18.

The total number of animats exposed above behaviour, TTS and PTS threshold criteria were scaled using the seeded density D_S and the real-world density D_R, where available. The scaling factor S_D is therefore

$$S_D = \frac{D_R}{D_S}. \quad (3)$$

The total number of real-world animals N_{exp} expected to be impacted above threshold is computed from the raw animat exposures and the scaling factors as

$$N_{exp} = S_A S_D. \quad (4)$$

The distribution of ranges of exposed animats was used to estimate the 95th percentile ranges at which the animats were exposed above threshold. Within the 95th percentile range, there are generally some proportion of animats that did not exceed threshold criteria.

During pile driving operations, exclusion zones of 500 m for turtles and 2000 m for pygmy blue whales will be in place. These will be managed using mitigation protocols determined by Woodside, and through their implementation, exposures to turtles and pygmy blue whales near the pile where sound levels are highest will be limited. The overall effect of implementing these exclusion zones was estimated using animat modelling by removing any exposures occurring within the exclusion zone.

Table 18. Exposure modelling scenarios and associated areas of concern for the simulation, along with estimated animal densities.

Animat scenario	Full area (km^2)	R_{min} (km)	Adjusted A_{full} (km^2)	$BIA_{clipped}$ (km^2)	30 m exclusion zone (km^2)	Adjusted $BIA_{clipped}$ (km^2)	Area-based scaling, S_A	Animal density (# per km^2)
Torosa								
Pygmy blue whale migrating	40000.0	0.0	40000.0	20162.0	370.7	19791.3	0.49	0.06902
Pygmy blue whale feeding	40000.0	0.0	40000.0	9839.0	370.7	9468.3	0.24	0.06902
Green turtle migrating	40000.0	0.0	40000.0	2015.9	NA	2015.9	0.05	NA
Green turtle inter-nesting	40000.0	7.9	39804.1	658.2	NA	658.2	0.02	1.79
Brecknock								
Pygmy blue whale migrating	40000.0	0.0	40000.0	20287.0	370.7	19916.3	0.5	0.06902
Pygmy blue whale feeding	40000.0	10.3	39664.1	11063.0	370.7	10692.3	0.3	0.06902
Green turtle migrating	40000.0	42.0	34458.2	2015.9	NA	2015.9	0.1	NA
Green turtle inter-nesting	40000.0	40.4	34872.4	658.2	NA	658.2	0.02	1.79

3.7.2. Pygmy blue whales

3.7.2.1. Animal behaviour

Two behavioural profiles were considered for pygmy blue whales, foraging and migration. The research summarised in this section was used to inform the species behavioural definition (Appendix G.2). Detailed, fine-scale diving behaviour of a migrating pygmy blue whale was derived from Owen et al. (2016) who equipped an individual with a multi-sensor tag off the west coast of Australia. The study identified areas of high residence using the horizontal movement data; the analysis of the dive data showed that the depth of migratory dives was highly consistent over time and unrelated to local bathymetry. Blue whales (*Balaenoptera musculus*) are known to primarily migrate and feed in the first few hundred metres of the water column (Croll et al. 2001, Goldbogen et al. 2011), with the deepest dive being reported from a pygmy blue whale being 506 m (Owen et al. 2016). Dives were identified as migratory, feeding, or exploratory behaviour. The mean depth of migratory dives (82% of all dives) was 14 m ± 4 m, and the whale spent 94% of observed time and completed 99% of observed migratory dives at water depths of less than 24 m. A total of 21 feeding dives were identified during the duration of the tag deployment (one week) with a mean maximum depth of 129 ± 183 m (range 13–505 m). The mean maximum depth of exploratory dives (107 ± 81 m, range 23–320 m) was similar to the mean maximum depth of feeding dives (129 m) and did not appear to be related to seafloor depth.

The behaviour of pygmy blue whales was modelled without migration bias, i.e. the animats were resident in the animat modelling area over the entire modelling period. In reality, pygmy blue whales can be expected to transit through the area in less than half a day (based on McCauley and Jenner 2010); accordingly, the approach used is conservative as it results in higher exposure levels and higher number of animals exposed to levels exceeding the criteria thresholds.

The two migratory behaviours (migratory dives and exploratory dives) were modelled at an even probability of occurrence (i.e. probability for transitioning from one behaviour to another was 0.5 for both) while dive data published by Owen et al. (2016) suggest a higher likelihood for migratory dives to occur. This approach was chosen in the absence of quantitative information on the true proportion between the two dive behaviours. It represents another conservative measure, given the assumption that for sub-sea piling, exposure levels are higher at depth as compared to the surface.

3.7.2.2. Density estimates

The entire region off the northwestern coast of Australia is a poorly studied with regard to the abundance and distribution of pygmy blue whales. As described in McCauley et al. (2018), there are two estimates for the Eastern Indian Ocean pygmy blue whale population size along the coastline of Western Australia (WA), the first calculated in 2004 by McCauley and Jenner (2010) at 662–1559 southbound animals, using passive acoustics, and the second calculated over 2002–2006 by Jenner et al. (2008) of 712–1754. Neither of these estimates account for whales further west in the Indian Ocean, and there is evidence that along the WA coast north of latitude ~ 19° S that the migratory pathway spreads out (Gavrilov et al. 2018), with not all animals following the Australian coastline; therefore it is unknown what proportion of the Eastern Indian Ocean pygmy blue whale population either follow the coast or travel further west (McCauley et al. 2018).

However, while near the coast, the observations in McCauley and Jenner (2010) suggested most pygmy blue whales pass along the shelf edge out to water depths of 1000 m but centred near the 500 m depth contour. The boundaries of the DoEE pygmy blue whale migration BIA are designed to reflect this general migratory pattern. The areas considered in this simulation were greater than the acoustic modelling region to provide a buffer zone around the sound fields to account for the possibility of animats moving into and out of the modelled sound fields.

McCauley et al. (2018) provides an estimate for the annual growth rate of pygmy blue whales at Portland (Victoria) of 4.3% per year. However, as pointed out by the authors, this growth rate applies only to the proportion of the population using the south eastern Australian coast, and as such may not reflect the growth rate of the full population. However, in the absence of other population growth estimates, this estimate has been applied as a conservative estimate to the proportion of the population also using the WA coast, in particular the migratory BIA.

Considering an annual growth rate of 4.3%, the two population estimates provided in McCauley and Jenner (2010) and Jenner et al. (2008) have been considered to determine the potential current population, and thus the possible percentage increase since the estimate was derived, as shown in Table 19.

Table 19. Population growth estimates based on 4.3% per annum.

Source	Year	Minimum estimate	Maximum estimate	Percentage increase
Based on McCauley and Jenner (2010)	2004, Estimated	662	1559	
	2019, Extrapolated	1245	2932	188%
Based on Jenner et al. (2008)	2002-2006, Estimate	712	1724	
	2019, Extrapolated	1231	2980	173%

The acoustic detection data published by McCauley and Jenner (2010) revealed a maximum of three pygmy blue whales on a single day passing through the area during their southward migration (November to late December). McCauley and Jenner (2010) estimated the listening range of this noise logger to be 120 km, which is assumed to be a radius, however, to apply precaution in this assessment the recorder listening area was conservatively calculated using a 60 km radius. Based on an average swimming speed for the southbound pygmy blue whales of five knots (9.26 km/hr), McCauley and Jenner (2010) calculated a transit time through the area of 0.54 days; therefore, the number of animals detected per day equates to an estimated density for vocalising animals in the area of 0.0031207 animals per km^2 for their study. As not all animals are emitting calls during their migration, this density estimate has to be corrected for the percentage of animals calling ('calling rate'). McCauley and Jenner (2010) proposed that 8.5–20% of the animals present in an area could be vocalising, considering information relating to humpback whales (8.5%, Cato et al. (2001)), and pygmy blue whales (<20%, (McCauley et al. 2001), to take a precautionary approach this study has adopted the lower bound (8.5%), with the resulting density shown in Table 20, which has been used in this assessment. If the vocalisation rate of pygmy blue whales in the Perth Canyon is applied, the resulting density of vocalising animals would be 2.35 times greater, and thus the correction factor for calling animals would be only 5, rather than 11.76.

The maximum number of three pygmy blue whales per day occurred in associated with the population estimate of 662–1559 whales presented in McCauley and Jenner (2010). If the population increases, it is estimated that the number of whales present on any one day would also increase proportionally. Therefore, the population increase estimate of 4.3% per year, and a corresponding Scaling Factor of 188% (Table 19), has been applied in this study, as shown in Table 20. This results in a revised estimate of the maximum number of animals which could be detected within the listening area per day being 5.64, and a real-world density of 0.0690392 animals per km^2.

Table 20. Density calculations

Variable / Factor	Estimate using data from McCauley and Jenner (2010)	Estimate considering 4.3% population growth since 2004
Number of animals in listening area (animals detected per day in listening area)	3	5.64
Recorder listening area (km^2) (McCauley and Jenner 2010)	11309.73	
Density of Vocalising Animals (animals/km^2)	0.0031207	0.0058683
Calling rate based on humpbacks (8.5% of animals present vocalise)	8.5%	
Correction factor for calling animals	11.76	
Real World Density of animals (D_R) (animals/km^2)	0.03671	0.0690392
Seeded Density (D_S) (animats/km^2)	15	
Scaling Factor (S_D)	0.0024476	0.0046026
Increase in Scaling Factor considering population growth		188%
Comparison of Seeded Density (D_S) to Real World Density of animals (D_R)	408.56	217.27

3.7.3. Green turtles

3.7.3.1. Animal behaviour

Two behavioural profiles were considered for green turtles, inter-nesting and migrating. The research summarised in this section inform the species behavioural definition (Appendix G.3). The migratory behaviour and habitat use of green turtles has been studied at various locations throughout their distribution range for Western Australia, but few studies provide quantitative information on the swim and dive behaviour of these animals.

Studies of the green turtle population nesting on Sandy Islet, Scott Reef by Guinea (2010, 2011), however, include behavioural parameters. Inter-nesting turtle records indicate a maximum dive depth of 45 m and an average dive duration of 15–25 minutes, with a dive duration range of 20 seconds to 55 minutes (Guinea 2011). Migratory turtle records indicate a maximum dive depth of 80 m (average: 49 m) and an average dive duration of 10–15 minutes.

Inter-nesting turtle swimming speeds are not available for the Scott Reef green turtle population. An analogue based on information from a satellite tagging study of green turtle behaviour and movements conducted by the Department of Biodiversity, Conservation and Attractions (DBCA) during the 2018 and 2019 nesting period at Ningaloo has been derived. The inferred average inter-nesting swimming speed for green turtles at Scott Reef adopted for this study was 1.4 km/h.

For the Scott Reef population, the average swim speed of migrating green turtles ranged from 1.3–2.7 km/h (Pendoley 2005, Guinea 2011).

3.7.3.2. Density estimates

Based on beach monitoring at Scott Reef, Guinea (2009) estimated a green turtle abundance of 779 ± 383 (± se) in the years 2008 and 2009. These numbers included counts of green turtles with flipper tags and an estimate from marking and recapturing individuals (identified by sprayed painted carapace) at Sandy Islet. The density of inter-nesting green turtles was defined by the highest estimates of green turtles (1162 individuals) at Scott Reef as recorded by Guinea (2009) and an estimated density of 1.79 turtles/km^2 based on the highest estimate, primarily using an inter-nesting area defined by the 50 m bathymetry around North and South Scott Reef. No density estimates were calculated for migrating green turtles because no data were available.

4. Results

4.1. Pile Driving: Torosa FPSO Anchor Piles

4.1.1. Received levels at 10 m

Since piles are distributed and directional sources, they cannot be accurately approximated by a point source with corresponding source levels. It is possible to compare the maximum modelled levels at short distances from the piles. Figure 16 shows the 1/3-octave-band levels for the receiver with the highest SEL at the closest horizontal range (10 m), for the three modelled penetrations. The levels above 1000 Hz were extrapolated using a 20 dB/decade decay rate to match acoustic measurements of impact pile driving of similarly sized piles (Illingworth & Rodkin 2007, Matuschek and Betke 2009). The modelled results at a distance of 10 m are included to provide results comparable to other pile driving reports and literature, such as Illingworth & Rodkin (2007), and Denes et al. (2016).

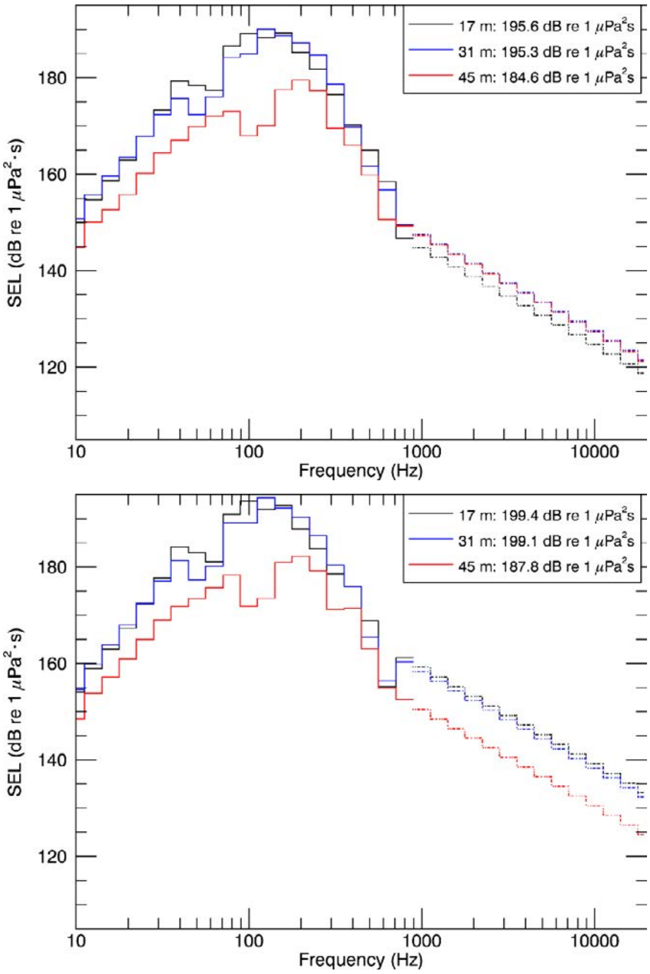

Figure 16. *Torosa*: One-third-octave-band levels for the receiver with highest SEL at 10 m horizontal range for impact pile driving using the IHC S-600 (top) and the IHC S-1200 (bottom), after high-frequency extrapolation (dashes indicate extrapolated portion of the spectrum). Legend items indicate the modelled pile penetration (Table 16) and the broadband SEL in dB re 1 μPa²·s.

4.1.2. Per-strike sound fields

Per-strike results for the proposed pile driving are presented in this section for maximum-over-depth SPL, SEL, and PK (tables in Section 4.1.2.1), maps and sound field vertical slices (Section 4.1.2.2).

4.1.2.1. Tabulated results

Tables 21–26 show the estimated distances for the various applicable per-strike effects criteria and isopleths of interest as maximum-over-depth.

Table 21. *Torosa piling, per-strike SEL:* Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the pile to modelled maximum-over-depth isopleths.

Per-strike SEL (L_E; dB re 1 µPa²·s)	**IHC S-600**						**IHC S-1200**					
	Penetration depth (m)						**Penetration depth (m)**					
	17		**31**		**45**		**17**		**31**		**45**	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
190	0.05	0.05	0.03	0.03	<0.02	<0.02	0.08	0.08	0.05	0.05	<0.02	<0.02
180	0.14	0.13	0.10	0.09	0.04	0.04	0.22	0.21	0.14	0.14	0.08	0.08
170	0.39	0.37	0.28	0.26	0.17	0.17	0.68	0.64	0.45	0.43	0.29	0.28
160	2.22	2.10	0.95	0.90	0.65	0.63	5.50	5.31	5.32	5.20	1.20	1.15
150	11.98	8.86	10.48	5.81	5.36	5.13	19.70	14.79	17.05	11.55	12.03	8.60
140	31.14	24.80	29.45	22.37	18.02	14.26	44.42	36.94	44.06	33.03	29.15	19.83
130	79.98	57.15	59.09	50.60	44.06	32.87	>79.98	*	>79.98	*	56.87	46.33
120	>79.98	*	>79.98	*	>79.98	*	>79.98	*	>79.98	*	>79.98	*

* Radii unresolvable due to R_{max} exceeding maximum modelled distance.

Table 22. *Torosa piling, SPL:* Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the pile to modelled maximum-over-depth isopleths.

SPL (L_p; dB re 1 µPa)	**IHC S-600**						**IHC S-1200**					
	Penetration depth (m)						**Penetration depth (m)**					
	17		**31**		**45**		**17**		**31**		**45**	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
200	0.04	0.03	0.03	0.03	<0.02	<0.02	0.07	0.07	0.04	0.04	<0.02	<0.02
190	0.13	0.13	0.09	0.09	0.04	0.04	0.20	0.18	0.13	0.12	0.07	0.07
180	0.33	0.31	0.25	0.23	0.15	0.15	0.59	0.57	0.40	0.38	0.26	0.25
170	2.08	1.99	0.79	0.75	0.55	0.52	5.27	5.05	4.83	1.97	0.93	0.90
160	10.48	6.74	9.14	5.57	5.28	5.11	17.15	11.63	16.29	10.95	9.68	5.51
150	29.72	22.93	25.15	18.23	17.11	13.09	44.23	34.18	38.69	29.81	24.22	17.97
140	65.33	55.01	58.31	46.69	38.63	29.94	>79.98	72.49	79.98	65.70	56.27	42.87
130	>79.98	*	>79.98	*	>79.98	*	>79.98	*	>79.98	*	>79.98	*

* Radii unresolvable due to R_{max} exceeding maximum modelled distance.

Table 23. *Torosa piling, marine mammal and turtle behavioural response thresholds, SPL*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the pile to modelled maximum-over-depth isopleths per penetration depth.

Threshold	**IHC S-600**						**IHC S-1200**					
	Penetration depth (m)						**Penetration depth (m)**					
	17		**31**		**45**		**17**		**31**		**45**	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
Marine mammal behavioural response (160 dB re 1 µPa SPL) (NMFS 2014)	10.48	6.74	9.14	5.57	5.28	5.11	17.15	11.63	16.29	10.95	9.68	5.51
Turtle behavioural response (166 dB re 1 µPa SPL) (NSF 2011)	5.11	4.99	2.07	1.97	0.95	0.91	9.11	5.66	9.06	5.46	4.84	4.46
Turtle behavioural disturbance (175 dB re 1 µPa SPL) (McCauley et al. 2000a, 2000b)	0.68	0.64	0.43	0.40	0.29	0.28	1.87	1.79	0.72	0.69	0.48	0.46

Table 24. *Torosa piling, marine mammal and turtle PTS and TTS PK thresholds*: Maximum (R_{max}) horizontal distances (in m) from the pile to maximum-over-depth isopleths.

Hearing group	**PTS**							**TTS**						
	PK threshold (L_{pk}; dB re 1 µPa)	**IHC S-600**			**IHC S-1200**			**PK threshold (L_{pk}; dB re 1 µPa)**	**IHC S-600**			**IHC S-1200**		
		Penetration depth (m)			Penetration depth (m)				Penetration depth (m)			Penetration depth (m)		
		17	31	45	17	31	45		17	31	45	17	31	45
LF cetaceans	219	<20	<20	<20	51	32	<20	213	76	51	<20	99	58	32
MF cetaceans	230	<20	<20	<20	<20	<20	<20	224	<20	<20	<20	<20	<20	<20
HF cetaceans	202	214	142	86	260	216	130	196	351	275	192	544	400	286
Turtles	232	<20	<20	<20	<20	<20	<20	226	<20	<20	<20	<20	<20	<20

Table 25. *Torosa piling, mortality and potential mortal recoverable injury thresholds (peak pressure level metric) for fish, fish eggs, and fish larvae*: Maximum (R_{max}) horizontal distances (in m) from the pile.

Marine animal group	**PK threshold (L_{pk}; dB re 1 µPa)**	**IHC S-600**			**IHC S-1200**		
		Penetration depth (m)			**Penetration depth (m)**		
		17	31	45	17	31	45
Fish: No swim bladder	213	76	51	<20	99	58	32
Fish: Swim bladder not involved in hearing, Swim bladder involved in hearing Fish eggs, and larvae	207	127	91	42	166	121	58

Table 26. *Torosa piling, modelled maximum-over-depth per-strike SEL, SPL, and PK at the receiver located at the Scott Reef coastal waters limit.*

Metric	**IHC S-600**			**IHC S-1200**		
	Penetration depth (m)			**Penetration depth (m)**		
	17	31	45	17	31	45
Unweighted SEL (L_E; dB re 1 µPa^2·s)	152.3	149.4	145.1	156.7	153.9	149.0
SPL (L_p; dB re 1 µPa)	160.8	157.9	153.7	165.2	162.5	157.6
PK (L_{pk}; dB re 1 µPa)	175.0	172.7	169.4	178.6	176.3	172.8

4.1.2.2. Sound field maps and vertical slices

Maps of the per-strike SPL results associated with the three modelled penetration depths are shown in Figures 17, 18, and 19 for the IHC S-600, and in Figures 20, 21, and 22 for the IHC S-1200. Per-strike SEL maps are shown in Appendix H.1. For each hammer, the shallowest modelled penetration has the farthest distances to all per-strike isopleths. Additionally, maps showing the isopleths for marine mammal behavioural criteria (160 dB re 1 µPa) for each of the three considered penetration depths are provided in Figures 23 and 24 for the IHC S-600 and the IHC S-1200, respectively, to demonstrate visually the reduction in extent with increased penetration depth. Vertical slice plots for all penetrations are shown in Figures 25–27 (IHC S-600) and Figures 28–30 (IHC S-1200).

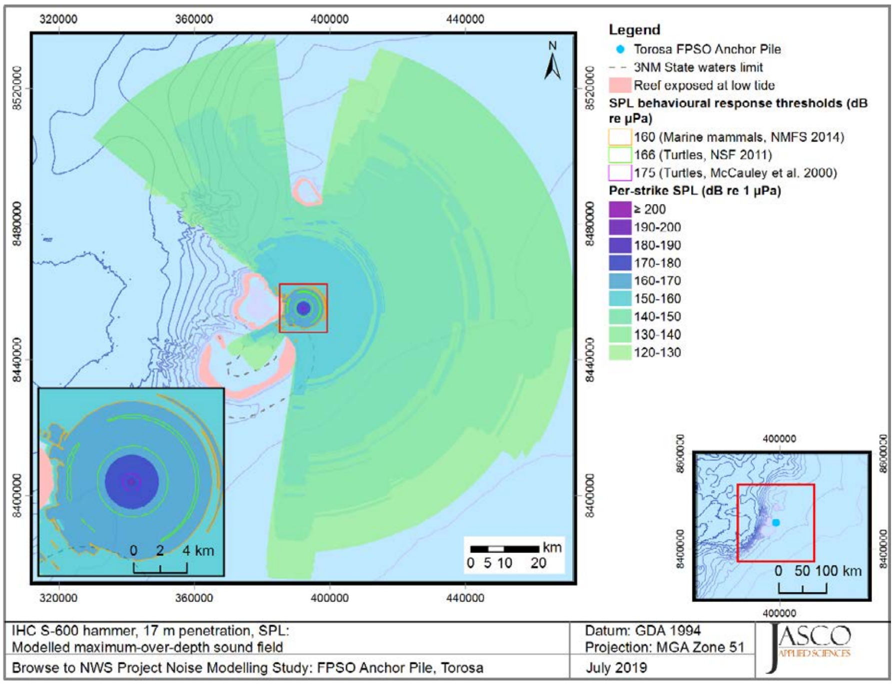

Figure 17. *Torosa, IHC S-600, SPL, 17 m penetration depth*: Sound level contour map, showing maximum-over-depth results. Isopleths for turtles (166 and 175 dB re 1 µPa) and marine mammal (160 dB re 1 µPa) behavioural criteria are shown.

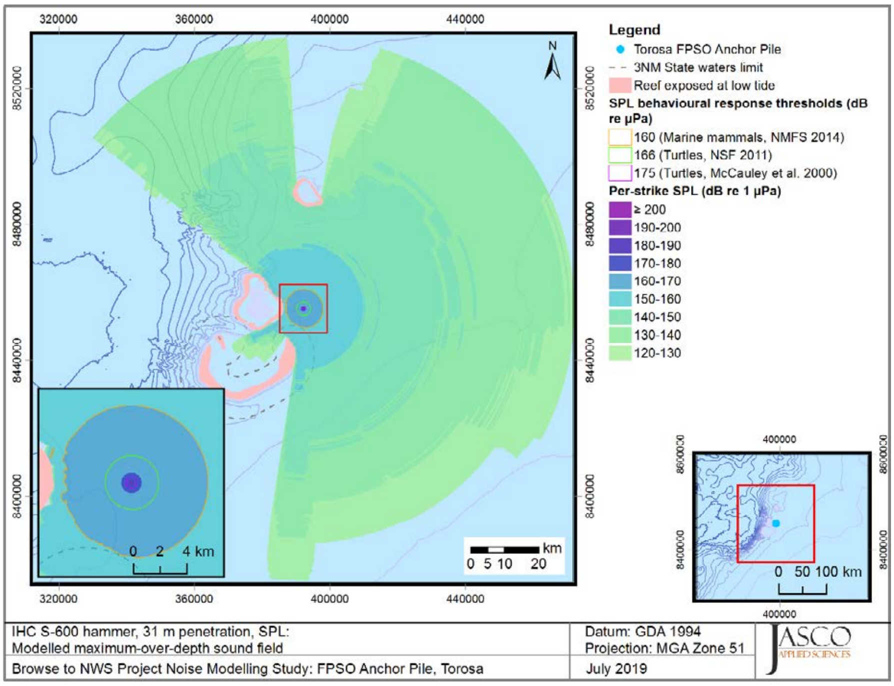

Figure 18. *Torosa, IHC S-600, SPL, 31 m penetration depth*: Sound level contour map, showing maximum-over-depth results. Isopleths for turtles (166 and 175 dB re 1 µPa) and marine mammal (160 dB re 1 µPa) behavioural criteria are shown.

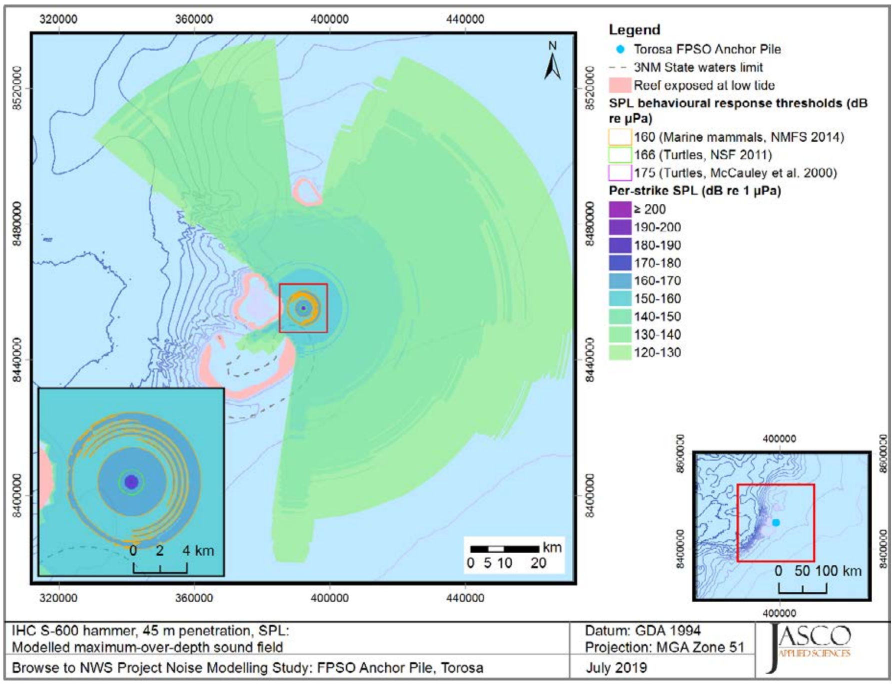

Figure 19. *Torosa, IHC S-600, SPL, 45 m penetration depth*: Sound level contour map, showing maximum-over-depth results. Isopleths for turtles (166 and 175 dB re 1 µPa) and marine mammal (160 dB re 1 µPa) behavioural criteria are shown.

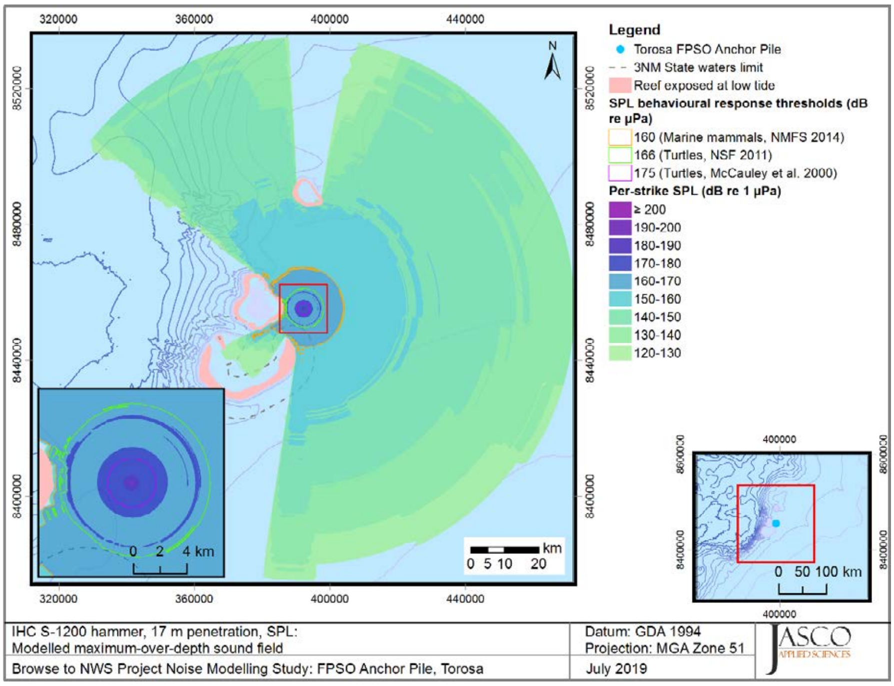

Figure 20. *Torosa, IHC S-1200, SPL, 17 m penetration depth*: Sound level contour map, showing unweighted maximum-over-depth results. Isopleths for turtles (166 and 175 dB re 1 µPa) and marine mammal (160 dB re 1 µPa) behavioural criteria are shown.

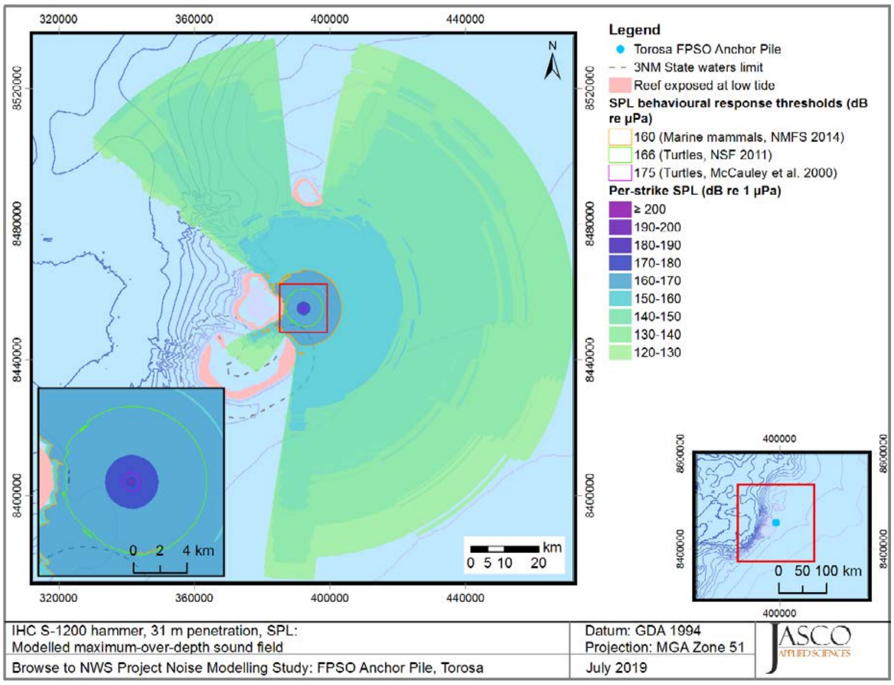

Figure 21. *Torosa, IHC S-1200, SPL, 31 m penetration depth*: Sound level contour map, showing maximum-over-depth results. Isopleths for turtles (166 and 175 dB re 1 µPa) and marine mammal (160 dB re 1 µPa) behavioural criteria are shown.

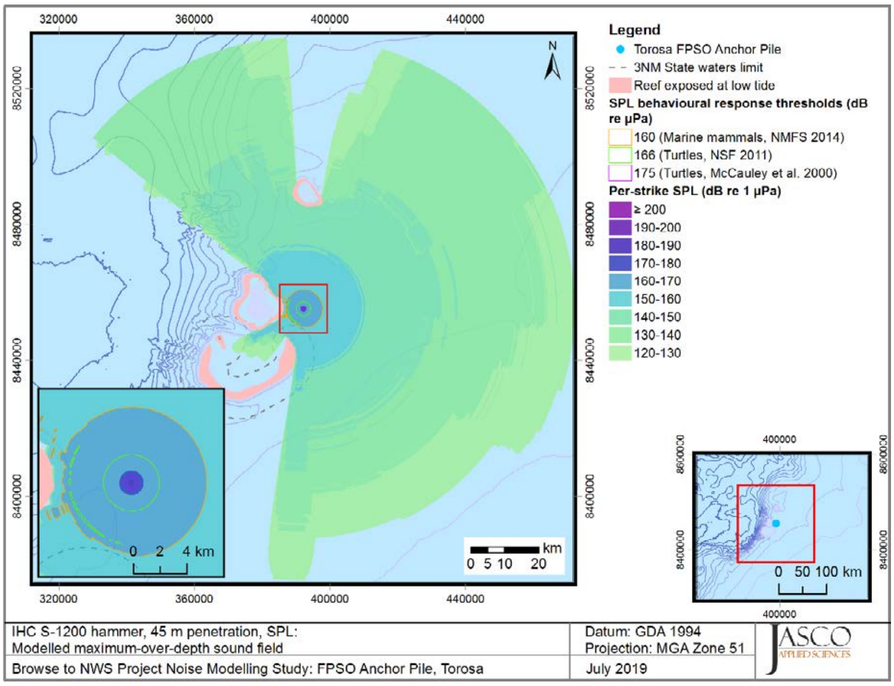

Figure 22. *Torosa, IHC S-1200, SPL, 45 m penetration depth*: Sound level contour map, showing maximum-over-depth results. Isopleths for turtles (166 and 175 dB re 1 µPa) and marine mammal (160 dB re 1 µPa) behavioural criteria are shown.

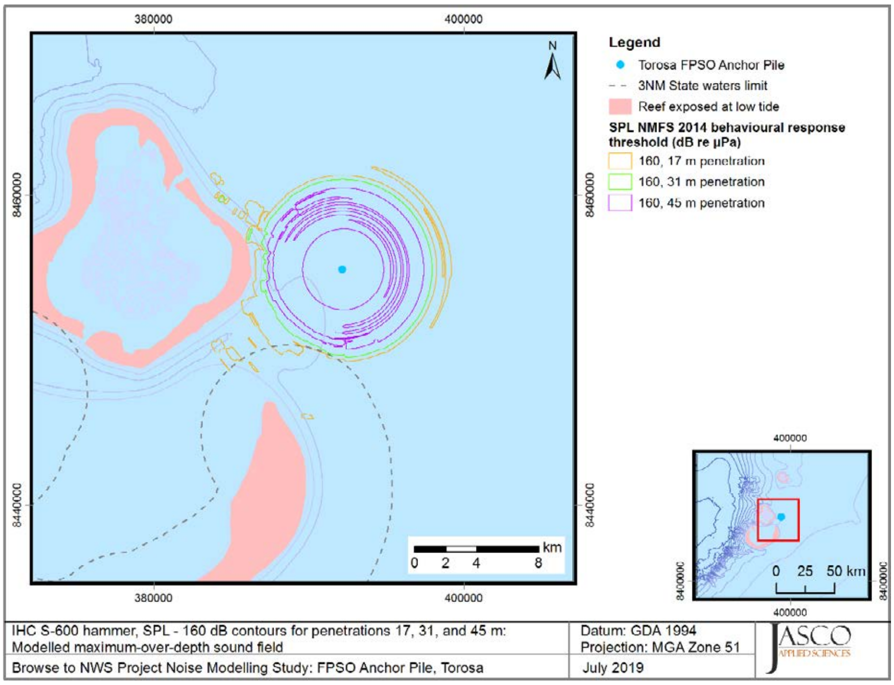

Figure 23. *Torosa, IHC S-600, SPL*: Sound level contour map showing unweighted maximum-over-depth SPL marine mammal (160 dB re 1 µPa) behavioural criteria results for all modelled penetration depths.

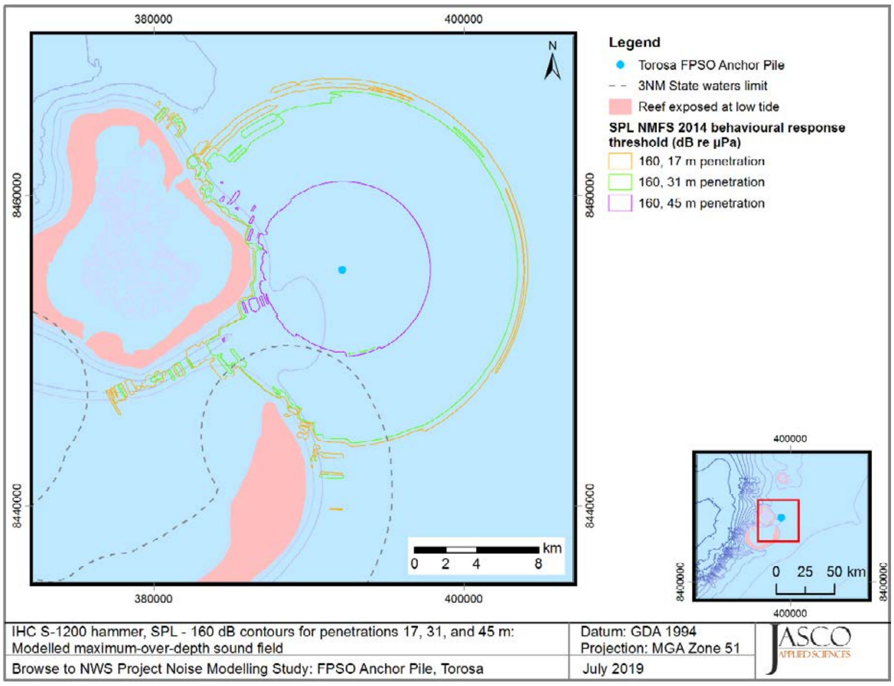

Figure 24. *Torosa, IHC S-1200, SPL*: Sound level contour map showing unweighted maximum-over-depth SPL marine mammal (160 dB re 1 µPa) behavioural criteria results for all modelled penetration depths.

4.1.2.2.1. Vertical slice plots

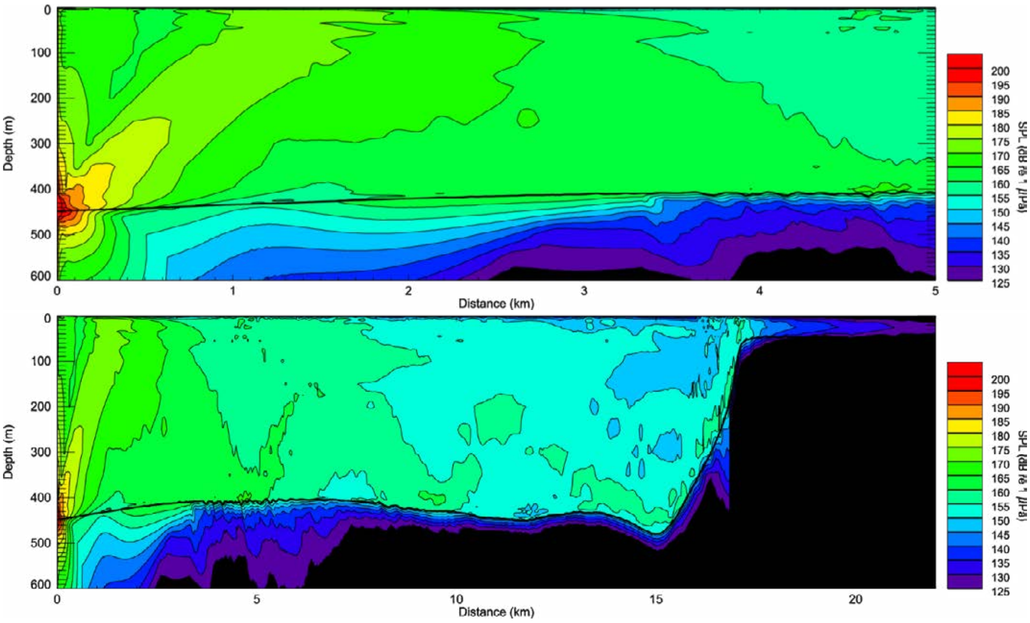

Figure 25. *Torosa, vertical slice, IHC S-600, SPL, 17 m penetration depth*: 0–5 km (top) and 0–22 km (bottom). Levels are shown along a single transect of azimuth 240°. The seabed outline is shown as a thick black line.

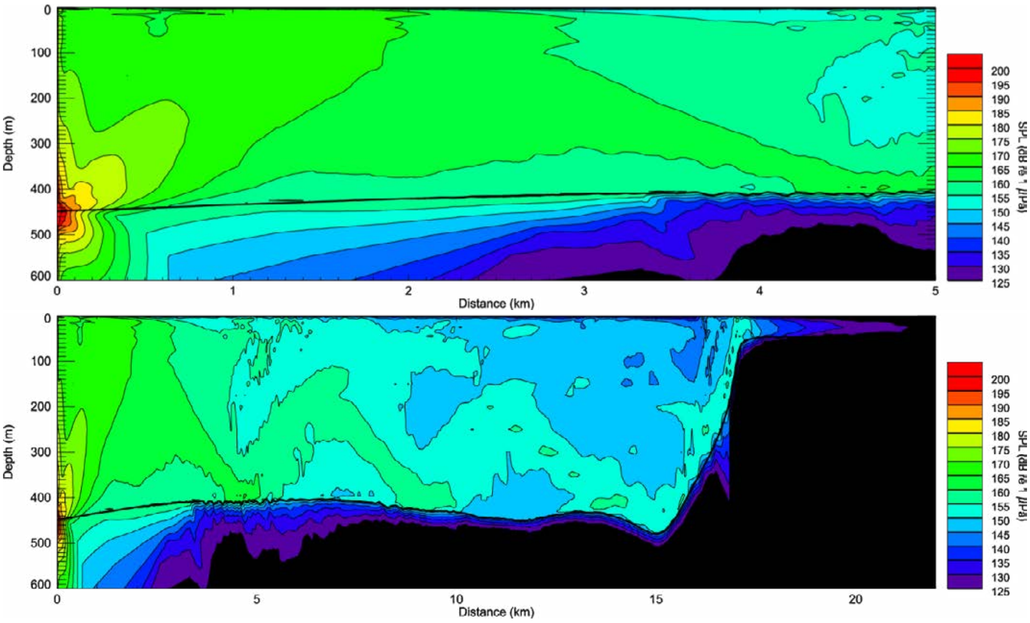

Figure 26. *Torosa, vertical slice, IHC S-600, SPL, 31 m penetration depth*: 0–5 km (top) and 0–22 km (bottom). Levels are shown along a single transect of azimuth 240°. The seabed outline is shown as a thick black line.

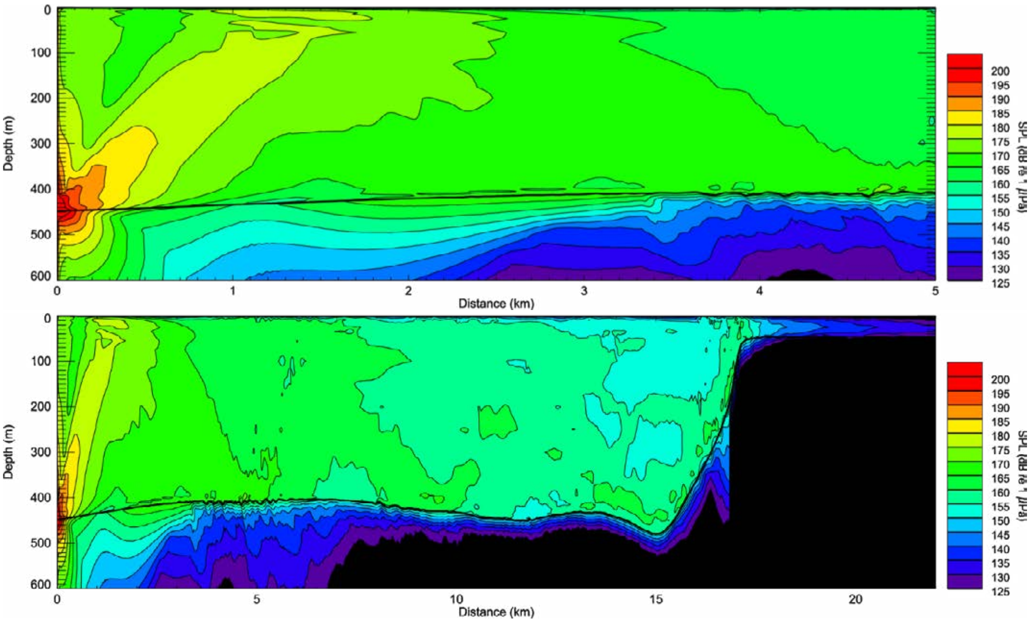

Figure 27. *Torosa, vertical slice, IHC S-600, SPL, 45 m penetration depth*: 0–5 km (top) and 0–22 km (bottom). Levels are shown along a single transect of azimuth 240°. The seabed outline is shown as a thick black line.

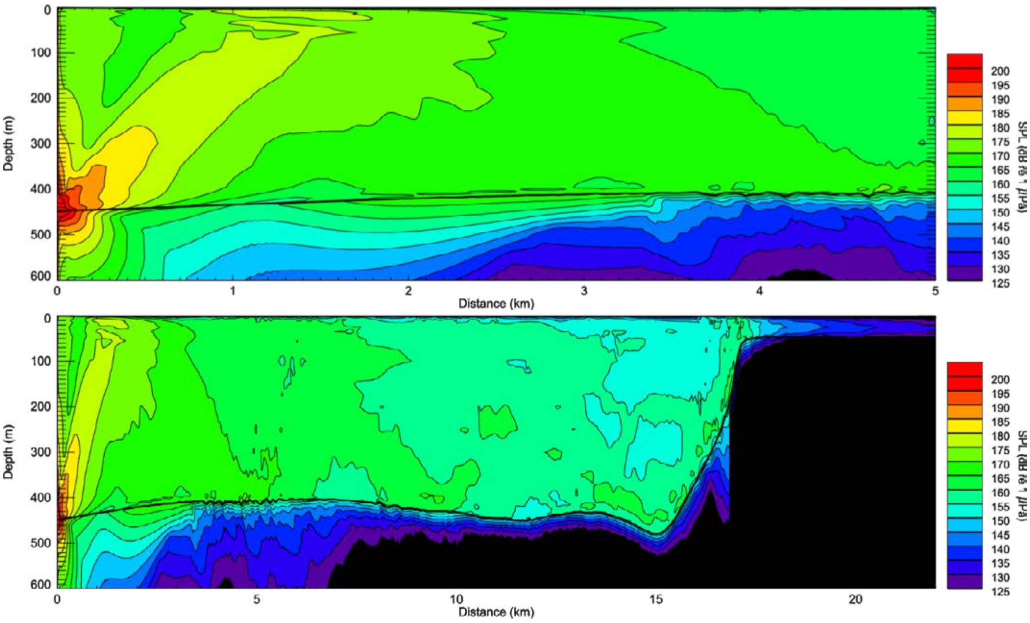

Figure 28. *Torosa, vertical slice, IHC S-1200, SPL, 17 m penetration depth*: 0–5 km (top) and 0–22 km (bottom). Levels are shown along a single transect of azimuth 240°. The seabed outline is shown as a thick black line.

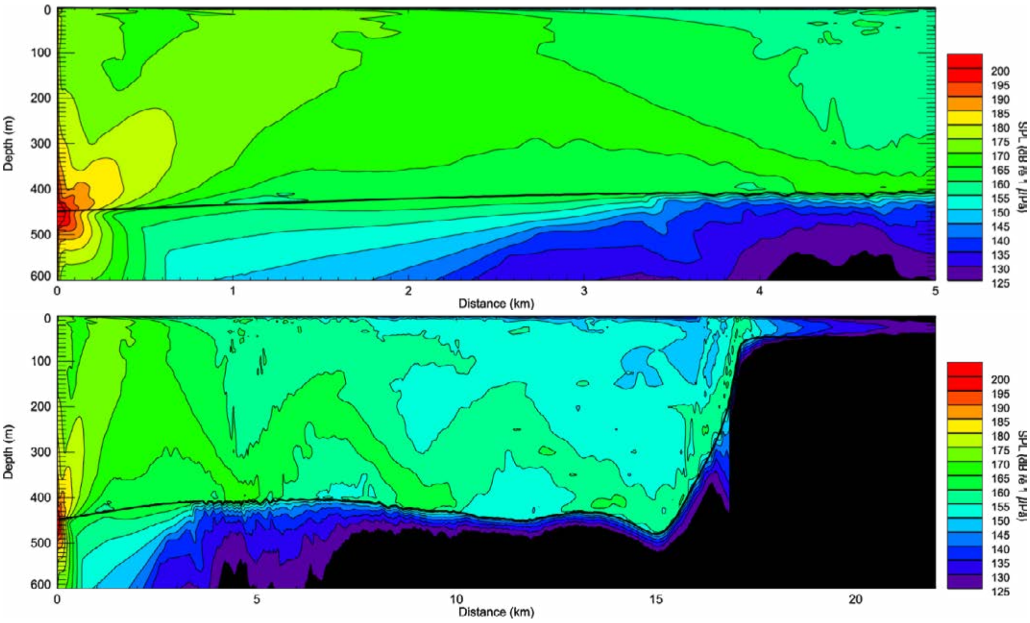

Figure 29. *Torosa, vertical slice, IHC S-1200, SPL, 31 m penetration depth*: 0–5 km (top) and 0–22 km (bottom). Levels are shown along a single transect of azimuth 240°. The seabed outline is shown as a thick black line.

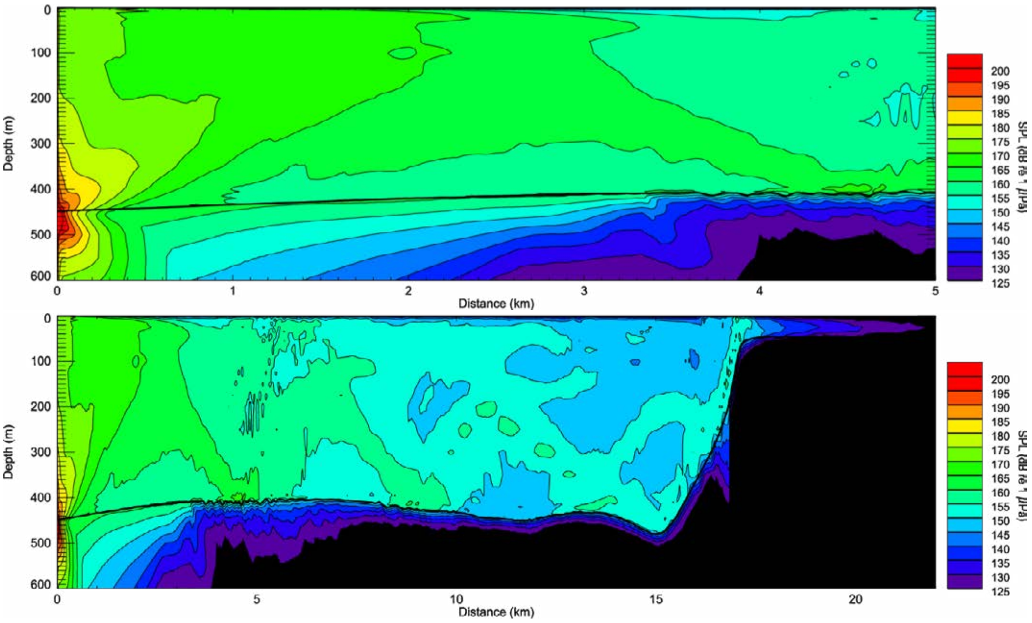

Figure 30. *Torosa, vertical slice, IHC S-1200, SPL, 45 m penetration depth*: 0–5 km (top) and 0–22 km (bottom). Levels are shown along a single transect of azimuth 240°. The seabed outline is shown as a thick black line.

Detailed plots of the sound fields along two transects for both the IHC S-600 and IHC S-1200 hammers relevant to the pygmy blue whale migratory behavioural profile (Table G-2) are shown in Figures 31–34. These plots highlight 1) the mean migratory dive depth (14 m), 2) 23 m – almost the deepest point of the migratory dives but the start point for exploratory dives, 3) the mean exploratory dive depth (107 m), and 4) the deepest point for exploratory dives (320 m), with all values from Owen et al. (2016).

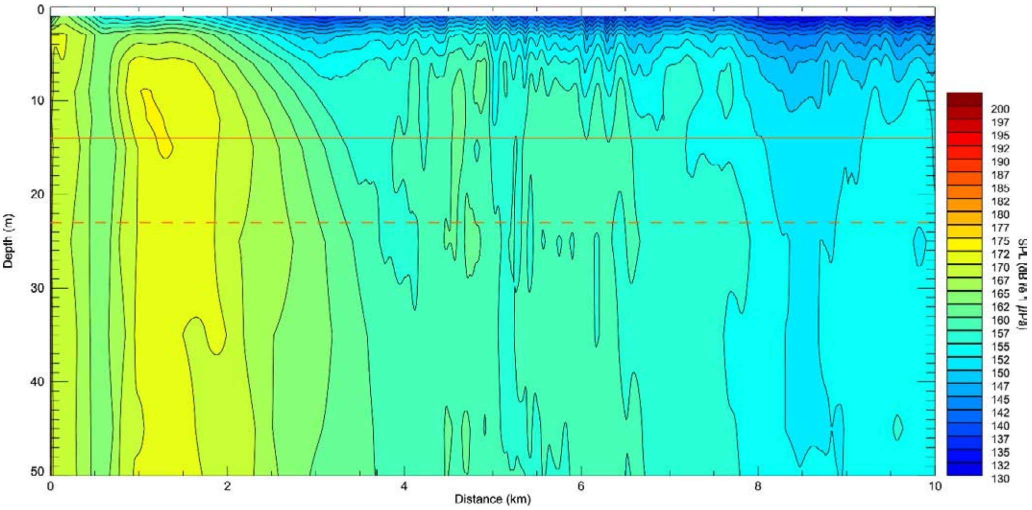

Figure 31. *Torosa, vertical slice, IHC S-600, SPL, 17 m penetration depth*: Levels are shown along a single transect of azimuth 240°, out to 10 km range, and down to 50 m depth, highlighting the depths of 14 and 23 m.

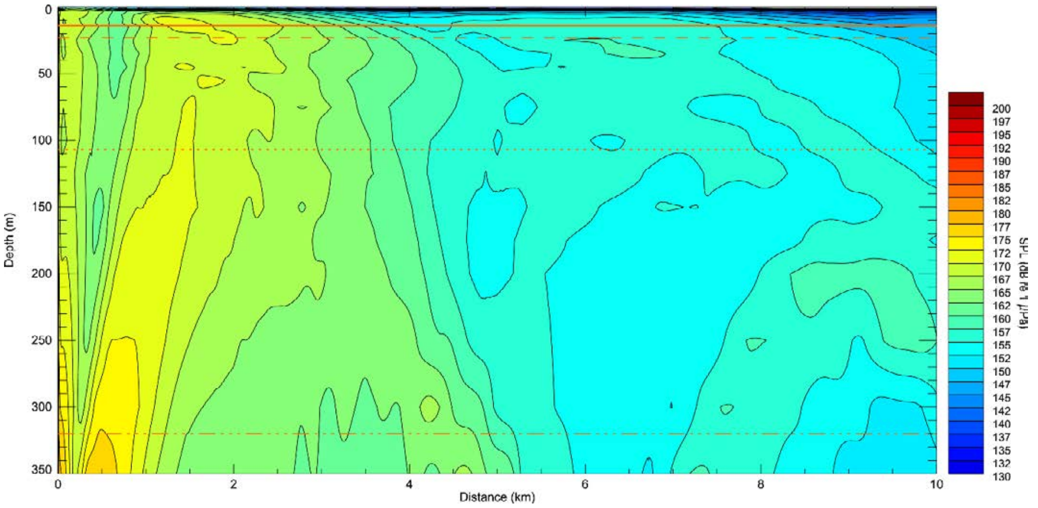

Figure 32. *Torosa, vertical slice, IHC S-600, SPL, 17 m penetration depth*: Levels are shown along a single transect of azimuth 240°, out to 10 km range, and down to 350 m depth, highlighting the depths of 14, 23, 107 and 320 m.

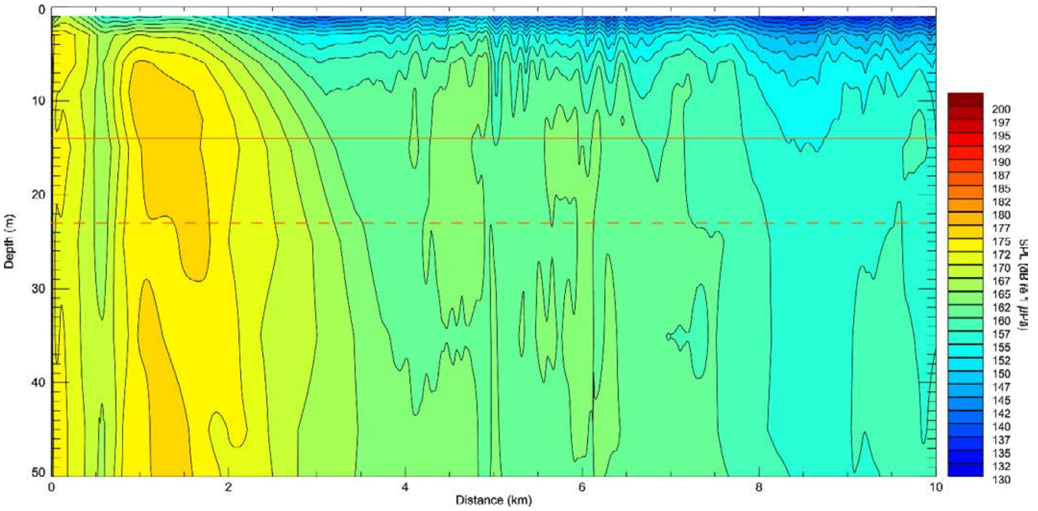

Figure 33. *Torosa, vertical slice, IHC S-1200, SPL, 17 m penetration depth*: Levels are shown along a single transect of azimuth 240°, out to 10 km range, and down to 50 m depth, highlighting the depths of 14 and 23 m.

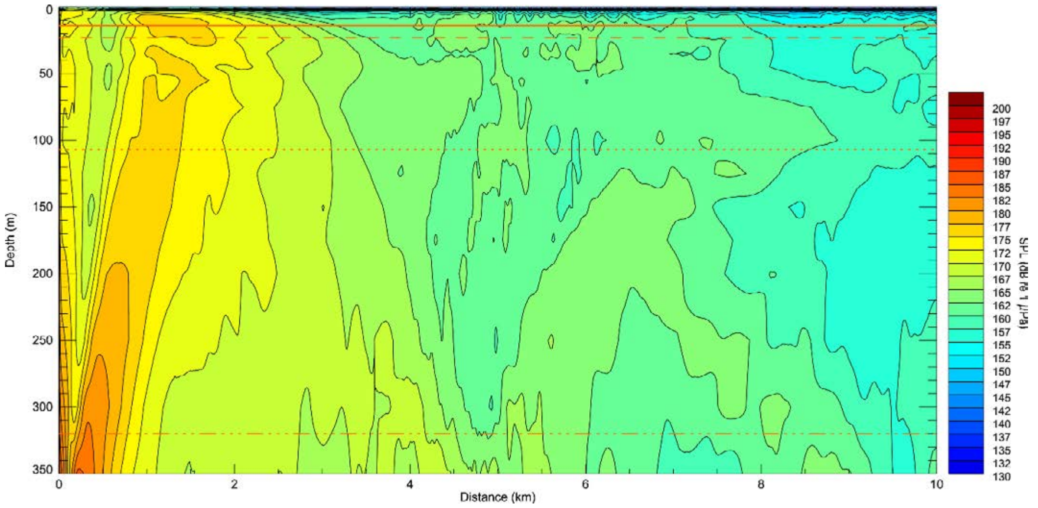

Figure 34. *Torosa, vertical slice, IHC S-1200, SPL, 17 m penetration depth*: Levels are shown along a single transect of azimuth 240°, out to 10 km range, and down to 350 m depth, highlighting the depths of 14, 23, 107 and 320 m.

4.1.3. Multiple Strike Sound Fields

Table 27 presents the SEL24h results relevant to marine mammals for the proposed pile driving operations, while Table 28 shows modelled distances to the cumulative exposure criteria contours for fish, fish eggs and larvae. The sound levels at the Scott Reef coastal waters limit are shown in Table 29. The sound level contour maps for cetaceans and turtles are presented in Figures 35 and 36 for the IHC S-600 and the IHC S-1200 hammers, respectively. The sound level contour maps for fish are presented in Figures 37 and 38 for the IHC S-600 and the IHC S-1200 hammers, respectively.

Table 27. *Torosa piling, SEL_{24}*: Maximum-over-depth distances (in km) to frequency-weighted SEL_{24h} based marine mammal PTS and TTS thresholds (NMFS 2018) and turtles (Finneran et al. 2017).

Hearing group	**PTS**					**TTS**				
	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s) #	**IHC S-600**		**IHC S-1200**		**Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s) #**	**IHC S-600**		**IHC S-1200**	
		R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)		R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
LF cetaceans	183	5.15	5.00	5.35	5.12	168	26.10	20.79	29.46	22.60
MF cetaceans	185	-	-	-	-	170	0.03	0.03	0.06	0.06
HF cetaceans	155	0.07	0.07	0.17	0.16	140	0.32	0.30	2.20	2.06
Turtles	204	0.24	0.23	0.25	0.25	189	4.79	2.36	5.07	4.94

Frequency weighted.
A dash indicates the level was not reached.

Table 28. *Torosa piling, SEL24*: Maximum-over-depth distances (in km) to SEL_{24h} based fish criteria. Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.

Marine animal group	**Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)**	**Distance**			
		IHC S-600		**IHC S-1200**	
		R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
Fish mortality and potential mortal injury					
I	219	0.06	0.06	0.06	0.06
II Fish eggs and larvae	210	0.15	0.14	0.15	0.15
III	207	0.21	0.20	0.22	0.21
Fish recoverable injury					
I	216	0.09	0.09	0.09	0.09
II, III	203	0.32	0.30	0.34	0.33
Fish TTS					
I, II, III	186	9.05	5.41	9.15	5.56

Table 29. *Torosa piling, SEL24*: Modelled maximum-over-depth SEL_{24h} at the receiver located at the Scott Reef coastal waters limit.

Frequency weighting	**SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)**	
	IHC S-600	IHC S-1200
Unweighted	183.4	184.3
LF cetaceans	177.6	178.0
MF cetaceans	128.2	130.7
HF cetaceans	117.5	124.5
Turtles	182.0	182.7

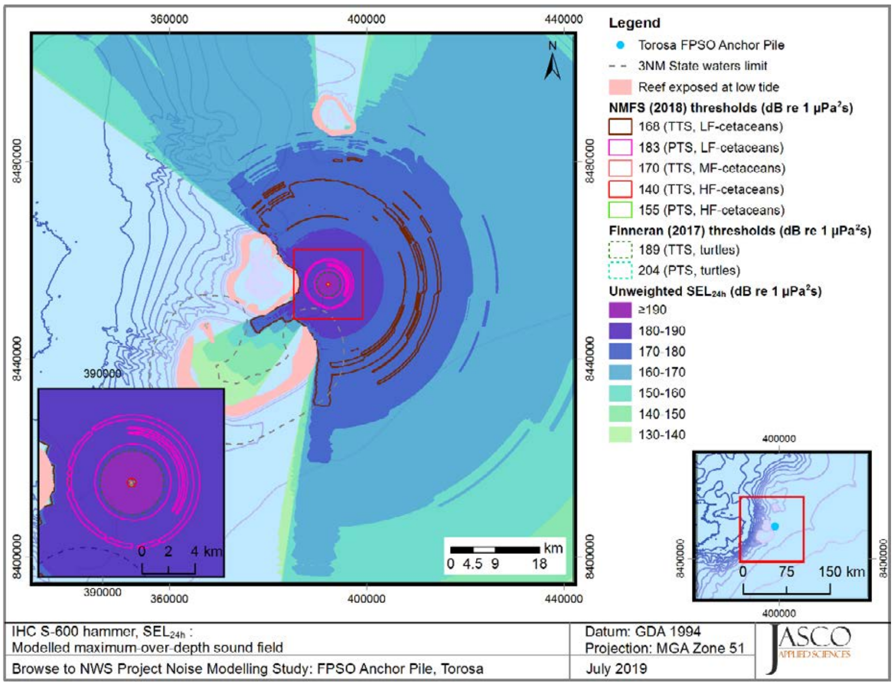

Figure 35. *Torosa, IHC S-600, SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with isopleths for low-, mid-, and high-frequency cetaceans and turtles. Threshold for mid-frequency cetacean PTS was not reached.

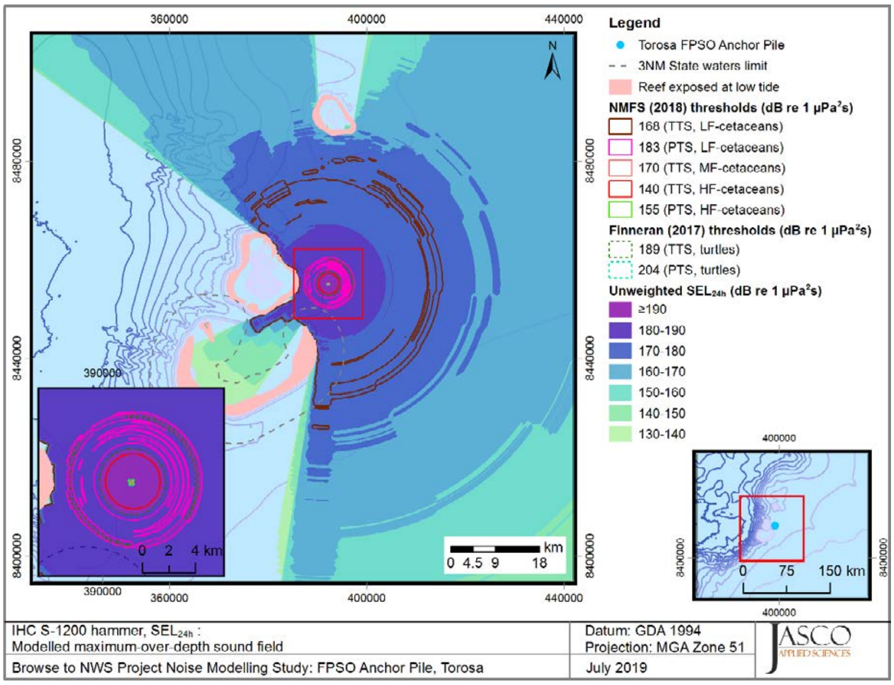

Figure 36. *Torosa, IHC S-1200, SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with isopleths for low-, mid-, and high-frequency cetaceans and turtles. Threshold for mid-frequency cetacean PTS was not reached.

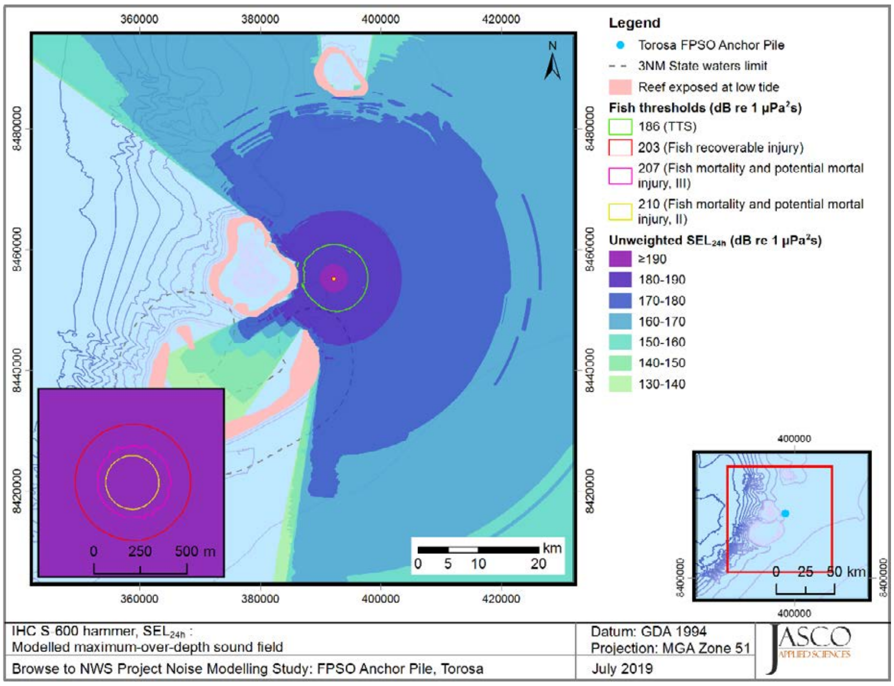

Figure 37. *Torosa, IHC S-600, SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with isopleths relevant to fish injury and TTS. Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.

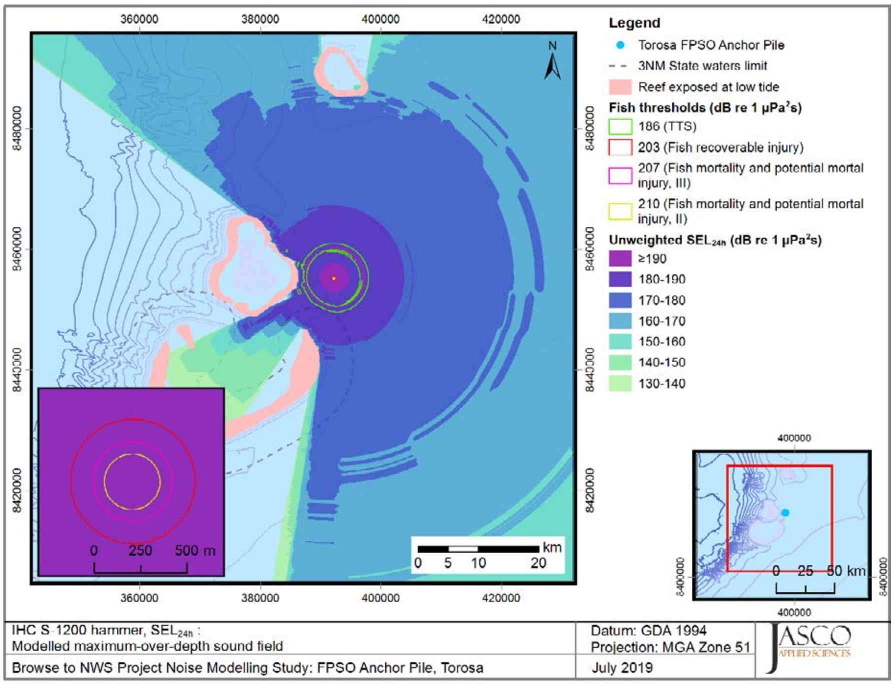

Figure 38. *Torosa, IHC S-1200, SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with isopleths relevant to fish injury and TTS. Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.

4.1.4. Animal Movement and Exposure Modelling

Summaries of the animat modelling results for inter-nesting and migrating green turtles are provided in Table 30, while those for migrating and foraging pygmy blue whales are provided in Table 31.

Table 30. *Torosa*: Summary of animat simulation results for migratory and inter-nesting turtles. Includes the distances to acoustic modelling thresholds (km), the 95th percentile exposure ranges (km), and the number of real-world individuals exposed above threshold (where densities are available). This summary includes both the original animat simulation results and the results excluding animats within a 500 m zone surrounding the pile, acoustic modelling results are presented in Tables 23, 24, and 27.

Threshold		**Distance to threshold from acoustic modelling**		**Migratory turtles**	**Migratory turtles with 500 m exclusion zone**		**Inter-nesting turtles**		**Inter-nesting turtles with 500 m exclusion zone**	
Threshold description	Sound level (dB)	R_{max} (km)	$R_{95\%}$ (km)	Range, P_{95} (km)	Range, P_{95} (km)	Reduction (%)	Range, P_{95} (km)	Number of individuals	Range, P_{95} (km)	Number of individuals
IHC S-600 hammer										
TTS, PK	226†	<0.02*		0.00	0.00	0	0.00	0.00	0.00	0.00
TTS, SEL_{24h}	189‡	4.79	2.36	1.65	1.69	20.67	0.00	0.00	0.00	0.00
PTS, PK	232†	<0.02*		0.00	0.00	0	0.00	0.00	0.00	0.00
PTS, SEL_{24h}	204‡	0.24	0.23	0.00	0.00	0	0.00	0.00	0.00	0.00
Behavioural response	166#	5.11	4.99	2.54	2.56	10.98	0.00	0.00	0.00	0.00
	175#	0.68	0.64	0.05	0.00	100.00	0.00	0.00	0.00	0.00
IHC S-1200 hammer										
TTS, PK	226†	<0.02*		0.00	0.00	0	0.00	0.00	0.00	0.00
TTS, SEL_{24h}	189‡	5.07	4.94	1.79	1.81	11.48	0.00	0.00	0.00	0.00
PTS, PK	232†	<0.02*		0.00	0.00	0	0.00	0.00	0.00	0.00
PTS, SEL_{24h}	204‡	0.25	0.25	0.00	0.00	0	0.00	0.00	0.00	0.00
Behavioural response	166#	9.11	5.66	4.64	4.71	4.25	0.00	0.00	0.00	0.00
	175#	1.87	1.79	1.77	1.78	6.25	0.00	0.00	0.00	0.00

† PK (L_{pk}; dB re 1 µPa)
‡ Turtle weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa^2·s)
# SPL (L_p; dB re 1 µPa)
* R_{max} reported for TTS PK and PTS PK from acoustic modelling

Table 31. *Torosa*: Summary of animat simulation results for migratory and foraging pygmy blue whales. Includes the distances to acoustic modelling thresholds (km), the 95th percentile exposure ranges (km), and the number of real-world individuals exposed above threshold (where densities are available). This summary includes both the original animat simulation results and the results excluding animats within a 2000 m zone surrounding the pile, acoustic modelling results are presented in Tables 23, 24 and 27.

Threshold		**Distance to threshold from acoustic modelling**		**Migrating pygmy blue whales**		**Migrating pygmy blue whales with 2000 m exclusion zone**		**Foraging pygmy blue whales**		**Foraging pygmy blue whales with 2000 m exclusion zone**	
Threshold description	Sound level (dB)	R_{max} (km)	$R_{95\%}$ (km)	Range, P_{95} (km)	Number of individuals	Range, P_{95} (km)	Number of individuals	Range, P_{95} (km)	Number of individuals	Range, P_{95} (km)	Number of individuals
IHC S-600 hammer											
TTS, PK	213†	0.08*		0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00
TTS, SEL_{24h}	168‡	26.10	20.79	7.27	1.28	7.72	1.05	10.75	1.65	10.84	1.52
PTS, PK	219†	< 0.02*		0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
PTS, SEL_{24h}	183‡	5.00	5.00	0.91	0.02	0.00	0.00	1.45	0.06	0.00	0.00
Behavioural response	160#	10.48	6.74	6.29	0.56	6.87	0.32	6.72	0.58	6.91	0.43
IHC S-1200 hammer											
TTS, PK	213†	0.1*		0.00	0.00	0.00	0.00	0.1	0.00	0.00	0.00
TTS, SEL_{24h}	168‡	29.46	22.60	8.34	1.30	8.58	1.13	11.92	1.75	12.03	1.64
PTS, PK	219†	0.05*		0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00
PTS, SEL_{24h}	183‡	5.35	5.12	1.31	0.02	0.00	0.00	1.57	0.06	2.09	0.00
Behavioural response	160#	17.15	11.63	9.14	1.41	9.73	1.22	10.72	1.39	10.83	1.28

† PK (L_{pk}; dB re 1 µPa)
‡ LF-weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa^2·s)
# SPL (L_p; dB re 1 µPa)
* R_{max} reported for TTS PK and PTS PK from acoustic modelling

4.2. Pile Driving: Brecknock FPSO Anchor Piles

4.2.1. Received levels at 10 m

Since piles are distributed and directional sources, they cannot be accurately approximated by a point source with corresponding source levels. It is possible to compare the maximum modelled levels at short distances from the piles. Figure 39 shows the 1/3-octave-band levels for the receiver with the highest SEL at the closest horizontal range (10 m), for the three modelled penetrations. The levels above 1000 Hz were extrapolated using a 20 dB/decade decay rate to match acoustic measurements of impact pile driving of similarly sized piles (Illingworth & Rodkin 2007, Matuschek and Betke 2009). The modelled results at a distance of 10 m are included to provide results comparable to other pile driving reports and literature, such as Illingworth & Rodkin (2007), and Denes et al. (2016).

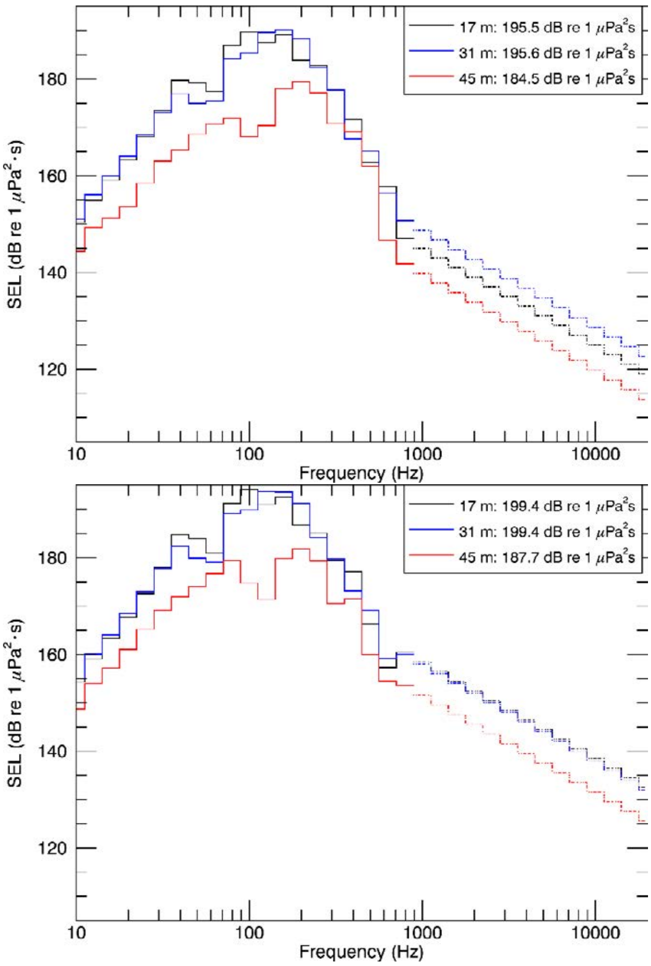

Figure 39. *Brecknock*: One-third-octave-band levels for the receiver with highest SEL at 10 m horizontal range for impact pile driving using the IHC S-600 (top) and the IHC S-1200 (bottom), after high-frequency extrapolation (dashes indicate extrapolated portion of the spectrum). Legend items indicate the modelled pile penetration (Table 16) and the broadband SEL in dB re 1 μPa^2·s.

4.2.2. Per-strike sound fields

Per-strike results for the proposed pile driving are presented in this section for maximum-over-depth SPL, SEL, and PK (tables in Section 4.2.2.1), maps and sound field vertical slices (Section 4.2.2.2).

4.2.2.1. Tabulated results

Tables 32–36 show the estimated distances for the various applicable per-strike effects criteria and isopleths of interest as maximum-over-depth.

Table 32. *Brecknock piling, per-strike SEL:* Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the pile to modelled maximum-over-depth isopleths.

Per-strike SEL (L_E; dB re 1 µPa²·s)	**IHC S-600**						**IHC S-1200**					
	Penetration depth (m)						**Penetration depth (m)**					
	17		**31**		**45**		**17**		**31**		**45**	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
190	0.03	0.03	<0.02	<0.02	-	-	0.06	0.06	0.03	0.03	-	-
180	0.12	0.11	0.09	0.09	0.04	0.04	0.20	0.20	0.14	0.13	0.07	0.07
170	0.38	0.37	0.28	0.25	0.16	0.15	0.67	0.63	0.44	0.41	0.27	0.26
160	2.31	2.18	0.91	0.85	0.61	0.57	5.76	5.21	2.26	2.13	1.01	0.97
150	10.60	7.42	6.62	6.24	5.41	5.03	17.06	13.23	13.07	10.99	6.40	5.89
140	28.89	23.24	23.11	19.12	16.63	12.42	43.63	35.59	39.08	28.08	23.02	18.45
130	>79.98	*	>79.98	*	41.18	29.74	>79.98	*	>79.98	*	79.69	73.15
120	>79.98	*	>79.98	*	>79.98	*	>79.98	*	>79.98	*	>79.98	*

* Radii unresolvable due to R_{max} exceeding maximum modelled distance.

Table 33. *Brecknock piling, SPL:* Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the pile to modelled maximum-over-depth isopleths.

SPL (L_p; dB re 1 µPa)	**IHC S-600**						**IHC S-1200**					
	Penetration depth (m)						**Penetration depth (m)**					
	17		**31**		**45**		**17**		**31**		**45**	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
200	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	0.05	0.03	0.03	<0.02	<0.02
190	0.11	0.10	0.08	0.07	0.03	0.03	0.18	0.17	0.13	0.12	0.06	0.06
180	0.33	0.31	0.25	0.23	0.14	0.13	0.56	0.54	0.39	0.37	0.24	0.23
170	2.04	1.94	0.77	0.72	0.51	0.49	2.87	2.70	2.02	1.92	0.83	0.78
160	7.06	6.40	6.40	5.78	4.54	4.41	13.97	11.87	11.51	10.26	6.19	5.61
150	24.76	21.29	21.35	17.05	13.92	10.99	42.30	30.79	31.07	25.70	21.39	16.94
140	>79.98	*	>79.98	*	31.59	26.41	>79.98	*	>79.98	*	74.59	63.09
130	>79.98	*	>79.98	*	>79.98	*	>79.98	*	>79.98	*	>79.98	*

* Radii unresolvable due to R_{max} exceeding maximum modelled distance.

Table 34. *Brecknock piling, marine mammal and turtle behavioural response thresholds, SPL*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the pile to modelled maximum-over-depth isopleths per penetration depth.

Threshold	**IHC S-600**						**IHC S-1200**					
	Penetration depth (m)						**Penetration depth (m)**					
	17		**31**		**45**		**17**		**31**		**45**	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
Marine mammal behavioural response (160 dB re 1 µPa SPL) (NMFS 2014)	7.06	6.40	6.40	5.78	4.54	4.41	13.97	11.87	11.51	10.26	6.19	5.61
Turtle behavioural response (166 dB re 1 µPa SPL) (NSF 2011)	2.87	2.70	2.06	1.95	0.84	0.80	6.38	5.92	5.93	5.51	2.12	2.04
Turtle behavioural disturbance (175 dB re 1 µPa SPL) (McCauley et al. 2000a, 2000b)	0.67	0.63	0.42	0.39	0.28	0.26	1.87	1.77	0.69	0.64	0.45	0.42

Table 35. *Brecknock piling, marine mammal and turtle PTS and TTS PK thresholds*: Maximum (R_{max}) horizontal distances (in m) from the pile to maximum-over-depth isopleths.

Hearing group	**PTS**							**TTS**						
	PK threshold (L_{pk}; dB re 1 µPa	**IHC S-600**			**IHC S-1200**			**PK threshold (L_{pk}; dB re 1 µPa**	**IHC S-600**			**IHC S-1200**		
		Penetration depth (m)			Penetration depth (m)				Penetration depth (m)			Penetration depth (m)		
		17	31	45	17	31	45		17	31	45	17	31	45
LF cetaceans	219	<20	<20	<20	<20	<20	<20	213	42	<20	<20	71	32	<20
MF cetaceans	230	<20	<20	<20	<20	<20	<20	224	<20	<20	<20	<20	<20	<20
HF cetaceans	202	186	148	76	258	216	121	196	364	275	177	559	402	270
Turtles	232	<20	<20	<20	<20	<20	<20	226	<20	<20	<20	<20	<20	<20

Table 36. *Brecknock piling, mortality and potential mortal recoverable injury thresholds (peak pressure level metric) for fish, fish eggs, and fish larvae*: Maximum (R_{max}) horizontal distances (in m) from the pile.

Marine animal group	**PK threshold (L_{pk}; dB re 1 µPa)**	**IHC S-600**			**IHC S-1200**		
		Penetration depth (m)			**Penetration depth (m)**		
		17	31	45	17	31	45
Fish: No swim bladder	213	42	<20	<20	71	32	<20
Fish: Swim bladder not involved in hearing, Swim bladder involved in hearing Fish eggs, and larvae	207	103	76	32	158	121	58

4.2.2.2. Sound field maps and vertical slices

Maps of the per-strike SPL results associated with the three modelled penetration depths are shown in Figures 40, 41, and 42 for the IHC S-600, and in Figures 43, 44, and 45 for the IHC S-1200. Per-strike SEL maps are shown in Appendix H.2. For each hammer, the shallowest modelled penetration has the farthest distances to all per-strike isopleths. Additionally, maps showing the isopleths for marine mammal behavioural criteria (160 dB re 1 µPa) for each of the three considered penetration depths are provided in Figures 46 and 47 for the IHC S-600 and the IHC S-1200, respectively, to demonstrate visually the reduction in extent with increased penetration depth. Vertical slice plots for all penetrations are shown in Figures 48–50 (IHC S-600) and Figures 51–53 (IHC S-1200).

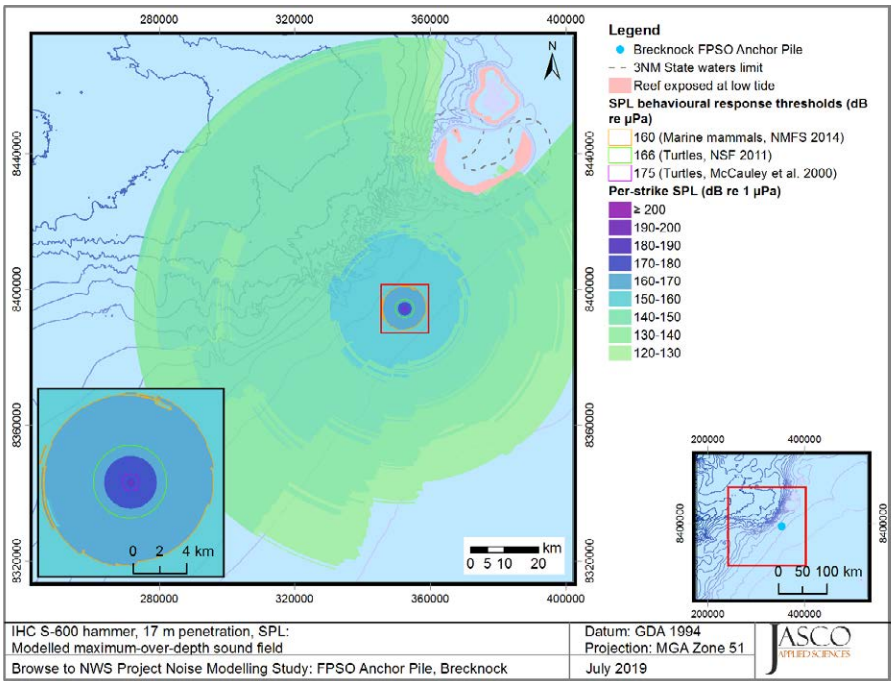

Figure 40. *Brecknock, IHC S-600, SPL, 17 m penetration depth*: Sound level contour map, showing maximum-over-depth results. Isopleths for turtles (166 and 175 dB re 1 µPa) and marine mammal (160 dB re 1 µPa) behavioural criteria are shown.

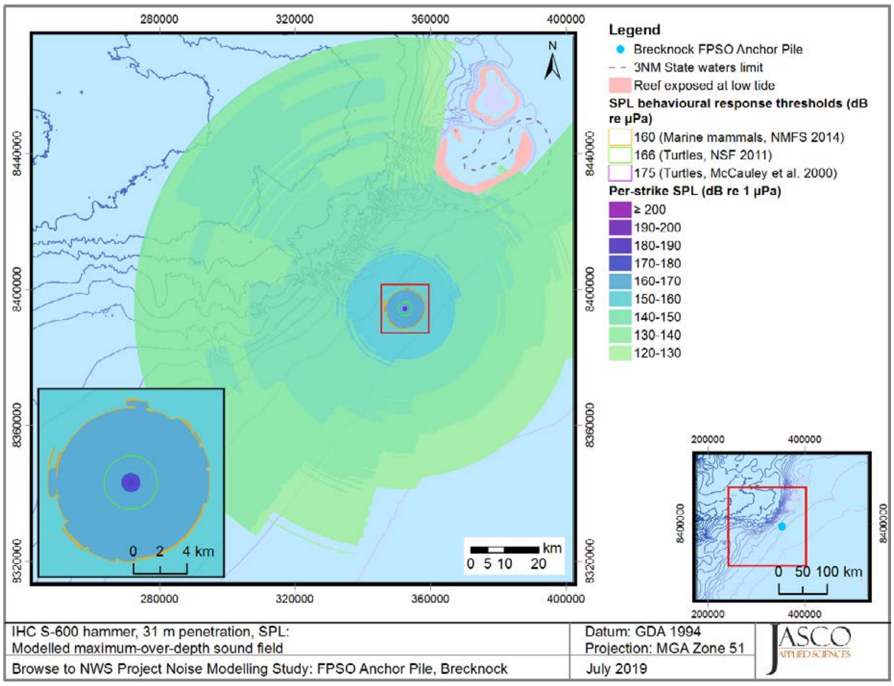

Figure 41. *Brecknock, IHC S-600, SPL, 31 m penetration depth*: Sound level contour map, showing maximum-over-depth results. Isopleths for turtles (166 and 175 dB re 1 µPa) and marine mammal (160 dB re 1 µPa) behavioural criteria are shown.

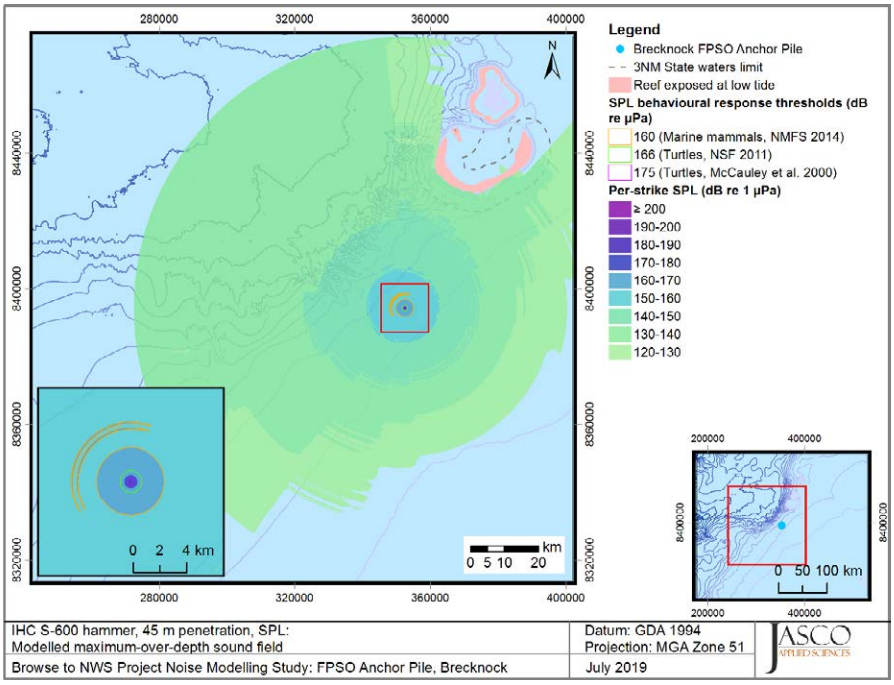

Figure 42. *Brecknock, IHC S-600, SPL, 45 m penetration depth*: Sound level contour map, showing maximum-over-depth results. Isopleths for turtles (166 and 175 dB re 1 µPa) and marine mammal (160 dB re 1 µPa) behavioural criteria are shown.

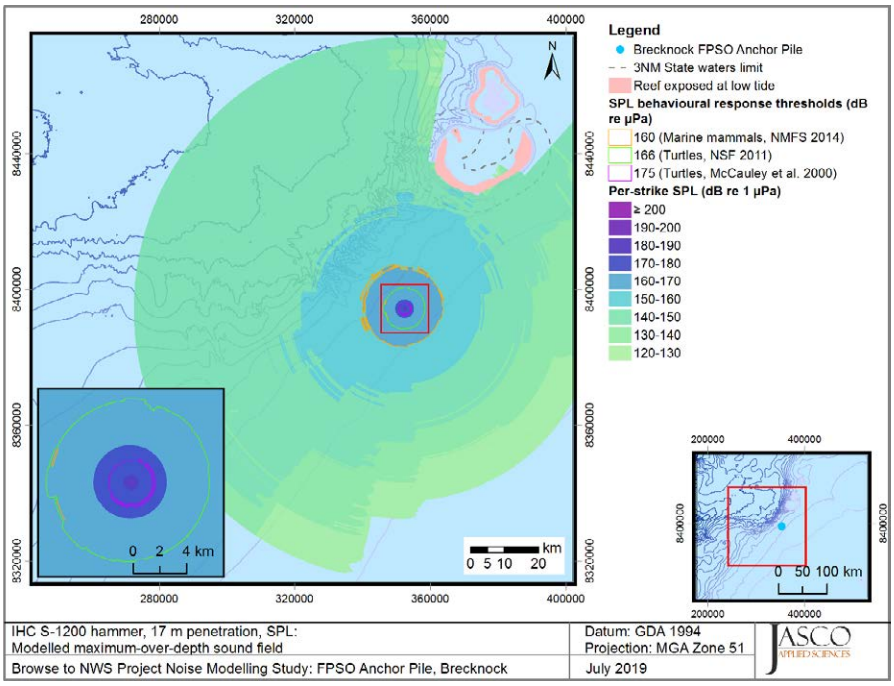

Figure 43. *Brecknock, IHC S-1200, SPL, 17 m penetration depth*: Sound level contour map, showing unweighted maximum-over-depth results. Isopleths for turtles (166 and 175 dB re 1 µPa) and marine mammal (160 dB re 1 µPa) behavioural criteria are shown.

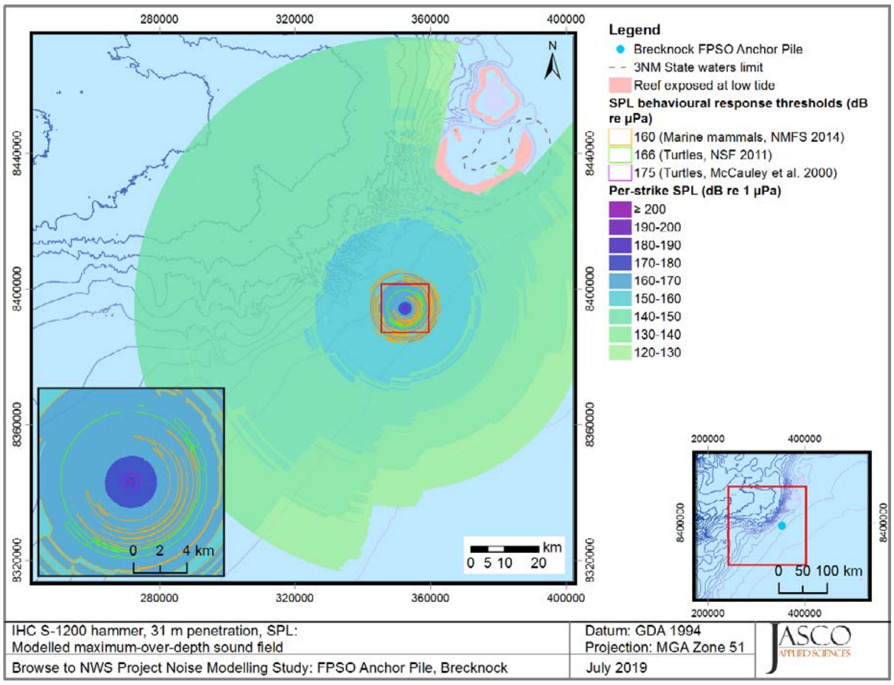

Figure 44. *Brecknock, IHC S-1200, SPL, 31 m penetration depth*: Sound level contour map, showing maximum-over-depth results. Isopleths for turtles (166 and 175 dB re 1 µPa) and marine mammal (160 dB re 1 µPa) behavioural criteria are shown.

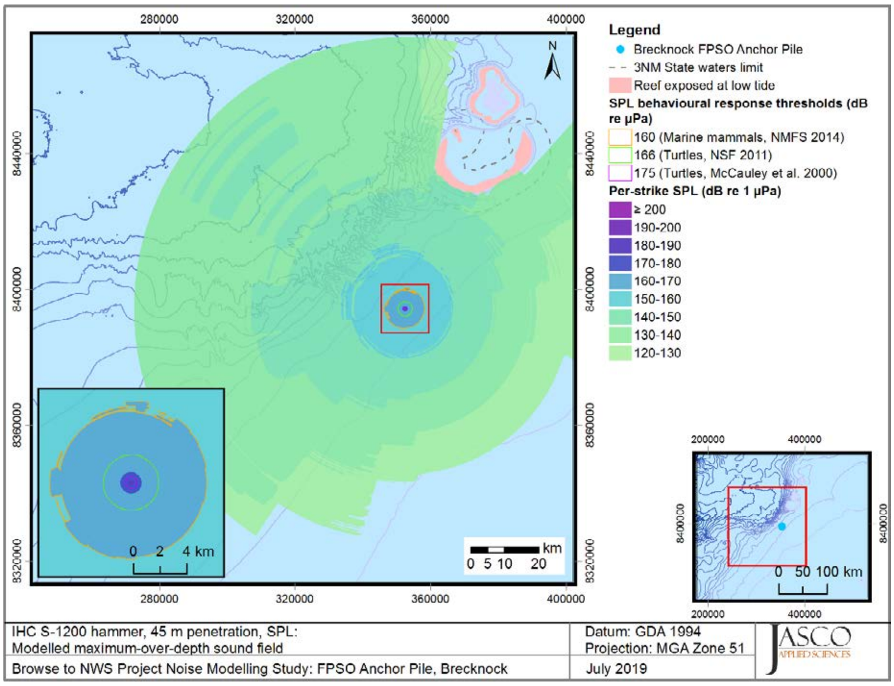

Figure 45. *Brecknock, IHC S-1200, SPL, 45 m penetration depth*: Sound level contour map, showing maximum-over-depth results. Isopleths for turtles (166 and 175 dB re 1 µPa) and marine mammal (160 dB re 1 µPa) behavioural criteria are shown.

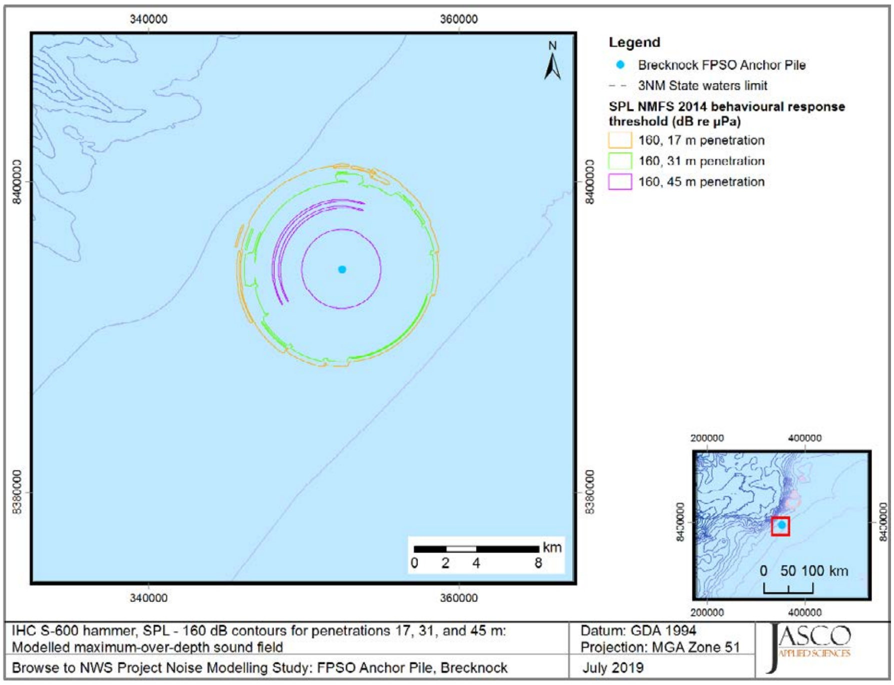

Figure 46. *Brecknock, IHC S-600, SPL*: Sound level contour map showing unweighted maximum-over-depth SPL marine mammal (160 dB re 1 µPa) behavioural criteria results for all modelled penetration depths.

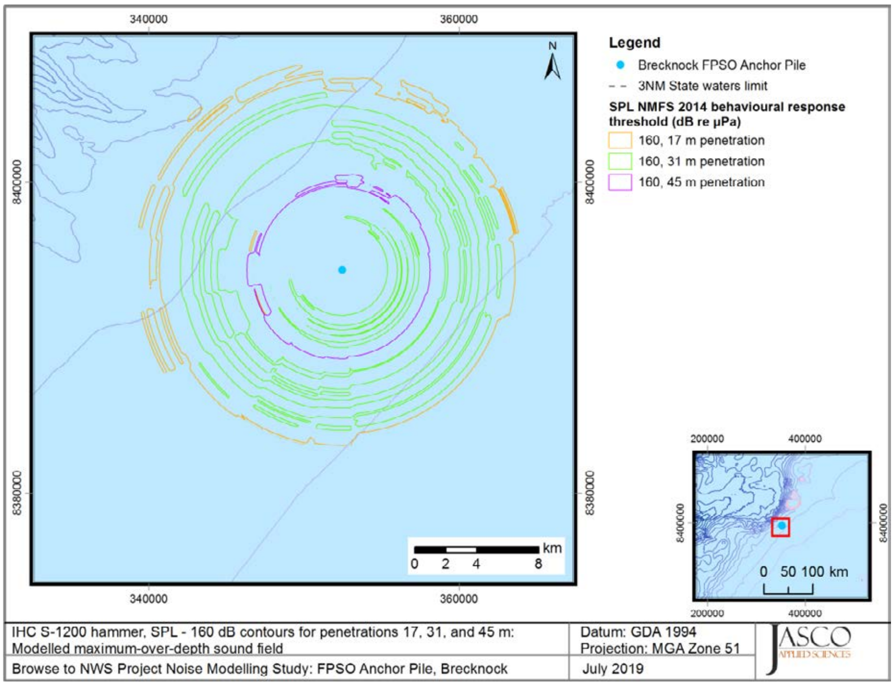

Figure 47. *Brecknock, IHC S-1200, SPL*: Sound level contour map showing unweighted maximum-over-depth SPL marine mammal (160 dB re 1 µPa) behavioural criteria results for all modelled penetration depths.

4.2.2.2.1. Vertical slice plots

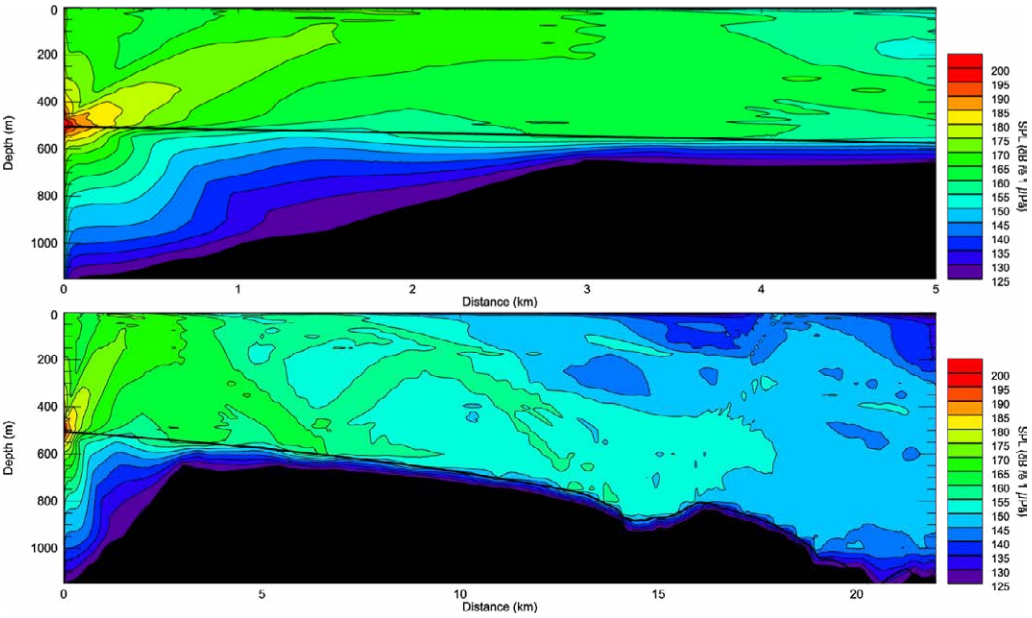

Figure 48. *Brecknock, vertical slice, IHC S-600, SPL, 17 m penetration depth*: 0–5 km (top) and 0–22 km (bottom). Levels are shown along a single transect of azimuth 315°. The seabed outline is shown as a thick black line.

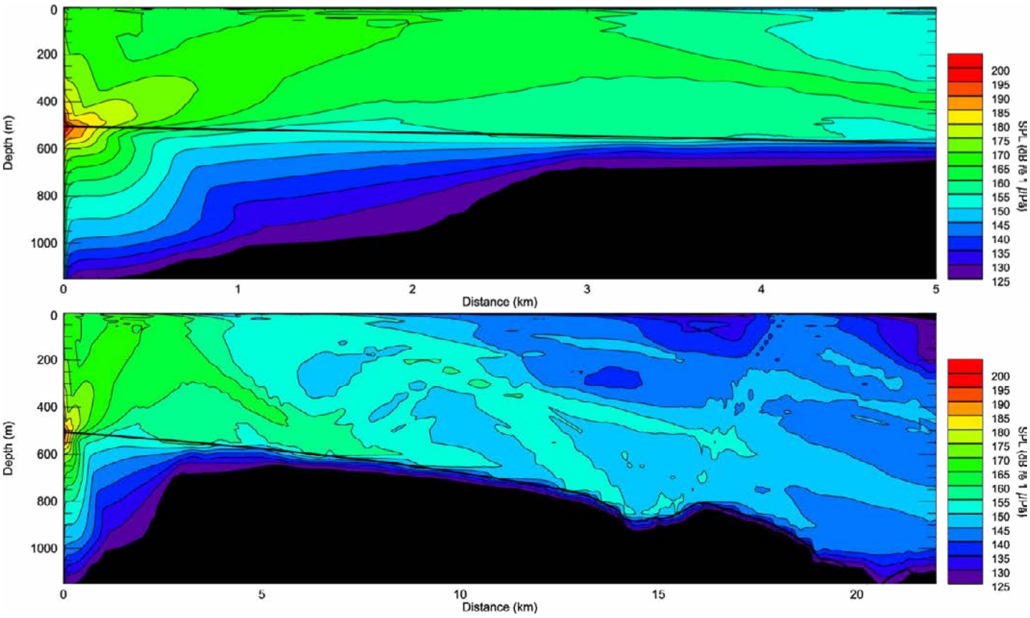

Figure 49. *Brecknock, vertical slice, IHC S-600, SPL, 31 m penetration depth*: 0–5 km (top) and 0–22 km (bottom). Levels are shown along a single transect of azimuth 315°. The seabed outline is shown as a thick black line.

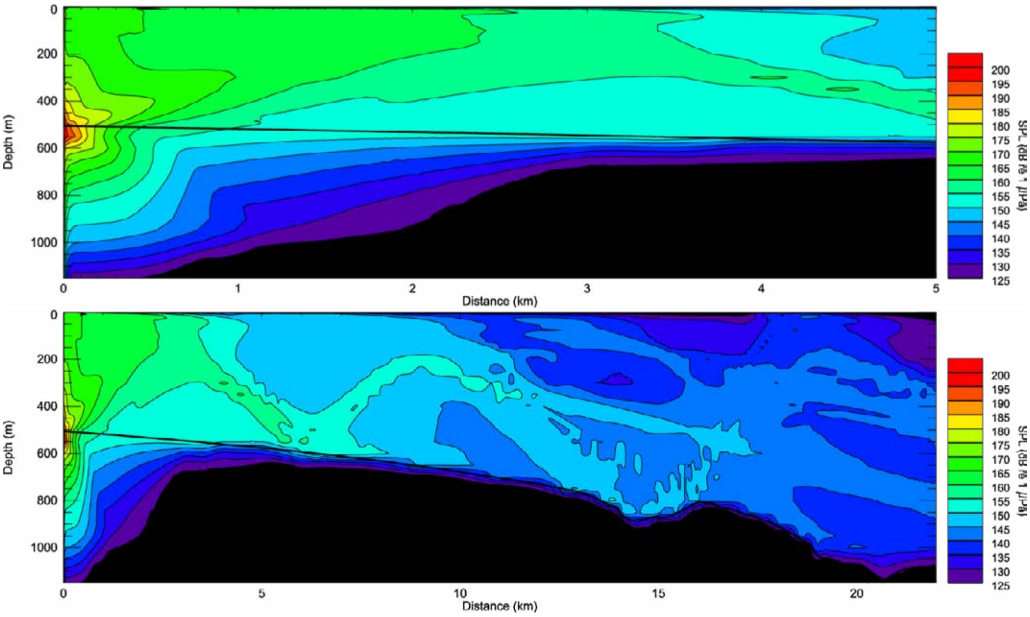

Figure 50. *Brecknock, vertical slice, IHC S-600, SPL, 45 m penetration depth*: 0–5 km (top) and 0–22 km (bottom). Levels are shown along a single transect of azimuth 315°. The seabed outline is shown as a thick black line.

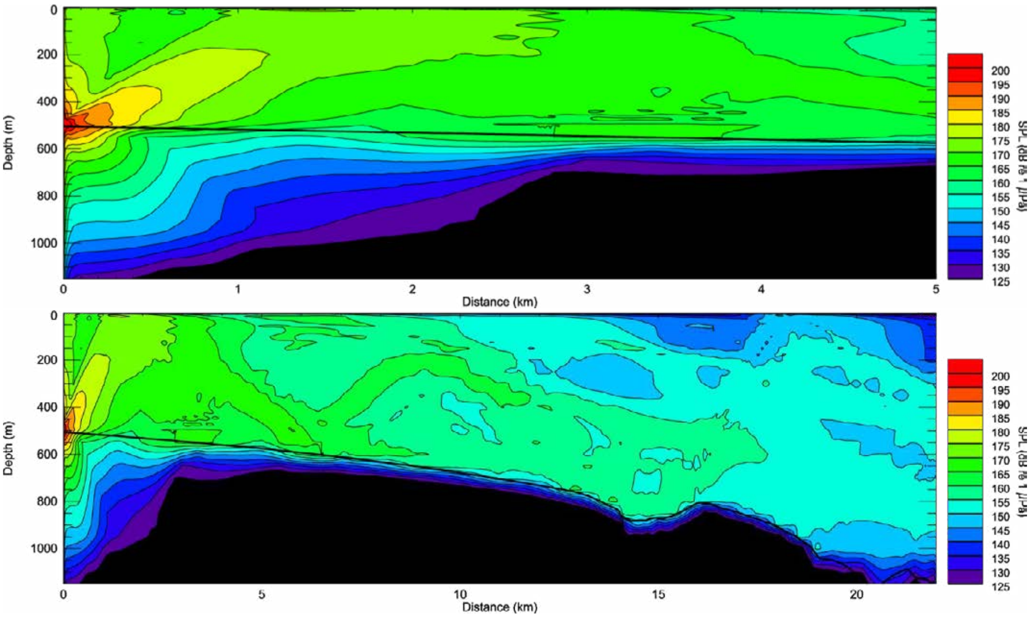

Figure 51. *Brecknock, vertical slice, IHC S-1200, SPL, 17 m penetration depth*: 0–5 km (top) and 0–22 km (bottom). Levels are shown along a single transect of azimuth 315°. The seabed outline is shown as a thick black line.

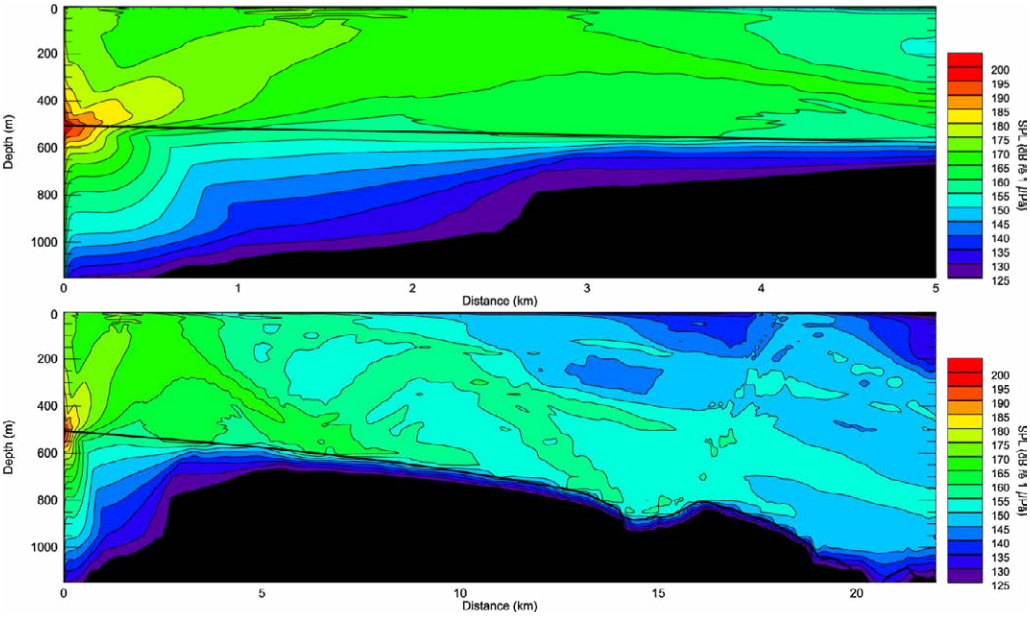

Figure 52. *Brecknock, vertical slice, IHC S-1200, SPL, 31 m penetration depth*: 0–5 km (top) and 0–22 km (bottom). Levels are shown along a single transect of azimuth 315°. The seabed outline is shown as a thick black line.

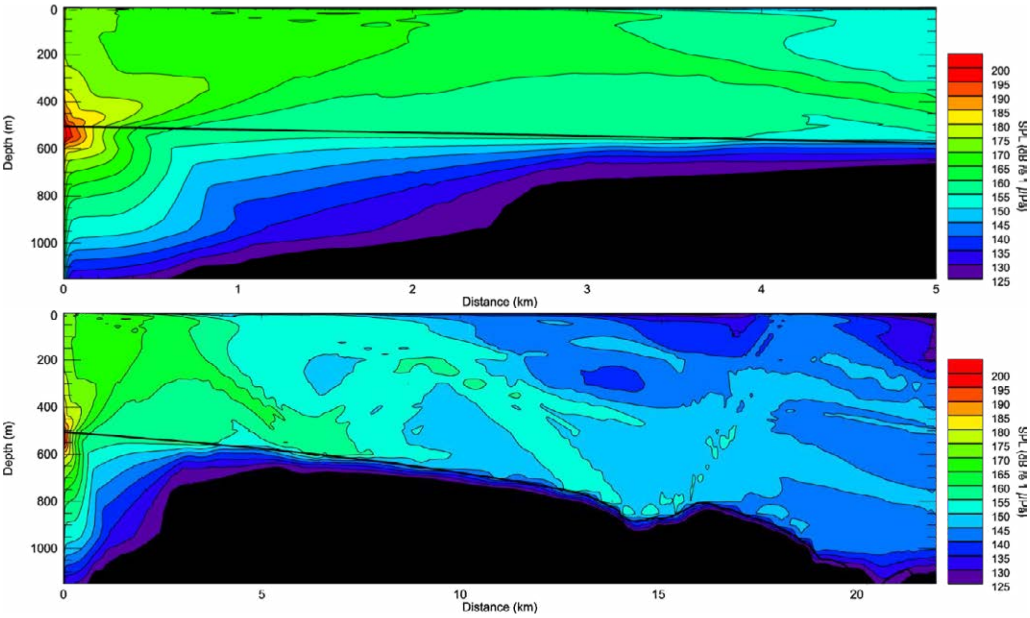

Figure 53. *Brecknock, vertical slice, IHC S-1200, SPL, 45 m penetration depth*: 0–5 km (top) and 0–22 km (bottom). Levels are shown along a single transect of azimuth 315°. The seabed outline is shown as a thick black line.

Detailed plots of the sound fields along two transects for both the IHC S-600 and IHC S-1200 hammers relevant to the pygmy blue whale migratory behavioural profile (Table G-2) are shown in Figures 58–61. These plots highlight 1) the mean migratory dive depth (14 m), 2) 23 m – almost the deepest point of the migratory dives but the start point for exploratory dives, 3) the mean exploratory dive depth (107 m), and 4) the deepest point for exploratory dives (320 m), with all values from Owen et al. (2016).

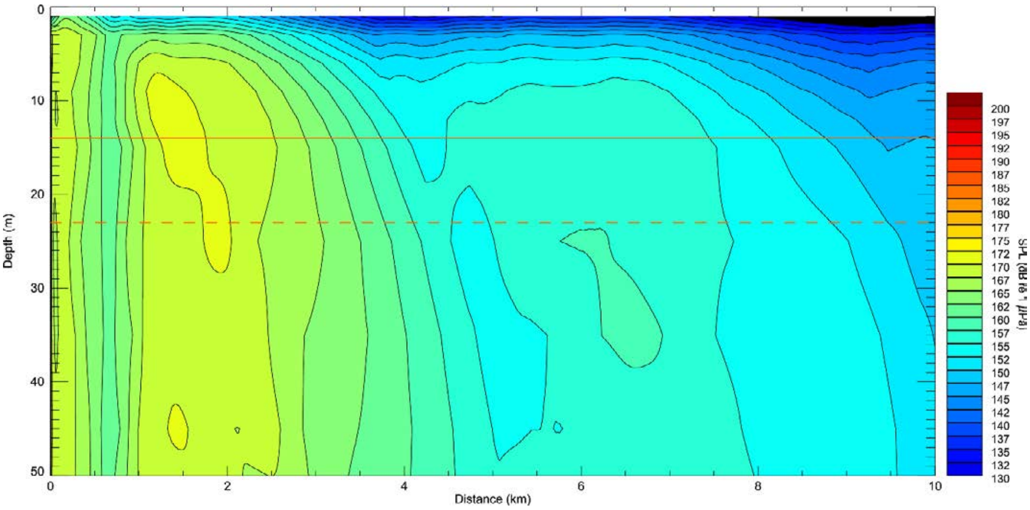

Figure 54. *Brecknock, vertical slice, IHC S-600, SPL, 17 m penetration depth*: Levels are shown along a single transect of azimuth 315°, out to 10 km range, and down to 50 m depth, highlighting the depths of 14 and 23 m.

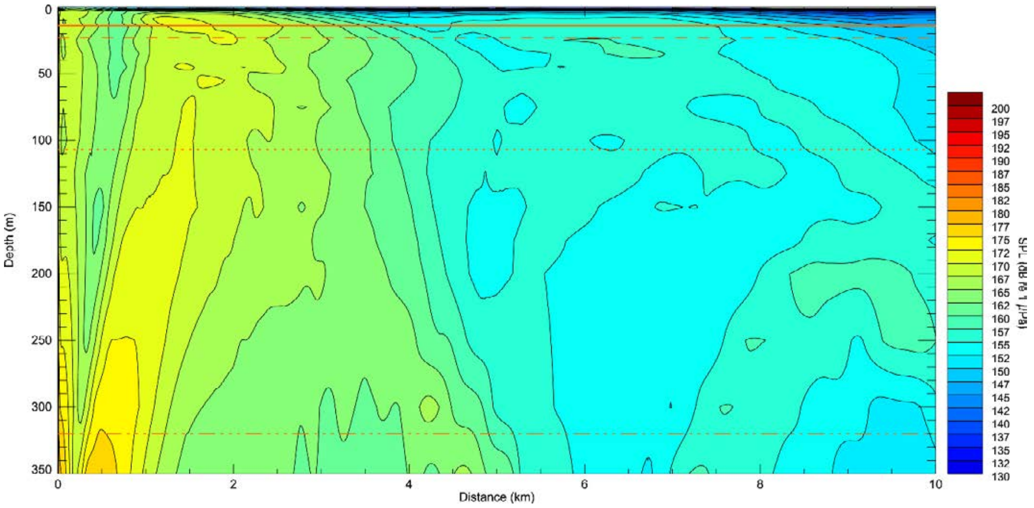

Figure 55. *Brecknock, vertical slice, IHC S-600, SPL, 17 m penetration depth*: Levels are shown along a single transect of azimuth 315°, out to 10 km range, and down to 350 m depth, highlighting the depths of 14, 23, 107 and 320 m.

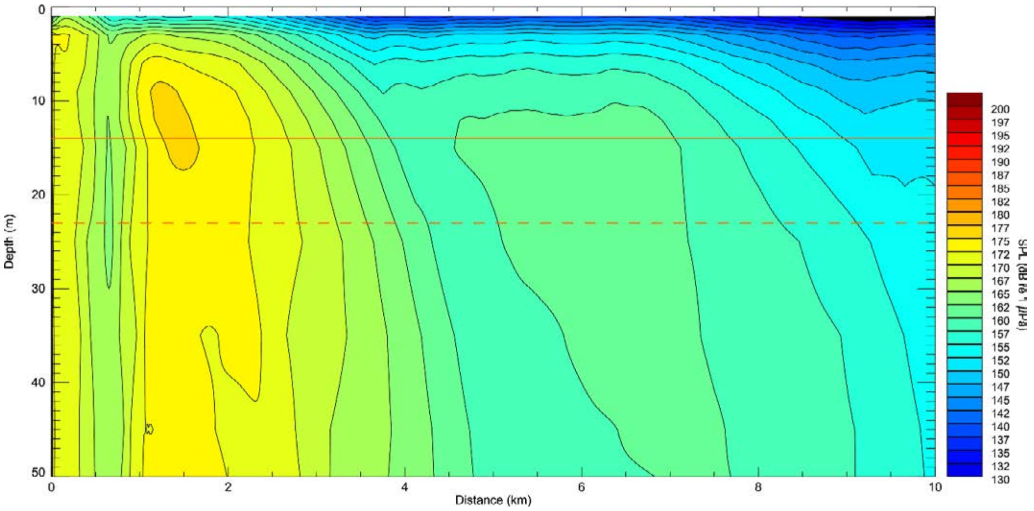

Figure 56. *Brecknock, vertical slice, IHC S-1200, SPL, 17 m penetration depth*: Levels are shown along a single transect of azimuth 315°, out to 10 km range, and down to 50 m depth, highlighting the depths of 14 and 23 m.

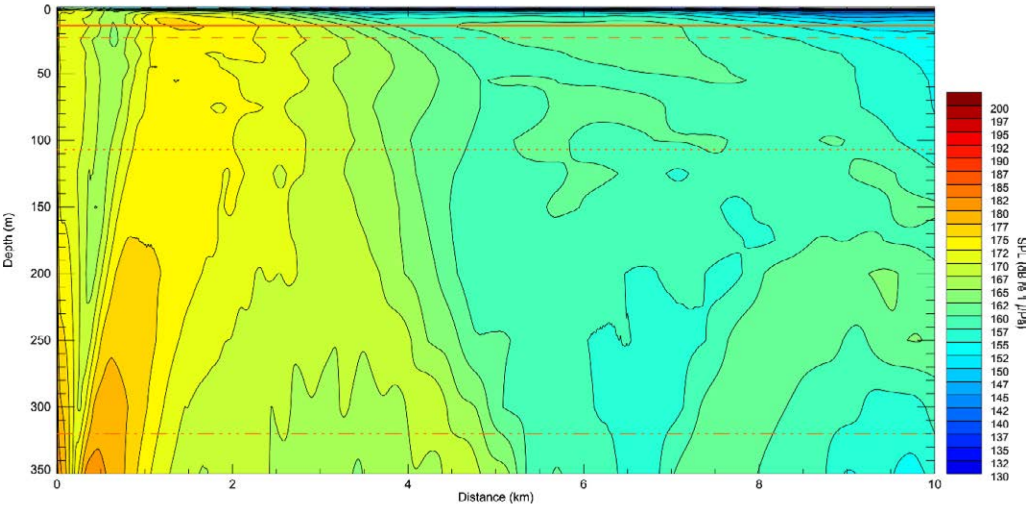

Figure 57. *Brecknock, vertical slice, IHC S-1200, SPL, 17 m penetration depth*: Levels are shown along a single transect of azimuth 315°, out to 10 km range, and down to 350 m depth, highlighting the depths of 14, 23, 107 and 320 m.

4.2.3. Multiple Strike Sound Fields

Table 37 presents the SEL_{24h} results relevant to marine mammals for the proposed pile driving operations, while Table 38 shows modelled distances to the cumulative exposure criteria contours for fish, fish eggs and larvae. The sound level contour maps for cetaceans and turtles are presented in Figures 58 and 59 for the IHC S-600 and the IHC S-1200 hammers, respectively. The sound level contour maps for fish are presented in Figures 60 and 61 for the IHC S-600 and the IHC S-1200 hammers, respectively.

Table 37. *Brecknock piling*: Maximum-over-depth distances (in km) to frequency-weighted SEL_{24h} based marine mammal PTS and TTS thresholds (NMFS 2018) and turtles (Finneran et al. 2017).

Hearing group	**PTS**					**TTS**				
	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s) #	**IHC S-600**		**IHC S-1200**		**Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)** #	**IHC S-600**		**IHC S-1200**	
		R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)		R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
LF cetaceans	183	4.58	4.05	4.62	4.40	168	23.11	20.04	24.75	20.80
MF cetaceans	185	-	-	-	-	170	<0.02	<0.02	0.05	0.05
HF cetaceans	155	0.06	0.06	0.17	0.16	140	0.33	0.31	2.33	2.20
Turtles	204	0.24	0.23	0.25	0.24	189	2.58	2.44	2.60	2.47

A dash indicates the level was not reached.
Frequency weighted.

Table 38. *Brecknock piling*: Maximum-over-depth distances (in km) to SEL_{24h} based fish criteria. Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.

Marine animal group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Distance			
		IHC S-600		IHC S-1200	
		R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
Fish mortality and potential mortal injury					
I	219	0.04	0.04	0.04	0.04
II Fish eggs and larvae	210	0.14	0.13	0.15	0.15
III	207	0.20	0.19	0.22	0.21
Fish recoverable injury					
I	216	0.06	0.06	0.07	0.07
II, III	203	0.31	0.29	0.34	0.32
Fish TTS					
I, II, III	186	6.12	5.54	6.27	5.74

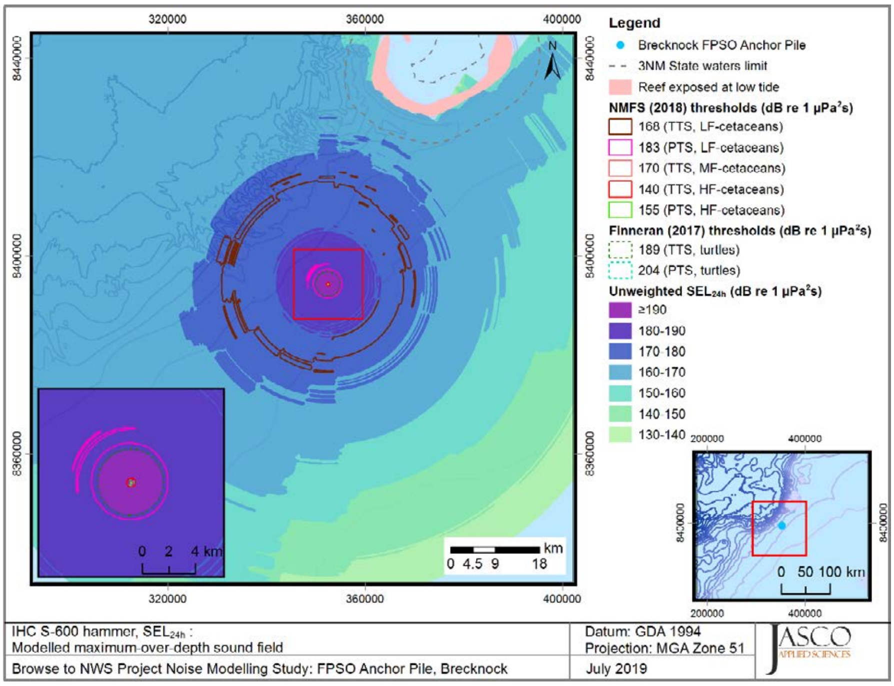

Figure 58. *Brecknock, IHC S-600, SEL_{24h}*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with isopleths for low-, mid-, and high-frequency cetaceans and turtles. Threshold for mid-frequency cetacean PTS was not reached.

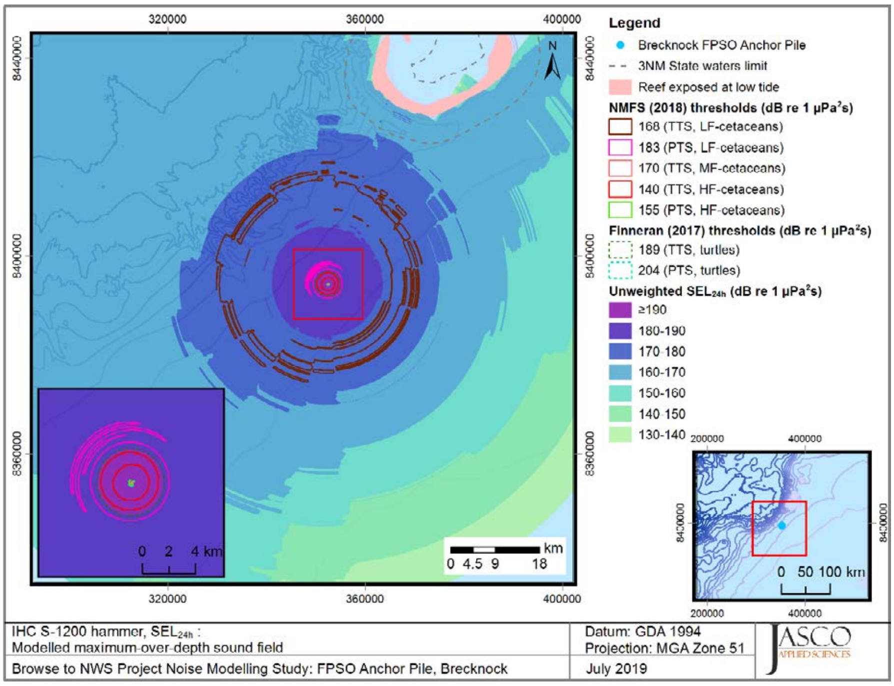

Figure 59. *Brecknock, IHC S-1200, SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with isopleths for low-, mid-, and high-frequency cetaceans and turtles. Threshold for mid-frequency cetacean PTS was not reached.

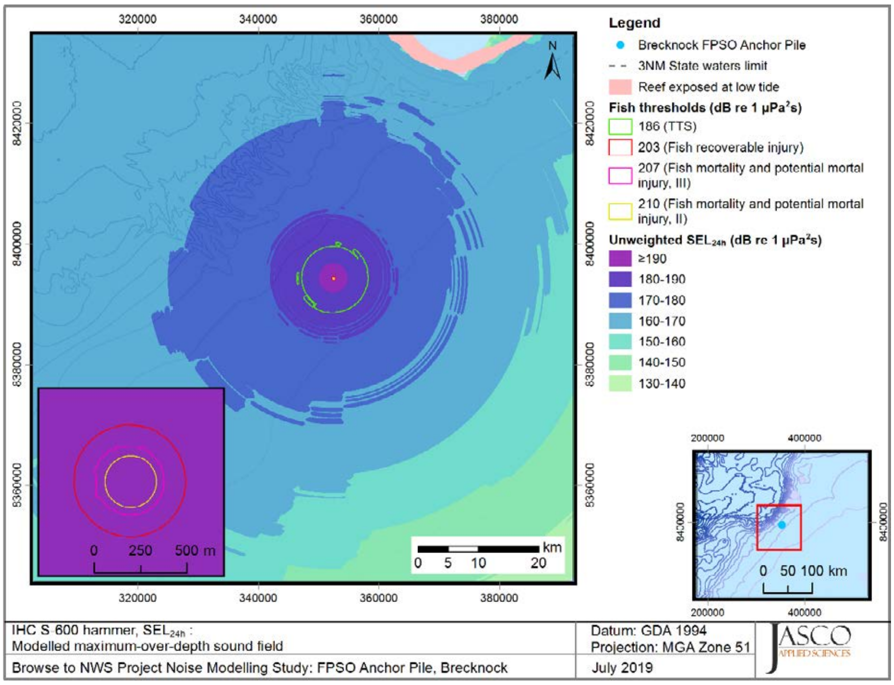

Figure 60. *Brecknock, IHC S-600, SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with isopleths relevant to fish injury and TTS. Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.

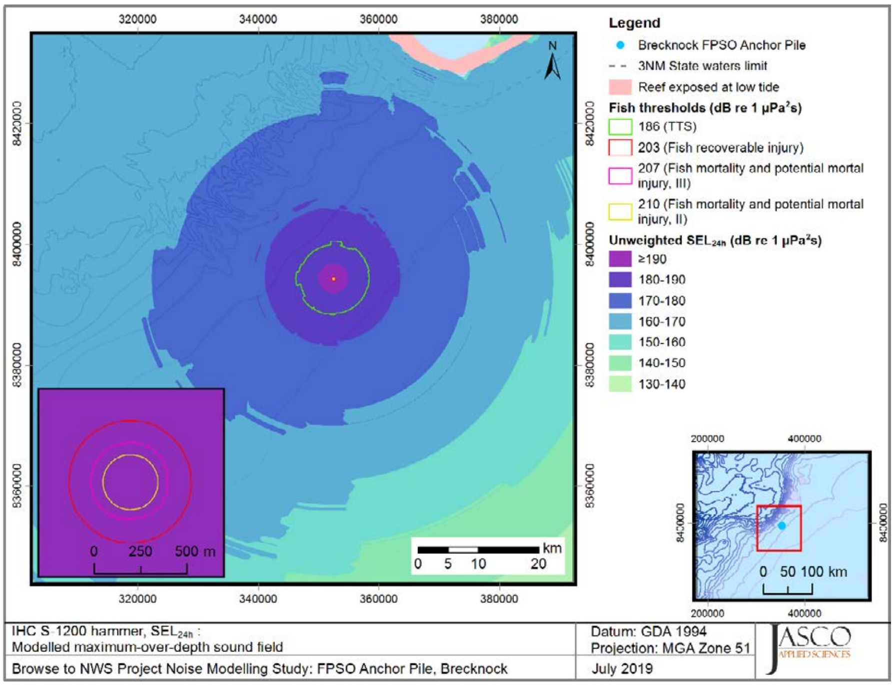

Figure 61. *Brecknock, IHC S-1200, SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with isopleths relevant to fish injury and TTS. Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.

4.2.4. Animal Movement and Exposure Modelling

Summaries of the animat modelling results for migrating and foraging pygmy blue whales are provided in Table 39. No exposures were recorded for migratory or inter-nesting turtles due to the distance from the pile of the Woodside defined BIAs.

Table 39. *Brecknock*: Summary of animat simulation results for migratory and foraging pygmy blue whales. Includes the distances to acoustic modelling thresholds (km), the 95th percentile exposure ranges (km), and the number of real-world individuals exposed above threshold (where densities are available). This summary includes both the original animat simulation results and the results excluding animats within a 2000 m zone surrounding the pile, acoustic modelling results are presented in Tables 34, 35, and 37.

Threshold		**Distance to threshold from acoustic modelling**		**Migrating pygmy blue whales**		**Migrating pygmy blue whales with 2000 m exclusion zone**		**Foraging pygmy blue whales**		**Foraging pygmy blue whales with 2000 m exclusion zone**	
Threshold description	Sound level (dB)	R_{max} (km)	$R_{95\%}$ (km)	Range, P_{95} (km)	Number of individuals	Range, P_{95} (km)	Number of individuals	Range, P_{95} (km)	Number of individuals	Range, P_{95} (km)	Number of individuals
IHC S-600 hammer											
TTS, PK	213†	0.04*		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TTS, SEL_{24h}	168‡	23.11	20.04	7.50	1.56	7.67	1.26	11.19	0.02	11.19	0.02
PTS, PK	219†	<0.02*		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PTS, SEL_{24h}	183‡	4.58	4.05	1.14	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Behavioural response	160#	7.06	6.40	3.75	0.62	3.91	0.32	0.00	0.00	0.00	0.00
IHC S-1200 hammer											
TTS, PK	213†	0.07*		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TTS, SEL_{24h}	168‡	24.75	20.80	8.07	1.67	8.18	1.45	12.05	0.08	12.05	0.08
PTS, PK	219†	<0.02*		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PTS, SEL_{24h}	183‡	4.62	4.40	1.26	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Behavioural response	160#	13.97	11.87	8.65	1.88	8.73	1.65	12.03	0.08	12.03	0.08

† PK (L_{pk}; dB re 1 µPa)
‡ LF-weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa^2·s)
# SPL (L_p; dB re 1 µPa)
* R_{max} reported for TTS PK and PTS PK from acoustic modelling

4.3. Vertical Seismic Profiling (VSP)

Per-pulse results for the proposed VSP are presented in this section for maximum-over-depth SPL, SEL, and PK (tables in Section 4.3.1.1), maps and sound field vertical slices (Section 4.3.1.2). Multiple pulse results are presented in Section 4.3.2. Table 40 shows the PK and per-pulse SEL source levels in the horizontal-plane broadside (perpendicular to the array), endfire (in-line with the array), and vertical directions. The vertical source level that accounts for the "surface ghost" (the out of phase reflected pulse from the water surface) is also presented to make it easier to compare the output of other seismic source models.

Table 40. Far-field source level specifications for the 750 in^3 array, for a 6 m operational depth. Source levels are for a point-like acoustic source with equivalent far-field acoustic output in the specified direction. Sound level metrics are per-pulse and unweighted.

Direction	**Peak source pressure level ($L_{S,pk}$) (dB re 1 µPa·m)**	**Per-pulse source SEL ($L_{S,E}$) (dB 1 µPa^{2}m^{2}s)**	
		10–2000 Hz	2000–25000 Hz
Broadside	239.8	214.0	168.7
Endfire	240.1	214.1	175.3
Vertical	239.7	214.0	173.2
Vertical (surface affected source level)	239.7	216.2	176.1

4.3.1. Per-pulse Sound Fields

4.3.1.1. Tabulated results

Per-pulse results for the 750 in³ seismic source operating at 6 m are presented for SPL, SEL, PK, and PK-PK, including seafloor PK and PK-PK. Tables 41–43 list the estimated ranges for the various applicable maximum-over-depth per-pulse effects criteria and isopleths of interest. Table 44 lists the estimated ranges for seafloor per-pulse effects criteria and isopleths of interest.

Table 41. *VSP, per-pulse SEL*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the 750 in^3 VSP array to modelled maximum-over-depth unweighted isopleths from the two modelled single impulse sites.

Per-pulse SEL (L_E; dB re 1 µPa²·s)	**Torosa TRD Well**		**Brecknock**	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
190	<0.04	<0.04	<0.04	<0.04
180	0.04	0.04	0.04	0.04
170	0.14	0.14	0.14	0.14
160†	0.53	0.52	0.46	0.45
150	1.74	1.65	1.98	1.85
140	5.10	3.98	4.86	4.37
130	12.81	11.19	16.12	14.38

† Low power zone assessment criteria DEWHA (2008).

Table 42. *VSP, SPL*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the 750 in^3 VSP array to modelled maximum-over-depth isopleths from the two modelled single impulse sites.

SPL (**L_p; dB re 1 µPa**)	**Torosa TRD Well**		**Brecknock**	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
200	<0.04	<0.04	<0.04	<0.04
190	<0.04	<0.04	<0.04	<0.04
180	0.13	0.13	0.13	0.13
175#	0.23	0.23	0.23	0.23
170	0.42	0.41	0.40	0.38
166†	0.81	0.77	0.72	0.69
160‡	1.60	1.52	1.70	1.59
150	4.20	3.60	3.98	3.22
140	11.22	10.33	13.43	11.20
130	28.23	22.32	27.84	23.36

Threshold for turtle behavioural response to impulsive noise (McCauley et al. 2000a).
† Threshold for turtle behavioural response to impulsive noise (NSF 2011).
‡ Cetacean behavioural threshold for impulsive sound sources (NMFS 2014).

Table 43. *VSP, PTS and TTS PK thresholds*: Maximum (R_{max}) horizontal distances (km) from the 750 in^3 VSP array to modelled maximum-over-depth peak pressure level (PK) thresholds based on the NOAA Technical Guidance (NMFS 2018) for cetaceans, and Popper et al. (2014) for fish and Finneran et al. (2017) for turtles, at the modelled sites (Table 8).

Hearing group	**PK threshold** (**L_{pk}; dB re 1 µPa**)	**Distance R_{max} (m)**	
		Torosa TRD Well	**Brecknock**
LF cetaceans (PTS)	219	12	12
LF cetaceans (TTS)	213	21	21
MF cetaceans (PTS)	230	—	—
MF cetaceans (TTS)	224	—	—
HF cetaceans (PTS)	202	68	68
HF cetaceans (TTS)	196	141	139
Fish: No swim bladder (also applied to sharks)	213	21	21
Fish: Swim bladder not involved in hearing; Swim bladder involved in hearing Turtles, fish eggs, and larvae	207	39	40
Turtles (PTS)	232	—	—
Turtles (TTS)	226	—	—

A dash indicates the level was not reached.

Table 44. *VSP, seafloor PK*: Maximum (R_{max}) horizontal distances (in m) from the 750 in^3 VSP array to modelled seafloor peak pressure level thresholds (PK) at the modelled sites (Table 8).

Hearing group/animal type	PK threshold (L_{pk}; dB re 1 µPa)	Distance R_{max} (m)	
		Torosa TRD Well	Brecknock
Sound levels for sponges and corals†	226	—	—
Fish: No swim bladder (also applied to sharks)	213	—	—
Fish: Swim bladder not involved in hearing; Swim bladder involved in hearing Turtles, fish eggs, and larvae	207	—	—

† Heyward et al. (2018)

A dash indicates the level was not reached.

4.3.1.2. Sound field maps and graphs

Maps of the per-pulse SPL results for the two VSP locations are shown in Figures 62 and 63. Per-pulse SEL maps are shown in Appendix H.2.

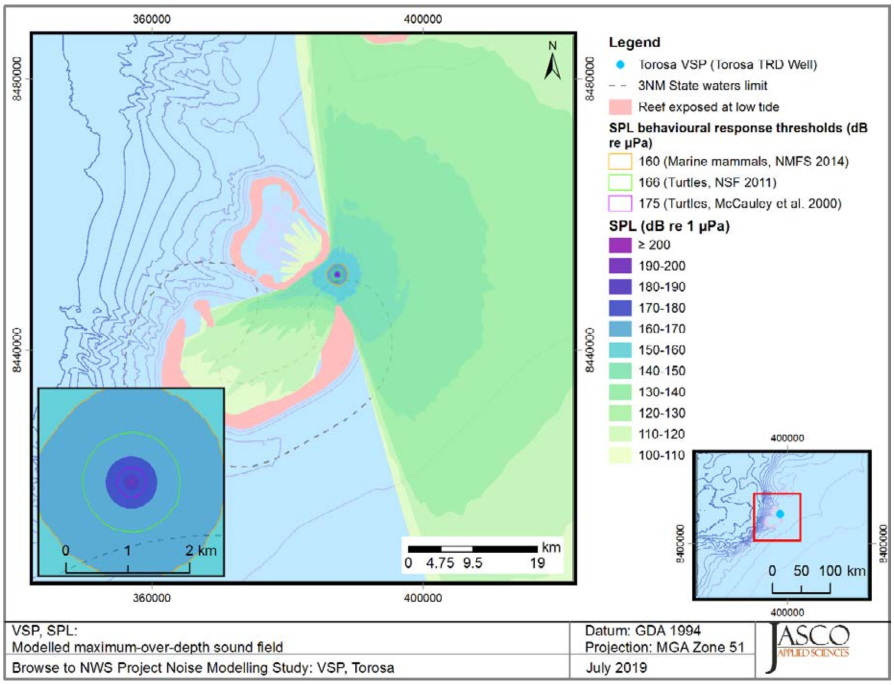

Figure 62. *Torosa TRD Well VSP, SPL:* Sound level contour map, showing maximum-over-depth results. Isopleths for turtles (166 and 175 dB re 1 µPa) and marine mammal (160 dB re 1 µPa) behavioural criteria are shown.

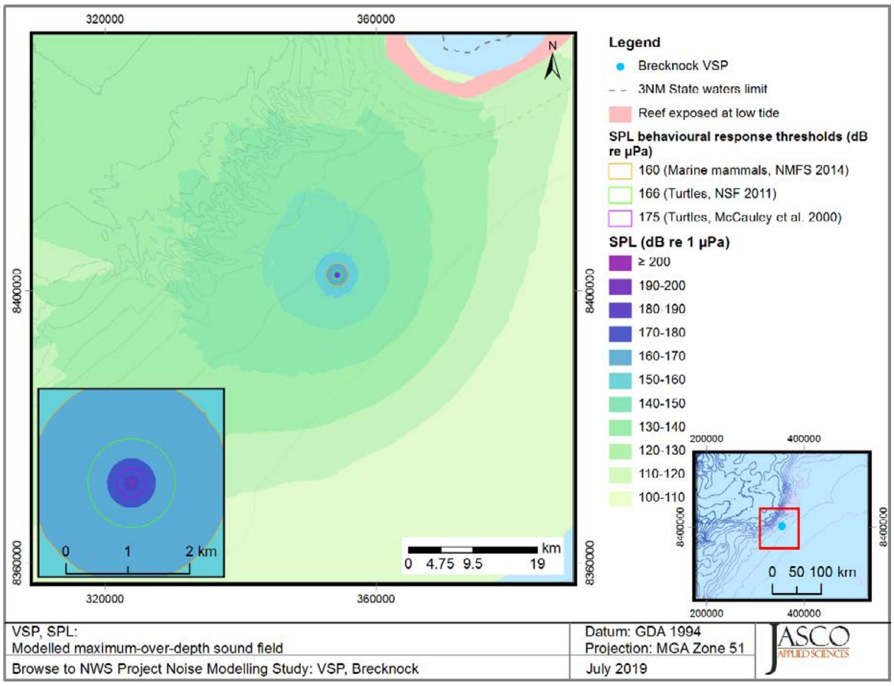

Figure 63. *Brecknock VSP, SPL:* Sound level contour map, showing maximum-over-depth results. Isopleths for turtles (166 and 175 dB re 1 µPa) and marine mammal (160 dB re 1 µPa) behavioural criteria are shown.

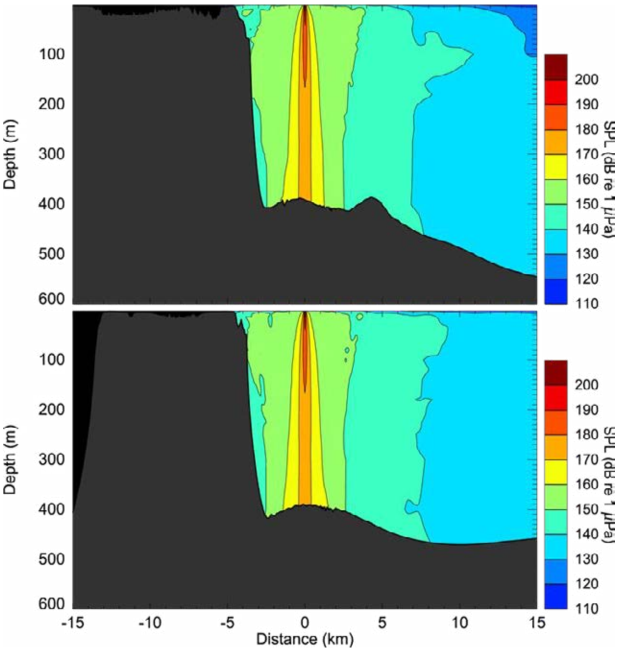

Figure 64. *Vertical slice, Torosa TRD Well VSP, SPL*: north–south (top) and east–west (bottom).

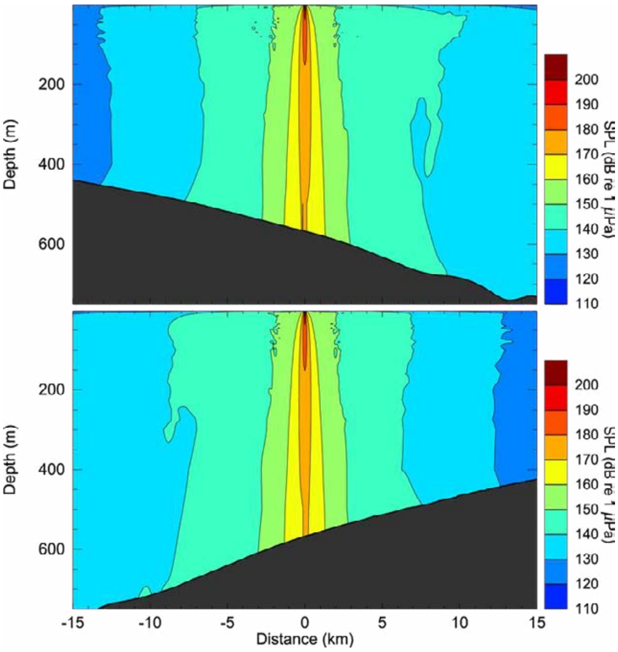

Figure 65. *Vertical slice, Brecknock VSP, SPL*: north–south (top) and east–west (bottom).

Multiple pulse

Multiple pulse results for a range of VSP impulses which potentially could occur within a 24 h period are shown in Tables 45 and 46. These results assume both stationary source and receivers, and are frequency-weighted in accordance with NMFS (2018) and Finneran et al. (2017).

Table 45. Torosa *VSP, multiple-pulse SEL*: Maximum ranges to frequency-weighted SEL_{24h} based marine mammal PTS and TTS thresholds NMFS (2018) and turtles (Finneran et al. 2017) from VSP operations, assuming different numbers of impulses during a 24 h period.

Hearing group	**Effect criteria**	**Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)** #	**Number of impulses**							
			1 R_{max} (m)	5 R_{max} (m)	10 R_{max} (m)	15 R_{max} (m)	25 R_{max} (m)	50 R_{max} (m)	100 R_{max} (m)	150 R_{max} (m)
LF cetaceans	PTS	183	-	-	0.04	0.06	0.08	0.11	0.16	0.20
	TTS	168	0.09	0.22	0.29	0.36	0.46	0.65	1.10	1.69
MF cetaceans	PTS	185	-	-	-	-	-	-	-	-
	TTS	170	-	-	-	-	-	-	-	-
HF cetaceans	PTS	155	-	-	-	-	-	-	-	-
	TTS	140	-	-	-	-	-	0.04	0.06	0.09
Turtles	PTS	204	-	-	-	-	-	-	-	-
	TTS	189	-	-	0.04	0.04	0.06	0.09	0.13	0.16

A dash indicates the level was not reached.
Frequency weighted.

Table 46. Brecknock *VSP, multiple-pulse SEL*: Maximum ranges to frequency-weighted SEL_{24h} based marine mammal PTS and TTS thresholds NMFS (2018) and turtles (Finneran et al. 2017) from VSP operations, assuming different numbers of impulses during a 24 h period.

Hearing group	**Effect criteria**	**Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)** [#]	**Number of impulses**							
			1 R_{max} (m)	5 R_{max} (m)	10 R_{max} (m)	15 R_{max} (m)	25 R_{max} (m)	50 R_{max} (m)	100 R_{max} (m)	150 R_{max} (m)
LF cetaceans	PTS	183	-	-	0.04	0.06	0.08	0.11	0.16	0.20
	TTS	168	0.09	0.22	0.29	0.36	0.46	0.64	1.10	1.69
MF cetaceans	PTS	185	-	-	-	-	-	-	-	-
	TTS	170	-	-	-	-	-	-	-	-
HF cetaceans	PTS	155	-	-	-	-	-	-	-	-
	TTS	140	-	-	-	-	-	0.04	0.06	0.09
Turtles	PTS	204	-	-	-	-	-	-	-	-
	TTS	189	-	-	0.04	0.04	0.06	0.09	0.13	0.16

A dash indicates the level was not reached.

[#] Frequency weighted.

4.4. Vessel noise (MODU, OSV, and FPSO)

Sound field results for the modelling scenarios involving the MODU, OSV and FPSO, both with and without DP and during offtake are presented for SPL (Tables 47–49) and SEL_{24h} (Tables 50 and 51) at Torosa and Brecknock. Areas within relevant threshold isopleths during offtake, including a comparison between individual FPSO's and aggregate FPSO's are presented for SPL and SEL_{24h} metrics in Tables 52–55. Ranges to fish thresholds are unchanged from the individual sources to aggregate scenarios, as the ranges are not greater than the modelling resolution.

4.4.1. Tabulated results

Table 47. *Torosa vessels, SPL*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the centroid of the modelled thrusters (MODU, OSV, and FPSO on DP) or from the centre of the vessel (FPSO without DP).

SPL (**L_p; dB re 1 µPa**)	**MODU**		**OSV**		**FPSO on DP**		**FPSO without DP**		**FPSO offtake**	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
190	<0.02	<0.02	-	-	-	-	-	-	-	-
180	0.05	0.05	<0.02	<0.02	<0.02	<0.02	-	-	<0.02	<0.02
170	0.06	0.06	0.05	0.05	<0.02	<0.02	<0.02	<0.02	0.04	0.04
160	0.06	0.06	0.05	0.05	0.04	0.04	<0.02	<0.02	0.04	0.04
150	0.17	0.17	0.07	0.07	0.12	0.12	<0.02	<0.02	0.13	0.13
140	0.52	0.51	0.18	0.17	0.40	0.40	0.04	0.04	0.92	0.81
130	2.32	2.22	0.57	0.55	1.83	1.77	0.17	0.17	2.13	1.96
120†	10.50	7.20	2.25	2.14	8.77	7.99	0.57	0.56	8.89	8.08
110	21.97	18.24	6.64	6.13	21.61	18.36	2.13	2.06	22.49	18.59
100	38.48	35.32	17.20	15.34	45.65	37.29	6.30	5.78	46.05	37.93

† Threshold for marine mammal behavioural response to continuous noise (NMFS 2014).
A dash indicates the level was not reached.
FPSO offtake includes an FPSO under DP, a noiseless condensate tanker and an OSV.

Table 48. *Brecknock vessels, SPL*: Maximum ($R_{\max}$) and 95% ($R_{95\%}$) horizontal distances (in km) from the centroid of the modelled thrusters (MODU, OSV, and FPSO on DP) or from the centre of the vessel (FPSO without DP).

SPL (L_p; dB re 1 µPa)	**MODU**		**OSV**		**FPSO on DP**		**FPSO without DP**		**FPSO offtake**	
	$R_{\max}$ (km)	$R_{95\%}$ (km)	$R_{\max}$ (km)	$R_{95\%}$ (km)	$R_{\max}$ (km)	$R_{95\%}$ (km)	$R_{\max}$ (km)	$R_{95\%}$ (km)	$R_{\max}$ (km)	$R_{95\%}$ (km)
190	<0.02	<0.02	-	-	-	-	-	-	-	-
180	0.05	0.05	0.02	0.02	<0.02	<0.02	-	-	0.03	0.03
170	0.06	0.06	0.06	0.06	<0.02	<0.02	<0.02	<0.02	0.04	0.04
160	0.06	0.06	0.06	0.06	0.04	0.04	<0.02	<0.02	0.06	0.06
150	0.17	0.17	0.06	0.06	0.12	0.12	<0.02	<0.02	0.12	0.12
140	0.52	0.50	0.19	0.18	0.40	0.39	0.04	0.04	0.90	0.82
130	2.68	2.54	0.57	0.54	1.78	1.72	0.16	0.16	2.19	2.01
120†	8.84	8.11	2.39	2.27	8.78	7.70	0.54	0.52	8.89	7.84
110	24.58	19.46	7.76	7.14	22.19	17.51	2.27	2.16	22.44	18.27
100	>80.0	*	21.72	16.80	47.13	34.74	7.66	7.04	47.84	35.51

† Threshold for marine mammal behavioural response to continuous noise (NMFS 2014).

* Radii unresolvable due to $R_{\max}$ exceeding maximum modelled distance.

A dash indicates the level was not reached.

FPSO offtake includes an FPSO under DP, a noiseless condensate tanker and an OSV.

Table 49. *Vessels, SPL, fish effect thresholds*: Maximum ($R_{\max}$) horizontal distances (km) from the vessels to modelled maximum-over-depth SPL thresholds based on the quantifiable thresholds for fish with a swim bladder involved in hearing (Popper et al. 2014).

SPL (L_p; dB re 1 µPa)	**MODU**		**OSV**		**FPSO on DP**		**FPSO without DP**		**FPSO Offtake**	
	$R_{\max}$ (km)	$R_{95\%}$ (km)	$R_{\max}$ (km)	$R_{95\%}$ (km)	$R_{\max}$ (km)	$R_{95\%}$ (km)	$R_{\max}$ (km)	$R_{95\%}$ (km)	$R_{\max}$ (km)	$R_{95\%}$ (km)
Torosa										
170†	0.06	0.06	0.05	0.05	<0.02	<0.02	-	-	0.04	0.04
158#	0.06	0.06	0.05	0.05	0.04	0.04	-	-	0.06	0.06
Brecknock										
170†	0.06	0.06	0.06	0.06	<0.02	<0.02	<0.02	<0.02	0.04	0.04
158#	0.06	0.06	0.06	0.06	0.04	0.04	<0.02	<0.02	0.06	0.06

† Recoverable injury

\# TTS

FPSO offtake includes an FPSO under DP, a noiseless condensate tanker and an OSV.

Table 50. *Torosa vessels, SEL*$_{24}$: Maximum-over-depth distances (in km) to PTS and TTS thresholds NMFS (2018) and turtles (Finneran et al. 2017) .

Hearing group	**Threshold for SEL$_{24h}$ ($L_{E,24h}$; dB re 1 µPa^2·s)** [#]	**MODU**		**OSV**		**FPSO on DP**		**FPSO without DP**		**FPSO offtake**	
		R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
PTS											
LF cetaceans	199	0.11	0.11	0.05	0.05	0.12	0.12	-	-	0.12	0.12
MF cetaceans	198	-	-	-	-	<0.02	<0.02	-	-	<0.02	<0.02
HF cetaceans	173	0.15	0.15	0.07	0.07	0.28	0.27	-	-	0.28	0.27
Turtles	220	0.06	0.06	0.05	0.05	<0.02	<0.02	-	-	<0.02	<0.02
TTS											
LF cetaceans	179	1.49	1.41	0.40	0.38	1.49	1.44	0.09	0.09	1.74	1.60
MF cetaceans	178	0.12	0.12	0.05	0.05	0.23	0.23	-	-	0.23	0.23
HF cetaceans	153	2.81	2.75	0.89	0.86	5.46	5.34	0.17	0.17	5.47	5.35
Turtles	200	0.13	0.13	0.05	0.05	0.06	0.06	-	-	0.06	0.06

A dash indicates the level was not reached.

[#] Frequency weighted.

FPSO offtake includes an FPSO under DP, a noiseless condensate tanker and an OSV.

Table 51. *Brecknock vessels, SEL*$_{24}$: Maximum-over-depth distances (in km) to PTS and TTS thresholds NMFS (2018) and turtles (Finneran et al. 2017).

Hearing group	**Threshold for SEL$_{24h}$ ($L_{E,24h}$ dB re 1 µPa^2·s)** [#]	**MODU**		**OSV**		**FPSO on DP**		**FPSO without DP**		**FPSO offtake**	
		R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
PTS											
LF cetaceans	199	0.11	0.11	0.06	0.06	0.12	0.12	<0.02	<0.02	0.12	0.12
MF cetaceans	198	-	-	-	-	<0.02	<0.02	-	-	<0.02	<0.02
HF cetaceans	173	0.15	0.15	0.07	0.07	0.28	0.27	<0.02	<0.02	0.28	0.27
Turtles	220	0.06	0.06	0.06	0.06	<0.02	<0.02	-	-	<0.02	<0.02
TTS											
LF cetaceans	179	1.00	0.97	0.40	0.38	1.33	1.28	0.09	0.09	1.68	1.54
MF cetaceans	178	0.12	0.12	0.06	0.06	0.23	0.23	<0.02	<0.02	0.23	0.23
HF cetaceans	153	2.78	2.74	0.89	0.86	5.45	5.34	0.17	0.17	5.47	5.35
Turtles	200	0.13	0.13	0.06	0.06	0.06	0.06	<0.02	<0.02	0.06	0.06

A dash indicates the level was not reached.

[#] Frequency weighted.

FPSO offtake includes an FPSO under DP, a noiseless condensate tanker and an OSV.

Table 52. *Vessels, SPL*: Areas (km^2, WGS84, geographic) for individual and aggregate FPSO offtake operations within isopleths corresponding to the threshold for marine mammal behavioural response to continuous noise (NMFS 2014).

SPL (**L_p; dB re 1 µPa**)	**Torosa**	**Brecknock**	**Aggregate**	**Difference between combined individual and aggregate**
	Area (km^2)	Area (km^2)	Area (km^2)	Area (km^2)
120†	192.9	181.5	374.4	0

† Threshold for marine mammal behavioural response to continuous noise (NMFS 2014).
FPSO offtake includes an FPSO under DP, a noiseless condensate tanker and an OSV.

Table 53. *Vessels, SEL_{24}*: Areas (km^2, WGS84, geographic) for combined FPSO offtake and MODU operations within isopleths corresponding to the thresholds for maximum-over-depth PTS and TTS thresholds for cetaceans (NMFS 2018) and turtles (Finneran et al. 2017).

Hearing group	**Threshold for SEL_{24h} ($L_{E,24h}$ dB re 1 µPa²·s) #**	**Torosa**	**Brecknock**	**Aggregate**	**Difference between combined individual and aggregate**
		Area (km^2)	Area (km^2)	Area (km^2)	Area (km^2)
PTS					
LF cetaceans	199	0.06	0.062	0.12	0
MF cetaceans	198	< 0.001	-	< 0.001	0
HF cetaceans	173	0.27	0.29	0.55	0
Turtles	220	0.002	0.005	0.007	0
TTS					
LF cetaceans	179	8.26	7.14	15.4	0
MF cetaceans	178	0.19	0.19	0.371	0
HF cetaceans	153	93.7	93.4	187.1	0
Turtles	200	0.036	0.037	0.073	0

A dash indicates the level was not reached.
Frequency weighted.
Only areas > 0.001 km^2 are resolved.
FPSO offtake includes an FPSO under DP, a noiseless condensate tanker and an OSV.

Table 54. *Vessels, SPL*: Areas (km^2, WGS84, geographic) for individual and aggregate FPSO (without DP) operations within isopleths corresponding to the threshold for marine mammal behavioural response to continuous noise (NMFS 2014).

SPL (**L_p; dB re 1 µPa**)	**Torosa**	**Brecknock**	**Aggregate**	**Difference between combined individual and aggregate**
	Area (km^2)	Area (km^2)	Area (km^2)	Area (km^2)
120†	1.0	0.9	1.9	0

† Threshold for marine mammal behavioural response to continuous noise (NMFS 2014).
FPSO offtake includes an FPSO under DP, a noiseless condensate tanker and an OSV.

Table 55. *Vessels, SEL24*: Areas (km^2, WGS84, geographic) for combined FPSO offtake and MODU operations within isopleths corresponding to the thresholds for maximum-over-depth PTS and TTS thresholds for cetaceans (NMFS 2018) and turtles (Finneran et al. 2017).

Hearing group	**Threshold for SEL$_{24h}$ ($L_{E,24h}$ dB re 1 µPa^2·s)**	**Torosa**	**Brecknock**	**Aggregate**	**Difference between combined individual and aggregate**
		Area (km^2)	Area (km^2)	Area (km^2)	Area (km^2)
PTS					
LF cetaceans	199	0.001	0.001	0.006	0.004†
MF cetaceans	198	-	-	-	-
HF cetaceans	173	< 0.001	< 0.001	-	0
Turtles	220	-	-	-	-
TTS					
LF cetaceans	179	0.033	0.033	0.067	0.004†
MF cetaceans	178	-	< 0.001	< 0.001	0
HF cetaceans	153	0.1	0.1	0.2	0
Turtles	200	0.001	0.001	0.007	0.005†

A dash indicates the level was not reached.
Only areas > 0.001 km^2 are resolved.
†Difference due to gridding artefact.
FPSO offtake includes an FPSO under DP, a noiseless condensate tanker and an OSV.

4.4.2. Sound Field Maps and Graphs

Maps of the estimated sound fields, threshold contours, and isopleths of interest for SPL and SEL$_{24h}$ sound fields have been presented at both modelling sites for individual locations for vessel modelling scenarios (Table 8) in Figures 66–85, and aggregate modelling scenarios in Figures 86–89.

4.4.2.1. Standalone scenarios

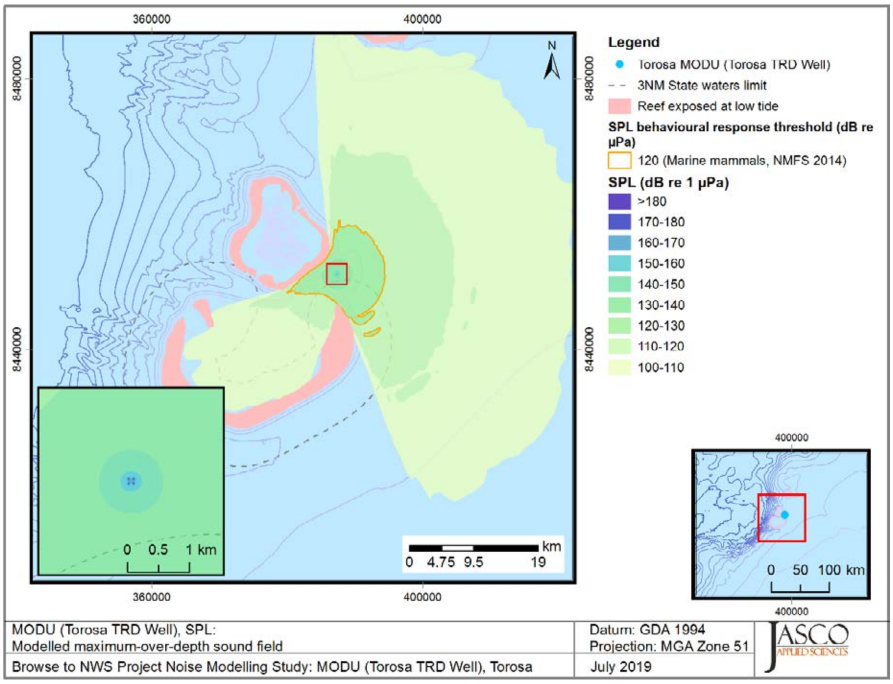

Figure 66. *Torosa, MODU, SPL*: Sound level contour map, showing maximum-over-depth results. Isopleth for marine mammal behavioural criteria (120 dB re 1 µPa) is shown.

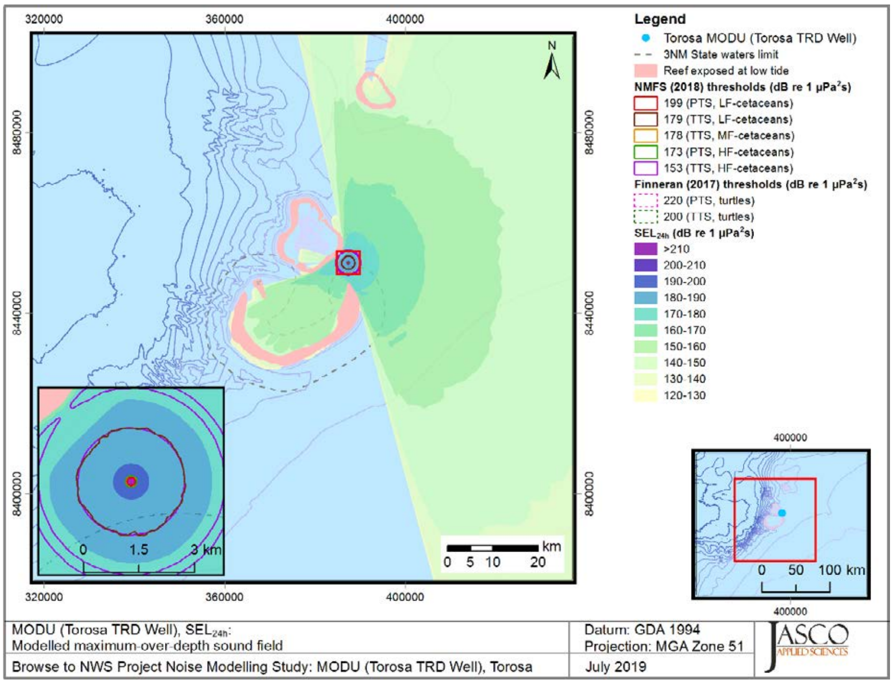

Figure 67. *Torosa, MODU, SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with isopleths for low-, mid-, and high-frequency cetaceans and turtles. Threshold for mid-frequency cetacean PTS was not reached.

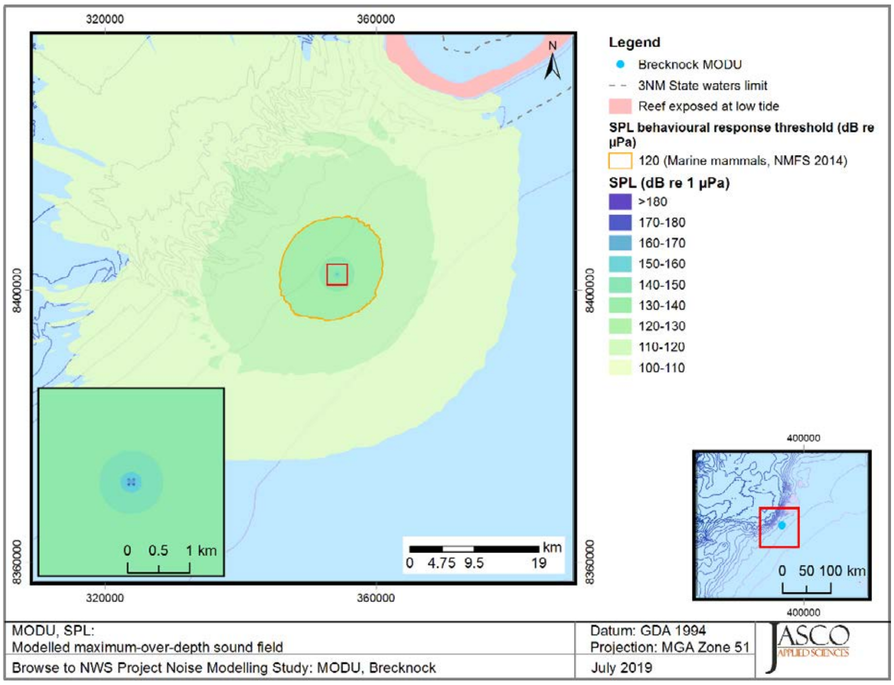

Figure 68. *Brecknock, MODU, SPL*: Sound level contour map, showing maximum-over-depth results. Isopleth for marine mammal behavioural criteria (120 dB re 1 µPa) is shown.

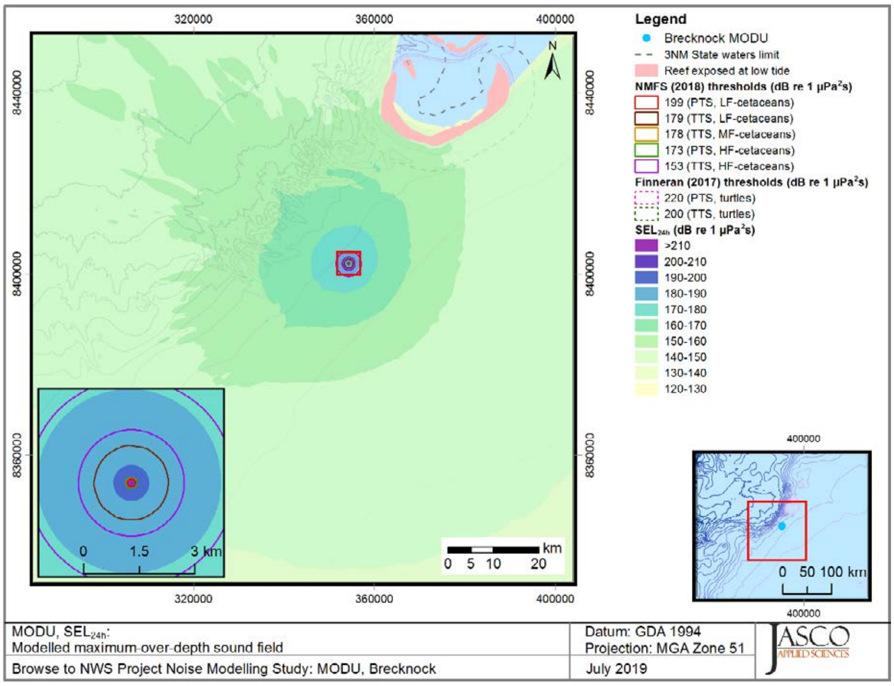

Figure 69. *Brecknock, MODU, SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with isopleths for low-, mid-, and high-frequency cetaceans and turtles. Threshold for mid-frequency cetacean PTS was not reached.

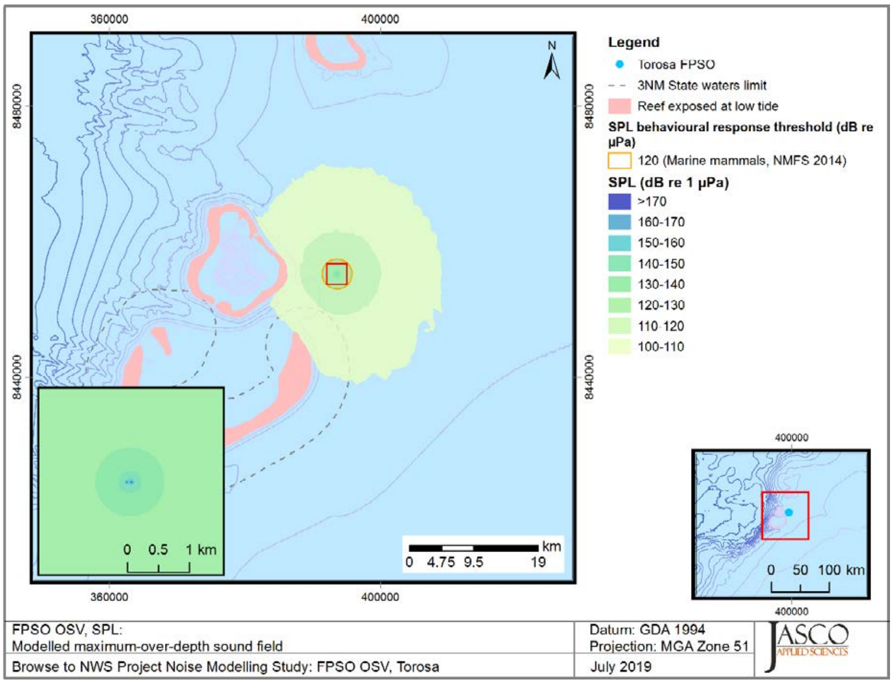

Figure 70. *Torosa, Support Vessel, SPL*: Sound level contour map, showing maximum-over-depth results. Isopleth for marine mammal behavioural criteria (120 dB re 1 µPa) is shown.

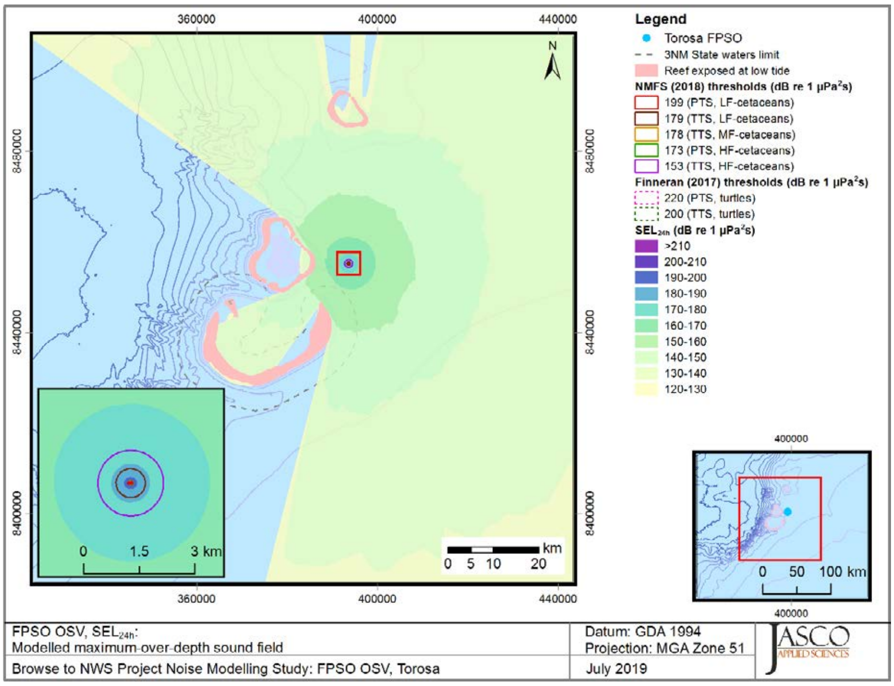

Figure 71. *Torosa, Support Vessel, SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with isopleths for low-, mid-, and high-frequency cetaceans and turtles. Threshold for mid-frequency cetacean PTS was not reached.

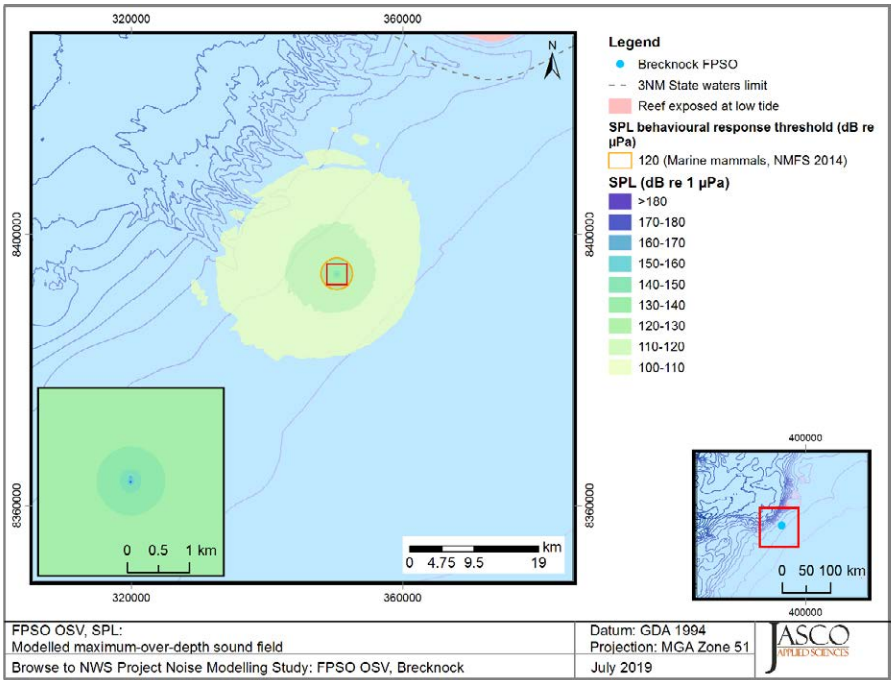

Figure 72. *Brecknock, Support Vessel, SPL*: Sound level contour map, showing maximum-over-depth results. Isopleth for marine mammal behavioural criteria (120 dB re 1 µPa) is shown.

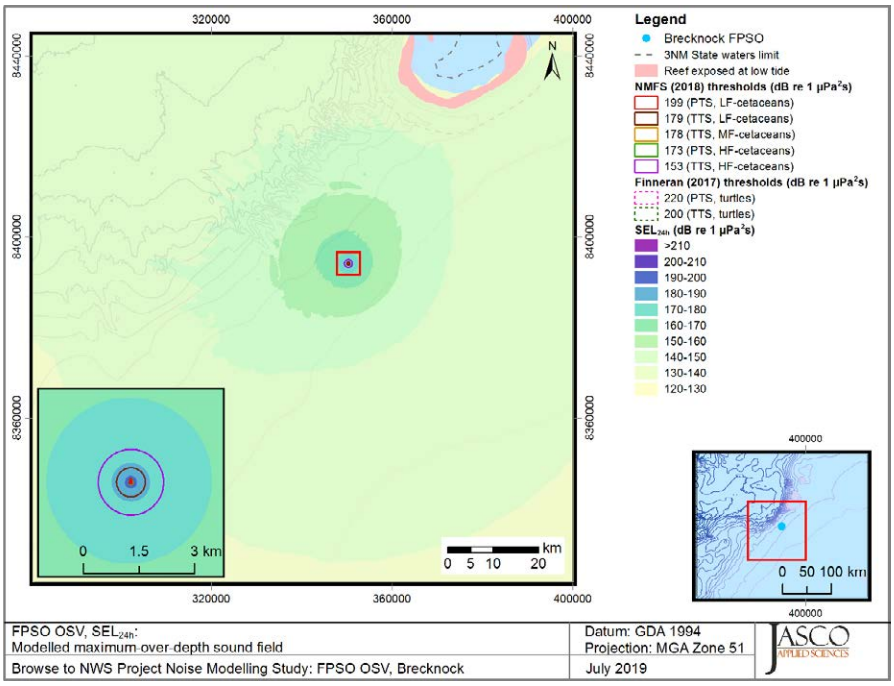

Figure 73. *Brecknock, Support Vessel, SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with isopleths for low-, mid-, and high-frequency cetaceans and turtles. Threshold for mid-frequency cetacean PTS was not reached.

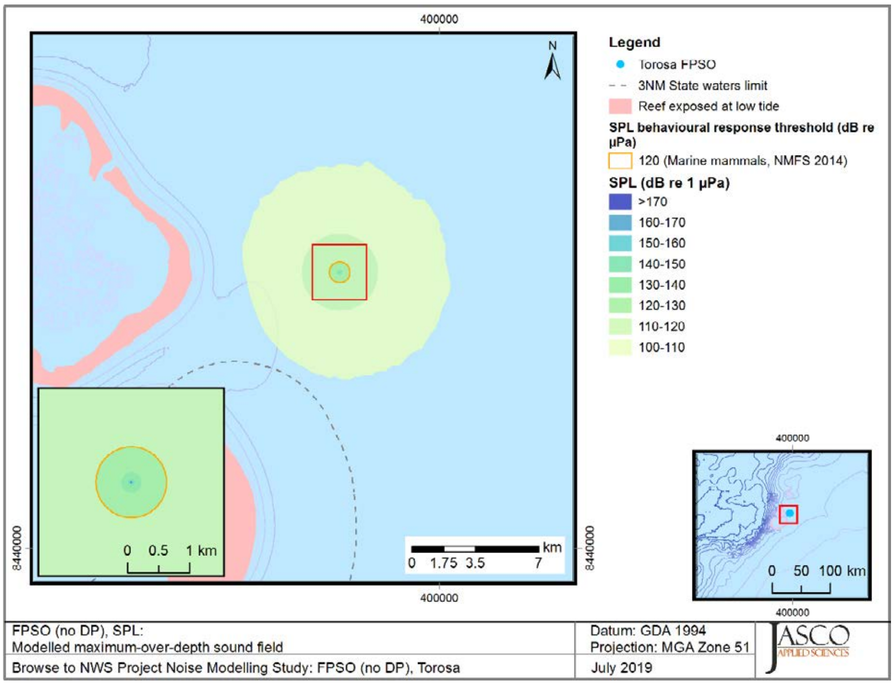

Figure 74. *Torosa, FPSO without DP, SPL*: Sound level contour map, showing maximum-over-depth results. Isopleth for marine mammal behavioural criteria (120 dB re 1 µPa) is shown.

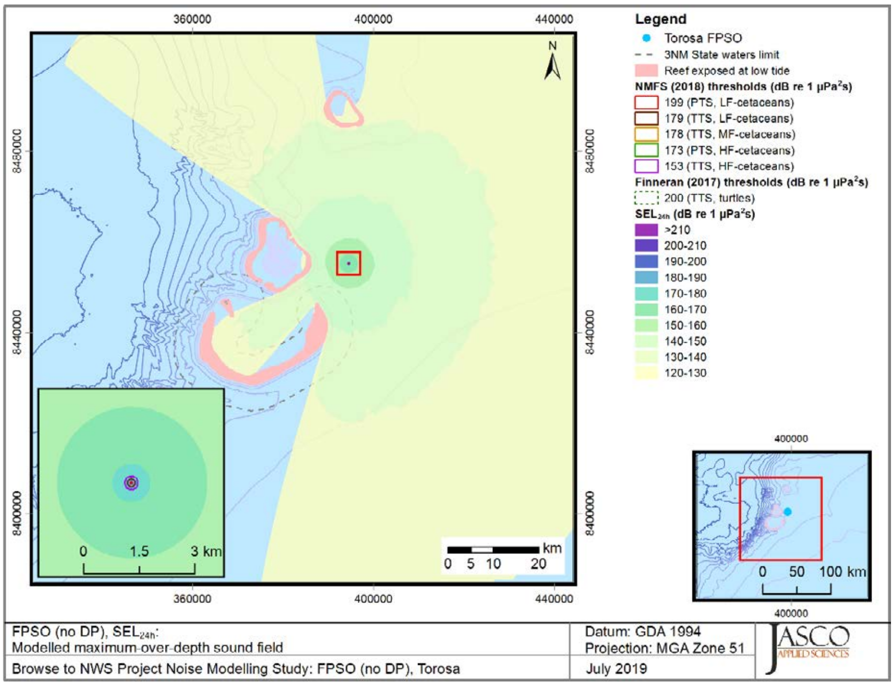

Figure 75. *Torosa, FPSO without DP, SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with isopleths for low-, mid-, and high-frequency cetaceans and turtles. Threshold for mid-frequency cetacean PTS was not reached.

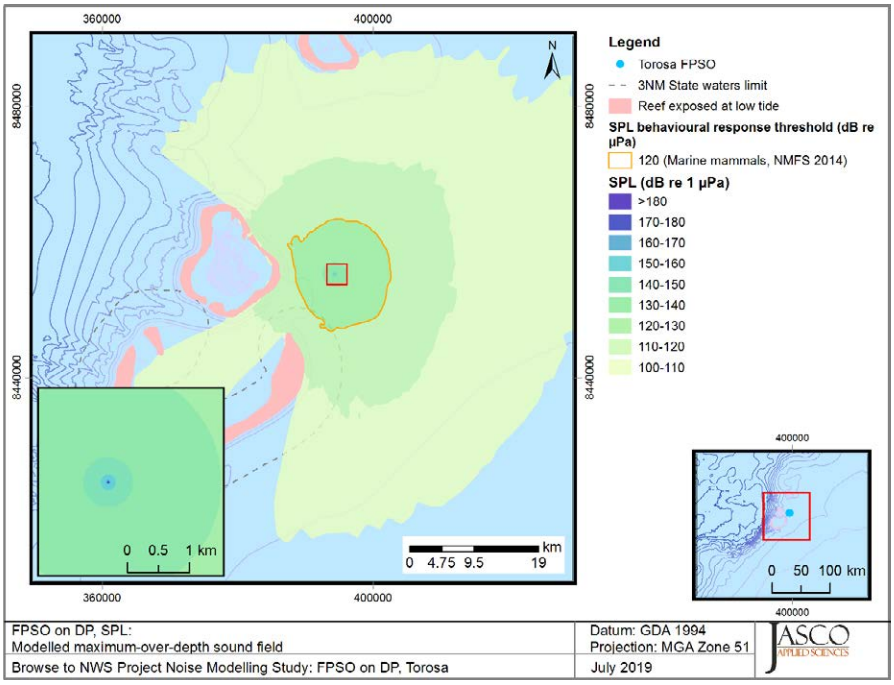

Figure 76. *Torosa, FPSO on DP, SPL*: Sound level contour map, showing maximum-over-depth results. Isopleth for marine mammal behavioural criteria (120 dB re 1 µPa) is shown.

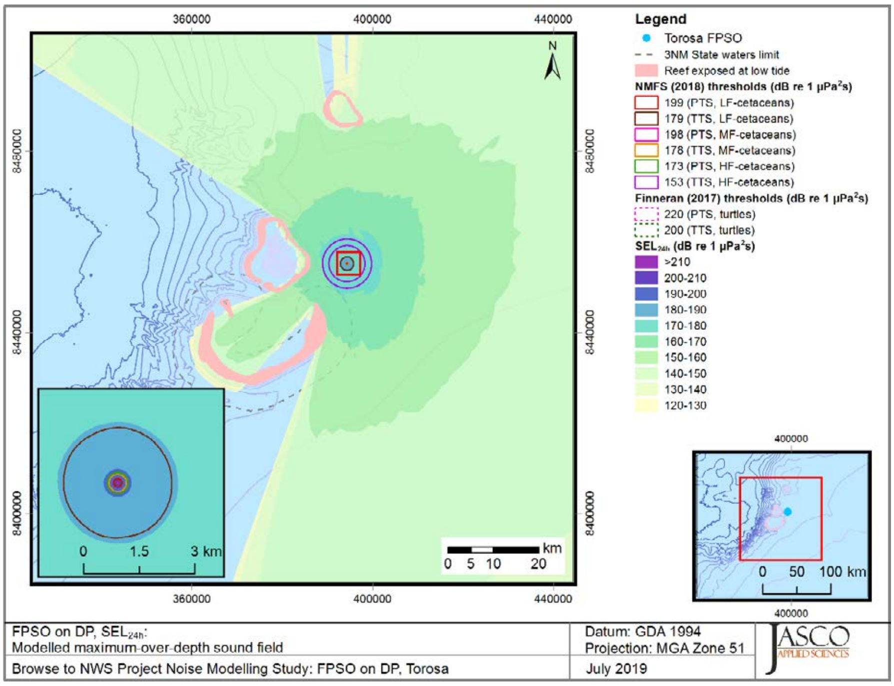

Figure 77. *Torosa, FPSO on DP, SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with isopleths for low-, mid-, and high-frequency cetaceans and turtles.

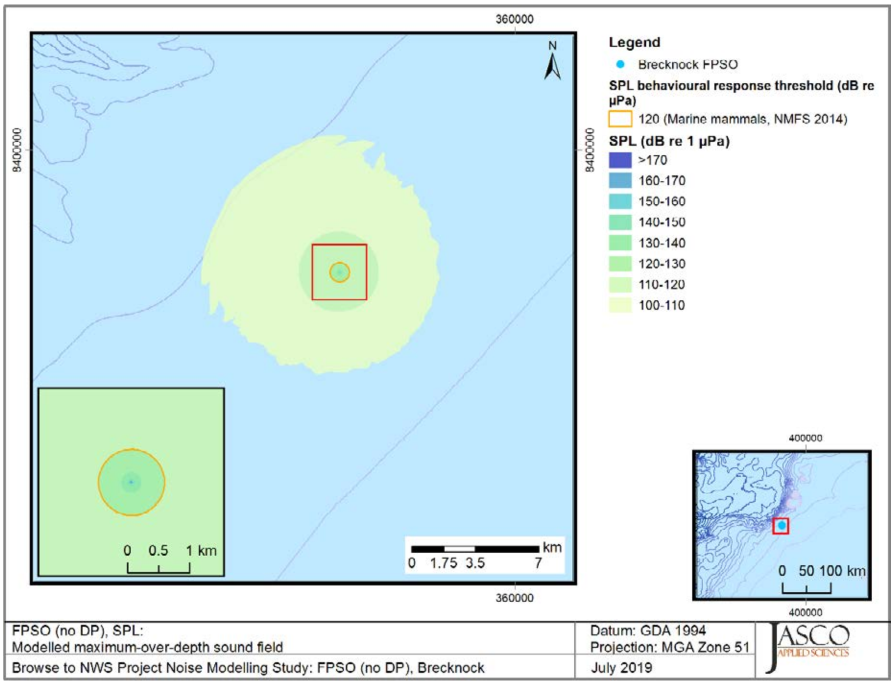

Figure 78. *Brecknock, FPSO without DP, SPL*: Sound level contour map, showing maximum-over-depth results. Isopleth for marine mammal behavioural criteria (120 dB re 1 µPa) is shown.

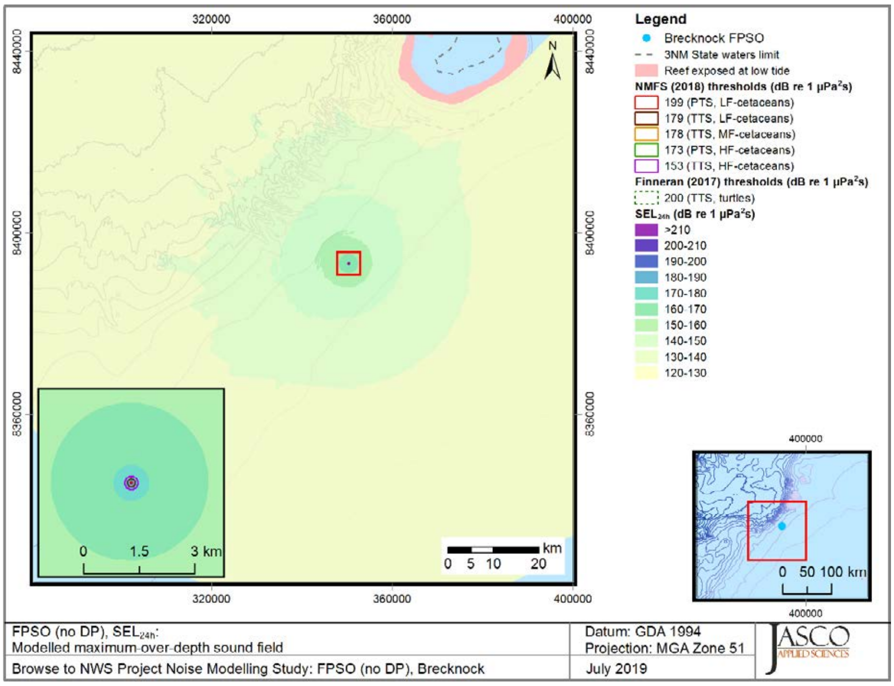

Figure 79. *Brecknock, FPSO without DP, SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with isopleths for low-, mid-, and high-frequency cetaceans and turtles. Threshold for mid-frequency cetacean PTS was not reached.

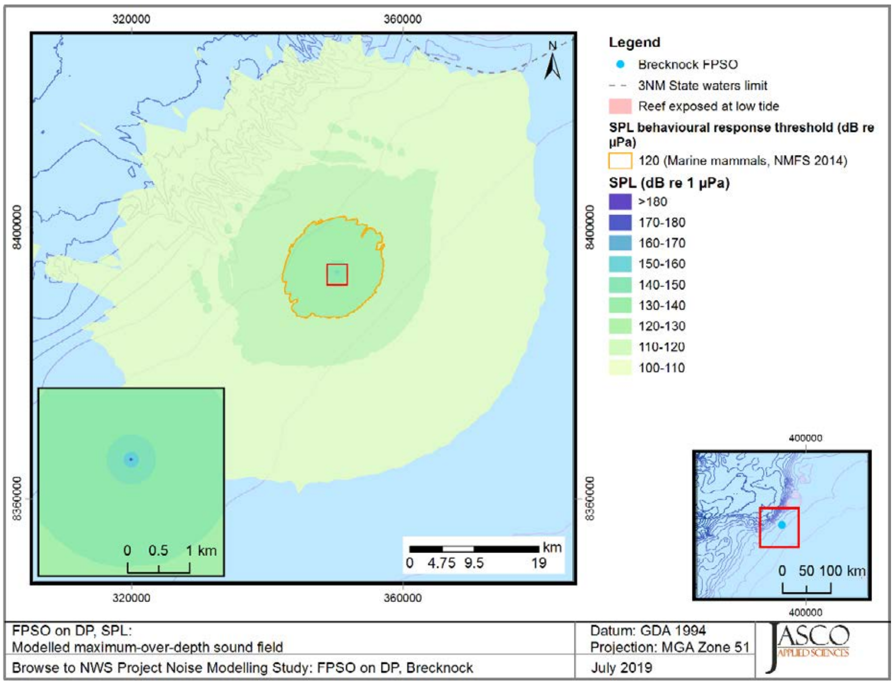

Figure 80. *Brecknock, FPSO on DP, SPL*: Sound level contour map, showing maximum-over-depth results. Isopleth for marine mammal behavioural criteria (120 dB re 1 µPa) is shown.

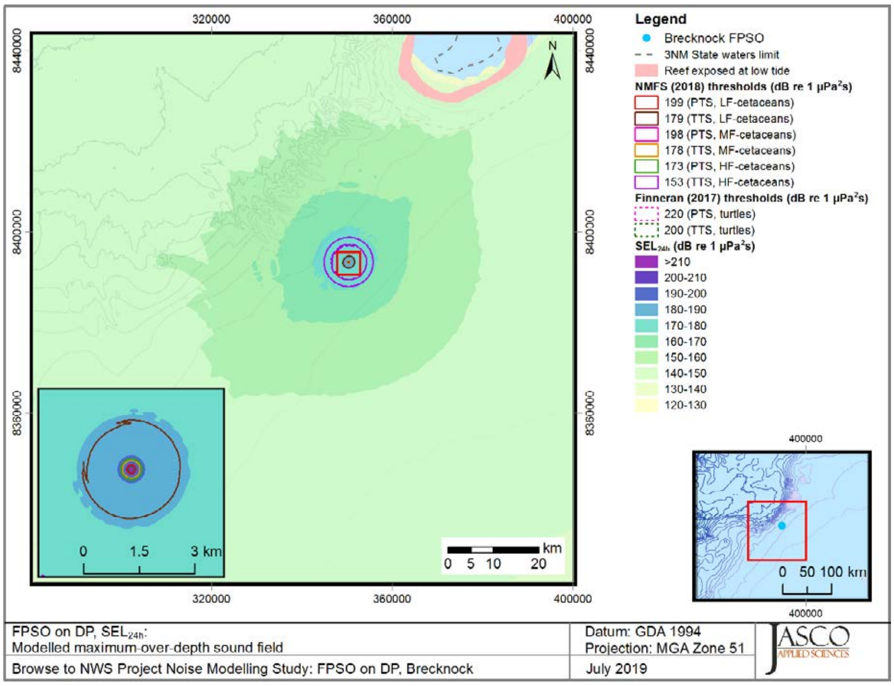

Figure 81. *Brecknock, FPSO on DP, SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with isopleths for low-, mid-, and high-frequency cetaceans and turtles.

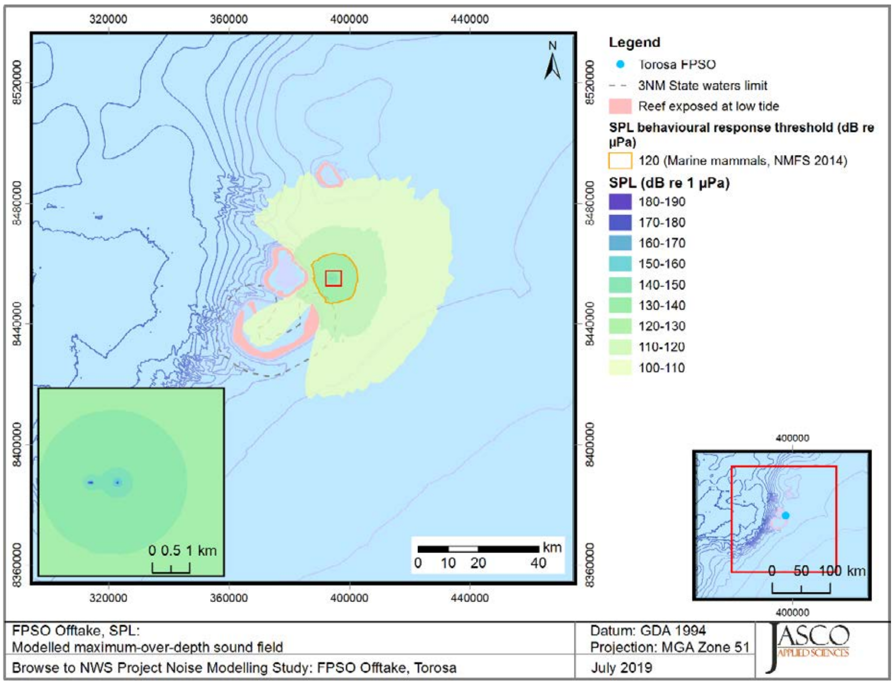

Figure 82. *Torosa, FPSO offtake, SPL*: Sound level contour map, showing maximum-over-depth results. Isopleth for marine mammal behavioural criteria (120 dB re 1 µPa) is shown.

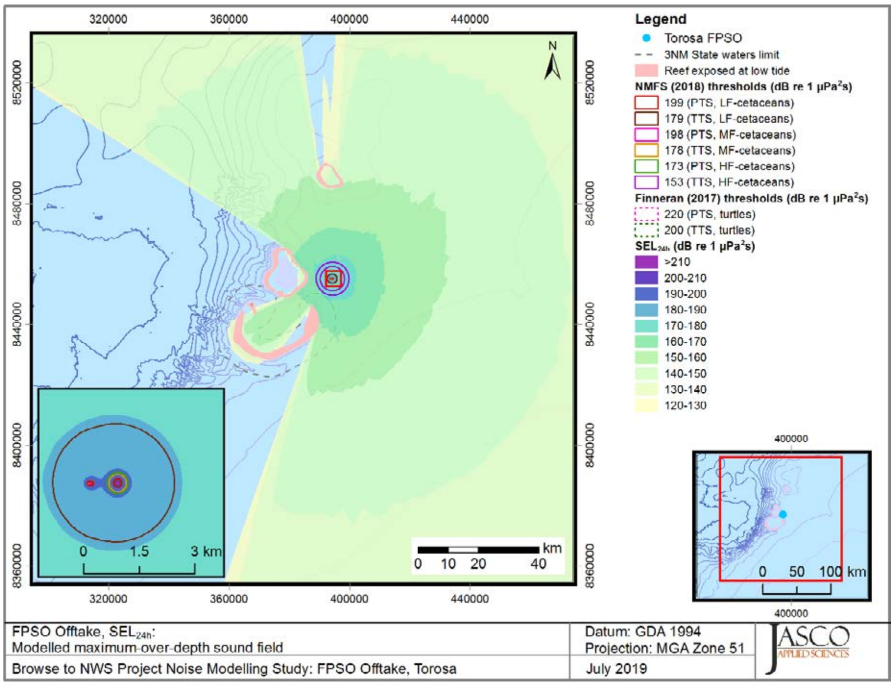

Figure 83. *Torosa, FPSO offtake, SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with isopleths for low-, mid-, and high-frequency cetaceans and turtles.

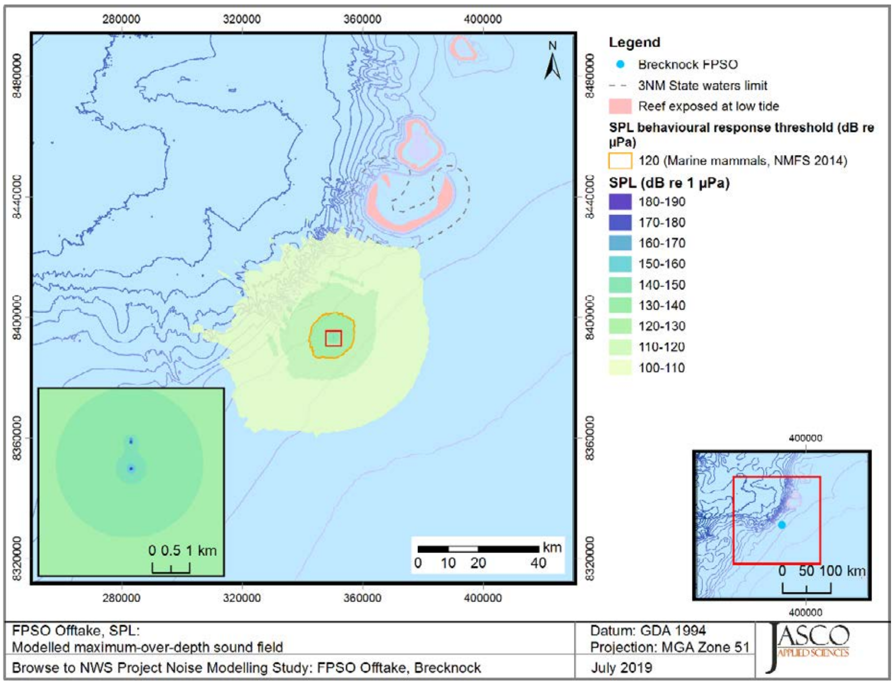

Figure 84. *Brecknock, FPSO offtake, SPL*: Sound level contour map, showing maximum-over-depth results. Isopleth for marine mammal behavioural criteria (120 dB re 1 µPa) is shown.

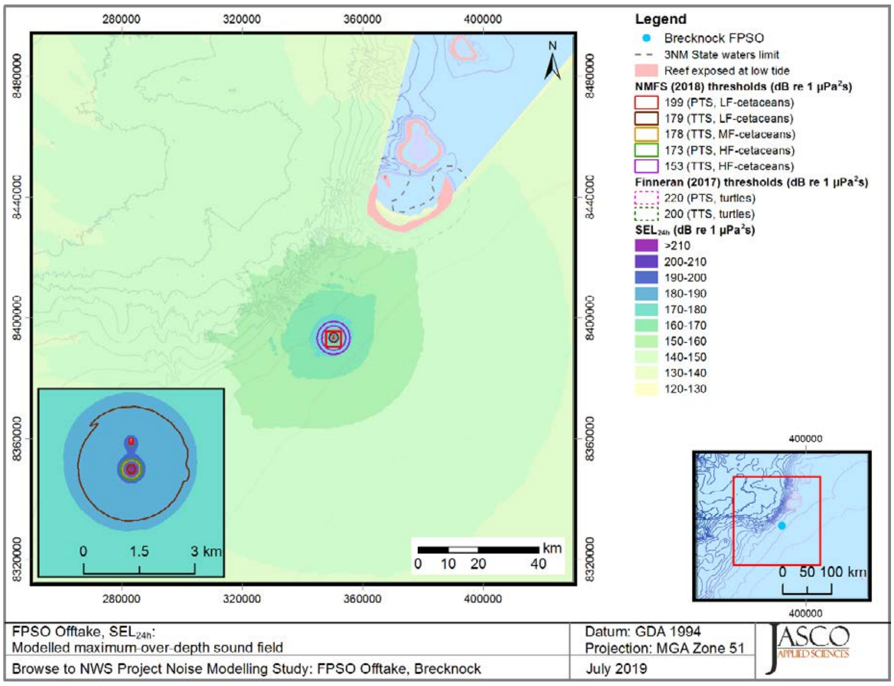

Figure 85. *Brecknock, FPSO offtake, SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with isopleths for low-, mid-, and high-frequency cetaceans and turtles. Threshold for mid-frequency cetacean PTS was not reached.

4.4.2.2. Aggregate scenarios

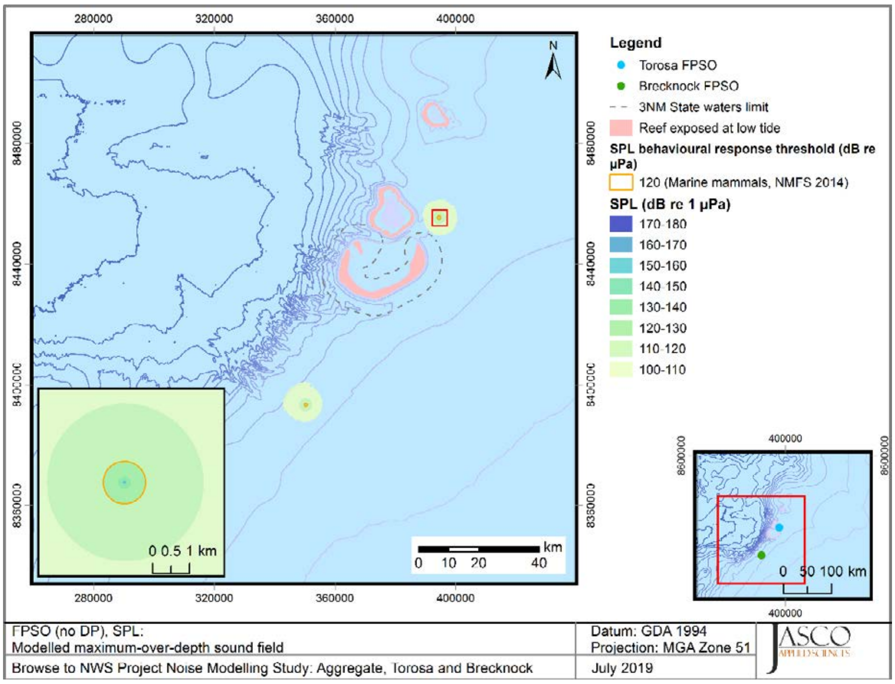

Figure 86. *Torosa and Brecknock, Aggregate FPSOs without DP, SPL*: Sound level contour map, showing maximum-over-depth results. Isopleth for marine mammal behavioural criteria (120 dB re 1 µPa) is shown.

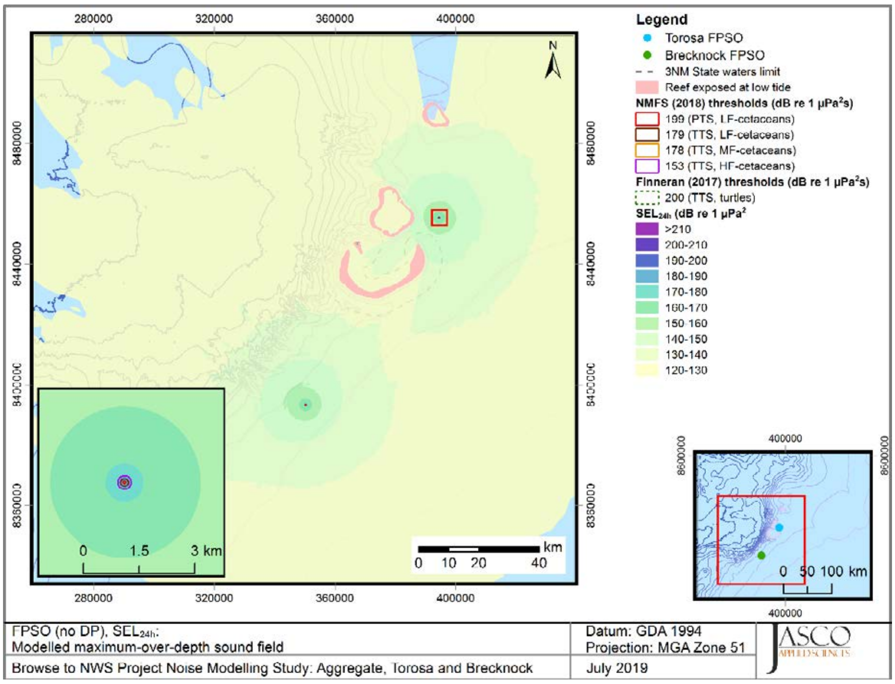

Figure 87. *Torosa and Brecknock, Aggregate FPSOs without DP, SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with isopleths for low-, mid-, and high-frequency cetaceans and turtles. Thresholds for mid- and high- frequency cetacean PTS was not reached.

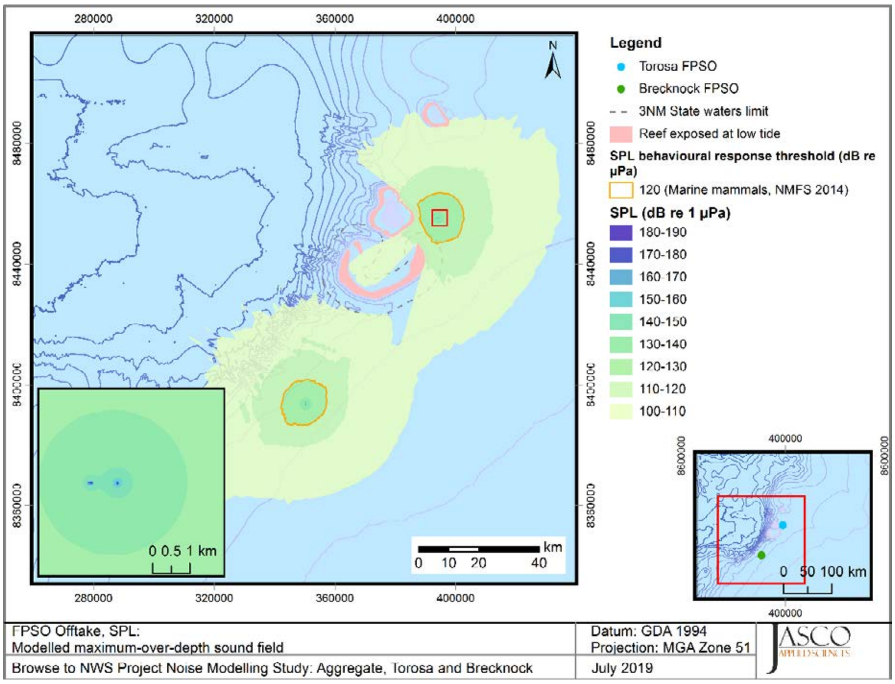

Figure 88. *Torosa and Brecknock, Aggregate FPSO offtake, SPL*: Sound level contour map, showing maximum-over-depth results. Isopleth for marine mammal behavioural criteria (120 dB re 1 µPa) is shown.

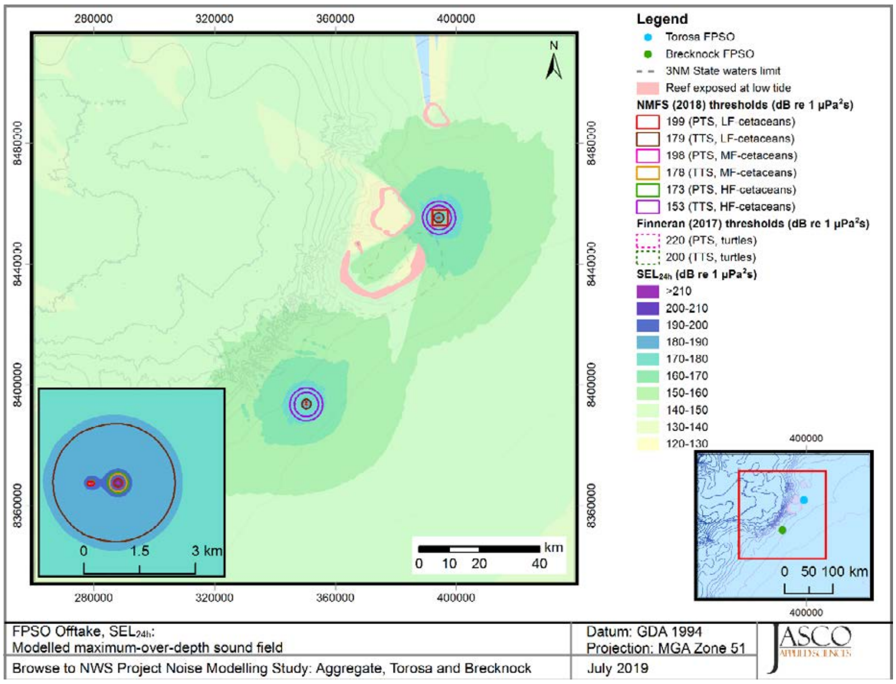

Figure 89. *Torosa and Brecknock, Aggregate FPSO offtake, SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL$_{24h}$ results, along with isopleths for low-, mid-, and high-frequency cetaceans and turtles.

5. Discussion and Summary

5.1. Pile Driving

5.1.1. Acoustic propagation

This study predicted underwater sound levels associated with impact driving of subsea piles to anchor the Torosa FPSO facility turret. The underwater sound field was modelled for 53.25 m long piles with a 5.5 m diameter with 60 mm wall thickness; The piles will be driven a total of 51.5 m into the seabed. The modelling applied a sound speed profile derived from a public database (Appendix F.3.2), and also accounted for bathymetric variations (Appendix F.3.1) and local geoacoustic properties (Appendix F.3.3). The broadband sound energy at 10 m for each penetration depth ranged from 184.6–199.4 dB re 1 μPa^2·s with the peak sound energy concentrated in the frequency range 70 to 300 Hz (Figure 16), with levels from the pile at the 17 m penetration depth having the highest energy.

Noise emissions from pile driving were considered here to be cylindrically isotropic (i.e., omnidirectional in the horizontal plane). As such, variations in noise that propagates across azimuths are attributed to the bathymetry alone, with this accounted for in the modelling methodology. When the hammer strikes the pile, noise propagates into the water as a downward Mach cone (see Appendix B). A portion of the energy from the strike is also reflected at the pile bottom, generating an upward Mach cone. This cycle of downward propagation, reflection, and upward propagation occurs multiple times per strike. At close range from the pile, noise levels are determined by the summation of Mach cones, which might add constructively (i.e., their summation results in a total wave with higher amplitude than the original ones) or destructively (i.e., wavefronts can cancel each other, resulting in low amplitudes). The way in which Mach cones combine with each other is strongly dependent on their frequency content, which is determined by the hammer forcing function and the pile dimensions.

Due to the relation between the speed of sound in steel (~5000 m/s) relative to the speed of sound in the water (~1490 m/s at the depth of the pile), the Mach cone propagates away from the pile and impinges the seabed at an angle of ~17°. The first bottom bounce occurs within 16 m from the pile, and the first surface bounce occurs within 1.5 from the pile. As shown in Figure 25, the Mach cone corresponding to the shallowest pile penetration introduces substantial energy that propagates through the water column, compared to the 45 m pile penetration scenario in Figure 27, for which underground sound propagation tends to dominate near the pile.

The modelling of the three penetration depths for each pile provides a detailed quantification of the associated sound levels for each penetration. The distances to all per-strike isopleths are farthest at the start of piling when most of the pile is in the water column, and distances are shortest at the end of piling when most of the pile is buried in the sediment. This is despite the per-strike pile penetration being less during the final stages of driving, and the increased resistance generating stronger stress-wave reflections at the pile toe. Therefore, the amount of pile in the water has greatest influence on the in-water sound levels. The isopleths for unweighted marine mammal behavioural thresholds for each penetration are presented on the same map for each hammer to assist with comparison (Figures 23 and 24 for Torosa and Figures 46 and 47 for Brecknock). The highest peak pressure levels are predicted to occur at the shallowest penetration (17 m) and for the IHC S-1200.

5.1.1.1. Propagation at Torosa

As evidenced in Figures 23 and 24, sound propagation around the pile is mostly isotropic, except along transects toward the North Scott Reef in the eastern direction. Along these transects, the following phenomena take place:

- Sound is significantly blocked when it reaches the exposed reefs, as the acoustic wavefront hits the limestone interface and reflects. This is due to the high impedance contrast between water and limestone. Note that the results presented here do not account for backpropagated sound.
- At azimuth 240˚ from the pile, sound propagates within the channel between the two reefs as far as the bathymetry allows (see Figures 25–30). Between 3–17 km from the pile, propagation takes place along a sand/gravel seabed, which enhances energy contributions from seabed reflections

in this direction (compared to those in directions away from the reef). At a range of approximately 17 km from the pile, the bathymetry abruptly reduces from ~440 m depth to 50 m depth.

- Beyond 17 km range from the pile, sound propagates along a shallow (50 m depth) waveguide, up to 30 km, where it reaches the shallow reef and sound is blocked. At ranges >17 km, despite bottom reflections being strong (due to the high acoustic contrast between water and limestone), sound propagation is not significant, as very small amount of energy enters the shallow waveguide (see Figures 25–30).

The enhanced propagation along sandy/gravel seabed is observed as "sound islands" in maps of SPL and SEL_{24h} criteria. The R_{max} radius is more representative of the effective extent of the footprint because the source is stationary and is more conservative, however, when determining potential impacts, the azimuthal distribution of sound should be considered, particularly at Torosa. Given the likely soil resistance, the modelling scenarios represent the maximum noise footprint from pile driving activities as a conservative estimate.

The maximum received level at the Scott Reef state waters limit (Table 9) is 160.8 or 165.2 dB re 1 µPa, depending upon the hammer used (Table 26).

5.1.1.2. Propagation at Brecknock

For Brecknock, sound interaction with the reefs only takes place at ranges of at least 30 km from the pile (in the northeast direction). Therefore, the different seabed types around the reefs have no influence on distances to the thresholds presented in this study (which when reached, occur at shorter ranges). At this location, sound propagation is mostly affected by bathymetry features. At ranges less than 13 km from the pile, the bathymetry varies smoothly from 400 m to 800 m from southeast–northwest direction. This smooth variation has little impact on sound propagation, resulting in mostly isotropic sound propagation (i.e. Figures 46 and 47). Beyond 13 km range from the pile, transects northwest from the pile encounter slightly rougher bathymetry features and steeper bathymetry decay, reaching water depths as deep as ~2.4 km 80 km from the pile. Contrary to this, transects southeast from the pile encounter a sharp decrease in water depth at ranges 50 km–60 km, reaching water depths ~100 m at 80 km from the pile. The influence of this asymmetry on sound propagation can be observed in the sound field maps in Section 4.2.2.2, for which sound propagates farther along downslope bathymetry lines.

5.1.2. Ranges to exposure thresholds

For criteria based on SEL_{24h} metrics, the ranges must be considered in context of the duration of operations. For the purposes of modelling, one pile will be driven per day; therefore, the corresponding sound level is denoted as SEL_{24h}; however, the estimated times for driving piles are 78.5 or 45.5 minutes (Torosa) and 80.1 or 47.4 minutes (Brecknock) for medium and high-power hammers, respectively (Table 16 for Torosa and Table 17 for Brecknock). SEL_{24h} is a cumulative metric that reflects the dosimetric impact of noise levels within the driving period, assuming that an animal is consistently exposed to such noise levels at a fixed position. The radii that correspond to SEL_{24h} typically represent an unlikely worst-case scenario for SEL-based exposure because, more realistically, marine fauna (mammals or fish) would not stay in the same location or at the same distance from a sound source for an extended period. Therefore, a reported radius for SEL_{24h} criteria does not mean that any animal travelling within this radius from the source *will* be exposed to PTS or TTS, but rather that it *could* be exposed if it remained within that range for the entire duration of the pile driving

For each sound level threshold, the maximum range (R_{max}) and the 95% range ($R_{95\%}$) were calculated. R_{max} is the distance to the farthest occurrence of the threshold level, at any depth. $R_{95\%}$ for a sound level is the radius of a circle, centred on the source, encompassing 95% of the sound at levels above threshold. Using $R_{95\%}$ reduces the sensitivity to extreme outlying values (the farthest 5% of ranges).

5.1.2.1. Marine mammals

The results for the NMFS (2018) criteria applied for marine mammal PTS and TTS consider both metrics within the criteria (PK and SEL), with SEL assessed here for a single pile within a 24 h period, i.e., a single pile per day. The metric with the longest distance must be applied, and these maximum distances along with the relevant metric are summarised in Table 56.

The maximum distances to the NMFS (2014) marine mammal behavioural response criterion of 160 dB re 1 µPa (SPL) are associated with the shallowest penetration of 17 m for both hammers, with the maximum distances summarised in Table 57.

Table 56. *Marine mammal injury and hearing sensitivity changes*: Maximum-over-depth distances (in km) from the pile to PTS and TTS thresholds (NMFS 2018). PK results are in Table 24 for Torosa and Table 35 for Brecknock and results for SEL$_{24h}$ are in Table 27 for Torosa and Table 37 for Brecknock.

Hearing group	**PTS**				**TTS**			
	IHC S-600		**IHC S-1200**		**IHC S-600**		**IHC S-1200**	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
Torosa								
LF cetaceans	5.15[#]	5.00[#]	5.35[#]	5.12[#]	26.10[#]	20.79[#]	29.46[#]	22.60[#]
MF cetaceans	<0.02[†]		<0.02[†]		0.03[#]		0.06[#]	0.06[#]
HF cetaceans	0.21[†]		0.26[†]		0.35[†]	0.30[#]	2.20[#]	2.06[#]
Brecknock								
LF cetaceans	4.58[#]	4.05[#]	4.62[#]	4.40[#]	23.11[#]	20.04[#]	24.75[#]	20.80[#]
MF cetaceans	<0.02[†]		<0.02[†]		<0.02[†]		0.05[#]	0.05[#]
HF cetaceans	0.19[†]		0.26[†]		0.36[†]	0.31[#]	2.33[#]	2.20[#]

[†] PK (L_{pk}; dB re 1 µPa)

[#] Frequency weighted SEL$_{24h}$ ($L_{\text{E,24h}}$). For the SEL$_{24h}$ criteria, the model does not account for shutdowns.

Table 57. *Marine mammal behaviour*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the piles to modelled maximum-over-depth isopleths for behavioural response thresholds, maximum across all three penetration depths. Results are in Tables 23 and 34.

SPL (L_p; dB re 1 µPa)	**IHC S-600**		**IHC S-1200**	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
Torosa				
160[†]	10.48	6.74	17.15	11.63
Brecknock				
160[†]	7.06	6.40	13.97	11.87

[†] Threshold for marine mammal behavioural response (NMFS 2014).

5.1.2.2. Turtles

The results for the Finneran et al. (2017) criteria applied for turtle PTS and TTS consider both metrics within the criteria (PK and SEL), with SEL assessed here for a single pile within a 24 h period, i.e., a single pile per day. The metric with the longest distance must be applied, and these maximum distances along with the relevant metric are summarised in Table 58.

The maximum distances to the two criteria considered, the NMFS criterion for behavioural response (SPL of 166 dB re 1 µPa) and a criterion for behavioural disturbance (SPL of 175 dB re 1 µPa)

(McCauley et al. 2000a, 2000b), are associated with the shallowest penetration of 17 m for both hammers, with the maximum distances summarised in Table 59.

Table 58. *Turtle injury and hearing sensitivity changes*: Maximum-over-depth distances (in km) to PTS and TTS thresholds from Finneran et al. (2017). PK results are in Table 24 for Torosa and Table 35 for Brecknock. Results for SEL_{24h} are in Table 27 for Torosa and Table 37 for Brecknock.

Hearing group	**PTS**				**TTS**			
	IHC S-600		**IHC S-1200**		**IHC S-600**		**IHC S-1200**	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
Torosa								
Turtles	0.24	0.23	0.25	0.25	4.79	2.36	5.07	4.94
Brecknock								
Turtles	0.24	0.23	0.25	0.24	2.58	2.44	2.60	2.47

All distances are associated with frequency weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s), not PK (L_{pk}; dB re 1 µPa). For the SEL_{24h} criteria, the model does not account for shutdowns.

Table 59. *Turtle behaviour*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the pile to modelled maximum-over-depth behavioural response thresholds, maximum across all three penetration depths. Results are in Tables 23 and 34.

SPL (L_p; dB re 1 µPa)	**IHC S-600**		**IHC S-1200**	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
Torosa				
175†	0.68	0.64	1.87	1.79
166‡	5.11	4.99	9.11	5.66
Brecknock				
175†	0.67	0.63	1.87	1.77
166‡	2.87	2.70	6.38	5.92

† Threshold for turtle behavioural response to impulsive noise (McCauley et al. 2000a, 2000b).
‡ Threshold for turtle behavioural response to impulsive noise (NSF 2011).

5.1.2.3. Fish, fish eggs, and fish larvae

The modelling study assessed the ranges for quantitative criteria from Popper et al. (2014) associated with mortality and potential mortal injury and impairment in the following:

- Fish without a swim bladder (also appropriate for sharks in the absence of other information)
- Fish with a swim bladder not used for hearing
- Fish that use their swim bladders for hearing
- Fish eggs, and fish larvae

Considering both per-strike modelled penetrations and associated SEL_{24h} scenario, along with both PK and SEL_{24h} metrics, in line with the conditions of the criteria, the maximum distances are summarised in Table 60 for Torosa and Table 61 for Brecknock.

Table 60. *Torosa fish effect thresholds:* Summary of maximum fish, fish eggs, and larvae injury and TTS onset distances for single impulse and SEL_{24h} modelled scenarios (PK values from Table 25, SEL_{24h} values from Table 28).

Relevant hearing group	Effect criteria	IHC S-600		IHC S-1200	
		Metric associated with longest distance to criteria	R_{max} (km)	Metric associated with longest distance to criteria	R_{max} (km)
Fish: No swim bladder	Injury	PK	0.08	PK	0.1
	TTS	SEL_{24h}	9.05	SEL_{24h}	9.15
Fish: Swim bladder not involved in hearing	Injury	SEL_{24h}	0.15	PK	0.17
	TTS	SEL_{24h}	9.05	SEL_{24h}	9.15
Fish: Swim bladder involved in hearing	Injury	SEL_{24h}	0.21	SEL_{24h}	0.22
	TTS	SEL_{24h}	9.05	SEL_{24h}	9.15
Fish eggs, and larvae	Injury	SEL_{24h}	0.15	PK	0.17

Table 61. *Brecknock fish effect thresholds*: Summary of maximum fish, fish eggs, and larvae injury and TTS onset distances for single impulse and SEL_{24h} modelled scenarios (PK values from Table 36, SEL_{24h} values from Table 38).

Relevant hearing group	Effect criteria	IHC S-600		IHC S-1200	
		Metric associated with longest distance to criteria	R_{max} (km)	Metric associated with longest distance to criteria	R_{max} (km)
Fish: No swim bladder	Injury	PK	0.04	PK	0.07
	TTS	SEL_{24h}	6.12	SEL_{24h}	6.27
Fish: Swim bladder not involved in hearing	Injury	SEL_{24h}	0.14	PK	0.16
	TTS	SEL_{24h}	6.12	SEL_{24h}	6.27
Fish: Swim bladder involved in hearing	Injury	SEL_{24h}	0.20	SEL_{24h}	0.22
	TTS	SEL_{24h}	6.12	SEL_{24h}	6.27
Fish eggs, and larvae	Injury	SEL_{24h}	0.14	PK	0.16

5.2. Animal movement and exposure modelling

The estimated sound fields produced by source and propagation models for the driving of a single pile were incorporated into the JASMINE sound exposure model to estimate the number of animals potentially exposed to levels above the defined thresholds. The range within which 95% of the exposure exceedances occur was also reported (95th percentile ranges, P_{95}, which could also be referred to as Exposure Range 95%, or $ER_{95\%}$). No density data were available for migratory green turtles (Section 3.7.3.2) therefore results are presented in terms of the 95th percentile ranges only. Mitigation of potential impacts through exclusion zones for turtles and pygmy blue whales (500 and 2000 m, respectively) were considered in the modelling.

5.2.1. Torosa FPSO anchor piles

Animal movement modelling simulation results predict that inter-nesting turtles are unlikely to be exposed above TTS, PTS, or behavioural thresholds for either of the two hammers at the Torosa location. Real-world densities are unavailable for migrating green turtles, so the true number of animals are not calculated in that case. However, there were no PTS PK, PTS SEL_{24h}, or TTS PK exposures above threshold for either hammer. Prior to considering exclusion zones, the 95th percentile range to TTS SEL_{24h} was 1.65 km and 1.79 km for the S-600 and S-1200 hammers, respectively. After considering a 500 m exclusion zone, the number of animals impacted was reduced by 20.7% for the S-600 hammer and 11.5% for the S-1200 hammer.

A number of migrating green turtles were exposed above both behavioural thresholds. The 95th percentile range to animats exceeding the behavioural disturbance threshold (175 dB re 1 µPa) was 50 m for the S-600 hammer and 1.77 km for the S-1200 hammer. Whilst the range to animats exceeding the behavioural response threshold (166 dB re 1 µPa) was 2.54 or 4.64 km for the S-600 or S-1200 hammer. The effectiveness of the exclusion zone in reducing exposures was moderate (less than 11%) in most cases. The exception being the exposures over the behavioural disturbance threshold for the S-600 hammer, in which the application of the exclusion zone reduced the number of animats exposed above threshold by 100%, or to zero.

Without considering the 2000 m exclusion zone, neither the migrating nor foraging pygmy blue whales are expected to be exposed above TTS PK or PTS PK thresholds for either of the two hammers. Regardless of hammer type, a total of 0.02 migrating pygmy blue whales are expected to be exposed above the PTS SEL_{24h} threshold, and a total of 0.06 foraging pygmy blue whales are expected to be exposed above the PTS SEL_{24h} threshold. The number of animats exposed above TTS SEL_{24h} was similar for between hammer types for migrating blue whales, with 1.28 or 1.30 individuals exposed for the S-600 and S-1200 hammer, respectively. The number of individual foraging blue whales exposed above TTS SEL_{24h} was slightly higher, but also similar between the two hammers, with 1.65 and 1.75 individuals for the S-600 and S-1200 hammers. After applying the 2000 m exclusion zone, the number of pygmy blue whales exposed above PTS SEL_{24h} threshold dropped to zero for both hammers.

The number of animals expected to be exposed above the 160 dB re 1 µPa (SPL) behavioural threshold ranges ranged from 0.58 for the foraging pygmy blue whale with the S-600 hammer, to 1.41 for the migrating pygmy blue whale with the S-1200 hammer.

For the thresholds which occur at a greater distance from the pile (TTS SEL_{24h}, and behavioural thresholds), more animats for both species and both hammers were exposed above threshold at larger ranges. Consequently, the effect of the exclusion zone wasn't significant for those metrics. Most of the ranges computed after the application of exclusion zones either increased or stayed the same, due to the influence on the statistical distribution of exposure ranges. In the cases where the exclusion zone encompassed all the exposures above threshold, there were no exposures remaining and the 95th percentile range therefore dropped to zero. Figure 90 shows the distribution of 95th percentile ranges before and after the application of the 2000 m exclusion zone for migrating pygmy blue whales above the behavioural threshold. After applying the exclusion zone, all of the close-range exposures were removed, which effectively shifted the entire distribution to longer ranges. This shift is reflected in the 0.58 km increase in 95th percentile range. Figure 91 shows the case where all the exposures above threshold occur within the exclusion zone range. Once the exposures below that range are excluded, the 95th percentile range defaults to zero.

The migratory behavioural profile includes migratory dives with a mean depth of 14 m ± 4 m (24 m maximum), and exploratory dives with a mean maximum depth of 107 ± 81 m (320 m maximum) (Section 3.7.2.1). These are included in the behavioural profile (Table G-2) as gaussian distributions. Due to the low sample size (a single animal), the variability across the population is unknown. To provide context if the distribution centres (means) are different, focused slice plots were produced (Figures 31–34). Within one standard deviation for the migratory dives, 4 m, there is minimal difference between the sound field distribution within the water column, and only a slight difference between the mean and maximum. For the exploratory dives, the levels are louder shallower than the mean or deeper than the mean depending upon the distance from the source. However, as the whales are moving up and down within the water column during their dives, they are exposed to a range of sound levels, including the quieter levels close to the surface.

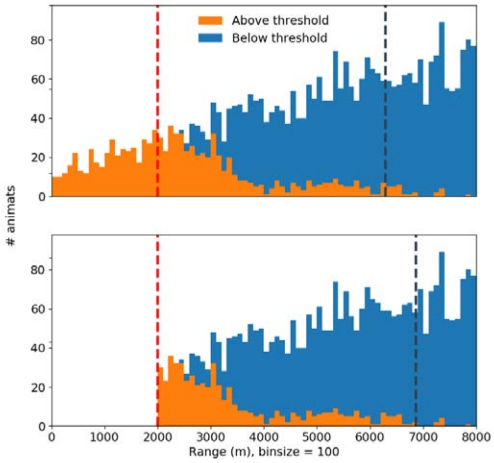

Figure 90. *Pygmy blue whale behavioural threshold*: Histograms of the distribution ranges for pygmy blue whale animat exposures for the S-600 hammer, showing (upper panel) exposures without and (lower panel) with an exclusion zone. Black dashed line: 95th percentile ranges. Red dashed line: 2000 m exclusion zone boundary.

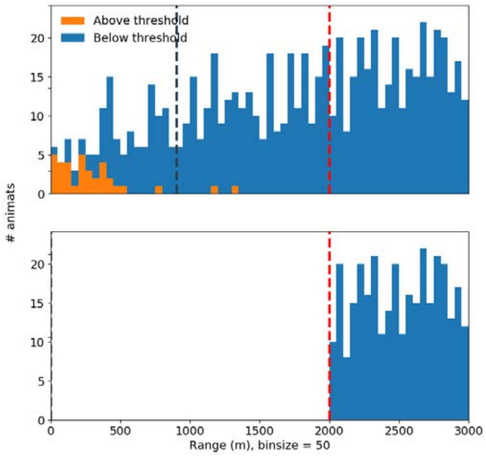

Figure 91. *Pygmy blue whale PTS threshold*: Histograms of the distribution ranges for pygmy blue whale animat exposures for the S-600 hammer, showing (upper panel) exposures without and (lower panel) with an exclusion zone. Black dashed line: 95th percentile ranges. Red dashed line: 2000 m exclusion zone boundary.

Implementing an exclusion zone of 500 m for green turtles and 2000 m for pygmy blue whales reduced all exposures above TTS and PTS threshold criteria to zero for both hammers, except for the TTS SEL_{24h} thresholds, where estimated exposures were only slightly reduced.

Interpretation of the 95th percentile ranges is nuanced and is the result of specific acoustic propagation characteristics as well as the probabilistic nature of the animal movement modelling simulation. As an example, Figure 92 shows vertical slices of SPL as a function of range and depth in the upper water column at a single azimuth (270°) for all three penetration depths for the IHC S-1200 hammer. The histograms in Figure 93 show how the probability of migrating green turtle exposures above threshold within the 95th percentile range varies as a function of the specific exposure threshold being applied (either 166 or 175 dB re 1 µPa in this case). A lower threshold level means that turtle animats further from the source will reach that threshold, therefore the computed 95th percentile range of all exposed turtle animats will be larger. Depending on the nature of the sound field as a function of range and depth, larger ranges may encompass different numbers of animats that are above and below sound threshold levels.

The example in Figure 93 demonstrates a case where, due to the nature of the acoustic propagation in the area, a lower proportion of the turtle animats within the higher threshold range are exposed above that threshold. For the S-1200 hammer, 45% of turtle animats within 4.64 km are exposed above the 166 dB SPL behavioural response threshold. For the same hammer, 58% of turtle animats within 1.77 km are above the 175 dB SPL increased behavioural disturbance threshold.

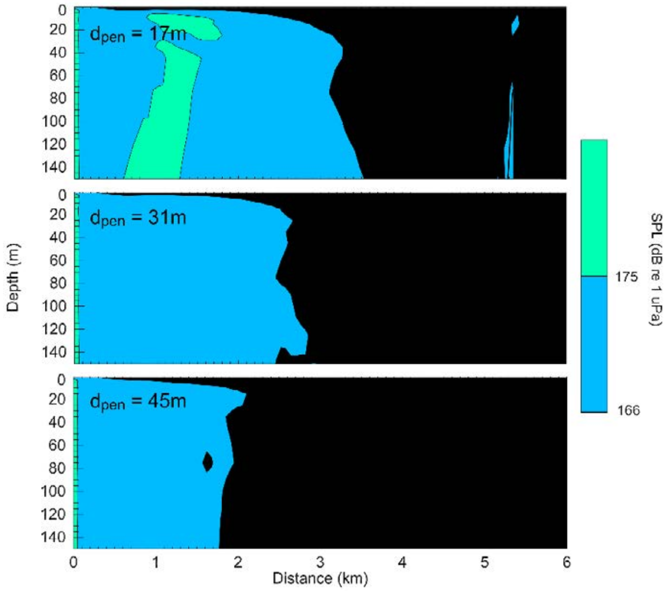

Figure 92. SPL (dB re 1µPa) for each of the modelled pile penetration depths (d_{pen}) as a function of distance from the piling location and depth in the upper 150 m of the water column for the IHC S-1200 hammer. Profiles are at an azimuth of 270°. Specific contours show the behavioural thresholds for green turtles.

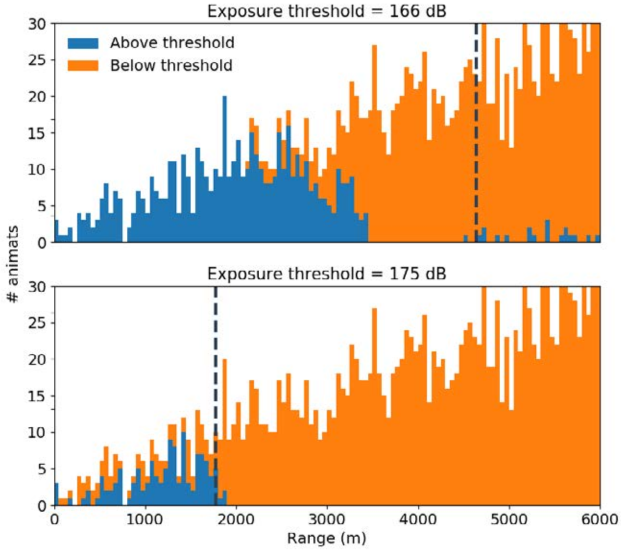

Figure 93. *Turtle behavioural threshold*: Histograms of the distribution ranges migrating green turtle animat exposures for the S-1200 hammer, showing (upper panel) exposures without and (lower panel) with an exclusion zone. Black dashed line: 95th percentile ranges. Red dashed line: 2000 m exclusion zone boundary.

5.2.2. Brecknock FPSO anchor piles

Animal movement modelling simulation results showed that green turtles were not exposed above threshold for PTS, TTS, or behaviour thresholds, even without applying the exclusion zone. This is because the Brecknock pile location is more than 40 km from either the modified inter-nesting or migration area BIAs.

Without consideration of the exclusion zone, pygmy blue whales have no exposures above PTS PK or TTS PK for either hammer. There were 0.02 exposures above PTS SEL_{24h} for the S-600 hammer, and 0.04 exposures above PTS SEL_{24h} for the S-1200 hammer. TTS SEL_{24h} exposures for migrating blue whales ranged from 1.56–1.67 for the S-600 and S-1200 hammers. The number of expected exposures above TTS_{24h} threshold for foraging pygmy blue whales was much lower since the Brecknock piling location is 10.3 km from the BIA: 0.02 individuals for the S-600 hammer and 0.08 individuals for the S-1200 hammer.

With the exclusion zone in place, the PTS SEL_{24h} exposures reduced to zero. The number of predicted exposures for foraging pygmy blue whales did not change as a result of applying an exclusion zone because of the large distance to the BIA.

The distribution of sound within the water column at depths relevant to the migratory behavioural profile, shown in Figures 58–61, follows a similar trend to that observed at Torosa, although the sound fields are quieter at greater ranges. Changes to migratory dive behaviour that result in a mean dive depth of a few metres deeper or shallower are, based on the presented results, unlikely to change the exposure ranges significantly.

5.3. VSP

5.3.1. Acoustic propagation

This study predicted underwater sound levels associated with VSP sources at Torosa TRD Well and Brecknock. The underwater sound field was modelled for a 750 in^3 seismic source array deployed at depth 6 m (Appendix C). Since the VSP source is mostly isotropic (vertically and horizontally), sound propagation for this source is driven by bathymetry features. For the Brecknock location, sound propagates larger distances towards the northwest, along downslope bathymetries. Similarly, for the Torosa TRD Well location sound from the VSP propagates mostly towards the north, passing along the west side of North Scott Reef. At both locations, sound is effectively blocked by the shallow reefs, which is more evident at the Torosa location due to its close proximity to the VSP source.

The overall broadband (10–25000 Hz) unweighted per-pulse SEL source level was 214.0 dB 1 μPa^2m^2s and 214.1 dB 1 μPa^2m^2s in the broadside and endfire directions, respectively. Additional results are presented in Table 40.

5.3.2. Ranges to exposure thresholds

The findings for the VSP operations pertaining each of the metrics and criteria for various marine species of interest are summarised below.

Marine mammals

- The maximum distance where the NMFS (2014) marine mammal behavioural response criterion of 160 dB re 1 µPa (SPL) could be exceeded varied between 1.6 and 1.7 km, provided in Table 42, with the distance being longer at Brecknock.
- The results for the criteria applied for marine mammal Permanent Threshold Shift (PTS), NMFS (2018), consider both metrics within the criteria (PK and SEL_{24h}), with results presented in Tables 43, 45 and 46.. The SEL_{24h} considers a range of impulses within 24 h, from 1 to 150. The applicable metric from the criteria, associated with the longest distance associated with either metric, depends upon the number of impulses with the 24 h. The ranges presented are based upon no more than 150 impulses within 24 h. A reported radius for SEL_{24h} criteria does not mean that marine mammals travelling within this radius of the source will be impacted, but rather that an

animal could be exposed to the sound level associated with auditory impairment (either PTS or TTS) if it remained in that location for either the duration of the activity or 24 hours.

PTS and TTS are not predicted to occur in mid-frequency cetaceans. For PTS in high-frequency cetaceans, the PK metric is always associated with the longest range (68 m), while for PTS in low-frequency cetaceans, for less than 10 impulses the range is greater due to the PK metric (12 m), but otherwise the range is determined by SEL_{24h}, with the maximum distance of 200 m being associated with 150 impulses at either Torosa TRD Well or Brecknock.

For TTS in high-frequency cetaceans the PK metric is always associated with the longest range (141 m), while for TTS in low-frequency cetaceans the range is determined by SEL_{24h}, with the maximum distance of 1 1.69 km for 150 impulses at Torosa TRD Well or Brecknock.

Turtles

- The VSP source is not predicted to cause PTS in turtles, as it doesn't cause either the PK or SEL_{24h} criteria from Finneran et al. (2017) to be exceeded at a distance greater than the horizontal modelling resolution (20 m) from the source (Tables 43 and 45).

  As with marine mammals, the SEL_{24h} considers a range of impulses within 24 h, from 1 to 150. While the TTS criteria due to the PK metric isn't exceeded, depending upon the number of impulses, the TTS SEL_{24h} criteria can be exceeded at up to 160 m for 150 impulses at Torosa TRD Well or Brecknock.
- Similarly to marine mammals, a reported radius for SEL_{24h} criteria does not mean that turtles travelling within this radius of the source will be impacted, but rather that an animal could be exposed to the sound level associated with auditory impairment (TTS) if it remained in that location for either the duration of the activity or 24 hours.
- The distances at where the two criteria considered in relation to turtle behaviour, behavioural response and disturbance, could be exceeded are summarised in Table 62.

Table 62. Distances to turtle behavioural response criteria (from Table 42).

SPL (L_p; **dB re 1 µPa**)	**Distance**	
	R_{max} (km)	$R_{95\%}$ (km)
Torosa TRD Well		
175†	0.23	0.23
166‡	0.81	0.77
Brecknock		
175†	0.23	0.23
166‡	0.72	0.69

† Threshold for turtle behavioural response to impulsive noise (McCauley et al. 2000a, McCauley et al. 2000b).
‡ Threshold for turtle behavioural response to impulsive noise (NSF 2011).

Fish, fish eggs, and fish larvae

- This modelling study assessed the ranges for quantitative criteria based on Popper et al. (2014) and considered both PK (seafloor and water column) and SEL_{24h} metrics associated with mortality and potential mortal injury and impairment (as defined in the criteria) in the following groups:
  - Fish without a swim bladder (also appropriate for sharks in the absence of other information)
  - Fish with a swim bladder that do not use it for hearing
  - Fish that use their swim bladders for hearing
  - Fish eggs and fish larvae
- Sound levels at the seafloor do not exceed any of the criteria.

- Based on PK metrics, acoustic injury could be sustained within a maximum horizontal distance of 21 m of the source for fish without a swim bladder, and within a maximum horizontal distance of 40 m for fish with a swim bladder, fish eggs, and fish larvae (Table 43). SEL_{24h} metrics for injury were not exceeded.

Sponges and Coral

- To assist with assessing the potential effects on sponges and coral receptors, the PK sound level at the seafloor directly underneath the VSP source was estimated at both modelling sites. It was found that the sound level of 226 dB re 1 µPa PK, a sound level associated with no effect (Heyward et al. 2018) was not reached.

5.4. Vessel Noise (MODU, OSV, and FPSO)

5.4.1. Acoustic propagation

This study predicted underwater sound levels associated with the operations of a Mobile Offshore Drilling Unit (MODU), FPSOs with and without DP operating, an OSV near each FPSO, and Offtake operations including an FPSO under DP, a noiseless condensate tanker and an OSV for locations at Torosa and Brecknock (Section 3.6). This includes aggregate scenarios which include FPSOs under normal operating conditions (without DP), as well as offtake operations, at both locations simultaneously.

Despite the different vessels having different source depths and either no thrusters or different thruster locations, sound propagation for these sources is driven by bathymetry features. The Torosa TRD Well location, where the MODU is located, is closer to the reef than the FPSO location, and thus the reef has an increased influence on the sound field. Sound propagates into South Scott Reef Lagoon, but the higher levels are restricted to the channel. The SPL sound field for sources located at Torosa (FPSO and OSV) above 120 dB are less influenced by the reef, although they are slightly attenuated in the direction of the reef for considering the FPSO under DP.

For the Brecknock location, sound propagates larger distances towards the northwest, along downslope bathymetries, with the influence apparent for all modelled sources.

Due to the distance of ~70 km between the Torosa and the Brecknock sites, as well as the blockage in line-of-sight due to the reef, contours for the criteria thresholds considered in this study do not combine between sites. Therefore, radii to criteria thresholds presented for FPSOs under normal operating conditions (without DP) and for offtake operations are still valid even in the case of simultaneous activity at Torosa and Brecknock. The only isopleths affected by simultaneous activities at both locations are those corresponding to the lower levels, below either 110 dB re 1 µPa or 170 dB re 1 $\mu Pa^2 \cdot s$ (unweighted) (Figures 87–89), which are not associated to any criteria.

5.4.2. Ranges to exposure thresholds

Marine mammals

The results for the NMFS (2018) criteria applied for marine mammal PTS and TTS for vessels are assessed here for a 24 h period. The maximum distances to PTS are summarised in Table 63, with complete results for PTS and TTS at the Torosa and Brecknock locations presented in Tables 50 and 51. The maximum distances to the NMFS (2014) marine mammal behavioural response criterion of 120 dB re 1 µPa (SPL) are summarised in Table 64, with complete results presented in Tables 47 and 48.

For aggregate scenarios considering both FPSO’s, it was found that due to the separation between the sites, distances to PTS, TTS, and behavioural thresholds remained unaltered compared to the individual operations (Tables 52–55). This was quantified by verifying that the total aggregate area within threshold isopleth for marine mammal behavioural response to continuous noise (NMFS 2014) equals the sum of the areas for the individual operations.

Table 63. *Marine mammal injury*: Maximum (R_{max}) horizontal distances (km) to modelled maximum-over-depth PTS threshold from NMFS (2018) for vessel-based scenarios.

Hearing group	Threshold for PTS, SEL_{24h} (dB re 1 µPa²·s) #	Distance R_{max} (km)				
		MODU	OSV	FPSO on DP	FPSO without DP	FPSO offtake
Torosa						
LF cetaceans	199	0.11	0.05	0.12	-	0.12
MF cetaceans	198	-	-	<0.02	-	<0.02
HF cetaceans	173	0.15	0.07	0.28	-	0.28
Brecknock						
LF cetaceans	199	0.11	0.06	0.12	<0.02	0.12
MF cetaceans	198	-	-	<0.02	-	<0.02
HF cetaceans	173	0.15	0.07	0.28	<0.02	0.28

Frequency weighted.
A dash indicates the level was not reached.
FPSO offtake includes an FPSO under DP, a noiseless condensate tanker and an OSV.

Table 64. *Marine mammal behaviour*: Summary of maximum behavioural disturbance distances for vessel-based scenarios, derived from Tables 47 and 48.

SPL (L_p; dB re 1 µPa)	Distance R_{max} (km)				
	MODU	OSV	FPSO on DP	FPSO without DP	FPSO Offtake
Torosa					
120†	10.50	2.25	8.77	0.57	8.89
Brecknock					
120†	8.84	2.39	8.78	0.54	8.89

† Threshold for marine mammal behavioural response to continuous noise (NMFS 2014).
FPSO offtake includes an FPSO under DP, a noiseless condensate tanker and an OSV.

Turtles

Results for the Finneran et al. (2017) criteria applied for turtle PTS and TTS for vessels are assessed here for a 24 h period. The maximum distances to PTS are summarised in Table 65, with complete results for PTS and TTS at the Torosa and Brecknock locations presented in Tables 50 and 51.

Table 65. *Turtle SEL_{24h} thresholds*: Maximum-over-depth distances (in km) to turtle PTS threshold (Finneran et al. 2017).

SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Distance R_{max} (km)				
	MODU	OSV	FPSO on DP	FPSO without DP	FPSO Offtake
Torosa					
220†	0.06	0.06	<0.02	-	<0.02
Brecknock					
220†	0.06	0.06	<0.02	-	<0.02

† Threshold for turtle-weighted SEL_{24h} (Finneran et al. 2017).
A dash indicates the level was not reached.
FPSO offtake includes an FPSO under DP, a noiseless condensate tanker and an OSV.

Fish

Sound produced by the vessel operations could cause physiological effects, and recoverable injury, to some fish species, but only if the animals are in very close proximity to the sound sources–within a planar distance of 60 m, for 48 h. Temporary impairment due to TTS could occur at similar short distances if fish remain at the same point within the sound field for long periods of time (12 h). The distances are farther for the MODU, and smallest for the FPSO without DP (Table 49).

For offtake operations, recoverable injury and temporary impairment could happen if fish remain within planar distances of <20 m and 40 m, respectively, from the FPSO or the OSV thrusters. There is no increased risk to fish from aggregate scenarios, with ranges to thresholds from the individual sources unchanged.

6. Glossary

1/3-octave
One third of an octave. Note: A one-third octave is approximately equal to one decidecade (1/3 oct ≈ 1.003 ddec; ISO 2017).

1/3-octave-band
Frequency band whose bandwidth is one one-third octave. Note: The bandwidth of a one-third octave-band increases with increasing centre frequency.

absorption
The reduction of acoustic pressure amplitude due to acoustic particle motion energy converting to heat in the propagation medium.

acoustic impedance
The ratio of the sound pressure in a medium to the rate of alternating flow of the medium through a specified surface due to the sound wave.

ambient noise
All-encompassing sound at a given place, usually a composite of sound from many sources near and far (ANSI S1.1-1994 R2004), e.g., shipping vessels, seismic activity, precipitation, sea ice movement, wave action, and biological activity.

attenuation
The gradual loss of acoustic energy from absorption and scattering as sound propagates through a medium.

Auditory frequency weighting (auditory weighting function, frequency-weighting function)
The process of band-pass filtering sounds to reduce the importance of inaudible or less-audible frequencies for individual species or groups of species of aquatic mammals (ISO 2017). One example is M-weighting introduced by Southall et al. (2007) to describe "Generalized frequency weightings for various functional hearing groups of marine mammals, allowing for their functional bandwidths and appropriate in characterizing auditory effects of strong sounds".

azimuth
A horizontal angle relative to a reference direction, which is often magnetic north or the direction of travel. In navigation it is also called bearing.

bandwidth
The range of frequencies over which a sound occurs. Broadband refers to a source that produces sound over a broad range of frequencies (e.g., seismic airguns, vessels) whereas narrowband sources produce sounds over a narrow frequency range (e.g., sonar) (ANSI/ASA S1.13-2005 R2010).

bar
Unit of pressure equal to 100 kPa, which is approximately equal to the atmospheric pressure on Earth at sea level. 1 bar is equal to 10^5 Pa or 10^{11} µPa.

broadband sound level
The total sound pressure level measured over a specified frequency range. If the frequency range is unspecified, it refers to the entire measured frequency range.

broadside direction
Perpendicular to the travel direction of a source. Compare with endfire direction.

cavitation
A rapid formation and collapse of vapor cavities (i.e., bubbles or voids) in water, most often caused by a rapid change in pressure. Fast-spinning vessel propellers typically cause cavitation, which creates a lot of noise.

cetacean
Any animal in the order Cetacea. These are aquatic, mostly marine mammals and include whales, dolphins, and porpoises.

compressional wave
A mechanical vibration wave in which the direction of particle motion is parallel to the direction of propagation. Also called primary wave or P-wave.

continuous sound
A sound whose sound pressure level remains above ambient sound during the observation period (ANSI/ASA S1.13-2005 R2010). A sound that gradually varies in intensity with time, for example, sound from a marine vessel.

decade
Logarithmic frequency interval whose upper bound is ten times larger than its lower bound (ISO 2006).

decidecade
One tenth of a decade (ISO 2017). Note: An alternative name for decidecade (symbol ddec) is "one-tenth decade". A decidecade is approximately equal to one third of an octave (1 ddec ≈ 0.3322 oct) and for this reason is sometimes referred to as a "one-third octave".

decidecade band
Frequency band whose bandwidth is one decidecade. Note: The bandwidth of a decidecade band increases with increasing centre frequency.

decibel (dB)
One-tenth of a bel. Unit of level when the base of the logarithm is the tenth root of ten, and the quantities concerned are proportional to power (ANSI S1.1-1994 R2004).

endfire direction
Parallel to the travel direction of a source. See also broadside direction.

ensonified
Exposed to sound.

far-field
The zone where, to an observer, sound originating from an array of sources (or a spatially distributed source) appears to radiate from a single point. The distance to the acoustic far-field increases with frequency.

fast-average sound pressure level
The time-averaged sound pressure levels calculated over the duration of a pulse (e.g., 90%-energy time window), using the leaky time integrator from Plomp and Bouman (1959) and a time constant of 125 ms. Typically used only for pulsed sounds.

fast Fourier transform (FFT)
A computationally efficiently algorithm for computing the discrete Fourier transform.

frequency
The rate of oscillation of a periodic function measured in cycles-per-unit-time. The reciprocal of the period. Unit: hertz (Hz). Symbol: *f*. 1 Hz is equal to 1 cycle per second.

hearing group
Groups of marine mammal species with similar hearing ranges. Commonly defined functional hearing groups include low-, mid-, and high-frequency cetaceans, pinnipeds in water, and pinnipeds in air.

geoacoustic
Relating to the acoustic properties of the seabed.

hearing threshold
The sound pressure level for any frequency of the hearing group that is barely audible for a given individual in the absence of significant background noise during a specific percentage of experimental trials.

hertz (Hz)
A unit of frequency defined as one cycle per second.

high-frequency (HF) cetacean
The functional cetacean hearing group that represents those odontocetes (toothed whales) specialized for hearing high frequencies.

intermittent sound
A level of sound that abruptly drops to the background noise level several times during the observation period.

impulsive sound
Sound that is typically brief and intermittent with rapid (within a few seconds) rise time and decay back to ambient levels (NOAA 2013, ANSI S12.7-1986 R2006). For example, seismic airguns and impact pile driving.

low-frequency (LF) cetacean
The functional cetacean hearing group that represents mysticetes (baleen whales) specialized for hearing low frequencies.

masking
Obscuring of sounds of interest by sounds at similar frequencies.

median
The 50th percentile of a statistical distribution.

mid-frequency (MF) cetacean
The functional cetacean hearing group that represents those odontocetes (toothed whales) specialized for mid-frequency hearing.

Monte Carlo simulation
The method of investigating the distribution of a non-linear multi-variate function by random sampling of all of its input variable distributions.

mysticete
Mysticeti, a suborder of cetaceans, use their baleen plates, rather than teeth, to filter food from water. They are not known to echolocate, but they use sound for communication. Members of this group include rorquals (Balaenopteridae), right whales (Balaenidae), and grey whales (*Eschrichtius robustus*).

non-impulsive sound
Sound that is broadband, narrowband or tonal, brief or prolonged, continuous or intermittent, and typically does not have a high peak pressure with rapid rise time (typically only small fluctuations in decibel level) that impulsive signals have (ANSI/ASA S3.20-1995 R2008). For example, marine vessels, aircraft, machinery, construction, and vibratory pile driving (NIOSH 1998, NOAA 2015).

octave
The interval between a sound and another sound with double or half the frequency. For example, one octave above 200 Hz is 400 Hz, and one octave below 200 Hz is 100 Hz.

odontocete
The presence of teeth, rather than baleen, characterizes these whales. Members of the Odontoceti are a suborder of cetaceans, a group comprised of whales, dolphins, and porpoises. The skulls of toothed whales are mostly asymmetric, an adaptation for their echolocation. This group includes sperm whales, killer whales, belugas, narwhals, dolphins, and porpoises.

otariid
A common term used to describe members of the Otariidae, eared seals, commonly called sea lions and fur seals. Otariids are adapted to a semi-aquatic life; they use their large fore flippers for propulsion. Their ears distinguish them from phocids. Otariids are one of the three main groups in the superfamily Pinnipedia; the other two groups are phocids and walrus.

parabolic equation method
A computationally efficient solution to the acoustic wave equation that is used to model transmission loss. The parabolic equation approximation omits effects of back-scattered sound, simplifying the computation of transmission loss. The effect of back-scattered sound is negligible for most ocean-acoustic propagation problems.

particle velocity
The physical speed of a particle in a material moving back and forth in the direction of the pressure wave. Unit: metre per second (m/s). Symbol: v.

peak pressure level (PK)
The maximum instantaneous sound pressure level, in a stated frequency band, within a stated period. Also called zero-to-peak pressure level. Unit: decibel (dB).

peak-to-peak pressure level (PK-PK)
The difference between the maximum and minimum instantaneous pressure levels. Unit: decibel (dB).

percentile level, exceedance
The sound level exceeded n% of the time during a measurement.

permanent threshold shift (PTS)
A permanent loss of hearing sensitivity caused by excessive noise exposure. PTS is considered auditory injury.

phocid
A common term used to describe all members of the family Phocidae. These true/earless seals are more adapted to in-water life than are otariids, which have more terrestrial adaptations. Phocids use their hind flippers to propel themselves. Phocids are one of the three main groups in the superfamily Pinnipedia; the other two groups are otariids and walrus.

phocid pinnipeds in water (PPW)
The functional pinniped hearing group that represents true/earless seals under water.

pinniped
A common term used to describe all three groups that form the superfamily Pinnipedia: phocids (true seals or earless seals), otariids (eared seals or fur seals and sea lions), and walrus.

point source
A source that radiates sound as if from a single point (ANSI S1.1-1994 R2004).

pressure, acoustic
The deviation from the ambient hydrostatic pressure caused by a sound wave. Also called overpressure. Unit: pascal (Pa). Symbol: p.

pressure, hydrostatic
The pressure at any given depth in a static liquid that is the result of the weight of the liquid acting on a unit area at that depth, plus any pressure acting on the surface of the liquid. Unit: pascal (Pa).

received level (RL)
The sound level measured (or that would be measured) at a defined location.

rms
root-mean-square.

signature
Pressure signal generated by a source.

sound
A time-varying pressure disturbance generated by mechanical vibration waves travelling through a fluid medium such as air or water.

sound exposure
Time integral of squared, instantaneous frequency-weighted sound pressure over a stated time interval or event. Unit: pascal-squared second ($Pa^2 \cdot s$) (ANSI S1.1-1994 R2004).

sound exposure level (SEL)
A cumulative measure related to the sound energy in one or more pulses. Unit: dB re 1 $\mu Pa^2 \cdot s$. SEL is expressed over the summation period (e.g., per-pulse SEL [for airguns], single-strike SEL [for pile drivers], 24-hour SEL).

sound exposure spectral density
Distribution as a function of frequency of the time-integrated squared sound pressure per unit bandwidth of a sound having a continuous spectrum (ANSI S1.1-1994 R2004). Unit: $\mu Pa^2 \cdot s/Hz$.

sound field
Region containing sound waves (ANSI S1.1-1994 R2004).

sound intensity
Sound energy flowing through a unit area perpendicular to the direction of propagation per unit time.

sound pressure level (SPL)
The decibel ratio of the time-mean-square sound pressure, in a stated frequency band, to the square of the reference sound pressure (ANSI S1.1-1994 R2004).

For sound in water, the reference sound pressure is one micropascal (p_0 = 1 μPa) and the unit for SPL is dB re 1 μPa^2:

$$L_p = 10 \log_{10}(p^2/p_0^2) = 20 \log_{10}(p/p_0)$$

Unless otherwise stated, SPL refers to the root-mean-square (rms) pressure level. See also 90% sound pressure level and fast-average sound pressure level. Non-rectangular time window functions may be applied during calculation of the rms value, in which case the SPL unit should identify the window type.

sound speed profile
The speed of sound in the water column as a function of depth below the water surface.

source level (SL)
The sound level measured in the far-field and scaled back to a standard reference distance of 1 metre from the acoustic centre of the source. Unit: dB re 1 μPa·m (pressure level) or dB re 1 $\mu Pa^2 \cdot s \cdot m$ (exposure level).

spectrogram
A visual representation of acoustic amplitude compared with time and frequency.

spectrum
An acoustic signal represented in terms of its power, energy, mean-square sound pressure, or sound exposure distribution with frequency.

temporary threshold shift (TTS)
Temporary loss of hearing sensitivity caused by excessive noise exposure.

transmission loss (TL)
The decibel reduction in sound level between two stated points that results from sound spreading away from an acoustic source subject to the influence of the surrounding environment. Also referred to as propagation loss.

wavelength
Distance over which a wave completes one cycle of oscillation. Unit: metre (m). Symbol: λ.

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Appendix A. Acoustic Metrics

A.1. Pressure Related Acoustic Metrics

Underwater sound pressure amplitude is measured in decibels (dB) relative to a fixed reference pressure of p_0 = 1 μPa. Because the perceived loudness of sound, especially impulsive noise such as from seismic airguns, pile driving, and sonar, is not generally proportional to the instantaneous acoustic pressure, several sound level metrics are commonly used to evaluate noise and its effects on marine life. We provide specific definitions of relevant metrics used in the accompanying report. Where possible we follow the ANSI and ISO standard definitions and symbols for sound metrics, but these standards are not always consistent.

The zero-to-peak sound pressure level (PK; L_{pk}; $L_{p,pk}$; dB re 1 μPa), is the maximum instantaneous sound pressure level in a stated frequency band attained by an acoustic pressure signal, *p*(*t*):

$$L_{p,pk} = 20\log_{10}\left[\frac{\max(|p(t)|)}{p_0}\right] \tag{A-1}$$

PK is often included as a criterion for assessing whether a sound is potentially injurious; however, because it does not account for the duration of a noise event, it is generally a poor indicator of perceived loudness.

The peak-to-peak sound pressure level (PK-PK; $L_{pk\text{-}pk}$; $L_{p,pk\text{-}pk}$; dB re 1 μPa) is the difference between the maximum and minimum instantaneous sound pressure levels in a stated frequency band attained by an impulsive sound, *p*(*t*):

$$L_{p,pk-pk} = 10\log_{10}\left\{\frac{[\max(p(t)) - \min(p(t))]^2}{p_0^2}\right\} \tag{A-2}$$

The sound pressure level (SPL; L_p; dB re 1 μPa) is the rms pressure level in a stated frequency band over a specified time window (*T*, s) containing the acoustic event of interest. It is important to note that SPL always refers to a rms pressure level and therefore not instantaneous pressure:

$$L_p = 10\log_{10}\left(\frac{1}{T}\int_T p^2(t)dt \Big/ p_0^2\right) \tag{A-3}$$

The SPL represents a nominal effective continuous sound over the duration of an acoustic event, such as the emission of one acoustic pulse, a marine mammal vocalization, the passage of a vessel, or over a fixed duration. Because the window length, *T*, is the divisor, events with similar sound exposure level (SEL) but more spread out in time have a lower SPL. A fixed window length of 0.125 s (critical duration defined by Tougaard et al. (2015)) is used in this study for impulsive sounds.

The sound exposure level (SEL; L_E; $L_{E,p}$; dB re 1 μPa²·s) is a measure related to the acoustic energy contained in one or more acoustic events (*N*). The SEL for a single event is computed from the time-integral of the squared pressure over the full event duration (*T*):

$$L_E = 10\log_{10}\left(\int_T p^2(t)dt \Big/ T_0 p_0^2\right) \tag{A-4}$$

where T_0 is a reference time interval of 1 s. The SEL continues to increase with time when non-zero pressure signals are present. It therefore can be construed as a dose-type measurement, so the integration time used must be carefully considered in terms of relevance for impact to the exposed recipients.

SEL can be calculated over periods with multiple acoustic events or over a fixed duration. For a fixed duration, the square pressure is integrated over the duration of interest. For multiple events, SEL can be computed by summing (in linear units) SEL of the *N* individual events:

$$L_{E,N} = 10\log_{10}\left(\sum_{i=1}^{N} 10^{\frac{L_{E,i}}{10}}\right) . \qquad \text{(A-5)}$$

If applied, the frequency weighting of an acoustic event should be specified, as in the case of weighted SEL (e.g., $L_{E,LFC,24h}$; Appendix A.3). The use of fast, slow, or impulse exponential-time-averaging or other time-related characteristics should else be specified.

A.2. Marine Mammal Impact Criteria

It has been long recognised that marine mammals can be adversely affected by underwater anthropogenic noise. For example, Payne and Webb (1971) suggested that communication distances of fin whales are reduced by shipping sounds. Subsequently, similar concerns arose regarding effects of other underwater noise sources and the possibility that impulsive sources—primarily airguns used in seismic surveys—could cause auditory injury. This led to a series of workshops held in the late 1990s, conducted to address acoustic mitigation requirements for seismic surveys and other underwater noise sources (NMFS 1998, ONR 1998, Nedwell and Turnpenny 1998, HESS 1999, Ellison and Stein 1999). In the years since these early workshops, a variety of thresholds have been proposed for both injury and disturbance. The following sections summarize the recent development of thresholds; however, this field remains an active research topic.

A.2.1. Injury

In recognition of shortcomings of the SPL-only based injury criteria, in 2005 NMFS sponsored the Noise Criteria Group to review literature on marine mammal hearing to propose new noise exposure criteria. Some members of this expert group published a landmark paper (Southall et al. 2007) that suggested assessment methods similar to those applied for humans. The resulting recommendations introduced dual acoustic injury criteria for impulsive sounds that included peak pressure level thresholds and SEL_{24h} thresholds, where the subscripted 24h refers to the accumulation period for calculating SEL. The peak pressure level criterion is not frequency weighted whereas SEL_{24h} is frequency weighted according to one of four marine mammal species hearing groups: low-, mid- and high-frequency cetaceans (LF, MF, and HF cetaceans, respectively) and Pinnipeds in Water (PINN). These weighting functions are referred to as M-weighting filters (analogous to the A-weighting filter for human; Appendix A.3). The SEL_{24h} thresholds were obtained by extrapolating measurements of onset levels of Temporary Threshold Shift (TTS) in belugas by the amount of TTS required to produce Permanent Threshold Shift (PTS) in chinchillas. The Southall et al. (2007) recommendations do not specify an exchange rate, which suggests that the thresholds are the same regardless of the duration of exposure (i.e., it implies a 3 dB exchange rate).

Wood et al. (2012) refined Southall et al.'s (2007) thresholds, suggesting lower injury values for LF and HF cetaceans while retaining the filter shapes. Their revised thresholds were based on TTS-onset levels in harbour porpoises from Lucke et al. (2009), which led to a revised impulsive sound PTS threshold for HF cetaceans of 179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$. Because there were no data available for baleen whales, Wood et al. (2012) based their recommendations for LF cetaceans on results obtained from MF cetacean studies. In particular they referenced Finneran and Schlundt (2010) research, which found mid-frequency cetaceans are more sensitive to non-impulsive sound exposure than Southall et al. (2007) assumed. Wood et al. (2012) thus recommended a more conservative TTS-onset level for LF cetaceans of 192 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$.

As of 2017, an optimal approach is not apparent. There is consensus in the research community that an SEL-based method is preferable either separately or in addition to an SPL-based approach to assess the potential for injuries. In August 2016, after substantial public and expert input into three draft versions and based largely on the above-mentioned literature (NOAA 2013, 2015, 2016), NMFS finalised technical guidance for assessing the effect of anthropogenic sound on marine mammal hearing (NMFS 2016). The guidance describes injury criteria with new thresholds and frequency weighting functions for the five hearing groups described by Finneran and Jenkins (2012). The latest revision to this work was published in 2018 (NMFS 2018). Southall et al. (2019) revisited the interim criteria published in 2007; all noise exposure criteria in NMFS (2018) and Southall et al. (2019) are identical (for impulsive and non-impulsive sounds), however the mid-frequency cetaceans from NMFS (2018) are classified as high-frequency cetaceans in Southall et al. (2019), and high-frequency cetaceans from NMFS (2018) are classified as very-high-frequency cetaceans in Southall et al. (2019). This report continues to apply the terminology from NMFS (2018) for consistency with other projects.

A.3. Marine Mammal Frequency Weighting

The potential for noise to affect animals depends on how well the animals can hear it. Noises are less likely to disturb or injure an animal if they are at frequencies that the animal cannot hear well. An exception occurs when the sound pressure is so high that it can physically injure an animal by non-auditory means (i.e., barotrauma). For sound levels below such extremes, the importance of sound components at particular frequencies can be scaled by frequency weighting relevant to an animal’s sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007).

A.3.1. Marine mammal frequency weighting functions

In 2015, a U.S. Navy technical report by Finneran (2015) recommended new auditory weighting functions. The overall shape of the auditory weighting functions is similar to human A-weighting functions, which follows the sensitivity of the human ear at low sound levels. The new frequency-weighting function is expressed as:

$$G(f) = K + 10\log_{10}\left[\left(\frac{(f/f_{lo})^{2a}}{\left[1+(f/f_{lo})^2\right]^a\left[1+(f/f_{hi})^2\right]^b}\right)\right] \tag{A-6}$$

Finneran (2015) proposed five functional hearing groups for marine mammals in water: low-, mid-, and high-frequency cetaceans, phocid pinnipeds, and otariid pinnipeds. The parameters for these frequency-weighting functions were further modified the following year (Finneran 2016) and were adopted in NOAA’s technical guidance that assesses noise impacts on marine mammals (NMFS 2016, NMFS 2018). Table A-1 lists the frequency-weighting parameters for each hearing group; Figure A-1 shows the resulting frequency-weighting curves.

Table A-1. Parameters for the auditory weighting functions used in this project as recommended by NMFS (2018).

Hearing group	**a**	**b**	**f_{lo} (Hz)**	**f_{hi} (kHz)**	***K* (dB)**
LF cetaceans (baleen whales)	1.0	2	200	19,000	0.13
MF cetaceans (dolphins, plus toothed, beaked, and bottlenose whales)	1.6	2	8,800	110,000	1.20
HF cetaceans (true porpoises, *Kogia*, river dolphins, cephalorhynchid, *Lagenorhynchus cruciger* and *L. australis*)	1.8	2	12,000	140,000	1.36

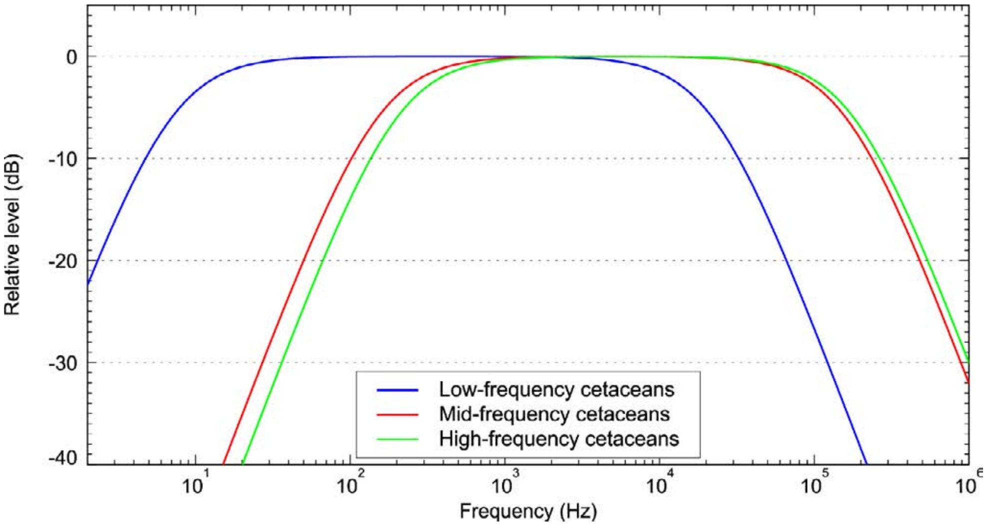


Figure A-1. Auditory weighting functions for functional marine mammal hearing groups as recommended by NMFS (2018).

Appendix B. Pile Driving Acoustic Source Model

A physical model of pile vibration and near-field sound radiation is used to calculate source levels of piles. The physical model employed in this study computes the underwater vibration and sound radiation of a pile by solving the theoretical equations of motion for axial and radial vibrations of a cylindrical shell. These equations of motion are solved subject to boundary conditions, which describe the forcing function of the hammer at the top of the pile and the soil resistance at the base of the pile (Figure B-1). Damping of the pile vibration due to radiation loading is computed for Mach waves emanating from the pile wall. The equations of motion are discretised using the finite difference (FD) method and are solved on a discrete time and depth mesh.

To model the sound emissions from the piles, the force of the pile driving hammers also had to be modelled. The force at the top of each pile was computed using the GRLWEAP 2010 wave equation model (GRLWEAP, Pile Dynamics 2010), which includes a large database of simulated hammers—both impact and vibratory—based on the manufacturer’s specifications. The forcing functions from GRLWEAP were used as inputs to the FD model to compute the resulting pile vibrations.

The sound radiating from the pile itself is simulated using a vertical VSP array of discrete point sources. The point sources are centred on the pile axis. Their amplitudes are derived using an inverse technique, such that their collective particle velocity—calculated using a near-field wave-number integration model—matches the particle velocity in the water at the pile wall. The sound field propagating away from the vertical source VSP array is then calculated using a time-domain acoustic propagation model (FWRAM, Appendix E.2). MacGillivray (2014) describes the theory behind the physical model in more detail. The accuracy of JASCO's pile driving model has been verified by comparing its output against benchmark scenarios (Lippert et al. 2016) and detailed measurement programs (Austin et al. 2016, Denes et al. 2016, MacGillivray 2018).

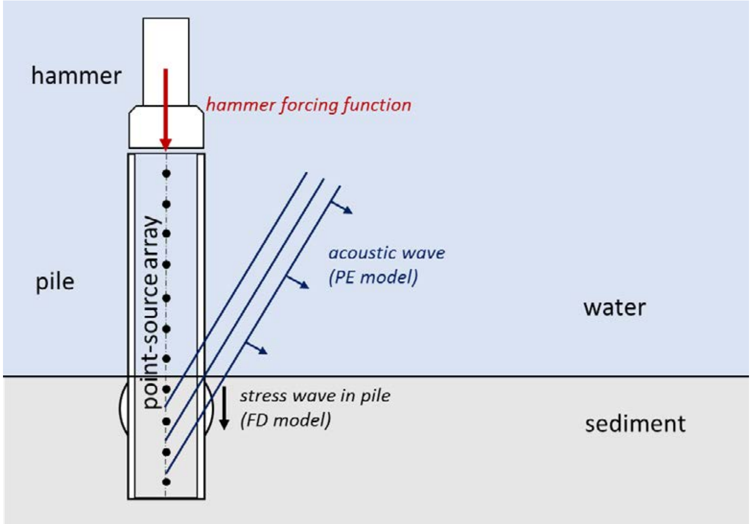


Figure B-1. Physical model geometry for impact driving of a cylindrical pile (vertical cross-section). The hammer forcing function is used with the finite difference (FD) model to compute the stress wave vibration in the pile. A vertical VSP array of point sources is used with the parabolic equation (PE) model to compute the acoustic waves that the pile wall radiates.

Appendix C. VSP Source

C.1. Airgun Array Source Model

The source levels and directivity of the seismic source were predicted with JASCO's Airgun Array Source Model (AASM). AASM includes low- and high-frequency modules for predicting different components of the seismic source spectrum. The low-frequency module is based on the physics of oscillation and radiation of airgun bubbles, as originally described by Ziolkowski (1970), that solves the set of parallel differential equations that govern bubble oscillations. Physical effects accounted for in the simulation include pressure interactions between airguns, port throttling, bubble damping, and generator-injector (GI) gun behaviour discussed by Dragoset (1984), Laws et al. (1990), and Landro (1992). A global optimisation algorithm tunes free parameters in the model to a large library of airgun source signatures.

While airgun signatures are highly repeatable at the low frequencies, which are used for seismic imaging, their sound emissions have a large random component at higher frequencies that cannot be predicted using a deterministic model. Therefore, AASM uses a stochastic simulation to predict the high-frequency (800−25,000 Hz) sound emissions of individual airguns, using a data-driven multiple-regression model. The multiple-regression model is based on a statistical analysis of a large collection of high quality seismic source signature data recently obtained from the Joint Industry Program (JIP) on Sound and Marine Life (Mattsson and Jenkerson 2008). The stochastic model uses a Monte-Carlo simulation to simulate the random component of the high-frequency spectrum of each airgun in an array. The mean high-frequency spectra from the stochastic model augment the low-frequency signatures from the physical model, allowing AASM to predict airgun source levels at frequencies up to 25,000 Hz.

AASM produces a set of "notional" signatures for each array element based on:

- Array layout
- Volume, operating depth, and firing pressure of each airgun
- Interactions between different airguns in the array

These notional signatures are the pressure waveforms of the individual airguns at a standard reference distance of 1 m; they account for the interactions with the other airguns in the array. The signatures are summed with the appropriate phase delays to obtain the far-field source signature of the entire array in all directions. This far-field array signature is filtered into 1/3-octave-bands to compute the source levels of the array as a function of frequency band and azimuthal angle in the horizontal plane (at the source depth), after which it is considered a directional point source in the far field.

A seismic array consists of many sources and the point source assumption is invalid in the near field where the array elements add incoherently. The maximum extent of the near field of an array (R_{nf}) is:

$$R_{\mathrm{nf}} < \frac{l^2}{4\lambda} \quad \text{(C-1)}$$

where λ is the sound wavelength and l is the longest dimension of the array (Lurton 2002, §5.2.4). For example, a seismic source length of l = 21 m yields a near-field range of 147 m at 2 kHz and 7 m at 100 Hz. Beyond this R_{nf} range, the array is assumed to radiate like a directional point source and is treated as such for propagation modelling.

The interactions between individual elements of the array create directionality in the overall acoustic emission. Generally, this directionality is prominent mainly at frequencies in the mid-range between tens of hertz to several hundred hertz. At lower frequencies, with acoustic wavelengths much larger than the inter-airgun separation distances, the directionality is small. At higher frequencies, the pattern of lobes is too finely spaced to be resolved and the effective directivity is less.

C.2. VSP Source Parameters

The layout of the seismic source is provided in Figure F-1. Details of the airgun parameters are provided in Table C-1.

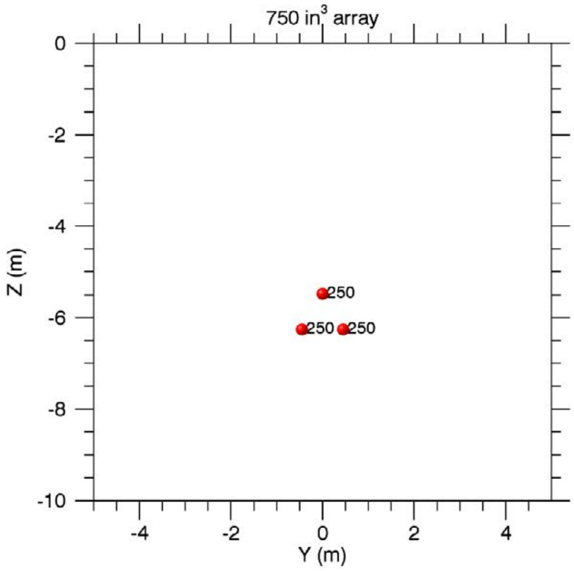


Figure C-1. Layout of the modelled 750 in^3 seismic source array. Operational depth is 6 m. The labels indicate the firing volume (in cubic inches) for each airgun. Also see Table C-1.

Table C-1. Layout of the modelled 750 in^3 seismic source array. Operational depth is 6 m. Firing pressure for all guns is 1800 psi. Also see Figure C-1.

Gun	x (m)	y (m)	z (m)	Volume (in^3)
1	0	0	5.48	250
2	0	-0.45	6.26	250
3	0	0.45	6.26	250

C.3. Array Source Levels and Directivity

Figure C-2 shows the broadside (perpendicular to the tow direction), endfire (parallel to the operational direction), and vertical overpressure signature and corresponding power spectrum levels for the 750 in^3 array (Appendix C.2). Horizontal 1/3-octave-band source levels shown as a function of band centre frequency and azimuth (Figure C-3) indicate that this array is mainly isotropic.

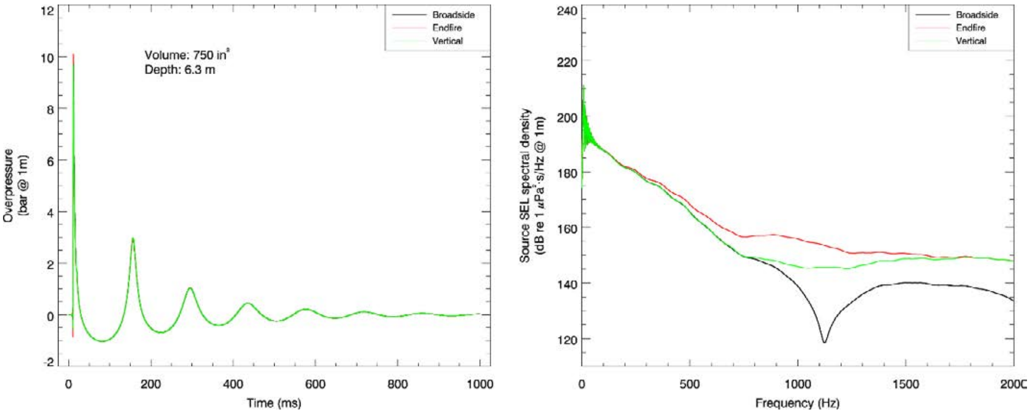
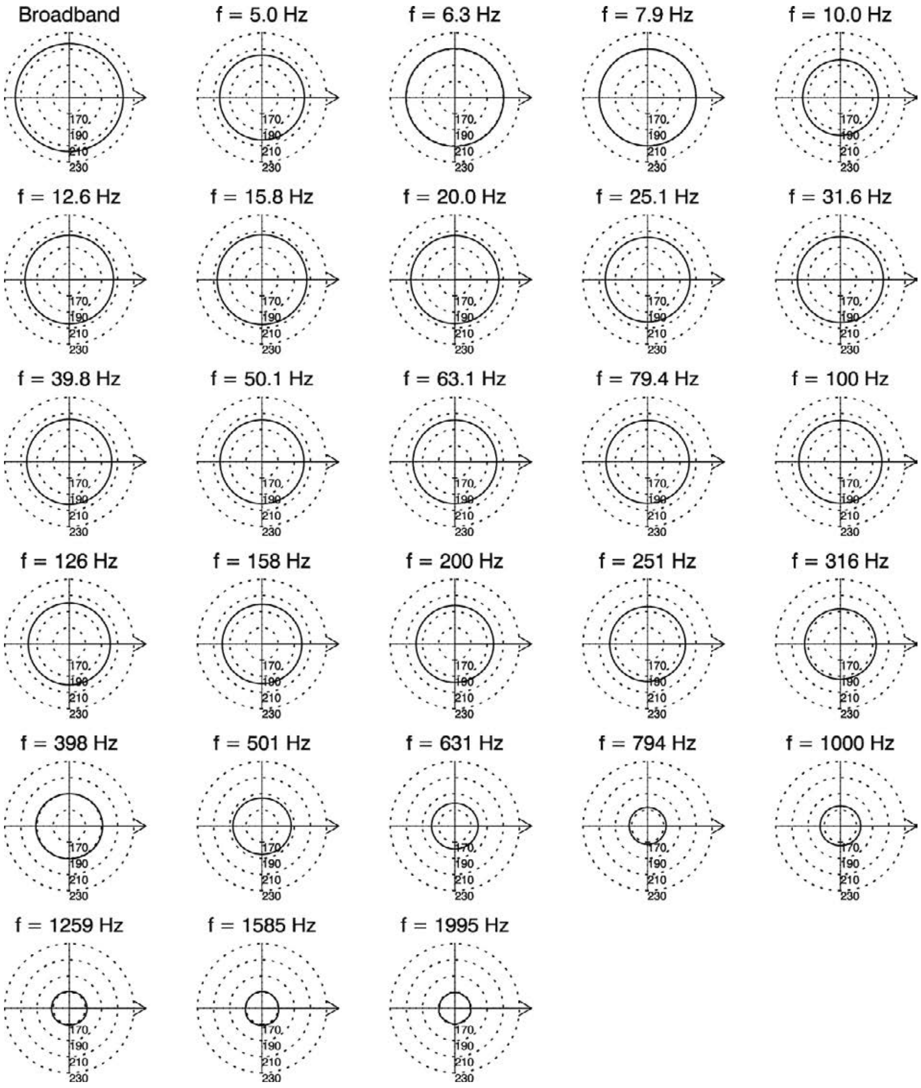


Figure C-2. Predicted source level details for the 750 in^3 array at a 6 m operational depth.(Left) the overpressure signature and (right) the power spectrum for in-plane horizontal (broadside), perpendicular (endfire), and vertical directions.



Broadband
f = 5.0 Hz
f = 6.3 Hz
f = 7.9 Hz
f = 10.0 Hz
f = 12.6 Hz
f = 15.8 Hz
f = 20.0 Hz
f = 25.1 Hz
f = 31.6 Hz
f = 39.8 Hz
f = 50.1 Hz
f = 63.1 Hz
f = 79.4 Hz
f = 100 Hz
f = 126 Hz
f = 158 Hz
f = 200 Hz
f = 251 Hz
f = 316 Hz
f = 398 Hz
f = 501 Hz
f = 631 Hz
f = 794 Hz
f = 1000 Hz
f = 1259 Hz
f = 1585 Hz
f = 1995 Hz

Figure C-3. Directionality of the predicted horizontal source levels for the 750 in^3 seismic source array, 10 Hz to 2 kHz. Source levels (in dB re 1 µPa^2·s m^2) are shown as a function of azimuth for the centre frequencies of the 1/3-octave-bands modelled; frequencies are shown above the plots. The perpendicular direction to the frame is to the right. Operational depth is 6 m.

Appendix D. Thruster Source Level Estimation

Underwater sound that radiates from vessels is produced mainly by propeller and thruster cavitation, with a smaller fraction of sound produced by sound transmitted through the hull, such as by engines, gearing, and other mechanical systems. Sound levels tend to be the highest when thrusters are used to position the vessel and when the vessel is transiting at high speeds. A vessel's sound signature depends on the vessel's size, power output, propulsion system, and the design characteristics of the given system (e.g., blade shape and size). A vessel produces broadband acoustic energy with most of the energy emitted below a few kilohertz. Sound from onboard machinery, particularly sound below 200 Hz, dominates the sound spectrum before cavitation begins—normally around 8–12 knots on many commercial vessels (Spence et al. 2007). Under higher speeds and higher propulsion system load, the acoustic output from the cavitation processes on the propeller blades dominates other sources of sound on the vessel such as machinery or hull vibration (Leggat et al. 1981).

A vessel equipped with propellers/thrusters has two primary sources of sound that propagate from the unit: the machinery and the propellers. For thrusters operating in the heavily loaded conditions, the acoustic energy generated by the cavitation processes on the propeller blades dominates (Leggat et al. 1981). The sound power from the propellers is proportional to the number of blades, the propeller diameter, and the propeller tip speed.

Based on an analysis of acoustic data, Ross (1976) provided the following formula for the sound levels from a vessel's propeller, operating in calm, open ocean conditions:

$$L_{100} = 155 + 60\log(u/25) + 10\log(B/4)\ , \qquad \text{(D-1)}$$

where L_{100} is the spectrum level at 100 Hz, u is the propeller tip speed (m/s), and B is the number of propeller blades. Equation D-1 gives the total energy produced by the propeller cavitation at frequencies between 100 Hz and 10 kHz. This equation is valid for a propeller tip speed between 15 and 50 m/s. The spectrum is assumed to be flat below 100 Hz. Its level is assumed to fall off at a rate of −6 dB per octave above 100 Hz (Figure D-1).

Another method of predicting the source level of a propeller was suggested by Brown (1977). For propellers operating in heavily loaded conditions, the formula for the sound spectrum level is:

$$\mathrm{SL}_B = 163 + 40\log D + 30\log N + 10\log B + 20\log f + 10\log(A_c/A_D)\ , \qquad \text{(D-2)}$$

where D is the propeller diameter (m), N is the propeller revolution rate per second, B is the number of blades, A_C is the area of the blades covered by cavitation, and A_D is the total propeller disc area. Similar to Ross's approach, the spectrum below 100 Hz is assumed to be flat. The tests with a naval propeller operating at off-design heavily loaded conditions showed that Equation D-2 should be used with a value of $(A_c/A_D) = 1$ (Leggat et al. 1981).

The combined source level for multiple thrusters operating together can be estimated using the formula:

$$\mathrm{SL}_{\mathrm{total}} = 10\log_{10}\sum_i 10^{\frac{SL_i}{10}}, \qquad \text{(D-3)}$$

where $\mathrm{SL}_{1,\ldots,N}$ are the source levels of individual thrusters. If the vessel is equipped with the same type of thrusters, the combined source level can be estimated using the formula:

$$\mathrm{SL}_N = \mathrm{SL} + 10\log N \qquad \text{(D-4)}$$

where N is the total number of thrusters of the same type.

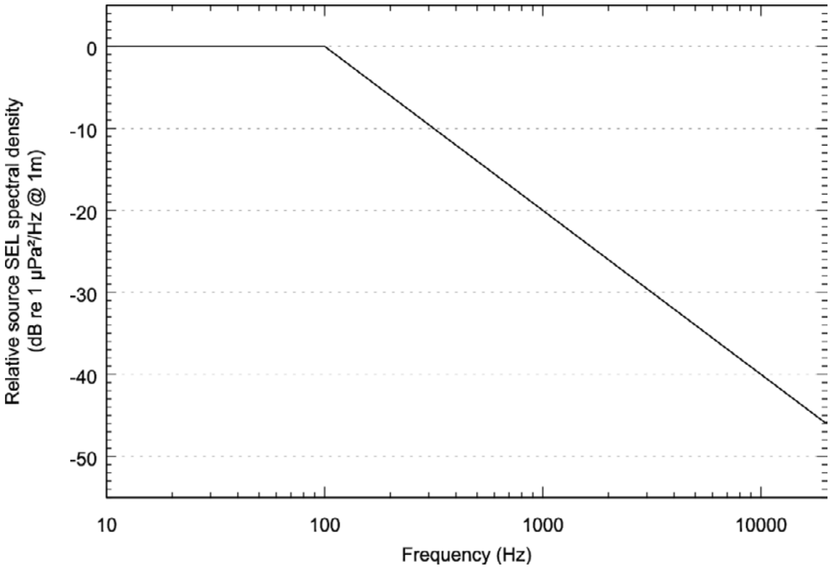


Figure D-1. Estimated sound spectrum from cavitating propeller (Leggat et al. 1981).

Appendix E. Sound Propagation Models

E.1. Transmission Loss

The propagation of sound through the environment was modelled by predicting the acoustic transmission loss—a measure, in decibels, of the decrease in sound level between a source and a receiver some distance away. Geometric spreading of acoustic waves is the predominant way by which transmission loss occurs. Transmission loss also happens when the sound is absorbed and scattered by the seawater, and absorbed scattered, and reflected at the water surface and within the seabed. Transmission loss depends on the acoustic properties of the ocean and seabed; its value changes with frequency.

If the acoustic source level (SL), expressed in dB re 1 µPa^{2}m^2, and transmission loss (TL), in units of dB, at a given frequency are known, then the received level (RL) at a receiver location can be calculated in dB re 1 µPa by:

$$\mathrm{RL} = \mathrm{SL} - \mathrm{TL} \tag{E-1}$$

E.2. Noise Propagation with FWRAM

For impulsive sounds from impact pile driving, time-domain representations of the pressure waves generated in the water are required to calculate SPL and peak pressure level. Furthermore, the pile must be represented as a distributed source to accurately characterise vertical directivity effects in the near-field zone. For this study, synthetic pressure waveforms were computed using JASCO's Full Waveform Range-dependent Acoustic Model (FWRAM). FWRAM computes acoustic propagation via a wide-angle parabolic equation solution to the acoustic wave equation (Collins 1993) based on a version of the U.S. Naval Research Laboratory's Range-dependent Acoustic Model (RAM), which has been modified to account for an elastic seabed (Zhang and Tindle 1995). The parabolic equation method has been extensively benchmarked and is widely employed in the underwater acoustics community (Collins et al. 1996). FWRAM accounts for the additional reflection loss at the seabed due to partial conversion of incident compressional waves to shear waves at the seabed and sub-bottom interfaces, and it includes wave attenuations in all layers. FWRAM incorporates the following site-specific environmental properties: a modelled area bathymetric grid, underwater sound speed as a function of depth, and a geoacoustic profile based on the overall stratified composition of the seafloor.

FWRAM computes pressure waveforms via Fourier synthesis of the modelled acoustic transfer function in closely spaced frequency bands. FWRAM employs the VSP array starter method to accurately model sound propagation from a spatially distributed source (MacGillivray and Chapman 2012).

Synthetic pressure waveforms from pile driving strikes were modelled and post-processed, after applying a travel time correction, to calculate standard SPL, SEL and PK metrics versus range and depth from the source.

E.3. MONM-BELLHOP

Long-range sound fields were computed using JASCO's Marine Operations Noise Model (MONM). Compared to VSTACK, MONM less accurately predicts steep-angle propagation for environments with higher shear speed but is well suited for effective longer-range estimation. This model computes sound propagation at frequencies of 10 Hz to 1.6 kHz via a wide-angle parabolic equation solution to the acoustic wave equation (Collins 1993) based on a version of the U.S. Naval Research Laboratory's Range-dependent Acoustic Model (RAM), which has been modified to account for a solid seabed (Zhang and Tindle 1995). MONM computes sound propagation at frequencies > 1.6 kHz via the BELLHOP Gaussian beam acoustic ray-trace model (Porter and Liu 1994).

The parabolic equation method has been extensively benchmarked and is widely employed in the underwater acoustics community (Collins et al. 1996). MONM accounts for the additional reflection loss at the seabed, which results from partial conversion of incident compressional waves to shear waves at the seabed and sub-bottom interfaces, and it includes wave attenuations in all layers. MONM incorporates the following site-specific environmental properties: a bathymetric grid of the modelled area, underwater sound speed as a function of depth, and a geoacoustic profile based on the overall stratified composition of the seafloor.

This version of MONM accounts for sound attenuation due to energy absorption through ion relaxation and viscosity of water in addition to acoustic attenuation due to reflection at the medium boundaries and internal layers (Fisher and Simmons 1977). The former type of sound attenuation is significant for frequencies higher than 5 kHz and cannot be neglected without noticeably affecting the model results.

MONM computes acoustic fields in three dimensions by modelling transmission loss within two-dimensional (2-D) vertical planes aligned along radials covering a 360° swath from the source, an approach commonly referred to as N×2-D. These vertical radial planes are separated by an angular step size of $\Delta\theta$, yielding N = 360°/$\Delta\theta$ number of planes (Figure E-1).

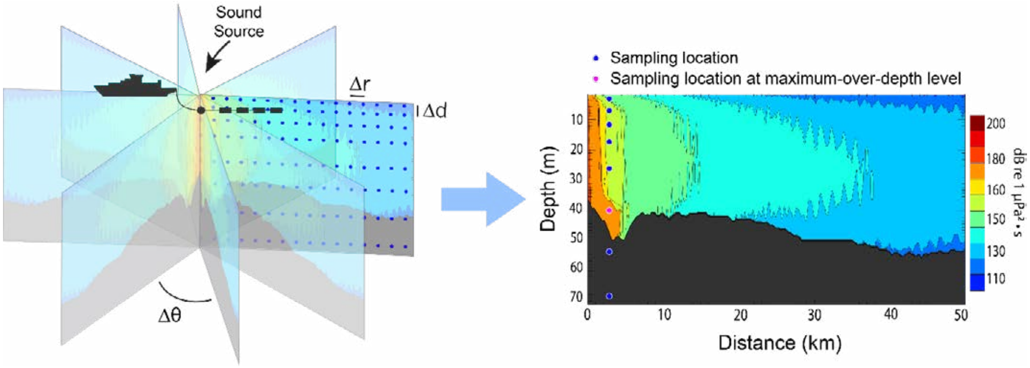


Figure E-1. The N×2-D and maximum-over-depth modelling approach used by MONM.

MONM treats frequency dependence by computing acoustic transmission loss at the centre frequencies of 1/3-octave-bands. Sufficiently many 1/3-octave-bands, starting at 10 Hz, are modelled to include most of the acoustic energy emitted by the source. At each centre frequency, the transmission loss is modelled within each of the N vertical planes as a function of depth and range from the source. The 1/3-octave-band received per-pulse SEL are computed by subtracting the band transmission loss values from the directional source level in that frequency band. Composite broadband received per-pulse SEL are then computed by summing the received 1/3-octave-band levels.

The received per-pulse (VSP source) or per-second vessel (MODU, FPSO, and OSV sources) SEL sound field within each vertical radial plane is sampled at various ranges from the source, generally with a fixed radial step size. At each sampling range along the surface, the sound field is sampled at various depths, with the step size between samples increasing with depth below the surface. The step sizes are chosen to provide increased coverage near the depth of the source and at depths of interest in terms of the sound speed profile. For areas with deep water, sampling is not performed at depths beyond those reachable by marine mammals. The received per-pulse or per-second SEL at a surface sampling location is taken as the maximum value that occurs over all samples within the water column, i.e., the maximum-over-depth received per-pulse SEL. These maximum-over-depth per-pulse SEL are presented as colour contours around the source.

An inherent variability in measured sound levels is caused by temporal variability in the environment and the variability in the signature of repeated acoustic impulses (sample sound source verification results is presented in Figure E-2). While MONM's predictions correspond to the averaged received levels, cautionary estimates of the threshold radii are obtained by shifting the best fit line (solid line, Figure E-2) upward so that the trend line encompasses 90% of all the data (dashed line, Figure E-2).

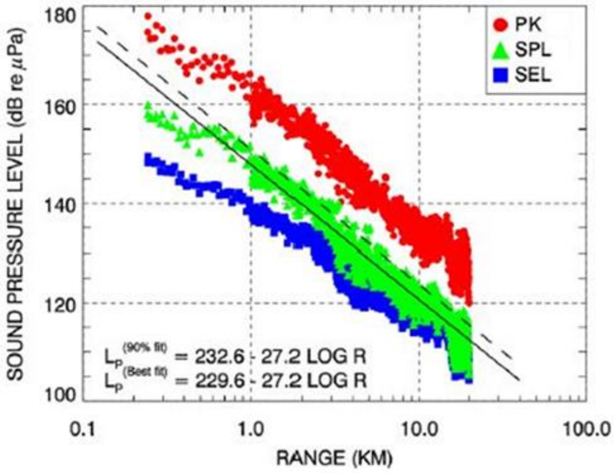


Figure E-2. PK and SPL and per-pulse SEL versus range from a 20 in^3 seismic source. Solid line is the least squares best fit to SPL. Dashed line is the best fit line increased by 3.0 dB to exceed 90% of all SPL values (90th percentile fit) (Ireland et al. 2009, Figure 10).

E.4. Wavenumber Integration Model

Sound pressure levels near the seismic source were modelled using JASCO's VSTACK wavenumber integration model. VSTACK computes synthetic pressure waveforms versus depth and range for arbitrarily layered, range-independent acoustic environments using the wavenumber integration approach to solve the exact (range-independent) acoustic wave equation. This model is valid over the full angular range of the wave equation and can fully account for the elasto-acoustic properties of the sub-bottom. Wavenumber integration methods are extensively used in the field of underwater acoustics and seismology where they are often referred to as reflectivity methods or discrete wavenumber methods. VSTACK computes sound propagation in arbitrarily stratified water and seabed layers by decomposing the outgoing field into a continuum of outward-propagating plane cylindrical waves. Seabed reflectivity in the model is dependent on the seabed layer properties: compressional and shear wave speeds, attenuation coefficients, and layer densities. The output of the model can be post-processed to yield estimates of the SEL, SPL, and PK.

VSTACK accurately predicts steep-angle propagation in the proximity of the source, but it is computationally slow at predicting sound pressures at large distances due to the need for smaller wavenumber steps with increasing distance. Additionally, VSTACK assumes range-invariant bathymetry with a horizontally stratified medium (i.e., a range-independent environment) which is azimuthally symmetric about the source. VSTACK is thus best suited to modelling the sound field near the source.

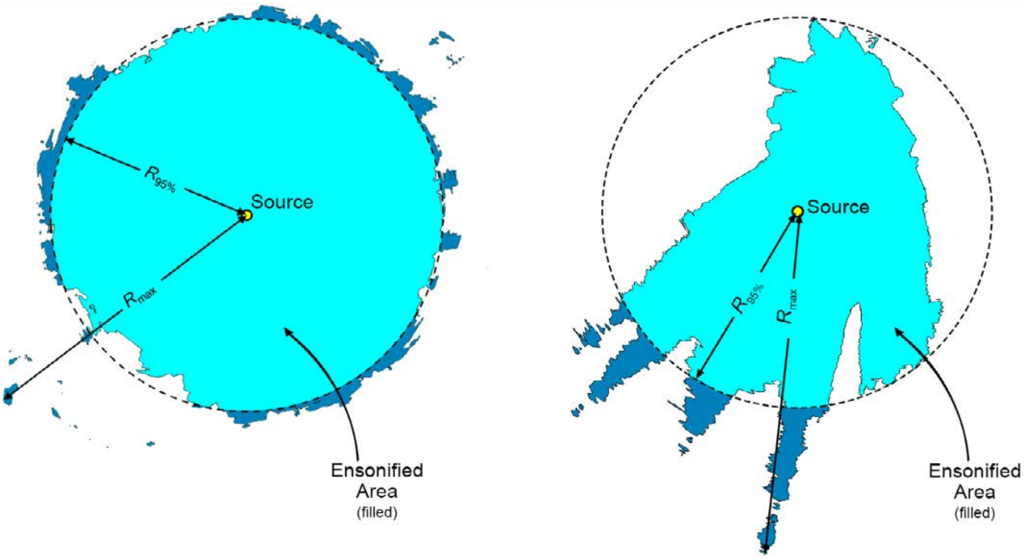
Appendix F. Methods and Parameters

This section describes the specifications of the seismic source that was used at all sites and the environmental parameters used in the propagation models.

F.1. Estimating Range to Thresholds Levels

Sound level contours were calculated based on the underwater sound fields predicted by the propagation models, sampled by taking the maximum value over all modelled depths above the sea floor for each location in the modelled region. The predicted distances to specific levels were computed from these contours. Two distances relative to the source are reported for each sound level: 1) R_{max}, the maximum range to the given sound level over all azimuths, and 2) $R_{95\%}$, the range to the given sound level after the 5% farthest points were excluded (see examples in Figure F-1).

The $R_{95\%}$ is used because sound field footprints are often irregular in shape. In some cases, a sound level contour might have small protrusions or anomalous isolated fringes. This is demonstrated in the image in Figure F-1(a). In cases such as this, where relatively few points are excluded in any given direction, R_{max} can misrepresent the area of the region exposed to such effects, and $R_{95\%}$ is considered more representative. In strongly asymmetric cases such as shown in Figure F-1(b), on the other hand, $R_{95\%}$ neglects to account for significant protrusions in the footprint. In such cases R_{max} might better represent the region of effect in specific directions. Cases such as this are usually associated with bathymetric features affecting propagation. The difference between R_{max} and $R_{95\%}$ depends on the source directivity and the non-uniformity of the acoustic environment.



(a) (b)

Figure F-1. Sample areas ensonified to an arbitrary sound level with R_{max} and $R_{95\%}$ ranges shown for two different scenarios. (a) Largely symmetric sound level contour with small protrusions. (b) Strongly asymmetric sound level contour with long protrusions. Light blue indicates the ensonified areas bounded by $R_{95\%}$; darker blue indicates the areas outside this boundary which determine R_{max}.

F.2. Estimating SPL from Modelled SEL Results

The per-pulse SEL of sound pulses is an energy-like metric related to the dose of sound received over a pulse's entire duration. The pulse SPL on the other hand, is related to its intensity over a specified time interval. Seismic pulses typically lengthen in duration as they propagate away from their source, due to seafloor and surface reflections, and other waveguide dispersion effects. The changes in pulse length, and therefore the time window considered, affect the numeric relationship between SPL and SEL. This study has applied a fixed window duration to calculate SPL (T_{fix} = 125 ms; see Appendix A.1), as implemented in Martin et al. (2017b). Full-waveform modelling was used to estimate SPL, but this type of modelling is computationally intensive, and can be prohibitively time consuming when run at high spatial resolution over large areas.

For the current study, FWRAM (Appendix E.2) was used to model synthetic seismic pulses over the frequency range 5–1024 Hz. This was performed along all broadside and endfire radials at two sites. FWRAM uses Fourier synthesis to recreate the signal in the time domain so that both the SEL and SPL from the source can be calculated. The differences between the SEL and SPL were extracted for all ranges and depths that corresponded to those generated from the high spatial-resolution results from MONM. A 125 ms fixed time window positioned to maximise the SPL over the pulse duration was applied. The resulting SEL -to-SPL offsets were averaged in 0.3 km range bins along each modelled radial and depth, and the 90th percentile was selected at each range to generate a generalised range-dependent conversion function for each site. The range- dependent conversion function was averaged between the two sites and applied to predicted per-pulse SEL results from MONM to model SPL values. Figure F-2 shows the conversion offsets for each site; the spatial variation is caused by changes in the received airgun pulse as it propagates from the source.

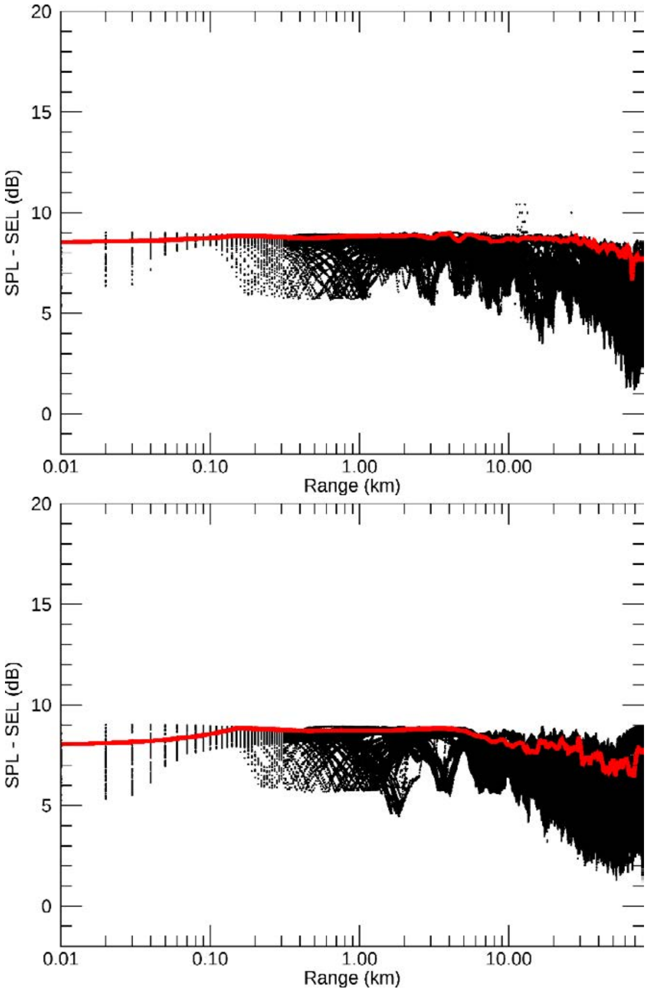


Figure F-2. Range-and-depth-dependent conversion offsets for converting SEL to SPL for seismic pulses for Torosa (top) and Brecknock (bottom) sites. Black dots are the modelled differences between SEL and SPL across different radials and receiver depths; the solid red line is the 90th percentile of the modelled differences at each range.

F.3. Environmental Parameters

F.3.1. Bathymetry

Water depths (Mean Sea Level) at close- and mid-range from the pile were provided by Woodside: within ~5–7 km from the pile, the data has a grid resolution of 2 m× 2 m, while data at the passage between Scott Reef South and Scott Reef Central has a grid resolution of 1 m× 1 m. Bathymetry data with grid resolution of 10 × 10 m was provided as far as 33 km northeast of the pile, and as far as 85 km southwest of the pile. Modelling was conducted along 80 km long radials emanating from the pile in all directions. For this reason, the high-resolution data was complemented using the Australian Bathymetry and Topography Grid, a 9 arc-second grid rendered for Australian waters (Whiteway 2009). The data were adjusted for an increase of 1.7 m in depth (Bureau of Meterology 2019), so the modelling results correspond to the most conservative propagation conditions at maximum tide at Scott Reef. Bathymetry data were re-gridded onto a Map Grid of Australia (MGA) coordinate projection (Zone 51) with a regular grid spacing of 50 × 50 m.

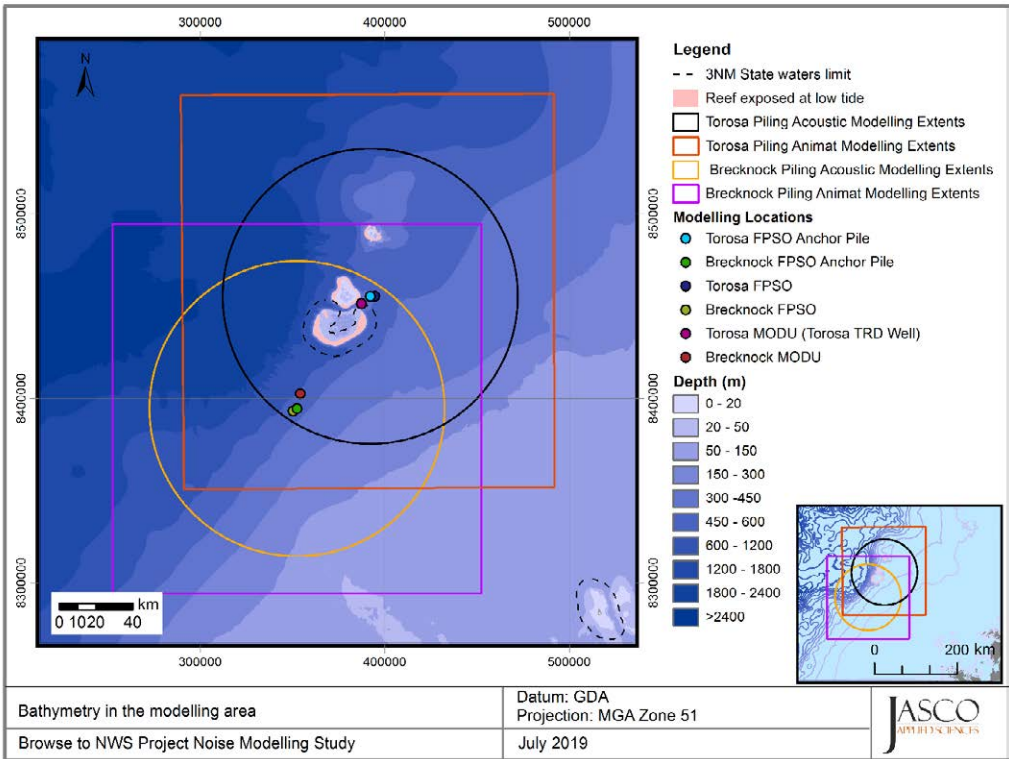


Figure F-3. Bathymetry in the modelled area.

F.3.2. Sound speed profile

The sound speed profile in the area was derived from temperature and salinity profiles from the U.S. Naval Oceanographic Office's *Generalized Digital Environmental Model V 3.0* (GDEM; Teague et al. 1990, Carnes 2009). GDEM provides an ocean climatology of temperature and salinity for the world's oceans on a latitude-longitude grid with 0.25° resolution, with a temporal resolution of one month, based on global historical observations from the U.S. Navy's Master Oceanographic Observational Data Set (MOODS). The climatology profiles include 78 fixed depth points to a maximum depth of 6800 m (where the ocean is that deep). The GDEM temperature-salinity profiles were converted to sound speed profiles according to Coppens (1981).

Mean monthly sound speed profiles were derived from the GDEM profiles at distances less than 76 km around the modelled site. The June sound speed profile is expected to be most favourable to longer-range sound propagation across the entire year. As such, June was selected for sound propagation modelling to ensure precautionary estimates of distances to received sound level thresholds. Figure F-4 shows the resulting profile, which was used as input to the sound propagation modelling.

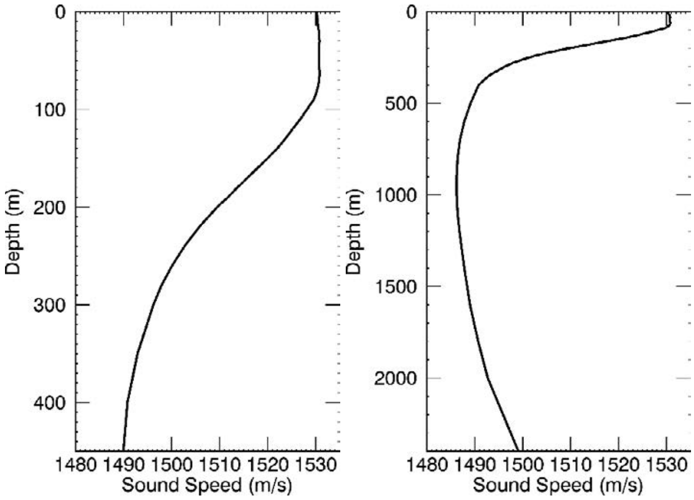


Figure F-4. The modelling sound speed profile corresponding to June: top 450 m (left) and full profile (right) Profiles are calculated from temperature and salinity profiles from *Generalized Digital Environmental Model* V 3.0 (GDEM; Teague et al. 1990, Carnes 2009).

F.3.3. Geoacoustics

As in previous acoustic studies in the area (Duncan 2014), the modelling area was divided into three seabed types (Figure F-5). A silt seabed typical of the continental slope was considered for the majority of the modelling area (Table F-1). A seabed consisting of coarse sand/gravel was used for areas in the vicinity of the reefs (Table F-2). Finally, the reefs were modelled as limestone (Table F-3), using the same equivalent fluid geoacoustic model as in Duncan et al (2014).

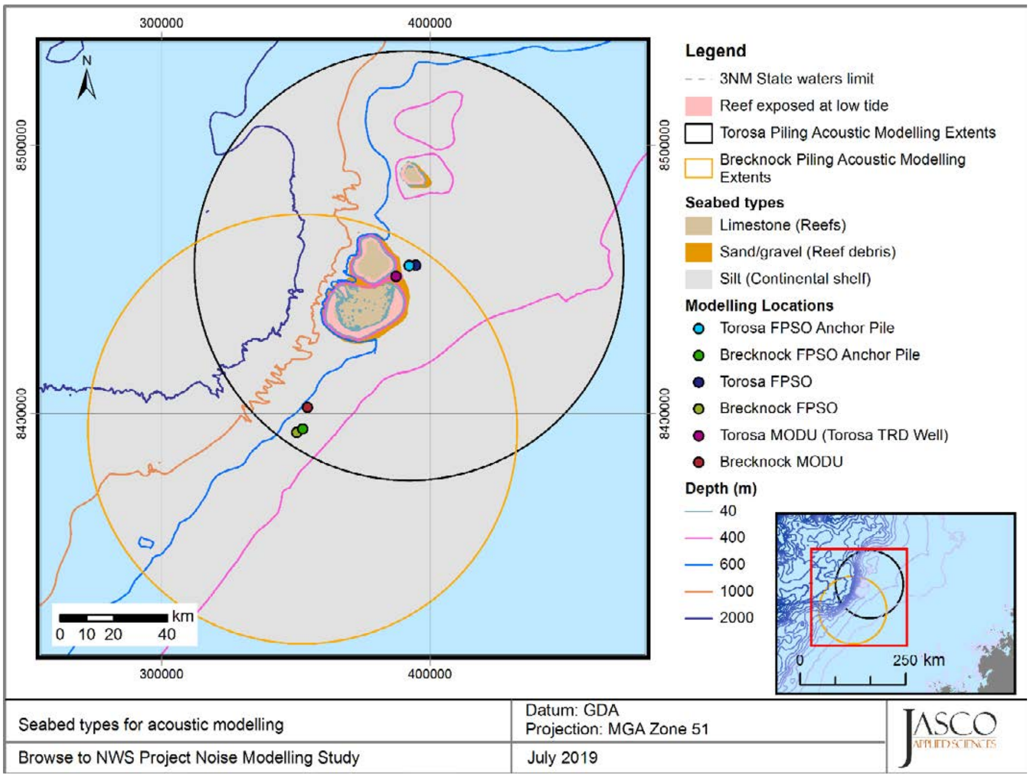


Figure F-5. Geographic boundaries of the seabed types considered in this study , following Duncan et al. (2014).

Table F-1. Continental slope geoacoustic profile. Within each depth range, each parameter varies linearly within the stated range. The compressional wave is the primary wave and the shear wave is the secondary wave.

Depth below seafloor (m)	Material	Density (g/cm³)	Compressional wave		Shear wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0–50	Silt	1.70–1.75	1566–1627	1.0	210	1.5
50–100		1.75–1.80	1627–1686			
100–150		1.80–1.85	1686–1742			
150–200		1.85–1.90	1742–1795			
>200		1.90	1795			

Table F-2. Reef debris geoacoustic profile Within each depth range, each parameter varies linearly within the stated range. The compressional wave is the primary wave and the shear wave is the secondary wave.

Depth below seafloor (m)	Material	Density (g/cm^3)	Compressional wave		Shear wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0–50	Sand/gravel	1.80–1.85	1714–1782	0.6	300	2.0
50–100		1.85–1.90	1782–1847			
100–150		1.90–1.95	1847–1908			
150–200		1.95–2.00	1908–1967			
>200		2.00	1967			

Table F-3. Reef geoacoustic profile and equivalent fluid modelThe compressional wave is the primary wave and the shear wave is the secondary wave.

Depth below seafloor (m)	Material	Elastic model					Fluid equivalent		
		Density (g/cm^3)	Compressional wave		Shear wave		Density (g/cm^3)	Compressional wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)		Speed (m/s)	Attenuation (dB/λ)
>0	Limestone	2.4	3000	0.1	1500	0.2	2.4	1350	14

F.4. Model Validation Information

Predictions from JASCO's propagation models (MONM, FWRAM, and VSTACK) have been validated against experimental data from a number of underwater acoustic measurement programs conducted by JASCO globally, including the United States and Canadian Artic, Canadian and southern United States waters, Greenland, Russia and Australia (Hannay and Racca 2005, Aerts et al. 2008, Funk et al. 2008, Ireland et al. 2009, O'Neill et al. 2010, Warner et al. 2010, Racca et al. 2012a, Racca et al. 2012b, Matthews and MacGillivray 2013, Martin et al. 2015, Racca et al. 2015, Martin et al. 2017a, Martin et al. 2017b, Warner et al. 2017, MacGillivray 2018, McPherson et al. 2018, McPherson and Martin 2018).

In addition, JASCO has conducted measurement programs associated with a significant number of anthropogenic activities which have included internal validation of the modelling (including McCrodan et al. 2011, Austin and Warner 2012, McPherson and Warner 2012, Austin and Bailey 2013, Austin et al. 2013, Zykov and MacDonnell 2013, Austin 2014, Austin et al. 2015, Austin and Li 2016, Martin and Popper 2016).

Appendix G. Animal Movement and Exposure Modelling

To assess the risk of impacts from exposure, an estimate of received sound levels for the animals in the area during pile driving is required. The sound field may be complex, and the sound received by a moving animal is a function of where the animal is at any given time. The sound source is stationary, and acoustic modelling can be used to predict the 3-D sound field. The location and movement of animals within the sound field, however, is unknown. Realistic animal movement within the sound field can be simulated. Repeated random sampling (Monte Carlo method simulating many animals within the operations area) is used to estimate the sound exposure history of the population of simulated animals during the operation.

Monte Carlo methods provide a heuristic approach for determining the probability distribution function (PDF) of complex situations, such as animals moving in a sound field. The probability of an event's occurrence is determined by the frequency with which it occurs in the simulation. The greater the number of random samples, in this case the more simulated animals (animats), the better the approximation of the PDF. Animats are randomly placed, or seeded, within the simulation boundary at a specified density (animats/km^2). Higher densities provide a finer PDF estimate resolution but require more computational resources. To ensure good representation of the PDF, the animat density is set as high as practical allowing for computation time. The animat density is much higher than the real-world density to ensure good representation of the PDF. The resulting PDF is scaled using the real-world density.

Several models for marine mammal movement have been developed (Ellison et al. 1987, Frankel et al. 2002, Houser 2006). These models use an underlying Markov chain to transition from one state to another based on probabilities determined from measured swimming behaviour. The parameters may represent simple states, such as the speed or heading of the animal, or complex states, such as likelihood of participating in foraging, play, rest, or travel. Attractions and aversions to variables like anthropogenic sounds and different depth ranges can be included in the models.

The JASCO Animal Simulation Model Including Noise Exposure (JASMINE) was based on the open-source Marine Mammal Movement and Behaviour Model (3MB; Houser 2006). JASMINE was used in this study to predict the exposure of virtual animals ('animats') to sound arising from the pile driving activities. Animats were programmed to behave like the species of interest likely to be present in the area of interest. The parameters used for forecasting realistic behaviours (e.g., diving, foraging, aversion, surface times, etc.) were determined and interpreted from marine species studies (e.g., tagging studies) where available, or reasonably extrapolated from related species. An individual animat's modelled sound exposure levels are summed over the total simulation duration, such as 24 h for the current simulation, to determine its total received energy, and then compared to the assumed threshold criteria.

JASMINE uses the same animal movement algorithms as the 3MB model (Houser 2006), but has been extended to be directly compatible with MONM and FWRAM acoustic field predictions, for inclusion of source tracks, and importantly for animats to change behavioural states based on time and space dependent modelled variables such as received levels for aversion behaviour, although aversion was not considered in this study.

G.1. Animal Movement Parameters

JASMINE uses previously measured behaviour to forecast behaviour in new situations and locations. The parameters used for forecasting realistic behaviour are determined (and interpreted) from marine species studies (e.g., tagging studies). Each parameter in the model is described as a probability distribution. When limited or no information is available for a species parameter, a Gaussian or uniform distribution may be chosen for that parameter. For the Gaussian distribution, the user determines the mean and standard deviation of the distribution from which parameter values are drawn. For the uniform distribution, the user determines the maximum and minimum distribution from which parameter values are drawn. When detailed information about the movement and behaviour of a species are available, a user-created distribution vector, including cumulative transition probabilities, may be used (referred to here as a vector model; Houser 2006). Different sets of parameters can be defined for different behaviour states. The probability of an animat starting out in or transitioning into a given behaviour state can in turn be defined in terms of the animat's current behavioural state, depth, and the time of day. In addition, each travel parameter and behavioural state has a termination function that governs how long the parameter value or overall behavioural state persists in simulation.

The parameters used in JASMINE describe animal movement in both the vertical and horizontal planes. The parameters relating to travel in these two planes are briefly described below.

Travel sub-models

- **Direction**– determines an animat's choice of direction in the horizontal plane. Sub-models are available for determining the heading of animats, allowing for movement to range from strongly biased to undirected. A random walk model can be used for behaviours with no directional preference, such as feeding and playing. In a random walk, all bearings are equally likely at each parameter transition time step. A correlated random walk can be used to smooth the changes in bearing by using the current heading as the mean of the distribution from which to draw the next heading. An additional variant of the correlated random walk is available that includes a directional bias for use in situations where animals have a preferred absolute direction, such as migration. A user-defined vector of directional probabilities can also be input to control animat heading. For more detailed discussion of these parameters, see Houser (2006) and Houser and Cross (1999).
- **Travel rate**–defines an animat's rate of travel in the horizontal plane. When combined with vertical speed and dive depth, the dive profile of the animat is produced.

Dive sub-models

- **Ascent rate**–defines an animat's rate of travel in the vertical plane during the ascent portion of a dive.
- **Descent rate**–defines an animat's rate of travel in the vertical plane during the descent portion of a dive.
- **Depth**–defines an animat's maximum dive depth.
- **Reversals**–determines whether multiple vertical excursions occur once an animat reaches the maximum dive depth. This behaviour is used to emulate the foraging behaviour of some marine mammal species at depth. Reversal-specific ascent and descent rates may be specified.
- **Surface interval**–determines the duration an animat spends at, or near, the surface before diving again.

G.1.1. Exposure integration time

The interval over which acoustic exposure (L_E) should be integrated and maximal exposure (L_p) determined is not well defined. Both Southall et al. (2007) and the NMFS (2018) recommend a 24 h baseline accumulation period, but state that there may be situations where this is not appropriate (e.g., a high-level source and confined population). Resetting the integration after 24 h can lead to overestimating the number of individual animals exposed because individuals can be counted multiple times during an operation. The type of animal movement engine used in this study simulates realistic movement using swimming behaviour collected over relatively short periods (hours to days) and does not include large-scale movement such as migratory circulation patterns. For this study, a single day was modelled.

Ideally, a simulation area is large enough to encompass the entire range of a population so that any animal that could approach the pile driving site during an operation is included. However, there are limits to the simulation area, and computational overhead increases with area. For practical reasons, the simulation area is limited in this analysis to a maximum distance from the piling operation. In the simulation, every animat that reaches a border is replaced by another animat entering at the opposing border—e.g., an animat crossing the northern border of the simulation is replaced by one entering the southern border at the same longitude. When this action places the animat in an inappropriate water depth, the animat is randomly placed on the map at a depth suited to its species definition. The exposures of all animats (including those leaving the simulation and those entering) are kept for analysis. This approach maintains a consistent animat density and allows for longer integration periods with finite simulation areas.

G.1.2. Seeding density and scaling

The exposure criteria for impulsive sounds were used to determine the number of animats exceeding exposure thresholds. To generate statistically reliable probability density functions, all simulations were seeded with a specific animat density over the entire simulation area. To evaluate potential injury (PTS), TTS, or behavioural disturbance, threshold exceedance was determined in a 24 h time window. From the numbers of animats exceeding threshold, the numbers of individual pygmy blue whales and green turtles predicted to exceed threshold were determined by scaling the animat results by the ratio of local real-world density to modelling density.

G.2. Pygmy Blue Whale Species-Specific Details

Table G-1. *Foraging pygmy blue whales*: Data values and references input in JASMINE to create diving behaviour (number values represent means [standard deviations] unless otherwise indicated).

Behaviour	Variable	Value	Reference
Deep foraging dive	Travel direction	Correlated random walk	Houser (2006), D. Houser, pers.comm.
	Perturbation value	10	Houser (2006), D. Houser, pers.comm.
	Termination coefficient	0.2	Houser (2006), D. Houser, pers.comm.
	Travel rate (m/s)	Gaussian 1.25 (0.42)	Sears and Perrin (2009)
	Ascent rate (m/s)	Gaussian 1.6 (0.5)	Goldbogen et al. (2011)
	Descent rate (m/s)	Gaussian 2.6 (0.5)	Goldbogen et al. (2011)
	Dive depth (m)	Gaussian 129.0 (183.0)	Owen et al. (2016)
	Reversals	3.5 (1.1)	Goldbogen et al. (2011)
	Probability of reversal	0.7	Approximated
	Reversal ascent dive rate (m/s)	Random 1.7–0.37	Goldbogen et al. (2011)
	Reversal descent dive rate (m/s)	Random 1.4–0.46	Goldbogen et al. (2011)
	Time in reversal (s)	Random 26.3–52.5	Approximated
	Surface interval (s)	Gaussian 162.0 (66.0)	Goldbogen et al. (2011)
	Bout duration (s)	Gaussian 12600 (1800)	Owen et al. (2016)
General	Shore following (m)	30	Approximated
	Depth limit on seeding (m)	100.0 (minimum), 110000.0 (maximum)	Approximated

Table G-2. *Migrating pygmy blue whales*: Data values and references input in JASMINE to create diving behaviour (number values represent means [standard deviations] unless otherwise indicated).

Behaviour	Variable	Value	
Migratory dive	Travel direction	Correlated random walk	Houser (2006), D. Houser, pers.comm.
	Perturbation value	10	Houser (2006), D. Houser, pers.comm.
	Termination coefficient	0.2	Houser (2006), D. Houser, pers.comm.
	Travel rate (m/s)	Gaussian 0.78 (0.61)	Sears and Perrin (2009)
	Ascent rate (m/s)	Gaussian 0.7 (0.2)	Goldbogen et al. (2011)
	Descent rate (m/s)	Gaussian 1.5 (0.1)	Goldbogen et al. (2011)
	Dive depth (m)	Gaussian 14.0 (4.0)	Owen et al. (2016)
	Reversals	No	Owen et al. (2016)
	Surface interval (s)	Gaussian 60.0 (66.0)	Owen et al. (2016), approximated
	Bout duration (s)	Gaussian 12060 (1800)	Owen et al. (2016)
Exploratory dive	Travel direction	Correlated random walk	Houser (2006), D. Houser, pers.comm.
	Perturbation value	10	Houser (2006), D. Houser, pers.comm.
	Termination coefficient	0.2	Houser (2006), D. Houser, pers.comm.
	Travel rate (m/s)	Gaussian 1.25 (0.42)	Sears and Perrin (2009)
	Ascent rate (m/s)	Gaussian 1.6 (0.5)	Goldbogen et al. (2011)
	Descent rate (m/s)	Gaussian 2.6 (0.5)	Goldbogen et al. (2011)
	Dive depth (m)	Gaussian 107.0 (81.0)	Owen et al. (2016)
	Reversals	No	Owen et al. (2016)
	Surface interval (s)	Gaussian 162.0 (66.0)	Goldbogen et al. (2011)
	Bout duration (s)	Gaussian 516 (120)	Owen et al. (2016)
General	Shore following (m)	30	Approximated
	Depth limit on seeding (m)	100.0 (minimum), 110000.0 (maximum)	Approximated

G.3. Green Turtle Species-Specific Details

Table G-3. *Inter-nesting green turtles*: Data values input in JASMINE to create diving behaviour (number values represent means [standard deviations] unless otherwise indicated). The references associated with the data values include Pendoley (2005), and Guinea (2011) (Section 3.7.3.1).

Behaviour	**Variable**	**Value**
Shallow diving	Travel direction	Correlated random walk
	Perturbation value	10
	Termination coefficient	0.2
	Travel rate (m/s)	Gaussian 0.69 (0.17)
	Ascent rate (m/s)	Gaussian 0.085 (0.021)
	Descent rate (m/s)	Gaussian 0.125 (0.049)
	Dive depth (m)	Random 0.0–2.0
	Bottom following	No
	Reversals	No
	Surface interval (s)	Gaussian 150.0 (15.0)
	Bout duration (s)	Gaussian 7800.0 (1200.0)
Feeding	Travel direction	Correlated random walk
	Perturbation value	10
	Termination coefficient	0.2
	Travel rate (m/s)	Gaussian 0.69 (0.17)
	Ascent rate (m/s)	Gaussian 0.045 (0.014)
	Descent rate (m/s)	Gaussian 0.02 (0.07)
	Dive depth (m)	Random 1.0–45.0
	Bottom following	Yes
	Reversals	Gaussian 1.0 (0.0)
	Probability of reversal	1
	Reversal ascent dive rate (m/s)	Gaussian 0.001 (0.001)
	Reversal descent dive rate (m/s)	Gaussian 0.0 (0.0)
	Time in reversal (s)	Gaussian 1694.0 (481.0)
	Surface interval (s)	Gaussian 300.0 (30.0)
	Bout duration (s)	Gaussian 14400.0 (400.0)
General	Shore following (m)	2
	Depth limit on seeding (m)	2.0 (minimum), 10000.0 (maximum)

Table G-4. *Migrating green turtles*: Data values input in JASMINE to create diving behaviour (number values represent means [standard deviations] unless otherwise indicated).

Behaviour	Variable	Value
Migration	Travel direction	Correlated random walk
	Perturbation value	10
	Termination coefficient	0.2
	Travel rate (m/s)	Gaussian 0.57 (0.03)
	Ascent rate (m/s)	Gaussian 0.15 (0.04)
	Descent rate (m/s)	Gaussian 0.34 (0.08)
	Dive depth (m)	Random 0.0–80.0
	Bottom following	No
	Reversals	No
	Surface interval (s)	Gaussian 30.0 (60.0)
General	Shore following (m)	0
	Depth limit on seeding (m)	0.0 (minimum), 10000.0 (maximum)

Appendix H. Additional Results

H.1. Torosa Piling SEL Contour Maps

Maps of the per-strike SEL results associated with the three modelled penetration depths are shown in Figures H-1, H-2 and H-3 for the IHC S-600, and in Figures H-4, H-5 and H-6 for the IHC S-1200.

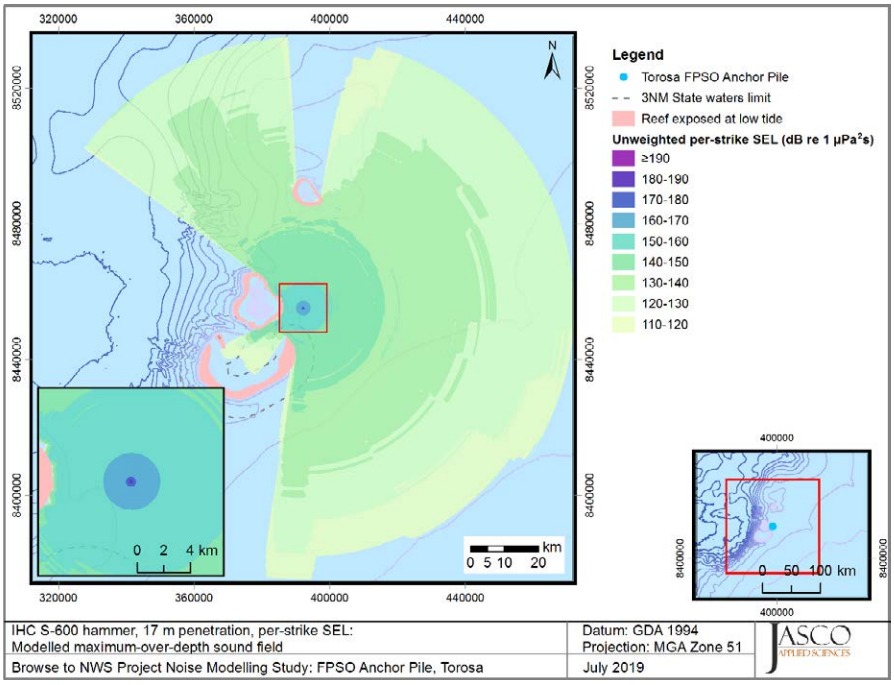


Figure H-1. *Torosa, IHC S-600, per-strike SEL, 17 m penetration depth*: Sound level contour map showing maximum-over-depth results.

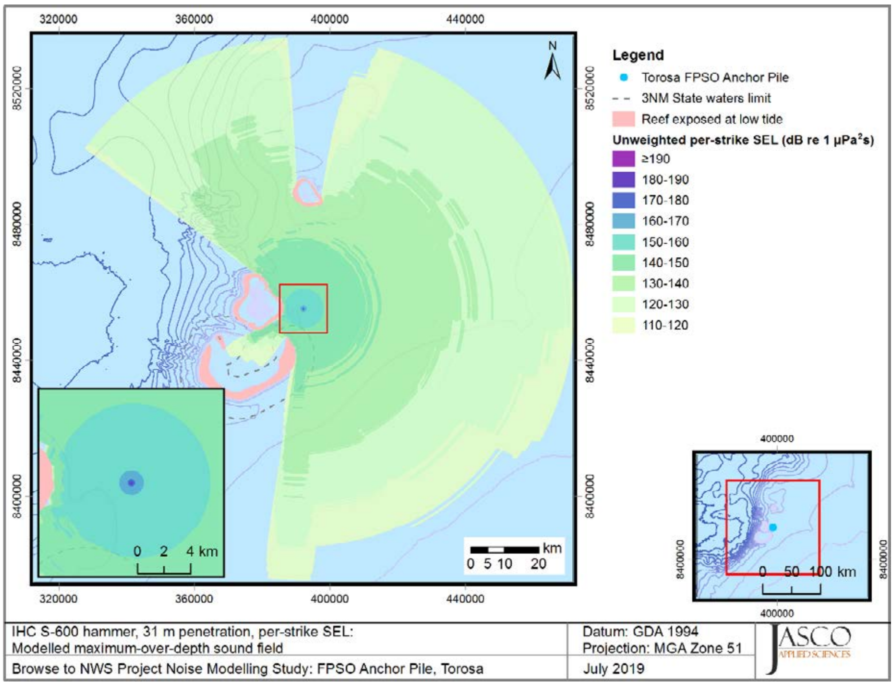


Figure H-2. *Torosa, IHC S-600, per-strike SEL, 31 m penetration depth*: Sound level contour map showing maximum-over-depth results.

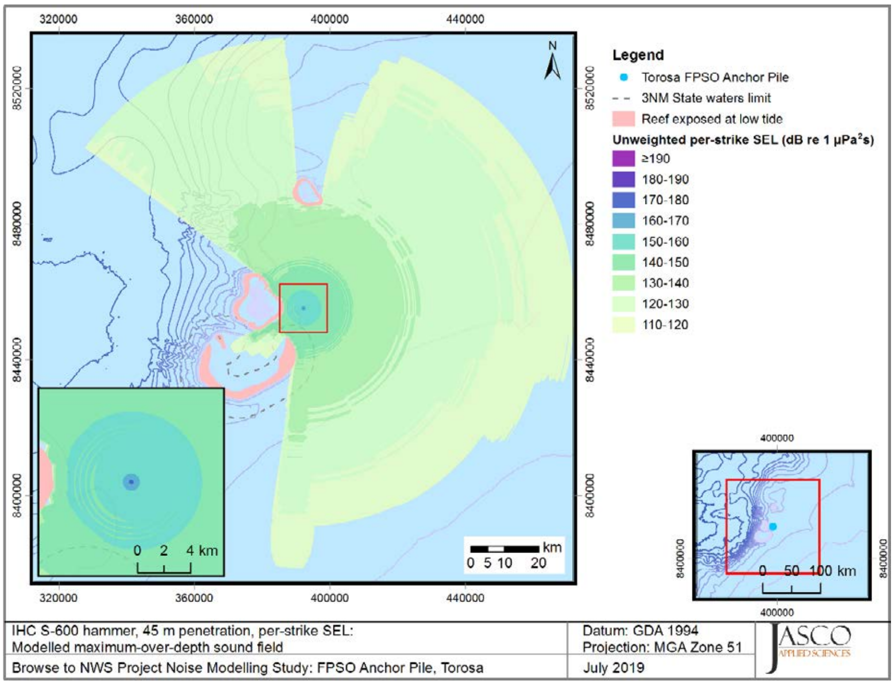


Figure H-3. *Torosa, IHC S-600, per-strike SEL, 45 m penetration depth*: Sound level contour map showing maximum-over-depth results.

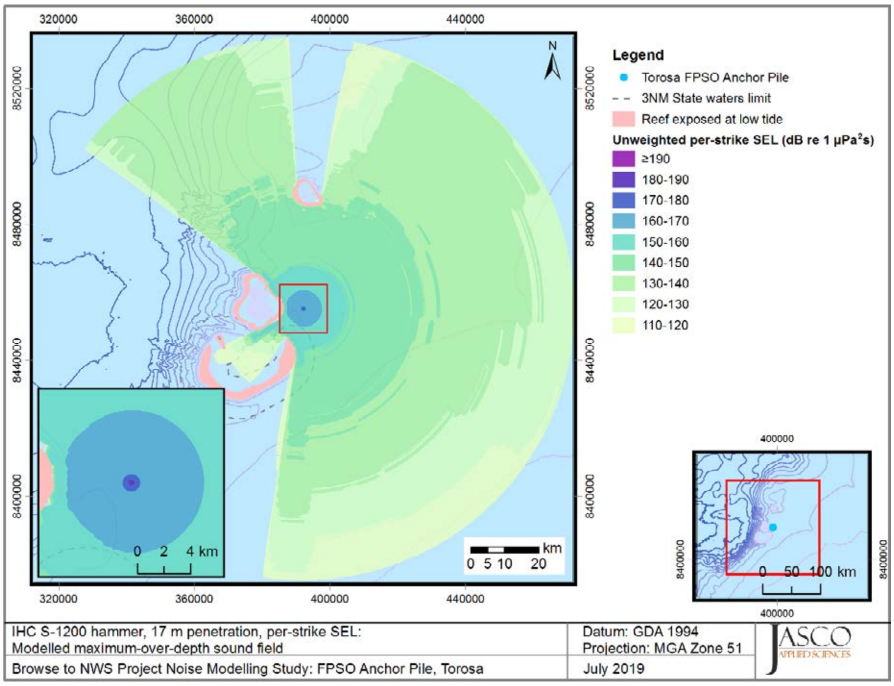


Figure H-4. *Torosa, IHC S-1200, per-strike SEL, 17 m penetration depth*: Sound level contour map showing maximum-over-depth results.

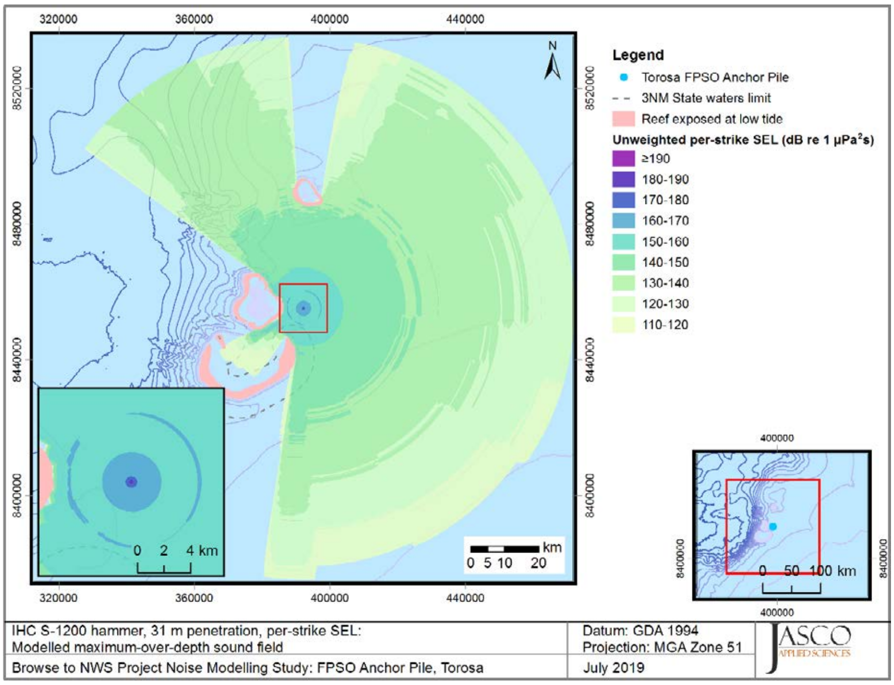


Figure H-5. *Torosa, IHC S-1200, per-strike SEL, 31 m penetration depth*: Sound level contour map showing maximum-over-depth results.

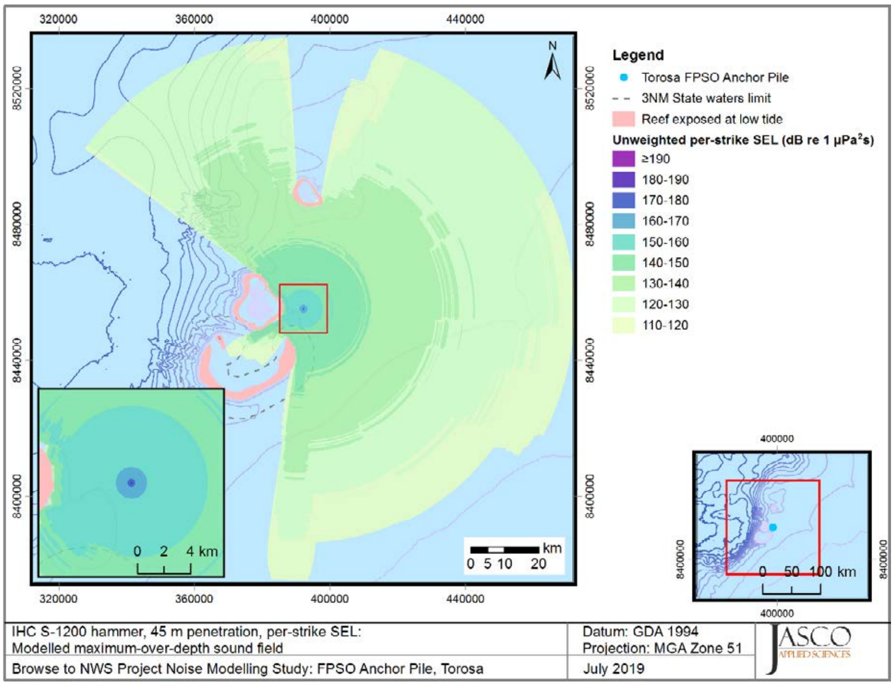


Figure H-6. *Torosa, IHC S-1200, per-strike SEL, 45 m penetration depth*: Sound level contour map showing maximum-over-depth results.

H.2. Brecknock Piling SEL Contour Maps

Maps of the per-strike SEL results associated with the three modelled penetration depths are shown in Figures H-7, H-8 and H-9 for the IHC S-600, and in Figures H-10, H-11 and H-12 for the IHC S-1200.

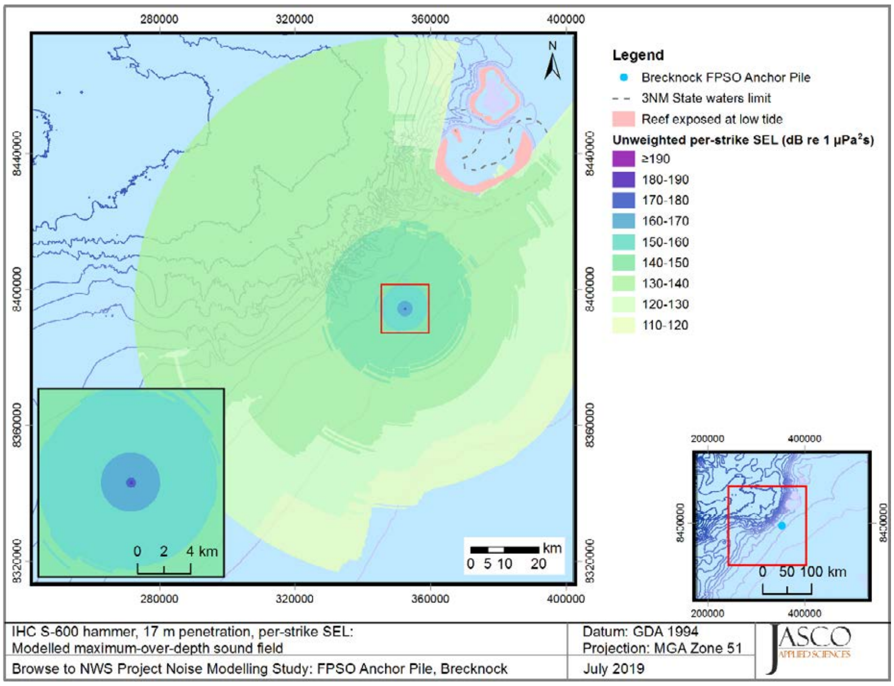


Figure H-7. *Brecknock, IHC S-600, per-strike SEL, 17 m penetration depth*: Sound level contour map showing maximum-over-depth results.

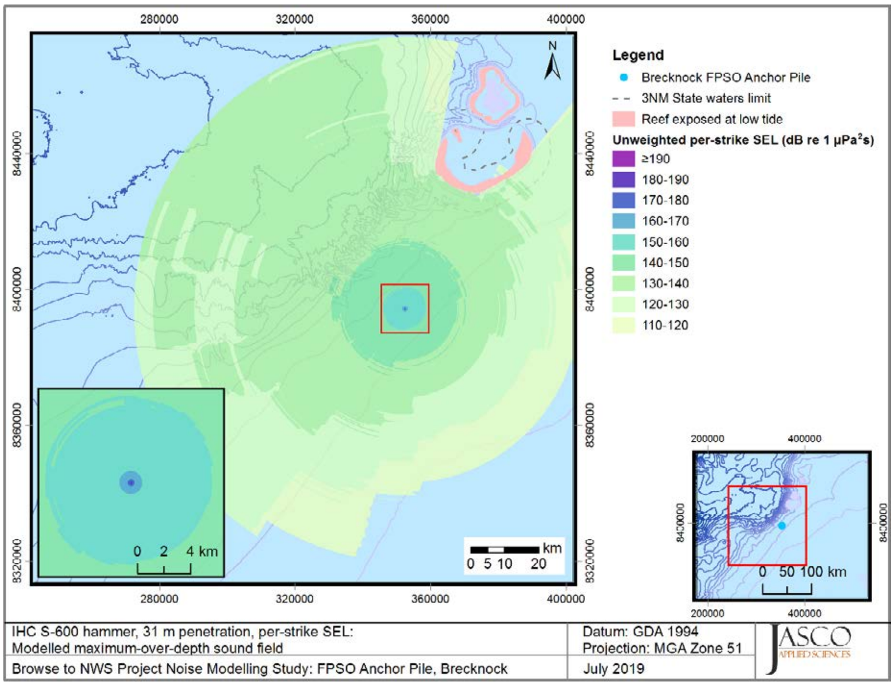


Figure H-8. *Brecknock, IHC S-600, per-strike SEL, 31 m penetration depth*: Sound level contour map showing maximum-over-depth results.

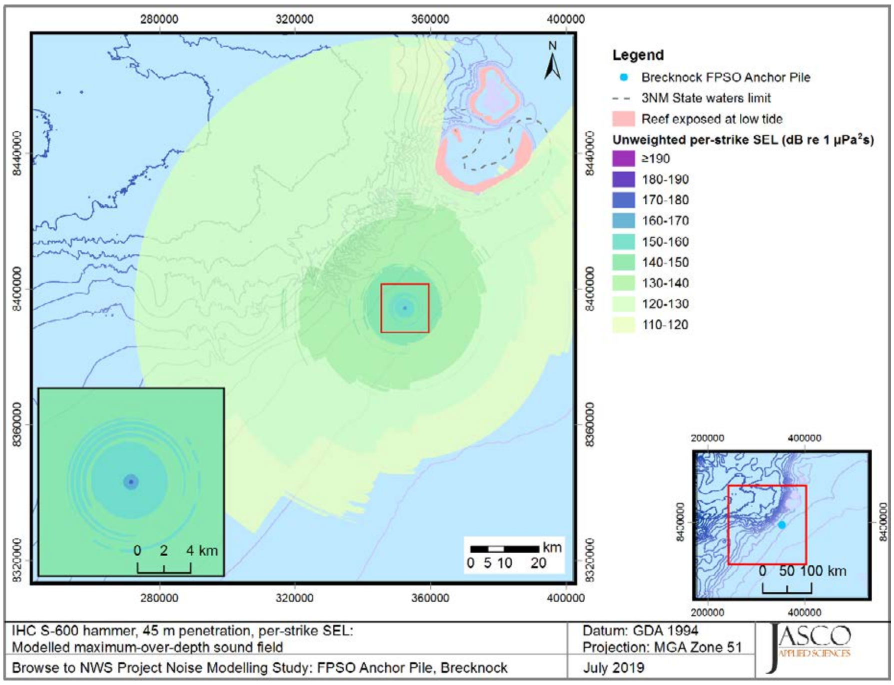


Figure H-9. *Brecknock, IHC S-600, per-strike SEL, 45 m penetration depth*: Sound level contour map showing maximum-over-depth results.

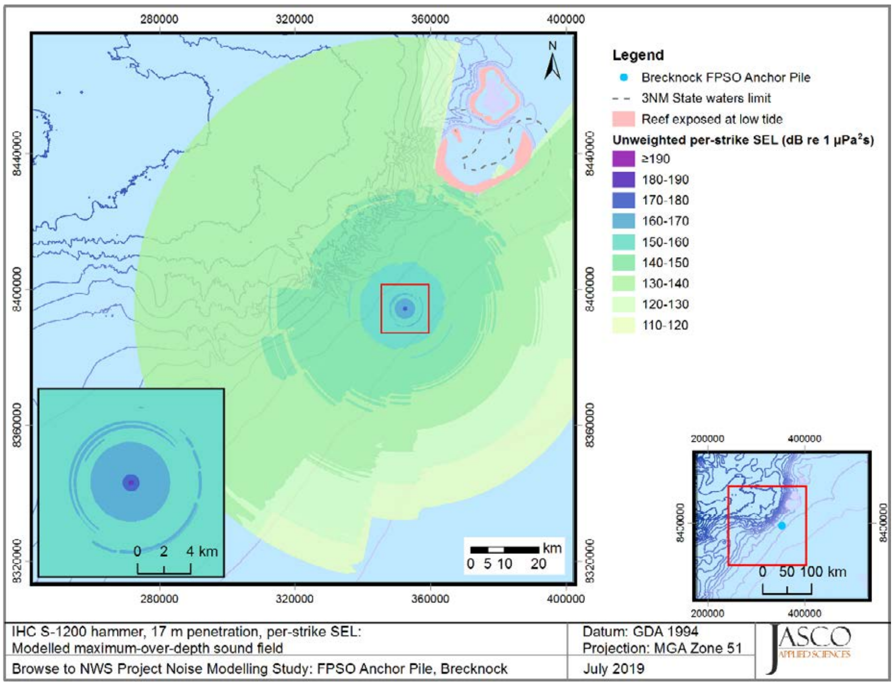


Figure H-10. *Brecknock, IHC S-1200, per-strike SEL, 17 m penetration depth*: Sound level contour map showing maximum-over-depth results.

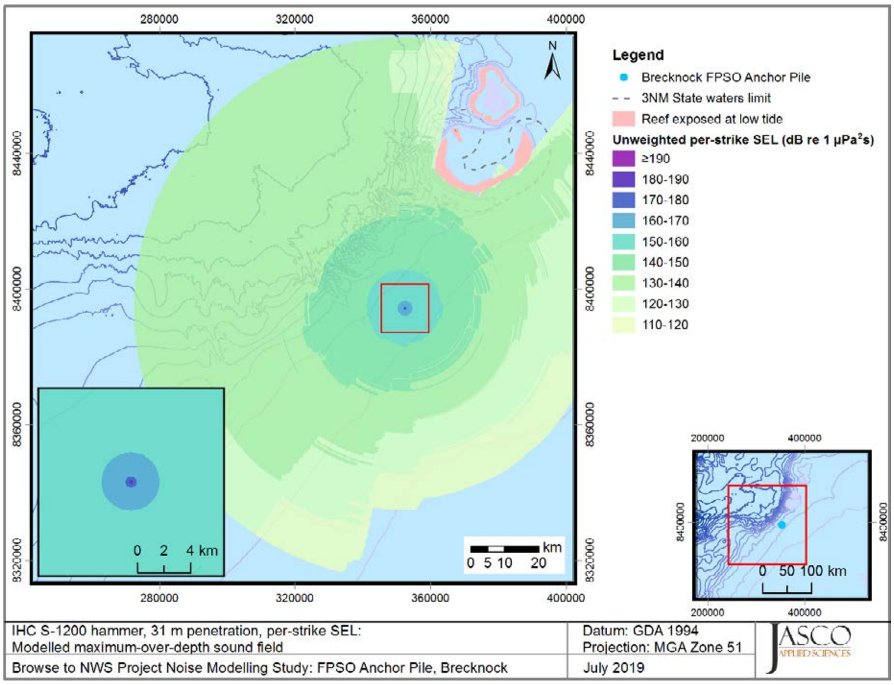


Figure H-11. *Brecknock, IHC S-1200, per-strike SEL, 31 m penetration depth*: Sound level contour map showing maximum-over-depth results.

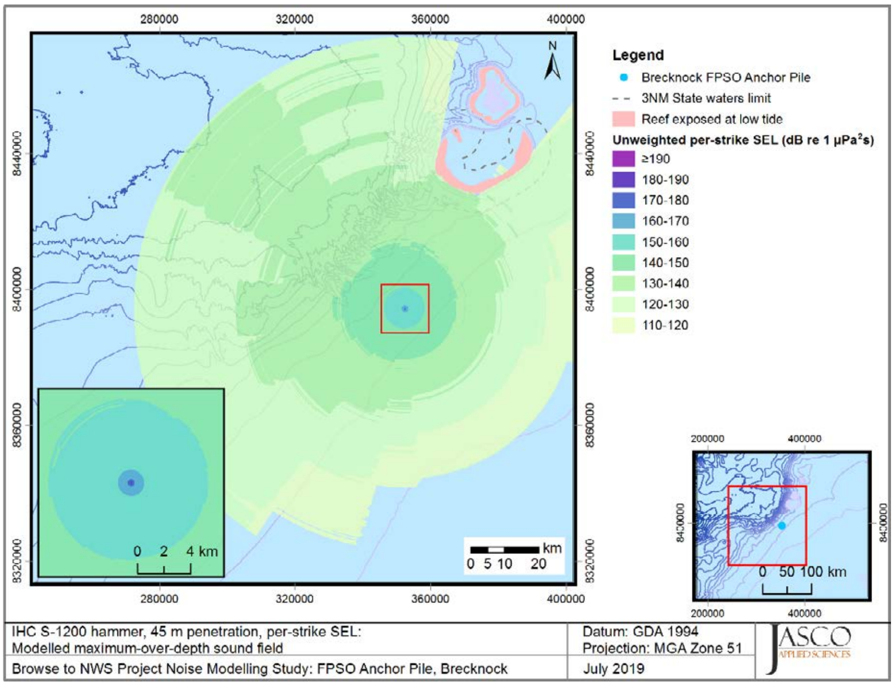


Figure H-12. *Brecknock, IHC S-1200, per-strike SEL, 45 m penetration depth*: Sound level contour map showing maximum-over-depth results.

H.3. VSP SEL Contour Maps

Maps of the per-pulse SEL results for the two VSP locations are shown in Figures H-13 and H-14.

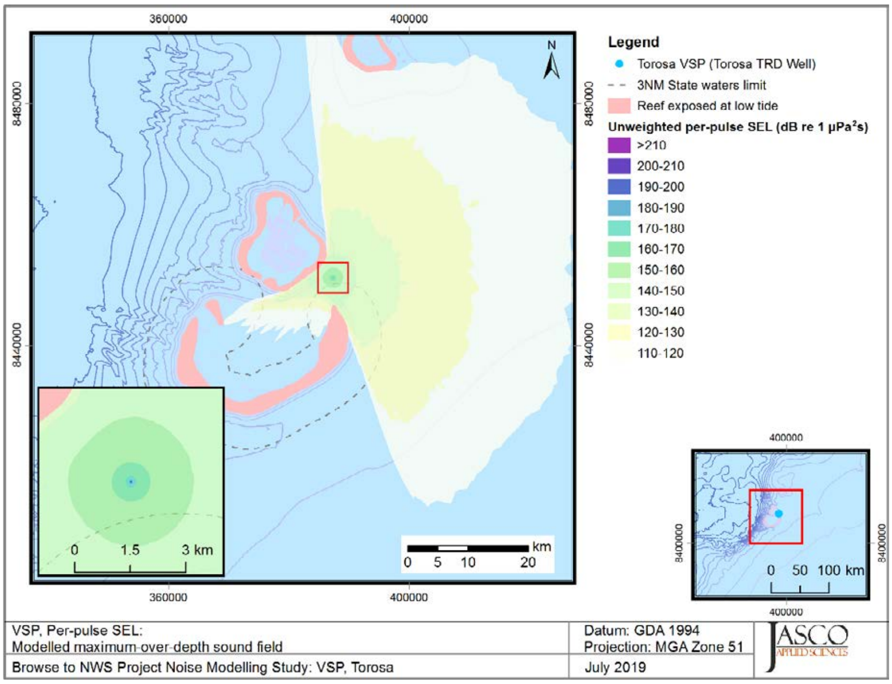


Figure H-13. *Torosa TRD Well VSP, per-pulse SEL:* Sound level contour map showing unweighted maximum-over-depth results.

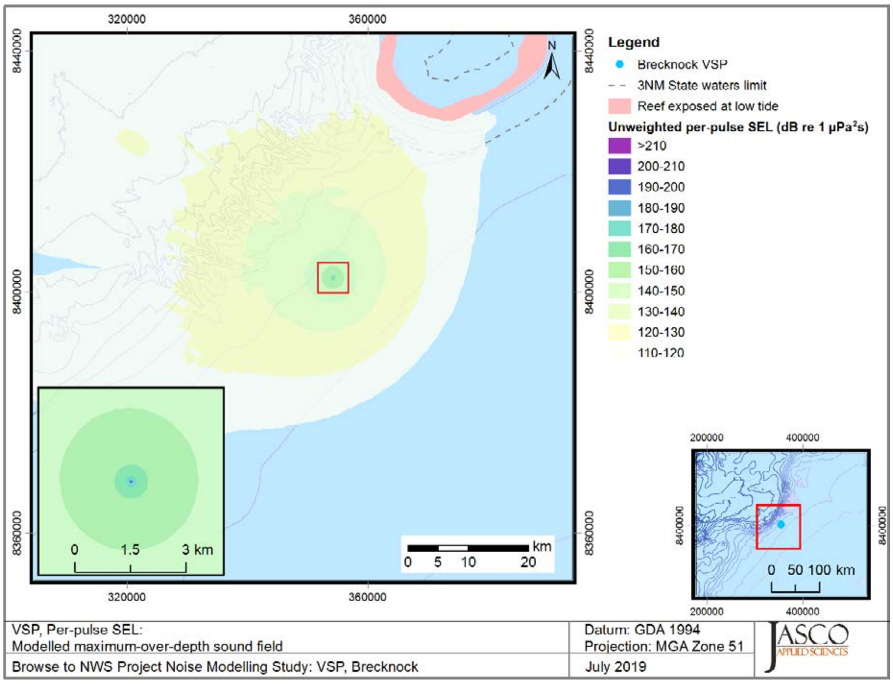


Figure H-14. *Brecknock VSP, per-pulse SEL:* Sound level contour map showing unweighted maximum-over-depth results.

Browse to North West Shelf Project Noise Modelling Study - Addendum

Additional Information

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Disclaimer:

The results presented herein are relevant within the specific context described in this report. They could be misinterpreted if not considered in the light of all the information contained in this report. Accordingly, if information from this report is used in documents released to the public or to regulatory bodies, such documents must clearly cite the original report, which shall be made readily available to the recipients in integral and unedited form.

Contents

Figures

Tables

1. Introduction

This report is an addendum to McPherson et al. (2019), and presents:

- Additional modelling scenarios:
    - The additional modelled scenarios consider both Floating Production Storage and Offloading (FPSO) facilities during offtake along with operations of a Mobile Offshore Drilling Unit (MODU) under dynamic positioning at either the Torosa TRD well or Brecknock. The FPSO operational noise during offtake, includes the FPSO under DP, an Offshore Support Vessel (OSV) near each FPSO (presented in isolation also) and a noiseless condensate tanker.
- Discussion of the interaction between impulsive and continuous sources from an acoustic modelling for impact assessment perspective.
- Calculations of the areas within relevant threshold isopleths for the static acoustic modelling sound fields were calculated from the area encompassed by the shape file representing the isopleths.
- Areas within specific threshold isopleths from the static sound field modelling results presented in McPherson et al. (2019) and this addendum. Additionally, the area of the overlap between considered Biologically Important Areas (BIAs) and the relevant isopleths is also calculated.
- For the assessment of turtle exposure through animal movement and exposure modelling, considering an additional BIA, that for the Department of Environment and Energy (DoEE) Green Turtle Inter-nesting Buffer located at Scott Reef – Sandy Islet.

The geographic coordinates for the modelled sites are provided in Table 1 and an overview of the modelling area is shown in Figure 1.

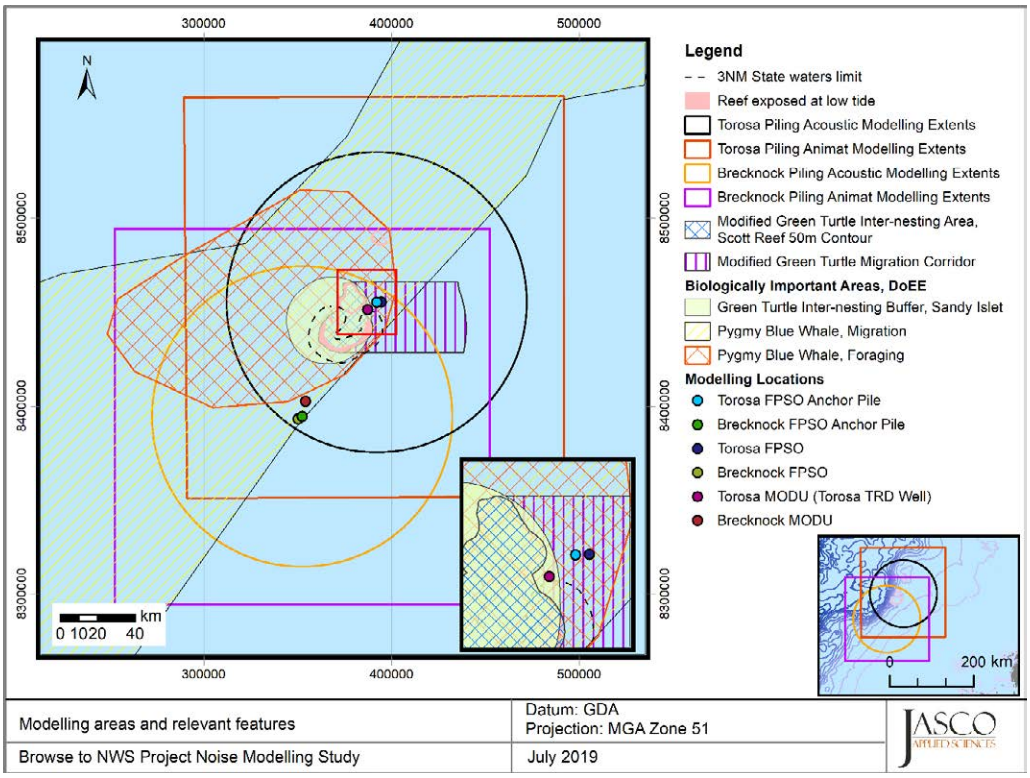

Figure 1. Overview of the modelled area and local features.

Table 1. Location details for the modelled sites.

Site	**Source**	**Latitude (S)**	**Longitude (E)**	**MGA (GDA94), Zone 51**		**Water depth (m)**
				X (m)	*Y* (m)	
Torosa	FPSO Anchor Pile	13° 58' 16.97"	122° 00' 05.23"	392148	8455212	448
	FPSO (turret)	13° 58' 15.06"	122° 01' 28.53"	394647	8455281	463
	OSV (bow)	13° 58' 15.06"	122° 00' 50.38"	393502.3	8455276	463
Torosa TRD Well	MODU (centre)	14° 00' 26.64"	121° 57' 23.58"	387315	8451207	391
	VSP (MODU centre)					
Brecknock	FPSO Anchor Pile	14° 31' 10.31"	121° 37' 50.58"	352456	8394373	506
	FPSO (turret)	14° 31' 51.44"	121° 36' 38.47"	350305	8393096	515
	OSV (bow)	14° 31' 14.19"	121° 36' 38.55"	350300.3	8394241	515
	MODU (centre)	14° 26' 49.45"	121° 38' 52.09"	354250	8402400	467
	VSP (MODU centre)					

2. Methods

In addition to the methods presented in McPherson et al. (2019), the methodology for the calculations of ensonified and exposed areas, both in their own right and overlapping relevant BIA’s, and the consideration of an additional green turtle BIA and an alternative number of individuals, is outlined in this addendum report.

2.1. Exposed Areas

The areas within relevant threshold isopleths for the static acoustic modelling sound fields were calculated from the area encompassed by the shape file representing the isopleths. These areas can be combined to create a simplistic representation of the area within which a threshold is exceeded to assist with the impact assessment.

For the animal movement and exposure modelling, a key output was the 95th percentile ranges (P_{95}), or the range within which 95% of the exposure exceedances. This range was converted into an area ($\pi^*(P_{95})^2$).

To calculate the overlap between the area within a threshold isopleth or P_{95} area of a pygmy blue whale or green turtle relevant BIA, the two features were mapped in Global Mapper (Global Mapper 2019) and the overlapping area calculated.

2.2. Animal Movement and Exposure Modelling

2.2.1. Assessment areas

Two areas of interest are defined for inter-nesting green turtles:(1) a modified Biologically Important Area (BIA) defined by the 50 m contour around North and South Scott Reef, including a corridor connecting the two reefs, and (2) the DoEE-defined inter-nesting BIA boundary around Scott Reef.

Figures 2 and 3 show maps of both of the BIAs for inter-nesting green turtles in relation to both the Torosa and Brecknock piling locations. Both maps also show the extents of the modelling and animat simulation area. To account for the difference between the animat simulation area and the BIAs, the final exposure estimates are scaled by the ratio of the clipped BIA relative to the simulation area.

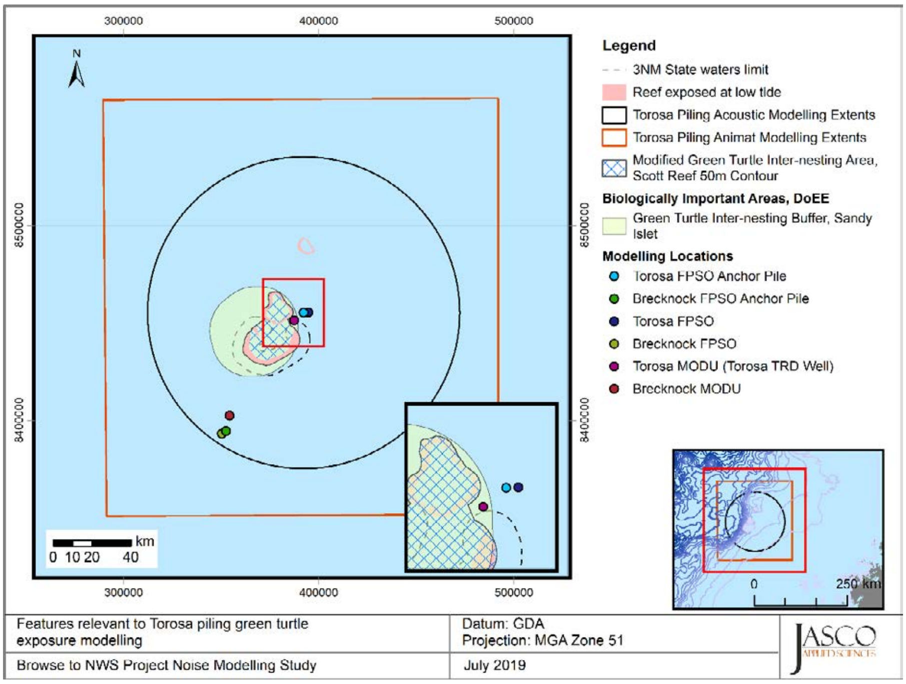

Figure 2. *Torosa:* Map of green turtle exposure modelling features, including modified BIAs for inter-nesting and migrating green turtles, along with extents for acoustic propagation modelling and animat modelling.

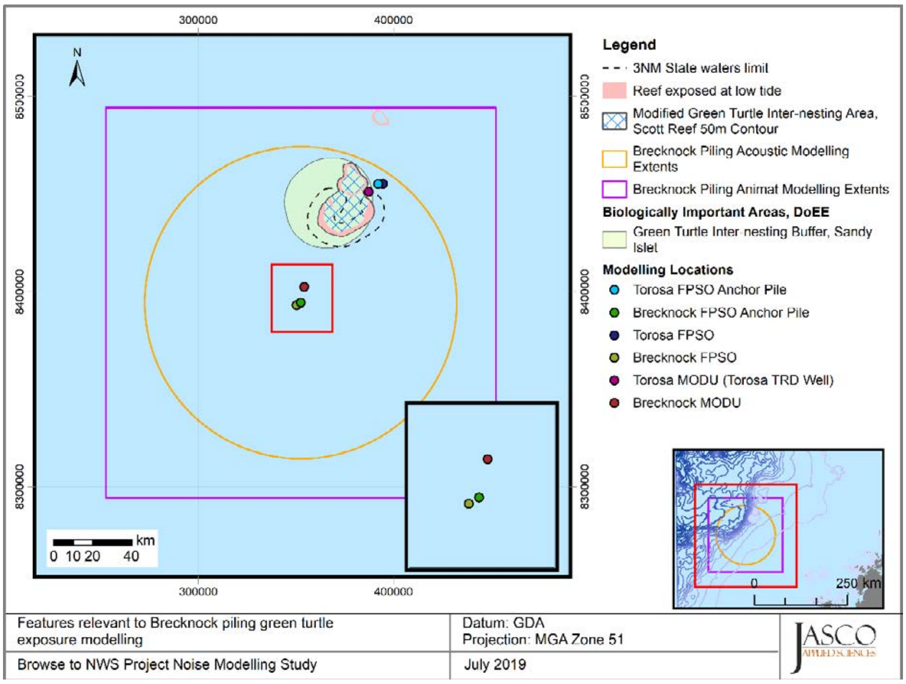

Figure 3. *Brecknock:* Map of green turtle exposure modelling features, including modified BIAs for inter-nesting and migrating green turtles, along with extents for acoustic propagation modelling and animat modelling.

2.2.2. Methodology

The exposure criteria for impulsive sounds (described in Section 2, McPherson et al. (2019)) were used to determine the number of animats exceeding thresholds. To evaluate potential injury (PTS), TTS, and behavioural disturbance, exposure results were summed over the driving of a single pile, which represents the exposure over 24 h, as only one pile will be driven per day.

Model simulations were run with animat seeding densities of 15 animats/km^2 for pygmy blue whales and 15 animats/km^2 green turtles to generate a statistically reliable probability density function (PDF) for each species. Seeding densities need to be high enough to adequately sample the underlying sound exposure PDF. Typically, for longer duration simulations (7-14 days), a seeding density of 0.5 animats/km^2 is sufficient. However, in this case, where the active duration of the pile driving is less than 80 minutes within 24 hours (78.5 or 80 minutes, IH S-600 hammer, Tables 16 and 17, McPherson et al. (2019)), the simulated density must be increased substantially to provide a comparably reliable sampling of the underlying PDF. A statistically equivalent result could also be accomplished by running several independent simulations at a lower seeding density; however, this is computationally less efficient. The number of simulated animats exposed above relevant thresholds can then be scaled by the ratio of the real-world density to the seeded animat density to convert to an estimate of the number of individual animals impacted.

The distribution of ranges of exposed animats was used to estimate the 95th percentile ranges at which the animats were exposed above threshold. Within the 95th percentile range, there are generally some proportion of animats that did not exceed threshold criteria.

The proposed number of individual green turtles in McPherson et al. (2019) was 1162, or a density of 1.79 turtles/km^2 within an inter-nesting area defined by the 50 m bathymetry around North and South Scott Reef, referred to as the ‘Modified Green Turtle Inter-nesting Area, Scott Reef 50 m Contour’. This addendum considers the possibility of 5000 individuals within this modified inter-nesting area.

Table 2. Exposure modelling scenarios and associated areas of concern for green turtle simulations, along with estimated animal densities.

Animat scenario	Full area (km^2)	R_{min} (km)	Adjusted A_{full} (km^2)	$BIA_{clipped}$ (km^2)	Area-based scaling, S_A	Number of turtles	Animal density (# per km^2)
Torosa							
DoEE Green Turtle Inter-nesting Buffer located at Scott Reef – Sandy Islet	40000.0	3.8	39954.6	1666.8	0.04	1162	0.70
						5000	3.00
Modified Green turtle inter-nesting buffer, Scott Reef 50 m contour	40000.0	7.9	39804.1	658.2	0.02	1162	1.79
						5000	7.70
Brecknock							
DoEE Green Turtle Inter-nesting Buffer located at Scott Reef – Sandy Islet	40000.0	29.7	37228.8	1666.8	0.04	1162	0.70
						5000	3.00
Modified Green turtle inter-nesting buffer, Scott Reef 50 m contour	40000.0	40.4	34872.4	658.2	0.02	1162	1.79
						5000	7.70

3. Results

3.1. Pile Driving: Torosa FPSO Anchor Piles

3.1.1. Areas within threshold isopleths

The area within threshold isopleths for low-frequency marine mammals and turtles for the Torosa FPSO pile driving scenarios are shown in Tables 3 and 4.

Table 3. *Torosa*: Areas (km^2) within isopleths corresponding to maximum-over-depth low-frequency cetacean PTS and TTS thresholds (NMFS 2018) and marine mammal behavioural response to continuous noise (NMFS 2014).

Threshold	**Area (km^2)**	**Area within PBW migratory BIA (km^2)**	**Area within PBW foraging BIA (km^2)**
IHC S-600 hammer			
LF cetacean PTS†	39.70	39.70	39.70
LF cetacean TTS†	943.80	803.40	623.70
Marine mammal behavioural response#	123.53	123.53	123.53
IHC S-1200 hammer			
LF cetacean PTS†	54.10	54.10	54.10
LF cetacean TTS†	1091.90	875.50	646.20
Marine mammal behavioural response#‡	376.75	376.75	333.82

† Frequency-weighted SEL$_{24h}$ based marine mammal PTS and TTS thresholds (NMFS 2018)
#160 dB re 1 µPa (SPL) (NMFS 2014)

Table 4. *Torosa*: Areas (km^2) within isopleths corresponding to maximum-over-depth turtle PTS and TTS (Finneran et al. 2017), behavioural response (NSF 2011) and disturbance (McCauley et al. 2000a, 2000b).

Threshold	**Area (km^2)**	**Area within Modified Migratory Corridor (km^2)**	**Area within Modified Turtle BIA (km^2)**	**Area within DoEE Green Turtle BIA (km^2)**
IHC S-600 hammer				
Turtle PTS†	0.20	0.00	0.20	0.00
Turtle TTS†	18.40	0.00	18.40	0.00
Turtle behavioural response#	52.85	0.00	26.46	0.66
Turtle behavioural disturbance‡	2.70	0.00	1.35	0.00
IHC S-1200 hammer				
Turtle PTS†	0.20	0.00	0.20	0.00
Turtle TTS†	23.00	0.00	23.00	1.18
Turtle behavioural response#	202.06	0.00	100.87	6.92
Turtle behavioural disturbance‡	21.12	0.16	10.56	0.00

† Frequency-weighted SEL$_{24h}$ based turtle PTS and TTS thresholds (Finneran et al. 2017)
#166 dB re 1 µPa (SPL) (NSF 2011)
‡175 dB re 1 µPa (SPL) (McCauley et al. 2000a, 2000b)

3.1.2. Area within 95th percentile ranges (P_{95})

The area within P_{95} ranges for pygmy blue whales and turtles for the Torosa FPSO pile driving scenarios are shown in Tables 5–8.

Table 5. *Torosa*: Area (km^2) within the 95th percentile exposure ranges, P_{95} (km), for pygmy blue whale animat simulation scenarios without an exclusion zone implemented.

Threshold	**Migrating**		**Foraging**	
	Area within P_{95} (km^2)	Area of PBW migratory BIA within P_{95} (km^2)	Area within P_{95} (km^2)	Area of PBW foraging BIA within P_{95} (km^2)
IHC S-600 hammer				
LF cetacean PTS†	2.60	2.6	6.61	6.6
LF cetacean TTS†	166.04	165.95	363.05	338.35
Marine mammal behavioural response#	124.29	124.23	141.87	141.79
IHC S-1200 hammer				
LF cetacean PTS†	5.39	5.387	7.74	7.739
LF cetacean TTS†	218.52	218.4	446.38	401.39
Marine mammal behavioural response#‡	262.45	262.31	361.03	336.78

† Frequency-weighted SEL_{24h} based marine mammal PTS and TTS thresholds (NMFS 2018)
#160 dB re 1 µPa (SPL) (NMFS 2014)

Table 6. *Torosa*: Area (km^2) within the 95th percentile exposure ranges, P_{95} (km), for pygmy blue whale animat simulation scenarios with a 2000 m exclusion zone implemented.

Threshold	**Migrating**		**Foraging**	
	Area within P_{95} (km^2)	Area of PBW migratory BIA within P_{95} (km^2)	Area within P_{95} (km^2)	Area of PBW foraging BIA within P_{95} (km^2)
IHC S-600 hammer				
LF cetacean PTS†	0.00	0.00	0.00	0.00
LF cetacean TTS†	187.23	187.13	369.15	343.07
Marine mammal behavioural response#	148.27	148.19	150.01	149.93
IHC S-1200 hammer				
LF cetacean PTS†	0.00	0.00	13.72	0.00
LF cetacean TTS†	231.27	231.15	454.65	407.5
Marine mammal behavioural response#‡	297.42	297.27	368.47	342.55

† Frequency-weighted SEL_{24h} based marine mammal PTS and TTS thresholds (NMFS 2018)
#160 dB re 1 µPa (SPL) (NMFS 2014)

Table 7. *Torosa*: Area (km^2) within the 95th percentile exposure ranges, P_{95} (km), for green turtle animat simulation scenarios without an exclusion zone implemented.

Threshold	**Migratory**		**Inter-nesting**			
	Area within P_{95} (km^2)	Area of Modified Migratory Corridor within P_{95} (km^2)	Modified Inter-nesting turtle BIA		DoEE Green Turtle BIA	
			Area within P_{95} (km^2)	Area of BIA within P_{95} (km^2)	Area within P_{95} (km^2)	Area of BIA within P_{95} (km^2)
IHC S-600 hammer						
Turtle PTS[†]	0.00	0.00	0.00	0.00	0.00	0.00
Turtle TTS[†]	8.55	8.55	0.00	0.00	0.00	0.00
Turtle behavioural response[#]	20.27	20.27	0.00	0.00	0.00	0.00
Turtle behavioural disturbance[‡]	0.01	0.00	0.00	0.00	0.00	0.00
IHC S-1200 hammer						
Turtle PTS[†]	0.00	0.00	0.00	0.00	0.00	0.00
Turtle TTS[†]	10.07	10.07	0.00	0.00	0.00	0.00
Turtle behavioural response[#]	67.64	67.64	0.00	0.00	128.68	18.13
Turtle behavioural disturbance[‡]	9.84	9.84	0.00	0.00	0.00	0.00

[†] Frequency-weighted SEL$_{24h}$ based turtle PTS and TTS thresholds (Finneran et al. 2017)

[#] 166 dB re 1 µPa (SPL) (NSF 2011)

[‡] 175 dB re 1 µPa (SPL) (McCauley et al. 2000a, 2000b)

Table 8. *Torosa*: Area (km^2) within the 95th percentile exposure ranges, P_{95} (km), for green turtle animat simulation scenarios with a 500 m exclusion zone implemented.

Threshold	**Migratory**		**Inter-nesting**			
	Area within P_{95} (km^2)	Area of Modified Migratory Corridor within P_{95} (km^2)	Modified Inter-nesting turtle BIA		DoEE Green Turtle BIA	
			Area within P_{95} (km^2)	Area of BIA within P_{95} (km^2)	Area within P_{95} (km^2)	Area of BIA within P_{95} (km^2)
IHC S-600 hammer						
Turtle PTS[†]	0.00	0.00	0.00	0.00	0.00	0.00
Turtle TTS[†]	8.97	8.97	0.00	0.00	0.00	0.00
Turtle behavioural response[#]	20.59	20.59	0.00	0.00	0.00	0.00
Turtle behavioural disturbance[‡]	0.00	0.00	0.00	0.00	0.00	0.00
IHC S-1200 hammer						
Turtle PTS[†]	0.00	0.00	0.00	0.00	0.00	0.00
Turtle TTS[†]	10.29	10.29	0.00	0.00	0.00	0.00
Turtle behavioural response[#]	69.69	69.69	0.00	0.00	128.68	18.13
Turtle behavioural disturbance[‡]	9.95	9.95	0.00	0.00	0.00	0.00

[†] Frequency-weighted SEL$_{24h}$ based turtle PTS and TTS thresholds (Finneran et al. 2017)

[#] 166 dB re 1 µPa (SPL) (NSF 2011)

[‡] 175 dB re 1 µPa (SPL) (McCauley et al. 2000a, 2000b)

3.1.3. Animal Movement and Exposure Modelling

Summaries of the animat modelling results at Torosa for inter-nesting green turtles with 1162 or 5000 individuals are provided in Table 9.

Table 9. *Torosa*: Summary of animat simulation results for inter-nesting turtles. Includes the distances to acoustic modelling thresholds (km), the 95th percentile exposure ranges (km), and the number of real-world individuals exposed above threshold. Acoustic modelling results are presented in McPherson et al. (2019).

Threshold		**Distance to threshold from acoustic modelling**		**Modified Inter-nesting BIA**						**DoEE Sandy Islet 20km BIA**					
				Inter-nesting turtles			**Inter-nesting turtles with 500 m exclusion zone**			**Inter-nesting turtles**			**Inter-nesting turtles with 500 m exclusion zone**		
Threshold description	Sound level (dB)	R_{max} (km)	$R_{95\%}$ (km)	Range, P_{95} (km)	Number of individuals (1162 total)	Number of individuals (5000 total)	Range, P_{95} (km)	Number of individuals (1162 total)	Number of individuals (5000 total)	Range, P_{95} (km)	Number of individuals (1162 total)	Number of individuals (5000 total)	Range, P_{95} (km)	Number of individuals (1162 total)	Number of individuals (5000 total)
IHC S600 Hammer															
TTS, PK	226†	<0.02*		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TTS, SEL$_{24h}$	189‡	4.79	2.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PTS, PK	232†	<0.02*		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PTS, SEL$_{24h}$	204‡	0.24	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Behavioural response	166#	5.11	4.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	175#	0.68	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IHC S1200 Hammer															
TTS, PK	226†	<0.02*		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TTS, SEL$_{24h}$	189‡	5.07	4.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PTS, PK	232†	<0.02*		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PTS, SEL$_{24h}$	204‡	0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Behavioural response	166#	9.11	5.66	0.00	0.00	0.00	0.00	0.00	0.00	**6.40**	**0.03**	**0.15**	**6.40**	**0.03**	**0.15**
	175#	1.87	1.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

† PK (L_{pk}; dB re 1 µPa)
‡ Turtle weighted SEL$_{24h}$ ($L_{E,24h}$; dB re 1 µPa^2·s)
# SPL (L_p; dB re 1 µPa)
* R_{max} reported for TTS PK and PTS PK from acoustic modelling

3.2. Pile Driving: Brecknock FPSO Anchor Piles

3.2.1. Areas within threshold isopleths

The area within threshold isopleths for low-frequency marine mammals and turtles for the Brecknock FPSO pile driving scenarios are shown in Tables 10 and 11.

Table 10. *Brecknock*: Areas (km^2) within isopleths corresponding to maximum-over-depth low-frequency cetacean PTS and TTS thresholds NMFS (2018) and marine mammal behavioural response to continuous noise (NMFS 2014).

Threshold	Area (km^2)	Area within PBW migratory BIA (km^2)	Area within PBW foraging BIA (km^2)
IHC S-600 hammer			
LF cetacean PTS†	27.90	21.80	0.00
LF cetacean TTS†	1048.20	695.20	224.50
Marine mammal behavioural response#	130.98	85.37	0.00
IHC S-1200 hammer			
LF cetacean PTS†	32.40	25.80	0.00
LF cetacean TTS†	1156.30	759.30	252.00
Marine mammal behavioural response#‡	431.09	289.47	20.44

† Frequency-weighted SEL$_{24h}$ based marine mammal PTS and TTS thresholds (NMFS 2018)
#160 dB re 1 µPa (SPL) (NMFS 2014)

Table 11. *Brecknock*: Areas (km^2) within isopleths corresponding to maximum-over-depth turtle PTS and TTS (Finneran et al. 2017), behavioural response (NSF 2011) and disturbance (McCauley et al. 2000a, 2000b).

Threshold	Area (km^2)	Area within Modified Migratory Corridor (km^2)	Area within Modified Turtle BIA (km^2)	Area within DoEE Green Turtle BIA (km^2)
IHC S-600 hammer				
Turtle PTS†	0.20	0.00	0.00	0.00
Turtle TTS†	19.60	0.00	0.00	0.00
Turtle behavioural response#	47.70	0.00	0.00	0.00
Turtle behavioural disturbance‡	2.57	0.00	0.00	0.00
IHC S-1200 hammer				
Turtle PTS†	0.20	0.00	0.00	0.00
Turtle TTS†	20.20	0.00	0.00	0.00
Turtle behavioural response#	230.18	0.00	0.00	0.00
Turtle behavioural disturbance‡	18.41	0.00	0.00	0.00

† Frequency-weighted SEL$_{24h}$ based turtle PTS and TTS thresholds (Finneran et al. 2017)
#166 dB re 1 µPa (SPL) (NSF 2011)
‡175 dB re 1 µPa (SPL) (McCauley et al. 2000a, 2000b)

3.2.2. Area within 95th percentile ranges (P_{95})

At Brecknock, no exposures were recorded for migratory or inter-nesting turtles due to the distance from the FPSO pile of any defined turtle BIAs, therefore no animat simulation results are presented for turtles at Brecknock.

Table 12. *Brecknock*: Area (km^2) within the 95th percentile exposure ranges, P_{95} (km), for pygmy blue whale animat simulation scenarios without an exclusion zone implemented.

Threshold	**Migrating**		**Foraging**	
	Area within P_{95} (km^2)	Area of PBW migratory BIA within P_{95} (km^2)	Area within P_{95} (km^2)	Area of PBW foraging BIA within P_{95} (km^2)
IHC S-600 hammer				
LF cetacean PTS†	4.08	4.07	0.00	0.00
LF cetacean TTS†	176.71	117.71	393.38	1.81
Marine mammal behavioural response#	44.18	35.51	0.00	0.00
IHC S-1200 hammer				
LF cetacean PTS†	4.99	4.97	0.00	0.00
LF cetacean TTS†	204.60	134.19	490.87	0.00
Marine mammal behavioural response#‡	235.06	152.04	454.65	7.91

† Frequency-weighted SEL_{24h} based marine mammal PTS and TTS thresholds (NMFS 2018)
#160 dB re 1 µPa (SPL) (NMFS 2014)

Table 13. *Brecknock*: Area (km^2) within the 95th percentile exposure ranges, P_{95} (km), for pygmy blue whale animat simulation scenarios with a 2000 m exclusion zone implemented.

Threshold	**Migrating**		**Foraging**	
	Area within P_{95} (km^2)	Area of PBW migratory BIA within P_{95} (km^2)	Area within P_{95} (km^2)	Area of PBW foraging BIA within P_{95} (km^2)
IHC S-600 hammer				
LF cetacean PTS†	0.00	0.00	0.00	0
LF cetacean TTS†	184.82	122.51	393.38	1.81
Marine mammal behavioural response#	48.03	38.09	0.00	0
IHC S-1200 hammer				
LF cetacean PTS†	0.00	0.00	0.00	0.00
LF cetacean TTS†	210.21	137.49	456.17	8.10
Marine mammal behavioural response#‡	239.43	154.59	454.65	7.91

† Frequency-weighted SEL_{24h} based marine mammal PTS and TTS thresholds (NMFS 2018)
#160 dB re 1 µPa (SPL) (NMFS 2014)

3.2.3. Animal Movement and Exposure Modelling

At Brecknock, no exposures were recorded for migratory or inter-nesting turtles due to the distance from the pile of any defined turtle BIAs, therefore no results are presented.

3.3. Vessel noise

3.3.1. Additional modelling results

3.3.1.1. Tabulated results

Modelling results for additional modelled scenarios considering both Floating Production Storage and Offloading (FPSO) facilities during offtake along with operations of a Mobile Offshore Drilling Unit (MODU) under dynamic positioning at either the Torosa TRD well or Brecknock are presented in Tables 14 and 15.

Table 14. *Vessels, SPL*: Areas (km^2, WGS84, geographic) for combined FPSO offtake and MODU operations within isopleths corresponding to the threshold for marine mammal behavioural response to continuous noise (NMFS 2014).

SPL (**L_p; dB re 1 µPa**)	**Both FPSO's offloading with MODU at Torosa TRD well**	**Both FPSO's offloading with MODU at Brecknock**
	Area (km^2)	Area (km^2)
120†	481.9	551.2

† Threshold for marine mammal behavioural response to continuous noise (NMFS 2014).
FPSO offtake (offloading) includes an FPSO under DP, a noiseless condensate tanker and an OSV.

Table 15. *Vessels, SEL_{24}*: Areas (km^2, WGS84, geographic) for combined FPSO offtake and MODU operations within isopleths corresponding to the thresholds for maximum-over-depth PTS and TTS thresholds for cetaceans (NMFS 2018) and turtles (Finneran et al. 2017).

Hearing group	**Threshold for SEL_{24h} ($L_{E,24h}$ dB re 1 µPa²·s) #**	**Both FPSO's offloading with MODU at Torosa TRD well**	**Both FPSO's offloading with MODU at Brecknock**
		Area (km^2)	Area (km^2)
PTS			
LF cetaceans	199	0.16	0.16
MF cetaceans	198	0.001	0.001
HF cetaceans	173	0.62	0.62
Turtles	220	0.017	0.016
TTS			
LF cetaceans	179	30.05	18.95
MF cetaceans	178	0.41	0.41
HF cetaceans	153	201.5	211.7
Turtles	200	0.13	0.13

A dash indicates the level was not reached.
Frequency weighted.
Only areas > 0.001 km^2 are resolved.
FPSO offtake (offloading) includes an FPSO under DP, a noiseless condensate tanker and an OSV.

3.3.1.2. Sound field maps

Maps of the estimated sound fields, threshold contours, and isopleths of interest for SPL and SEL_{24h} sound fields have been presented for the aggregate FPSO and MODU modelling scenarios (Table 1 details source locations) in Figures 4–7.

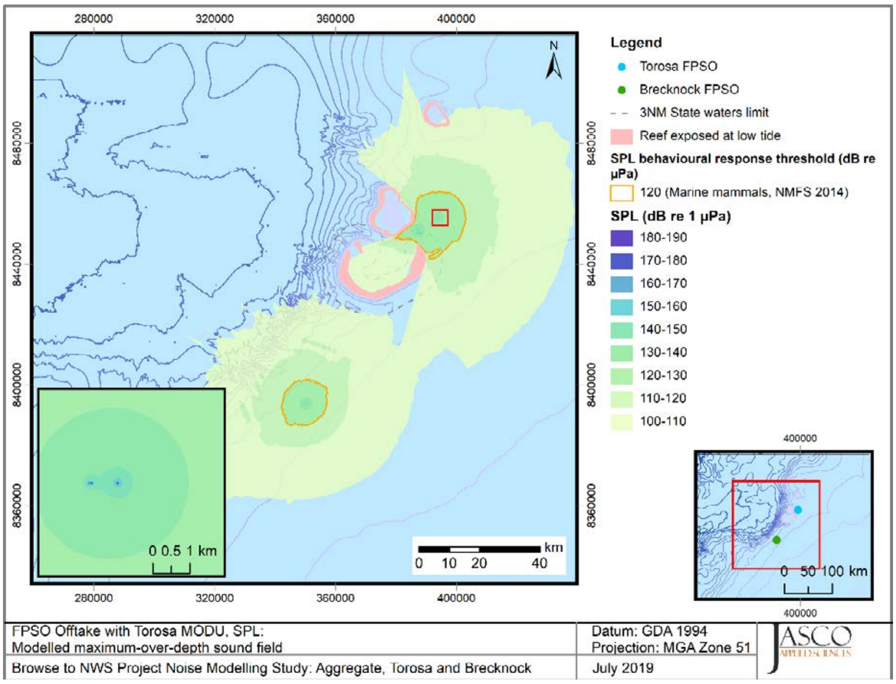

Figure 4. *Torosa and Brecknock, Aggregate FPSO offtake and MODU at Torosa TRD well, SPL*: Sound level contour map, showing maximum-over-depth results. Isopleth for marine mammal (120 dB re 1 µPa) behavioural criteria is shown.

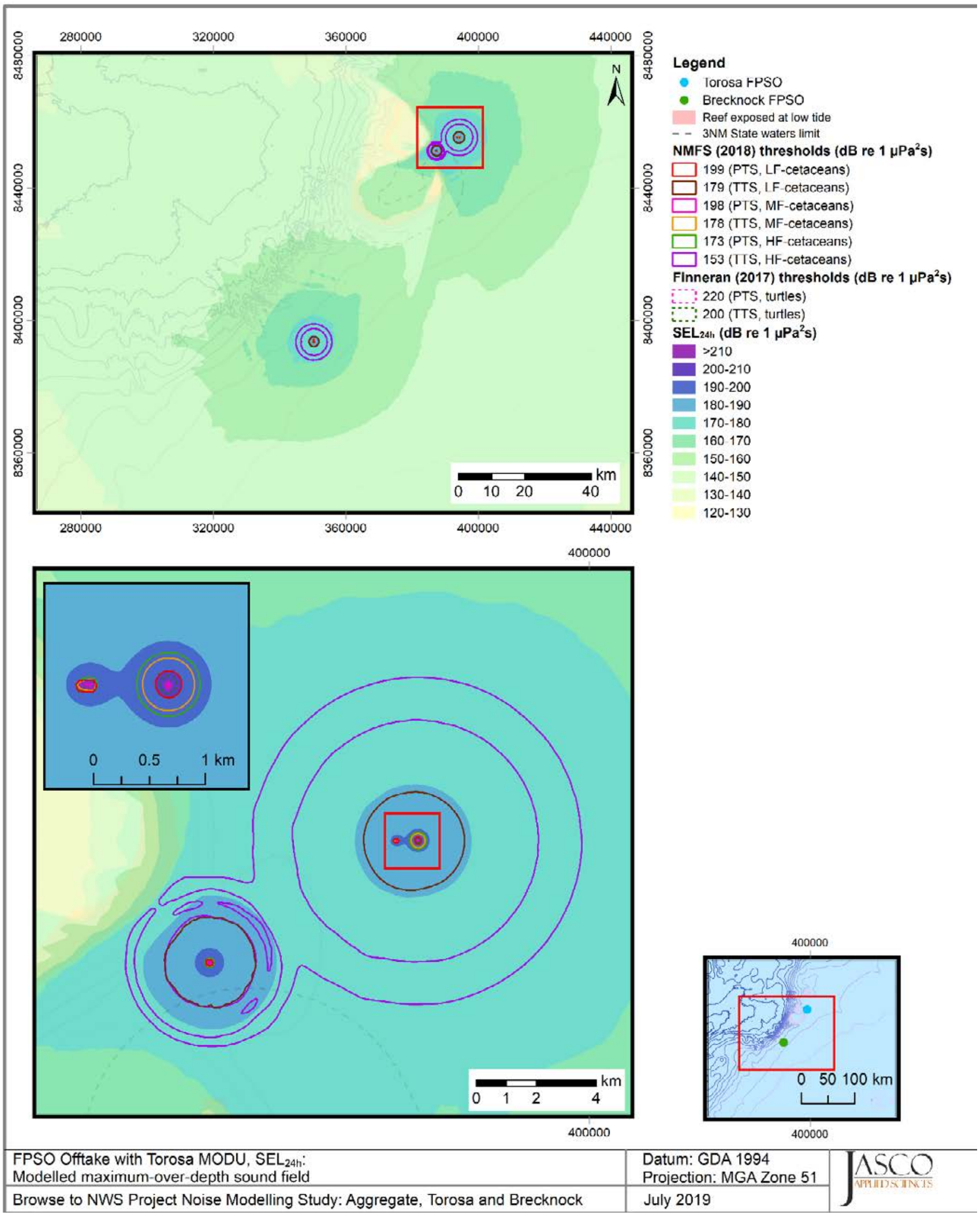

Figure 5. *Torosa and Brecknock, Aggregate FPSO offtake and MODU at Torosa TRD well, SEL$_{24h}$*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with isopleths for low-, mid-, and high-frequency cetaceans and turtles.

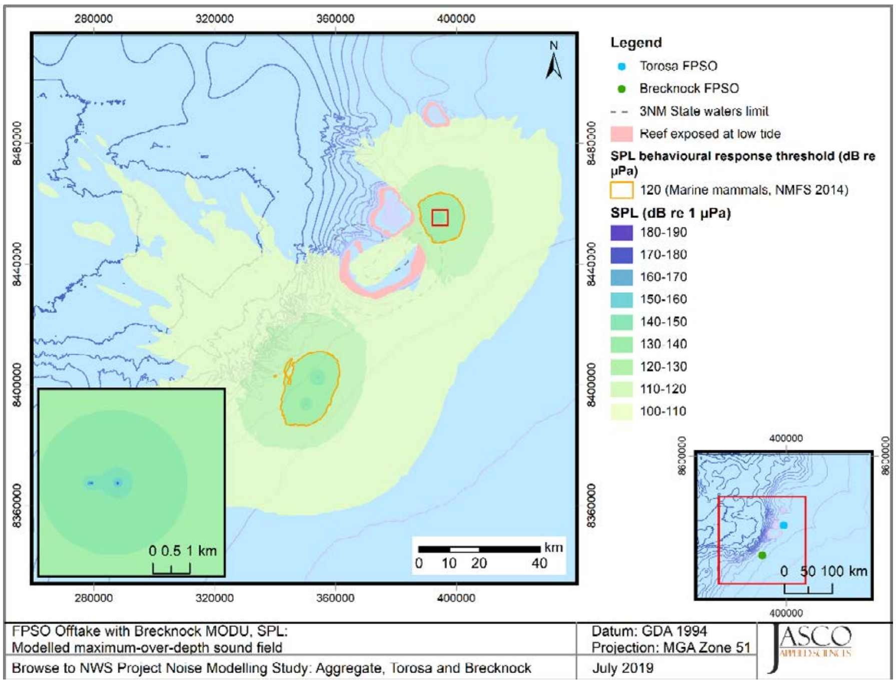

Figure 6. *Torosa and Brecknock, Aggregate FPSO offtake and MODU at Brecknock, SPL*: Sound level contour map, showing maximum-over-depth results. Isopleth for marine mammal (120 dB re 1 µPa) behavioural criteria is shown.

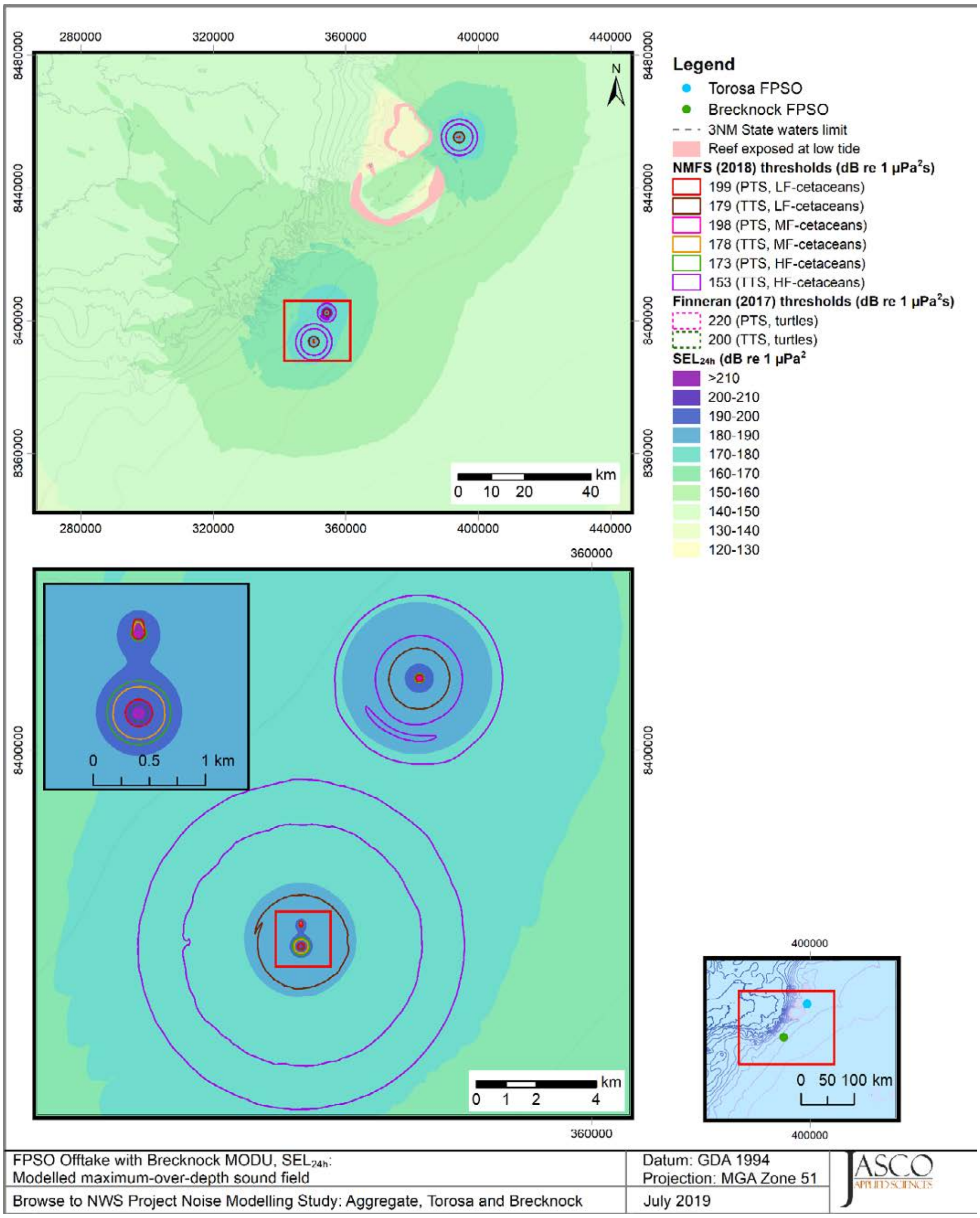

Figure 7. *Torosa and Brecknock, Aggregate FPSO offtake and MODU at Brecknock, SEL24h*: Sound level contour map showing unweighted maximum-over-depth SEL24h results, along with isopleths for low-, mid-, and high-frequency cetaceans and turtles.

3.3.2. Exposed Areas

The area within threshold isopleth for marine mammal behavioural response to continuous noise (NMFS 2014) from the vessel scenarios considered in McPherson et al. (2019) and Section 3.3.1.1 are presented in Table 16, along with the area of each pygmy blue whale BIA in which the threshold is exceeded.

Table 16. Ensonified areas within 120 dB re 1 µPa (SPL) isopleth, and the ensonified area of the pygmy blue whale (PBW) migratory and foraging BIA’s.

Scenario Name	**Area within 120 dB re 1 µPa (SPL) isopleth† (km²)**	**Area within PBW migratory BIA (km²)**	**Area within PBW foraging BIA (km²)**
Torosa			
MODU	111.2	111.2	111.2
FPSO on DP	183.4	183.4	164.8
FPSO without DP	1.0	1.0	1.0
Offtake Support Vessel on DP	15.3	15.3	15.3
FPSO Offtake	192.9	192.9	174.2
Brecknock			
MODU	185.7	180.7	47.6
FPSO on DP	173.3	134.3	0.0
FPSO without DP	1.1	1.1	0.0
Offtake Support Vessel on DP	17.1	17.0	0.0
FPSO Offtake	181.5	139.9	0.0
Aggregate			
FPSO without DP at both Torosa and Brecknock	1.9	1.9	1.0
FPSO Offtake at both Torosa and Brecknock	374.5	332.8	174.2
FPSO Offtake at both Torosa and Brecknock, and MODU at Torosa	481.9	440.2	274.6
FPSO Offtake at both Torosa and Brecknock, and MODU at Brecknock	551.2	491.2	232.3

† Threshold for marine mammal behavioural response to continuous noise (NMFS 2014).

4. Discussion

This addendum presents exposure areas for isopleths representing specific thresholds from the static sound field modelling results and scenarios originally presented in McPherson et al. (2019). Two additional aggregate scenarios are presented in this addendum. The presented areas are associated with noise exposures and thresholds both continuous and impulsive noise sources respectively.

This study presents areas of exposure associated with continuous noise source underwater sound levels from scenarios that include the operations of a Mobile Offshore Drilling Unit (MODU), FPSOs with and without DP operating, an OSV near each FPSO, and Offtake operations including an FPSO under DP, a noiseless condensate tanker and an OSV for locations at Torosa and Brecknock.

Areas of exposure associated with impulsive noise sources from scenarios that include impact driving of subsea piles to anchor the Torosa and Brecknock FPSO facility turret are also presented.

The areas presented in both this addendum and McPherson et al. (2019) represent the areas from the considered modelling scenarios and specific sources. Depending upon the metric and threshold, these areas can be combined to create a simplistic representation of the area within which a threshold is exceeded to assist with the impact assessment.

4.1. Cumulative Scenarios from Impulsive and Continuous Sources

4.1.1. Areas associated with PTS and TTS thresholds

Considering the different characterises of continuous versus impulsive sources, the adopted noise exposure criteria NMFS (2018) considers several received level thresholds and two metrics to assess the effect of noise on marine mammals of the considered sources. One set of metrics and thresholds apply to continuous (non-pulsed) noise sources and a different set apply to impulsive sources. Considering this, it is not possible to present distances to thresholds for cumulative scenarios that contain both pile driving and vessel noise (impulsive and continuous sources). The total exposed area for marine mammal PTS or TTS could be calculated considering the individual exposure areas to determine the maximum exposed area for a cumulative scenario with both continuous and impulsive sources; however this is likely an unduly simplistic and un-assessable given the NMFS (2018) exposure criteria. It also depends upon the time period the different sources under consideration are operational.

Furthermore, the NMFS (2018) criteria were developed considering impulsive source and continuous sources separately, it is therefore appropriate to assess impulsive and continuous (pile driving and vessel noise) separately. No criteria exist for received levels with impulsive and continuous character and it is not currently known what the effect of a received levels with impulsive and continuous character would have on marine mammal PTS and TTS thresholds and spatial extent, if any.

4.1.2. Behavioural Areas

Similar to the points above in regard to PTS and TTS thresholds, an aggregate area considering the behavioural response to sound could be calculated from pile driving and vessel operations. However, ability to assess the source specific spatial extent of behavioural thresholds would be lost in an aggregate impulsive and continuous scenario because the threshold is associated with different sound levels.

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Chapter 10 D.4 RPS Marine Discharge Modelling Report

MAKING
COMPLEX
EASY

BROWSE TO NWS PROJECT - MARINE DISCHARGE MODELLING

Report

MAW0814J
Browse to NWS Project -
Marine Discharge Modelling
Rev 3
27 November 2019

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REPORT

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EXECUTIVE SUMMARY

RPS was commissioned by Woodside Energy Ltd (Woodside) to undertake a marine dispersion modelling study of proposed water discharges from the proposed Browse Joint Venture (BJV) Floating Production Storage and Offloading (FPSO) facilities. The Browse hydrocarbon resource is located in the Brecknock, Calliance and Torosa reservoirs located approximately 425 km north of Broome and approximately 290 km off the Kimberley coastline.

The BJV propose to develop the Browse resource using two FPSO facilities with up to 1,100 million standard cubic feet per day (MMscf/d) export capacity (annual daily average). The proposed FPSOs will be supplied by a subsea production system and will export gas to existing North West Shelf (NWS) Project infrastructure via a ~85 km spur line and a ~900 km Browse Trunkline (BTL), which will tie in near the North Rankin Complex (NRC).

Woodside Energy Ltd (Woodside) is Operator for and on behalf of the BJV: Woodside Browse Pty Ltd, Shell Australia Pty Ltd (Shell), BP Developments Australia Pty Ltd (BP), Japan Australia LNG (MIMI Browse) Pty Ltd (MIMI) and PetroChina International Investment (Australia) Pty Ltd (PetroChina).

The proposed Browse to NWS Project involves the processing of hydrocarbons and as a result will produce cooling water (CW) and produced water (PW). In situ hydrostatic pressure testing may be performed following installation of the BTL/inter-field spur line. If required, this will occur during commissioning. Hydrotesting will require hydrotest fluid to be introduced and left in situ to protect the infrastructure from corrosion. Hydrotest fluids will be directly discharged to sea from the Pipeline End Terminals (PLETs).

The principal aim of the study was to quantify the possible extents of the near-field and far-field mixing zones based on:

- The predicted dilution levels for chlorine in the CW discharge and the temperature differential between the discharge and the ambient receiving water;
- The predicted dilution levels for total oil (including benzene, toluene, ethylbenzene and xylene; BTEX), mercury and monoethylene glycol (MEG) in the PW discharge;
- The predicted dilution levels for biocide in the hydrotest discharge.

This will indicate the concentrations of these constituents and the temperature of the plume at the limits of the mixing zones (i.e. the predictions of dilution or cooling relative to the source characteristics).

To accurately determine the dilution of the discharges and the total potential area of influence, the effect of near-field mixing needs to be considered first, followed by an investigation of the far-field mixing performance. Different modelling approaches are required for calculating near-field and far-field dilutions due to the differing hydrodynamic scales.

To assess the rate of mixing of the chlorine in the CW stream from the Torosa FPSO, dispersion modelling was carried out for a flow rate of 720,000 m^3/d at a discharge depth of 12 m below the water surface.

To assess the rate of mixing of the total oil, mercury and MEG in the PW stream from the Torosa FPSO, dispersion modelling was carried out for flow rates of 5,723 m^3/d and 490 m^3/d at a discharge depth of 14 m below the water surface.

To assess the rate of mixing of the biocide in the hydrotest stream from each PLET, dispersion modelling was carried out for a flow rate of 25 m^3/min (36,000 m^3/d) at three discharge locations in water depths of 117 m, 461 m and 539 m.

The potential area that may be influenced by the discharge streams was assessed for three distinct seasons: (i) summer (December to February); (ii) the transitional periods (March and September to November); and (iii) winter (April to August). An annualised aggregation of outcomes was also assembled.

The main findings of the study are as follows:

Near-Field Modelling

Cooling Water Discharges

- The results show that due to the momentum of the discharge a turbulent mixing zone is created in the immediate vicinity of the discharge point, which is 12 m below the water surface (Case C). Medium and strong currents are shown to increase the extent of the turbulent mixing zone. Following this initial mixing, the positively buoyant plume is predicted to rise in the water column.
- The plume is predicted to plunge up to 16 m below the sea surface in all seasons.
- Increased ambient current strengths are shown to increase the horizontal distance travelled by the plume from the discharge point.
- The maximum horizontal distance travelled by the plume under annualised average current speeds is predicted as 37.8 m.
- The maximum diameter of the plume at the end of the near-field zone is predicted as 15.2 m.
- For all seasons, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to reach the trapping depth (at which the predictions of dispersion are halted due to the plume reaching equilibrium with the ambient receiving water) closer to the discharge point, which slows the rate of dilution.
- The average dilution levels of the plume upon reaching the trapping depth under annualised average current speeds are predicted to be 1:13.5 for Case C. Additionally, the minimum dilution levels of the plume (i.e. dilution of the plume centreline) upon encountering the trapping depth under annualised average current speeds are predicted to be 1:6.3 for Case C.
- The predictions of dilution rely on the persistence of current speed and direction over time and do not account for any build-up of plume concentrations due to slack currents or current reversals.

Produced Water Discharges

- The results show that due to the momentum of the discharges a turbulent mixing zone is created in the immediate vicinity of the discharge point, which is 14 m below the water surface (Cases P and M). Medium and strong currents are shown to increase the extent of the turbulent mixing zone. Following this initial mixing, the positively buoyant plumes are predicted to rise in the water column.
- For Cases P and M, the plume is predicted to rise towards the water surface after the momentum of the initial discharge is lost.
- Increased ambient current strengths are shown to increase the horizontal distance travelled by the plume from the discharge point.
- For both discharges, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted as 20.2 m.
- For both discharges, the maximum diameter of the plume at the end of the near-field zone is predicted as 11.7 m.
- For all combinations of discharge case and season, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to reach the trapping depth (at which the predictions of dispersion are halted due to the plume reaching equilibrium with the ambient receiving water) closer to the discharge point, which slows the rate of dilution.

- The average dilution levels of the plume upon reaching the trapping depth under annualised average current speeds are predicted to be 1:204 for Case P and 1:1,222 for Case M. Additionally, the minimum dilution levels of the plume (i.e. dilution of the plume centreline) upon encountering the trapping depth under annualised average current speeds are predicted to be 1:70 for Case P and 1:323 for Case M.

- The predictions of dilution rely on the persistence of current speed and direction over time and do not account for any build-up of plume concentrations due to slack currents or current reversals.

Hydrotest Discharges

- The results show that due to the momentum of the discharges a turbulent mixing zone is created in the immediate vicinity of the discharge points, which are 117 m (Case H1), 461 m (Cases H2 and H3b) and 539 m (Case H3a) below the water surface. Following this initial mixing, the near neutrally buoyant plumes are predicted to travel laterally in the water column.

- Increased ambient current strengths are shown to increase the horizontal distance travelled by the plume from the discharge point.

- For all discharges, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted as being in the range 50-77 m.

- For all discharges, the maximum diameter of the plume at the end of the near-field zone is predicted as being in the range 16-24 m.

- For all combinations of discharge case and season, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to reach the trapping depth (at which the predictions of dispersion are halted due to the plume reaching equilibrium with the ambient receiving water) closer to the discharge point, which slows the rate of dilution.

- The average dilution levels of the plume upon reaching the trapping depth under annualised average current speeds are predicted to be 1:111 for Case H1, 1:166 for Case H2, 1:172 for Case H3a and 1:166 for Case H3b. Additionally, the minimum dilution levels of the plume (i.e. dilution of the plume centreline) upon encountering the trapping depth under annualised average current speeds are predicted to be 1:41 for Case H1, 1:62 for Case H2, 1:65 for Case H3a and 1:62 for Case H3b.

- The predictions of dilution rely on the persistence of current speed and direction over time and do not account for any build-up of plume concentrations due to slack currents or current reversals.

Far-Field Modelling

Cooling Water Discharges

- Instantaneous concentrations (based on a 60-second model time step) are considered when calculating dilution contours.

- The minimum level of dilution achieved at or within the Scott Reef receptor at the 95th percentile in any season is predicted to be 1:125 for Case C.

- For Case C, annualised results show dilution to reach an example level of 1:100 is achieved within an area of influence extending up to 4.2 km at the 95th percentile. The discharged plumes are predicted to travel predominantly along a north-northwest/south-southeast axis throughout the year, which is broadly parallel to the Scott Reef receptor boundary.

- For Case C, annualised results show the area of exposure defined by the 1:100 dilution contour is predicted to reach a maximum value of 3.7 km^2 at the 95th percentile.

- The maximum depth reached by the discharge across all seasons is predicted as 20 m for Case C.

- Considering the relative rates of acclimation of the plume characteristics with the ambient water, the limiting factor for the plume's area of influence is likely to be defined by its chlorine constituent rather than its temperature.

- An example 3 °C plume-ambient temperature differential is forecast to be met within 120 m at the 95th percentile across all seasons.

Produced Water Discharges

- Instantaneous concentrations (based on a 60-second model time step) are considered when calculating dilution contours.

- The minimum levels of dilution achieved at or within the Scott Reef receptor at the 95th percentile in any season are predicted to be 1:1,507 for Case P and 1:17,674 for Case M.

- For Case P, annualised results show dilution to reach an example level of 1:300 is achieved within an area of influence extending up to 0.9 km at the 95th percentile. The discharged plumes are predicted to travel predominantly along a north-northwest/south-southeast axis throughout the year, which is broadly parallel to the Scott Reef receptor boundary, with trajectories to the south-southeast forecast to be longer.

- For Case P, annualised results show the area of exposure defined by the 1:300 dilution contour is predicted to reach a maximum value of 0.7 km^2 at the 95th percentile.

- The maximum depth reached by the discharge across all seasons is predicted as 19 m for Case P.

Hydrotest Discharges

- Concentrations calculated following application of a rolling 48-hour median to the instantaneous data are considered when calculating dilution contours.

- The minimum levels of dilution achieved at or within the nearest receptor at the 95th percentile in any season are predicted to be >>1:20,000 for Case H1 (Rankin Bank), 1:4,440 for Case H2 (Scott Reef), >1:20,000 for Case H3a (Scott Reef) and 1:2,711 for Case H3b (Scott Reef).

- For Cases H1, H2, H3a and H3b, annualised results show dilution to reach an example level of 1:10,000 is achieved within an area of influence extended up to 16.1 km, 12.5 km, 23.4 km and 8.2 km, respectively, at the 95th percentile. The predominant plume travel directions throughout the year are forecast to be south-westerly (Case H1), along a north-northwest/south-southeast axis (Cases H2 and H3a) and along a north-east/south-west axis (Case H3a).

- For Cases H1, H2, H3a and H3b, annualised results show the area of exposure defined by the 1:10,000 dilution contour is predicted to reach a maximum of 79.2 km^2, 87.1 km^2, 89.4 km^2 and 40.8 km^2, respectively, at the 95th percentile.

Key Observations

Cooling Water Discharges

- The discharge will be initially positively buoyant and will rise in the water column, and may resurface in the vicinity of the discharge point prior to acclimation with ambient receiving water conditions.

- At the 95th percentile, plumes for Case C are not expected to reach the Scott Reef 3 nm State water boundary at dilution levels less than 1:125 in any season.

- At the 95th percentile, temperature acclimation of the plume with ambient waters is expected to occur within 120 m of the discharge point in any season and plume temperature will not be a relevant factor at the Scott Reef 3 nm State water boundary.

Produced Water Discharges

- At the 95th percentile, plumes are not expected to reach the Scott Reef 3 nm State water boundary at dilution levels less than 1:1,507 for Case P and 1:17,674 for Case M in any season.

Hydrotest Discharges

- Due to significant variations in the magnitude and directionality of the hindcast currents at each location where potential discharges will occur, predicted outcomes are markedly different.
- Transport patterns will reflect the predominant drift current trajectories at each location, with tidal movements a particularly important driver of dispersion for the deeper discharges. Greater variability in current trajectories is expected near the water surface due to the influence of wind, but, because the plumes are discharged at the seabed and are not positively buoyant, they will not experience these variations.
- At the 95th percentile, plumes are not expected to reach the Scott Reef 3 nm State water boundary at dilution levels less than 1:4,440 for Case H2, 1:20,000 for Case H3a and 1:2,711 for Case H3b in any season. For Case H1, the dilution level of any plumes that may reach Rankin Bank is expected to be significantly greater than 1:20,000.

1 INTRODUCTION

1.1 Background

RPS was commissioned by Woodside Energy Ltd (Woodside) to undertake a marine dispersion modelling study of proposed water discharges from the proposed Browse Joint Venture (BJV) Floating Production Storage and Offloading (FPSO) facilities. The Browse hydrocarbon resource is located in the Brecknock, Calliance and Torosa reservoirs located approximately 425 km north of Broome and approximately 290 km off the Kimberley coastline.

The BJV propose to develop the Browse resource using two FPSO facilities with up to 1,100 million standard cubic feet per day (MMscf/d) export capacity (annual daily average). The proposed FPSOs will be supplied by a subsea production system and will export gas to existing North West Shelf (NWS) Project infrastructure via a ~85 km spur line and a ~900 km Browse Trunkline (BTL), which will tie in near the North Rankin Complex (NRC).

Woodside Energy Ltd (Woodside) is Operator for and on behalf of the BJV: Woodside Browse Pty Ltd, Shell Australia Pty Ltd (Shell), BP Developments Australia Pty Ltd (BP), Japan Australia LNG (MIMI Browse) Pty Ltd (MIMI) and PetroChina International Investment (Australia) Pty Ltd (PetroChina).

The proposed Browse to NWS Project involves the processing of hydrocarbons and as a result will produce cooling water (CW) and produced water (PW). In situ hydrostatic pressure testing may be performed following installation of the BTL/inter-field spur line. If required, this will occur during commissioning. Hydrotesting will require hydrotest fluid to be introduced and left in situ to protect the infrastructure from corrosion. Hydrotest fluids will be directly discharged to sea from the Pipeline End Terminals (PLETs).

The principal aim of the study was to quantify the possible extents of the near-field and far-field mixing zones based on:

- The predicted dilution levels for chlorine in the CW discharge and the temperature differential between the discharge and the ambient receiving water;
- The predicted dilution levels for total oil (including benzene, toluene, ethylbenzene and xylene; BTEX), mercury and monoethylene glycol (MEG) in the PW discharge;
- The predicted dilution levels for biocide in the hydrotest discharge.

This will indicate the concentrations of these constituents and the temperature of the plume at the limits of the mixing zones (i.e. the predictions of dilution or cooling relative to the source characteristics).

To accurately determine the dilution of the discharges and the total potential area of influence, the effect of near-field mixing needs to be considered first, followed by an investigation of the far-field mixing performance. Different modelling approaches are required for calculating near-field and far-field dilutions due to the differing hydrodynamic scales.

To assess the rate of mixing of the chlorine in the CW stream from the Torosa FPSO (location shown in Table 1.1 and Figure 1.1), dispersion modelling was carried out for a flow rate of 720,000 m^3/d at a discharge depth of 12 m below the water surface.

To assess the rate of mixing of the total oil, mercury and MEG in the PW stream from the Torosa FPSO, dispersion modelling was carried out for flow rates of 5,723 m^3/d and 490 m^3/d at a discharge depth of 14 m below the water surface.

To assess the rate of mixing of the biocide in the hydrotest stream from each PLET (locations shown in Table 1.1 and Figure 1.1), dispersion modelling was carried out for a flow rate of 25 m^3/min (36,000 m^3/d) at three discharge locations in water depths of 117 m, 461 m and 539 m.

The potential area that may be influenced by the discharge streams was assessed for three distinct seasons: (i) summer (December to February); (ii) the transitional periods (March and September to November); and (iii) winter (April to August). An annualised aggregation of outcomes was also assembled.

All discharge characteristics used as input to the modelling are specified in the Model Input Form for this study (Woodside, 2019).

Table 1.1 Locations of the proposed Torosa FPSO and PLETs used as the release sites for the dispersion modelling assessment.

Release Site	Latitude (S)	Longitude (E)	Water Depth (m)
Torosa FPSO	13° 58' 15.06"	122° 01' 28.53"	481
Torosa PLET	13° 58' 41.70"	122° 01' 26.76"	461
Brecknock/Calliance PLET	14° 32' 21.92"	121° 37' 34.23"	539
NRC Tie-In PLET	19° 36' 41.37"	116° 10' 23.53"	117

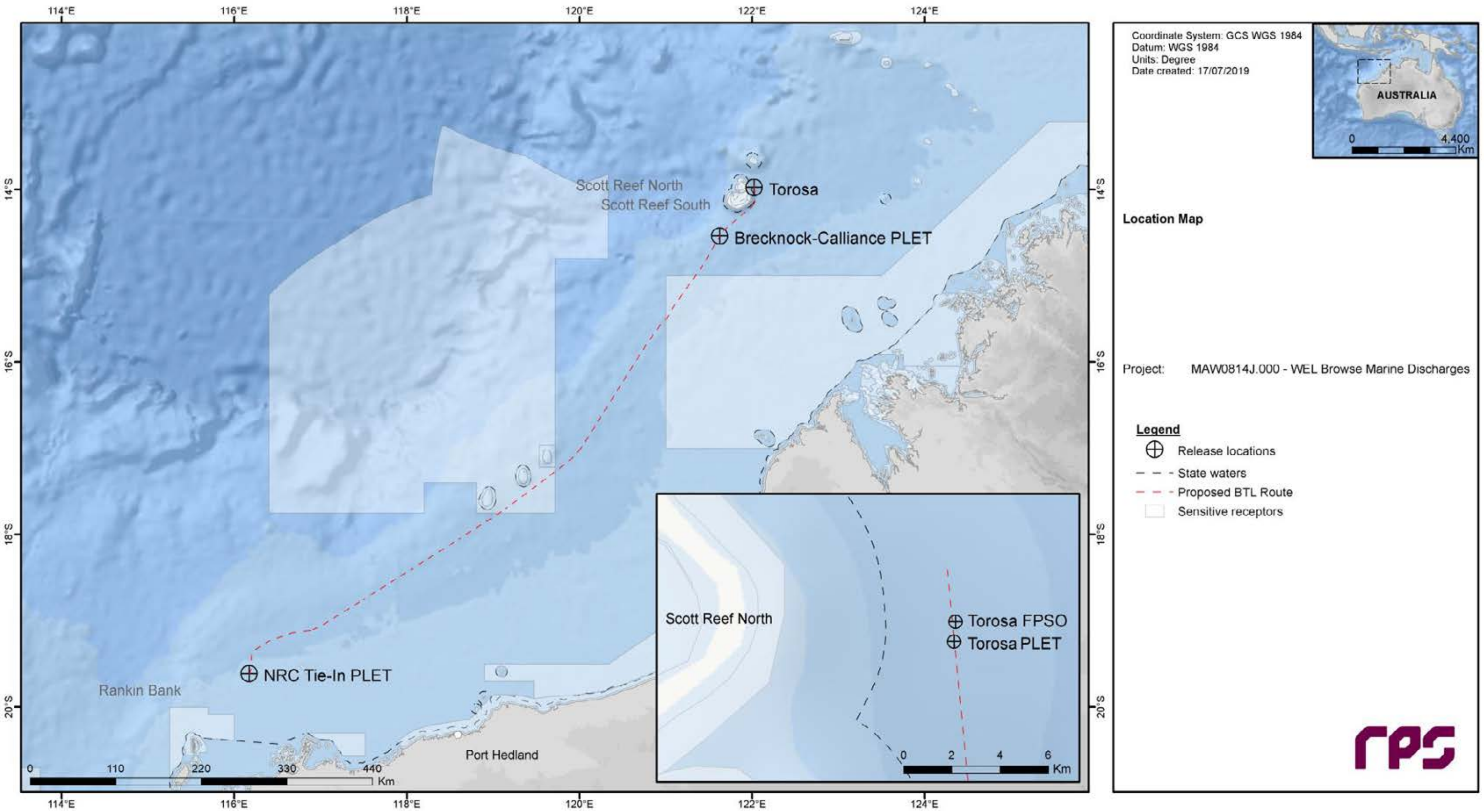


Figure 1.1 Locations of the proposed Torosa FPSO and PLETs, on the North West Shelf and in proximity to Scott Reef, off the Kimberley Coast of Western Australia.

1.2 Modelling Scope

The physical mixing of the CW, PW and hydrotest plumes was first investigated for the near-field mixing zone. The limits of the near-field mixing zone are defined by the area where the levels of mixing and dilution are controlled by a plume's initial jet momentum and the buoyancy flux, resulting from density differences between the plume and the receiving water. When the plume encounters a boundary such as the water surface, near-field mixing is complete. At this point, the plume is considered to enter the far-field mixing zone.

The scope of the modelling included the following components:

- Collation of a suitable three-dimensional, spatially-varying current data set surrounding the Torosa FPSO and NRC tie-in, Torosa and Brecknock/Calliance PLET locations for a ten-year (2006-2015) hindcast period. The current data set included the combined influence of drift and tidal currents and was suitably long as to be indicative of interannual variability in ocean currents. The current data set was validated against metocean data collected in the Browse project area, and also against independent tidal predictions at many locations within the model domain including the NRC area.

- Derivation of statistical distributions for the current speed and directions for use in the near-field modelling. Analyses included percentile distributions and development of current roses. This analysis was important to ensure that current data samples applied in the dispersion model were statistically representative.

- Collation of seasonally-varying vertical water density profiles at the Torosa FPSO and NRC tie-in, Torosa and Brecknock/Calliance PLET locations for use as input to the dispersion models.

- Near-field modelling conducted for each unique discharge to assess the initial mixing of the discharge due to turbulence and subsequent entrainment of ambient water. This modelling was conducted at high spatial and temporal resolution (scales of metres and seconds, respectively).

- Outcomes from the near-field modelling included estimates of the width, shape and orientation of the plumes, and resulting constituent concentrations and dilutions, for each discharge at a range of incident current speeds.

- Establishment of a far-field dispersion model to repeatedly assess discharge scenarios under different sample conditions, with each sample represented by a unique time sequence of current flow, chosen at random from the time series of current data.

- Analysis of the results of all simulations to quantify, by return frequency, the potential extent and shape of the mixing zone.

2 MODELLING METHODS

2.1 Near-Field Modelling

2.1.1 Overview

Numerical modelling was applied to quantify the area of influence of CW, PW and hydrotest water discharges, in terms of the distribution of the maximum constituent concentrations that might occur with distance from the source given defined discharge configurations, source concentrations, and the distribution of the metocean conditions affecting the discharge location.

The dispersion of the CW, PW and hydrotest discharges will depend, initially, on the geometry and hydrodynamics of the discharges themselves, where the induced momentum and buoyancy effects dominate over background processes. This region is generally referred to as the near-field zone and is characterised by variations over short time and space scales. As the discharges mix with the ambient waters, the momentum and buoyancy signatures are eroded, and the background – or ambient – processes become dominant.

The shape and orientation of the discharged water plumes, and hence the distribution and dilution rate of the plume, will vary significantly with natural variation in prevailing water currents. Therefore, to best calculate the likely outcomes of the discharges, it is necessary to simulate discharge under a statistically representative range of current speeds representative of the Torosa FPSO and NRC tie-in, Torosa and Brecknock/Calliance PLET locations.

2.1.2 Description of Near-Field Model: Updated Merge

The near-field mixing and dispersion of the water discharge was simulated using the Updated Merge (UM3) flow model. The UM3 model is a three-dimensional Lagrangian steady-state plume trajectory model designed for simulating single and multiple-port submerged discharges in a range of configurations, available within the Visual Plumes modelling package provided by the United States Environmental Protection Agency (Frick *et al.*, 2003). The UM3 model was selected because it has been extensively tested for various discharges and found to predict observed dilutions more accurately (Roberts & Tian, 2004) than other near-field models (i.e. RSB and CORMIX).

In the UM3 model, the equations for conservation of mass, momentum, and energy are solved at each time step, giving the dilution along the plume trajectory. To determine the change of each term, UM3 follows the shear (or Taylor) entrainment hypothesis and the projected-area-entrainment (PAE) hypothesis, which quantifies forced entrainment in the presence of a background ocean current. The flows begin as round buoyant jets and can merge to a plane buoyant jet (Carvalho *et al.*, 2002). Model output consists of plume characteristics including centreline dilution, rise-rate, width, centreline height and plume diameter. Dilution is reported as the “effective dilution”, the ratio of the initial concentration to the concentration of the plume at a given point, following Baumgartner *et al.* (1994).

The near-field zone ends where the discharged plume reaches a physical boundary or assumes the same density as the ambient water.

Figure 2.1 and Figure 2.2 show conceptual diagrams of the dispersion and fates of positively and negatively buoyant discharges, respectively, and the idealised representation of the discharge phases.

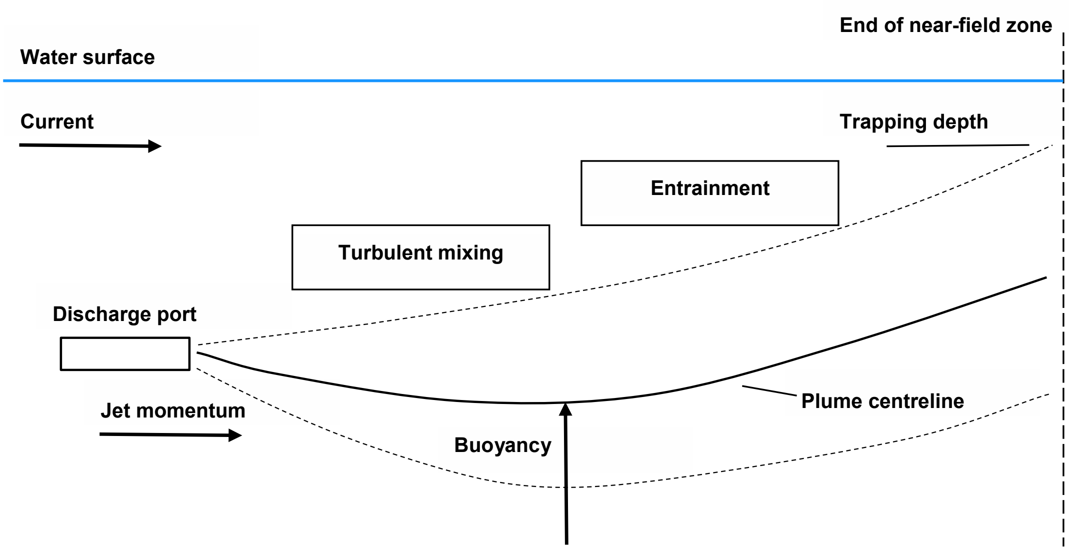


Figure 2.1 Conceptual diagram showing the general behaviour of a positively buoyant discharge.

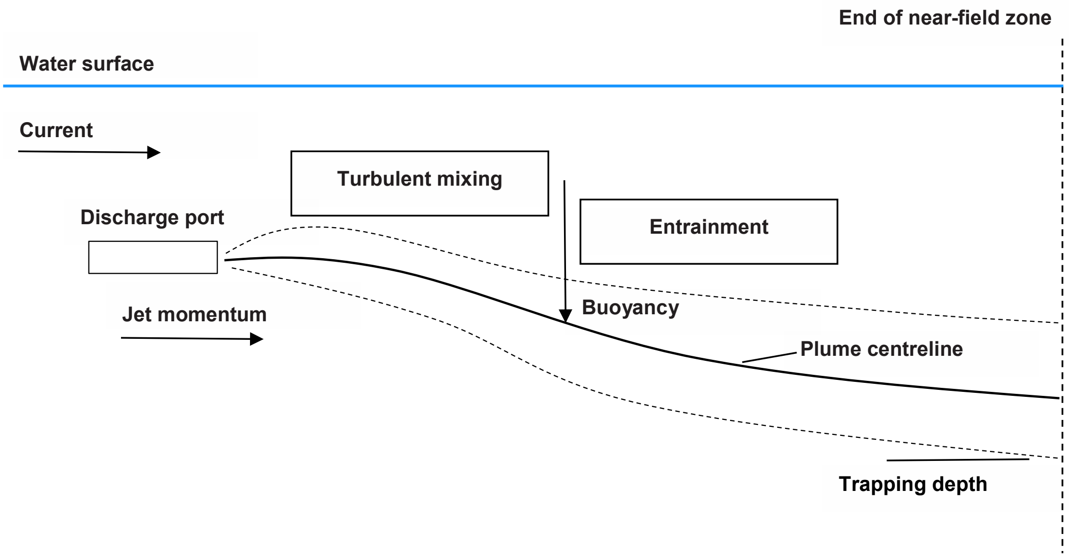


Figure 2.2 Conceptual diagram showing the general behaviour of a negatively buoyant discharge.

2.1.3 Setup of Near-Field Model

2.1.3.1 Discharge Characteristics

The CW discharge characteristics for Case C are summarised in Table 2.1. Case C represents the continuous discharge of CW at peak rates from the facility.

The PW discharge characteristics for Cases P and M are summarised in Table 2.2. Case P represents the continuous discharge of PW at peak rates from the facility. Case M represents an intermittent discharge of MEG as part of the PW stream during start-up and early operations. Note that the maximum MEG specification assumed for the purposes of modelling has since been updated, which is reflected in the Environmental Impact Statement (EIS)/Environmental Review Document (ERD).

The hydrotest discharge characteristics for Cases H1, H2, H3a and H3b are summarised in Table 2.3. These cases represent potential one-off discharges of hydrotest fluid from PLETs at the NRC tie-in, Torosa and Brecknock/Calliance locations following installation and commissioning of the BTL and inter-field spur line.

Indicative concentrations of the constituents of interest within the CW (chlorine), PW (total oil, mercury and MEG) and hydrotest (biocide) discharges are described in Table 2.4, Table 2.5 and Table 2.6, respectively. The indicated concentrations were based on the engineering definitions available at the time of commissioning the dispersion modelling study and should not be considered definitive.

Table 2.1 Summary of the CW discharge characteristics.

Parameter	Case C
Discharge location	Torosa FPSO
Discharge coordinates	13° 58' 15.06" S 122° 01' 28.53" E
Flow rate (m^3/d)	720,000
Outlet pipe internal diameter (m) [in]	2 x 0.91 [2 x 36]
Outlet pipe orientation	Horizontal
Depth of pipe below sea surface (m)	12
Discharge salinity (ppt)	35
Discharge temperature (°C)	50

Table 2.2 Summary of the PW discharge characteristics.

Parameter	Case P	Case M
Discharge location	Torosa FPSO	
Discharge coordinates	13° 58' 15.06" S 122° 01' 28.53" E	
Flow rate (m^3/d)	5,723	490
Outlet pipe internal diameter (m) [in]	0.15 [6]	
Outlet pipe orientation	Horizontal	
Depth of pipe below sea surface (m)	14	
Discharge salinity (ppt)	9.5	0.0
Discharge temperature (°C)	50	

Table 2.3 Summary of the hydrotest discharge characteristics.

Parameter	Case H1	Case H2	Case H3a	Case H3b
Discharge location	NRC Tie-In PLET	Torosa PLET	Breck./Cal. PLET	Torosa PLET
Discharge coordinates	19° 36' 41.37" S 116° 10' 23.53" E	13° 58' 41.70" S 122° 01' 26.76" E	14° 32' 21.92" S 121° 37' 34.23" E	13° 58' 41.70" S 122° 01' 26.76" E
Flow rate (m^3/min)	25			
Discharge volume (m^3)	736,000	846,000	790,000	56,000
Discharge duration (hours)	490	564	527	37
Outlet pipe internal diameter (m) [in]	0.2 [7.9]			
Outlet pipe orientation	Horizontal			
Depth of pipe below sea surface (m)	117	461	539	461
Discharge salinity (ppt)	Ambient (seabed)			
Discharge temperature (°C)	Ambient (seabed)			

Table 2.4 Constituent of interest within the CW discharge.

Constituent/Property	Indicative Source Concentration or Temperature
Chlorine	0.2 ppm 0.5 ppm
Temperature	50 °C

Table 2.5 Constituents of interest within the PW discharges.

Constituent	Indicative Source Concentration (mg/L)
Total Oil (including BTEX)	30
Mercury	0.03
MEG	79,000

Table 2.6 Constituent of interest within the hydrotest discharges.

Constituent	Indicative Source Concentration (ppm)
Biocide	600

2.1.3.2 Ambient Environmental Conditions

Inputs of ambient environmental conditions to the UM3 model included a vertical profile of temperature and salinity, along with constant current speeds and general direction. The temperature and salinity profiles are required to accurately account for the buoyancy of the diluting plume, while the current speeds control the intensity of initial mixing and the deflection of the CW, PW and hydrotest plumes. These inputs are described in the following sections.

2.1.3.2.1 Ambient Temperature and Salinity

Temperature and salinity data applied to the near-field modelling was sourced from the World Ocean Atlas 2013 (WOA13) database produced by the National Oceanographic Data Centre (National Oceanic and Atmospheric Administration, NOAA) and its co-located World Data Center for Oceanography (Levitus *et al.*, 2013).

Table 2.7, Table 2.8 and Table 2.9 show the average seasonal water temperature and salinity levels at varying depths from 0 m to 500 m (depending on the location). This data can be considered representative of seasonal conditions at the Torosa FPSO/PLET, Brecknock/Calliance PLET and NRC tie-in PLET locations, respectively.

The seasonal temperature profiles exhibit a reasonably consistent reduction in temperature with increasing depth. Salinity levels are generally more consistent and exhibit a vertically well-mixed water body (34.3-34.6 practical salinity unit, PSU), irrespective of season or depth.

Table 2.7 Average temperature and salinity levels adjacent to the proposed Torosa FPSO/PLET locations.

Season	Depth (m)	Temperature (°C)	Salinity (PSU)
Summer	0	29.7	34.6
	20	29.4	34.6
	50	28.0	34.5
	200	16.5	34.6
	500	8.7	34.6
Transitional	0	28.5	34.4
	20	28.1	34.4
	50	26.9	34.4
	200	16.1	34.6
	500	8.7	34.6
Winter	0	27.6	34.3
	20	27.6	34.3
	50	27.2	34.4
	200	17.1	34.6
	500	8.7	34.6
Annualised	0	28.4	34.4
	20	28.2	34.4
	50	27.3	34.4
	200	16.6	34.6
	500	8.7	34.6

Table 2.8 Average temperature and salinity levels adjacent to the proposed Brecknock/Calliance PLET location.

Season	Depth (m)	Temperature (°C)	Salinity (PSU)
Summer	0	29.7	34.6
	20	29.4	34.6
	50	28.0	34.5
	200	16.5	34.6
	500	8.7	34.6
Transitional	0	28.5	34.4
	20	28.1	34.4
	50	26.9	34.4
	200	16.1	34.6
	500	8.7	34.6
Winter	0	27.6	34.3
	20	27.6	34.3
	50	27.2	34.4
	200	17.1	34.6
	500	8.7	34.6
Annualised	0	28.4	34.4
	20	28.2	34.4
	50	27.3	34.4
	200	16.6	34.6
	500	8.7	34.6

Table 2.9 Average temperature and salinity levels adjacent to the proposed NRC tie-in PLET location.

Season	Depth (m)	Temperature (°C)	Salinity (PSU)
Summer	0	28.5	34.8
	20	28.3	34.8
	50	26.8	34.8
	200	20.6	34.9
Transitional	0	27.1	34.8
	20	26.8	34.8
	50	25.4	34.8
	200	20.9	35.0
Winter	0	27.0	34.9
	20	26.9	34.9
	50	26.4	34.9
	200	21.2	34.9
Annualised	0	27.4	34.8
	20	27.2	34.8
	50	26.2	34.8
	200	20.9	34.9

2.1.3.2.2 Ambient Current

Ocean current data was sourced from a ten-year hindcast data set of combined large-scale ocean (BRAN) and tidal currents. The data was statistically analysed to determine the 5th, 50th and 95th percentile current speeds. These statistical current speeds can be considered representative of seasonal conditions at the Torosa FPSO/PLET, Brecknock/Calliance PLET and NRC tie-in PLET locations.

Table 2.10, Table 2.11 and Table 2.12 present the steady-state, unidirectional current speeds at varying depths used as input to the near-field model as forcing for each discharge case at the Torosa FPSO/PLET, Brecknock/Calliance PLET and NRC tie-in PLET locations, respectively:

- 5th percentile current speed: weak currents, low dilution and slow advection.
- 50th percentile (median) current speed: average currents, moderate dilution and advection.
- 95th percentile current speed: strong currents, high dilution and rapid advection to nearby areas.

The 5th, 50th and 95th percentile values are referenced as weak, medium and strong current speeds, respectively.

Table 2.10 Adopted ambient current conditions adjacent to the proposed Torosa FPSO/PLET locations.

Season	Depth (m)	5th Percentile (Weak) Current Speed (m/s)	50th Percentile (Medium) Current Speed (m/s)	95th Percentile (Strong) Current Speed (m/s)
Summer	2.5	0.038	0.145	0.316
	22.7	0.032	0.128	0.296
	56.7	0.027	0.118	0.281
	205.2	0.019	0.100	0.251
	545.5	0.013	0.095	0.221
Transitional	2.5	0.037	0.141	0.316
	22.7	0.033	0.132	0.299
	56.7	0.028	0.120	0.294
	205.2	0.019	0.104	0.269
	545.5	0.013	0.097	0.282
Winter	2.5	0.031	0.130	0.283
	22.7	0.027	0.124	0.275
	56.7	0.024	0.113	0.266
	205.2	0.019	0.100	0.247
	545.5	0.012	0.091	0.278
Annualised	2.5	0.034	0.137	0.303
	22.7	0.030	0.128	0.289
	56.7	0.026	0.116	0.280
	205.2	0.019	0.101	0.256
	545.5	0.012	0.094	0.267

Table 2.11 Adopted ambient current conditions adjacent to the proposed Brecknock/Calliance PLET location.

Season	Depth (m)	5th Percentile (Weak) Current Speed (m/s)	50th Percentile (Medium) Current Speed (m/s)	95th Percentile (Strong) Current Speed (m/s)
Summer	2.5	0.042	0.155	0.316
	22.7	0.043	0.151	0.306
	56.7	0.042	0.149	0.301
	205.2	0.041	0.146	0.297
	545.5	0.040	0.142	0.290
Transitional	2.5	0.044	0.163	0.327
	22.7	0.044	0.161	0.326
	56.7	0.044	0.159	0.323
	205.2	0.043	0.158	0.320
	545.5	0.042	0.154	0.313
Winter	2.5	0.039	0.144	0.300
	22.7	0.038	0.143	0.299
	56.7	0.038	0.143	0.299
	205.2	0.038	0.143	0.298
	545.5	0.038	0.143	0.295
Annualised	2.5	0.042	0.153	0.314
	22.7	0.041	0.151	0.311
	56.7	0.041	0.150	0.308
	205.2	0.040	0.149	0.306
	545.5	0.040	0.146	0.300

Table 2.12 Adopted ambient current conditions adjacent to the proposed NRC tie-in PLET location.

Season	Depth (m)	5th Percentile (Weak) Current Speed (m/s)	50th Percentile (Medium) Current Speed (m/s)	95th Percentile (Strong) Current Speed (m/s)
Summer	2.5	0.043	0.167	0.357
	22.7	0.043	0.165	0.345
	56.7	0.042	0.161	0.342
	130.0	0.042	0.161	0.342
Transitional	2.5	0.042	0.173	0.374
	22.7	0.046	0.170	0.366
	56.7	0.041	0.164	0.360
	130.0	0.041	0.164	0.360
Winter	2.5	0.050	0.183	0.365
	22.7	0.047	0.175	0.355
	56.7	0.043	0.164	0.350
	130.0	0.043	0.164	0.350
Annualised	2.5	0.045	0.176	0.366
	22.7	0.046	0.171	0.357
	56.7	0.042	0.163	0.352
	130.0	0.042	0.163	0.352

2.2 Far-Field Modelling

2.2.1 Overview

The far-field modelling expands on the near-field work by allowing the time-varying nature of currents to be included, and the potential for recirculation of the plume back to the discharge location to be assessed. In this case, concentrations near the discharge point can be increased due to the discharge plume mixing with the remnant plume from an earlier time. This may be a potential source of episodic increases in plume concentrations in the receiving waters.

2.2.2 Description of Far-Field Model: CHEMMAP

The mixing and dispersion of the CW discharges was predicted using the three-dimensional discharge and plume behaviour model, CHEMMAP (French-McCay & Isaji, 2004; French-McCay *et al.*, 2006).

CHEMMAP predicts the movement and fate of a wide variety of chemical products, including floating, sinking, soluble/insoluble chemicals and product mixtures (French-McCay & Isaji, 2004). CHEMMAP incorporates many important chemical modelling components, including: transport and spreading of floating chemicals; transport of dissolved or particulate chemicals in three dimensions; evaporation or volatilisation of chemicals at the surface; dissolution; re-suspension; sedimentation; and degradation of chemicals in air, water and sediments (French-McCay *et al.*, 2006).

The most important inputs associated with the chemical model are the physical properties relating to the released chemical. The properties used to predict the fate and transport of each chemical include density, vapour pressure, water solubility, environmental degradation rates, adsorbed/dissolved partitioning coefficients (K_{OW}, K_{OC}), viscosity and surface tension (French-McCay *et al.*, 2006). CHEMMAP contains its own chemical database and the information found within this database is compiled from published literature sources (French-McCay & Payne, 2008).

The transport algorithm within CHEMMAP depends heavily on the precision of the input current data (French-McCay & Whittier, 2004). The model uses a Lagrangian three-dimensional transport model to predict the movement of the chemical in the water column, on the surface and in the air (French-McCay & Whittier, 2004).

For each time step, the model calculates the phase transfer percentages and changes the state of particular proportions of the spilled chemical (French-McCay & Isaji, 2004). This may mean that a chemical changes from a substance floating on the surface to a gas, or is dissolved into the water column. The evaporation algorithm used in the CHEMMAP model has been tested by comparison to experimental data from Kawamura & Mackay (1987) and French-McCay & Whittier (2004).

2.2.3 Description of Far-Field Model: MUDMAP

The mixing and dispersion of the PW and hydrotest discharges was predicted using the three-dimensional discharge and plume behaviour model, MUDMAP (Koh & Chang, 1973; Khondaker, 2000).

The far-field calculation (passive dispersion stage) employs a particle-based, random walk procedure. Any chemicals/constituents within the discharge stream are represented by a sample of Lagrangian particles. These particles are moved in three dimensions over each subsequent time step according to the prevailing local current data as well as horizontal and vertical mixing coefficients.

MUDMAP treats the Lagrangian particles as conservative tracers (i.e. they are not removed over time to account for chemical interactions, decay or precipitation). Predicted concentrations will therefore be conservative overestimates where these processes actually do occur. Each particle represents a proportion of the discharge, by mass, and particles are released at a given rate to represent the rate of the discharge (mass per unit time). Concentrations of constituents are predicted over time by counting the number of particles that occur within a given depth level and grid square and converting this value to mass per unit volume.

The system has been extensively validated and applied for discharge operations in Australian waters (e.g. Burns *et al.*, 1999; King & McAllister, 1997, 1998).

2.2.4 Stochastic Modelling

A stochastic modelling procedure was applied in the far-field modelling to sample a representative set of conditions that could affect the distribution of constituents. This approach involves multiple possible simulations of a given discharge scenario and season (50 for the CW and PW discharges; 25 for the hydrotest discharges), with each simulation being carried out under a randomly-selected period of currents. This methodology ensures that the calculated movement and fate of each discharge is representative of the range of prevailing currents at the discharge location. Once the stochastic modelling is complete, all simulations are statistically analysed to develop the distribution of outcomes based on time and event.

The stochastic simulations are jointly processed as an aggregated set for each season. This is done by building a time series of maximum constituent concentrations, at any depth in the water column within each model grid cell, for all time steps of all replicate simulations. The resultant time series at each grid cell is a representation of the stochastic outcomes, and this is statistically analysed to allow percentile data (representing the percentage of time that particular concentrations occur) to be generated. The resultant percentile concentration contours, and the initial source concentration of the discharge, are used to determine the dilution contours for each percentile.

To calculate the tabulated results of dilutions at particular distances from the source location, all grid cells at the specified radial distances (e.g. 100 m), including a buffer zone of 10 m either side (e.g. every grid cell in the 90-110 m range), are interrogated. The minimum dilution is calculated as the lowest value in any individual non-zero grid cell within the defined range, including the buffer zone. The average dilution is calculated as the average value across all non-zero grid cells within the defined range, including the buffer zone. This is done for all defined radial distances from the source location for each percentile.

The process is similar on the outer edge of the Scott Reef receptor, where there is a 10 m buffer zone, but on the inside the entire receptor area is considered in order to capture details of the plume characteristics at all points predicted to be affected. The analysis is therefore not restricted only to the receptor boundary line. The minimum dilution is calculated as the lowest value in any individual non-zero grid cell within the receptor area (plus the 10 m outer buffer), while the average dilution is calculated as the average value across all non-zero grid cells within the receptor area (plus the 10 m outer buffer). In practice, because the aggregated plume concentrations generally decrease as the plume penetrates further into the receptor (with dilution levels therefore increasing), the minimum dilutions identified by the analysis are usually found on or very close to the boundary line.

2.2.5 Setup of Far-Field Model

2.2.5.1 Discharge Characteristics

The CHEMMAP and MUDMAP models simulated the discharge into a time-varying current field with the initial dilution set by the near-field results described in Section 2.1.

The CW and PW discharge scenarios were modelled as a continuous discharge using 50 simulations for each season, while the hydrotest discharge scenarios were modelled as a one-off discharge using 25 simulations for each season. A reduced number of hydrotest simulations was justified in light of the significantly longer duration of most of these scenarios (>20 days in three of four cases) relative to the duration of all CW and PW scenarios (5 days). Even with fewer replicates, the range of environmental conditions sampled from the ten-year hindcast data set during the hydrotest simulations was similarly extensive to (or more extensive than) that sampled during the CW and PW simulations.

Once the simulations were complete, they were reported on a seasonal basis: (i) summer (December to February); (ii) transitional (March and September to November) and (iii) winter (April to August). The CW, PW and hydrotest discharge characteristics for all cases are summarised in Table 2.13, Table 2.14 and Table 2.15, respectively.

Table 2.13 Summary of far-field CW discharge modelling assumptions.

Parameter	Case C
Hindcast modelling period	2006-2015
Seasons	Summer (December to February) Transitional (March and September to November) Winter (April to August) Annual
Flow rate (m^3/d)	720,000
Discharge depth (m)	12
Discharge salinity (ppt)	35
Discharge temperature (°C)	50
Number of simulations	150 (50 per season)
Simulated discharge type	Continuous
Simulated discharge period (days)	5

Table 2.14 Summary of far-field PW discharge modelling assumptions.

Parameter	Case P	Case M
Hindcast modelling period	2006-2015	
Seasons	Summer (December to February) Transitional (March and September to November) Winter (April to August) Annual	
Flow rate (m^3/d)	5,723	490
Discharge depth (m)	14	
Discharge salinity (ppt)	9.5	0.0
Discharge temperature (°C)	50	
Number of simulations	150 (50 per season)	
Simulated discharge type	Continuous	
Simulated discharge period (days)	5	

Table 2.15 Summary of far-field hydrotest discharge modelling assumptions.

Parameter	Case H1	Case H2	Case H3a	Case H3b
Hindcast modelling period	2006-2015			
Seasons	Summer (December to February) Transitional (March and September to November) Winter (April to August) Annual			
Flow rate (m^3/min)	25			
Discharge volume (m^3)	736,000	846,000	790,000	56,000
Discharge duration (hours)	490	564	527	37
Discharge depth (m)	117	461	539	461
Discharge salinity (ppt)	Ambient (seabed)			
Discharge temperature (°C)	Ambient (seabed)			
Number of simulations	75 (25 per season)			
Simulated discharge type	One-off			
Simulated discharge period (days)	21	24	22	4

2.2.5.2 Mixing Parameters

The horizontal and vertical dispersion coefficients represent the mixing and diffusion caused by turbulence, both of which are sub-grid-scale processes. Both coefficients are expressed in units of rate of area change per second (m^2/s). Increasing the horizontal dispersion coefficient will increase the horizontal spread of the discharge plume and decrease the centreline concentrations faster. Increasing the vertical dispersion coefficient spreads the discharge across the vertical layers (or depths) faster.

Spatially constant, conservative dispersion coefficients of 0.25 m^2/s and 0.00001 m^2/s were used to control the spreading of the CW, PW and hydrotest plumes in the horizontal and vertical directions, respectively. Each of the mixing parameters was selected following extensive sensitivity testing to recreate the plume characteristics predicted by the near-field modelling. It would be expected that the in situ mixing dynamics would be greater under average and high energy conditions by a factor of 10 (King & McAllister, 1997, 1998) and thus the far-field model results are designed to produce a worst-case result for concentration extents.

2.2.5.3 Grid Configuration

CHEMMAP and MUDMAP each use a three-dimensional grid to represent the geographic region under study (water depth and bathymetric profiles). Due to the rapid mixing and small-scale effect of the effluent discharge, it was necessary to use a fine grid with a resolution of 40 m x 40 m (CW and hydrotest discharges) and 20 m x 20 m (PW discharges) to track the movement and fate of the discharge plume. The extent of the grid region measured approximately 40 km (longitude or x-axis) by 40 km (latitude or y-axis) for CW and hydrotest discharges, and approximately 20 km by 20 km for PW discharges, each of which was subdivided horizontally into 1,000 x 1,000 cells. The vertical resolution was set to 1 m (CW and PW discharges) and 2 m (hydrotest discharges).

2.2.1 Regional Ocean Currents

2.2.1.1 Background

The area of interest for this study is located within the influence of the Indonesian Throughflow, a large-scale current system characterised as a series of migrating gyres and connecting jets that are steered by the continental shelf. While the mass flow is generally towards the south-west, year-round, the internal gyres generate local currents in all directions. As these gyres migrate through the area, large spatial variations in the speed and direction of currents will occur at a given location over time. Further south of the project area, the Leeuwin Current becomes the dominant large-scale current system, flowing poleward down the pressure gradient along the Western Australian coastline and past Cape Leeuwin.

Offshore regions with water depths exceeding 100-200 m experience significant large-scale drift currents. These drift currents can be relatively strong (1-2 knots) and complex, manifesting as a series of eddies, meandering currents and connecting flows. These offshore drift currents also tend to persist longer (days to weeks) than tidal current flows (hours between reversals) and thus will have greater influence upon the net trajectory of plumes over time scales exceeding a few hours.

On the continental shelf, in shallower waters around Scott Reef and closer to the inshore region of the Kimberley Coast, surface winds and tidal dynamics dominate over the large scale current flows (Condie & Andrewartha, 2008). In comparison to drift currents, tidal currents generate only relatively short tidal migrations (distance travelled by a parcel of water over a tidal cycle) that follow an elliptical path with a period of about 12 hours in the study region. Hence, tidal currents add variability to the longer-term drift patterns of an entrained plume.

Wind shear on the water surface also generates local-scale currents that can persist for extended periods (hours to days) and result in long trajectories. Persistent winds along the mainland coast can induce Ekman transport, where surface waters move offshore and facilitate upwelling events in which cold nutrient-rich waters from the deep Indian Ocean are brought to the surface. However, due to the opposing transport of warm tropical waters by the Leeuwin Current, large-scale persistent upwelling along the Western Australian coast is suppressed. Therefore, upwelling events are sporadic, short-term and localised to areas of the coastline where the continental shelf narrows, including the area around the Capes and the Ningaloo coast (IMOS, 2015). This process is seasonal/transient and affected by the strength of the Leeuwin Current, with minimal upwelling in times with strong Leeuwin Current flow.

The current-induced transport of plumes can be variably affected by combinations of tidal, wind-induced and density-induced drift currents. Depending on their local influence, it is critical to consider all these potential advective mechanisms to rigorously understand patterns of potential transport from a given discharge location.

To appropriately allow for temporal and spatial variation in the current field, dispersion modelling requires the current speed and direction over a spatial grid covering the potential migration trajectories of plumes. As long-term measured current data is not available for simultaneous periods over a network of locations covering the offshore areas relevant to this study, the analysis relied upon hindcasts of the circulation generated through numerical modelling by internationally recognised organisations.

A composite modelled ocean current data product was derived by combining predictions of mesoscale circulation currents, available at daily resolution from global ocean models, with predictions of the hourly tidal currents generated by the RPS HYDROMAP model. By combining a drift current model with a tidal model, the influences of inter-annual and seasonal drift patterns, and the more regular variations in tide, were depicted, ensuring nearshore and offshore hydrodynamic processes were represented.

2.2.1.2 Mesoscale Circulation

2.2.1.2.1 Description of Mesoscale Model: BRAN

Two mesoscale ocean current data sets were considered for the study: the CSIRO (Commonwealth Scientific and Industrial Research Organisation) global ocean model, BRAN (Bluelink ReANalysis); and the HYCOM (Hybrid Coordinate Ocean Model) Consortium's global ocean model, HYCOM. Based on a hydrodynamic model validation conducted by RPS, the output of the BRAN (Oke *et al.*, 2008, 2009; Schiller *et al.*, 2008) ocean model, which is sponsored by the Australian Government through the Commonwealth Bureau of Meteorology (BoM), Royal Australian Navy and CSIRO, was chosen for representation of the drift currents that affect the area. BRAN is a data-assimilative, three-dimensional ocean model that has been run as a hindcast for many periods and is now used for ocean forecasting (Schiller *et al.*, 2008).

BRAN routinely assimilates sea level anomaly data, tide gauge data, sea surface temperature and in situ temperature and salinity measurements (Oke *et al.*, 2009). Comparisons of BRAN hindcast outputs to satellite and independent in situ observations found that BRAN was reliably representing the broad-scale ocean circulation, the mesoscale surface eddy field, and shelf circulation around Australia (Oke *et al.*, 2008; Schiller *et al.*, 2008). Additionally, reanalysis of past periods using the BRAN model has been shown to realistically represent upwelling events, in particular along the Bonney Coast of South Australia, a region of frequent wind-driven upwellings (Oke *et al.*, 2009).

The BRAN predictions for drift currents are produced at a horizontal spatial resolution of approximately 0.1° over the region, at a frequency of once per day, averaged over the 24-hour period. Hence, the BRAN model data provides estimates of mesoscale circulation with horizontal resolution suitable to resolve eddies of a few tens of kilometres' diameter, as well as connecting stream currents of similar spatial scale. Drift currents that are represented over the inner shelf waters in the BRAN data are principally attributable to wind induced drift.

There are several versions of the BRAN database available. The latest BRAN simulation spans the period of January 1994 to August 2016. From this database, three-dimensional data representing horizontal water movement at discrete depths was extracted for all points in the model domain for the years 2006-2015 (inclusive). The data was assumed to be a suitably representative sample of the current conditions over the study area for future years.

Although this data should represent effects of upwelling and downwelling processes on horizontal transport at a given depth, the data does not explicitly represent vertical currents between horizontal layers. This was considered reasonable because vertical currents associated with episodic upwelling and downwelling events are relatively small in magnitude (3-30 cm/s; Kampf *et al.*, 2004) compared to horizontal currents represented in the tidal and non-tidal current data (0.5-2 m/s), and considering allowances for dispersion rates in the horizontal (0.1-50 m/s) and vertical (1-10 cm/s) planes.

2.2.1.2.2 Mesoscale Current Validation

The suitability of the BRAN ocean model product was evaluated by comparing the predicted currents to those measured within the Browse project area. The validation included both quantitative and qualitative comparisons between measured and modelled data at a range of depths through the water column, at three available measurement locations shown in Figure 2.3: Browse C1-1 (three depth layers), B2-1 (eight depth layers) and G2-1 (three depth layers).

Time series comparisons of modelled and measured current magnitude, direction, and U/V velocity components are presented for sites B2-1 (Figure 2.4 and Figure 2.5), C1-1 (Figure 2.6 and Figure 2.7) and G2-1 (Figure 2.8 and Figure 2.9). For the purposes of brevity and clarity, only a surface and mid-depth time series at each site was selected for presentation. The time series comparisons revealed that, at two of the sites (B2-1 and G2-1), the BRAN model offered a good match in magnitude and direction of the measured current velocity in the upper water column; however, the magnitudes of the peaks and troughs were often underpredicted at the deeper levels. At the C1-1 site, the BRAN model captured the range in current magnitude at each depth; however, the timing of peaks and troughs in the measured current velocity and direction was not well-matched. Given the location of this site in close proximity to Scott Reef, with steep gradients in the bathymetry and the relatively coarse resolution of the ocean model (relative to the tidal model), this was not unexpected.

A quantitative analysis of the BRAN model's skill at replicating the drift currents was conducted using the Index of Agreement (IOA), presented in Willmott (1981) and Willmott *et al.* (1985), and the Mean Absolute Error (MAE), discussed in Willmott (1982) and Willmott & Matsuura (2005). A perfect agreement can be said to exist between the model and field observations if the IOA gives a measure of one, and complete disagreement will produce an IOA measure of zero (Willmott, 1981). The MAE is simply the average of the absolute values of the differences between the observed and modelled values.

The IOA and MAE values derived from comparisons of the U/V velocity components over the full measurement period at sites B2-1, C1-1 and G2-1 for all available water depths are presented in Table 2.16. The results confirm the conclusions drawn from analysis of the comparison time series plots. The IOA for both velocity components is good at sites B2-1 and G2-1 in the upper water column but reduces at deeper layers. This reflects the generally good match in the range, magnitude and direction of the measured and modelled drift currents at these sites, particularly in the upper water column. The IOA for both velocity components at site C1-1 is low, suggesting a poor agreement, reflecting the poor match in the timing of peaks and troughs in velocity observed in the time series plots.

Overall, the BRAN model data offered a reasonable match to the field measurements within the Browse project area, particularly in the upper water column. Given the stochastic methodology applied in far-field modelling, the use of a ten-year hindcast of BRAN current data allowed a realistic spatial distribution of potential plume trajectories and extents to be captured in aggregate. The BRAN model was considered suitable for use in the marine dispersion modelling studies.

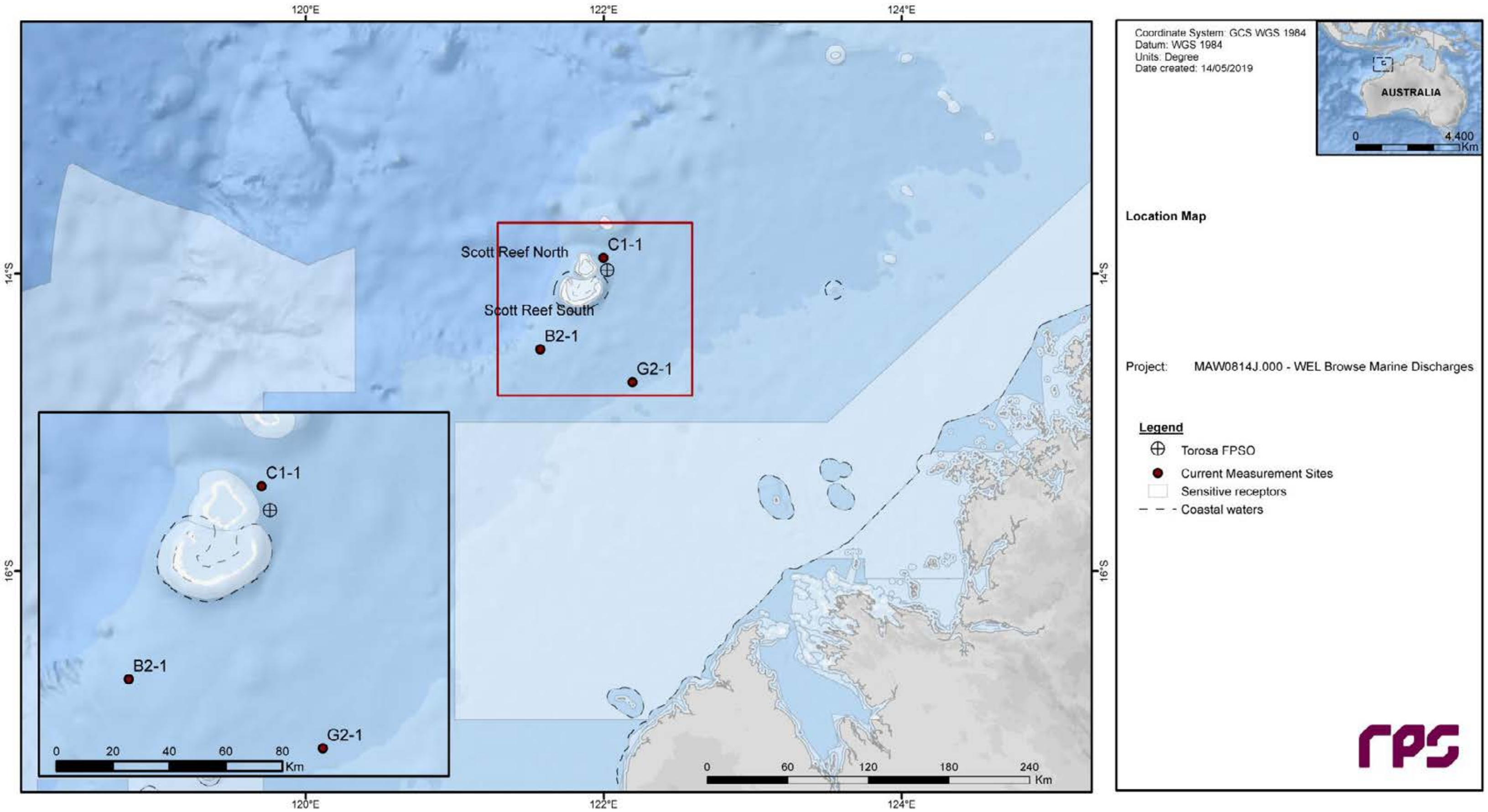


Figure 2.3 Locations of the proposed Torosa FPSO and the current measurement sites used for model validation, in proximity to Scott Reef, off the Kimberley Coast of Western Australia.

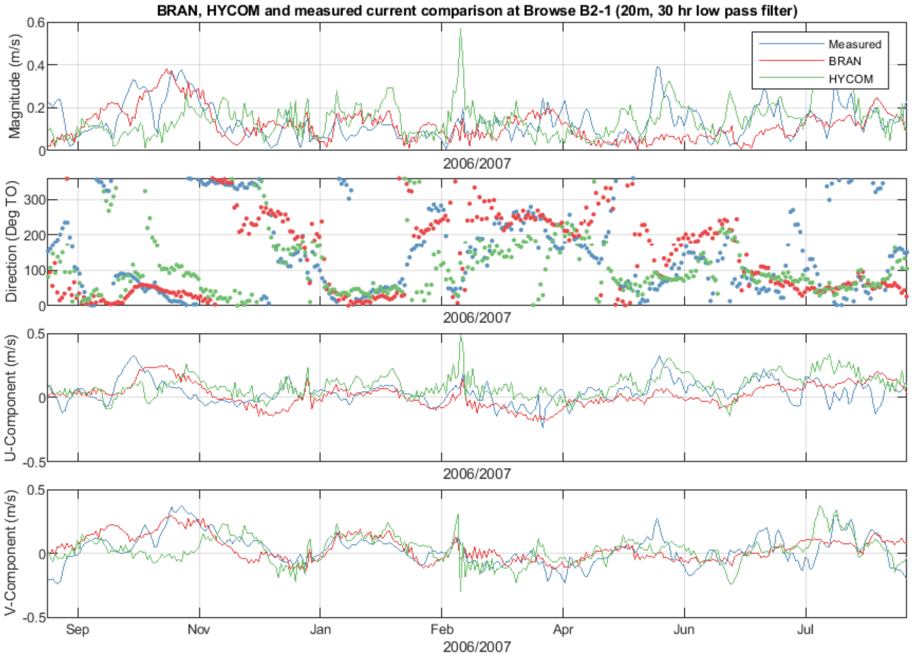


Figure 2.4 Comparisons between BRAN-predicted (red line), HYCOM-predicted (green line) and measured (blue line) non-tidal current data at site B2-1, at a depth of approximately 20 m, for the period of August 2006 to July 2007.

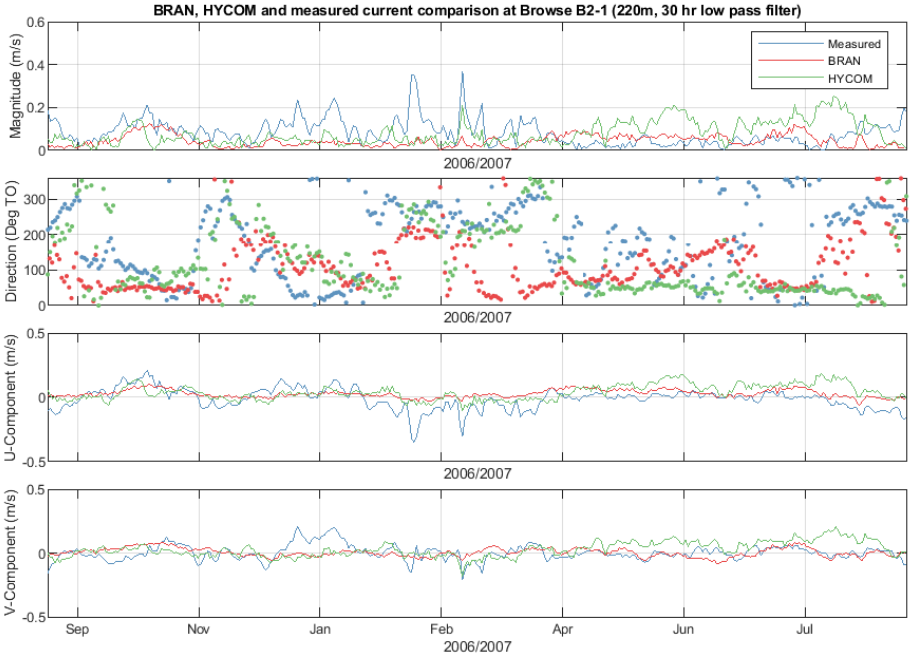


Figure 2.5 Comparisons between BRAN-predicted (red line), HYCOM-predicted (green line) and measured (blue line) non-tidal current data at site B2-1, at a depth of approximately 220 m, for the period of August 2006 to July 2007.

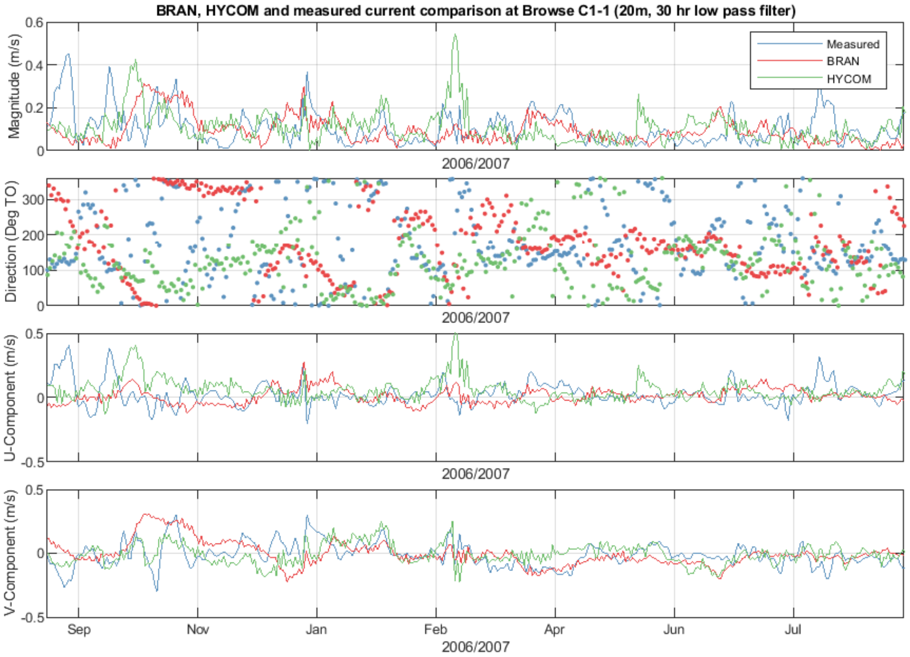


Figure 2.6 Comparisons between BRAN-predicted (red line), HYCOM-predicted (green line) and measured (blue line) non-tidal current data at site C1-1, at a depth of approximately 20 m, for the period of August 2006 to July 2007.

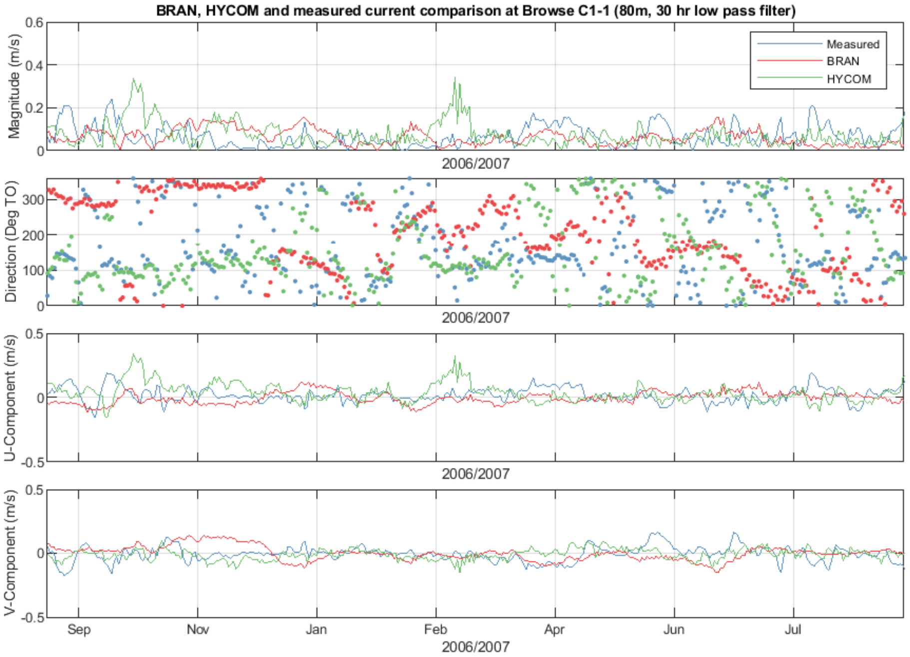


Figure 2.7 Comparisons between BRAN-predicted (red line), HYCOM-predicted (green line) and measured (blue line) non-tidal current data at site C1-1, at a depth of approximately 80 m, for the period of August 2006 to July 2007.

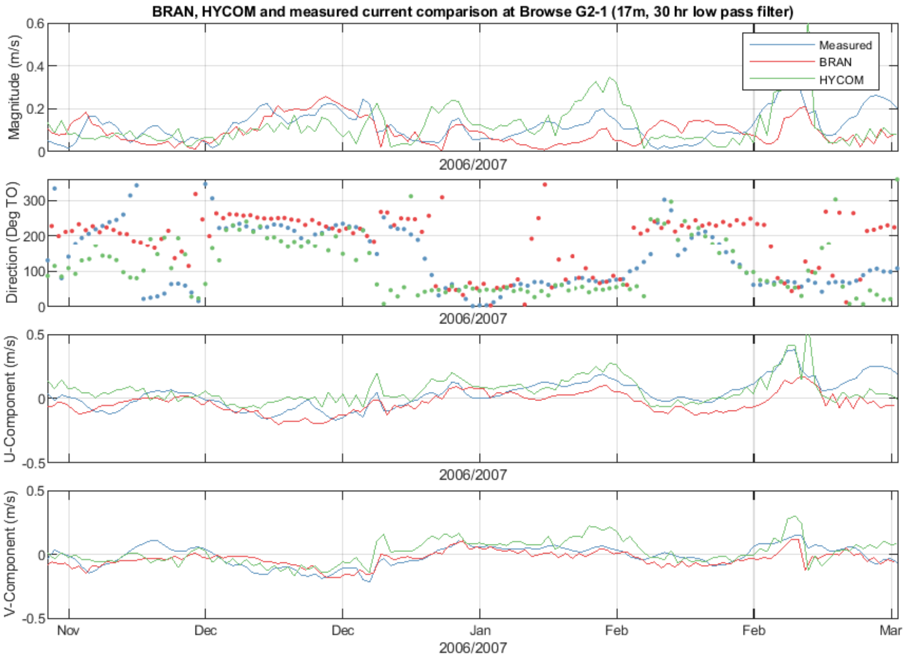


Figure 2.8 Comparisons between BRAN-predicted (red line), HYCOM-predicted (green line) and measured (blue line) non-tidal current data at site G2-1, at a depth of approximately 17 m, for the period of August 2006 to July 2007.

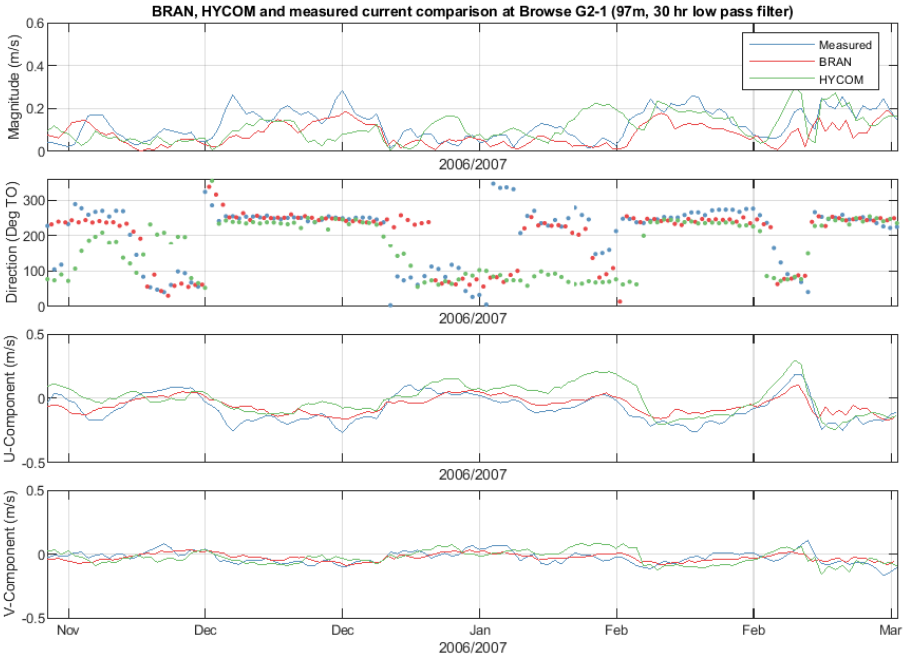


Figure 2.9 Comparisons between BRAN-predicted (red line), HYCOM-predicted (green line) and measured (blue line) non-tidal current data at site G2-1, at a depth of approximately 97 m, for the period of August 2006 to July 2007.

Table 2.16 Statistical comparison of BRAN-predicted and measured non-tidal current speeds along orthogonal component axes at the three measurement sites (2006-2007).

Site	Depth (m)	IOA		MAE (m/s)	
		U Component	V Component	U Component	V Component
B2-1	20.0	0.65	0.76	0.08	0.08
	60.0	0.68	0.77	0.06	0.06
	100.0	0.65	0.73	0.05	0.05
	160.0	0.70	0.63	0.05	0.05
	220.0	0.52	0.43	0.06	0.05
	300.0	0.47	0.52	0.04	0.04
	420.0	0.34	0.53	0.03	0.03
	547.4	0.46	0.40	0.02	0.02
C1-1	20.0	0.29	0.53	0.08	0.08
	80.0	0.28	0.32	0.06	0.06
	472.4	0.25	0.29	0.03	0.04
G2-1	17.0	0.71	0.81	0.08	0.05
	97.0	0.82	0.72	0.06	0.03
	192.0	0.45	0.17	0.06	0.06

2.2.1.2.3 Mesoscale Currents at the Discharge Locations

Figure 2.10, Figure 2.11 and Figure 2.12 show the seasonal distribution of current speeds and directions for the BRAN data points closest to the Torosa FPSO/PLET, Brecknock/Calliance PLET and NRC tie-in PLET locations, respectively. Note that the convention for defining current direction is the direction towards which the current flows.

The data near the Torosa locations (Figure 2.10) shows that current speeds and directions vary between seasons. In general, during summer (December to February) currents have the strongest average speed (0.13 m/s with a maximum of 0.42 m/s). Lower current speeds are typical of the transitional (March and September to November; 0.11 m/s with a maximum of 0.36 m/s) and winter (April to August; 0.10 m/s with a maximum of 0.28 m/s) seasons. Flow is expected to occur with a reasonably equitable distribution in all directions, but northerly and westerly flows are slightly more prevalent across the year.

The data near the Brecknock/Calliance location (Figure 2.11) shows that current speeds and directions are relatively consistent between seasons. In general, during summer currents have the strongest average speed (0.13 m/s with a maximum of 0.41 m/s). North-easterly flows are expected to be dominant across all seasons.

The data near the NRC tie-in location (Figure 2.12) shows that current speeds and directions are relatively consistent between seasons. In general, during the transitional season currents have the strongest average speed (0.10 m/s), with maximum current speeds of 0.40 m/s occurring during summer. South-westerly flows are expected to be dominant across all seasons.

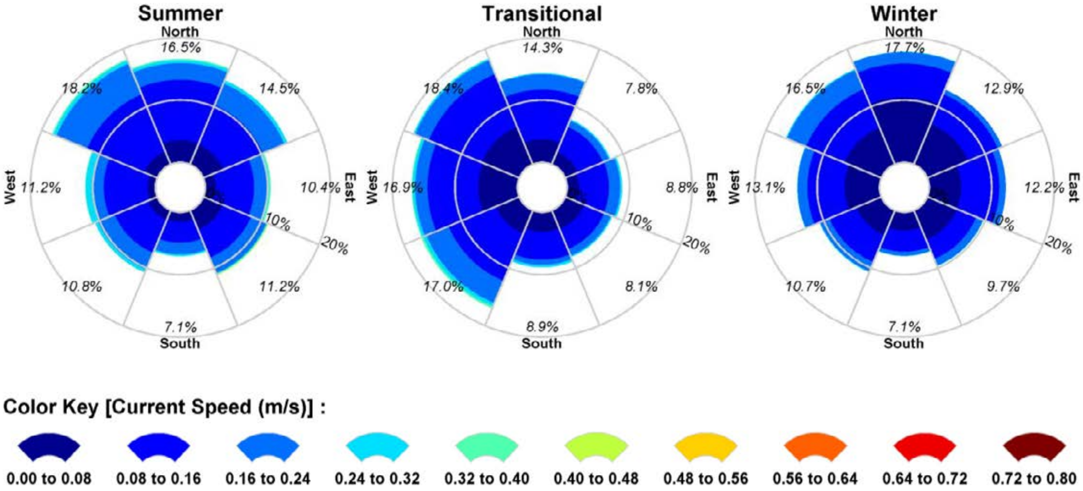


Figure 2.10 Seasonal current distribution (2006-2015, inclusive) derived from the BRAN database near to the proposed Torosa FPSO/PLET locations. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

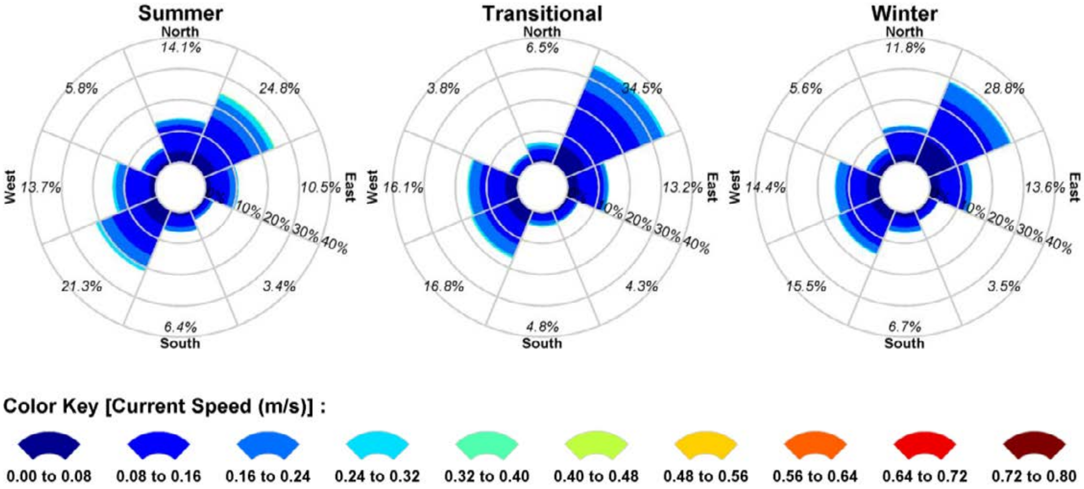


Figure 2.11 Seasonal current distribution (2006-2015, inclusive) derived from the BRAN database near to the proposed Brecknock/Calliance PLET location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

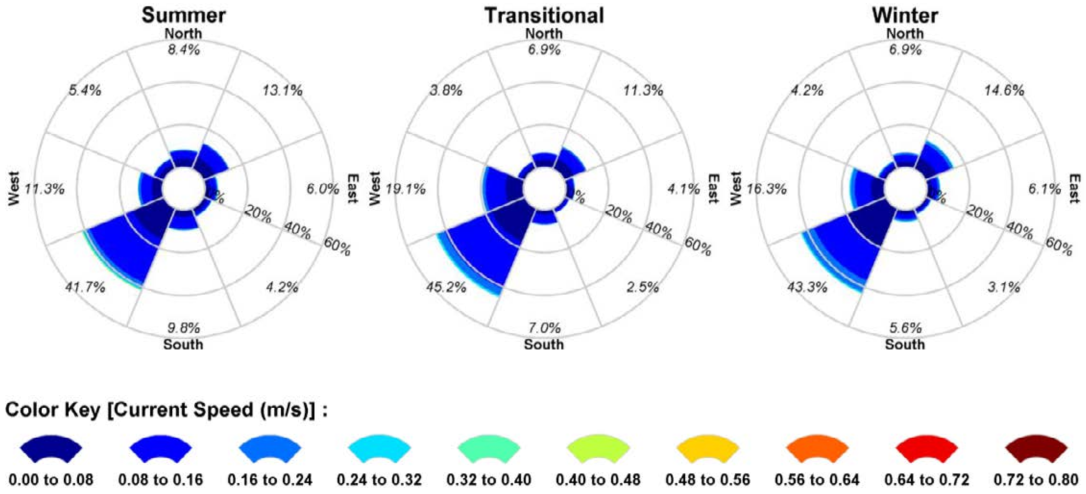


Figure 2.12 Seasonal current distribution (2006-2015, inclusive) derived from the BRAN database near to the proposed NRC tie-in PLET location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

2.2.1.3 Tidal Circulation

2.2.1.3.1 Description of Tidal Model: HYDROMAP

As the BRAN model does not include tidal forcing, and because the data is only available at a daily frequency, a tidal model was developed for the study region using RPS' three-dimensional hydrodynamic model, HYDROMAP.

The model formulations and output (current speed, direction and sea level) of this model have been validated through field measurements around the world for more than 30 years (Isaji & Spaulding, 1984, 1986; Isaji *et al.*, 2001; Zigic *et al.*, 2003). HYDROMAP current data has also been widely used as input to forecasts and hindcasts of oil spill migrations in Australian waters. This modelling system forms part of the National Marine Oil Spill Contingency Plan for the Australian Maritime Safety Authority (AMSA, 2002).

HYDROMAP simulates the flow of ocean currents within a model region due to forcing by astronomical tides, wind stress and bottom friction. The model employs a sophisticated dynamically nested-gridding strategy, supporting up to six levels of spatial resolution within a single domain. This allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, or of particular interest to a study.

The numerical solution methodology of HYDROMAP follows that of Davies (1977a, 1977b) with further developments for model efficiency by Owen (1980) and Gordon (1982). A more detailed presentation of the model can be found in Isaji & Spaulding (1984).

2.2.1.3.2 Tidal Domain Setup

A HYDROMAP model was established over a domain that extended approximately 3,300 km east-west by 3,100 km north-south over the eastern Indian Ocean. The grid extends beyond Eucla in the south and beyond Bathurst Island in the north (Figure 2.13). Approximately 98,600 cells were used to define the region, with four layers of sub-gridding applied to provide variable resolution throughout the domain. The resolution at the primary level was 15 km. The finer levels were defined by subdividing these cells into 4, 16 and 64 cells, resulting in resolutions of 7.5 km, 3.75 km and 1.88 km.

The finer grids were allocated in a step-wise fashion to areas where higher resolution of circulation patterns was required to resolve flows through channels, around shorelines or over more complex bathymetry. Figure 2.14 shows a zoomed subset of the hydrodynamic model grid in the Scott Reef region, showing the finer resolution grids surrounding Scott Reef, the numerous shoals and islands, and complex areas of the mainland coastline.

Modelling of the tidal circulation at relatively fine scales in the topographically-complex area around Scott Reef was achieved using an additional model sub-domain with resolutions ranging down to <500 m. Major tidal channels that occur across the reef flats of North Scott Reef were represented in this model, with tidal current flows across the rest of the flats known to be minimal.

High-resolution (~50 m) bathymetric data covering Scott and Seringapatam Reefs and the Brecknock, Torosa and Calliance gas fields was supplied by Woodside. Beyond these areas, bathymetric data used to define the three-dimensional shape of the study domain was extracted from the Geoscience Australia 250 m resolution bathymetry database (GA, 2009) and the CMAP electronic chart database, supplemented where necessary with manual digitisation of chart data supplied by the Australian Hydrographic Office. Depths in the domain ranged from shallow intertidal areas through to approximately 7,200 m.

2.2.1.3.3 Tidal Boundary Conditions

Ocean boundary data for the HYDROMAP model was obtained from the TOPEX/Poseidon global tidal database (TPXO7.2) of satellite-measured altimetry data, which provided estimates of tidal amplitudes and phases for the eight dominant tidal constituents (designated as K_2, S_2, M_2, N_2, K_1, P_1, O_1 and Q_1) at a horizontal scale of approximately 0.25°. Using the tidal data, sea surface heights are firstly calculated along the open boundaries at each time step in the model.

The TOPEX/Poseidon satellite data is produced, and quality controlled by the US National Atmospheric and Space Agency (NASA). The satellites, equipped with two highly accurate altimeters capable of taking sea level measurements accurate to less than ±5 cm, measured oceanic surface elevations (and the resultant tides) for over 13 years (1992-2005). In total, these satellites carried out more than 62,000 orbits of the planet. The TOPEX/Poseidon tidal data has been widely used amongst the oceanographic community, being the subject of more than 2,100 research publications (e.g. Andersen, 1995; Ludicone *et al.*, 1998; Matsumoto *et al.*, 2000; Kostianoy *et al.*, 2003; Yaremchuk & Tangdong, 2004; Qiu & Chen, 2010). As such, the TOPEX/Poseidon tidal data is considered suitably accurate for this study.

2.2.1.3.4 Tidal Elevation Validation

For the purpose of verification of the tidal predictions, the model output was compared against independent predictions of tides using the XTide database (Flater, 1998). The XTide database contains harmonic tidal constituents derived from measured water level data at locations around the world. Overall, there are more than 120 tidal stations within the HYDROMAP model domain; however, some of these are located in areas that are not sufficiently resolved by this large-scale ocean model. More than 80 stations along the coastline were suitable for comparisons of the model performance with the observed data. These stations covered the mid-to-northwest regions of the Western Australian coastline, encompassing the locales of the marine discharges considered in this study (Figure 2.13 and Figure 2.14). For the purposes of brevity and clarity, a selected representative subset of the available tidal station validation data is presented here.

Water level time series for the selected subset of ten stations are shown in Figure 2.15 and Figure 2.16 for a one-month period (January 2018). All comparisons show that the model produces a very good match to the known tidal behaviour for a wide range of tidal amplitudes and clearly represents the varying diurnal and semi-diurnal nature of the tidal signal.

The model skill was further evaluated through a comparison of the predicted and observed tidal constituents, derived from an analysis of model-predicted time series at each of the tidal station locations. Scatter plots of the observed and modelled amplitude (top) and phase (bottom) of the five dominant tidal constituents (S_2, M_2, N_2, K_1 and O_1) for all relevant stations within the model domain (>80) are presented in Figure 2.17. The red line on each plot shows the 1:1 line, which would indicate a perfect match between the modelled and observed data. Note that the data is generally closely aligned to the 1:1 line demonstrating the high quality of the model performance.

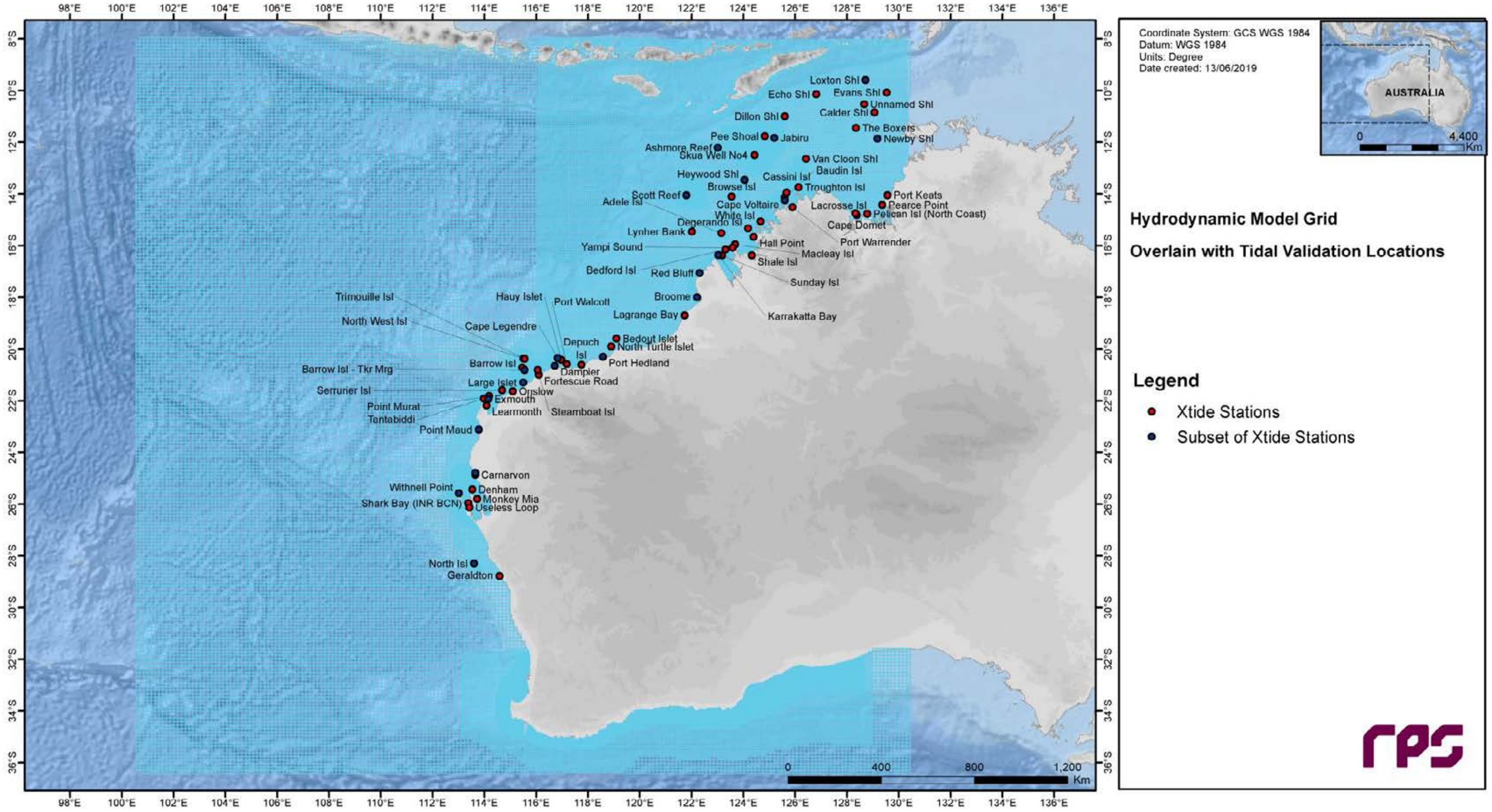


Figure 2.13 Hydrodynamic model grid (blue wire mesh) used to generate the tidal currents, showing the full domain in context with the continental land mass and the locations available for tidal comparisons (red and blue labelled dots). Higher-resolution areas are indicated by the denser mesh zones.

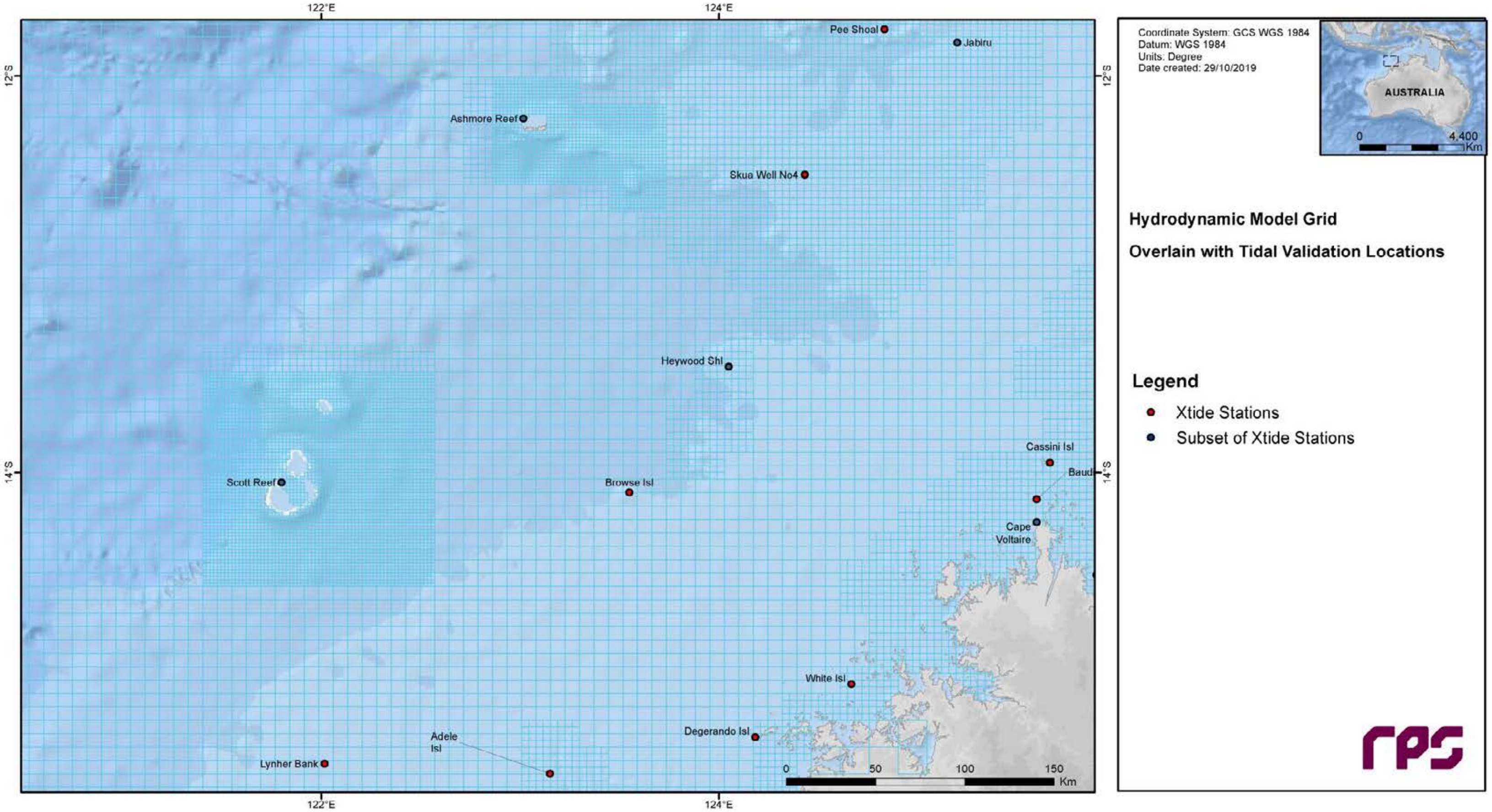


Figure 2.14 Zoomed subset of the hydrodynamic model grid (blue wire mesh) for the Scott Reef area, showing the locations available for tidal comparisons (red and blue labelled dots). Higher-resolution areas are indicated by the denser mesh zones.

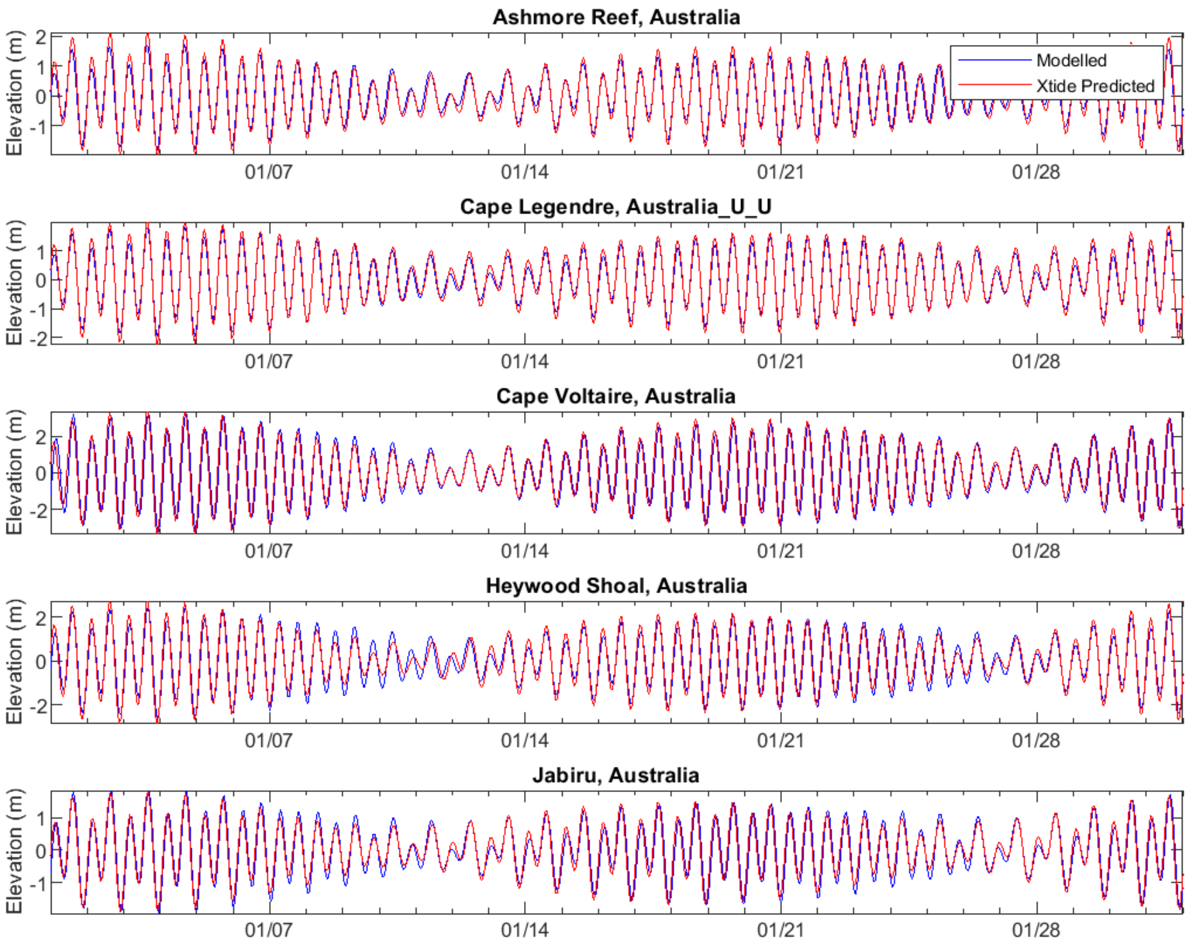


Figure 2.15 Comparisons between the predicted (blue line) and observed (red line) surface elevation variations at five locations in the north-east of the tidal model domain for January 2018.

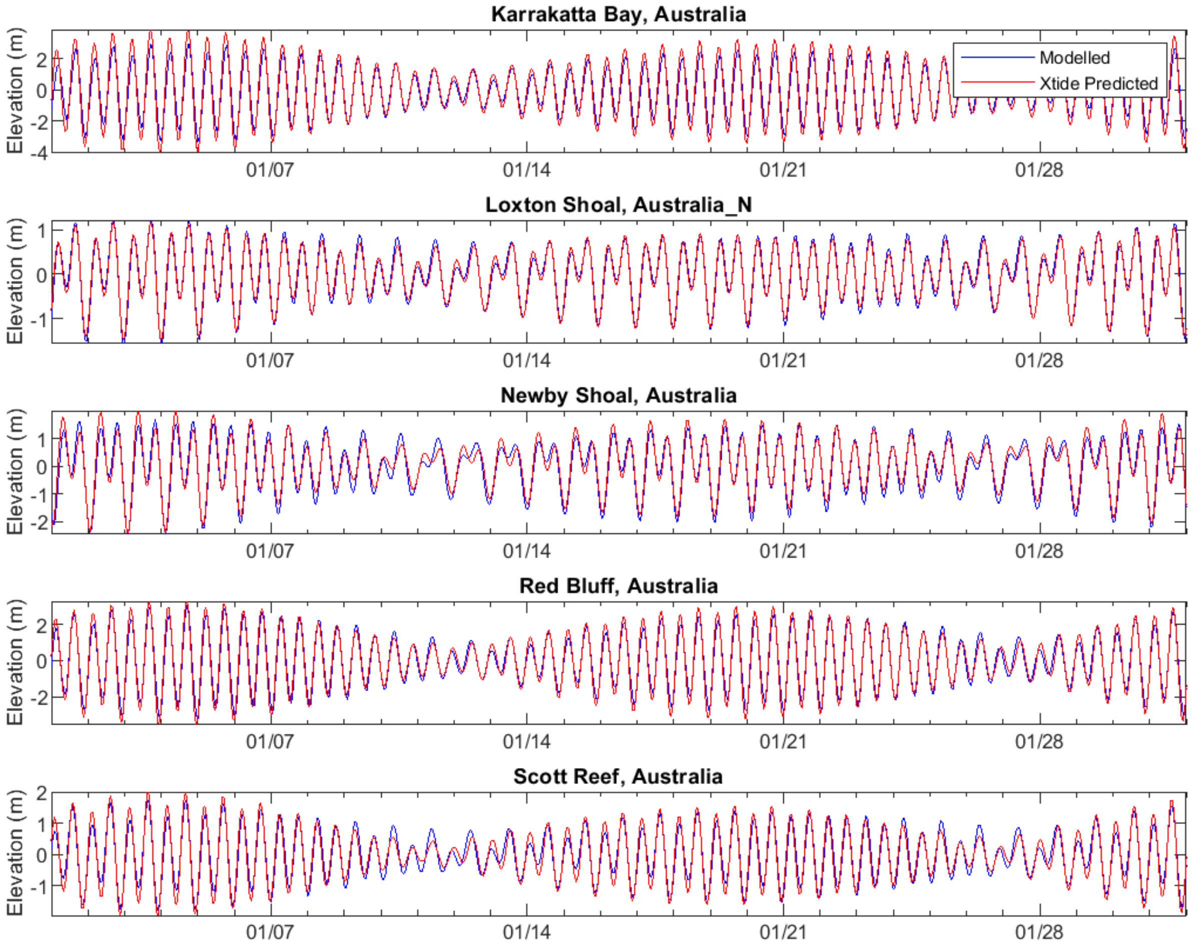
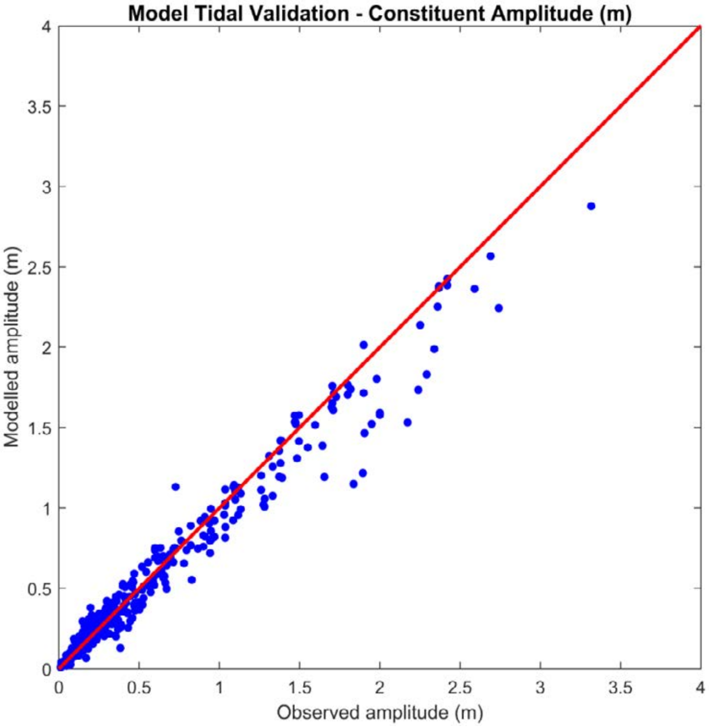


Figure 2.16 Comparisons between the predicted (blue line) and observed (red line) surface elevation variations at five locations in the north-east of the tidal model domain for January 2018.



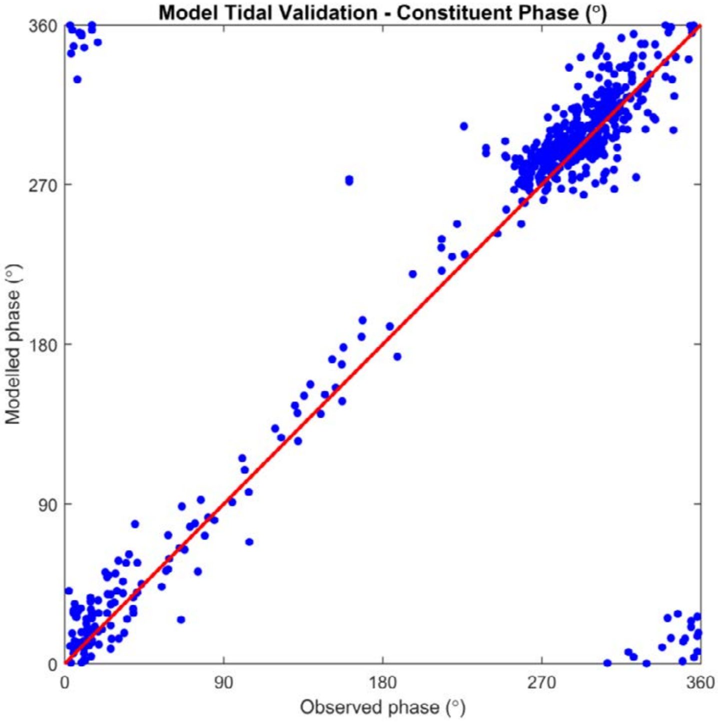


Figure 2.17 **Comparisons between modelled and observed tidal constituent amplitudes (top) and phases (bottom) at all relevant stations (>80) in the HYDROMAP model domain. The red line indicates a 1:1 correlation between the modelled and observed data.**

2.2.1.3.5 Tidal Currents at the Discharge Locations

Figure 2.18, Figure 2.19 and Figure 2.20 show the seasonal distribution of current speeds and directions for the HYDROMAP data points closest to the Torosa FPSO/PLET, Brecknock/Calliance PLET and NRC tie-in PLET locations, respectively. Note that the convention for defining current direction is the direction towards which the current flows.

The current data indicates cyclical tidal flow directions along a northwest-southeast axis at all locations, with maximum speeds of around 0.35 m/s, 0.35 m/s and 0.45 m/s at the Torosa, Brecknock/Calliance and NRC tie-in locations, respectively.

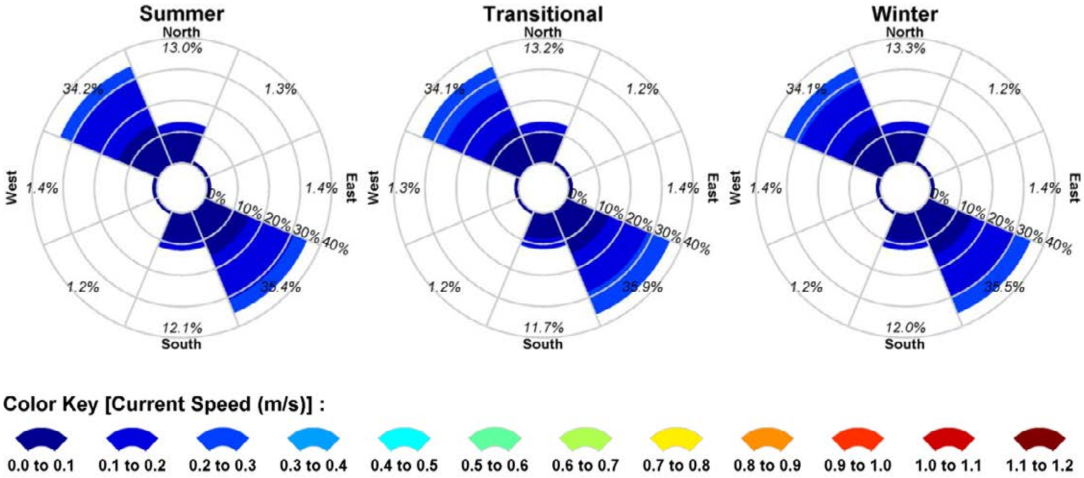


Figure 2.18 Seasonal current distribution (2006-2015, inclusive) derived from the HYDROMAP database near to the proposed Torosa FPSO/PLET locations. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

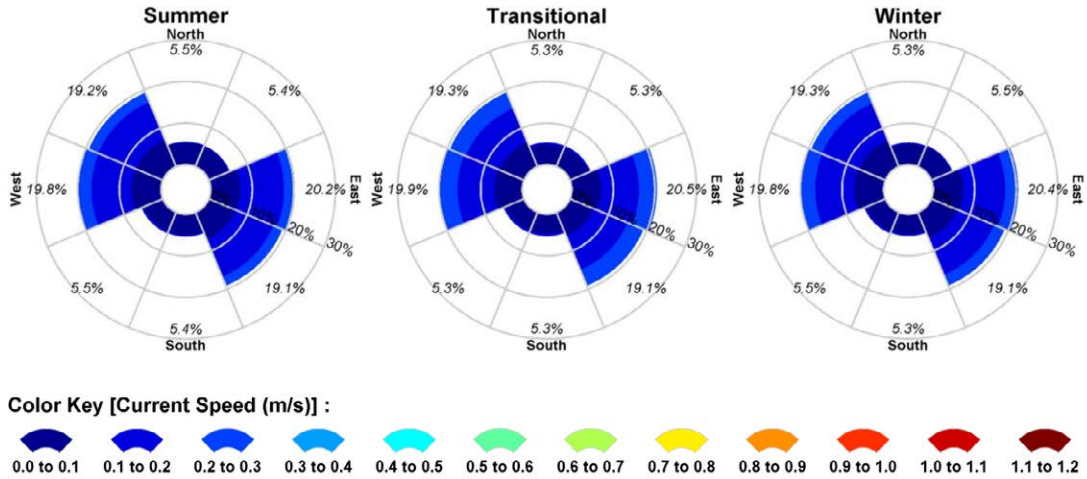


Figure 2.19 Seasonal current distribution (2006-2015, inclusive) derived from the HYDROMAP database near to the proposed Brecknock/Calliance PLET location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

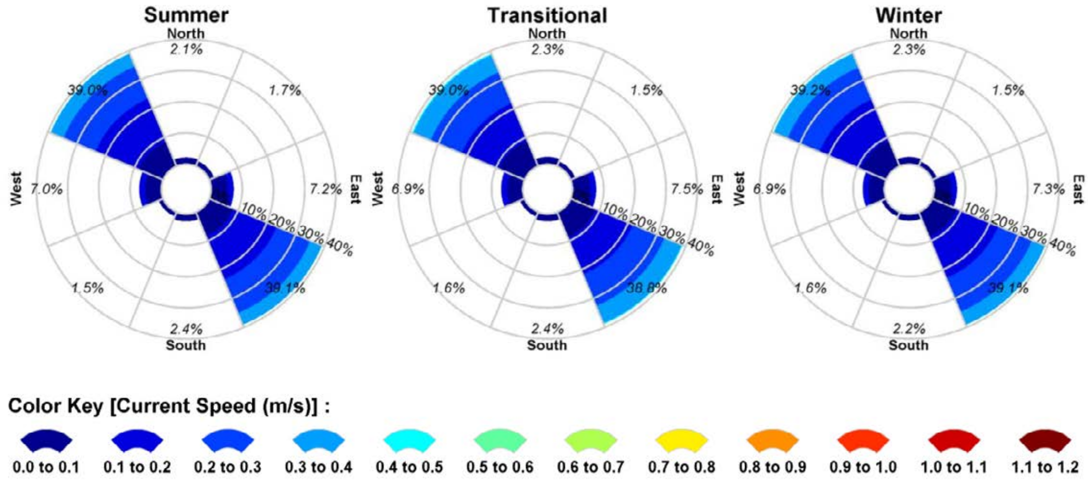


Figure 2.20 Seasonal current distribution (2006-2015, inclusive) derived from the HYDROMAP database near to the proposed NRC tie-in PLET location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

3 MODELLING RESULTS

3.1 Near-Field Modelling

3.1.1 Cooling Water Discharges

3.1.1.1 Overview

In the following sections, information for each of the modelled discharge cases is presented first in a table summarising the predicted plume characteristics in the near-field mixing zone under varying current speeds, and then in further tables summarising the concentrations of chlorine and the amount of dilution at the end of the near-field mixing zone for each season and for the annual period.

Figure 3.1 to Figure 3.4 (note the differing x-axis and y-axis aspect ratios) show the change in average dilution and temperature of the plume at a discharge rate of 720,000 m^3/d and depth of 12 m, under varying seasonal conditions (summer, transitional, winter and annual) and current speeds (weak, medium and strong). The figures show the predicted horizontal distance travelled by the plume before the trapping depth is reached (i.e. before the plume becomes neutrally buoyant).

The results show that due to the momentum of the discharge a turbulent mixing zone is created in the immediate vicinity of the discharge point, which is 12 m below the water surface. Medium and strong currents are shown to increase the extent of the turbulent mixing zone. Following this initial mixing, the positively buoyant plume is predicted to rise in the water column. The plume is predicted to plunge up to 16 m below the sea surface in all seasons. Increased ambient current strengths are shown to increase the horizontal distance travelled by the plume from the discharge point.

Table 3.1 shows the predicted plume characteristics for the varying seasonal conditions and current speeds. High annualised currents push the plume to a maximum horizontal distance of 42.4 m for the Case C discharge. The annualised maximum diameter of the plume at the end of the near-field zone is forecast to be 15.2 m for the Case C discharge.

For all seasons, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to reach the trapping depth closer to the discharge point, which slows the rate of dilution (Table 3.1). The annualised average dilution levels of the plume upon reaching the trapping depth under medium currents are predicted to be 1:13.5 for Case C. Additionally, the annualised minimum dilution levels of the plume (i.e. dilution of the plume centreline) upon encountering the trapping depth under medium currents are predicted to be 1:6.3 for Case C. Note that these predictions of dilution rely on the persistence of current speed and direction over time and do not account for any build-up of plume concentrations due to slack currents or current reversals.

3.1.1.2 Results – Tables and Figures

3.1.1.2.1 Discharge Case C: Flow Rate of 720,000 m^3/day at 12 m Depth

Table 3.1 Predicted plume characteristics at the end of the near-field mixing zone for the 12 m depth discharge for each season and current speed.

Season	Surface Current Speed (m/s)	Plume Diameter (m) at Depth [m]	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Annual	Weak (0.03)	15.1 [6.9]	29.84	1.62	6.3	12.5	35.5
	Medium (0.14)	15.1 [7.0]	29.70	1.48	6.3	13.5	37.8
	Strong (0.30)	15.2 [7.2]	29.86	1.25	6.4	15.6	42.4
Summer	Weak (0.04)	15.1 [7.0]	31.01	1.50	6.3	12.5	35.6
	Medium (0.16)	15.1 [7.2]	30.88	1.38	6.2	13.5	37.8
	Strong (0.32)	15.3 [7.2]	30.66	1.16	6.4	15.9	43.1
Transitional	Weak (0.04)	15.1 [6.9]	29.92	1.60	6.3	12.5	35.5
	Medium (0.14)	15.1 [7.1]	29.78	1.47	6.3	13.5	37.8
	Strong (0.32)	15.1 [7.3]	29.58	1.27	6.3	15.6	42.3
Winter	Weak (0.03)	15.1 [6.8]	29.12	1.68	6.3	12.4	35.4
	Medium (0.13)	15.2 [6.9]	28.87	1.54	6.3	13.5	37.8
	Strong (0.28)	15.1 [7.2]	28.78	1.36	6.4	15.2	41.6

Table 3.2 Concentrations of chlorine and plume-ambient temperature difference, and number of dilutions, at the end of the near-field stage for the annual period. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 12.5, 13.5 and 15.6, respectively.

Constituent	Source Concentration or Temperature	End of Near-Field Concentration or ΔT		
		5th %ile 12.5x Dilution	50th %ile 13.5x Dilution	95th %ile 15.6x Dilution
Chlorine in Water (ppm)	0.2	0.016	0.015	0.013
	0.5	0.040	0.037	0.032
Δ Temperature (°C)	50	1.62	1.48	1.25

Table 3.3 Concentrations of chlorine and plume-ambient temperature difference, and number of dilutions, at the end of the near-field stage for the summer season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 12.5, 13.5 and 15.9, respectively.

Constituent	Source Concentration or Temperature	End of Near-Field Concentration or ΔT 5th %ile 12.5x Dilution	50th %ile 13.5x Dilution	95th %ile 15.9x Dilution
Chlorine in Water (ppm)	0.2	0.016	0.015	0.013
	0.5	0.040	0.037	0.031
Δ Temperature (°C)	50	1.50	1.38	1.16

Table 3.4 Concentrations of chlorine and plume-ambient temperature difference, and number of dilutions, at the end of the near-field stage for the transitional season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 12.5, 13.5 and 15.6, respectively.

Constituent	Source Concentration or Temperature	End of Near-Field Concentration or ΔT 5th %ile 12.5x Dilution	50th %ile 13.5x Dilution	95th %ile 15.6x Dilution
Chlorine in Water (ppm)	0.2	0.016	0.015	0.013
	0.5	0.040	0.037	0.032
Δ Temperature (°C)	50	1.60	1.47	1.27

Table 3.5 Concentrations of chlorine and plume-ambient temperature difference, and number of dilutions, at the end of the near-field stage for the winter season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 12.4, 13.5 and 15.2, respectively.

Constituent	Source Concentration or Temperature	End of Near-Field Concentration or ΔT 5th %ile 12.4x Dilution	50th %ile 13.5x Dilution	95th %ile 15.2x Dilution
Chlorine in Water (ppm)	0.2	0.016	0.015	0.013
	0.5	0.040	0.037	0.033
Δ Temperature (°C)	50	1.68	1.54	1.36

3.1.1.2.1.1 Annualised

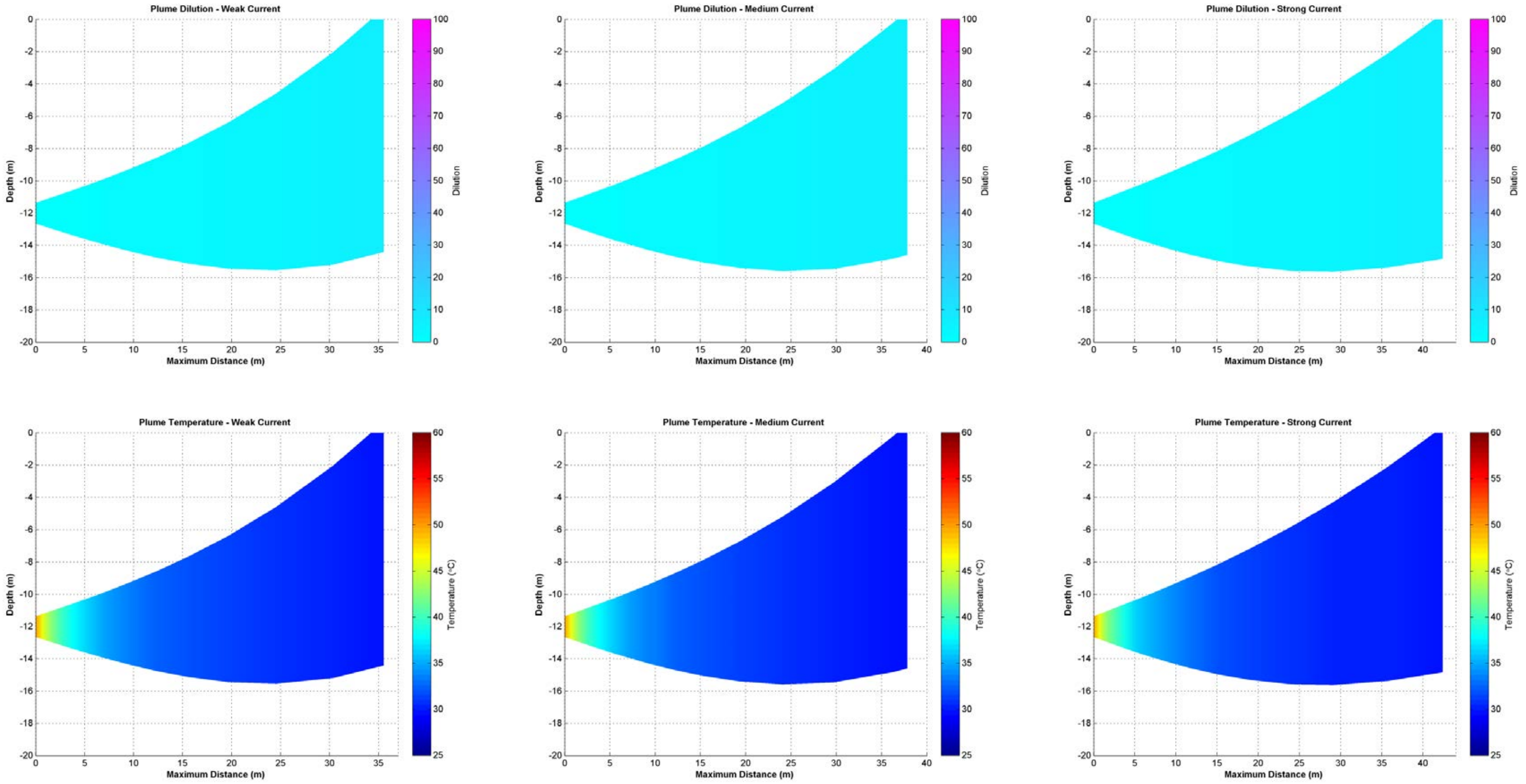


Figure 3.1 Near-field average dilution and temperature results for constant weak, medium and strong annualised currents (12 m depth discharge at 720,000 m^3/d flow rate).

3.1.1.2.1.2 Summer

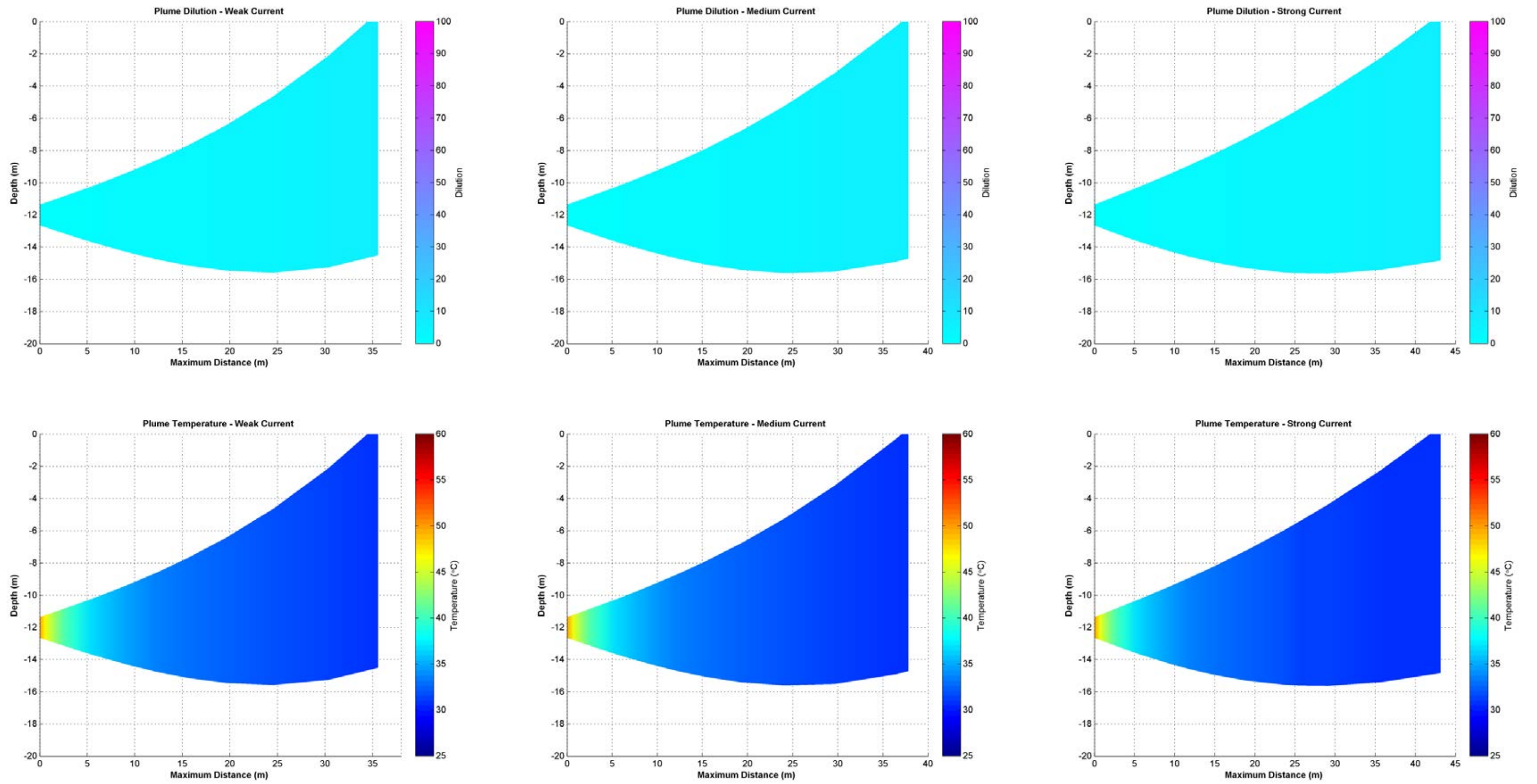


Figure 3.2 Near-field average dilution and temperature results for constant weak, medium and strong summer currents (12 m depth discharge at 720,000 m^3/d flow rate).

3.1.1.2.1.3 Transitional

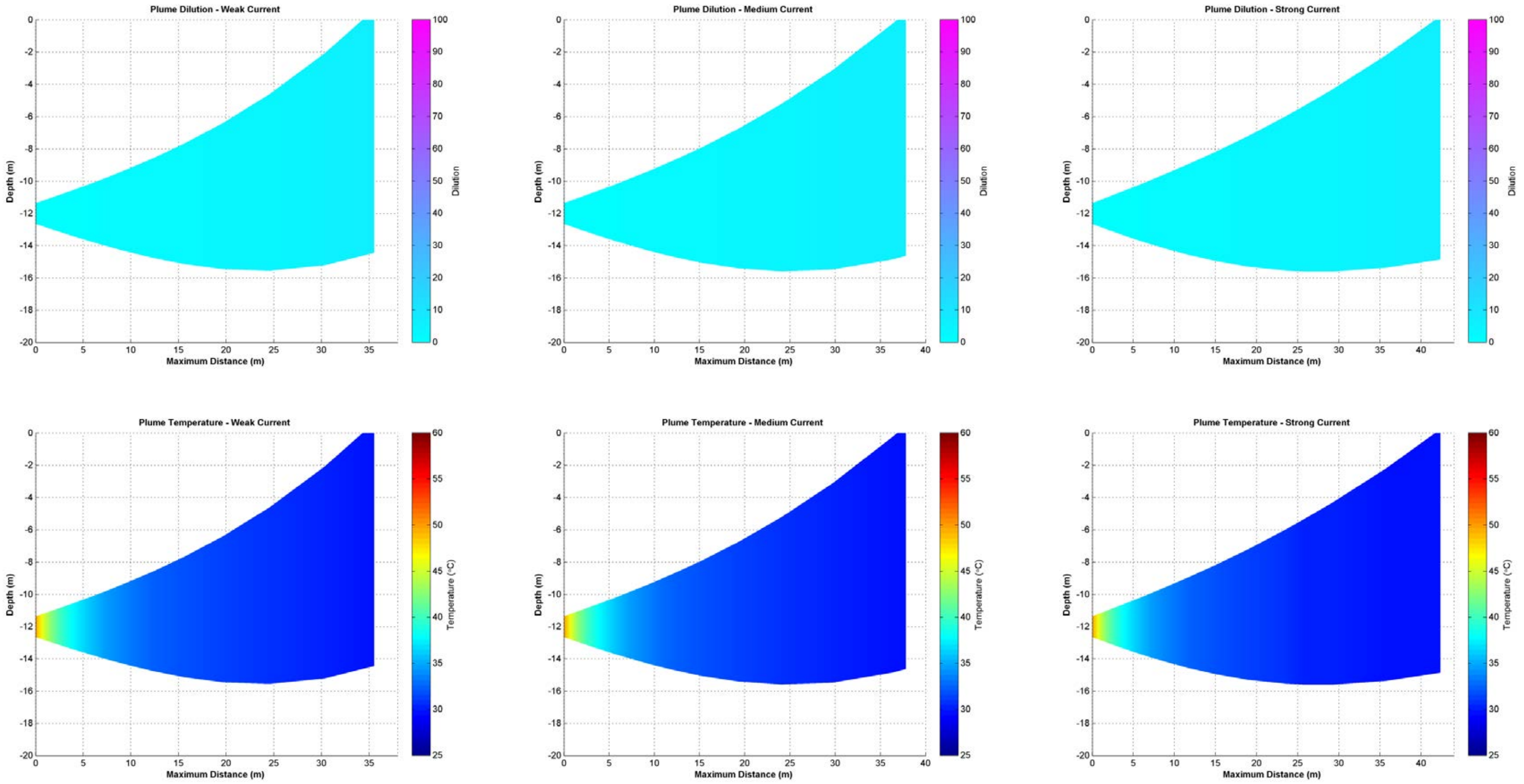


Figure 3.3 Near-field average dilution and temperature results for constant weak, medium and strong transitional currents (12 m depth discharge at 720,000 m^3/d flow rate).

3.1.1.2.1.4 Winter

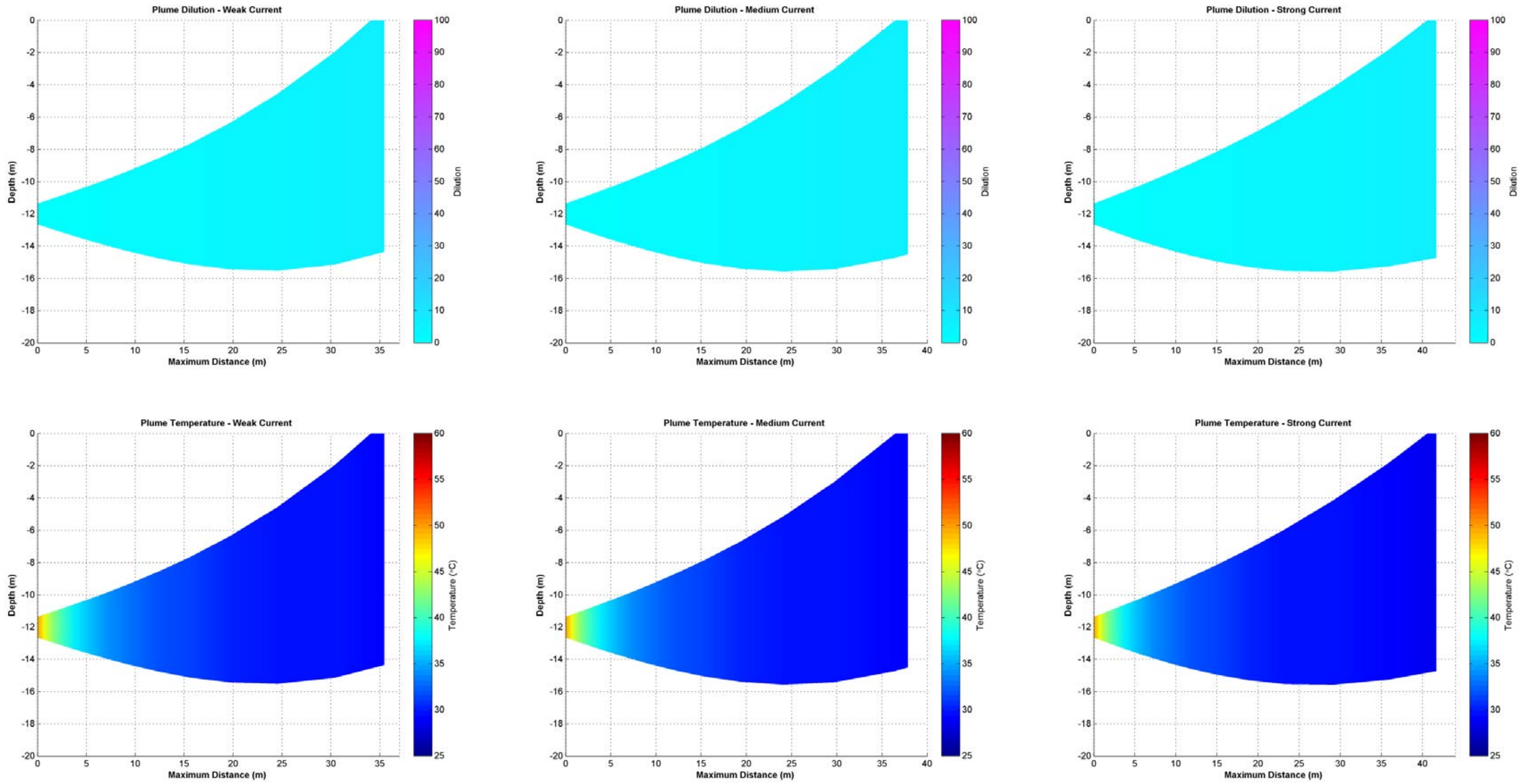


Figure 3.4 Near-field average dilution and temperature results for constant weak, medium and strong winter currents (12 m depth discharge at 720,000 m^3/d flow rate).

3.1.2 Produced Water Discharges

3.1.2.1 Overview

In the following sections, information for each of the modelled discharge cases is presented first in a table summarising the predicted plume characteristics in the near-field mixing zone under varying current speeds, and then in further tables summarising the concentrations of total oil, mercury and MEG, and the amount of dilution, at the end of the near-field mixing zone for each season and for the annual period.

Figure 3.5 to Figure 3.12 (note the differing x-axis and y-axis aspect ratios) show the change in average dilution and temperature of the plume under varying discharge rates (5,723 m^3/d and 490 m^3/d), seasonal conditions (summer, transitional, winter and annual), and current speeds (weak, medium and strong). The figures show the predicted horizontal distance travelled by the plume before the trapping depth is reached (i.e. before the plume becomes neutrally buoyant).

The results show that due to the momentum of the discharges a turbulent mixing zone is created in the immediate vicinity of the discharge point, which is 14 m (Cases P and M) below the water surface. Medium and strong currents are shown to increase the extent of the turbulent mixing zone. Following this initial mixing, the positively buoyant plumes are predicted to rise in the water column. In each case, the plume is predicted to rise towards the water surface after the momentum of the initial discharge is lost. Increased ambient current strengths are shown to increase the horizontal distance travelled by the plume from the discharge point.

Table 3.6 and Table 3.11 show the predicted plume characteristics for the varying discharge rates, seasonal conditions, and current speeds. High annualised currents push the plume to a maximum horizontal distance of 43.8 m and 43.4 m for the Case P and M discharges, respectively. The annualised maximum diameter of the plume at the end of the near-field zone is forecast to be 11.7 m for Case P and 8.0 m for Case M.

For all combinations of discharge case and season, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to reach the trapping depth closer to the discharge point, which slows the rate of dilution (Table 3.6 and Table 3.11). The annualised average dilution levels of the plume upon reaching the trapping depth under medium currents are predicted to be 1:204 for Case P and 1:1,222 for Case M. Additionally, the annualised minimum dilution levels of the plume (i.e. dilution of the plume centreline) upon encountering the trapping depth under medium currents are predicted to be 1:70 for Case P and 1:323 for Case M. Note that these predictions of dilution rely on the persistence of current speed and direction over time and do not account for any build-up of plume concentrations due to slack currents or current reversals.

3.1.2.2 Results – Tables and Figures

3.1.2.2.1 Discharge Case P: Flow Rate of 5,723 m^3/day at 14 m Depth

Table 3.6 Predicted plume characteristics at the end of the near-field mixing zone for the 14 m depth discharge for each season and current speed.

Season	Surface Current Speed (m/s)	Plume Diameter (m) at Depth [m]	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Annual	Weak (0.03)	5.6 [0.8]	28.46	0.06	40	79	12.6
	Medium (0.14)	9.9 [4.2]	28.29	0.00	70	204	19.6
	Strong (0.30)	11.7 [5.7]	28.59	0.00	136	508	43.8
Summer	Weak (0.04)	5.7 [1.0]	29.72	0.02	40	81	12.8
	Medium (0.15)	10.1 [4.5]	29.55	0.00	72	217	20.3
	Strong (0.32)	11.7 [5.7]	29.48	0.00	140	529	40.3
Transitional	Weak (0.04)	5.7 [0.9]	28.55	0.05	40	80	12.7
	Medium (0.14)	10.0 [4.3]	28.38	0.00	71	213	20.0
	Strong (0.32)	11.7 [5.7]	28.29	0.00	141	529	46.0
Winter	Weak (0.03)	5.5 [1.0]	27.68	0.08	38	76	12.3
	Medium (0.13)	9.7 [4.0]	27.51	0.00	68	193	18.9
	Strong (0.28)	11.6 [5.6]	27.42	0.00	127	469	39.6

Table 3.7 Concentrations of total oil and mercury, and number of dilutions, at the end of the near-field stage for the annual period. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 79, 204 and 508, respectively.

Constituent	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)		
		5th %ile	50th %ile	95th %ile
		79x Dilution	204x Dilution	508x Dilution
Total Oil (including BTEX)	30	0.38	0.15	0.06
Mercury	0.03	$3.80*10^{-4}$	$1.47*10^{-4}$	$5.91*10^{-5}$

Table 3.8 **Concentrations of total oil and mercury, and number of dilutions, at the end of the near-field stage for the summer season. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 81, 217 and 529, respectively.**

Constituent	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)		
		5th %ile	50th %ile	95th %ile
		81x Dilution	217x Dilution	529x Dilution
Total Oil (including BTEX)	30	0.37	0.14	0.06
Mercury	0.03	$3.70*10^{-4}$	$1.38*10^{-4}$	$5.67*10^{-5}$

Table 3.9 **Concentrations of total oil and mercury, and number of dilutions, at the end of the near-field stage for the transitional season. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 80, 213 and 529, respectively.**

Constituent	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)		
		5th %ile	50th %ile	95th %ile
		80x Dilution	213x Dilution	529x Dilution
Total Oil (including BTEX)	30	0.38	0.14	0.06
Mercury	0.03	$3.75*10^{-5}$	$1.41*10^{-4}$	$5.67*10^{-5}$

Table 3.10 **Concentrations of total oil and mercury, and number of dilutions, at the end of the near-field stage for the winter season. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 76, 193 and 469, respectively.**

Constituent	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)		
		5th %ile	50th %ile	95th %ile
		76x Dilution	193x Dilution	469x Dilution
Total Oil (including BTEX)	30	0.39	0.16	0.06
Mercury	0.03	$3.95*10^{-4}$	$1.55*10^{-4}$	$6.40*10^{-5}$

3.1.2.2.1.1 Annualised

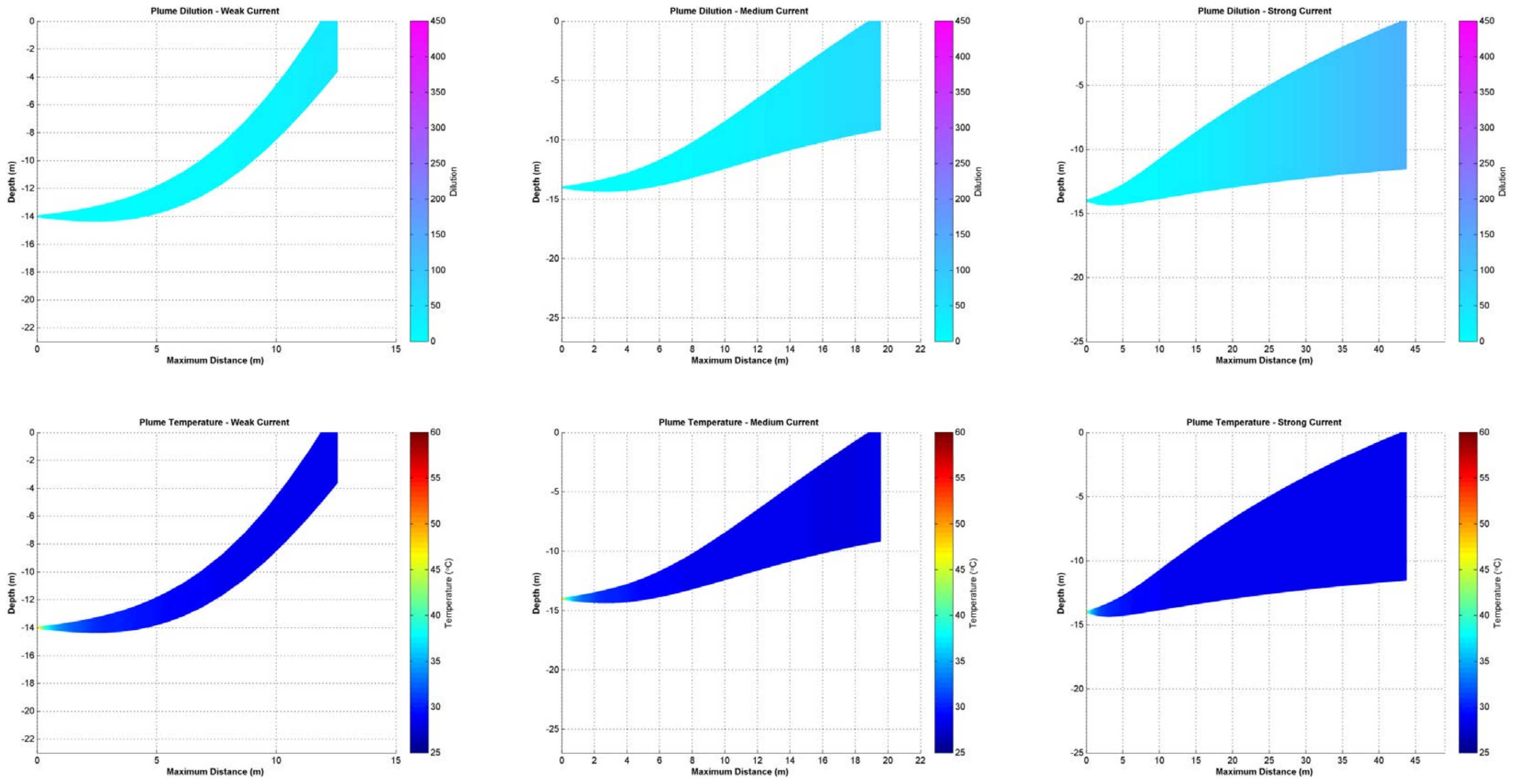


Figure 3.5 Near-field average dilution and temperature results for constant weak, medium and strong annualised currents (14 m depth discharge at 5,723 m^3/d flow rate).

3.1.2.2.1.2 Summer

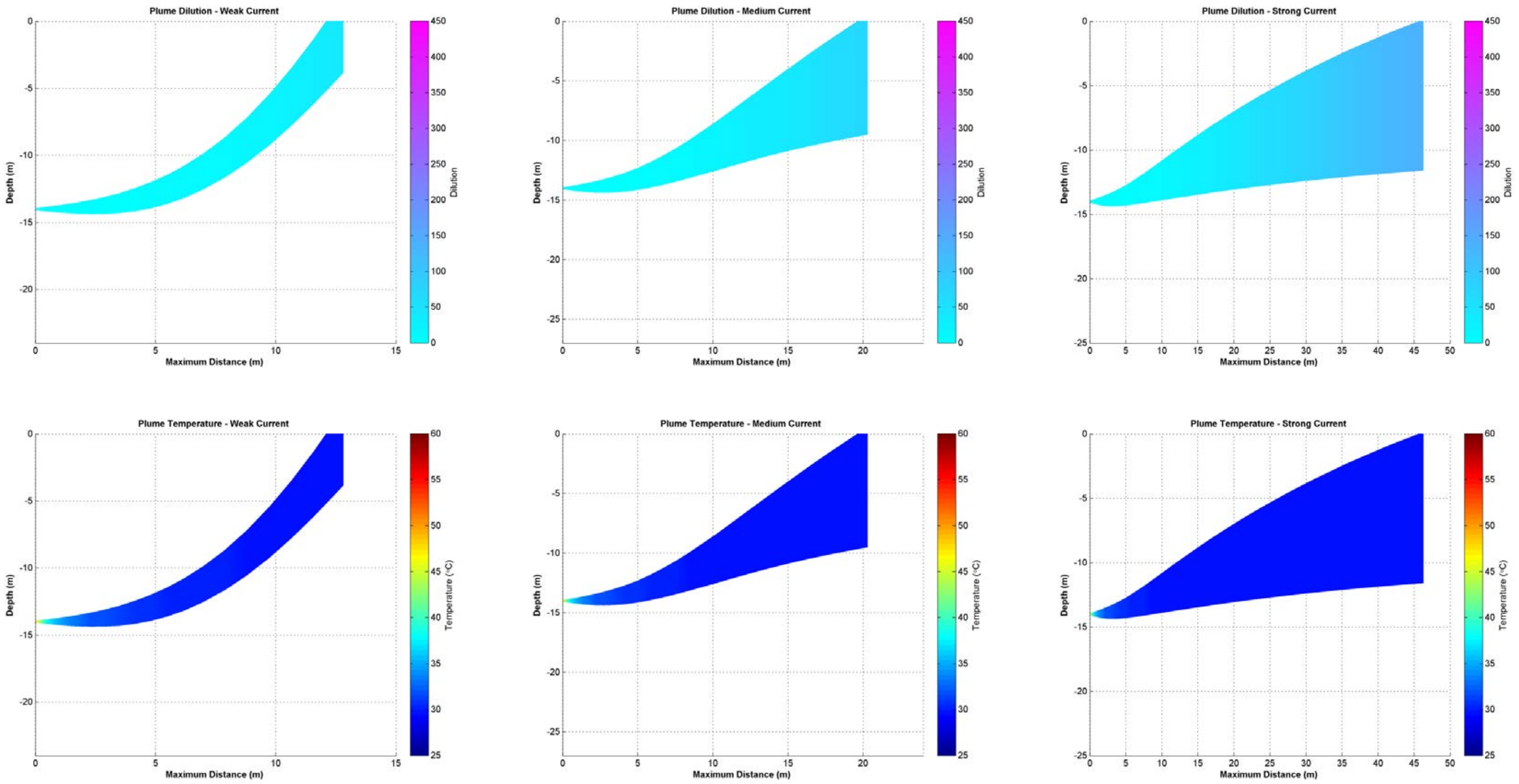


Figure 3.6 Near-field average dilution and temperature results for constant weak, medium and strong summer currents (14 m depth discharge at 5,723 m^3/d flow rate).

3.1.2.2.1.3 Transitional

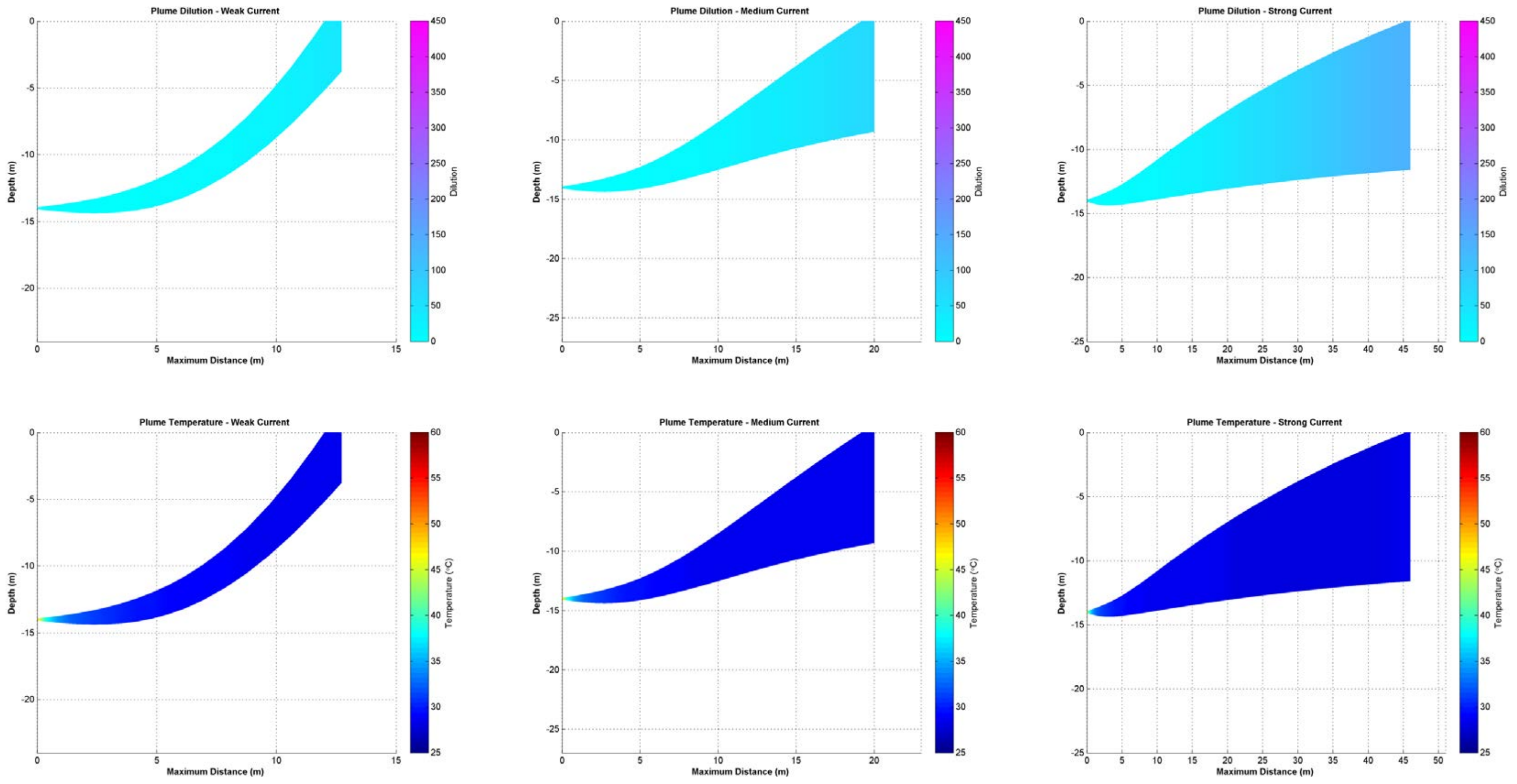


Figure 3.7 Near-field average dilution and temperature results for constant weak, medium and strong transitional currents (14 m depth discharge at 5,723 m^3/d flow rate).

3.1.2.2.1.4 Winter

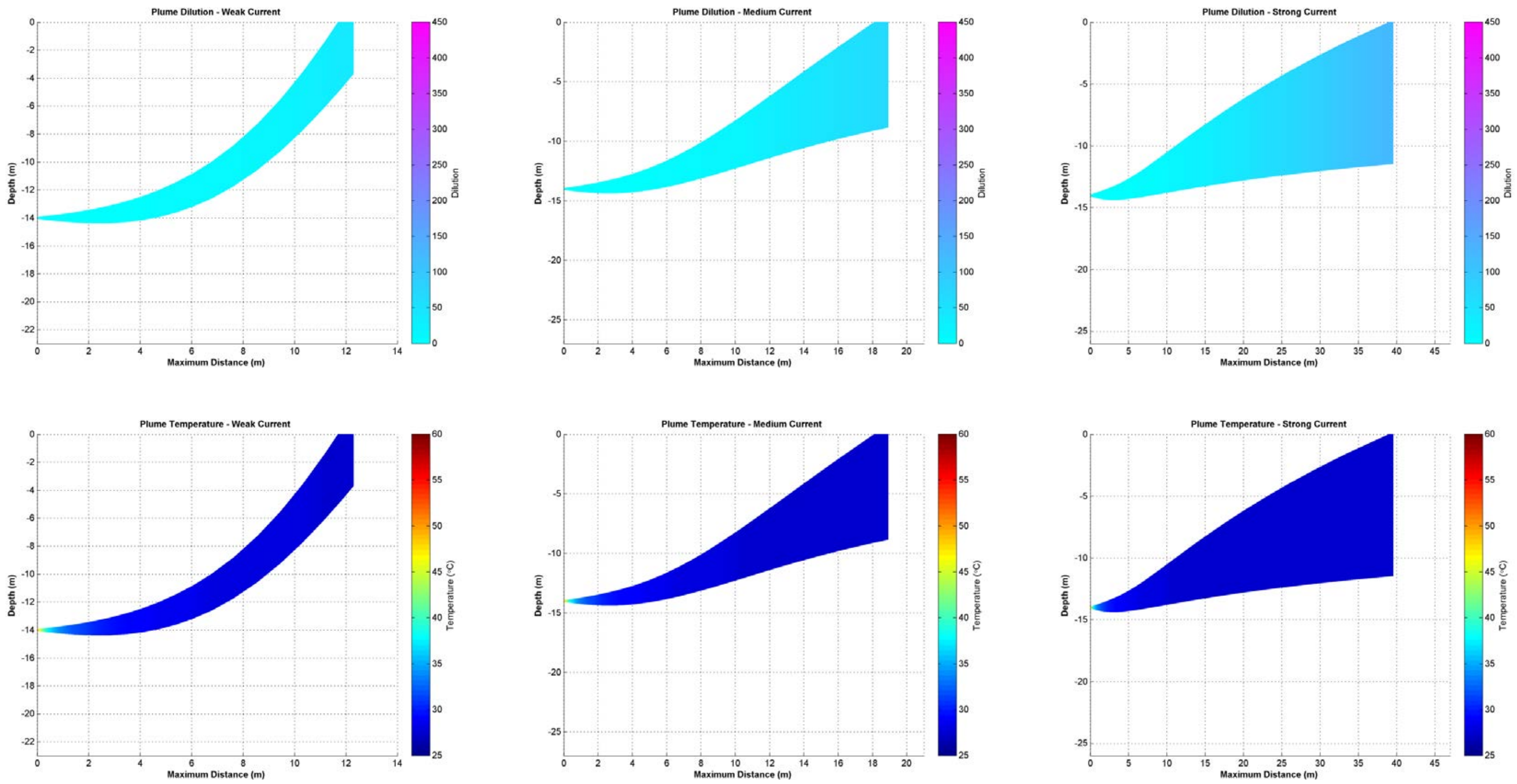


Figure 3.8 Near-field average dilution and temperature results for constant weak, medium and strong winter currents (14 m depth discharge at 5,723 m^3/d flow rate).

3.1.2.2.2 Discharge Case M: Flow Rate of 490 m^3/day at 14 m Depth

Table 3.11 Predicted plume characteristics at the end of the near-field mixing zone for the 14 m depth discharge for each season and current speed.

Season	Surface Current Speed (m/s)	Plume Diameter (m) at Depth [m]	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Annual	Weak (0.03)	4.8 [0.9]	28.35	0.00	143	295	4.3
	Medium (0.14)	8.0 [7.2]	28.16	0.00	323	1,222	20.2
	Strong (0.30)	6.2 [9.1]	28.49	0.00	410	1,592	43.4
Summer	Weak (0.04)	5.2 [1.1]	29.63	0.00	153	327	4.8
	Medium (0.15)	7.7 [7.5]	29.43	0.00	313	1,191	20.7
	Strong (0.32)	6.0 [7.4]	29.45	0.00	401	1,558	44.0
Transitional	Weak (0.04)	5.1 [1.1]	28.44	0.00	150	318	4.7
	Medium (0.14)	7.9 [7.3]	28.29	0.00	321	1,217	20.6
	Strong (0.32)	6.1 [7.5]	28.26	0.00	418	1,620	45.3
Winter	Weak (0.03)	4.6 [0.6]	27.56	0.00	137	280	4.0
	Medium (0.13)	8.2 [6.8]	27.38	0.00	327	1,233	19.7
	Strong (0.28)	6.5 [9.0]	27.32	0.00	427	1,655	42.5

Table 3.12 Concentrations of MEG and number of dilutions at the end of the near-field stage for the annual period. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 295, 1,222 and 1,592, respectively.

Constituent	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)		
		5th %ile 295x Dilution	50th %ile 1,222x Dilution	95th %ile 1,592x Dilution
MEG	79,000	267.80	64.65	49.62

Table 3.13 Concentrations of MEG and number of dilutions at the end of the near-field stage for the summer season. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 327, 1,191 and 1,558, respectively.

Constituent	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)		
		5th %ile	50th %ile	95th %ile
		327x Dilution	1,191x Dilution	1,558x Dilution
MEG	79,000	241.59	66.33	50.71

Table 3.14 Concentrations of MEG and number of dilutions at the end of the near-field stage for the transitional season. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 318, 1,217 and 1,620, respectively.

Constituent	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)		
		5th %ile	50th %ile	95th %ile
		318x Dilution	1,217x Dilution	1,620x Dilution
MEG	79,000	248.43	64.91	48.77

Table 3.15 Concentrations of MEG and number of dilutions at the end of the near-field stage for the winter season. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 280, 1,233 and 1,655, respectively.

Constituent	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)		
		5th %ile	50th %ile	95th %ile
		280x Dilution	1,233x Dilution	1,655x Dilution
MEG	79,000	282.14	64.07	47.73

3.1.2.2.2.1 Annualised

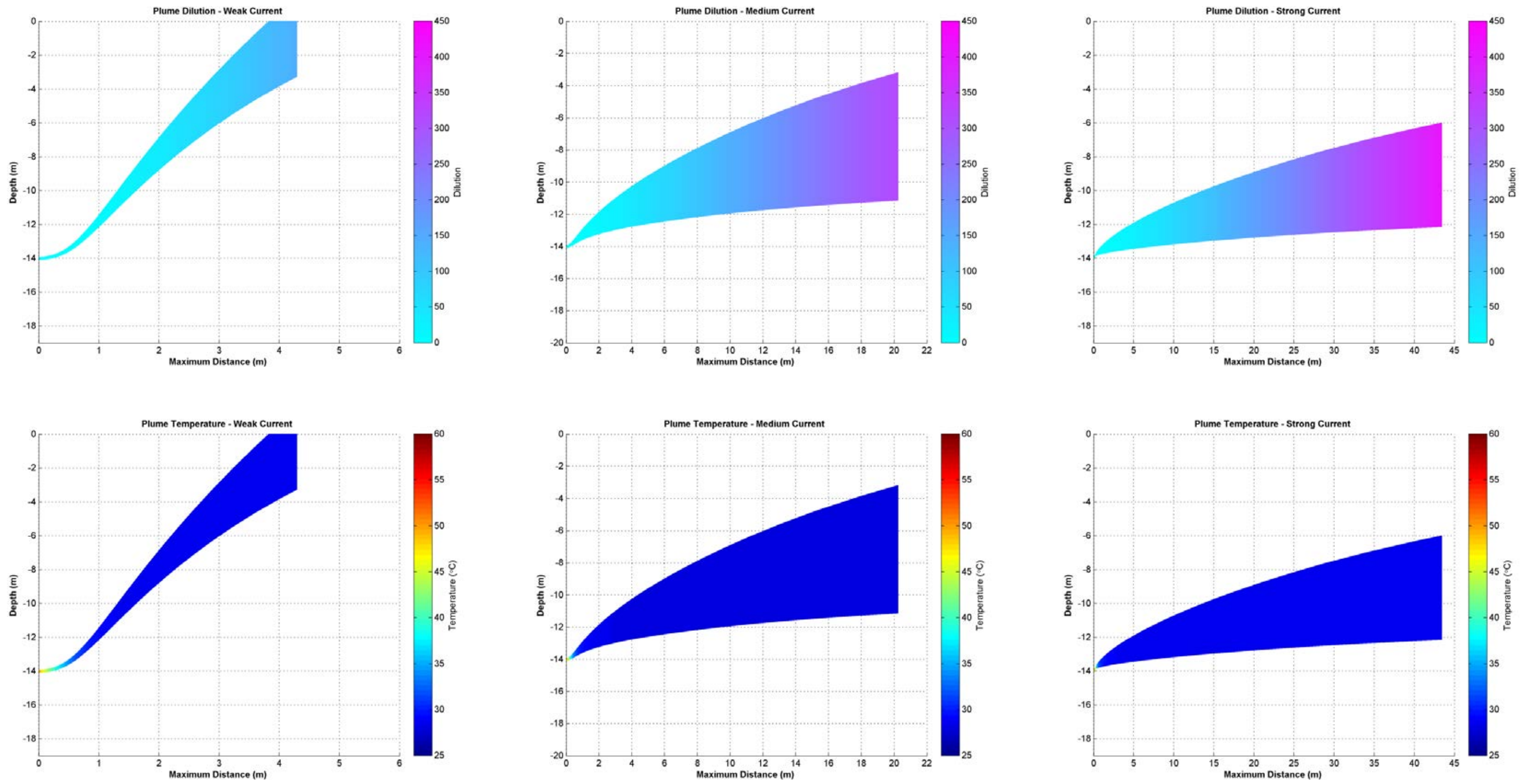


Figure 3.9 Near-field average dilution and temperature results for constant weak, medium and strong annualised currents (14 m depth discharge at 490 m^3/d flow rate).

3.1.2.2.2.2 Summer

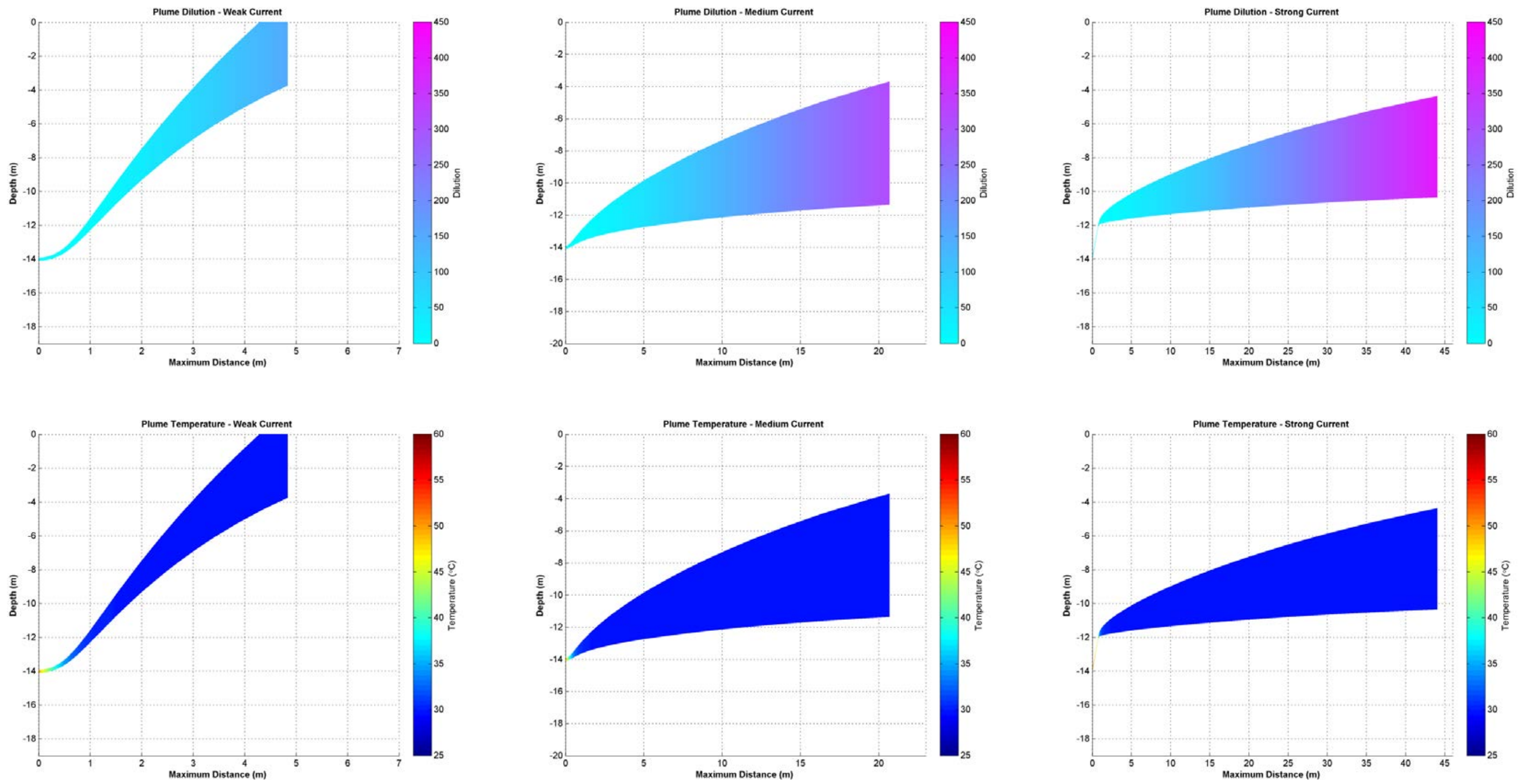


Figure 3.10 Near-field average dilution and temperature results for constant weak, medium and strong summer currents (14 m depth discharge at 490 m^3/d flow rate).

3.1.2.2.2.3 Transitional

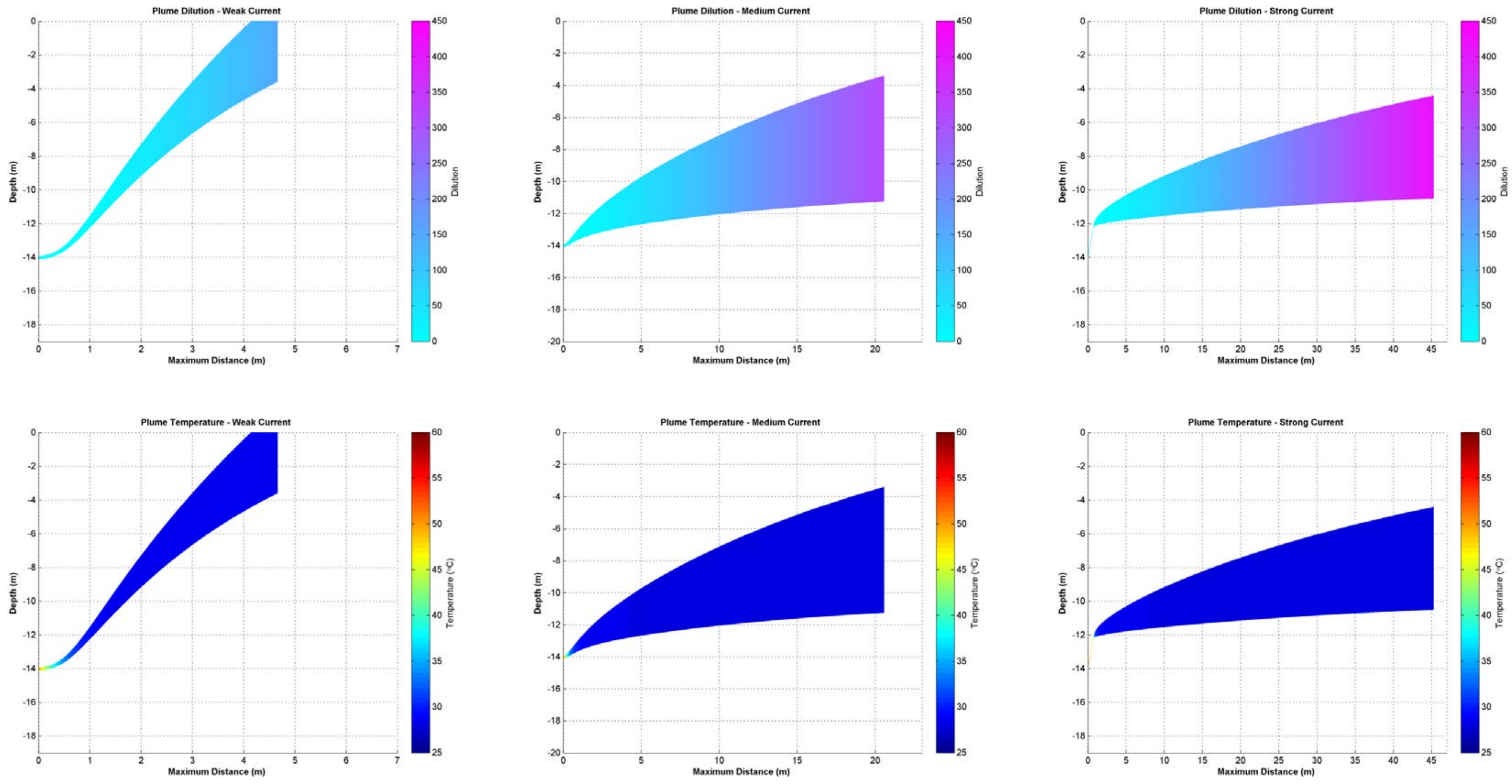


Figure 3.11 Near-field average dilution and temperature results for constant weak, medium and strong transitional currents (14 m depth discharge at 490 m^3/d flow rate).

3.1.2.2.2.4 Winter

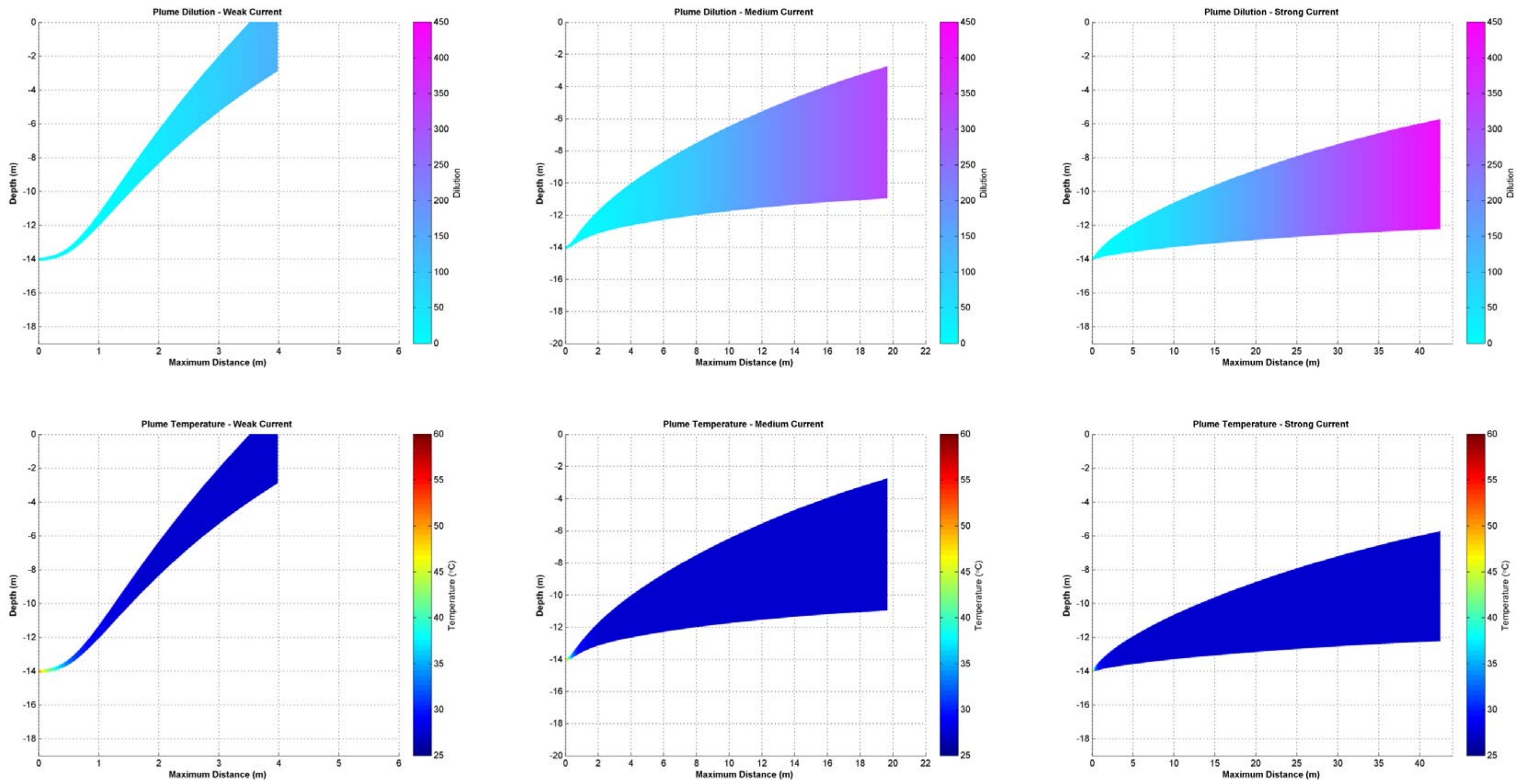


Figure 3.12 Near-field average dilution and temperature results for constant weak, medium and strong winter currents (14 m depth discharge at 490 m^3/d flow rate).

3.1.3 Hydrotest Discharges

3.1.3.1 Overview

In the following sections, information for each of the modelled discharge cases is presented first in a table summarising the predicted plume characteristics in the near-field mixing zone under varying current speeds, and then in further tables summarising the concentrations of biocide and the amount of dilution at the end of the near-field mixing zone for each season and for the annual period.

Figure 3.13 to Figure 3.28 (note the differing x-axis and y-axis aspect ratios) show the change in average dilution and temperature of the plume at a discharge rate of 25 m^3/min, under varying discharge depths (117 m, 461 m and 539 m), seasonal conditions (summer, transitional, winter and annual) and current speeds (weak, medium and strong). The figures show the predicted horizontal distance travelled by the plume before the trapping depth is reached (i.e. before the plume becomes neutrally buoyant).

The results show that due to the momentum of the discharges a turbulent mixing zone is created in the immediate vicinity of the discharge points, which are 117 m (Case H1), 461 m (Cases H2 and H3b) and 539 m (Case H3a) below the water surface. Following this initial mixing, the near neutrally buoyant plumes are predicted to travel laterally in the water column. Increased ambient current strengths are shown to increase the horizontal distance travelled by the plume from the discharge point.

Table 3.16, Table 3.21, Table 3.26 and Table 3.31 show the predicted plume characteristics for the varying discharge depths, seasonal conditions and current speeds. High annualised currents push the plume to a maximum horizontal distance of 64.5 m, 101.2 m, 103.0 m and 101.2 m for the Case H1, H2, H3a and H3b discharges, respectively. The annualised maximum diameter of the plume at the end of the near-field zone is forecast to be 15.8 m for Case H1, 23.4 m for Case H2, 24.0 m for Case H3a and 23.4 m for Case H3b.

For all combinations of discharge case and season, the primary factor influencing dilution of the plume is the strength of the ambient current. The annualised average dilution levels of the plume upon reaching the trapping depth under medium currents are predicted to be 1:111 for Case H1, 1:166 for Case H2, 1:172 for Case H3a and 1:166 for Case H3b. Additionally, the annualised minimum dilution levels of the plume (i.e. dilution of the plume centreline) upon encountering the trapping depth under medium currents are predicted to be 1:41 for Case H1, 1:62 for Case H2, 1:65 for Case H3a and 1:62 for Case H3b. Note that these predictions of dilution rely on the persistence of current speed and direction over time and do not account for any build-up of plume concentrations due to slack currents or current reversals.

3.1.3.2 Results – Tables and Figures

3.1.3.2.1 Discharge Case H1: NRC Tie-In Hydrotest Discharge of 736,000 m^3 at 117 m Depth

Table 3.16 Predicted plume characteristics at the end of the near-field mixing zone for the NRC tie-in 736,000 m^3 hydrotest discharge for each season and current speed.

Season	Surface Current Speed (m/s)	Plume Diameter (m) at Depth [m]	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Annual	Weak (0.04)	15.8 [116.0]	23.42	0.00	41	90	41.7
	Medium (0.16)	14.8 [116.0]	23.42	0.00	41	111	49.5
	Strong (0.35)	13.2 [116.0]	23.42	0.00	43	136	64.5
Summer	Weak (0.04)	13.4 [116.0]	23.61	0.00	42	125	57.6
	Medium (0.16)	14.5 [116.0]	23.61	0.00	41	109	48.5
	Strong (0.34)	13.2 [116.0]	23.61	0.00	43	133	62.8
Transitional	Weak (0.04)	15.5 [115.9]	22.78	0.00	41	88	40.9
	Medium (0.16)	14.7 [115.9]	22.78	0.00	41	111	49.5
	Strong (0.36)	13.0 [115.9]	22.77	0.00	43	136	64.8
Winter	Weak (0.04)	14.1 [116.1]	23.89	0.00	45	139	64.7
	Medium (0.16)	15.3 [116.2]	23.89	0.00	43	118	52.5
	Strong (0.35)	13.7 [116.1]	23.89	0.00	45	144	69.1

Table 3.17 Concentrations of biocide and number of dilutions at the end of the near-field stage for the annual period. Note from Table 3.16 that dilutions at the 5th, 50th and 95th percentile current speeds were 90, 111 and 136, respectively.

Constituent	Source Concentration (ppm)	End of Near-Field Concentration (ppm)		
		5th %ile	50th %ile	95th %ile
		90x Dilution	111x Dilution	136x Dilution
Biocide	600	6.7	5.4	4.4

Table 3.18 Concentrations of biocide and number of dilutions at the end of the near-field stage for the summer season. Note from Table 3.16 that dilutions at the 5th, 50th and 95th percentile current speeds were 125, 109 and 133, respectively.

Constituent	Source Concentration (ppm)	End of Near-Field Concentration (ppm) 5th %ile 125x Dilution	 50th %ile 109x Dilution	 95th %ile 133x Dilution
Biocide	600	4.8	5.5	4.5

Table 3.19 Concentrations of biocide and number of dilutions at the end of the near-field stage for the transitional season. Note from Table 3.16 that dilutions at the 5th, 50th and 95th percentile current speeds were 88, 111 and 136, respectively.

Constituent	Source Concentration (ppm)	End of Near-Field Concentration (ppm) 5th %ile 88x Dilution	 50th %ile 111x Dilution	 95th %ile 136x Dilution
Biocide	600	6.8	5.4	4.4

Table 3.20 Concentrations of biocide and number of dilutions at the end of the near-field stage for the winter season. Note from Table 3.16 that dilutions at the 5th, 50th and 95th percentile current speeds were 139, 118 and 144, respectively.

Constituent	Source Concentration (ppm)	End of Near-Field Concentration (ppm) 5th %ile 139x Dilution	 50th %ile 118x Dilution	 95th %ile 144x Dilution
Biocide	600	4.3	5.1	4.2

3.1.3.2.1.1 Annualised

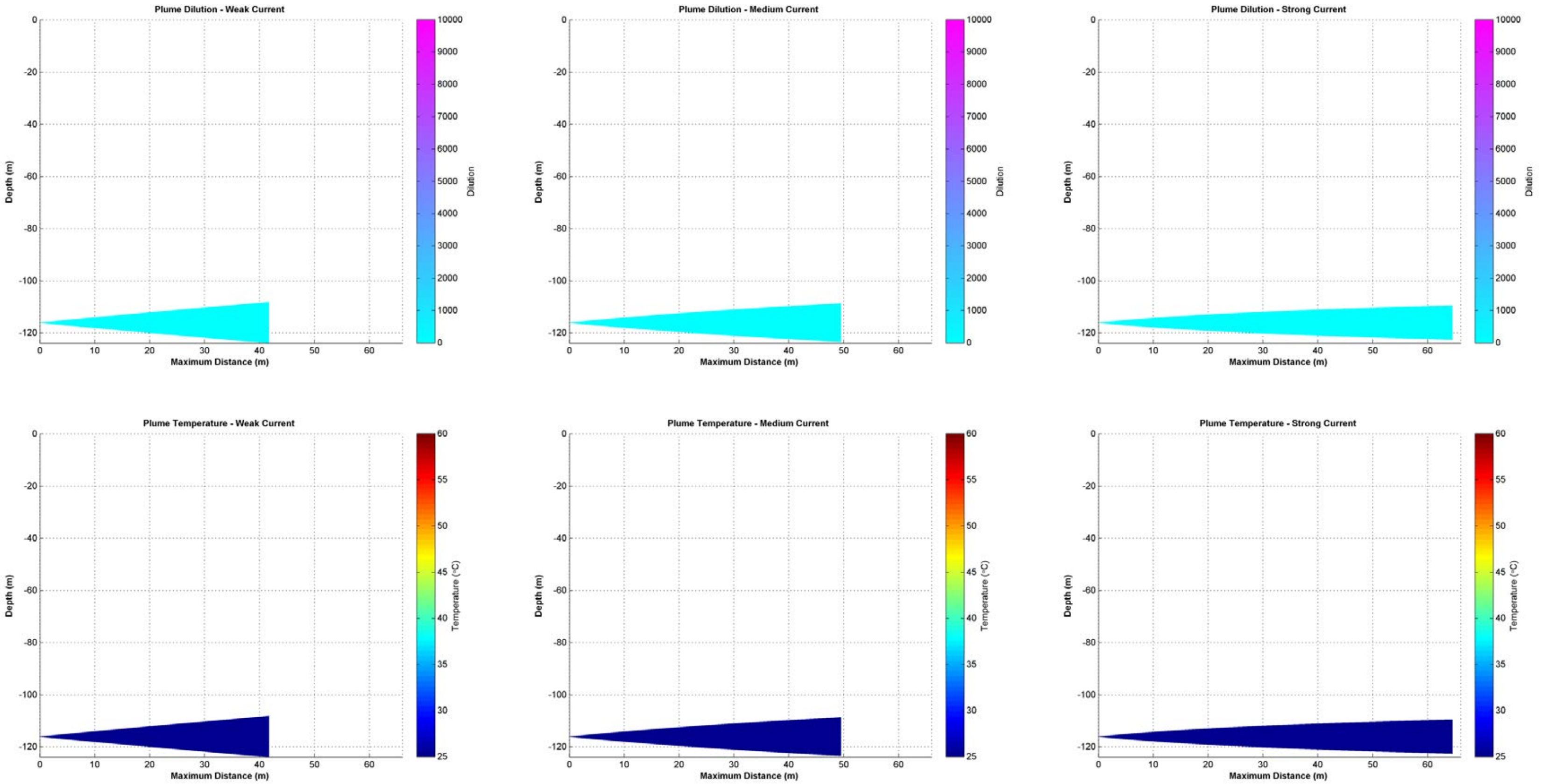


Figure 3.13 Near-field average dilution and temperature results for constant weak, medium and strong annualised currents (NRC tie-in 736,000 m^3 hydrotest discharge).

3.1.3.2.1.2 Summer

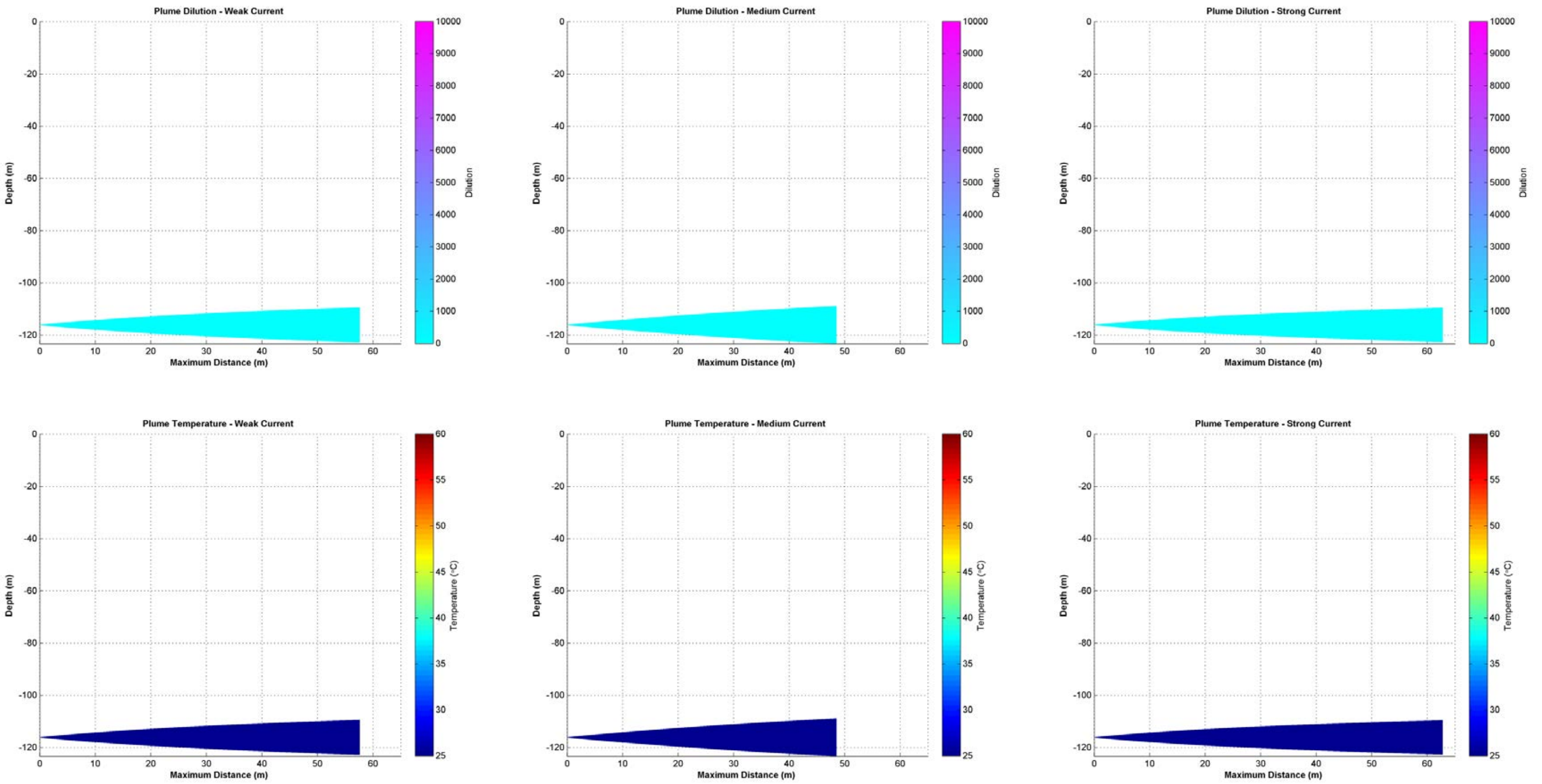


Figure 3.14 Near-field average dilution and temperature results for constant weak, medium and strong summer currents (NRC tie-in 736,000 m^3 hydrotest discharge).

3.1.3.2.1.3 Transitional

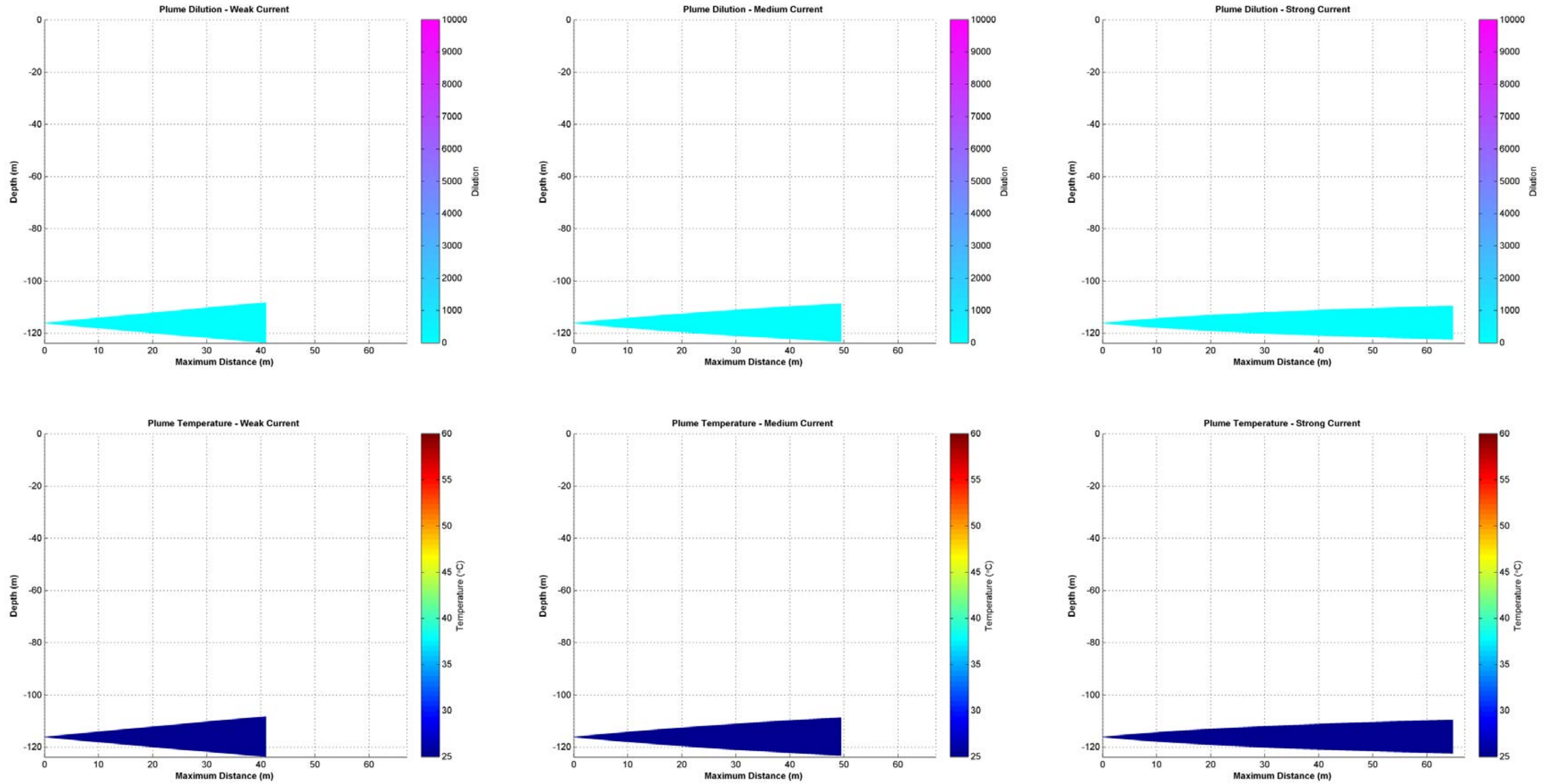


Figure 3.15 Near-field average dilution and temperature results for constant weak, medium and strong transitional currents (NRC tie-in 736,000 m^3 hydrotest discharge).

3.1.3.2.1.4 Winter

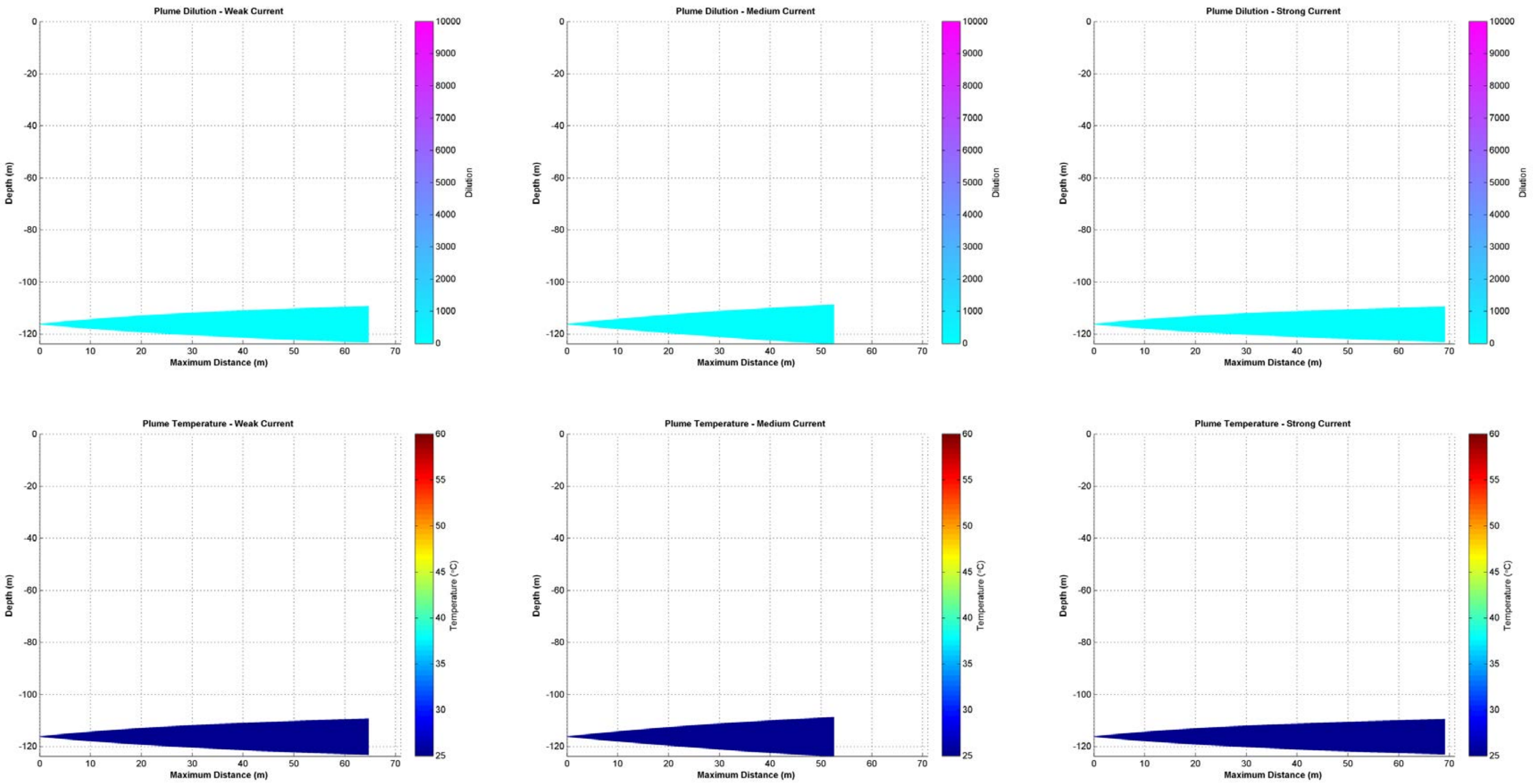


Figure 3.16 Near-field average dilution and temperature results for constant weak, medium and strong winter currents (NRC tie-in 736,000 m^3 hydrotest discharge).

3.1.3.2.2 Discharge Case H2: Torosa Hydrotest Discharge of 846,000 m^3 at 461 m Depth

Table 3.21 Predicted plume characteristics at the end of the near-field mixing zone for the Torosa 846,000 m^3 hydrotest discharge for each season and current speed.

Season	Surface Current Speed (m/s)	Plume Diameter (m) at Depth [m]	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Annual	Weak (0.02)	23.4 [460.5]	10.67	0.00	61	126	59.9
	Medium (0.10)	22.3 [460.4]	10.68	0.00	62	166	73.6
	Strong (0.26)	19.5 [460.3]	10.68	0.00	66	210	101.2
Summer	Weak (0.02)	23.7 [460.5]	10.65	0.00	62	136	63.3
	Medium (0.10)	22.3 [460.4]	10.65	0.00	62	166	73.6
	Strong (0.25)	19.5 [460.3]	10.65	0.00	66	210	101.1
Transitional	Weak (0.02)	23.8 [460.4]	10.55	0.00	62	128	61.0
	Medium (0.10)	22.7 [460.3]	10.55	0.00	64	172	76.6
	Strong (0.27)	19.8 [460.3]	10.55	0.00	68	218	106.5
Winter	Weak (0.02)	23.0 [460.5]	10.80	0.00	60	123	58.8
	Medium (0.10)	22.1 [460.4]	10.80	0.00	62	162	72.2
	Strong (0.25)	19.4 [460.3]	10.80	0.00	65	206	98.5

Table 3.22 Concentrations of biocide and number of dilutions at the end of the near-field stage for the annual period. Note from Table 3.21 that dilutions at the 5th, 50th and 95th percentile current speeds were 126, 166 and 210, respectively.

Constituent	Source Concentration (ppm)	End of Near-Field Concentration (ppm)		
		5th %ile	50th %ile	95th %ile
		126x Dilution	166x Dilution	210x Dilution
Biocide	600	4.8	3.6	2.9

Table 3.23 Concentrations of biocide and number of dilutions at the end of the near-field stage for the summer season. Note from Table 3.21 that dilutions at the 5th, 50th and 95th percentile current speeds were 136, 166 and 210, respectively.

Constituent	Source Concentration (ppm)	End of Near-Field Concentration (ppm)		
		5th %ile	50th %ile	95th %ile
		136x Dilution	166x Dilution	210x Dilution
Biocide	600	4.4	3.6	2.9

Table 3.24 Concentrations of biocide and number of dilutions at the end of the near-field stage for the transitional season. Note from Table 3.21 that dilutions at the 5th, 50th and 95th percentile current speeds were 128, 172 and 218, respectively.

Constituent	Source Concentration (ppm)	End of Near-Field Concentration (ppm)		
		5th %ile	50th %ile	95th %ile
		128x Dilution	172x Dilution	218x Dilution
Biocide	600	4.7	3.5	2.8

Table 3.25 Concentrations of biocide and number of dilutions at the end of the near-field stage for the winter season. Note from Table 3.21 that dilutions at the 5th, 50th and 95th percentile current speeds were 123, 162 and 206, respectively.

Constituent	Source Concentration (ppm)	End of Near-Field Concentration (ppm)		
		5th %ile	50th %ile	95th %ile
		123x Dilution	162x Dilution	206x Dilution
Biocide	600	4.9	3.7	2.9

3.1.3.2.2.1 Annualised

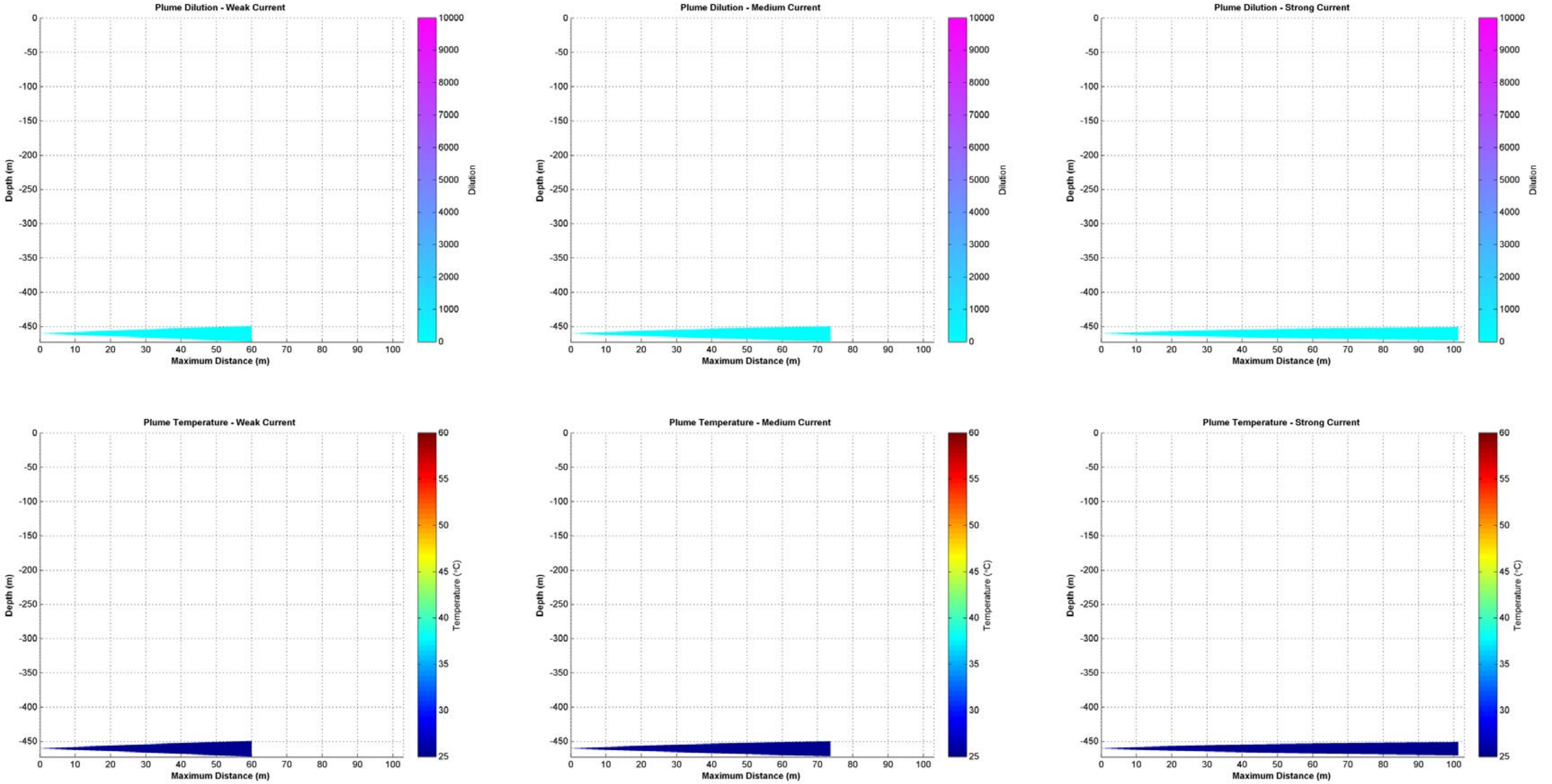


Figure 3.17 Near-field average dilution and temperature results for constant weak, medium and strong annualised currents (Torosa 846,000 m^3 hydrotest discharge).

3.1.3.2.2.2 Summer

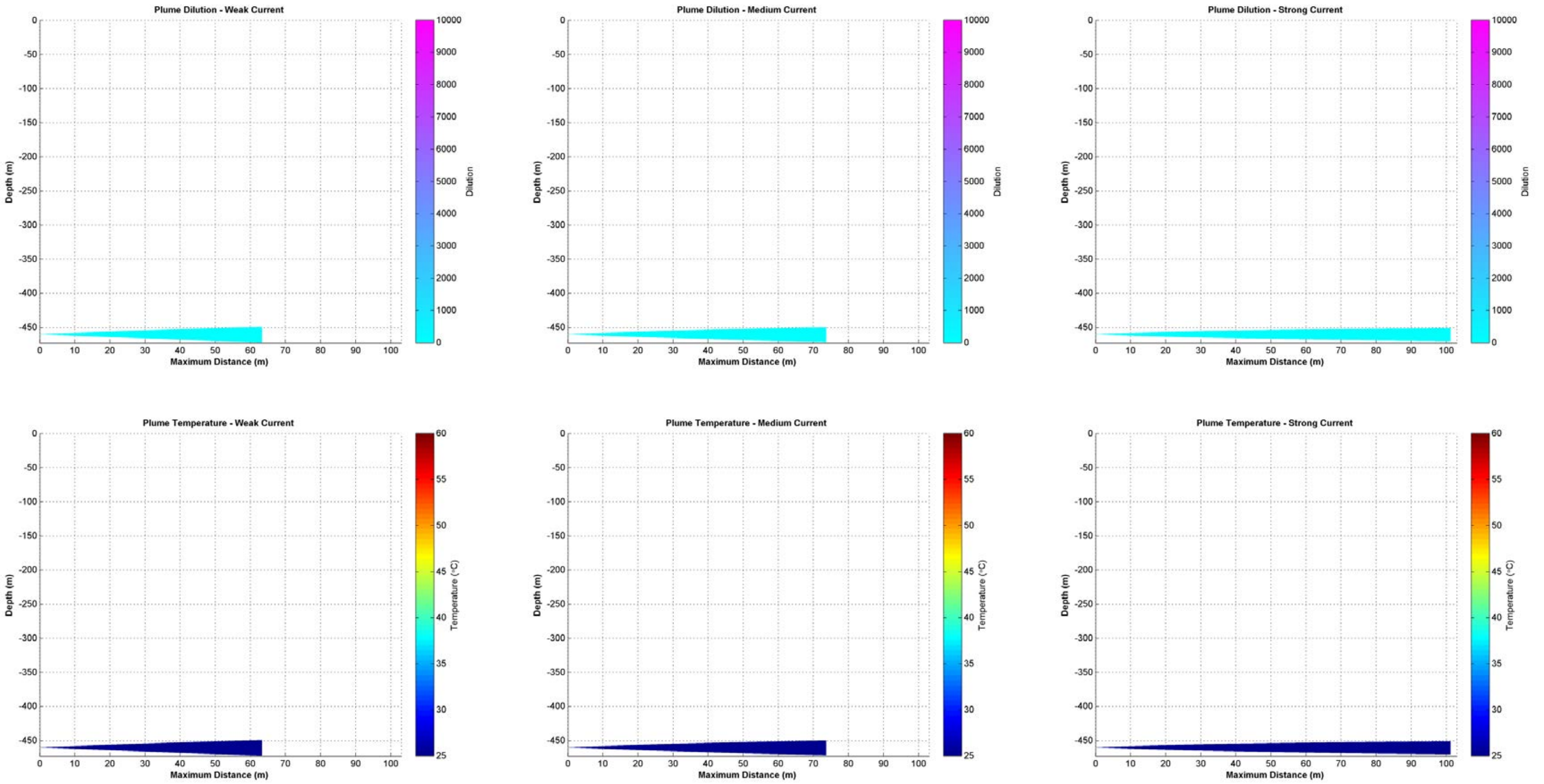


Figure 3.18 Near-field average dilution and temperature results for constant weak, medium and strong summer currents (Torosa 846,000 m^3 hydrotest discharge).

3.1.3.2.2.3 Transitional

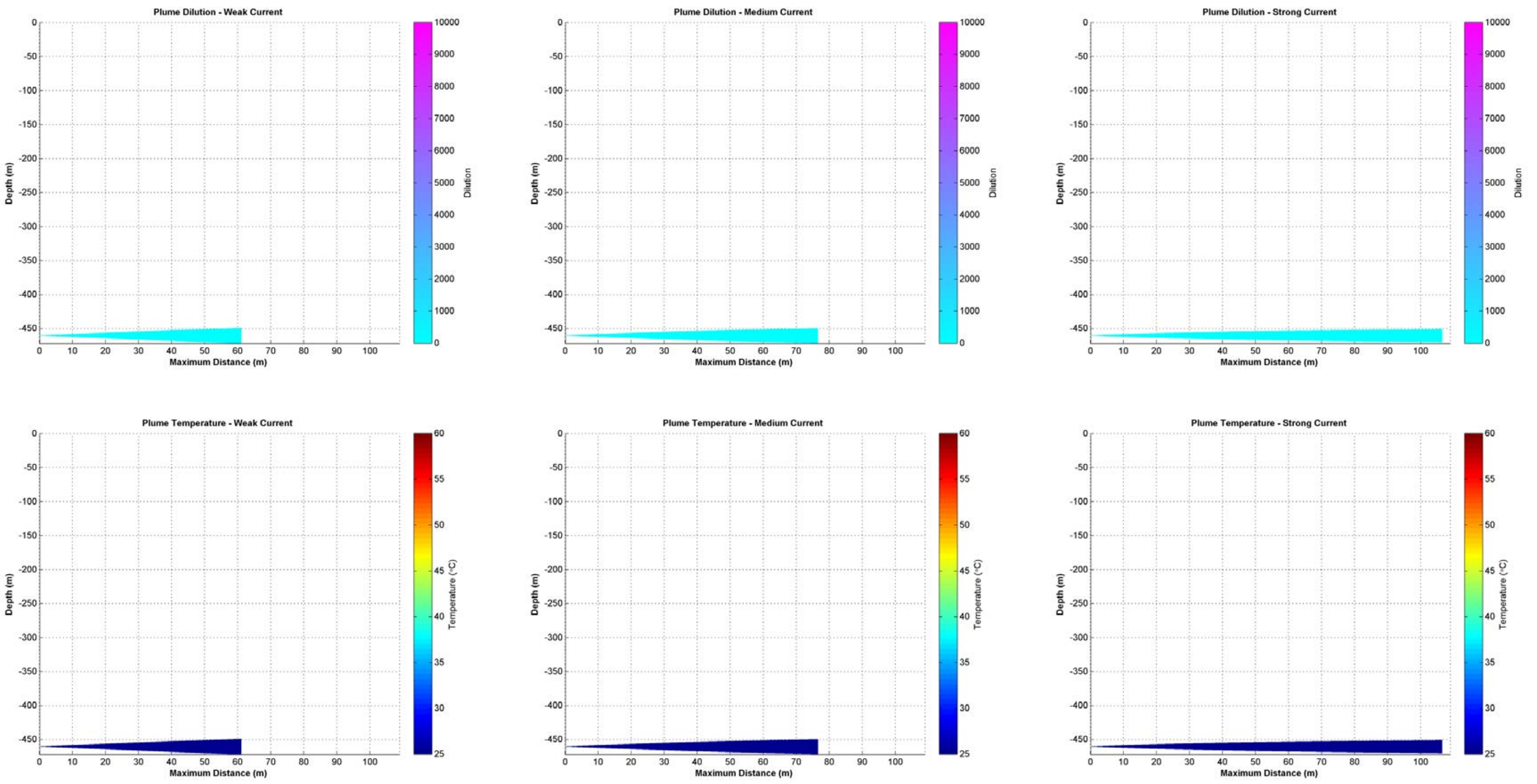


Figure 3.19 Near-field average dilution and temperature results for constant weak, medium and strong transitional currents (Torosa 846,000 m^3 hydrotest discharge).

3.1.3.2.2.4 Winter

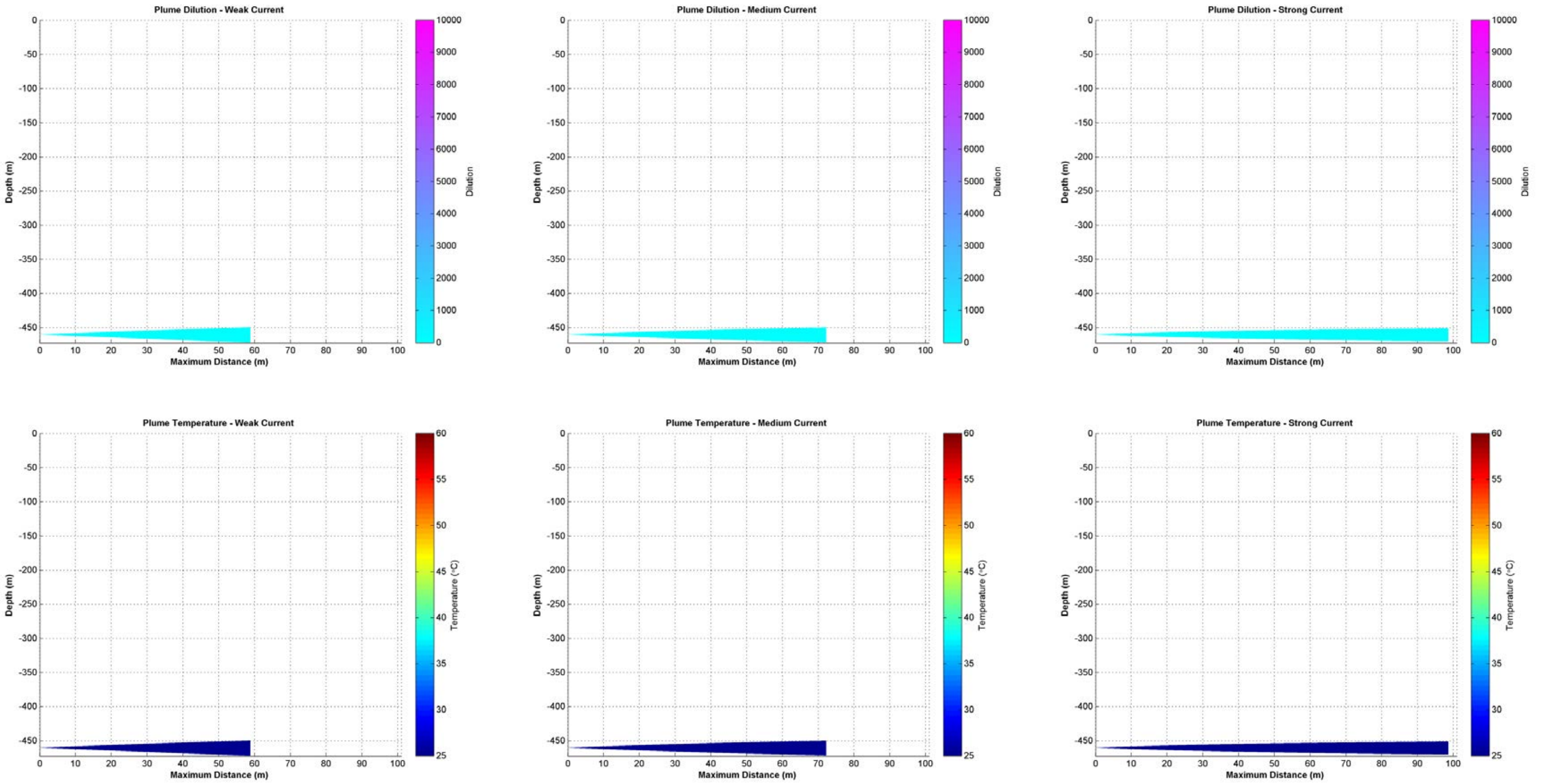


Figure 3.20 Near-field average dilution and temperature results for constant weak, medium and strong winter currents (Torosa 846,000 m^3 hydrotest discharge).

3.1.3.2.3 Discharge Case H3a: Brecknock/Calliance Hydrotest Discharge of 790,000 m^3 at 539 m Depth

Table 3.26 Predicted plume characteristics at the end of the near-field mixing zone for the Brecknock/Calliance 790,000 m^3 hydrotest discharge for each season and current speed.

Season	Surface Current Speed (m/s)	Plume Diameter (m) at Depth [m]	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Annual	Weak (0.02)	24.0 [538.1]	8.87	0.00	63	128	61.3
	Medium (0.10)	23.0 [538.1]	8.87	0.00	65	172	76.6
	Strong (0.26)	20.0 [538.1]	8.87	0.00	67	214	103.0
Summer	Weak (0.02)	24.3 [538.1]	8.87	0.00	64	141	65.5
	Medium (0.10)	23.0 [538.1]	8.87	0.00	64	172	76.6
	Strong (0.25)	20.3 [538.1]	8.87	0.00	68	218	105.3
Transitional	Weak (0.02)	24.8 [538.1]	8.86	0.00	65	133	63.6
	Medium (0.10)	23.2 [538.1]	8.86	0.00	65	176	78.1
	Strong (0.27)	20.3 [538.1]	8.86	0.00	69	223	108.1
Winter	Weak (0.02)	24.0 [538.1]	8.88	0.00	63	128	61.3
	Medium (0.10)	22.6 [538.1]	8.88	0.00	63	166	73.6
	Strong (0.25)	19.9 [538.1]	8.88	0.00	66	210	100.3

Table 3.27 Concentrations of biocide and number of dilutions at the end of the near-field stage for the annual period. Note from Table 3.26 that dilutions at the 5th, 50th and 95th percentile current speeds were 128, 172 and 214, respectively.

Constituent	Source Concentration (ppm)	End of Near-Field Concentration (ppm)		
		5th %ile	50th %ile	95th %ile
		128x Dilution	172x Dilution	214x Dilution
Biocide	600	4.7	3.5	2.8

Table 3.28 Concentrations of biocide and number of dilutions at the end of the near-field stage for the summer season. Note from Table 3.26 that dilutions at the 5th, 50th and 95th percentile current speeds were 141, 172 and 218, respectively.

Constituent	Source Concentration (ppm)	End of Near-Field Concentration (ppm)		
		5th %ile	50th %ile	95th %ile
		141x Dilution	172x Dilution	218x Dilution
Biocide	600	4.3	3.5	2.8

Table 3.29 Concentrations of biocide and number of dilutions at the end of the near-field stage for the transitional season. Note from Table 3.26 that dilutions at the 5th, 50th and 95th percentile current speeds were 133, 176 and 223, respectively.

Constituent	Source Concentration (ppm)	End of Near-Field Concentration (ppm)		
		5th %ile	50th %ile	95th %ile
		133x Dilution	176x Dilution	223x Dilution
Biocide	600	4.5	3.4	2.7

Table 3.30 Concentrations of biocide and number of dilutions at the end of the near-field stage for the winter season. Note from Table 3.26 that dilutions at the 5th, 50th and 95th percentile current speeds were 128, 166 and 210, respectively.

Constituent	Source Concentration (ppm)	End of Near-Field Concentration (ppm)		
		5th %ile	50th %ile	95th %ile
		128x Dilution	166x Dilution	210x Dilution
Biocide	600	4.7	3.6	2.9

3.1.3.2.3.1 Annualised

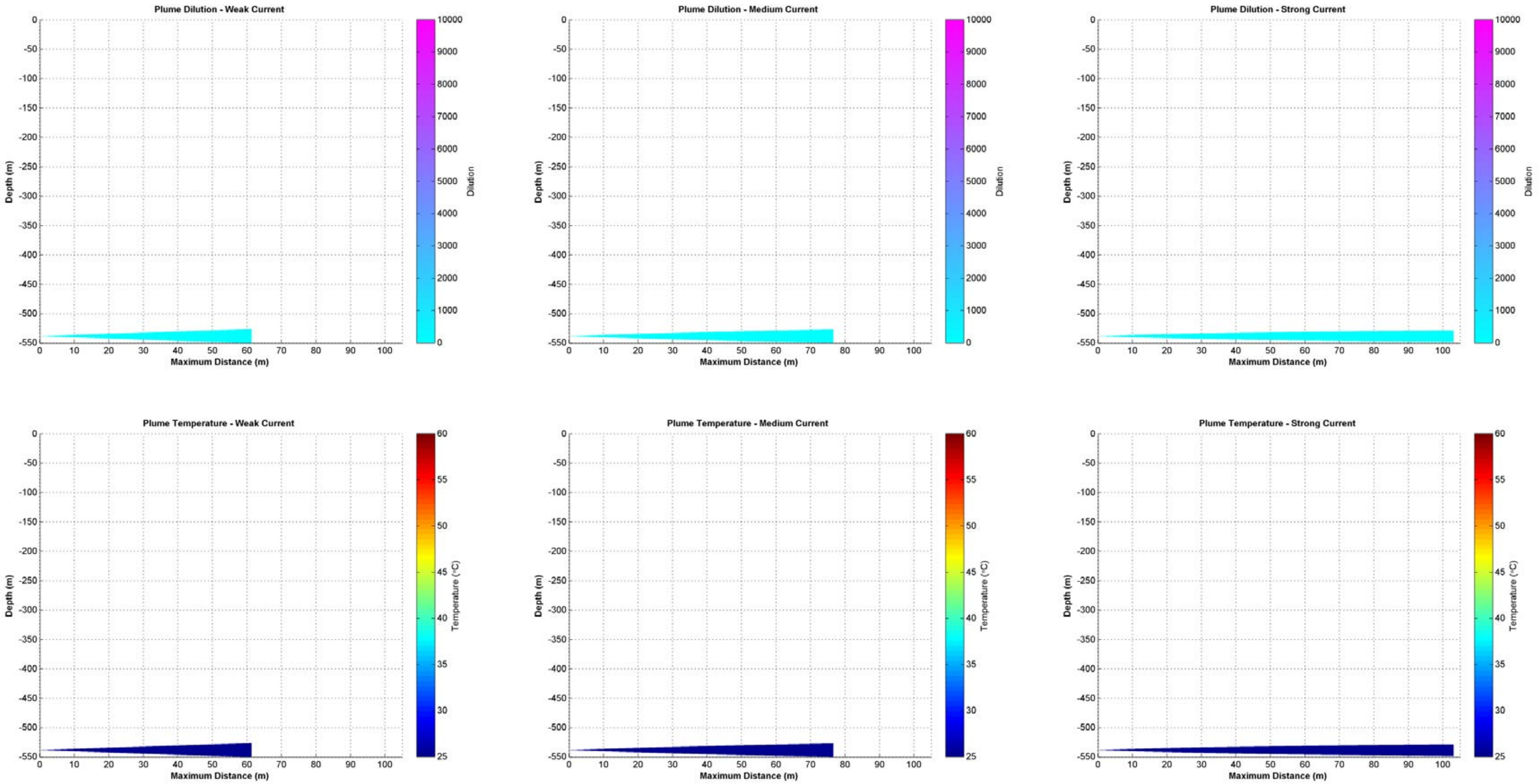


Figure 3.21 Near-field average dilution and temperature results for constant weak, medium and strong annualised currents (Brecknock/Calliance 790,000 m^3 hydrotest discharge).

3.1.3.2.3.2 Summer

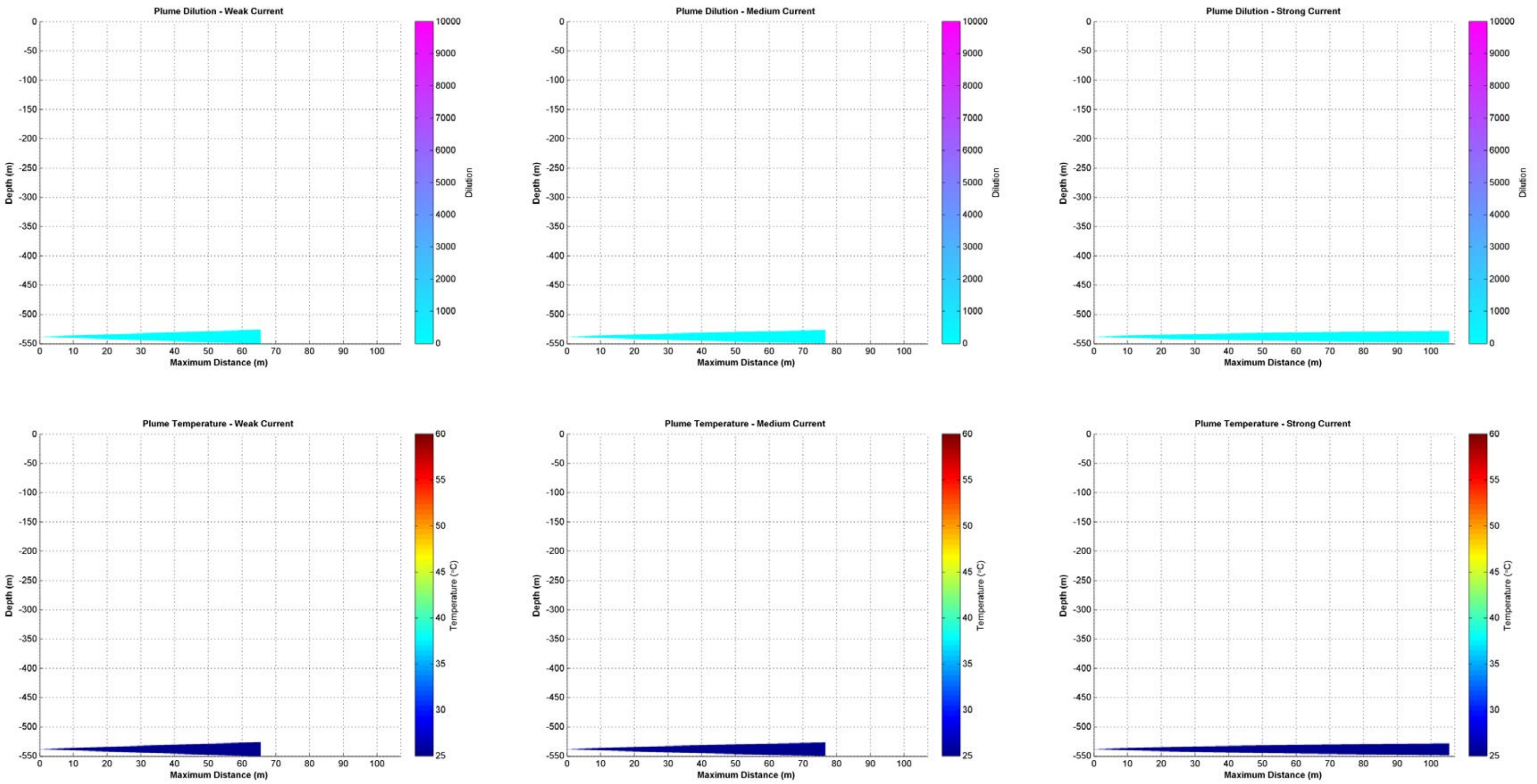


Figure 3.22 Near-field average dilution and temperature results for constant weak, medium and strong summer currents (Brecknock/Calliance 790,000 m^3 hydrotest discharge).

3.1.3.2.3.3 Transitional

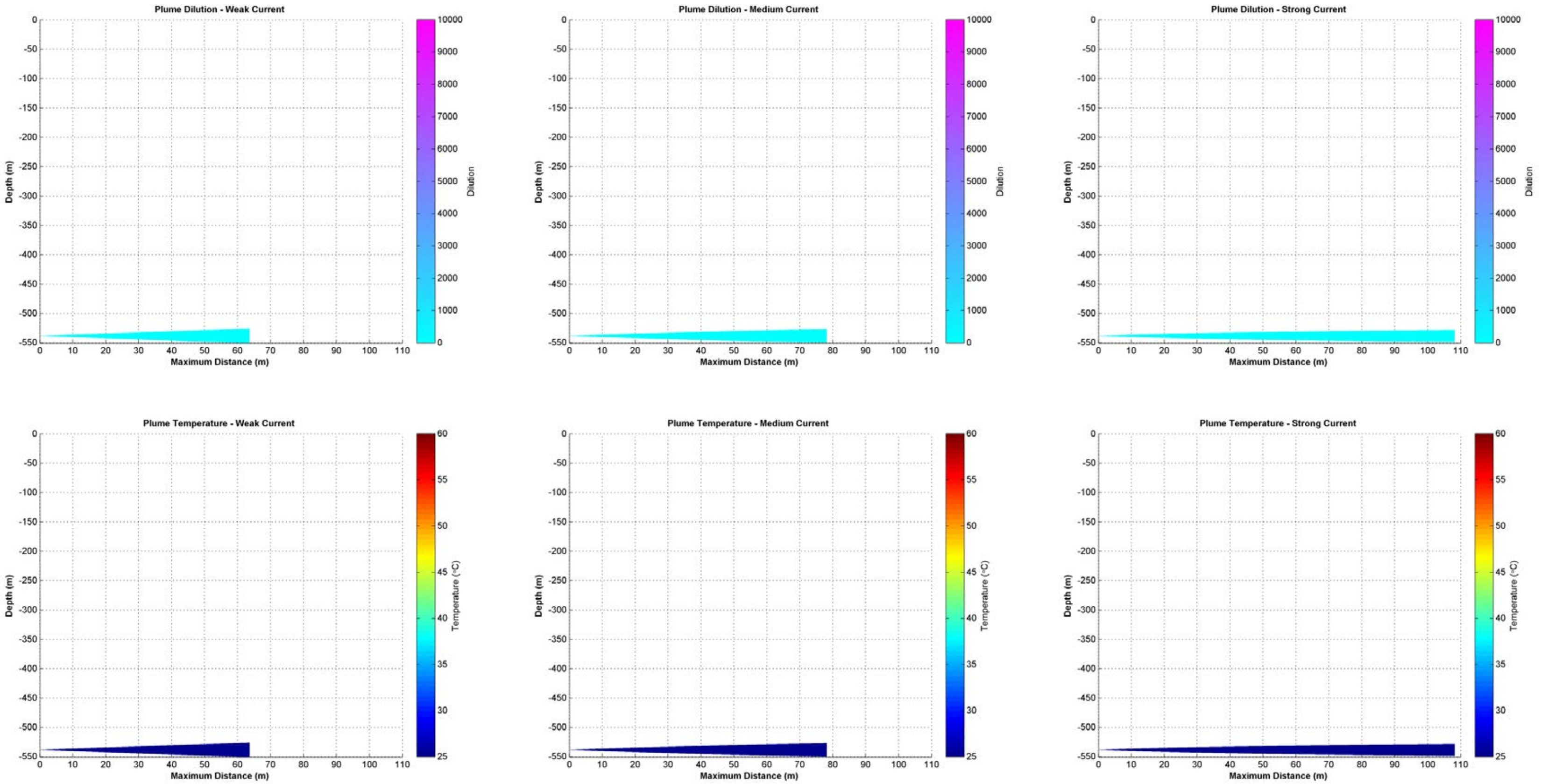


Figure 3.23 Near-field average dilution and temperature results for constant weak, medium and strong transitional currents (Brecknock/Calliance 790,000 m^3 hydrotest discharge).

3.1.3.2.3.4 Winter

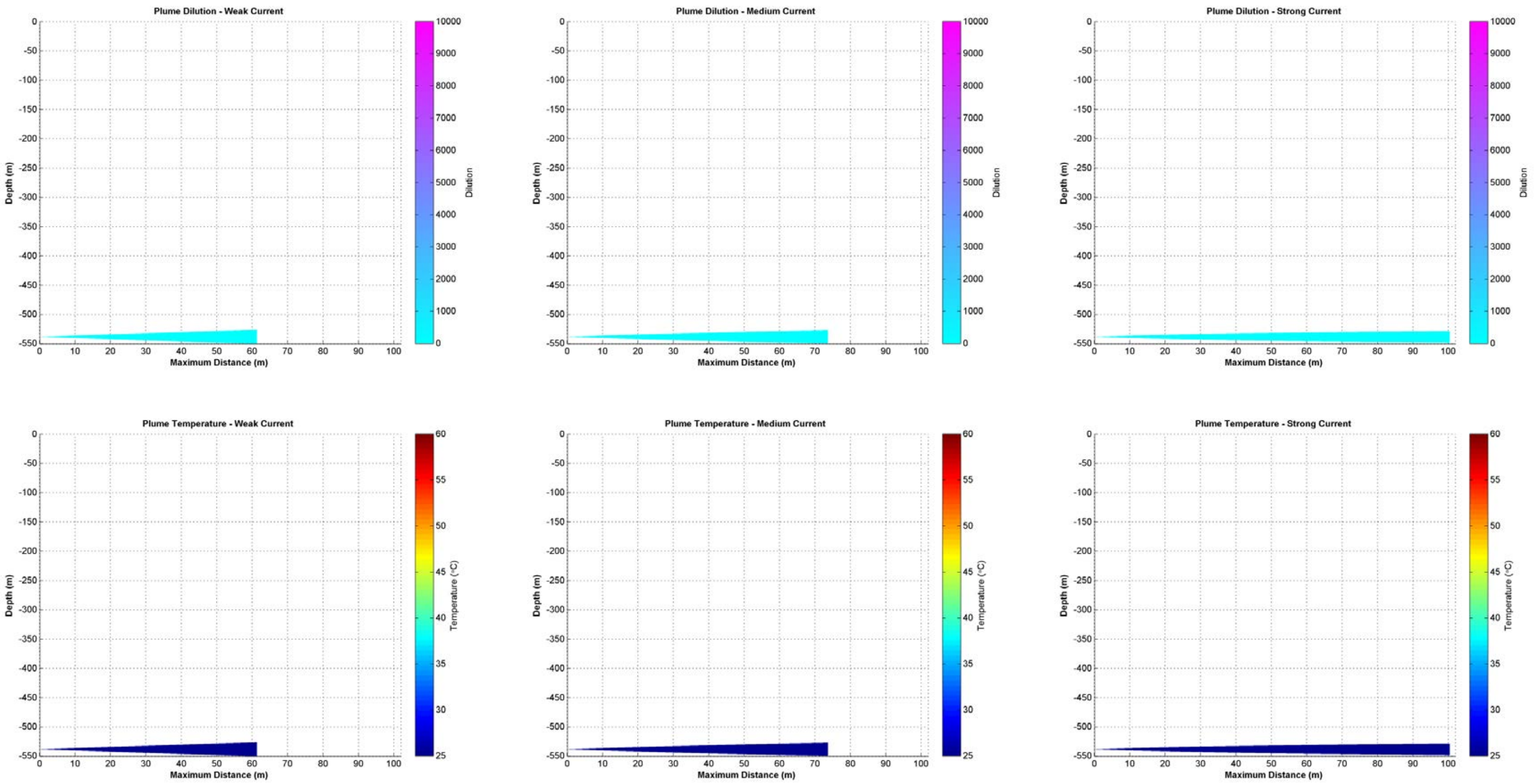


Figure 3.24 Near-field average dilution and temperature results for constant weak, medium and strong winter currents (Brecknock/Calliance 790,000 m^3 hydrotest discharge).

3.1.3.2.4 Discharge Case H3b: Torosa Hydrotest Discharge of 56,000 m^3 at 461 m Depth

Table 3.31 Predicted plume characteristics at the end of the near-field mixing zone for the Torosa 56,000 m^3 hydrotest discharge for each season and current speed.

Season	Surface Current Speed (m/s)	Plume Diameter (m) at Depth [m]	Plume Temperature (°C)	Plume-Ambient Temperature Difference (°C)	Plume Dilution (1:x)		Maximum Horizontal Distance (m)
					Minimum	Average	
Annual	Weak (0.02)	23.4 [460.5]	10.67	0.00	61	126	59.9
	Medium (0.10)	22.3 [460.4]	10.68	0.00	62	166	73.6
	Strong (0.26)	19.5 [460.3]	10.68	0.00	66	210	101.2
Summer	Weak (0.02)	23.7 [460.5]	10.65	0.00	62	136	63.3
	Medium (0.10)	22.3 [460.4]	10.65	0.00	62	166	73.6
	Strong (0.25)	19.5 [460.3]	10.65	0.00	66	210	101.1
Transitional	Weak (0.02)	23.8 [460.4]	10.55	0.00	62	128	61.0
	Medium (0.10)	22.7 [460.3]	10.55	0.00	64	172	76.6
	Strong (0.27)	19.8 [460.3]	10.55	0.00	68	218	106.5
Winter	Weak (0.02)	23.0 [460.5]	10.80	0.00	60	123	58.8
	Medium (0.10)	22.1 [460.4]	10.80	0.00	62	162	72.2
	Strong (0.25)	19.4 [460.3]	10.80	0.00	65	206	98.5

Table 3.32 Concentrations of biocide and number of dilutions at the end of the near-field stage for the annual period. Note from Table 3.31 that dilutions at the 5th, 50th and 95th percentile current speeds were 126, 166 and 210, respectively.

Constituent	Source Concentration (ppm)	End of Near-Field Concentration (ppm)		
		5th %ile	50th %ile	95th %ile
		126x Dilution	166x Dilution	210x Dilution
Biocide	600	4.8	3.6	2.9

Table 3.33 **Concentrations of biocide and number of dilutions at the end of the near-field stage for the summer season. Note from Table 3.31 that dilutions at the 5th, 50th and 95th percentile current speeds were 136, 166 and 210, respectively.**

Constituent	Source Concentration (ppm)	End of Near-Field Concentration (ppm)		
		5th %ile	50th %ile	95th %ile
		136x Dilution	166x Dilution	210x Dilution
Biocide	600	4.4	3.6	2.9

Table 3.34 **Concentrations of biocide and number of dilutions at the end of the near-field stage for the transitional season. Note from Table 3.31 that dilutions at the 5th, 50th and 95th percentile current speeds were 128, 172 and 218, respectively.**

Constituent	Source Concentration (ppm)	End of Near-Field Concentration (ppm)		
		5th %ile	50th %ile	95th %ile
		128x Dilution	172x Dilution	218x Dilution
Biocide	600	4.7	3.5	2.8

Table 3.35 **Concentrations of biocide and number of dilutions at the end of the near-field stage for the winter season. Note from Table 3.31 that dilutions at the 5th, 50th and 95th percentile current speeds were 123, 162 and 206, respectively.**

Constituent	Source Concentration (ppm)	End of Near-Field Concentration (ppm)		
		5th %ile	50th %ile	95th %ile
		123x Dilution	162x Dilution	206x Dilution
Biocide	600	4.9	3.7	2.9

3.1.3.2.4.1 Annualised

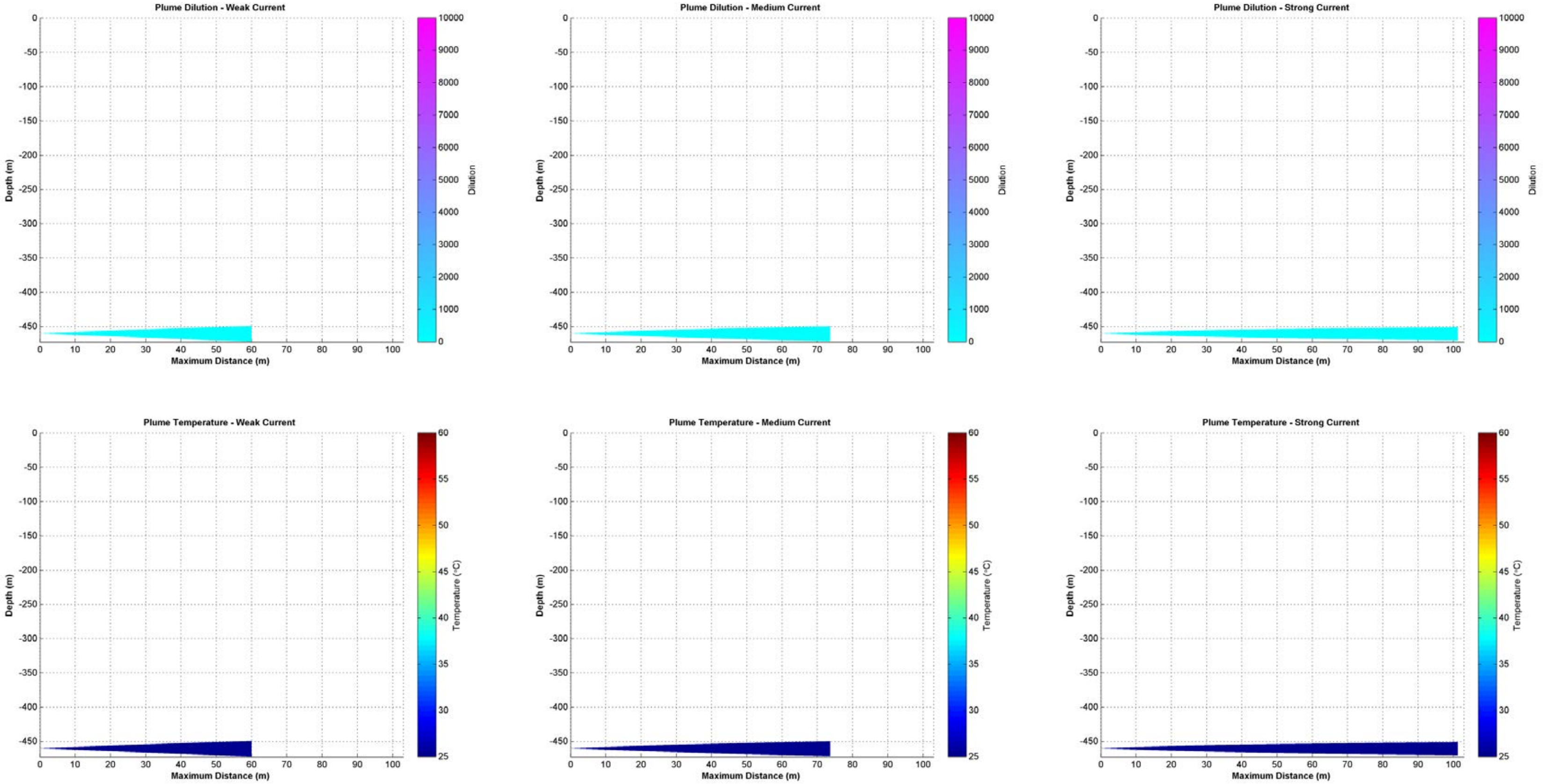


Figure 3.25 Near-field average dilution and temperature results for constant weak, medium and strong annualised currents (Torosa 56,000 m^3 hydrotest discharge).

3.1.3.2.4.2 Summer

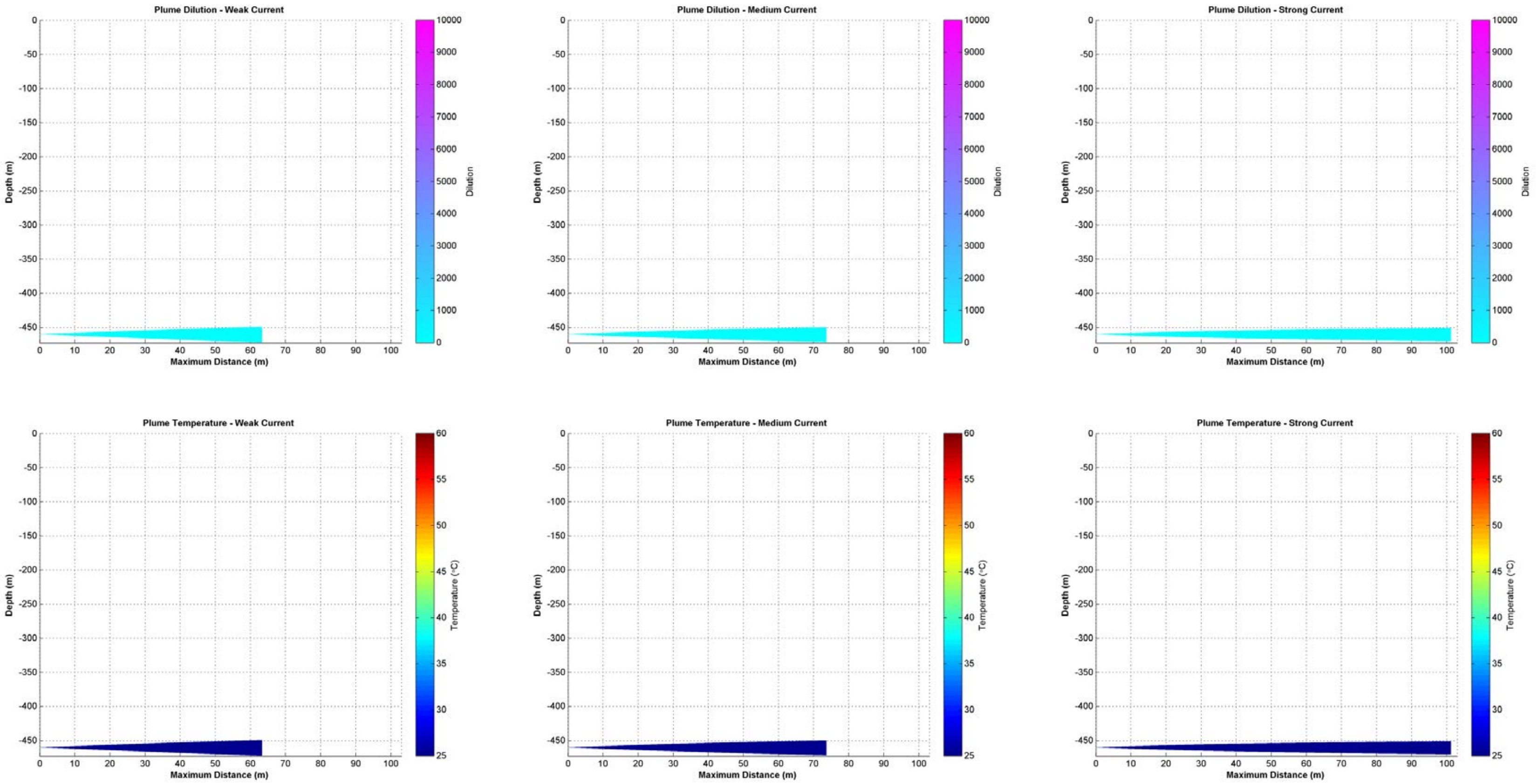


Figure 3.26 Near-field average dilution and temperature results for constant weak, medium and strong summer currents (Torosa 56,000 m^3 hydrotest discharge).

3.1.3.2.4.3 Transitional

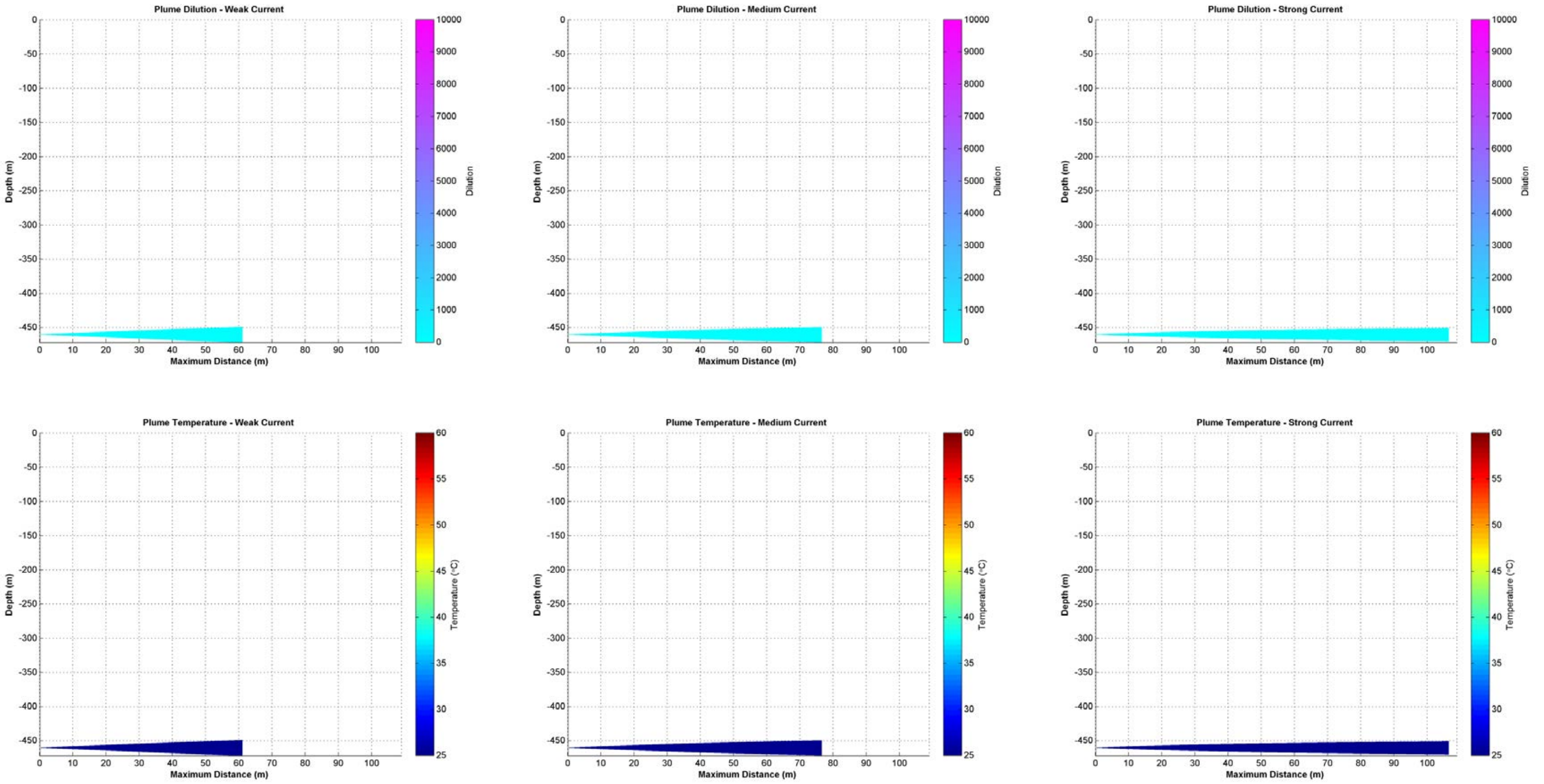


Figure 3.27 Near-field average dilution and temperature results for constant weak, medium and strong transitional currents (Torosa 56,000 m^3 hydrotest discharge).

3.1.3.2.4.4 Winter

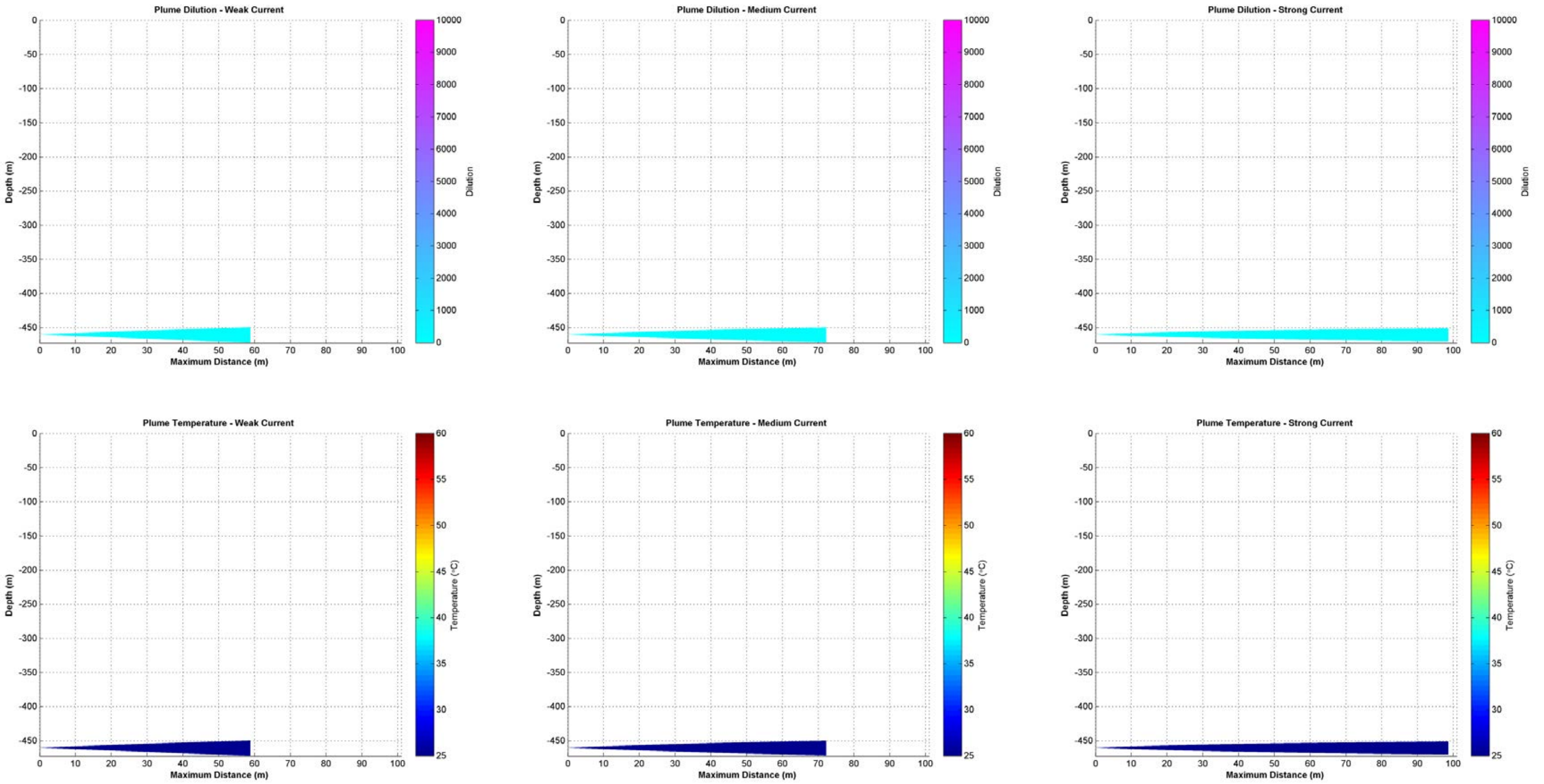


Figure 3.28 Near-field average dilution and temperature results for constant weak, medium and strong winter currents (Torosa 56,000 m^3 hydrotest discharge).

3.2 Far-Field Modelling

3.2.1 Overview

It is important to note that near-field and far-field modelling are used to describe different processes and scales of effect, and therefore the far-field modelling results will not necessarily correspond to the outcomes at the end of the near-field mixing zone for any given discharge scenario. The far-field results included episodes of pooling of the discharge plume under weak currents, which caused lower dilutions (higher concentrations) further from the discharge location when the pooled plume was advected away. Episodes of recirculation – where the plume moved back under the discharge at some later time due to the oscillatory nature of the tide – were also observed, compounding the pooling effect and further lowering the dilution values.

3.2.2 Interpretation of Percentile Dilution Contours

For each of the modelled discharge cases, the results for all simulations were combined and a statistical analysis performed to produce percentile contours of dilution. In the following sections, outcomes based on 95th percentile dilution contours are presented.

Calculation of 95th percentile statistics is a common approach to assessing the impact of dispersing plumes and captures the variability in outcomes, for all but the most ephemeral and extreme forcing conditions, in the data set under consideration. Impact assessment criteria for water quality are often defined using similar statistical indicators.

Note that the percentile figures do not represent the location of a plume at any point in time; they are a statistical and spatial summary of the percentage of time that particular dilution values occur across all replicate simulations and time steps. For example, if the 95th percentile minimum dilution at a particular location in the model domain is predicted as a value of 100, this means that for 95% of the time the dilution level will be higher than 100 and for only 5% of the time the dilution level will be lower than 100. A comparison of instantaneous plume extent snapshots, as shown in Figure 3.29 (CW discharges), Figure 3.41 (PW discharges) and Figure 3.56 (hydrotest discharges), with the percentile images for the corresponding discharge demonstrates the significant difference between an instantaneous snapshot and a cumulative estimate of coverage over several days and many individual simulations.

Dilution contours are calculated from the ratios of dispersing constituent concentrations in the receiving waters to the initial concentration of the constituent in the discharge. Note that this assumes the background concentration of the constituent in the receiving waters is zero and there is no significant biodegradation of the discharged constituent over the short duration of the dispersion process.

Table 3.36 summarises the initial concentrations of chlorine, as specified, and the equivalent dispersed concentrations required to yield particular dilution levels (1:100, 1:200 and 1:400).

Table 3.36 Initial concentrations of chlorine and equivalent concentrations at example dilution levels.

Parameter	Chlorine Concentration (ppm)	
Initial concentration in discharge	0.2	0.5
Initial concentration in receiving waters	0.0	
Concentration at 1:100 dilution	0.002	0.005
Concentration at 1:200 dilution	0.001	0.0025
Concentration at 1:400 dilution	0.0005	0.00125

Table 3.37 summarises the initial concentrations of total oil (including BTEX), mercury and MEG, as specified, and the equivalent dispersed concentrations required to yield particular dilution levels (1:100, 1:200 and 1:400).

Table 3.37 Initial concentrations of total oil, mercury and MEG, and equivalent concentrations at example dilution levels.

Parameter	Total Oil Concentration (mg/L)	Mercury Concentration (mg/L)	MEG Concentration (mg/L)
Initial concentration in discharge	30.0	0.03	79,000.0
Initial concentration in receiving waters	0.0	0.00	0.0
Concentration at 1:100 dilution	0.3	0.0003	790.0
Concentration at 1:200 dilution	0.15	0.00015	395.0
Concentration at 1:400 dilution	0.075	0.000075	197.5

Table 3.38 summarises the initial concentrations of biocide, as specified, and the equivalent dispersed concentrations required to yield particular dilution levels (1:100, 1:200, 1:400 and 1:10,000).

Table 3.38 Initial concentrations of biocide and equivalent concentrations at example dilution levels.

Parameter	Biocide Concentration (ppm)
Initial concentration in discharge	600.0
Initial concentration in receiving waters	0.0
Concentration at 1:100 dilution	6.0
Concentration at 1:200 dilution	3.0
Concentration at 1:400 dilution	1.5
Concentration at 1:10,000 dilution	0.06

These concentrations may be useful to consider when interpreting the contour plots of percentile dilutions.

3.2.3 Cooling Water Discharges

3.2.3.1 General Observations

Figure 3.29 shows example time series snapshots of predicted dilutions during a single simulation at 3-hour intervals from 01:00 to 16:00 on 20th January 2013. This simulation – selected merely to be representative of typical conditions – considers the Case C discharge at 12 m BMSL. The spatially-varying orientation of the plume with the currents and the rapidly-varying nature of the concentrations around the source can be observed. The snapshots also show the combined effect of the tide and the drift currents, with a clear tidal oscillation.

These snapshots illustrate that the dilutions (and in turn concentrations) become more variable over time because of changes in current speed and direction. Higher dilutions (lower concentrations) are predicted during periods of increased current speed, whereas patches of lower dilutions (higher concentrations) tend to accumulate during the turning of the tide or during periods of weak drift currents. During prolonged periods of lowered current speed, the plume has a more continuous appearance, with higher-concentration patches moving as a unified group.

The snapshots in Figure 3.29 show a clear separation between a contiguous plume emanating from the source and a more distant detached plume. The detached plume contains higher constituent concentrations than the surrounding waters, which is the result of a recirculation episode at an earlier time in the discharge where the existing plume passed over the source once more. Within the main plume, another sub-plume likely to break off in the future can be seen.

These findings agree with the research of King & McAllister (1997, 1998) who noted that concentrations within effluent plumes generated by an offshore platform were patchy and likely to peak around the reversal of the tides.

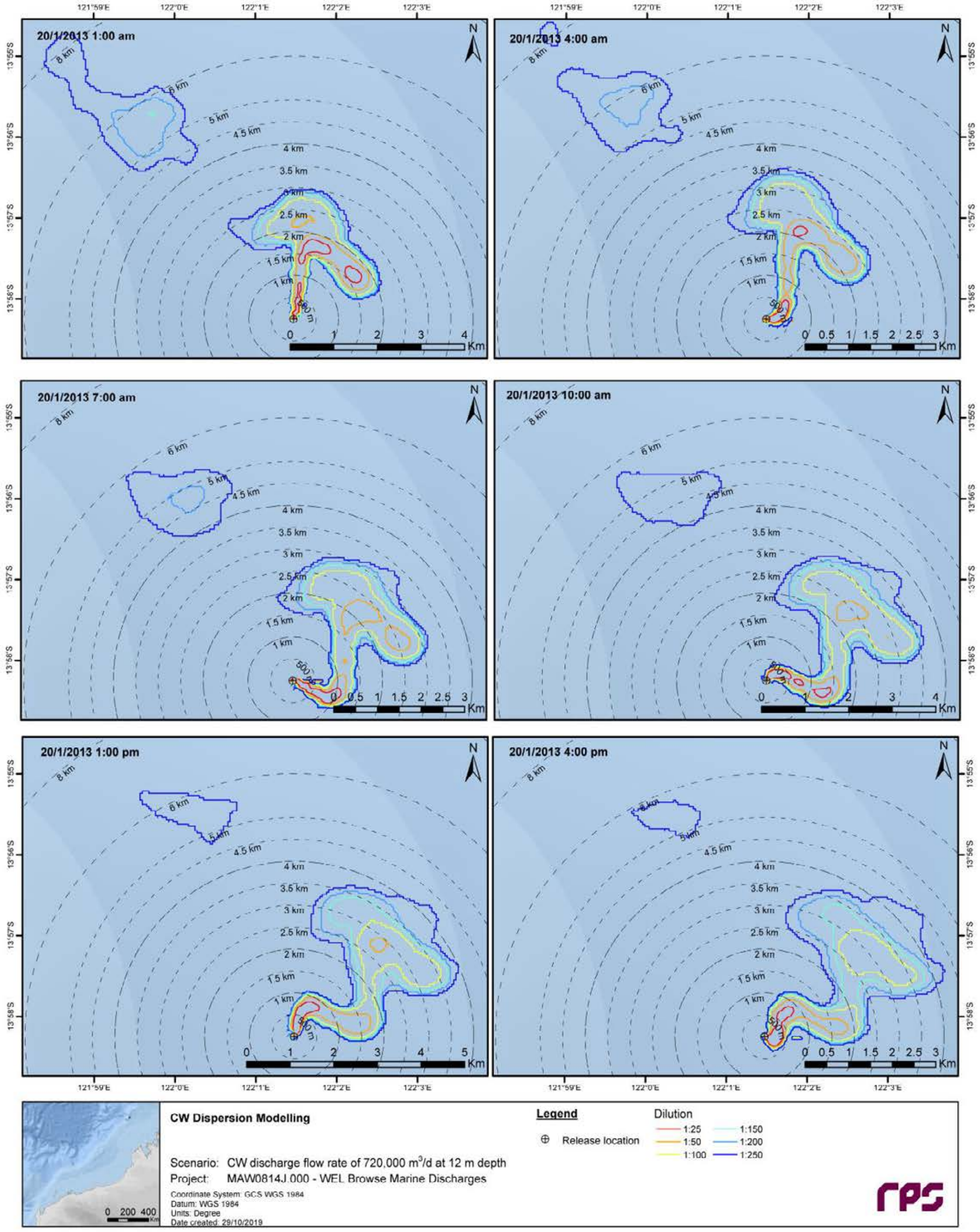


Figure 3.29 Snapshots of predicted dilution levels, at 3-hour intervals from 01:00 to 16:00 on 20th January 2013, for Case C (12 m depth discharge at 720,000 m^3/d flow rate).

3.2.3.2 Seasonal Analysis

3.2.3.2.1 Summary

The model outputs over the ten-year hindcast period (2006-2015) were combined and analysed on a seasonal basis (summer, transitional and winter). This approach assists with identifying the potential exposure to surrounding sensitive receptors whilst considering inter-annual variability in ocean current conditions.

Table 3.39 summarises for Case C the average and minimum dilution achieved at specific radial distances from the discharge location – as well as at or within the Scott Reef area defined by the 3 nm State water boundary – for each season and percentile.

Table 3.40 provides for Case C a summary of the maximum distances from the discharge location to achieve an example dilution level of 1:100 for each season and percentile. The results indicate that the release of effluent under all seasonal conditions results in slow dispersion within the ambient environment. A 1:100 dilution is achieved within an area of influence ranging from 3.7-4.2 km at the 95th percentile.

Table 3.41 provides for Case C a summary of the total areas of coverage for the 1:100 dilution contour for each season and percentile. The area of exposure defined by the relevant dilution contour is predicted to reach a maximum value of 1.9-2.3 km^2 at the 95th percentile.

Table 3.42 provides for Case C a summary of the maximum depths from the discharge location to achieve 1:100 dilution for each season and percentile. The maximum depth is observed in summer and winter, with a prediction of 20 m.

Table 3.43 provides a summary of the maximum distances from the discharge location and total areas of coverage to achieve an example 3 °C plume-ambient temperature differential for each season and percentile. This differential is forecast to be met within 120 m at the 95th percentile.

For Case C, the aggregated spatial extents of the minimum dilutions for each season at the 95th percentile are presented in Figure 3.30 to Figure 3.32. Note that the contours represent the lowest predicted dilution (highest concentration) at any given time step through the water column and do not consider frequency or duration. The discharged plumes are predicted to travel in predominantly northerly directions during summer and transitional months, and south-easterly directions during winter.

The results presented assume that no processes other than dilution would reduce the source concentrations over time, and therefore can be considered as conservative outcomes.

For Case C, Figure 3.33 to Figure 3.35 show the aggregated spatial extents of the maximum plume-ambient temperature differential for each season at the 95th percentile.

Seasonal water column cross-section figures of 95th percentile dilution, extracted along perpendicular transects running through the origin point of the discharge (one of which is broadly aligned with the principal travel direction of the plume), are presented in Figure 3.36 to Figure 3.38. Although initially slightly positively buoyant due to its elevated temperature, the discharged plume is predicted to achieve density equilibrium with the receiving waters relatively quickly. The plume centreline – where highest concentrations and lowest dilutions are found – will tend to remain entrained more than 10 m below the water surface.

3.2.3.2.2 Discharge Case C: Flow Rate of 720,000 m^3/day at 12 m Depth

Table 3.39 Average and minimum dilutions (1:x) achieved at specific radial distances from the CW discharge location in each season for Case C (12 m depth discharge at 720,000 m^3/d flow rate).

Distance (m)	Summer						Transitional						Winter					
	95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum
Scott Reef (3 nm State Water Boundary)	559	357	471	69	288	24	573	250	394	50	202	23	527	125	409	50	230	8
20	3	2	1	1	1	1	2	2	1	1	1	1	2	2	1	1	0	0
50	8	7	3	1	1	1	6	5	3	1	1	1	4	4	2	1	1	1
100	14	5	5	3	2	1	8	5	5	3	2	1	7	5	4	3	1	1
200	22	9	8	5	3	2	15	9	7	4	3	2	15	8	7	4	3	2
300	42	13	13	6	6	3	25	12	10	6	5	3	21	11	10	6	4	2
400	38	16	14	8	5	3	28	13	11	7	5	2	30	13	13	7	6	3
500	63	18	21	9	8	4	44	15	15	8	7	3	34	15	15	8	7	4
600	60	20	20	10	8	4	46	18	16	8	8	4	47	17	20	8	8	3
700	88	23	28	11	11	4	67	22	20	11	9	4	49	19	20	9	9	3
800	82	25	27	12	11	5	66	24	21	11	10	3	67	18	24	11	11	4
900	118	27	34	15	14	5	99	26	25	12	12	5	65	20	25	10	12	6
1,000	102	29	33	14	14	5	95	30	26	14	12	6	84	24	30	11	13	5
1,100	146	31	42	15	17	6	144	32	32	15	14	5	81	24	30	12	13	5
1,200	145	31	41	14	16	5	141	34	32	16	14	4	111	25	37	11	15	4
1,300	176	34	51	16	19	6	182	37	38	15	15	5	112	28	38	11	16	4
1,400	173	38	49	18	18	6	169	38	37	15	16	5	148	31	46	11	18	4
1,500	224	39	58	17	19	7	229	42	42	17	18	7	149	32	45	13	19	5
1,600	220	41	57	19	20	7	209	45	43	17	18	6	197	36	50	13	21	6
1,700	262	45	65	21	24	7	204	45	48	19	20	6	182	37	50	12	21	7
1,800	251	45	65	19	24	7	204	50	48	20	21	8	231	41	55	13	23	6
1,900	302	50	72	21	26	7	250	50	55	19	21	7	208	39	53	15	22	6
2,000	300	48	77	22	28	7	231	54	58	20	22	7	258	45	62	15	25	5
2,100	290	48	75	22	28	8	226	50	65	24	23	7	239	45	61	17	24	5
2,200	339	50	81	21	31	10	251	56	75	22	23	8	304	46	70	19	27	7
2,300	301	50	80	25	32	10	247	63	76	21	25	9	265	50	71	21	28	8
2,400	331	56	88	24	33	9	285	59	71	22	28	8	299	55	83	22	32	7
2,500	322	56	91	28	34	8	293	63	76	24	32	9	292	60	87	23	31	7
2,600	349	63	100	32	35	10	323	71	79	26	32	8	318	62	95	22	33	7
2,700	331	69	101	33	34	11	322	73	83	33	35	9	312	63	95	20	33	7
2,800	369	71	107	32	37	10	364	82	86	36	36	11	346	63	103	20	35	6
2,900	348	71	113	31	37	11	328	83	98	34	41	11	334	63	100	23	35	6
3,000	365	74	115	31	40	12	362	71	90	35	37	10	339	71	111	23	37	9
3,100	375	76	118	29	42	12	341	71	104	34	42	11	352	71	111	23	40	8
3,200	390	83	115	32	46	14	356	83	95	30	44	11	371	71	124	22	43	9
3,300	389	83	120	31	50	14	357	83	116	30	47	11	368	76	117	25	41	9
3,400	394	83	123	33	53	14	380	86	107	33	46	13	353	79	133	24	43	7
3,500	405	83	134	34	55	15	362	97	122	34	47	15	369	83	127	21	43	7

	Summer						Transitional						Winter					
Distance (m)	95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum
3,600	410	79	135	36	55	16	398	97	115	33	47	13	387	83	145	20	44	7
3,700	429	83	150	31	60	17	391	100	131	34	51	15	422	83	131	20	45	10
3,800	409	83	149	32	65	14	366	100	137	40	51	14	370	83	143	23	44	8
3,900	416	83	166	35	73	13	369	100	154	45	51	14	395	92	143	27	45	8
4,000	412	86	166	39	76	13	362	100	155	46	54	12	378	100	160	28	48	8
4,100	419	98	179	40	80	15	379	100	168	43	53	12	396	100	158	29	50	9
4,200	429	100	196	42	79	16	361	100	186	42	60	12	425	100	181	28	53	11
4,300	427	100	210	38	82	18	377	100	183	38	58	14	417	125	175	29	56	10
4,400	445	100	219	40	84	18	402	114	208	45	63	18	396	125	196	33	59	10
4,500	460	100	236	42	91	16	422	116	200	45	64	15	422	125	192	34	61	11
4,600	436	100	239	42	90	14	401	125	219	46	69	14	435	125	208	36	69	11
4,700	446	118	252	42	95	16	408	125	207	46	70	17	430	129	196	41	69	13
4,800	445	125	240	40	92	19	397	132	223	50	70	18	451	129	213	40	74	13
4,900	489	125	260	45	101	18	429	130	213	52	74	16	452	134	200	46	69	14
5,000	488	125	251	45	91	17	429	167	225	56	77	14	442	136	220	45	73	14
5,500	461	125	277	58	113	24	425	167	226	63	127	17	481	167	233	57	83	17
6,000	461	167	300	62	113	24	424	250	224	69	147	25	482	250	242	71	99	22
6,500	478	167	329	50	108	27	472	250	256	83	149	22	488	250	262	85	125	25
7,000	542	230	337	72	115	26	506	250	269	100	145	28	484	250	281	71	132	25
7,500	568	250	370	86	139	31	585	500	290	100	161	36	495	250	289	71	141	29
8,000	541	250	382	101	157	29	523	483	302	125	172	42	497	250	332	84	145	11
8,500	508	250	408	125	169	36	540	500	300	83	173	40	520	250	353	100	162	28
9,000	527	285	405	100	175	41	522	500	307	83	175	42	559	250	383	100	181	31
9,500	511	500	431	100	188	38	522	500	322	100	173	55	515	387	381	100	196	33
10,000	536	500	431	125	195	42	528	500	334	100	175	38	577	500	391	100	203	42
10,500	531	500	447	136	225	45	515	500	346	100	188	42	568	500	403	125	211	45
11,000	530	500	424	125	224	50	520	500	349	100	197	46	633	500	408	125	205	45
11,500	533	500	432	125	236	56	543	500	364	125	201	48	538	500	410	125	216	50
12,000	521	500	435	167	251	42	535	500	369	125	217	56	530	500	418	125	217	50
12,500	513	500	463	167	262	45	543	500	393	130	228	51	556	500	403	125	233	56
13,000	500	500	458	167	267	56	507	500	398	167	234	56	548	500	411	157	237	56
13,500	500	500	469	250	277	56	508	500	409	167	247	56	575	500	412	167	229	56
14,000	567	500	469	250	279	59	531	500	411	126	244	57	566	500	430	167	247	50
14,500	515	500	478	250	296	61	569	500	410	125	261	63	500	500	443	125	257	56
15,000	514	500	479	250	293	64	564	500	441	167	257	61	500	500	461	167	266	65
15,500	516	500	496	250	300	61	618	500	446	130	266	63	500	500	453	176	283	71
16,000	500	500	487	250	298	60	582	500	458	167	268	63	526	500	450	214	278	64
16,500	561	500	496	250	317	57	523	500	465	167	260	70	500	500	459	250	296	71
17,000	500	500	491	250	323	55	525	500	470	167	274	60	524	500	466	250	297	71
17,500	548	500	501	462	334	53	659	500	467	167	276	64	500	500	466	250	313	71
18,000	545	500	501	500	331	24	500	500	474	167	275	81	527	500	461	250	314	71
18,500	533	500	503	491	332	50	944	500	474	167	280	58	525	500	470	197	315	71
19,000	618	500	506	500	338	24	1,500	500	474	125	296	56	700	500	476	250	320	63
19,500	-	-	499	250	354	23	-	-	478	176	282	63	500	500	476	250	328	63

	Summer						Transitional						Winter					
Distance (m)	95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum
20,000	-	-	505	500	357	39	-	-	482	250	272	50	500	500	480	176	312	63

Table 3.40 **Maximum distance from the CW discharge location to achieve 1:100 dilution in each season for Case C (12 m depth discharge at 720,000 m³/d flow rate).**

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Summer	4,158
	Transitional	3,734
	Winter	3,975
99th	Summer	7,601
	Transitional	9,445
	Winter	10,011
100th	Summer	21,497
	Transitional	22,675
	Winter	20,947

Table 3.41 **Total area of coverage for 1:100 dilution in each season for Case C (12 m depth discharge at 720,000 m³/d flow rate).**

Percentile	Season	Total area (km²) of coverage for given dilution
95th	Summer	1.88
	Transitional	2.09
	Winter	2.27
99th	Summer	9.39
	Transitional	11.52
	Winter	10.78
100th	Summer	47.50
	Transitional	51.31
	Winter	64.18

Table 3.42 **Maximum depth from the CW discharge location to achieve 1:100 dilution in each season for Case C (12 m depth discharge at 720,000 m³/d flow rate).**

Season	Maximum depth (m) from discharge location to achieve given dilution
Summer	20
Transitional	19
Winter	20

Table 3.43 Maximum distance from the CW discharge location, and corresponding total area of coverage, to achieve 3 °C plume-ambient ΔT in each season for Case C (12 m depth discharge at 720,000 m³/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given ΔT	Total area (km²) of coverage for given ΔT
95th	Summer	107	0.004
	Transitional	114	0.006
	Winter	120	0.008
99th	Summer	264	0.024
	Transitional	293	0.029
	Winter	318	0.038
100th	Summer	1242	0.217
	Transitional	1,708	0.311
	Winter	2,914	0.377

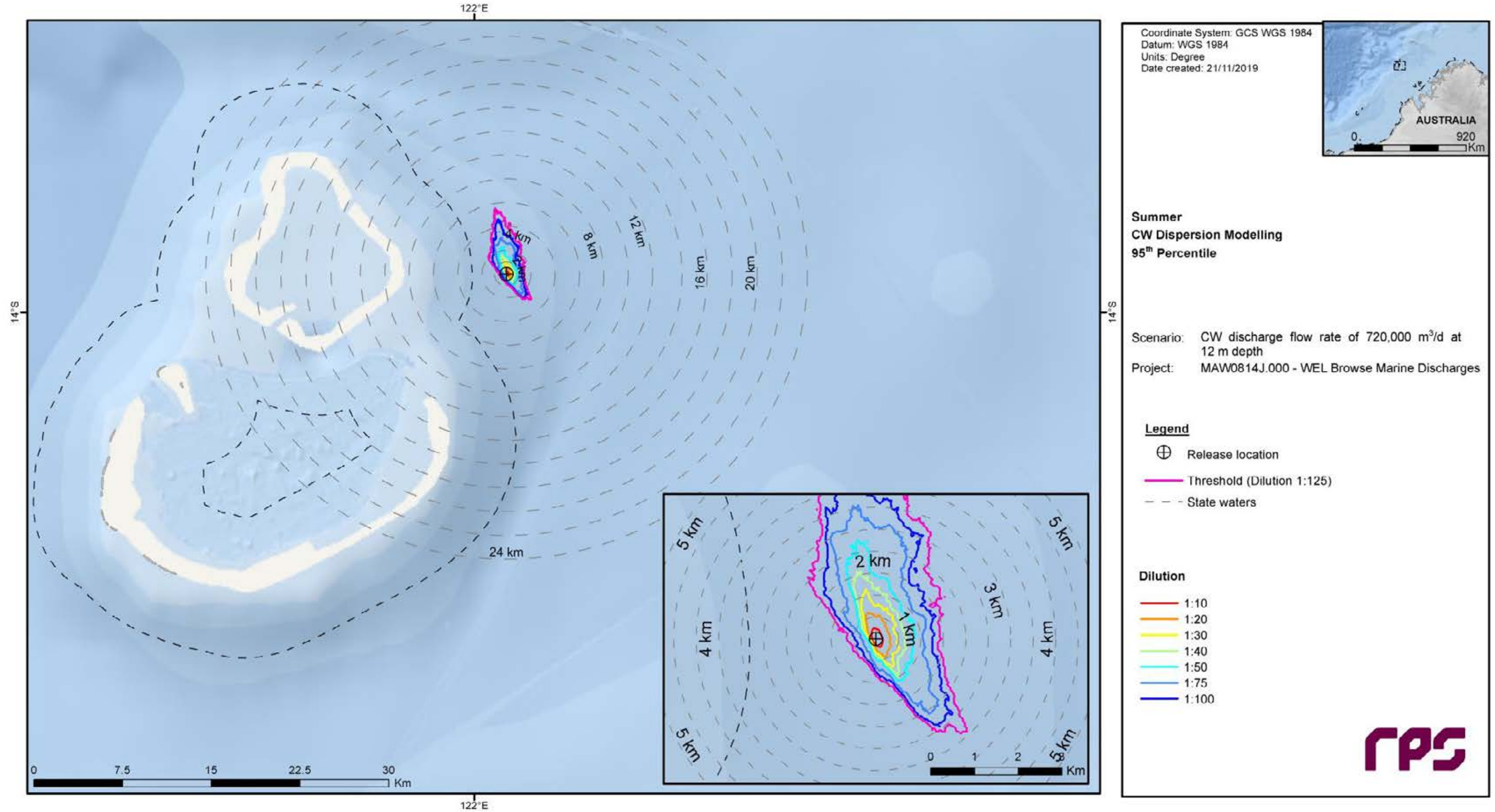


Figure 3.30 Predicted minimum dilutions at the 95th percentile under summer conditions for Case C (12 m depth discharge at 720,000 m^3/d flow rate).

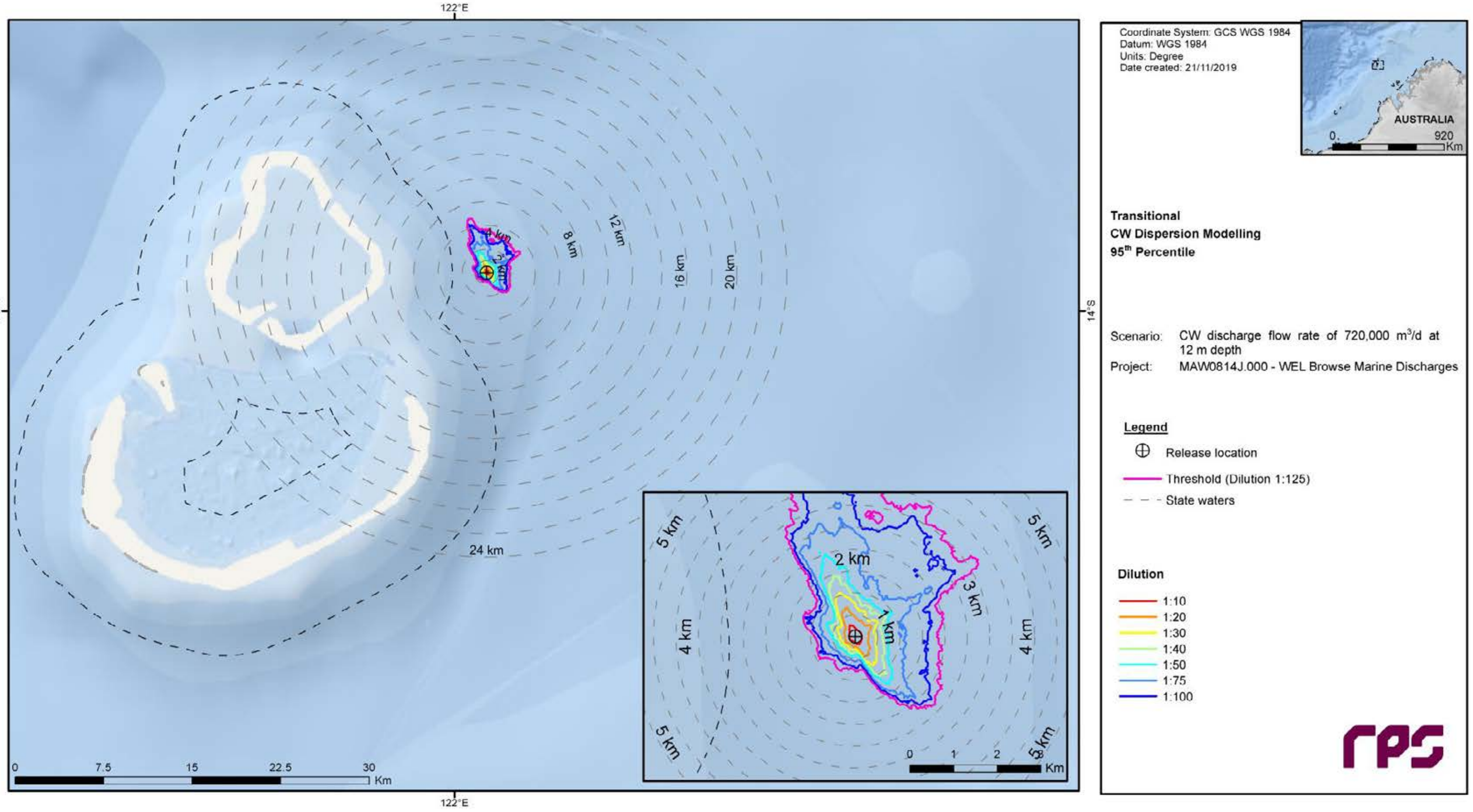


Figure 3.31 Predicted minimum dilutions at the 95th percentile under transitional conditions for Case C (12 m depth discharge at 720,000 m^3/d flow rate).

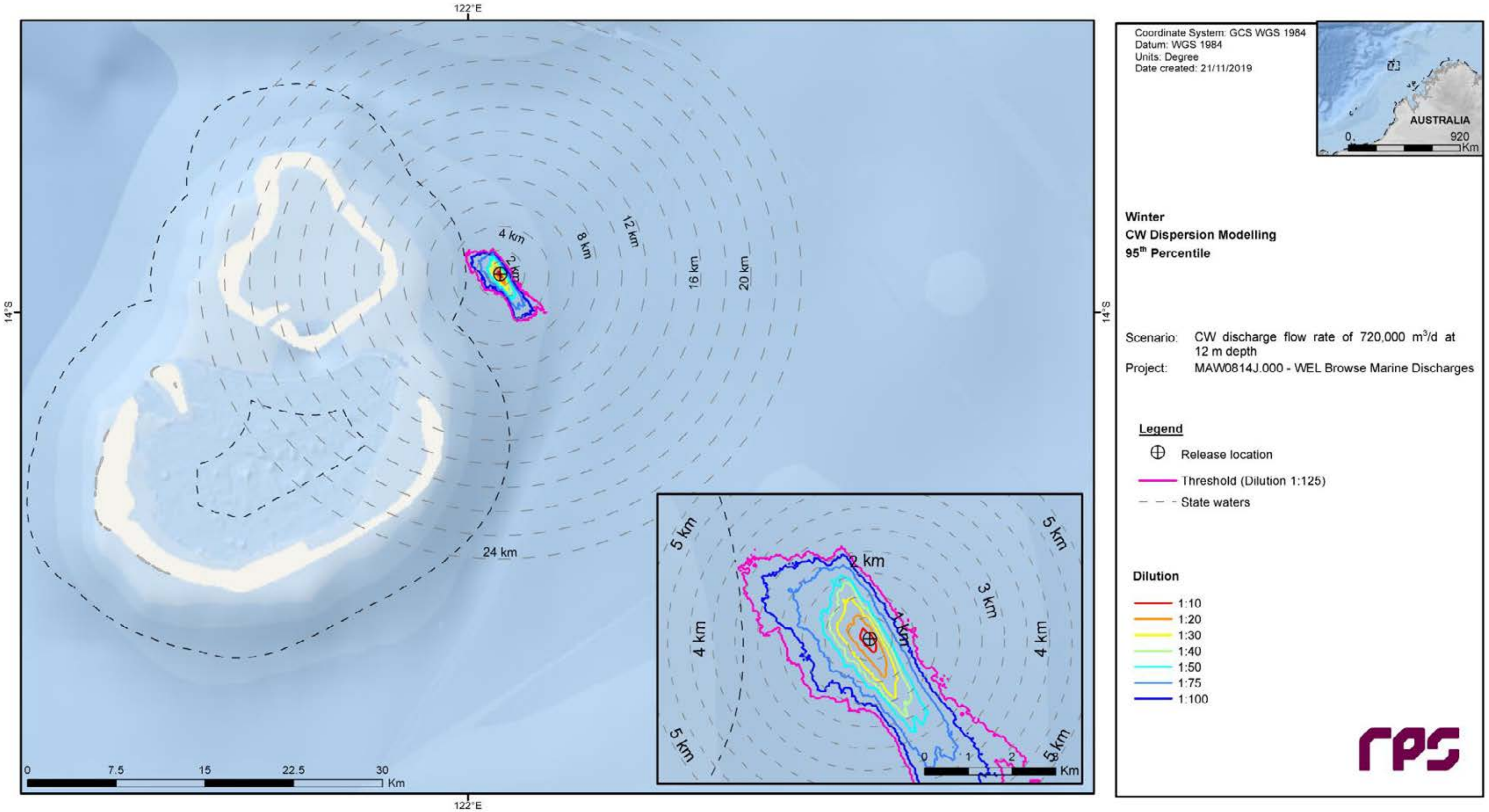


Figure 3.32 Predicted minimum dilutions at the 95th percentile under winter conditions for Case C (12 m depth discharge at 720,000 m^3/d flow rate).

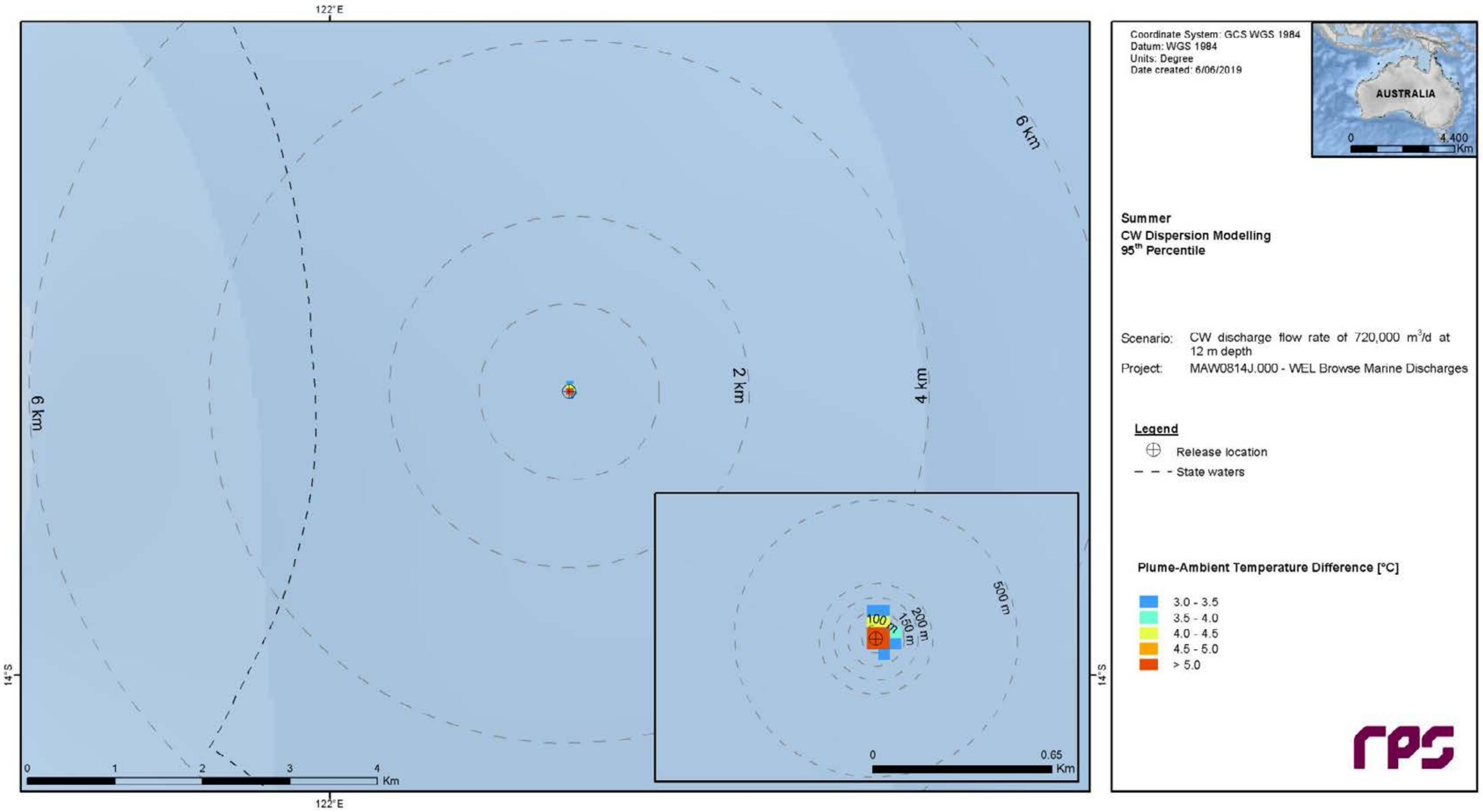


Figure 3.33 Predicted maximum plume-ambient ΔT at the 95th percentile under summer conditions for Case C (12 m depth discharge at 720,000 m^3/d flow rate).

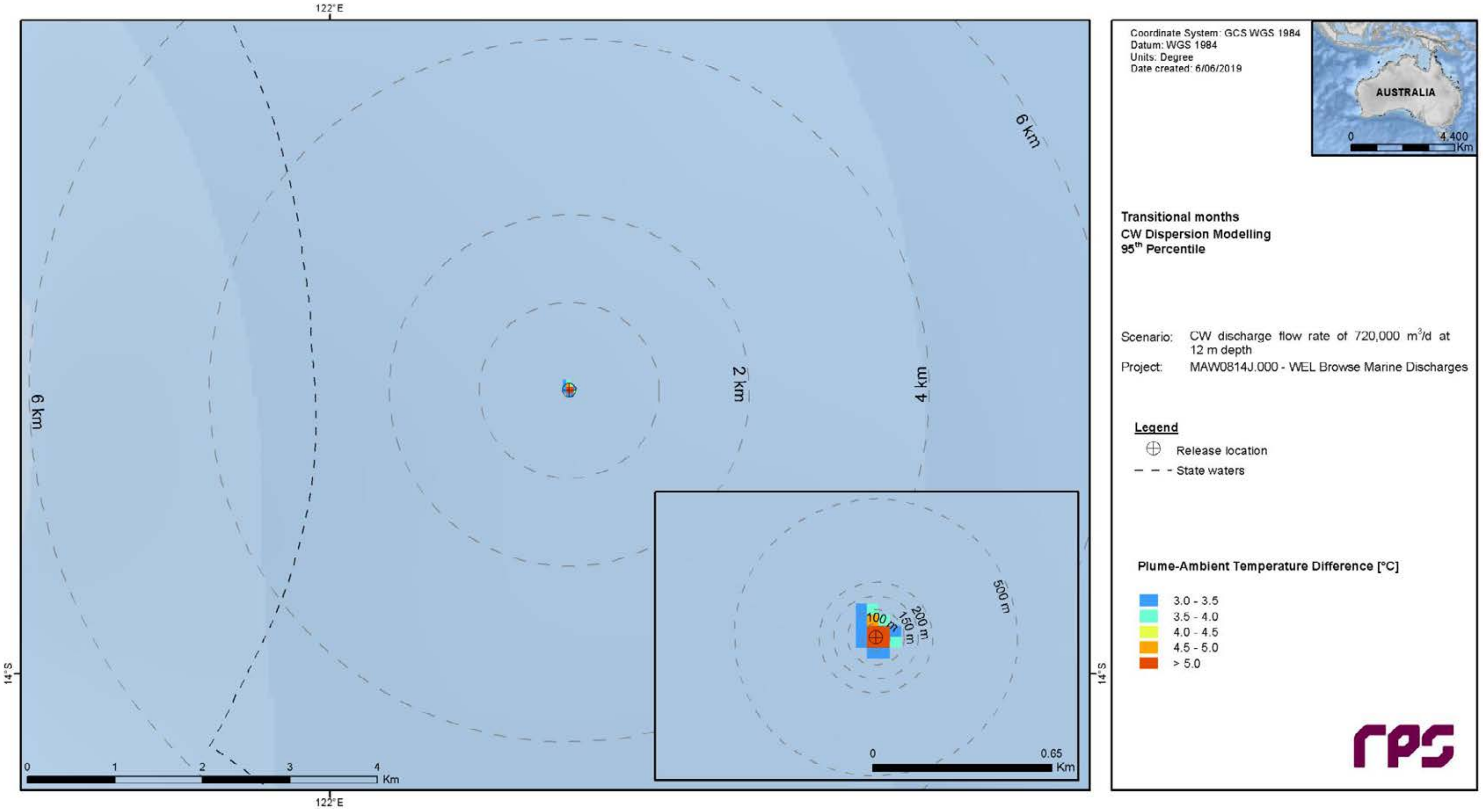


Figure 3.34 Predicted maximum plume-ambient ΔT at the 95th percentile under transitional conditions for Case C (12 m depth discharge at 720,000 m^3/d flow rate).

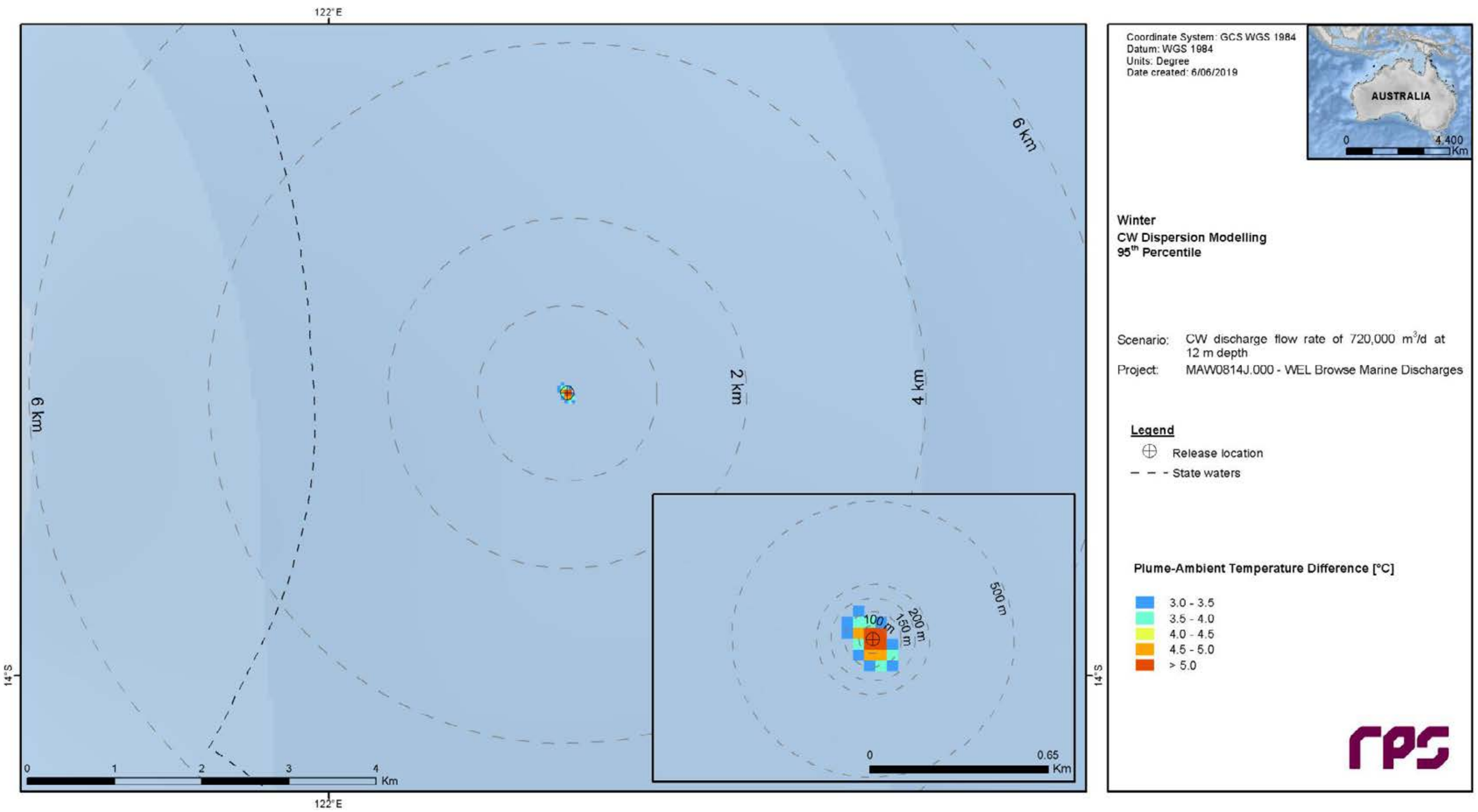


Figure 3.35 Predicted maximum plume-ambient ΔT at the 95th percentile under winter conditions for Case C (12 m depth discharge at 720,000 m^3/d flow rate).

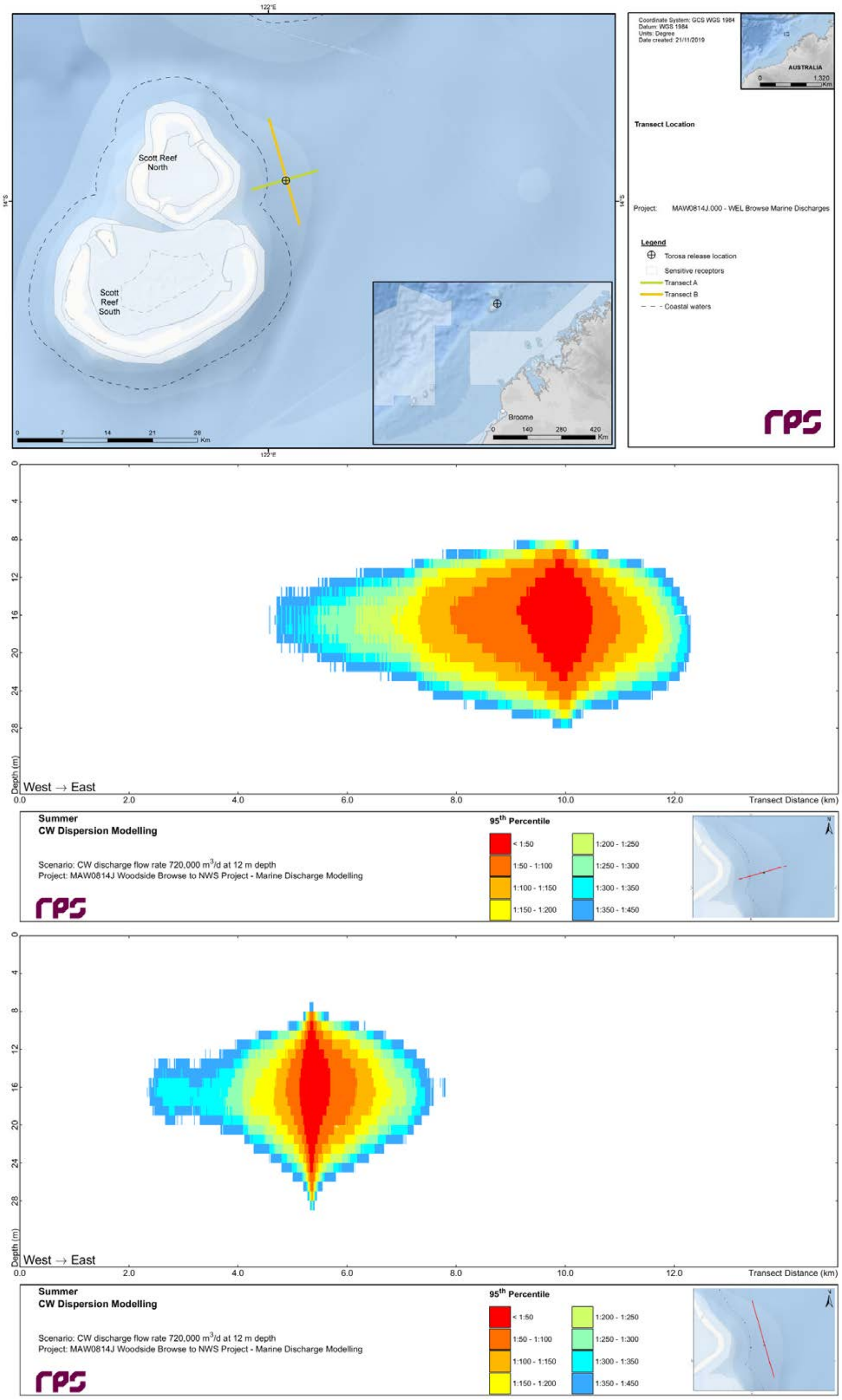


Figure 3.36 Vertical cross-section plots of predicted minimum dilutions at the 95th percentile under summer conditions for Case C (12 m depth discharge at 720,000 m^3/d flow rate). Transect locations are shown in the top panel, with transect A shown in the middle panel and transect B shown in the bottom panel. Spatial representation of this data is shown in Figure 3.30.

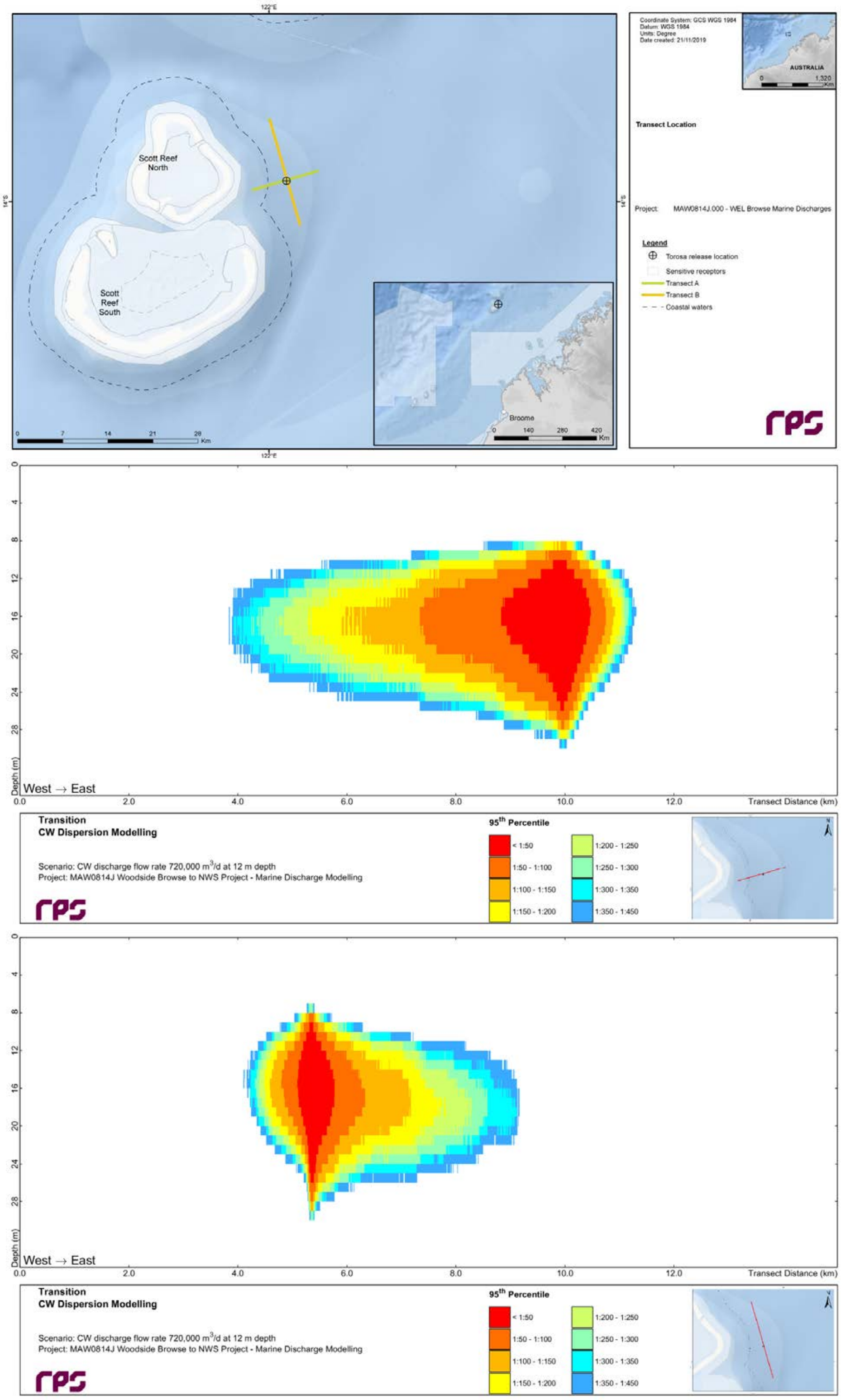


Figure 3.37 Vertical cross-section plots of predicted minimum dilutions at the 95th percentile under transitional conditions for Case C (12 m depth discharge at 720,000 m^3/d flow rate). Transect locations are shown in the top panel, with transect A shown in the middle panel and transect B shown in the bottom panel. Spatial representation of this data is shown in Figure 3.31.

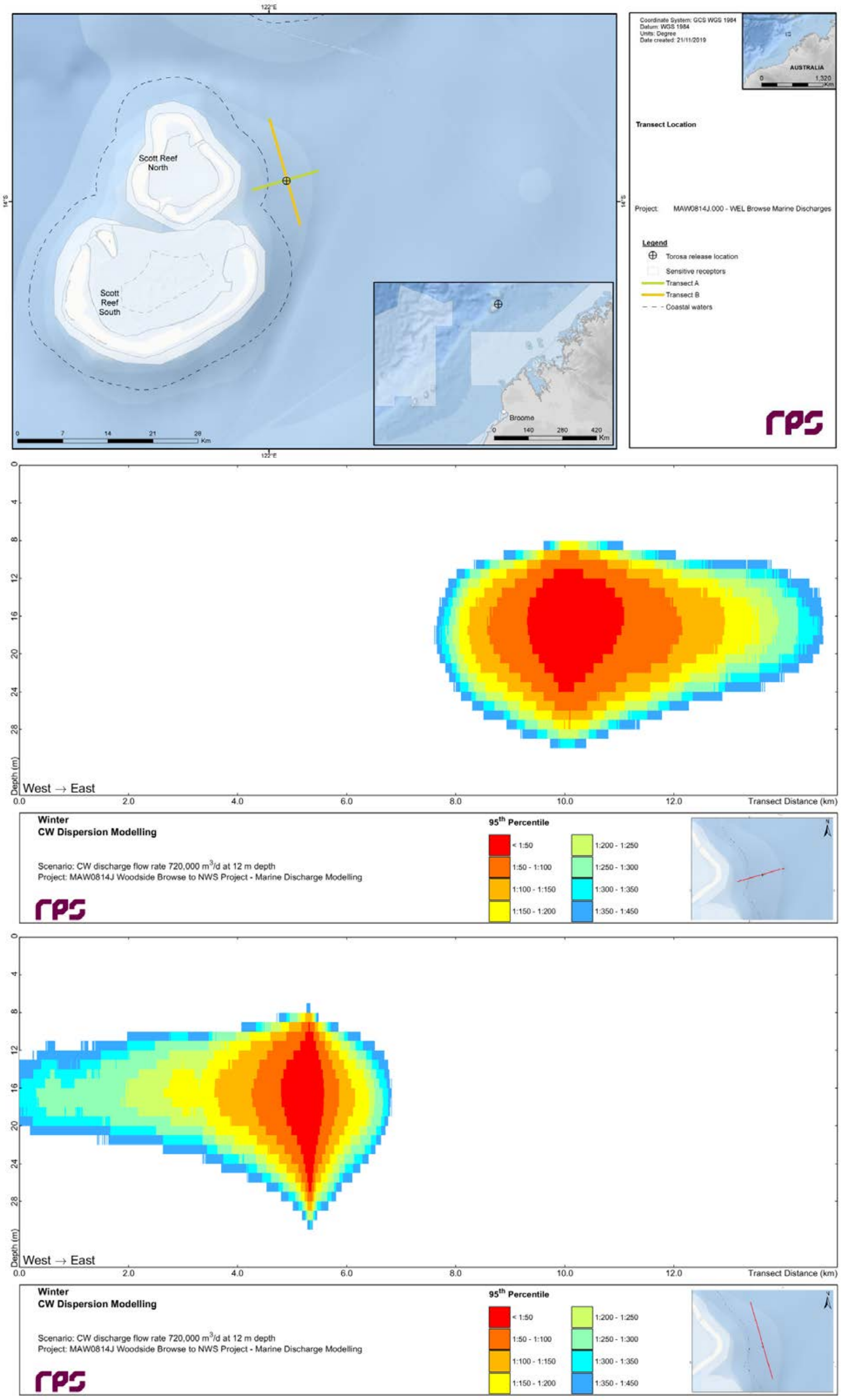


Figure 3.38 Vertical cross-section plots of predicted minimum dilutions at the 95th percentile under winter conditions for Case C (12 m depth discharge at 720,000 m^3/d flow rate). Transect locations are shown in the top panel, with transect A shown in the middle panel and transect B shown in the bottom panel. Spatial representation of this data is shown in Figure 3.32.

3.2.3.3 Annualised Analysis

3.2.3.3.1 Summary

The model outputs for each season (summer, transitional and winter) over the ten-year hindcast period (2006-2015) were combined and analysed on an annualised basis.

Table 3.44 summarises for Case C the average and minimum dilution achieved at specific radial distances from the discharge location – as well as at or within the Scott Reef area defined by the 3 nm State water boundary – for each percentile over the annual period.

The minimum level of dilution achieved at or within the Scott Reef receptor at the 95th percentile in any season is predicted to be 1:125 for Case C.

Table 3.45 provides for Case C a summary of the annualised maximum distances from the discharge location to achieve an example dilution level of 1:100 for each percentile. The results indicate that the release of effluent under all seasonal conditions results in slow dispersion within the ambient environment. Dilution to reach the 1:100 level at the 95th percentile – this being the maximum spatial extent of the relevant dilution contour from the discharge location in any season – is achieved within a maximum area of influence of 4.2 km.

Table 3.46 provides for Case C a summary of the annualised total areas of coverage for the 1:100 dilution contour for each percentile. The area of exposure defined by the relevant dilution contour is predicted to reach a maximum value of 3.7 km^2 at the 95th percentile across all seasons.

Table 3.47 provides a summary of the annualised maximum distances from the discharge location and total areas of coverage to achieve an example 3 °C plume-ambient temperature differential for each percentile. This differential is forecast to be met within 120 m at the 95th percentile across all seasons.

For Case C, the aggregated spatial extents of the minimum dilutions at the 95th percentile are presented in Figure 3.39. Note that the contours represent the lowest predicted dilution (highest concentration) at any given time step through the water column and do not consider frequency or duration.

The results presented assume that no processes other than dilution would reduce the source concentrations over time, and therefore can be considered as conservative outcomes.

For Case C, Figure 3.40 shows the aggregated spatial extents of the maximum plume-ambient temperature differential at the 95th percentile.

3.2.3.3.2 Discharge Case C: Flow Rate of 720,000 m^3/day at 12 m Depth

Table 3.44 Annualised average and minimum dilutions (1:x) achieved at specific radial distances from the CW discharge location for Case C (12 m depth discharge at 720,000 m^3/d flow rate).

Distance (m)	95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum
Scott Reef (3 nm State Water Boundary)	530	125	393	50	188	8
20	2	2	1	1	0	0
50	4	4	2	1	1	1
100	6	5	3	3	1	1
200	11	8	5	4	2	2
300	16	11	8	6	3	2
400	20	13	10	7	4	2
500	25	15	12	8	6	3
600	30	17	14	8	6	3
700	34	19	16	9	7	3
800	40	18	18	11	8	3
900	45	20	21	10	10	5
1,000	51	24	22	11	10	5
1,100	57	24	24	12	11	5
1,200	63	25	25	11	11	4
1,300	70	28	29	11	13	4
1,400	75	31	30	11	13	4
1,500	82	32	33	13	15	5
1,600	87	36	34	13	15	6
1,700	96	37	36	12	17	6
1,800	102	41	36	13	17	6
1,900	110	39	39	15	17	6
2,000	121	45	40	15	18	5
2,100	126	45	42	17	18	5
2,200	140	46	43	19	19	7
2,300	151	50	47	21	21	8
2,400	191	55	49	22	21	7
2,500	188	56	51	23	22	7
2,600	221	62	54	22	23	7
2,700	213	63	57	20	25	7
2,800	237	63	60	20	25	6
2,900	231	63	62	23	26	6
3,000	251	71	65	23	27	9
3,100	249	71	65	23	28	8
3,200	266	71	67	22	29	9
3,300	264	76	66	25	30	9
3,400	284	79	71	24	31	7
3,500	291	83	71	21	32	7

Distance (m)	95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum
3,600	313	79	76	20	33	7
3,700	315	83	76	20	35	10
3,800	312	83	83	23	35	8
3,900	339	83	85	27	37	8
4,000	314	86	92	28	37	8
4,100	359	98	92	29	38	9
4,200	323	100	103	28	40	11
4,300	341	100	105	29	40	10
4,400	340	100	114	33	42	10
4,500	357	100	113	34	43	11
4,600	359	100	123	36	44	11
4,700	378	118	124	41	45	13
4,800	379	125	126	40	45	13
4,900	596	125	128	45	46	14
5,000	398	125	134	45	47	14
5,500	448	125	159	57	56	17
6,000	431	167	180	62	63	22
6,500	447	167	198	50	71	22
7,000	478	230	206	71	73	25
7,500	495	250	229	71	85	29
8,000	494	250	254	84	88	11
8,500	489	250	276	83	99	28
9,000	496	250	303	83	103	31
9,500	499	387	305	100	112	33
10,000	500	500	319	100	120	38
10,500	500	500	344	100	133	42
11,000	500	500	336	100	146	45
11,500	500	500	352	125	152	48
12,000	505	500	360	125	162	42
12,500	500	500	360	125	165	45
13,000	500	500	370	157	171	56
13,500	500	500	376	167	183	56
14,000	500	500	391	126	182	50
14,500	500	500	405	125	197	56
15,000	507	500	426	167	208	61
15,500	500	500	440	130	209	61
16,000	500	500	439	167	195	60
16,500	510	500	456	167	242	57
17,000	500	500	464	167	216	55
17,500	511	500	465	167	228	53
18,000	527	500	473	167	356	24
18,500	517	500	481	167	232	50
19,000	554	500	477	125	232	24
19,500	500	500	478	176	249	23

Distance (m)	95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum
20,000	500	500	483	176	232	39

Table 3.45 Annualised maximum distance from the CW discharge location to achieve 1:100 dilution for Case C (12 m depth discharge at 720,000 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Annual	4,158
99th		10,011
100th		22,675

Table 3.46 Annualised total area of coverage for 1:100 dilution for Case C (12 m depth discharge at 720,000 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Annual	3.73
99th		17.52
100th		93.42

Table 3.47 Annualised maximum distance from the CW discharge location, and corresponding total area of coverage, to achieve 3 °C plume-ambient ΔT in each season for Case C (12 m depth discharge at 720,000 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given ΔT	Total area (km^2) of coverage for given ΔT
95th	Annual	120	0.009
99th		318	0.046
100th		2,914	0.499

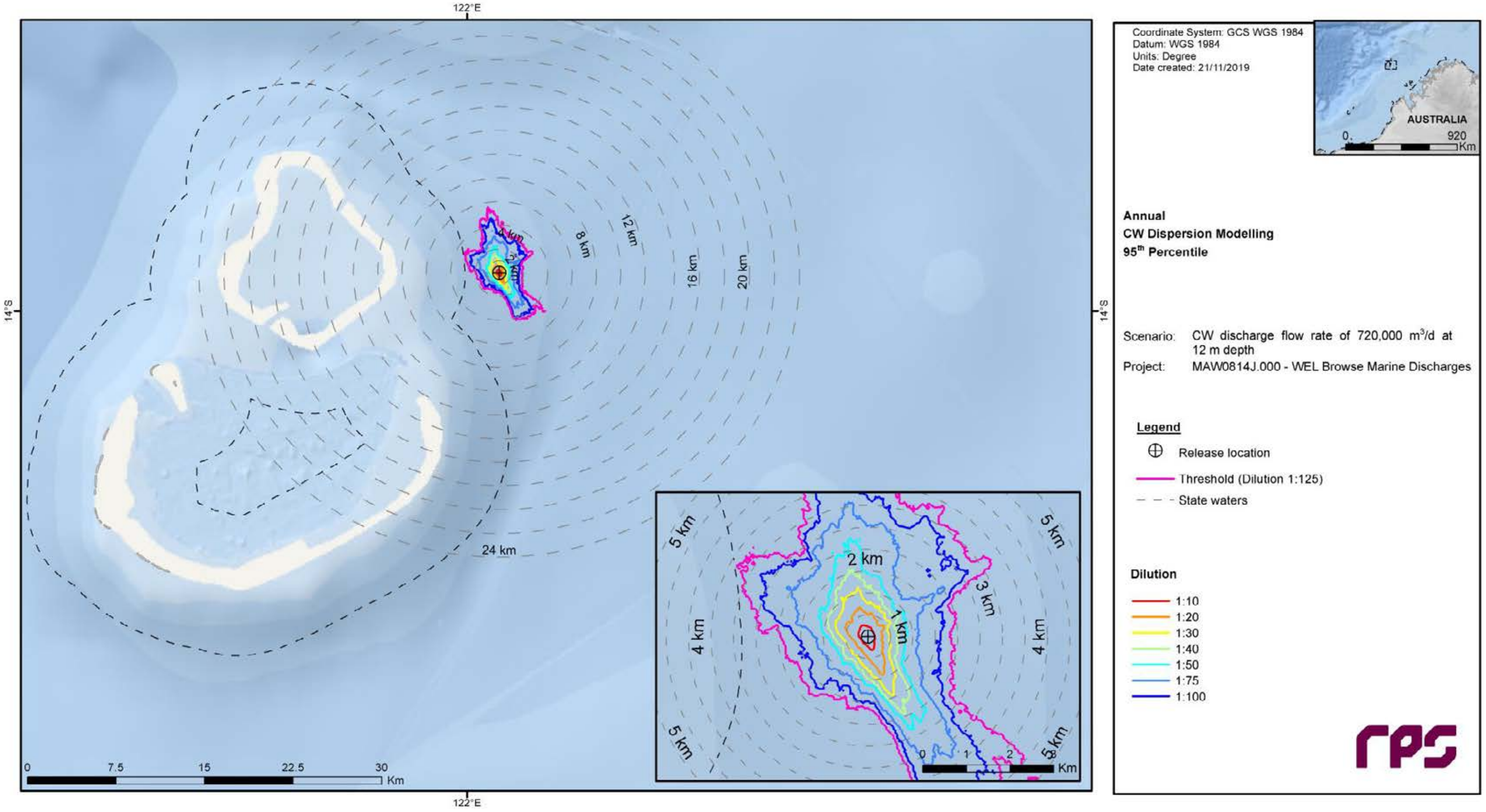


Figure 3.39 Predicted annualised minimum dilutions at the 95th percentile for Case C (12 m depth discharge at 720,000 m^3/d flow rate).

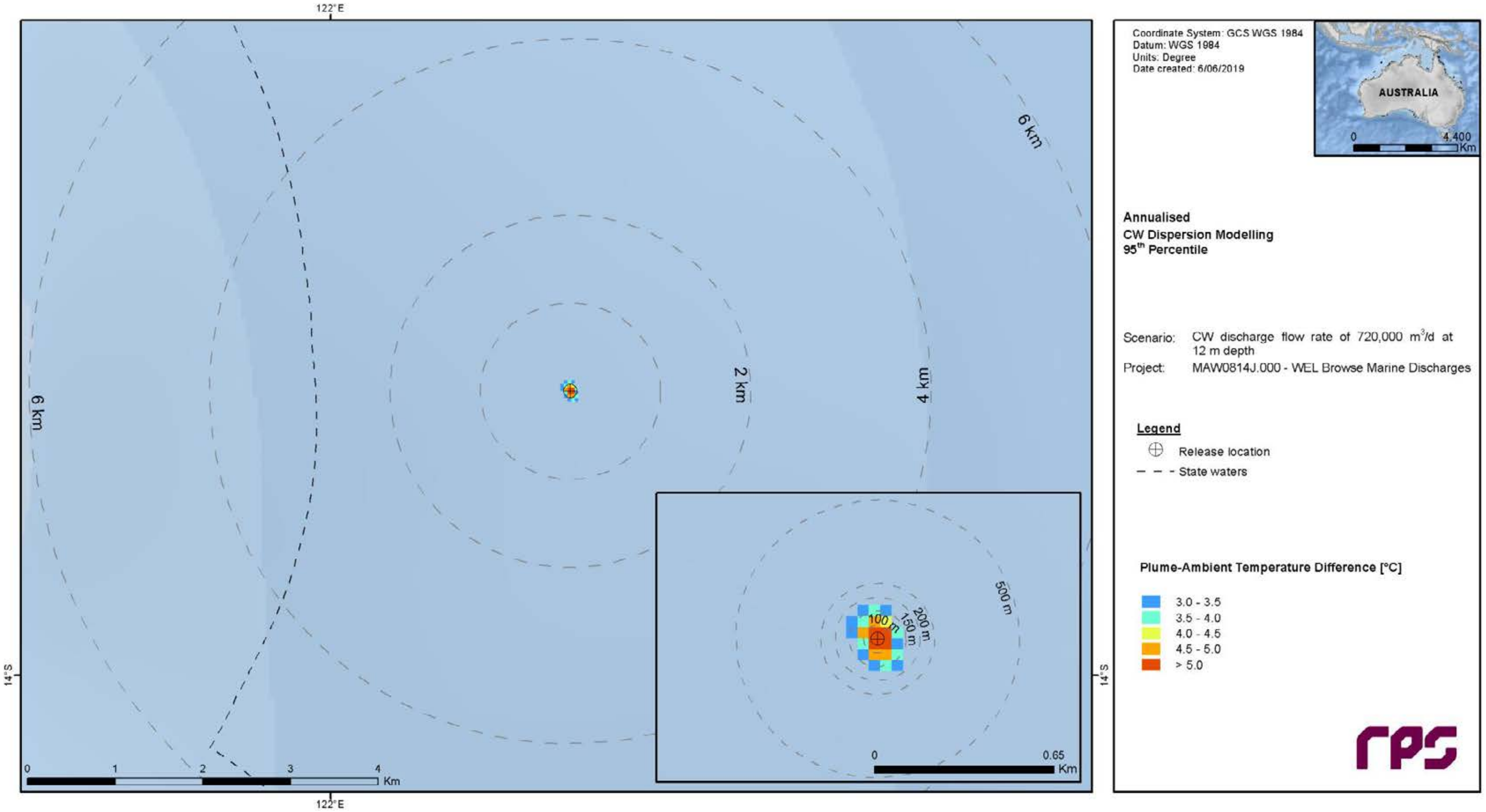


Figure 3.40 Predicted annualised maximum plume-ambient ΔT at the 95th percentile for Case C (12 m depth discharge at 720,000 m^3/d flow rate).

3.2.4 Produced Water Discharges

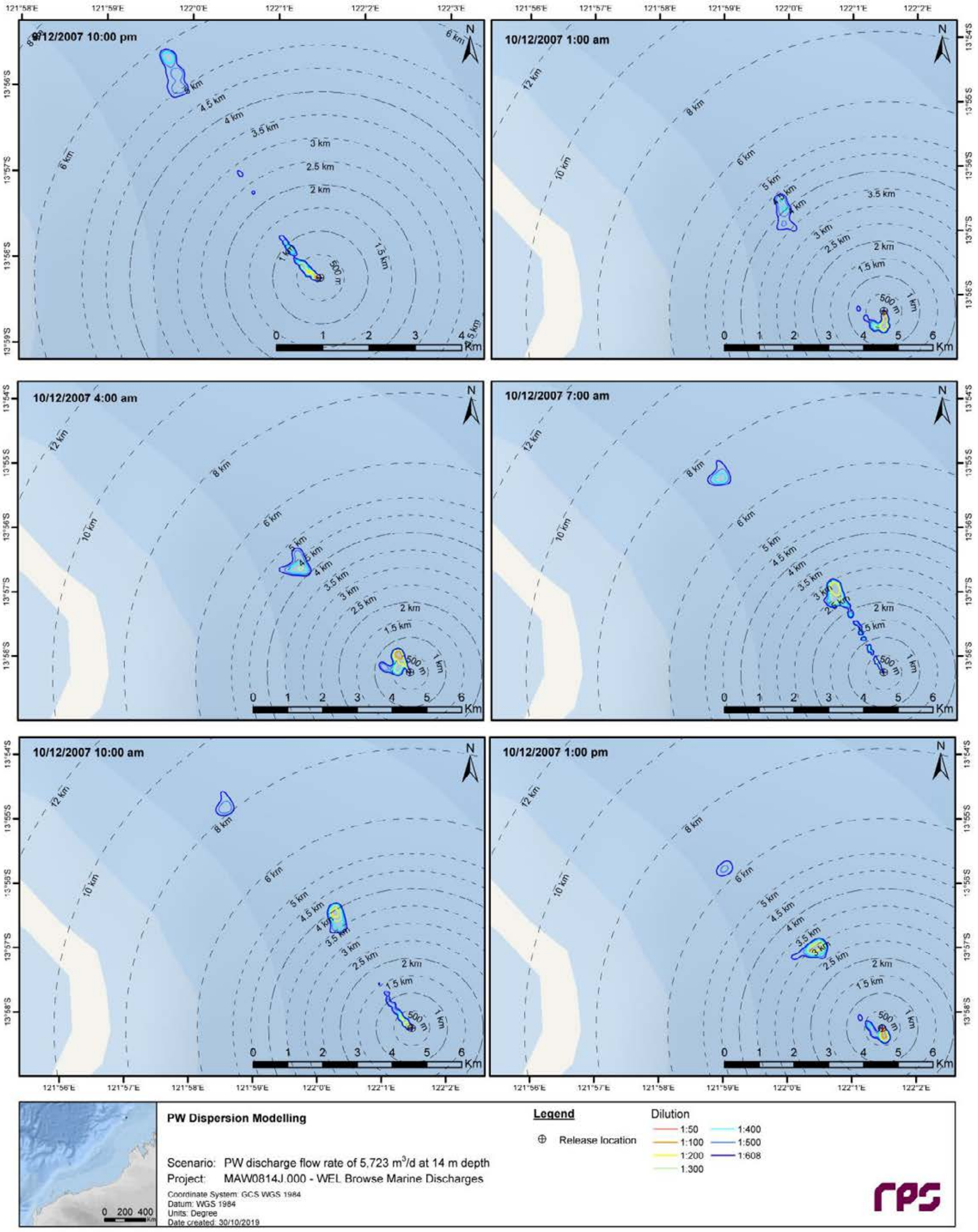
3.2.4.1 General Observations

Figure 3.41 shows example time series snapshots of predicted dilutions during a single simulation at 3-hour intervals from 22:00 on 9th December 2007 to 13:00 on 10th December 2007. This simulation – selected merely to be representative of typical conditions – considers the Case P discharge at 14 m BMSL. The spatially-varying orientation of the plume with the currents and the rapidly-varying nature of the concentrations around the source can be observed. The snapshots also show the combined effect of the tide and the drift currents, with a clear tidal oscillation.

These snapshots illustrate that the dilutions (and in turn concentrations) become more variable over time because of changes in current speed and direction. Higher dilutions (lower concentrations) are predicted during periods of increased current speed, whereas patches of lower dilutions (higher concentrations) tend to accumulate during the turning of the tide or during periods of weak drift currents. During prolonged periods of lowered current speed, the plume has a more continuous appearance, with higher-concentration patches moving as a unified group.

The snapshots in Figure 3.41 show a clear “string of pearls” pattern, where a relatively thin plume emanating from the source is punctuated with higher-concentration plume patches which separate over time from the contiguous plume. This pattern is attributable to periodic tide reversals which cause the existing plume to repeatedly pass over the source.

These findings agree with the research of King & McAllister (1997, 1998) who noted that concentrations within effluent plumes generated by an offshore platform were patchy and likely to peak around the reversal of the tides.


9/12/2007 10:00 pm

10/12/2007 1:00 am

10/12/2007 4:00 am

10/12/2007 7:00 am

10/12/2007 10:00 am

10/12/2007 1:00 pm

PW Dispersion Modelling

Scenario: PW discharge flow rate of 5,723 m^3/d at 14 m depth
Project: MAW0814J.000 - WEL Browse Marine Discharges
Coordinate System: GCS WGS 1984
Datum: WGS 1984
Units: Degree
Date created: 30/10/2019

Figure 3.41 Snapshots of predicted dilution levels, at 3-hour intervals from 22:00 on 9th December 2007 to 13:00 on 10th December 2007, for Case P (14 m depth discharge at 5,723 m^3/d flow rate).

3.2.4.2 Seasonal Analysis

3.2.4.2.1 Summary

The model outputs over the ten-year hindcast period (2006-2015) were combined and analysed on a seasonal basis (summer, transitional and winter). This approach assists with identifying the potential exposure to surrounding sensitive receptors whilst considering inter-annual variability in ocean current conditions.

Table 3.48 and Table 3.52 summarise, for Cases P and M respectively, the average and minimum dilution achieved at specific radial distances from the discharge location – as well as at or within the Scott Reef area defined by the 3 nm State water boundary – for each season and percentile.

Table 3.49 provides for Case P a summary of the maximum distances from the discharge location to achieve an example dilution level of 1:300 for each season and percentile. The results indicate that the release of effluent under all seasonal conditions results in rapid dispersion within the ambient environment. A 1:300 dilution is achieved within an area of influence ranging from 0.6-0.9 km at the 95th percentile.

Table 3.50 provides for Case P a summary of the total areas of coverage for the 1:300 dilution contour for each season and percentile. The area of exposure defined by the relevant dilution contour is predicted to reach a maximum value of 0.4-0.6 km^2 at the 95th percentile.

Table 3.51 provides for Case P a summary of the maximum depths from the discharge location to achieve 1:300 dilution for each season and percentile. The maximum depth is observed in winter, with a prediction of 19 m.

For Cases P and M, the aggregated spatial extents of the minimum dilutions for each season at the 95th percentile are presented in Figure 3.42 to Figure 3.44 and Figure 3.48 to Figure 3.50, respectively. Note that the contours represent the lowest predicted dilution (highest concentration) at any given time step through the water column and do not consider frequency or duration. The discharged plumes are predicted to travel in predominantly northerly directions during summer and transitional months, and south-easterly directions during winter.

The results presented assume that no processes other than dilution would reduce the source concentrations over time, and therefore can be considered as conservative outcomes.

Seasonal water column cross-section figures of 95th percentile dilution, extracted along perpendicular transects running through the origin point of the discharge (one of which is broadly aligned with the principal travel direction of the plume), are presented in Figure 3.45 to Figure 3.47 (Case P) and Figure 3.51 to Figure 3.53 (Case M). Although initially buoyant due to elevated temperature, the discharged plumes are predicted to quickly achieve density equilibrium with the receiving waters and rapidly dilute. This is particularly evident for the Case M discharge. The Case P plume centreline – where highest concentrations and lowest dilutions are found – will tend to remain entrained in a thin layer around 15 m below the water surface.

3.2.4.2.2 Discharge Case P: Flow Rate of 5,723 m^3/day at 14 m Depth

Table 3.48 Average and minimum dilutions (1:x) achieved at specific radial distances from the PW discharge location in each season for Case P (14 m depth discharge at 5,723 m^3/d flow rate).

	Summer						Transitional						Winter					
Distance (m)	95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum
Scott Reef (3 nm State Water Boundary	>20,000	1,658	>20,000	582	>20,000	159	>20,000	1,507	12,321	588	1,287	224	>20,000	3,897	>20,000	747	1,593	211
20	46	27	29	18	21	13	46	27	29	18	20	12	43	24	28	17	19	12
50	64	27	39	18	26	13	64	30	39	20	25	13	61	25	37	18	23	13
100	102	67	57	37	36	24	105	73	57	42	33	24	96	59	52	35	32	22
200	181	118	91	63	51	33	199	133	92	67	48	32	176	100	82	54	47	29
300	266	163	121	79	63	36	315	185	126	86	64	42	271	135	117	65	62	32
400	348	200	151	92	77	45	424	217	155	98	75	36	354	155	153	71	74	37
500	432	234	182	99	93	46	522	266	181	108	85	43	432	181	182	82	89	39
600	525	263	208	109	105	47	624	309	210	126	98	49	510	217	212	92	101	45
700	601	296	235	134	112	54	731	359	232	144	103	48	575	253	235	109	111	47
800	688	339	258	138	125	58	869	410	256	152	113	48	651	270	261	111	122	52
900	785	378	281	138	142	63	1,030	462	281	162	125	50	732	288	287	116	131	55
1,000	876	405	305	148	148	59	1,243	527	307	176	133	59	816	306	316	120	144	57
1,100	972	451	327	150	152	65	1,482	583	334	202	146	60	896	319	338	131	153	53
1,200	1,078	480	353	156	163	63	1,897	635	366	230	155	61	982	333	364	144	164	54
1,300	1,206	525	379	164	179	70	2,276	687	392	232	165	59	1,076	358	392	149	168	62
1,400	1,393	573	402	185	190	64	2,929	740	420	241	175	76	1,185	376	415	152	177	65
1,500	1,594	591	431	202	194	79	3,910	761	449	260	185	66	1,289	376	436	149	192	67
1,600	1,845	640	463	215	207	77	5,611	818	476	268	192	67	1,390	379	459	161	200	61
1,700	2,144	699	488	215	209	76	7,355	872	505	273	195	70	1,481	378	479	173	206	65
1,800	2,575	756	522	203	217	71	9,598	887	536	289	203	83	1,619	382	504	180	218	67
1,900	3,260	806	559	214	231	87	13,470	963	567	307	220	79	1,814	390	528	176	228	81
2,000	4,255	872	599	219	241	79	>20,000	1,042	597	312	231	85	2,014	393	557	174	233	82
2,100	5,610	936	638	231	253	73	>20,000	1,057	631	317	243	79	2,225	410	585	172	243	78
2,200	7,701	939	670	261	268	85	>20,000	1,059	672	337	253	94	2,494	414	613	176	257	77
2,300	11,595	1,035	697	278	276	98	>20,000	1,050	702	353	261	106	2,725	419	635	187	265	78
2,400	18,757	1,032	733	280	279	89	>20,000	1,106	738	355	269	94	3,043	419	662	185	275	88
2,500	>20,000	1,082	764	284	294	77	>20,000	1,158	773	360	275	92	3,522	434	696	181	282	85
2,600	>20,000	1,110	792	306	309	101	>20,000	1,259	808	361	292	98	4,184	452	724	186	285	85
2,700	>20,000	1,170	825	313	320	89	>20,000	1,370	847	429	305	112	4,964	487	758	189	293	95
2,800	>20,000	1,173	863	325	322	85	>20,000	1,482	889	476	310	95	5,915	525	794	197	302	102
2,900	>20,000	1,264	897	351	324	115	>20,000	1,516	926	530	313	105	7,368	551	821	213	305	93
3,000	>20,000	1,304	940	370	338	133	>20,000	1,558	966	519	312	101	9,837	617	858	229	316	96
3,100	>20,000	1,306	984	373	346	115	>20,000	1,554	1,013	539	312	104	14,201	674	887	259	335	112
3,200	>20,000	1,363	1,031	402	356	112	>20,000	1,547	1,059	558	318	129	>20,000	693	923	268	347	107
3,300	>20,000	1,400	1,092	415	364	100	>20,000	1,541	1,112	571	331	145	>20,000	736	964	290	355	108
3,400	>20,000	1,514	1,157	437	366	115	>20,000	1,586	1,171	663	350	161	>20,000	785	1,005	277	366	114
3,500	>20,000	1,621	1,212	465	371	130	>20,000	1,641	1,227	688	357	145	>20,000	814	1,053	293	369	105

Distance (m)	Summer						Transitional						Winter					
	95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum
3,600	>20,000	1,723	1,310	479	388	115	>20,000	1,758	1,306	710	371	118	>20,000	827	1,115	297	370	107
3,700	>20,000	1,933	1,413	494	402	122	>20,000	1,836	1,378	707	387	113	>20,000	872	1,186	342	370	128
3,800	>20,000	1,918	1,527	485	407	128	>20,000	1,906	1,474	722	396	132	>20,000	939	1,263	383	378	120
3,900	>20,000	2,007	1,757	507	417	105	>20,000	1,930	1,606	743	402	155	>20,000	959	1,350	420	395	123
4,000	>20,000	2,007	2,175	479	441	124	>20,000	2,008	1,771	712	412	131	>20,000	1,027	1,446	431	415	98
4,100	>20,000	2,035	2,797	512	464	128	>20,000	2,043	1,965	759	427	135	>20,000	1,057	1,540	436	443	133
4,200	>20,000	2,119	4,229	503	497	140	>20,000	2,119	2,259	770	435	138	>20,000	1,079	1,629	440	470	123
4,300	>20,000	2,270	6,721	523	528	145	>20,000	2,190	2,716	778	442	129	>20,000	1,086	1,723	441	479	128
4,400	>20,000	2,327	11,948	508	548	138	>20,000	2,221	3,282	768	453	152	>20,000	1,113	1,836	452	481	155
4,500	>20,000	2,390	>20,000	541	565	138	>20,000	2,260	4,092	801	469	167	>20,000	1,132	1,963	468	490	190
4,600	>20,000	2,388	>20,000	594	578	148	>20,000	2,365	4,794	807	477	171	>20,000	1,145	2,080	451	502	167
4,700	>20,000	2,493	>20,000	588	595	175	>20,000	2,328	6,113	894	484	151	>20,000	1,173	2,199	437	513	160
4,800	>20,000	2,528	>20,000	583	611	173	>20,000	2,416	8,130	888	495	123	>20,000	1,281	2,314	443	521	154
4,900	>20,000	2,770	>20,000	622	624	165	>20,000	2,473	11,170	885	506	168	>20,000	1,341	2,466	452	538	144
5,000	>20,000	2,890	>20,000	702	622	178	>20,000	2,699	14,522	928	519	160	>20,000	1,411	2,617	522	554	154
5,500	>20,000	3,689	>20,000	829	693	135	>20,000	3,414	>20,000	1,044	585	202	>20,000	1,817	4,076	663	616	172
6,000	>20,000	4,963	>20,000	868	831	184	>20,000	3,935	>20,000	1,140	629	218	>20,000	1,770	6,329	656	669	216
6,500	>20,000	5,730	>20,000	1,041	1,340	180	>20,000	4,256	>20,000	1,264	695	211	>20,000	1,948	11,642	713	742	136
7,000	>20,000	7,581	>20,000	1,408	8,610	193	>20,000	5,134	>20,000	1,529	780	279	>20,000	2,339	>20,000	810	805	228
7,500	>20,000	9,188	>20,000	1,544	14,106	196	>20,000	5,873	>20,000	1,602	843	246	>20,000	2,559	>20,000	886	869	212
8,000	>20,000	10,325	>20,000	1,691	8,039	175	>20,000	7,291	>20,000	1,738	928	258	>20,000	3,119	>20,000	935	996	169
8,500	>20,000	11,510	>20,000	1,547	8,882	302	>20,000	9,959	>20,000	1,870	1,333	205	>20,000	4,023	>20,000	1,161	1,050	205
9,000	>20,000	14,088	>20,000	1,799	12,035	259	>20,000	>20,000	>20,000	2,065	4,552	237	>20,000	3,950	>20,000	1,193	1,104	263
9,500	>20,000	18,786	>20,000	1,970	14,365	313	>20,000	>20,000	>20,000	1,963	9,189	176	>20,000	3,474	>20,000	1,190	1,211	290
10,000	>20,000	18,697	>20,000	1,913	10,858	345	>20,000	>20,000	>20,000	1,951	11,644	404	>20,000	4,721	>20,000	1,309	1,313	374

Table 3.49 **Maximum distance from the PW discharge location to achieve 1:300 dilution in each season for Case P (14 m depth discharge at 5,723 m^3/d flow rate).**

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Summer	699
	Transitional	584
	Winter	948
99th	Summer	2,576
	Transitional	1,883
	Winter	3,607
100th	Summer	9,349
	Transitional	10,493
	Winter	10,493

Table 3.50 **Total area of coverage for 1:300 dilution in each season for Case P (14 m depth discharge at 5,723 m^3/d flow rate).**

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Summer	0.47
	Transitional	0.40
	Winter	0.62
99th	Summer	4.36
	Transitional	3.57
	Winter	5.50
100th	Summer	37.52
	Transitional	54.79
	Winter	36.23

Table 3.51 **Maximum depth from the PW discharge location to achieve 1:300 dilution in each season for Case P (14 m depth discharge at 5,723 m^3/d flow rate).**

Season	Maximum depth (m) from discharge location to achieve given dilution
Summer	18
Transitional	18
Winter	19

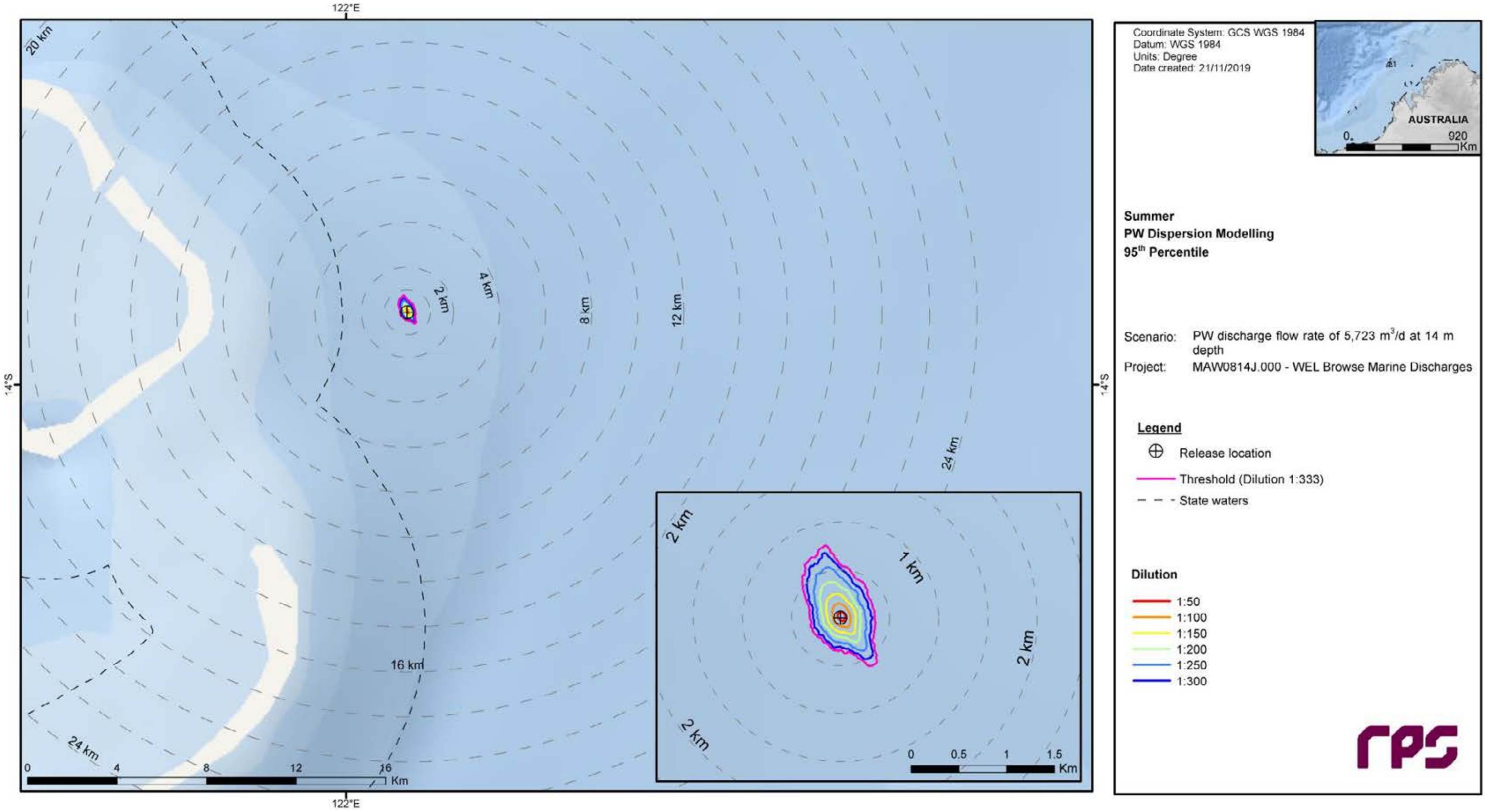


Figure 3.42 Predicted minimum dilutions at the 95th percentile under summer conditions for Case P (14 m depth discharge at 5,723 m^3/d flow rate).

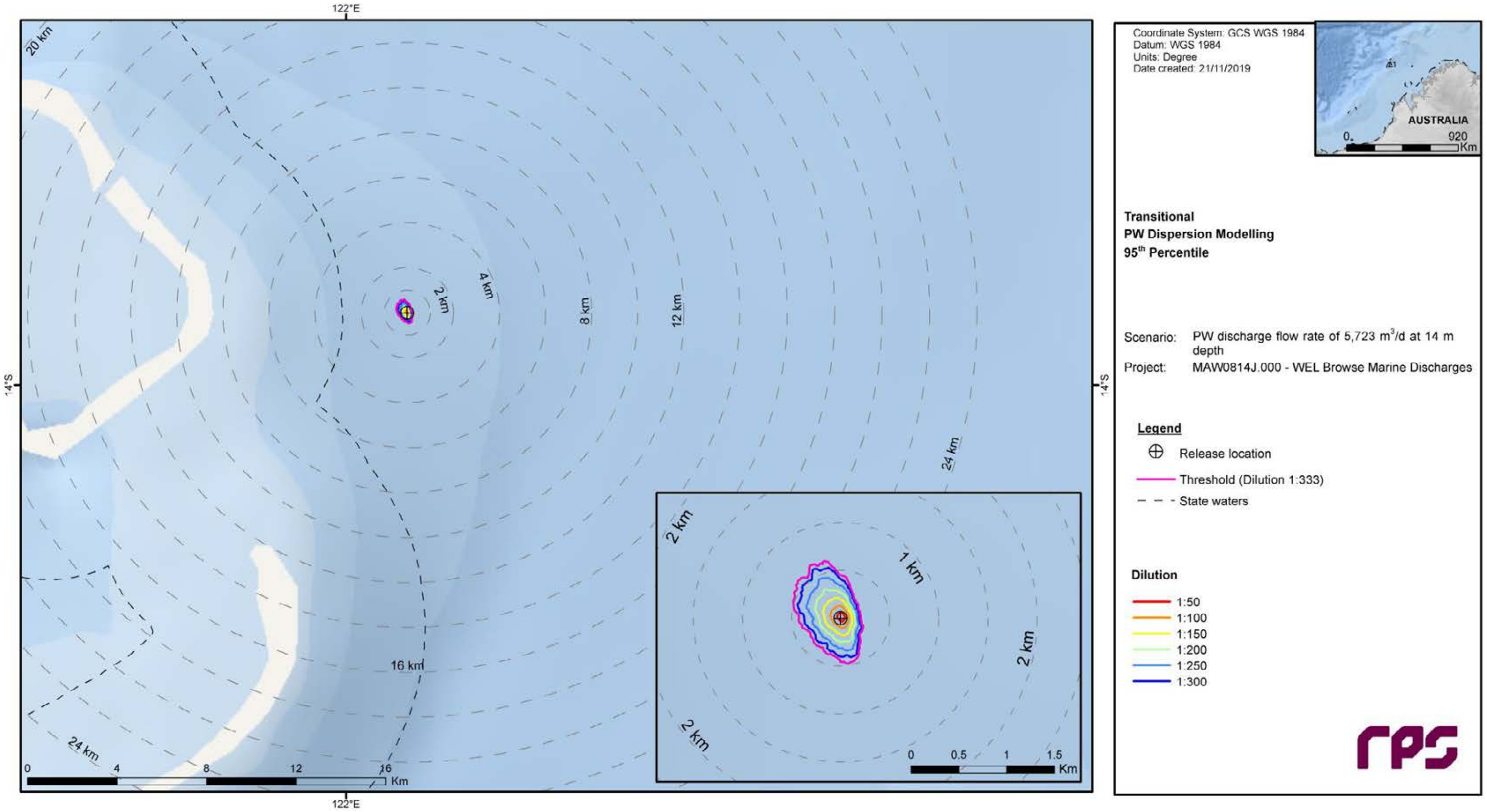


Figure 3.43 Predicted minimum dilutions at the 95th percentile under transitional conditions for Case P (14 m depth discharge at 5,723 m^3/d flow rate).

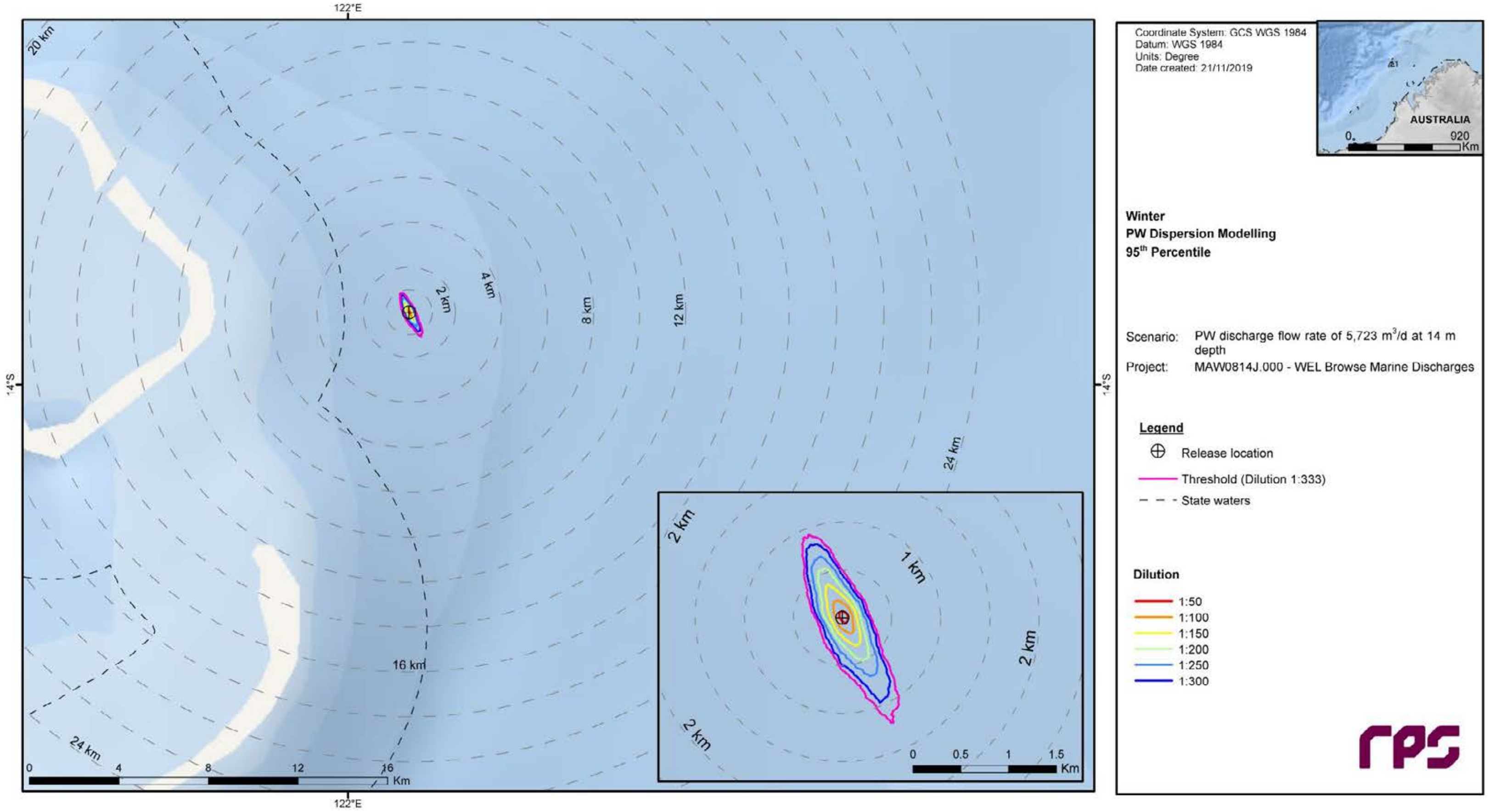


Figure 3.44 Predicted minimum dilutions at the 95th percentile under winter conditions for Case P (14 m depth discharge at 5,723 m^3/d flow rate).

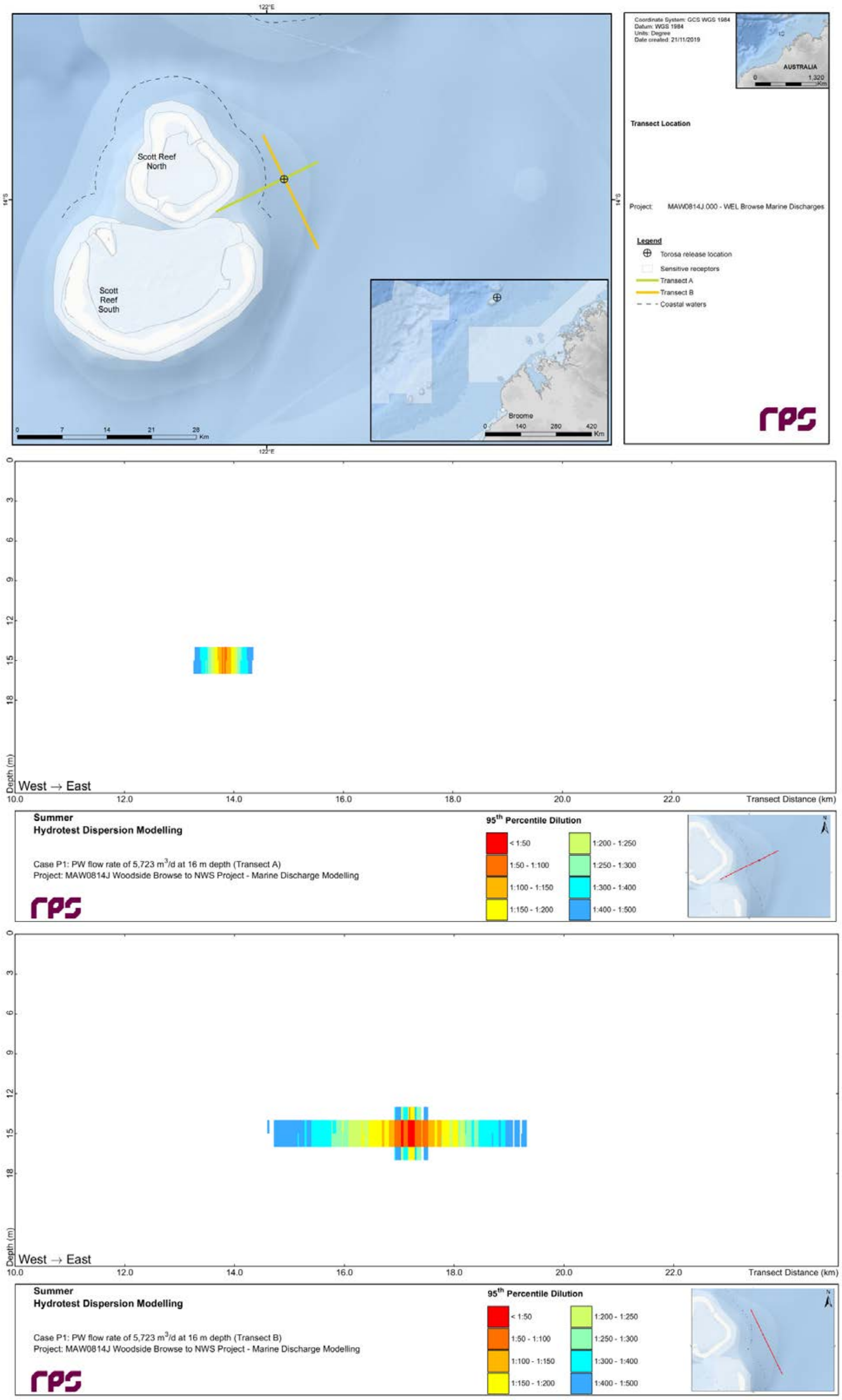


Figure 3.45 Vertical cross-section plots of predicted minimum dilutions at the 95th percentile under summer conditions for Case P (14 m depth discharge at 5,723 m^3/d flow rate). Transect locations are shown in the top panel, with transect A shown in the middle panel and transect B shown in the bottom panel. Spatial representation of this data is shown in Figure 3.42.

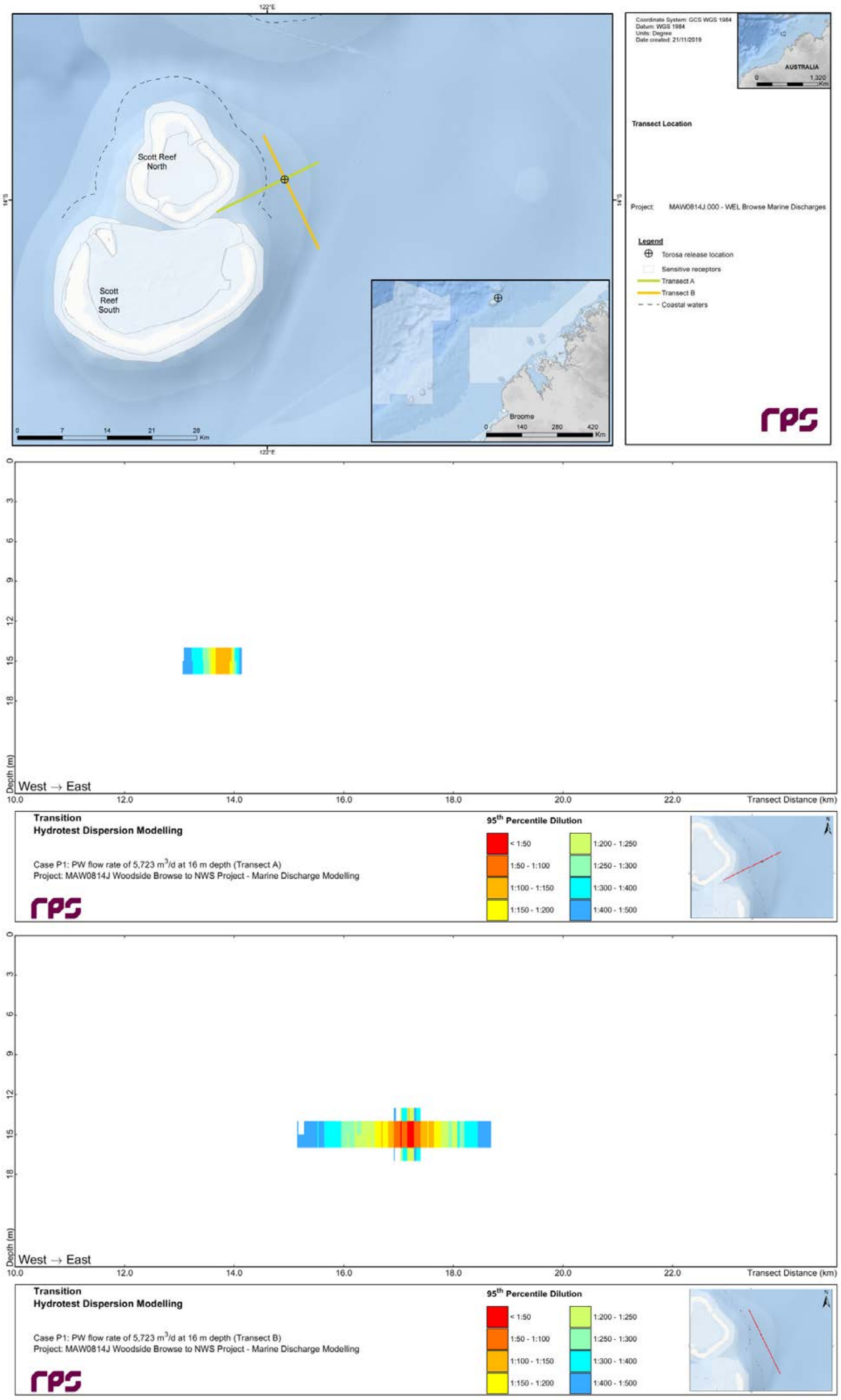


Figure 3.46 Vertical cross-section plots of predicted minimum dilutions at the 95th percentile under transitional conditions for Case P (14 m depth discharge at 5,723 m^3/d flow rate). Transect locations are shown in the top panel, with transect A shown in the middle panel and transect B shown in the bottom panel. Spatial representation of this data is shown in Figure 3.43.

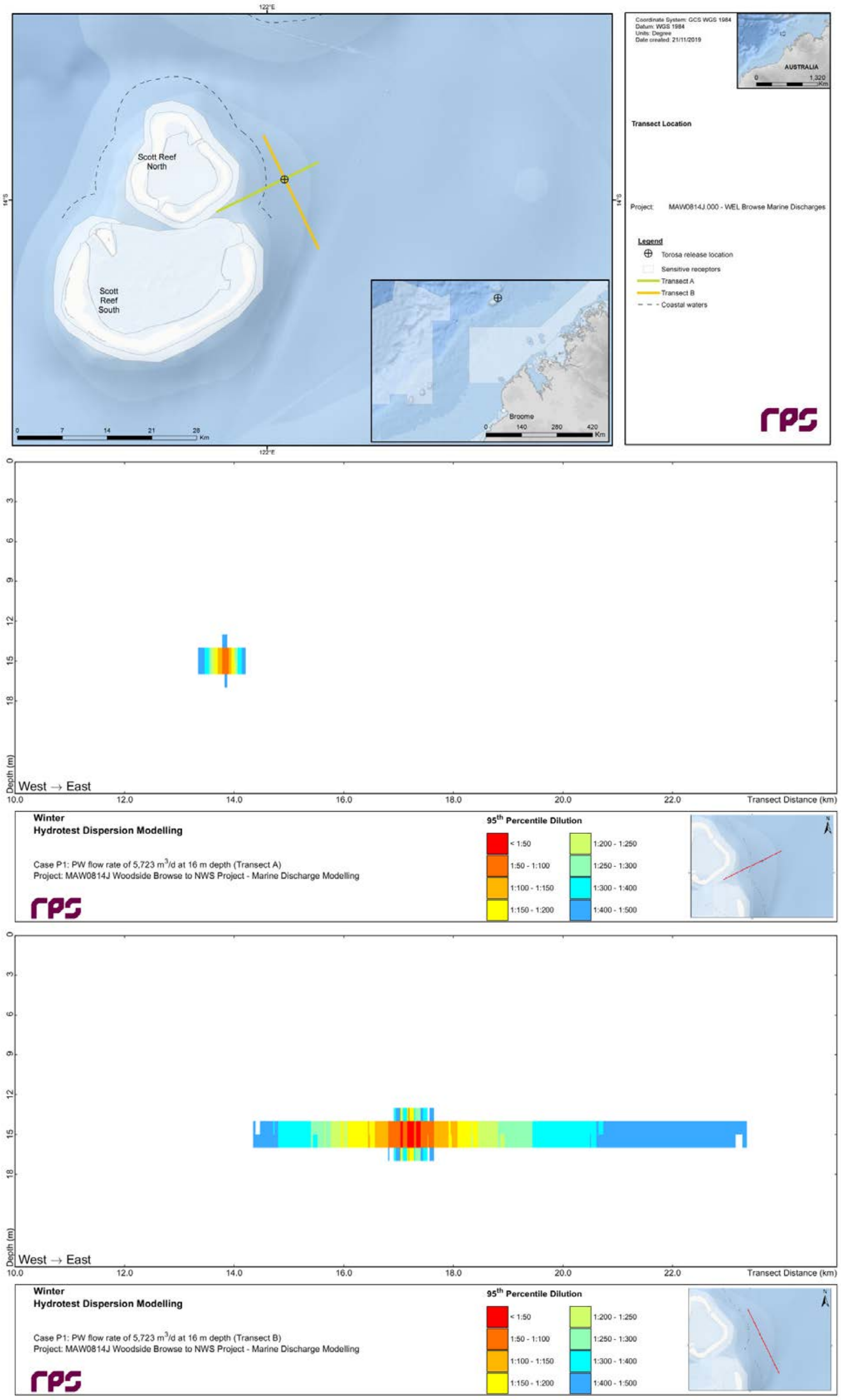


Figure 3.47 Vertical cross-section plots of predicted minimum dilutions at the 95th percentile under winter conditions for Case P (14 m depth discharge at 5,723 m^3/d flow rate). Transect locations are shown in the top panel, with transect A shown in the middle panel and transect B shown in the bottom panel. Spatial representation of this data is shown in Figure 3.44.

3.2.4.2.3 Discharge Case M: Flow Rate of 490 m^3/day at 14 m Depth

Table 3.52 Average and minimum dilutions (1:x) achieved at specific radial distances from the PW discharge location in each season for Case M (14 m depth discharge at 490 m^3/d flow rate).

Distance (m)	Summer						Transitional						Winter					
	95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum
Scott Reef (3 nm State Water Boundary	>20,000	19,974	>20,000	6,594	>20,000	1,949	>20,000	17,674	>20,000	6,758	13,838	2,219	>20,000	>20,000	>20,000	9,259	>20,000	3,138
20	509	283	314	189	200	138	492	274	304	189	198	130	598	321	333	199	211	127
50	710	289	421	195	277	120	696	319	408	208	254	123	913	396	446	220	244	126
100	1,166	675	625	409	364	221	1,182	763	620	457	354	271	1,766	906	691	463	347	211
200	2,091	1,320	1,001	665	548	344	2,283	1,474	1,004	735	541	335	3,615	1,538	1,205	744	554	316
300	3,101	1,830	1,368	915	668	442	3,676	2,014	1,402	939	716	446	5,563	2,069	1,834	866	760	382
400	4,089	2,187	1,705	1,068	839	463	5,007	2,471	1,741	1,046	810	420	7,054	2,742	2,442	1,056	926	418
500	5,092	2,597	2,040	1,148	1,004	523	6,132	3,006	2,053	1,209	942	427	8,716	3,344	2,907	1,202	1,083	444
600	6,127	2,946	2,373	1,300	1,153	580	7,400	3,435	2,375	1,410	1,061	486	10,413	3,983	3,364	1,379	1,284	472
700	7,096	3,505	2,650	1,508	1,220	579	8,665	4,205	2,651	1,636	1,154	548	12,381	4,648	3,647	1,513	1,383	549
800	8,133	3,777	2,897	1,542	1,373	640	10,500	4,744	2,921	1,779	1,315	626	14,941	5,074	4,064	1,746	1,526	573
900	9,274	4,252	3,206	1,659	1,521	732	12,345	5,393	3,212	1,819	1,438	675	18,297	5,654	4,488	1,872	1,643	599
1,000	10,357	4,751	3,492	1,698	1,623	735	15,026	5,777	3,526	1,937	1,507	555	>20,000	5,940	4,899	1,914	1,818	667
1,100	11,434	5,126	3,756	1,875	1,703	648	18,287	6,659	3,823	2,293	1,668	653	>20,000	6,247	5,254	2,011	1,914	657
1,200	12,815	5,500	4,029	1,910	1,750	710	>20,000	7,432	4,189	2,544	1,789	769	>20,000	6,763	5,696	2,371	2,019	712
1,300	14,475	5,997	4,322	1,964	1,982	755	>20,000	8,005	4,527	2,765	1,901	724	>20,000	7,151	6,043	2,394	2,198	728
1,400	16,690	6,517	4,664	2,208	2,060	709	>20,000	8,465	4,890	2,764	1,985	788	>20,000	7,468	6,388	2,531	2,330	793
1,500	19,484	6,983	4,996	2,332	2,153	851	>20,000	8,708	5,213	2,870	2,036	691	>20,000	7,504	6,731	2,575	2,504	749
1,600	>20,000	7,427	5,336	2,584	2,255	756	>20,000	9,388	5,545	3,024	2,138	768	>20,000	8,039	7,052	2,810	2,703	705
1,700	>20,000	7,984	5,633	2,434	2,279	909	>20,000	9,403	5,911	2,980	2,244	919	>20,000	8,500	7,296	2,850	2,741	907
1,800	>20,000	8,728	5,994	2,511	2,404	866	>20,000	10,478	6,254	3,091	2,293	821	>20,000	9,023	7,658	2,940	2,851	920
1,900	>20,000	9,122	6,442	2,483	2,554	979	>20,000	11,278	6,599	3,450	2,410	945	>20,000	9,318	8,023	3,133	2,901	983
2,000	>20,000	9,650	6,876	2,453	2,631	953	>20,000	11,970	6,923	3,533	2,544	896	>20,000	10,351	8,507	3,118	3,061	1,117
2,100	>20,000	10,333	7,365	2,628	2,783	928	>20,000	12,262	7,350	3,480	2,702	878	>20,000	11,045	9,020	3,190	3,214	1,039
2,200	>20,000	10,743	7,781	2,784	2,878	965	>20,000	12,369	7,759	3,665	2,789	1,136	>20,000	12,082	9,671	3,387	3,427	1,139
2,300	>20,000	12,654	8,126	3,000	2,985	1,010	>20,000	12,284	8,147	3,808	2,902	1,240	>20,000	13,142	10,464	3,360	3,500	1,022
2,400	>20,000	12,675	8,443	3,295	3,116	937	>20,000	13,449	8,563	4,081	2,976	1,050	>20,000	14,592	11,201	3,585	3,657	1,287
2,500	>20,000	12,901	8,801	3,468	3,285	873	>20,000	14,581	8,910	4,269	3,067	995	>20,000	15,153	12,057	3,861	3,917	1,158
2,600	>20,000	13,820	9,159	3,356	3,348	1,126	>20,000	15,120	9,273	4,399	3,185	934	>20,000	16,879	13,111	4,030	4,018	1,292
2,700	>20,000	13,842	9,644	3,533	3,509	1,068	>20,000	16,296	9,738	4,978	3,328	1,199	>20,000	>20,000	14,359	4,181	4,100	1,298
2,800	>20,000	14,320	10,081	3,805	3,621	1,064	>20,000	17,107	10,273	5,265	3,394	1,145	>20,000	>20,000	15,507	4,417	4,296	1,063
2,900	>20,000	14,523	10,458	3,653	3,631	1,373	>20,000	18,364	10,820	6,055	3,410	1,142	>20,000	>20,000	16,567	4,980	4,426	1,275
3,000	>20,000	15,357	10,961	4,226	3,750	1,205	>20,000	18,296	11,258	6,005	3,505	1,118	>20,000	>20,000	17,843	5,324	4,845	1,476
3,100	>20,000	15,803	11,404	4,380	3,854	1,270	>20,000	17,922	11,758	6,404	3,541	1,012	>20,000	>20,000	19,165	5,483	5,048	1,570
3,200	>20,000	15,758	12,036	4,444	3,990	1,152	>20,000	18,464	12,202	6,172	3,594	1,283	>20,000	>20,000	>20,000	6,254	5,172	1,421
3,300	>20,000	16,259	12,761	4,863	4,070	1,223	>20,000	18,295	12,817	6,407	3,716	1,672	>20,000	>20,000	>20,000	6,894	5,256	1,396
3,400	>20,000	17,437	13,541	5,216	4,090	1,338	>20,000	18,922	13,495	7,212	3,890	1,554	>20,000	>20,000	>20,000	6,736	5,468	1,380
3,500	>20,000	18,712	14,510	5,240	4,173	1,392	>20,000	>20,000	14,132	7,873	4,048	1,592	>20,000	>20,000	>20,000	7,139	5,618	1,275

Distance (m)	Summer						Transitional						Winter					
	95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum
3,600	>20,000	>20,000	15,485	5,498	4,292	1,356	>20,000	>20,000	15,111	8,006	4,214	1,340	>20,000	>20,000	>20,000	7,502	5,814	1,725
3,700	>20,000	>20,000	16,732	5,636	4,471	1,498	>20,000	>20,000	16,150	8,120	4,348	1,360	>20,000	>20,000	>20,000	7,664	6,079	1,791
3,800	>20,000	>20,000	18,163	5,451	4,561	1,277	>20,000	>20,000	17,200	8,196	4,481	1,519	>20,000	>20,000	>20,000	8,112	6,157	1,320
3,900	>20,000	>20,000	>20,000	5,874	4,699	1,033	>20,000	>20,000	18,503	8,574	4,597	1,782	>20,000	>20,000	>20,000	8,367	6,404	1,394
4,000	>20,000	>20,000	>20,000	5,663	4,883	1,408	>20,000	>20,000	>20,000	8,463	4,637	1,822	>20,000	>20,000	>20,000	8,956	6,663	2,004
4,100	>20,000	>20,000	>20,000	5,551	5,235	1,373	>20,000	>20,000	>20,000	8,289	4,753	1,585	>20,000	>20,000	>20,000	9,121	6,897	1,569
4,200	>20,000	>20,000	>20,000	5,777	5,670	1,498	>20,000	>20,000	>20,000	8,409	4,905	1,650	>20,000	>20,000	>20,000	9,074	7,140	1,533
4,300	>20,000	>20,000	>20,000	5,794	6,046	1,720	>20,000	>20,000	>20,000	8,805	5,021	1,331	>20,000	>20,000	>20,000	9,517	7,379	1,669
4,400	>20,000	>20,000	>20,000	5,899	6,258	1,634	>20,000	>20,000	>20,000	9,279	5,127	1,520	>20,000	>20,000	>20,000	9,709	7,626	1,935
4,500	>20,000	>20,000	>20,000	6,269	6,492	1,512	>20,000	>20,000	>20,000	9,278	5,276	2,117	>20,000	>20,000	>20,000	9,966	7,880	2,091
4,600	>20,000	>20,000	>20,000	6,649	6,751	1,718	>20,000	>20,000	>20,000	9,345	5,477	2,145	>20,000	>20,000	>20,000	10,450	8,126	1,973
4,700	>20,000	>20,000	>20,000	6,135	6,824	1,769	>20,000	>20,000	>20,000	9,423	5,584	1,778	>20,000	>20,000	>20,000	10,746	8,099	1,503
4,800	>20,000	>20,000	>20,000	6,857	7,007	1,897	>20,000	>20,000	>20,000	10,111	5,694	1,304	>20,000	>20,000	>20,000	10,966	8,353	1,715
4,900	>20,000	>20,000	>20,000	7,617	7,110	1,777	>20,000	>20,000	>20,000	10,406	5,731	1,484	>20,000	>20,000	>20,000	11,181	8,949	2,010
5,000	>20,000	>20,000	>20,000	8,483	6,983	1,627	>20,000	>20,000	>20,000	10,595	5,862	1,867	>20,000	>20,000	>20,000	11,720	10,203	2,061
5,500	>20,000	>20,000	>20,000	10,137	7,735	1,554	>20,000	>20,000	>20,000	12,207	6,514	1,995	>20,000	>20,000	>20,000	14,353	>20,000	1,986
6,000	>20,000	>20,000	>20,000	10,198	9,343	2,268	>20,000	>20,000	>20,000	13,468	7,230	2,663	>20,000	>20,000	>20,000	16,626	>20,000	2,544
6,500	>20,000	>20,000	>20,000	12,938	16,210	2,033	>20,000	>20,000	>20,000	14,729	7,999	2,580	>20,000	>20,000	>20,000	19,532	>20,000	3,381
7,000	>20,000	>20,000	>20,000	15,857	>20,000	2,032	>20,000	>20,000	>20,000	16,846	8,739	2,871	>20,000	>20,000	>20,000	>20,000	>20,000	3,138
7,500	>20,000	>20,000	>20,000	18,105	>20,000	2,215	>20,000	>20,000	>20,000	17,839	9,655	3,121	>20,000	>20,000	>20,000	>20,000	>20,000	4,803
8,000	>20,000	>20,000	>20,000	19,378	>20,000	2,241	>20,000	>20,000	>20,000	19,821	10,262	3,510	>20,000	>20,000	>20,000	>20,000	>20,000	3,366
8,500	>20,000	>20,000	>20,000	18,180	>20,000	2,646	>20,000	>20,000	>20,000	>20,000	13,784	1,918	>20,000	>20,000	>20,000	>20,000	>20,000	3,778
9,000	>20,000	>20,000	>20,000	>20,000	>20,000	2,230	>20,000	>20,000	>20,000	>20,000	>20,000	2,652	>20,000	>20,000	>20,000	>20,000	>20,000	3,583
9,500	>20,000	>20,000	>20,000	>20,000	>20,000	4,418	>20,000	>20,000	>20,000	>20,000	>20,000	1,986	>20,000	>20,000	>20,000	>20,000	>20,000	4,627
10,000	>20,000	>20,000	>20,000	>20,000	>20,000	3,464	>20,000	>20,000	>20,000	>20,000	>20,000	3,440	>20,000	>20,000	>20,000	>20,000	>20,000	4,007

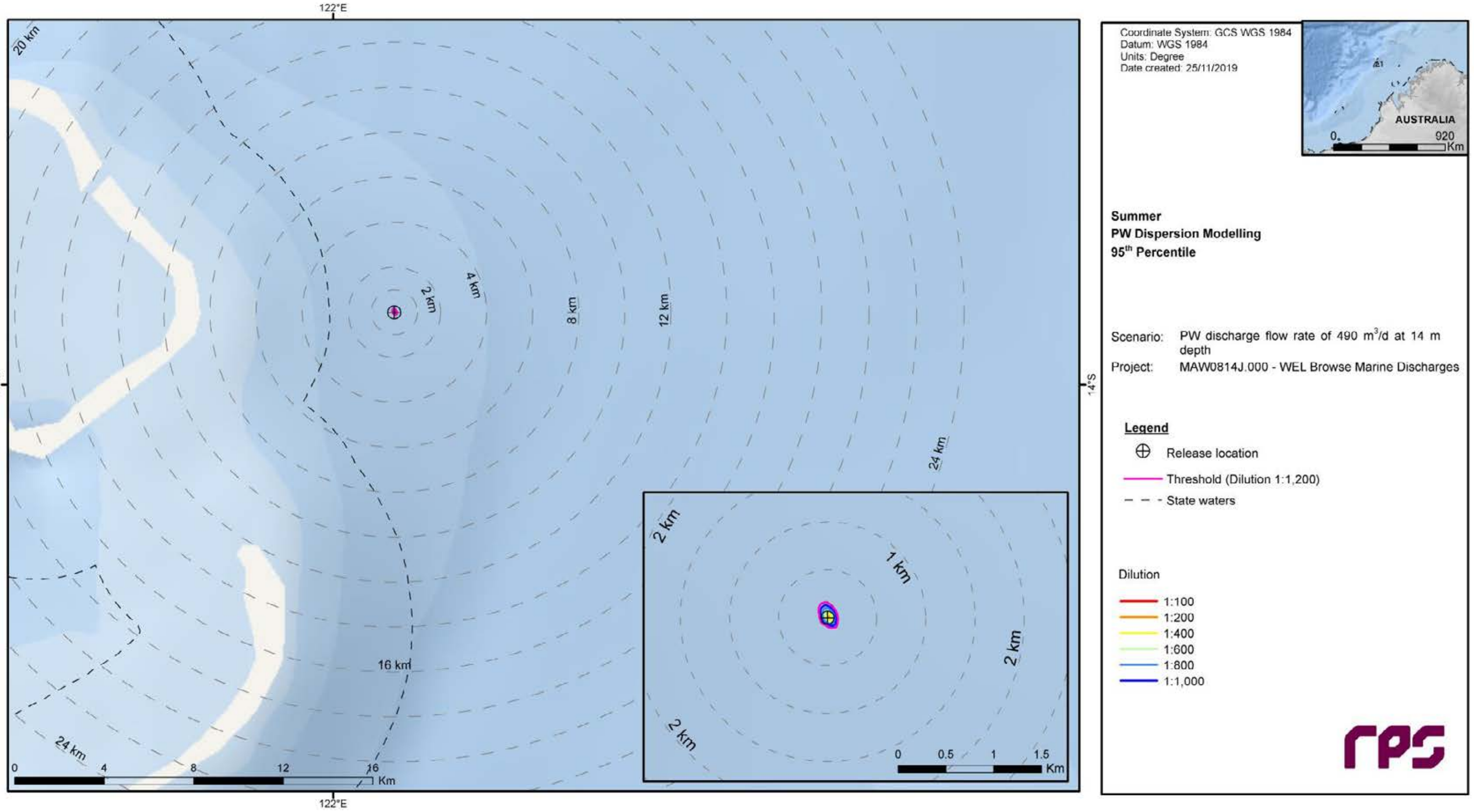


Figure 3.48 Predicted minimum dilutions at the 95th percentile under summer conditions for Case M (14 m depth discharge at 490 m^3/d flow rate).

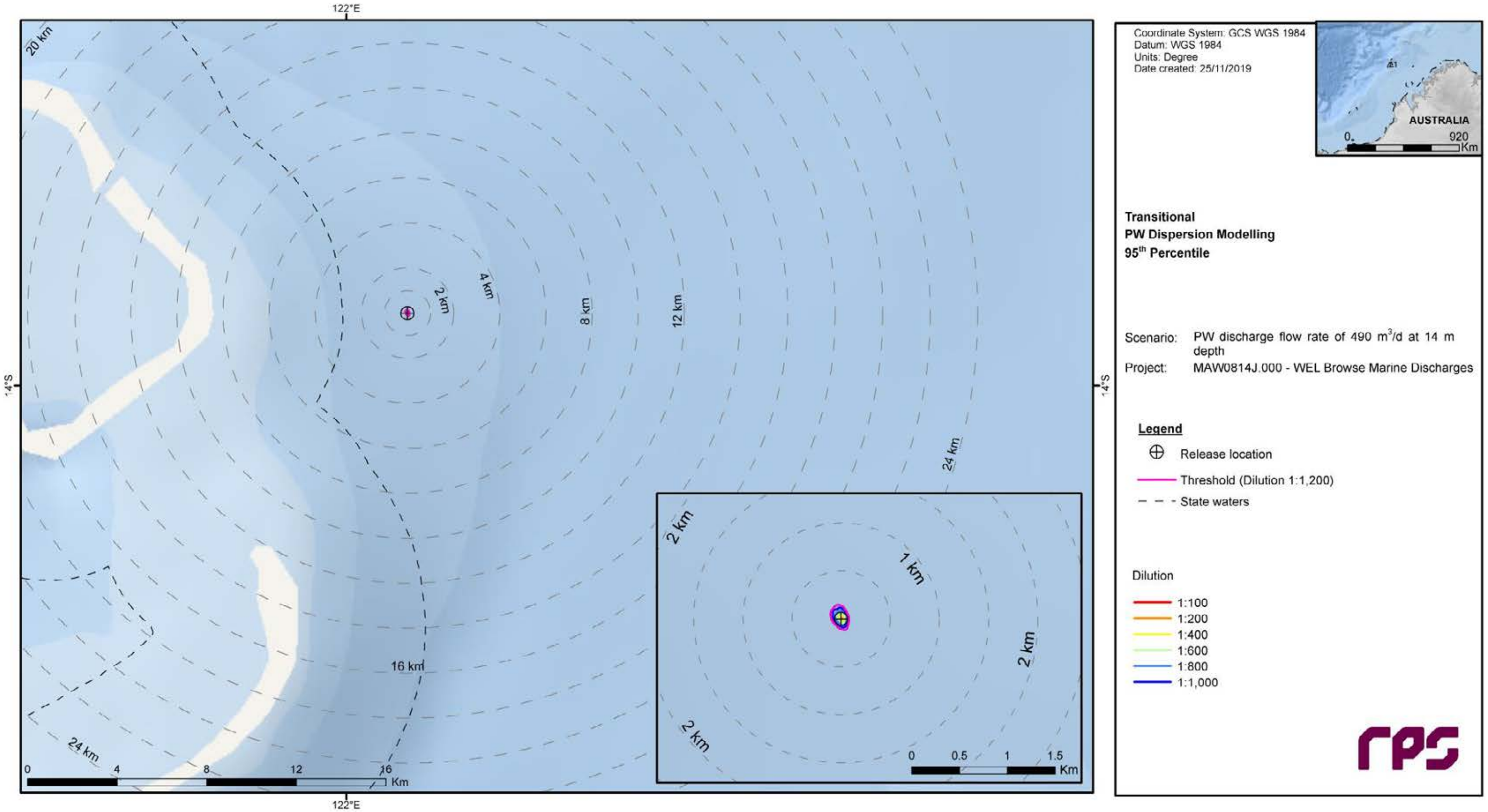


Figure 3.49 Predicted minimum dilutions at the 95th percentile under transitional conditions for Case M (14 m depth discharge at 490 m^3/d flow rate).

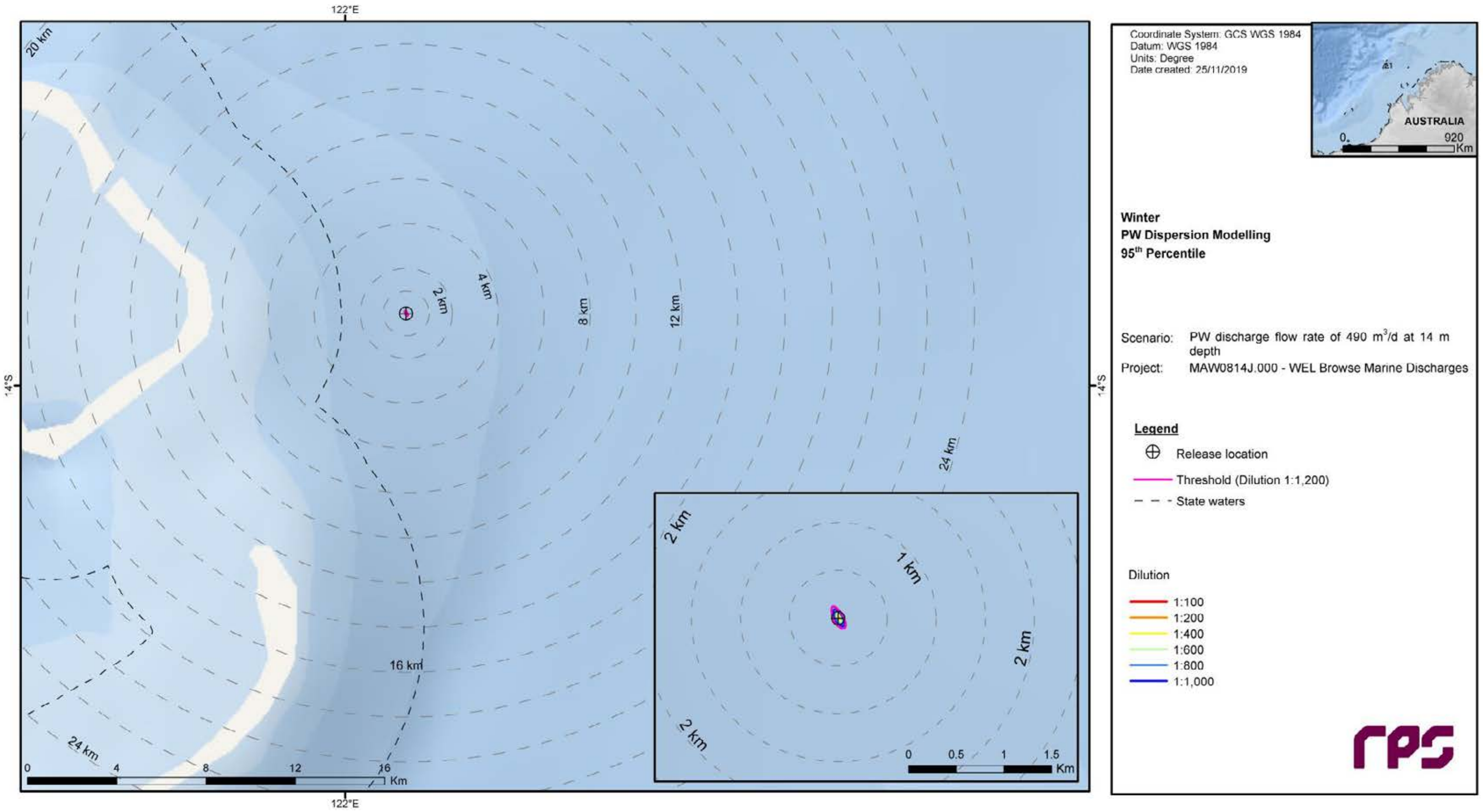


Figure 3.50 Predicted minimum dilutions at the 95th percentile under winter conditions for Case M (14 m depth discharge at 490 m^3/d flow rate).

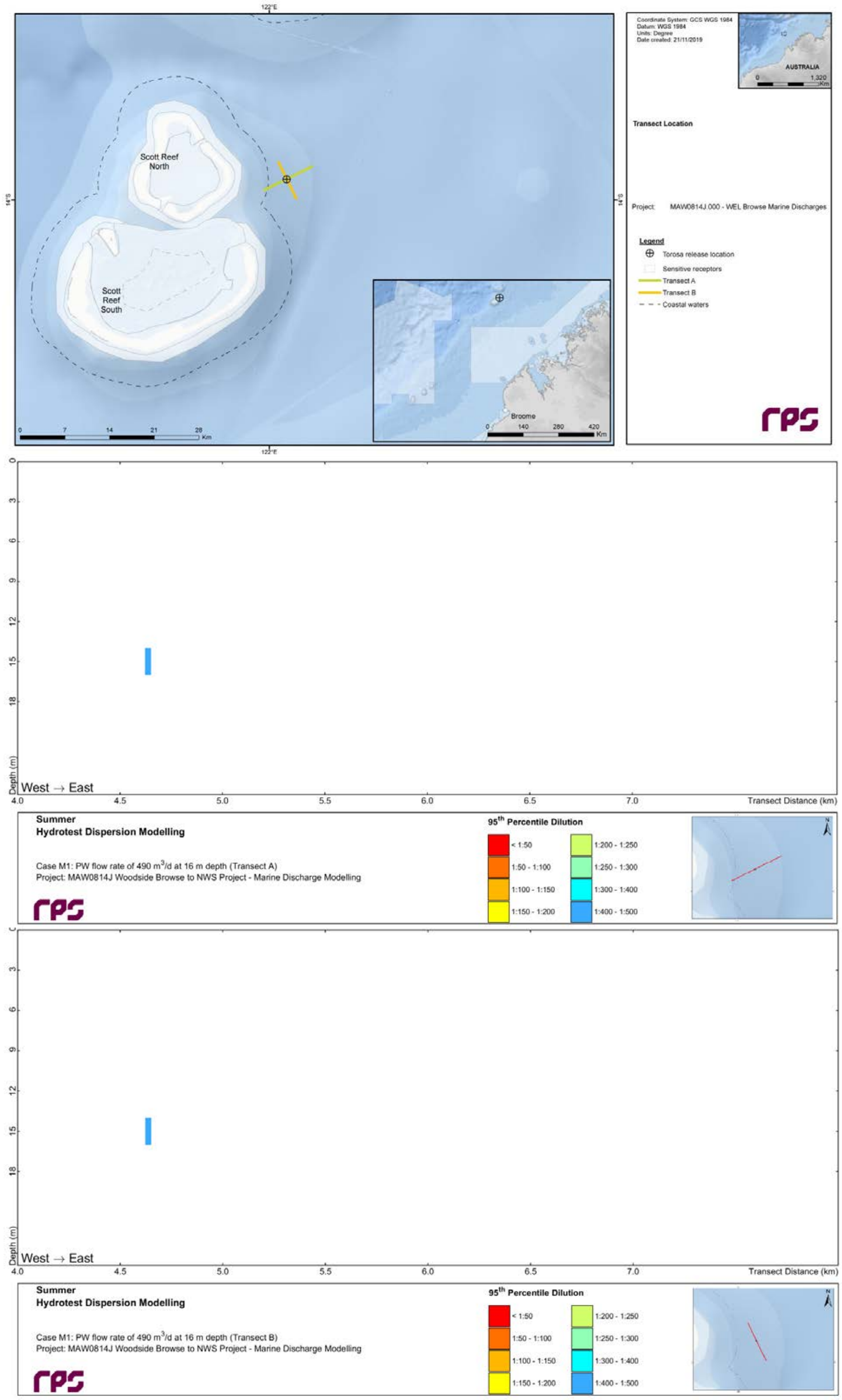


Figure 3.51 Vertical cross-section plots of predicted minimum dilutions at the 95th percentile under summer conditions for Case M (14 m depth discharge at 490 m^3/d flow rate). Transect locations are shown in the top panel, with transect A shown in the middle panel and transect B shown in the bottom panel. Spatial representation of this data is shown in Figure 3.48.

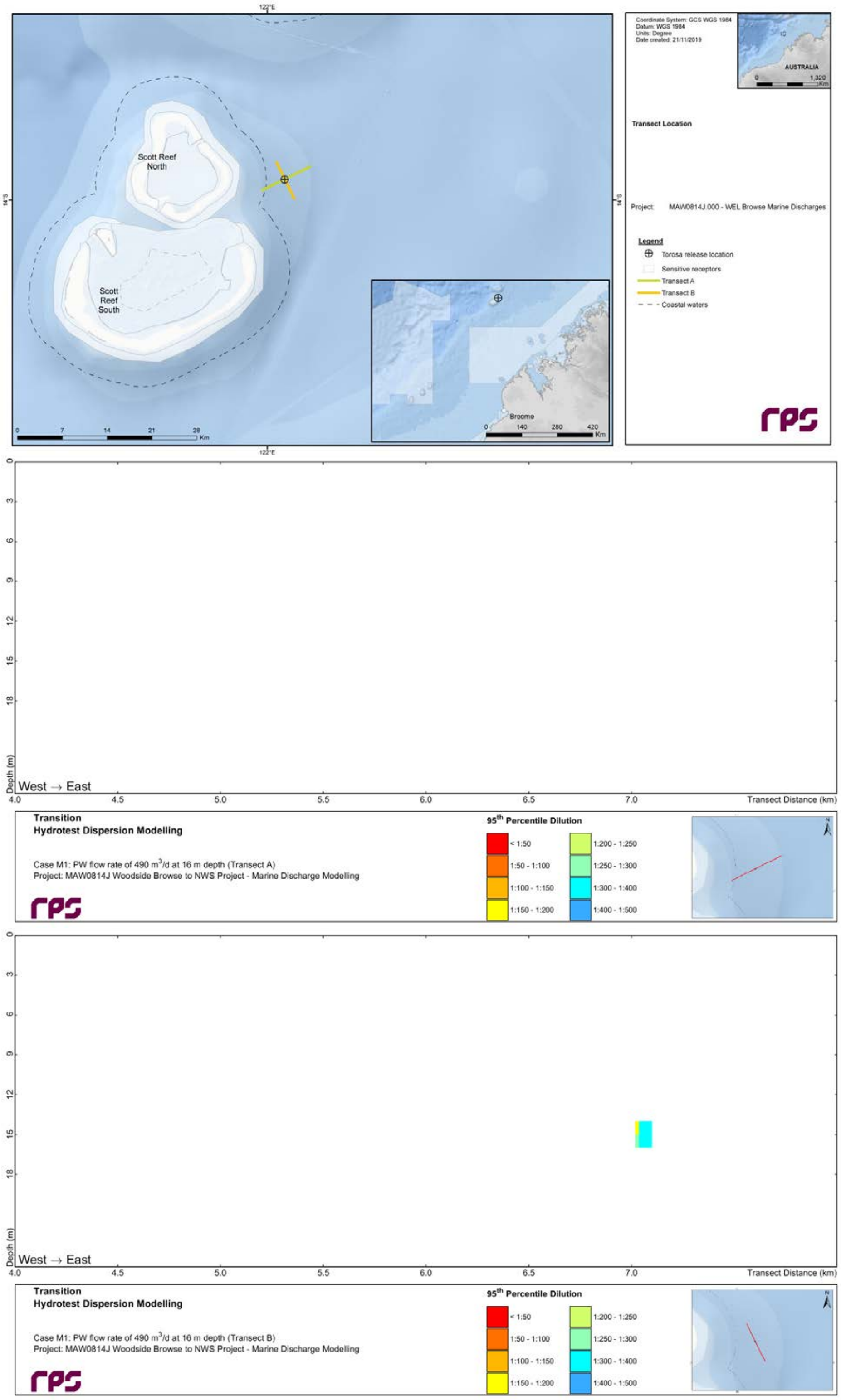


Figure 3.52 Vertical cross-section plots of predicted minimum dilutions at the 95th percentile under transitional conditions for Case M (14 m depth discharge at 490 m^3/d flow rate). Transect locations are shown in the top panel, with transect A shown in the middle panel and transect B shown in the bottom panel. Spatial representation of this data is shown in Figure 3.49.

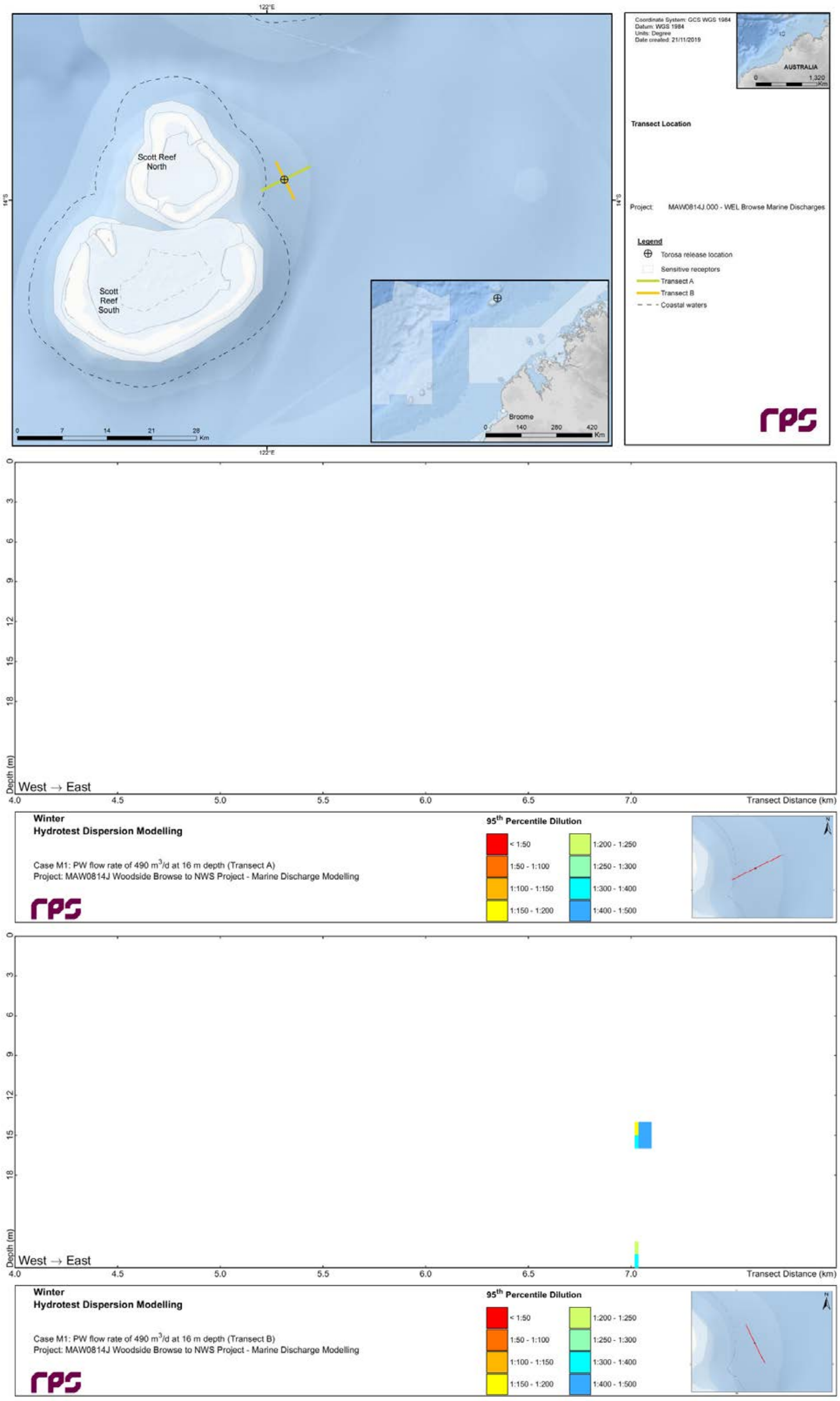


Figure 3.53 Vertical cross-section plots of predicted minimum dilutions at the 95th percentile under winter conditions for Case M (14 m depth discharge at 490 m^3/d flow rate). Transect locations are shown in the top panel, with transect A shown in the middle panel and transect B shown in the bottom panel. Spatial representation of this data is shown in Figure 3.50.

3.2.4.3 Annualised Analysis

3.2.4.3.1 Summary

The model outputs for each season (summer, transitional and winter) over the ten-year hindcast period (2006-2015) were combined and analysed on an annualised basis.

Table 3.53 and Table 3.56 summarise, for Cases P and M respectively, the average and minimum dilution achieved at specific radial distances from the discharge location – as well as at or within the Scott Reef area defined by the 3 nm State water boundary – for each percentile over the annual period.

The minimum levels of dilution achieved at or within the Scott Reef receptor at the 95th percentile in any season are predicted to be 1:1,507 for Case P and 1:17,674 for Case M.

Table 3.54 provides for Case P a summary of the annualised maximum distances from the discharge location to achieve an example dilution level of 1:300 for each percentile. The results indicate that the release of effluent under all seasonal conditions results in rapid dispersion within the ambient environment. Dilution to reach the 1:300 level at the 95th percentile – this being the maximum spatial extent of the relevant dilution contour from the discharge location in any season – is achieved within a maximum area of influence of 0.9 km.

Table 3.55 provides for Case P a summary of the annualised total areas of coverage for the 1:300 dilution contour for each percentile. The area of exposure defined by the relevant dilution contour is predicted to reach a maximum value of 0.7 km^2 at the 95th percentile across all seasons.

For Cases P and M, the aggregated spatial extents of the minimum dilutions at the 95th percentile are presented in Figure 3.54 and Figure 3.55, respectively. Note that the contours represent the lowest predicted dilution (highest concentration) at any given time step through the water column and do not consider frequency or duration.

The results presented assume that no processes other than dilution would reduce the source concentrations over time, and therefore can be considered as conservative outcomes.

3.2.4.3.2 Discharge Case P: Flow Rate of 5,723 m³/day at 14 m Depth

Table 3.53 Annualised average and minimum dilutions (1:x) achieved at specific radial distances from the PW discharge location for Case P (14 m depth discharge at 5,723 m³/d flow rate).

Distance (m)	95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum
Scott Reef (3 nm State Water Boundary	>20,000	1,507	6,405	582	967	159
20	43	24	28	17	20	12
50	58	25	37	18	25	13
100	90	59	51	35	33	24
200	158	100	79	54	48	32
300	231	135	109	65	64	42
400	296	155	134	71	75	36
500	359	181	158	82	85	43
600	429	217	182	92	98	49
700	486	253	204	109	103	48
800	552	270	225	111	113	48
900	622	288	245	116	125	50
1,000	679	306	266	120	133	59
1,100	735	319	286	131	146	60
1,200	796	333	307	144	155	61
1,300	856	358	330	149	165	59
1,400	941	376	350	152	175	76
1,500	1,008	376	373	149	185	66
1,600	1,067	379	394	161	192	67
1,700	1,112	378	413	173	195	70
1,800	1,185	382	434	180	203	83
1,900	1,279	390	455	176	220	79
2,000	1,381	393	481	174	231	85
2,100	1,490	410	504	172	243	79
2,200	1,627	414	529	176	253	94
2,300	1,728	419	551	187	261	106
2,400	1,852	419	576	185	269	94
2,500	2,013	434	605	181	275	92
2,600	2,179	452	628	186	292	98
2,700	2,378	487	652	189	305	112
2,800	2,564	525	678	197	310	95
2,900	2,758	551	695	213	313	105
3,000	3,052	617	721	229	312	101
3,100	3,364	674	744	259	266	104
3,200	3,789	693	770	268	276	107
3,300	4,315	736	791	290	288	100
3,400	5,055	785	822	277	297	114
3,500	6,029	814	841	293	302	105

Distance (m)	95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum
3,600	7,404	827	880	297	306	107
3,700	9,229	872	915	342	308	113
3,800	12,085	939	952	383	312	120
3,900	16,678	959	998	420	326	105
4,000	>20,000	1,027	1,042	431	340	98
4,100	>20,000	1,057	1,080	436	354	128
4,200	>20,000	1,079	1,123	440	361	123
4,300	>20,000	1,086	1,170	441	368	128
4,400	>20,000	1,113	1,207	452	373	138
4,500	>20,000	1,132	1,247	468	382	138
4,600	>20,000	1,145	1,283	451	391	148
4,700	>20,000	1,173	1,309	437	398	151
4,800	>20,000	1,281	1,336	443	403	123
4,900	>20,000	1,341	1,371	452	411	144
5,000	>20,000	1,411	1,396	522	420	154
5,500	>20,000	1,817	1,627	663	473	135
6,000	>20,000	1,770	1,984	656	520	184
6,500	>20,000	1,948	2,388	713	554	136
7,000	>20,000	2,339	2,698	810	596	193
7,500	>20,000	2,559	3,023	886	651	196
8,000	>20,000	3,119	3,587	935	716	169
8,500	>20,000	4,023	4,546	1,161	763	205
9,000	>20,000	3,950	7,741	1,193	824	237
9,500	>20,000	3,474	18,674	1,190	890	176
10,000	>20,000	4,721	>20,000	1,309	940	345

Table 3.54 Annualised maximum distance from the PW discharge location to achieve 1:300 dilution for Case P (14 m depth discharge at 5,723 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Annual	948
99th		3,607
100th		10,493

Table 3.55 Annualised total area of coverage for 1:300 dilution for Case P (14 m depth discharge at 5,723 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Annual	0.73
99th		6.77
100th		54.79

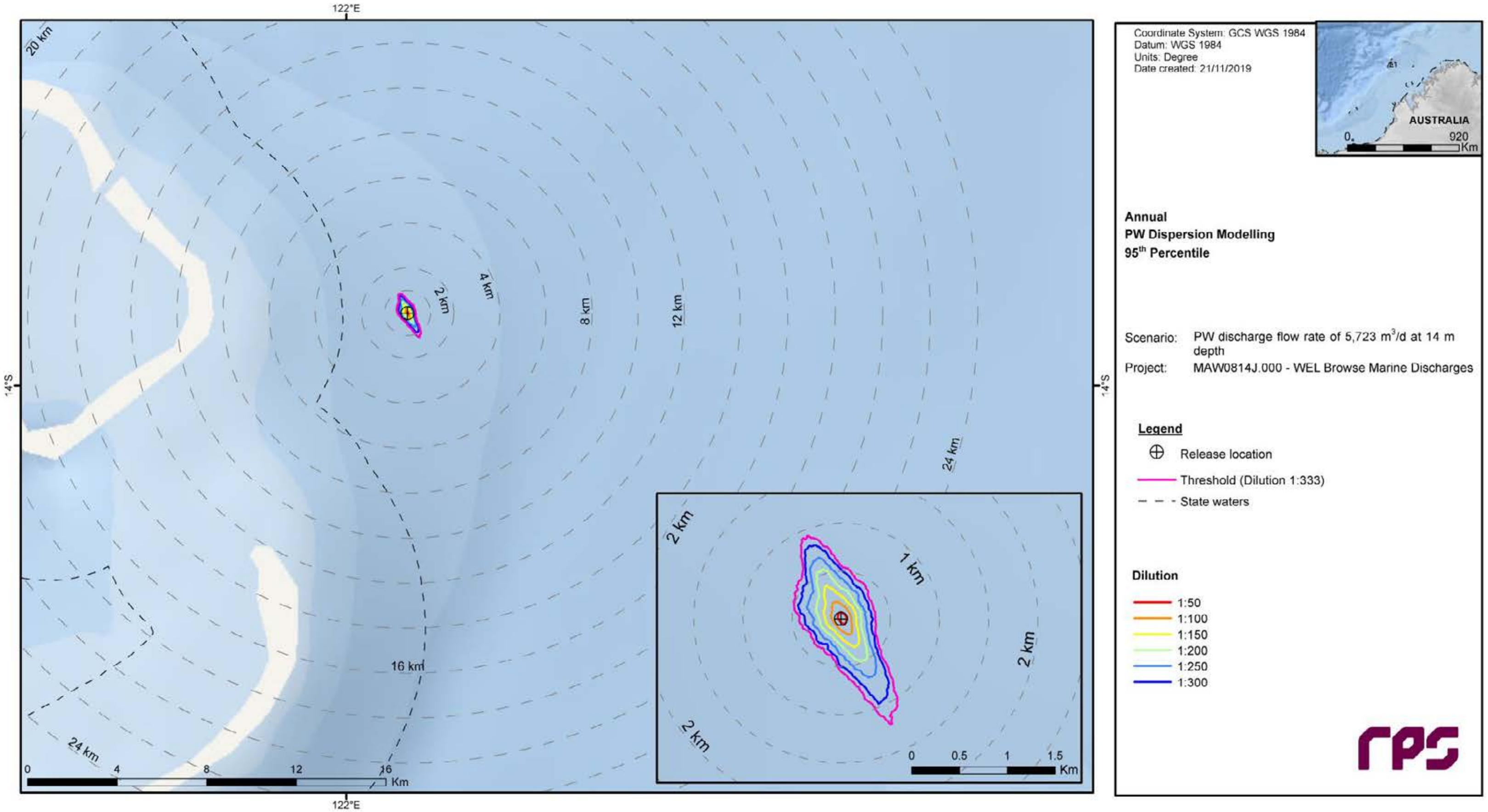


Figure 3.54 Predicted annualised minimum dilutions at the 95th percentile for Case P (14 m depth discharge at 5,723 m^3/d flow rate).

3.2.4.3.3 Discharge Case M: Flow Rate of 490 m^3/day at 14 m Depth

Table 3.56 Annualised average and minimum dilutions (1:x) achieved at specific radial distances from the PW discharge location for Case M (14 m depth discharge at 490 m^3/d flow rate).

Distance (m)	95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum
Scott Reef (3 nm State Water Boundary	>20,000	17,674	>20,000	6,594	10,796	1,949
20	489	274	303	189	184	127
50	675	289	401	195	235	120
100	1,092	675	597	409	323	211
200	1,929	1,320	941	665	484	316
300	2,826	1,830	1,282	866	596	382
400	3,655	2,187	1,598	1,046	707	418
500	4,429	2,597	1,880	1,148	823	427
600	5,319	2,946	2,161	1,300	962	472
700	6,100	3,505	2,399	1,508	1,036	548
800	6,989	3,777	2,625	1,542	1,189	573
900	7,820	4,252	2,904	1,659	1,275	599
1,000	8,577	4,751	3,155	1,698	1,386	555
1,100	9,387	5,126	3,404	1,875	1,465	648
1,200	10,247	5,500	3,624	1,910	1,537	710
1,300	11,177	5,997	3,866	1,964	1,702	724
1,400	12,486	6,517	4,156	2,208	1,754	709
1,500	13,951	6,983	4,458	2,332	1,871	691
1,600	15,337	7,427	4,761	2,584	1,988	705
1,700	17,059	7,984	4,976	2,434	2,005	907
1,800	19,271	8,728	5,263	2,511	2,075	821
1,900	>20,000	9,122	5,598	2,483	2,196	945
2,000	>20,000	9,650	5,902	2,453	2,276	896
2,100	>20,000	10,333	6,258	2,628	2,404	878
2,200	>20,000	10,743	6,602	2,784	2,515	965
2,300	>20,000	12,284	6,850	3,000	2,639	1,010
2,400	>20,000	12,675	7,119	3,295	2,706	937
2,500	>20,000	12,901	7,475	3,468	2,789	873
2,600	>20,000	13,820	7,800	3,356	2,890	934
2,700	>20,000	13,842	8,154	3,533	2,989	1,068
2,800	>20,000	14,320	8,479	3,805	3,053	1,063
2,900	>20,000	14,523	8,768	3,653	3,048	1,142
3,000	>20,000	15,357	9,173	4,226	3,116	1,118
3,100	>20,000	15,803	9,528	4,380	3,134	1,012
3,200	>20,000	15,758	9,987	4,444	3,246	1,152
3,300	>20,000	16,259	10,430	4,863	3,363	1,223
3,400	>20,000	17,437	10,945	5,216	3,441	1,338
3,500	>20,000	18,712	11,430	5,240	3,536	1,275

Distance (m)	95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum
3,600	>20,000	>20,000	11,987	5,498	3,651	1,340
3,700	>20,000	>20,000	12,429	5,636	3,788	1,360
3,800	>20,000	>20,000	12,958	5,451	3,833	1,277
3,900	>20,000	>20,000	13,681	5,874	3,977	1,033
4,000	>20,000	>20,000	14,318	5,663	4,098	1,408
4,100	>20,000	>20,000	14,977	5,551	4,206	1,373
4,200	>20,000	>20,000	15,707	5,777	4,299	1,498
4,300	>20,000	>20,000	16,479	5,794	4,360	1,331
4,400	>20,000	>20,000	17,102	5,899	4,459	1,520
4,500	>20,000	>20,000	17,786	6,269	4,602	1,512
4,600	>20,000	>20,000	18,369	6,649	4,715	1,718
4,700	>20,000	>20,000	19,029	6,135	4,765	1,503
4,800	>20,000	>20,000	19,895	6,857	4,831	1,304
4,900	>20,000	>20,000	>20,000	7,617	4,892	1,484
5,000	>20,000	>20,000	>20,000	8,483	5,021	1,627
5,500	>20,000	>20,000	>20,000	10,137	5,726	1,554
6,000	>20,000	>20,000	>20,000	10,198	6,298	2,268
6,500	>20,000	>20,000	>20,000	12,938	6,979	2,033
7,000	>20,000	>20,000	>20,000	15,857	7,497	2,032
7,500	>20,000	>20,000	>20,000	17,839	8,263	2,215
8,000	>20,000	>20,000	>20,000	19,378	8,753	2,241
8,500	>20,000	>20,000	>20,000	18,180	9,328	1,918
9,000	>20,000	>20,000	>20,000	>20,000	9,904	2,230
9,500	>20,000	>20,000	>20,000	>20,000	10,805	1,986
10,000	>20,000	>20,000	>20,000	>20,000	11,991	3,440

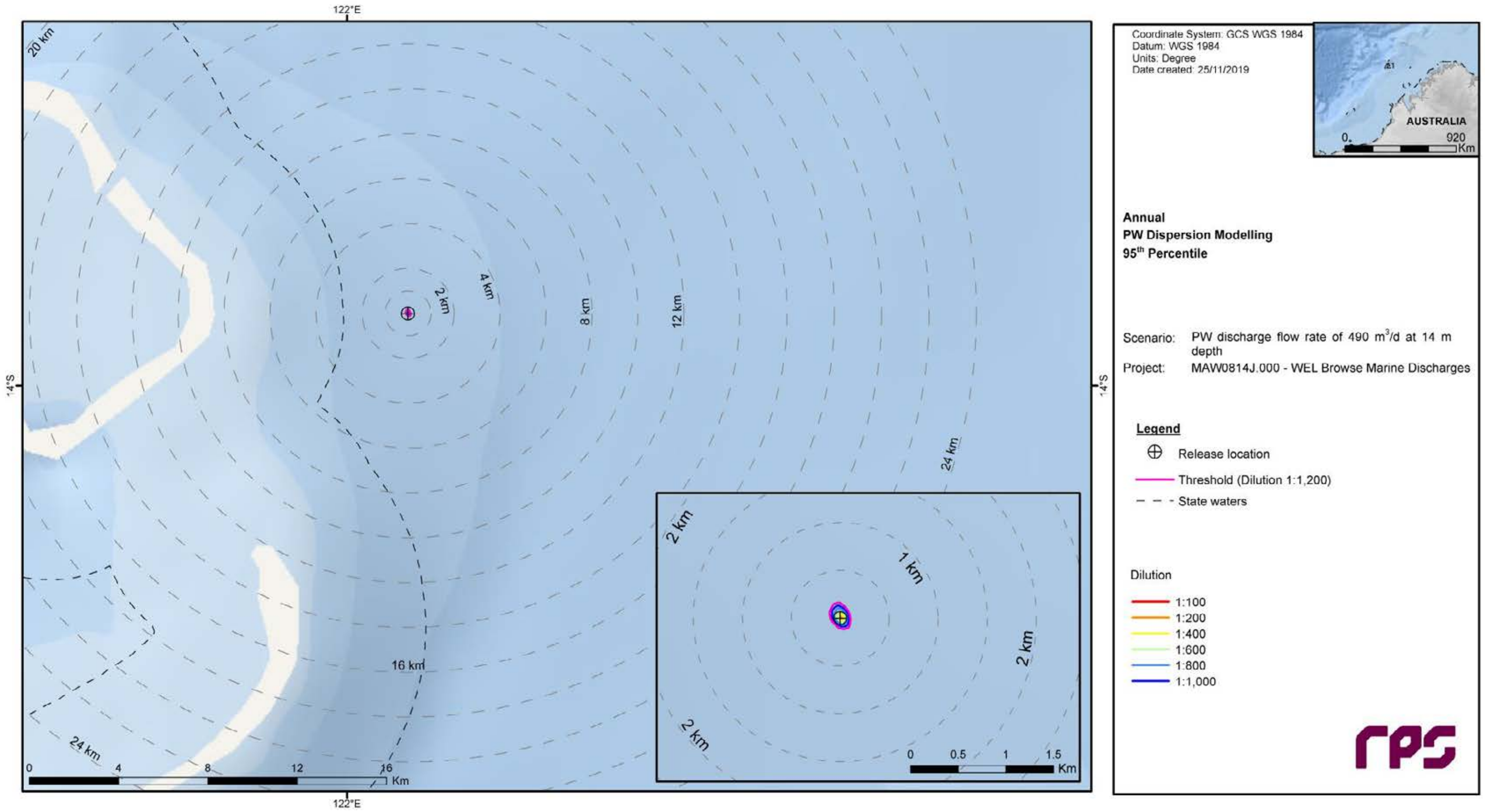


Figure 3.55 Predicted annualised minimum dilutions at the 95th percentile for Case M (14 m depth discharge at 490 m^3/d flow rate).

3.2.5 Hydrotest Discharges

3.2.5.1 General Observations

Figure 3.56 shows example time series snapshots of predicted dilutions during a single simulation at 4-hour intervals from 00:00 to 20:00 on 12th January 2010. This simulation – selected merely to be representative of typical conditions – considers the Case H1 discharge of 736,000 m^3 at 117 m BMSL at the PLET near the NRC. The spatially-varying orientation of the plume with the currents and the rapidly-varying nature of the concentrations around the source can be observed. The snapshots also show the combined effect of the tide and the drift currents, with a clear tidal oscillation.

These snapshots illustrate that the dilutions (and in turn concentrations) become more variable over time because of changes in current speed and direction. Higher dilutions (lower concentrations) are predicted during periods of increased current speed, whereas patches of lower dilutions (higher concentrations) tend to accumulate during the turning of the tide or during periods of weak drift currents. During prolonged periods of lowered current speed, the plume has a more continuous appearance, with higher-concentration patches moving as a unified group.

The snapshots in Figure 3.56 show a contiguous plume emanating from the source. Within this plume, higher-concentration patches – attributable to periodic tide reversals which cause the existing plume to repeatedly pass over the source – are most evident closer to the source, while towards the outermost extents a highly-diluted sub-plume has begun to detach from the main plume.

These findings agree with the research of King & McAllister (1997, 1998) who noted that concentrations within effluent plumes generated by an offshore platform were patchy and likely to peak around the reversal of the tides.

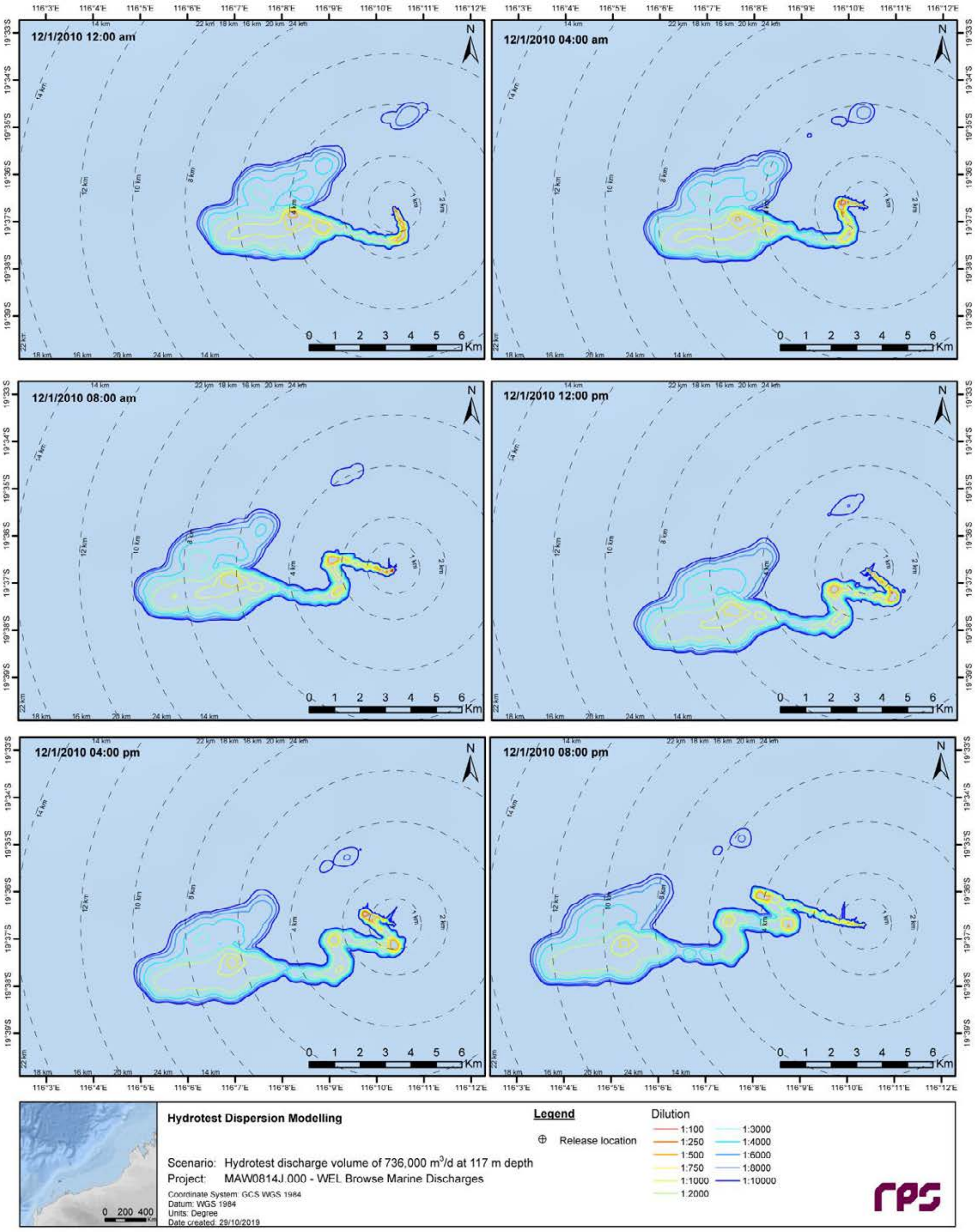


Figure 3.56 Snapshots of predicted dilution levels, at 4-hour intervals from 00:00 to 20:00 on 12th January 2010, for Case H1 (NRC tie-in PLET 736,000 m^3 hydrotest discharge).

3.2.5.2 Seasonal Analysis

3.2.5.2.1 Summary

The model outputs over the ten-year hindcast period (2006-2015) were combined and analysed on a seasonal basis (summer, transitional and winter). This approach assists with identifying the potential exposure to surrounding sensitive receptors whilst considering inter-annual variability in ocean current conditions.

Table 3.57, Table 3.61, Table 3.65 and Table 3.69 summarise, for Cases H1, H2, H3a and H3b respectively, the average and minimum dilution achieved at specific radial distances from the discharge location – as well as at or within the boundary of the nearest sensitive receptor – for each season and percentile, with the application of a rolling 48-hour median to the data. The discharge location for Case H1 is distant from Scott Reef and the nearest receptor is Rankin Bank, while for Cases H2, H3a and H3b the nearest receptor is Scott Reef (defined by the 3 nm State water boundary).

Table 3.58, Table 3.62, Table 3.66 and Table 3.70 provide, for Cases H1, H2, H3a and H3b respectively, summaries of the maximum distances from the discharge location to achieve an example dilution level of 1:10,000 for each season and percentile. The results indicate that the release of effluent under all seasonal conditions results in slow dispersion within the ambient environment. For Case H1, a 1:10,000 dilution is achieved within an area of influence ranging from 9.0-16.1 km at the 95th percentile (Table 3.58), with the predominant plume travel direction being south-westerly throughout the year (Figure 3.57 to Figure 3.59). For Case H2, the maximum spatial extent of the relevant dilution contour varies from 8.0-12.5 km at the 95th percentile (Table 3.62), with the predominant axis of plume movement being north-northwest/south-southeast throughout the year (Figure 3.63 to Figure 3.65). For Case H3a, the maximum spatial extent of the relevant dilution contour is in the range 15.5-23.4 km at the 95th percentile (Table 3.66), with plumes travelling mostly to the north-east during transitional months, the south-west during winter, and both the north-east and south-west during summer (Figure 3.69 to Figure 3.71). For Case H3b, dilution to reach the 1:10,000 level is achieved within a distance of 7.3-8.2 km at the 95th percentile (Table 3.70), with plumes moving along a north-northwest/south-southeast axis throughout the year (Figure 3.75 to Figure 3.77).

Table 3.59, Table 3.63, Table 3.67 and Table 3.71 provide, for Cases H1, H2, H3a and H3b respectively, summaries of the total areas of coverage for the 1:10,000 dilution contour for each season and percentile. For Case H1, the area of exposure defined by the relevant dilution contour is predicted to reach a maximum value of 36.2-44.3 km^2 at the 95th percentile (Table 3.59). For Case H2, the corresponding maximum area of exposure is 30.7-74.6 km^2 at the 95th percentile (Table 3.63). For Case H3a, the maximum area of exposure is predicted to be 38.3-57.3 km^2 at the 95th percentile (Table 3.67). For Case H3b, the maximum area of exposure is forecast as 18.2-22.2 km^2 at the 95th percentile (Table 3.71).

Table 3.60, Table 3.64, Table 3.68 and Table 3.72 provide, for Cases H1, H2, H3a and H3b respectively, summaries of the maximum depths from the discharge location to achieve 1:10,000 dilution for each season and percentile. Given the near-seabed depths of each discharge and the near neutrally buoyant nature of the plumes, maximum depths are predicted as equivalent to the seabed depth in each case.

For Cases H1, H2, H3a and H3b, the aggregated spatial extents of the minimum dilutions for each season at the 95th percentile are presented in Figure 3.57 to Figure 3.59, Figure 3.63 to Figure 3.65, Figure 3.69 to Figure 3.71 and Figure 3.75 to Figure 3.77, respectively. Note that the contours represent the lowest predicted dilution (highest concentration) at any given time step through the water column and do not consider frequency or duration.

The results presented assume that no processes other than dilution would reduce the source concentrations over time, and therefore can be considered as conservative outcomes.

Seasonal water column cross-section figures of 95th percentile dilution, extracted along perpendicular transects running through the origin points of the discharge (one of which is broadly aligned with the principal travel direction of the plume at each location), are presented in Figure 3.60 to Figure 3.62 (Case H1), Figure 3.66 to Figure 3.68 (Case H2), Figure 3.72 to Figure 3.74 (Case H3a) and Figure 3.78 to Figure 3.80 (Case H3b). In each case, the neutrally buoyant plumes are predicted to remain relatively close to the seabed as they disperse. It is evident that the plumes will be heavily influenced by local bathymetry features and may travel up slopes if currents in the lower water column are conducive to this effect. For the Case H1 discharge, the plume centreline will remain at a depth of more than 100 m below the water surface. For Cases H2, H3a and H3b, the plume centrelines will remain at depths of more than 450 m.

It should be noted that the bathymetry slopes shown in the water column cross-section figures are exaggerated due to the spatial scales used; the vertical axis is presented in units of metres, while the horizontal axis is presented in units of kilometres.

3.2.5.2.2 Discharge Case H1: NRC Tie-In PLET Hydrotest Discharge of 736,000 m^3 at 117 m Depth

Table 3.57 Average and minimum dilutions (1:x) achieved at specific radial distances from the hydrotest discharge location in each season for Case H1 (NRC tie-in PLET 736,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.

Distance (m)	Summer						Transitional						Winter					
	95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum
Rankin Bank †	>>20,000	>>20,000	>>20,000	>>20,000	>>20,000	>>20,000	>>20,000	>>20,000	>>20,000	>>20,000	>>20,000	>>20,000	>>20,000	>>20,000	>>20,000	>>20,000	>>20,000	>>20,000
20	553	230	235	172	230	163	676	288	429	183	386	178	1,093	537	566	391	441	377
50	392	183	168	115	149	109	582	287	215	131	197	130	712	350	452	289	315	215
100	1,815	540	975	377	809	313	1,425	524	932	300	793	297	2,085	499	590	323	499	298
200	2,810	1,339	1,664	709	1,481	510	2,395	1,108	1,507	969	1,264	655	3,584	1,146	919	644	804	616
300	3,514	1,447	2,139	719	1,590	663	3,192	1,502	1,910	1,052	1,693	988	5,106	1,529	1,189	684	988	624
400	3,995	1,609	2,344	1,053	1,889	867	3,551	1,605	2,110	975	1,957	967	5,819	1,787	1,511	697	1,145	680
500	4,684	1,845	2,481	1,109	1,933	1,092	5,343	1,941	2,641	1,115	2,080	1,053	8,225	2,353	1,926	791	1,566	699
600	5,009	1,956	2,761	1,478	2,230	1,178	6,156	1,973	2,867	1,218	2,280	1,086	7,532	2,284	2,606	904	1,931	801
700	5,747	2,259	2,846	1,684	2,238	1,289	10,815	1,927	3,230	1,249	2,722	1,135	9,427	2,278	3,051	1,067	2,435	984
800	6,069	2,271	3,190	1,546	2,689	1,341	12,742	2,074	3,702	1,399	2,895	1,182	9,588	2,699	2,987	1,071	2,427	1,063
900	6,329	2,040	3,256	1,516	2,763	1,386	>20,000	2,375	4,539	1,433	3,535	1,226	10,594	2,496	3,197	1,258	2,731	998
1,000	6,770	1,941	3,483	1,449	3,052	1,430	18,831	2,329	3,883	1,453	3,280	1,205	13,772	2,680	3,395	1,359	2,824	989
1,100	6,775	2,170	3,522	1,354	2,956	1,344	>20,000	2,550	6,732	1,480	4,997	1,360	15,439	2,854	3,625	1,298	3,012	1,184
1,200	7,212	2,284	3,788	1,400	3,265	1,379	19,634	2,607	4,605	1,586	3,180	1,392	19,550	2,978	4,707	1,428	3,885	1,338
1,300	7,035	2,002	3,849	1,254	3,103	1,243	>20,000	2,723	12,484	1,769	6,443	1,450	18,632	2,715	4,169	1,444	3,313	1,378
1,400	7,477	2,000	3,825	1,265	3,173	1,159	>20,000	2,689	6,550	1,780	4,090	1,573	>20,000	2,436	5,107	1,475	3,873	1,407
1,500	7,760	2,049	3,875	1,236	3,241	1,143	>20,000	2,869	17,886	1,791	9,591	1,651	>20,000	2,458	5,618	1,618	4,430	1,544
1,600	8,162	1,783	3,782	1,315	3,241	1,280	>20,000	2,967	9,061	1,793	5,313	1,626	>20,000	2,748	5,698	1,634	4,260	1,620
1,700	9,047	1,912	3,969	1,306	3,335	1,259	>20,000	2,762	>20,000	1,966	14,352	1,831	>20,000	2,801	7,826	1,594	5,194	1,547
1,800	9,473	1,851	4,154	1,313	3,543	1,224	>20,000	2,740	>20,000	1,847	>20,000	1,741	>20,000	2,870	8,758	1,645	5,585	1,497
1,900	10,691	2,119	4,192	1,248	3,651	1,224	>20,000	2,463	>20,000	1,729	13,737	1,672	>20,000	2,821	11,536	1,662	6,575	1,623
2,000	11,831	2,068	4,303	1,370	3,792	1,281	>20,000	2,428	>20,000	1,526	12,445	1,494	>20,000	2,914	12,260	1,884	7,428	1,676
2,100	15,635	2,200	4,777	1,472	4,070	1,342	>20,000	2,825	>20,000	1,347	>20,000	1,323	>20,000	2,945	16,569	1,883	11,504	1,772
2,200	19,535	2,106	5,016	1,419	4,439	1,380	>20,000	2,641	>20,000	1,230	>20,000	1,230	>20,000	3,106	>20,000	2,069	13,942	1,625
2,300	>20,000	2,362	5,477	1,620	4,526	1,463	>20,000	2,791	>20,000	1,273	>20,000	1,243	>20,000	3,169	>20,000	1,965	15,895	1,694
2,400	>20,000	2,259	6,036	1,577	5,067	1,508	>20,000	2,857	>20,000	1,301	>20,000	1,301	>20,000	3,284	>20,000	2,010	>20,000	1,930
2,500	>20,000	2,326	6,817	1,721	5,835	1,511	>20,000	2,952	>20,000	1,356	>20,000	1,324	>20,000	3,445	>20,000	1,974	>20,000	1,885
2,600	>20,000	2,407	7,464	1,748	6,478	1,648	>20,000	3,028	>20,000	1,543	>20,000	1,356	>20,000	3,469	>20,000	2,295	>20,000	1,936
2,700	>20,000	2,485	8,558	1,622	7,421	1,578	>20,000	2,949	>20,000	1,574	>20,000	1,433	>20,000	3,478	>20,000	2,505	>20,000	2,191
2,800	>20,000	2,782	10,105	1,586	8,523	1,515	>20,000	2,762	>20,000	1,676	>20,000	1,522	>20,000	3,579	>20,000	2,724	>20,000	2,429
2,900	>20,000	2,806	12,737	1,729	10,612	1,508	>20,000	2,930	>20,000	1,692	>20,000	1,566	>20,000	3,643	>20,000	2,781	>20,000	2,494
3,000	>20,000	2,974	14,934	1,940	12,290	1,596	>20,000	3,014	>20,000	1,807	>20,000	1,733	>20,000	3,681	>20,000	2,753	>20,000	2,323
3,100	>20,000	3,156	19,321	1,914	15,551	1,675	>20,000	3,048	>20,000	1,923	>20,000	1,841	>20,000	3,665	>20,000	2,934	>20,000	2,658
3,200	>20,000	3,218	>20,000	1,713	>20,000	1,588	>20,000	3,205	>20,000	2,145	>20,000	1,977	>20,000	3,763	>20,000	2,865	>20,000	2,487
3,300	>20,000	2,775	>20,000	1,524	>20,000	1,406	>20,000	3,228	>20,000	2,242	>20,000	1,871	>20,000	3,801	>20,000	2,943	>20,000	2,505
3,400	>20,000	3,181	>20,000	1,459	>20,000	1,378	>20,000	3,156	>20,000	2,285	>20,000	2,015	>20,000	3,895	>20,000	3,103	>20,000	2,371
3,500	>20,000	3,397	>20,000	1,717	>20,000	1,537	>20,000	3,299	>20,000	2,280	>20,000	2,029	>20,000	4,003	>20,000	3,114	>20,000	2,653

Distance (m)	Summer						Transitional						Winter					
	95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum
3,600	>20,000	3,173	>20,000	1,897	>20,000	1,540	>20,000	3,126	>20,000	2,172	>20,000	2,006	>20,000	3,911	>20,000	3,095	>20,000	2,865
3,700	>20,000	3,296	>20,000	1,892	>20,000	1,592	>20,000	3,196	>20,000	2,142	>20,000	1,962	>20,000	4,005	>20,000	3,100	>20,000	3,015
3,800	>20,000	3,389	>20,000	1,895	>20,000	1,750	>20,000	3,410	>20,000	2,013	>20,000	1,990	>20,000	3,913	>20,000	3,136	>20,000	2,951
3,900	>20,000	3,301	>20,000	2,199	>20,000	1,782	>20,000	3,598	>20,000	1,966	>20,000	1,896	>20,000	4,072	>20,000	3,116	>20,000	2,969
4,000	>20,000	3,011	>20,000	2,110	>20,000	1,893	>20,000	3,664	>20,000	1,855	>20,000	1,828	>20,000	4,118	>20,000	3,061	>20,000	2,963
4,100	>20,000	3,353	>20,000	2,281	>20,000	2,105	>20,000	3,755	>20,000	1,712	>20,000	1,712	>20,000	3,984	>20,000	3,114	>20,000	3,003
4,200	>20,000	3,288	>20,000	2,301	>20,000	2,180	>20,000	4,225	>20,000	1,745	>20,000	1,745	>20,000	4,127	>20,000	3,253	>20,000	3,157
4,300	>20,000	3,045	>20,000	2,327	>20,000	2,135	>20,000	4,499	>20,000	1,751	>20,000	1,739	>20,000	4,330	>20,000	3,382	>20,000	3,250
4,400	>20,000	3,134	>20,000	2,216	>20,000	2,110	>20,000	4,401	>20,000	1,857	>20,000	1,823	>20,000	4,485	>20,000	3,435	>20,000	3,234
4,500	>20,000	3,362	>20,000	2,133	>20,000	2,073	>20,000	4,428	>20,000	1,941	>20,000	1,887	>20,000	4,594	>20,000	3,345	>20,000	3,280
4,600	>20,000	3,214	>20,000	2,505	>20,000	2,334	>20,000	4,851	>20,000	1,952	>20,000	1,919	>20,000	4,709	>20,000	3,492	>20,000	3,034
4,700	>20,000	3,567	>20,000	2,412	>20,000	2,326	>20,000	4,927	>20,000	2,105	>20,000	2,087	>20,000	4,693	>20,000	3,570	>20,000	3,100
4,800	>20,000	3,655	>20,000	2,364	>20,000	2,246	>20,000	4,742	>20,000	2,208	>20,000	2,208	>20,000	4,744	>20,000	3,442	>20,000	2,961
4,900	>20,000	4,243	>20,000	2,105	>20,000	1,977	>20,000	4,791	>20,000	2,353	>20,000	2,353	>20,000	4,711	>20,000	3,210	>20,000	3,182
5,000	>20,000	4,165	>20,000	2,239	>20,000	2,147	>20,000	4,529	>20,000	2,697	>20,000	2,614	>20,000	4,781	>20,000	3,185	>20,000	3,141
5,500	>20,000	4,347	>20,000	3,192	>20,000	2,966	>20,000	5,158	>20,000	3,325	>20,000	3,325	>20,000	4,680	>20,000	3,374	>20,000	3,308
6,000	>20,000	4,982	>20,000	3,145	>20,000	2,925	>20,000	6,005	>20,000	3,770	>20,000	3,749	>20,000	4,591	>20,000	3,452	>20,000	3,428
6,500	>20,000	5,131	>20,000	3,254	>20,000	3,154	>20,000	6,397	>20,000	4,493	>20,000	3,830	>20,000	4,546	>20,000	3,452	>20,000	3,435
7,000	>20,000	5,251	>20,000	3,341	>20,000	3,288	>20,000	6,860	>20,000	5,276	>20,000	4,567	>20,000	4,493	>20,000	3,406	>20,000	3,357
7,500	>20,000	5,634	>20,000	2,761	>20,000	2,744	>20,000	8,130	>20,000	5,337	>20,000	5,312	>20,000	4,458	>20,000	3,367	>20,000	3,367
8,000	>20,000	5,963	>20,000	2,733	>20,000	2,733	>20,000	8,957	>20,000	6,364	>20,000	5,198	>20,000	4,460	>20,000	3,326	>20,000	3,273
8,500	>20,000	5,565	>20,000	2,884	>20,000	2,855	>20,000	9,353	>20,000	6,112	>20,000	5,415	>20,000	4,543	>20,000	3,403	>20,000	3,390
9,000	>20,000	6,359	>20,000	3,302	>20,000	3,139	>20,000	9,972	>20,000	5,969	>20,000	5,425	>20,000	4,572	>20,000	3,428	>20,000	3,428
9,500	>20,000	7,226	>20,000	3,632	>20,000	3,354	>20,000	9,814	>20,000	6,077	>20,000	5,683	>20,000	4,578	>20,000	3,435	>20,000	3,380
10,000	>20,000	7,581	>20,000	4,687	>20,000	3,937	>20,000	11,125	>20,000	6,481	>20,000	5,760	>20,000	4,568	>20,000	3,541	>20,000	3,474
10,500	>20,000	7,442	>20,000	4,364	>20,000	4,333	>20,000	11,990	>20,000	7,268	>20,000	5,664	>20,000	4,769	>20,000	3,592	>20,000	3,535
11,000	>20,000	8,052	>20,000	4,673	>20,000	4,435	>20,000	13,816	>20,000	8,001	>20,000	5,101	>20,000	5,428	>20,000	3,723	>20,000	3,613
11,500	>20,000	9,539	>20,000	4,513	>20,000	4,198	>20,000	13,941	>20,000	8,196	>20,000	6,015	>20,000	6,091	>20,000	3,736	>20,000	3,583
12,000	>20,000	8,899	>20,000	5,294	>20,000	4,619	>20,000	15,768	>20,000	8,313	>20,000	6,896	>20,000	6,543	>20,000	3,705	>20,000	3,600
12,500	>20,000	9,118	>20,000	5,135	>20,000	5,135	>20,000	14,843	>20,000	7,992	>20,000	6,614	>20,000	7,314	>20,000	3,684	>20,000	3,618
13,000	>20,000	9,205	>20,000	5,283	>20,000	5,154	>20,000	17,184	>20,000	8,782	>20,000	6,609	>20,000	8,300	>20,000	3,579	>20,000	3,510
13,500	>20,000	8,498	>20,000	5,203	>20,000	5,054	>20,000	16,561	>20,000	8,403	>20,000	6,260	>20,000	8,594	>20,000	3,642	>20,000	3,510
14,000	>20,000	9,434	>20,000	5,569	>20,000	5,557	>20,000	18,060	>20,000	8,989	>20,000	6,575	>20,000	8,792	>20,000	3,589	>20,000	3,449
14,500	>20,000	10,651	>20,000	6,548	>20,000	6,548	>20,000	18,839	>20,000	9,169	>20,000	7,484	>20,000	9,113	>20,000	3,557	>20,000	3,533
15,000	>20,000	9,083	>20,000	5,776	>20,000	5,158	>20,000	17,544	>20,000	9,209	>20,000	7,009	>20,000	9,565	>20,000	3,552	>20,000	3,541
15,500	>20,000	8,200	>20,000	6,099	>20,000	5,644	>20,000	17,479	>20,000	10,989	>20,000	8,041	>20,000	10,215	>20,000	3,487	>20,000	3,487
16,000	>20,000	10,216	>20,000	6,871	>20,000	6,393	>20,000	18,161	>20,000	12,295	>20,000	8,962	>20,000	10,548	>20,000	3,439	>20,000	3,431
16,500	>20,000	11,229	>20,000	7,298	>20,000	6,337	>20,000	19,711	>20,000	11,482	>20,000	9,618	>20,000	10,280	>20,000	3,429	>20,000	3,421
17,000	>20,000	12,207	>20,000	5,353	>20,000	5,067	>20,000	20,911	>20,000	12,773	>20,000	10,466	>20,000	11,325	>20,000	3,502	>20,000	3,470
17,500	>20,000	12,542	>20,000	6,492	>20,000	5,554	>20,000	19,018	>20,000	14,177	>20,000	12,157	>20,000	10,275	>20,000	3,511	>20,000	3,472
18,000	>20,000	14,165	>20,000	7,919	>20,000	7,443	>20,000	>20,000	>20,000	16,524	>20,000	13,079	>20,000	11,163	>20,000	3,480	>20,000	3,431
18,500	>20,000	13,062	>20,000	7,783	>20,000	6,989	>20,000	>20,000	>20,000	16,917	>20,000	13,834	>20,000	10,508	>20,000	3,464	>20,000	3,405
19,000	>20,000	14,856	>20,000	7,712	>20,000	7,413	>20,000	>20,000	>20,000	16,572	>20,000	15,453	>20,000	9,756	>20,000	3,439	>20,000	3,399
19,500	>20,000	14,621	>20,000	8,526	>20,000	7,629	>20,000	>20,000	>20,000	16,159	>20,000	15,368	>20,000	9,634	>20,000	3,432	>20,000	3,428

	Summer						Transitional						Winter					
Distance (m)	95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum
20,000	>20,000	15,117	>20,000	8,581	>20,000	7,833	>20,000	>20,000	>20,000	17,067	>20,000	14,802	>20,000	9,854	>20,000	3,447	>20,000	3,447

† This receptor is outside the model domain and predictions of dilution are unavailable at or within its boundaries. Given the high levels of dilution predicted within the extent of the model domain (20 km) in the direction of Rankin Bank, and the remaining distance (~40 km) from the edge of the model domain to the receptor, it can be assumed that a minimum dilution level of >>20,000 will occur at or within the receptor boundaries at all percentiles.

Table 3.58 Maximum distance from the hydrotest discharge location to achieve 1:10,000 dilution in each season for Case H1 (NRC tie-in PLET 736,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Summer	16,137
	Transitional	9,829
	Winter	8,965
99th	Summer	22,551
	Transitional	15,322
	Winter	16,158
100th	Summer	22,925
	Transitional	16,685
	Winter	17,989

Table 3.59 Total area of coverage for 1:10,000 dilution in each season for Case H1 (NRC tie-in PLET 736,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Summer	44.30
	Transitional	40.70
	Winter	36.20
99th	Summer	150.90
	Transitional	107.30
	Winter	90.50
100th	Summer	182.70
	Transitional	141.00
	Winter	109.80

Table 3.60 Maximum depth from the hydrotest discharge location to achieve 1:10,000 dilution in each season for Case H1 (NRC tie-in PLET 736,000 m^3 hydrotest discharge).

Season	Maximum depth (m) from sea surface to achieve given dilution
Summer	117 (seabed)
Transitional	117 (seabed)
Winter	117 (seabed)

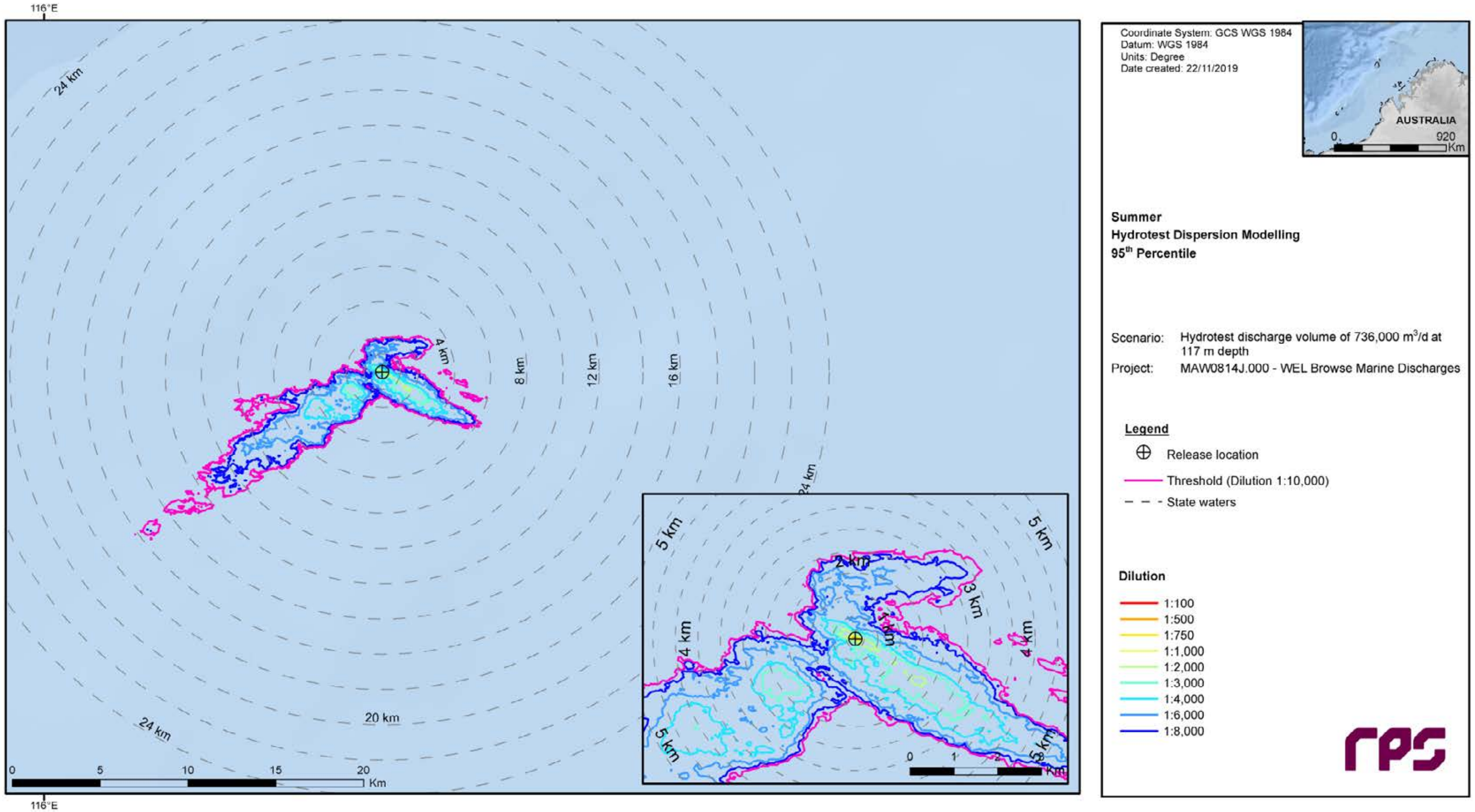


Figure 3.57 Predicted minimum dilutions at the 95th percentile under summer conditions for Case H1 (NRC tie-in PLET 736,000 m^3 hydrotest discharge), with a rolling 48-hour median of the dilution data.

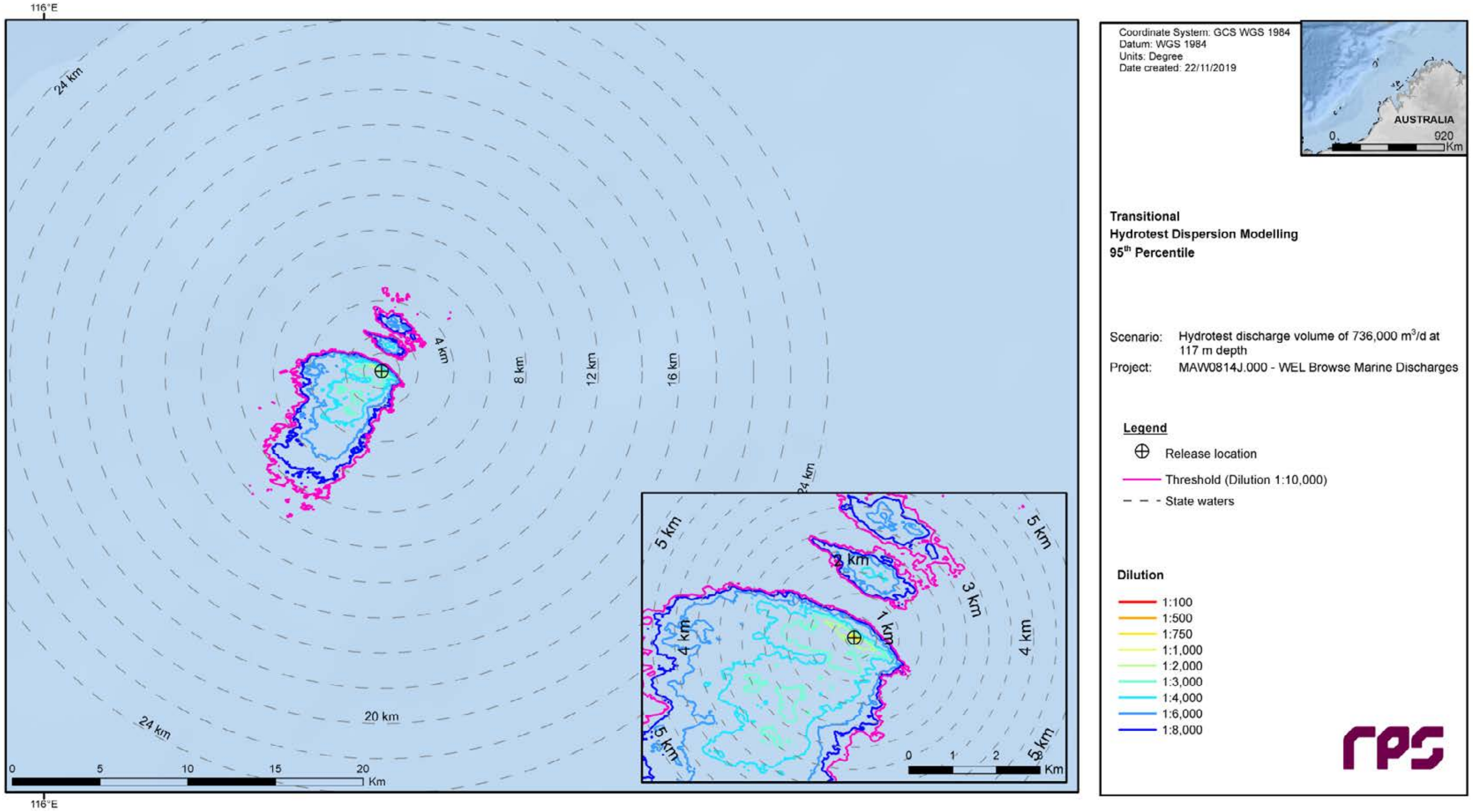


Figure 3.58 Predicted minimum dilutions at the 95th percentile under transitional conditions for Case H1 (NRC tie-in PLET 736,000 m^3 hydrotest discharge), with a rolling 48-hour median of the dilution data.

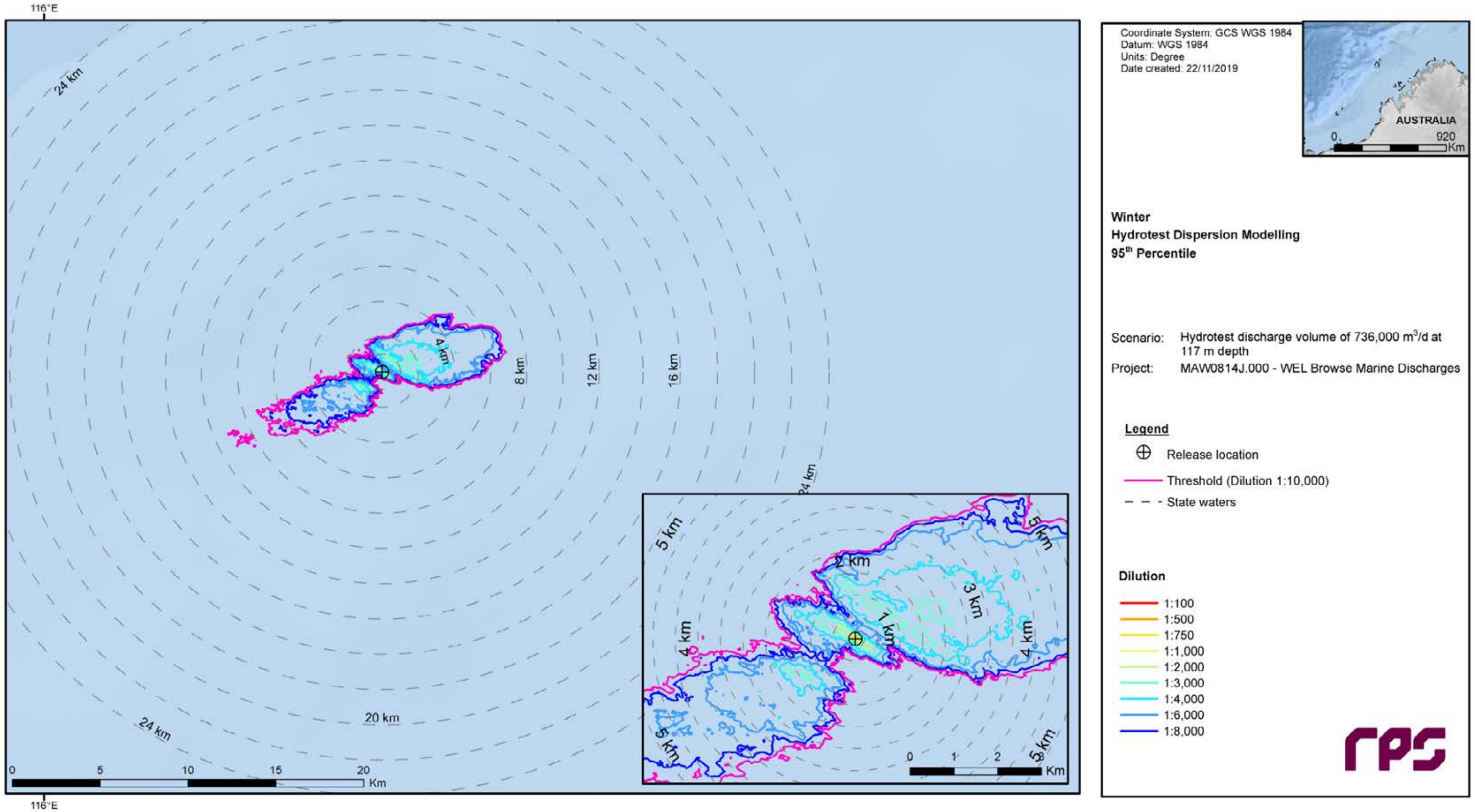


Figure 3.59 Predicted minimum dilutions at the 95th percentile under winter conditions for Case H1 (NRC tie-in PLET 736,000 m^3 hydrotest discharge), with a rolling 48-hour median of the dilution data.

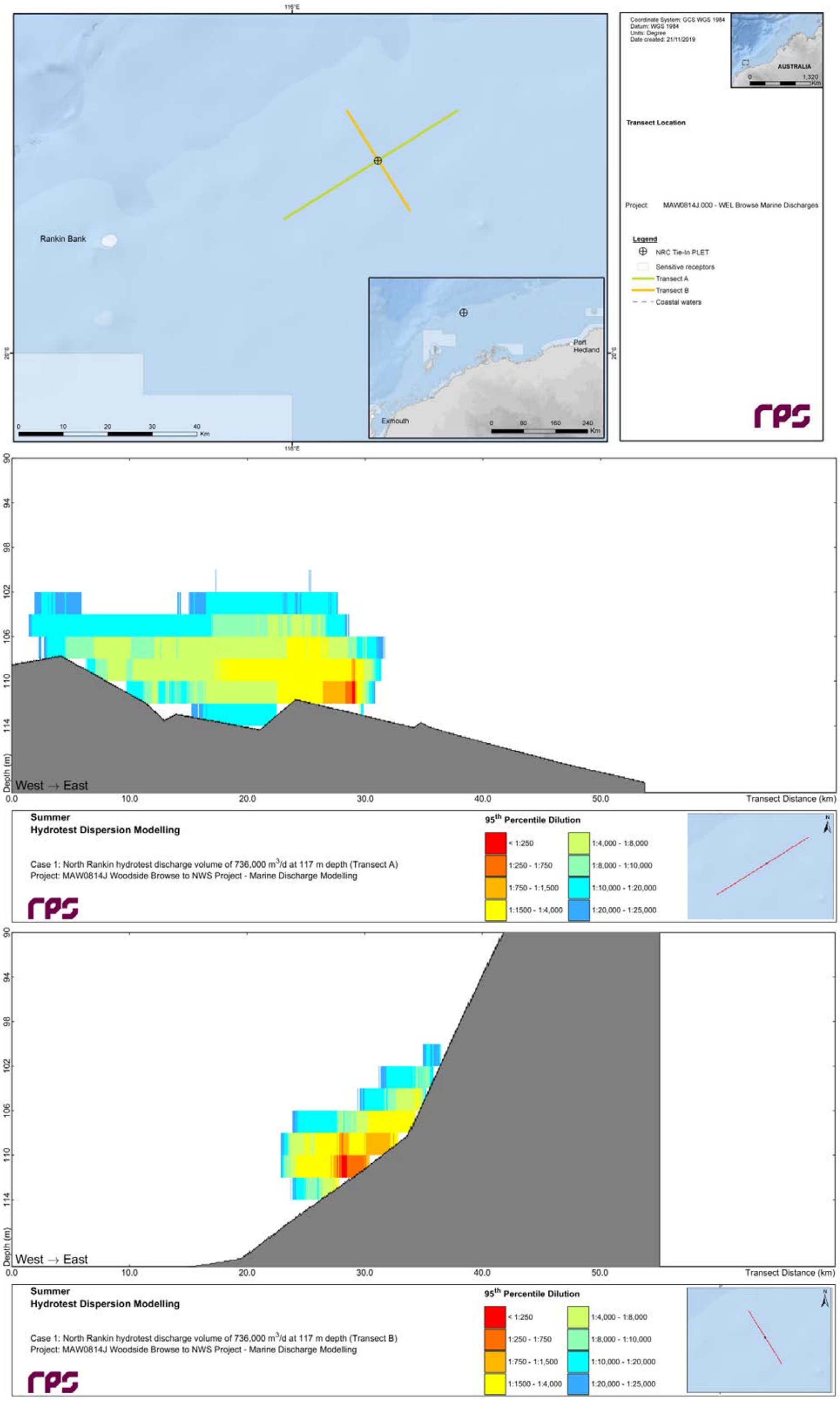


Figure 3.60 Vertical cross-section plots of predicted minimum dilutions at the 95th percentile under summer conditions for Case H1 (NRC tie-in PLET 736,000 m^3 hydrotest discharge). Transect locations are shown in the top panel, with transect A shown in the middle panel and transect B shown in the bottom panel. Spatial representation of this data is shown in Figure 3.57.

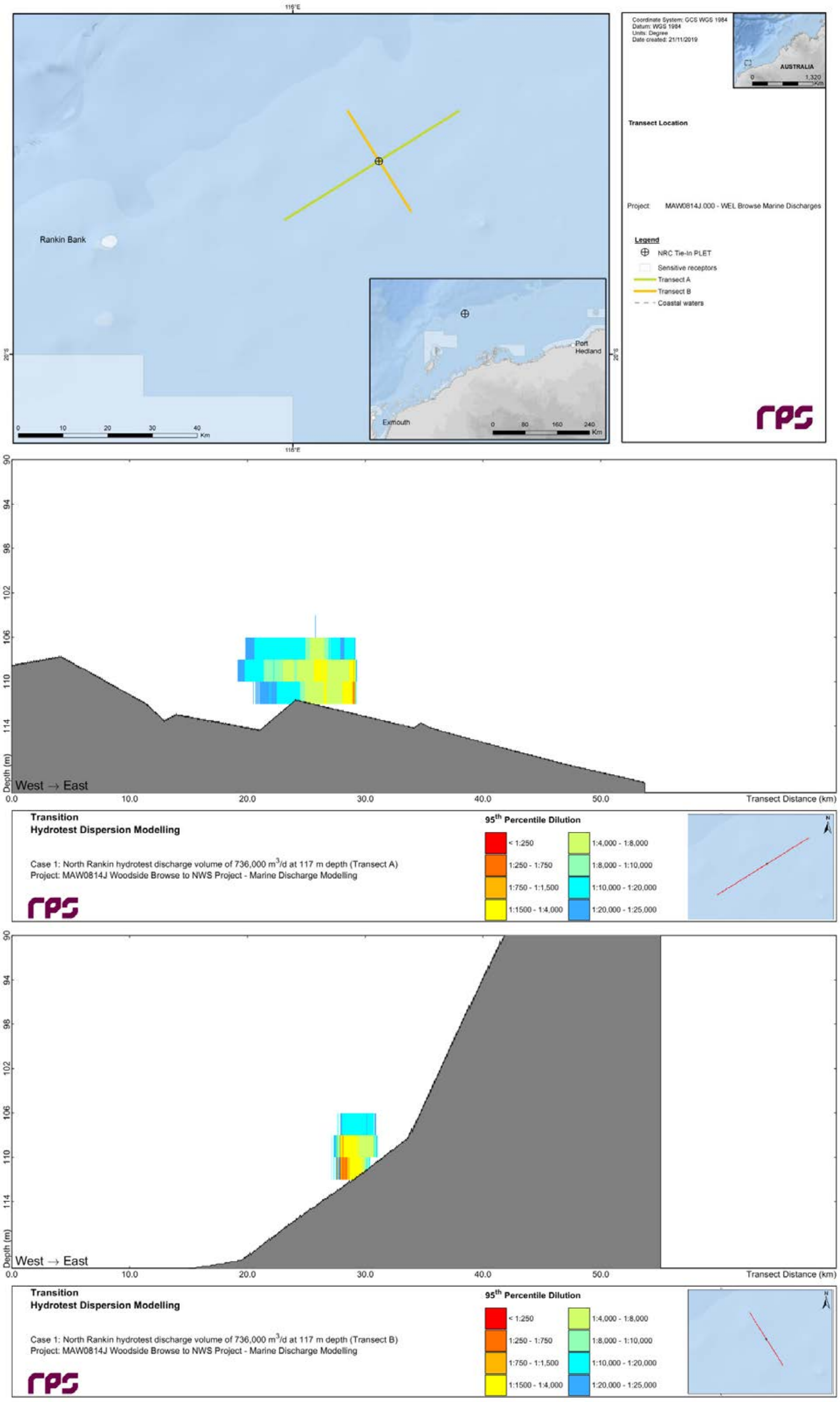


Figure 3.61 Vertical cross-section plots of predicted minimum dilutions at the 95th percentile under transitional conditions for Case H1 (NRC tie-in PLET 736,000 m^3 hydrotest discharge). Transect locations are shown in the top panel, with transect A shown in the middle panel and transect B shown in the bottom panel. Spatial representation of this data is shown in Figure 3.58.

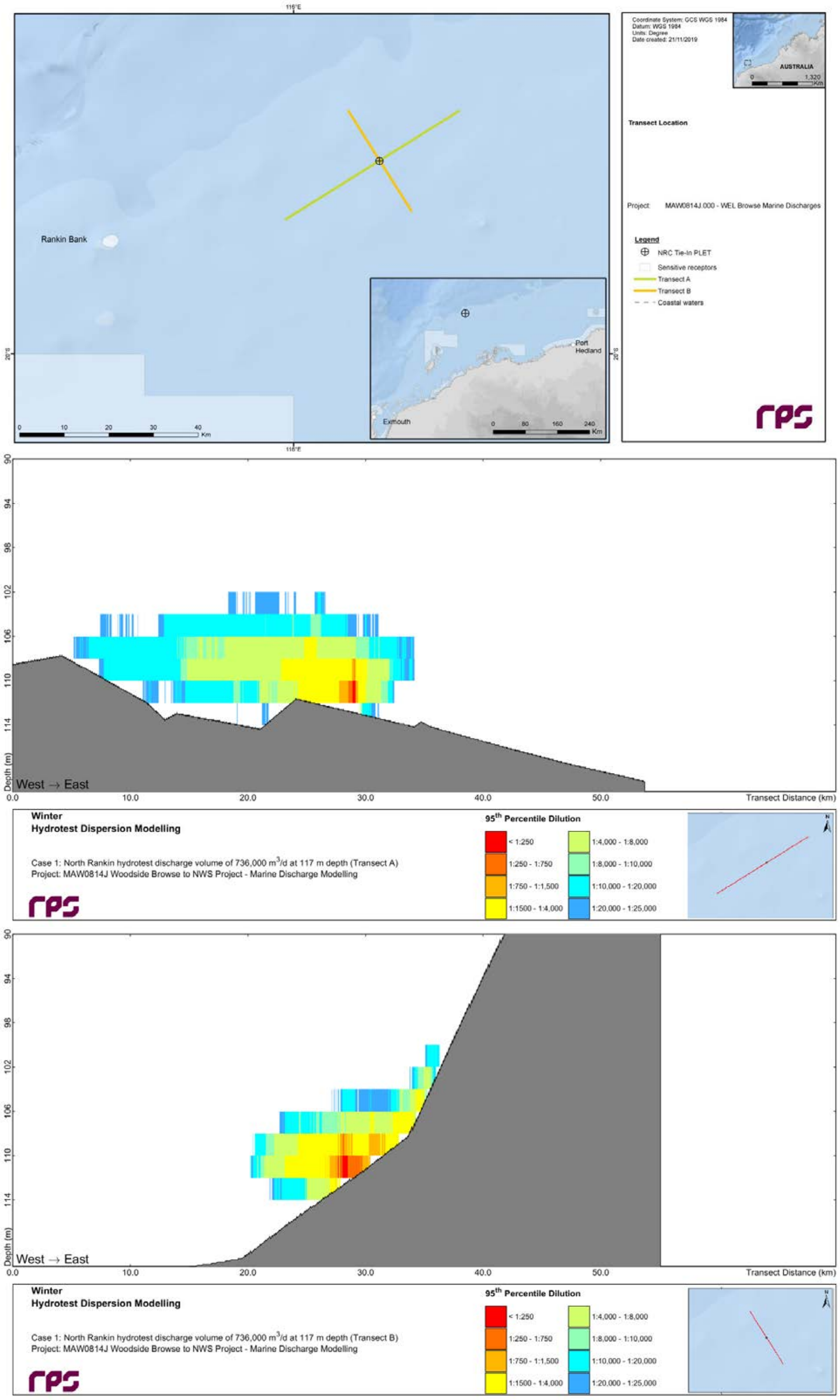


Figure 3.62 Vertical cross-section plots of predicted minimum dilutions at the 95th percentile under winter conditions for Case H1 (NRC tie-in PLET 736,000 m³ hydrotest discharge). Transect locations are shown in the top panel, with transect A shown in the middle panel and transect B shown in the bottom panel. Spatial representation of this data is shown in Figure 3.59.

3.2.5.2.3 Discharge Case H2: Torosa PLET Hydrotest Discharge of 846,000 m^3 at 461 m Depth

Table 3.61 Average and minimum dilutions (1:x) achieved at specific radial distances from the hydrotest discharge location in each season for Case H2 (Torosa PLET 846,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.

Distance (m)	Summer						Transitional						Winter					
	95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum
Scott Reef (3 nm State Water Boundary)	>20,000	5,458	>20,000	3,635	>20,000	3,631	>20,000	4,440	>20,000	1,805	>20,000	1,633	>20,000	>20,000	>20,000	17,049	>20,000	13,688
20	1,155	1,078	724	692	618	571	785	743	573	546	545	523	1,627	1,606	1,395	1,349	1,352	1,324
50	1,108	896	697	602	583	532	753	626	556	516	527	491	1,629	1,553	1,371	1,224	1,293	1,098
100	1,049	800	660	540	584	469	723	560	549	458	514	426	1,636	1,380	1,197	899	1,134	861
200	1,114	661	646	484	551	415	806	433	575	322	530	297	1,731	1,094	1,434	626	1,279	612
300	1,075	618	642	396	593	354	840	382	583	253	528	245	1,571	825	1,248	525	1,142	486
400	1,052	507	700	389	654	371	855	388	642	262	559	243	1,593	822	1,272	551	1,219	498
500	1,149	434	786	311	735	303	935	364	712	239	606	230	1,584	822	1,281	527	1,225	527
600	1,264	271	825	232	780	205	1,074	289	771	232	650	214	1,777	648	1,494	532	1,414	468
700	1,477	299	920	249	859	240	1,265	453	892	236	737	230	2,024	933	1,520	631	1,442	631
800	1,457	91	941	74	864	69	1,311	117	958	95	775	91	2,344	338	1,510	260	1,443	248
900	1,776	441	1,046	341	986	295	1,489	561	1,079	356	920	332	3,398	1,039	1,644	846	1,595	835
1,000	1,711	292	1,108	272	1,024	256	1,662	608	1,161	250	975	238	6,568	1,085	1,694	901	1,627	810
1,100	2,103	340	1,139	293	1,093	280	1,832	735	1,260	379	1,069	340	9,996	1,188	1,755	919	1,695	783
1,200	1,893	410	1,161	275	1,081	264	1,995	725	1,388	599	1,180	528	>20,000	1,231	1,906	975	1,825	952
1,300	2,378	385	1,272	322	1,190	310	2,399	766	1,491	645	1,291	562	>20,000	1,466	2,163	1,080	2,057	1,003
1,400	2,369	466	1,318	274	1,170	272	2,985	800	1,588	666	1,387	590	>20,000	1,760	2,363	997	2,220	961
1,500	3,658	505	1,599	288	1,444	274	4,542	758	1,733	654	1,548	582	>20,000	2,099	2,681	1,076	2,557	1,036
1,600	3,820	484	1,508	317	1,268	310	6,851	797	1,818	648	1,594	627	>20,000	2,302	3,003	1,026	2,890	999
1,700	6,518	503	1,967	333	1,684	309	7,362	837	1,955	624	1,702	596	>20,000	2,350	3,506	1,050	3,384	1,004
1,800	7,709	536	1,798	341	1,510	336	16,707	920	2,075	615	1,844	567	>20,000	2,250	5,049	1,097	4,882	1,016
1,900	18,884	561	2,794	334	2,442	326	>20,000	960	2,261	619	1,998	586	>20,000	2,418	6,982	1,118	6,784	1,073
2,000	15,848	619	2,186	358	2,035	348	>20,000	1,012	2,419	740	2,132	654	>20,000	2,590	13,315	1,199	13,015	1,141
2,100	>20,000	654	2,835	369	2,622	366	>20,000	973	2,599	741	2,248	664	>20,000	2,579	>20,000	1,227	>20,000	1,142
2,200	>20,000	701	2,516	391	2,283	391	>20,000	972	2,734	802	2,382	636	>20,000	2,535	>20,000	1,249	>20,000	1,232
2,300	>20,000	734	3,543	422	3,189	422	>20,000	1,061	3,086	776	2,624	694	>20,000	2,642	>20,000	1,230	>20,000	1,211
2,400	>20,000	764	3,448	443	3,106	440	>20,000	1,083	3,343	790	2,838	750	>20,000	2,657	>20,000	1,316	>20,000	1,223
2,500	>20,000	811	5,856	490	5,286	484	>20,000	1,132	3,693	902	3,000	820	>20,000	2,845	>20,000	1,356	>20,000	1,263
2,600	>20,000	838	6,669	478	6,099	470	>20,000	1,153	4,007	965	3,228	920	>20,000	2,872	>20,000	1,431	>20,000	1,330
2,700	>20,000	827	>20,000	517	>20,000	508	>20,000	1,281	4,086	979	3,411	898	>20,000	3,122	>20,000	1,475	>20,000	1,406
2,800	>20,000	801	19,007	495	11,108	495	>20,000	1,415	4,150	1,062	3,496	1,006	>20,000	3,158	>20,000	1,534	>20,000	1,409
2,900	>20,000	825	>20,000	592	>20,000	592	>20,000	1,479	4,484	1,095	3,786	992	>20,000	3,108	>20,000	1,653	>20,000	1,502
3,000	>20,000	827	>20,000	610	>20,000	610	>20,000	1,563	4,524	1,113	3,785	989	>20,000	2,843	>20,000	1,849	>20,000	1,671
3,100	>20,000	877	>20,000	667	>20,000	653	>20,000	1,586	5,025	1,209	4,168	1,075	>20,000	3,038	>20,000	1,833	>20,000	1,733
3,200	>20,000	898	>20,000	676	>20,000	661	>20,000	1,703	5,134	1,135	4,255	946	>20,000	3,261	>20,000	2,018	>20,000	1,852
3,300	>20,000	919	>20,000	680	>20,000	651	>20,000	1,768	5,586	1,059	4,595	1,006	>20,000	3,225	>20,000	2,238	>20,000	1,899
3,400	>20,000	936	>20,000	723	>20,000	670	>20,000	1,833	5,721	1,032	4,763	1,032	>20,000	3,318	>20,000	2,179	>20,000	1,919

Distance (m)	Summer						Transitional						Winter					
	95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum
3,500	>20,000	961	>20,000	749	>20,000	726	>20,000	1,918	6,472	1,092	5,443	1,092	>20,000	3,467	>20,000	1,931	>20,000	1,797
3,600	>20,000	973	>20,000	769	>20,000	744	>20,000	1,930	6,428	1,244	5,588	1,170	>20,000	3,417	>20,000	1,938	>20,000	1,672
3,700	>20,000	971	>20,000	844	>20,000	815	>20,000	2,042	6,820	1,270	5,810	1,154	>20,000	3,733	>20,000	2,433	>20,000	1,947
3,800	>20,000	1,035	>20,000	882	>20,000	833	>20,000	2,077	7,159	1,281	5,958	1,153	>20,000	4,326	>20,000	2,650	>20,000	2,435
3,900	>20,000	1,095	>20,000	883	>20,000	834	>20,000	2,069	7,789	1,340	6,631	1,129	>20,000	4,993	>20,000	2,779	>20,000	2,662
4,000	>20,000	1,092	>20,000	904	>20,000	863	>20,000	2,162	9,795	1,538	7,253	1,304	>20,000	4,866	>20,000	2,812	>20,000	2,338
4,100	>20,000	1,127	>20,000	909	>20,000	861	>20,000	2,273	16,720	1,622	7,871	1,350	>20,000	5,320	>20,000	3,137	>20,000	2,790
4,200	>20,000	1,187	>20,000	927	>20,000	917	>20,000	2,420	>20,000	1,534	9,750	1,417	>20,000	5,487	>20,000	2,933	>20,000	2,443
4,300	>20,000	1,157	>20,000	940	>20,000	903	>20,000	2,592	>20,000	1,653	13,429	1,392	>20,000	6,131	>20,000	3,229	>20,000	2,996
4,400	>20,000	1,177	>20,000	942	>20,000	899	>20,000	2,776	>20,000	1,641	19,452	1,508	>20,000	5,974	>20,000	3,163	>20,000	2,712
4,500	>20,000	1,232	>20,000	975	>20,000	971	>20,000	2,948	>20,000	1,704	>20,000	1,460	>20,000	6,572	>20,000	3,540	>20,000	3,061
4,600	>20,000	1,266	>20,000	990	>20,000	983	>20,000	2,941	19,797	1,736	>20,000	1,503	>20,000	6,772	>20,000	3,209	>20,000	2,836
4,700	>20,000	1,312	>20,000	1,000	>20,000	966	>20,000	2,973	>20,000	1,756	>20,000	1,552	>20,000	6,878	>20,000	3,824	>20,000	3,147
4,800	>20,000	1,367	>20,000	1,062	>20,000	990	>20,000	2,983	>20,000	1,666	>20,000	1,578	>20,000	6,533	>20,000	3,627	>20,000	3,085
4,900	>20,000	1,356	>20,000	1,166	>20,000	1,040	>20,000	3,089	>20,000	1,692	>20,000	1,569	>20,000	6,649	>20,000	4,278	>20,000	3,430
5,000	>20,000	1,433	>20,000	1,147	>20,000	1,126	>20,000	3,263	>20,000	1,744	>20,000	1,542	>20,000	7,169	>20,000	4,174	>20,000	3,407
5,500	>20,000	1,709	>20,000	1,099	>20,000	1,053	>20,000	2,824	>20,000	2,044	>20,000	1,816	>20,000	6,251	>20,000	4,433	>20,000	3,581
6,000	>20,000	2,499	>20,000	1,267	>20,000	1,253	>20,000	3,563	>20,000	2,264	>20,000	1,788	>20,000	5,487	>20,000	3,452	>20,000	3,154
6,500	>20,000	3,378	>20,000	1,318	>20,000	1,279	>20,000	4,575	>20,000	2,490	>20,000	2,233	>20,000	6,558	>20,000	3,153	>20,000	3,028
7,000	>20,000	3,415	>20,000	1,375	>20,000	1,364	>20,000	4,705	>20,000	2,943	>20,000	2,897	>20,000	8,080	>20,000	3,708	>20,000	3,708
7,500	>20,000	4,097	>20,000	1,603	>20,000	1,343	>20,000	5,401	>20,000	2,921	>20,000	2,832	>20,000	9,916	>20,000	3,262	>20,000	3,262
8,000	>20,000	4,260	>20,000	1,838	>20,000	1,357	>20,000	6,053	>20,000	2,898	>20,000	2,850	>20,000	10,340	>20,000	2,824	>20,000	2,824
8,500	>20,000	5,139	>20,000	1,992	>20,000	1,778	>20,000	5,583	>20,000	2,865	>20,000	2,591	>20,000	10,489	>20,000	2,446	>20,000	2,446
9,000	>20,000	5,771	>20,000	2,228	>20,000	2,040	>20,000	6,144	>20,000	2,582	>20,000	2,582	>20,000	14,289	>20,000	2,196	>20,000	2,196
9,500	>20,000	5,848	>20,000	2,646	>20,000	2,500	>20,000	6,882	>20,000	2,614	>20,000	2,614	>20,000	14,114	>20,000	2,080	>20,000	1,997
10,000	>20,000	7,837	>20,000	2,543	>20,000	2,506	>20,000	7,382	>20,000	2,763	>20,000	2,763	>20,000	13,940	>20,000	2,396	>20,000	2,150
10,500	>20,000	7,331	>20,000	2,618	>20,000	2,618	>20,000	7,757	>20,000	2,751	>20,000	2,751	>20,000	12,248	>20,000	3,044	>20,000	2,332
11,000	>20,000	9,182	>20,000	2,611	>20,000	2,611	>20,000	8,233	>20,000	2,611	>20,000	2,611	>20,000	11,943	>20,000	4,979	>20,000	2,382
11,500	>20,000	9,742	>20,000	3,389	>20,000	2,946	>20,000	8,606	>20,000	2,700	>20,000	2,700	>20,000	14,753	>20,000	7,075	>20,000	2,971
12,000	>20,000	12,750	>20,000	3,287	>20,000	3,287	>20,000	10,586	>20,000	3,220	>20,000	3,220	>20,000	>20,000	>20,000	9,657	>20,000	4,603
12,500	>20,000	9,813	>20,000	3,039	>20,000	3,039	>20,000	13,141	>20,000	3,506	>20,000	3,506	>20,000	>20,000	>20,000	11,476	>20,000	6,736
13,000	>20,000	14,773	>20,000	3,218	>20,000	2,645	>20,000	13,043	>20,000	3,873	>20,000	3,873	>20,000	>20,000	>20,000	11,570	>20,000	10,298
13,500	>20,000	16,076	>20,000	3,558	>20,000	2,954	>20,000	17,355	>20,000	3,681	>20,000	3,681	>20,000	>20,000	>20,000	14,334	>20,000	13,501
14,000	>20,000	17,912	>20,000	4,504	>20,000	4,102	>20,000	>20,000	>20,000	3,852	>20,000	3,852	>20,000	>20,000	>20,000	16,087	>20,000	14,850
14,500	>20,000	>20,000	>20,000	4,824	>20,000	3,729	>20,000	>20,000	>20,000	4,087	>20,000	4,087	>20,000	>20,000	>20,000	16,118	>20,000	14,576
15,000	>20,000	>20,000	>20,000	5,529	>20,000	3,814	>20,000	>20,000	>20,000	4,011	>20,000	4,011	>20,000	>20,000	>20,000	15,242	>20,000	14,677
15,500	>20,000	>20,000	>20,000	6,176	>20,000	5,318	>20,000	>20,000	>20,000	3,617	>20,000	3,617	>20,000	>20,000	>20,000	15,483	>20,000	14,598
16,000	>20,000	19,435	>20,000	9,973	>20,000	4,574	>20,000	>20,000	>20,000	4,011	>20,000	4,011	>20,000	>20,000	>20,000	18,962	>20,000	16,699
16,500	>20,000	19,642	>20,000	9,086	>20,000	4,014	>20,000	>20,000	>20,000	4,190	>20,000	4,190	>20,000	>20,000	>20,000	>20,000	>20,000	17,591
17,000	>20,000	>20,000	>20,000	8,607	>20,000	5,338	>20,000	>20,000	>20,000	4,605	>20,000	4,605	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
17,500	>20,000	16,380	>20,000	9,961	>20,000	4,674	>20,000	>20,000	>20,000	5,229	>20,000	5,132	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
18,000	>20,000	15,789	>20,000	11,302	>20,000	5,614	>20,000	>20,000	>20,000	5,435	>20,000	5,265	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
18,500	>20,000	17,692	>20,000	10,869	>20,000	7,902	>20,000	>20,000	>20,000	4,904	>20,000	4,904	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
19,000	>20,000	>20,000	>20,000	12,354	>20,000	10,458	>20,000	>20,000	>20,000	5,183	>20,000	5,143	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000

	Summer						Transitional						Winter					
Distance (m)	95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum
19,500	>20,000	>20,000	>20,000	14,338	>20,000	11,667	>20,000	>20,000	>20,000	6,873	>20,000	6,648	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
20,000	>20,000	>20,000	>20,000	13,964	>20,000	13,515	>20,000	>20,000	>20,000	6,826	>20,000	6,787	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000

Table 3.62 **Maximum distance from the hydrotest discharge location to achieve 1:10,000 dilution in each season for Case H2 (Torosa PLET 846,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.**

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Summer	12,496
	Transitional	11,855
	Winter	7,983
99th	Summer	17,703
	Transitional	20,555
	Winter	12,184
100th	Summer	18,920
	Transitional	20,723
	Winter	12,958

Table 3.63 **Total area of coverage for 1:10,000 dilution in each season for Case H2 (Torosa PLET 846,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.**

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Summer	74.60
	Transitional	42.70
	Winter	30.70
99th	Summer	140.60
	Transitional	194.40
	Winter	70.00
100th	Summer	164.80
	Transitional	224.60
	Winter	84.90

Table 3.64 **Maximum depth from the hydrotest discharge location to achieve 1:10,000 dilution in each season for Case H2 (Torosa PLET 846,000 m^3 hydrotest discharge).**

Season	Maximum depth (m) from sea surface to achieve given dilution
Summer	461 (seabed)
Transitional	461 (seabed)
Winter	461 (seabed)

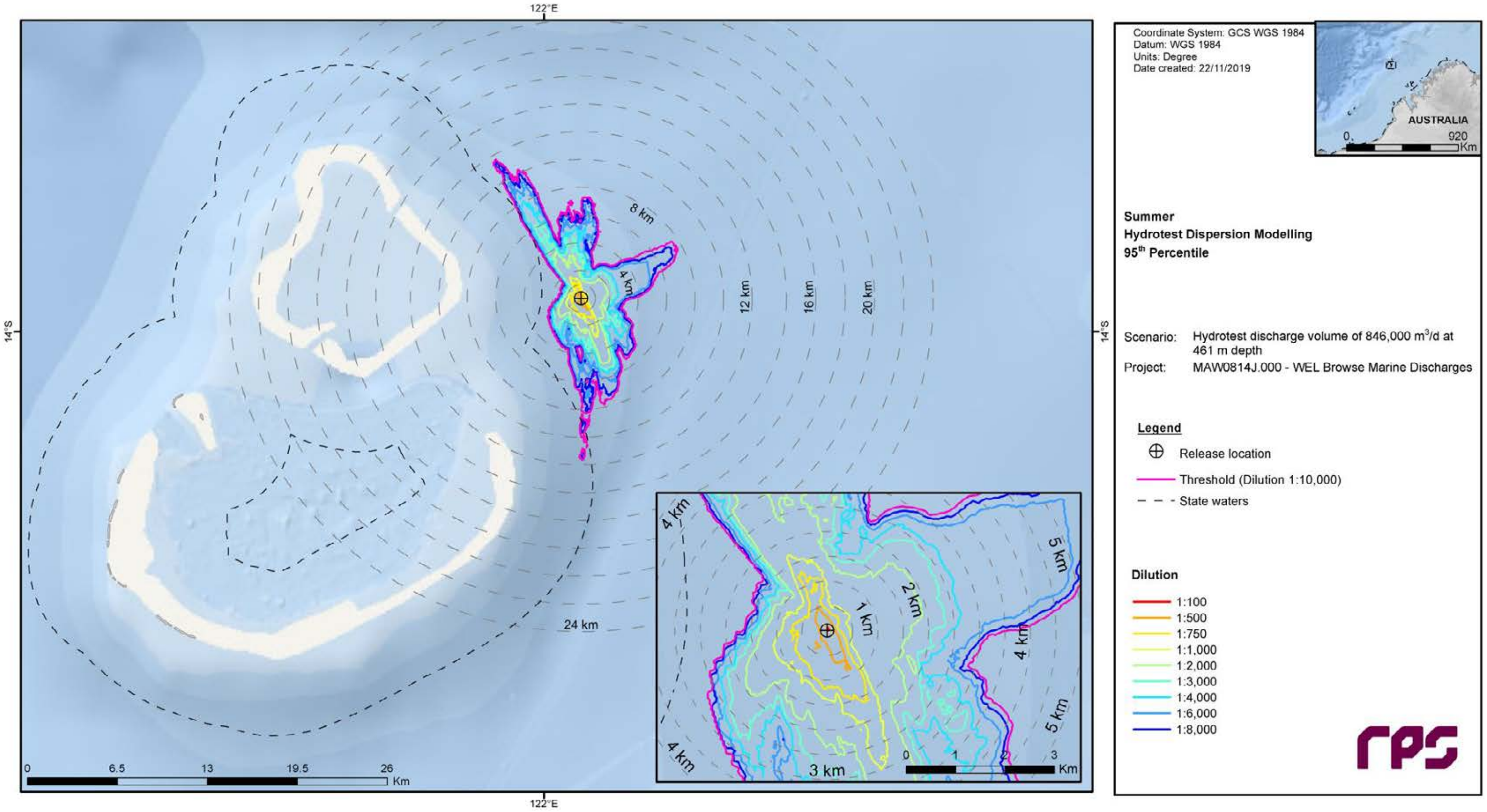


Figure 3.63 Predicted minimum dilutions at the 95th percentile under summer conditions for Case H2 (Torosa PLET 846,000 m^3 hydrotest discharge), with a rolling 48-hour median of the dilution data.

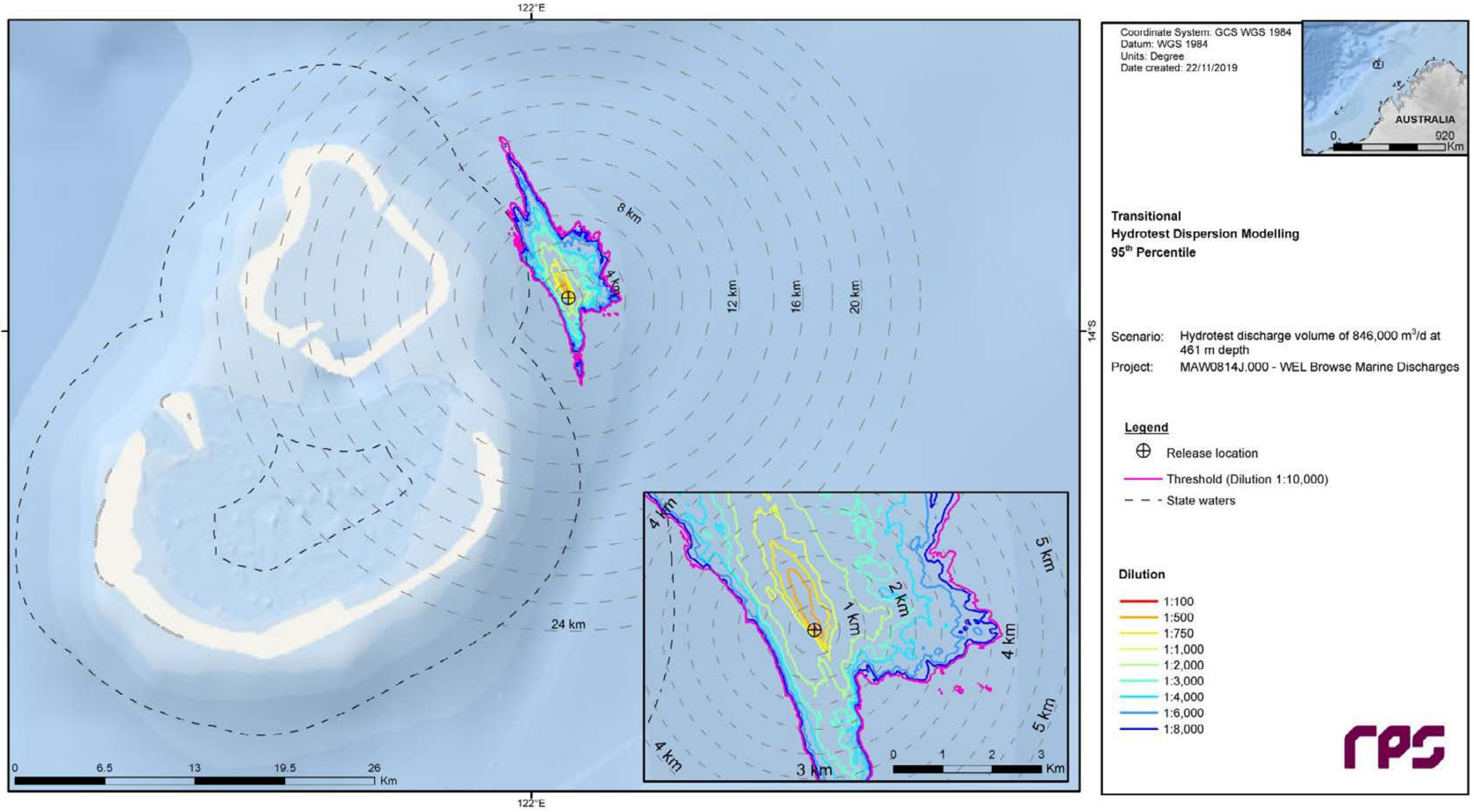


Figure 3.64 Predicted minimum dilutions at the 95th percentile under transitional conditions for Case H2 (Torosa PLET 846,000 m^3 hydrotest discharge), with a rolling 48-hour median of the dilution data.

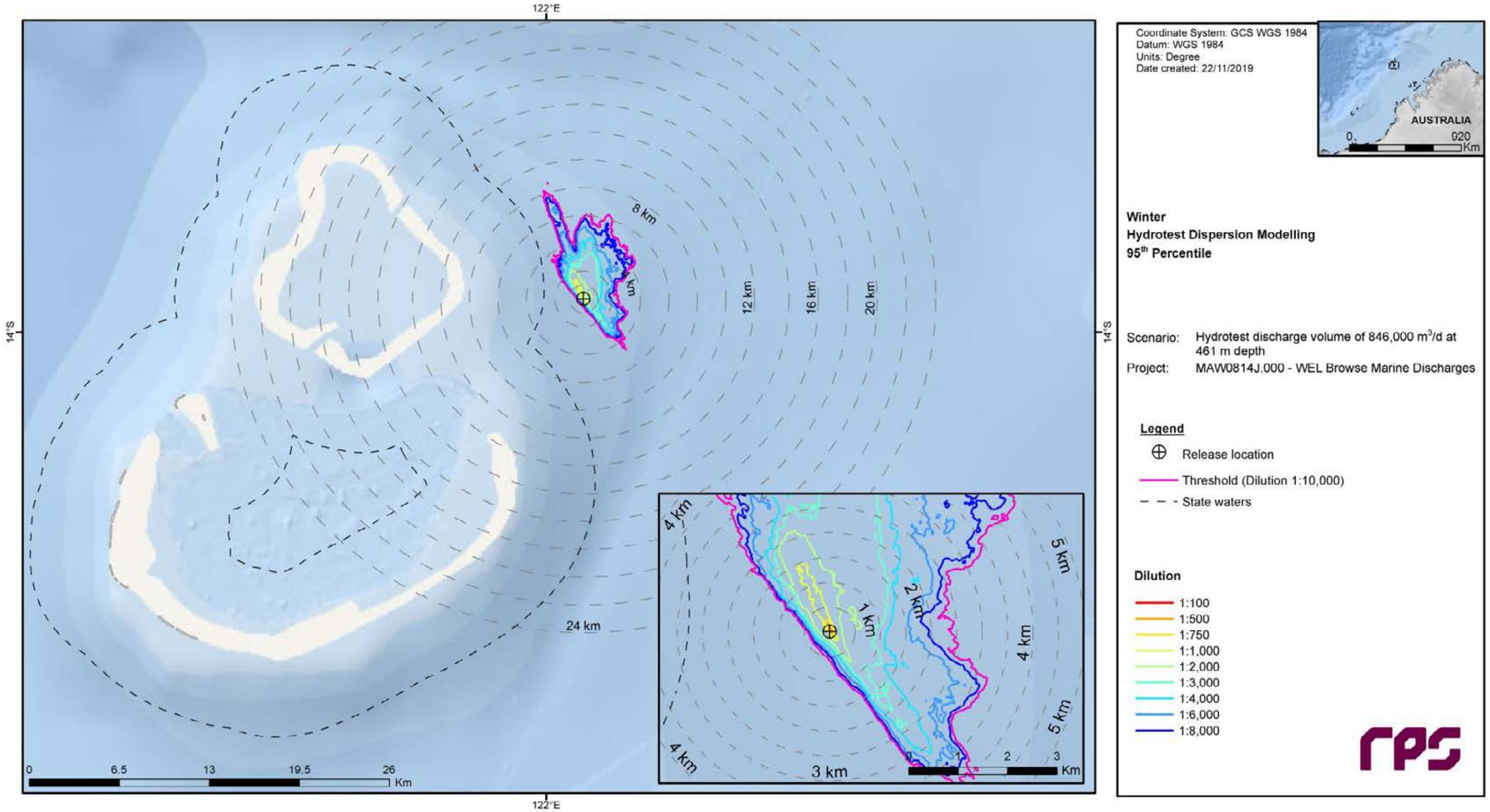


Figure 3.65 Predicted minimum dilutions at the 95th percentile under winter conditions for Case H2 (Torosa PLET 846,000 m^3 hydrotest discharge), with a rolling 48-hour median of the dilution data.

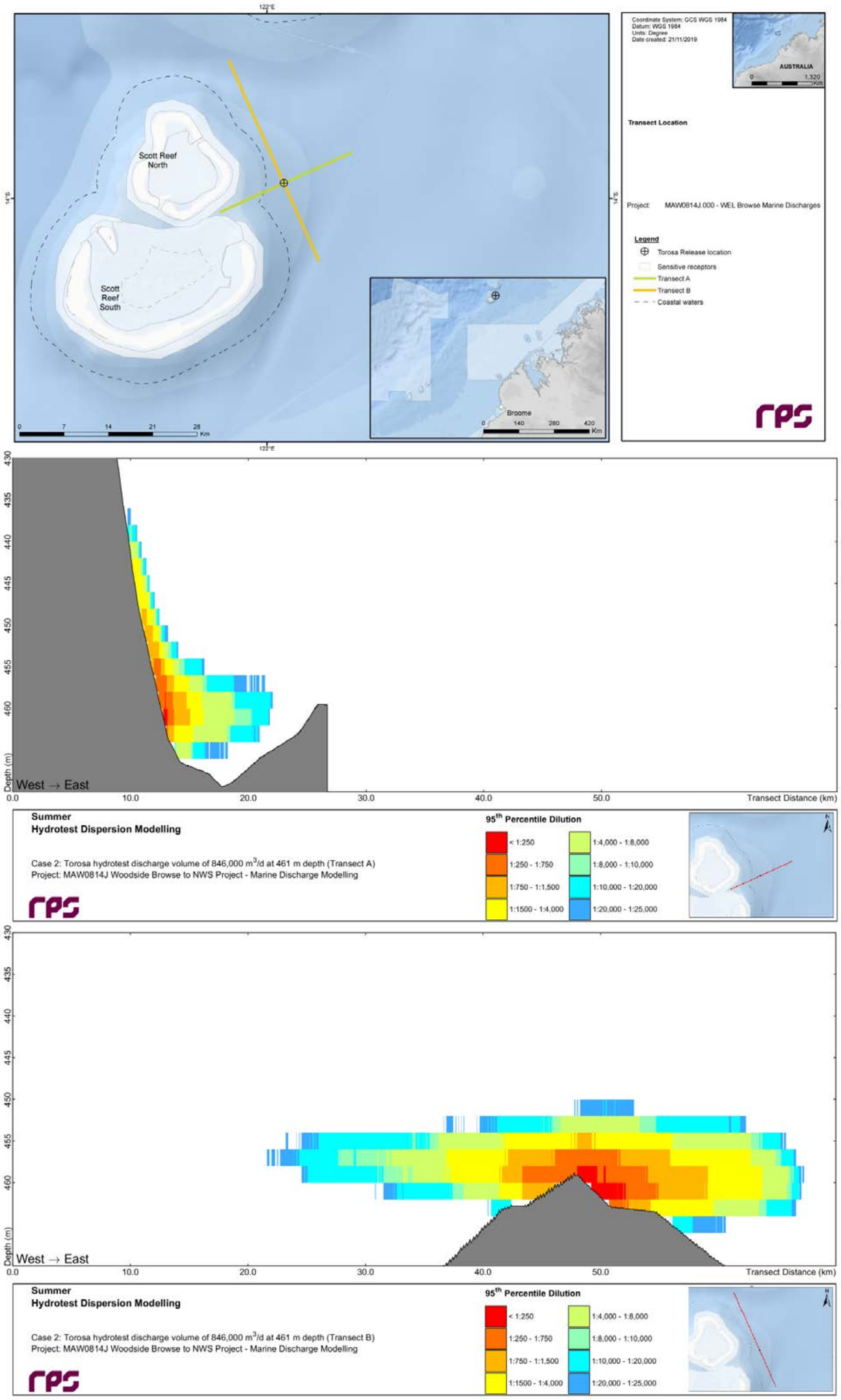


Figure 3.66 Vertical cross-section plots of predicted minimum dilutions at the 95th percentile under summer conditions for Case H2 (Torosa PLET 846,000 m^3 hydrotest discharge). Transect locations are shown in the top panel, with transect A shown in the middle panel and transect B shown in the bottom panel. Spatial representation of this data is shown in Figure 3.63.

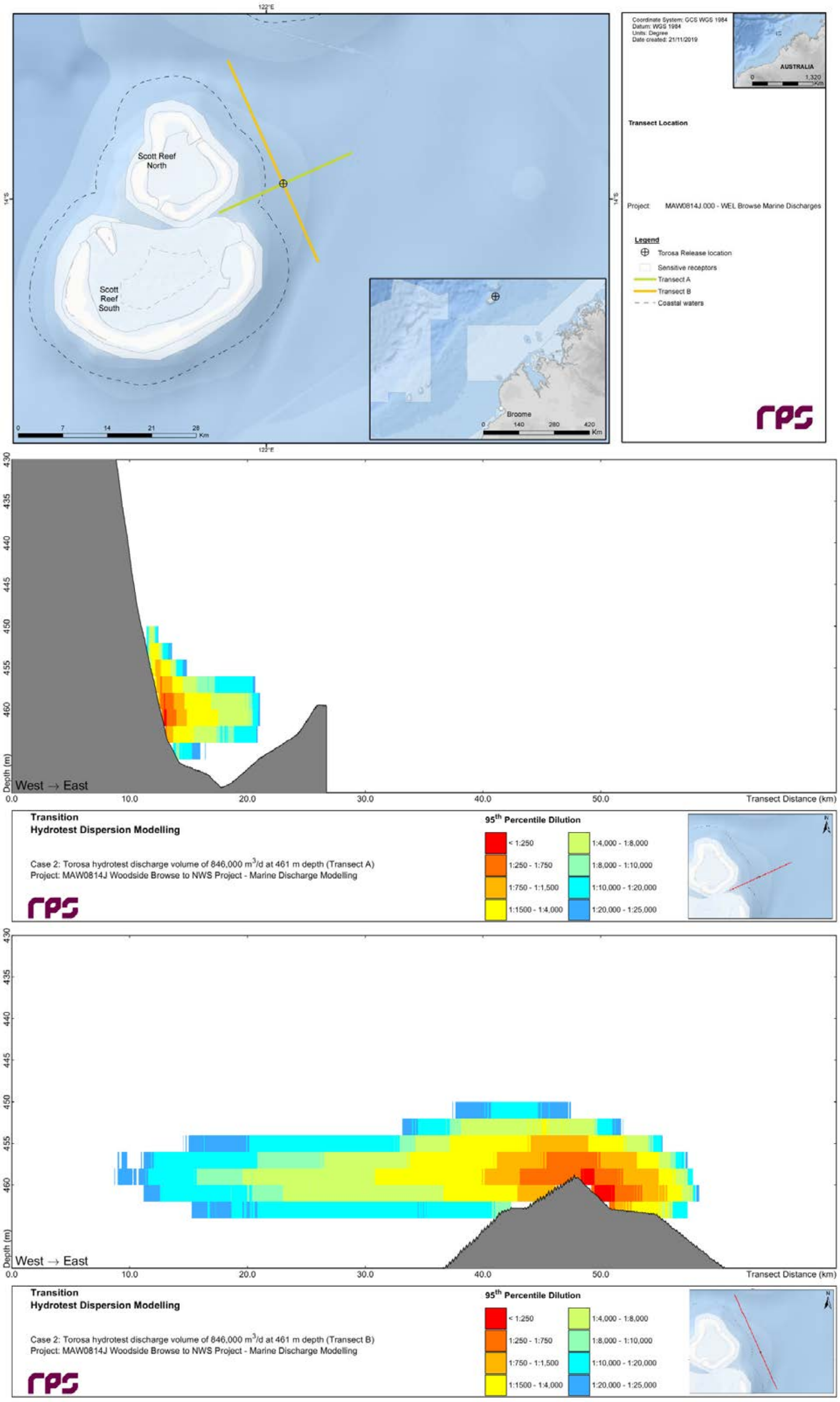


Figure 3.67 Vertical cross-section plots of predicted minimum dilutions at the 95th percentile under transitional conditions for Case H2 (Torosa PLET 846,000 m^3 hydrotest discharge). Transect locations are shown in the top panel, with transect A shown in the middle panel and transect B shown in the bottom panel. Spatial representation of this data is shown in Figure 3.64.

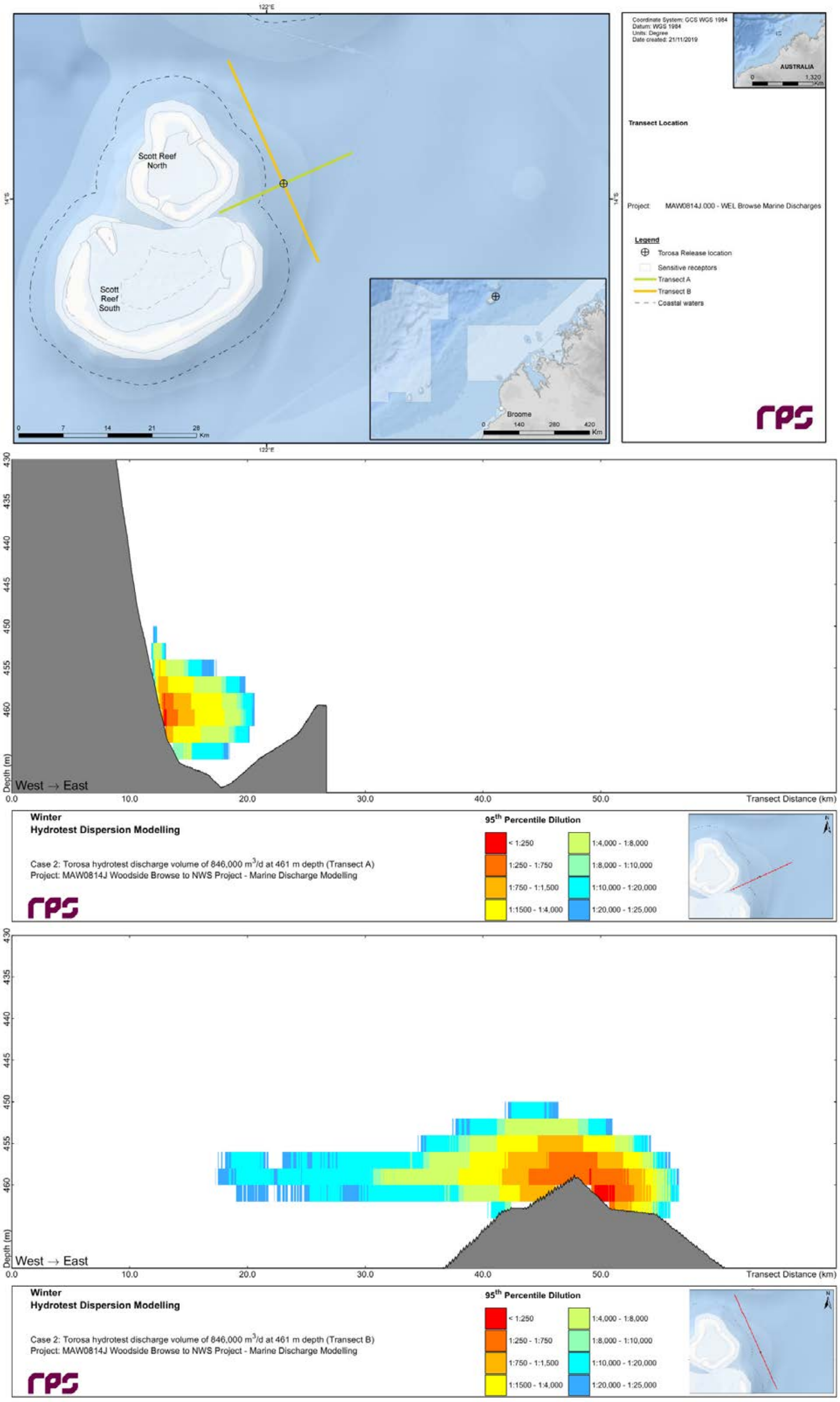


Figure 3.68 Vertical cross-section plots of predicted minimum dilutions at the 95th percentile under winter conditions for Case H2 (Torosa PLET 846,000 m^3 hydrotest discharge). Transect locations are shown in the top panel, with transect A shown in the middle panel and transect B shown in the bottom panel. Spatial representation of this data is shown in Figure 3.65.

3.2.5.2.4 Discharge Case H3a: Brecknock/Calliance PLET Hydrotest Discharge of 790,000 m^3 at 539 m Depth

Table 3.65 Average and minimum dilutions (1:x) achieved at specific radial distances from the hydrotest discharge location in each season for Case H3a (Brecknock/Calliance PLET 790,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.

Distance (m)	Summer						Transitional						Winter					
	95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum
Scott Reef (3 nm State Water Boundary) †	>>20,000	>20,000	>>20,000	>20,000	>>20,000	>20,000	>>20,000	>20,000	>>20,000	>20,000	>>20,000	>20,000	>>20,000	>20,000	>>20,000	>20,000	>>20,000	>20,000
20	508	508	353	353	324	324	1,066	1,066	366	366	318	318	1,520	1,520	1,014	1,014	522	522
50	826	74	465	72	398	71	1,342	87	831	74	629	73	1,797	90	1,443	80	1,130	79
100	1,611	334	1,072	165	838	139	1,954	411	1,217	157	986	145	2,856	1,412	2,019	440	1,796	296
200	2,285	1,513	1,396	412	1,141	371	2,024	1,291	1,313	321	1,026	267	3,825	1,616	2,420	1,179	2,302	1,001
300	3,081	1,780	2,049	663	1,709	634	2,356	1,371	1,747	703	1,511	593	4,927	2,140	3,330	1,620	3,016	1,450
400	3,085	1,874	1,899	646	1,596	622	2,302	1,445	1,572	1,014	1,316	781	4,878	2,246	3,460	1,871	3,168	1,592
500	3,475	2,192	2,176	776	1,855	709	2,712	1,562	1,695	1,020	1,500	912	5,428	2,531	3,820	1,788	3,356	1,747
600	3,508	2,210	2,229	910	1,966	860	2,652	1,580	1,613	877	1,384	778	5,873	2,885	3,786	1,981	3,446	1,823
700	3,868	2,298	2,376	1,014	2,022	780	3,070	1,847	1,955	985	1,672	972	6,567	2,644	3,828	1,979	3,418	1,841
800	3,743	2,167	2,428	1,162	2,119	840	3,128	1,559	1,962	862	1,579	840	8,172	2,592	4,021	1,936	3,540	1,629
900	3,993	2,277	2,631	1,281	2,294	866	3,569	1,850	2,301	1,041	1,912	1,041	9,493	2,356	4,126	1,674	3,674	1,517
1,000	4,041	2,363	2,710	1,130	2,436	942	3,766	1,609	2,374	1,051	1,887	992	10,720	2,269	3,924	1,806	3,506	1,517
1,100	4,276	2,189	2,905	1,197	2,649	959	4,133	1,979	2,676	931	2,197	864	14,246	2,208	3,941	1,612	3,541	1,416
1,200	4,248	2,128	2,992	922	2,732	881	4,395	1,856	2,793	1,006	2,215	921	>20,000	2,304	3,836	1,578	3,422	1,355
1,300	4,621	2,081	3,016	1,091	2,759	993	4,876	1,924	3,044	1,003	2,628	1,003	>20,000	2,342	4,105	1,536	3,610	1,283
1,400	4,886	1,960	3,086	953	2,827	888	5,012	1,913	3,129	1,383	2,715	1,232	>20,000	2,188	4,059	1,456	3,499	1,109
1,500	5,561	2,235	3,173	874	2,861	822	6,099	2,084	3,506	1,309	3,001	1,258	>20,000	2,145	4,473	1,541	3,810	1,167
1,600	5,507	2,188	3,084	820	2,822	753	6,602	2,230	3,765	1,304	3,238	1,304	>20,000	2,083	4,336	1,424	3,804	1,204
1,700	6,407	2,327	3,371	772	3,063	726	10,432	2,296	4,069	1,250	3,476	1,159	>20,000	2,163	5,201	1,300	4,185	1,163
1,800	6,067	2,168	3,358	787	3,066	726	11,269	2,409	4,543	1,213	3,882	1,033	>20,000	2,375	5,598	1,363	4,393	1,197
1,900	6,939	2,121	3,762	811	3,344	772	>20,000	2,558	4,830	1,199	4,126	1,107	>20,000	2,011	7,887	1,321	5,363	1,161
2,000	6,825	2,088	3,634	783	3,332	783	>20,000	2,429	5,013	1,185	4,307	921	>20,000	2,172	9,393	1,215	6,307	1,150
2,100	7,987	2,169	4,179	862	3,758	862	>20,000	2,461	5,610	1,265	4,562	1,010	>20,000	2,198	14,586	1,262	10,058	1,155
2,200	8,132	2,057	4,138	971	3,749	971	>20,000	2,563	5,340	1,257	4,381	976	>20,000	2,128	19,283	1,367	11,468	1,237
2,300	9,429	2,166	4,578	1,117	4,119	1,071	>20,000	2,601	6,462	1,448	4,944	1,116	>20,000	2,279	>20,000	1,407	17,353	1,307
2,400	9,949	2,382	4,508	1,085	4,035	1,058	>20,000	2,750	6,175	1,330	4,936	1,225	>20,000	2,247	>20,000	1,474	>20,000	1,324
2,500	11,729	2,567	4,985	1,232	4,370	1,159	>20,000	2,682	8,091	1,485	5,299	1,310	>20,000	2,513	>20,000	1,525	>20,000	1,327
2,600	12,902	2,590	4,967	1,372	4,422	1,272	>20,000	2,943	7,807	1,391	5,408	1,264	>20,000	2,265	>20,000	1,636	>20,000	1,472
2,700	14,779	2,683	5,544	1,654	4,818	1,498	>20,000	3,040	11,029	1,625	5,732	1,393	>20,000	2,570	>20,000	1,700	>20,000	1,501
2,800	17,003	2,854	5,623	1,833	4,913	1,643	>20,000	3,445	10,830	1,766	6,024	1,584	>20,000	2,724	>20,000	1,653	>20,000	1,626
2,900	18,629	2,889	5,880	1,726	5,036	1,588	>20,000	3,283	>20,000	1,641	6,587	1,565	>20,000	2,563	>20,000	1,664	>20,000	1,630
3,000	>20,000	2,837	6,011	1,810	5,169	1,629	>20,000	3,470	15,471	1,964	6,961	1,705	>20,000	2,660	>20,000	1,707	>20,000	1,643
3,100	>20,000	2,910	6,083	1,753	5,255	1,638	>20,000	4,532	>20,000	1,993	7,447	1,719	>20,000	2,744	>20,000	1,665	>20,000	1,568
3,200	>20,000	2,988	6,368	1,709	5,531	1,549	>20,000	4,433	>20,000	1,868	7,602	1,575	>20,000	2,905	>20,000	1,776	>20,000	1,688
3,300	>20,000	2,941	6,538	1,784	5,592	1,514	>20,000	4,457	>20,000	1,844	8,648	1,582	>20,000	3,022	>20,000	1,805	>20,000	1,637
3,400	>20,000	3,048	7,261	1,853	6,093	1,754	>20,000	4,343	>20,000	1,867	8,886	1,473	>20,000	3,306	>20,000	1,877	>20,000	1,776

Distance (m)	Summer						Transitional						Winter					
	95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum
3,500	>20,000	3,059	7,582	1,737	6,234	1,723	>20,000	4,568	>20,000	1,832	10,689	1,428	>20,000	3,210	>20,000	1,865	>20,000	1,687
3,600	>20,000	3,092	8,550	1,636	6,797	1,578	>20,000	4,677	>20,000	2,188	11,249	1,422	>20,000	3,392	>20,000	1,868	>20,000	1,799
3,700	>20,000	3,138	9,211	1,593	6,975	1,512	>20,000	4,946	>20,000	2,346	15,034	1,803	>20,000	3,407	>20,000	1,868	>20,000	1,796
3,800	>20,000	3,205	10,248	1,671	7,798	1,644	>20,000	5,268	>20,000	2,309	17,936	1,924	>20,000	3,548	>20,000	1,799	>20,000	1,741
3,900	>20,000	3,196	11,207	1,685	8,073	1,672	>20,000	5,244	>20,000	2,274	>20,000	2,023	>20,000	3,766	>20,000	1,738	>20,000	1,665
4,000	>20,000	3,134	12,363	1,758	8,948	1,749	>20,000	5,305	>20,000	2,309	>20,000	2,058	>20,000	3,589	>20,000	1,799	>20,000	1,717
4,100	>20,000	3,150	13,381	1,788	10,118	1,786	>20,000	5,739	>20,000	2,247	>20,000	2,071	>20,000	4,034	>20,000	1,729	>20,000	1,676
4,200	>20,000	3,089	14,306	1,995	11,234	1,954	>20,000	5,299	>20,000	2,194	>20,000	2,040	>20,000	4,173	>20,000	1,766	>20,000	1,720
4,300	>20,000	3,164	15,387	2,093	11,927	1,989	>20,000	4,824	>20,000	2,052	>20,000	1,965	>20,000	4,156	>20,000	1,893	>20,000	1,739
4,400	>20,000	3,028	16,818	2,375	12,763	2,261	>20,000	5,121	>20,000	2,056	>20,000	1,954	>20,000	4,195	>20,000	1,867	>20,000	1,744
4,500	>20,000	3,225	>20,000	2,382	15,095	2,294	>20,000	5,077	>20,000	2,132	>20,000	2,042	>20,000	4,335	>20,000	1,949	>20,000	1,711
4,600	>20,000	3,185	>20,000	2,678	15,482	2,414	>20,000	5,028	>20,000	2,095	>20,000	2,046	>20,000	4,343	>20,000	1,930	>20,000	1,724
4,700	>20,000	3,287	>20,000	2,671	18,224	2,660	>20,000	5,548	>20,000	1,993	>20,000	1,930	>20,000	4,510	>20,000	2,010	>20,000	1,833
4,800	>20,000	3,303	>20,000	2,752	18,952	2,749	>20,000	5,752	>20,000	2,028	>20,000	1,964	>20,000	4,561	>20,000	2,137	>20,000	1,869
4,900	>20,000	3,642	>20,000	2,552	>20,000	2,552	>20,000	4,988	>20,000	2,273	>20,000	1,977	>20,000	4,639	>20,000	2,122	>20,000	1,924
5,000	>20,000	3,924	>20,000	2,392	>20,000	2,392	>20,000	4,912	>20,000	2,360	>20,000	2,240	>20,000	4,717	>20,000	2,132	>20,000	1,981
5,500	>20,000	4,260	>20,000	2,917	>20,000	2,917	>20,000	5,473	>20,000	2,994	>20,000	2,218	>20,000	5,440	>20,000	2,119	>20,000	1,921
6,000	>20,000	4,650	>20,000	3,295	>20,000	3,009	>20,000	8,198	>20,000	3,130	>20,000	3,002	>20,000	6,786	>20,000	2,321	>20,000	2,028
6,500	>20,000	4,880	>20,000	4,189	>20,000	4,008	>20,000	7,996	>20,000	3,624	>20,000	2,808	>20,000	6,708	>20,000	2,475	>20,000	2,134
7,000	>20,000	5,429	>20,000	4,610	>20,000	4,462	>20,000	8,123	>20,000	3,579	>20,000	2,326	>20,000	6,180	>20,000	2,742	>20,000	2,182
7,500	>20,000	5,848	>20,000	4,692	>20,000	4,565	>20,000	9,851	>20,000	4,266	>20,000	2,714	>20,000	5,819	>20,000	2,577	>20,000	2,412
8,000	>20,000	7,250	>20,000	4,762	>20,000	4,747	>20,000	9,519	>20,000	4,639	>20,000	3,482	>20,000	7,374	>20,000	2,256	>20,000	2,256
8,500	>20,000	6,268	>20,000	3,842	>20,000	3,768	>20,000	8,986	>20,000	4,787	>20,000	4,087	>20,000	9,036	>20,000	2,732	>20,000	2,684
9,000	>20,000	5,187	>20,000	3,351	>20,000	3,263	>20,000	10,263	>20,000	4,974	>20,000	4,214	>20,000	8,925	>20,000	3,348	>20,000	2,904
9,500	>20,000	4,857	>20,000	3,147	>20,000	3,065	>20,000	9,153	>20,000	4,552	>20,000	3,475	>20,000	9,394	>20,000	4,337	>20,000	3,207
10,000	>20,000	5,514	>20,000	3,992	>20,000	3,772	>20,000	8,754	>20,000	4,303	>20,000	2,591	>20,000	10,090	>20,000	4,554	>20,000	3,509
10,500	>20,000	8,244	>20,000	5,100	>20,000	4,523	>20,000	10,008	>20,000	5,131	>20,000	2,738	>20,000	9,122	>20,000	4,535	>20,000	3,805
11,000	>20,000	9,735	>20,000	5,875	>20,000	5,143	>20,000	12,903	>20,000	5,212	>20,000	5,091	>20,000	8,851	>20,000	4,932	>20,000	4,199
11,500	>20,000	9,050	>20,000	5,300	>20,000	4,536	>20,000	10,941	>20,000	4,826	>20,000	4,590	>20,000	10,174	>20,000	5,261	>20,000	4,367
12,000	>20,000	6,800	>20,000	4,318	>20,000	4,227	>20,000	12,968	>20,000	5,444	>20,000	5,188	>20,000	10,983	>20,000	4,622	>20,000	4,501
12,500	>20,000	5,854	>20,000	4,223	>20,000	4,009	>20,000	13,397	>20,000	5,736	>20,000	5,332	>20,000	13,818	>20,000	6,506	>20,000	5,614
13,000	>20,000	5,567	>20,000	4,395	>20,000	4,312	>20,000	12,972	>20,000	5,402	>20,000	5,198	>20,000	14,801	>20,000	6,558	>20,000	6,219
13,500	>20,000	5,689	>20,000	4,654	>20,000	4,467	>20,000	12,555	>20,000	6,278	>20,000	6,008	>20,000	11,572	>20,000	6,132	>20,000	5,891
14,000	>20,000	7,012	>20,000	6,096	>20,000	5,359	>20,000	11,853	>20,000	5,756	>20,000	5,348	>20,000	10,221	>20,000	6,033	>20,000	5,677
14,500	>20,000	8,689	>20,000	5,214	>20,000	5,080	>20,000	11,228	>20,000	5,366	>20,000	5,167	>20,000	9,560	>20,000	6,417	>20,000	5,899
15,000	>20,000	6,872	>20,000	5,372	>20,000	5,120	>20,000	9,472	>20,000	5,369	>20,000	5,038	>20,000	12,124	>20,000	7,067	>20,000	6,542
15,500	>20,000	7,539	>20,000	4,633	>20,000	4,487	>20,000	10,728	>20,000	5,119	>20,000	4,967	>20,000	14,879	>20,000	7,288	>20,000	6,154
16,000	>20,000	5,381	>20,000	4,293	>20,000	4,274	>20,000	13,673	>20,000	5,914	>20,000	5,739	>20,000	12,373	>20,000	6,079	>20,000	5,578
16,500	>20,000	6,935	>20,000	4,584	>20,000	4,470	>20,000	16,705	>20,000	6,383	>20,000	5,895	>20,000	10,093	>20,000	7,637	>20,000	6,673
17,000	>20,000	7,454	>20,000	4,686	>20,000	4,458	>20,000	19,614	>20,000	7,292	>20,000	6,657	>20,000	8,925	>20,000	7,429	>20,000	6,996
17,500	>20,000	11,966	>20,000	7,090	>20,000	6,090	>20,000	16,612	>20,000	6,742	>20,000	6,629	>20,000	9,676	>20,000	6,955	>20,000	6,351
18,000	>20,000	16,895	>20,000	8,070	>20,000	7,853	>20,000	17,274	>20,000	6,442	>20,000	6,040	>20,000	9,502	>20,000	6,863	>20,000	6,625
18,500	>20,000	12,999	>20,000	7,638	>20,000	7,272	>20,000	13,545	>20,000	5,598	>20,000	5,371	>20,000	10,774	>20,000	7,293	>20,000	6,714
19,000	>20,000	11,331	>20,000	6,491	>20,000	6,321	>20,000	13,205	>20,000	5,650	>20,000	5,650	>20,000	12,959	>20,000	7,498	>20,000	6,792

	Summer						Transitional						Winter					
Distance (m)	95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum
19,500	>20,000	9,513	>20,000	5,379	>20,000	4,960	>20,000	15,452	>20,000	6,640	>20,000	6,547	>20,000	13,913	>20,000	6,707	>20,000	6,342
20,000	>20,000	8,823	>20,000	5,738	>20,000	5,589	>20,000	14,091	>20,000	7,962	>20,000	7,292	>20,000	11,724	>20,000	6,888	>20,000	5,927

† This receptor is outside the model domain and predictions of dilution are unavailable at or within its boundaries. Given the high levels of dilution predicted within the extent of the model domain (20 km) in the direction of Scott Reef, and the remaining distance (~12 km) from the edge of the model domain to the receptor, it can be assumed that a minimum dilution level of >20,000 will occur at or within the receptor boundaries at all percentiles.

Table 3.66 Maximum distance from the hydrotest discharge location to achieve 1:10,000 dilution in each season for Case H3a (Brecknock/Calliance PLET 790,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Summer	23,421
	Transitional	15,474
	Winter	18,032
99th	Summer	26,400
	Transitional	22,836
	Winter	24,340
100th	Summer	26,502
	Transitional	22,923
	Winter	24,556

Table 3.67 Total area of coverage for 1:10,000 dilution in each season for Case H3a (Brecknock/Calliance PLET 790,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Summer	57.30
	Transitional	42.20
	Winter	38.30
99th	Summer	160.80
	Transitional	172.00
	Winter	175.80
100th	Summer	189.00
	Transitional	222.50
	Winter	213.60

Table 3.68 Maximum depth from the hydrotest discharge location to achieve 1:10,000 dilution in each season for Case H3a (Brecknock/Calliance PLET 790,000 m^3 hydrotest discharge).

Season	Maximum depth (m) from sea surface to achieve given dilution
Summer	539 (seabed)
Transitional	539 (seabed)
Winter	539 (seabed)

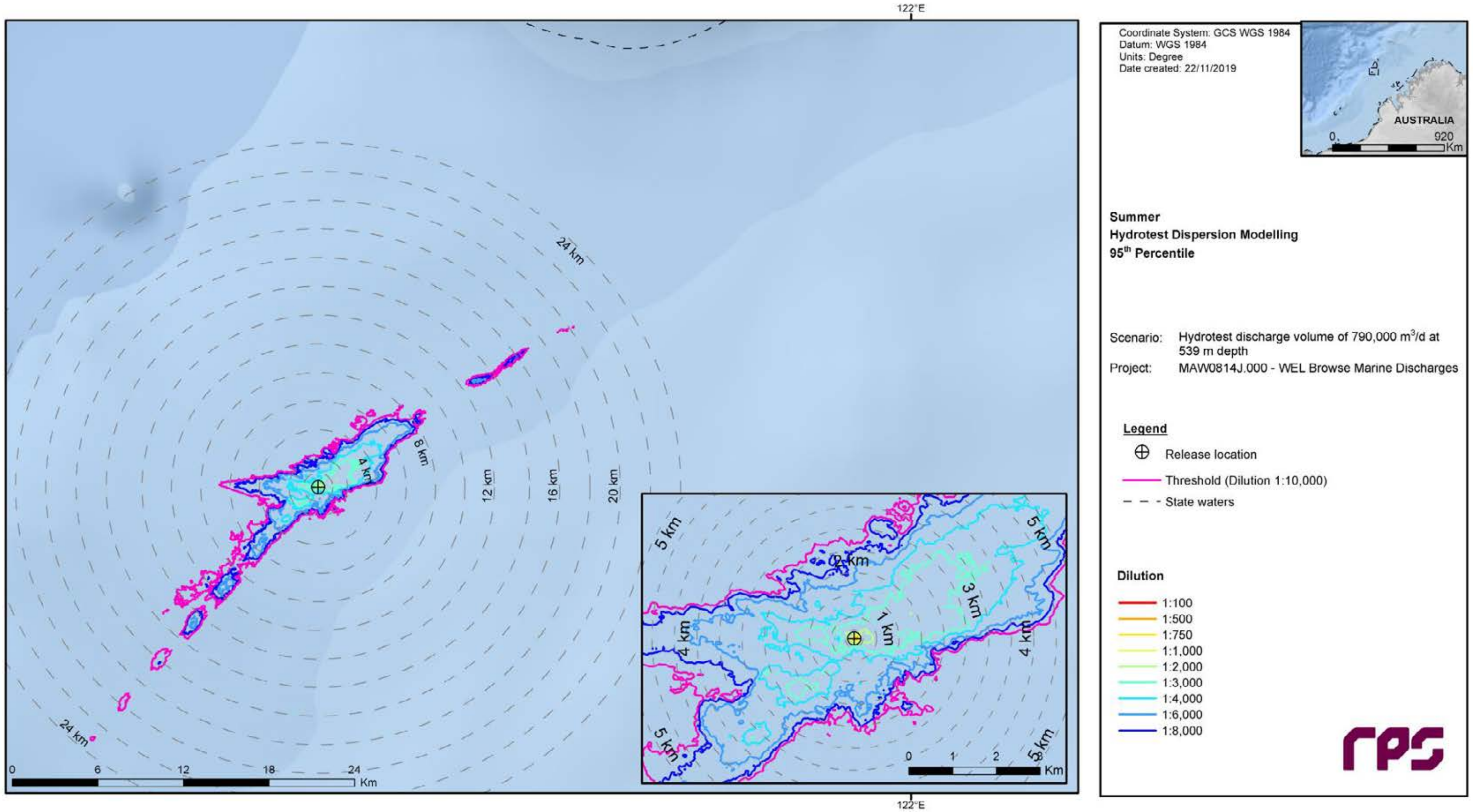


Figure 3.69 Predicted minimum dilutions at the 95th percentile under summer conditions for Case H3a (Brecknock/Calliance PLET 790,000 m^3 hydrotest discharge), with a rolling 48-hour median of the dilution data.

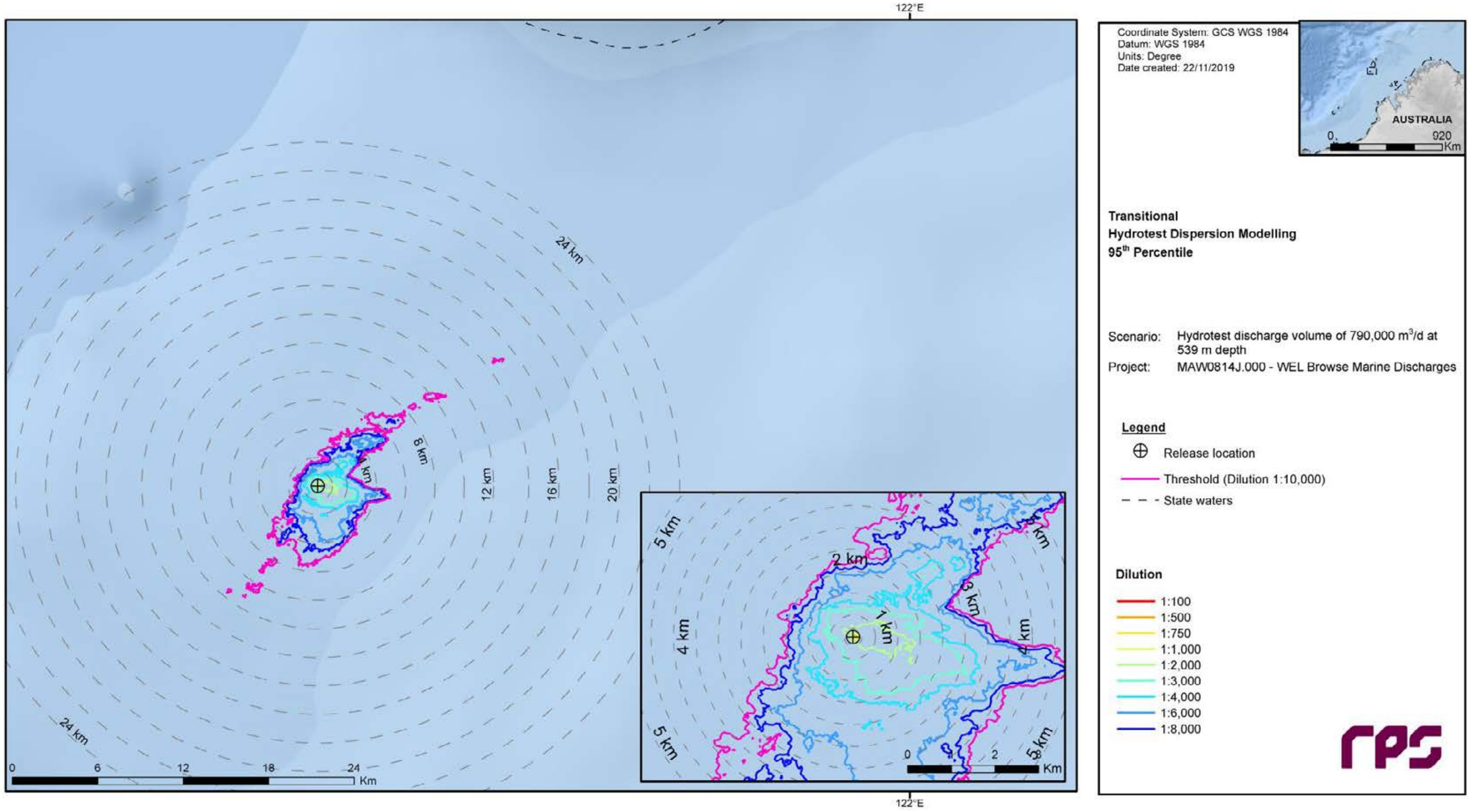


Figure 3.70 Predicted minimum dilutions at the 95th percentile under transitional conditions for Case H3a (Brecknock/Calliance PLET 790,000 m^3 hydrotest discharge), with a rolling 48-hour median of the dilution data.

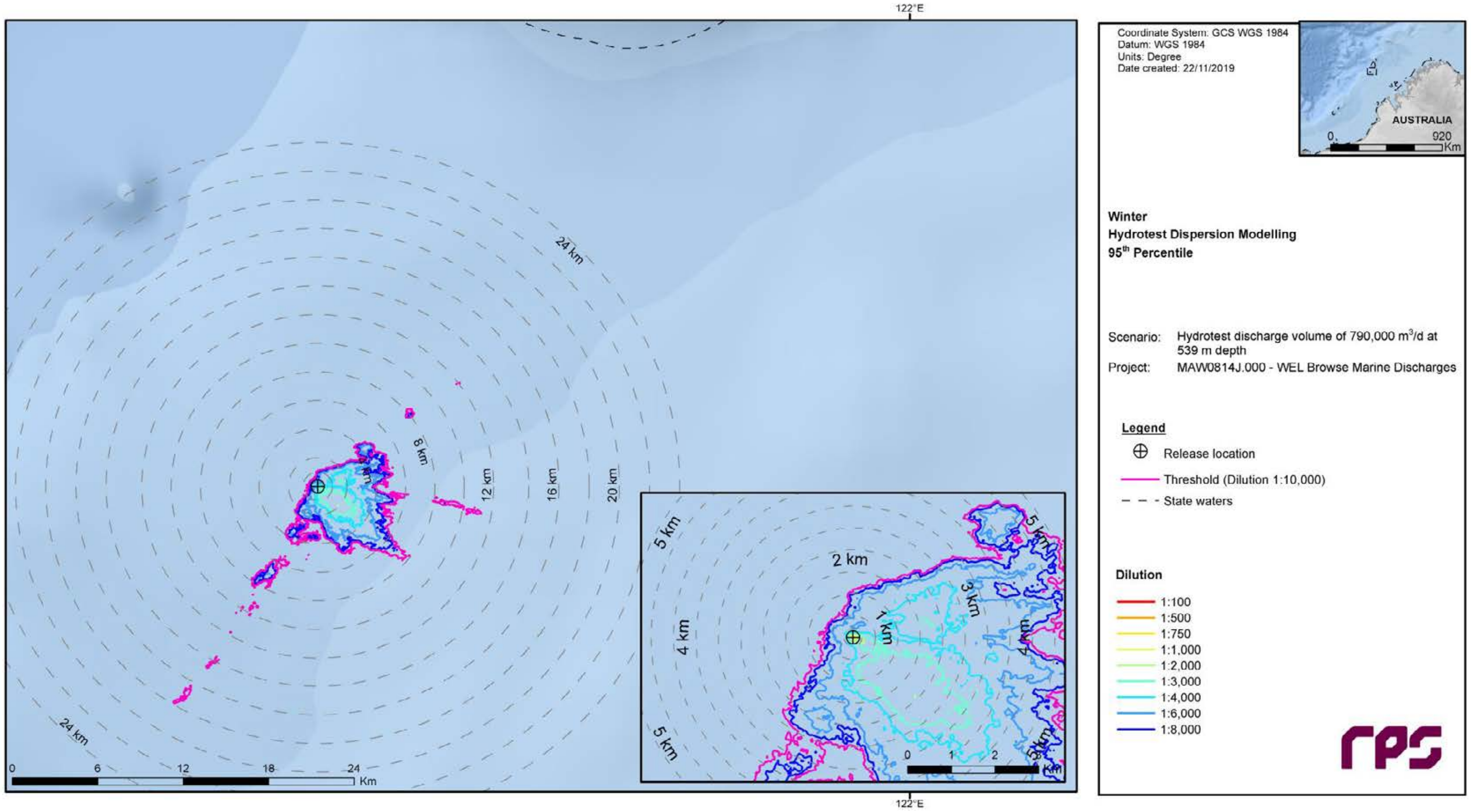


Figure 3.71 Predicted minimum dilutions at the 95th percentile under winter conditions for Case H3a (Brecknock/Calliance PLET 790,000 m^3 hydrotest discharge), with a rolling 48-hour median of the dilution data.

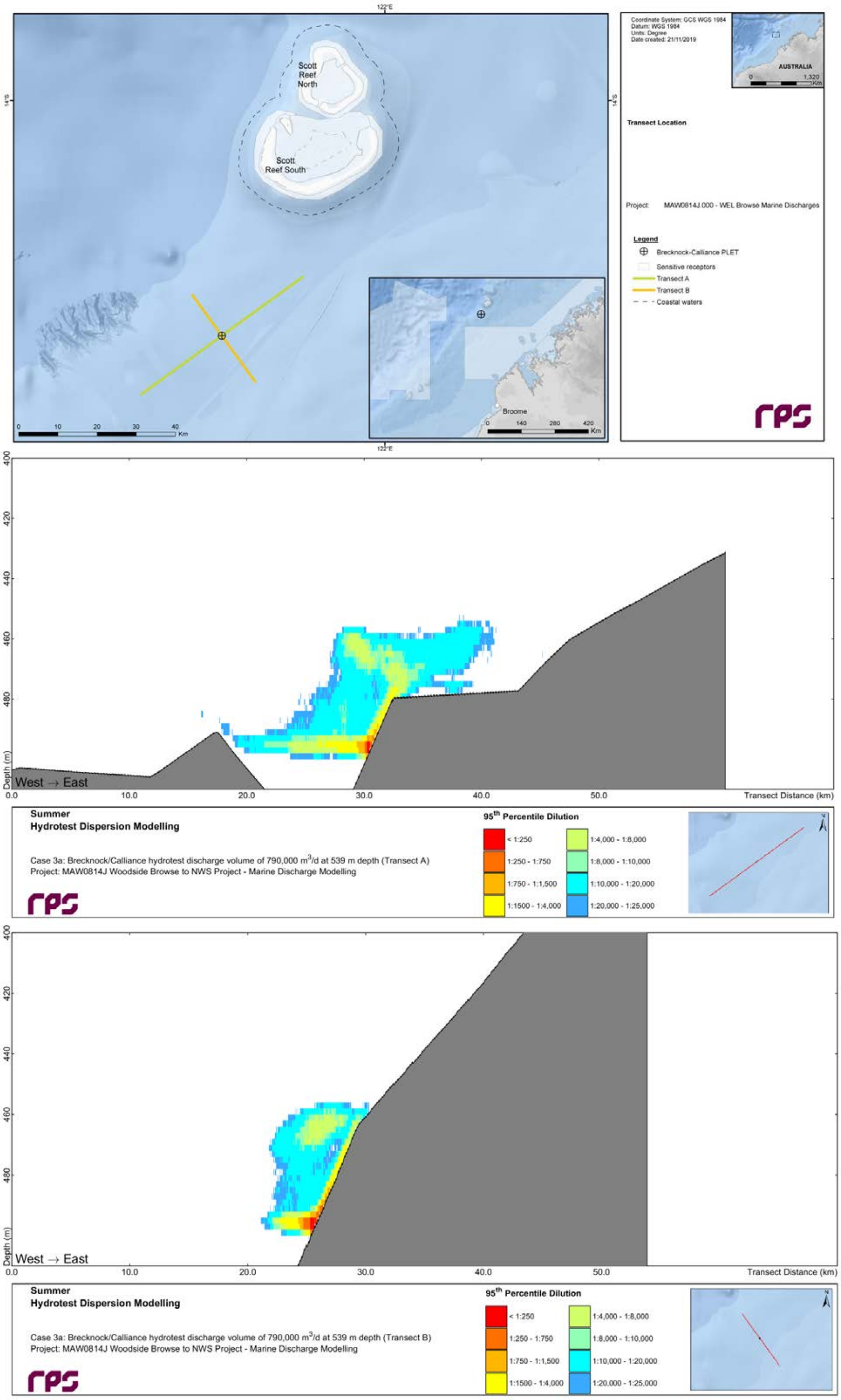


Figure 3.72 Vertical cross-section plots of predicted minimum dilutions at the 95th percentile under summer conditions for Case H3a (Brecknock/Calliance PLET 790,000 m^3 hydrotest discharge). Transect locations are shown in the top panel, with transect A shown in the middle panel and transect B shown in the bottom panel. Spatial representation of this data is shown in Figure 3.69.

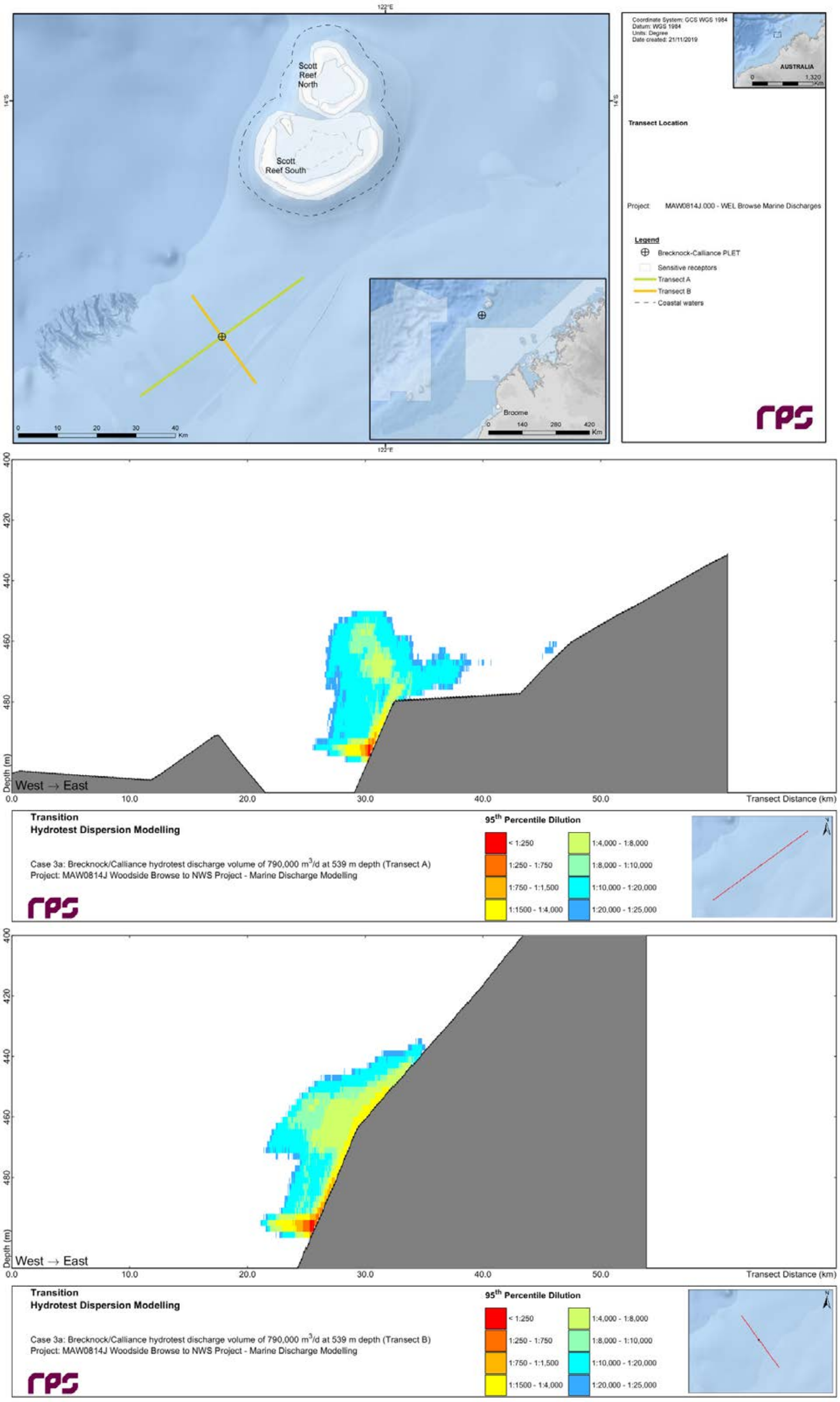


Figure 3.73 Vertical cross-section plots of predicted minimum dilutions at the 95th percentile under transitional conditions for Case H3a (Brecknock/Calliance PLET 790,000 m^3 hydrotest discharge). Transect locations are shown in the top panel, with transect A shown in the middle panel and transect B shown in the bottom panel. Spatial representation of this data is shown in Figure 3.70.

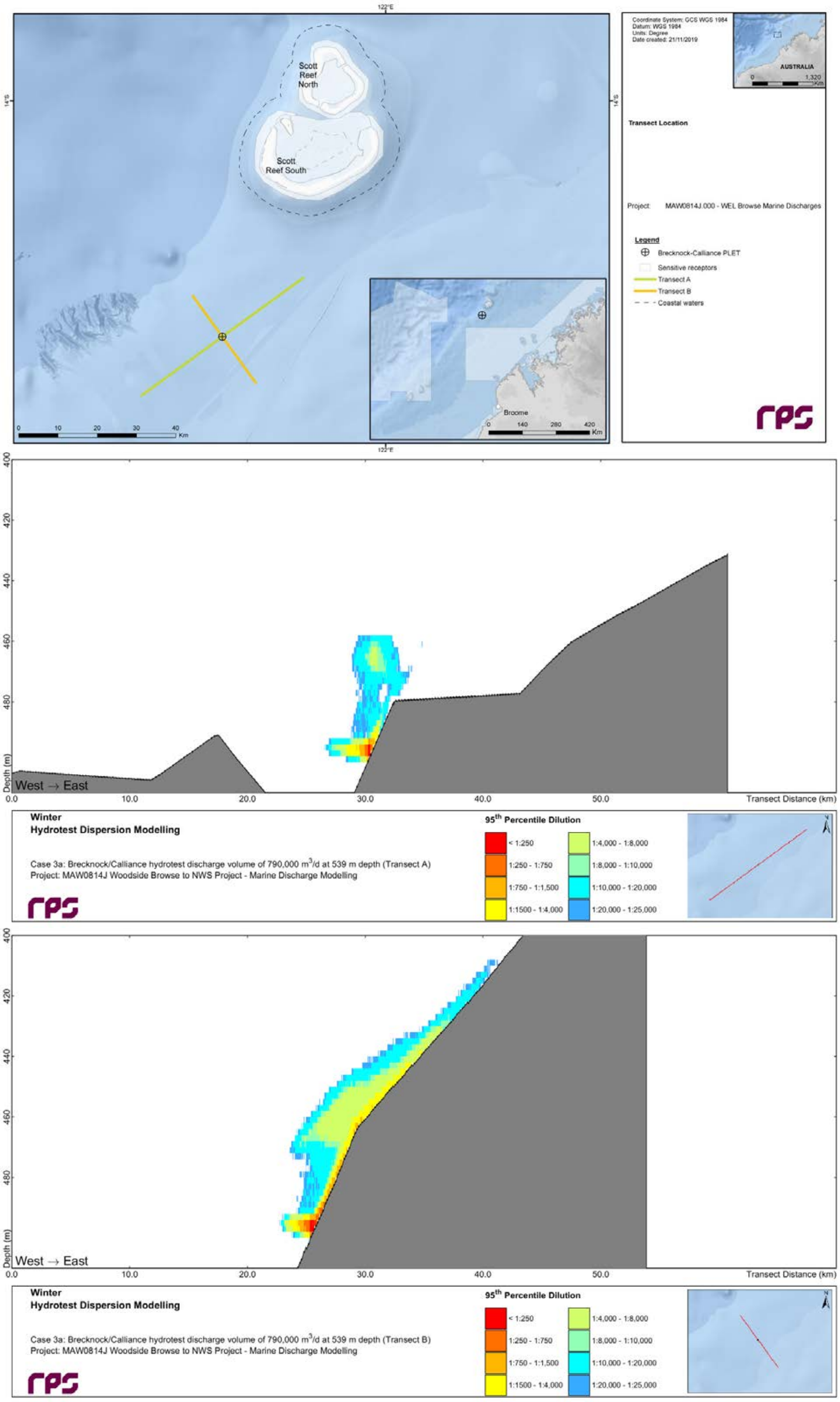


Figure 3.74 Vertical cross-section plots of predicted minimum dilutions at the 95th percentile under winter conditions for Case H3a (Brecknock/Calliance PLET 790,000 m^3 hydrotest discharge). Transect locations are shown in the top panel, with transect A shown in the middle panel and transect B shown in the bottom panel. Spatial representation of this data is shown in Figure 3.71.

3.2.5.2.5 Discharge Case H3b: Torosa PLET Hydrotest Discharge of 56,000 m^3 at 461 m Depth

Table 3.69 Average and minimum dilutions (1:x) achieved at specific radial distances from the hydrotest discharge location in each season for Case H3b (Torosa PLET 56,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.

Distance (m)	Summer						Transitional						Winter					
	95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum
Scott Reef (3 nm State Water Boundary)	>20,000	>20,000	>20,000	3,610	>20,000	3,428	>20,000	2,711	>20,000	1,531	>20,000	1,530	>20,000	10,480	>20,000	2,400	>20,000	2,326
20	1,058	1,030	273	258	149	145	1,688	1,677	1,089	980	1,089	980	779	730	608	584	590	578
50	1,039	945	277	250	160	145	1,612	1,482	1,026	859	1,026	859	746	691	619	598	594	577
100	975	766	300	241	162	131	1,568	1,264	1,055	737	1,046	737	779	663	589	488	559	485
200	972	553	347	236	188	123	1,693	868	1,174	529	1,164	517	940	642	608	374	549	348
300	907	415	325	157	187	96	1,683	626	1,161	422	1,128	367	1,015	675	574	300	507	297
400	935	337	317	115	184	76	1,923	572	1,242	340	1,201	306	1,148	593	614	302	550	302
500	1,028	234	334	104	194	64	1,859	440	1,198	274	1,157	262	1,224	570	724	294	658	291
600	1,149	164	363	76	215	53	2,240	445	1,492	326	1,443	320	1,378	517	822	317	755	315
700	1,268	226	413	96	229	65	2,533	652	1,527	272	1,474	268	1,543	685	1,014	460	937	422
800	1,318	58	416	37	223	28	2,762	346	1,742	133	1,665	87	1,709	379	1,095	208	1,023	132
900	1,600	290	480	104	260	84	3,309	663	2,092	341	1,964	330	2,061	810	1,296	475	1,260	475
1,000	1,847	228	536	109	314	61	4,258	1,048	2,198	424	2,058	289	2,440	689	1,438	512	1,408	512
1,100	2,239	284	584	133	339	78	5,666	1,376	2,269	764	2,167	641	3,461	741	1,690	504	1,656	493
1,200	2,688	403	602	148	328	91	12,214	1,282	2,291	839	2,206	689	6,846	951	1,858	579	1,808	579
1,300	3,999	477	636	179	342	82	>20,000	1,272	2,540	872	2,420	823	>20,000	749	2,346	578	2,167	578
1,400	4,980	600	651	182	354	103	>20,000	1,342	2,705	983	2,542	931	>20,000	1,004	2,725	595	2,426	585
1,500	9,013	781	709	197	378	113	>20,000	1,643	3,021	968	2,883	929	>20,000	1,078	3,618	628	2,724	618
1,600	11,297	793	738	195	385	86	>20,000	1,636	3,228	1,119	3,079	1,049	>20,000	1,168	5,316	689	3,520	672
1,700	17,879	1,228	820	209	406	96	>20,000	1,722	3,756	1,159	3,475	1,076	>20,000	1,170	7,188	747	3,684	734
1,800	>20,000	1,176	895	258	433	114	>20,000	1,659	4,671	1,101	4,011	1,023	>20,000	1,245	>20,000	783	6,682	772
1,900	>20,000	1,126	962	315	441	110	>20,000	1,499	5,411	1,206	4,286	1,167	>20,000	1,453	>20,000	878	9,002	869
2,000	>20,000	1,134	1,051	317	480	145	>20,000	1,448	7,412	1,178	5,146	1,129	>20,000	1,726	>20,000	1,280	>20,000	1,208
2,100	>20,000	1,129	1,125	427	485	129	>20,000	1,454	9,542	1,146	6,089	1,136	>20,000	1,770	>20,000	1,328	>20,000	1,279
2,200	>20,000	1,179	1,266	445	520	163	>20,000	1,439	13,951	1,217	7,948	1,129	>20,000	1,930	>20,000	1,305	>20,000	1,267
2,300	>20,000	1,269	1,339	498	542	201	>20,000	1,591	>20,000	1,126	14,396	1,126	>20,000	1,818	>20,000	1,337	>20,000	1,212
2,400	>20,000	1,295	1,547	473	580	205	>20,000	1,723	>20,000	1,221	>20,000	1,135	>20,000	2,206	>20,000	1,331	>20,000	1,298
2,500	>20,000	1,505	1,819	582	599	199	>20,000	1,547	>20,000	1,229	>20,000	913	>20,000	3,776	>20,000	1,319	>20,000	1,319
2,600	>20,000	1,479	2,053	569	655	168	>20,000	1,735	>20,000	1,156	>20,000	1,026	>20,000	3,319	>20,000	1,134	>20,000	1,134
2,700	>20,000	1,824	2,312	509	661	189	>20,000	2,012	>20,000	1,096	>20,000	1,032	>20,000	3,474	>20,000	1,209	>20,000	1,209
2,800	>20,000	1,689	2,755	589	721	199	>20,000	1,987	>20,000	1,192	>20,000	1,168	>20,000	3,643	>20,000	1,166	>20,000	1,166
2,900	>20,000	1,997	3,316	590	792	209	>20,000	2,160	>20,000	1,362	>20,000	1,297	>20,000	3,947	>20,000	1,188	>20,000	1,188
3,000	>20,000	1,746	3,579	596	871	190	>20,000	2,603	>20,000	1,294	>20,000	1,294	>20,000	3,426	>20,000	1,209	>20,000	1,209
3,100	>20,000	1,847	4,018	735	901	175	>20,000	1,996	>20,000	1,263	>20,000	1,263	>20,000	3,150	>20,000	1,444	>20,000	1,444
3,200	>20,000	1,746	4,642	631	934	168	>20,000	2,839	>20,000	1,308	>20,000	1,308	>20,000	3,147	>20,000	1,443	>20,000	1,443
3,300	>20,000	1,779	7,138	579	917	171	>20,000	1,870	>20,000	1,305	>20,000	1,305	>20,000	3,261	>20,000	1,504	>20,000	1,504
3,400	>20,000	1,725	11,699	564	946	188	>20,000	2,570	>20,000	1,300	>20,000	1,300	>20,000	3,469	>20,000	1,475	>20,000	1,475

	Summer						Transitional						Winter					
Distance (m)	95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum
3,500	>20,000	1,793	>20,000	617	1,064	201	>20,000	2,192	>20,000	1,285	>20,000	1,285	>20,000	3,148	>20,000	1,513	>20,000	1,513
3,600	>20,000	1,762	>20,000	684	1,275	217	>20,000	2,828	>20,000	1,438	>20,000	1,428	>20,000	2,681	>20,000	1,547	>20,000	1,547
3,700	>20,000	1,833	>20,000	728	1,646	230	>20,000	2,635	>20,000	1,481	>20,000	1,481	>20,000	2,572	>20,000	1,623	>20,000	1,623
3,800	>20,000	1,839	>20,000	763	>20,000	214	>20,000	3,103	>20,000	1,494	>20,000	1,494	>20,000	2,624	>20,000	1,653	>20,000	1,653
3,900	>20,000	1,822	>20,000	801	14,756	204	>20,000	3,322	>20,000	1,569	>20,000	1,569	>20,000	2,742	>20,000	1,680	>20,000	1,680
4,000	>20,000	1,712	13,226	857	>20,000	193	>20,000	3,230	>20,000	1,663	>20,000	1,663	>20,000	2,552	>20,000	1,536	>20,000	1,536
4,100	>20,000	1,793	>20,000	883	>20,000	199	>20,000	3,222	>20,000	1,603	>20,000	1,603	>20,000	2,794	>20,000	1,492	>20,000	1,492
4,200	>20,000	1,804	>20,000	887	>20,000	221	>20,000	3,016	>20,000	1,611	>20,000	1,611	>20,000	2,684	>20,000	1,526	>20,000	1,526
4,300	>20,000	1,919	>20,000	885	14,453	244	>20,000	3,621	>20,000	1,585	>20,000	1,585	>20,000	2,718	>20,000	1,291	>20,000	1,291
4,400	>20,000	2,019	>20,000	925	>20,000	263	>20,000	3,042	>20,000	1,727	>20,000	1,727	>20,000	2,769	>20,000	1,178	>20,000	1,178
4,500	>20,000	2,221	>20,000	947	>20,000	274	>20,000	4,809	>20,000	1,698	>20,000	1,698	>20,000	2,603	>20,000	1,297	>20,000	1,297
4,600	>20,000	2,263	>20,000	908	>20,000	332	>20,000	3,322	>20,000	1,753	>20,000	1,690	>20,000	2,371	>20,000	1,173	>20,000	1,173
4,700	>20,000	2,342	>20,000	943	>20,000	353	>20,000	5,107	>20,000	1,815	>20,000	1,815	>20,000	2,204	>20,000	1,135	>20,000	1,135
4,800	>20,000	2,358	>20,000	1,031	>20,000	352	>20,000	3,242	>20,000	1,783	>20,000	1,769	>20,000	2,475	>20,000	1,198	>20,000	1,192
4,900	>20,000	2,662	>20,000	945	>20,000	341	>20,000	3,829	>20,000	1,970	>20,000	1,912	>20,000	2,109	>20,000	1,315	>20,000	1,298
5,000	>20,000	2,563	>20,000	991	>20,000	340	>20,000	3,450	>20,000	2,034	>20,000	1,988	>20,000	1,840	>20,000	1,324	>20,000	1,290
5,500	>20,000	3,487	>20,000	1,361	>20,000	403	>20,000	2,919	>20,000	2,351	>20,000	2,351	>20,000	2,365	>20,000	1,253	>20,000	1,246
6,000	>20,000	3,776	>20,000	1,337	>20,000	448	>20,000	3,386	>20,000	1,962	>20,000	1,962	>20,000	6,688	>20,000	1,689	>20,000	1,644
6,500	>20,000	5,042	>20,000	1,547	>20,000	459	>20,000	3,423	>20,000	2,371	>20,000	2,371	>20,000	9,115	>20,000	1,612	>20,000	1,461
7,000	>20,000	7,561	>20,000	1,611	>20,000	483	>20,000	6,039	>20,000	3,549	>20,000	3,113	>20,000	10,226	>20,000	1,542	>20,000	1,458
7,500	>20,000	8,350	>20,000	2,002	>20,000	507	>20,000	4,503	>20,000	3,390	>20,000	3,390	>20,000	15,276	>20,000	1,801	>20,000	1,513
8,000	>20,000	14,430	>20,000	2,032	>20,000	563	>20,000	7,494	>20,000	3,847	>20,000	3,847	>20,000	>20,000	>20,000	3,542	>20,000	2,187
8,500	>20,000	>20,000	>20,000	2,236	>20,000	568	>20,000	13,983	>20,000	3,068	>20,000	3,068	>20,000	>20,000	>20,000	6,469	>20,000	5,723
9,000	>20,000	>20,000	>20,000	2,757	>20,000	830	>20,000	>20,000	>20,000	4,611	>20,000	3,839	>20,000	>20,000	>20,000	8,769	>20,000	7,591
9,500	>20,000	>20,000	>20,000	2,741	>20,000	763	>20,000	>20,000	>20,000	5,610	>20,000	5,111	>20,000	>20,000	>20,000	10,876	>20,000	9,512
10,000	>20,000	>20,000	>20,000	2,519	>20,000	649	>20,000	>20,000	>20,000	6,567	>20,000	5,777	>20,000	>20,000	>20,000	9,320	>20,000	7,556
10,500	>20,000	>20,000	>20,000	1,938	>20,000	672	>20,000	>20,000	>20,000	6,425	>20,000	6,425	>20,000	>20,000	>20,000	9,876	>20,000	6,540
11,000	>20,000	>20,000	>20,000	2,234	>20,000	689	>20,000	>20,000	>20,000	5,956	>20,000	5,956	>20,000	>20,000	>20,000	10,693	>20,000	5,653
11,500	>20,000	>20,000	>20,000	2,907	>20,000	770	>20,000	>20,000	>20,000	8,539	>20,000	8,539	>20,000	>20,000	>20,000	16,627	>20,000	8,898
12,000	>20,000	>20,000	>20,000	4,288	>20,000	802	>20,000	>20,000	>20,000	13,055	>20,000	11,702	>20,000	>20,000	>20,000	>20,000	>20,000	11,939
12,500	>20,000	>20,000	>20,000	3,636	>20,000	875	>20,000	>20,000	>20,000	17,960	>20,000	17,960	>20,000	>20,000	>20,000	>20,000	>20,000	18,065
13,000	>20,000	>20,000	>20,000	3,075	>20,000	1,080	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
13,500	>20,000	>20,000	>20,000	3,342	>20,000	942	>20,000	>20,000	>20,000	>20,000	>20,000	14,415	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
14,000	>20,000	>20,000	>20,000	3,301	>20,000	1,381	>20,000	>20,000	>20,000	>20,000	>20,000	12,962	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
14,500	>20,000	>20,000	>20,000	3,650	>20,000	1,641	>20,000	>20,000	>20,000	>20,000	>20,000	18,419	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
15,000	>20,000	>20,000	>20,000	5,180	>20,000	1,486	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
15,500	>20,000	>20,000	>20,000	5,433	>20,000	1,727	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
16,000	>20,000	>20,000	>20,000	5,818	>20,000	1,605	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
16,500	>20,000	>20,000	>20,000	4,291	>20,000	1,299	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
17,000	>20,000	>20,000	>20,000	4,952	>20,000	1,539	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
17,500	>20,000	>20,000	>20,000	8,096	>20,000	1,557	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
18,000	>20,000	>20,000	>20,000	11,854	>20,000	1,710	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
18,500	>20,000	>20,000	>20,000	14,403	>20,000	2,416	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
19,000	>20,000	>20,000	>20,000	15,606	>20,000	2,273	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000

Distance (m)	Summer						Transitional						Winter					
	95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile		95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum
19,500	>20,000	>20,000	>20,000	15,981	>20,000	2,249	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
20,000	>20,000	>20,000	>20,000	>20,000	>20,000	2,213	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000

Table 3.70 **Maximum distance from the hydrotest discharge location to achieve 1:10,000 dilution in each season for Case H3b (Torosa PLET 56,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.**

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Summer	7,822
	Transitional	8,230
	Winter	7,303
99th	Summer	13,845
	Transitional	11,639
	Winter	10,492
100th	Summer	13,845
	Transitional	11,639
	Winter	11,570

Table 3.71 **Total area of coverage for 1:10,000 dilution in each season for Case H3b (Torosa PLET 56,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.**

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Summer	19.79
	Transitional	22.16
	Winter	18.24
99th	Summer	46.39
	Transitional	57.31
	Winter	40.47
100th	Summer	54.24
	Transitional	63.87
	Winter	45.76

Table 3.72 **Maximum depth from the hydrotest discharge location to achieve 1:10,000 dilution in each season for Case H3b (Torosa PLET 56,000 m^3 hydrotest discharge).**

Season	Maximum depth (m) from sea surface to achieve given dilution
Summer	461 (seabed)
Transitional	461 (seabed)
Winter	461 (seabed)

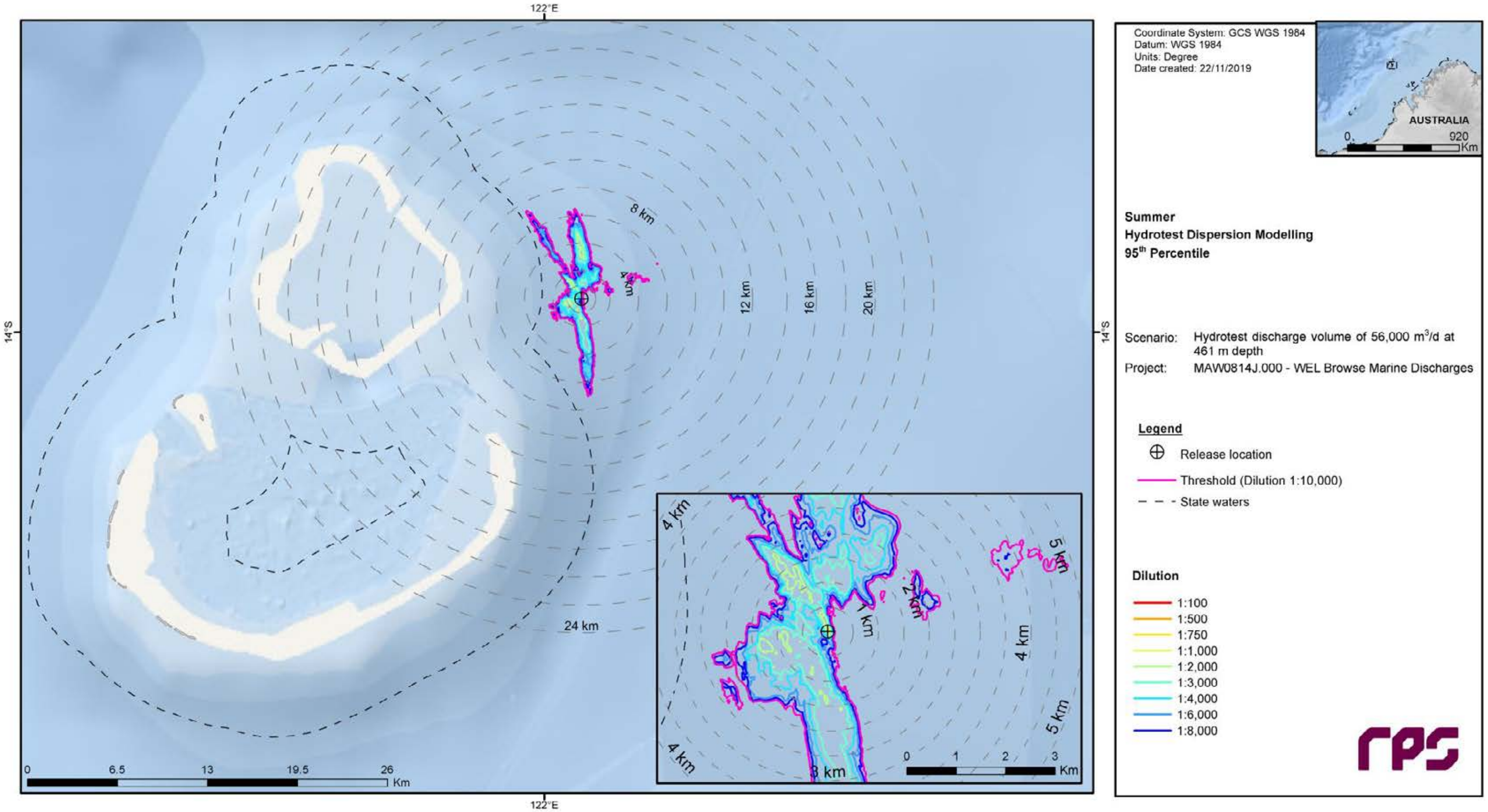


Figure 3.75 Predicted minimum dilutions at the 95th percentile under summer conditions for Case H3b (Torosa PLET 56,000 m^3 hydrotest discharge), with a rolling 48-hour median of the dilution data.

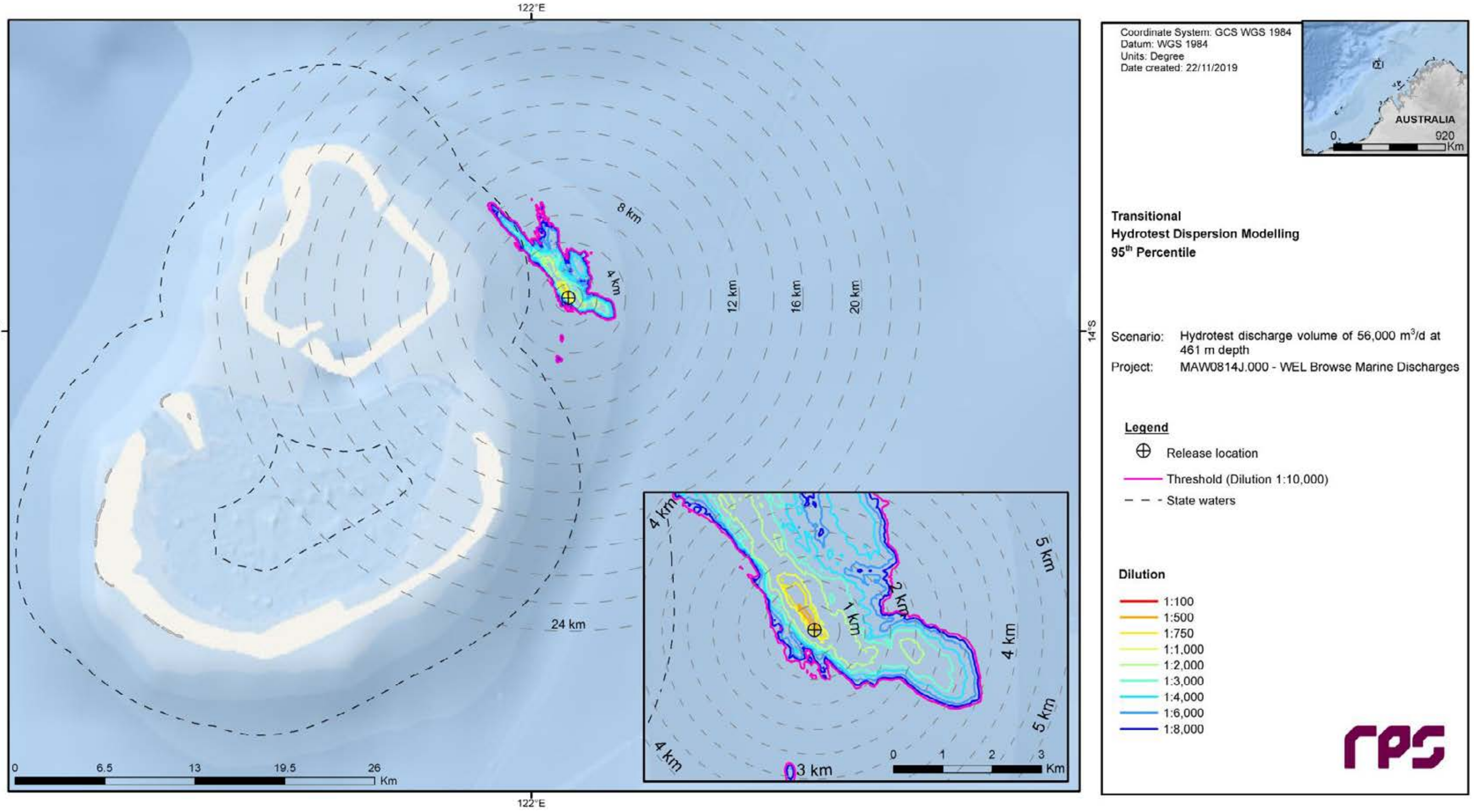


Figure 3.76 Predicted minimum dilutions at the 95th percentile under transitional conditions for Case H3b (Torosa PLET 56,000 m^3 hydrotest discharge), with a rolling 48-hour median of the dilution data.

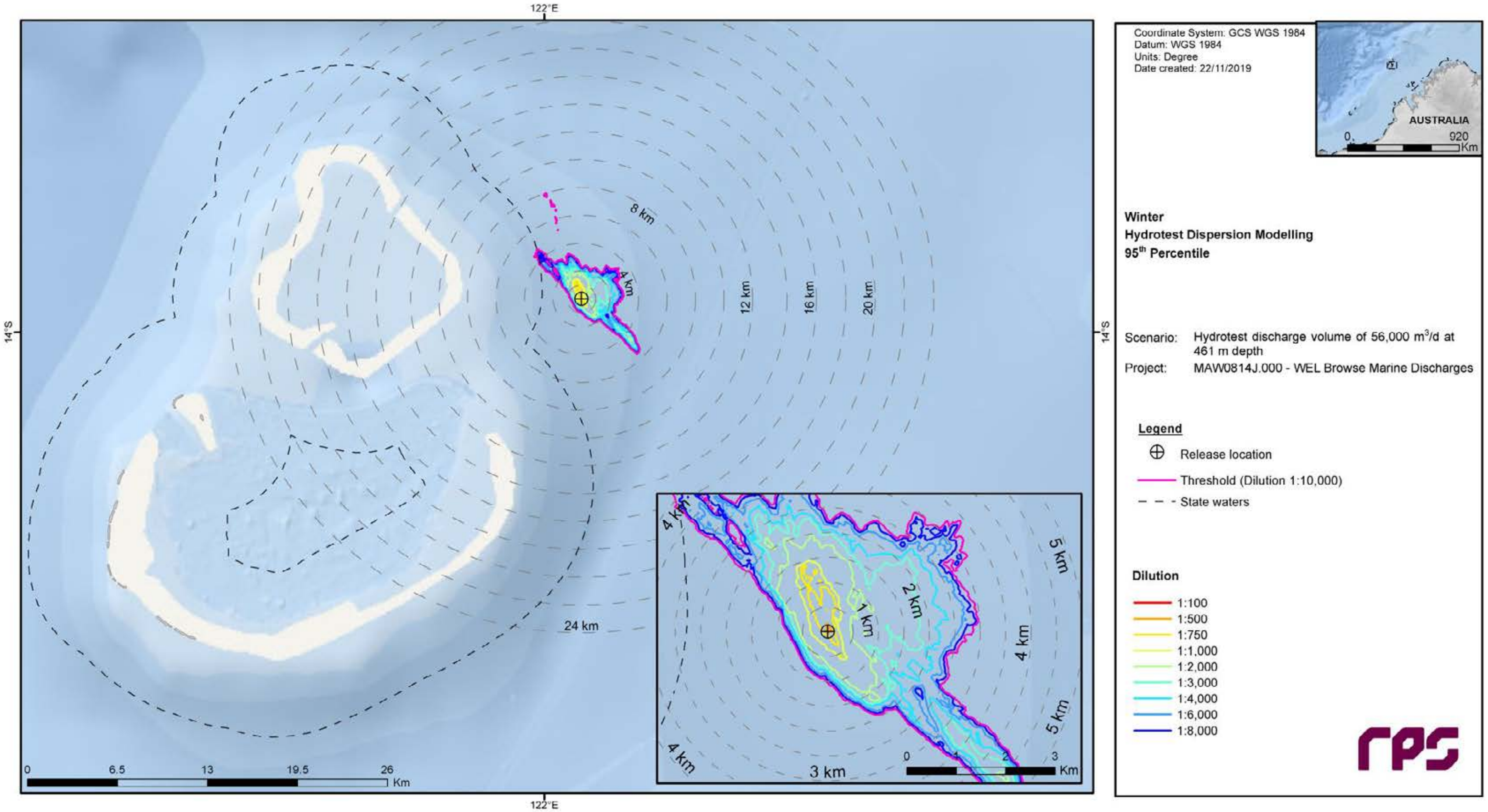


Figure 3.77 Predicted minimum dilutions at the 95th percentile under winter conditions for Case H3b (Torosa PLET 56,000 m^3 hydrotest discharge), with a rolling 48-hour median of the dilution data.

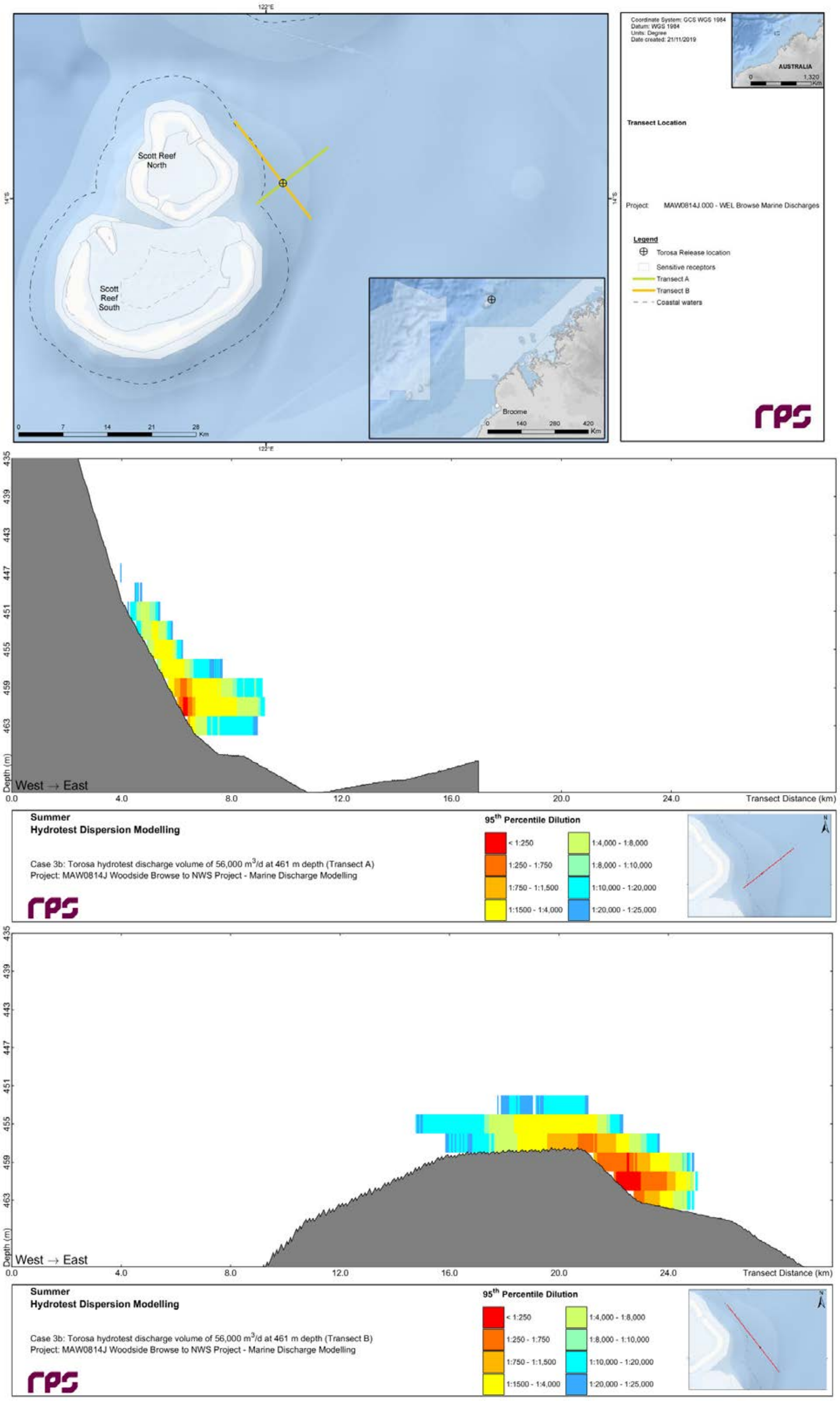


Figure 3.78 Vertical cross-section plots of predicted minimum dilutions at the 95th percentile under summer conditions for Case H3b (Torosa PLET 56,000 m^3 hydrotest discharge). Transect locations are shown in the top panel, with transect A shown in the middle panel and transect B shown in the bottom panel. Spatial representation of this data is shown in Figure 3.75.

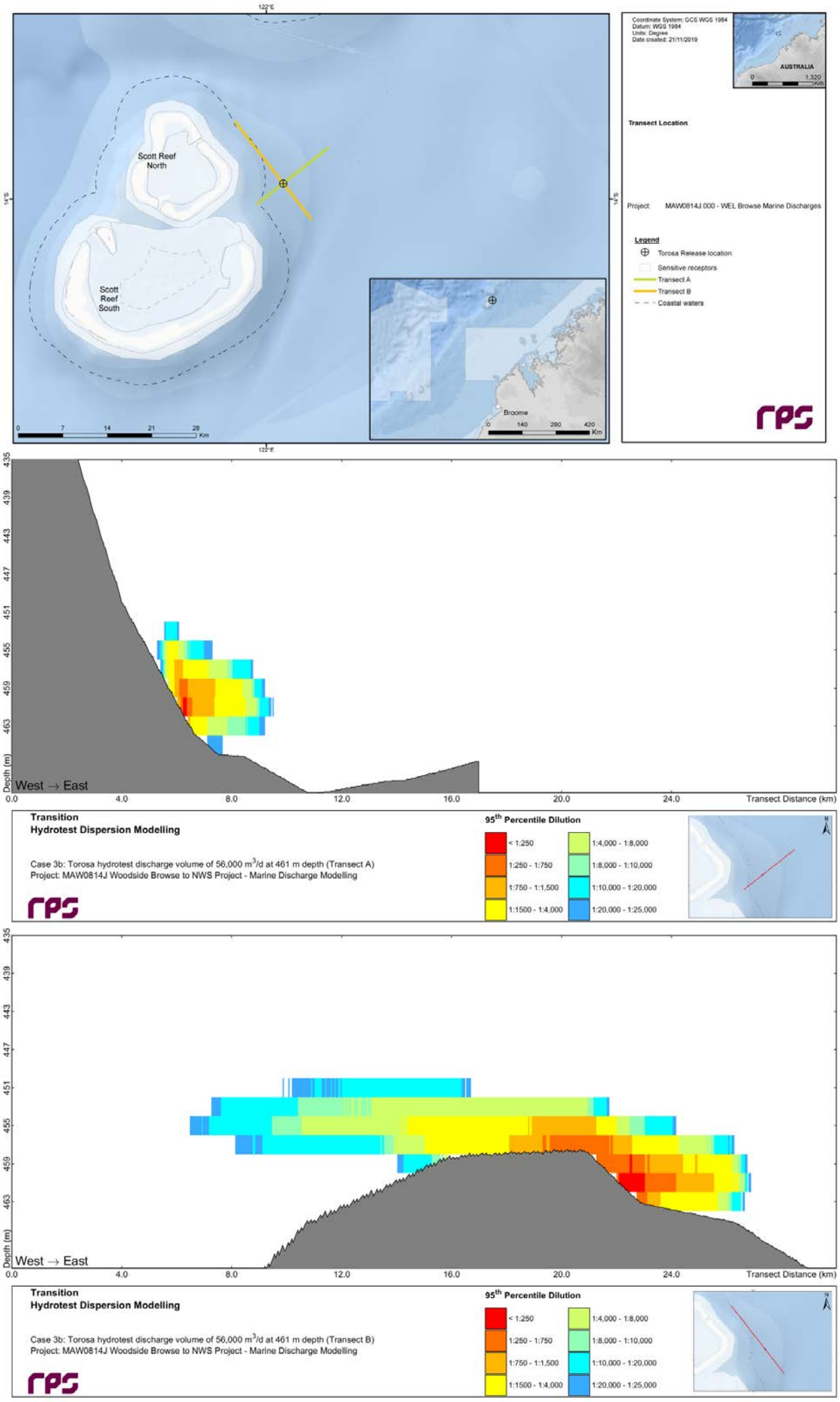


Figure 3.79 Vertical cross-section plots of predicted minimum dilutions at the 95th percentile under transitional conditions for Case H3b (Torosa PLET 56,000 m^3 hydrotest discharge). Transect locations are shown in the top panel, with transect A shown in the middle panel and transect B shown in the bottom panel. Spatial representation of this data is shown in Figure 3.76.

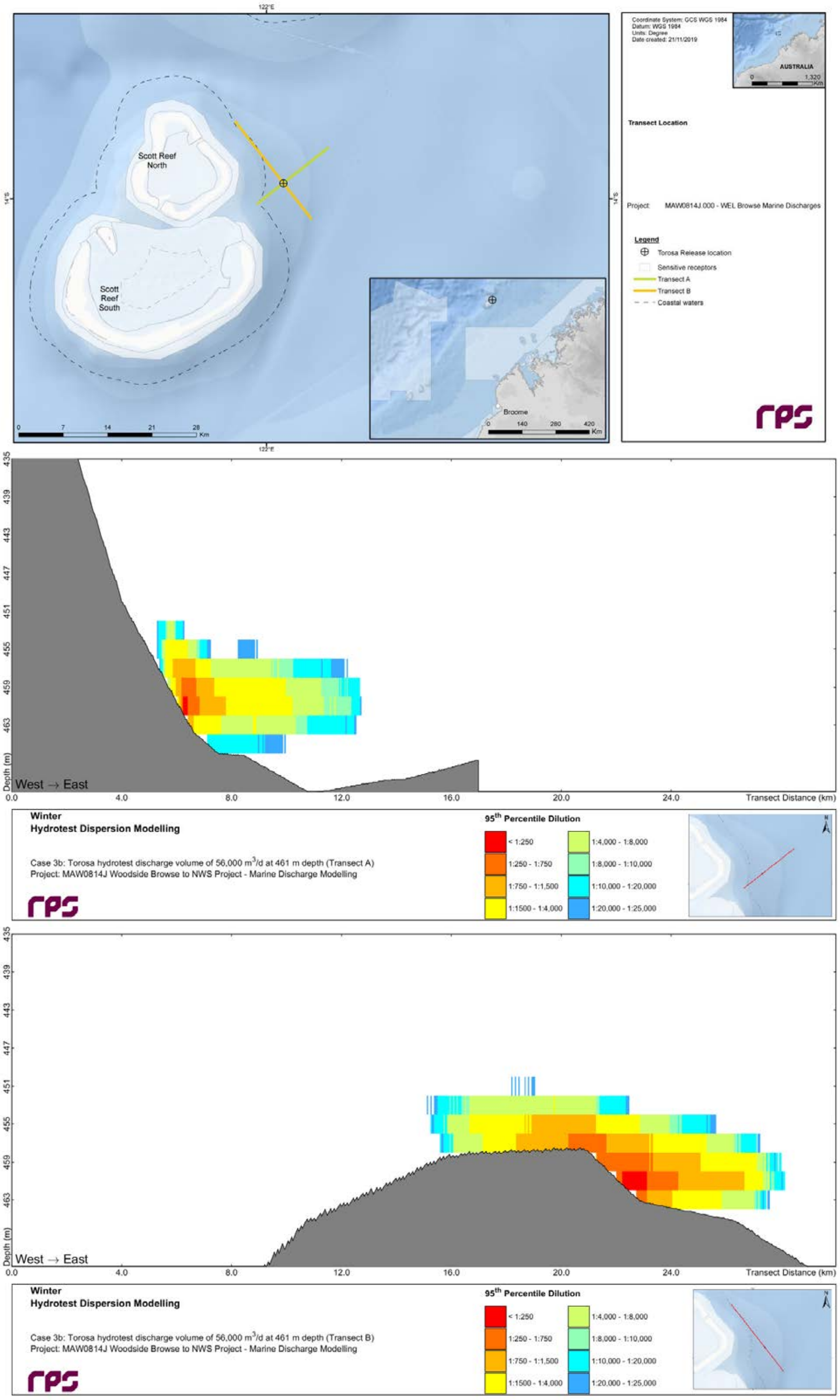


Figure 3.80 Vertical cross-section plots of predicted minimum dilutions at the 95th percentile under winter conditions for Case H3b (Torosa PLET 56,000 m^3 hydrotest discharge). Transect locations are shown in the top panel, with transect A shown in the middle panel and transect B shown in the bottom panel. Spatial representation of this data is shown in Figure 3.77.

3.2.5.3 Annualised Analysis

3.2.5.3.1 Summary

The model outputs for each season (summer, transitional and winter) over the ten-year hindcast period (2006-2015) were combined and analysed on an annualised basis.

Table 3.73, Table 3.76, Table 3.79 and Table 3.82 summarise, for Cases H1, H2, H3a and H3b respectively, the average and minimum dilution achieved at specific radial distances from the discharge location – as well as at or within the boundary of the nearest sensitive receptor – for each percentile over the annual period, with the application of a rolling 48-hour median to the data. The discharge location for Case H1 is distant from Scott Reef and the nearest receptor is Rankin Bank, while for Cases H2, H3a and H3b the nearest receptor is Scott Reef (defined by the 3 nm State water boundary).

The minimum levels of dilution achieved at or within the Scott Reef receptor at the 95th percentile in any season are predicted to be 1:4,440 for Case H2 and 1:2,711 for Case H3b. For Cases H1 and H3a, the discharge locations are sufficiently distant from the nearest receptors – Rankin Bank and Scott Reef, respectively – that the model domains could not encompass the receptors. The expected number of dilutions at the receptors has been inferred from the outcomes at the limits of the model domains. The minimum levels of dilution achieved at the 95th percentile in any season are predicted to be in excess of 1:20,000 at Scott Reef in Case H3a and significantly in excess of 1:20,000 at Rankin Bank in Case H1.

Table 3.74, Table 3.77, Table 3.80 and Table 3.83 provide, for Cases H1, H2, H3a and H3b respectively, summaries of the annualised maximum distances from the discharge location to achieve an example dilution level of 1:10,000 for each percentile. The results indicate that the release of effluent under all seasonal conditions results in slow dispersion within the ambient environment. Dilution to reach the 1:10,000 level at the 95th percentile – this being the maximum spatial extent of the relevant dilution contour from the discharge location in any season – is achieved within a maximum area of influence of: 16.1 km (Case H1), with the maximum extent found to the south-west (Figure 3.81); 12.5 km (Case H2), with the maximum extent found to the north-west (Figure 3.82); 23.4 km (Case H3a), with the maximum extent found to the south-west (Figure 3.83); and 8.2 km (Case H3b), with the maximum extent found to the north-west (Figure 3.84).

Table 3.75, Table 3.78, Table 3.81 and Table 3.84 provide, for Cases H1, H2, H3a and H3b respectively, summaries of the annualised total areas of coverage for the 1:10,000 dilution contour for each percentile. The area of exposure defined by the relevant dilution contour, at the 95th percentile across all seasons, is predicted to reach maximum values of 79.2 km^2 (Case H1), 87.1 km^2 (Case H2), 89.4 km^2 (Case H3a) and 40.8 km^2 (Case H3b).

For Cases H1, H2, H3a and H3b, the aggregated spatial extents of the minimum dilutions at the 95th percentile are presented in Figure 3.81, Figure 3.82, Figure 3.83 and Figure 3.84, respectively. Note that the contours represent the lowest predicted dilution (highest concentration) at any given time step through the water column and do not consider frequency or duration.

The results presented assume that no processes other than dilution would reduce the source concentrations over time, and therefore can be considered as conservative outcomes.

3.2.5.3.2 Discharge Case H1: NRC Tie-In PLET Hydrotest Discharge of 736,000 m^3 at 117 m Depth

Table 3.73 Annualised average and minimum dilutions (1:x) achieved at specific radial distances from the hydrotest discharge location for Case H1 (NRC tie-in PLET 736,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.

Distance (m)	95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum
Rankin Bank †	>>20,000	>>20,000	>>20,000	>>20,000	>>20,000	>>20,000
20	553	230	235	172	230	163
50	392	183	168	115	149	109
100	1,301	499	576	300	482	297
200	2,189	1,108	906	644	783	510
300	2,950	1,447	1,147	684	982	624
400	3,268	1,605	1,407	697	1,138	680
500	3,634	1,845	1,480	791	1,334	699
600	3,212	1,956	1,624	904	1,448	801
700	3,546	1,927	1,689	1,067	1,558	984
800	3,361	2,074	1,891	1,071	1,709	1,063
900	3,599	2,040	1,909	1,258	1,753	998
1,000	3,505	1,941	1,986	1,359	1,787	989
1,100	3,640	2,170	2,013	1,298	1,847	1,184
1,200	3,861	2,284	2,148	1,400	1,931	1,338
1,300	3,825	2,002	2,245	1,254	1,974	1,243
1,400	4,133	2,000	2,405	1,265	2,084	1,159
1,500	4,181	2,049	2,477	1,236	2,204	1,143
1,600	4,410	1,783	2,525	1,315	2,235	1,280
1,700	4,553	1,912	2,664	1,306	2,332	1,259
1,800	5,002	1,851	2,787	1,313	2,429	1,224
1,900	5,725	2,119	2,814	1,248	2,534	1,224
2,000	6,422	2,068	2,828	1,370	2,581	1,281
2,100	8,673	2,200	3,015	1,347	2,723	1,323
2,200	9,836	2,106	3,230	1,230	2,959	1,230
2,300	13,270	2,362	3,387	1,273	3,022	1,243
2,400	11,465	2,259	3,618	1,301	3,230	1,301
2,500	14,318	2,326	3,756	1,356	3,431	1,324
2,600	12,872	2,407	4,124	1,543	3,713	1,356
2,700	19,660	2,485	4,473	1,574	4,048	1,433
2,800	>20,000	2,762	4,885	1,586	4,346	1,515
2,900	>20,000	2,806	5,790	1,692	5,078	1,508
3,000	>20,000	2,974	6,425	1,807	5,607	1,596
3,100	>20,000	3,048	8,928	1,914	7,533	1,675
3,200	>20,000	3,205	11,514	1,713	9,239	1,588
3,300	>20,000	2,775	12,956	1,524	10,400	1,406
3,400	>20,000	3,156	15,831	1,459	11,688	1,378

Distance (m)	95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum
3,500	>20,000	3,299	17,820	1,717	11,929	1,537
3,600	>20,000	3,126	>20,000	1,897	13,100	1,540
3,700	>20,000	3,196	>20,000	1,892	12,950	1,592
3,800	>20,000	3,389	>20,000	1,895	18,687	1,750
3,900	>20,000	3,301	>20,000	1,966	14,990	1,782
4,000	>20,000	3,011	>20,000	1,855	17,570	1,828
4,100	>20,000	3,353	>20,000	1,712	>20,000	1,712
4,200	>20,000	3,288	>20,000	1,745	>20,000	1,745
4,300	>20,000	3,045	>20,000	1,751	>20,000	1,739
4,400	>20,000	3,134	>20,000	1,857	>20,000	1,823
4,500	>20,000	3,362	>20,000	1,941	>20,000	1,887
4,600	>20,000	3,214	>20,000	1,952	>20,000	1,919
4,700	>20,000	3,567	>20,000	2,105	>20,000	2,087
4,800	>20,000	3,655	>20,000	2,208	>20,000	2,208
4,900	>20,000	4,243	>20,000	2,105	>20,000	1,977
5,000	>20,000	4,165	>20,000	2,239	>20,000	2,147
5,500	>20,000	4,347	>20,000	3,192	>20,000	2,966
6,000	>20,000	4,568	>20,000	3,145	>20,000	2,925
6,500	>20,000	5,131	>20,000	3,254	>20,000	3,154
7,000	>20,000	5,251	>20,000	3,341	>20,000	3,288
7,500	>20,000	5,634	>20,000	2,761	>20,000	2,744
8,000	>20,000	5,963	>20,000	2,733	>20,000	2,733
8,500	>20,000	5,565	>20,000	2,884	>20,000	2,855
9,000	>20,000	6,359	>20,000	3,302	>20,000	3,139
9,500	>20,000	7,226	>20,000	3,632	>20,000	3,354
10,000	>20,000	7,581	>20,000	4,339	>20,000	3,937
10,500	>20,000	7,442	>20,000	4,364	>20,000	4,333
11,000	>20,000	8,052	>20,000	4,673	>20,000	4,435
11,500	>20,000	9,539	>20,000	4,513	>20,000	4,198
12,000	>20,000	8,899	>20,000	5,294	>20,000	4,619
12,500	>20,000	9,118	>20,000	5,135	>20,000	5,135
13,000	>20,000	9,205	>20,000	5,283	>20,000	5,154
13,500	>20,000	8,498	>20,000	5,203	>20,000	5,054
14,000	>20,000	9,434	>20,000	5,569	>20,000	5,557
14,500	>20,000	10,651	>20,000	6,548	>20,000	6,548
15,000	>20,000	9,083	>20,000	5,776	>20,000	5,158
15,500	>20,000	8,200	>20,000	6,099	>20,000	5,644
16,000	>20,000	10,216	>20,000	6,871	>20,000	6,393
16,500	>20,000	11,229	>20,000	7,298	>20,000	6,337
17,000	>20,000	12,207	>20,000	5,353	>20,000	5,067
17,500	>20,000	12,542	>20,000	6,492	>20,000	5,554
18,000	>20,000	14,165	>20,000	7,919	>20,000	7,443
18,500	>20,000	13,062	>20,000	7,783	>20,000	6,989
19,000	>20,000	14,856	>20,000	7,712	>20,000	7,413

Distance (m)	95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum
19,500	>20,000	14,621	>20,000	8,526	>20,000	7,629
20,000	>20,000	15,117	>20,000	8,581	>20,000	7,833

† This receptor is outside the model domain and predictions of dilution are unavailable at or within its boundaries. Given the high levels of dilution predicted within the extent of the model domain (20 km) in the direction of Rankin Bank, and the remaining distance (~40 km) from the edge of the model domain to the receptor, it can be assumed that a minimum dilution level of >>20,000 will occur at or within the receptor boundaries at all percentiles.

Table 3.74 Annualised maximum distance from the hydrotest discharge location to achieve 1:10,000 dilution for Case H1 (NRC tie-in PLET 736,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Annual	16,137
99th		22,551
100th		22,925

Table 3.75 Annualised total area of coverage for 1:10,000 dilution for Case H1 (NRC tie-in PLET 736,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Annual	79.20
99th		217.20
100th		270.40

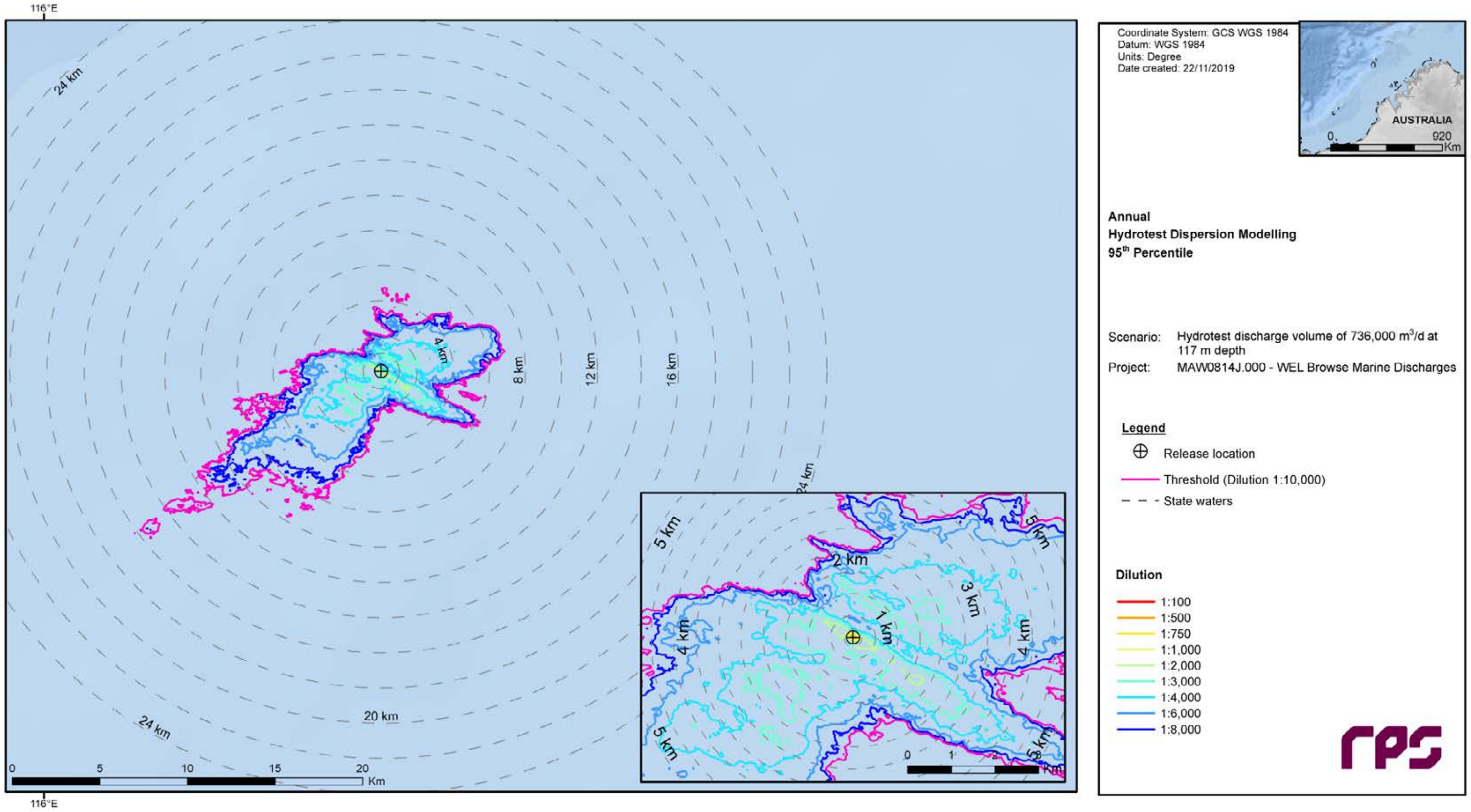


Figure 3.81 Predicted annualised minimum dilutions at the 95th percentile for Case H1 (NRC tie-in PLET 736,000 m^3 hydrotest discharge), with a rolling 48-hour median of the dilution data.

3.2.5.3.3 Discharge Case H2: Torosa PLET Hydrotest Discharge of 846,000 m^3 at 461 m Depth

Table 3.76 Annualised average and minimum dilutions (1:x) achieved at specific radial distances from the hydrotest discharge location for Case H2 (Torosa PLET 846,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.

Distance (m)	95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum
Scott Reef (3 nm State Water Boundary)	>20,000	4,440	>20,000	1,805	>20,000	1,633
20	785	743	573	546	545	523
50	753	626	556	516	527	491
100	723	560	549	458	514	426
200	806	433	571	322	512	297
300	839	382	559	253	511	245
400	855	388	600	262	522	243
500	933	364	641	239	539	230
600	1,032	271	715	232	605	205
700	1,168	299	789	236	679	230
800	1,150	91	845	74	715	69
900	1,245	441	956	341	848	295
1,000	1,269	292	989	250	868	238
1,100	1,382	340	1,045	293	942	280
1,200	1,420	410	1,061	275	962	264
1,300	1,648	385	1,142	322	1,059	310
1,400	1,685	466	1,156	274	1,076	272
1,500	2,275	505	1,298	288	1,222	274
1,600	2,267	484	1,265	317	1,162	310
1,700	3,340	503	1,397	333	1,277	309
1,800	3,121	536	1,448	341	1,337	336
1,900	4,959	561	1,599	334	1,443	326
2,000	3,952	619	1,581	358	1,478	348
2,100	5,589	654	1,716	369	1,561	366
2,200	5,267	701	1,691	391	1,549	391
2,300	8,435	734	1,827	422	1,660	422
2,400	6,670	764	1,830	443	1,689	440
2,500	10,251	811	1,959	490	1,821	484
2,600	9,727	838	2,046	478	1,891	470
2,700	14,682	827	2,189	517	2,030	508
2,800	14,079	801	2,276	495	2,052	495
2,900	>20,000	825	2,561	592	2,271	592
3,000	>20,000	827	2,748	610	2,380	610
3,100	>20,000	877	2,901	667	2,566	653
3,200	>20,000	898	3,010	676	2,644	661
3,300	>20,000	919	3,388	680	2,903	651
3,400	>20,000	936	3,445	723	2,952	670

Distance (m)	95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum
3,500	>20,000	961	3,620	749	3,177	726
3,600	>20,000	973	3,771	769	3,285	744
3,700	>20,000	971	3,994	844	3,488	815
3,800	>20,000	1,035	4,081	882	3,484	833
3,900	>20,000	1,095	4,603	883	3,968	834
4,000	>20,000	1,092	4,652	904	56,220	863
4,100	>20,000	1,127	4,970	909	4,244	861
4,200	>20,000	1,187	294,350	927	4,315	917
4,300	>20,000	1,157	5,720	940	4,794	903
4,400	>20,000	1,177	5,962	942	5,044	899
4,500	>20,000	1,232	7,254	975	6,123	971
4,600	>20,000	1,266	7,461	990	6,237	983
4,700	>20,000	1,312	9,728	1,000	8,112	966
4,800	>20,000	1,367	10,372	1,062	8,925	990
4,900	>20,000	1,356	13,333	1,166	11,551	1,040
5,000	>20,000	1,433	13,752	1,147	12,196	1,126
5,500	>20,000	1,709	>20,000	1,099	>20,000	1,053
6,000	>20,000	2,499	>20,000	1,267	>20,000	1,253
6,500	>20,000	3,378	>20,000	1,318	>20,000	1,279
7,000	>20,000	3,415	>20,000	1,375	>20,000	1,364
7,500	>20,000	4,097	>20,000	1,603	>20,000	1,343
8,000	>20,000	4,260	>20,000	1,838	>20,000	1,357
8,500	>20,000	5,139	>20,000	1,992	>20,000	1,778
9,000	>20,000	5,771	>20,000	2,196	>20,000	2,040
9,500	>20,000	5,848	>20,000	2,080	>20,000	1,997
10,000	>20,000	7,382	>20,000	2,396	>20,000	2,150
10,500	>20,000	7,331	>20,000	2,618	>20,000	2,332
11,000	>20,000	8,233	>20,000	2,611	>20,000	2,382
11,500	>20,000	8,606	>20,000	2,700	>20,000	2,700
12,000	>20,000	10,586	>20,000	3,220	>20,000	3,220
12,500	>20,000	9,813	>20,000	3,039	>20,000	3,039
13,000	>20,000	13,043	>20,000	3,218	>20,000	2,645
13,500	>20,000	16,076	>20,000	3,558	>20,000	2,954
14,000	>20,000	17,912	>20,000	3,852	>20,000	3,852
14,500	>20,000	>20,000	>20,000	4,087	>20,000	3,729
15,000	>20,000	>20,000	>20,000	4,011	>20,000	3,814
15,500	>20,000	>20,000	>20,000	3,617	>20,000	3,617
16,000	>20,000	19,435	>20,000	4,011	>20,000	4,011
16,500	>20,000	19,642	>20,000	4,190	>20,000	4,014
17,000	>20,000	>20,000	>20,000	4,605	>20,000	4,605
17,500	>20,000	16,380	>20,000	5,229	>20,000	4,674
18,000	>20,000	15,789	>20,000	5,435	>20,000	5,265
18,500	>20,000	17,692	>20,000	4,904	>20,000	4,904
19,000	>20,000	>20,000	>20,000	5,183	>20,000	5,143

Distance (m)	95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum
19,500	>20,000	>20,000	>20,000	6,873	>20,000	6,648
20,000	>20,000	>20,000	>20,000	6,826	>20,000	6,787

Table 3.77 Annualised maximum distance from the hydrotest discharge location to achieve 1:10,000 dilution for Case H2 (Torosa PLET 846,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Annual	12,496
99th		20,555
100th		20,723

Table 3.78 Annualised total area of coverage for 1:10,000 dilution for Case H2 (Torosa PLET 846,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Annual	87.10
99th		252.90
100th		292.70

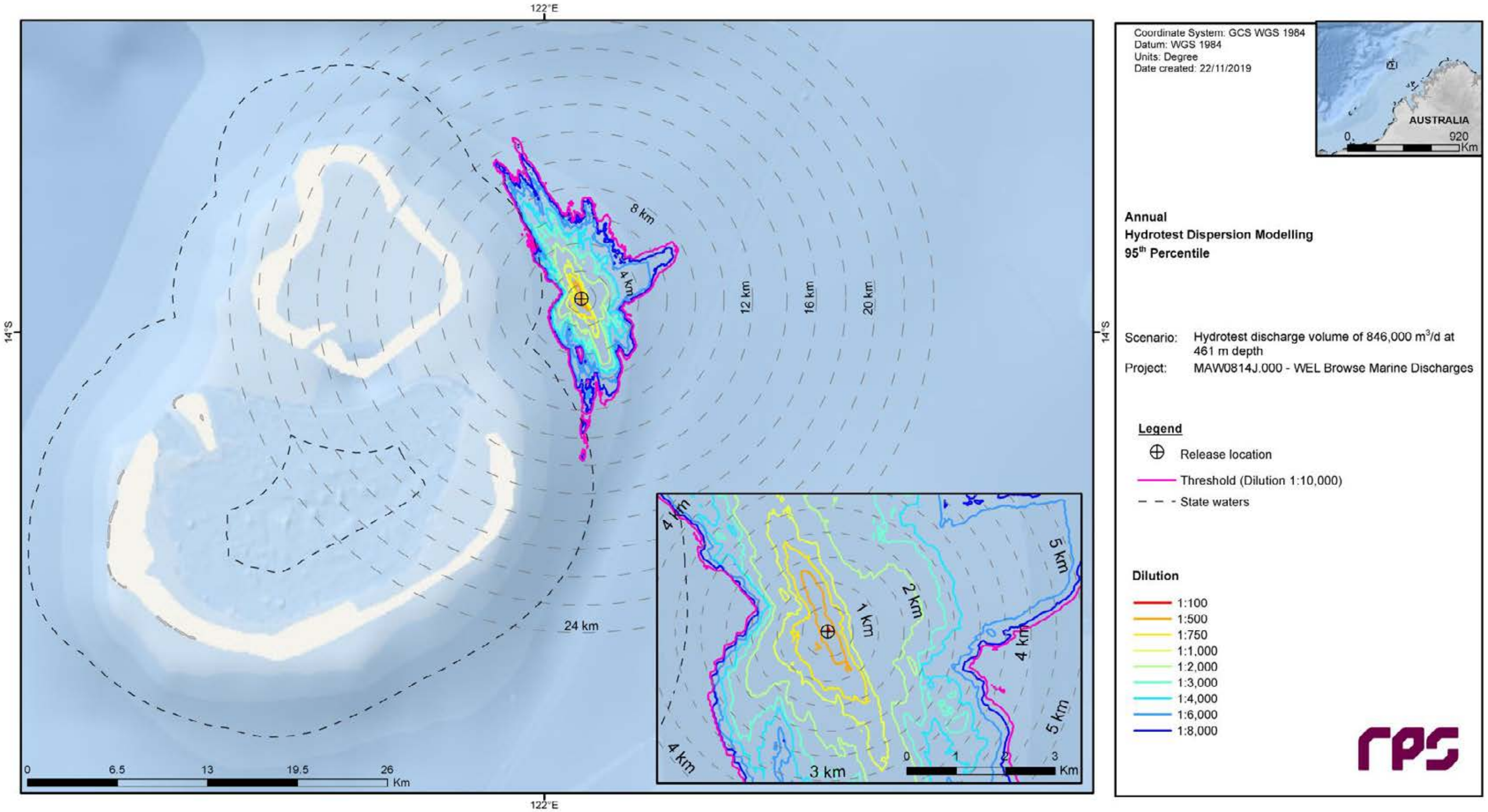


Figure 3.82 Predicted annualised minimum dilutions at the 95th percentile for Case H2 (Torosa PLET 846,000 m^3 hydrotest discharge), with a rolling 48-hour median of the dilution data.

3.2.5.3.4 Discharge Case H3a: Brecknock/Calliance PLET Hydrotest Discharge of 790,000 m^3 at 539 m Depth

Table 3.79 Annualised average and minimum dilutions (1:x) achieved at specific radial distances from the hydrotest discharge location for Case H3a (Brecknock/Calliance PLET 790,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.

Distance (m)	**95th Percentile**		**99th Percentile**		**100th Percentile**	
	Average	**Minimum**	**Average**	**Minimum**	**Average**	**Minimum**
Scott Reef (3 nm State Water Boundary) †	>>20,000	>20,000	>>20,000	>20,000	>>20,000	>20,000
20	508	508	353	353	318	318
50	826	74	465	72	398	71
100	1,611	334	1,070	157	817	139
200	2,007	1,291	1,167	321	923	267
300	2,351	1,371	1,695	663	1,476	593
400	2,286	1,445	1,486	646	1,245	622
500	2,608	1,562	1,642	776	1,462	709
600	2,599	1,580	1,542	877	1,352	778
700	2,959	1,847	1,833	985	1,586	780
800	2,959	1,559	1,823	862	1,514	840
900	3,199	1,850	2,101	1,041	1,740	866
1,000	3,271	1,609	2,151	1,051	1,740	942
1,100	3,412	1,979	2,291	931	1,924	864
1,200	3,504	1,856	2,402	922	1,948	881
1,300	3,685	1,924	2,494	1,003	2,165	993
1,400	3,844	1,913	2,542	953	2,284	888
1,500	3,993	2,084	2,623	874	2,337	822
1,600	4,175	2,083	2,581	820	2,353	753
1,700	>20,000	2,163	2,701	772	2,406	726
1,800	>20,000	2,168	2,736	787	2,435	726
1,900	4,517	2,011	2,767	811	2,441	772
2,000	4,760	2,088	2,923	783	2,587	783
2,100	4,945	2,169	3,130	862	2,703	862
2,200	5,331	2,057	3,251	971	2,819	971
2,300	5,567	2,166	3,466	1,117	2,896	1,071
2,400	6,068	2,247	3,598	1,085	3,087	1,058
2,500	>20,000	2,513	3,722	1,232	3,110	1,159
2,600	6,842	2,265	3,950	1,372	3,401	1,264
2,700	6,751	2,570	3,957	1,625	3,436	1,393
2,800	7,438	2,724	4,270	1,653	3,760	1,584
2,900	>20,000	2,563	4,241	1,641	3,804	1,565
3,000	8,966	2,660	4,519	1,707	4,108	1,629
3,100	8,906	2,744	>20,000	1,665	4,123	1,568
3,200	10,312	2,905	4,870	1,709	4,428	1,549
3,300	>20,000	2,941	4,930	1,784	4,412	1,514
3,400	13,559	3,048	5,502	1,853	4,899	1,473

Distance (m)	95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum
3,500	14,586	3,059	5,597	1,737	4,854	1,428
3,600	>20,000	3,092	6,490	1,636	5,394	1,422
3,700	>20,000	3,138	7,114	1,593	5,483	1,512
3,800	>20,000	3,205	8,050	1,671	6,142	1,644
3,900	>20,000	3,196	8,682	1,685	6,200	1,665
4,000	>20,000	3,134	9,520	1,758	7,055	1,717
4,100	>20,000	3,150	10,208	1,729	7,994	1,676
4,200	>20,000	3,089	10,079	1,766	8,739	1,720
4,300	>20,000	3,164	10,326	1,893	8,843	1,739
4,400	>20,000	3,028	10,529	1,867	8,993	1,744
4,500	>20,000	3,225	12,226	1,949	9,976	1,711
4,600	>20,000	3,185	14,096	1,930	9,690	1,724
4,700	>20,000	3,287	18,124	1,993	9,962	1,833
4,800	>20,000	3,303	19,313	2,028	9,207	1,869
4,900	>20,000	3,642	>20,000	2,122	9,535	1,924
5,000	>20,000	3,924	>20,000	2,132	8,527	1,981
5,500	>20,000	4,260	>20,000	2,119	8,314	1,921
6,000	>20,000	4,650	>20,000	2,321	8,286	2,028
6,500	>20,000	4,880	>20,000	2,475	9,838	2,134
7,000	>20,000	5,429	>20,000	2,742	18,503	2,182
7,500	>20,000	5,819	>20,000	2,577	>20,000	2,412
8,000	>20,000	7,250	>20,000	2,256	>20,000	2,256
8,500	>20,000	6,268	>20,000	2,732	>20,000	2,684
9,000	>20,000	5,187	>20,000	3,348	>20,000	2,904
9,500	>20,000	4,857	>20,000	3,147	>20,000	3,065
10,000	>20,000	5,514	>20,000	3,992	>20,000	2,591
10,500	>20,000	8,244	>20,000	4,535	>20,000	2,738
11,000	>20,000	8,851	>20,000	4,932	>20,000	4,199
11,500	>20,000	9,050	>20,000	4,826	>20,000	4,367
12,000	>20,000	6,800	>20,000	4,318	>20,000	4,227
12,500	>20,000	5,854	>20,000	4,223	>20,000	4,009
13,000	>20,000	5,567	>20,000	4,395	>20,000	4,312
13,500	>20,000	5,689	>20,000	4,654	>20,000	4,467
14,000	>20,000	7,012	>20,000	5,756	>20,000	5,348
14,500	>20,000	8,689	>20,000	5,214	>20,000	5,080
15,000	>20,000	6,872	>20,000	5,369	>20,000	5,038
15,500	>20,000	7,539	>20,000	4,633	>20,000	4,487
16,000	>20,000	5,381	>20,000	4,293	>20,000	4,274
16,500	>20,000	6,935	>20,000	4,584	>20,000	4,470
17,000	>20,000	7,454	>20,000	4,686	>20,000	4,458
17,500	>20,000	9,676	>20,000	6,742	>20,000	6,090
18,000	>20,000	9,502	>20,000	6,442	>20,000	6,040
18,500	>20,000	10,774	>20,000	5,598	>20,000	5,371
19,000	>20,000	11,331	>20,000	5,650	>20,000	5,650

Distance (m)	95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum
19,500	>20,000	9,513	>20,000	5,379	>20,000	4,960
20,000	>20,000	8,823	>20,000	5,738	>20,000	5,589

† This receptor is outside the model domain and predictions of dilution are unavailable at or within its boundaries. Given the high levels of dilution predicted within the extent of the model domain (20 km) in the direction of Scott Reef, and the remaining distance (~12 km) from the edge of the model domain to the receptor, it can be assumed that a minimum dilution level of >20,000 will occur at or within the receptor boundaries at all percentiles.

Table 3.80 Annualised maximum distance from the hydrotest discharge location to achieve 1:10,000 dilution for Case H3a (Brecknock/Calliance PLET 790,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Annual	23,421
99th		26,400
100th		26,502

Table 3.81 Annualised total area of coverage for 1:10,000 dilution for Case H3a (Brecknock/Calliance PLET 790,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Annual	89.40
99th		324.30
100th		390.50

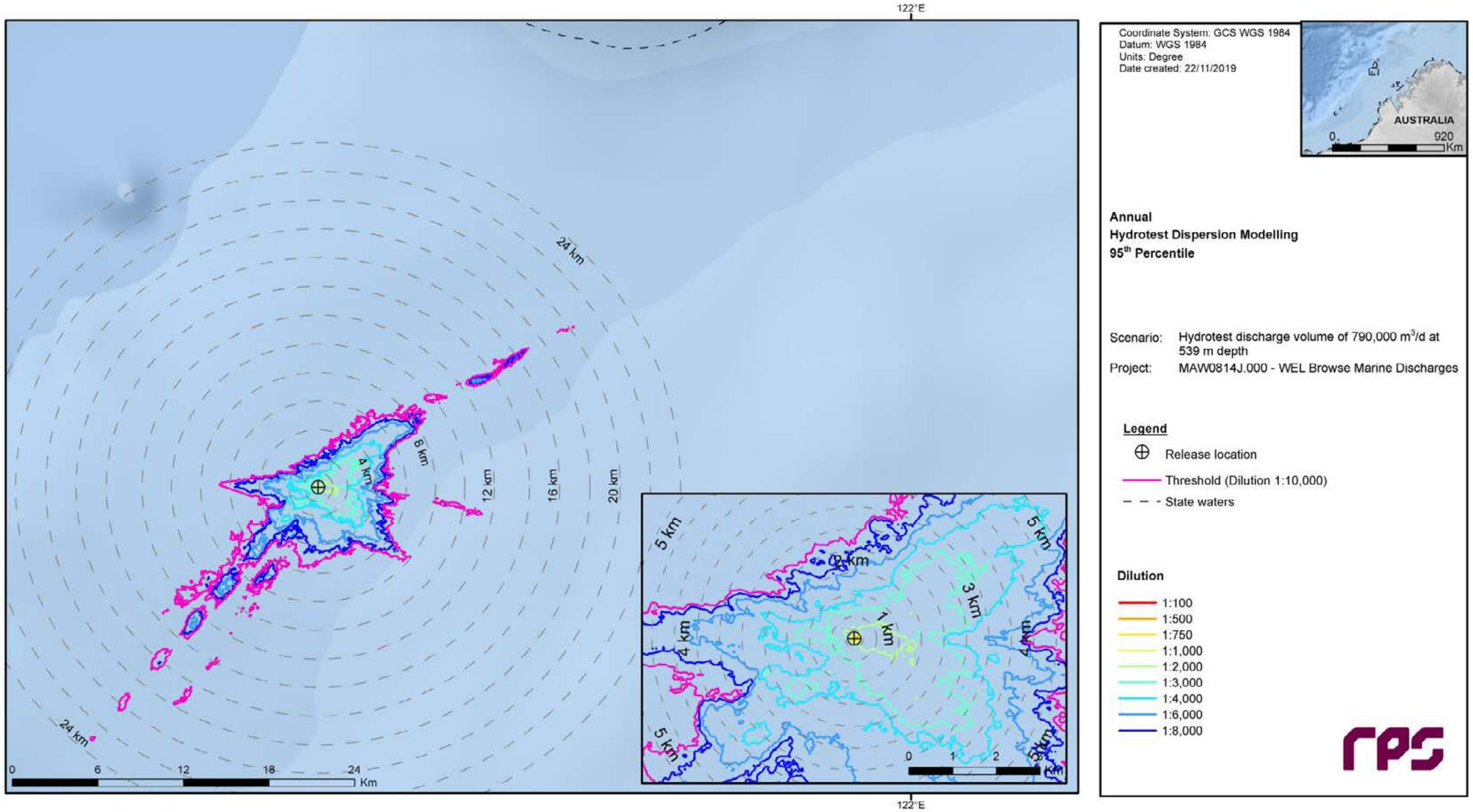


Figure 3.83 Predicted annualised minimum dilutions at the 95th percentile for Case H3a (Brecknock/Calliance PLET 790,000 m^3 hydrotest discharge), with a rolling 48-hour median of the dilution data.

3.2.5.3.5 Discharge Case H3b: Torosa PLET Hydrotest Discharge of 56,000 m^3 at 461 m Depth

Table 3.82 Annualised average and minimum dilutions (1:x) achieved at specific radial distances from the hydrotest discharge location for Case H3b (Torosa PLET 56,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.

Distance (m)	95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum
Scott Reef (3 nm State Water Boundary)	>20,000	2,711	>20,000	1,531	>20,000	1,530
20	779	730	608	584	590	578
50	746	691	619	598	594	577
100	779	663	589	488	559	485
200	940	642	608	374	549	348
300	1,000	626	574	300	507	297
400	1,135	572	590	302	530	302
500	1,162	440	602	231	545	231
600	1,356	445	706	159	649	159
700	1,516	652	838	148	781	148
800	1,664	346	895	97	851	70
900	1,995	663	1,113	341	1,085	330
1,000	2,334	689	1,201	416	1,173	289
1,100	2,946	741	1,373	399	1,350	399
1,200	3,312	951	1,490	402	1,459	402
1,300	4,265	749	1,711	447	1,642	447
1,400	3,741	1,004	1,642	481	1,571	481
1,500	6,178	1,078	1,914	559	1,710	559
1,600	5,580	1,168	1,791	689	1,723	672
1,700	11,774	1,170	2,136	747	1,903	734
1,800	14,208	1,245	2,293	783	2,157	772
1,900	>20,000	1,453	2,755	878	2,586	869
2,000	>20,000	1,448	2,832	1,178	2,565	1,129
2,100	>20,000	1,454	3,165	1,146	2,831	1,136
2,200	>20,000	1,439	3,051	1,217	2,765	1,129
2,300	>20,000	1,591	3,358	1,126	>20,000	1,126
2,400	>20,000	1,722	3,262	1,221	3,063	1,135
2,500	>20,000	1,547	4,221	1,229	>20,000	913
2,600	>20,000	1,578	>20,000	1,134	>20,000	1,026
2,700	>20,000	2,012	7,335	1,096	6,036	1,032
2,800	>20,000	1,712	13,266	1,166	6,751	1,166
2,900	>20,000	2,160	>20,000	1,188	14,070	1,188
3,000	>20,000	1,779	>20,000	1,209	16,907	1,209
3,100	>20,000	1,949	>20,000	1,263	>20,000	1,263
3,200	>20,000	1,720	>20,000	1,308	>20,000	1,308
3,300	>20,000	1,750	>20,000	1,305	>20,000	1,305
3,400	>20,000	1,852	>20,000	1,300	>20,000	1,300

Distance (m)	95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum
3,500	>20,000	1,815	>20,000	1,285	>20,000	1,285
3,600	>20,000	1,726	16,669	1,438	14,106	1,428
3,700	>20,000	1,776	>20,000	1,481	>20,000	1,481
3,800	>20,000	2,117	18,415	1,494	13,545	1,494
3,900	>20,000	2,014	>20,000	1,569	>20,000	1,569
4,000	>20,000	2,538	>20,000	1,536	>20,000	1,536
4,100	>20,000	2,255	>20,000	1,492	>20,000	1,492
4,200	>20,000	2,400	>20,000	1,526	>20,000	1,526
4,300	>20,000	2,115	>20,000	1,291	>20,000	1,291
4,400	>20,000	2,453	>20,000	1,178	>20,000	1,178
4,500	>20,000	2,376	>20,000	1,297	>20,000	1,297
4,600	>20,000	2,371	>20,000	1,173	>20,000	1,173
4,700	>20,000	2,204	>20,000	1,135	>20,000	1,135
4,800	>20,000	2,475	>20,000	1,198	>20,000	1,192
4,900	>20,000	2,109	>20,000	1,315	>20,000	1,298
5,000	>20,000	1,840	>20,000	1,324	>20,000	1,290
5,500	>20,000	2,365	>20,000	1,253	>20,000	1,246
6,000	>20,000	3,386	>20,000	1,689	>20,000	1,644
6,500	>20,000	3,423	>20,000	1,612	>20,000	1,461
7,000	>20,000	6,039	>20,000	1,542	>20,000	1,458
7,500	>20,000	4,503	>20,000	1,801	>20,000	1,513
8,000	>20,000	7,494	>20,000	3,542	>20,000	2,187
8,500	>20,000	13,983	>20,000	3,068	>20,000	3,068
9,000	>20,000	>20,000	>20,000	4,611	>20,000	3,839
9,500	>20,000	>20,000	>20,000	5,610	>20,000	5,111
10,000	>20,000	>20,000	>20,000	6,567	>20,000	5,777
10,500	>20,000	>20,000	>20,000	6,425	>20,000	5,381
11,000	>20,000	>20,000	>20,000	5,529	>20,000	5,529
11,500	>20,000	>20,000	>20,000	8,539	>20,000	8,539
12,000	>20,000	>20,000	>20,000	12,075	>20,000	11,702
12,500	>20,000	>20,000	>20,000	17,960	>20,000	17,960
13,000	>20,000	>20,000	>20,000	18,800	>20,000	18,800
13,500	>20,000	>20,000	>20,000	9,105	>20,000	9,105
14,000	>20,000	>20,000	>20,000	13,245	>20,000	12,962
14,500	>20,000	>20,000	>20,000	16,575	>20,000	14,560
15,000	>20,000	>20,000	>20,000	14,604	>20,000	12,981
15,500	>20,000	>20,000	>20,000	18,969	>20,000	17,076
16,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
16,500	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
17,000	>20,000	>20,000	>20,000	>20,000	>20,000	19,356
17,500	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
18,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
18,500	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
19,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000

Distance (m)	95th Percentile		99th Percentile		100th Percentile	
	Average	Minimum	Average	Minimum	Average	Minimum
19,500	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000
20,000	>20,000	>20,000	>20,000	>20,000	>20,000	>20,000

Table 3.83 Annualised maximum distance from the hydrotest discharge location to achieve 1:10,000 dilution for Case H3b (Torosa PLET 56,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Annual	8,230
99th		13,845
100th		13,845

Table 3.84 Annualised total area of coverage for 1:10,000 dilution for Case H3b (Torosa PLET 56,000 m^3 hydrotest discharge), with application of a rolling 48-hour median to the dilution data.

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Annual	40.80
99th		92.70
100th		105.80

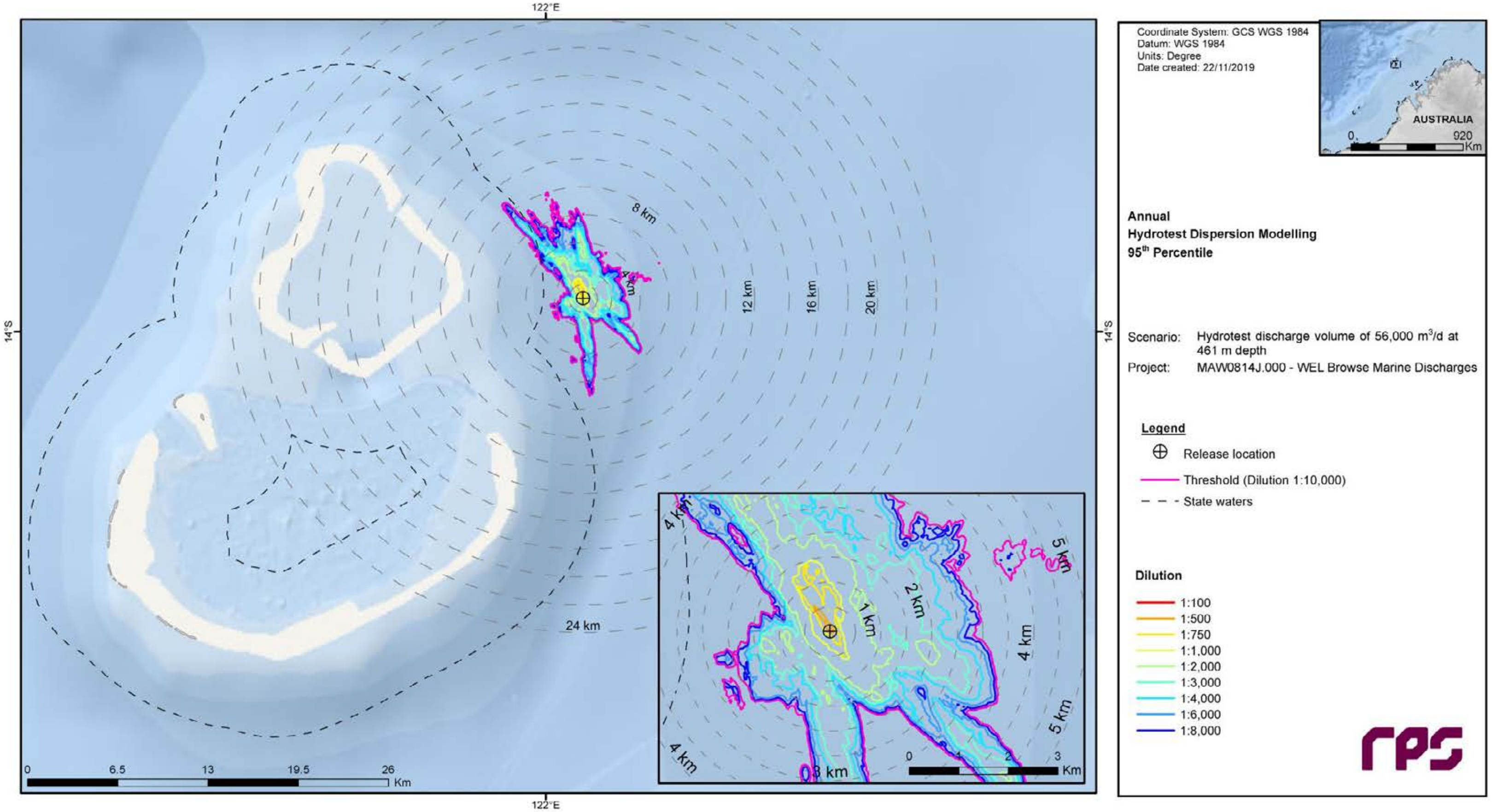


Figure 3.84 Predicted annualised minimum dilutions at the 95th percentile for Case H3b (Torosa PLET 56,000 m^3 hydrotest discharge), with a rolling 48-hour median of the dilution data.

4 CONCLUSIONS

The main findings of the study are as follows:

Near-Field Modelling

Cooling Water Discharges

- The results show that due to the momentum of the discharge a turbulent mixing zone is created in the immediate vicinity of the discharge point, which is 12 m below the water surface (Case C). Medium and strong currents are shown to increase the extent of the turbulent mixing zone. Following this initial mixing, the positively buoyant plume is predicted to rise in the water column.
- The plume is predicted to plunge up to 16 m below the sea surface in all seasons.
- Increased ambient current strengths are shown to increase the horizontal distance travelled by the plume from the discharge point.
- The maximum horizontal distance travelled by the plume under annualised average current speeds is predicted as 37.8 m.
- The maximum diameter of the plume at the end of the near-field zone is predicted as 15.2 m.
- For all seasons, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to reach the trapping depth (at which the predictions of dispersion are halted due to the plume reaching equilibrium with the ambient receiving water) closer to the discharge point, which slows the rate of dilution.
- The average dilution levels of the plume upon reaching the trapping depth under annualised average current speeds are predicted to be 1:13.5 for Case C. Additionally, the minimum dilution levels of the plume (i.e. dilution of the plume centreline) upon encountering the trapping depth under annualised average current speeds are predicted to be 1:6.3 for Case C.
- The predictions of dilution rely on the persistence of current speed and direction over time and do not account for any build-up of plume concentrations due to slack currents or current reversals.

Produced Water Discharges

- The results show that due to the momentum of the discharges a turbulent mixing zone is created in the immediate vicinity of the discharge point, which is 14 m below the water surface (Cases P and M). Medium and strong currents are shown to increase the extent of the turbulent mixing zone. Following this initial mixing, the positively buoyant plumes are predicted to rise in the water column.
- For Cases P and M, the plume is predicted to rise towards the water surface after the momentum of the initial discharge is lost.
- Increased ambient current strengths are shown to increase the horizontal distance travelled by the plume from the discharge point.
- For both discharges, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted as 20.2 m.
- For both discharges, the maximum diameter of the plume at the end of the near-field zone is predicted as 11.7 m.
- For all combinations of discharge case and season, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to reach the trapping depth (at which the

predictions of dispersion are halted due to the plume reaching equilibrium with the ambient receiving water) closer to the discharge point, which slows the rate of dilution.

- The average dilution levels of the plume upon reaching the trapping depth under annualised average current speeds are predicted to be 1:204 for Case P and 1:1,222 for Case M. Additionally, the minimum dilution levels of the plume (i.e. dilution of the plume centreline) upon encountering the trapping depth under annualised average current speeds are predicted to be 1:70 for Case P and 1:323 for Case M.

- The predictions of dilution rely on the persistence of current speed and direction over time and do not account for any build-up of plume concentrations due to slack currents or current reversals.

Hydrotest Discharges

- The results show that due to the momentum of the discharges a turbulent mixing zone is created in the immediate vicinity of the discharge points, which are 117 m (Case H1), 461 m (Cases H2 and H3b) and 539 m (Case H3a) below the water surface. Following this initial mixing, the near neutrally buoyant plumes are predicted to travel laterally in the water column.

- Increased ambient current strengths are shown to increase the horizontal distance travelled by the plume from the discharge point.

- For all discharges, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted as being in the range 50-77 m.

- For all discharges, the maximum diameter of the plume at the end of the near-field zone is predicted as being in the range 16-24 m.

- For all combinations of discharge case and season, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to reach the trapping depth (at which the predictions of dispersion are halted due to the plume reaching equilibrium with the ambient receiving water) closer to the discharge point, which slows the rate of dilution.

- The average dilution levels of the plume upon reaching the trapping depth under annualised average current speeds are predicted to be 1:111 for Case H1, 1:166 for Case H2, 1:172 for Case H3a and 1:166 for Case H3b. Additionally, the minimum dilution levels of the plume (i.e. dilution of the plume centreline) upon encountering the trapping depth under annualised average current speeds are predicted to be 1:41 for Case H1, 1:62 for Case H2, 1:65 for Case H3a and 1:62 for Case H3b.

- The predictions of dilution rely on the persistence of current speed and direction over time and do not account for any build-up of plume concentrations due to slack currents or current reversals.

Far-Field Modelling

Cooling Water Discharges

- Instantaneous concentrations (based on a 60-second model time step) are considered when calculating dilution contours.

- The minimum level of dilution achieved at or within the Scott Reef receptor at the 95th percentile in any season is predicted to be 1:125 for Case C.

- For Case C, annualised results show dilution to reach an example level of 1:100 is achieved within an area of influence extending up to 4.2 km at the 95th percentile. The discharged plumes are predicted to travel predominantly along a north-northwest/south-southeast axis throughout the year, which is broadly parallel to the Scott Reef receptor boundary.

- For Case C, annualised results show the area of exposure defined by the 1:100 dilution contour is predicted to reach a maximum value of 3.7 km^2 at the 95th percentile.

- The maximum depth reached by the discharge across all seasons is predicted as 20 m for Case C.
- Considering the relative rates of acclimation of the plume characteristics with the ambient water, the limiting factor for the plume's area of influence is likely to be defined by its chlorine constituent rather than its temperature.
- An example 3 °C plume-ambient temperature differential is forecast to be met within 120 m at the 95th percentile across all seasons.

Produced Water Discharges

- Instantaneous concentrations (based on a 60-second model time step) are considered when calculating dilution contours.
- The minimum levels of dilution achieved at or within the Scott Reef receptor at the 95th percentile in any season are predicted to be 1:1,507 for Case P and 1:17,674 for Case M.
- For Case P, annualised results show dilution to reach an example level of 1:300 is achieved within an area of influence extending up to 0.9 km at the 95th percentile. The discharged plumes are predicted to travel predominantly along a north-northwest/south-southeast axis throughout the year, which is broadly parallel to the Scott Reef receptor boundary, with trajectories to the south-southeast forecast to be longer.
- For Case P, annualised results show the area of exposure defined by the 1:300 dilution contour is predicted to reach a maximum value of 0.7 km^2 at the 95th percentile.
- The maximum depth reached by the discharge across all seasons is predicted as 19 m for Case P.

Hydrotest Discharges

- Concentrations calculated following application of a rolling 48-hour median to the instantaneous data are considered when calculating dilution contours.
- The minimum levels of dilution achieved at or within the nearest receptor at the 95th percentile in any season are predicted to be >>1:20,000 for Case H1 (Rankin Bank), 1:4,440 for Case H2 (Scott Reef), >1:20,000 for Case H3a (Scott Reef) and 1:2,711 for Case H3b (Scott Reef).
- For Cases H1, H2, H3a and H3b, annualised results show dilution to reach an example level of 1:10,000 is achieved within an area of influence extended up to 16.1 km, 12.5 km, 23.4 km and 8.2 km, respectively, at the 95th percentile. The predominant plume travel directions throughout the year are forecast to be south-westerly (Case H1), along a north-northwest/south-southeast axis (Cases H2 and H3a) and along a north-east/south-west axis (Case H3a).
- For Cases H1, H2, H3a and H3b, annualised results show the area of exposure defined by the 1:10,000 dilution contour is predicted to reach a maximum of 79.2 km^2, 87.1 km^2, 89.4 km^2 and 40.8 km^2, respectively, at the 95th percentile.

Key Observations

Cooling Water Discharges

- The discharge will be initially positively buoyant and will rise in the water column, and may resurface in the vicinity of the discharge point prior to acclimation with ambient receiving water conditions.
- At the 95th percentile, plumes for Case C are not expected to reach the Scott Reef 3 nm State water boundary at dilution levels less than 1:125 in any season.

- At the 95th percentile, temperature acclimation of the plume with ambient waters is expected to occur within 120 m of the discharge point in any season and plume temperature will not be a relevant factor at the Scott Reef 3 nm State water boundary.

Produced Water Discharges

- At the 95th percentile, plumes are not expected to reach the Scott Reef 3 nm State water boundary at dilution levels less than 1:1,507 for Case P and 1:17,674 for Case M in any season.

Hydrotest Discharges

- Due to significant variations in the magnitude and directionality of the hindcast currents at each location where potential discharges will occur, predicted outcomes are markedly different.

- Transport patterns will reflect the predominant drift current trajectories at each location, with tidal movements a particularly important driver of dispersion for the deeper discharges. Greater variability in current trajectories is expected near the water surface due to the influence of wind, but, because the plumes are discharged at the seabed and are not positively buoyant, they will not experience these variations.

- At the 95th percentile, plumes are not expected to reach the Scott Reef 3 nm State water boundary at dilution levels less than 1:4,440 for Case H2, 1:20,000 for Case H3a and 1:2,711 for Case H3b in any season. For Case H1, the dilution level of any plumes that may reach Rankin Bank is expected to be significantly greater than 1:20,000.

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Chapter 10 D.5 RPS Oil Spill Modelling Report

BROWSE TO NWS PROJECT - QUANTITATIVE SPILL RISK ASSESSMENT

Report

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EXECUTIVE SUMMARY

RPS was commissioned by Woodside Energy Ltd (Woodside) to undertake a quantitative spill risk assessment of hypothetical hydrocarbon spill scenarios related to the proposed Browse Joint Venture (BJV) Browse to North West Shelf Project. The Browse hydrocarbon resource includes the Brecknock, Calliance and Torosa reservoirs, which are approximately 400 km north of Broome.

The primary assessment location is in the vicinity of complex reef structures consisting of Scott Reef North, Scott Reef South and Seringapatam Reef. These are coral atolls that rise steeply from the surrounding shelf.

The main objective of the study was to provide an assessment of the probabilities of oil contact (at greater than defined minimum concentrations), the potential concentrations that might be involved, and the minimum state of weathering of the oil in the case of a release of hydrocarbons. The assessment considers several specific spill scenarios involving different sources, spill durations and oil types, which were defined by Woodside to represent credible scenarios.

Woodside identified four hydrocarbon spill scenarios for investigation, including one two-phase surface/subsea well blowout scenario and three other surface inventory/fuel spill scenarios.

Oil spill modelling was undertaken using a three-dimensional oil spill trajectory and weathering model, SIMAP (Spill Impact Mapping and Analysis Program), which is designed to simulate the transport, spreading and weathering of specific oil types under the influence of changing meteorological and oceanographic forces. Near-field subsea discharge modelling was undertaken using OILMAP, which predicts the droplet sizes that are generated by the turbulence of the discharge as well as the centreline velocity, buoyancy, width and trapping depth (if any) of the rising gas and oil plumes.

To define trends and variations in the potential outcomes of a given scenario, a stochastic modelling process was followed for all scenarios, whereby SIMAP was applied to repeatedly simulate the defined spill scenarios using different samples of current and wind data selected randomly from historic time series data representative of the study area. Results of the repeated simulations were then statistically analysed and mapped to define contours of risk around the release point.

The main findings of this study are as follows:

Metocean Influences

- Tidal flows within the reef complex will have a significant influence on the short-term trajectory of any oil spilled at the modelled release sites, irrespective of the seasonal conditions.
- Large-scale drift currents will have a significant influence on the trajectory of any oil spilled at the modelled release sites, irrespective of the seasonal conditions. The prevailing drift currents will determine the trajectory of oil that is entrained beneath the water surface.
- Interactions with the prevailing wind will provide additional variation in the trajectory of spilled oil, and marked variation in the prevailing drift current and wind conditions will be expected over the duration of a long-term release. This will be expected to increase the spread of hydrocarbons during any single event.

Oil Characteristics

- The unstabilised Torosa Condensate mixture specified for the sea-surface release phase of the Scenario 1 blowout is a pre-processed condensate that is a mixture of volatile and persistent hydrocarbons with significant proportions of highly volatile and residual components. If the sea-surface release phase unstabilised Torosa Condensate mixture is exposed to the atmosphere, around 17% of the mass is expected to evaporate in around 24 hours, another 33% within a few days, and the remaining 51% is expected to persist in the marine environment until decayed due to photochemical and biological degradation. If the unstabilised Torosa Condensate mixture specified for the subsea release phase were to be exposed to the atmosphere, these proportions are expected to be 54%, 21% and 25%, respectively.

- Stabilised Torosa Condensate, which refers to condensate which has been processed by the FPSO and which has been considered in Scenarios 2 and 3, contains a significant proportion of volatile compounds and a low proportion of residual hydrocarbons. If exposed to the atmosphere, around 78% of the mass will be expected to evaporate in around 24 hours, another 8% within a few days, and the remaining 14% will be expected to persist in the marine environment until decayed.
- Marine diesel is a mixture of volatile and persistent hydrocarbons with low percentages of highly volatile and residual components and has been considered in Scenario 4. If exposed to the atmosphere, around 41% of the mass would be expected to evaporate in around 24 hours, another 54% within a few days, and the remaining 5% would be expected to persist in the marine environment until decayed.
- For all hydrocarbon types, the influence of entrainment will regulate the degree of mass retention in the environment.

Summary of Stochastic Assessment Results

Interpretation of Contour Figures

- The mapped spatial outcomes of the stochastic assessment for each scenario are an aggregation of the predicted oil trajectories over the full duration of many individual hydrocarbon spill simulations and indicate the probability of exposure at defined concentrations for individual locations at some point in time after commencement of the spill event.
- These outcomes do not depict a hydrocarbon slick or plume at any particular instant in time, nor do they represent the overall coverage predicted over the full duration of an individual hydrocarbon spill simulation.

Scenario 1: Long-Term (77-Day) Surface/Subsea Blowout of Unstabilised Torosa Condensate at the TRA-C Well

- The location of the release is adjacent to the Scott Reef system. Most of the predicted impacts from this scenario are focused on the receptors that comprise the Scott Reef system. Note that the set of receptor boundaries that define the Scott Reef system for the purposes of this study have some intentional overlapping areas, and this implies duplicated reporting of some oil impacts.
- Floating oil at concentrations equal to or greater than the 10 g/m^2 threshold could potentially be found up to 143 km from the spill site.
- Floating oil concentrations at the 10 g/m^2 threshold are predicted to be focused on the Scott Reef system. Floating oil at 10 g/m^2 reaches Scott Reef North in all replicate simulations, but as Scott Reef North is treated as a submerged feature floating oil is predicted to drift over rather than make direct contact with this receptor. Scott Reef Central – Sandy Islet is treated as an emergent feature. This receptor is predicted to be contacted by floating oil concentrations of 10 g/m^2 with a probability of 8% and a minimum time to contact of 46 hours after commencement of release.
- The Scott Reef Central – Sandy Islet receptor is predicted to experience shoreline oil accumulation in excess of the 100 g/m^2 threshold with a probability of 92%. With regard to shoreline receptors further from the release location, Cartier Island (22%) and Ashmore Reef (18%) are predicted to have the highest probabilities of shoreline oil accumulation in excess of the 100 g/m^2 threshold.
- Potential for accumulation of oil on shorelines is predicted to be significant for Scott Reef Central – Sandy Islet, with a maximum accumulated volume of 827 m^3 and a maximum local accumulated concentration of 34.3 kg/m^2. The predicted zone of shoreline impact is restricted to Sandy Islet. Note that the boundaries of two other receptors, Scott Reef Central and Scott Reef South, overlap with the same shoreline as Scott Reef Central – Sandy Islet so reported accumulations for these receptors are a duplication.
- Entrained oil at concentrations equal to or greater than the 100 ppb threshold is predicted to be found up to approximately 863 km from the spill site.

- Contact by entrained oil at concentrations equal to or greater than 100 ppb is generally predicted for Scott Reef receptors including Scott Reef North (100%). Seringapatam Reef is also predicted to be contacted at 100 ppb (87%).
- The maximum entrained oil concentration forecast for any receptor is predicted as 23.6 ppm at Scott Reef North.
- Dissolved aromatic hydrocarbons at concentrations equal to or greater than the 50 ppb threshold are predicted to be found up to around 673 km from the spill site.
- Contact by dissolved aromatic hydrocarbons at concentrations equal to or greater than 50 ppb is generally predicted for Scott Reef receptors including Scott Reef North (100%). Seringapatam Reef is also predicted to be contacted at 50 ppb (85%).
- The maximum dissolved aromatic hydrocarbon concentration forecast for any receptor is predicted as 13.9 ppm at Scott Reef North.

Scenario 2: Short-Term (24-Hour) Surface Release of Stabilised Torosa Condensate after a Vessel Cargo Tank Rupture at the Torosa FPSO Location

- The location of the release is adjacent to the Scott Reef system. Most of the predicted impacts from this scenario are focused on the receptors that comprise the Scott Reef system.
- Floating oil at concentrations equal to or greater than the 10 g/m^2 threshold could potentially be found up to 126 km from the spill site.
- Floating oil concentrations at the 10 g/m^2 threshold are predicted to be focused on the Scott Reef system. The Scott Reef South and Scott Reef Central shoreline receptors are predicted to be contacted by floating oil concentrations at the 10 g/m^2 threshold with probabilities of 6.5% and 2%, respectively. At these receptors, the corresponding minimum times to contact at this threshold are 21 hours and 57 hours.
- The three Scott Reef receptors that share a common shoreline, Scott Reef South, Scott Reef Central and Scott Reef Central – Sandy Islet, are predicted to experience shoreline oil accumulation in excess of the 100 g/m^2 threshold with a probability of 20.5%.
- Potential for accumulation of oil on shorelines is predicted to be moderate, with a maximum accumulated volume of 212 m^3 and a maximum local accumulated concentration of 9.5 kg/m^2 forecast at the Scott Reef South, Scott Reef Central and Scott Reef Central – Sandy Islet receptors.
- Entrained oil at concentrations equal to or greater than the 100 ppb threshold is predicted to be found up to around 890 km from the spill site.
- Contact by entrained oil at concentrations equal to or greater than 100 ppb is generally predicted for Scott Reef receptors including Scott Reef North (48.5%). Seringapatam Reef is also predicted to be contacted at 100 ppb (22.5%).
- The maximum entrained oil concentration forecast for any receptor is predicted as 30.5 ppm at Scott Reef North. This result is greater than the maximum concentration forecast in Scenario 1, where a larger total volume of oil is released. The difference in maximum entrained oil concentration is attributable to the higher release rate in Scenario 2 (18,000 m^3/day compared to 1,846 m^3/day for Scenario 1). The Scott Reef North receptor is close enough to the release site that the peak concentration is influenced more by the rate of oil released in one day than the total volume of oil released.
- Dissolved aromatic hydrocarbons at concentrations equal to or greater than the 50 ppb threshold are predicted to be found up to around 517 km from the spill site.
- Contact by dissolved aromatic hydrocarbons at concentrations equal to or greater than 50 ppb is generally predicted for Scott Reef receptors including Scott Reef North (41.5%). Seringapatam Reef is also predicted to be contacted at 50 ppb (15.5%).

- The maximum dissolved aromatic hydrocarbon concentration forecast for any receptor is predicted as 12.7 ppm at Scott Reef North.

Scenario 3: Short-Term (Instantaneous) Surface Release of Stabilised Torosa Condensate after an FPSO Offtake System Failure at the Torosa FPSO Location

- The location of the release is adjacent to the Scott Reef system. Most of the predicted impacts from this scenario are focused on the receptors that comprise the Scott Reef system.
- Floating oil at concentrations equal to or greater than the 10 g/m^2 threshold could potentially be found up to 67 km from the spill site.
- The Scott Reef South receptor is predicted to be contacted by floating oil concentrations at the 10 g/m^2 threshold with a probability of 1.5% and a minimum contact time of 24 hours.
- The Scott Reef shoreline, encompassed by the Scott Reef South, Scott Reef Central and Scott Reef Central – Sandy Islet receptors, is predicted to experience shoreline oil accumulation in excess of the 100 g/m^2 threshold with a probability of 2.5%.
- Potential for accumulation of oil on shorelines is predicted to be low, with a maximum accumulated volume of 8 m^3 and a maximum local accumulated concentration of 715 g/m^2 forecast at three Scott Reef shoreline receptors.
- Entrained oil at concentrations equal to or greater than the 100 ppb threshold is predicted to be found up to around 242 km from the spill site.
- Contact by entrained oil at concentrations equal to or greater than 100 ppb is predicted at various northern Scott Reef receptors, including Scott Reef North (28%), Scott Reef North – Flats (25%) and Scott Reef North – Lagoon (20%).
- The maximum entrained oil concentration forecast for any receptor is predicted as 6.4 ppm at Scott Reef North and Scott Reef North – Flats.
- Dissolved aromatic hydrocarbons at concentrations equal to or greater than the 50 ppb threshold are predicted to be found up to around 271 km from the spill site.
- Contact by dissolved aromatic hydrocarbons at concentrations equal to or greater than 50 ppb is predicted at Scott Reef North (23%) and Scott Reef North – Flats (22.5%).
- The maximum dissolved aromatic hydrocarbon concentration forecast for any receptor is predicted as 1.8 ppm at Scott Reef North and Scott Reef North – Lagoon.

Scenario 4: Short-Term (Instantaneous) Surface Release of Marine Diesel after a Vessel Fuel Tank Rupture near the Rowley Shoals

- The location of the release is adjacent to Mermaid Reef. Most of the predicted impacts from this scenario are focused in the vicinity of the Rowley Shoals.
- Floating oil at concentrations equal to or greater than the 10 g/m^2 threshold could potentially be found up to 82 km from the spill site.
- Given that the spill location lies within the Argo-Rowley Terrace Marine Park area, floating oil at concentrations equal to or greater than 10 g/m^2 is forecast at this receptor with a probability of 100% and a minimum time to contact of less than 1 hour. The Rowley Shoals – Mermaid Reef Marine Park shoreline receptor is predicted to be contacted by floating oil concentrations at the 10 g/m^{2}threshold with a probability of 15%, with a corresponding minimum contact time of 5 hours. At the Rowley Shoals – Clerke Reef State Marine Park and Rowley Shoals – Imperieuse Reef State Marine Park shoreline receptors, probabilities of floating oil contact at the 10 g/m^2 threshold are forecast to be 1% or less.

- The Rowley Shoals – Mermaid Reef Marine Park receptor is predicted to experience shoreline oil accumulation in excess of the 100 g/m^2 threshold with a probability of 1%.
- Potential for accumulation of oil on shorelines is predicted to be low, with a maximum accumulated volume of 6 m^3 forecast at the Rowley Shoals – Clerke Reef State Marine Park and a maximum local accumulated concentration of 491 g/m^2 forecast at the Rowley Shoals – Mermaid Reef Marine Park.
- Entrained oil at concentrations equal to or greater than the 500 ppb threshold is predicted to be found up to around 371 km from the spill site.
- Contact by entrained oil at concentrations equal to or greater than 500 ppb is predicted at Argo-Rowley Terrace Marine Park (57%), Rowley Shoals – Mermaid Reef Marine Park (33.5%) and Rowley Shoals – Clerke Reef State Marine Park (7.5%).
- The maximum entrained oil concentration forecast for any receptor is predicted as 167.6 ppm at Argo-Rowley Terrace Marine Park.
- Dissolved aromatic hydrocarbons at concentrations equal to or greater than the 500 ppb threshold are predicted to be found up to around 43 km from the spill site.
- Contact by dissolved aromatic hydrocarbons at concentrations equal to or greater than 500 ppb is predicted at Argo-Rowley Terrace Marine Park (8.5%) and Rowley Shoals – Mermaid Reef Marine Park (1.5%).
- The maximum dissolved aromatic hydrocarbon concentration forecast for any receptor is predicted as 2.2 ppm at Argo-Rowley Terrace Marine Park.

1 INTRODUCTION

1.1 Background

RPS was commissioned by Woodside Energy Ltd (Woodside) to undertake a quantitative spill risk assessment of hypothetical hydrocarbon spill scenarios related to the proposed Browse Joint Venture (BJV) Browse to North West Shelf Project. The Browse hydrocarbon resource is located in the Brecknock, Calliance and Torosa reservoirs located approximately 425 km north of Broome and approximately 290 km off the Kimberley coastline.

The BJV propose to develop the Browse resource using two FPSO facilities with up to 1,100 million standard cubic feet per day (MMscf/d) export capacity (annual daily average). The proposed FPSOs will be supplied by a subsea production system and will export gas to existing North West Shelf (NWS) Project infrastructure via a ~85 km spur line and a ~900 km Browse Trunkline (BTL), which will tie in near the North Rankin Complex (NRC).

Woodside Energy Ltd (Woodside) is Operator for and on behalf of the BJV: Woodside Browse Pty Ltd, Shell Australia Pty Ltd (Shell), BP Developments Australia Pty Ltd (BP), Japan Australia LNG (MIMI Browse) Pty Ltd (MIMI) and PetroChina International Investment (Australia) Pty Ltd (PetroChina).

The assessment focused on the risk of exposure to hydrocarbons for surrounding resources and sensitive receptors if defined spill scenarios were to occur. The main objectives of the study were to provide an assessment, through stochastic spill modelling, of the probabilities of oil contact (at greater than defined minimum concentrations), the potential concentrations that might be involved, and the minimum state of weathering of the oil in case of a release of hydrocarbons.

Woodside identified four hydrocarbon spill scenarios for investigation, including a two phase sea-surface/subsea well blowout and three surface inventory/fuel spills (Woodside, 2019). Each scenario was modelled in a stochastic manner and assessed over an annual period in this study.

The regional context of the spill location for each assessed scenario is shown in Figure 1.1.

The details of the scenarios assessed in this study are summarised in Table 1.1 and listed here:

- Scenario 1: A long-term (77-day) uncontrolled release of 142,154 m^3 of unstabilised Torosa Condensate from the TRA-C well (13° 58' 12.5" S, 121° 58' 37.7" E), with a 5-day surface release phase followed by a 72-day subsea release phase, representing loss of containment after a loss of well control.
- Scenario 2: A short-term (24-hour) uncontrolled surface release of 18,000 m^3 of stabilised Torosa Condensate at the Torosa FPSO location (13° 58' 15.1" S, 122° 01' 28.5" E), representing loss of containment after a vessel cargo tank rupture.
- Scenario 3: A short-term (instantaneous) surface release of 768 m^3 of stabilised Torosa Condensate at the Torosa FPSO location (13° 58' 15.1" S, 122° 01' 28.5" E), representing loss of containment after an FPSO offtake system failure.
- Scenario 4: A short-term (instantaneous) surface release of 2,000 m^3 of marine diesel near the Rowley Shoals (17° 16' 52.8" S, 119° 39' 30.8" E), representing loss of containment after a vessel fuel tank rupture.

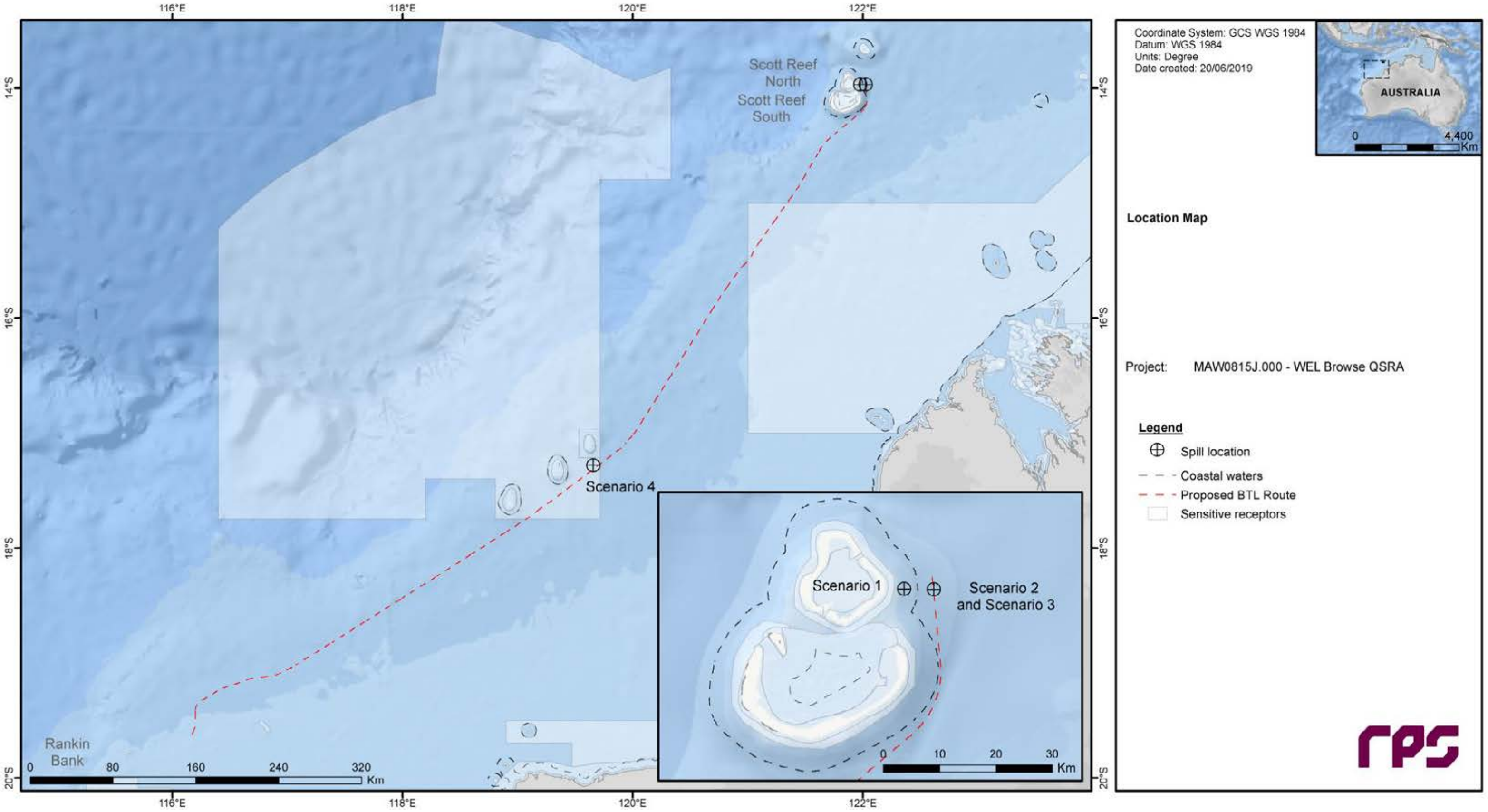

Figure 1.1 Locations of the modelled hydrocarbon spill scenario release sites.

1.2 Stochastic Modelling of Spill Scenarios

Oil spill modelling was undertaken using a three-dimensional oil spill trajectory and weathering model, SIMAP (Spill Impact Mapping and Analysis Program), which is designed to simulate the transport, spreading and weathering of specific oil types under the influence of changing meteorological and oceanographic forces. Near-field subsea discharge modelling was undertaken using OILMAP, which predicts the droplet sizes that are generated by the turbulence of the discharge as well as the centreline velocity, buoyancy, width and trapping depth (if any) of the rising gas and oil plumes.

The SIMAP model simulates both surface and subsea releases and uses the unique physical and chemical properties of an oil type to calculate rates of evaporation and viscosity change, including the tendency to form oil-in-water emulsions. Moreover, the unique transport and dispersion of surface slicks and in-water components (entrained and dissolved) are modelled separately. Thus, the model can be used to understand the wider potential consequences of a spill, including direct contact to slick oil for surface features and exposure to entrained and dissolved oil for organisms in the water column.

To define trends and variations in the potential outcomes of a given scenario, a stochastic modelling scheme was followed in this study, whereby SIMAP was applied to repeatedly simulate the defined spill scenarios using different samples of current and wind data selected randomly from an historic time series of wind and current data representative of the study area. Results of the replicate simulations were then statistically analysed and mapped to define contours of risk around the release point.

For this purpose, a long-term archive of spatially-variable wind and current data covering the Timor Sea and eastern Indian Ocean spanning 10 years (2006-2015, inclusive) was assembled. Current patterns accounted for temporal and spatial variations in large-scale drift currents over the outer shelf waters (typically >200 m depth) together with tidal and wind-driven currents. Modelling was carried out using current and wind data sampled from the data archive to quantify annualised risks of contact at surrounding locations.

Each simulation was run for the duration of the specified spill, plus a further period after the cessation of discharge to allow a sufficient time period for oil concentrations to decrease below the threshold concentrations applied in the analysis. It is expected that remnant floating oil, which may be present at low thresholds at the end of each simulation, would represent highly weathered and degraded products.

It is important to note that the modelling results presented in this document relate to the predicted outcomes once defined spill events have occurred. The probability of the spill scenarios occurring is not considered. The results should therefore be viewed as a guide to the likely outcomes should the spill scenarios occur. Furthermore, the results are presented in terms of statistical probability maps, based on many simulations under different conditions. Different locations within the potential zone of influence would be affected under each different time series of environmental forces. Consequently, these contours for the potential zone of influence will cover a larger area than the area that is likely to be affected during any one single spill event. The contours should therefore be judged as contours of probability and not representations of the area swept by individual spill slicks.

Risk estimates were calculated from the multiple replicate simulations for each assessed scenario, including the probability of contact, the minimum time to contact, and the potential concentrations that might be involved.

The results of the stochastic modelling are presented in Section 3.

Table 1.1 Summary of the hydrocarbon spill scenarios assessed in a stochastic manner in this study.

Scenario	Description	Oil Type	Spilled Volume (m^3)	Release Coordinates	Release Depth (m BMSL)	Spill Duration	Simulation Duration	Period
1	Loss of well control at the TRA-C well	Unstabilised Torosa Condensate	142,154	13° 58' 12.5" S 121° 58' 37.7" E	425	77 days	100 days	Annual
2	Loss of containment after a vessel cargo tank rupture	Stabilised Torosa Condensate	18,000	13° 58' 15.1" S 122° 01' 28.5" E	0	24 hours	56 days	Annual
3	Loss of containment after an FPSO offtake system failure	Stabilised Torosa Condensate	768	13° 58' 15.1" S 122° 01' 28.5" E	0	Instantaneous	42 days	Annual
4	Loss of containment after a vessel fuel tank rupture	Marine Diesel	2,000	17° 16' 52.8" S 119° 39' 30.8" E	0	Instantaneous	42 days	Annual

1.3 Deterministic Analysis

After assessing the stochastic modelling outcomes for all scenarios, Woodside determined there was a requirement for additional model outputs to be provided for selected replicate simulations of each scenario in order to contextualise the stochastic contours.

The results of the deterministic analysis are presented in Section 4.

1.4 Report Structure

The near-field and far-field computational models, risk assessment methodology, environmental data used as input to the models, environmental threshold trigger levels defined for the assessment, characteristics of the oil types used in the modelling of the defined scenarios, and discharge plume characteristics for the subsea release scenario are described in detail in Section 2.

Contour figures and tabulated results showing risk estimates for the receptors nominated by Woodside, produced for defined floating oil, entrained oil and dissolved aromatic hydrocarbon threshold concentrations, are presented in Section 3 to summarise the stochastic modelling outcomes.

Tabulated results for floating oil, entrained oil, dissolved aromatic hydrocarbons and shoreline oil are presented in Section 4 to summarise the outcomes of the deterministic analysis.

The overall findings of the study are summarised in Section 5.

2 MODELLING METHODOLOGY

2.1 Description of the Models

2.1.1 SIMAP

The spill modelling was carried out using a purpose-developed oil spill trajectory and fates model, SIMAP (Spill Impact Mapping and Assessment Program). This model is designed to simulate the transport and weathering processes that affect the outcomes of hydrocarbon spills to the sea, accounting for the specific oil type, spill scenario, and prevailing wind and current patterns.

SIMAP is an evolution of the US EPA Natural Resource Damage Assessment model (French & Rines, 1997; French, 1998; French *et al.*, 1999) and is designed to simulate the fate and effects of spilled oils and fuels for both the surface slick and the three-dimensional plume that is generated in the water column. SIMAP includes algorithms to account for both physical transport and weathering processes. The latter are important for accounting for the partitioning of the spilled mass over time between the water surface (surface slick), water column (entrained oil and dissolved compounds), atmosphere (evaporated compounds) and land (stranded oil). The model also accounts for the interaction between weathering and transport processes.

The physical transport algorithms calculate transport and spreading by physical forces, including surface tension, gravity and wind and current forces for both surface slicks and oil within the water column. The fates algorithms calculate all of the weathering processes known to be important for oil spilled to marine waters. These include droplet and slick formation, entrainment by wave action, emulsification, dissolution of soluble components, sedimentation, evaporation, bacterial and photo-chemical decay and shoreline interactions. These algorithms account for the specific oil type being considered.

Evaporation rates vary over space and time dependent on the prevailing sea temperatures, wind and current speeds, the surface area of the slick and entrained droplets that are exposed to the atmosphere as well as the state of weathering of the oil. Evaporation rates will decrease over time, depending on the calculated rate of loss of the more volatile compounds. By this process, the model can differentiate between the fates of different oil types.

Entrainment, dissolution and emulsification rates are correlated to wave energy, which is accounted for by estimating wave heights from the sustained wind speed, direction and fetch (i.e. distance downwind from land barriers) at different locations in the domain. Dissolution rates are dependent upon the proportion of soluble, short-chained hydrocarbon compounds, and the surface area at the oil/water interface of slicks. Dissolution rates are also strongly affected by the level of turbulence. For example, dissolution rates will be relatively high at the site of the release for a deep-sea discharge at high pressure.

In contrast, the release of hydrocarbons onto the water surface will not generate high concentrations of soluble compounds. However, subsequent exposure of the surface slick to breaking waves will enhance entrainment of oil into the upper water column as oil droplets, which will enhance dissolution of the soluble components. Because the compounds that have high solubility also have high volatility, the processes of evaporation and dissolution will be in dynamic competition with the balance dictated by the nature of the release and the weather conditions that affect the oil after release. The SIMAP weathering algorithms include terms to represent these dynamic processes. Technical descriptions of the algorithms used in SIMAP and validations against real spill events are provided in French (1998), French *et al.* (1999) and French-McCay (2004).

Input specifications for oil types include the density, viscosity, pour-point, distillation curve (volume of oil distilled off versus temperature) and the aromatic/aliphatic component ratios within given boiling point ranges. The model calculates a distribution of the oil by mass into the following components:

- Surface-bound or floating oil.
- Entrained oil (non-dissolved oil droplets that are physically entrained by wave action).
- Dissolved hydrocarbons (principally the aromatic and short-chained aliphatic compounds).

- Evaporated hydrocarbons.
- Sedimented hydrocarbons.
- Decayed hydrocarbons.

2.1.2 OILMAP

SIMAP uses specifications of the depth of release to represent spills onto the water surface or into the water column. For subsea release scenarios, where oil will initially be entrained in the water column as droplets of oil in suspension, it is necessary to define the size-distribution of the droplets and their initial vertical distribution following the initial (within minutes) discharge processes. These processes include the jet induced by the discharge and the dynamic evolution of any associated gas plume. This size distribution will regulate the time for oil droplets to rise to near the sea surface and affect their ability to surface and become floating oil.

High pressure releases (such as a pipeline rupture or gas/oil blowout) tend to generate a distribution with a small to median size (300 µm or less; Johansen, 2003). Due to their larger surface area to volume ratio, droplets of decreasing size will rise under buoyancy at a quadratically slower rate due to viscous resistance exerted by the surrounding water, which can be theoretically derived using Stokes' Law:

$$V = [2 * 9.81 * R^2(\rho_o - \rho_w)] / 9\mu$$

Where: V is the rising velocity of oil droplets; ρ_o and ρ_w are the mass density of oil and water, respectively; R is the radius of the oil droplet; and μ is the dynamic viscosity of water.

If oil is discharged with little or no gas, the oil droplets must rise to the surface under their own buoyancy (resisted by water viscosity) after the dissipation of a relatively short (~1-2 m) discharge jet. However, if gas is discharged with the oil, it will rapidly expand on exiting the pressurised reservoir and continue to expand as it rises and water pressure reduces. As the discharge moves upward, the density difference between the expanding gas bubbles in the plume and the receiving water results in a buoyant force which drives the plume of gas, oil and water towards the surface.

Oil in the release is rapidly mixed by the turbulence in the rising plume. These droplets (typically a few micrometres to millimetres in diameter) are rapidly transported upward by the rising plume; their individual rise velocities contributing little to their upward motion. As the plume rises, it continues to entrain ambient water, which reduces the buoyancy of the mixture and increases the radius of the plume (Chen & Yapa, 2007; Spaulding *et al.*, 2000).

In shallow water (<200 m) the rising plume of gas, oil and water will tend to reach the sea surface before deflecting as a radial, surface flow zone which will spread the oil droplets rapidly away from the centre of the plume (Spaulding *et al.*, 2000). The velocity and oil concentrations in this surface flow zone decrease while the depth of the zone increases. Finally in the far field, where the plume buoyancy has been dissipated, ambient currents and the turbulence generated by wind generated waves will determine the subsequent transport and dispersion of the oil droplets.

As water depths increase, the buoyancy of the rising plume is likely to be lost before the plume reaches the surface, because the gas begins to dissolve into the water column due to increased water temperatures and the density of the plume equalises with the surrounding water (Chen & Yapa, 2007; Spaulding *et al.*, 2000). This results in a situation where the oil droplets will have a further distance to rise to the surface under their own buoyancy and be subject to horizontal displacement due to the prevailing water currents. The reduced velocity of these droplets will also increase their susceptibility to trapping by stratification in the water column, and mixing in the near surface layer (typically 5-10 m depth) generated by surface waves.

As water depths increase further (beyond ~600 m), resulting in higher pressure and colder temperatures at the release depth, a further complication can arise due to part or all of the gas volume converting to a hydrate structure – a solid ice-like lattice structure with specific gravities on the order of 0.92 to 0.96 (Chen & Yapa, 2007; Spaulding *et al.*, 2000). The conversion of the gas into gas-hydrates deprives the plume of its principal source of buoyancy, leaving the oil droplets and gas hydrates to rise a longer distance under their own buoyancy to reach the surface. Hence, oil droplets will have a longer period during which they will be subject to horizontal transport by currents acting at the depth that they occupy.

OILMAP is an oil spill trajectory and fates model extended for the prediction of oil from subsea oil/gas blowouts, including those in deep water (>600 m) where gas hydrate formation can affect the fate of discharged oil (Spaulding *et al.*, 2000). The blowout model predicts the droplet sizes that are generated by the turbulence of the discharge as well as the centreline velocity, buoyancy, width and trapping depth (if any) of the rising gas plume. Inputs to the model include the depth (hence water pressure); discharge rate; hole size; oil density and viscosity, and the vertical temperature/salinity profile of the receiving water. This model was applied to supply the droplet size distribution and the plume dimensions to the SIMAP model, for the long-term discharge simulations.

2.2 Calculation of Exposure Risks

The stochastic model within SIMAP performs a large number of simulations for a given spill site, randomly varying the spill time for each simulation. The model uses the spill time to select samples of current and wind data from a long time series of wind and current data for the area. Hence, the transport and weathering of each slick will be subject to a different sample of wind and current conditions.

This stochastic sampling approach provides an objective measure of the possible outcomes of a spill, because environmental conditions will be selected at a rate that is proportional to the frequency that these conditions occur over the study region. More simulations will tend to use the most commonly occurring conditions, while conditions that are more unusual will be represented less frequently.

During each simulation, the SIMAP model records the location (by latitude, longitude and depth) of each of the particles (representing a given mass of oil) on or in the water column, at regular time steps. For any particles that contact a shoreline, the model records the accumulation of oil mass that arrives on each section of shoreline over time, less any mass that is lost to evaporation and/or subsequent removal by current and wind forces.

The collective records from all simulations are then analysed by dividing the study region into a three-dimensional grid. For oil particles that are classified as being at the water surface (floating oil), the sum of the mass in all oil particles (including accounting for spreading and dispersion effects) located within a grid cell, divided by the area of the cell provides estimates of the concentration of oil in that grid cell, at each time step. For entrained and dissolved oil particles, concentrations are calculated at each time step by summing the mass of particles within a grid cell and dividing by the volume of the grid cell.

The concentrations of oil calculated for each grid cell, at each time step, are then analysed to determine whether concentration estimates exceed defined threshold concentrations over time.

Risks are then summarised as follows:

- The probability of exposure to a location is calculated by dividing the number of spill simulations where any instantaneous contact occurred above a specified threshold at that location by the total number of replicate spill simulations. For example, if contact occurred at a location (above a specified threshold) during 21 out of 100 simulations, a probability of exposure of 21% is indicated.
- The minimum potential time to a shoreline location is calculated by the shortest time over which oil at a concentration above a particular threshold was calculated to travel from the source to the location in any of the replicate simulations.
- The maximum potential concentration of oil predicted for each shoreline section is the greatest mass per m^2 of shoreline calculated to strand at any location within that section during any of the replicate simulations.
- The average of the maximum concentrations of oil predicted to potentially accumulate on each shoreline section is calculated by determining the greatest mass per m^2 of shoreline during each replicate simulation and calculating an average of these estimates across the simulations.

- Similar treatments are undertaken for entrained oil and dissolved aromatic hydrocarbons.

Thus, the minimum time to shoreline and the maximum potential concentration estimates indicate the worst potential outcome of the modelled spill scenario for each section of shoreline. However, the average over the replicates presents an average of the potential outcomes, in terms of oil that could strand.

Note also that results quoted for sections of shoreline or shoal are derived for any individual location within that section or shoal, as a conservative estimate. Locations will represent shoreline lengths of the order of ~1 km, while sections or regions will represent shorelines spanning tens to hundreds of kilometres and we do not imply that the maximum potential concentrations quoted will occur over the full extent of each section. We therefore warn against multiplying the maximum concentration estimates by the full area of the section because this will greatly overestimate the total volume expected on that section.

The maximum entrained hydrocarbon and maximum dissolved aromatic hydrocarbon concentration are calculated for water locations surrounding each defined shoreline (see Section 3.1). These zones are defined to provide a buffer area around shallow (<10 m) habitats to allow for spatial errors in model forecasts. The greatest calculated value at any time step during any replicate simulation is listed. These values therefore represent worst-case localised estimates (within a grid cell). The averages over all replicate values represent a central tendency of these simulated worst-case estimates.

2.3 Inputs to the Risk Assessment

2.3.1 Current Data

2.3.1.1 Background

The area of interest for this study is located within the influence of the Indonesian Throughflow, a large-scale current system characterised as a series of migrating gyres and connecting jets that are steered by the continental shelf. While the mass flow is generally towards the south-west, year-round, the internal gyres generate local currents in all directions. As these gyres migrate through the area, large spatial variations in the speed and direction of currents will occur at a given location over time. Further south of the project area, the Leeuwin Current becomes the dominant large-scale current system, flowing poleward down the pressure gradient along the Western Australian coastline and past Cape Leeuwin.

Offshore regions with water depths exceeding 100-200 m experience significant large-scale drift currents. These drift currents can be relatively strong (1-2 knots) and complex, manifesting as a series of eddies, meandering currents and connecting flows. These offshore drift currents also tend to persist longer (days to weeks) than tidal current flows (hours between reversals) and thus will have greater influence upon the net trajectory of plumes over time scales exceeding a few hours.

On the continental shelf, in shallower waters around Scott Reef and closer to the inshore region of the Kimberley Coast, surface winds and tidal dynamics dominate over the large scale current flows (Condie & Andrewartha, 2008). In comparison to drift currents, tidal currents generate only relatively short tidal migrations (distance travelled by a parcel of water over a tidal cycle) that follow an elliptical path with a period of about 12 hours in the study region. Hence, tidal currents add variability to the longer-term drift patterns of an entrained plume.

Wind shear on the water surface also generates local-scale currents that can persist for extended periods (hours to days) and result in long trajectories. Persistent winds along the mainland coast can induce Ekman transport, where surface waters move offshore and facilitate upwelling events in which cold nutrient-rich waters from the deep Indian Ocean are brought to the surface. However, due to the opposing transport of warm tropical waters by the Leeuwin Current, large-scale persistent upwelling along the Western Australian coast is suppressed. Therefore, upwelling events are sporadic, short-term and localised to areas of the coastline where the continental shelf narrows, including the area around the Capes and the Ningaloo coast (IMOS, 2015). This process is seasonal/transient and affected by the strength of the Leeuwin Current, with minimal upwelling in times with strong Leeuwin Current flow.

The current-induced transport of plumes can be variably affected by combinations of tidal, wind-induced and density-induced drift currents. Depending on their local influence, it is critical to consider all these potential advective mechanisms to rigorously understand patterns of potential transport from a given discharge location.

To appropriately allow for temporal and spatial variation in the current field, dispersion modelling requires the current speed and direction over a spatial grid covering the potential migration trajectories of plumes. As long-term measured current data is not available for simultaneous periods over a network of locations covering the offshore areas relevant to this study, the analysis relied upon hindcasts of the circulation generated through numerical modelling by internationally recognised organisations.

A composite modelled ocean current data product was derived by combining predictions of mesoscale circulation currents, available at daily resolution from global ocean models, with predictions of the hourly tidal currents generated by the RPS HYDROMAP model. By combining a drift current model with a tidal model, the influences of inter-annual and seasonal drift patterns, and the more regular variations in tide, were depicted, ensuring nearshore and offshore hydrodynamic processes were represented.

2.3.1.2 Mesoscale Circulation

2.3.1.2.1 Description of Mesoscale Model: BRAN

Two mesoscale ocean current data sets were considered for the study: the CSIRO (Commonwealth Scientific and Industrial Research Organisation) global ocean model, BRAN (Bluelink ReANalysis); and the HYCOM (Hybrid Coordinate Ocean Model) Consortium's global ocean model, HYCOM. Based on a hydrodynamic model validation conducted by RPS, the output of the BRAN (Oke *et al.*, 2008, 2009; Schiller *et al.*, 2008) ocean model, which is sponsored by the Australian Government through the Commonwealth Bureau of Meteorology (BoM), Royal Australian Navy and CSIRO, was chosen for representation of the drift currents that affect the area. BRAN is a data-assimilative, three-dimensional ocean model that has been run as a hindcast for many periods and is now used for ocean forecasting (Schiller *et al.*, 2008).

BRAN routinely assimilates sea level anomaly data, tide gauge data, sea surface temperature and in situ temperature and salinity measurements (Oke *et al.*, 2009). Comparisons of BRAN hindcast outputs to satellite and independent in situ observations found that BRAN was reliably representing the broad-scale ocean circulation, the mesoscale surface eddy field, and shelf circulation around Australia (Oke *et al.*, 2008; Schiller *et al.*, 2008). Additionally, reanalysis of past periods using the BRAN model has been shown to realistically represent upwelling events, in particular along the Bonney Coast of South Australia, a region of frequent wind-driven upwellings (Oke *et al.*, 2009).

The BRAN predictions for drift currents are produced at a horizontal spatial resolution of approximately 0.1° over the region, at a frequency of once per day, averaged over the 24-hour period. Hence, the BRAN model data provides estimates of mesoscale circulation with horizontal resolution suitable to resolve eddies of a few tens of kilometres' diameter, as well as connecting stream currents of similar spatial scale. Drift currents that are represented over the inner shelf waters in the BRAN data are principally attributable to wind induced drift.

There are several versions of the BRAN database available. The latest BRAN simulation spans the period of January 1994 to August 2016. From this database, three-dimensional data representing horizontal water movement at discrete depths was extracted for all points in the model domain for the years 2006-2015 (inclusive). The data was assumed to be a suitably representative sample of the current conditions over the study area for future years.

Although this data should represent effects of upwelling and downwelling processes on horizontal transport at a given depth, the data does not explicitly represent vertical currents between horizontal layers. This was considered reasonable because vertical currents associated with episodic upwelling and downwelling events are relatively small in magnitude (3-30 cm/s; Kampf *et al.*, 2004) compared to horizontal currents represented in the tidal and non-tidal current data (0.5-2 m/s), and considering allowances for dispersion rates in the horizontal (0.1-50 m/s) and vertical (1-10 cm/s) planes.

2.3.1.2.2 Mesoscale Current Validation

The suitability of the BRAN ocean model product was evaluated by comparing the predicted currents to those measured within the Browse project area. The validation included both quantitative and qualitative comparisons between measured and modelled data at a range of depths through the water column, at three available measurement locations shown in Figure 2.1: Browse C1-1 (three depth layers), B2-1 (eight depth layers) and G2-1 (three depth layers).

Time series comparisons of modelled and measured current magnitude, direction, and U/V velocity components are presented for sites B2-1 (Figure 2.2 and Figure 2.3), C1-1 (Figure 2.4 and Figure 2.5) and G2-1 (Figure 2.6 and Figure 2.7). For the purposes of brevity and clarity, only a surface and mid-depth time series at each site was selected for presentation. The time series comparisons revealed that, at two of the sites (B2-1 and G2-1), the BRAN model offered a good match in magnitude and direction of the measured current velocity in the upper water column; however, the magnitudes of the peaks and troughs were often underpredicted at the deeper levels. At the C1-1 site, the BRAN model captured the range in current magnitude at each depth; however, the timing of peaks and troughs in the measured current velocity and direction was not well-matched. Given the location of this site in close proximity to Scott Reef, with steep gradients in the bathymetry and the relatively coarse resolution of the ocean model (relative to the tidal model), this was not unexpected.

A quantitative analysis of the BRAN model's skill at replicating the drift currents was conducted using the Index of Agreement (IOA), presented in Willmott (1981) and Willmott *et al.* (1985), and the Mean Absolute Error (MAE), discussed in Willmott (1982) and Willmott & Matsuura (2005). A perfect agreement can be said to exist between the model and field observations if the IOA gives a measure of one, and complete disagreement will produce an IOA measure of zero (Willmott, 1981). The MAE is simply the average of the absolute values of the differences between the observed and modelled values.

The IOA and MAE values derived from comparisons of the U/V velocity components over the full measurement period at sites B2-1, C1-1 and G2-1 for all available water depths are presented in Table 2.1. The results confirm the conclusions drawn from analysis of the comparison time series plots. The IOA for both velocity components is good at sites B2-1 and G2-1 in the upper water column but reduces at deeper layers. This reflects the generally good match in the range, magnitude and direction of the measured and modelled drift currents at these sites, particularly in the upper water column. The IOA for both velocity components at site C1-1 is low, suggesting a poor agreement, reflecting the poor match in the timing of peaks and troughs in velocity observed in the time series plots.

Overall, the BRAN model data offered a reasonable match to the field measurements within the Browse project area, particularly in the upper water column. Given the stochastic methodology applied in far-field modelling, the use of a ten-year hindcast of BRAN current data allowed a realistic spatial distribution of potential plume trajectories and extents to be captured in aggregate. The BRAN model was considered suitable for use in the marine dispersion modelling studies.

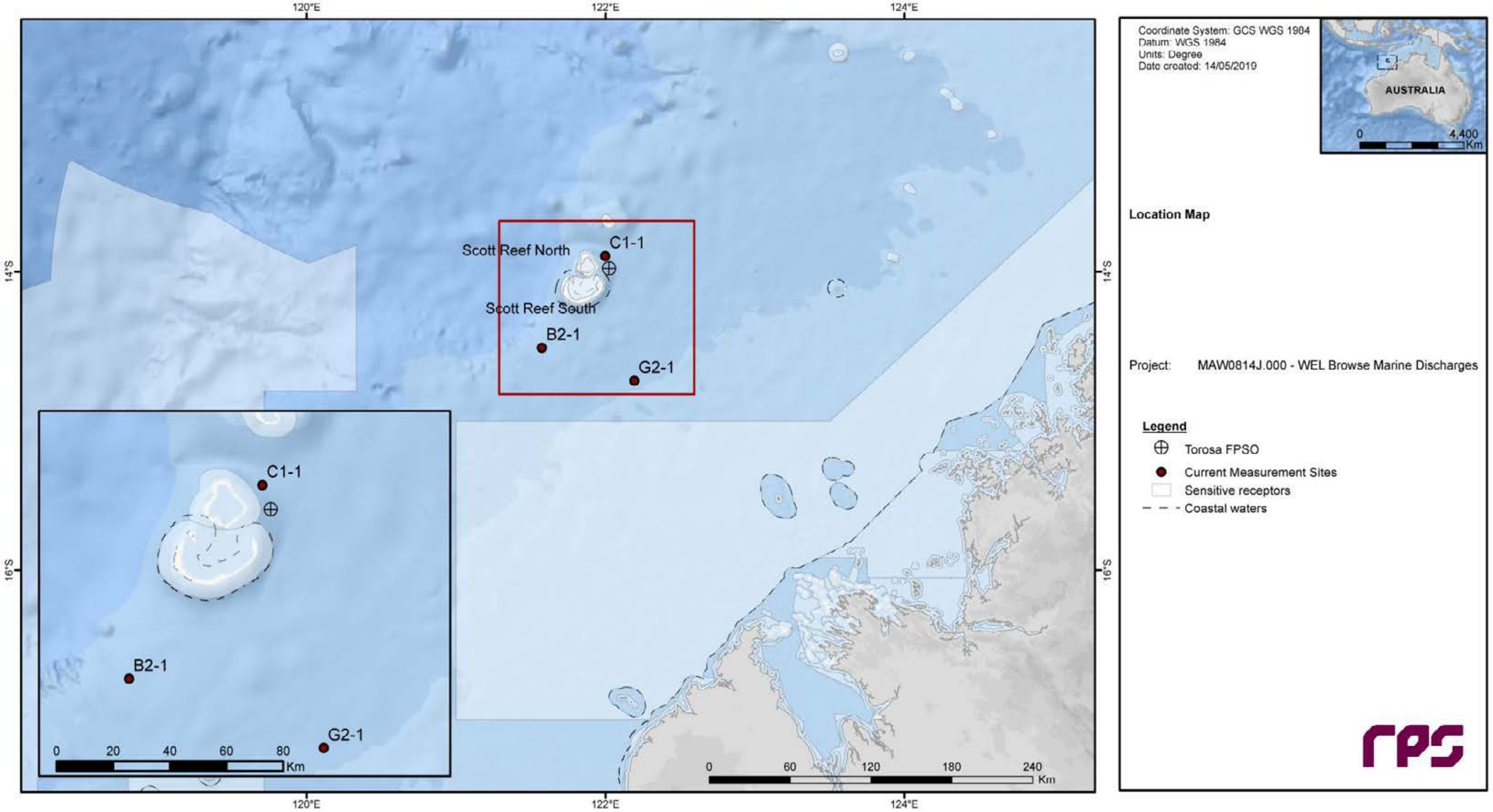

Figure 2.1 Locations of the proposed Torosa FPSO and the current measurement sites used for model validation, in proximity to Scott Reef, off the Kimberley Coast of Western Australia.

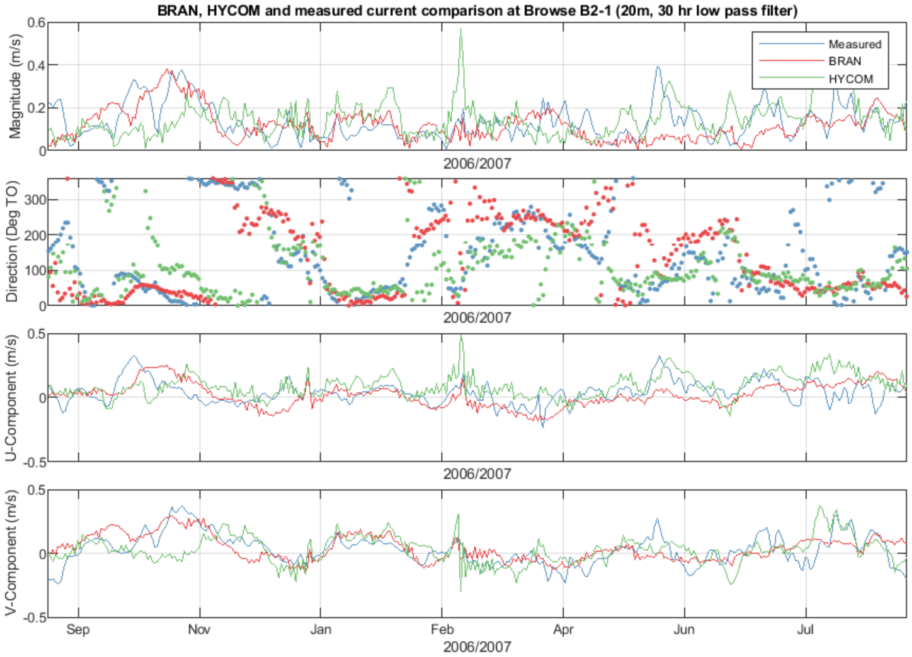

Figure 2.2 Comparisons between BRAN-predicted (red line), HYCOM-predicted (green line) and measured (blue line) non-tidal current data at site B2-1, at a depth of approximately 20 m, for the period of August 2006 to July 2007.

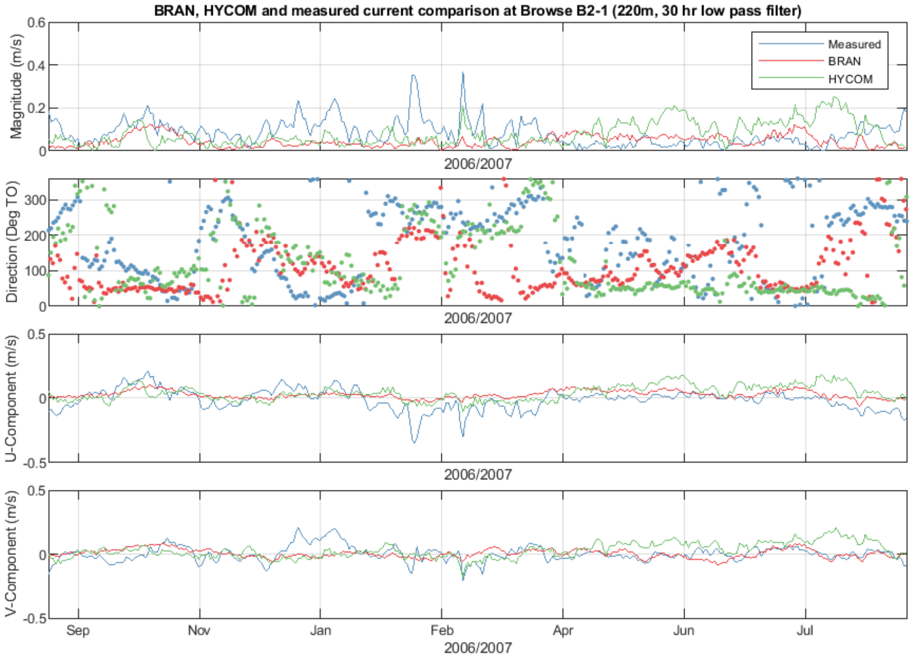

Figure 2.3 Comparisons between BRAN-predicted (red line), HYCOM-predicted (green line) and measured (blue line) non-tidal current data at site B2-1, at a depth of approximately 220 m, for the period of August 2006 to July 2007.

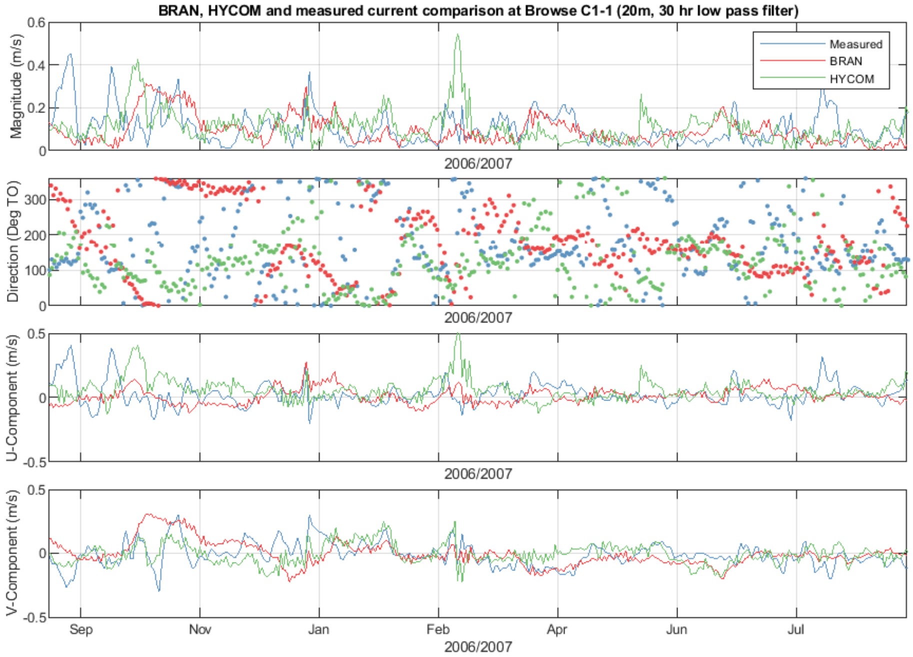

Figure 2.4 Comparisons between BRAN-predicted (red line), HYCOM-predicted (green line) and measured (blue line) non-tidal current data at site C1-1, at a depth of approximately 20 m, for the period of August 2006 to July 2007.

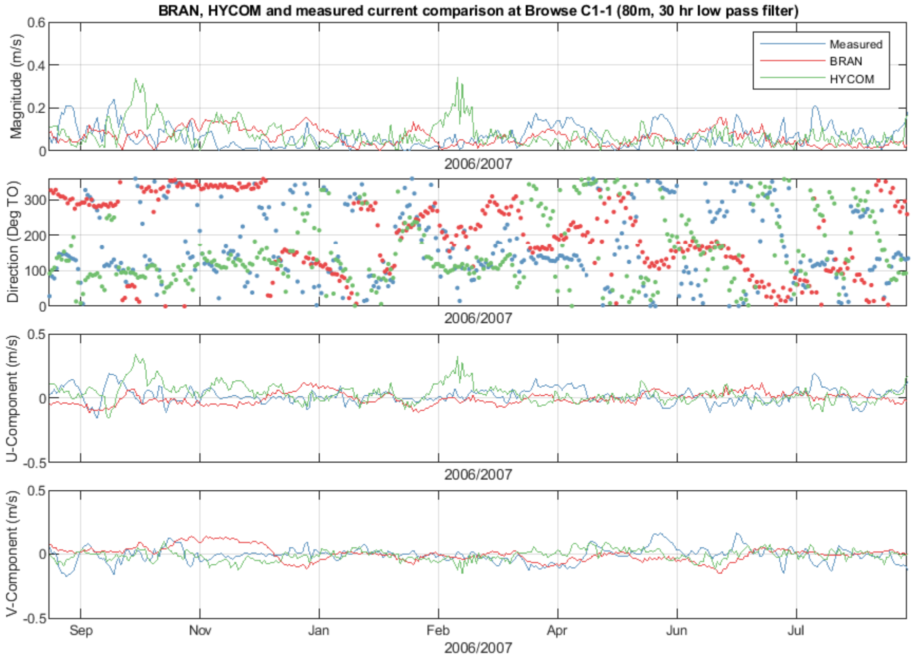

Figure 2.5 Comparisons between BRAN-predicted (red line), HYCOM-predicted (green line) and measured (blue line) non-tidal current data at site C1-1, at a depth of approximately 80 m, for the period of August 2006 to July 2007.

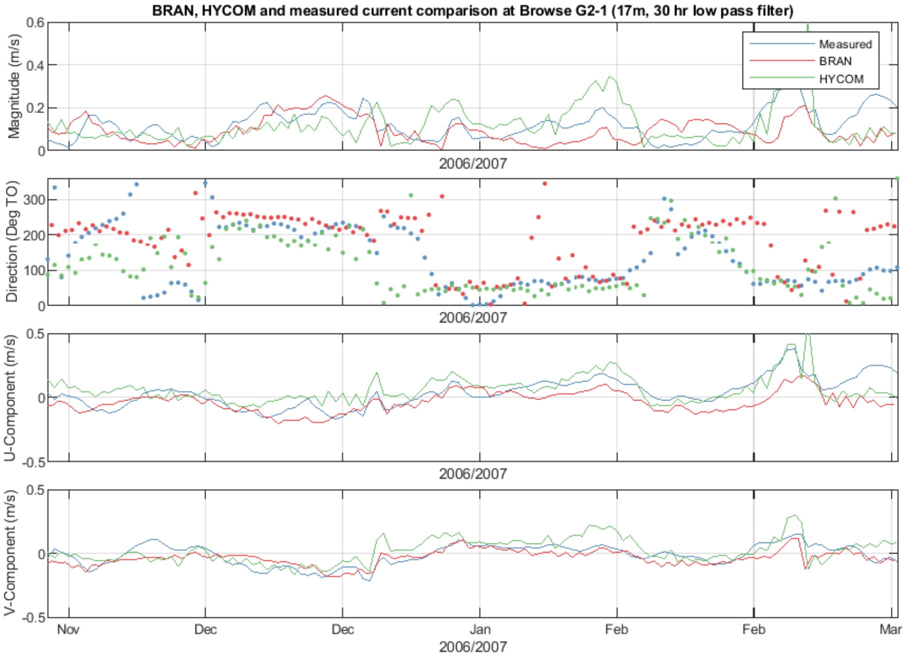

Figure 2.6 Comparisons between BRAN-predicted (red line), HYCOM-predicted (green line) and measured (blue line) non-tidal current data at site G2-1, at a depth of approximately 17 m, for the period of August 2006 to July 2007.

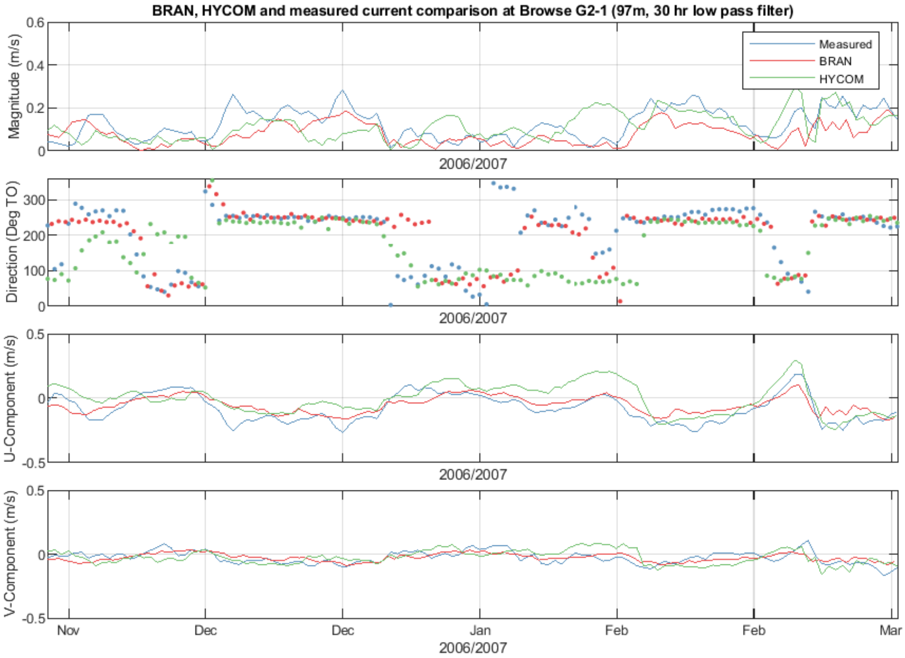

Figure 2.7 Comparisons between BRAN-predicted (red line), HYCOM-predicted (green line) and measured (blue line) non-tidal current data at site G2-1, at a depth of approximately 97 m, for the period of August 2006 to July 2007.

Table 2.1 Statistical comparison of BRAN-predicted and measured non-tidal current speeds along orthogonal component axes at the three measurement sites (2006-2007).

Site	Depth (m)	IOA		MAE (m/s)	
		U Component	V Component	U Component	V Component
B2-1	20.0	0.65	0.76	0.08	0.08
	60.0	0.68	0.77	0.06	0.06
	100.0	0.65	0.73	0.05	0.05
	160.0	0.70	0.63	0.05	0.05
	220.0	0.52	0.43	0.06	0.05
	300.0	0.47	0.52	0.04	0.04
	420.0	0.34	0.53	0.03	0.03
	547.4	0.46	0.40	0.02	0.02
C1-1	20.0	0.29	0.53	0.08	0.08
	80.0	0.28	0.32	0.06	0.06
	472.4	0.25	0.29	0.03	0.04
G2-1	17.0	0.71	0.81	0.08	0.05
	97.0	0.82	0.72	0.06	0.03
	192.0	0.45	0.17	0.06	0.06

2.3.1.2.3 Mesoscale Currents at the Spill Locations

Figure 2.8 and Figure 2.9 show the monthly distributions of current speeds and directions for the BRAN data points closest to the spill locations for Scenarios 1 to 3 and Scenario 4, respectively. Note that the convention for defining current direction is the direction towards which the current flows.

The data indicates that higher average current speeds are characteristic of the November to March period, with the highest average speeds (0.14 m/s) occurring near the Scenario 1 to 3 spill sites in November. Lower average current speeds are more common during the April to September period, with the lowest average speeds (0.04 m/s) occurring near the Scenario 1 to 3 spill sites in August. Peak current speeds across all months and sites are approximately 0.40 m/s.

The prevailing current direction at the spill sites varies throughout the year, with north-easterly currents dominant between November and February and south-westerly currents dominant in April and May. Current directions during the March and June to October periods are variable across all sites.

The extracted current data near the spill locations provides an insight into the expected initial behaviour of any released oil due to the drift currents alone. Oil moving beyond the release sites, particularly towards the coast, would be subject to considerable variation in the drift current regime.

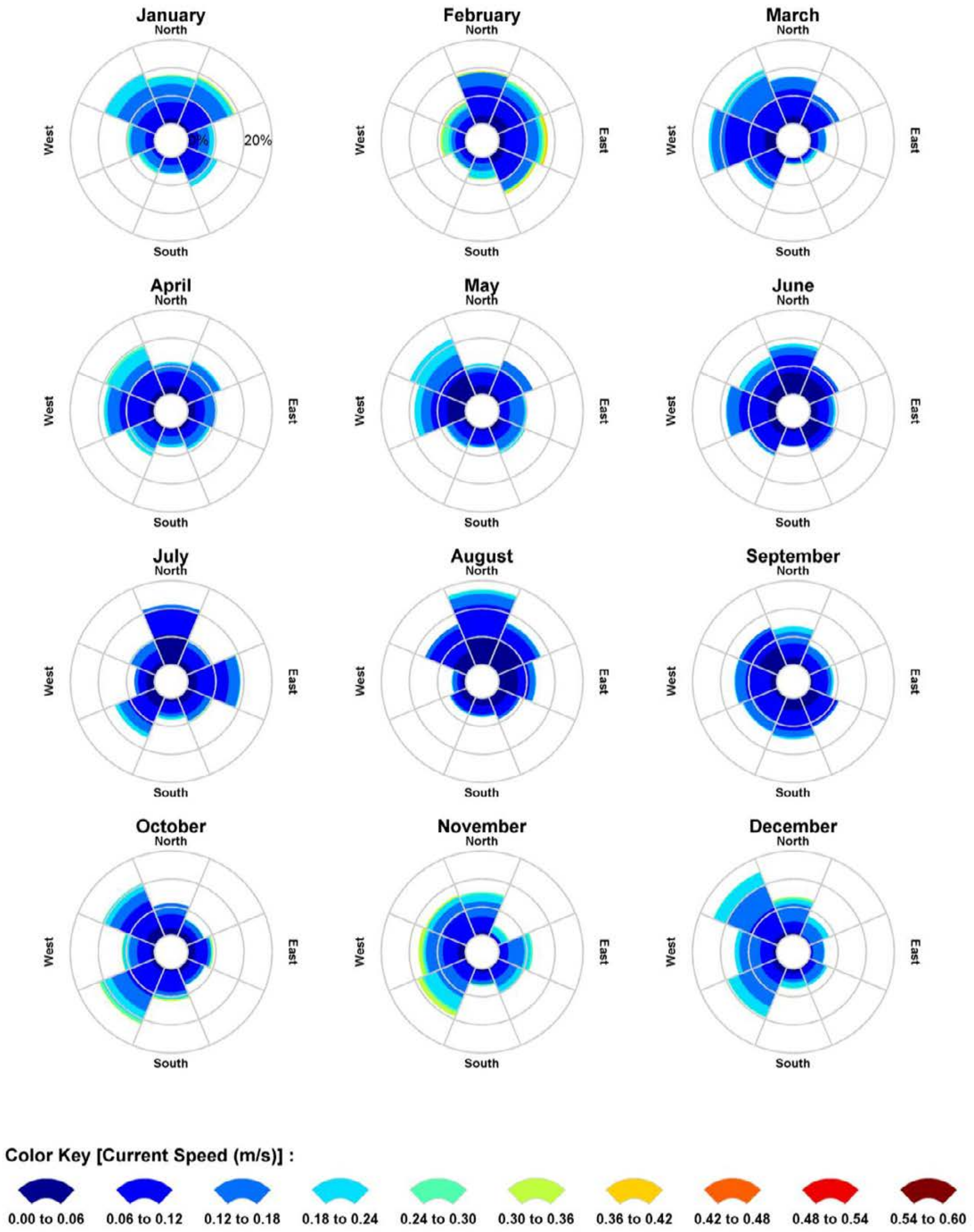

Figure 2.8 Monthly current distribution (2006-2015, inclusive) derived from the BRAN database near to the Scenario 1, 2 and 3 spill locations. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

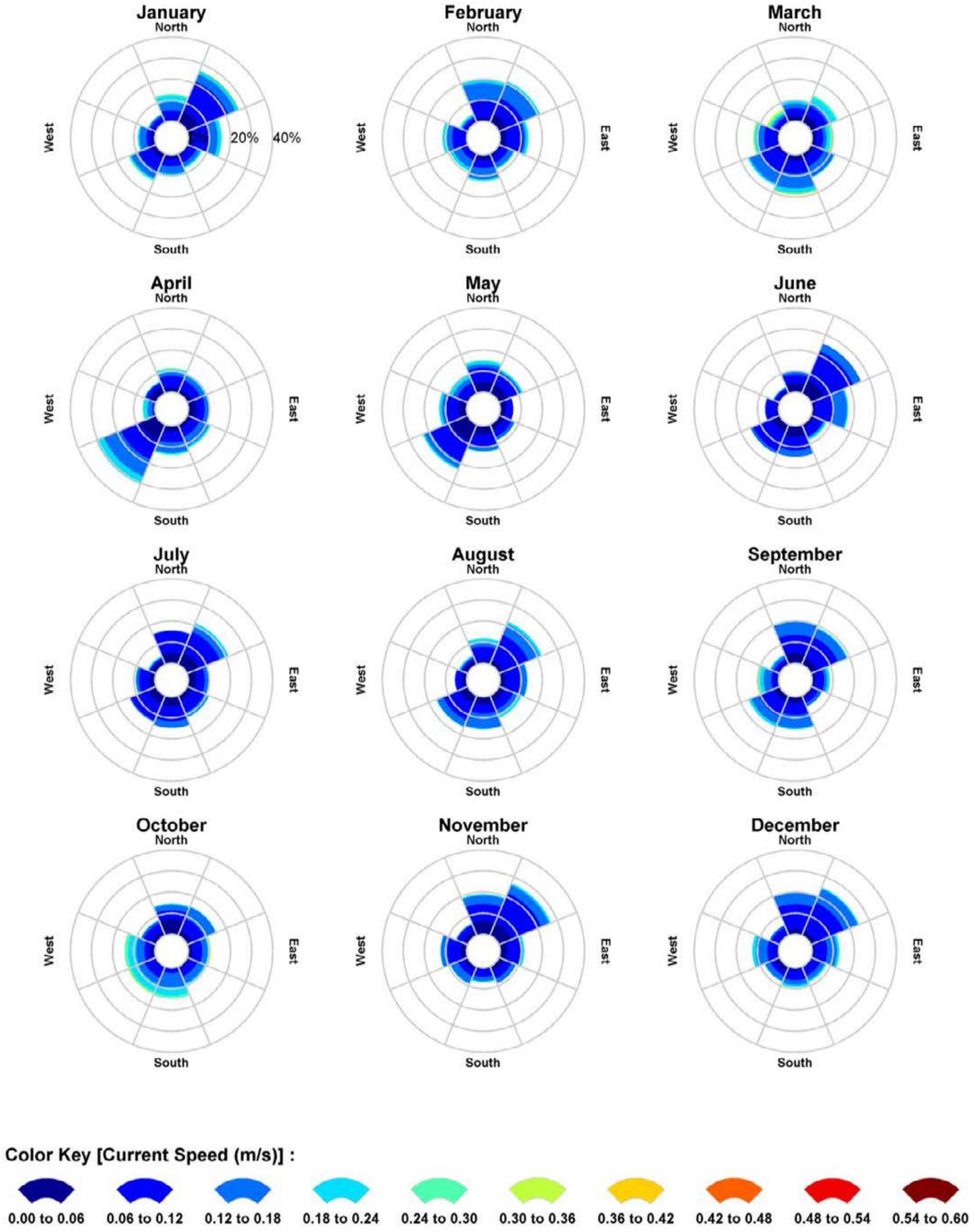

Figure 2.9 **Monthly current distribution (2006-2015, inclusive) derived from the BRAN database near to the Scenario 4 spill location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.**

2.3.1.3 Tidal Circulation

2.3.1.3.1 Description of Tidal Model: HYDROMAP

As the BRAN model does not include tidal forcing, and because the data is only available at a daily frequency, a tidal model was developed for the study region using RPS' three-dimensional hydrodynamic model, HYDROMAP.

The model formulations and output (current speed, direction and sea level) of this model have been validated through field measurements around the world for more than 30 years (Isaji & Spaulding, 1984, 1986; Isaji *et al.*, 2001; Zigic *et al.*, 2003). HYDROMAP current data has also been widely used as input to forecasts and hindcasts of oil spill migrations in Australian waters. This modelling system forms part of the National Marine Oil Spill Contingency Plan for the Australian Maritime Safety Authority (AMSA, 2002).

HYDROMAP simulates the flow of ocean currents within a model region due to forcing by astronomical tides, wind stress and bottom friction. The model employs a sophisticated dynamically nested-gridding strategy, supporting up to six levels of spatial resolution within a single domain. This allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, or of particular interest to a study.

The numerical solution methodology of HYDROMAP follows that of Davies (1977a, 1977b) with further developments for model efficiency by Owen (1980) and Gordon (1982). A more detailed presentation of the model can be found in Isaji & Spaulding (1984).

2.3.1.3.2 Tidal Domain Setup

A HYDROMAP model was established over a domain that extended approximately 3,300 km east-west by 3,100 km north-south over the eastern Indian Ocean. The grid extends beyond Eucla in the south and beyond Bathurst Island in the north (Figure 2.10). Approximately 98,600 cells were used to define the region, with four layers of sub-gridding applied to provide variable resolution throughout the domain. The resolution at the primary level was 15 km. The finer levels were defined by subdividing these cells into 4, 16 and 64 cells, resulting in resolutions of 7.5 km, 3.75 km and 1.88 km.

The finer grids were allocated in a step-wise fashion to areas where higher resolution of circulation patterns was required to resolve flows through channels, around shorelines or over more complex bathymetry. Figure 2.11 shows a zoomed subset of the hydrodynamic model grid in the Scott Reef region, showing the finer resolution grids surrounding Scott Reef, the numerous shoals and islands, and complex areas of the mainland coastline.

Modelling of the tidal circulation at relatively fine scales in the topographically-complex area around Scott Reef was achieved using an additional model sub-domain with resolutions ranging down to <500 m. Major tidal channels that occur across the reef flats of North Scott Reef were represented in this model, with tidal current flows across the rest of the flats known to be minimal.

High-resolution (~50 m) bathymetric data covering Scott and Seringapatam Reefs and the Brecknock, Torosa and Calliance gas fields was supplied by Woodside. Beyond these areas, bathymetric data used to define the three-dimensional shape of the study domain was extracted from the Geoscience Australia 250 m resolution bathymetry database (GA, 2009) and the CMAP electronic chart database, supplemented where necessary with manual digitisation of chart data supplied by the Australian Hydrographic Office. Depths in the domain ranged from shallow intertidal areas through to approximately 7,200 m.

2.3.1.3.3 Tidal Boundary Conditions

Ocean boundary data for the HYDROMAP model was obtained from the TOPEX/Poseidon global tidal database (TPXO7.2) of satellite-measured altimetry data, which provided estimates of tidal amplitudes and phases for the eight dominant tidal constituents (designated as K_2, S_2, M_2, N_2, K_1, P_1, O_1 and Q_1) at a horizontal scale of approximately 0.25°. Using the tidal data, sea surface heights are firstly calculated along the open boundaries at each time step in the model.

The TOPEX/Poseidon satellite data is produced, and quality controlled by the US National Atmospheric and Space Agency (NASA). The satellites, equipped with two highly accurate altimeters capable of taking sea level measurements accurate to less than ±5 cm, measured oceanic surface elevations (and the resultant tides) for over 13 years (1992-2005). In total, these satellites carried out more than 62,000 orbits of the planet. The TOPEX/Poseidon tidal data has been widely used amongst the oceanographic community, being the subject of more than 2,100 research publications (e.g. Andersen, 1995; Ludicone *et al.*, 1998; Matsumoto *et al.*, 2000; Kostianoy *et al.*, 2003; Yaremchuk & Tangdong, 2004; Qiu & Chen, 2010). As such, the TOPEX/Poseidon tidal data is considered suitably accurate for this study.

2.3.1.3.4 Tidal Elevation Validation

For the purpose of verification of the tidal predictions, the model output was compared against independent predictions of tides using the XTide database (Flater, 1998). The XTide database contains harmonic tidal constituents derived from measured water level data at locations around the world. Overall, there are more than 120 tidal stations within the HYDROMAP model domain; however, some of these are located in areas that are not sufficiently resolved by this large-scale ocean model. More than 80 stations along the coastline were suitable for comparisons of the model performance with the observed data. These stations covered the mid-to-northwest regions of the Western Australian coastline, encompassing the locales of the marine discharges considered in this study (Figure 2.10 and Figure 2.11). For the purposes of brevity and clarity, a selected representative subset of the available tidal station validation data is presented here.

Water level time series for the selected subset of ten stations are shown in Figure 2.12 and Figure 2.13 for a one-month period (January 2018). All comparisons show that the model produces a very good match to the known tidal behaviour for a wide range of tidal amplitudes and clearly represents the varying diurnal and semi-diurnal nature of the tidal signal.

The model skill was further evaluated through a comparison of the predicted and observed tidal constituents, derived from an analysis of model-predicted time series at each of the tidal station locations. Scatter plots of the observed and modelled amplitude (top) and phase (bottom) of the five dominant tidal constituents (S_2, M_2, N_2, K_1 and O_1) for all relevant stations within the model domain (>80) are presented in Figure 2.14. The red line on each plot shows the 1:1 line, which would indicate a perfect match between the modelled and observed data. Note that the data is generally closely aligned to the 1:1 line demonstrating the high quality of the model performance.

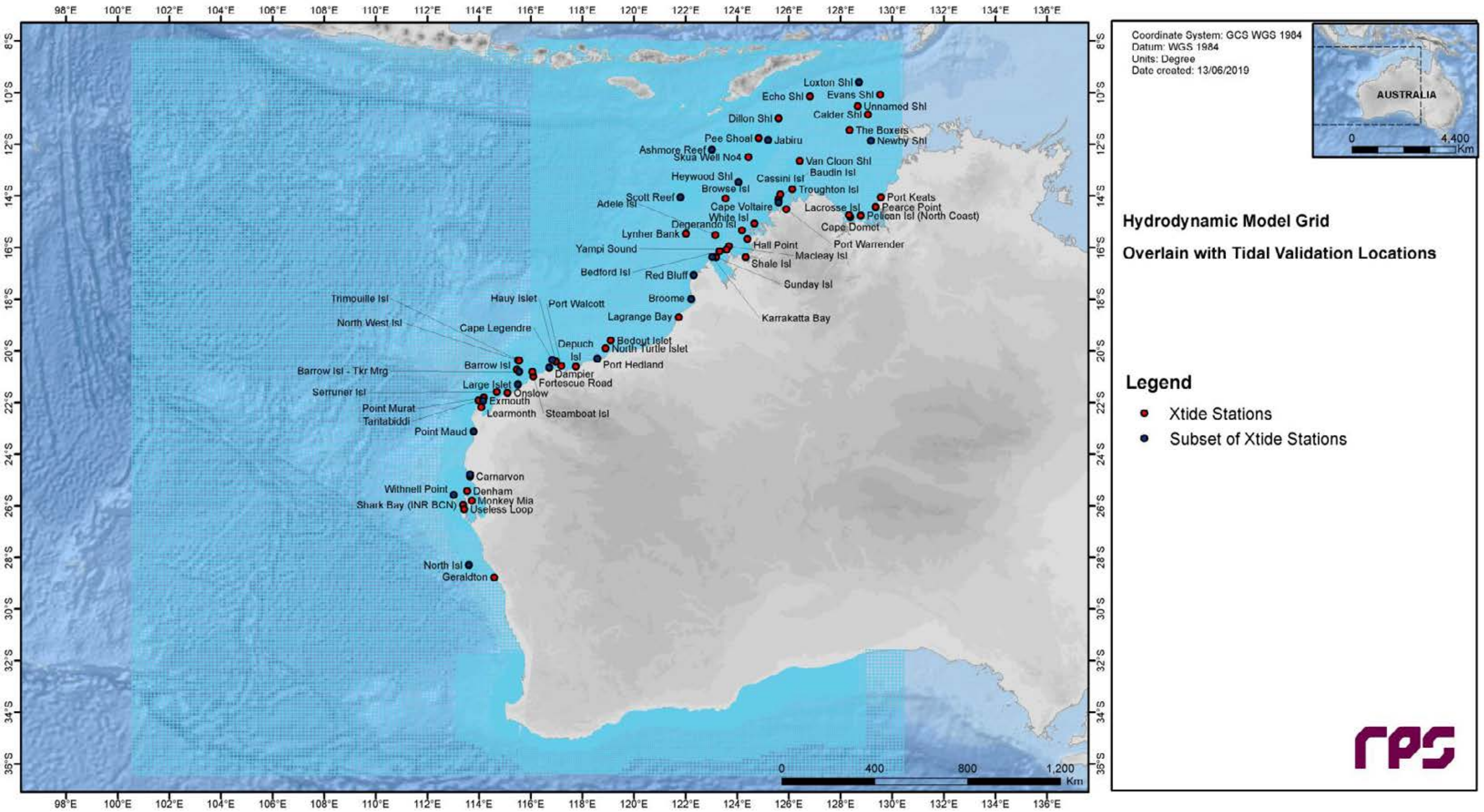

Figure 2.10 Hydrodynamic model grid (blue wire mesh) used to generate the tidal currents, showing the full domain in context with the continental land mass and the locations available for tidal comparisons (red and blue labelled dots). Higher-resolution areas are indicated by the denser mesh zones.

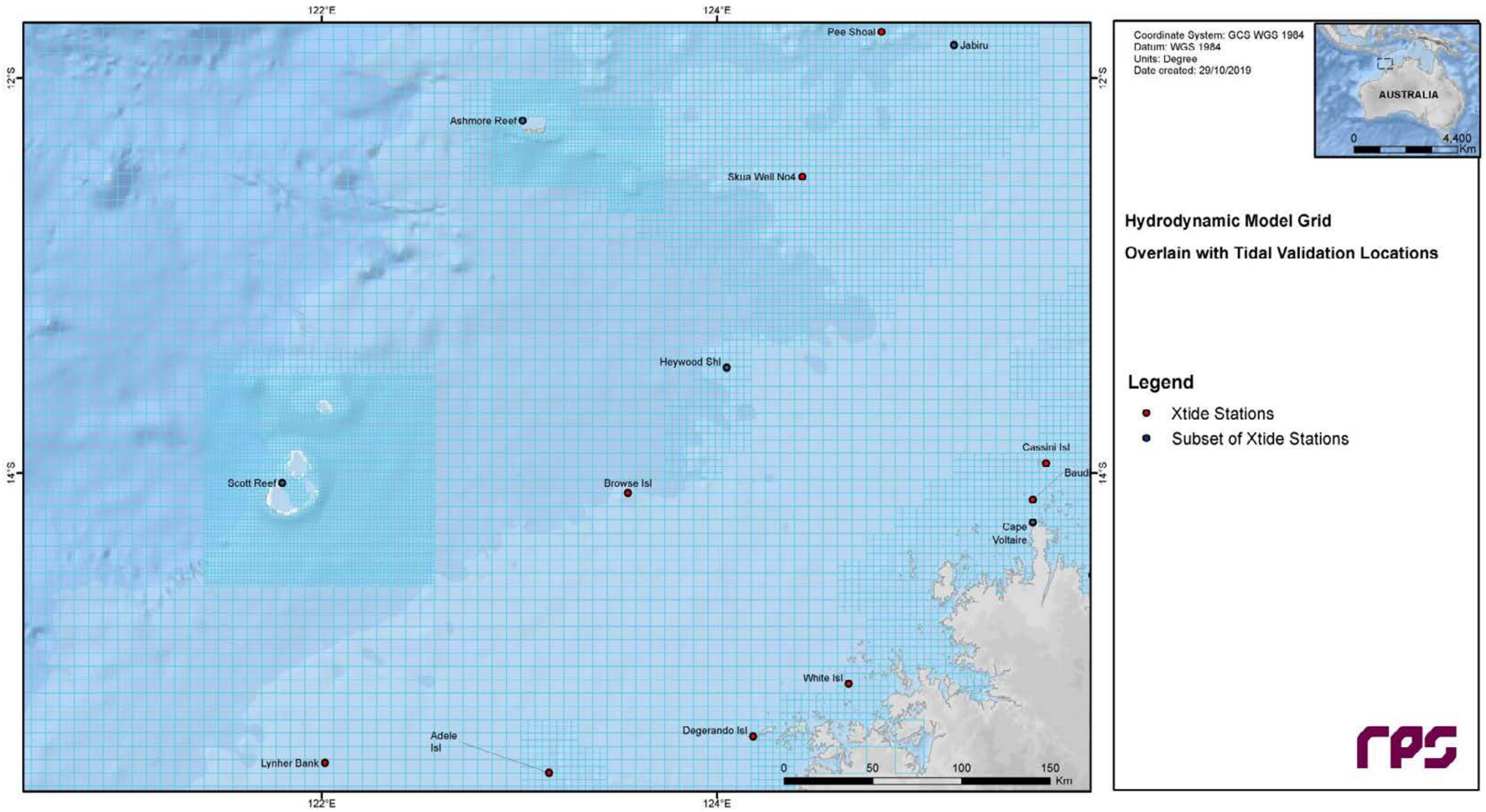

Figure 2.11 Zoomed subset of the hydrodynamic model grid (blue wire mesh) for the Scott Reef area, showing the locations available for tidal comparisons (red and blue labelled dots). Higher-resolution areas are indicated by the denser mesh zones.

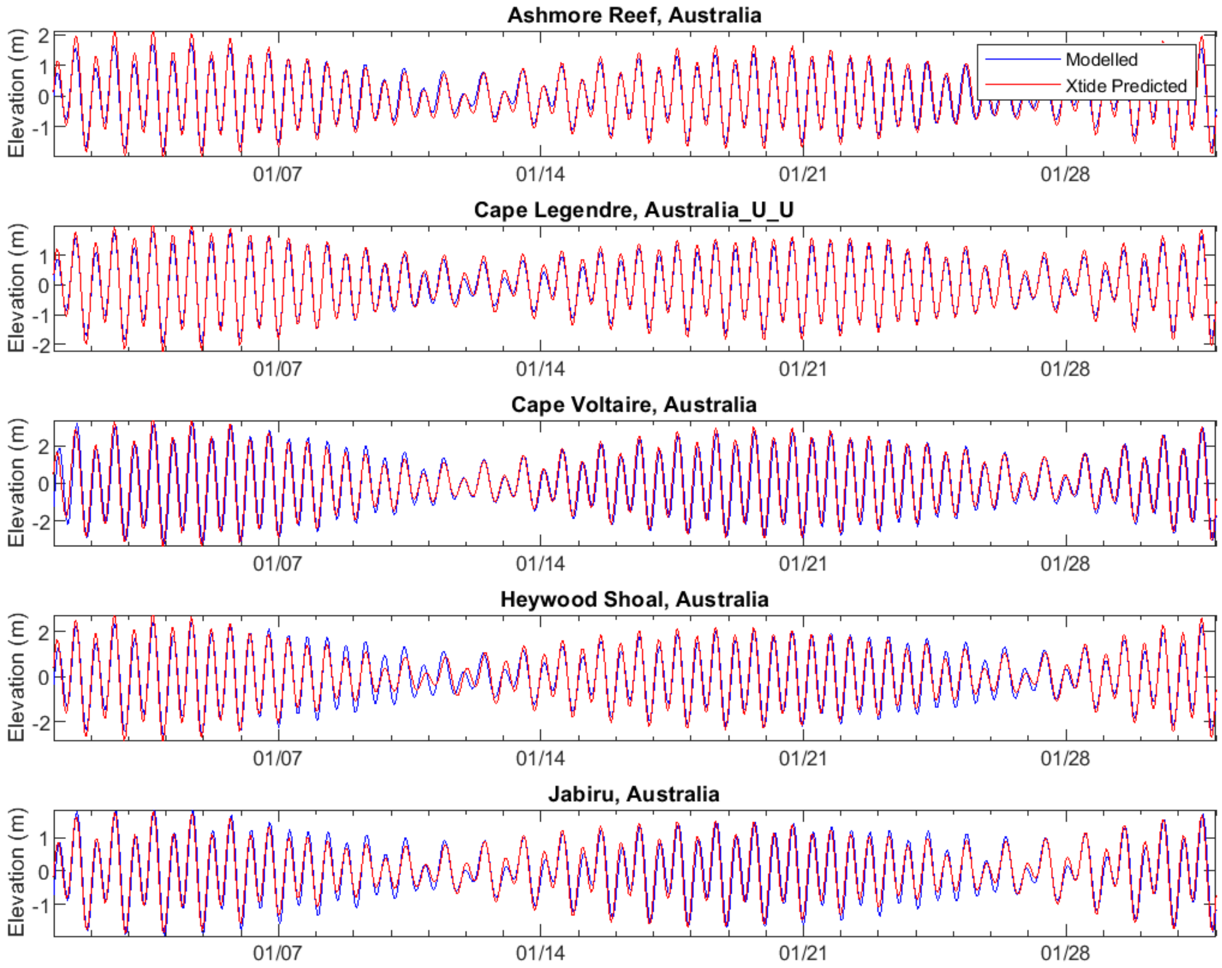

Figure 2.12 Comparisons between the predicted (blue line) and observed (red line) surface elevation variations at five locations in the north-east of the tidal model domain for January 2018.

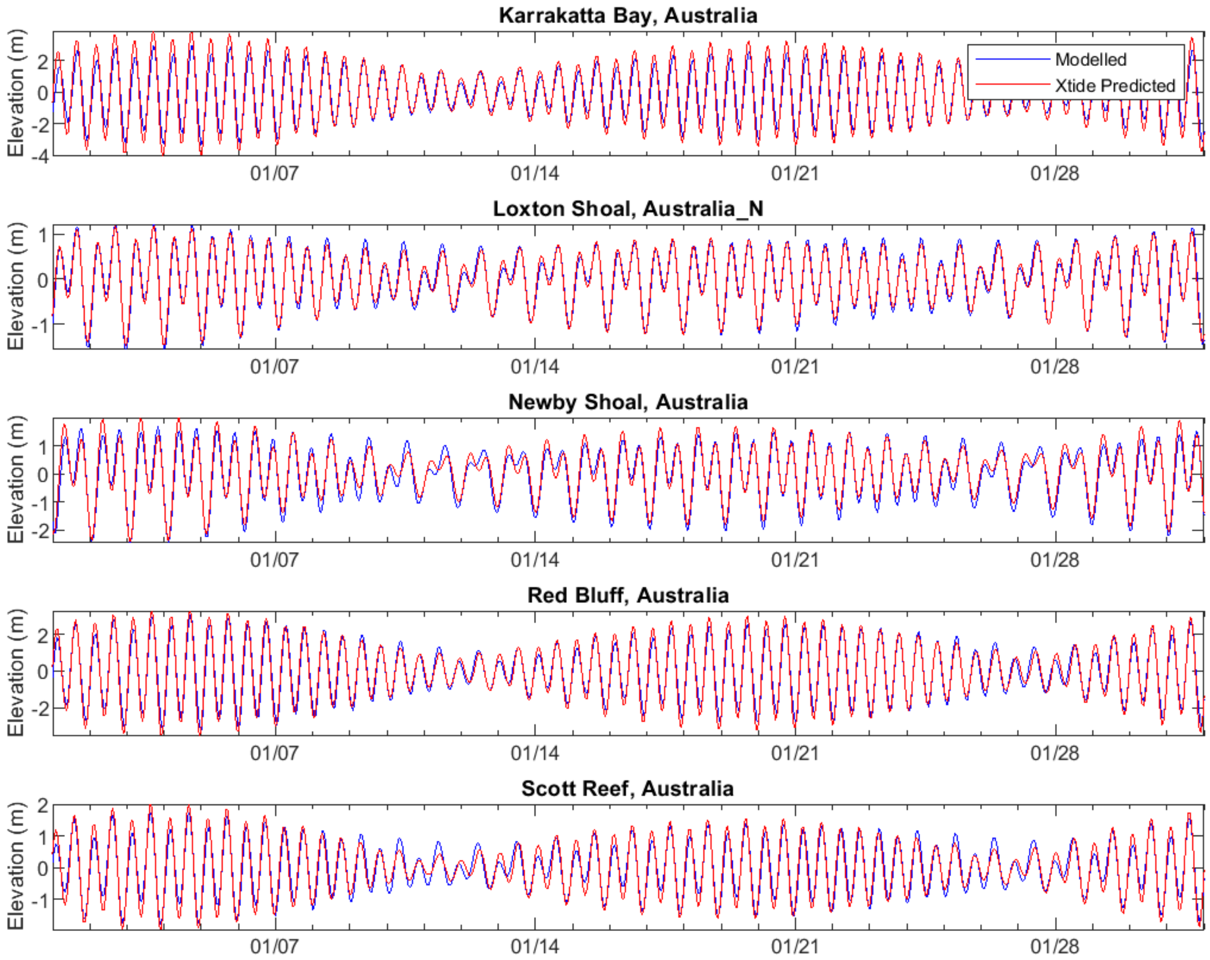

Figure 2.13 Comparisons between the predicted (blue line) and observed (red line) surface elevation variations at five locations in the north-east of the tidal model domain for January 2018.

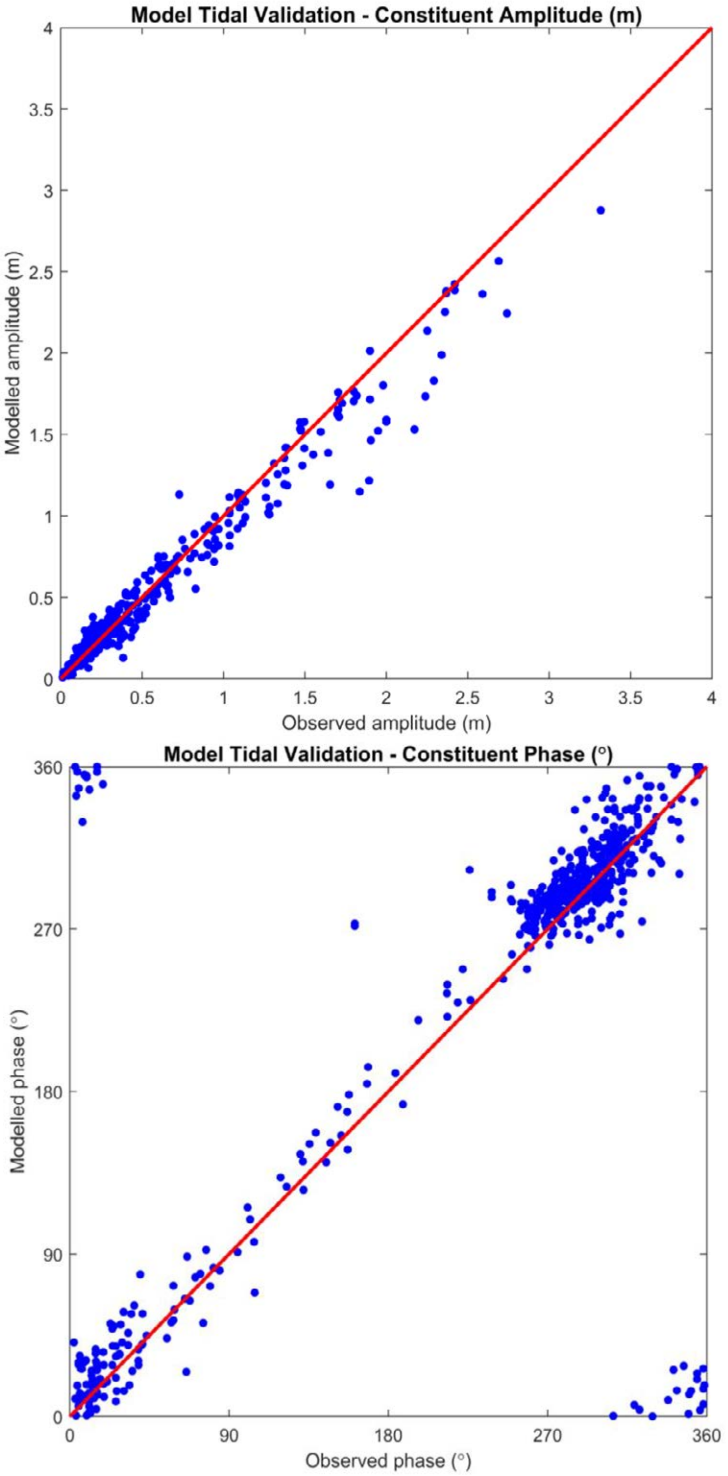

Figure 2.14 Comparisons between modelled and observed tidal constituent amplitudes (top) and phases (bottom) at all relevant stations (>80) in the HYDROMAP model domain. The red line indicates a 1:1 correlation between the modelled and observed data.

2.3.1.3.5 Tidal Currents at the Spill Locations

Figure 2.15 to Figure 2.17 show the monthly distributions of current speeds and directions for the HYDROMAP data points closest to the spill locations for Scenario 1, Scenarios 2 and 3, and Scenario 4, respectively. Note that the convention for defining current direction is the direction towards which the current flows.

The data indicates cyclical tidal flow directions along a northwest-southeast axis at the Scenario 2 to 4 sites, and along a north-south axis at the Scenario 1 site which is relatively close to Scott Reef and experiences steering of the tidal flow direction around the reef. Maximum speeds at the Scenario 1 to 3 sites are approximately 0.25-0.3 m/s, with peak speeds at the Scenario 4 site being around 0.4 m/s.

The extracted current data near the spill locations provides an insight into the expected initial behaviour of any released oil due to the tidal currents alone. Oil moving beyond the release sites, particularly towards the coast, would be subject to considerable variation in the tidal current regime.

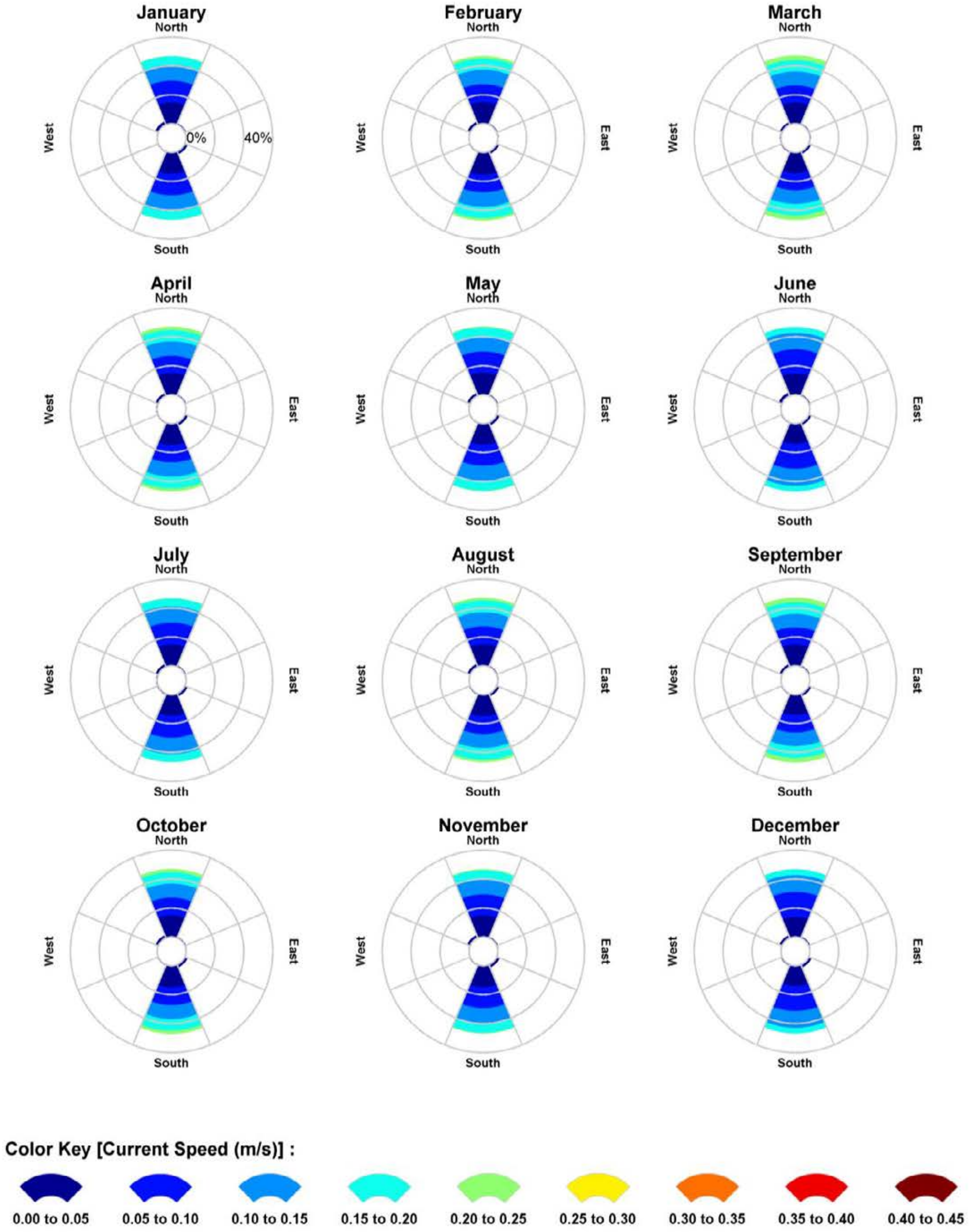

Figure 2.15 Monthly current distribution (2006-2015, inclusive) derived from the HYDROMAP database near to the Scenario 1 spill location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

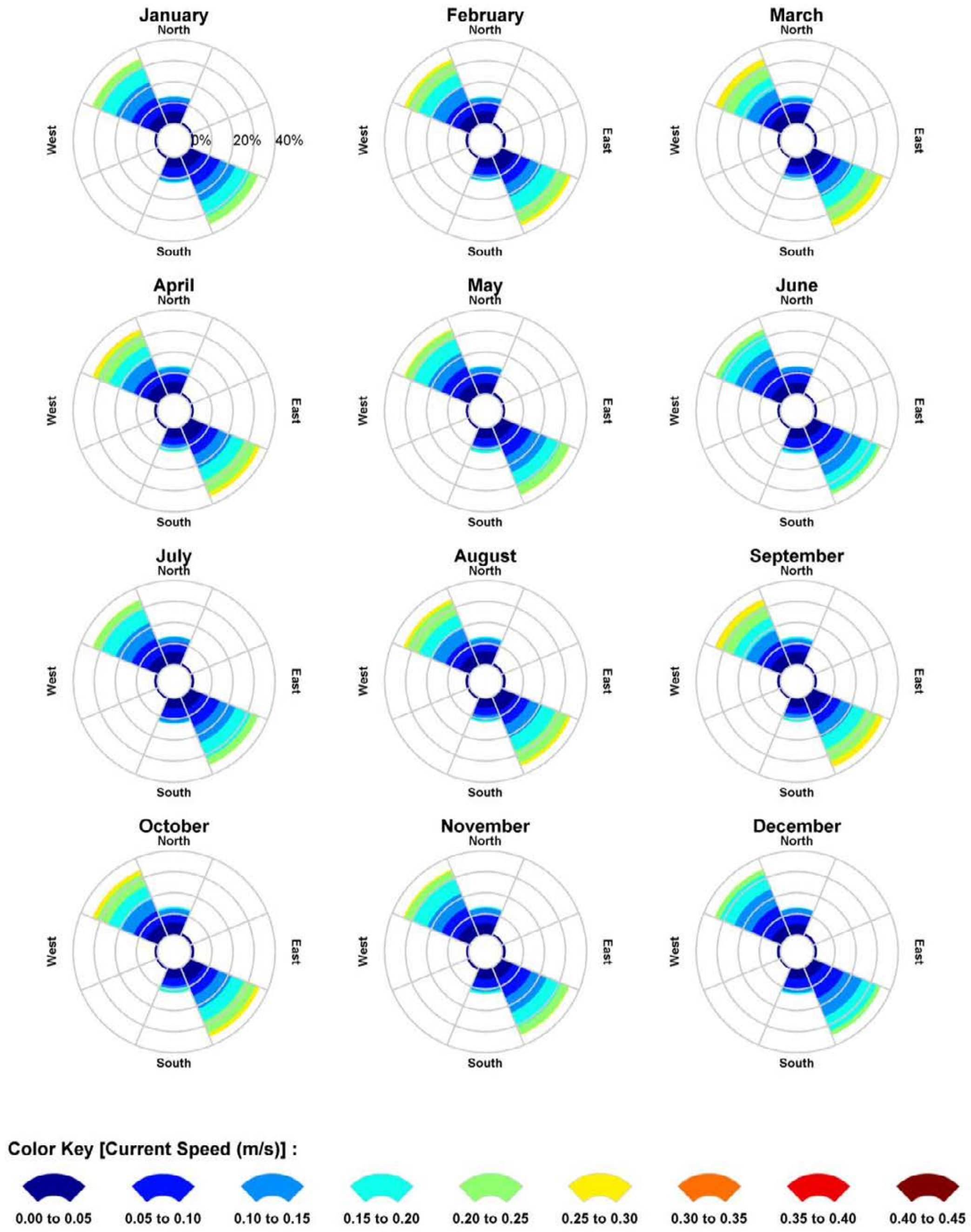

Figure 2.16 Monthly current distribution (2006-2015, inclusive) derived from the HYDROMAP database near to the Scenario 2 and 3 spill locations. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

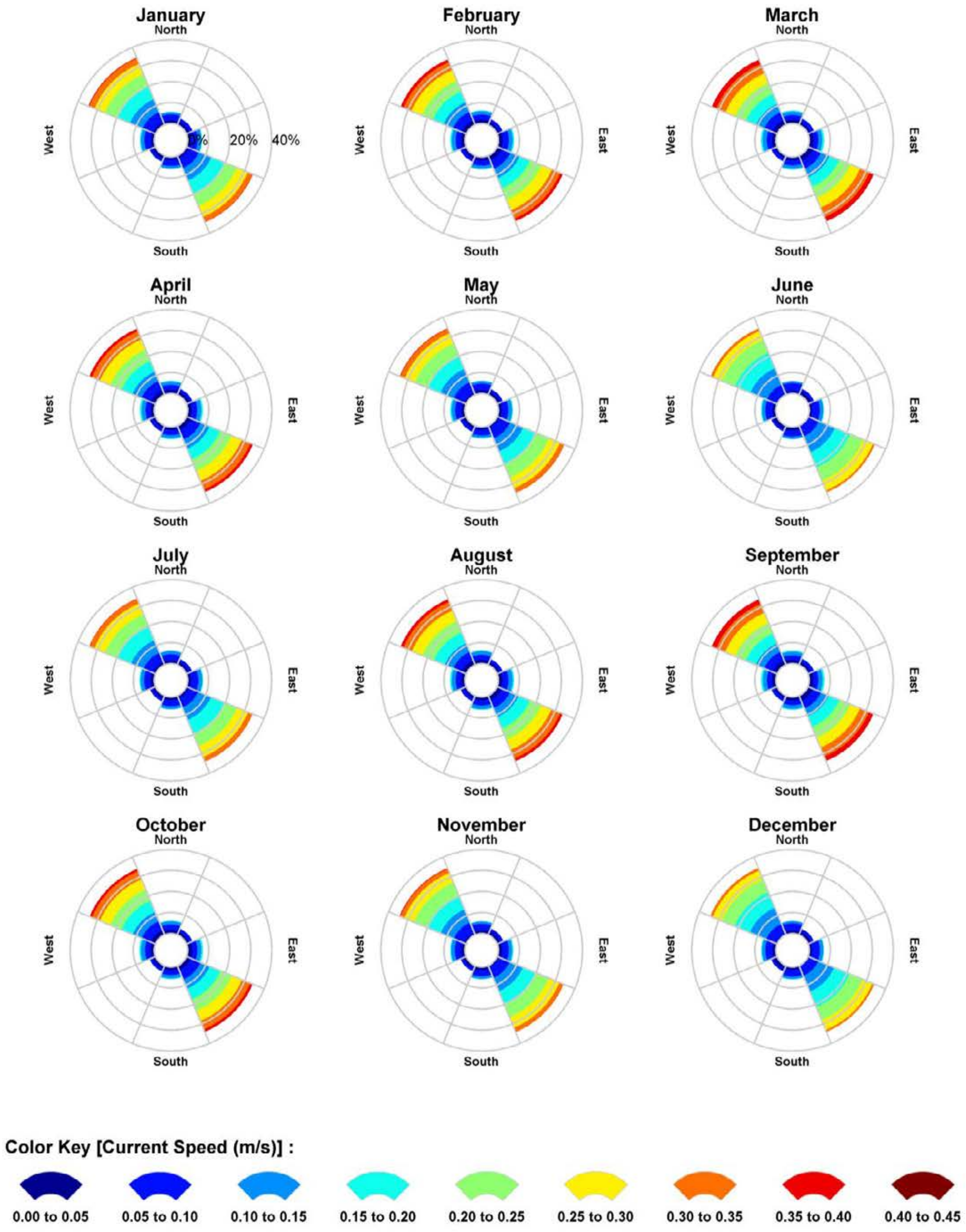

Figure 2.17 Monthly current distribution (2006-2015, inclusive) derived from the HYDROMAP database near to the Scenario 4 spill location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

2.3.2 Wind Data

To account for the influence of the wind on surface-bound oil slicks, representation of the wind conditions was provided by spatial wind fields sourced from the National Center for Environmental Prediction (NCEP), via the National Oceanic and Atmospheric Administration (NOAA) and Cooperative Institute for Research in Environmental Sciences (CIRES) Climate Diagnostics Center (CDC). The NCEP Climate Forecast System Reanalysis (CFSR; Saha *et al.*, 2010) is a fully-coupled, data-assimilative hindcast model representing the interaction between the Earth's oceans, land and atmosphere. The gridded data output, including surface winds, is available at 0.25° resolution and 1-hourly time intervals.

Time series of wind speed and direction were extracted from the CFSR database for all nodes in the model domain for the same temporal coverage as the current data (2006-2015, inclusive). The data was assumed to be a suitably representative sample of the wind conditions over the study area for future years.

Figure 2.18 and Figure 2.19 show the monthly distributions of wind speeds and directions for the CFSR data points closest to the spill locations for Scenarios 1 to 3 and Scenario 4, respectively. Note that the convention for defining wind direction is the direction from which the wind blows.

The wind data indicates predominantly easterly directions between May and July at the Scenario 1 to 3 spill sites, and westerly/south-westerly directions dominating in the October to February period. At the Scenario 4 spill site, easterly/south-easterly directions are most common between April and August, with southerly and westerly directions most prominent between September and March. Average wind speeds across the year near all spill sites vary in the range 5.9-6.5 m/s, with year-round maximum speeds of 25.5-29.4 m/s.

The extracted wind data near the spill location suggests possible initial trajectories due to the wind acting on surface slicks in the absence of any current effects. Note that the actual trajectories of surface slicks will be the net result of a combination of the prevailing wind and current vectors acting at a given time and location.

Figure 2.18 Monthly wind distribution (2006-2015, inclusive) derived from the CFSR database near to the Scenario 1, 2 and 3 spill locations. The colour key shows the wind magnitude, the compass direction provides the direction from which the wind is blowing, and the size of the wedge gives the percentage of the record.

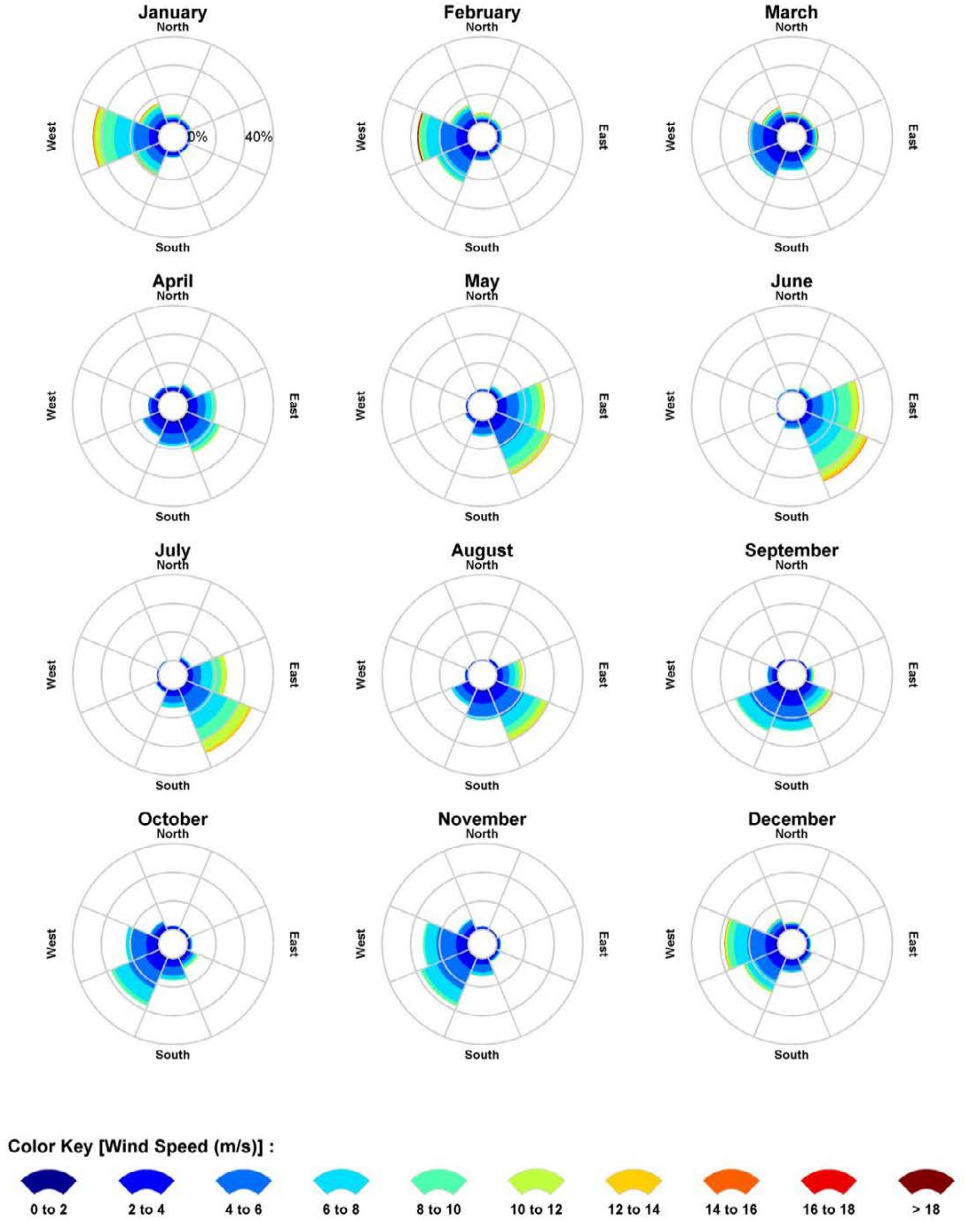

Figure 2.19 Monthly wind distribution (2006-2015, inclusive) derived from the CFSR database near to the Scenario 4 spill location. The colour key shows the wind magnitude, the compass direction provides the direction from which the wind is blowing, and the size of the wedge gives the percentage of the record.

2.3.3 Water Temperature and Salinity Data

The World Ocean Atlas 2013 (WOA13) is provided by NOAA and is a hindcast model of the climatological fields of in situ temperature, salinity, and a number of additional variables (NOAA, 2013a). WOA13 has a 0.25° resolution and has standard depth levels ranging from the water surface to 5,500 m (Locarnini *et al.*, 2013; Zweng *et al.*, 2013). Vertical profiles of sea temperature and salinity at the spill locations were retrieved from a data point in the WOA13 database near the Torosa FPSO location (13° 52' 30" S, 121° 52' 30" E), with monthly averages used as input to both SIMAP and OILMAP.

Figure 2.20 shows the variation in water temperature and salinity both seasonally and over depth. During the period from May to September, surface mixing is evident over the upper 50-100 m of the water column (where the depth is approximately 300 m at this location). In contrast, during the period from October to April, the surface mixed layer is shallower, indicating stronger thermal stratification. The average temperature over the upper 300 m of the water column varies between approximately 10-30 °C across the year, while the average salinity over this depth range varies between approximately 33.8-34.8 PSU year-round.

2.3.4 Dispersion

A horizontal dispersion coefficient of 10 m^2/s was used to account for dispersive processes acting at the surface that are below the scale of resolution of the input current field, based on typical values for coastal waters (Okubo, 1971). Dispersion rates within the water column (applicable for entrained and dissolved plumes of hydrocarbons) were specified at 1 m^2/s, based on empirical data for the dispersion of hydrocarbon plumes over the North West Shelf (King & McAllister, 1998).

2.3.5 Replication

Multiple replicate simulations were completed for the defined scenarios to account for trends and variations in the trajectory and weathering of spilled oil, with an even number of replicates completed using samples of metocean data that commenced within each month. For Scenario 1, a total of 100 replicate simulations were run over an annual period; for Scenarios 2-4, a total of 200 replicate simulations were run over an annual period.

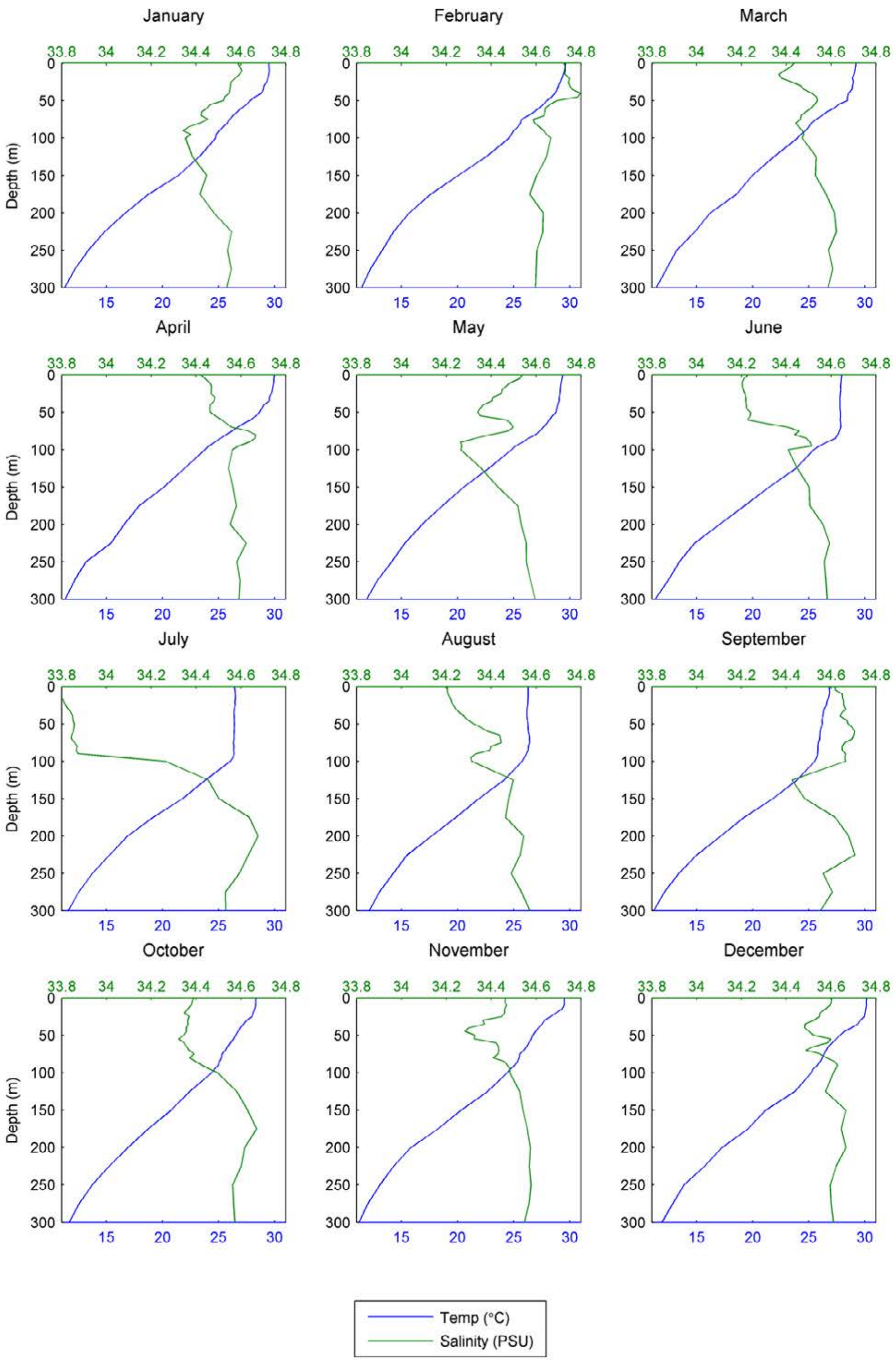

Figure 2.20 Temperature (blue line) and salinity (green line) profiles derived from the WOA13 database near the Torosa FPSO location (13° 52' 30" S, 121° 52' 30" E). Depth of 0 m is the water surface.

2.3.6 Contact Thresholds

2.3.6.1 Overview

The SIMAP model will track oil concentrations to very low levels. Hence, it is useful to define meaningful threshold concentrations for the recording of contact by oil components and determining the probability of exposure at a location (calculated from the number of replicate simulations in which this contact occurred).

The judgement of meaningful levels is complicated and will depend upon the mode of action, sensitivity of the biota contacted, the duration of the contact and the particular toxicity of the compounds that are represented in the oil. The latter factor is further complicated by the change in the composition of an oil type over time due to weathering processes. Without specific testing of the oil types, at different states of weathering against a wide range of the potential local receptors, such considerations are beyond the scope of this investigation.

For this case, thresholds for floating, entrained and dissolved aromatic hydrocarbons were specified by Woodside for use in defining the potential zone of influence of the spill event. These thresholds are summarised in Table 2.2 and discussed afterwards.

Table 2.2 Summary of the thresholds applied in this study.

Floating Oil Concentration (g/m^2)	Shoreline Oil Concentration (g/m^2)	Entrained Oil Concentration (ppb)	Dissolved Aromatic Hydrocarbon Concentration (ppb)
1 10	100	100 (Scenarios 1-3) 500 (Scenario 4)	50 (Scenarios 1-3) 500 (Scenario 4)

2.3.6.2 Floating Oil

Floating oil concentrations are relevant to describing the risks of oil coating emergent reefs, vegetation in the littoral zone and shoreline habitats, as well as the risk to wildlife found on the water surface, such as marine mammals, reptiles and birds.

Estimates for the minimal thickness of floating oil that might result in harm to seabirds through ingestion from preening of contaminated feathers, or the loss of the thermal protection of their feathers, has been estimated by different researchers at approximately 10 g/m^2 (French-McCay, 2009) to 25 g/m^2 (Scholten *et al.*, 1996; Koops *et al.*, 2004). Hence, the 10 g/m^2 threshold is likely to be moderately conservative in terms of environmental harm for effects on seabirds, for example. The lower threshold of 1 g/m^2 is likely to be an indicator of where there is a visual presence of an oil slick that may trigger social and economic impacts but where there is little potential for environmental impact.

It is important to note that real spill events generate surface slicks that break up into multiple patches separated by areas of open water. Concentrations calculated and presented in this study represent necessary areal averaging over discrete model cells, and therefore indicate the potential for both higher and lower relative concentrations in the surrounding space.

2.3.6.3 Shoreline Oil

Shoreline oil concentrations are relevant to describing the risks of oil contact/stranding on shorelines and beaches. French *et al.* (1996) and French-McCay (2009) have defined an oil exposure threshold of 100 g/m^2 for shorebirds and wildlife (furbearing aquatic mammals and marine reptiles) on or along the shore, which is based on studies for sub-lethal and lethal impacts. The 100 g/m^2 threshold has been used in previous environmental risk assessment studies (French-McCay *et al.*, 2004, 2011, 2012; French-McCay, 2003; NOAA, 2013b). This threshold is also recommended in the Australian Maritime Safety Authority's foreshore assessment guide as the acceptable minimum thickness that does not inhibit the potential for recovery and is best remediated by natural coastal processes alone (AMSA, 2015).

2.3.6.4 Entrained Oil

Oil can be entrained into the water column from surface slicks due to wind and wave-induced turbulence, or be generated subsea by a pressurised discharge at depth. Entrained oil presents a number of possible mechanisms for exerting exposure. The entrained oil droplets may contain soluble compounds and hence have the potential to generate elevated concentrations of dissolved hydrocarbons (e.g. if mixed by breaking waves against a shoreline). Physical and chemical effects of the entrained oil droplets have also been demonstrated through direct contact with organisms; for example, through physical coating of gills and body surfaces, or accidental ingestion (NRC, 2005).

A review of the concentrations of physically entrained oil that has been demonstrated to have harmful effects in laboratory studies (NRC, 2005) showed wide variation depending on the test organisms and the initial oil mixture. For mortality of molluscs, reported LC_{50} values range from 500 ppb to 2,000 ppb with 96-hour exposure. Wider exposure sensitivities are displayed by species of crustaceans (100 ppb to 258,000 ppm) with 96-hour exposure, while marine fish larvae appear yet more sensitive with LC_{50} values as low as 45 ppb after 24-hour exposure.

As indicators of potential exposure, thresholds for concentrations of entrained oil were defined at 100 ppb and 500 ppb. These thresholds are particularly relevant for short duration (acute) exposure to organisms or fixed habitats affected by the dynamically-varying oil plume.

2.3.6.5 Dissolved Aromatic Hydrocarbons

The mode of action of soluble hydrocarbons is a narcotic effect resulting from uptake into the tissues of organisms. This effect is additive, increasing with exposure concentration or with time of exposure (French, 2000; NRC, 2005) For many oil mixtures, the concentration of aromatic hydrocarbons, and specifically the polyaromatic hydrocarbons (PAHs), in the water-soluble fraction is the best predictor of the toxicity of the oil.

As indicators of potential exposure, thresholds for concentrations of dissolved aromatic hydrocarbons were defined at 50 ppb and 500 ppb. Because exposure times may be short (<1-2 hours) in the case of a slick passing over a fixed habitat (such as a reef), due to fluctuations in the plume location with changing environmental conditions, and because marine organisms can typically tolerate concentrations of toxic hydrocarbons that are two or more orders of magnitude higher over such short durations (Pace *et al.*, 1995; French, 2000), these thresholds are likely to be indicative of potentially harmful exposure to fixed habitats over short exposure durations.

2.3.7 Oil Characteristics

2.3.7.1 Overview

Characteristics of unstabilised Torosa Condensate (pre-processed condensate) and stabilised Torosa Condensate (condensate which has been processed by the FPSO) were specified from data supplied by Woodside (Woodside, 2019), and are summarised alongside characteristics for marine diesel in Table 2.3.

For Scenario 1, a different unstabilised Torosa Condensate mixture was specified for the sea-surface and subsea release phases. The formulation used in the sea-surface release phase is referred to as unstabilised Torosa Condensate (surface). The formulation used in the subsea release phase is referred to as unstabilised Torosa Condensate (subsea).

Table 2.3 Characteristics of the oil types used in the modelling of Scenarios 1-4.

Oil Type	Density (g/cm^3)	Viscosity (cP)	Component	Volatile (%)	Semi-Volatile (%)	Low Volatility (%)	Residual (%)	Aromatics (%)
			Boiling point (°C)	**<180 C4 to C10**	**180 - 265 C11 to C15**	**265 - 380 C16 to C20**	**>380 >C20**	**Of whole oil <380 BP**
Unstabilised Torosa Condensate (subsea)	0.780 at 25 °C	1.092 at 20 °C	**% of total**	14.5	39.9	20.7	24.9	26.2
			% aromatics	2.5	8.8	14.9	-	-
Unstabilised Torosa Condensate (surface)	0.813 at 25 °C	2.519 at 25 °C	**% of total**	1.0	15.5	32.8	50.7	26.9
			% aromatics	0.2	3.1	23.6	-	-
Stabilised Torosa Condensate	0.780 at 20 °C	1.092 at 20 °C	**% of total**	57.0	21.0	8.0	14.0	19.6
			% aromatics	10.3	4.3	5.0	-	-
Marine Diesel	0.829 at 25 °C	4.000 at 25 °C	**% of total**	6.0	34.6	54.4	5.0	3.0
			% aromatics	1.8	1.0	0.2	-	-

The boiling points are dictated by the length of the carbon chains, with the longer and more complex compounds having a higher boiling point, and therefore lower volatility and evaporation rate.

The aromatic components within the volatile to low-volatility range are also soluble (with decreasing solubility following decreasing volatility) and will dissolve across the oil-water interface. The rate of dissolution will increase with increase in surface area. Hence, dissolution rates will be higher under discharge conditions that generate smaller oil droplets.

Atmospheric weathering will commence if and when oil droplets float to the water surface. Typical evaporation times once the hydrocarbons reach the surface and are exposed to the atmosphere are:

- Up to 12 hours for the C4 to C10 compounds (or less than 180 °C BP);
- Up to 24 hours for the C11 to C15 compounds (180-265 °C BP);
- Several days for the C16 to C20 compounds (265-380 °C BP); and
- Not applicable for the residual compounds (BP > 380 °C), which will resist evaporation, persist in the marine environment for longer periods, and be subject to relatively slow degradation.

The actual fate of released oil in the marine environment will depend greatly on the amount of oil that reaches the surface, either through the initial release or by rising after discharge in the water column.

2.3.7.2 Unstabilised Torosa Condensate (Surface/Subsea)

Two formulations of unstabilised Torosa Condensate (pre-processed condensate) were used in Scenario 1. Unstabilised Torosa Condensate (surface) contains a high proportion (50.7% by mass) of hydrocarbon compounds that will not evaporate at atmospheric temperatures; this proportion is lower but still significant (24.9%) for unstabilised Torosa Condensate (subsea). These compounds will persist in the marine environment.

The unweathered mixtures of unstabilised Torosa Condensate (surface) and unstabilised Torosa Condensate (subsea) have dynamic viscosities of 0.81 cP and 0.78 cP, respectively. The pour point of the whole oils (<15 °C) ensures that they will remain in a liquid state over the annual temperature range observed in the Timor Sea.

The mixtures are composed of hydrocarbons that have a wide range of boiling points and volatilities at atmospheric temperatures, and which will begin to evaporate at different rates on exposure to the atmosphere. Evaporation rates will increase with temperature, but in general about 1.0% of the unstabilised Torosa Condensate (surface) mass has the capacity to evaporate within the first 12 hours (BP < 180 °C); a further 15.5% could evaporate within the first 24 hours (180 °C < BP < 265 °C); and a further 32.8% could evaporate over several days (265 °C < BP < 380 °C). For unstabilised Torosa Condensate (subsea), 14.5% of the mass has the capacity to evaporate within the first 12 hours (BP < 180 °C); a further 39.9% could evaporate within the first 24 hours (180 °C < BP < 265 °C); and a further 20.7% could evaporate over several days (265 °C < BP < 380 °C).

Selective evaporation of the lower boiling-point components will lead to a shift in the physical properties of the remaining mixtures, including an increase in the viscosity and pour point. Although removal of the volatile compounds through evaporation and dissolution will result in an increase in density of the remaining oil, the mixtures are unlikely to solidify or sink as they weather.

The whole oils have low asphaltene content (0.66%), indicating a low propensity for the mixtures to take up water to form water-in-oil emulsion over the weathering cycle.

Soluble aromatic hydrocarbons contribute approximately 26.9% and 26.2% by mass of the unstabilised Torosa Condensate (surface) and unstabilised Torosa Condensate (subsea) oils, respectively. Each oil contains a significant proportion (surface, 23.6%; subsea, 14.9%) in the C16-C20 range of hydrocarbons; these compounds will evaporate slowly, resulting in the potential for dissolution of a proportion of them into the water.

2.3.7.3 Stabilised Torosa Condensate

Stabilised Torosa Condensate (condensate which has been processed by the FPSO) was used in Scenarios 2 and 3. Stabilised Torosa Condensate contains a moderate proportion (14.0% by mass) of hydrocarbon compounds that will not evaporate at atmospheric temperatures. These compounds will persist in the marine environment.

The unweathered mixture has a dynamic viscosity of 0.78 cP. The pour point of the whole oil (<15 °C) ensures that it will remain in a liquid state over the annual temperature range observed in the Timor Sea.

The mixture is composed of hydrocarbons that have a wide range of boiling points and volatilities at atmospheric temperatures, and which will begin to evaporate at different rates on exposure to the atmosphere. Evaporation rates will increase with temperature, but in general about 57.0% of the stabilised Torosa Condensate mass has the capacity to evaporate within the first 12 hours (BP < 180 °C); a further 21.0% could evaporate within the first 24 hours (180 °C < BP < 265 °C); and a further 8.0% could evaporate over several days (265 °C < BP < 380 °C).

Selective evaporation of the lower boiling-point components will lead to a shift in the physical properties of the remaining mixture, including an increase in the viscosity and pour point. Although removal of the volatile compounds through evaporation and dissolution will result in an increase in density of the remaining oil, the mixture is unlikely to solidify or sink as it weathers.

The whole oil has low asphaltene content (0.66%), indicating a low propensity for the mixture to take up water to form water-in-oil emulsion over the weathering cycle.

Soluble aromatic hydrocarbons contribute approximately 19.6% by mass of the whole oil, with a significant proportion (10.3%) in the C4-C10 range of hydrocarbons. These compounds will evaporate rapidly, reducing the potential for dissolution of a proportion of them into the water.

2.3.7.4 Marine Diesel

Marine diesel was used in Scenario 4. Marine diesel is a mixture of volatile and persistent hydrocarbons with low proportions of highly volatile and residual components. In general, about 6% of the oil mass should evaporate within the first 12 hours (BP < 180 °C); a further 35% should evaporate within the first 24 hours (180 °C < BP < 265 °C); and a further 54% should evaporate over several days (265 °C < BP < 380 °C). Approximately 5% of the oil is shown to be persistent. The aromatic content of the oil is approximately 3%.

If released in the marine environment and in contact with the atmosphere (i.e. surface spill), approximately 41% by mass of this oil is predicted to evaporate over the first couple of days depending upon the prevailing conditions, with further evaporation slowing over time. The heavier (low volatility) components of the oil have a tendency to entrain into the upper water column due to wind-generated waves, but can subsequently resurface if wind-waves abate. Therefore, the heavier components of this oil can remain entrained or on the sea surface for an extended period, with associated potential for dissolution of the soluble aromatic fraction.

2.3.8 Weathering Characteristics

2.3.8.1 Overview

A series of model weather tests were conducted to illustrate the potential behaviour of unstabilised Torosa Condensate (surface and subsea), stabilised Torosa Condensate and marine diesel when exposed to idealised and representative environmental conditions:

- Instantaneous release (1-hour discharge) onto the water surface at a discharge rate of 50 m^3/hr under calm wind conditions (constant 5 knots), assuming low seasonal water temperature (27 °C) and average air temperature (25 °C). Slick also subject to ambient tidal and drift currents.
- Instantaneous release (1-hour discharge) onto the water surface at a discharge rate of 50 m^3/hr under variable wind conditions (4-19 knots, drawn from representative data files), assuming low seasonal water temperature (27 °C) and average air temperature (25 °C). Slick also subject to ambient tidal and drift currents.

The first case is indicative of cumulative weathering rates under calm conditions that would not generate entrainment, while the second case may represent conditions that could cause a minor degree of entrainment. Both scenarios provide examples of potential behaviour during periods of a spill event, once the oil reaches the surface.

2.3.8.2 Unstabilised Torosa Condensate (Surface/Subsea)

Weathering results are presented for the unstabilised Torosa Condensate mixture that was used in the modelling of the sea-surface release phase, referred to as unstabilised Torosa Condensate (surface), and for the unstabilised Torosa Condensate mixture that was used in the modelling of the subsea release phase, referred to as unstabilised Torosa Condensate (subsea).

The results for the constant-wind case indicate that a significant proportion of unstabilised Torosa Condensate (surface, Figure 2.21; subsea, Figure 2.23) will tend to persist on the sea surface (46% and 15%, respectively, after 7 days) during calm wind conditions, with low levels of entrainment and around 40% (surface) and 70% (subsea) of the spilled volume expected to evaporate within the first 24 hours under light winds. The results for the variable-wind case (surface, Figure 2.22; subsea, Figure 2.24) indicate that the wind conditions will have a large impact on the proportion of unstabilised Torosa Condensate that remains afloat, with very little oil mass predicted to persist on the sea surface (<2% after 24 hours). This is largely due to the higher wind speeds within this test case (>5 knots) generating significant entrainment events, with almost all of the oil mass becoming entrained shortly after release. The higher proportion of entrained oil predicted in the variable-wind case also results in a larger proportion of the oil dissolving: 30% (surface) and 16% (subsea) after 7 days compared with <6% under calm conditions.

The evaporation rate observed in the first 24 hours is similar in both weathering tests; however, as the wind speed increases in the variable-wind case, increased entrainment reduces the proportion of oil available for evaporation, resulting in around 17% (surface) and 50% (subsea) of the spill volume expected to evaporate after 7 days as compared to 39% (surface) and 69% (subsea) in the lower-wind case.

Biological and photochemical degradation is predicted to contribute to the decay of the floating slicks in both weathering cases, with increased levels of entrainment and dissolution in the variable-wind case resulting in a higher proportion of oil decaying: 25% (surface) and 16% (subsea) after 7 days compared with 12% (surface) and 6% (subsea) under calm conditions.

Under calm conditions where entrainment is restricted, a proportion of the spilled mass of unstabilised Torosa Condensate will be expected to remain floating on the water surface. In these circumstances, some components of the remaining floating oil will evaporate and/or degrade over time scales of several weeks to a few months, with the entrained oil reducing concentration through degradation over similar time scales. This long weathering duration will extend the area of potential effect, requiring the break-up and dispersion of the slicks to reduce concentrations below the thresholds considered in this study.

2.3.8.3 Stabilised Torosa Condensate

The results for the constant-wind case (Figure 2.25) indicate that a small proportion of stabilised Torosa Condensate will tend to persist on the sea surface (6% after 7 days) during calm wind conditions, with negligible levels of entrainment and around 80% of the spilled volume expected to evaporate within the first 24 hours under light winds. The results for the variable-wind case (Figure 2.26) indicate that the wind conditions will have a large impact on the proportion of stabilised Torosa Condensate that remains afloat, with very little oil mass predicted to persist on the sea surface (<1% after 24 hours). This is largely due to the higher wind speeds within this test case (>5 knots) generating significant entrainment events, with almost all of the oil mass becoming entrained shortly after release. The higher proportion of entrained oil predicted in the variable-wind case also results in a larger proportion of the oil dissolving: 11% after 7 days compared with <2% under calm conditions.

The evaporation rate observed in the first 24 hours is similar in both weathering tests; however, as the wind speed increases in the variable-wind case, increased entrainment reduces the proportion of oil available for evaporation, resulting in around 73% of the spill volume expected to evaporate after 7 days as compared to 84% in the lower-wind case.

Biological and photochemical degradation is predicted to contribute to the decay of the floating slicks in both weathering cases, with increased levels of entrainment and dissolution in the variable-wind case resulting in a higher proportion of oil decaying: 8% after 7 days compared with 3% under calm conditions.

Under calm conditions where entrainment is restricted, a proportion of the spilled mass of stabilised Torosa Condensate will be expected to remain floating on the water surface. In these circumstances, some components of the remaining floating oil will evaporate and/or degrade over time scales of several weeks to a few months, with the entrained oil reducing concentration through degradation over similar time scales. This long weathering duration will extend the area of potential effect, requiring the break-up and dispersion of the slicks to reduce concentrations below the thresholds considered in this study.

2.3.8.4 Marine Diesel

The mass balance forecast for the constant-wind case (Figure 2.27) for marine diesel shows that approximately 45% of the oil is predicted to evaporate within 24 hours. Under these calm conditions the majority of the remaining oil on the water surface will weather at a slower rate due to being comprised of the longer-chain compounds with higher boiling points. Evaporation of the residual compounds will slow significantly, and they will then be subject to more gradual decay through biological and photochemical processes.

Under the variable-wind case (Figure 2.28), where the winds are of greater strength, entrainment of marine diesel into the water column is indicated to be significant. Approximately 24 hours after the spill, around 45% of the oil mass is forecast to have entrained and a further 35% is forecast to have evaporated, leaving only a small proportion of the oil floating on the water surface (<1%). The residual compounds will tend to remain entrained beneath the surface under conditions that generate wind waves (approximately >6 m/s).

The increased level of entrainment in the variable-wind case will result in a higher percentage of biological and photochemical degradation, where the decay of the floating slicks and oil droplets in the water column occurs at an approximate rate of 1.8% per day with an accumulated total of ~13% after 7 days, in comparison to a rate of ~0.2% per day and an accumulated total of 1.5% after 7 days in the constant-wind case. Given the large proportion of entrained oil and the tendency for it to remain mixed in the water column, the remaining hydrocarbons will decay and/or evaporate over time scales of several weeks to a few months. This long weathering duration will extend the area of potential effect, requiring the break-up and dispersion of the slicks and droplets to reduce concentrations below the thresholds considered in this study.

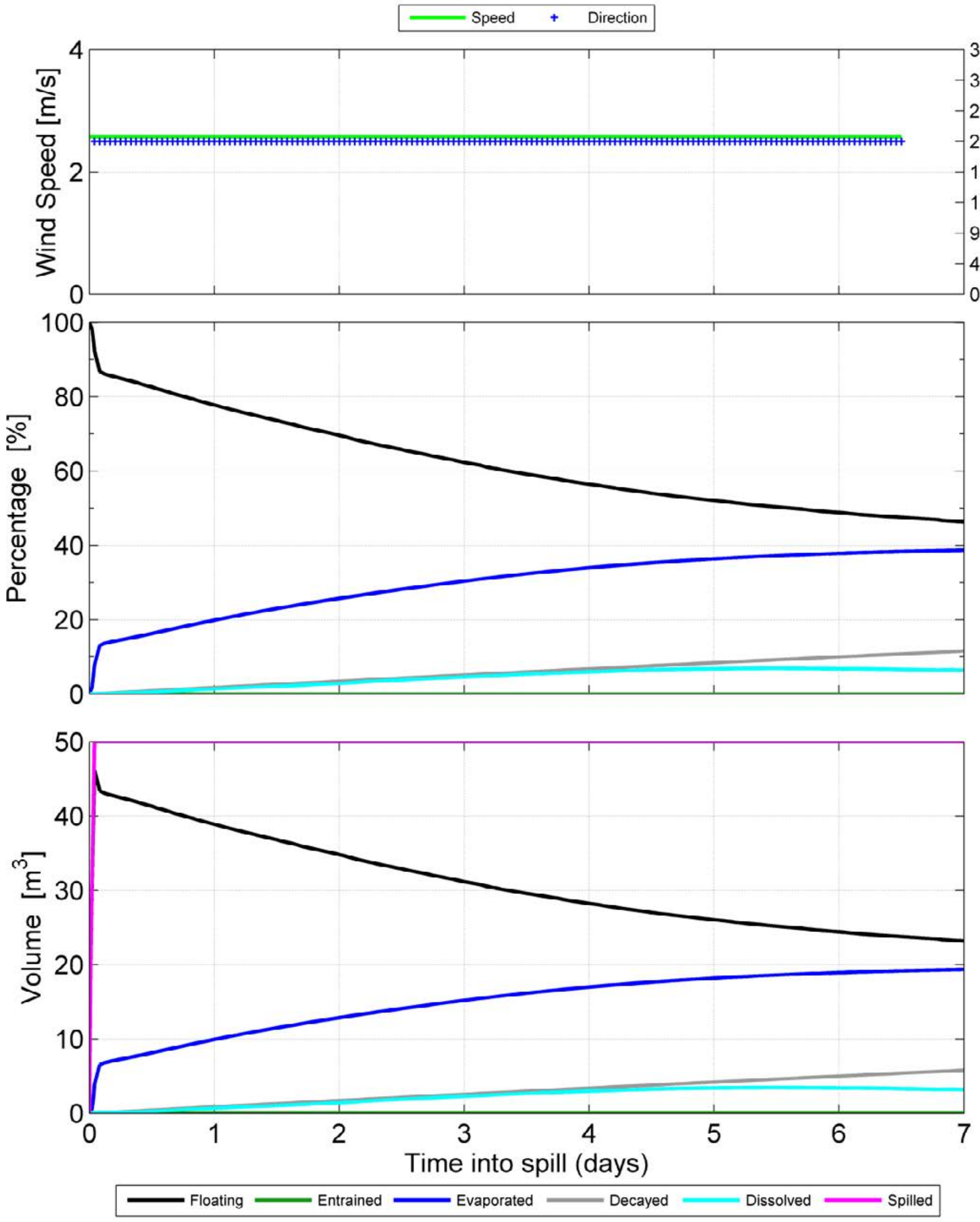

Figure 2.21 Mass balance plot representing, as proportion (middle panel) and volume (bottom panel), the weathering of unstabilised Torosa Condensate (surface) spilled onto the water surface as a one-off release (50 m^3 over 1 hour) and subject to a constant 5 kn (2.6 m/s) wind at 27 °C water temperature and 25 °C air temperature.

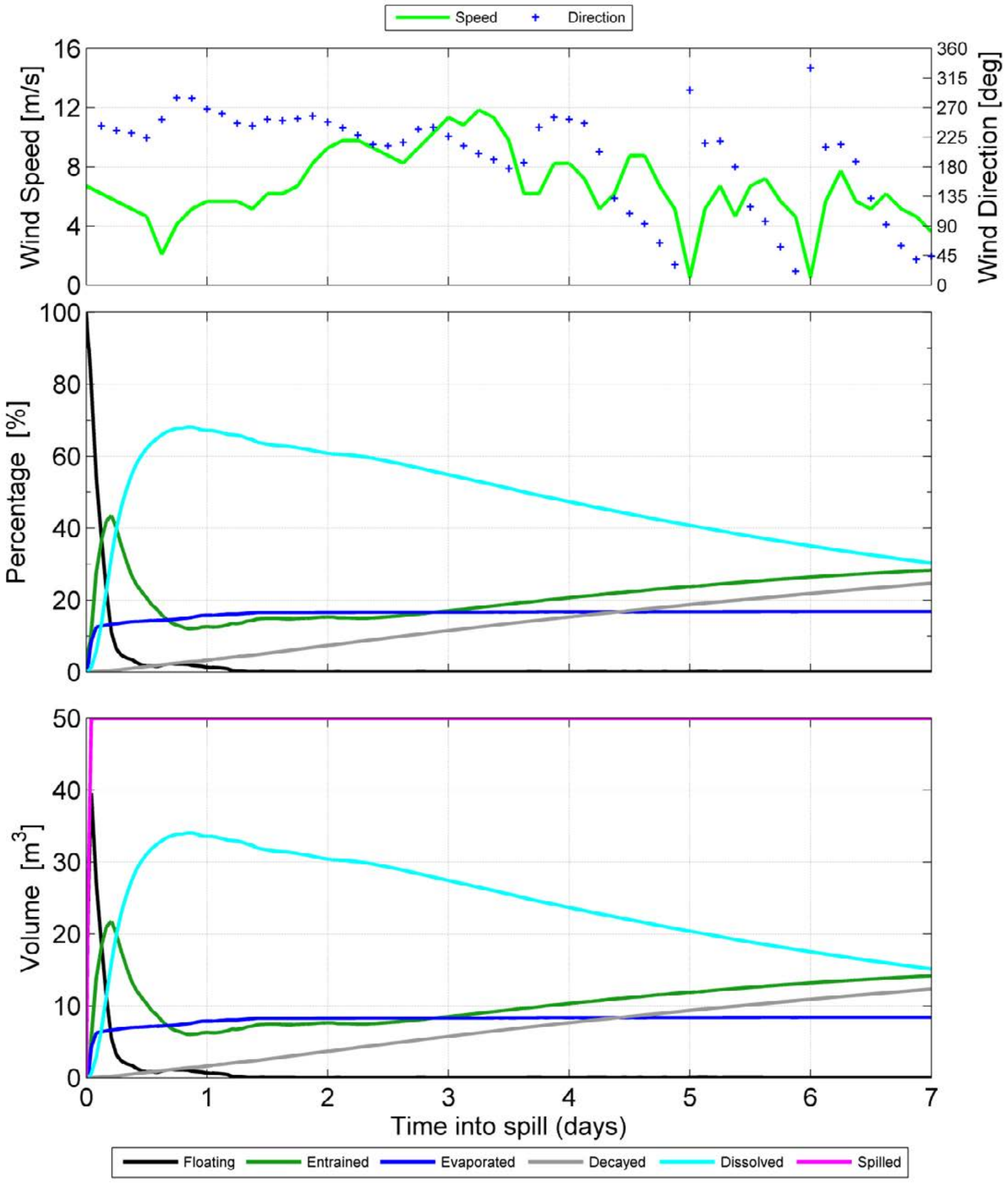

Figure 2.22 Mass balance plot representing, as proportion (middle panel) and volume (bottom panel), the weathering of unstabilised Torosa Condensate (surface) spilled onto the water surface as a one-off release (50 m^3 over 1 hour) and subject to variable wind at 27 °C water temperature and 25 °C air temperature.

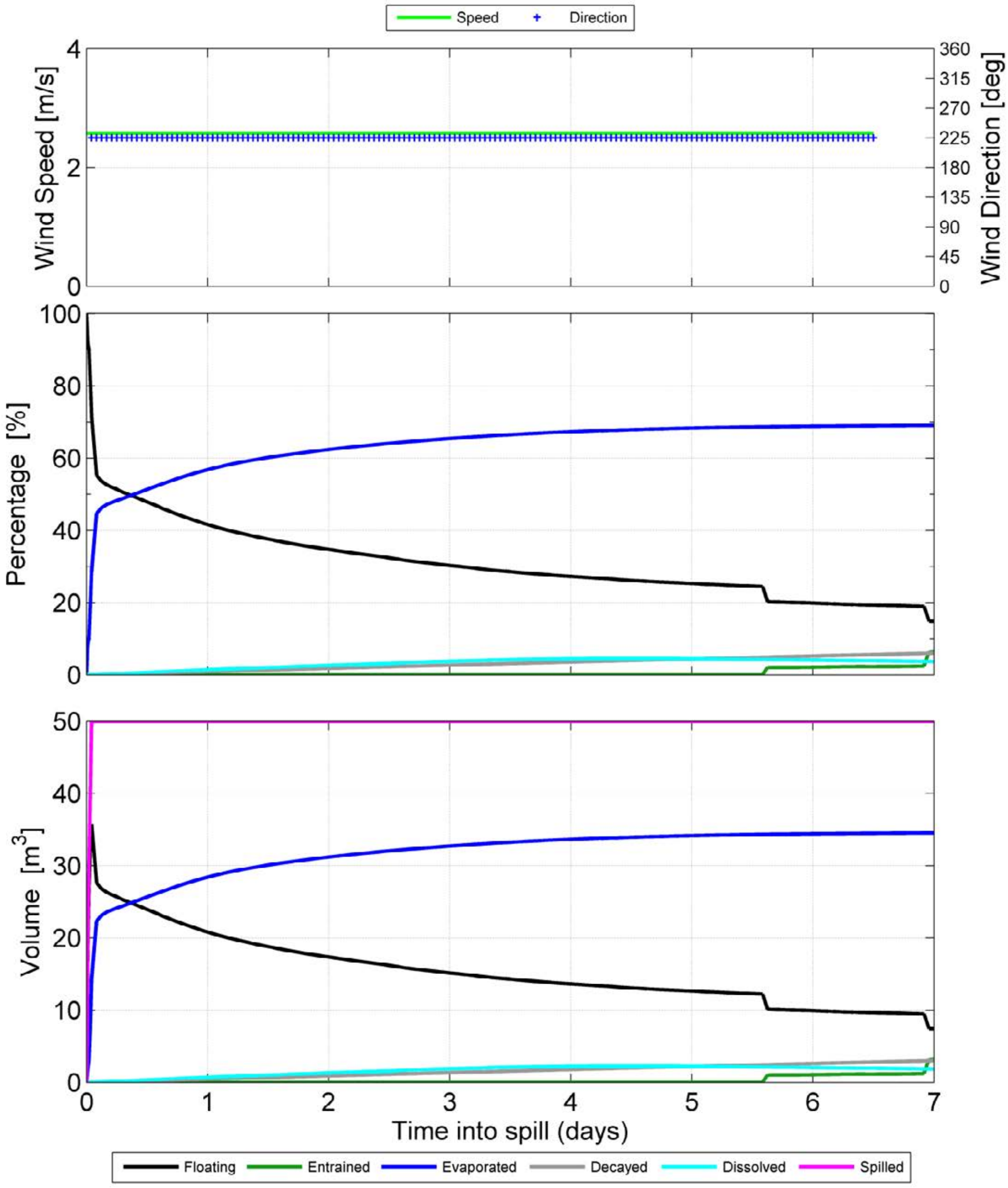

Figure 2.23 Mass balance plot representing, as proportion (middle panel) and volume (bottom panel), the weathering of unstabilised Torosa Condensate (subsea) spilled onto the water surface as a one-off release (50 m^3 over 1 hour) and subject to a constant 5 kn (2.6 m/s) wind at 27 °C water temperature and 25 °C air temperature.

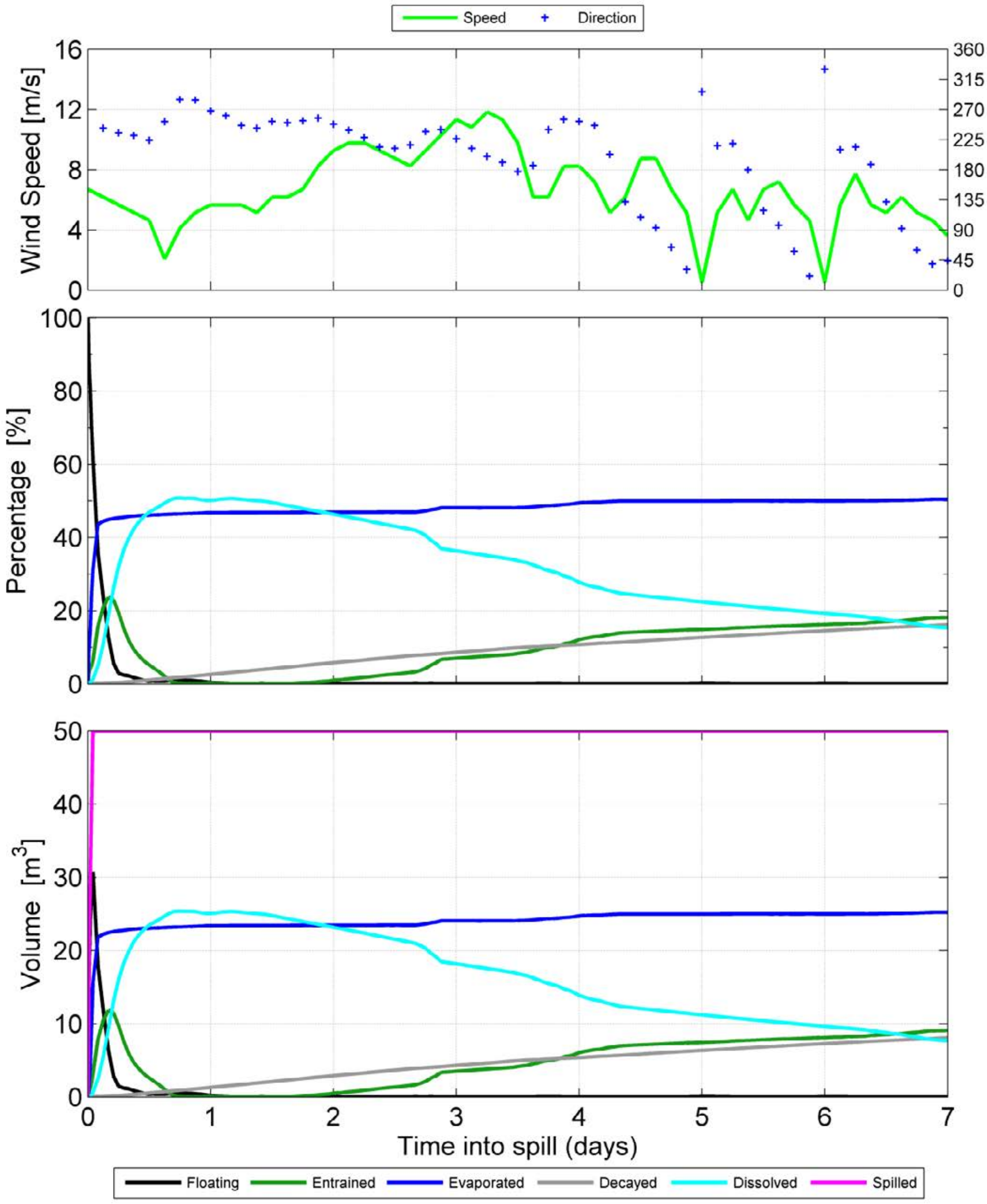

Figure 2.24 Mass balance plot representing, as proportion (middle panel) and volume (bottom panel), the weathering of unstabilised Torosa Condensate (subsea) spilled onto the water surface as a one-off release (50 m^3 over 1 hour) and subject to variable wind at 27 °C water temperature and 25 °C air temperature.

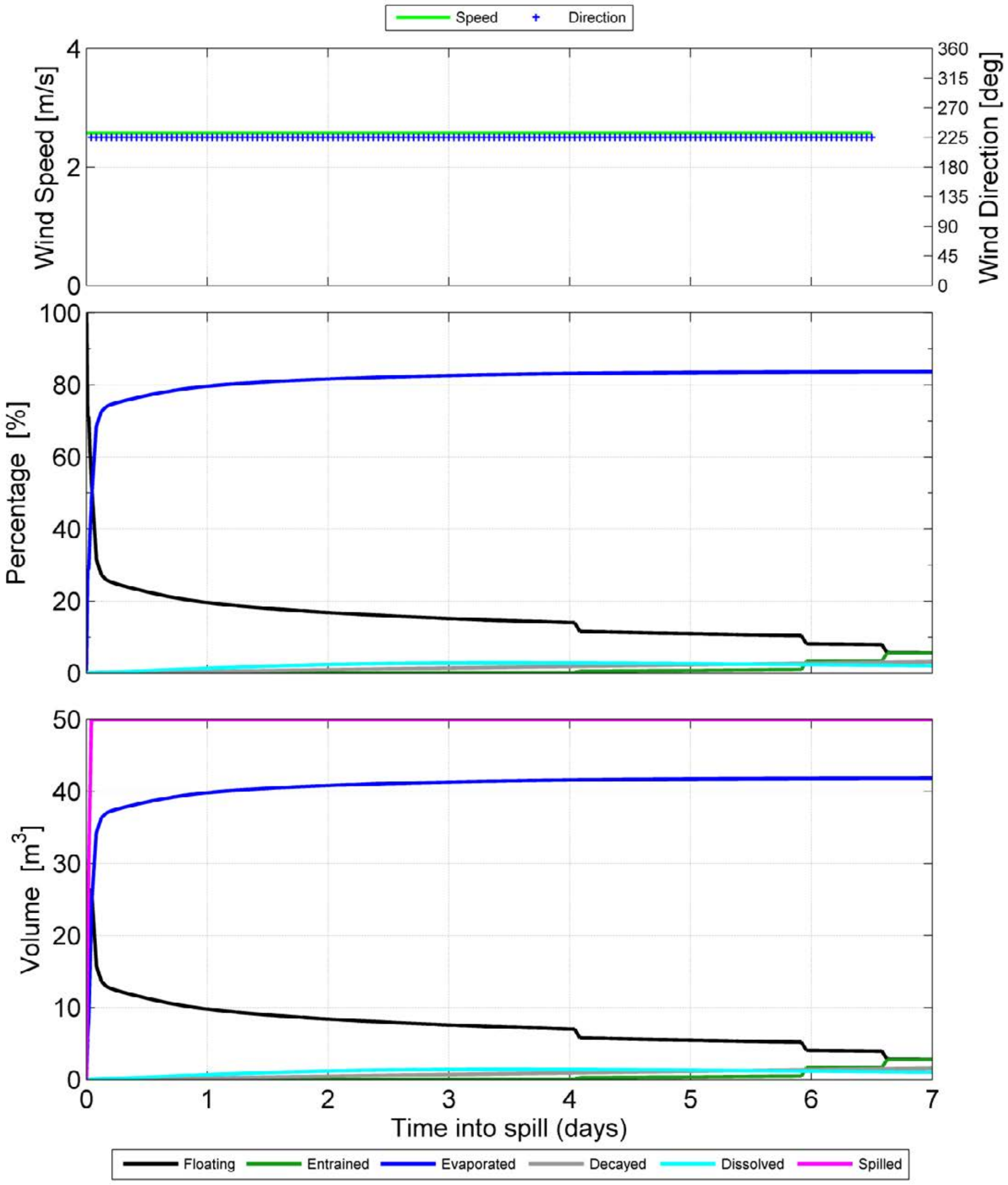

Figure 2.25 Mass balance plot representing, as proportion (middle panel) and volume (bottom panel), the weathering of stabilised Torosa Condensate spilled onto the water surface as a one-off release (50 m^3 over 1 hour) and subject to a constant 5 kn (2.6 m/s) wind at 27 °C water temperature and 25 °C air temperature.

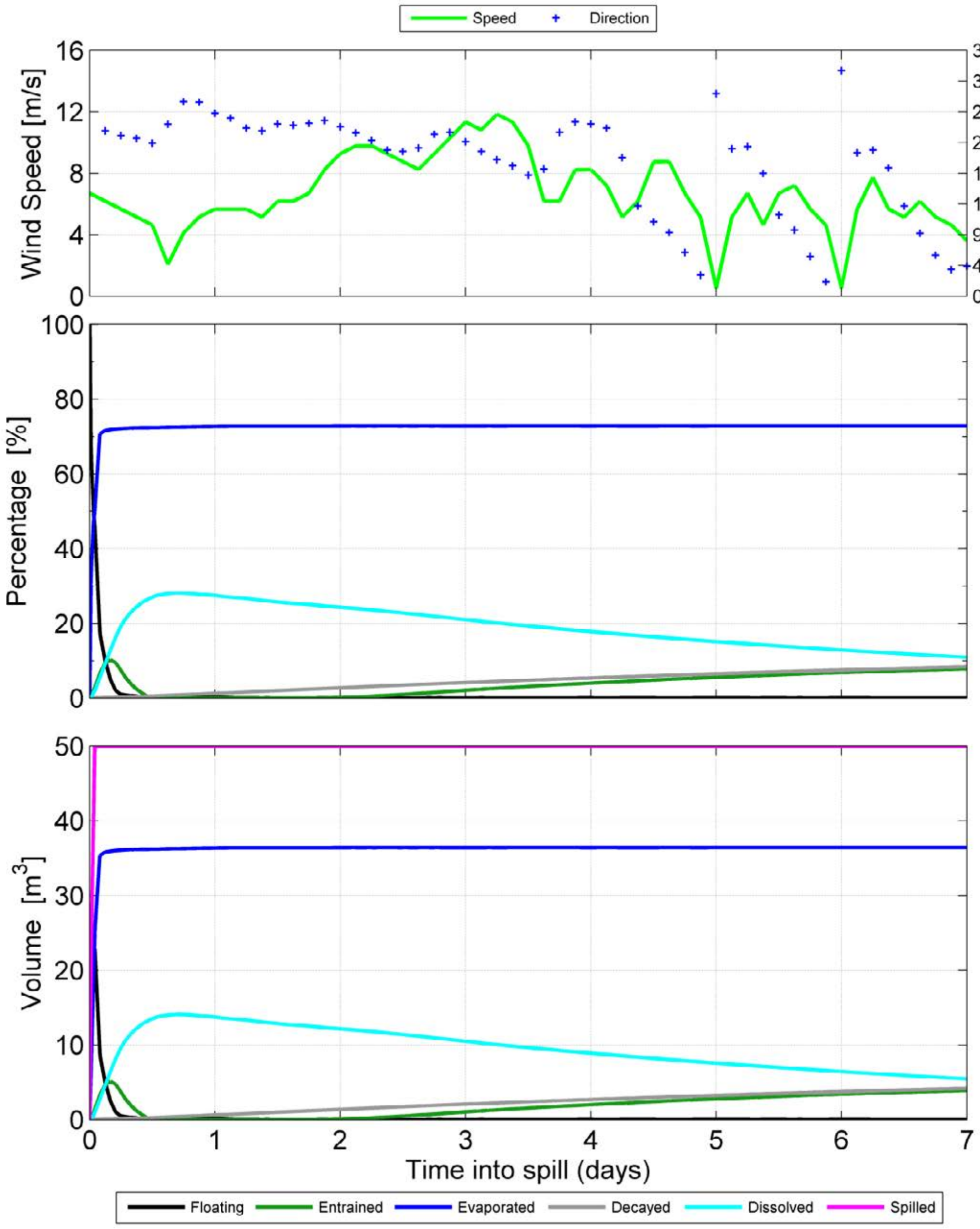

Figure 2.26 Mass balance plot representing, as proportion (middle panel) and volume (bottom panel), the weathering of stabilised Torosa Condensate spilled onto the water surface as a one-off release (50 m^3 over 1 hour) and subject to variable wind at 27 °C water temperature and 25 °C air temperature.

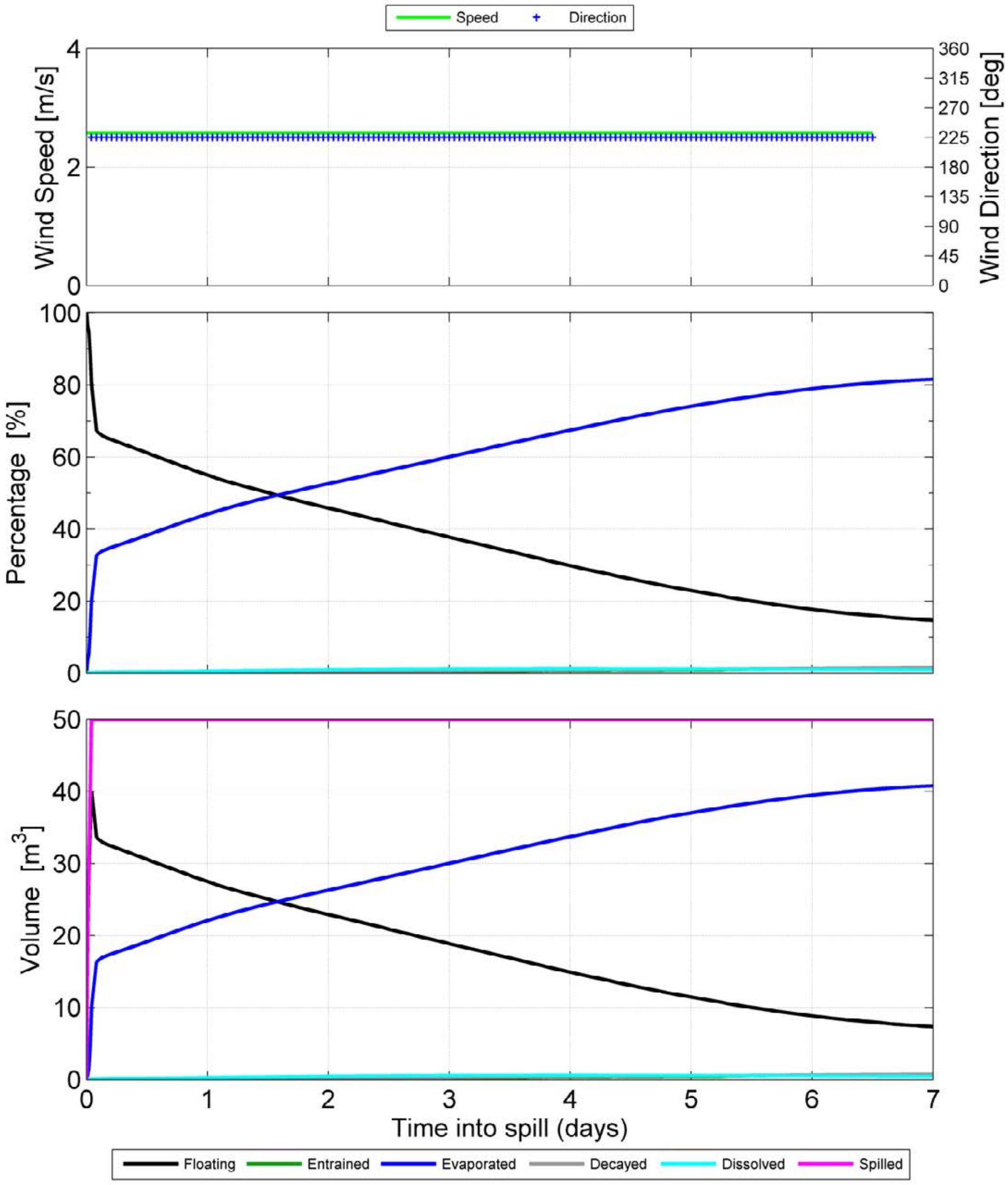

Figure 2.27 Mass balance plot representing, as proportion (middle panel) and volume (bottom panel), the weathering of marine diesel spilled onto the water surface as a one-off release (50 m^3 over 1 hour) and subject to a constant 5 kn (2.6 m/s) wind at 27 °C water temperature and 25 °C air temperature.

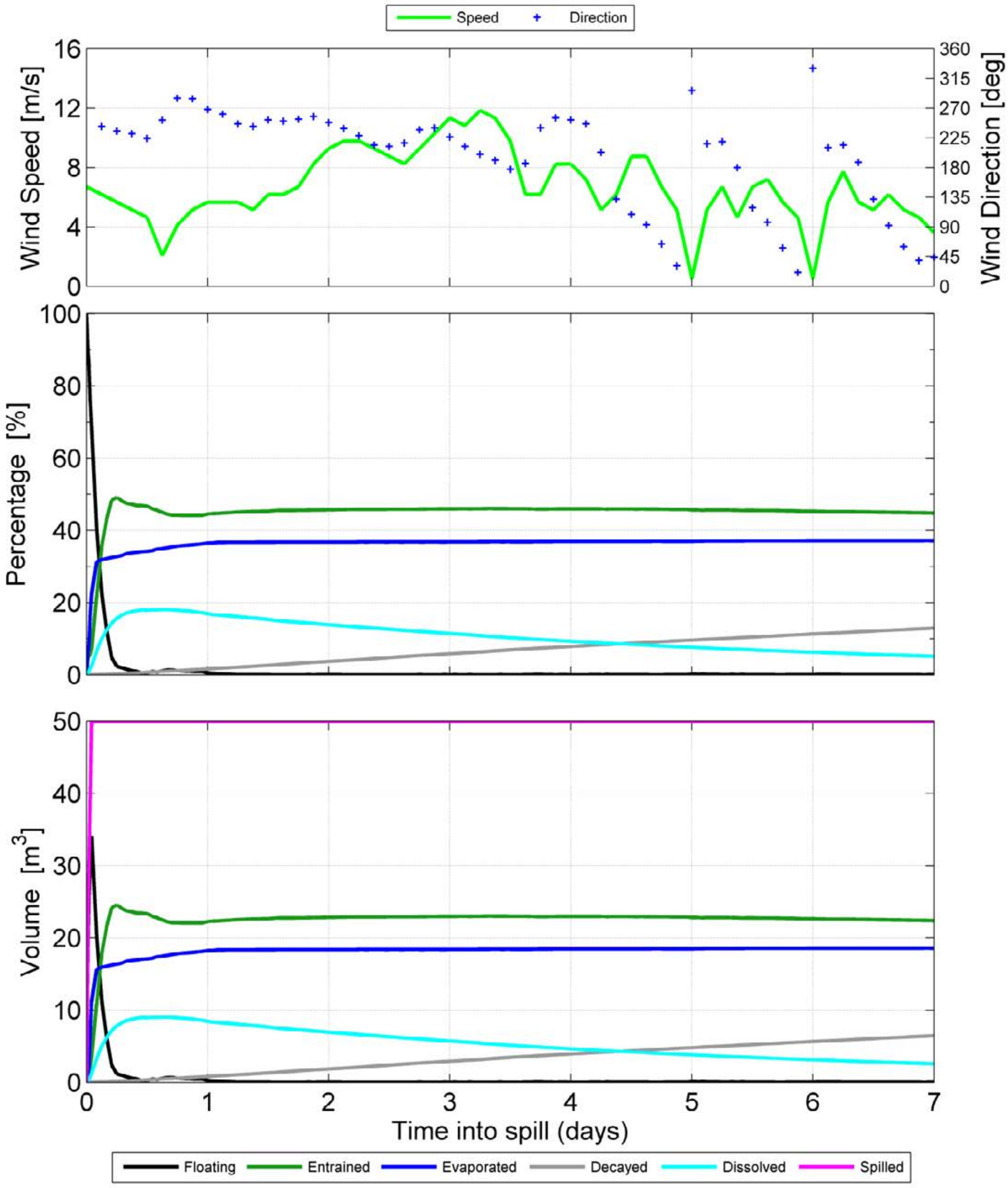

Figure 2.28 Mass balance plot representing, as proportion (middle panel) and volume (bottom panel), the weathering of marine diesel spilled onto the water surface as a one-off release (50 m^3 over 1 hour) and subject to variable wind at 27 °C water temperature and 25 °C air temperature.

2.3.9 Emulsification Characteristics

Studies have shown strong evidence that the asphaltene content of oil mixtures is the most important contributing factor for stabilising emulsions, alongside other contributing properties such as density, viscosity and resin content (Fingas, 2010; Fingas & Fieldhouse, 2004, 2015). Fingas & Fieldhouse (2005) analysed a large body of oil types for emulsion stability and defined four water-in-oil types: stable, mesostable, entrained and unstable. Only stable, mesostable and entrained water-in-oil emulsions hold a relatively high proportion of water (> ~20% and up to 80%) and will persist for long periods (several weeks to more than a year) once formed, despite a reduction in mixing energy (Figure 2.29). Oil mixtures that do not hold significant amounts of water (<6%) when mixed are characterised as unstable.

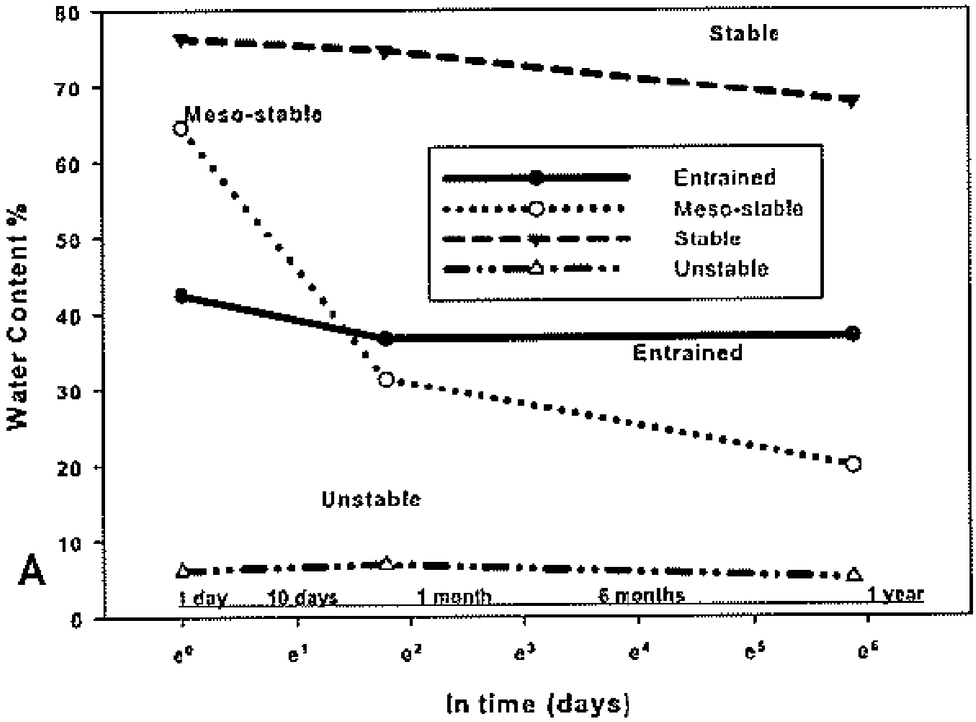

Figure 2.29 Average properties of emulsion stability groups (Fingas & Fieldhouse, 2004).

Fingas & Fieldhouse (2015) lists oil types that form stable or mesostable emulsions. Universally, these have densities ranging from 0.89 g/cm^3 to >1.0 g/cm^3, high or very high viscosities (14-20,000 cP) and high asphaltene content (1-17%). Oil types that form entrained emulsions have densities >0.96 g/cm^3 and very high viscosities (>6,000 cP). Oil types that form unstable emulsions have low asphaltene or resin content (<1%) and either low or high densities (<0.85 g/cm^3 or >1.0 g/cm^3) with either low or high viscosities (<100 cP or >800,000 cP).

The densities, viscosities and asphaltene content of the unstabilised and stabilised Torosa Condensates are indicative of unstable water-in-oil emulsion with <6% water content.

2.3.10 Subsea Discharge Characteristics

2.3.10.1 Overview

High-pressure releases that involve mixed gas and oil will tend to generate relatively small droplet sizes that have slow rise rates, due to viscous resistance imparted by the surrounding seawater, and may become trapped by density layers in the water column (Chen & Yapa, 2002). The buoyancy of the gas cloud may lift entrained oil droplets towards the surface and, in the case of blowouts in relatively shallow water (<100-200 m), the rising column of gas and entrained water can lift the oil to the surface at a substantially faster rate than would occur from the relative buoyancy of the oil alone, opposed by the viscosity of the water column.

For deeper releases (200-500 m), the gas will expand to entrain oil droplets towards the surface, but the gas and oil will then tend to separate before the oil surfaces because the gas either goes into solution or accelerates away from the oil droplets. The height at which the gas lift ceases is referred to as the trapping height. The rate at which oil rises from the trapping height will be determined by a number of factors, including the relative buoyancy of the oil versus local water density, the size of the droplets (increased viscous resistance for smaller sizes), the presence of density barriers in the water column and the action of shear currents that might be present in the water column.

Given the water temperature and pressure that would be expected at the specified discharge depth, the potential for methane and other gases to convert to gas hydrates (semi-solid crystalline structures that would affect the buoyancy of the plume; Figure 2.30) was considered in this study.

The OILMAP model, described in Section 2.1.2, was used in this study to predict the behaviour of the rising plume of gas-oil-water and the oil droplet distribution resulting from the subsea discharge in Scenario 1.

Inputs to the OILMAP model included specification of the discharge rate, hole size, gas-to-oil ratio, and the temperature of the oil on exiting and before subsequent cooling by the ambient water. The model input also included temperature and salinity profiles representative of the location. Summaries of the inputs to and outputs of the OILMAP simulations for Scenario 1 are presented in the following section.

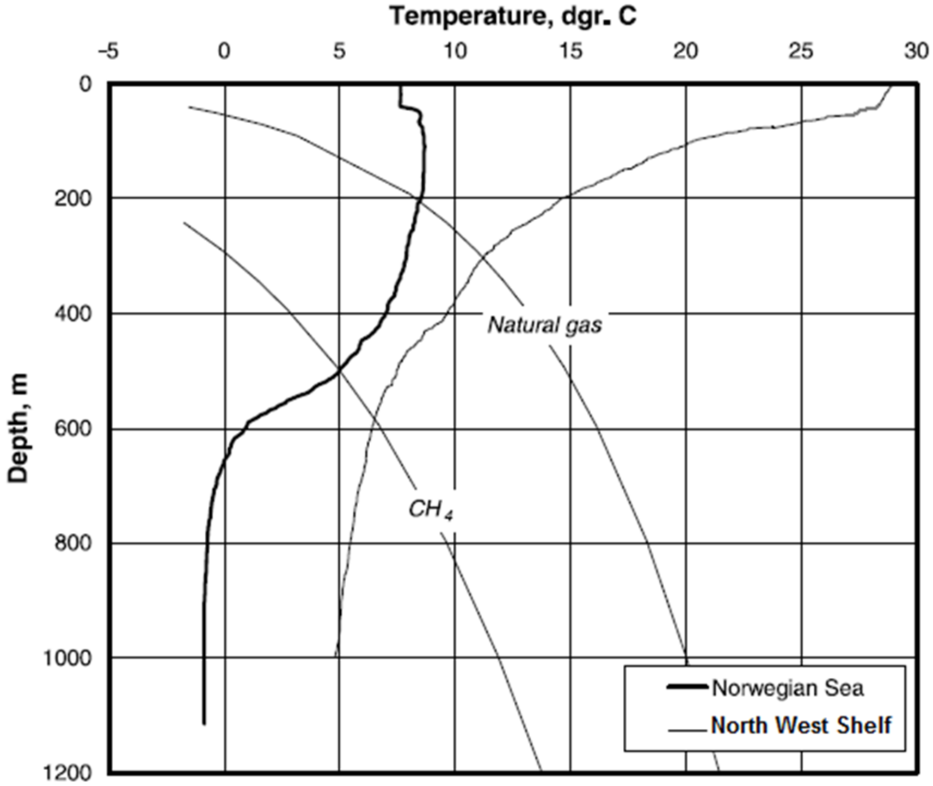

Figure 2.30 Theoretical equilibrium lines for hydrate formation based on the temperature and pressure at the release point. The line for "natural gas" assumes 80% methane, 10% ethane and 10% propane. Typical indicative sea temperature profiles with depth are indicated (Johansen, 2003).

2.3.10.2 Scenario 1: Long-Term (77-Day) Surface/Subsea Blowout of Unstabilised Torosa Condensate at the TRA-C Well

The OILMAP input parameters and the resulting output parameters that were used as input into SIMAP are presented in Table 2.4 for Scenario 1. The model input also included temperature and salinity profiles representative of the location.

The results of the OILMAP simulation for Scenario 1 predict that the discharge will generate a cone of rising gas that will entrain the oil droplets and ambient sea water up to the water surface. The mixed plume is initially forecast to jet towards the water surface with a vertical velocity of around 7.6 m/s, gradually slowing and increasing in plume diameter as more ambient water is entrained. The diameter of the central cone of rising water and oil at the point of surfacing is predicted to be approximately 27 m.

The high discharge velocity and turbulence generated by the expanding gas plume is predicted to generate relatively small oil droplets (<150 µm) that will have very low rise velocities (<0.25 cm/s). These droplets will be subject to mixing due to turbulence generated by the lateral displacement of the rising plume, as well as vertical mixing induced by wind and breaking waves. Therefore, despite reaching the surface due to the lift produced by the rising plume, the droplets will then tend to remain within the wave-mixed layer of the water column (3-10 m deep, depending on the conditions), where they can resist surfacing due to their weak buoyancy relative to other mixing processes.

The ongoing nature of the release combined with the potential for the plume to breach the water surface may present other hazards, including conditions that may lead to high local concentrations of atmospheric volatiles. These issues should be considered when evaluating the practicality of response operations at or near the blowout site. The results suggest that beyond the immediate vicinity of the blowout the majority of the released hydrocarbons will be present in the upper layers of the ocean, with the potential for oil to form floating slicks under sufficiently calm local wind conditions.

Table 2.4 Near-field subsea discharge model parameters for Scenario 1.

OILMAP	Parameter	Value
Inputs	Release depth (m BMSL)	425
	Oil density (g/cm^3) (at 20 °C)	0.78
	Oil viscosity (cP) (at 20 °C)	1.09
	Oil temperature (°C)	139
	Hole diameter (m) [in]	0.22 [8.5]
	Gas:oil ratio (m^3/m^3) [scf/bbl]	17,632 [98,992]
	Oil flow rate (m^3/d) [bbl/d]	1,845 [11,607]
Outputs	Plume diameter (m)	27.2
	Plume height (m ASB)	425 (surface)
	Plume initial rise velocity (m/s)	7.6
	Plume terminal rise velocity (m/s)	5.1
Predicted Oil Droplet Size Distribution	20% droplets of size (μm)	37.4
	20% droplets of size (μm)	54.6
	20% droplets of size (μm)	70.9
	20% droplets of size (μm)	92.2
	20% droplets of size (μm)	134.6

3 STOCHASTIC ASSESSMENT RESULTS

3.1 Overview

Predictions for the probability of contact and time to contact by oil concentrations equalling or exceeding defined thresholds for floating oil, entrained oil and dissolved aromatic hydrocarbons are provided in the following sections to summarise the results of the annualised stochastic modelling.

Contour maps present estimates for the annualised probability of contact by instantaneous concentrations of at least the defined minimum threshold concentrations (1 g/m^2, 10 g/m^2, 50 g/m^2 and 100 g/m^2 for floating oil; 100 g/m^2 and 250 g/m^2 for shoreline oil; 500 ppb for entrained oil and dissolved aromatic hydrocarbons) for at least one time step. These contours summarise the outcomes for all replicate simulations commencing across the annual period – a total of 100 replicate simulations for Scenario 1 and 200 replicate simulations for Scenarios 2 to 4.

Readers should note that the contour maps presented in this report do not represent the predicted coverage of any one hydrocarbon spill or a depiction of a slick or plume at any particular instant in time. Rather, the contours are a composite of a large number of theoretical slick paths, integrated over the full duration of the simulations relevant to the assessed scenario. The contour maps should be treated as indications of the probability of exposure at defined concentrations, for individual locations, at some point in time after the defined spill commences, given the trends and variations in metocean conditions that occur around the study area.

Locations with higher probability ratings were exposed during a greater number of spill simulations, indicating that the combination of the prevailing wind and current conditions are more likely to result in contact to these locations if the spill scenario were to occur in the future. The areas outside of the lowest-percentage contour indicate that contact will be less likely under the range of prevailing conditions for this region than areas falling within higher probability contours. It is important to note that the probabilities are derived from the samples of data used in the modelling. Therefore, locations that are not calculated to receive exposure at threshold concentrations or greater in any of the replicate simulations might possibly be contacted if very unusual conditions were to occur. Hence, we do not attribute a probability of nil to areas beyond the lowest probability contour.

Tables are presented to summarise estimates of contact risk for locations within potentially sensitive receptors that were defined by Woodside. All sensitive receptors historically considered for Woodside spill risk assessments were included in the analysis, with those outlined here being the receptors shown to be at risk of contact for each assessed scenario.

The probability estimates for contact by floating oil that are presented in the tables summarise the probability that oil will arrive at shorelines as floating films at the specified threshold concentration or greater for at least one time step (1 hour).

The minimum time estimates shown in the tables present the shortest time for any oil to drift from the source to any part of the sensitive receptor, relative to the commencement of the spill. These times then indicate the minimum weathering time for oil that might make contact with the resource.

The mean and maximum shoreline concentrations indicate the concentrations forecast to potentially accumulate over time on any discrete part of a shoreline (calculated for individual portions of 0.8 km length). Accumulated concentrations are calculated by summing the mass of oil that arrives at any concentration (including < threshold) over time at a model cell and subtracting any mass lost through evaporation and washing off, where relevant.

The maximum local accumulated concentration in the worst replicate spill is the greatest accumulation predicted for any point on the shoreline during any replicate simulation, and thus represents an extreme estimate. The maximum local accumulated concentration averaged over all replicate spills is the greatest concentration calculated for any point on the shoreline after averaging over all replicate simulations.

Note that it is possible that oil films arriving at concentrations that are less than the threshold may accumulate over the course of a spill event to result in concentrations that apparently exceed the threshold. Hence, the mean expected and maximum concentrations of accumulated oil can exceed the threshold applied to the probability calculations for the arrival of floating oil even where no instantaneous exceedances above threshold are predicted. It is important to understand that the two parameters (floating concentration and shoreline concentration) are quite distinct, calculated in different ways and representative of alternative outcomes. The floating probability estimates and the shoreline accumulative estimates should therefore be treated as independent estimators of different exposure outcomes, and not directly compared.

For the entrained and dissolved components, the tabulated results summarise interrogations of cells representing the water surrounding the sensitive receptor shorelines (or submerged features), with individual buffer zones. Buffer zones were defined with consideration of the bathymetry bordering each receptor, natural boundaries, or sensible legislative boundaries.

The modelling for each assessed scenario assumed no mitigation efforts are undertaken to collect or otherwise affect the natural transport and weathering of the oil.

The predicted outcomes based on the modelling results are discussed in the following sections in terms of floating, entrained and dissolved aromatic hydrocarbons. Discussion is based around the outcomes of stochastic risk contours. Plots of the Environment that May Be Affected (EMBA) and minimum time to exceedance of concentration thresholds are presented for the assessed thresholds.

Figure 3.1 shows transect lines intersecting at the release locations along which maximum entrained oil and dissolved aromatic hydrocarbon concentrations in the water column were extracted for each assessed scenario.

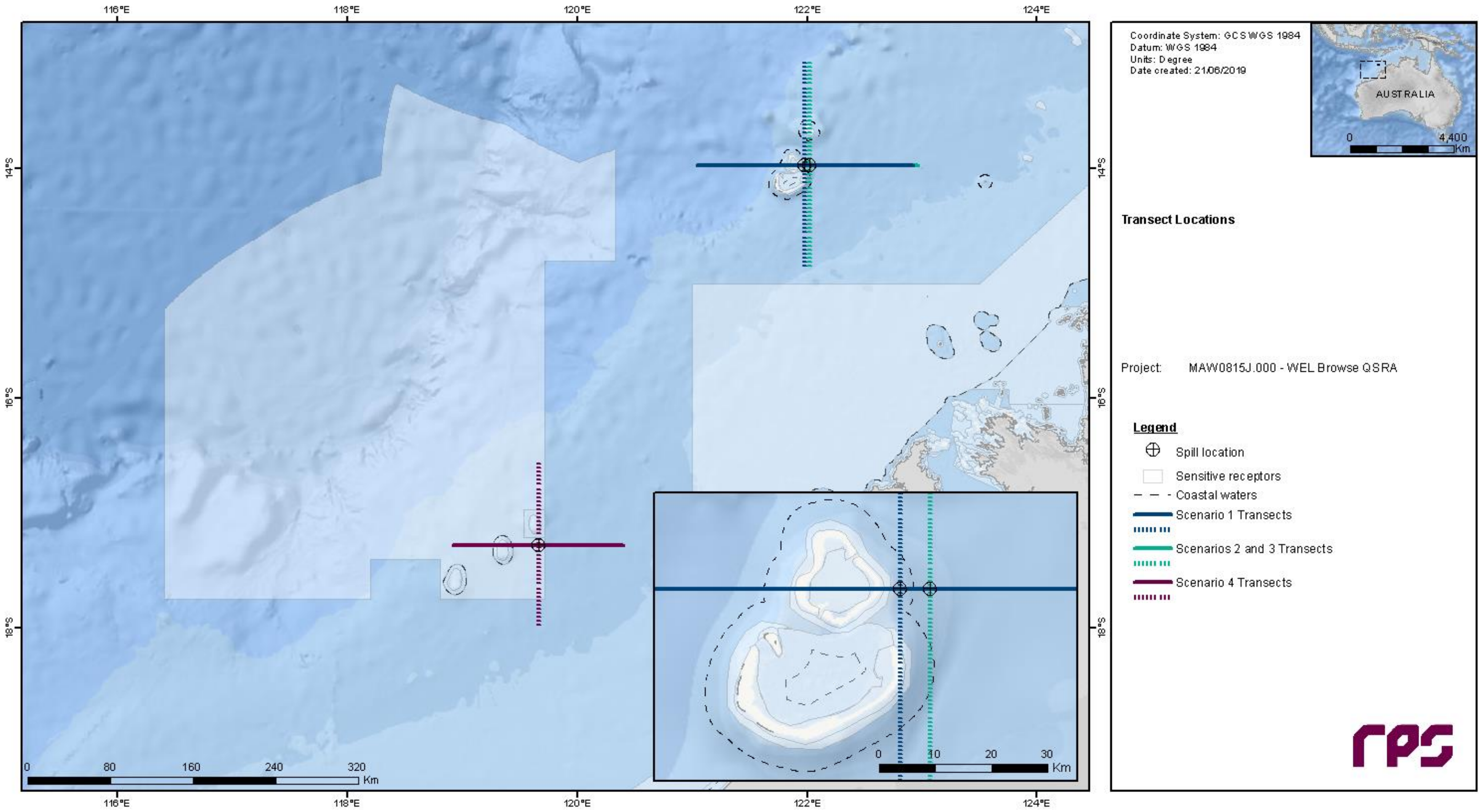

Figure 3.1 Locations of cross-sections, over a varying latitude (dashed line) and longitude (solid line), along which the distributions of maximum entrained oil and dissolved aromatic hydrocarbon concentrations were extracted for each spill scenario in this study.

3.2 Scenario 1: Long-Term (77-Day) Surface/Subsea Blowout of Unstabilised Torosa Condensate at the TRA-C Well

3.2.1 Discussion of Results

3.2.1.1 Overview

This scenario investigated the probability of exposure to surrounding regions by oil resulting from a long-term (77-day) surface/subsea release of 142,154 m^3 of unstabilised Torosa Condensate at the TRA-C well during operations at any time of year, with no mitigation measures applied.

During the initial surface release phase, the volatile fractions of the oil (16.5%) are likely to evaporate within 24 hours of exposure to the atmosphere. The low-volatility fraction of the condensate (32.8%) will take longer times of the order of days to weeks to evaporate, and the remaining fraction (50.7%) is expected to persist for an extended period of time as residual oil.

During the subsea release phase, the small oil droplets rapidly transported to the sea surface by the rising gas plume will be susceptible to re-entrainment into the wave mixed layer under typical wind conditions. It is likely that the bulk of the oil mass will remain entrained in the water column until degradation processes occur. Due to the weak buoyancy of the oil droplets, the formation of floating slicks is unlikely, and therefore only a small fraction of the volatile compounds is likely to be exposed to the atmosphere. Considering the spill volume and low levels of evaporation expected, there is a high potential for dissolution of soluble aromatic compounds.

3.2.1.2 Floating and Shoreline Oil

The probability contour figures for floating oil indicate that concentrations equal to or greater than the 10 g/m^2 threshold could potentially be found, in the form of slicks, up to 143 km from the spill site (Figure 3.3).

The Scott Reef South, Scott Reef Central and Scott Reef Central – Sandy Islet shoreline receptors are predicted to be contacted by floating oil concentrations at the 10 g/m^2 threshold with probabilities of 45%, 9% and 8%, respectively (Table 3.1). At these receptors, the corresponding minimum times to contact at this threshold are 18 hours, 42 hours and 46 hours.

The Scott Reef South, Scott Reef Central and Scott Reef Central – Sandy Islet receptors are predicted to experience shoreline oil accumulation in excess of the 100 g/m^2 threshold with a probability of 92% (Table 3.1). Potential for accumulation of oil on shorelines is predicted to be significant, with a maximum accumulated volume of 827 m^3 and a maximum local accumulated concentration of 34.3 kg/m^2 forecast at these receptors (Table 3.1). The predicted zone of shoreline impact is restricted to Sandy Islet, at which these three receptors overlap. Sandy Islet is treated as an emergent feature, while the intertidal reefs to the north and south are treated as submerged features for the purposes of this study.

The forecast annualised minimum times to contact and EMBA for floating oil at or above the 1 g/m^2 and 10 g/m^2 threshold concentrations are depicted in Figure 3.4 to Figure 3.7.

3.2.1.3 Entrained Oil

Entrained oil at concentrations equal to or greater than the 100 ppb threshold is predicted to be found up to around 863 km from the spill site (Figure 3.9).

Contact by entrained oil at concentrations equal to or greater than 100 ppb is predicted at Scott Reef North, Scott Reef North – Flats and Scott Reef North – Lagoon with probabilities of 100% (Table 3.2). The maximum entrained oil concentration forecast for any receptor is predicted as 23.6 ppm at Scott Reef North.

The forecast annualised minimum times to contact and EMBA for entrained oil at or above the 100 ppb threshold concentration are depicted in Figure 3.10 and Figure 3.11, respectively.

The cross-sectional transects of maximum entrained oil concentrations in the vicinity of the release site show that concentrations above 25,000 ppb are expected to extend from the sea surface to depths of around 20 m (Figure 3.12).

3.2.1.4 Dissolved Aromatic Hydrocarbons

Dissolved aromatic hydrocarbons at concentrations equal to or greater than the 50 ppb threshold are predicted to be found up to around 673 km from the spill site (Figure 3.13).

Contact by dissolved aromatic hydrocarbons at concentrations equal to or greater than 50 ppb is predicted at Scott Reef North, Scott Reef North – Flats and Scott Reef North – Lagoon with probabilities of 100% (Table 3.3). The maximum dissolved aromatic hydrocarbon concentration forecast for any receptor is predicted as 13.9 ppm at Scott Reef North.

The forecast annualised minimum times to contact and EMBA for dissolved aromatic hydrocarbons at or above the 500 ppb threshold concentration are depicted in Figure 3.14 and Figure 3.15, respectively.

The cross-sectional transects of maximum dissolved aromatic hydrocarbon concentrations in the vicinity of the release site show that concentrations above 10,000 ppb are expected to extend from the sea surface to depths of around 20 m (Figure 3.16).

3.2.2 Results Tables and Figures

3.2.2.1 Floating and Shoreline Oil

Table 3.1 Expected annualised floating and shoreline oil outcomes at sensitive receptors resulting from a 77-day surface/subsea release of unstabilised Torosa Condensate at the TRA-C well.

Receptor	Probability (%) of floating oil concentration		Minimum time to receptor (hours) for floating oil at		Probability (%) of shoreline oil concentration	Minimum time to receptor (hours) for shoreline oil at	Maximum local accumulated concentration (g/m^2)		Maximum accumulated volume (m^3) along this shoreline	
	≥1 g/m^2	≥10 g/m^2	≥1 g/m^2	≥10 g/m^2	≥100 g/m^2	≥100 g/m^2	averaged over all replicate simulations	in the worst replicate simulation	averaged over all replicate simulations	in the worst replicate simulation
Argo-Rowley Terrace Marine Park *	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Ashmore Reef Marine Park	<1	<1	NC	NC	18	547	302	6,657	23	157
Browse Island*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Buccaneer & Bonaparte Archipelagos	<1	<1	NC	NC	2	2,349	3.9	155	<1	8
Cartier Island Marine Park	<1	<1	NC	NC	22	851	87	1,744	8	38
Glomar Shoals & Rankin Bank*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Hibernia Reef*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Indonesia	<1	<1	NC	NC	3	1,722	10	457	8	52
Indonesian Boundary	<1	<1	NC	NC	3	1,722	10	457	6	57
Kimberley Marine Park *	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Kimberley Coast	<1	<1	NC	NC	1	2,345	2.7	205	<1	14
Lacepede Islands	<1	<1	NC	NC	<1	NC	0.2	12	<1	<1
Oceanic Shoals Marine Park *	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Pulau Roti	<1	<1	NC	NC	<1	NC	0.2	24	<1	2
Rowley Shoals - Clerke Reef State Marine Park	<1	<1	NC	NC	8	1,103	38	583	3	16
Rowley Shoals - Imperieuse Reef State Marine Park	<1	<1	NC	NC	8	1,198	34	557	3	18
Rowley Shoals - Mermaid Reef Marine Park	<1	<1	NC	NC	9	1,038	75	1,059	4	25
Scott Reef North*	100	100	2	3	NA	NA	NA	NA	NA	NA
Scott Reef South	88	45	16	18	92	42	8,495	34,279	339	827
Seringapatam Reef*	46	10	30	33	NA	NA	NA	NA	NA	NA
Sumba	<1	<1	NC	NC	3	1,742	10	457	4	36
Ashmore Reef	<1	<1	NC	NC	18	547	302	6,657	23	157
Big Bank Shoals*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Camden Sound	<1	<1	NC	NC	<1	NC	<0.1	7.5	<1	<1
Cartier Island	<1	<1	NC	NC	22	851	87	1,744	8	38
Dampier Peninsula Coast - Mid Section	<1	<1	NC	NC	<1	NC	<0.1	2.1	<1	<1
Dampier Peninsula Coast - North Section	<1	<1	NC	NC	<1	NC	<0.1	2	<1	<1
Lalang-garram - Camden Sound Marine Park	<1	<1	NC	NC	1	2,395	1.5	149	<1	6

Receptor	Probability (%) of floating oil concentration		Minimum time to receptor (hours) for floating oil at		Probability (%) of shoreline oil concentration	Minimum time to receptor (hours) for shoreline oil at	Maximum local accumulated concentration (g/m^2)		Maximum accumulated volume (m^3) along this shoreline	
	≥1 g/m^2	≥10 g/m^2	≥1 g/m^2	≥10 g/m^2	≥100 g/m^2	≥100 g/m^2	averaged over all replicate simulations	in the worst replicate simulation	averaged over all replicate simulations	in the worst replicate simulation
Rowley Shoals - Clerke Reef	<1	<1	NC	NC	8	1,103	38	583	3	16
Rowley Shoals - Imperieuse Reef	<1	<1	NC	NC	8	1,198	34	557	3	18
Rowley Shoals - Mermaid Reef	<1	<1	NC	NC	9	1,038	75	1,059	4	25
Sahul Banks*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Savu	<1	<1	NC	NC	<1	NC	0.8	38	<1	5
Scott Reef Central	56	9	31	42	92	42	8,495	34,279	339	827
Scott Reef Central - Sandy Islet	51	8	39	46	92	42	8,495	34,279	339	827
Scott Reef North - Flats*	100	99	3	4	NA	NA	NA	NA	NA	NA
Scott Reef North - Lagoon*	100	94	6	7	NA	NA	NA	NA	NA	NA
Scott Reef South - Flats*	62	19	31	34	NA	NA	NA	NA	NA	NA
Scott Reef South - Lagoon*	88	47	14	15	NA	NA	NA	NA	NA	NA
Adele Island	<1	<1	NC	NC	<1	NC	1.4	54	<1	2
Barracouta Shoal*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Echuca Shoal*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Eighty Mile Beach Marine Park *	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Eugene McDermott Shoal*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Fantome Bank*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Heywood Shoal*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Oceanic Shoals - Deep Shoal 1*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Oceanic Shoals Region - Gale-Favell-Baldwin Banks*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Oceanic Shoals Region - Margaret Harries Banks*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Oceanic Shoals Region - The Boxers*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Timor Leste	<1	<1	NC	NC	1	2,387	1.6	160	<1	7
Timor West	<1	<1	NC	NC	<1	NC	1.1	65	<1	9
Van Cloon Shoal*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Vulcan & Goeree Shoals*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
WA Coastline	<1	<1	NC	NC	2	1,892	3.9	205	2	19

NC: No contact to receptor predicted for specified threshold. NA: Not applicable.

* Floating oil will not accumulate on submerged features and at open ocean locations.

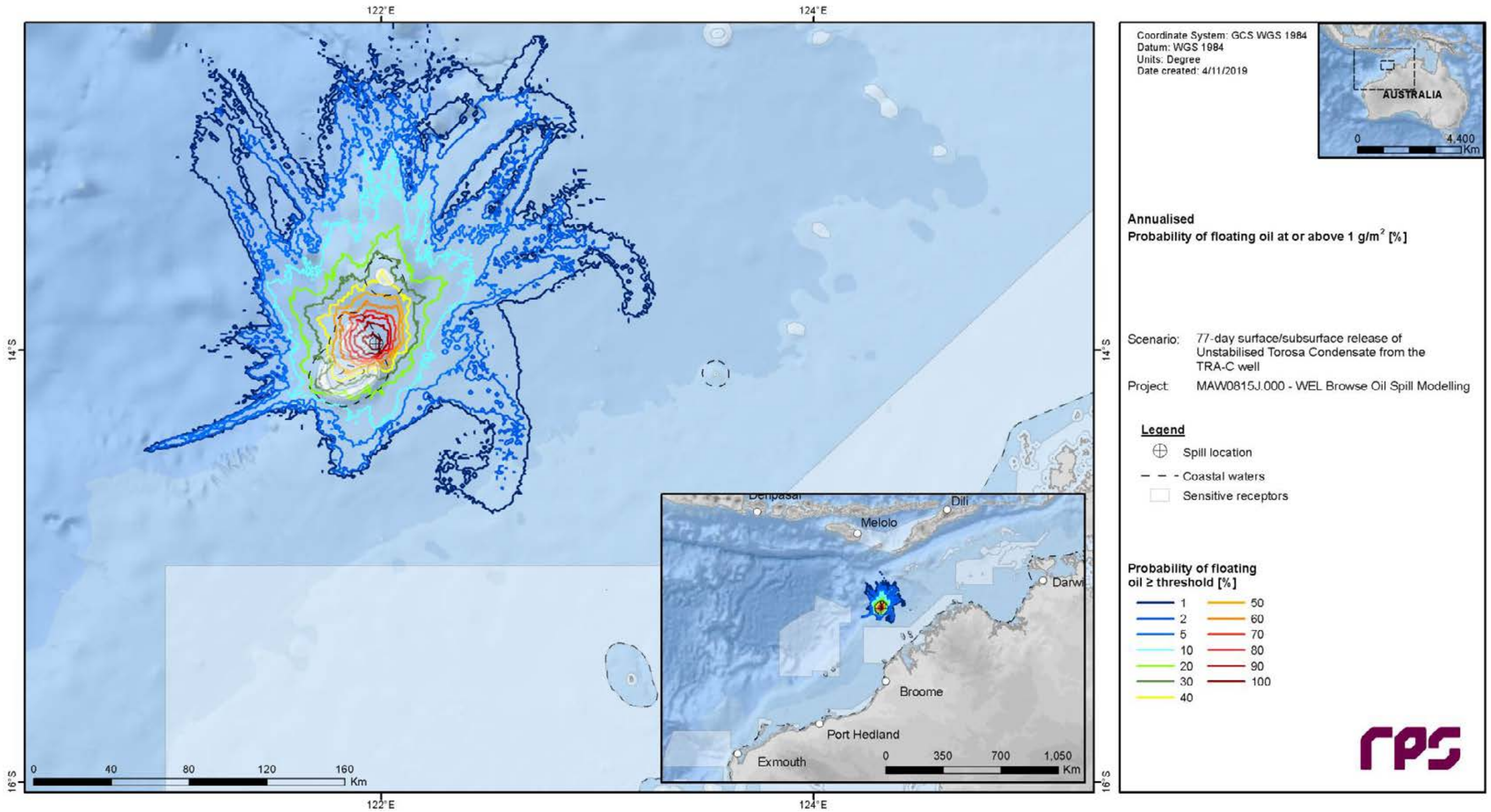

Figure 3.2 Predicted annualised probability of floating oil concentrations at or above 1 g/m^2 resulting from a 77-day surface/subsea release of unstabilised Torosa Condensate at the TRA-C well.

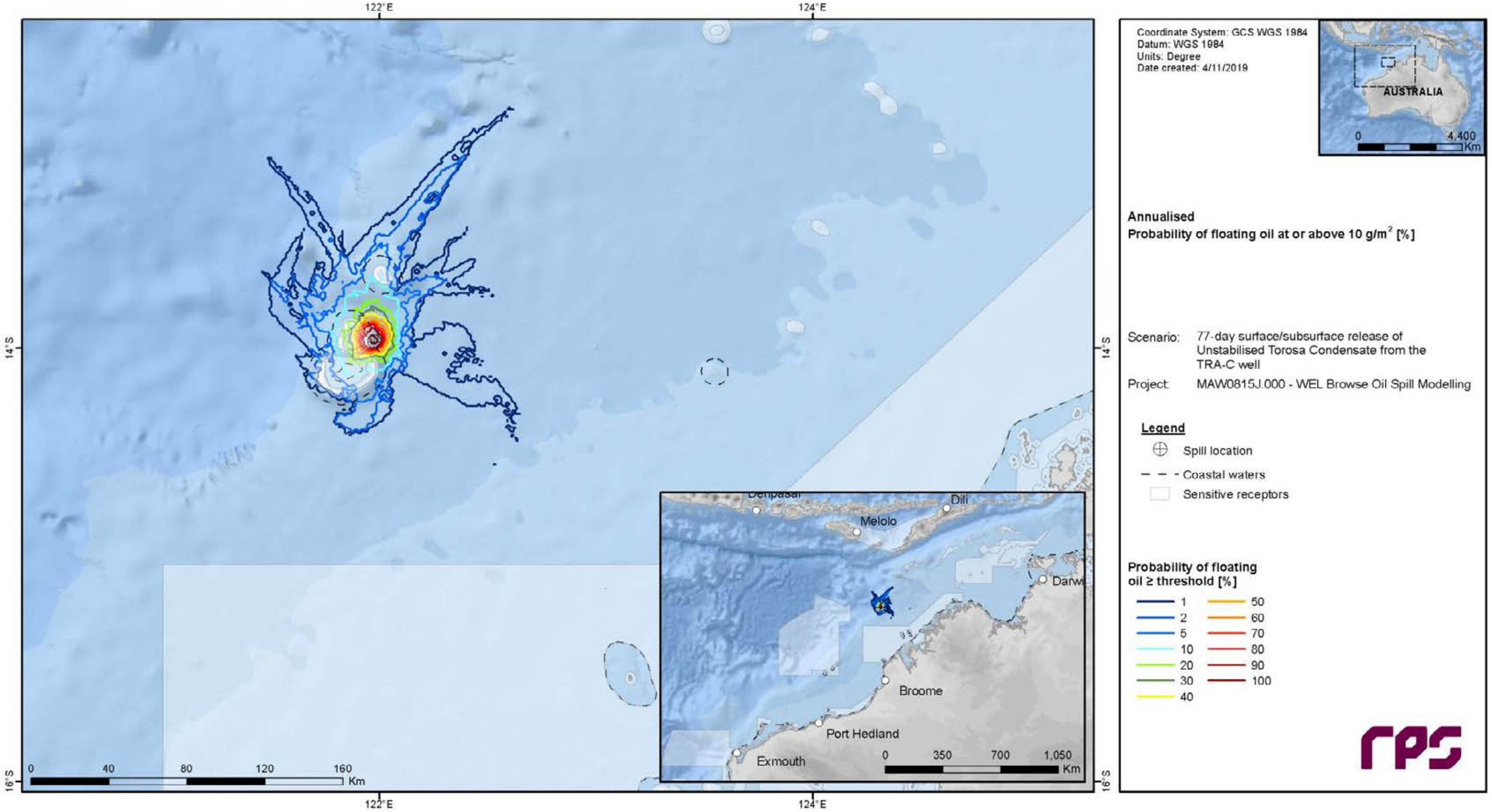

Figure 3.3 Predicted annualised probability of floating oil concentrations at or above 10 g/m^2 resulting from a 77-day surface/subsea release of unstabilised Torosa Condensate at the TRA-C well.

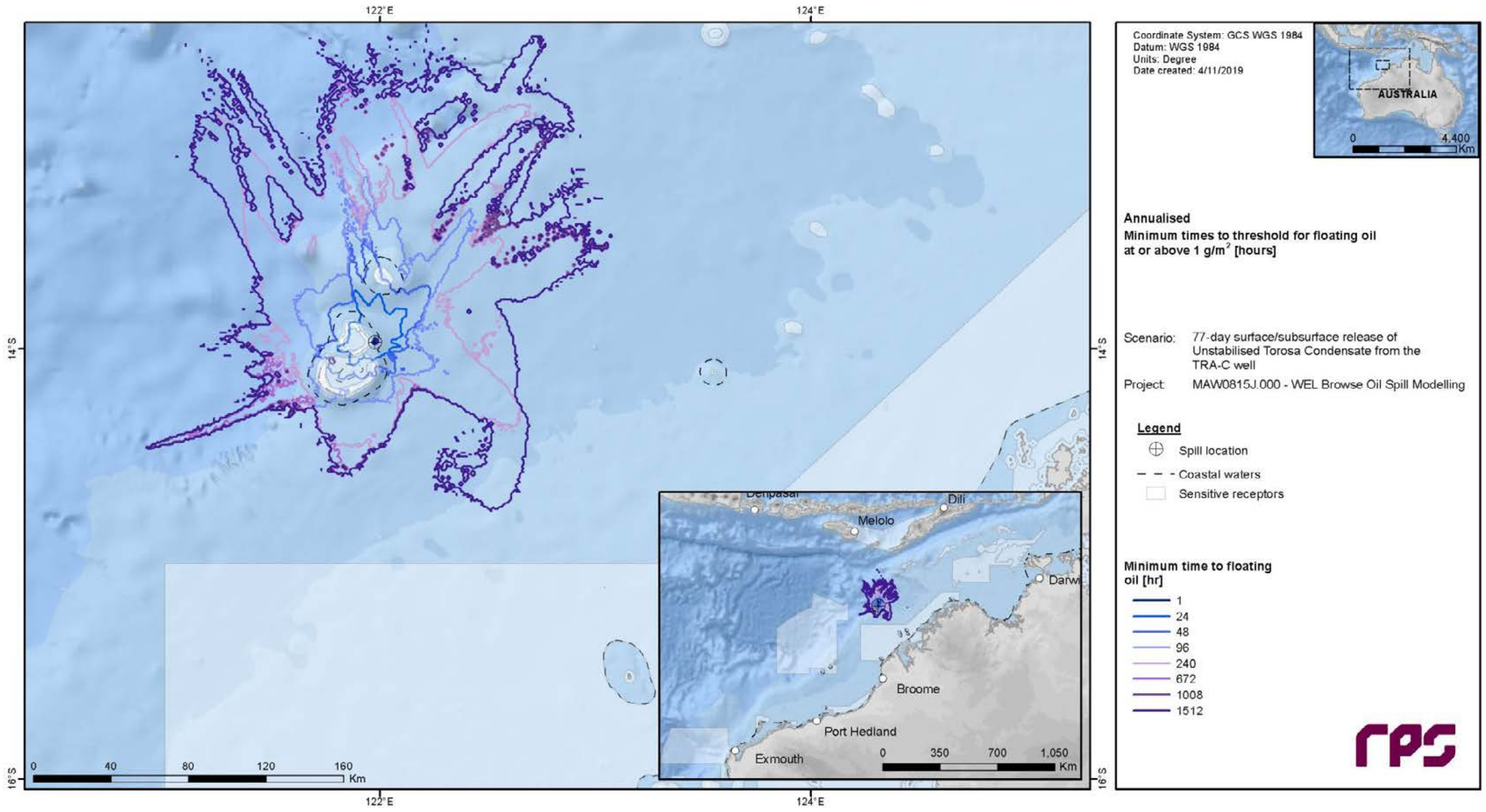

Figure 3.4 Predicted annualised minimum times to contact by floating oil concentrations at or above 1 g/m^2 resulting from a 77-day surface/subsea release of unstabilised Torosa Condensate at the TRA-C well.

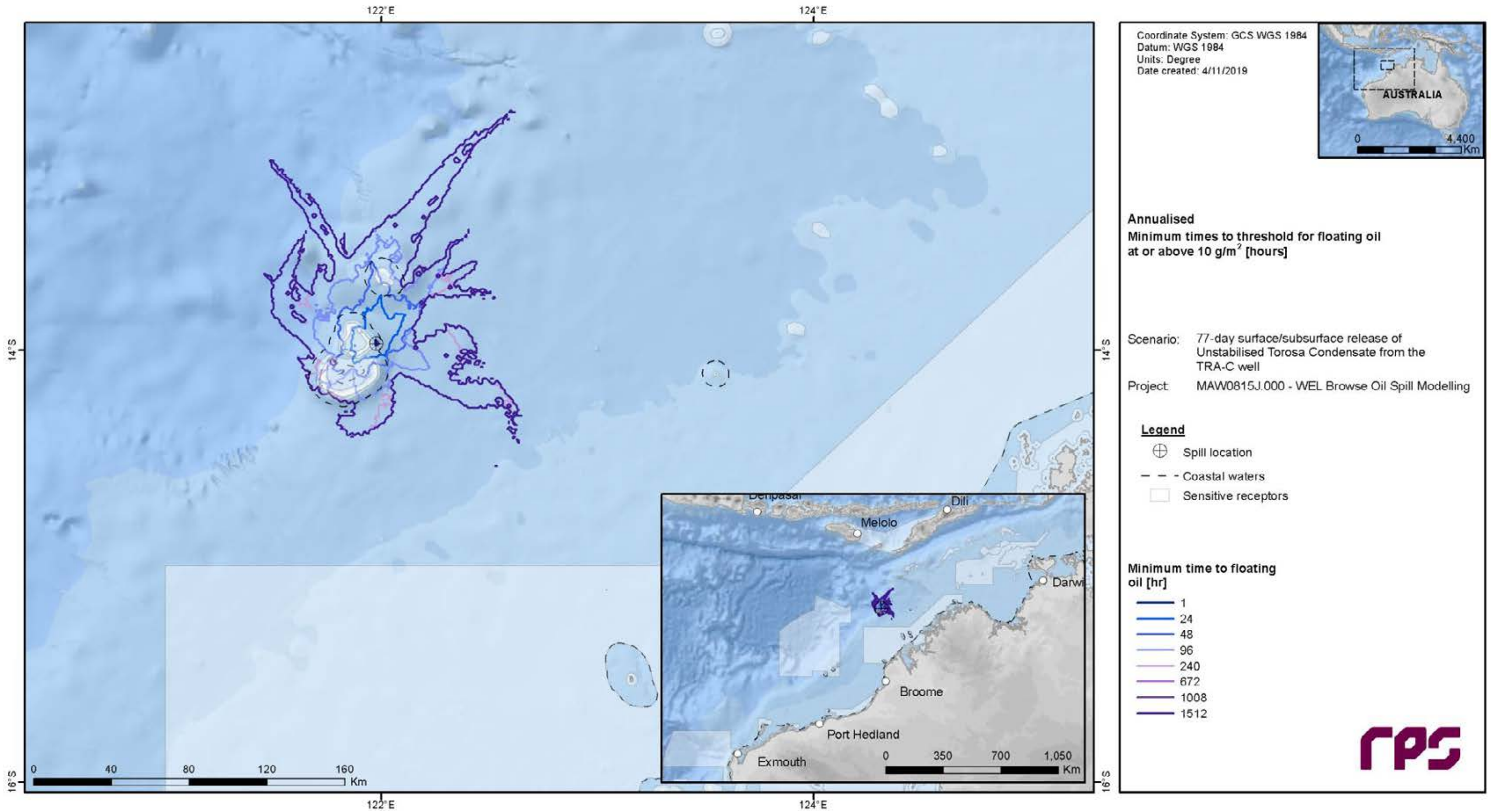

Figure 3.5 Predicted annualised minimum times to contact by floating oil concentrations at or above 10 g/m^2 resulting from a 77-day surface/subsea release of unstabilised Torosa Condensate at the TRA-C well.

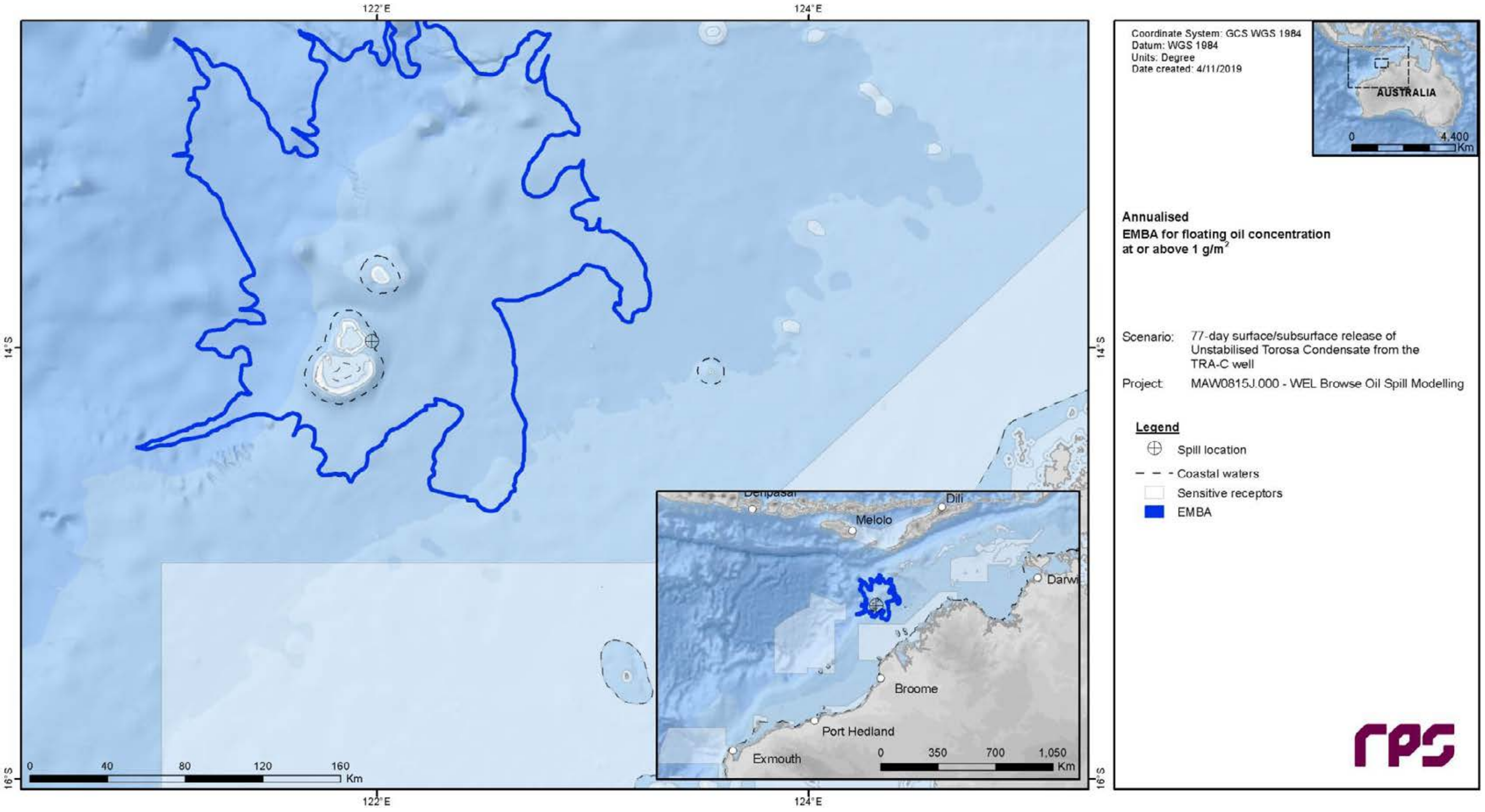

Figure 3.6 Predicted annualised EMBA of floating oil concentrations at or above 1 g/m^2 resulting from a 77-day surface/subsea release of unstabilised Torosa Condensate at the TRA-C well.

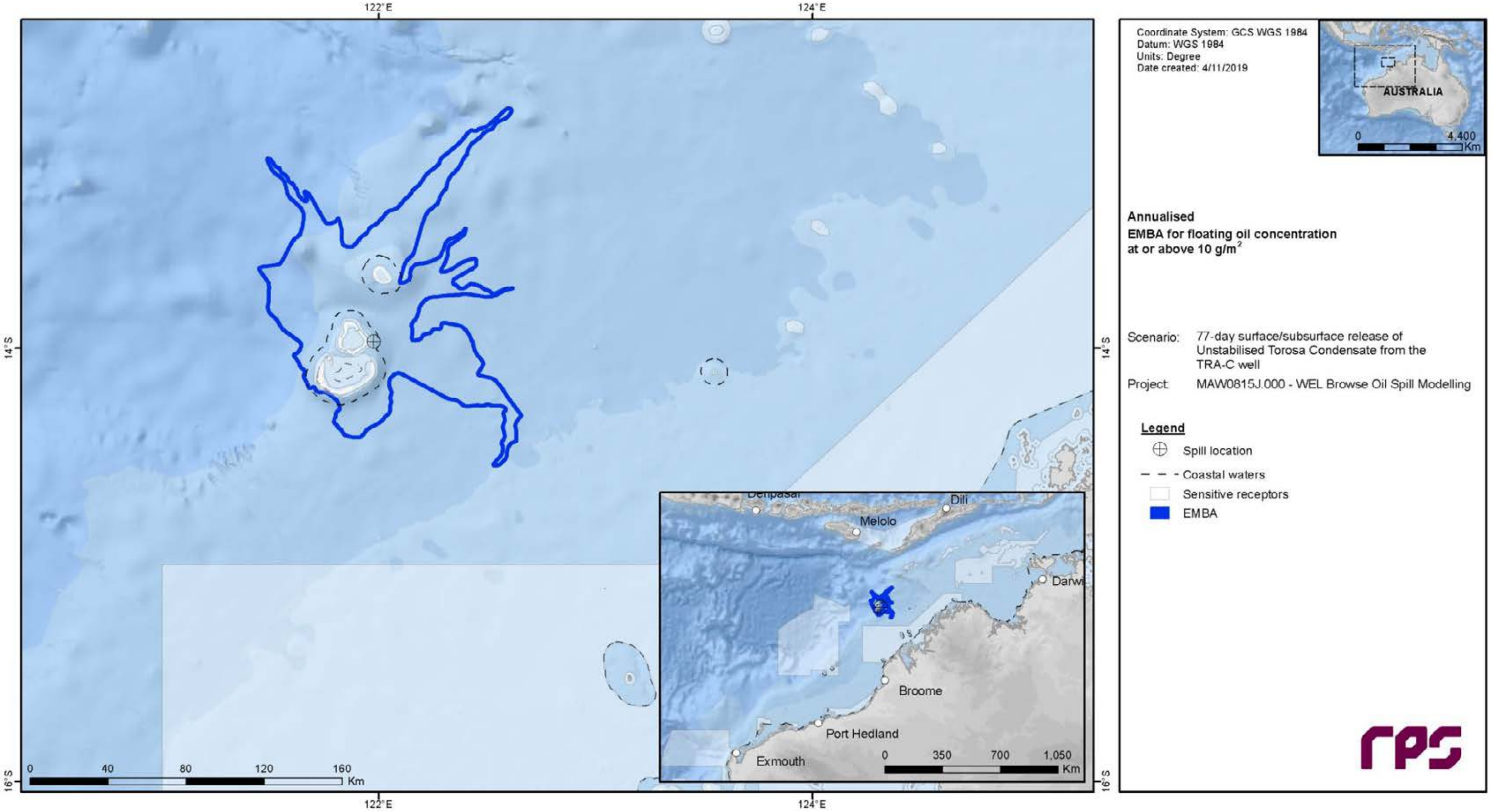

Figure 3.7 Predicted annualised EMBA of floating oil concentrations at or above 10 g/m^2 resulting from a 77-day surface/subsea release of unstabilised Torosa Condensate at the TRA-C well.

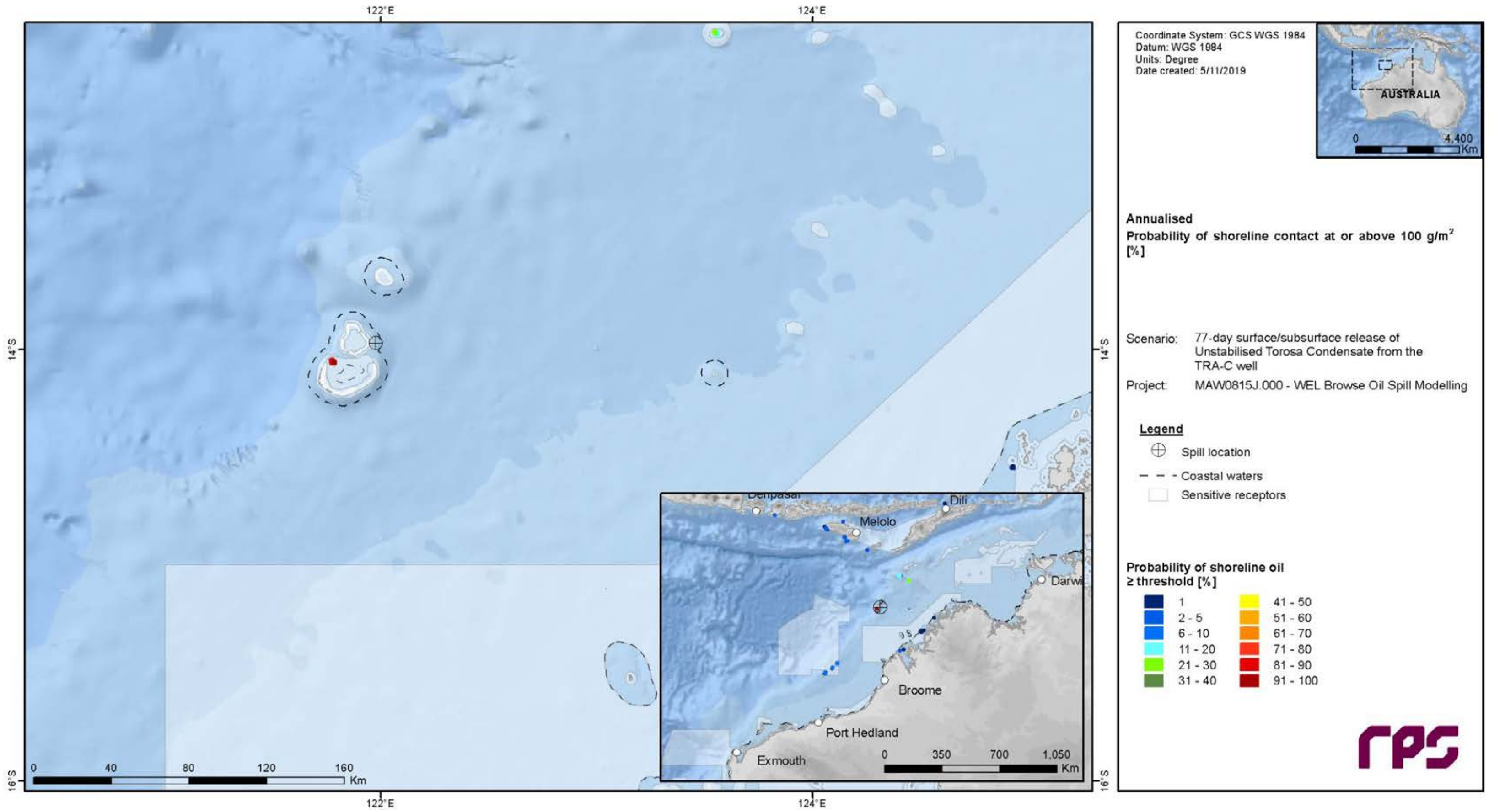

Figure 3.8 Predicted annualised probability of shoreline oil concentrations at or above 100 g/m^2 resulting from a 77-day surface/subsea release of unstabilised Torosa Condensate at the TRA-C well.

3.2.2.2 Entrained Oil

Table 3.2 Expected annualised entrained oil outcomes at sensitive receptors resulting from a 77-day surface/subsea release of unstabilised Torosa Condensate at the TRA-C well.

Receptor	Probability (%) of entrained oil concentration ≥100 ppb	Minimum time to receptor (hours) for entrained oil at ≥100 ppb	Maximum entrained oil concentration (ppb) averaged over all replicate simulations	Maximum entrained oil concentration (ppb) at any depth, in the worst replicate simulation
Argo-Rowley Terrace Marine Park	21	394	64	719
Ashmore Reef Marine Park	8	390	28	602
Browse Island	3	700	17	305
Buccaneer & Bonaparte Archipelagos	<1	NC	<1	53
Cartier Island Marine Park	13	478	32	345
Glomar Shoals & Rankin Bank	<1	NC	<1	<1
Hibernia Reef	8	355	15	328
Indonesia	<1	NC	2	33
Indonesian Boundary	<1	NC	3	96
Kimberley Marine Park	31	334	77	1,010
Kimberley Coast	<1	NC	2	98
Lacepede Islands	<1	NC	<1	3
Oceanic Shoals Marine Park	1	987	3	101
Pulau Roti	<1	NC	<1	2
Rowley Shoals - Clerke Reef State Marine Park	<1	NC	6	86
Rowley Shoals - Imperieuse Reef State Marine Park	<1	NC	3	44
Rowley Shoals - Mermaid Reef Marine Park	8	1,036	10	137
Scott Reef North	100	3	7,858	23,584
Scott Reef South	97	13	3,576	11,647
Seringapatam Reef	87	37	1,241	5,213
Sumba	<1	NC	<1	19
Ashmore Reef	8	397	26	502
Big Bank Shoals	<1	NC	<1	9
Camden Sound	<1	NC	<1	38
Cartier Island	13	498	30	301
Dampier Peninsula Coast - Mid Section	<1	NC	<1	<1
Dampier Peninsula Coast - North Section	<1	NC	<1	3

Receptor	Probability (%) of entrained oil concentration ≥100 ppb	Minimum time to receptor (hours) for entrained oil at ≥100 ppb	Maximum entrained oil concentration (ppb) averaged over all replicate simulations	Maximum entrained oil concentration (ppb) at any depth, in the worst replicate simulation
Lalang-garram - Camden Sound Marine Park	<1	NC	<1	50
Rowley Shoals - Clerke Reef	<1	NC	5	61
Rowley Shoals - Imperieuse Reef	<1	NC	2	30
Rowley Shoals - Mermaid Reef	8	1,055	9	119
Sahul Banks	<1	NC	3	51
Savu	<1	NC	<1	11
Scott Reef Central	92	29	2,079	7,648
Scott Reef Central - Sandy Islet	91	35	2,079	7,648
Scott Reef North - Flats	100	4	6,259	18,068
Scott Reef North - Lagoon	100	6	3,762	10,505
Scott Reef South - Flats	94	21	2,873	9,004
Scott Reef South - Lagoon	97	12	3,387	11,747
Adele Island	<1	NC	2	71
Barracouta Shoal	8	621	29	348
Echuca Shoal	<1	NC	10	77
Eighty Mile Beach Marine Park	<1	NC	<1	2
Eugene McDermott Shoal	6	973	17	155
Fantome Bank	1	1,935	6	149
Heywood Shoal	5	867	16	144
Oceanic Shoals - Deep Shoal 1	<1	NC	<1	18
Oceanic Shoals Region - Gale-Favell-Baldwin Banks	<1	NC	2	27
Oceanic Shoals Region - Margaret Harries Banks	<1	NC	<1	24
Oceanic Shoals Region - The Boxers	<1	NC	<1	12
Timor Leste	<1	NC	<1	8
Timor West	<1	NC	<1	4
Van Cloon Shoal	<1	NC	<1	25
Vulcan & Goeree Shoals	10	535	23	227
WA Coastline	<1	NC	3	93

NC: No contact to receptor predicted for specified threshold.

* Probabilities and maximum concentrations calculated at depth of submerged feature.

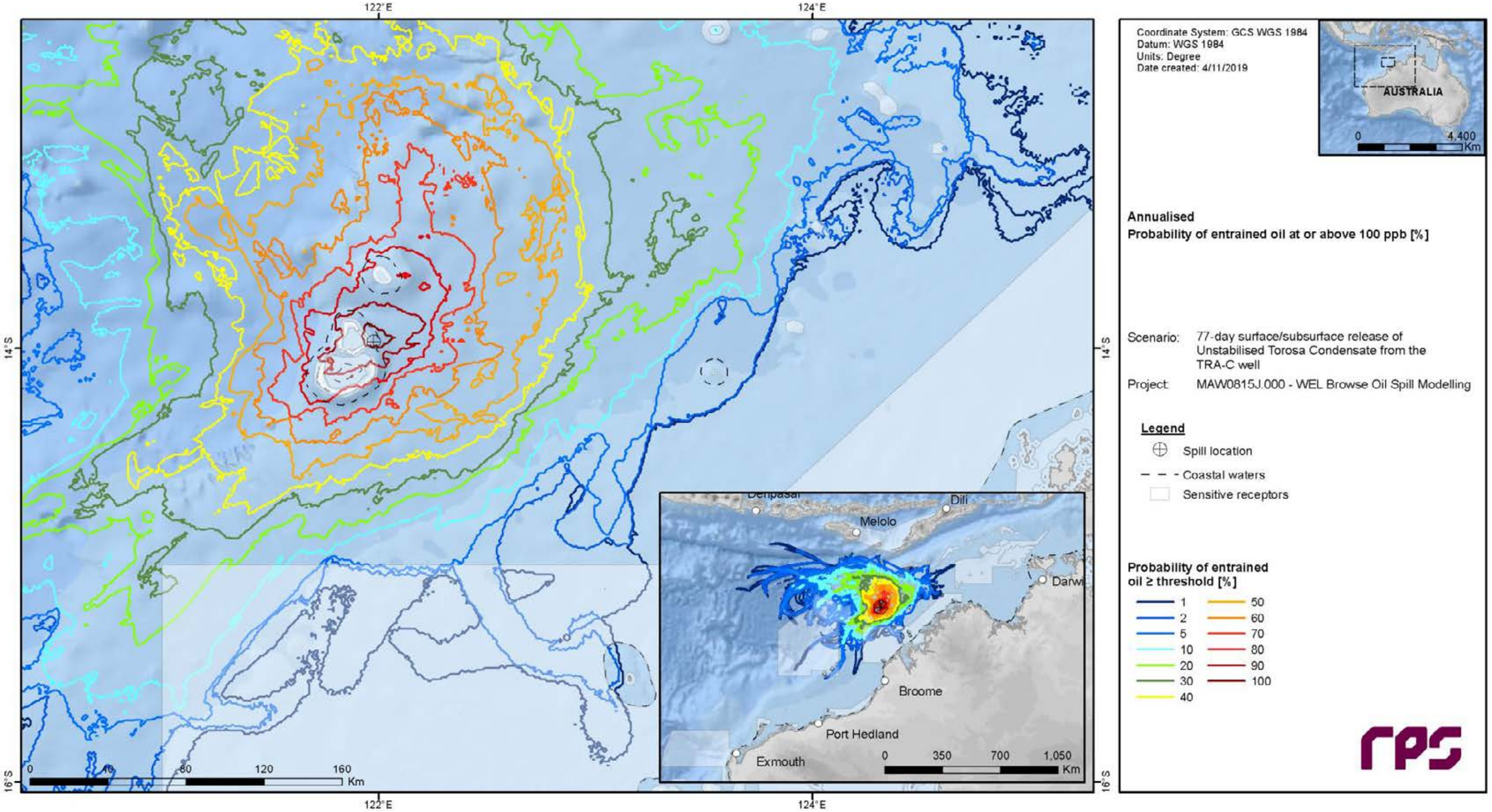

Figure 3.9 Predicted annualised probability of entrained oil concentrations at or above 100 ppb resulting from a 77-day surface/subsea release of unstabilised Torosa Condensate at the TRA-C well.

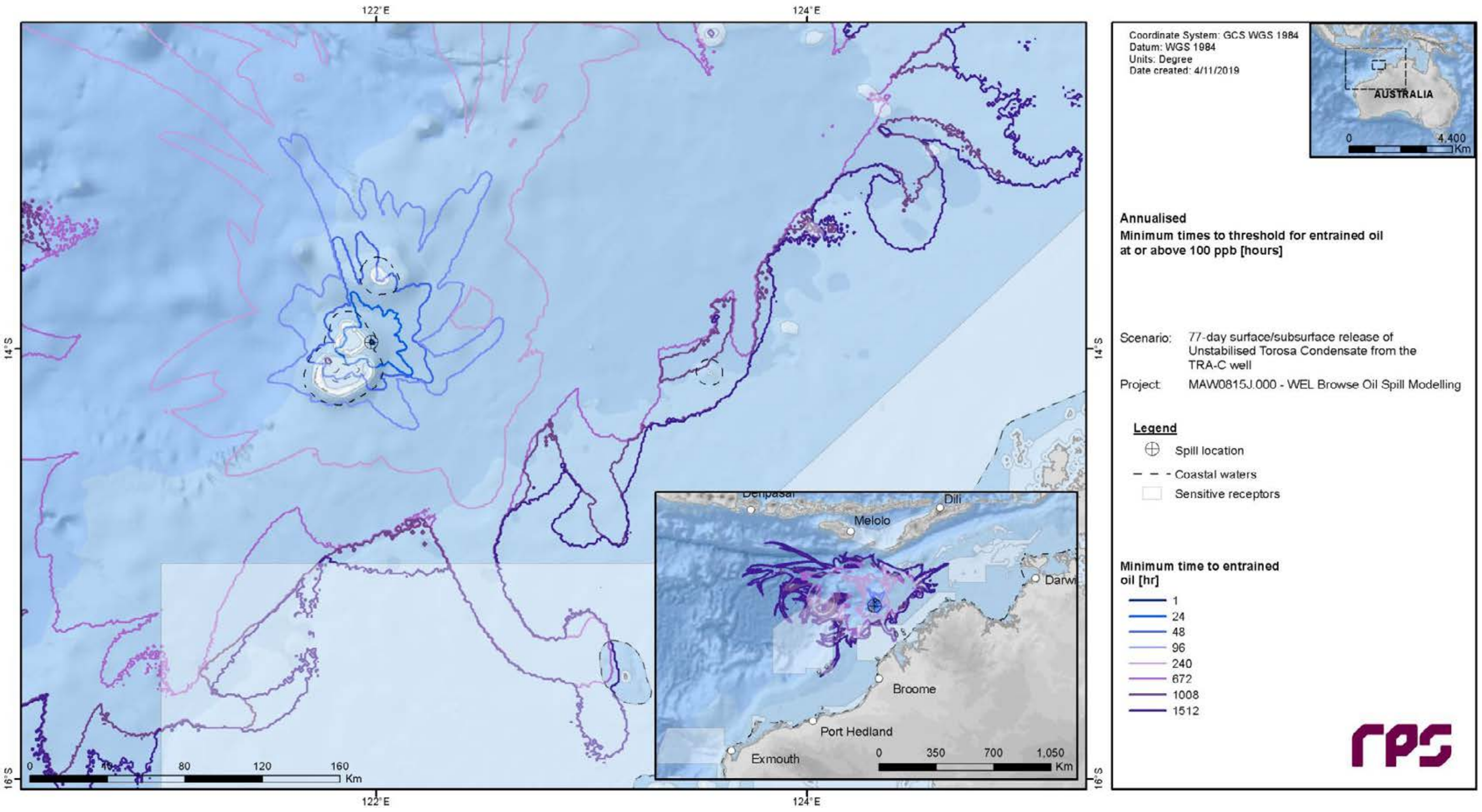

Figure 3.10 Predicted annualised minimum times to contact by entrained oil concentrations at or above 100 ppb resulting from a 77-day surface/subsea release of unstabilised Torosa Condensate at the TRA-C well.

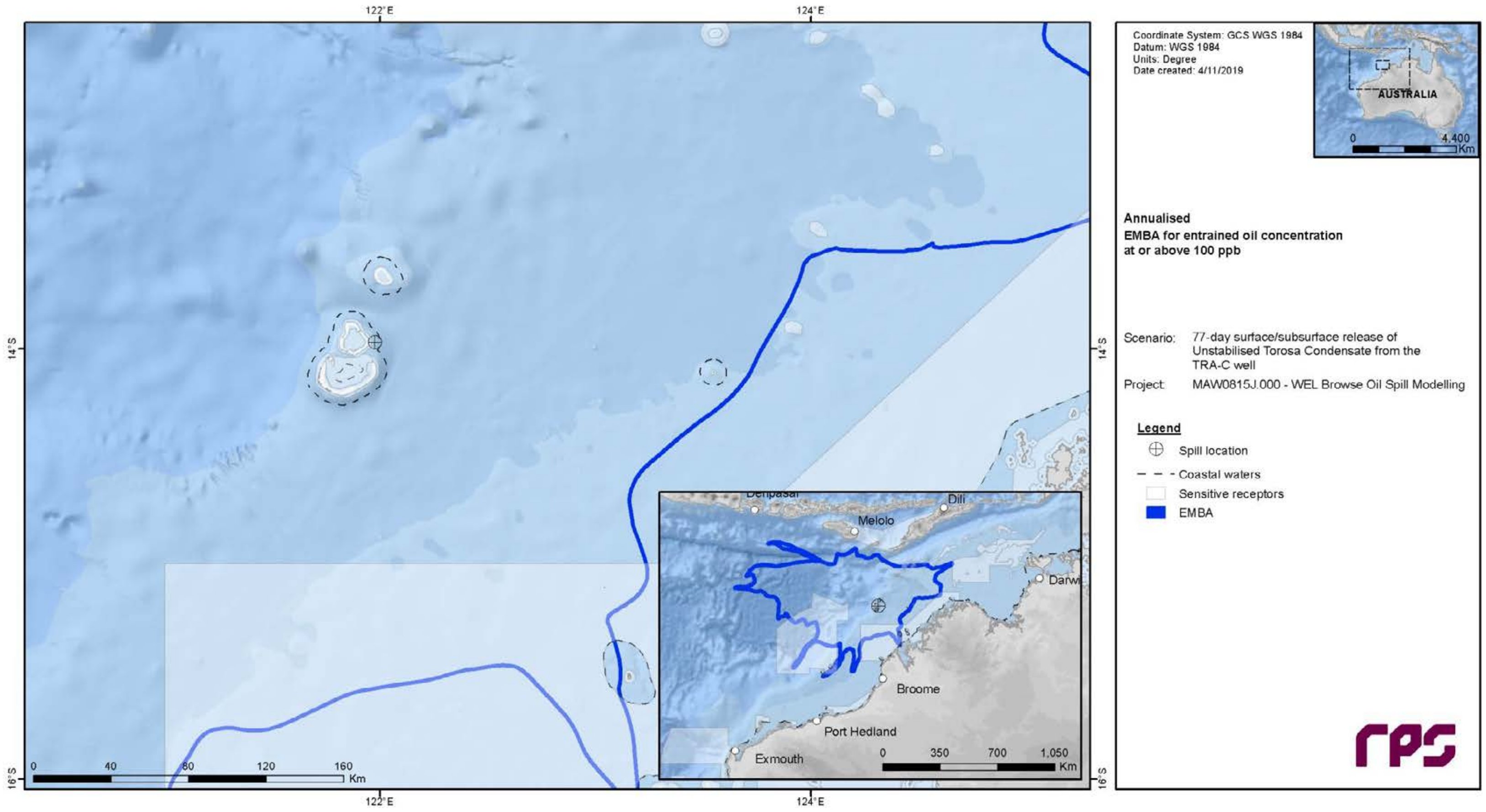

Figure 3.11 Predicted annualised EMBA of entrained oil concentrations at or above 100 ppb resulting from a 77-day surface/subsea release of unstabilised Torosa Condensate at the TRA-C well.

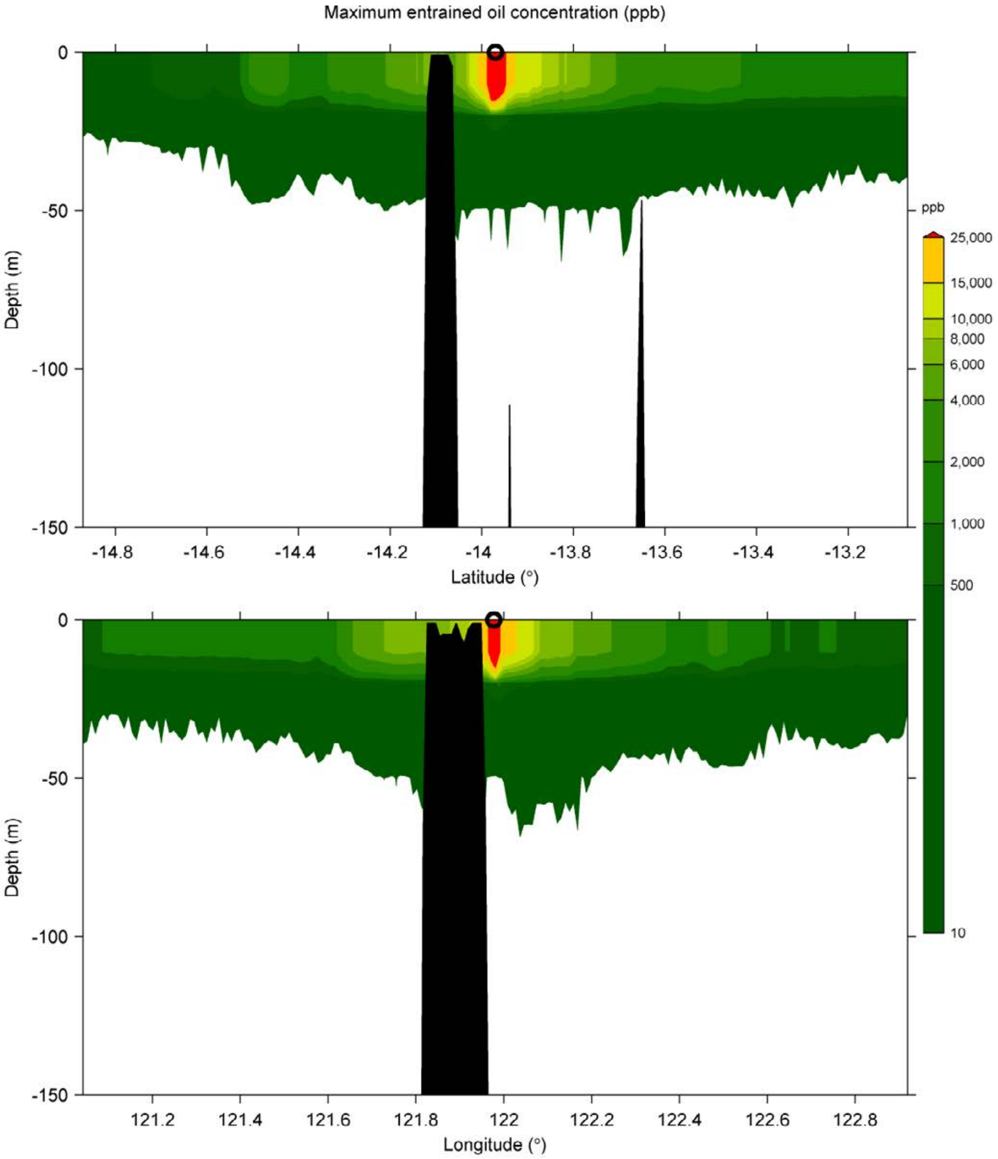

Figure 3.12 Cross-section transects of predicted annualised maximum entrained oil concentrations for a 77-day surface/subsea release of unstabilised Torosa Condensate at the TRA-C well. Transect locations are shown in Figure 3.1.

3.2.2.3 Dissolved Aromatic Hydrocarbons

Table 3.3 Expected annualised dissolved aromatic hydrocarbon outcomes at sensitive receptors resulting from a 77-day surface/subsea release of unstabilised Torosa Condensate at the TRA-C well.

Receptor	Probability (%) of dissolved aromatic hydrocarbon concentration	Maximum dissolved aromatic hydrocarbon concentration (ppb)	
	≥50 ppb	averaged over all replicate simulations	at any depth, in the worst replicate simulation
Argo-Rowley Terrace Marine Park	10	15	860
Ashmore Reef Marine Park	6	9	291
Browse Island	1	2	58
Buccaneer & Bonaparte Archipelagos	<1	<1	<1
Cartier Island Marine Park	10	15	394
Glomar Shoals & Rankin Bank	<1	<1	NC
Hibernia Reef	3	3	155
Indonesia	1	<1	71
Indonesian Boundary	1	<1	86
Kimberley Marine Park	19	32	1,281
Kimberley Coast	<1	<1	<1
Lacepede Islands	<1	<1	<1
Oceanic Shoals Marine Park	<1	<1	<1
Pulau Roti	<1	<1	<1
Rowley Shoals - Clerke Reef State Marine Park	<1	<1	10
Rowley Shoals - Imperieuse Reef State Marine Park	<1	<1	5
Rowley Shoals - Mermaid Reef Marine Park	<1	<1	25
Scott Reef North	100	3,839	13,907
Scott Reef South	98	2,659	12,404
Seringapatam Reef	85	957	6,635
Sumba	<1	<1	7
Ashmore Reef	5	6	198
Big Bank Shoals	<1	<1	<1
Camden Sound	<1	<1	<1
Cartier Island	9	13	332
Dampier Peninsula Coast - Mid Section	<1	<1	<1
Dampier Peninsula Coast - North Section	<1	<1	<1
Lalang-garram - Camden Sound Marine Park	<1	<1	<1

Receptor	Probability (%) of dissolved aromatic hydrocarbon concentration	Maximum dissolved aromatic hydrocarbon concentration (ppb)	
	≥50 ppb	averaged over all replicate simulations	at any depth, in the worst replicate simulation
Rowley Shoals - Clerke Reef	<1	<1	9
Rowley Shoals - Imperieuse Reef	<1	<1	5
Rowley Shoals - Mermaid Reef	<1	<1	25
Sahul Banks	<1	<1	2
Savu	<1	<1	13
Scott Reef Central	92	1,420	7,015
Scott Reef Central - Sandy Islet	91	1,420	7,015
Scott Reef North - Flats	100	3,582	10,655
Scott Reef North - Lagoon	100	2,611	9,652
Scott Reef South - Flats	94	2,659	12,404
Scott Reef South - Lagoon	98	2,572	11,654
Adele Island	<1	<1	2
Barracouta Shoal	1	3	62
Echuca Shoal	<1	<1	9
Eighty Mile Beach Marine Park	<1	<1	<1
Eugene McDermott Shoal	<1	<1	30
Fantome Bank	1	2	141
Heywood Shoal	<1	<1	16
Oceanic Shoals - Deep Shoal 1	<1	<1	<1
Oceanic Shoals Region - Gale-Favell-Baldwin Banks	<1	<1	<1
Oceanic Shoals Region - Margaret Harries Banks	<1	<1	<1
Oceanic Shoals Region - The Boxers	<1	<1	<1
Timor Leste	<1	<1	<1
Timor West	<1	<1	<1
Van Cloon Shoal	<1	<1	<1
Vulcan & Goeree Shoals	2	3	68
WA Coastline	<1	<1	2

NC: No contact to receptor predicted for specified threshold.

* Probabilities and maximum concentrations calculated at depth of submerged feature.

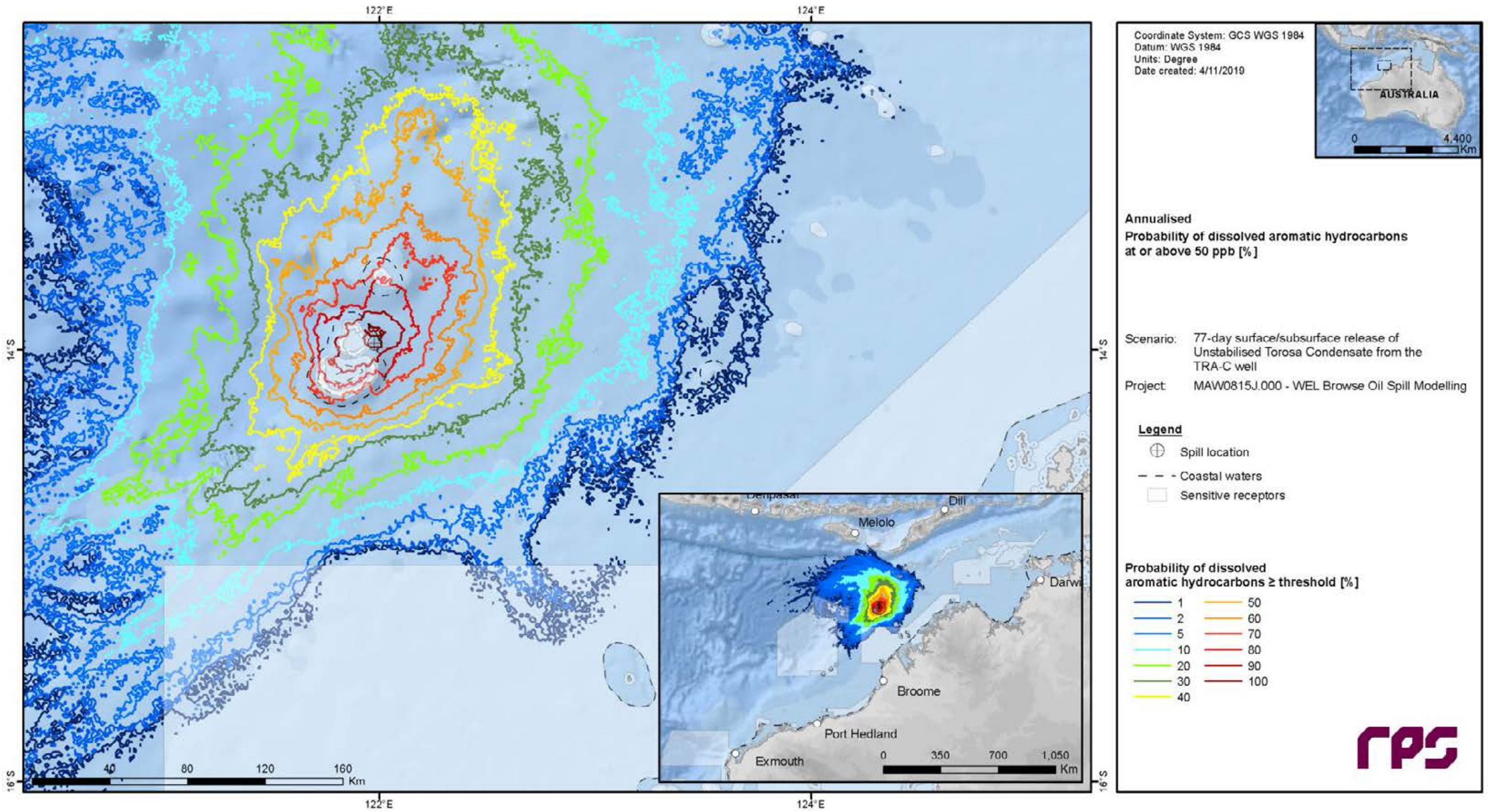

Figure 3.13 Predicted annualised probability of dissolved aromatic hydrocarbon concentrations at or above 50 ppb resulting from a 77-day surface/subsea release of unstabilised Torosa Condensate at the TRA-C well.

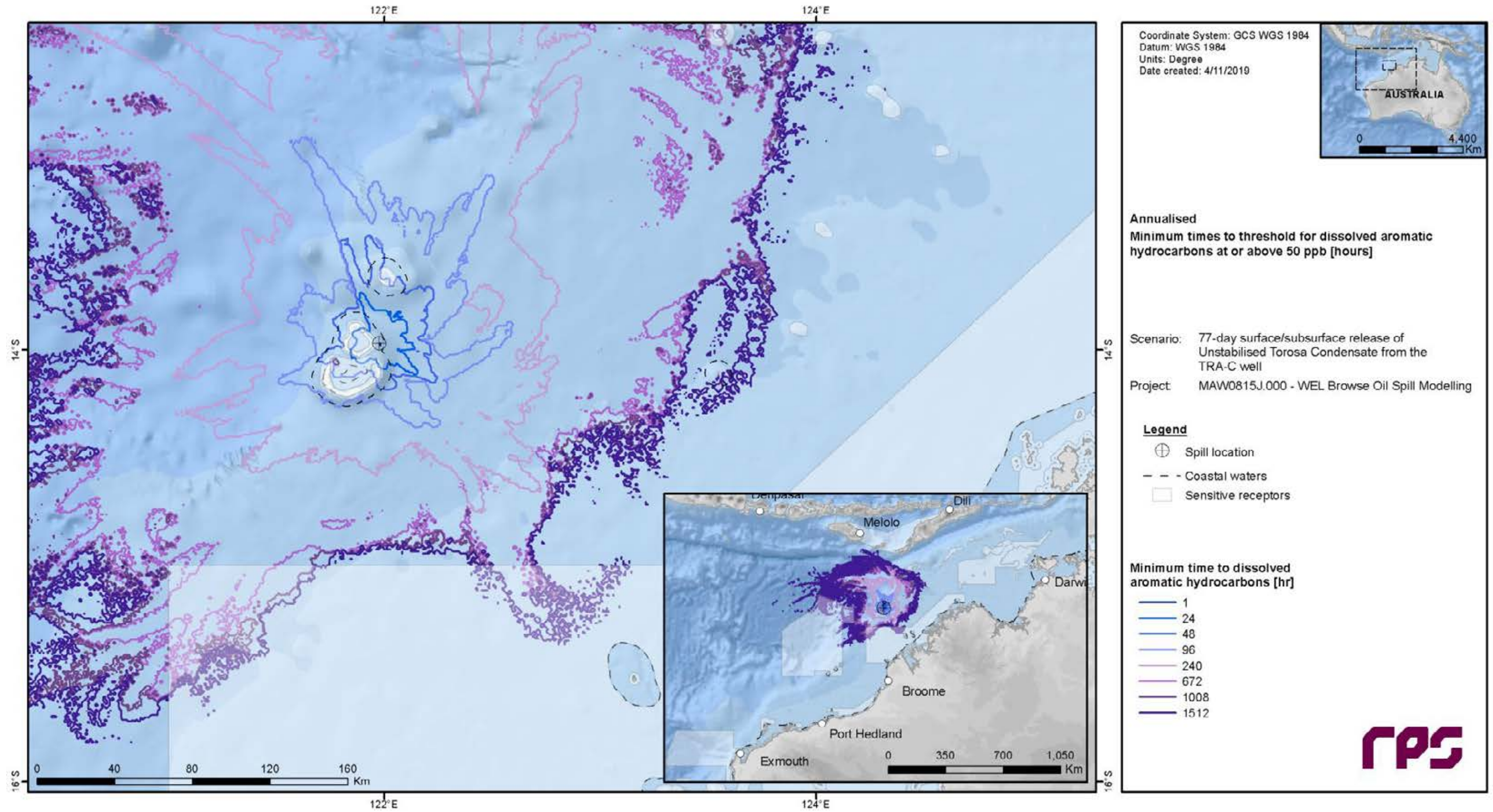

Figure 3.14 Predicted annualised minimum times to contact by dissolved aromatic hydrocarbon concentrations at or above 50 ppb resulting from a 77-day surface/subsea release of unstabilised Torosa Condensate at the TRA-C well.

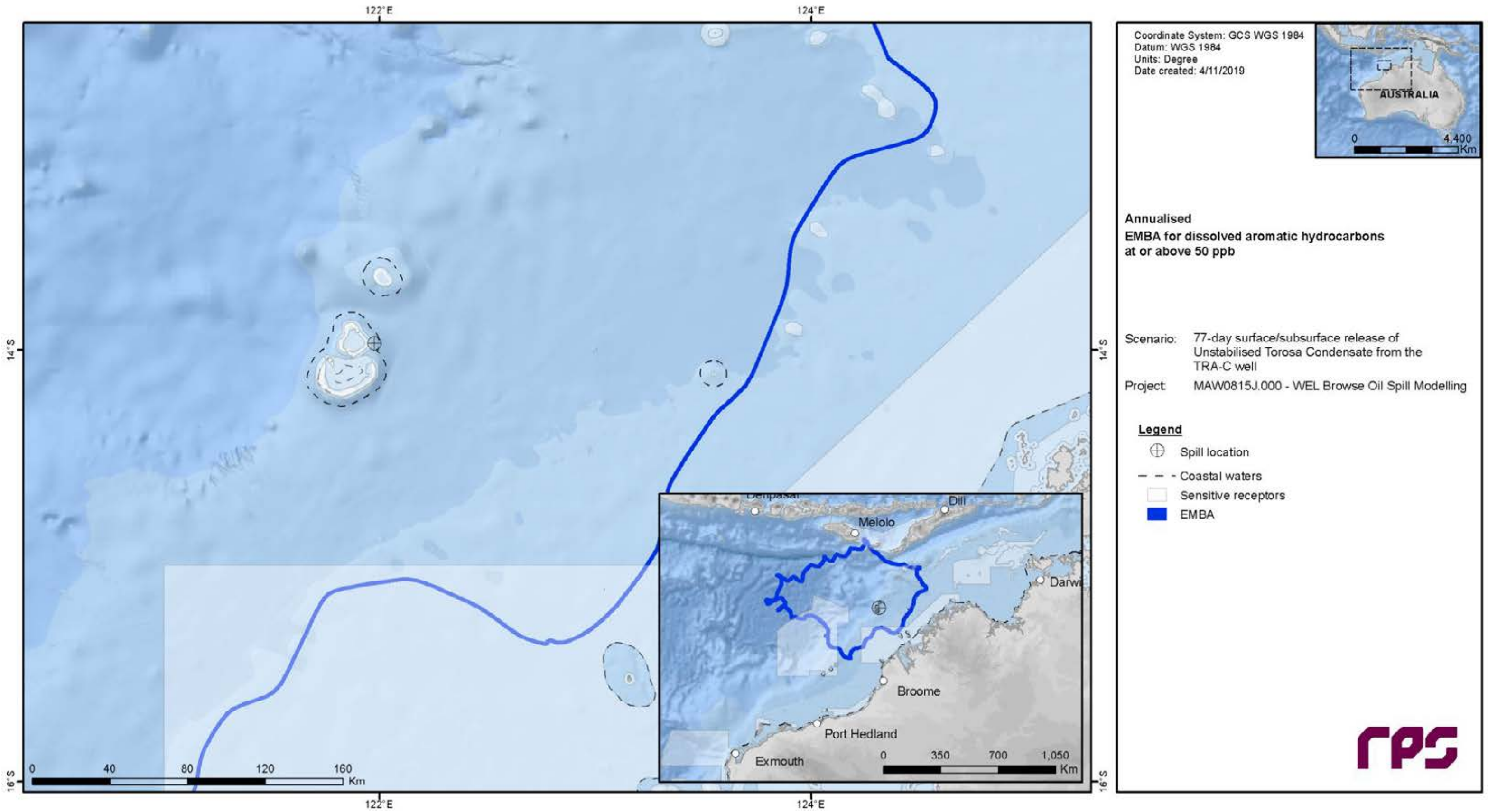

Figure 3.15 Predicted annualised EMBA of dissolved aromatic hydrocarbon concentrations at or above 50 ppb resulting from a 77-day surface/subsea release of unstabilised Torosa Condensate at the TRA-C well.

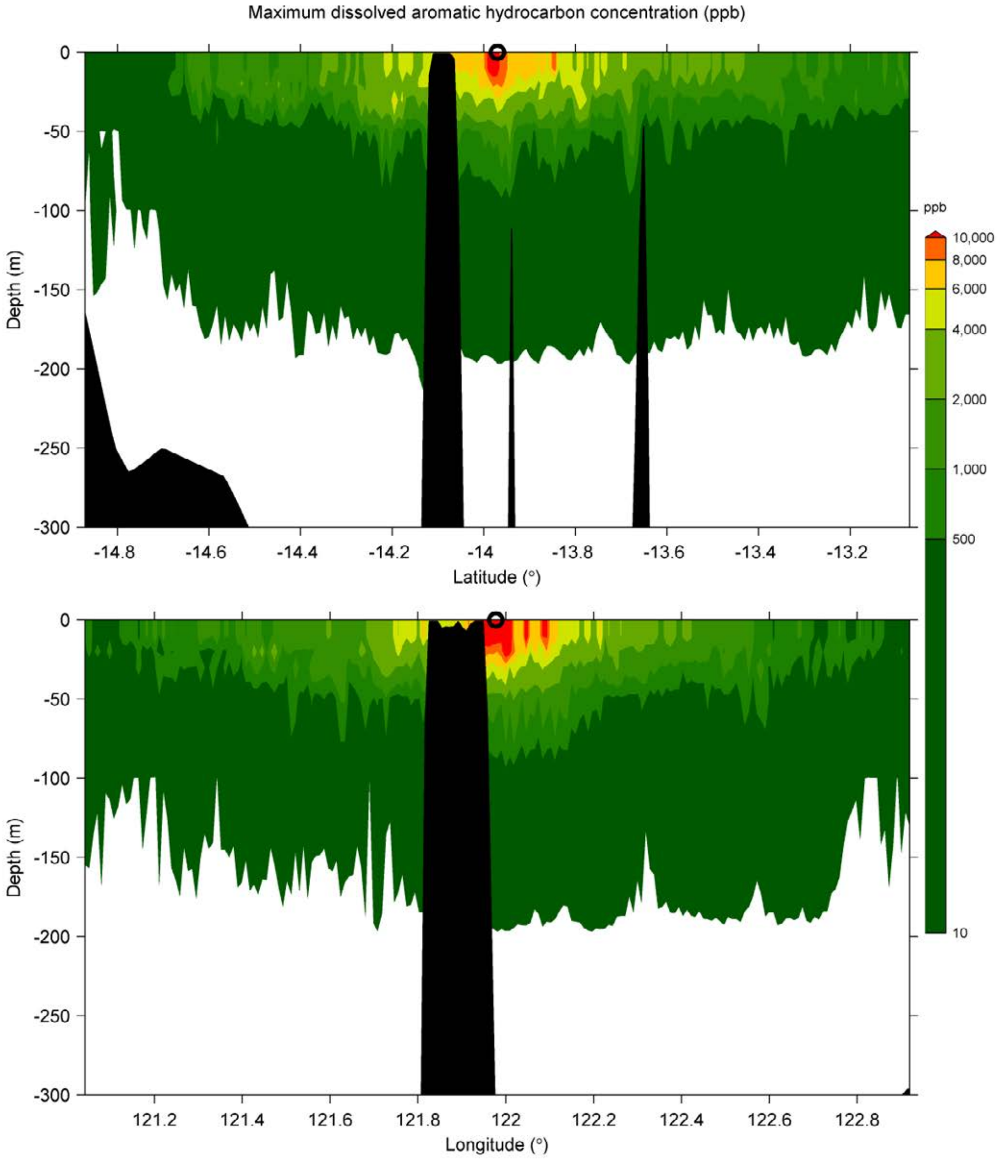

Figure 3.16 Cross-section transects of predicted annualised maximum dissolved aromatic hydrocarbon concentrations for a 77-day surface/subsea release of unstabilised Torosa Condensate at the TRA-C well. Transect locations are shown in Figure 3.1.

3.3 Scenario 2: Short-Term (24-Hour) Surface Release of Stabilised Torosa Condensate after a Vessel Cargo Tank Rupture at the Torosa FPSO Location

3.3.1 Discussion of Results

3.3.1.1 Overview

This scenario investigated the probability of exposure to surrounding regions by oil resulting from a short-term (24-hour) surface release of 18,000 m^3 of stabilised Torosa Condensate after a vessel cargo tank rupture from a vessel collision at the Torosa FPSO location during operations at any time of year, with no mitigation measures applied.

During the surface release, the volatile fractions of the oil (78.0%) are likely to evaporate within 24 hours of exposure to the atmosphere. The low-volatility fraction of the condensate (8.0%) will take longer times of the order of days to weeks to evaporate, and the remaining fraction (14.0%) is expected to persist for an extended period of time as residual oil.

3.3.1.2 Floating and Shoreline Oil

The probability contour figures for floating oil indicate that concentrations equal to or greater than the 10 g/m^2 threshold could potentially be found, in the form of slicks, up to 126 km from the spill site (Figure 3.18).

The Scott Reef South and Scott Reef Central shoreline receptors are predicted to be contacted by floating oil concentrations at the 10 g/m^2 threshold with probabilities of 6.5% and 2%, respectively (Table 3.4). At these receptors, the corresponding minimum times to contact at this threshold are 21 hours and 57 hours.

The Scott Reef South, Scott Reef Central and Scott Reef Central – Sandy Islet receptors are predicted to experience shoreline oil accumulation in excess of the 100 g/m^2 threshold with a probability of 20.5% (Table 3.4). Potential for accumulation of oil on shorelines is predicted to be moderate, with a maximum accumulated volume of 212 m^3 and a maximum local accumulated concentration of 9.5 kg/m^2 forecast at these receptors (Table 3.4).

The forecast annualised minimum times to contact and EMBA for floating oil at or above the 1 g/m^2 and 10 g/m^2 threshold concentrations are depicted in Figure 3.19 to Figure 3.22.

3.3.1.3 Entrained Oil

Entrained oil at concentrations equal to or greater than the 100 ppb threshold is predicted to be found up to around 890 km from the spill site (Figure 3.24).

Contact by entrained oil at concentrations equal to or greater than 100 ppb is predicted at Scott Reef North (48.5%), Scott Reef North – Flats (46%) and Scott Reef North – Lagoon (40%), as well as several other sensitive receptors with probabilities of less than 30% (Table 3.5). The maximum entrained oil concentration forecast for any receptor is predicted as 30.5 ppm at Scott Reef North. This is greater than the maximum concentration forecast in Scenario 1, and this result is attributable to the equivalent release rate in Scenario 2 being higher (1,846 m^3/day of unstabilised Torosa Condensate each day versus 18,000 m^3/day of stabilised Torosa Condensate in one day). The oil plume will initially be more concentrated in the latter case and will be likely to move as a more coherent mass for a sustained duration before diffusion processes act to reduce the peak concentrations.

The forecast annualised minimum times to contact and EMBA for entrained oil at or above the 100 ppb threshold concentration are depicted in Figure 3.25 and Figure 3.26, respectively.

The cross-sectional transects of maximum entrained oil concentrations in the vicinity of the release site show that concentrations above 25,000 ppb are expected to extend from the sea surface to depths of around 20 m (Figure 3.27).

3.3.1.4 Dissolved Aromatic Hydrocarbons

Dissolved aromatic hydrocarbons at concentrations equal to or greater than the 50 ppb threshold are predicted to be found up to around 517 km from the spill site (Figure 3.28).

Contact by dissolved aromatic hydrocarbons at concentrations equal to or greater than 50 ppb is predicted at Scott Reef North (41.5%), Scott Reef North – Flats (39.5%) and Scott Reef North – Lagoon (33.5%), as well as several other receptors with probabilities of less than 25% (Table 3.6). The maximum dissolved aromatic hydrocarbon concentration forecast for any receptor is predicted as 12.7 ppm at Scott Reef North.

The forecast annualised minimum times to contact and EMBA for dissolved aromatic hydrocarbons at or above the 50 ppb threshold concentration are depicted in Figure 3.29 and Figure 3.30, respectively.

The cross-sectional transects of maximum dissolved aromatic hydrocarbon concentrations in the vicinity of the release site show that concentrations above 10,000 ppb are expected to extend from the sea surface to depths of around 15 m (Figure 3.31).

3.3.2 Results Tables and Figures

3.3.2.1 Floating and Shoreline Oil

Table 3.4 Expected annualised floating and shoreline oil outcomes at sensitive receptors resulting from a 24-hour surface release of stabilised Torosa Condensate after a vessel cargo tank rupture at the Torosa FPSO location.

Receptor	Probability (%) of floating oil concentration		Minimum time to receptor (hours) for floating oil at		Probability (%) of shoreline oil concentration	Minimum time to receptor (hours) for shoreline oil at	Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline	
	≥1 g/m²	≥10 g/m²	≥1 g/m²	≥10 g/m²	≥100 g/m²	≥100 g/m²	averaged over all replicate simulations	in the worst replicate simulation	averaged over all replicate simulations	in the worst replicate simulation
Argo-Rowley Terrace Marine Park *	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Ashmore Reef Marine Park	<1	<1	NC	NC	1	615	3.6	208	<1	4
Browse Island*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Buccaneer & Bonaparte Archipelagos	<1	<1	NC	NC	<1	NC	0.3	28	<1	2
Cartier Island Marine Park	<1	<1	NC	NC	1	410	3	204	<1	5
Glomar Shoals & Rankin Bank*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Hibernia Reef*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Indonesia	<1	<1	NC	NC	<1	NC	0.4	74	<1	8
Indonesian Boundary	<1	<1	NC	NC	<1	NC	<0.1	8.2	<1	<1
Kimberley Marine Park *	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Kimberley Coast	<1	<1	NC	NC	<1	NC	0.5	45	<1	3
Lacepede Islands	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Oceanic Shoals Marine Park *	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Pulau Roti	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Rowley Shoals - Clerke Reef State Marine Park	<1	<1	NC	NC	<1	NC	0.5	98	<1	4
Rowley Shoals - Imperieuse Reef State Marine Park	<1	<1	NC	NC	<1	NC	0.3	65	<1	2
Rowley Shoals - Mermaid Reef Marine Park	<1	<1	NC	NC	<1	NC	0.2	25	<1	<1
Scott Reef North*	34	22.5	7	7	NA	NA	NA	NA	NA	NA
Scott Reef South	12	6.5	18	21	20.5	39	320	9,535	13	212
Seringapatam Reef*	7	4	37	41	NA	NA	NA	NA	NA	NA
Sumba	<1	<1	NC	NC	<1	NC	<0.1	8.2	<1	<1
Ashmore Reef	<1	<1	NC	NC	1	615	3.6	208	<1	4
Big Bank Shoals*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Camden Sound	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Cartier Island	<1	<1	NC	NC	1	410	3	204	<1	5
Dampier Peninsula Coast - Mid Section	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Dampier Peninsula Coast - North Section	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Lalang-garram - Camden Sound Marine Park	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC

Receptor	Probability (%) of floating oil concentration		Minimum time to receptor (hours) for floating oil at		Probability (%) of shoreline oil concentration	Minimum time to receptor (hours) for shoreline oil at	Maximum local accumulated concentration (g/m²)		Maximum accumulated volume (m³) along this shoreline	
	≥1 g/m²	≥10 g/m²	≥1 g/m²	≥10 g/m²	≥100 g/m²	≥100 g/m²	averaged over all replicate simulations	in the worst replicate simulation	averaged over all replicate simulations	in the worst replicate simulation
Rowley Shoals - Clerke Reef	<1	<1	NC	NC	<1	NC	0.5	98	<1	4
Rowley Shoals - Imperieuse Reef	<1	<1	NC	NC	<1	NC	0.3	65	<1	2
Rowley Shoals - Mermaid Reef	<1	<1	NC	NC	<1	NC	0.2	25	<1	<1
Sahul Banks*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Savu	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Scott Reef Central	5	2	34	57	20.5	39	320	9,535	13	212
Scott Reef Central - Sandy Islet	5	1	37	68	20.5	39	320	9,535	13	212
Scott Reef North - Flats*	29.5	20	8	9	NA	NA	NA	NA	NA	NA
Scott Reef North - Lagoon*	25	12	9	11	NA	NA	NA	NA	NA	NA
Scott Reef South - Flats*	7.5	4	22	29	NA	NA	NA	NA	NA	NA
Scott Reef South - Lagoon*	12	4.5	19	22	NA	NA	NA	NA	NA	NA
Adele Island	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Barracouta Shoal*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Echuca Shoal*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Eighty Mile Beach Marine Park *	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Eugene McDermott Shoal*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Fantome Bank*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Heywood Shoal*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Oceanic Shoals - Deep Shoal 1*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Oceanic Shoals Region - Gale-Favell-Baldwin Banks*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Oceanic Shoals Region - Margaret Harries Banks*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Oceanic Shoals Region - The Boxers*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Timor Leste	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Timor West	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Van Cloon Shoal*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Vulcan & Goeree Shoals*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
WA Coastline	<1	<1	NC	NC	<1	NC	0.5	47	<1	4

NC: No contact to receptor predicted for specified threshold. NA: Not applicable.

* Floating oil will not accumulate on submerged features and at open ocean locations.

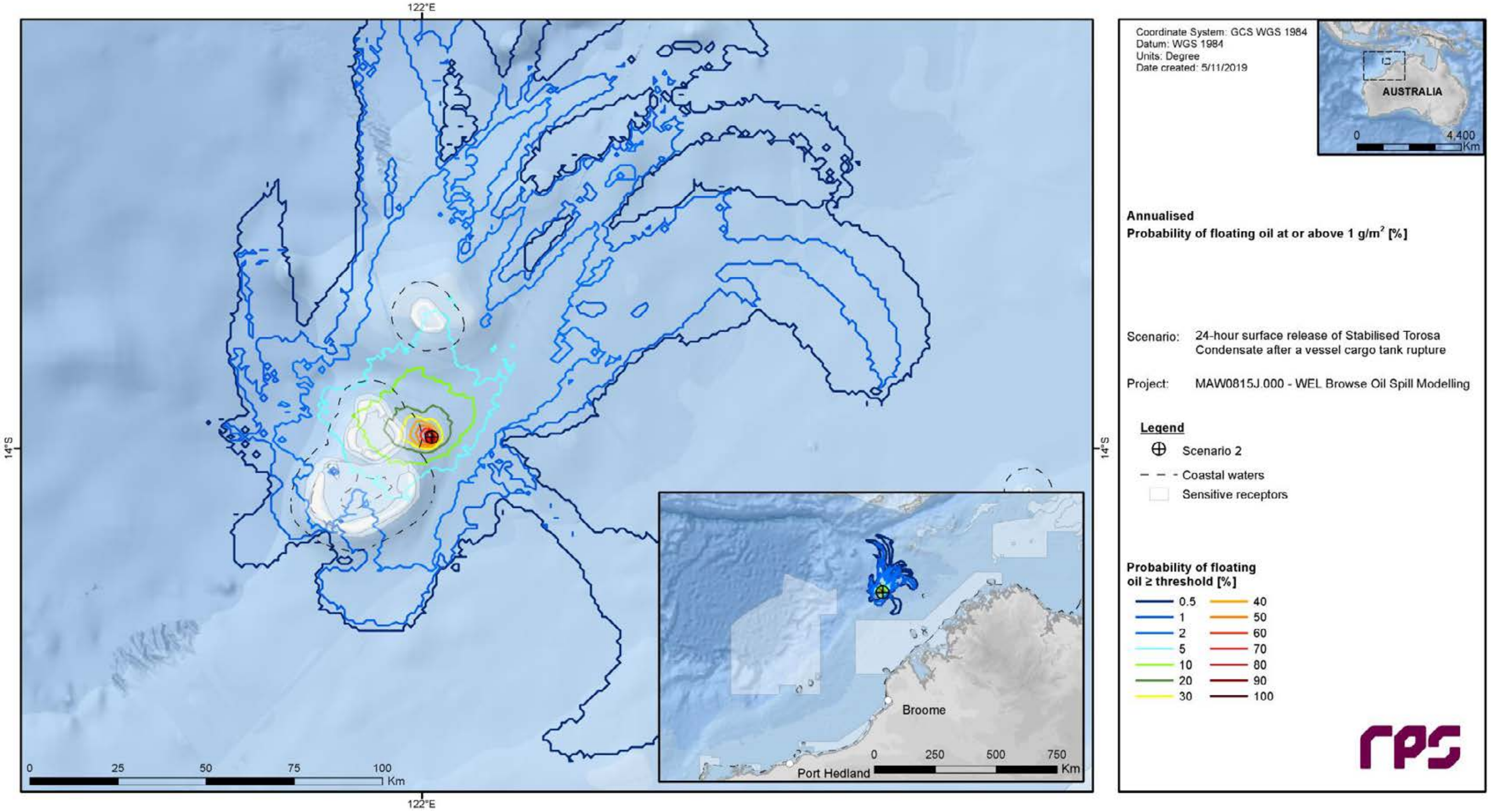

Figure 3.17 Predicted annualised probability of floating oil concentrations at or above 1 g/m^2 resulting from a 24-hour surface release of stabilised Torosa Condensate after a vessel cargo tank rupture at the Torosa FPSO location.

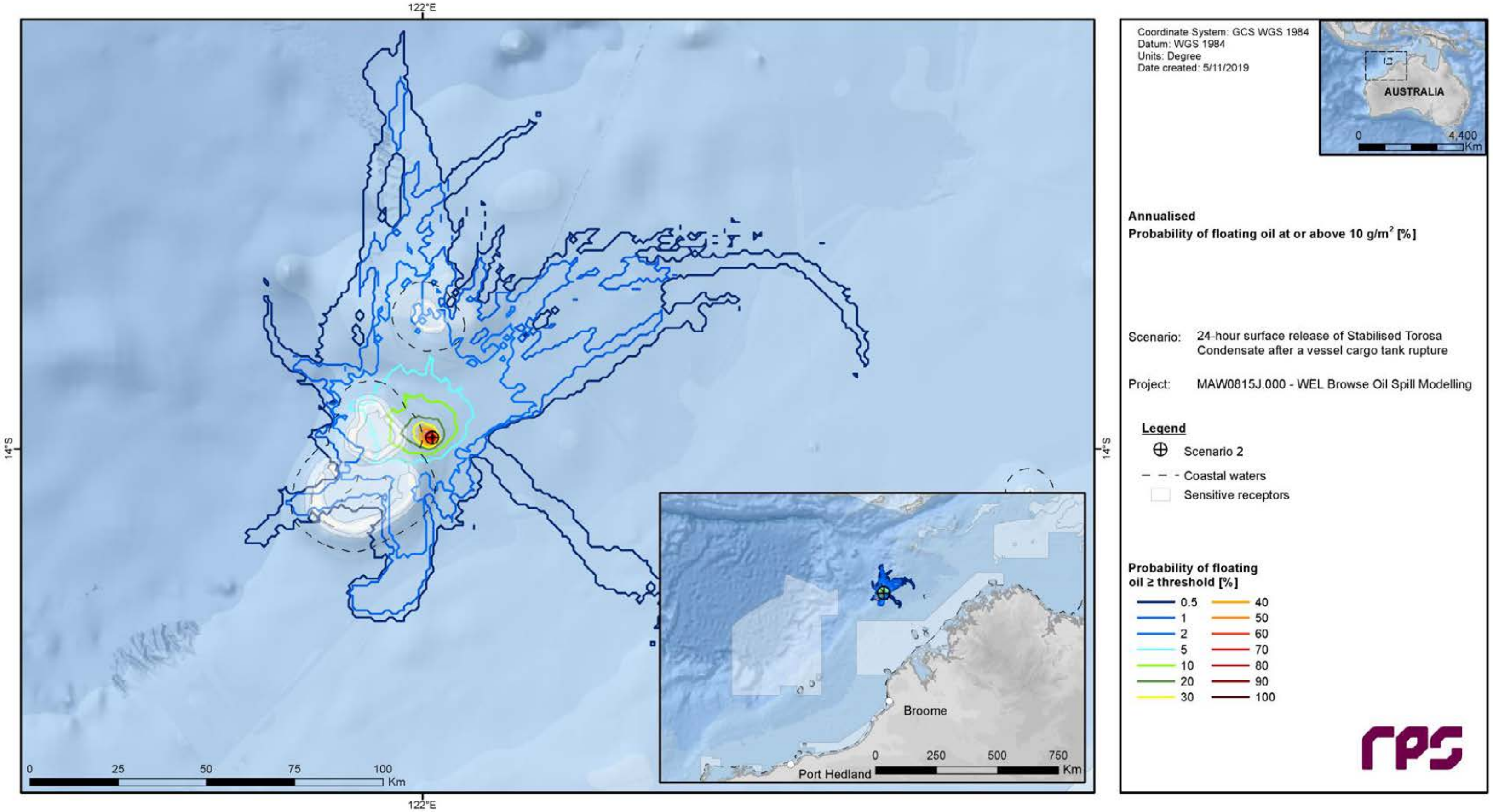

Figure 3.18 Predicted annualised probability of floating oil concentrations at or above 10 g/m^2 resulting from a 24-hour surface release of stabilised Torosa Condensate after a vessel cargo tank rupture at the Torosa FPSO location.

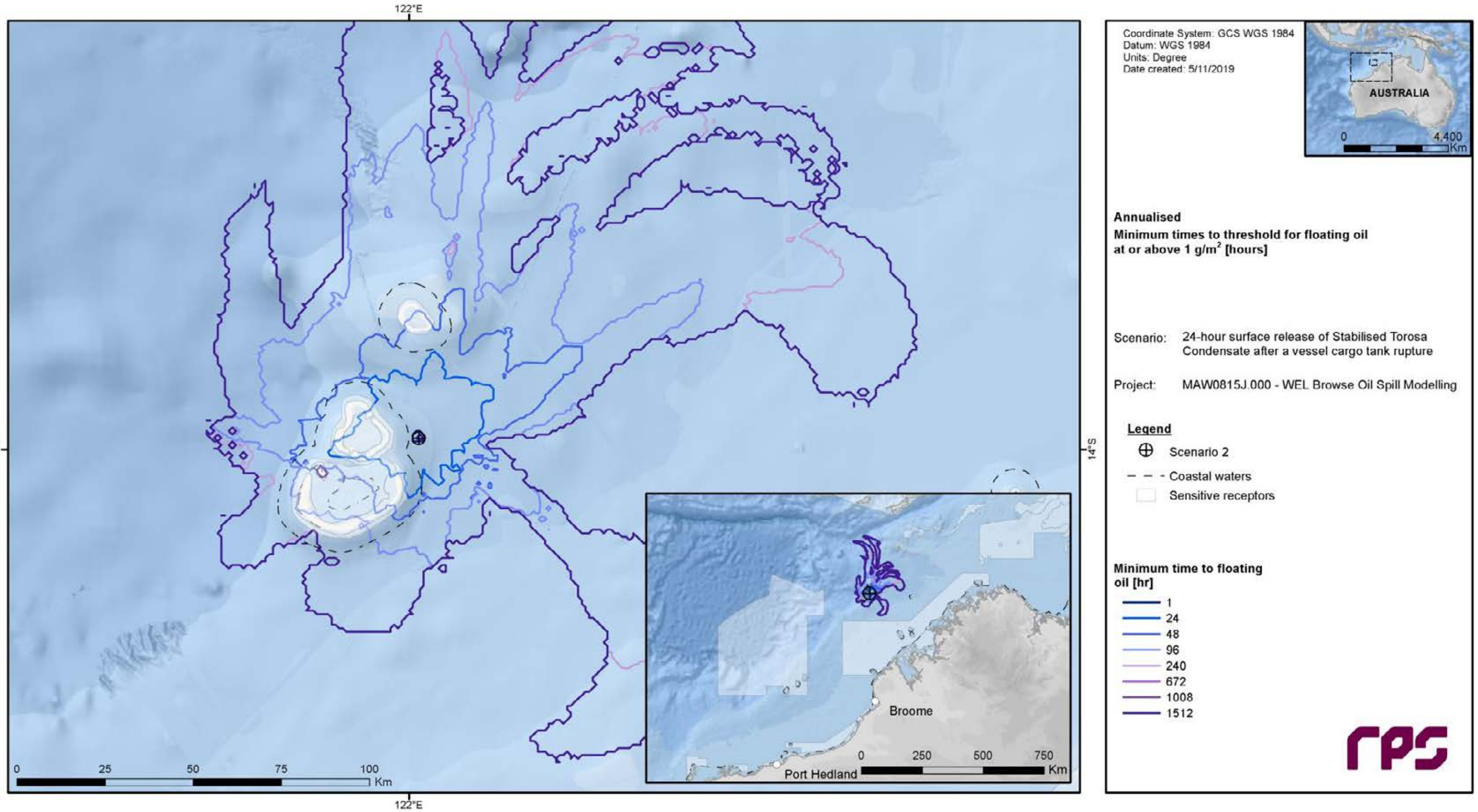

Figure 3.19 Predicted annualised minimum times to contact by floating oil concentrations at or above 1 g/m^2 resulting from a 24-hour surface release of stabilised Torosa Condensate after a vessel cargo tank rupture at the Torosa FPSO location.

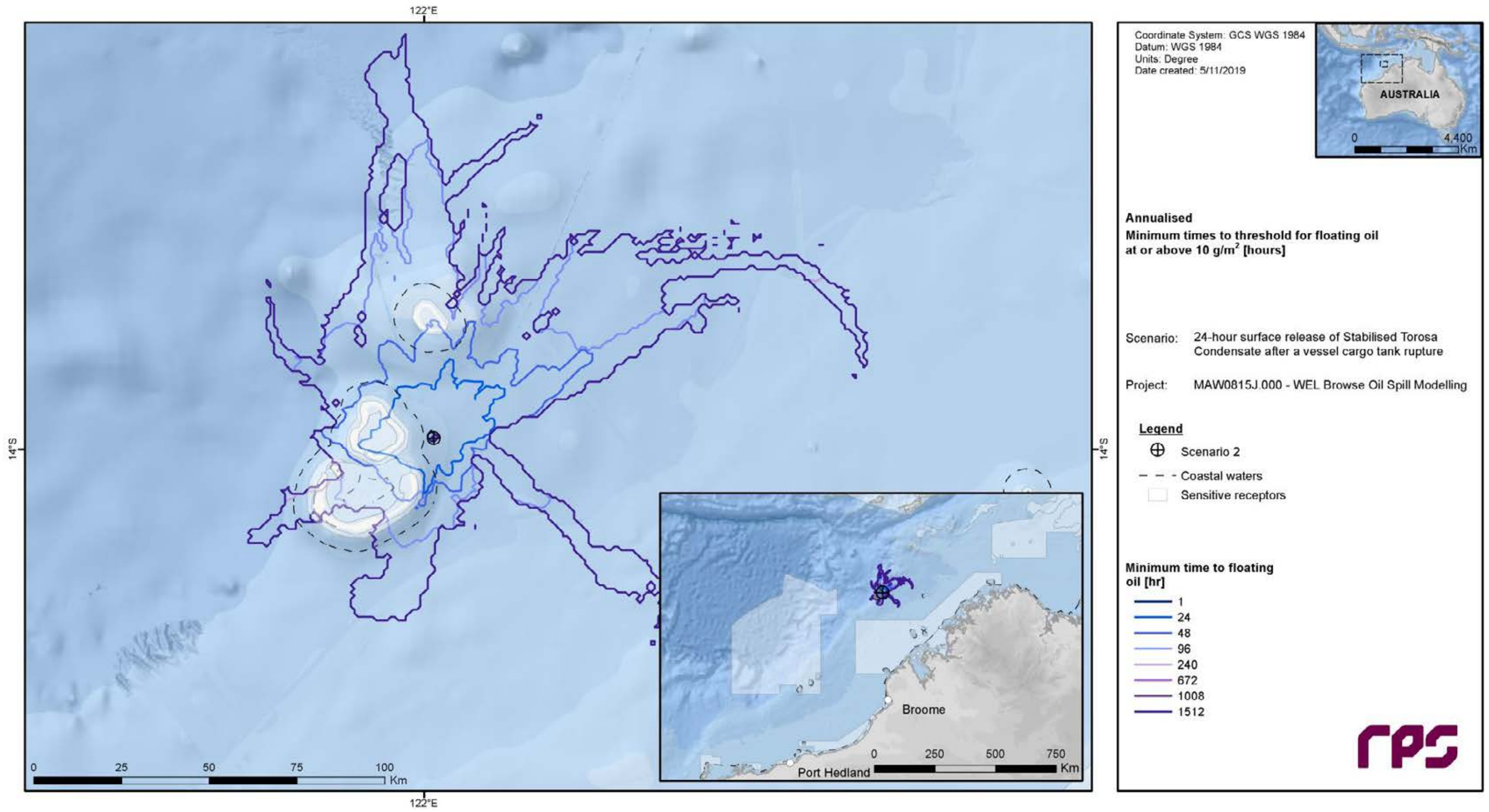

Figure 3.20 Predicted annualised minimum times to contact by floating oil concentrations at or above 10 g/m^2 resulting from a 24-hour surface release of stabilised Torosa Condensate after a vessel cargo tank rupture at the Torosa FPSO location.

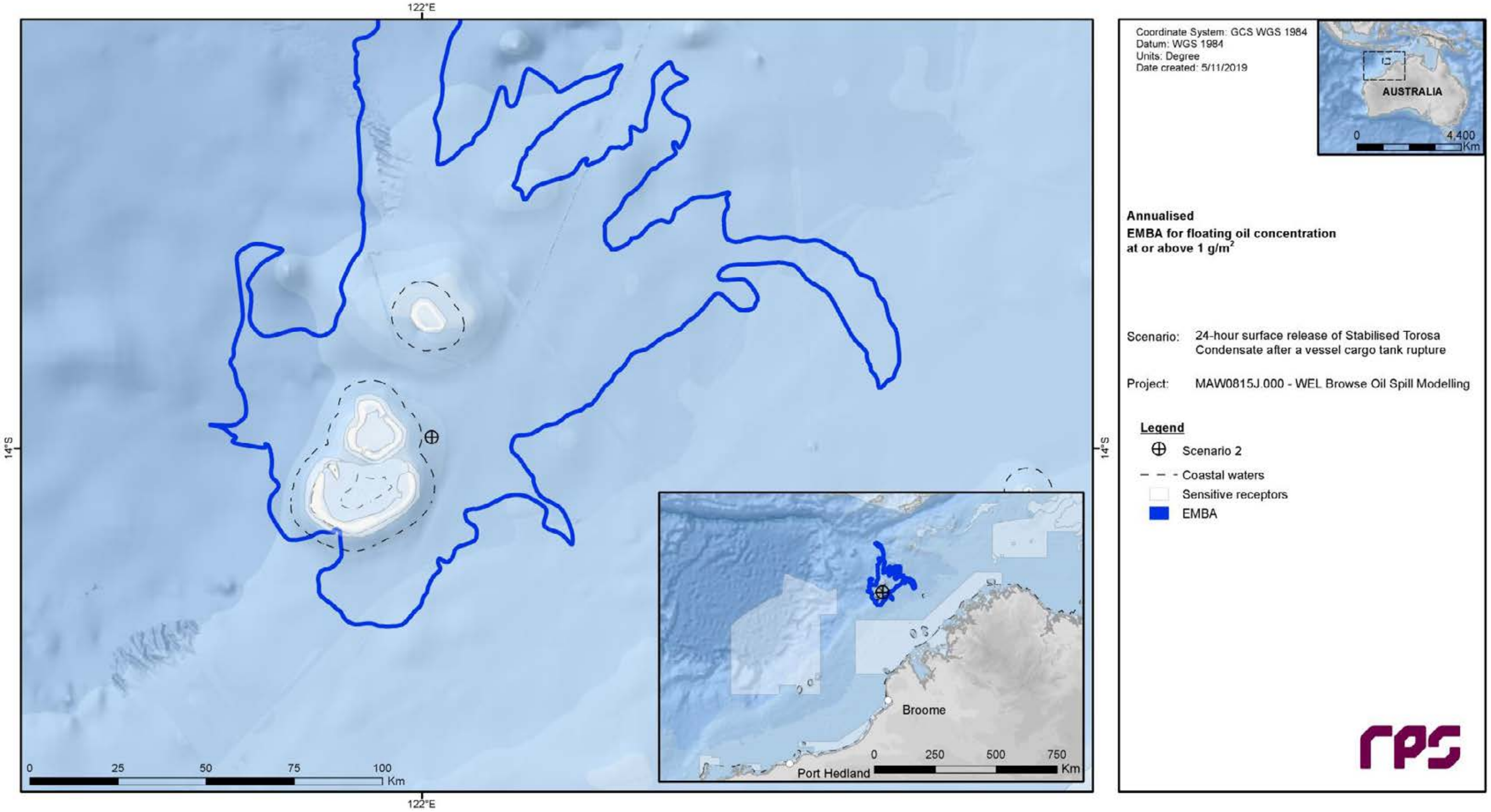

Figure 3.21 Predicted annualised EMBA of floating oil concentrations at or above 1 g/m^2 resulting from a 24-hour surface release of stabilised Torosa Condensate after a vessel cargo tank rupture at the Torosa FPSO location.

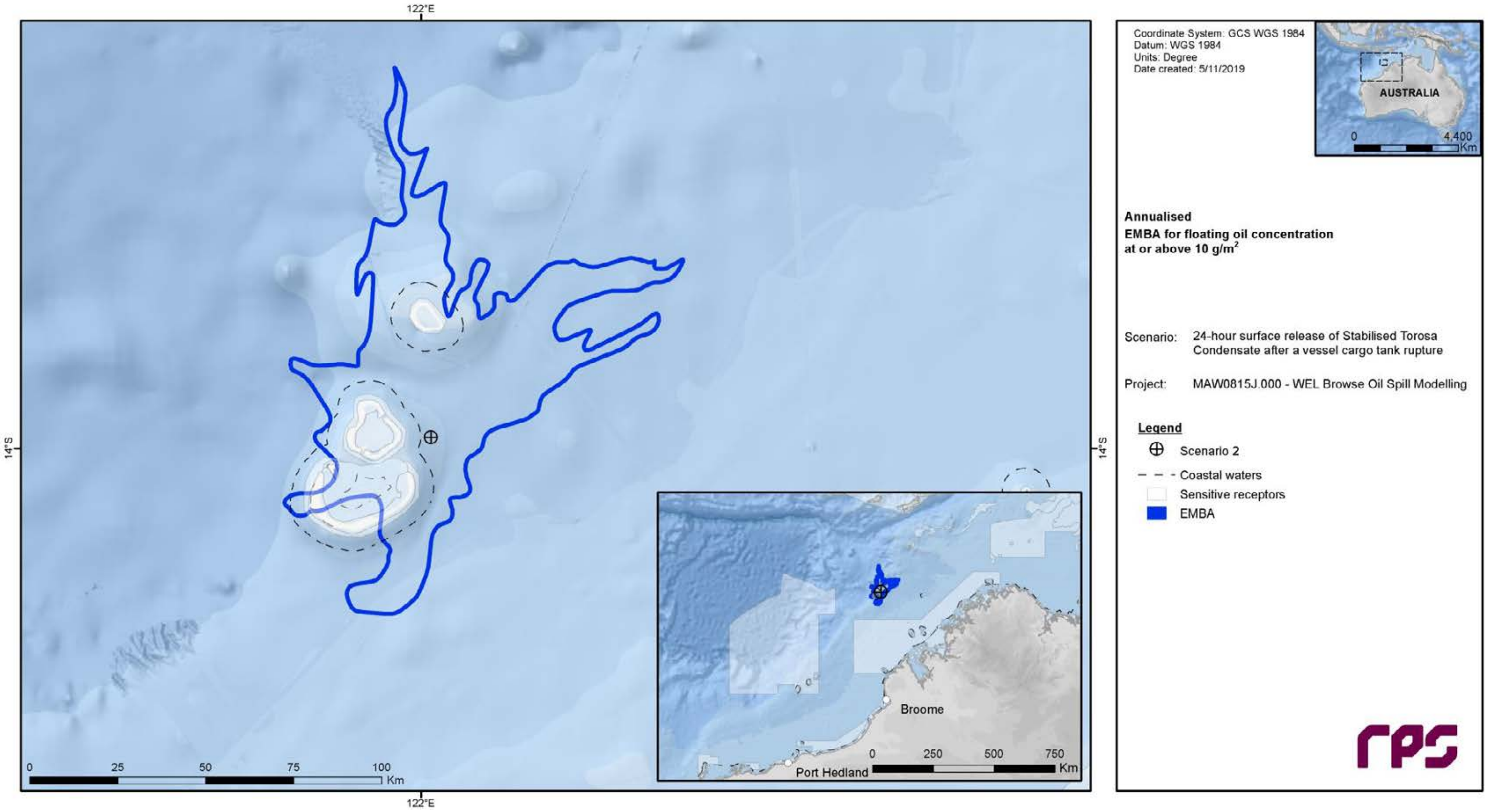

Figure 3.22 Predicted annualised EMBA of floating oil concentrations at or above 10 g/m^2 resulting from a 24-hour surface release of stabilised Torosa Condensate after a vessel cargo tank rupture at the Torosa FPSO location.

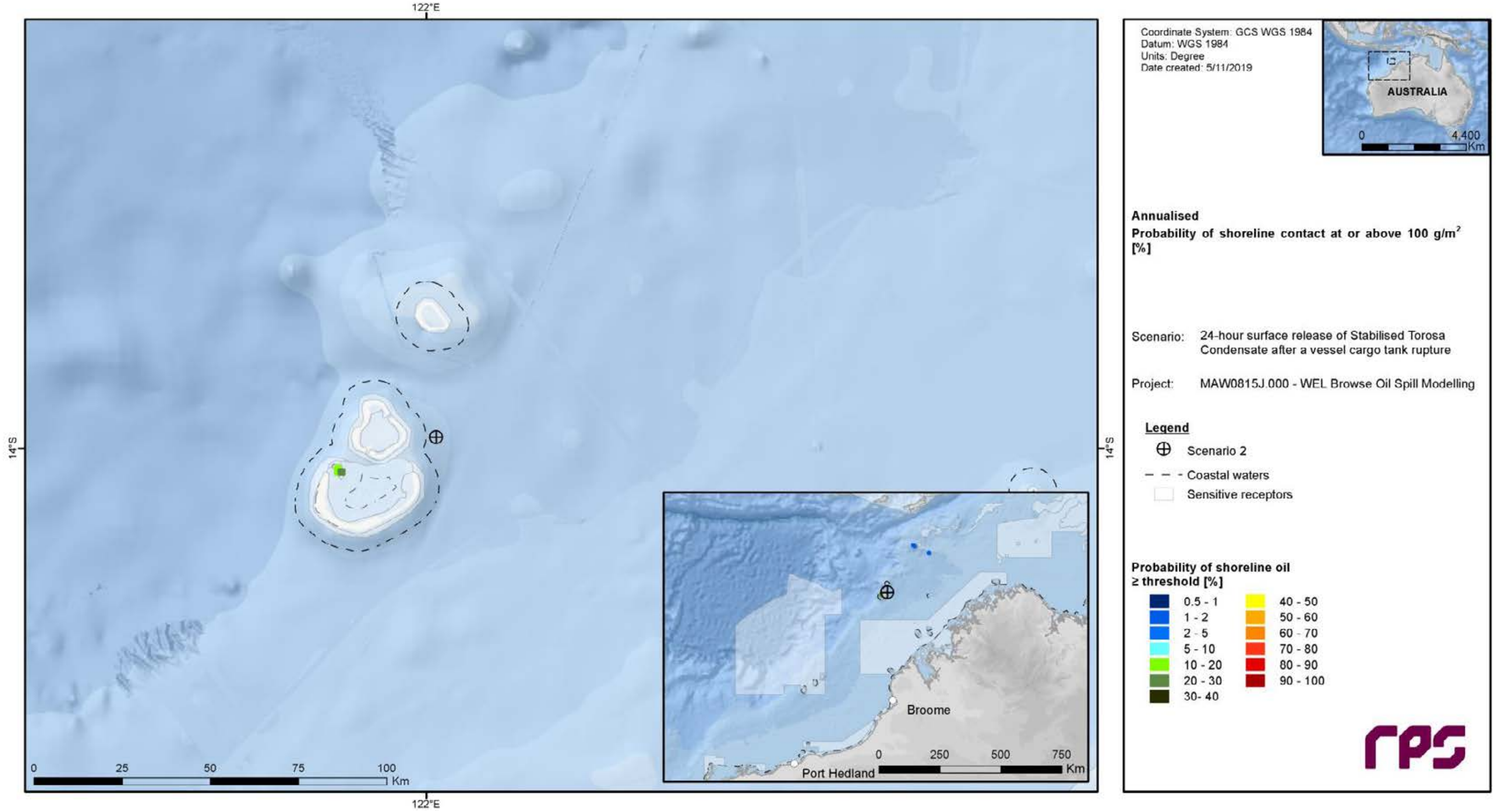

Figure 3.23 Predicted annualised probability of shoreline oil concentrations at or above 100 g/m^2 resulting from a 24-hour surface release of stabilised Torosa Condensate after a vessel cargo tank rupture at the Torosa FPSO location.

3.3.2.2 Entrained Oil

Table 3.5 Expected annualised entrained oil outcomes at sensitive receptors resulting from a 24-hour surface release of stabilised Torosa Condensate after a vessel cargo tank rupture at the Torosa FPSO location.

Receptor	Probability (%) of entrained oil concentration ≥100 ppb	Minimum time to receptor (hours) for entrained oil at ≥100 ppb	Maximum entrained oil concentration (ppb)	
			averaged over all replicate simulations	at any depth, in the worst replicate simulation
Argo-Rowley Terrace Marine Park	1.5	464	5	545
Ashmore Reef Marine Park	2.5	287	14	1,118
Browse Island	<1	NC	2	77
Buccaneer & Bonaparte Archipelagos	<1	NC	<1	54
Cartier Island Marine Park	1.5	374	6	444
Glomar Shoals & Rankin Bank	<1	NC	NC	NC
Hibernia Reef	<1	344	3	406
Indonesia	<1	NC	<1	19
Indonesian Boundary	<1	593	2	341
Kimberley Marine Park	4.5	271	14	704
Kimberley Coast	<1	NC	<1	82
Lacepede Islands	<1	NC	NC	NC
Oceanic Shoals Marine Park	<1	NC	<1	56
Pulau Roti	<1	NC	NC	NC
Rowley Shoals - Clerke Reef State Marine Park	<1	NC	<1	40
Rowley Shoals - Imperieuse Reef State Marine Park	<1	NC	<1	40
Rowley Shoals - Mermaid Reef Marine Park	<1	NC	<1	89
Scott Reef North	48.5	7	2,775	30,461
Scott Reef South	29.5	17	1,115	21,848
Seringapatam Reef	22.5	30	375	10,263
Sumba	<1	NC	<1	2
Ashmore Reef	2.5	292	12	916
Big Bank Shoals	<1	NC	<1	3
Camden Sound	<1	NC	<1	10
Cartier Island	1.5	386	6	358
Dampier Peninsula Coast - Mid Section	<1	NC	NC	NC

Receptor	Probability (%) of entrained oil concentration ≥100 ppb	Minimum time to receptor (hours) for entrained oil at ≥100 ppb	Maximum entrained oil concentration (ppb) averaged over all replicate simulations	Maximum entrained oil concentration (ppb) at any depth, in the worst replicate simulation
Dampier Peninsula Coast - North Section	<1	NC	<1	<1
Lalang-garram - Camden Sound Marine Park	<1	NC	<1	34
Rowley Shoals - Clerke Reef	<1	NC	<1	34
Rowley Shoals - Imperieuse Reef	<1	NC	<1	37
Rowley Shoals - Mermaid Reef	<1	NC	<1	58
Sahul Banks	<1	NC	<1	60
Savu	<1	NC	<1	8
Scott Reef Central	27	31	472	21,848
Scott Reef Central - Sandy Islet	24.5	35	472	21,848
Scott Reef North - Flats	46	8	2,134	22,127
Scott Reef North - Lagoon	40	10	1,086	15,894
Scott Reef South - Flats	26.5	23	639	17,516
Scott Reef South - Lagoon	29.5	17	1,115	21,437
Adele Island	<1	NC	<1	34
Barracouta Shoal	1	402	6	726
Echuca Shoal	<1	924	2	129
Eighty Mile Beach Marine Park	<1	NC	NC	NC
Eugene McDermott Shoal	1.5	824	4	204
Fantome Bank	<1	916	<1	129
Heywood Shoal	1.5	591	5	184
Oceanic Shoals - Deep Shoal 1	<1	NC	<1	5
Oceanic Shoals Region - Gale-Favell-Baldwin Banks	<1	NC	<1	34
Oceanic Shoals Region - Margaret Harries Banks	<1	NC	<1	<1
Oceanic Shoals Region - The Boxers	<1	NC	NC	NC
Timor Leste	<1	NC	NC	NC
Timor West	<1	NC	NC	NC
Van Cloon Shoal	<1	NC	<1	2
Vulcan & Goeree Shoals	2.5	533	7	206
WA Coastline	<1	NC	<1	77

NC: No contact to receptor predicted for specified threshold.

* Probabilities and maximum concentrations calculated at depth of submerged feature.

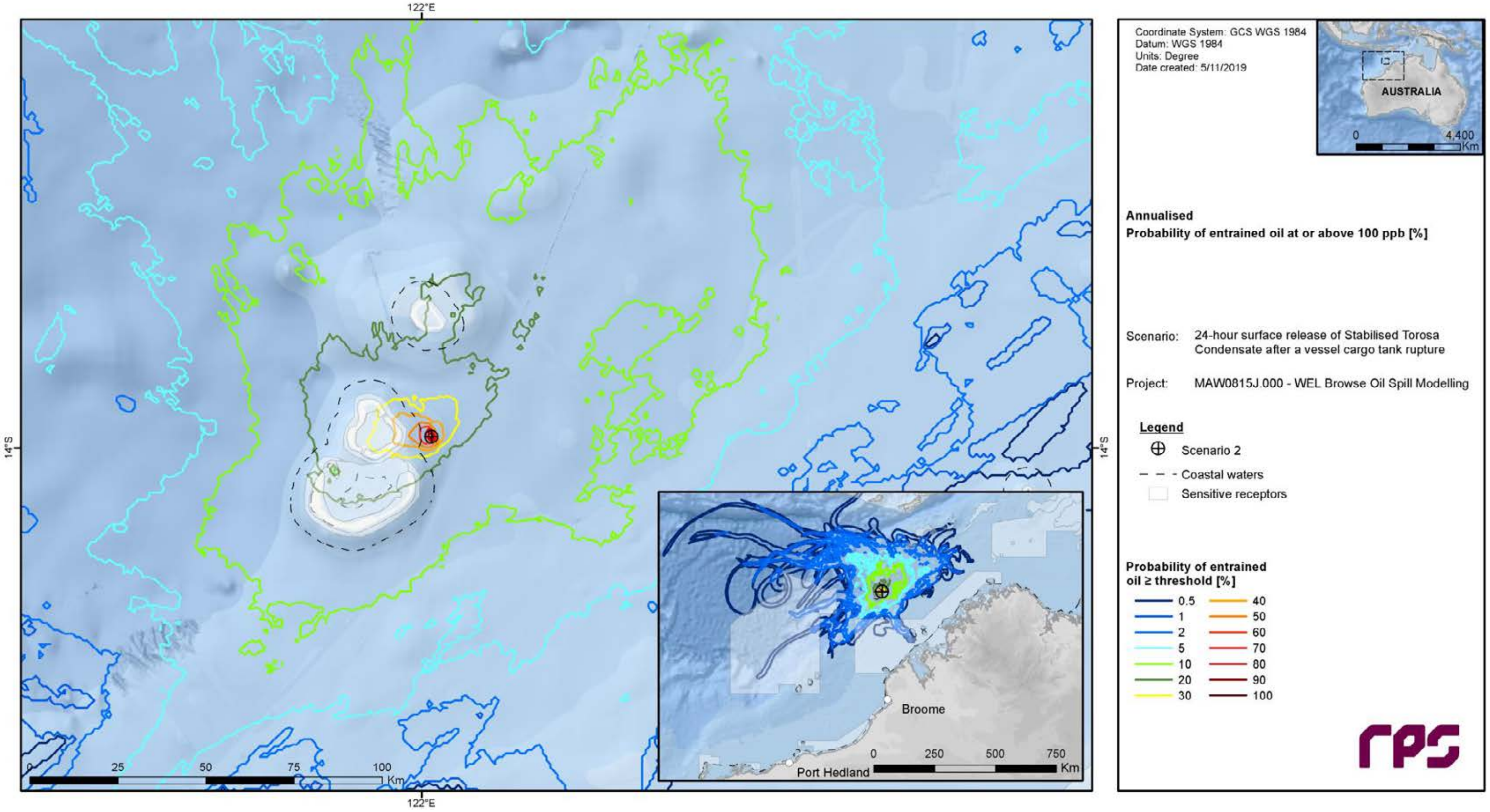

Figure 3.24 Predicted annualised probability of entrained oil concentrations at or above 100 ppb resulting from a 24-hour surface release of stabilised Torosa Condensate after a vessel cargo tank rupture at the Torosa FPSO location.

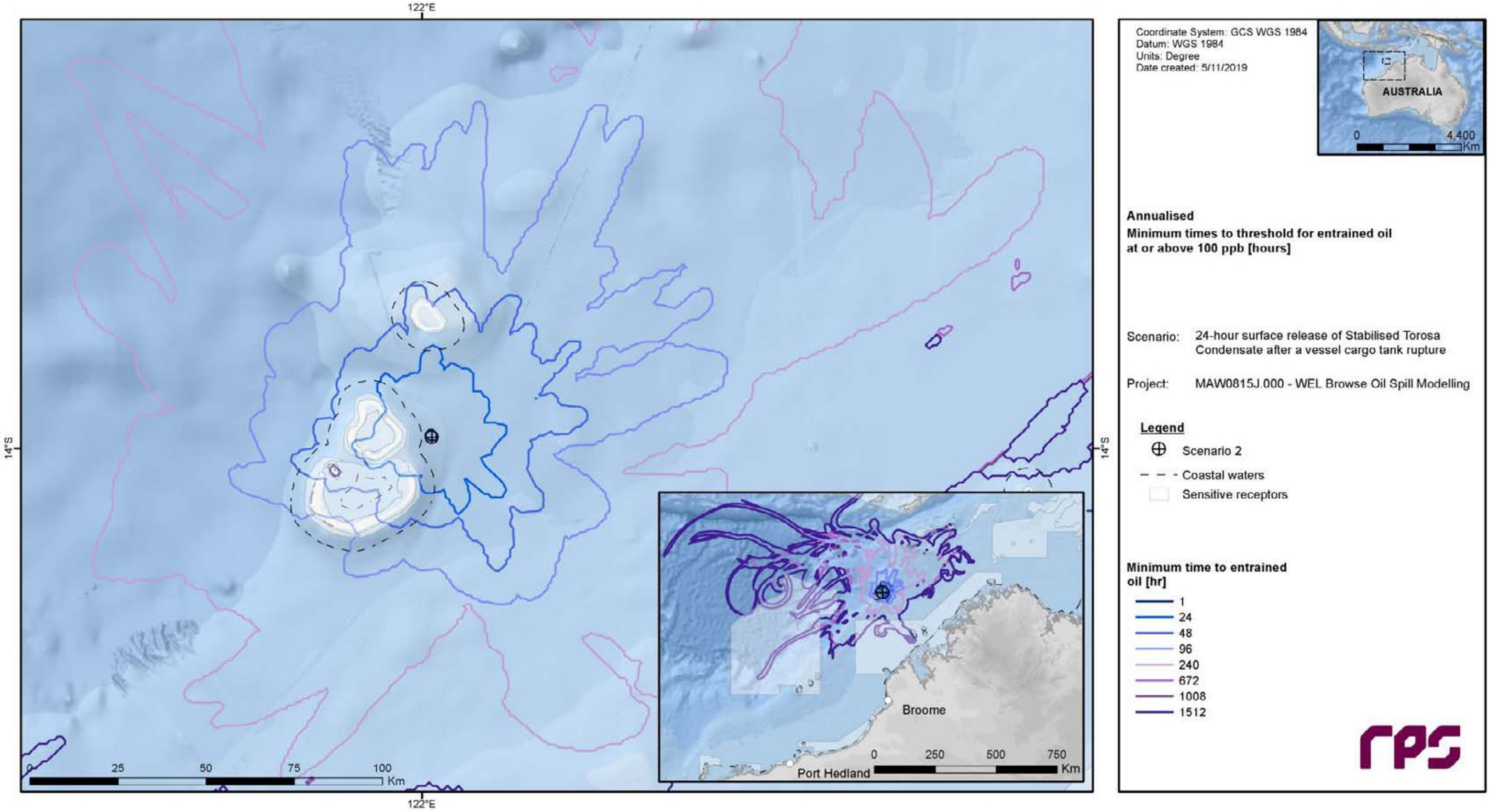

Figure 3.25 Predicted annualised minimum times to contact by entrained oil concentrations at or above 100 ppb resulting from a 24-hour surface release of stabilised Torosa Condensate after a vessel cargo tank rupture at the Torosa FPSO location.

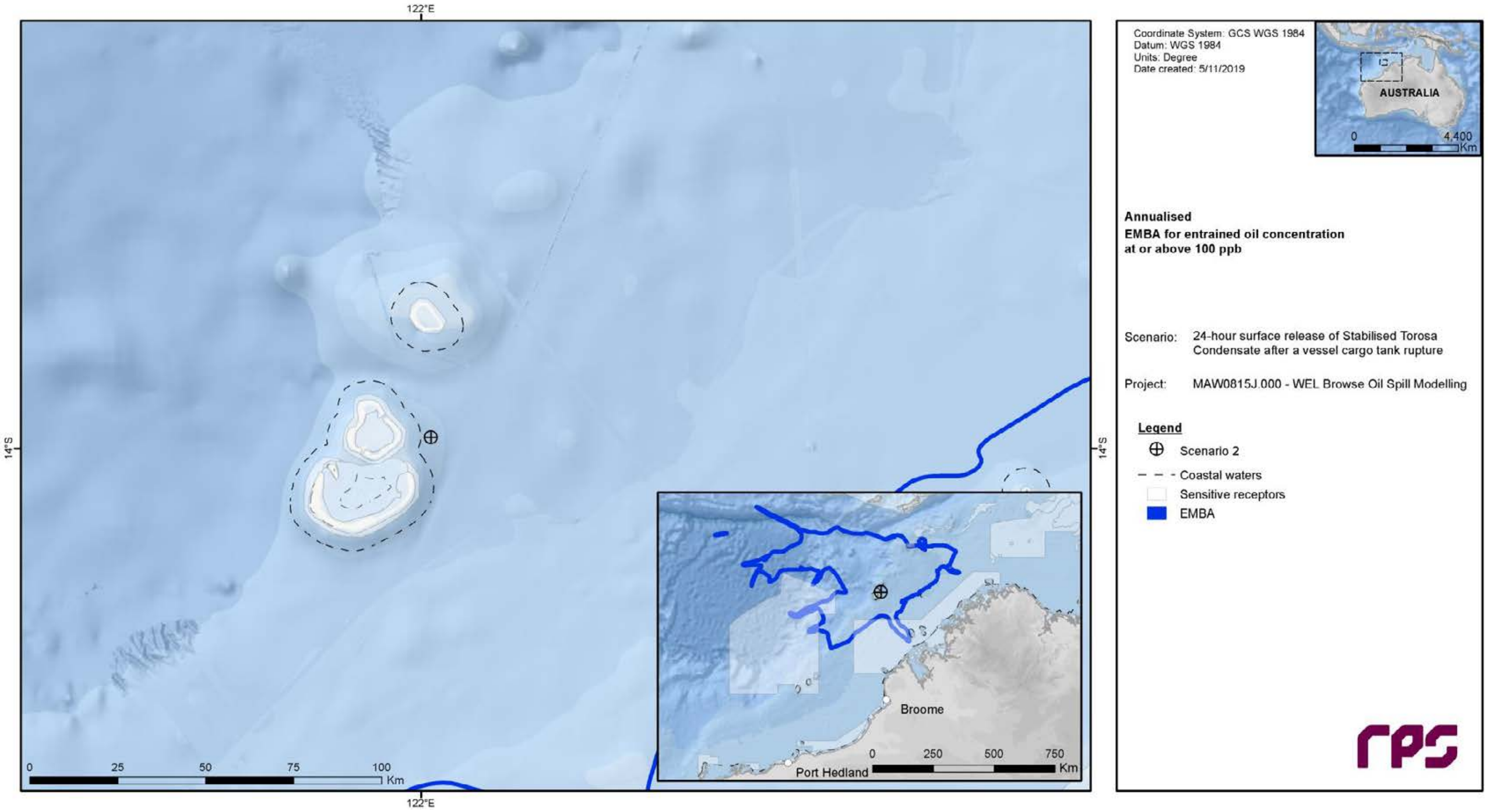

Figure 3.26 Predicted annualised EMBA of entrained oil concentrations at or above 100 ppb resulting from a 24-hour surface release of stabilised Torosa Condensate after a vessel cargo tank rupture at the Torosa FPSO location.

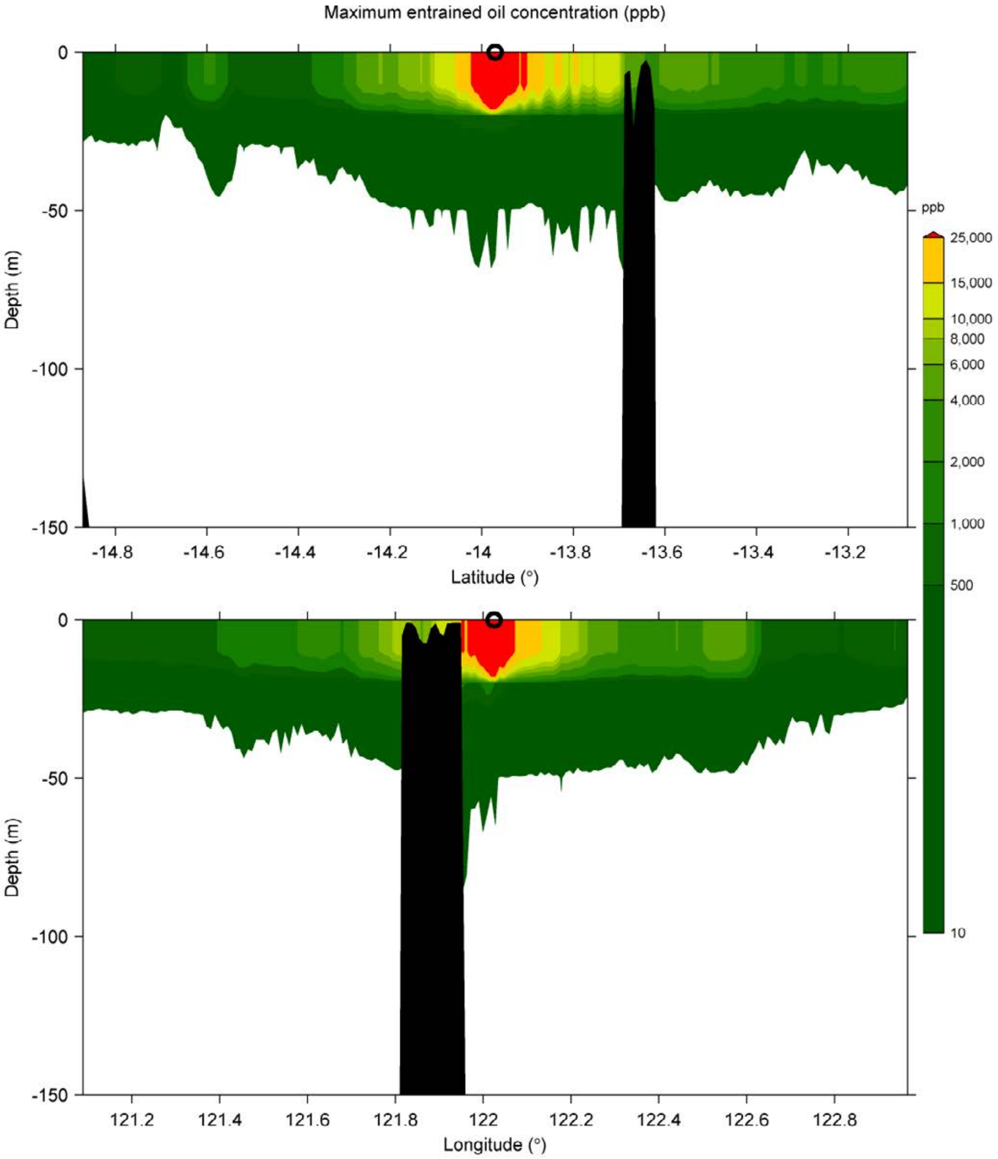

Figure 3.27 Cross-section transects of predicted annualised maximum entrained oil concentrations for a 24-hour surface release of stabilised Torosa Condensate after a vessel cargo tank rupture at the Torosa FPSO location. Transect locations are shown in Figure 3.1.

3.3.2.3 Dissolved Aromatic Hydrocarbons

Table 3.6 Expected annualised dissolved aromatic hydrocarbon outcomes at sensitive receptors resulting from a 24-hour surface release of stabilised Torosa Condensate after a vessel cargo tank rupture at the Torosa FPSO location.

Receptor	Probability (%) of dissolved aromatic hydrocarbon concentration	Maximum dissolved aromatic hydrocarbon concentration (ppb)	
	≥50 ppb	averaged over all replicate simulations	at any depth, in the worst replicate simulation
Argo-Rowley Terrace Marine Park	1.5	2	164
Ashmore Reef Marine Park	1.5	3	272
Browse Island	<1	<1	2
Buccaneer & Bonaparte Archipelagos	<1	NC	NC
Cartier Island Marine Park	<1	<1	40
Glomar Shoals & Rankin Bank	<1	NC	NC
Hibernia Reef	<1	<1	96
Indonesia	<1	<1	<1
Indonesian Boundary	<1	NC	NC
Kimberley Marine Park	2	3	416
Kimberley Coast	<1	NC	NC
Lacepede Islands	<1	NC	NC
Oceanic Shoals Marine Park	<1	NC	NC
Pulau Roti	<1	NC	NC
Rowley Shoals - Clerke Reef State Marine Park	<1	NC	NC
Rowley Shoals - Imperieuse Reef State Marine Park	<1	NC	NC
Rowley Shoals - Mermaid Reef Marine Park	<1	<1	5
Scott Reef North	41.5	683	12,749
Scott Reef South	24.5	334	9,440
Seringapatam Reef	15.5	125	6,095
Sumba	<1	NC	NC
Ashmore Reef	1.5	2	221
Big Bank Shoals	<1	NC	NC
Camden Sound	<1	NC	NC
Cartier Island	<1	<1	34
Dampier Peninsula Coast - Mid Section	<1	NC	NC
Dampier Peninsula Coast - North Section	<1	NC	NC
Lalang-garram - Camden Sound Marine Park	<1	NC	NC

Receptor	Probability (%) of dissolved aromatic hydrocarbon concentration	Maximum dissolved aromatic hydrocarbon concentration (ppb)	
	≥50 ppb	averaged over all replicate simulations	at any depth, in the worst replicate simulation
Rowley Shoals - Clerke Reef	<1	NC	NC
Rowley Shoals - Imperieuse Reef	<1	NC	NC
Rowley Shoals - Mermaid Reef	<1	<1	3
Sahul Banks	<1	NC	NC
Savu	<1	NC	NC
Scott Reef Central	18.5	129	5,777
Scott Reef Central - Sandy Islet	16.5	129	5,777
Scott Reef North - Flats	39.5	583	12,034
Scott Reef North - Lagoon	33.5	364	11,196
Scott Reef South - Flats	18.5	203	6,554
Scott Reef South - Lagoon	24.5	334	9,440
Adele Island	<1	<1	<1
Barracouta Shoal	<1	<1	32
Echuca Shoal	<1	<1	3
Eighty Mile Beach Marine Park	<1	NC	NC
Eugene McDermott Shoal	<1	<1	<1
Fantome Bank	<1	<1	12
Heywood Shoal	<1	<1	11
Oceanic Shoals - Deep Shoal 1	<1	NC	NC
Oceanic Shoals Region - Gale-Favell-Baldwin Banks	<1	NC	NC
Oceanic Shoals Region - Margaret Harries Banks	<1	NC	NC
Oceanic Shoals Region - The Boxers	<1	NC	NC
Timor Leste	<1	NC	NC
Timor West	<1	NC	NC
Van Cloon Shoal	<1	NC	NC
Vulcan & Goeree Shoals	<1	<1	15
WA Coastline	<1	<1	<1

NC: No contact to receptor predicted for specified threshold.

* Probabilities and maximum concentrations calculated at depth of submerged feature.

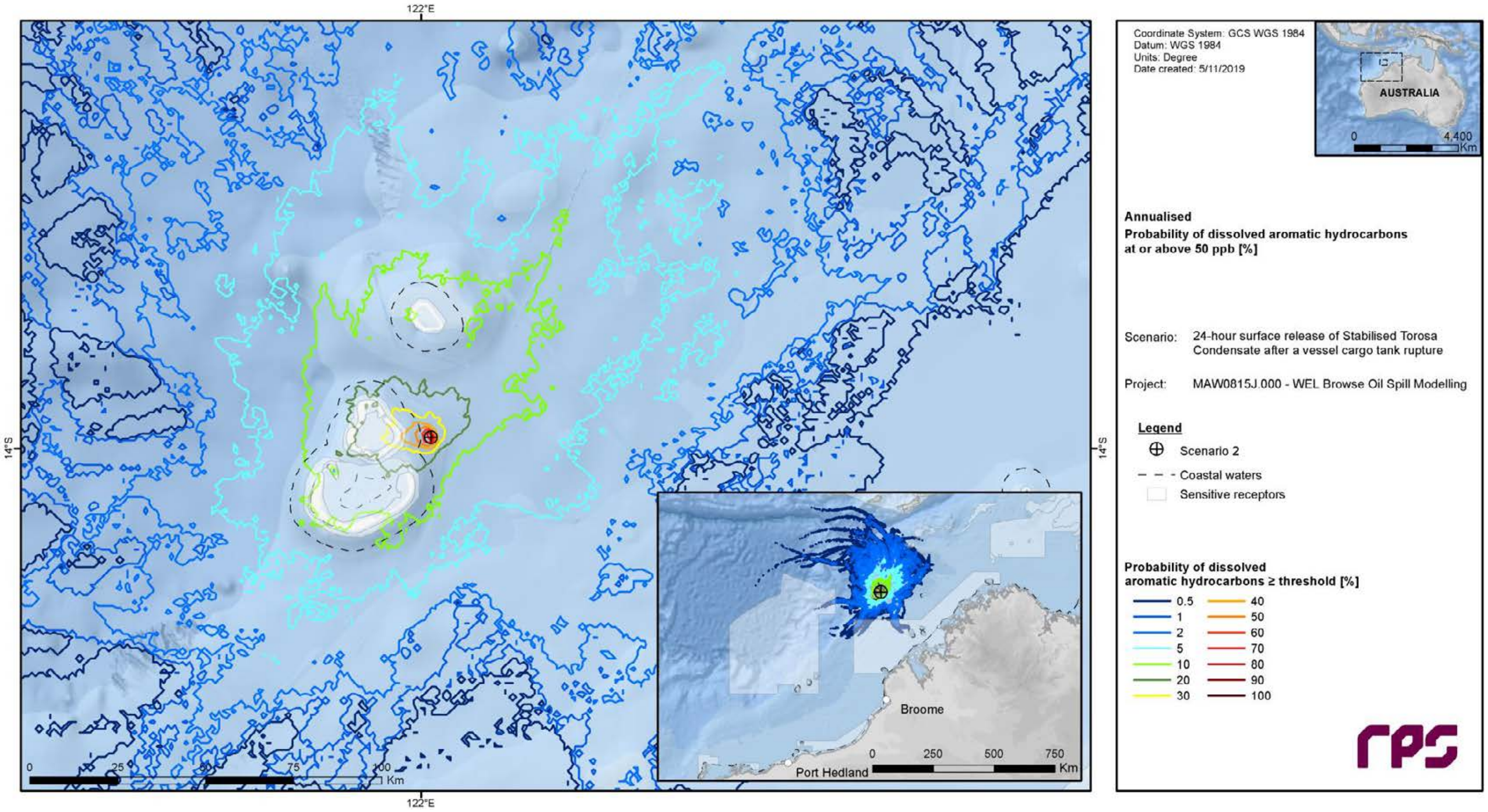

Figure 3.28 Predicted annualised probability of dissolved aromatic hydrocarbon concentrations at or above 50 ppb resulting from a 24-hour surface release of stabilised Torosa Condensate after a vessel cargo tank rupture at the Torosa FPSO location.

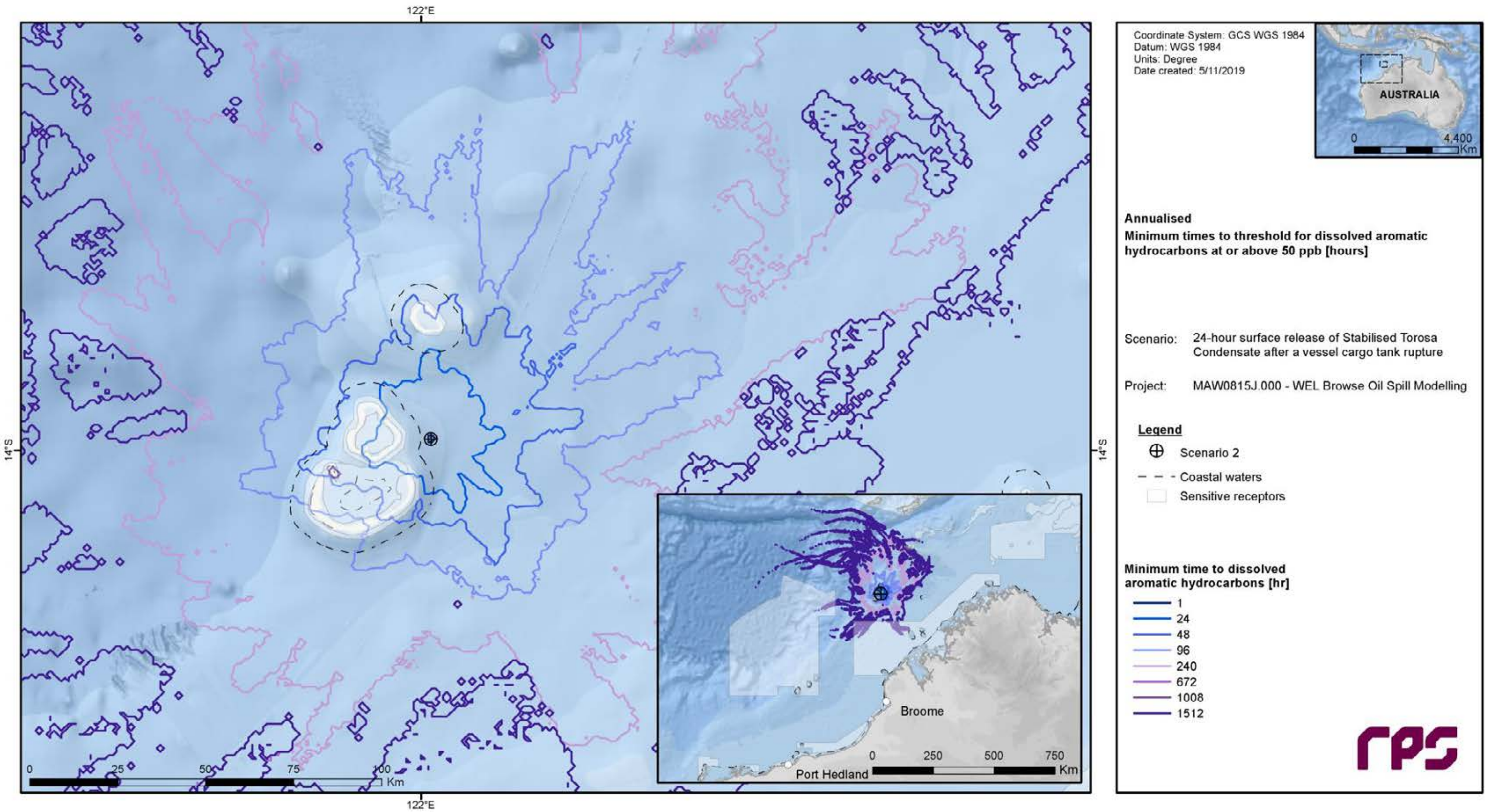

Figure 3.29 Predicted annualised minimum times to contact by dissolved aromatic hydrocarbon concentrations at or above 50 ppb resulting from a 24-hour surface release of stabilised Torosa Condensate after a vessel cargo tank rupture at the Torosa FPSO location.

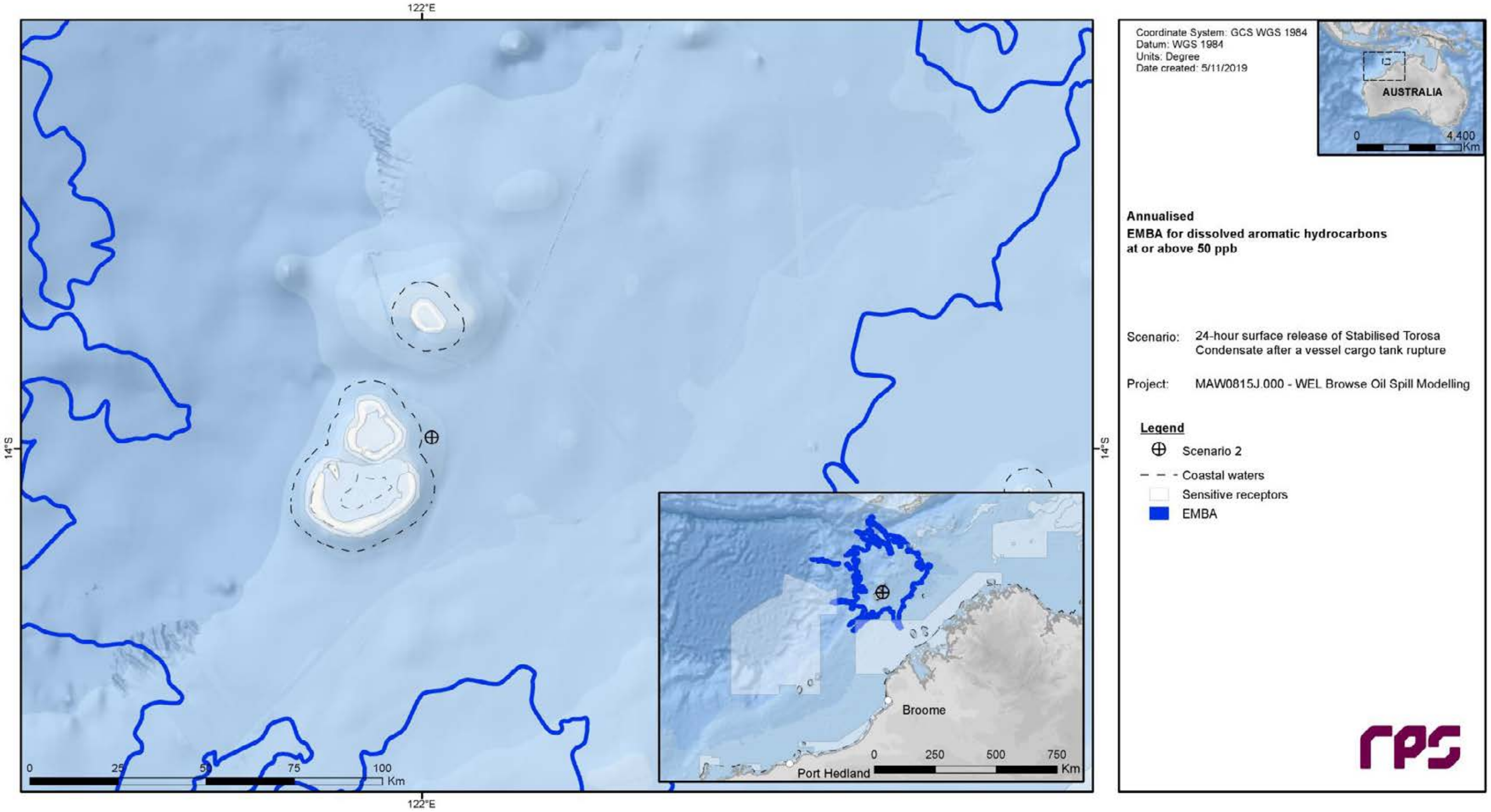

Figure 3.30 Predicted annualised EMBA of dissolved aromatic hydrocarbon concentrations at or above 50 ppb resulting from a 24-hour surface release of stabilised Torosa Condensate after a vessel cargo tank rupture at the Torosa FPSO location.

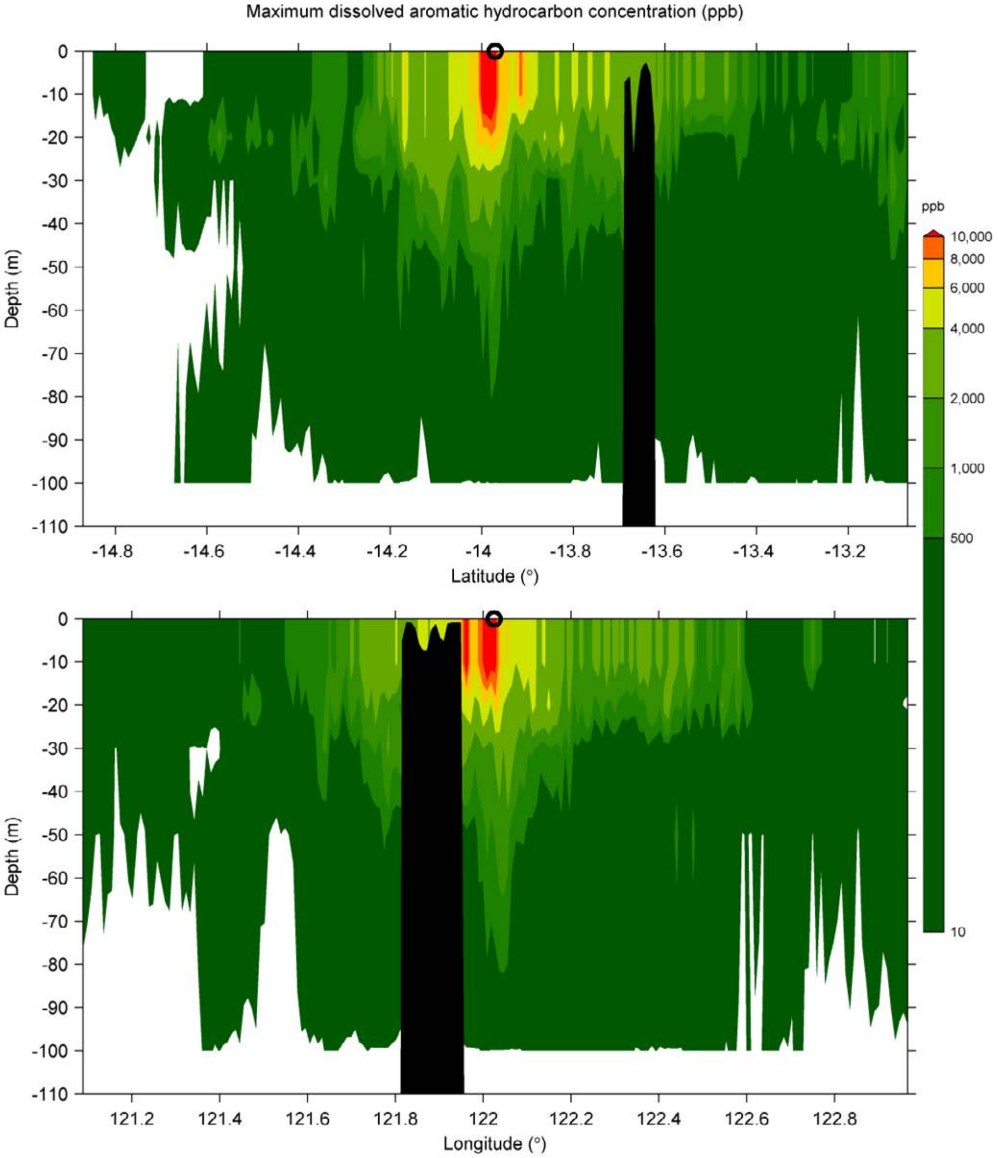

Figure 3.31 Cross-section transects of predicted annualised maximum dissolved aromatic hydrocarbon concentrations for a 24-hour surface release of stabilised Torosa Condensate after a vessel cargo tank rupture at the Torosa FPSO location. Transect locations are shown in Figure 3.1.

3.4 Scenario 3: Short-Term (Instantaneous) Surface Release of Stabilised Torosa Condensate after an FPSO Offtake System Failure at the Torosa FPSO Location

3.4.1 Discussion of Results

3.4.1.1 Overview

This scenario investigated the probability of exposure to surrounding regions by oil resulting from a short-term (instantaneous) surface release of 768 m^3 of stabilised Torosa Condensate after an FPSO offtake system failure at the Torosa FPSO location during operations at any time of year, with no mitigation measures applied.

During the surface release, the volatile fractions of the oil (78.0%) are likely to evaporate within 24 hours of exposure to the atmosphere. The low-volatility fraction of the condensate (8.0%) will take longer times of the order of days to weeks to evaporate, and the remaining fraction (14.0%) is expected to persist for an extended period of time as residual oil.

3.4.1.2 Floating and Shoreline Oil

The probability contour figures for floating oil indicate that concentrations equal to or greater than the 10 g/m^2 threshold could potentially be found, in the form of slicks, up to 67 km from the spill site (Figure 3.33).

The Scott Reef South shoreline receptor is predicted to be contacted by floating oil concentrations at the 10 g/m^2 threshold with a probability of 1.5% and a minimum contact time of 24 hours (Table 3.7).

The Scott Reef South, Scott Reef Central and Scott Reef Central – Sandy Islet receptors are predicted to experience shoreline oil accumulation in excess of the 100 g/m^2 threshold with a probability of 2.5% (Table 3.7). Potential for accumulation of oil on shorelines is predicted to be low, with a maximum accumulated volume of 8 m^3 and a maximum local accumulated concentration of 715 g/m^2 forecast at these receptors (Table 3.7).

The forecast annualised minimum times to contact and EMBA for floating oil at or above the 1 g/m^2 and 10 g/m^2 threshold concentrations are depicted in Figure 3.34 to Figure 3.37.

3.4.1.3 Entrained Oil

Entrained oil at concentrations equal to or greater than the 100 ppb threshold is predicted to be found up to around 242 km from the spill site (Figure 3.39).

Contact by entrained oil at concentrations equal to or greater than 100 ppb is predicted at Scott Reef North (28%), Scott Reef North – Flats (25%) and Scott Reef North – Lagoon (20%; Table 3.8). The maximum entrained oil concentration forecast for any receptor is predicted as 6.4 ppm at Scott Reef North and Scott Reef North – Flats.

The forecast annualised minimum times to contact and EMBA for entrained oil at or above the 100 ppb threshold concentration are depicted in Figure 3.40 and Figure 3.41, respectively.

The cross-sectional transects of maximum entrained oil concentrations in the vicinity of the release site show that concentrations above 15,000 ppb are expected to extend from the sea surface to depths of around 15 m (Figure 3.42).

3.4.1.4 Dissolved Aromatic Hydrocarbons

Dissolved aromatic hydrocarbons at concentrations equal to or greater than the 50 ppb threshold are predicted to be found up to around 271 km from the spill site (Figure 3.43).

Contact by dissolved aromatic hydrocarbons at concentrations equal to or greater than 50 ppb is predicted at Scott Reef North (23%) and Scott Reef North – Flats (22.5%; Table 3.9). The maximum dissolved aromatic hydrocarbon concentration forecast for any receptor is predicted as 1.8 ppm at Scott Reef North and Scott Reef North – Lagoon.

The forecast annualised minimum times to contact and EMBA for dissolved aromatic hydrocarbons at or above the 50 ppb threshold concentration are depicted in Figure 3.44 and Figure 3.45, respectively.

The cross-sectional transects of maximum dissolved aromatic hydrocarbon concentrations in the vicinity of the release site show that concentrations above 1,000 ppb are expected to extend from the sea surface to depths of around 10 m (Figure 3.46).

3.4.2 Results Tables and Figures

3.4.2.1 Floating and Shoreline Oil

Table 3.7 Expected annualised floating and shoreline oil outcomes at sensitive receptors resulting from an instantaneous surface release of stabilised Torosa Condensate after an FPSO offtake system failure at the Torosa FPSO location.

Receptor	Probability (%) of floating oil concentration		Minimum time to receptor (hours) for floating oil at		Probability (%) of shoreline oil concentration	Minimum time to receptor (hours) for shoreline oil at	Maximum local accumulated concentration (g/m^2)		Maximum accumulated volume (m^3) along this shoreline	
	≥1 g/m^2	≥10 g/m^2	≥1 g/m^2	≥10 g/m^2	≥100 g/m^2	≥100 g/m^2	averaged over all replicate simulations	in the worst replicate simulation	averaged over all replicate simulations	in the worst replicate simulation
Argo-Rowley Terrace Marine Park *	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Ashmore Reef Marine Park	<1	<1	NC	NC	<1	NC	0.1	15	<1	<1
Browse Island*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Buccaneer & Bonaparte Archipelagos	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Cartier Island Marine Park	<1	<1	NC	NC	<1	NC	<0.1	13	<1	<1
Glomar Shoals & Rankin Bank*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Hibernia Reef*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Indonesia	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Indonesian Boundary	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Kimberley Marine Park *	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Kimberley Coast	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Lacepede Islands	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Oceanic Shoals Marine Park *	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Pulau Roti	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Rowley Shoals - Clerke Reef State Marine Park	<1	<1	NC	NC	<1	NC	<0.1	11	<1	<1
Rowley Shoals - Imperieuse Reef State Marine Park	<1	<1	NC	NC	<1	NC	<0.1	4.8	<1	<1
Rowley Shoals - Mermaid Reef Marine Park	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Scott Reef North*	11.5	5.5	6	7	NA	NA	NA	NA	NA	NA
Scott Reef South	3	1.5	17	24	2.5	61	12	715	<1	8
Seringapatam Reef*	3.5	<1	38	45	NA	NA	NA	NA	NA	NA
Sumba	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Ashmore Reef	<1	<1	NC	NC	<1	NC	0.1	15	<1	<1
Big Bank Shoals*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Camden Sound	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Cartier Island	<1	<1	NC	NC	<1	NC	<0.1	13	<1	<1
Dampier Peninsula Coast - Mid Section	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Dampier Peninsula Coast - North Section	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Lalang-garram - Camden Sound Marine Park	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC

Receptor	Probability (%) of floating oil concentration		Minimum time to receptor (hours) for floating oil at		Probability (%) of shoreline oil concentration	Minimum time to receptor (hours) for shoreline oil at	Maximum local accumulated concentration (g/m^2)		Maximum accumulated volume (m^3) along this shoreline	
	≥1 g/m^2	≥10 g/m^2	≥1 g/m^2	≥10 g/m^2	≥100 g/m^2	≥100 g/m^2	averaged over all replicate simulations	in the worst replicate simulation	averaged over all replicate simulations	in the worst replicate simulation
Rowley Shoals - Clerke Reef	<1	<1	NC	NC	<1	NC	<0.1	11	<1	<1
Rowley Shoals - Imperieuse Reef	<1	<1	NC	NC	<1	NC	<0.1	4.8	<1	<1
Rowley Shoals - Mermaid Reef	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Sahul Banks*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Savu	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Scott Reef Central	1	<1	50	NC	2.5	61	12	715	<1	8
Scott Reef Central - Sandy Islet	1	<1	60	NC	2.5	61	12	715	<1	8
Scott Reef North - Flats*	11.5	4.5	7	8	NA	NA	NA	NA	NA	NA
Scott Reef North - Lagoon*	8.5	2.5	9	11	NA	NA	NA	NA	NA	NA
Scott Reef South - Flats*	2.5	1	22	31	NA	NA	NA	NA	NA	NA
Scott Reef South - Lagoon*	3	1.5	19	22	NA	NA	NA	NA	NA	NA
Adele Island	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Barracouta Shoal*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Echuca Shoal*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Eighty Mile Beach Marine Park *	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Eugene McDermott Shoal*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Fantome Bank*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Heywood Shoal*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Oceanic Shoals - Deep Shoal 1*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Oceanic Shoals Region - Gale-Favell-Baldwin Banks*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Oceanic Shoals Region - Margaret Harries Banks*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Oceanic Shoals Region - The Boxers*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Timor Leste	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Timor West	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Van Cloon Shoal*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Vulcan & Goeree Shoals*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
WA Coastline	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC

NC: No contact to receptor predicted for specified threshold. NA: Not applicable.

* Floating oil will not accumulate on submerged features and at open ocean locations.

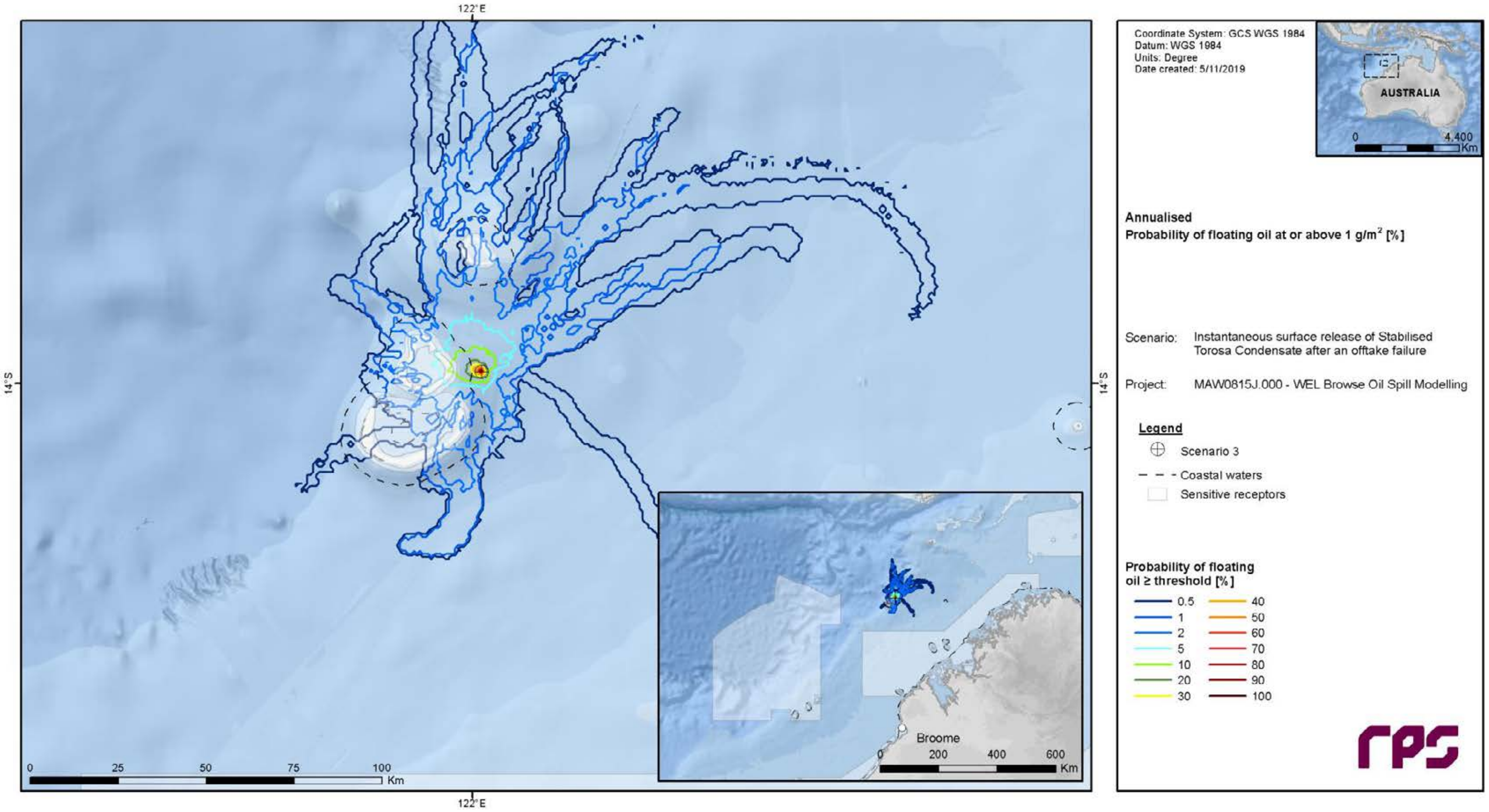

Figure 3.32 Predicted annualised probability of floating oil concentrations at or above 1 g/m^2 resulting from an instantaneous surface release of stabilised Torosa Condensate after an FPSO offtake system failure at the Torosa FPSO location.

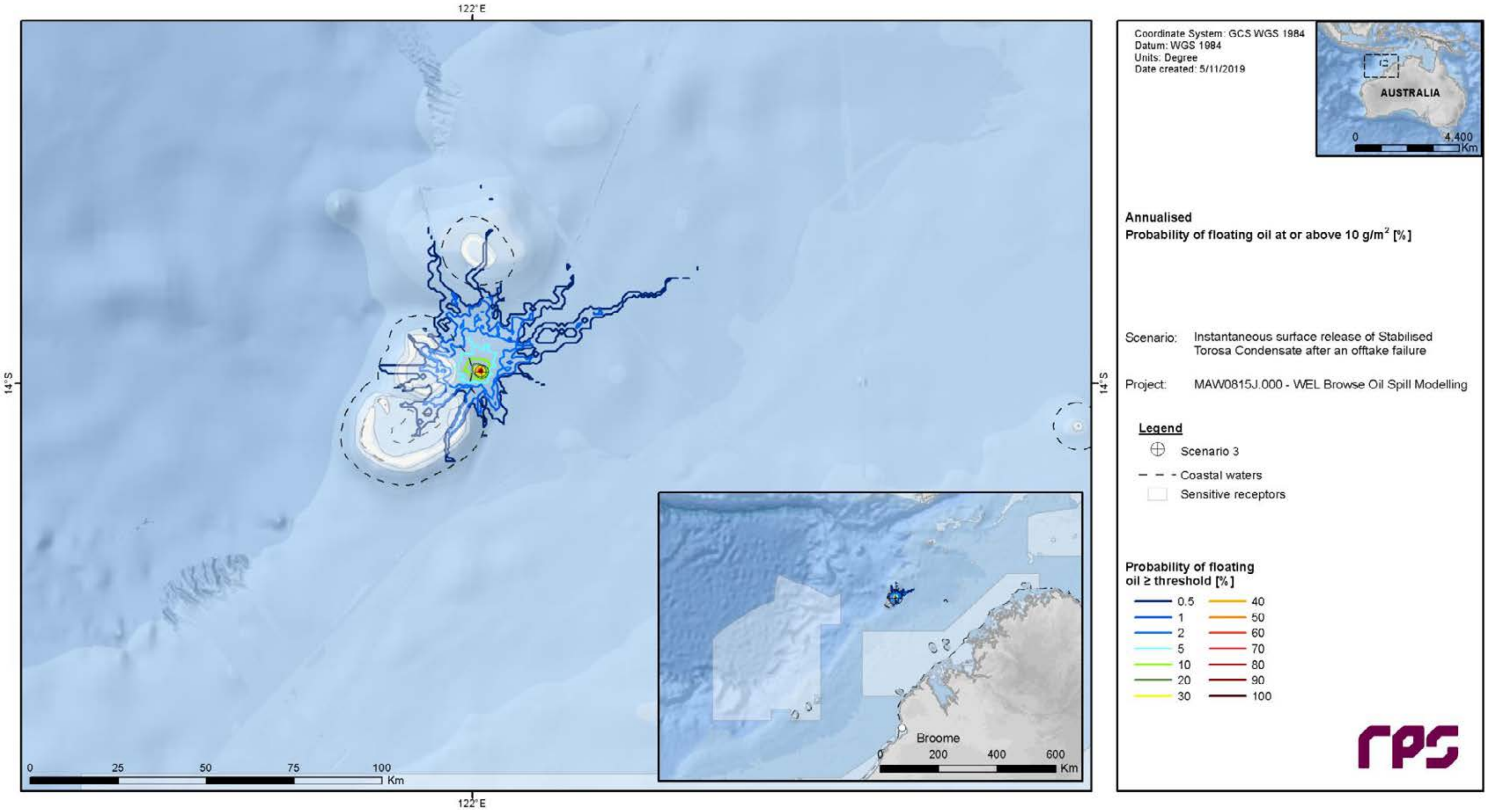

Figure 3.33 Predicted annualised probability of floating oil concentrations at or above 10 g/m^2 resulting from an instantaneous surface release of stabilised Torosa Condensate after an FPSO offtake system failure at the Torosa FPSO location.

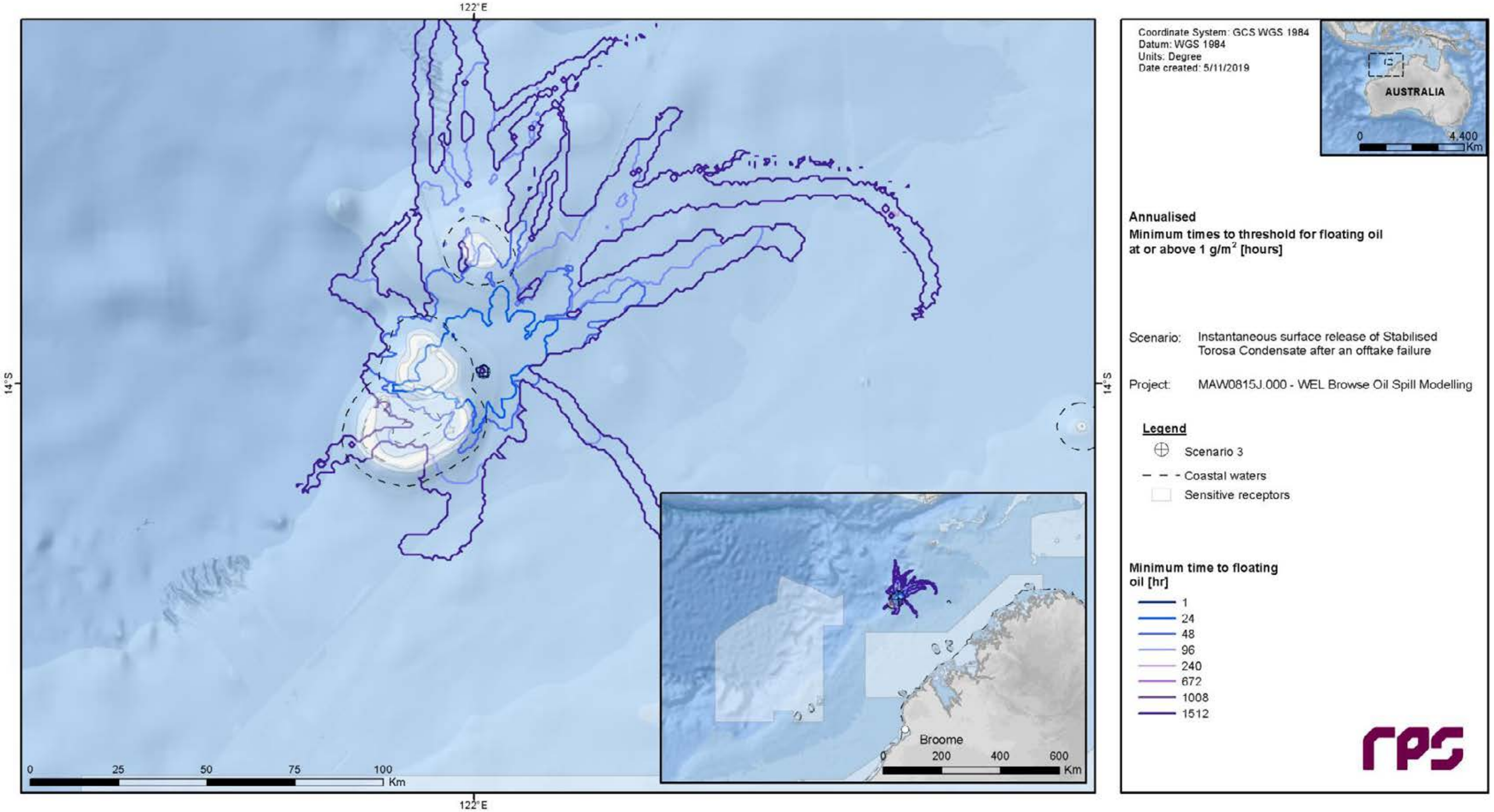

Figure 3.34 Predicted annualised minimum times to contact by floating oil concentrations at or above 1 g/m^2 resulting from an instantaneous surface release of stabilised Torosa Condensate after an FPSO offtake system failure at the Torosa FPSO location.

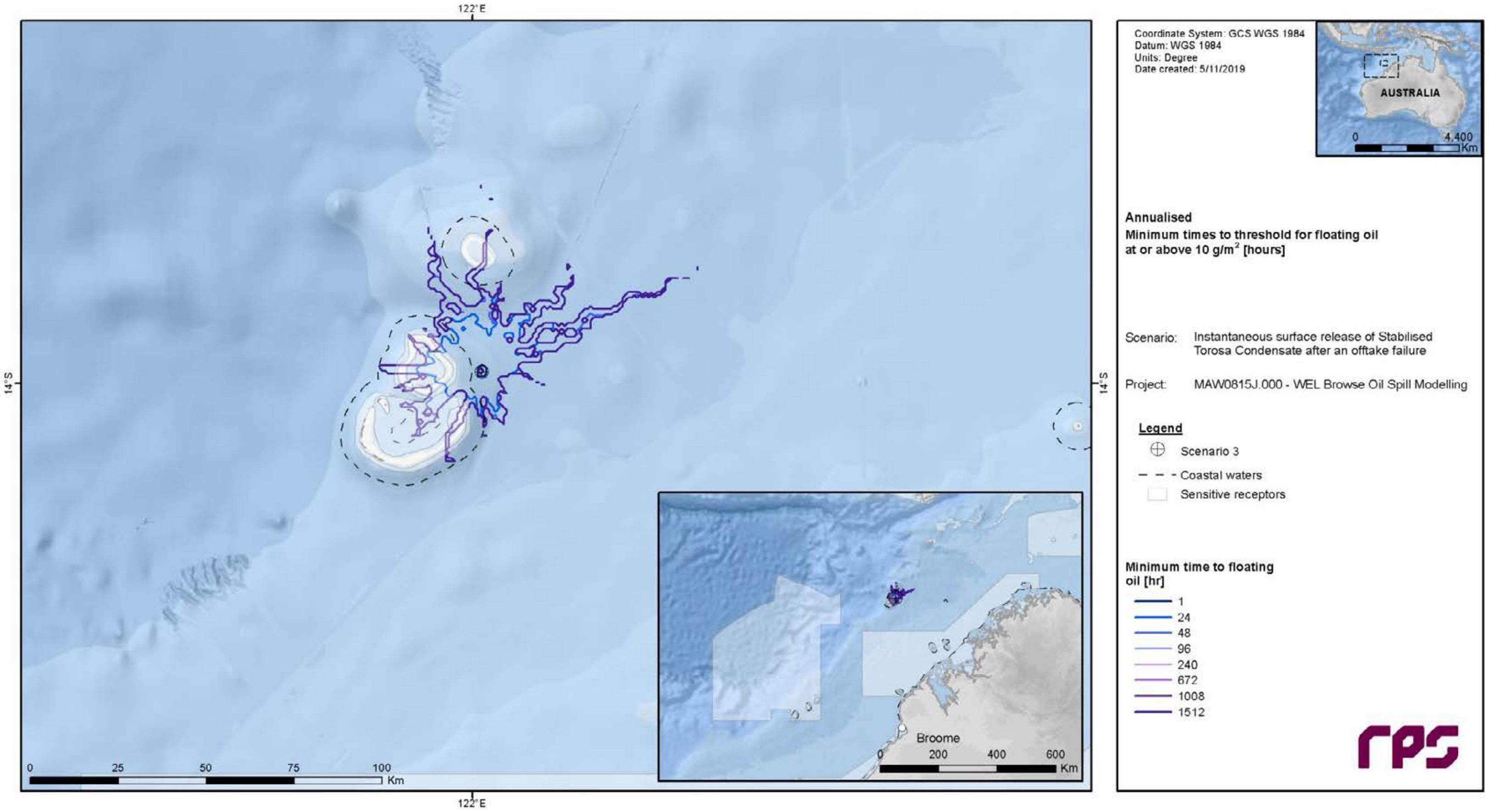

Figure 3.35 Predicted annualised minimum times to contact by floating oil concentrations at or above 10 g/m^2 resulting from an instantaneous surface release of stabilised Torosa Condensate after an FPSO offtake system failure at the Torosa FPSO location.

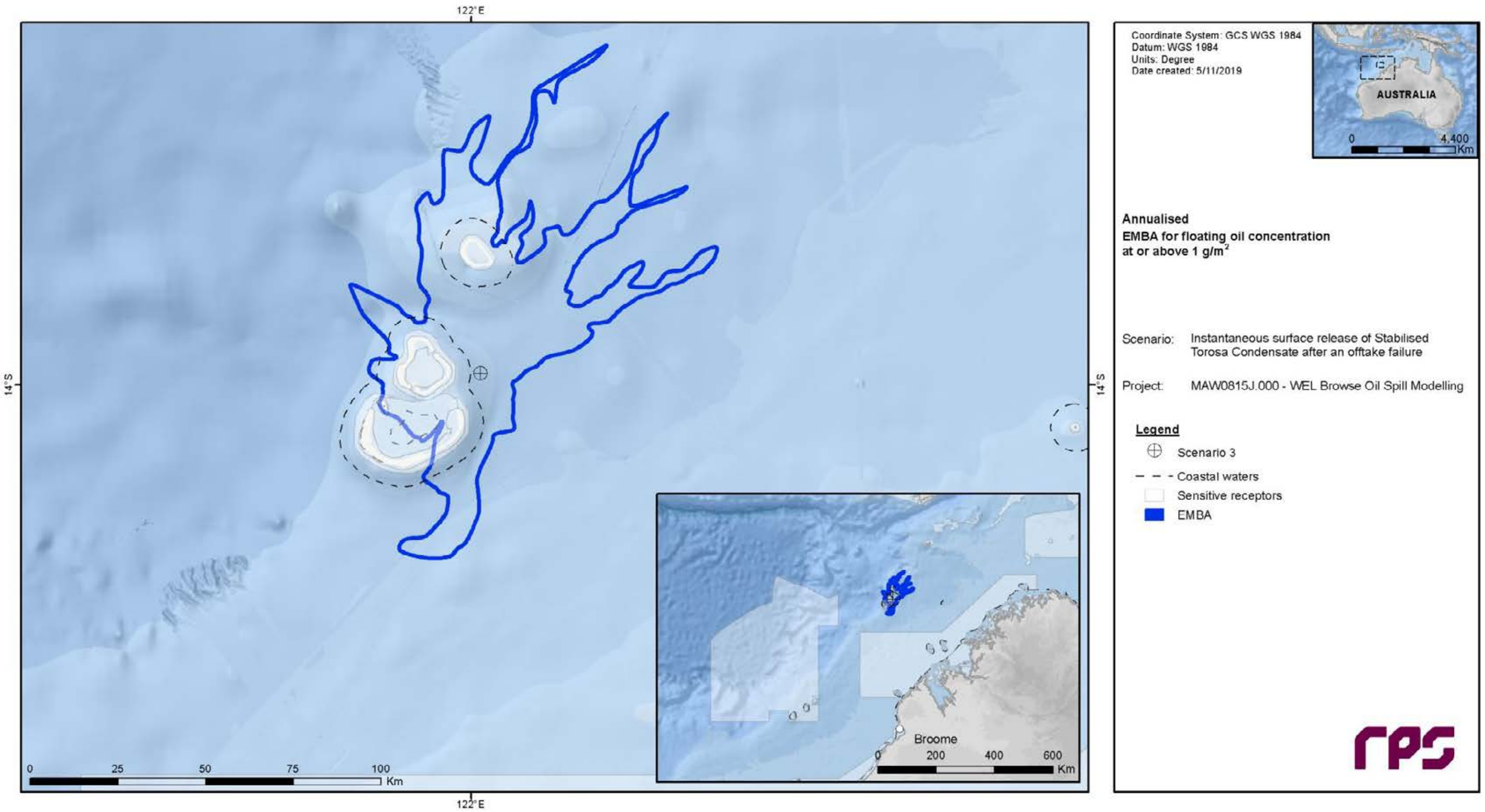

Figure 3.36 Predicted annualised EMBA of floating oil concentrations at or above 1 g/m^2 resulting from an instantaneous surface release of stabilised Torosa Condensate after an FPSO offtake system failure at the Torosa FPSO location.

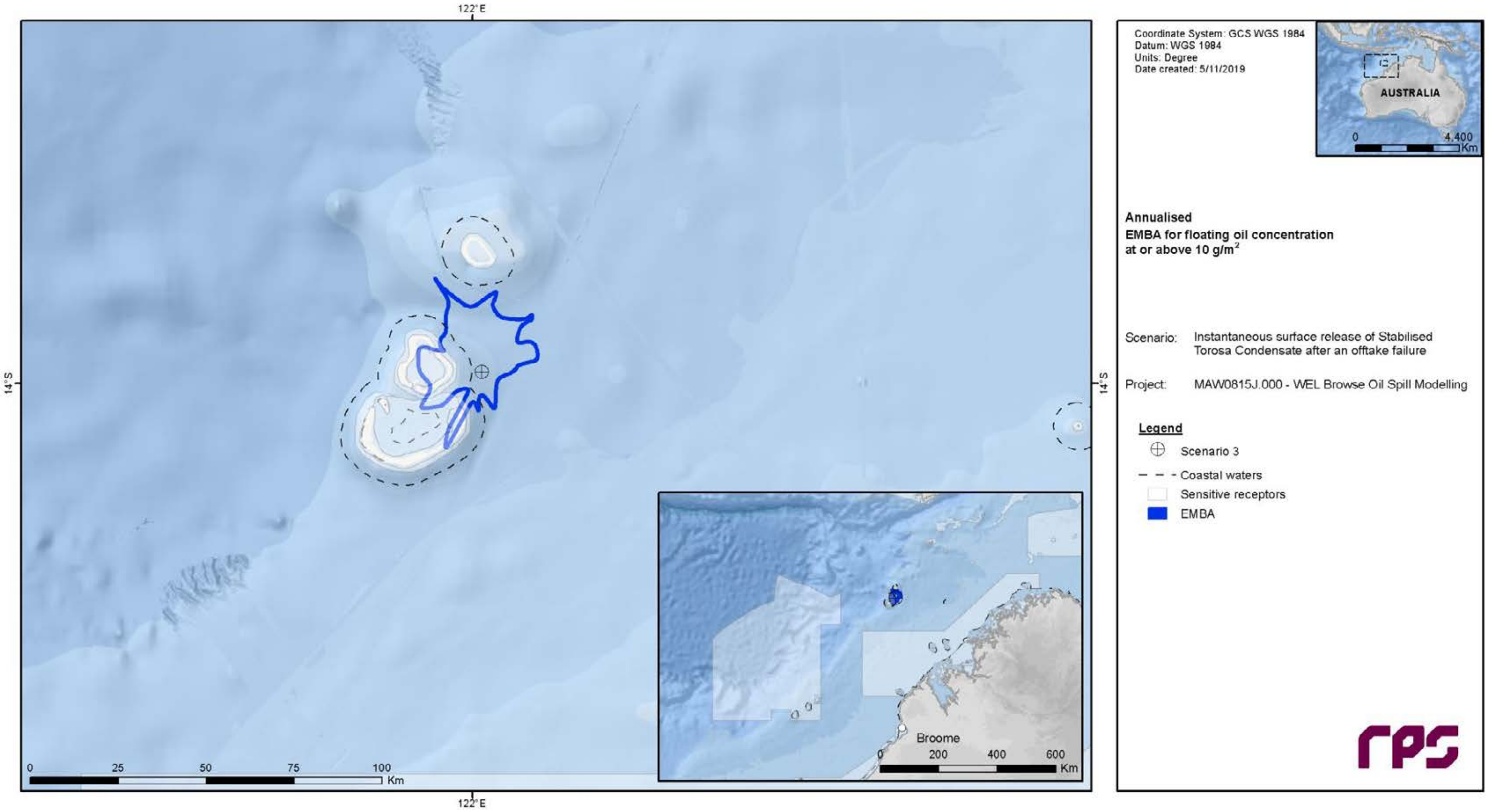

Figure 3.37 Predicted annualised EMBA of floating oil concentrations at or above 10 g/m^2 resulting from an instantaneous surface release of stabilised Torosa Condensate after an FPSO offtake system failure at the Torosa FPSO location.

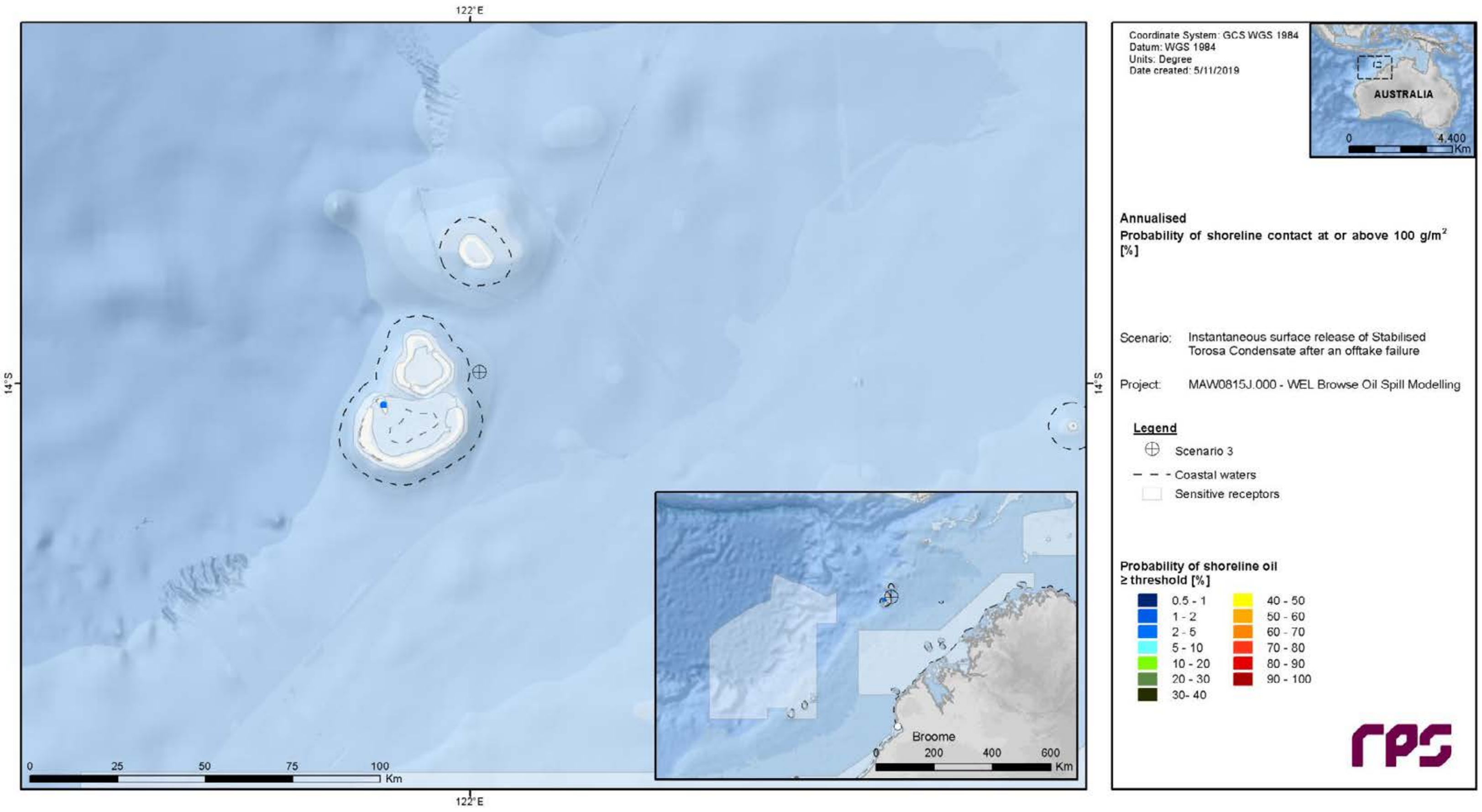

Figure 3.38 Predicted annualised probability of shoreline oil concentrations at or above 100 g/m^2 resulting from an instantaneous surface release of stabilised Torosa Condensate after an FPSO offtake system failure at the Torosa FPSO location.

3.4.2.2 Entrained Oil

Table 3.8 Expected annualised entrained oil outcomes at sensitive receptors resulting from an instantaneous surface release of stabilised Torosa Condensate after an FPSO offtake system failure at the Torosa FPSO location.

Receptor	Probability (%) of entrained oil concentration ≥100 ppb	Minimum time to receptor (hours) for entrained oil at ≥100 ppb	Maximum entrained oil concentration (ppb) averaged over all replicate simulations	Maximum entrained oil concentration (ppb) at any depth, in the worst replicate simulation
Argo-Rowley Terrace Marine Park	<1	NC	<1	44
Ashmore Reef Marine Park	<1	302	<1	121
Browse Island	<1	NC	<1	5
Buccaneer & Bonaparte Archipelagos	<1	NC	<1	<1
Cartier Island Marine Park	<1	NC	<1	17
Glomar Shoals & Rankin Bank	<1	NC	NC	NC
Hibernia Reef	<1	NC	<1	19
Indonesia	<1	NC	<1	3
Indonesian Boundary	<1	NC	<1	19
Kimberley Marine Park	<1	NC	<1	45
Kimberley Coast	<1	NC	<1	<1
Lacepede Islands	<1	NC	NC	NC
Oceanic Shoals Marine Park	<1	NC	<1	<1
Pulau Roti	<1	NC	NC	NC
Rowley Shoals - Clerke Reef State Marine Park	<1	NC	<1	4
Rowley Shoals - Imperieuse Reef State Marine Park	<1	NC	<1	4
Rowley Shoals - Mermaid Reef Marine Park	<1	NC	<1	2
Scott Reef North	28	6	278	6,391
Scott Reef South	13.5	17	84	2,935
Seringapatam Reef	7.5	29	26	1,207
Sumba	<1	NC	<1	<1
Ashmore Reef	<1	310	<1	109
Big Bank Shoals	<1	NC	NC	NC
Camden Sound	<1	NC	NC	NC
Cartier Island	<1	NC	<1	17
Dampier Peninsula Coast - Mid Section	<1	NC	NC	NC

Receptor	Probability (%) of entrained oil concentration ≥100 ppb	Minimum time to receptor (hours) for entrained oil at ≥100 ppb	Maximum entrained oil concentration (ppb) averaged over all replicate simulations	Maximum entrained oil concentration (ppb) at any depth, in the worst replicate simulation
Dampier Peninsula Coast - North Section	<1	NC	<1	<1
Lalang-garram - Camden Sound Marine Park	<1	NC	<1	<1
Rowley Shoals - Clerke Reef	<1	NC	<1	4
Rowley Shoals - Imperieuse Reef	<1	NC	<1	4
Rowley Shoals - Mermaid Reef	<1	NC	<1	2
Sahul Banks	<1	NC	<1	2
Savu	<1	NC	<1	2
Scott Reef Central	9.5	31	31	973
Scott Reef Central - Sandy Islet	8.5	35	31	879
Scott Reef North - Flats	25	7	232	6,391
Scott Reef North - Lagoon	20	10	95	2,979
Scott Reef South - Flats	9	22	40	1,916
Scott Reef South - Lagoon	14.5	18	83	2,887
Adele Island	<1	NC	<1	<1
Barracouta Shoal	<1	NC	<1	52
Echuca Shoal	<1	NC	<1	12
Eighty Mile Beach Marine Park	<1	NC	NC	NC
Eugene McDermott Shoal	<1	NC	<1	10
Fantome Bank	<1	NC	<1	8
Heywood Shoal	<1	NC	<1	18
Oceanic Shoals - Deep Shoal 1	<1	NC	NC	NC
Oceanic Shoals Region - Gale-Favell-Baldwin Banks	<1	NC	NC	NC
Oceanic Shoals Region - Margaret Harries Banks	<1	NC	NC	NC
Oceanic Shoals Region - The Boxers	<1	NC	NC	NC
Timor Leste	<1	NC	NC	NC
Timor West	<1	NC	NC	NC
Van Cloon Shoal	<1	NC	NC	NC
Vulcan & Goeree Shoals	<1	NC	<1	15
WA Coastline	<1	NC	<1	2

NC: No contact to receptor predicted for specified threshold.

* Probabilities and maximum concentrations calculated at depth of submerged feature.

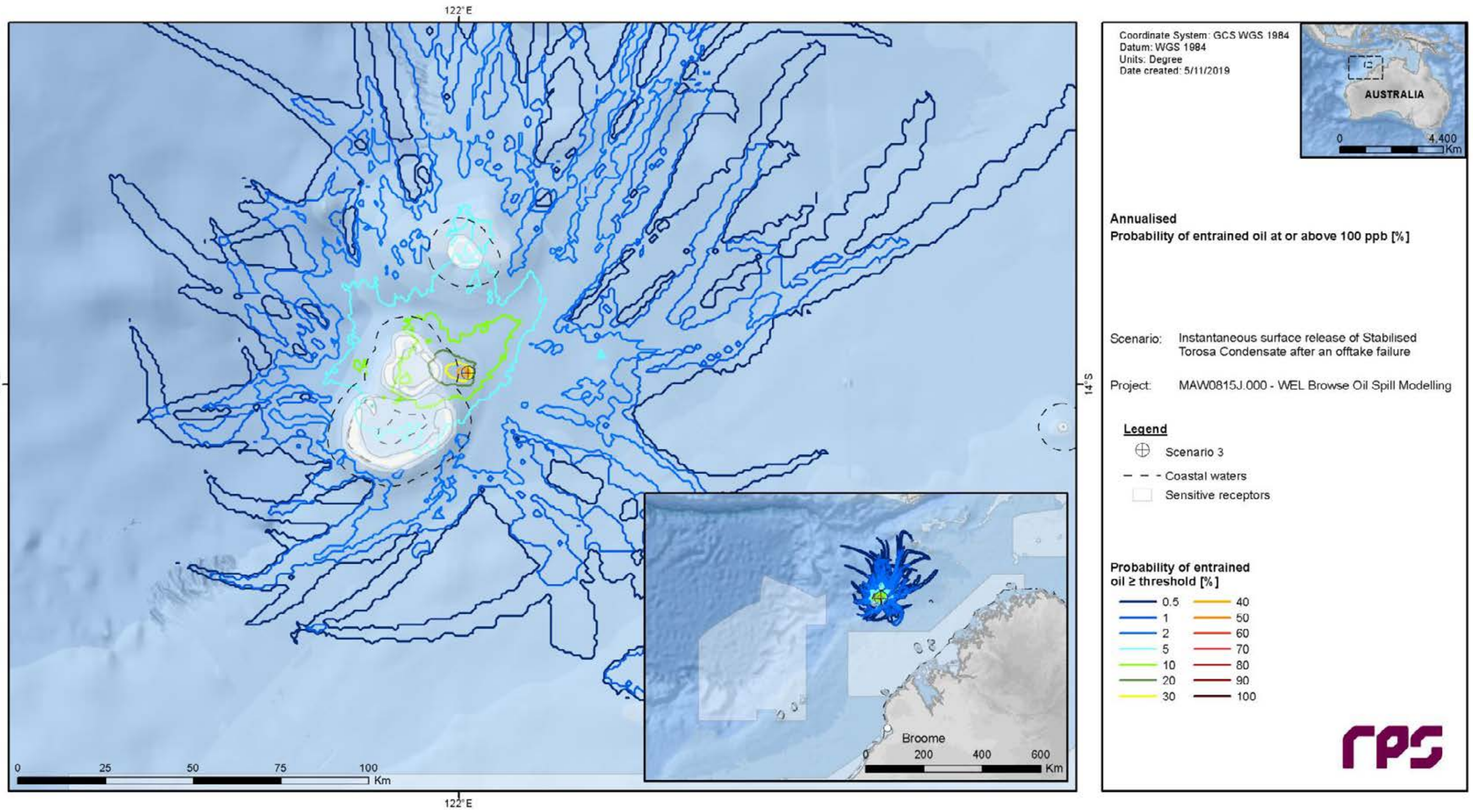

Figure 3.39 Predicted annualised probability of entrained oil concentrations at or above 100 ppb resulting from an instantaneous surface release of stabilised Torosa Condensate after an FPSO offtake system failure at the Torosa FPSO location.

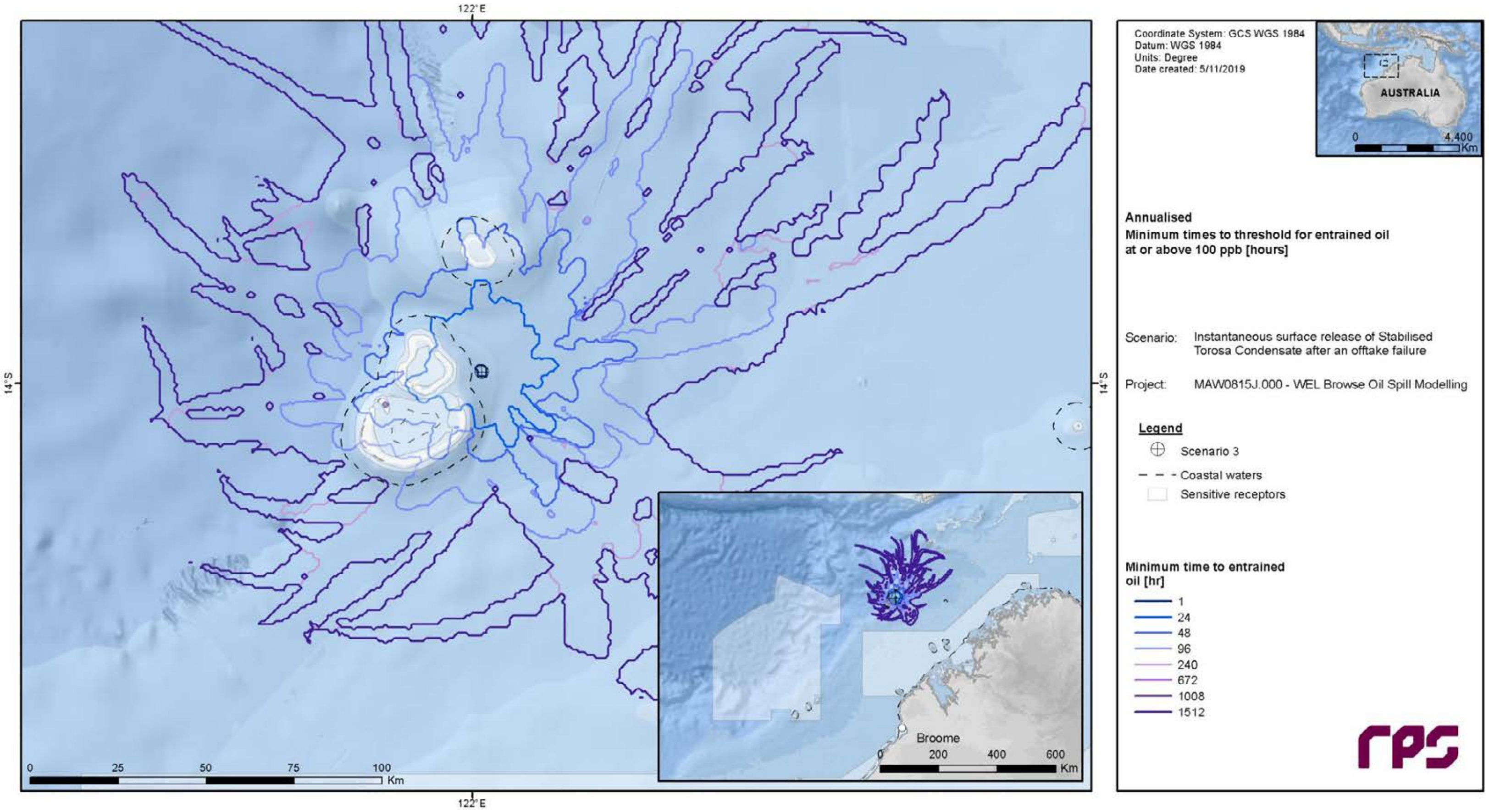

Figure 3.40 Predicted annualised minimum times to contact by entrained oil concentrations at or above 100 ppb resulting from an instantaneous surface release of stabilised Torosa Condensate after an FPSO offtake system failure at the Torosa FPSO location.

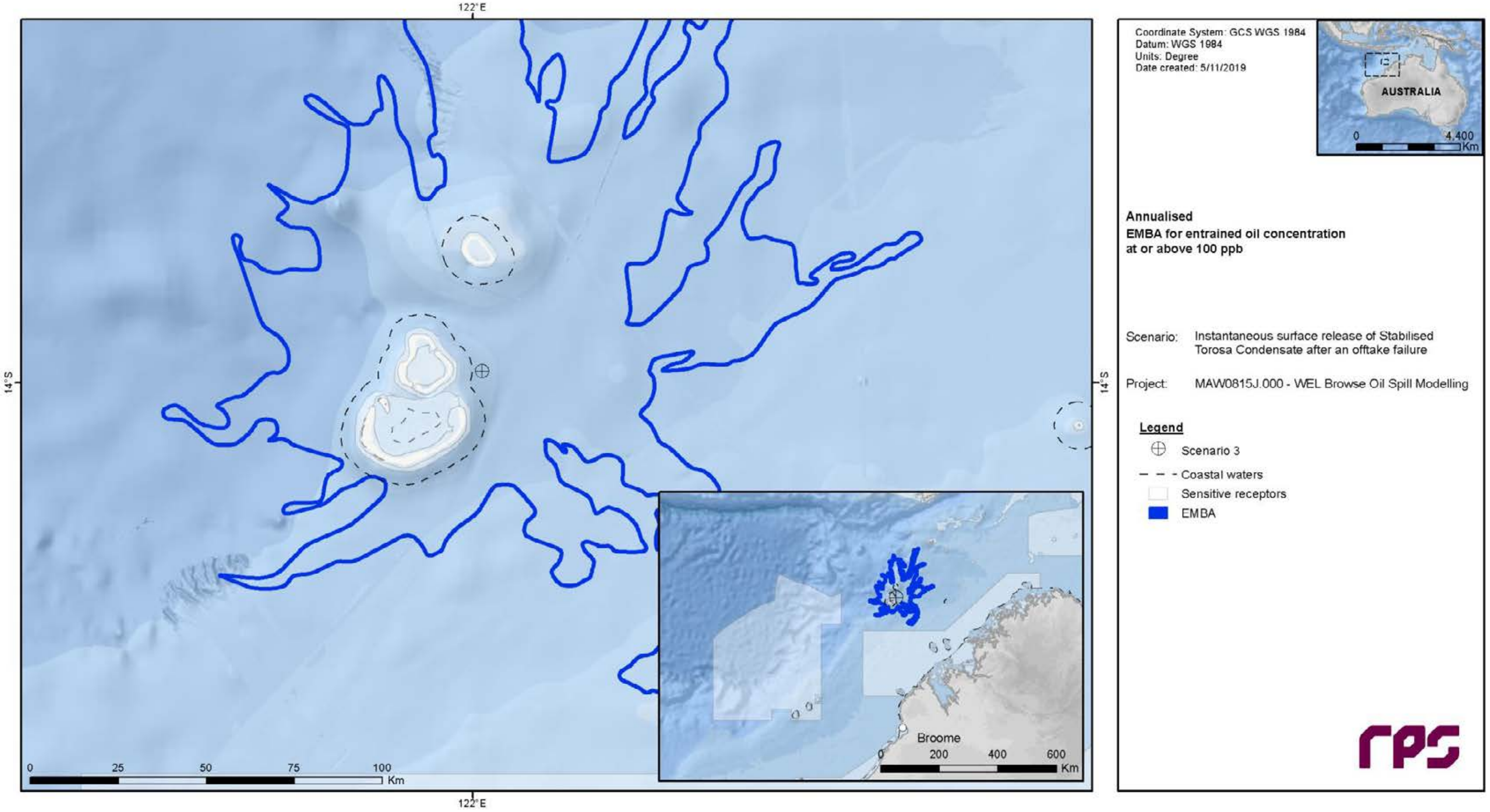

Figure 3.41 Predicted annualised EMBA of entrained oil concentrations at or above 100 ppb resulting from an instantaneous surface release of stabilised Torosa Condensate after an FPSO offtake system failure at the Torosa FPSO location.

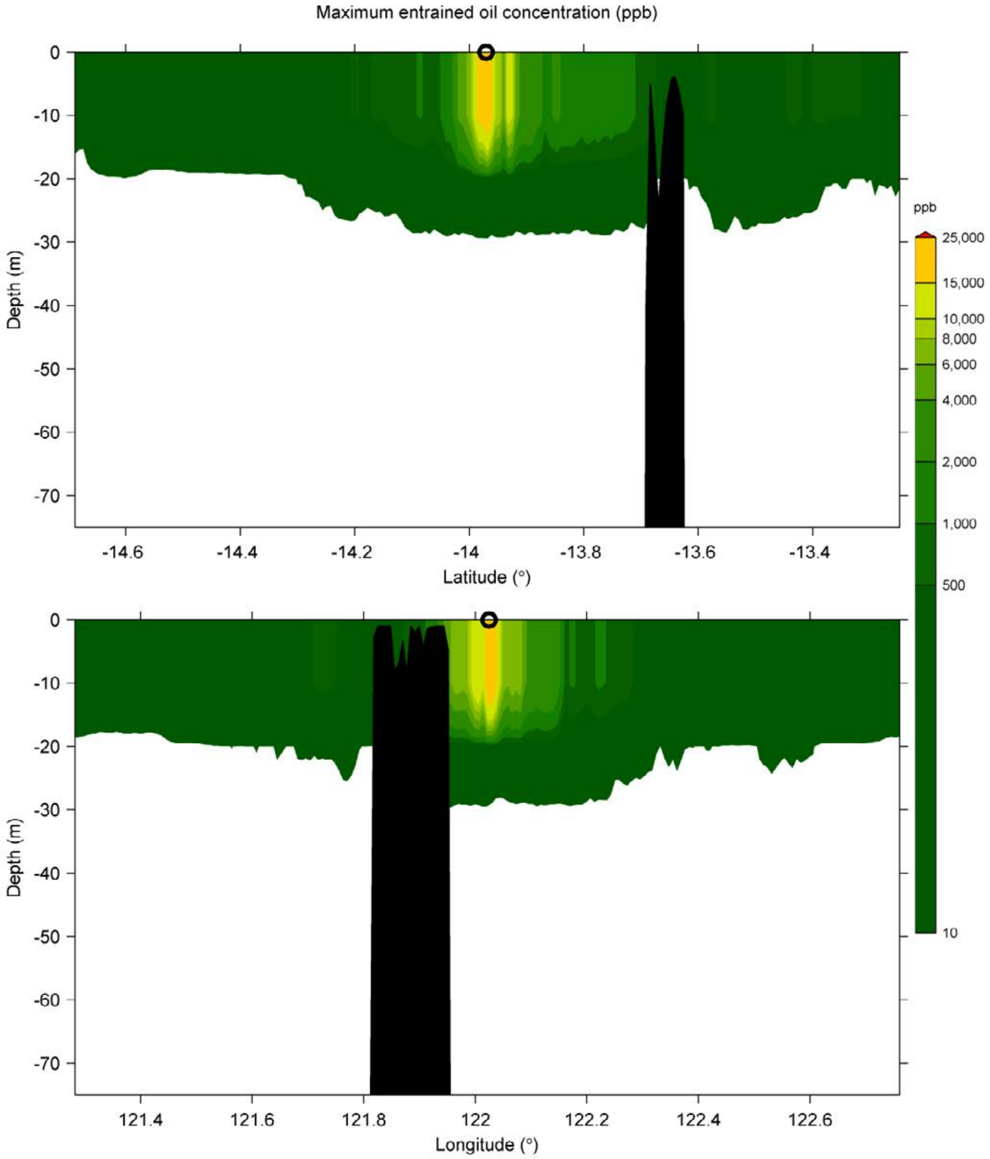

Figure 3.42 Cross-section transects of predicted annualised maximum entrained oil concentrations for an instantaneous surface release of stabilised Torosa Condensate after an FPSO offtake system failure at the Torosa FPSO location. Transect locations are shown in Figure 3.1.

3.4.2.3 Dissolved Aromatic Hydrocarbons

Table 3.9 Expected annualised dissolved aromatic hydrocarbon outcomes at sensitive receptors resulting from an instantaneous surface release of stabilised Torosa Condensate after an FPSO offtake system failure at the Torosa FPSO location.

Receptor	Probability (%) of dissolved aromatic hydrocarbon concentration	Maximum dissolved aromatic hydrocarbon concentration (ppb)	
	≥50 ppb	averaged over all replicate simulations	at any depth, in the worst replicate simulation
Argo-Rowley Terrace Marine Park	<1	<1	24
Ashmore Reef Marine Park	<1	<1	9
Browse Island	<1	<1	<1
Buccaneer & Bonaparte Archipelagos	<1	NC	NC
Cartier Island Marine Park	<1	<1	9
Glomar Shoals & Rankin Bank	<1	NC	NC
Hibernia Reef	<1	<1	11
Indonesia	<1	NC	NC
Indonesian Boundary	<1	NC	NC
Kimberley Marine Park	<1	<1	54
Kimberley Coast	<1	NC	NC
Lacepede Islands	<1	NC	NC
Oceanic Shoals Marine Park	<1	NC	NC
Pulau Roti	<1	NC	NC
Rowley Shoals - Clerke Reef State Marine Park	<1	NC	NC
Rowley Shoals - Imperieuse Reef State Marine Park	<1	NC	NC
Rowley Shoals - Mermaid Reef Marine Park	<1	<1	<1
Scott Reef North	23	76	1,791
Scott Reef South	11.5	36	1,249
Seringapatam Reef	7.5	13	881
Sumba	<1	NC	NC
Ashmore Reef	<1	<1	7
Big Bank Shoals	<1	NC	NC
Camden Sound	<1	NC	NC
Cartier Island	<1	<1	5
Dampier Peninsula Coast - Mid Section	<1	NC	NC
Dampier Peninsula Coast - North Section	<1	NC	NC
Lalang-garram - Camden Sound Marine Park	<1	NC	NC
Rowley Shoals - Clerke Reef	<1	NC	NC

Receptor	**Probability (%) of dissolved aromatic hydrocarbon concentration**	**Maximum dissolved aromatic hydrocarbon concentration (ppb)**	
	≥50 ppb	**averaged over all replicate simulations**	**at any depth, in the worst replicate simulation**
Rowley Shoals - Imperieuse Reef	<1	NC	NC
Rowley Shoals - Mermaid Reef	<1	<1	<1
Sahul Banks	<1	NC	NC
Savu	<1	NC	NC
Scott Reef Central	7.5	12	971
Scott Reef Central - Sandy Islet	7.5	10	516
Scott Reef North - Flats	22.5	69	1,749
Scott Reef North - Lagoon	15.5	42	1,791
Scott Reef South - Flats	9	19	961
Scott Reef South - Lagoon	11	30	1,166
Adele Island	<1	<1	<1
Barracouta Shoal	<1	<1	<1
Echuca Shoal	<1	<1	<1
Eighty Mile Beach Marine Park	<1	NC	NC
Eugene McDermott Shoal	<1	<1	<1
Fantome Bank	<1	<1	<1
Heywood Shoal	<1	<1	<1
Oceanic Shoals - Deep Shoal 1	<1	NC	NC
Oceanic Shoals Region - Gale-Favell-Baldwin Banks	<1	NC	NC
Oceanic Shoals Region - Margaret Harries Banks	<1	NC	NC
Oceanic Shoals Region - The Boxers	<1	NC	NC
Timor Leste	<1	NC	NC
Timor West	<1	NC	NC
Van Cloon Shoal	<1	NC	NC
Vulcan & Goeree Shoals	<1	<1	2
WA Coastline	<1	<1	<1

NC: No contact to receptor predicted for specified threshold.

* Probabilities and maximum concentrations calculated at depth of submerged feature.

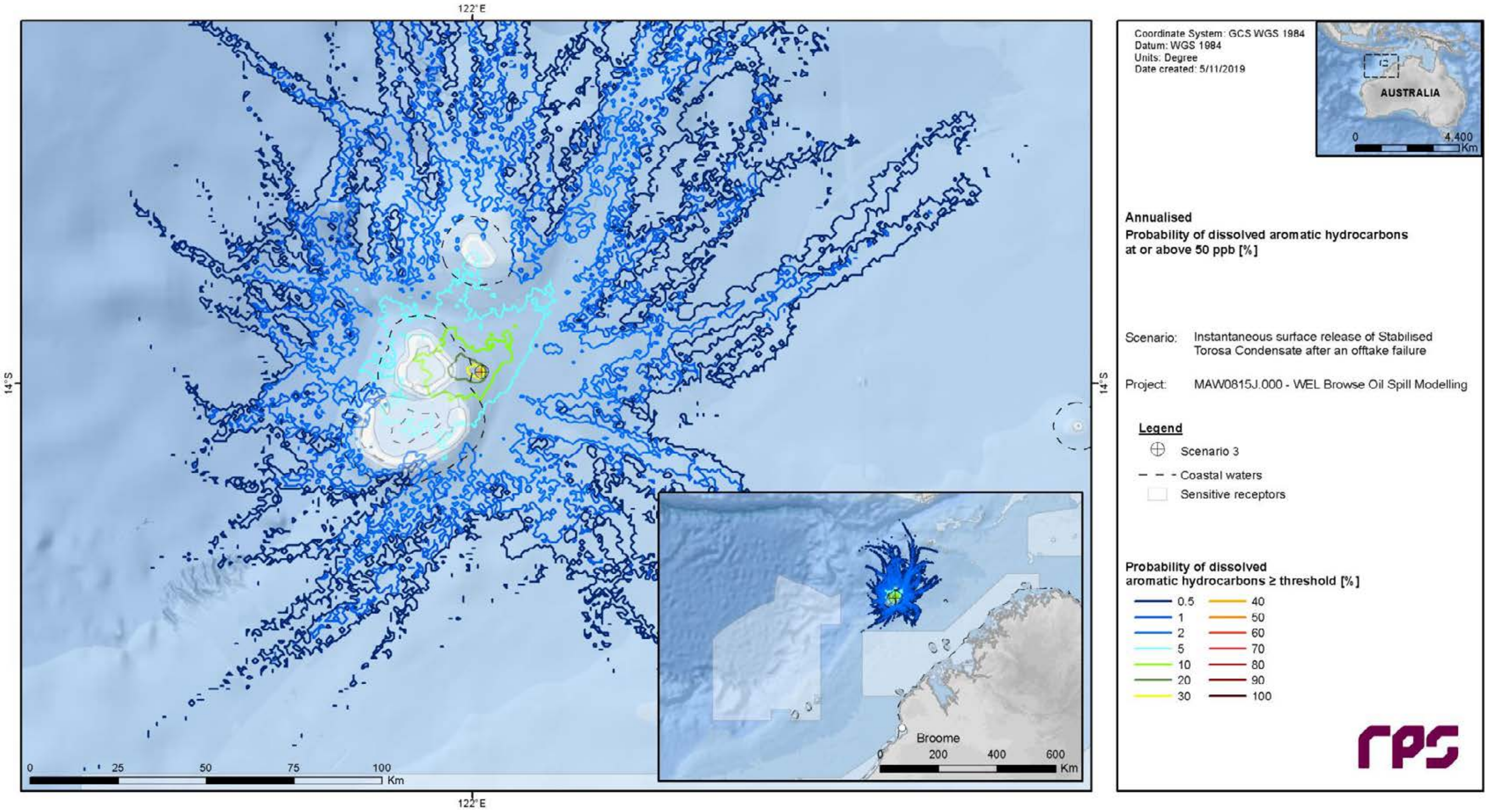

Figure 3.43 Predicted annualised probability of dissolved aromatic hydrocarbon concentrations at or above 50 ppb resulting from an instantaneous surface release of stabilised Torosa Condensate after an FPSO offtake system failure at the Torosa FPSO location.

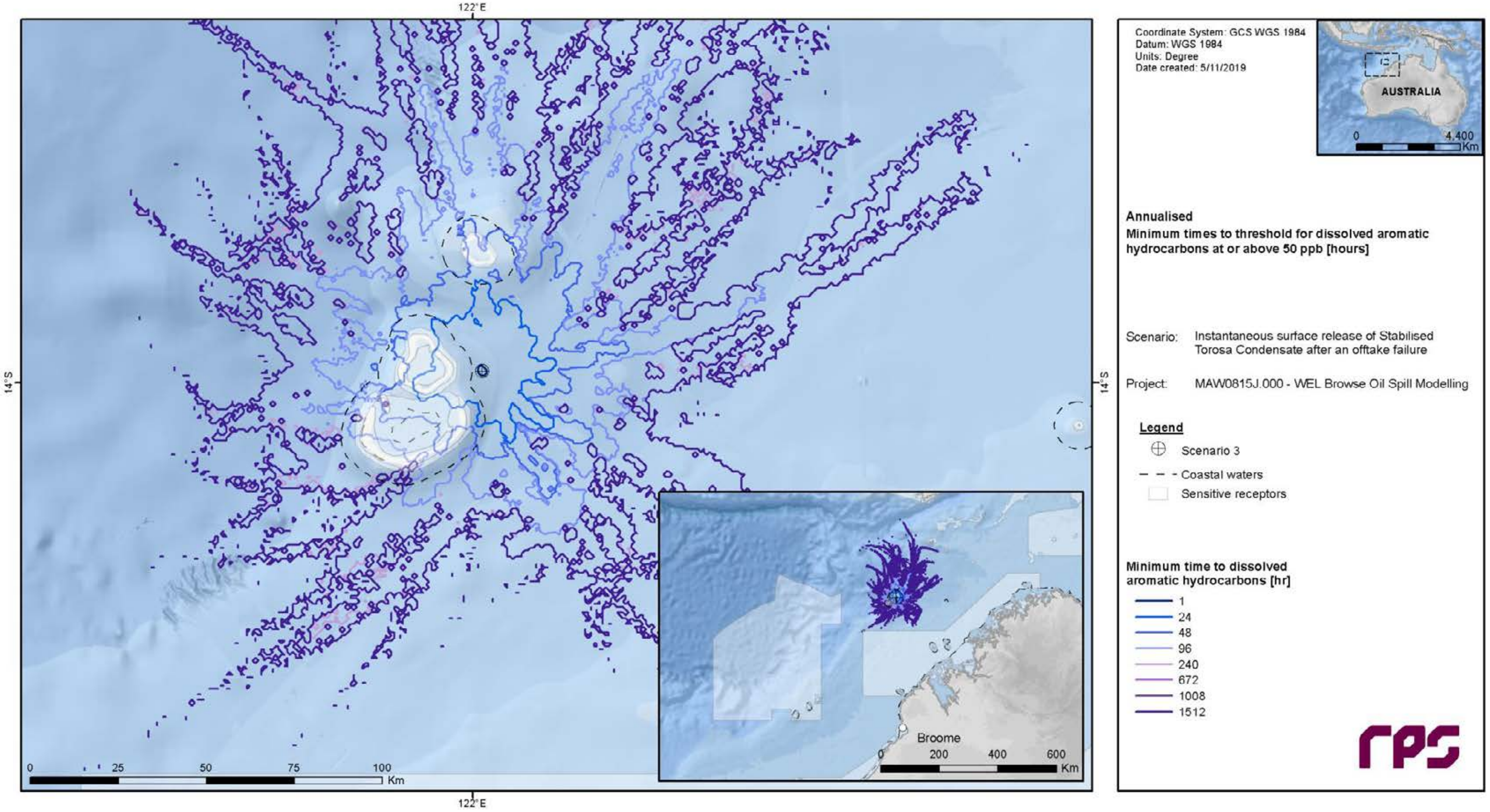

Figure 3.44 Predicted annualised minimum times to contact by dissolved aromatic hydrocarbon concentrations at or above 50 ppb resulting from an instantaneous surface release of stabilised Torosa Condensate after an FPSO offtake system failure at the Torosa FPSO location.

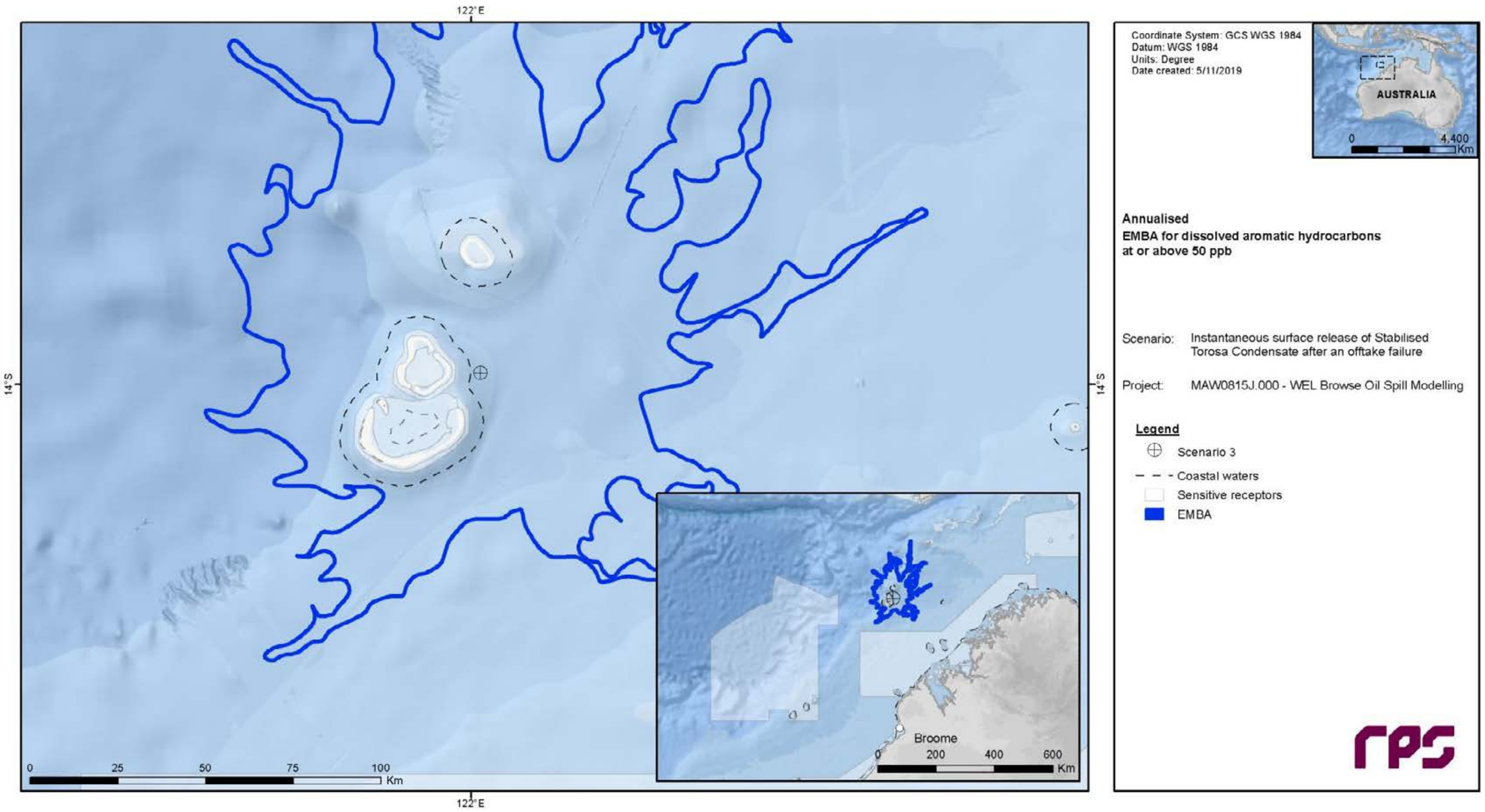

Figure 3.45 Predicted annualised EMBA of dissolved aromatic hydrocarbon concentrations at or above 50 ppb resulting from an instantaneous surface release of stabilised Torosa Condensate after an FPSO offtake system failure at the Torosa FPSO location.

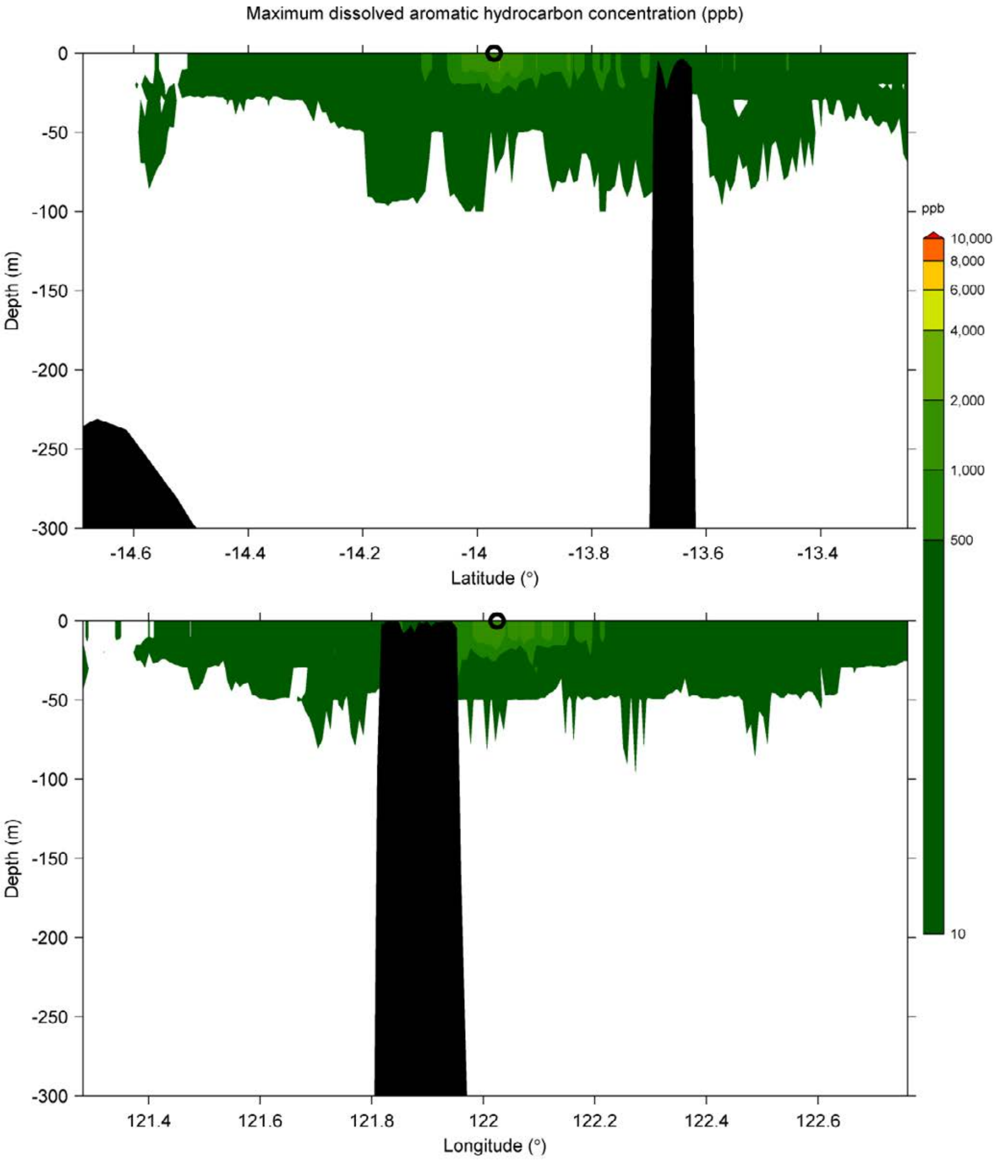

Figure 3.46 Cross-section transects of predicted annualised maximum dissolved aromatic hydrocarbon concentrations for an instantaneous surface release of stabilised Torosa Condensate after an FPSO offtake system failure at the Torosa FPSO location. Transect locations are shown in Figure 3.1.

3.5 Scenario 4: Short-Term (Instantaneous) Surface Release of Marine Diesel after a Vessel Fuel Tank Rupture near the Rowley Shoals

3.5.1 Discussion of Results

3.5.1.1 Overview

This scenario investigated the probability of exposure to surrounding regions by oil resulting from a short-term (instantaneous) surface release of 2,000 m^3 of marine diesel after a vessel fuel tank rupture from a vessel collision near the Rowley Shoals during operations at any time of year, with no mitigation measures applied.

During the surface release, the volatile fractions of the oil (40.6%) are likely to evaporate within 24 hours of exposure to the atmosphere. The low-volatility fraction of the diesel (54.4%) will take longer times of the order of days to weeks to evaporate, and the remaining fraction (5.0%) is expected to persist for an extended period of time as residual oil.

3.5.1.2 Floating and Shoreline Oil

The probability contour figures for floating oil indicate that concentrations equal to or greater than the 10 g/m^2 threshold could potentially be found, in the form of slicks, up to 82 km from the spill site (Figure 3.48).

Given that the spill location lies within the Argo-Rowley Terrace Marine Park area, floating oil at concentrations equal to or greater than 100 g/m^2 is forecast at this receptor with a probability of 100% and a minimum time to contact of less than 1 hour (Table 3.10). The Rowley Shoals – Mermaid Reef Marine Park shoreline receptor is predicted to be contacted by floating oil concentrations at the 10 g/m^2 threshold with probability of 15%, with a corresponding minimum contact times of 5 hours (Table 3.10). At the Rowley Shoals – Clerke Reef State Marine Park and Rowley Shoals – Imperieuse Reef State Marine Park shoreline receptors, probabilities of floating oil contact at the 10 g/m^2 threshold are forecast to be 1% or less.

The Rowley Shoals – Mermaid Reef Marine Park receptor is predicted to experience shoreline oil accumulation in excess of the 100 g/m^2 threshold with a probability of 1% (Table 3.10). Potential for accumulation of oil on shorelines is predicted to be low, with a maximum accumulated volume of 6 m^3 forecast at the Rowley Shoals – Clerke Reef State Marine Park and a maximum local accumulated concentration of 491 g/m^2 forecast at the Rowley Shoals – Mermaid Reef Marine Park (Table 3.10).

The forecast annualised minimum times to contact and EMBA for floating oil at or above the 1 g/m^2 and 10 g/m^2 threshold concentrations are depicted in Figure 3.49 to Figure 3.52.

3.5.1.3 Entrained Oil

Entrained oil at concentrations equal to or greater than the 500 ppb threshold is predicted to be found up to around 371 km from the spill site (Figure 3.54).

Contact by entrained oil at concentrations equal to or greater than 500 ppb is predicted at Argo-Rowley Terrace Marine Park (57%), Rowley Shoals – Mermaid Reef Marine Park (33.5%) and Rowley Shoals – Clerke Reef State Marine Park (7.5%; Table 3.11). The maximum entrained oil concentration forecast for any receptor is predicted as 167.6 ppm at Argo-Rowley Terrace Marine Park.

The forecast annualised minimum times to contact and EMBA for entrained oil at or above the 500 ppb threshold concentration are depicted in Figure 3.55 and Figure 3.56, respectively.

The cross-sectional transects of maximum entrained oil concentrations in the vicinity of the release site show that concentrations above 25,000 ppb are expected to extend from the sea surface to depths of around 20 m (Figure 3.57).

3.5.1.4 Dissolved Aromatic Hydrocarbons

Dissolved aromatic hydrocarbons at concentrations equal to or greater than the 500 ppb threshold are predicted to be found up to around 43 km from the spill site (Figure 3.58).

Contact by dissolved aromatic hydrocarbons at concentrations equal to or greater than 500 ppb is predicted at Argo-Rowley Terrace Marine Park (8.5%) and Rowley Shoals – Mermaid Reef Marine Park (1.5%; Table 3.12). The maximum dissolved aromatic hydrocarbon concentration forecast for any receptor is predicted as 2.2 ppm at Argo-Rowley Terrace Marine Park.

The forecast annualised minimum times to contact and EMBA for dissolved aromatic hydrocarbons at or above the 500 ppb threshold concentration are depicted in Figure 3.59 and Figure 3.60, respectively.

The cross-sectional transects of maximum dissolved aromatic hydrocarbon concentrations in the vicinity of the release site show that concentrations above 2,000 ppb are expected to extend from the sea surface to depths of around 10 m (Figure 3.61).

3.5.2 Results Tables and Figures

3.5.2.1 Floating and Shoreline Oil

Table 3.10 Expected annualised floating and shoreline oil outcomes at sensitive receptors resulting from an instantaneous surface release of marine diesel after a vessel fuel tank rupture near the Rowley Shoals.

Receptor	Probability (%) of floating oil concentration		Minimum time to receptor (hours) for floating oil at		Probability (%) of shoreline oil concentration	Minimum time to receptor (hours) for shoreline oil at	Maximum local accumulated concentration (g/m^2)		Maximum accumulated volume (m^3) along this shoreline	
	≥1 g/m^2	≥10 g/m^2	≥1 g/m^2	≥10 g/m^2	≥100 g/m^2	≥100 g/m^2	averaged over all replicate simulations	in the worst replicate simulation	averaged over all replicate simulations	in the worst replicate simulation
Argo-Rowley Terrace Marine Park *	100	100	1	1	NA	NA	NA	NA	NA	NA
Ashmore Reef Marine Park	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Browse Island*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Buccaneer & Bonaparte Archipelagos	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Cartier Island Marine Park	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Glomar Shoals & Rankin Bank*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Hibernia Reef*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Indonesia	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Indonesian Boundary	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Kimberley Marine Park *	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Kimberley Coast	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Lacepede Islands	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Oceanic Shoals Marine Park *	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Pulau Roti	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Rowley Shoals - Clerke Reef State Marine Park	1.5	1	35	37	<1	76	2.9	438	<1	6
Rowley Shoals - Imperieuse Reef State Marine Park	<1	<1	NC	NC	<1	NC	0.4	17	<1	<1
Rowley Shoals - Mermaid Reef Marine Park	23	15	5	5	1	100	5	491	<1	5
Scott Reef North*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Scott Reef South	<1	<1	NC	NC	<1	NC	<0.1	2	<1	<1
Seringapatam Reef*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Sumba	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Ashmore Reef	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Big Bank Shoals*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Camden Sound	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Cartier Island	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Dampier Peninsula Coast - Mid Section	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Dampier Peninsula Coast - North Section	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Lalang-garram - Camden Sound Marine Park	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC

Receptor	Probability (%) of floating oil concentration		Minimum time to receptor (hours) for floating oil at		Probability (%) of shoreline oil concentration	Minimum time to receptor (hours) for shoreline oil at	Maximum local accumulated concentration (g/m^2)		Maximum accumulated volume (m^3) along this shoreline	
	≥1 g/m^2	≥10 g/m^2	≥1 g/m^2	≥10 g/m^2	≥100 g/m^2	≥100 g/m^2	averaged over all replicate simulations	in the worst replicate simulation	averaged over all replicate simulations	in the worst replicate simulation
Rowley Shoals - Clerke Reef	<1	<1	68	74	<1	76	2.9	438	<1	6
Rowley Shoals - Imperieuse Reef	<1	<1	NC	NC	<1	NC	0.4	17	<1	<1
Rowley Shoals - Mermaid Reef	8	4	16	17	1	100	5	491	<1	5
Sahul Banks*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Savu	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Scott Reef Central	<1	<1	NC	NC	<1	NC	<0.1	2	<1	<1
Scott Reef Central - Sandy Islet	<1	<1	NC	NC	<1	NC	<0.1	2	<1	<1
Scott Reef North - Flats*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Scott Reef North - Lagoon*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Scott Reef South - Flats*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Scott Reef South - Lagoon*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Adele Island	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Barracouta Shoal*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Echuca Shoal*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Eighty Mile Beach Marine Park *	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Eugene McDermott Shoal*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Fantome Bank*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Heywood Shoal*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Oceanic Shoals - Deep Shoal 1*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Oceanic Shoals Region - Gale-Favell-Baldwin Banks*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Oceanic Shoals Region - Margaret Harries Banks*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Oceanic Shoals Region - The Boxers*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Timor Leste	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Timor West	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC
Van Cloon Shoal*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
Vulcan & Goeree Shoals*	<1	<1	NC	NC	NA	NA	NA	NA	NA	NA
WA Coastline	<1	<1	NC	NC	<1	NC	NC	NC	NC	NC

NC: No contact to receptor predicted for specified threshold. NA: Not applicable.

* Floating oil will not accumulate on submerged features and at open ocean locations.

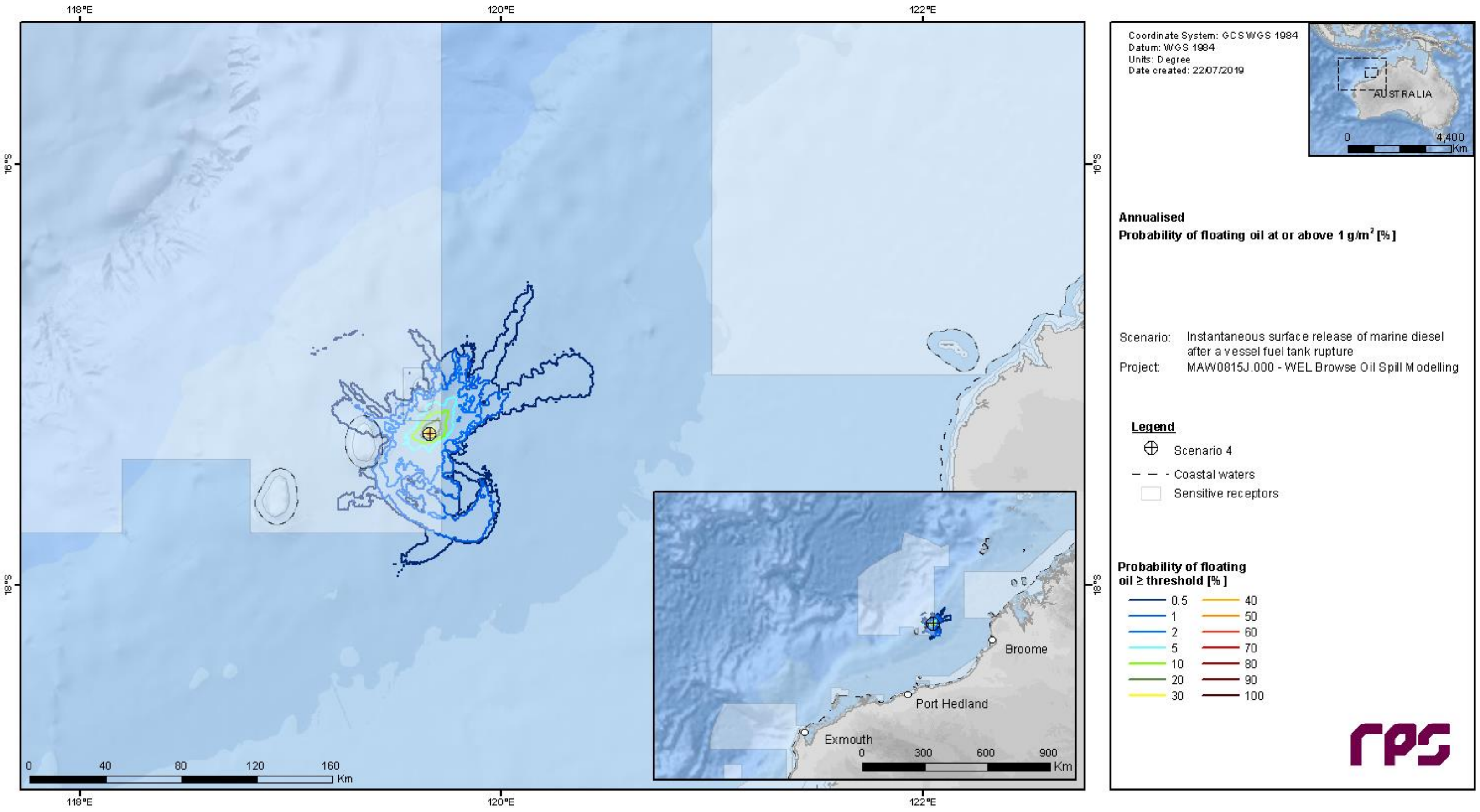

Figure 3.47 Predicted annualised probability of floating oil concentrations at or above 1 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel fuel tank rupture near the Rowley Shoals.

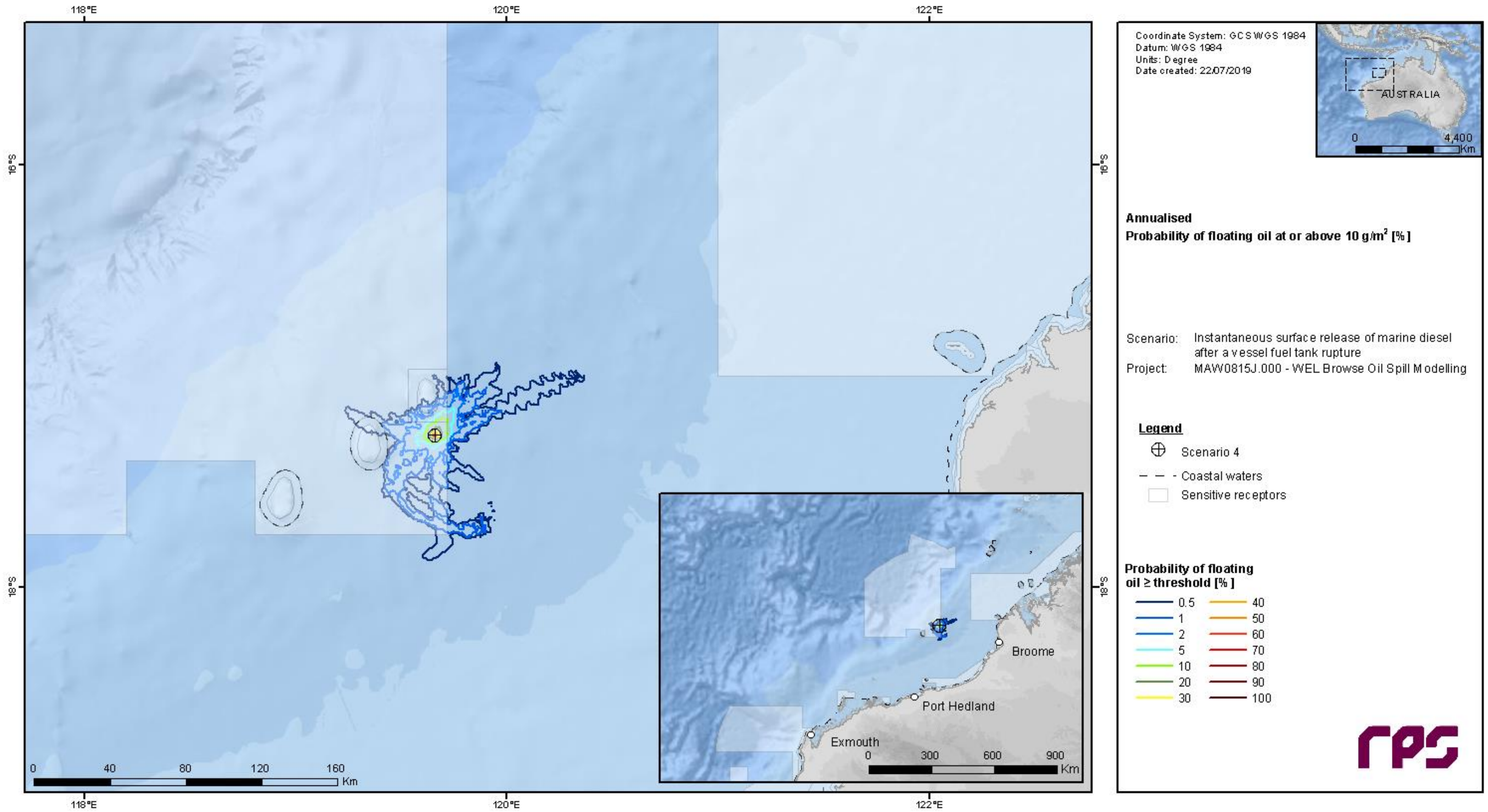

Figure 3.48 Predicted annualised probability of floating oil concentrations at or above 10 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel fuel tank rupture near the Rowley Shoals.

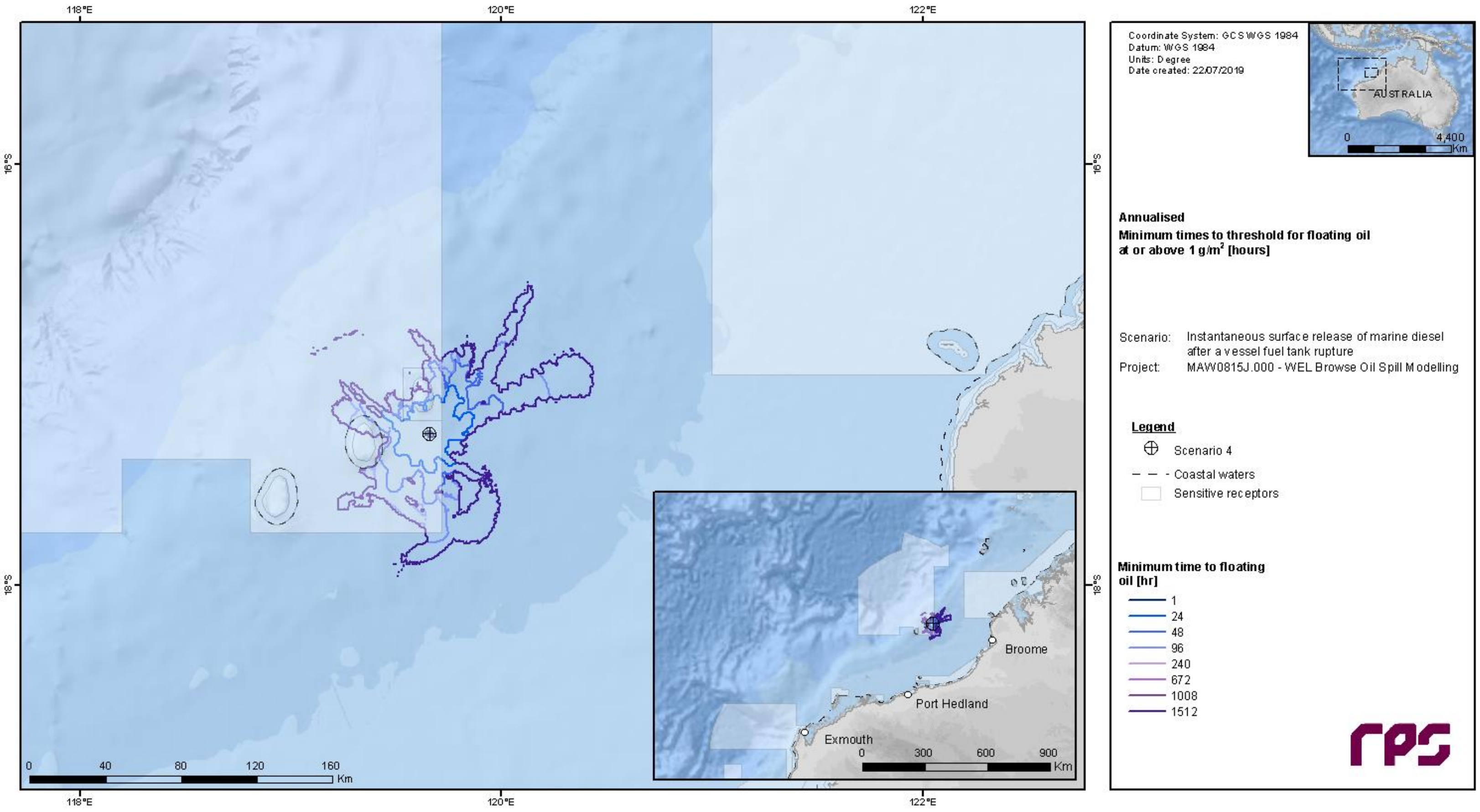

Figure 3.49 Predicted annualised minimum times to contact by floating oil concentrations at or above 1 g/m² resulting from an instantaneous surface release of marine diesel after a vessel fuel tank rupture near the Rowley Shoals.

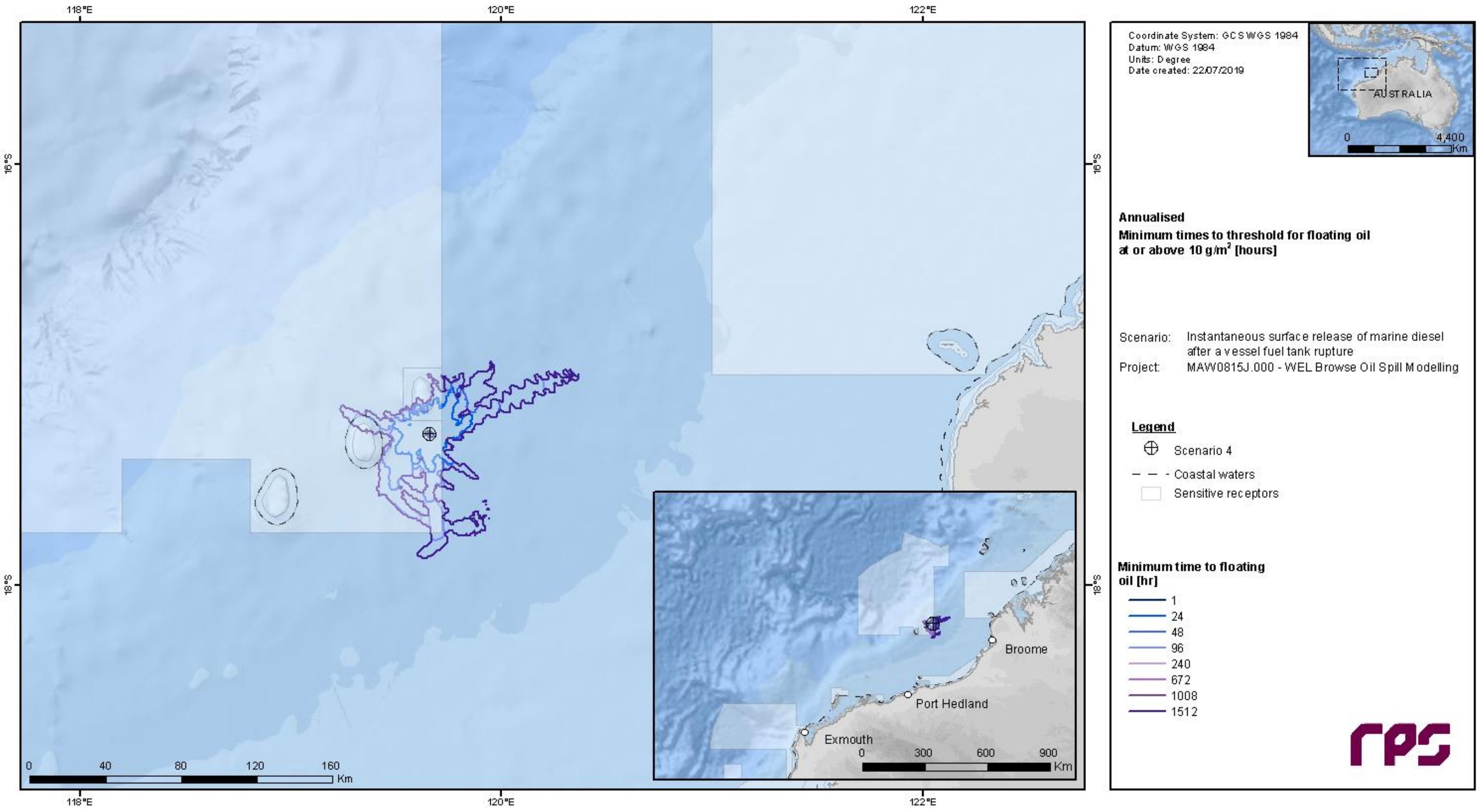

Figure 3.50 Predicted annualised minimum times to contact by floating oil concentrations at or above 10 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel fuel tank rupture near the Rowley Shoals.

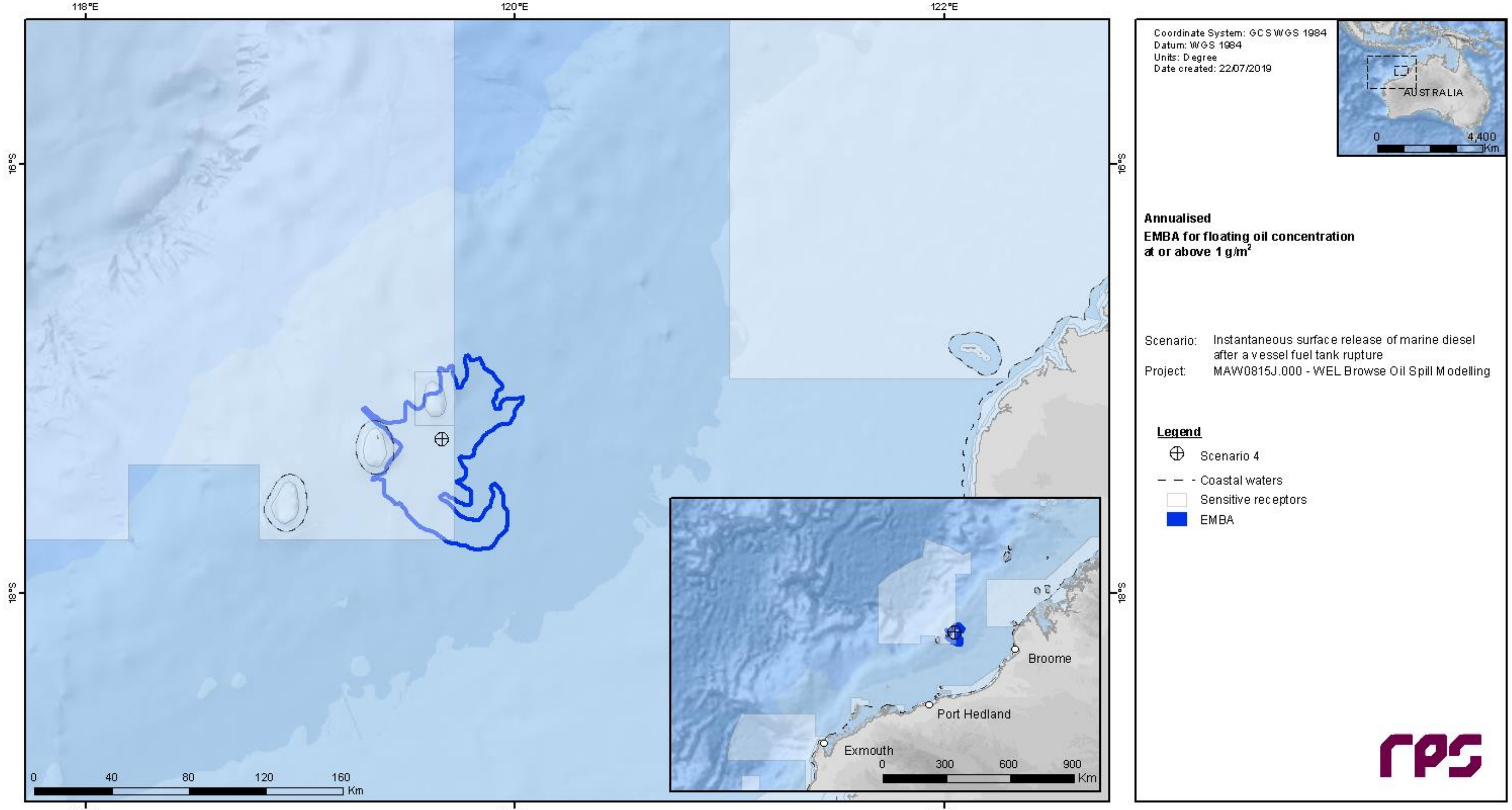

Figure 3.51 Predicted annualised smoothed EMBA of floating oil concentrations at or above 1 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel fuel tank rupture near the Rowley Shoals.

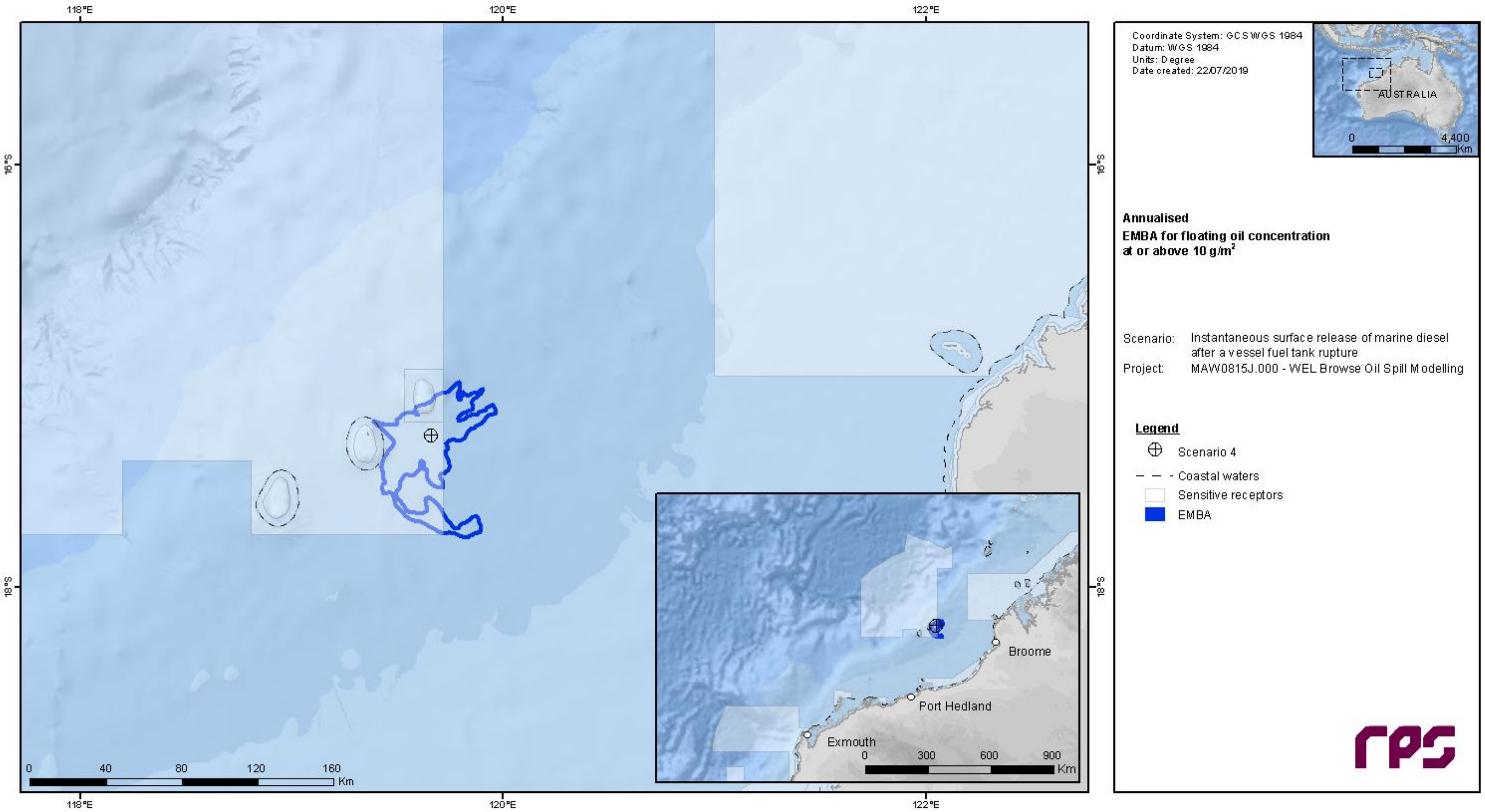

Figure 3.52 Predicted annualised smoothed EMBA of floating oil concentrations at or above 10 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel fuel tank rupture near the Rowley Shoals.

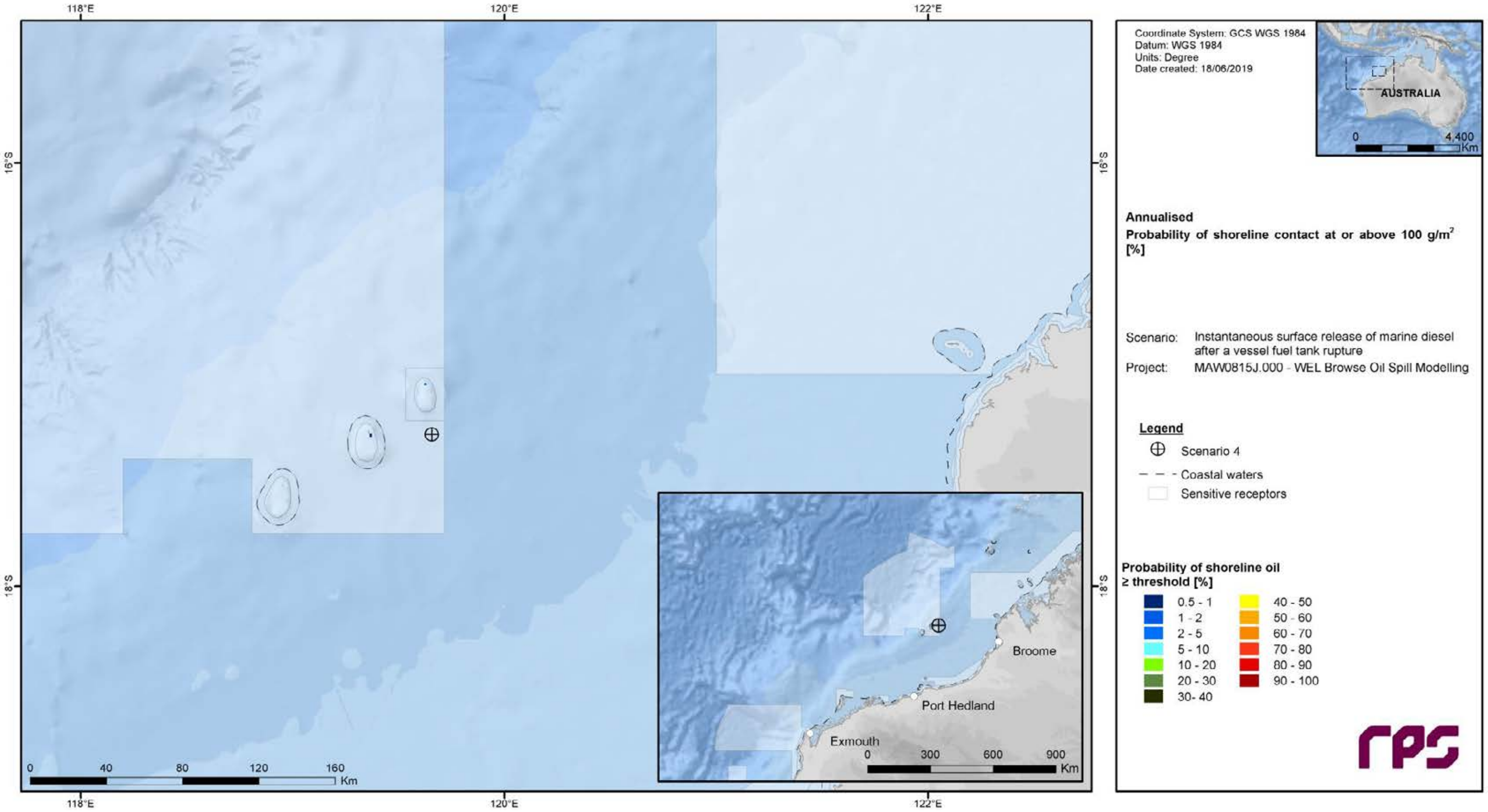

Figure 3.53 Predicted annualised probability of shoreline oil concentrations at or above 100 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel fuel tank rupture near the Rowley Shoals.

3.5.2.2 Entrained Oil

Table 3.11 Expected annualised entrained oil outcomes at sensitive receptors resulting from an instantaneous surface release of marine diesel after a vessel fuel tank rupture near the Rowley Shoals.

Receptor	Probability (%) of entrained oil concentration ≥500 ppb	Minimum time to receptor (hours) for entrained oil at ≥500 ppb	Maximum entrained oil concentration (ppb) averaged over all replicate simulations	Maximum entrained oil concentration (ppb) at any depth, in the worst replicate simulation
Argo-Rowley Terrace Marine Park	57	1	13,271	167,600
Ashmore Reef Marine Park	<1	NC	NC	NC
Browse Island	<1	NC	NC	NC
Buccaneer & Bonaparte Archipelagos	<1	NC	NC	NC
Cartier Island Marine Park	<1	NC	NC	NC
Glomar Shoals & Rankin Bank	<1	NC	<1	81
Hibernia Reef	<1	NC	NC	NC
Indonesia	<1	NC	NC	NC
Indonesian Boundary	<1	NC	NC	NC
Kimberley Marine Park	<1	NC	5	423
Kimberley Coast	<1	NC	NC	NC
Lacepede Islands	<1	NC	NC	NC
Oceanic Shoals Marine Park	<1	NC	NC	NC
Pulau Roti	<1	NC	NC	NC
Rowley Shoals - Clerke Reef State Marine Park	7.5	26	182	11,204
Rowley Shoals - Imperieuse Reef State Marine Park	2.5	86	35	3,019
Rowley Shoals - Mermaid Reef Marine Park	33.5	7	2,420	38,749
Scott Reef North	<1	NC	<1	84
Scott Reef South	<1	NC	2	125
Seringapatam Reef	<1	NC	<1	13
Sumba	<1	NC	NC	NC
Ashmore Reef	<1	NC	NC	NC
Big Bank Shoals	<1	NC	NC	NC
Camden Sound	<1	NC	NC	NC
Cartier Island	<1	NC	NC	NC
Dampier Peninsula Coast - Mid Section	<1	NC	NC	NC

Receptor	Probability (%) of entrained oil concentration ≥500 ppb	Minimum time to receptor (hours) for entrained oil at ≥500 ppb	Maximum entrained oil concentration (ppb) averaged over all replicate simulations	Maximum entrained oil concentration (ppb) at any depth, in the worst replicate simulation
Dampier Peninsula Coast - North Section	<1	NC	NC	NC
Lalang-garram - Camden Sound Marine Park	<1	NC	NC	NC
Rowley Shoals - Clerke Reef	6.5	39	122	9,363
Rowley Shoals - Imperieuse Reef	2	129	35	3,019
Rowley Shoals - Mermaid Reef	21.5	17	893	14,365
Sahul Banks	<1	NC	NC	NC
Savu	<1	NC	NC	NC
Scott Reef Central	<1	NC	<1	96
Scott Reef Central - Sandy Islet	<1	NC	<1	88
Scott Reef North - Flats	<1	NC	<1	81
Scott Reef North - Lagoon	<1	NC	<1	84
Scott Reef South - Flats	<1	NC	2	125
Scott Reef South - Lagoon	<1	NC	<1	105
Adele Island	<1	NC	NC	NC
Barracouta Shoal	<1	NC	NC	NC
Echuca Shoal	<1	NC	NC	NC
Eighty Mile Beach Marine Park	<1	NC	<1	<1
Eugene McDermott Shoal	<1	NC	NC	NC
Fantome Bank	<1	NC	NC	NC
Heywood Shoal	<1	NC	NC	NC
Oceanic Shoals - Deep Shoal 1	<1	NC	NC	NC
Oceanic Shoals Region - Gale-Favell-Baldwin Banks	<1	NC	NC	NC
Oceanic Shoals Region - Margaret Harries Banks	<1	NC	NC	NC
Oceanic Shoals Region - The Boxers	<1	NC	NC	NC
Timor Leste	<1	NC	NC	NC
Timor West	<1	NC	NC	NC
Van Cloon Shoal	<1	NC	NC	NC
Vulcan & Goeree Shoals	<1	NC	NC	NC
WA Coastline	<1	NC	NC	NC

NC: No contact to receptor predicted for specified threshold.

* Probabilities and maximum concentrations calculated at depth of submerged feature.

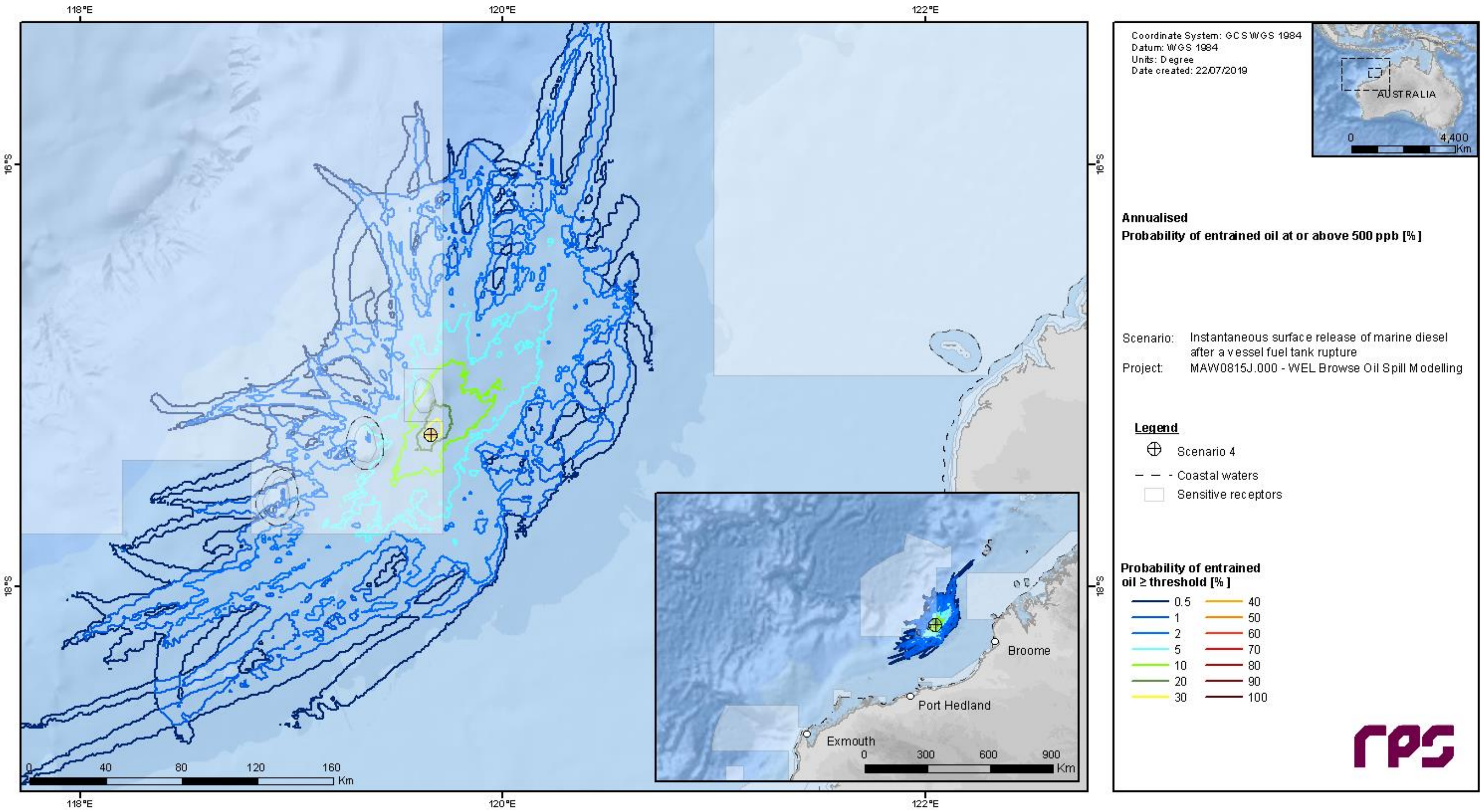

Figure 3.54 Predicted annualised probability of entrained oil concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel fuel tank rupture near the Rowley Shoals.

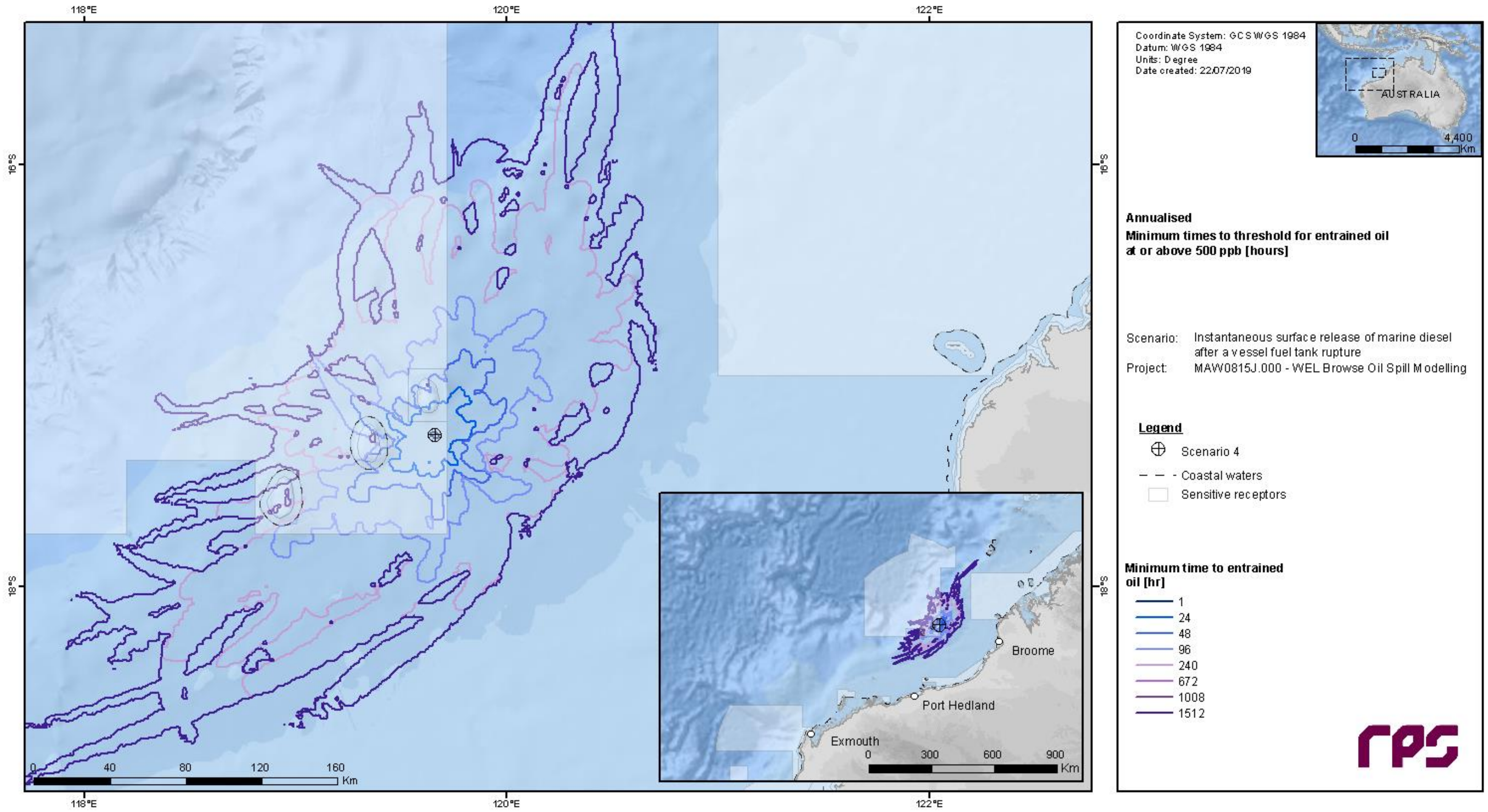

Figure 3.55 Predicted annualised minimum times to contact by entrained oil concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel fuel tank rupture near the Rowley Shoals.

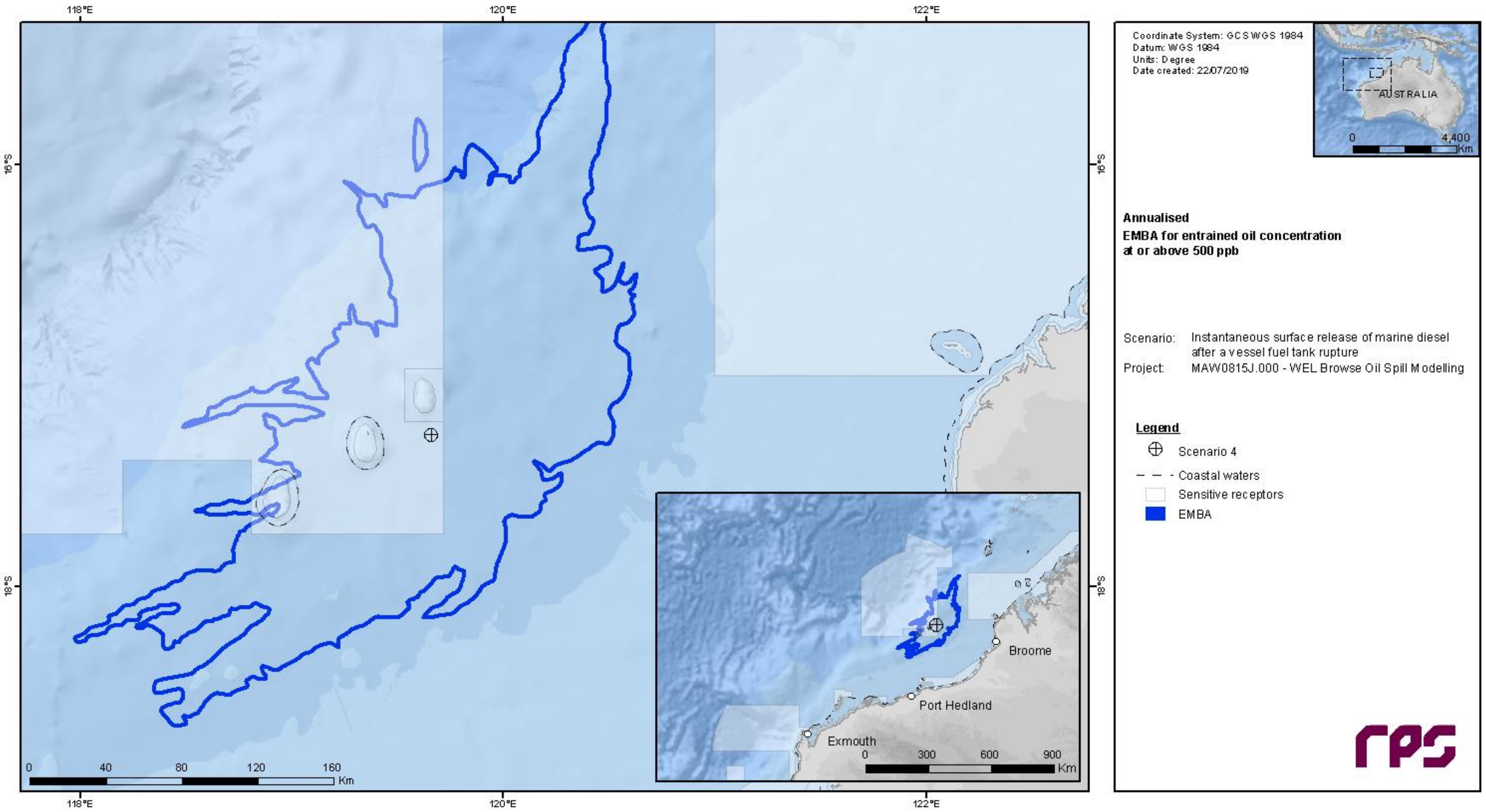

Figure 3.56 Predicted annualised smoothed EMBA of entrained oil concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel fuel tank rupture near the Rowley Shoals.

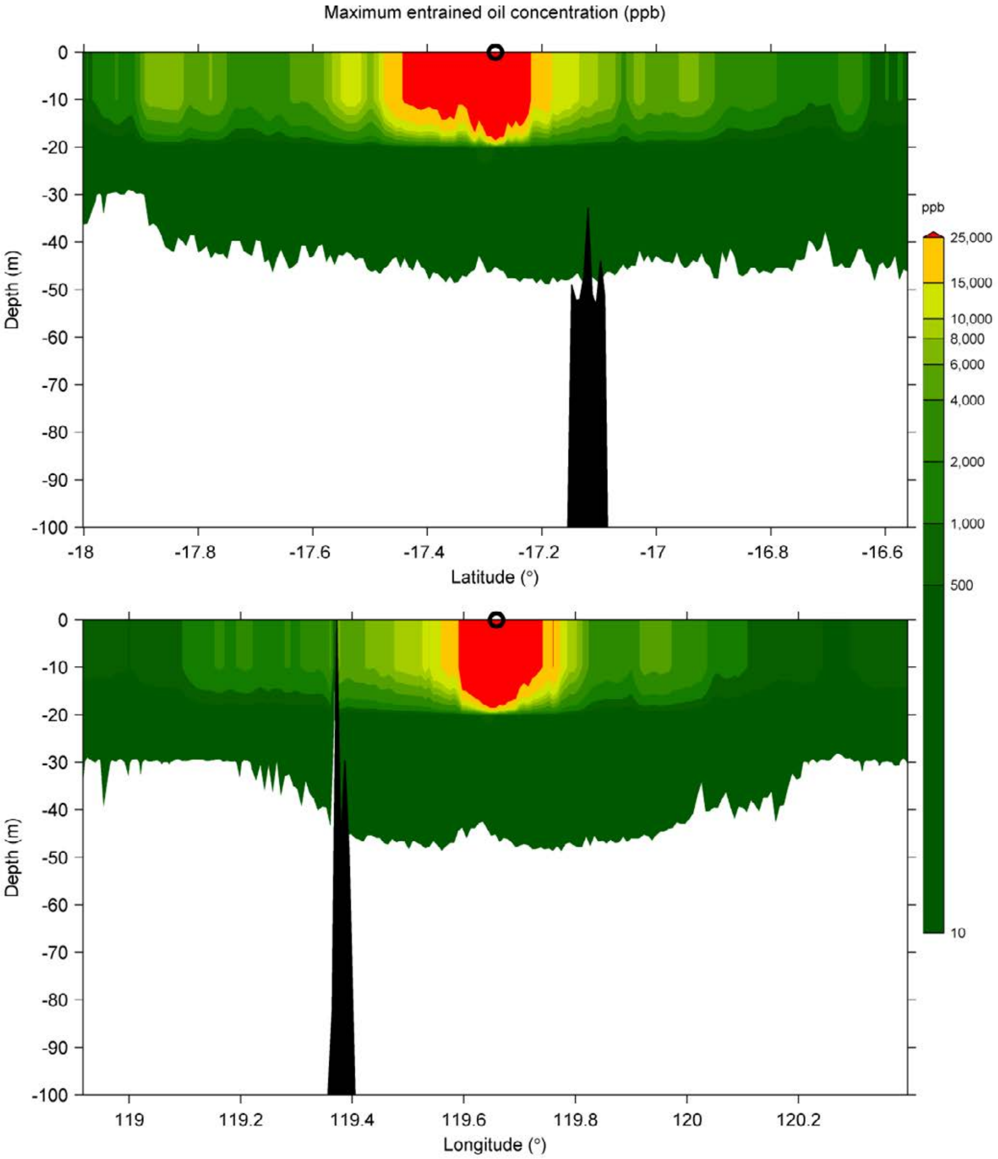

Figure 3.57 Cross-section transects of predicted annualised maximum entrained oil concentrations for an instantaneous surface release of marine diesel after a vessel fuel tank rupture near the Rowley Shoals. Transect locations are shown in Figure 3.1.

3.5.2.3 Dissolved Aromatic Hydrocarbons

Table 3.12 Expected annualised dissolved aromatic hydrocarbon outcomes at sensitive receptors resulting from an instantaneous surface release of marine diesel after a vessel fuel tank rupture near the Rowley Shoals.

Receptor	Probability (%) of dissolved aromatic hydrocarbon concentration	Maximum dissolved aromatic hydrocarbon concentration (ppb)	
	≥500 ppb	averaged over all replicate simulations	at any depth, in the worst replicate simulation
Argo-Rowley Terrace Marine Park	8.5	141	2,214
Ashmore Reef Marine Park	<1	NC	NC
Browse Island	<1	NC	NC
Buccaneer & Bonaparte Archipelagos	<1	NC	NC
Cartier Island Marine Park	<1	NC	NC
Glomar Shoals & Rankin Bank	<1	<1	<1
Hibernia Reef	<1	NC	NC
Indonesia	<1	NC	NC
Indonesian Boundary	<1	NC	NC
Kimberley Marine Park	<1	<1	3
Kimberley Coast	<1	NC	NC
Lacepede Islands	<1	NC	NC
Oceanic Shoals Marine Park	<1	NC	NC
Pulau Roti	<1	NC	NC
Rowley Shoals - Clerke Reef State Marine Park	<1	4	309
Rowley Shoals - Imperieuse Reef State Marine Park	<1	<1	134
Rowley Shoals - Mermaid Reef Marine Park	1.5	37	910
Scott Reef North	<1	NC	NC
Scott Reef South	<1	NC	NC
Seringapatam Reef	<1	NC	NC
Sumba	<1	NC	NC
Ashmore Reef	<1	NC	NC
Big Bank Shoals	<1	NC	NC
Camden Sound	<1	NC	NC
Cartier Island	<1	NC	NC
Dampier Peninsula Coast - Mid Section	<1	NC	NC
Dampier Peninsula Coast - North Section	<1	NC	NC
Lalang-garram - Camden Sound Marine Park	<1	NC	NC
Rowley Shoals - Clerke Reef	<1	3	309
Rowley Shoals - Imperieuse Reef	<1	<1	100
Rowley Shoals - Mermaid Reef	<1	18	502

Receptor	Probability (%) of dissolved aromatic hydrocarbon concentration	Maximum dissolved aromatic hydrocarbon concentration (ppb)	
	≥500 ppb	averaged over all replicate simulations	at any depth, in the worst replicate simulation
Sahul Banks	<1	NC	NC
Savu	<1	NC	NC
Scott Reef Central	<1	NC	NC
Scott Reef Central - Sandy Islet	<1	NC	NC
Scott Reef North - Flats	<1	NC	NC
Scott Reef North - Lagoon	<1	NC	NC
Scott Reef South - Flats	<1	NC	NC
Scott Reef South - Lagoon	<1	NC	NC
Adele Island	<1	NC	NC
Barracouta Shoal	<1	NC	NC
Echuca Shoal	<1	NC	NC
Eighty Mile Beach Marine Park	<1	NC	NC
Eugene McDermott Shoal	<1	NC	NC
Fantome Bank	<1	NC	NC
Heywood Shoal	<1	NC	NC
Oceanic Shoals - Deep Shoal 1	<1	NC	NC
Oceanic Shoals Region - Gale-Favell-Baldwin Banks	<1	NC	NC
Oceanic Shoals Region - Margaret Harries Banks	<1	NC	NC
Oceanic Shoals Region - The Boxers	<1	NC	NC
Timor Leste	<1	NC	NC
Timor West	<1	NC	NC
Van Cloon Shoal	<1	NC	NC
Vulcan & Goeree Shoals	<1	NC	NC
WA Coastline	<1	NC	NC

NC: No contact to receptor predicted for specified threshold.

* Probabilities and maximum concentrations calculated at depth of submerged feature.

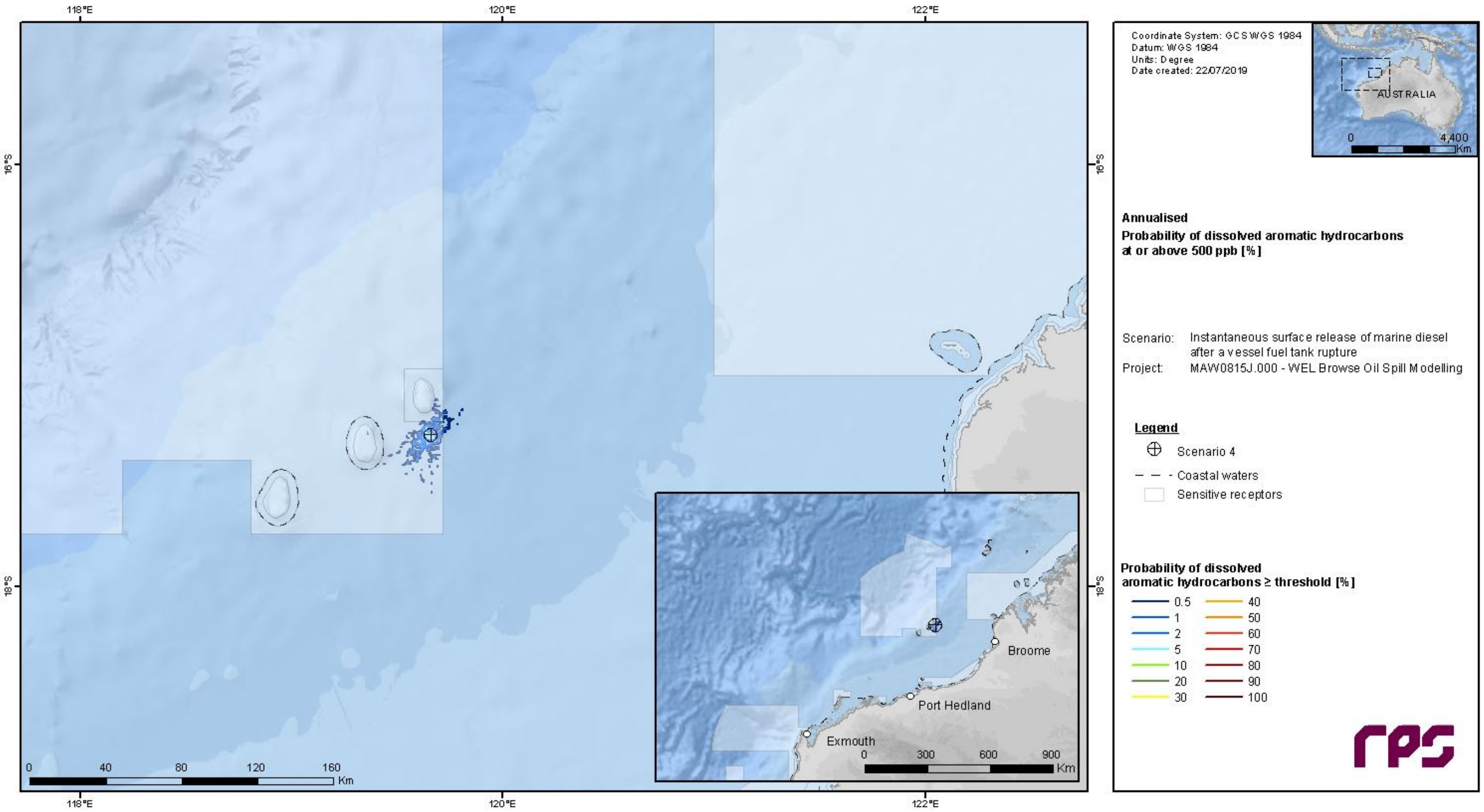

Figure 3.58 Predicted annualised probability of dissolved aromatic hydrocarbon concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel fuel tank rupture near the Rowley Shoals.

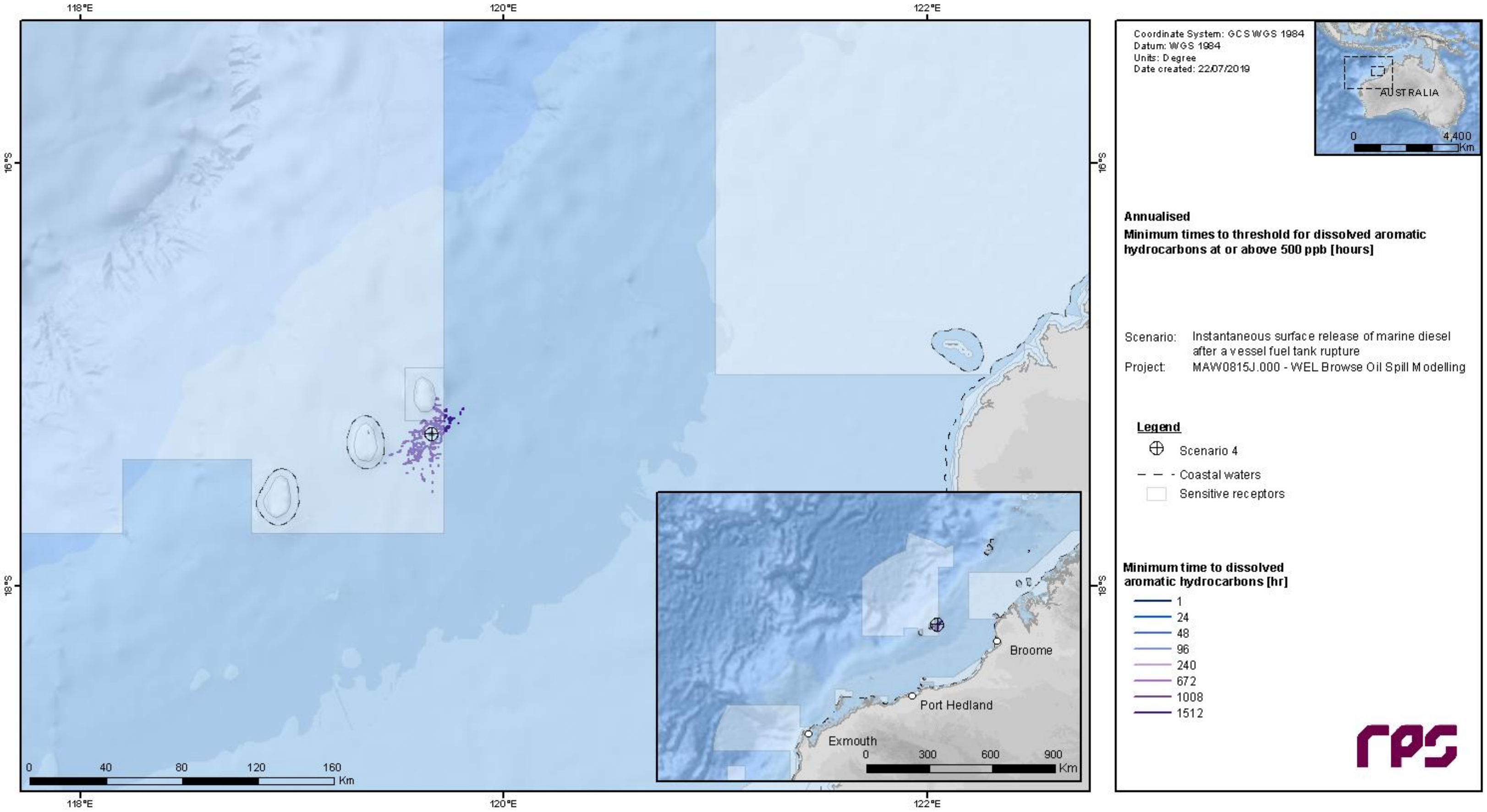

Figure 3.59 Predicted annualised minimum times to contact by dissolved aromatic hydrocarbon concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel fuel tank rupture near the Rowley Shoals.

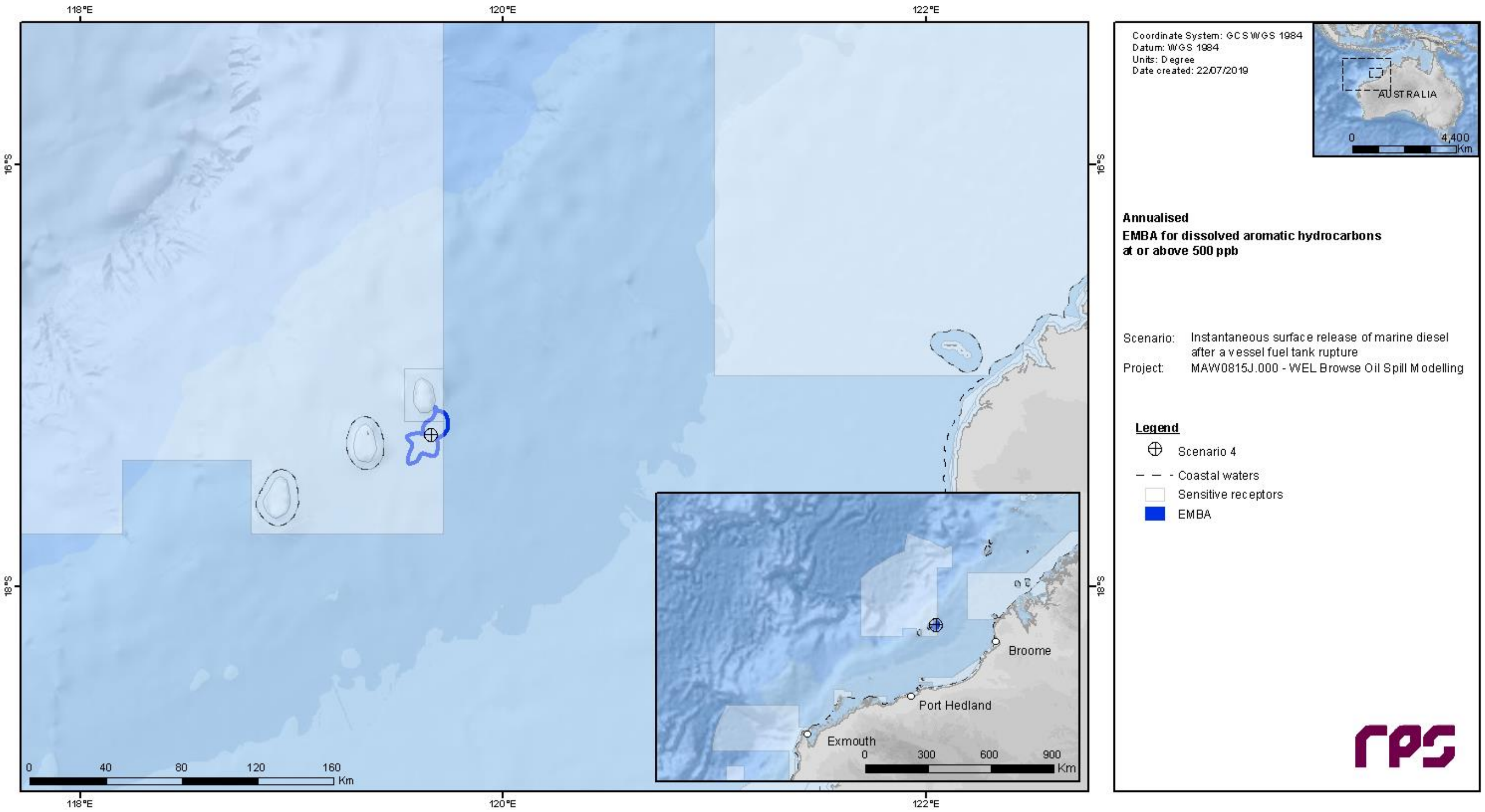

Figure 3.60 Predicted annualised smoothed EMBA of dissolved aromatic hydrocarbon concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel fuel tank rupture near the Rowley Shoals.

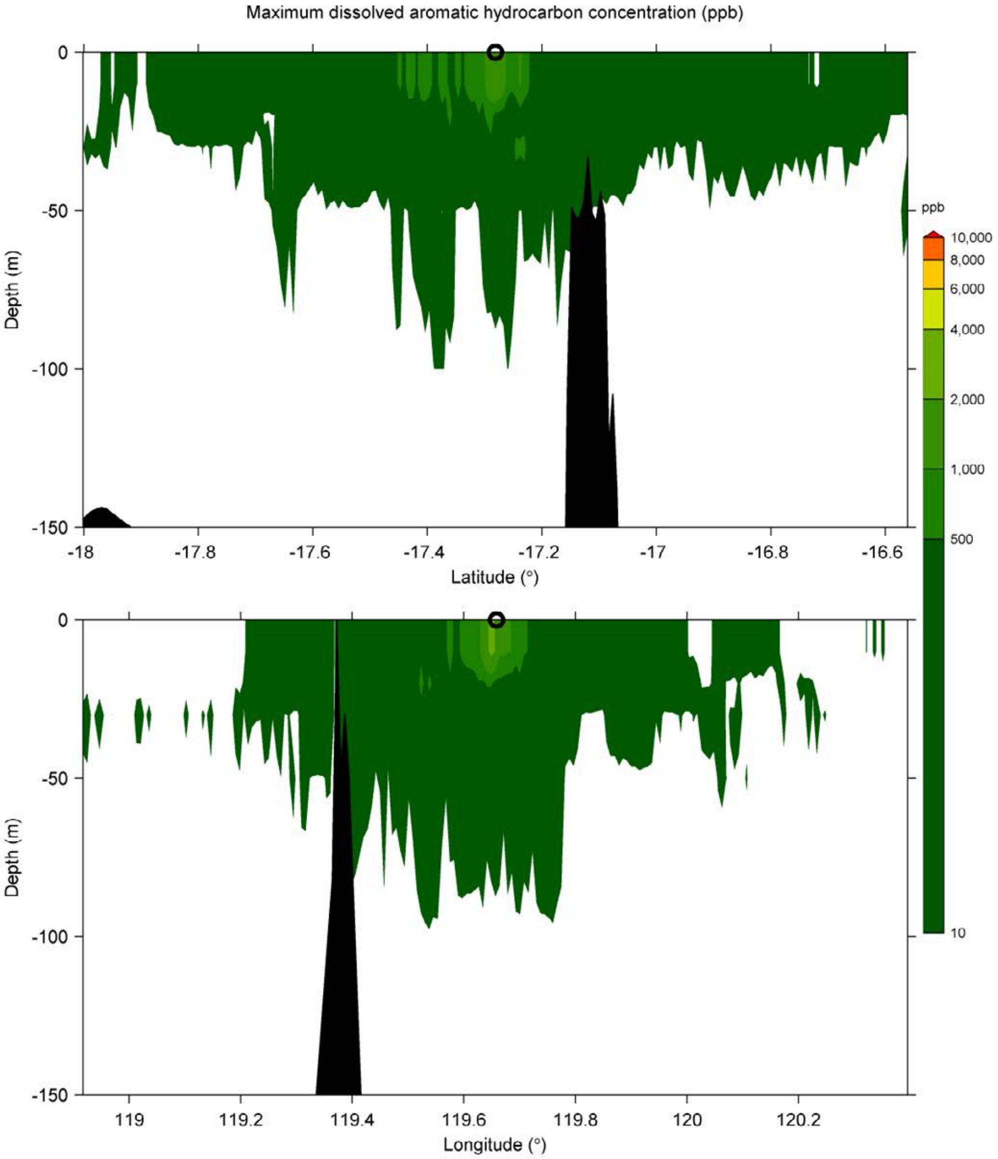

Figure 3.61 Cross-section transects of predicted annualised maximum dissolved aromatic hydrocarbon concentrations for an instantaneous surface release of marine diesel after a vessel fuel tank rupture near the Rowley Shoals. Transect locations are shown in Figure 3.1.

4 DETERMINISTIC ASSESSMENT RESULTS

4.1 Overview

To provide additional context to the outcomes of the stochastic assessment presented in Section 3, deterministic model runs of interest were selected from the stochastic set of replicate simulations for each scenario according to the following criteria:

- Minimum time to floating oil contact with the offshore edge(s) of any shoreline receptor polygon (at a threshold of 10 g/m^2);
- Minimum time to entrained/dissolved oil contact with the offshore edge(s) of any shoreline receptor polygon (at a threshold of 500 ppb);
- Minimum time to commencement of oil accumulation at any shoreline receptor (at a threshold of 100 g/m^2);
- Maximum cumulative oil volume accumulated across all shoreline receptors and at any individual shoreline receptor (at concentrations in excess of 100 g/m^2).

A time series compilation of figures from each deterministic replicate simulation (i.e. a single spill event) for each scenario is presented in the following sections. Each of the figure compilations includes areal exposure at discrete time intervals during the simulation.

4.2 Scenario 1: Long-Term (77-Day) Surface/Subsea Blowout of Unstabilised Torosa Condensate at the TRA-C Well

4.2.1 Simulation with Minimum Time to Oil Contact and Accumulation at Any Shoreline Receptor at Defined Thresholds

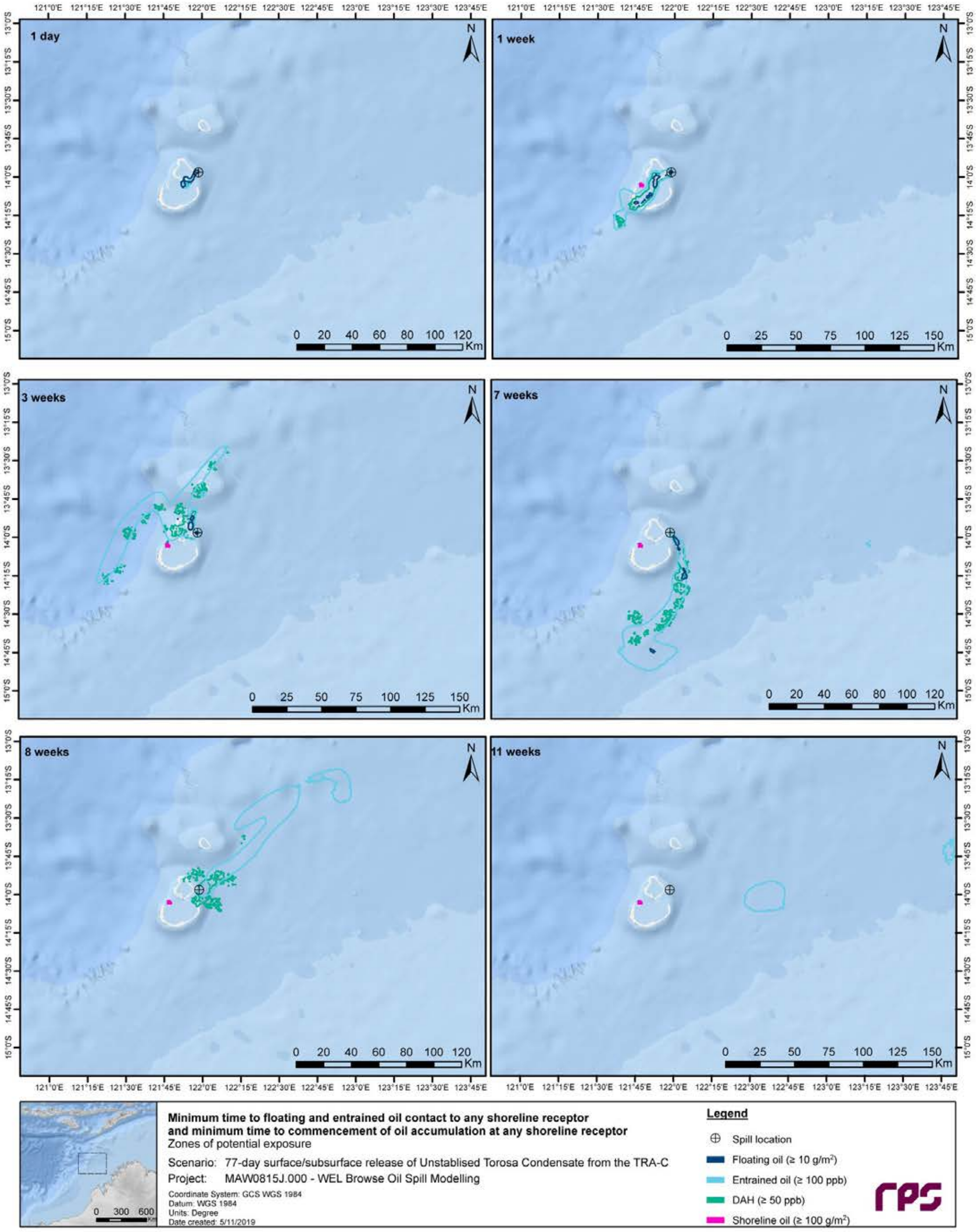

Figure 4.1 Time-varying areal extent of potential exposure at defined floating oil, entrained oil, dissolved aromatic hydrocarbon and shoreline oil threshold concentrations, resulting from a 77-day surface/subsea release of unstabilised Torosa Condensate at the TRA-C well, for the replicate case with the minimum time to floating oil contact with the offshore edge(s) of any shoreline receptor polygon (at a threshold of 10 g/m^2), the minimum time to entrained/dissolved oil contact with the offshore edge(s) of any shoreline receptor polygon (at a threshold of 500 ppb) and the minimum time to commencement of oil accumulation at any shoreline receptor (at a threshold of 100 g/m^2).

4.2.2 Simulation with Maximum Oil Accumulation across All Shoreline Receptors and at Any Individual Shoreline Receptor at Defined Threshold

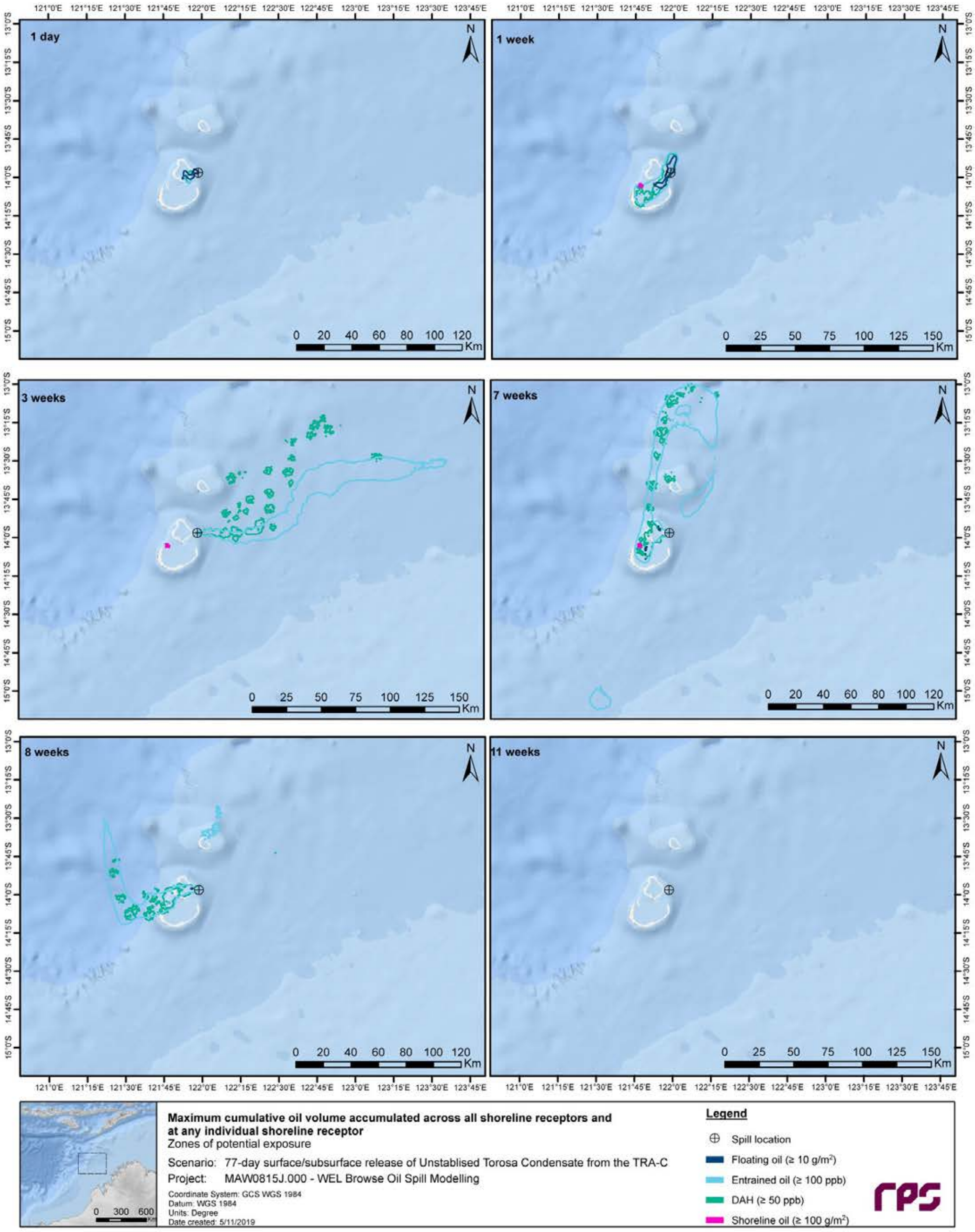

Figure 4.2 Time-varying areal extent of potential exposure at defined floating oil, entrained oil, dissolved aromatic hydrocarbon and shoreline oil threshold concentrations, resulting from a 77-day surface/subsea release of unstabilised Torosa Condensate at the TRA-C well, for the replicate case with the maximum cumulative oil volume accumulated across all shoreline receptors and at any individual shoreline receptor (exceeding a threshold of 100 g/m^2).

4.3 Scenario 2: Short-Term (24-Hour) Surface Release of Stabilised Torosa Condensate after a Vessel Cargo Tank Rupture at the Torosa FPSO Location

4.3.1 Simulation with Minimum Time to Floating Oil Contact at Any Shoreline Receptor at Defined Threshold

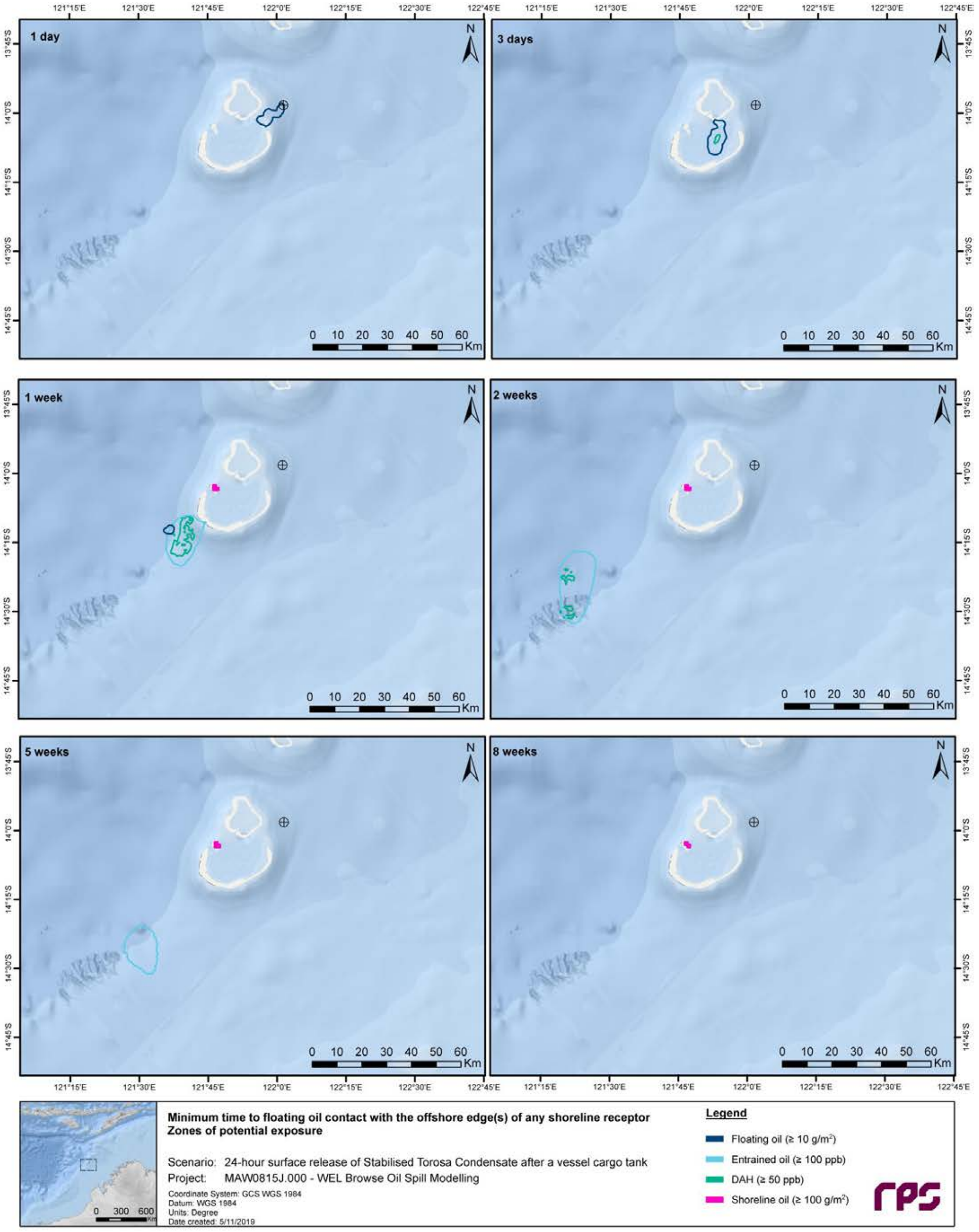

Figure 4.3 Time-varying areal extent of potential exposure at defined floating oil, entrained oil, dissolved aromatic hydrocarbon and shoreline oil threshold concentrations, resulting from a 24-hour surface release of stabilised Torosa Condensate after a vessel cargo tank rupture at the Torosa FPSO location, for the replicate case with the minimum time to floating oil contact with the offshore edge(s) of any shoreline receptor polygon (at a threshold of 10 g/m^2).

4.3.2 Simulation with Minimum Time to Entrained/Dissolved Oil Contact at Any Shoreline Receptor at Defined Threshold

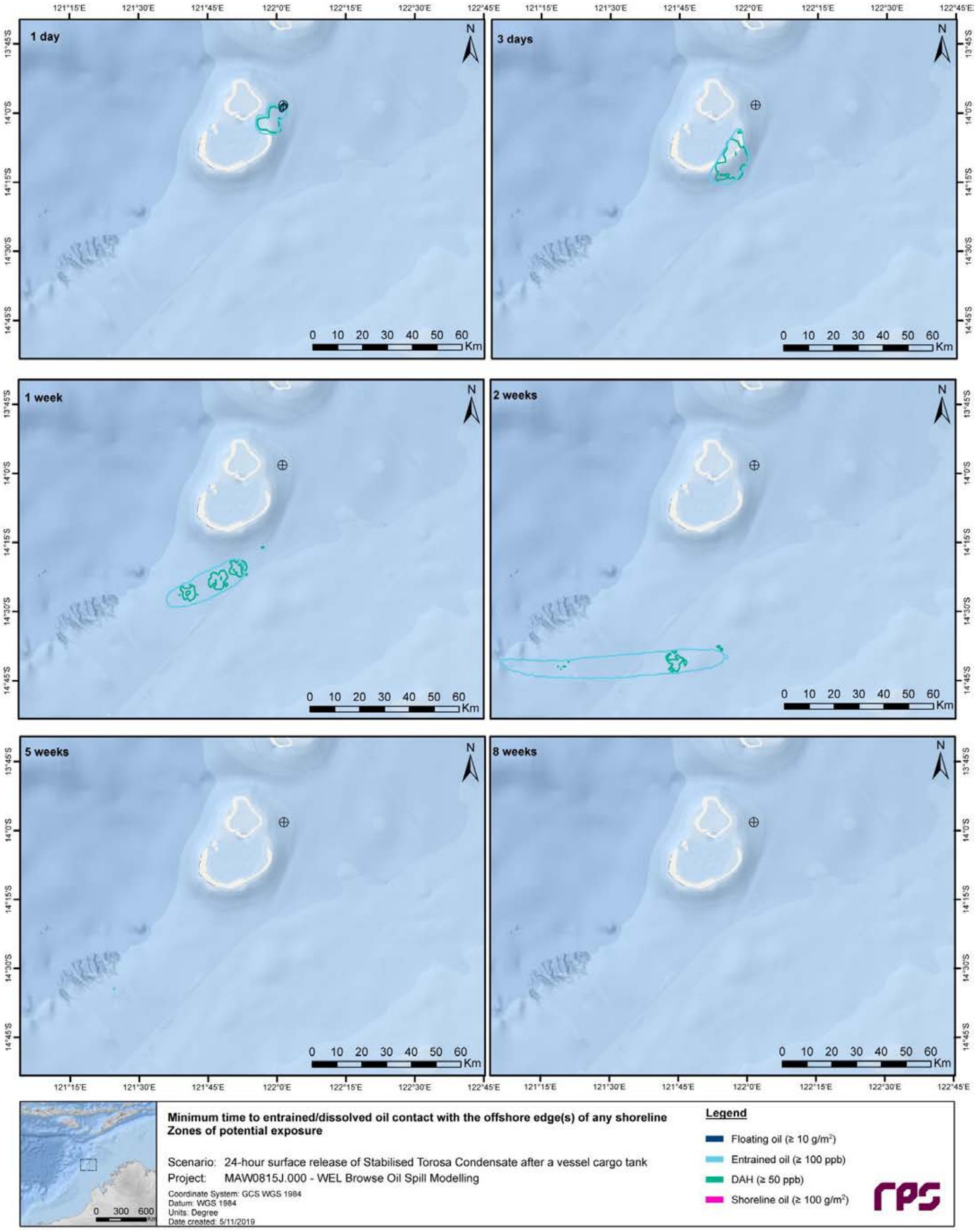

Figure 4.4 Time-varying areal extent of potential exposure at defined floating oil, entrained oil, dissolved aromatic hydrocarbon and shoreline oil threshold concentrations, resulting from a 24-hour surface release of stabilised Torosa Condensate after a vessel cargo tank rupture at the Torosa FPSO location, for the replicate case with the minimum time to entrained/dissolved oil contact with the offshore edge(s) of any shoreline receptor polygon (at a threshold of 500 ppb).

4.3.3 Simulation with Minimum Time to Oil Accumulation at Any Shoreline Receptor at Defined Threshold

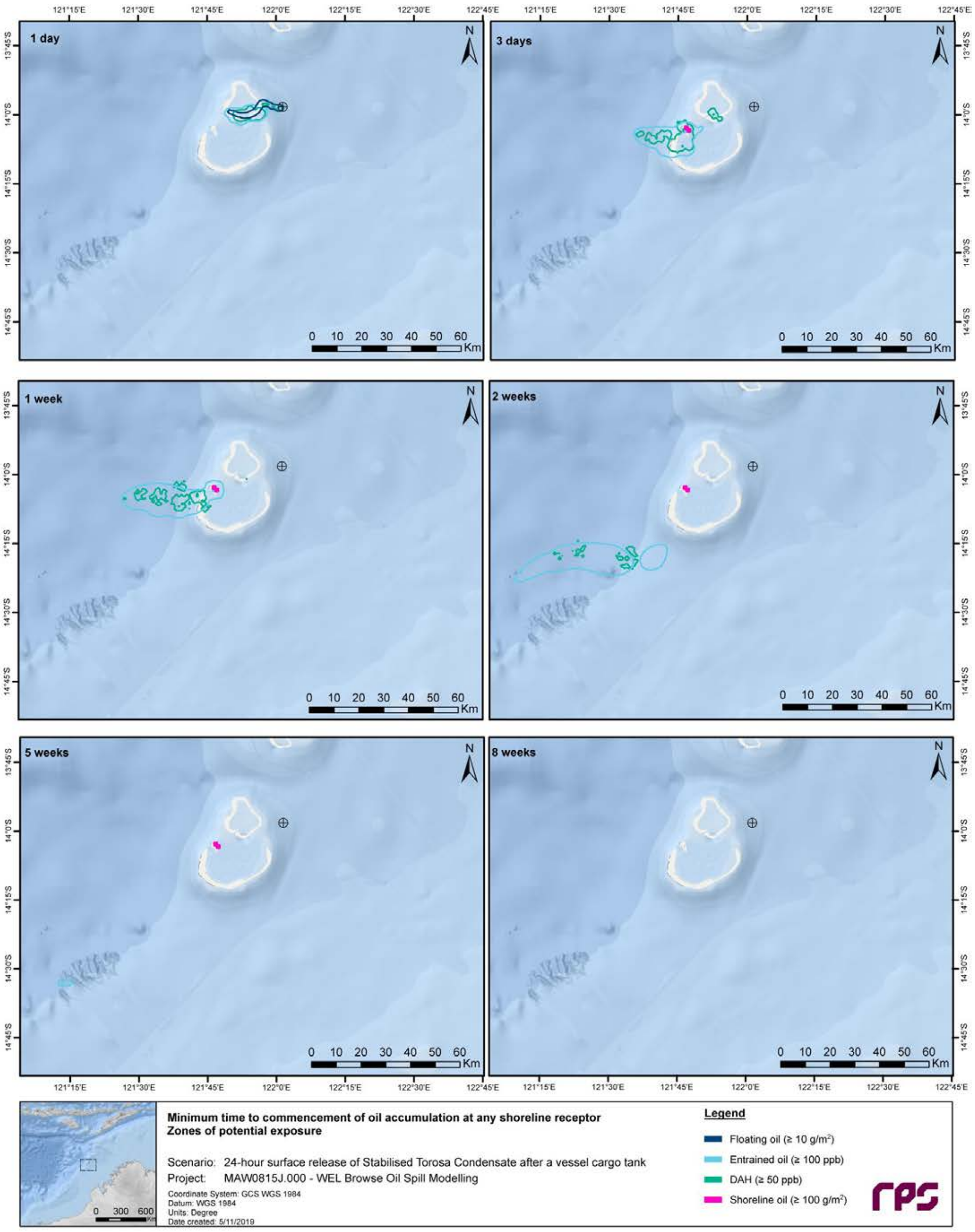

Figure 4.5 **Time-varying areal extent of potential exposure at defined floating oil, entrained oil, dissolved aromatic hydrocarbon and shoreline oil threshold concentrations, resulting from a 24-hour surface release of stabilised Torosa Condensate after a vessel cargo tank rupture at the Torosa FPSO location, for the replicate case with the minimum time to commencement of oil accumulation at any shoreline receptor (at a threshold of 100 g/m^2).**

4.3.4 Simulation with Maximum Oil Accumulation across All Shoreline Receptors and at Any Individual Shoreline Receptor at Defined Threshold

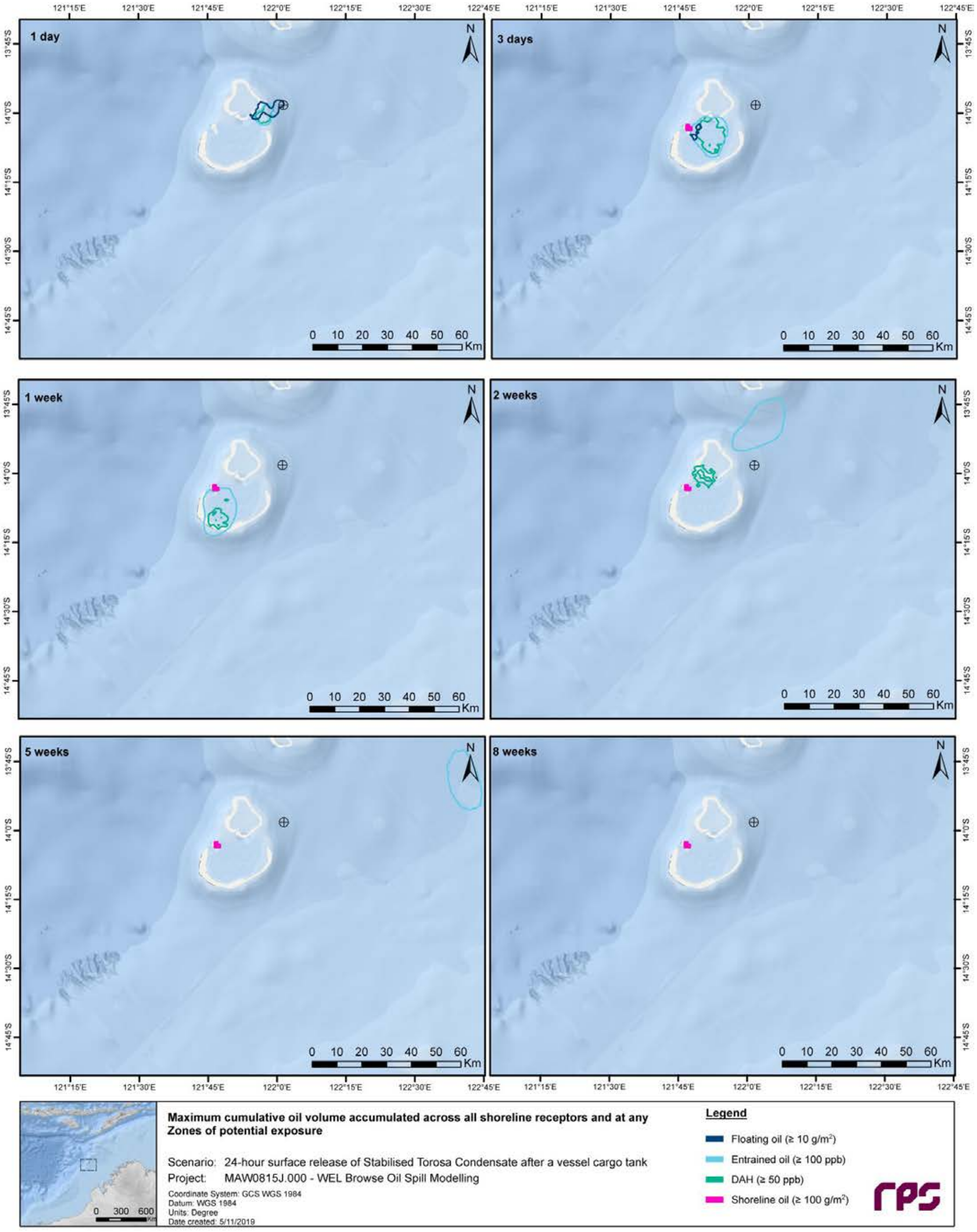

Figure 4.6 Time-varying areal extent of potential exposure at defined floating oil, entrained oil, dissolved aromatic hydrocarbon and shoreline oil threshold concentrations, resulting from a 24-hour surface release of stabilised Torosa Condensate after a vessel cargo tank rupture at the Torosa FPSO location, for the replicate case with the maximum cumulative oil volume accumulated across all shoreline receptors and at any individual shoreline receptor (exceeding a threshold of 100 g/m^2).

4.4 Scenario 3: Short-Term (Instantaneous) Surface Release of Stabilised Torosa Condensate after an FPSO Offtake System Failure at the Torosa FPSO Location

4.4.1 Simulation with Maximum Oil Accumulation across All Shoreline Receptors and at Any Individual Shoreline Receptor at Defined Threshold

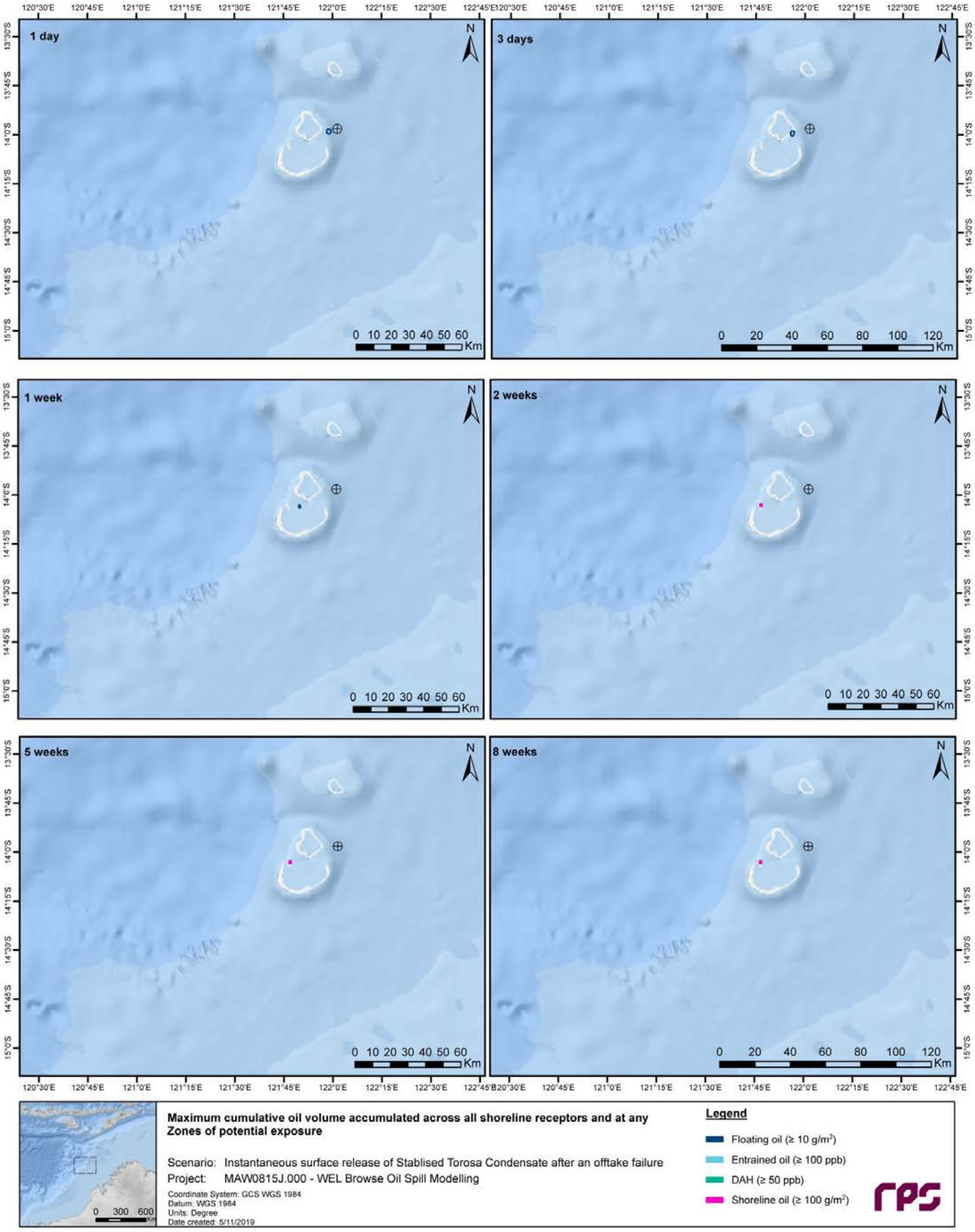

Figure 4.7 Time-varying areal extent of potential exposure at defined floating oil, entrained oil, dissolved aromatic hydrocarbon and shoreline oil threshold concentrations, resulting from an instantaneous surface release of stabilised Torosa Condensate after an FPSO offtake system failure at the Torosa FPSO location, for the replicate case with the maximum cumulative oil volume accumulated across all shoreline receptors and at any individual shoreline receptor (exceeding a threshold of 100 g/m^2).

4.5 Scenario 4: Short-Term (Instantaneous) Surface Release of Marine Diesel after a Vessel Fuel Tank Rupture near the Rowley Shoals

4.5.1 Simulation with Maximum Oil Accumulation across All Shoreline Receptors and at Any Individual Shoreline Receptor at Defined Threshold

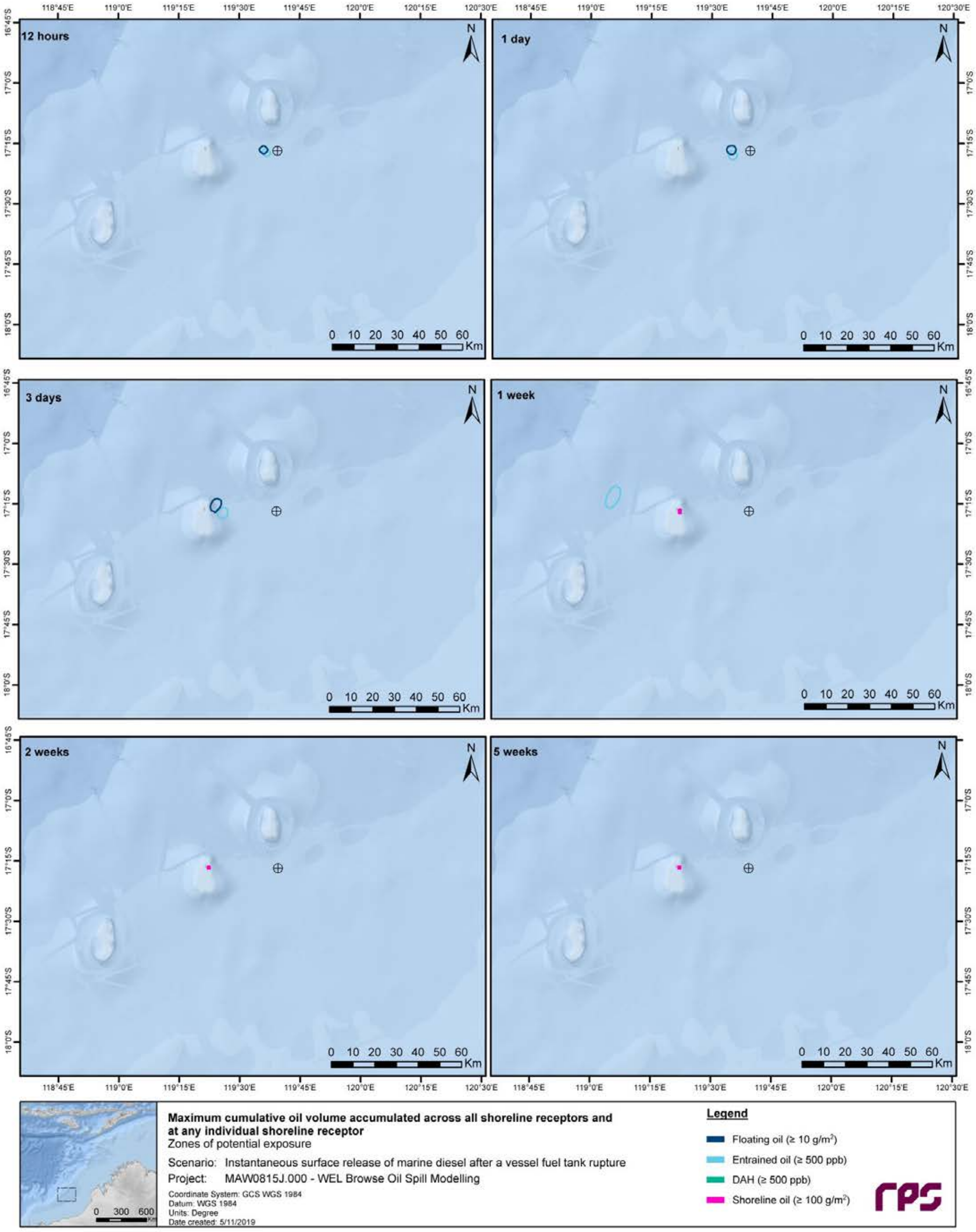

Figure 4.8 Time-varying areal extent of potential exposure at defined floating oil, entrained oil, dissolved aromatic hydrocarbon and shoreline oil threshold concentrations, resulting from an instantaneous surface release of marine diesel after a vessel fuel tank rupture near the Rowley Shoals, for the replicate case with the maximum cumulative oil volume accumulated across all shoreline receptors and at any individual shoreline receptor (exceeding a threshold of 100 g/m^2).

5 CONCLUSIONS

The main findings of this study are as follows:

Metocean Influences

- Tidal flows within the reef complex will have a significant influence on the short-term trajectory of any oil spilled at the modelled release sites, irrespective of the seasonal conditions.
- Large-scale drift currents will have a significant influence on the trajectory of any oil spilled at the modelled release sites, irrespective of the seasonal conditions. The prevailing drift currents will determine the trajectory of oil that is entrained beneath the water surface.
- Interactions with the prevailing wind will provide additional variation in the trajectory of spilled oil, and marked variation in the prevailing drift current and wind conditions will be expected over the duration of a long-term release. This will be expected to increase the spread of hydrocarbons during any single event.

Oil Characteristics

- The unstabilised Torosa Condensate mixture specified for the sea-surface release phase of the Scenario 1 blowout is a pre-processed condensate that is a mixture of volatile and persistent hydrocarbons with significant proportions of highly volatile and residual components. If the sea-surface release phase unstabilised Torosa Condensate mixture is exposed to the atmosphere, around 17% of the mass is expected to evaporate in around 24 hours, another 33% within a few days, and the remaining 51% is expected to persist in the marine environment until decayed due to photochemical and biological degradation. If the unstabilised Torosa Condensate mixture specified for the subsea release phase were to be exposed to the atmosphere, these proportions are expected to be 54%, 21% and 25%, respectively.
- Stabilised Torosa Condensate, which refers to condensate which has been processed by the FPSO and which has been considered in Scenarios 2 and 3, contains a significant proportion of volatile compounds and a low proportion of residual hydrocarbons. If exposed to the atmosphere, around 78% of the mass will be expected to evaporate in around 24 hours, another 8% within a few days, and the remaining 14% will be expected to persist in the marine environment until decayed.
- Marine diesel is a mixture of volatile and persistent hydrocarbons with low percentages of highly volatile and residual components and has been considered in Scenario 4. If exposed to the atmosphere, around 41% of the mass would be expected to evaporate in around 24 hours, another 54% within a few days, and the remaining 5% would be expected to persist in the marine environment until decayed.
- For all hydrocarbon types, the influence of entrainment will regulate the degree of mass retention in the environment.

Summary of Stochastic Assessment Results

Interpretation of Contour Figures

- The mapped spatial outcomes of the stochastic assessment for each scenario are an aggregation of the predicted oil trajectories over the full duration of many individual hydrocarbon spill simulations and indicate the probability of exposure at defined concentrations for individual locations at some point in time after commencement of the spill event.
- These outcomes do not depict a hydrocarbon slick or plume at any particular instant in time, nor do they represent the overall coverage predicted over the full duration of an individual hydrocarbon spill simulation.

Scenario 1: Long-Term (77-Day) Surface/Subsea Blowout of Unstabilised Torosa Condensate at the TRA-C Well

- The location of the release is adjacent to the Scott Reef system. Most of the predicted impacts from this scenario are focused on the receptors that comprise the Scott Reef system. Note that the set of receptor boundaries that define the Scott Reef system for the purposes of this study have some intentional overlapping areas, and this implies duplicated reporting of some oil impacts.
- Floating oil at concentrations equal to or greater than the 10 g/m^2 threshold could potentially be found up to 143 km from the spill site.
- Floating oil concentrations at the 10 g/m^2 threshold are predicted to be focused on the Scott Reef system. Floating oil at 10 g/m^2 reaches Scott Reef North in all replicate simulations, but as Scott Reef North is treated as a submerged feature floating oil is predicted to drift over rather than make direct contact with this receptor. Scott Reef Central – Sandy Islet is treated as an emergent feature. This receptor is predicted to be contacted by floating oil concentrations of 10 g/m^2 with a probability of 8% and a minimum time to contact of 46 hours after commencement of release.
- The Scott Reef Central – Sandy Islet receptor is predicted to experience shoreline oil accumulation in excess of the 100 g/m^2 threshold with a probability of 92%. With regard to shoreline receptors further from the release location, Cartier Island (22%) and Ashmore Reef (18%) are predicted to have the highest probabilities of shoreline oil accumulation in excess of the 100 g/m^2 threshold.
- Potential for accumulation of oil on shorelines is predicted to be significant for Scott Reef Central – Sandy Islet, with a maximum accumulated volume of 827 m^3 and a maximum local accumulated concentration of 34.3 kg/m^2. The predicted zone of shoreline impact is restricted to Sandy Islet. Note that the boundaries of two other receptors, Scott Reef Central and Scott Reef South, overlap with the same shoreline as Scott Reef Central – Sandy Islet so reported accumulations for these receptors are a duplication.
- Entrained oil at concentrations equal to or greater than the 100 ppb threshold is predicted to be found up to approximately 863 km from the spill site.
- Contact by entrained oil at concentrations equal to or greater than 100 ppb is generally predicted for Scott Reef receptors including Scott Reef North (100%). Seringapatam Reef is also predicted to be contacted at 100 ppb (87%).
- The maximum entrained oil concentration forecast for any receptor is predicted as 23.6 ppm at Scott Reef North.
- Dissolved aromatic hydrocarbons at concentrations equal to or greater than the 50 ppb threshold are predicted to be found up to around 673 km from the spill site.
- Contact by dissolved aromatic hydrocarbons at concentrations equal to or greater than 50 ppb is generally predicted for Scott Reef receptors including Scott Reef North (100%). Seringapatam Reef is also predicted to be contacted at 50 ppb (85%).
- The maximum dissolved aromatic hydrocarbon concentration forecast for any receptor is predicted as 13.9 ppm at Scott Reef North.

Scenario 2: Short-Term (24-Hour) Surface Release of Stabilised Torosa Condensate after a Vessel Cargo Tank Rupture at the Torosa FPSO Location

- The location of the release is adjacent to the Scott Reef system. Most of the predicted impacts from this scenario are focused on the receptors that comprise the Scott Reef system.
- Floating oil at concentrations equal to or greater than the 10 g/m^2 threshold could potentially be found up to 126 km from the spill site.

- Floating oil concentrations at the 10 g/m^2 threshold are predicted to be focused on the Scott Reef system. The Scott Reef South and Scott Reef Central shoreline receptors are predicted to be contacted by floating oil concentrations at the 10 g/m^2 threshold with probabilities of 6.5% and 2%, respectively. At these receptors, the corresponding minimum times to contact at this threshold are 21 hours and 57 hours.
- The three Scott Reef receptors that share a common shoreline, Scott Reef South, Scott Reef Central and Scott Reef Central – Sandy Islet, are predicted to experience shoreline oil accumulation in excess of the 100 g/m^2 threshold with a probability of 20.5%.
- Potential for accumulation of oil on shorelines is predicted to be moderate, with a maximum accumulated volume of 212 m^3 and a maximum local accumulated concentration of 9.5 kg/m^2 forecast at the Scott Reef South, Scott Reef Central and Scott Reef Central – Sandy Islet receptors.
- Entrained oil at concentrations equal to or greater than the 100 ppb threshold is predicted to be found up to around 890 km from the spill site.
- Contact by entrained oil at concentrations equal to or greater than 100 ppb is generally predicted for Scott Reef receptors including Scott Reef North (48.5%). Seringapatam Reef is also predicted to be contacted at 100 ppb (22.5%).
- The maximum entrained oil concentration forecast for any receptor is predicted as 30.5 ppm at Scott Reef North. This result is greater than the maximum concentration forecast in Scenario 1, where a larger total volume of oil is released. The difference in maximum entrained oil concentration is attributable to the higher release rate in Scenario 2 (18,000 m^3/day compared to 1,846 m^3/day for Scenario 1). The Scott Reef North receptor is close enough to the release site that the peak concentration is influenced more by the rate of oil released in one day than the total volume of oil released.
- Dissolved aromatic hydrocarbons at concentrations equal to or greater than the 50 ppb threshold are predicted to be found up to around 517 km from the spill site.
- Contact by dissolved aromatic hydrocarbons at concentrations equal to or greater than 50 ppb is generally predicted for Scott Reef receptors including Scott Reef North (41.5%). Seringapatam Reef is also predicted to be contacted at 50 ppb (15.5%).
- The maximum dissolved aromatic hydrocarbon concentration forecast for any receptor is predicted as 12.7 ppm at Scott Reef North.

Scenario 3: Short-Term (Instantaneous) Surface Release of Stabilised Torosa Condensate after an FPSO Offtake System Failure at the Torosa FPSO Location

- The location of the release is adjacent to the Scott Reef system. Most of the predicted impacts from this scenario are focused on the receptors that comprise the Scott Reef system.
- Floating oil at concentrations equal to or greater than the 10 g/m^2 threshold could potentially be found up to 67 km from the spill site.
- The Scott Reef South receptor is predicted to be contacted by floating oil concentrations at the 10 g/m^2 threshold with a probability of 1.5% and a minimum contact time of 24 hours.
- The Scott Reef shoreline, encompassed by the Scott Reef South, Scott Reef Central and Scott Reef Central – Sandy Islet receptors, is predicted to experience shoreline oil accumulation in excess of the 100 g/m^2 threshold with a probability of 2.5%.
- Potential for accumulation of oil on shorelines is predicted to be low, with a maximum accumulated volume of 8 m^3 and a maximum local accumulated concentration of 715 g/m^2 forecast at three Scott Reef shoreline receptors.
- Entrained oil at concentrations equal to or greater than the 100 ppb threshold is predicted to be found up to around 242 km from the spill site.

- Contact by entrained oil at concentrations equal to or greater than 100 ppb is predicted at various northern Scott Reef receptors, including Scott Reef North (28%), Scott Reef North – Flats (25%) and Scott Reef North – Lagoon (20%).
- The maximum entrained oil concentration forecast for any receptor is predicted as 6.4 ppm at Scott Reef North and Scott Reef North – Flats.
- Dissolved aromatic hydrocarbons at concentrations equal to or greater than the 50 ppb threshold are predicted to be found up to around 271 km from the spill site.
- Contact by dissolved aromatic hydrocarbons at concentrations equal to or greater than 50 ppb is predicted at Scott Reef North (23%) and Scott Reef North – Flats (22.5%).
- The maximum dissolved aromatic hydrocarbon concentration forecast for any receptor is predicted as 1.8 ppm at Scott Reef North and Scott Reef North – Lagoon.

Scenario 4: Short-Term (Instantaneous) Surface Release of Marine Diesel after a Vessel Fuel Tank Rupture near the Rowley Shoals

- The location of the release is adjacent to Mermaid Reef. Most of the predicted impacts from this scenario are focused in the vicinity of the Rowley Shoals.
- Floating oil at concentrations equal to or greater than the 10 g/m^2 threshold could potentially be found up to 82 km from the spill site.
- Given that the spill location lies within the Argo-Rowley Terrace Marine Park area, floating oil at concentrations equal to or greater than 10 g/m^2 is forecast at this receptor with a probability of 100% and a minimum time to contact of less than 1 hour. The Rowley Shoals – Mermaid Reef Marine Park shoreline receptor is predicted to be contacted by floating oil concentrations at the 10 g/m^{2}threshold with a probability of 15%, with a corresponding minimum contact time of 5 hours. At the Rowley Shoals – Clerke Reef State Marine Park and Rowley Shoals – Imperieuse Reef State Marine Park shoreline receptors, probabilities of floating oil contact at the 10 g/m^2 threshold are forecast to be 1% or less.
- The Rowley Shoals – Mermaid Reef Marine Park receptor is predicted to experience shoreline oil accumulation in excess of the 100 g/m^2 threshold with a probability of 1%.
- Potential for accumulation of oil on shorelines is predicted to be low, with a maximum accumulated volume of 6 m^3 forecast at the Rowley Shoals – Clerke Reef State Marine Park and a maximum local accumulated concentration of 491 g/m^2 forecast at the Rowley Shoals – Mermaid Reef Marine Park.
- Entrained oil at concentrations equal to or greater than the 500 ppb threshold is predicted to be found up to around 371 km from the spill site.
- Contact by entrained oil at concentrations equal to or greater than 500 ppb is predicted at Argo-Rowley Terrace Marine Park (57%), Rowley Shoals – Mermaid Reef Marine Park (33.5%) and Rowley Shoals – Clerke Reef State Marine Park (7.5%).
- The maximum entrained oil concentration forecast for any receptor is predicted as 167.6 ppm at Argo-Rowley Terrace Marine Park.
- Dissolved aromatic hydrocarbons at concentrations equal to or greater than the 500 ppb threshold are predicted to be found up to around 43 km from the spill site.
- Contact by dissolved aromatic hydrocarbons at concentrations equal to or greater than 500 ppb is predicted at Argo-Rowley Terrace Marine Park (8.5%) and Rowley Shoals – Mermaid Reef Marine Park (1.5%).
- The maximum dissolved aromatic hydrocarbon concentration forecast for any receptor is predicted as 2.2 ppm at Argo-Rowley Terrace Marine Park.

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