SCARBOROUGH OFFSHORE PROJECT PROPOSAL

Development Division
Revision 2
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Woodside

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ACRONYMS AND ABBREVIATIONS

Acronym	Description
AFFF	Aqueous Film Forming Foam
AFMA	Australian Fisheries Management Authority
AHS	Australian Hydrographic Service
AIMS	Australian Institute of Marine Science
ALARP	as low as reasonably practicable
AMFA	Australian Fisheries Management Authority
AMOSC	Australian Marine Oil Spill Centre
AMPs	Australian Marine Parks
AMSA	Australian Maritime Safety Authority
AODN	Australian Ocean Data Network
APPEA	Australian Petroleum Production and Exploration Association
AUV	autonomous underwater vehicle
BHA	bottom hole assembly
BIA	biologically important areas
BOD	biological oxygen demand
BOP	blow out preventer
BRUVS	baited remote underwater video stations
BTEX	benzene, toluene, ethylbenzene and xylenes
CAMBA	China Australia Migratory Bird Agreement
CCR	crushed calcareous rock
CITES	International Convention on International Trade in Endangered Species of Wild Fauna and Flora
CME	Chamber of Minerals and Energy of Western Australia
COLREGS	Convention on the International Regulations for Preventing Collisions at Sea 1972
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTE	critical technology elements
DAP	data access portal
DBCA	Department of Biodiversity, Conservation and Attractions
DEE	Department of Environment and Energy
DEWHA	Department of the Environment, Heritage, Water and the Arts, ACT
DJTSI	Department of Jobs, Tourism, Science and Innovation
DMIRS	Department of Mines, Industry Regulation and Safety
DoEE	Department of the Environment and Energy
DoF	Department of Fisheries
DoT	Department of Transport
DP	dynamic positioning
DPaW	Department of Parks and Wildlife
DPIRD	Department of Primary Industries and Regional Development
DST	drill stem test

Acronym	Description
DWER	Department of Water and Environmental Regulation
E&P	exploration and production
EGPMF	Exmouth Gulf Prawn Managed Fishery
EMBA	environment that may be affected
EP	environmental plan
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
EPO	environment protection order
EPO	environmental performance outcomes
ESD	ecologically sustainable development
FEED	front end engineering design
FFFP	film-forming fluoroprotein foams
FID	final investment decision
FLNG	floating liquefied natural gas
FPU	floating production unit
FWS	United States Fish and Wildlife Service
GHG	greenhouse gas
GVP	gross value of production
H2S	hydrogen sulphide
HFC	hydrofluorocarbons
HSEQ	health safety, environment and quality
IAOGP	International Association of Oil & Gas Producers
IAPP	International Air Pollution Prevention
IGEM	Industry-Government Environmental Meta-database
ILTs	in-line tee
IMCRA	Integrated Marine and Coastal Regionalisation of Australia
IMS	invasive marine species
ISV	Subsea installation vessel
JAMBA	Japan Australia Migratory Bird Agreement
KEF	Key Ecological Features
KLC	Kimberly Land Council
KP	kilometre point
LE	equivalent sound level
Lp	sound pressure level
Lpk	peak sound pressure level
LBL	long baseline
LNG	liquified natural gas
MAC	Murujuga Aboriginal Corporation
MARPOL	International Convention for the Prevention of Pollution from Ships
MBES	multi-beam echo sounder

Acronym	Description
MDO	marine diesel oil
MEG	Mono-Ethylene Glycol
MMAs	marine management area
MMF	mackerel managed fishery
MNES	matters of national environmental significance
MODU	mobile offshore drilling unit
MP	marine park
NBPMF	Nickol Bay Prawn Managed Fishery
NCPMF	North Coast Prawn Managed Fisheries
NDE	non-destructive examination
NES	national environmental significance
NICNAS	Commonwealth Government's National Industrial Chemicals Notification and Assessment Scheme
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NOPTA	National Offshore Petroleum Titles Administrator
NTU	nephelometric turbidity unit
NWBM	non-water based muds
NWMR	North-west Marine Region
NWS	North West Shelf
NWSTF	North West Slope Trawl Fishery
ODS	ozone depleting substances
OPEP	oil pollution emergency plan
OPGGS Act	Offshore Petroleum and Greenhouse Gas Storage Act 2006
OPMF	Onslow Prawn Managed Fishery
OPP	Offshore Project Proposal
OSMP	Operational and Scientific Monitoring Plan
PFAS	poly-fluoroalkyl substances
PK	peak sound level
PNEC	predicted no effect concentration
PPA	Pilbara Ports Authority
PRCs	perfluorocarbons
PTS	permanent hearing loss
RFSU	ready for start-up
ROV	remotely operated vehicle
SBTF	southern Bluefin Tuna Fishery
SCE	solid control equipment
SCM	subsea control module
SDUs	subsea distribution units
SEEMP	ship energy efficiency management plan

Acronym	Description
SEL	sound exposure level
SIV	subsea installation vessels
SMPEP	shipboard marine pollution emergency plan
SOLAS	safety of life at sea
SOPEP	shipboard oil pollution emergency plan
SPL	sound pressure level
SPRAT	species profile and threats database
SSDP	southern seawater desalination plant
SSF	specimen shell managed fishery
SURF	subsea umbilicals, risers and flowlines
TAC	total allowable catch
TACC	Dampier Technical Advisory and Consultative Committee
TcF	trillion cubic feet
TD	total depth
TPH	total petroleum hydrocarbons
TRL	technology readiness level
TSEP	Trunkline system expansion project
TSHD	trailing suction hopper dredgers
TSS	total suspended solids
TTS	temporary hearing threshold shift
UNCLOS	United Nations Convention on the Law of the Sea 1982
USBL	ultra-short baseline
VOCs	volatile organic compounds
VSP	vertical seismic profiling
WA	Western Australia
WAF	Water Accommodated Fractions
WAFIC	Western Australia Fishing Industries Council
WAITOC	Western Australian Indigenous Tourism Operators Council
WAMSI	Western Australian Marine Science Institution
WBS	water based muds
WCDSC	West Coast Deep Sea Crustacean Managed Fishery
WDTF	Western Deepwater Trawl Fishery
WHO	World Health Organisation
WMS	Woodside Management System
WOMP	Well Operations Management Plan
Woodside	Woodside Energy Limited
WSTF	Western Skipjack Tuna Fishery
WTBF	Western Tuna and Billfish Fishery
WWF	World Wildlife Fund

Acronym	Description
XC	Xanthomonas campestris / xanthan gum

UNITS

Unit	Description
°C	degrees Celsius
µg/L	micrograms per litre
µm	micrometre
bbl/day	barrels per day
Bq/m3	becquerels per cubic metre
cui	cubic inches
dB	decibel
dB re 1 µPa2.s	dB level of the time-integrated, squared sound pressure normalised to a one second period
DO (%SAT)	dissolved oxygen %saturation
FTU	Formazin turbidity unit
g/m^2	grams per metre squared
ha	hectare
Hz	hertz
kHz	kilo hertz
km	kilometre
kPa	kilopascal
L	litre
Lux	unit of illuminance
m	metre
m^2	metres squared
m^3/d	cubic metre per day
m^3/day	cubic metres per days
m^3/hr	cubic metres per hour
ML/day	megalitre per day
mm	millimetre
Mm3	cubic megametre
MMScf	millions of standard cubic feet
mol	mole
mS/cm	milli siemens per *centimetre*
Mt	metric tons
NTU	nephelometric turbidity unit
pH	hydrogen ion concentration
ppm	parts per million
psi	pounds per square inch
SEL24h	?
t	tonne
Tcf (100%, 2C)	trillion cubic feet (Ethane)
TSS	total suspended solids

Unit	Description
µg/m3	micrograms per cubic metre
w/w	weight by weight
µPa	micropascal

EXECUTIVE SUMMARY

ES1. INTRODUCTION

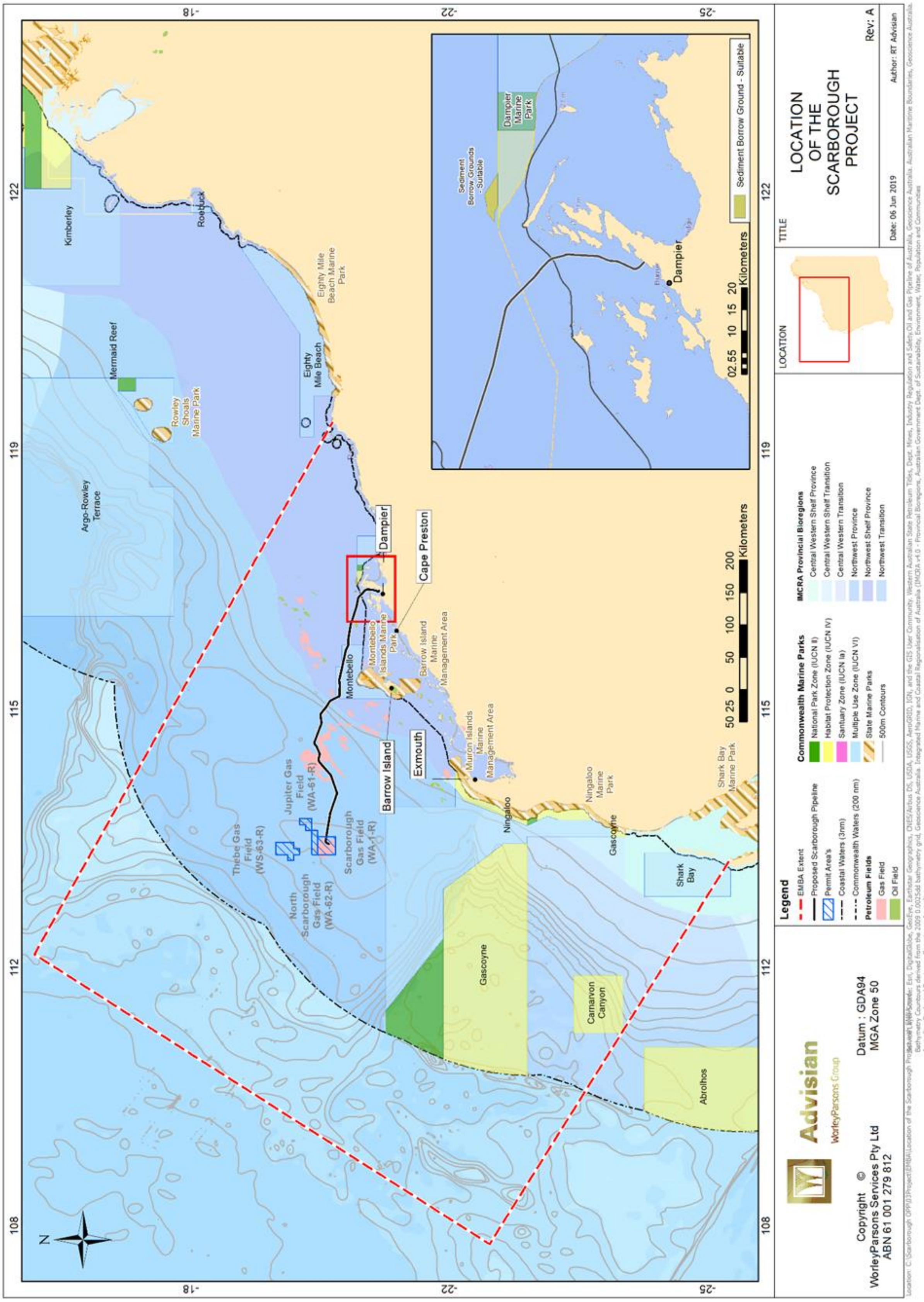
The Scarborough gas resource, located in Commonwealth waters approximately 375 km off the Burrup Peninsula, forms part of the Greater Scarborough gas fields, comprising the Scarborough, North Scarborough, Thebe and Jupiter gas fields.

Woodside Energy Limited (Woodside), is proposing to develop the gas resource through new offshore facilities. These facilities are proposed to be connected to the mainland through an approximately 430 km trunkline to an onshore facility. Woodside's preferred concept is to process Scarborough gas through a brownfield expansion of the existing Pluto LNG onshore facility (Pluto Train 2) (Figure ES-1).

The proposed offshore development, referred to as 'Scarborough', targets the commercialisation of the Scarborough and North Scarborough gas fields, through the construction of a number of subsea, high-rate gas wells, tied back to a semi-submersible Floating Production Unit (FPU) moored in approximately 900 m of water close to the Scarborough field (Figure ES-2).

The proposed development of Scarborough is an integral part of Woodside's Burrup Hub vision for a regional gas hub which will secure economic growth and local employment opportunities for Western Australia. In addition to the development of the Scarborough and North Scarborough fields, the Thebe and Jupiter gas fields provide opportunities for future tieback to Scarborough Project infrastructure. As the proposed export trunkline route crosses the Carnarvon Basin, in close proximity to other undeveloped fields, Woodside is also engaging with other resource owners to explore opportunities for future development.

Woodside propose to commence front end engineering design activities in 2019 targeting a final investment decision (FID) in 2020 to be ready for start-up (RFSU) in 2023. Achieving these milestones is subject to all necessary joint venture approvals, regulatory approvals and appropriate commercial arrangements being finalised.



Note: Refer to Section ES5 for definition of Environment that may be Affected (EMBA)

Figure ES-1: Location of the proposed development of Scarborough

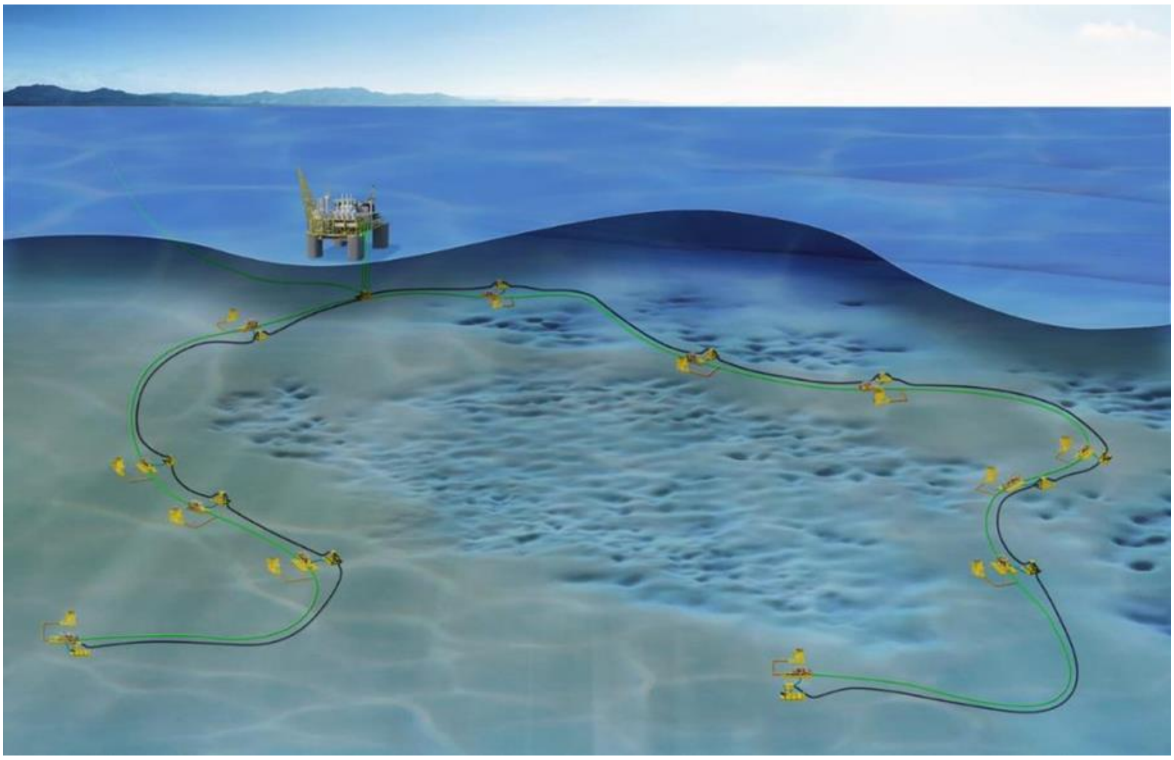


Figure ES-2: Schematic of the upstream components of the proposed development of Scarborough (note schematic not to scale)

Proponent

Woodside is Operator of the various joint ventures relating to the Scarborough, North Scarborough, Thebe and Jupiter fields., which comprise both Woodside and BHP Billiton Petroleum (North West Shelf) Pty Ltd (**"BHP"**). Current equity participation of the joint venture is as described in Table ES-0.1.

Table ES-0.1: Scarborough equity participants

Gas Fields	Woodside Interest	BHP Interest
Scarborough (WA-1-R)	75%	25%
North Scarborough (WA-62-R)	50%	50%
Thebe (WA-63-R)	50%	50%
Jupiter (WA-61-R)	50%	50%

Woodside is the largest Australian natural gas producer. The company operates Australia's biggest resource development, the North West Shelf Project (NWS Project) in Western Australia.

Woodside recognises that strong environmental performance is essential to success and continued growth. Woodside has an established methodology to identify impacts and risks and assess potential consequences of activities. Strong partnerships, sound research and transparency are the key elements of Woodside's approach to the environment.

Document Purpose and Scope

This Offshore Project Proposal (OPP) has been prepared by Woodside as Operator of WA-1-R, WA 62-R, WA 61-R and WA-63-R in accordance with the requirements of the *Offshore Petroleum and*

Greenhouse Gas Storage (Environment) Regulations 2009 (Environment Regulations), and associated guidelines.

Under the Environment Regulations, an OPP is required to be submitted for all offshore projects to the National Offshore Petroleum Safety and Environment Management Authority (NOPSEMA) for authorisation. The OPP process involves the proponent's evaluation and NOPSEMA's assessment of the potential environmental impacts and risks of petroleum activities conducted over the life of an offshore project. The process includes a public comment period and requires a proponent to ensure environmental impacts and risks will be managed to acceptable levels.

Unlike the previous EPBC Act process, the requirement for an OPP applies to all offshore projects regardless of the potential level of impact or risk to the environment that the project may present.

More information can be found on the OPP process on NOPSEMA's website https://www.nopsema.gov.au/environmental-management/assessment-process/offshore-project-proposals/

This OPP presents the assessment of the potential environmental impacts and risks associated with the project. It is an early stage, whole-of-project assessment which, subject to acceptance by NOPSEMA, will form the basis for future activity-specific EPs that will be prepared and submitted to NOPSEMA, and will be required to be assessed and accepted prior to any activity related to Scarborough to commence.

As required under the Environment Regulations, the content of this OPP includes:

- a description of the project, including location and proposed timetable
- a description of the environment that may be affected by the project, including details of relevant environmental values and sensitivities
- environmental performance outcomes for the project
- a description of any feasible alternative to the project, or alternative activity to that forming part of the project
- a description of the legislative and other requirements that apply to the project
- a description and evaluation of the environmental impacts and risks of the project, appropriate to the nature and scale of each impact or risk
- a summary of any public comments made and how they were evaluated and addressed
- a demonstration of any changes made to the proposal as a result of public comment.

The contents of this OPP are in accordance with the requirements of the OPGGS (Environment) Regulations and align with current OPP content guidelines (N-04790-GN-1663) and NOPSEMA OPP Assessment Policy (N-04790-PL-1650).

ES2. WOODSIDE HEALTH, SAFETY AND ENVIRONMENTAL MANAGEMENT SYSTEM

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. Environmental management is one of the components of the overall WMS.

Within the WMS, the overall direction for Environment is set through Woodside's corporate Health Safety, Environment and Quality (HSEQ) Policy. 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 employees, contractors and Joint Venture partners engaging in activities under Woodside operational control. Key principles of the policy include:

- 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 assessment and evidence-based decision making
- Taking a collaborative and proactive approach with our stakeholders
- Requiring contractors to comply with our HSEQ expectations in a mutually beneficial manner
- Publicly reporting on HSEQ performance

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 the Scarborough OPP and subsequent EPs will be implemented through a management framework specific to Scarborough but integrated into the WMS.

ES3. ENVIRONMENTAL LEGISLATION AND OTHER ENVIRONMENTAL MANAGEMENT REQUIREMENTS

Scarborough is located in Commonwealth waters and therefore falls under Commonwealth jurisdiction. The legislation of relevance to Scarborough include:

- The *Environmental Protection and Conservation Act 1999* - The EPBC Act is the Commonwealth Government's primary environmental legislation. This is the principal statute for the protection and management of matters of National Environmental Significance (NES). Under the EPBC Act, any action that is likely to have a significant impact on matters of NES must not be undertaken without the approval of the Minister. Actions with the potential to impact on matters of NES trigger the Commonwealth environmental assessment and approval process. Assessment under the EPBC Act, administered by the Department of Environment and Energy (DEE) includes an assessment of the impacts of a proposal on matters of NES listed under Part 3 of the EPBC Act.
- The *Offshore Petroleum and Greenhouse Gas Storage Act 2006* - The OPGGS Act is the principal Act governing offshore petroleum exploration and production in Commonwealth waters. Specific environmental, resource management and safety obligations are set out in associated Regulations:
    - Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009

- Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011 (Resource Management and Administration Regulations)
- Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Environment Regulations)

The assessment process under the OPGGS Act, administered by NOPSEMA, aims to ensure all impacts and risks of a petroleum activity are acceptable and as low as reasonably practicable (ALARP).

Beyond the OPP, other approvals required under the OPGGS Act and associated regulations. Unless an offshore petroleum activity has prior approval under the EPBC Act (pre-2014), an OPP must be accepted by NOPSEMA before the proponent can submit EPs and other related approvals for activities that make up the project: These are outlined below:

- EPs - Under the Environment Regulations, a titleholder is required to have in place an accepted EP before commencing a petroleum activity. The EP 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 EP must include an implementation strategy to demonstrate that the impacts and risks can be managed to ALARP and an acceptable level and to describe how appropriate environmental performance outcomes, standards and measurement criteria outlined in the EP will be met. The EP must also provide a summary of all consultation undertaken with relevant persons. EPs will be supported with appropriate oil pollution emergency plans (OPEPs) and operational and scientific monitoring plan (OSMPs), which are required as a part of an EP's implementation strategy, noting that these may be developed to support a range of activities or phases of a project. The EPs will be submitted and accepted by NOPSEMA before the activities listed above can commence.
- Other Petroleum Activity Approvals - In addition to environmental approvals as discussed, the Resource Management and Administration Regulations also require that a Safety Case and a Well Operations Management Plan (WOMP) are assessed and accepted by NOPSEMA for petroleum facilities, along with any relevant licences to support pipelines, infrastructure and production.

ES4. DESCRIPTION OF THE PROJECT AND ALTERNATIVES ANALYSIS

Project Overview

Key components of the proposed development of Scarborough include:

- Surface infrastructure – Floating Production Unit (FPU) in approximately 900 m of water over the Scarborough reservoir
- Subsea infrastructure - infield infrastructure, including wellheads, manifolds, flowlines and umbilicals, export trunkline and communications lines
- Wells – anticipated to drilling in two phases. Drilling of the Scarborough and North Scarborough gas fields, with potential for future fields (including Thebe and Jupiter gas fields) to be tied back to the facility
- Trunkline installation – installation of a 32-inch gas trunkline to extend for a total of 430 km using piling to support anchoring of pipelay vessel and trenching and backfill (for nearshore only)

- Commissioning – Commissioning of the overall production system will be conducted from the FPU once on location
- Operations – hydrocarbon extraction and processing will take place at the FPU, to meet the export trunkline specifications. Gas will be exported via the trunkline.
- Decommissioning - the facilities will be decommissioned in accordance with good oilfield practice and relevant legislation and practice at the time

Project Schedule

As Operator, Woodside are proposing to conduct FEED activities in 2019 to support the Operator's targeted Final Investment Decision (FID) in 2020, as well as obtaining all primary approvals. The first drilling phase is scheduled in 2020 followed by the installation of the trunkline in 2022, ready for start-up and FPU installation in 2023 and phase 2 drilling (potentially including Thebe and Jupiter) in 2025. Decommissioning is expected to be commence in 2055[1].

Project Location

The proposed Scarborough and North Scarborough fields are located in permits WA-1-R and WA-62-R (Permit Area), in Commonwealth waters approximately 375 km north west off the Burrup Peninsula in the North West of Australia. Water depths within the Permit Area range between approximately 900 m to 1000 m. Wells may also be drilled and tied back to the FPU from the Thebe and Jupiter fields, located in permits WA-63-R and WA-61-R respectively.

All subsea and subsurface infield infrastructure and wells are located in Commonwealth waters. The trunkline from the FPU to the onshore Pluto LNG Facility will be the only part of the offshore development which traverses into State waters. The trunkline route is shown in Figure ES-2. The location at which the trunkline will cross into State waters is about 20 km north-west from the shore and in water depths of 31 m.

Project Stages

Key stages of the development and associated activities are:

- Development drilling which includes:
  - Geotechnical surveys
  - Drilling operations
  - Well completion
  - Well flow-back
- Installation and commissioning which includes:
  - Installation of FPU
  - Installation of subsea infrastructure
  - Pre-commissioning
  - Trunkline installation
  - Pipeline stabilisation

[1] *If additional or third-party reservoirs have been tied into Scarborough Project infrastructure, this could increase the project's economic life and therefor delay decommissioning activities.*

- Operations which includes:
  - FPU operations
  - Hydrocarbon extraction
  - Hydrocarbon processing
  - Hydrocarbon export via pipeline
- Inspection, maintenance and repair which includes:
  - Inspection
  - Maintenance and repair
  - Well intervention
- Decommissioning which includes:
  - Removal of subsea infrastructure (subject to other provisions of the OPGGS Act)
  - Well abandonment
- Support operations which includes:
  - Mobile offshore drilling unit (MODU) operations
  - Vessel operations
  - Remotely operated vehicle (ROV) operations
  - Helicopter operations

Assessment of Alternatives

Woodside has considered development options and undertaken a comparative assessment (including a 'no development' option) to identify the benefits, risks and impacts of each. The comparative assessment process used by Woodside evaluated options against a set of criteria, including environment and safety.

Five development concept options were identified for Scarborough. In consideration of all the assessment drivers, Woodside's preferred development concept is that Scarborough gas would be processed through a brownfield expansion of the Pluto LNG Facility, where additional LNG processing capacity and domestic gas infrastructure will be installed. The composition of Scarborough gas is well suited to the Pluto LNG Facility, which is designed for lean gas and nitrogen removal.

As part of Woodside's preferred concept of a brownfield expansion of the existing Woodside-operated Pluto LNG Facility to process Scarborough gas, Woodside is considering and assessing a range of options for facilities, activities, installation and construction methods, including mooring of construction vessels, manning of the FPU, piling techniques, trunkline route and MODU design. These are detailed in the OPP.

ES5. DESCRIPTION OF THE ENVIRONMENT

The proposed development of Scarborough occurs in Commonwealth waters off the northwest coast of Western Australia (WA), within the North-west Marine Region (NWMR) (Integrated Marine and Coastal Regionalisation of Australia (IMCRA) 4.0). The target fields occur within the Northern Carnarvon Basin on the Exmouth Plateau, and are about 375 km offshore from Dampier, in water depths of approximately 900 – 970 m, with the proposed trunkline ultimately crossing into State waters along the same alignment as the Pluto Gas Export Pipeline (Figure 4.3).

The environmental context of the proposed development of Scarborough has been described according to zones of relevance to the project:

- The Project Area, which is divided further into the Offshore Project Area (the area covered by WA-1-R, WA-62-R, WA-61-R, and WA-63-R), the Trunkline Project Area (the proposed trunkline route with a 1 km buffer either side) and the Borrow Grounds Project Area (the proposed location for the borrow grounds).
- The environment that may be affected (EMBA) by Scarborough, which is the largest spatial extent where unplanned events could have an environmental consequence on the surrounding environment (Figure 5.2). 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 spill scenario (i.e. a 2,000 m3 vessel fuel tank rupture; refer to Section 7.2.6). 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 scenario. While the EMBA considers all hydrocarbon phases, it is characterised by the low exposure zone for entrained hydrocarbons. The EMBA has been set with some buffer (approximately a minimum of 50 km) to accommodate exposure below these levels (noting that below these levels any biological impacts are not expected to occur). The EMBA also extended inshore to accommodate for a spill scenario occurring anywhere along the trunkline route and simplified to a rectangular shape for ease of use. The modelling that was used to derive the EMBA is detailed in the report provide in Appendix I.

Studies and reviews of the Exmouth Plateau and North West Shelf have been compiled and/or undertaken to provide an understanding of the physical, biological and socio-economic environmental conditions within the Project Area. These studies contribute to long-term datasets for the region and the majority have been made available in the public domain.

A summary of the existing environment relevant to the proposed development of Scarborough is provide below.

Marine Regional Characteristics

The Offshore Project Area, and the western part of the Trunkline Project Area, is in the Northwest IMCRA Province. As the trunkline traverses the continental shelf it crosses into the Northwest Shelf IMCRA Province (Figure 5.1). These provinces are the start of a transition between tropical and temperate marine areas; and include migration routes and breeding locations for some important whale and bird species (DEWHA, 2008a). No additional IMCRA Provinces occur in the EMBA.

The continental shelf in the vicinity of the Project Area is wide, with a change of slope at about the 20 m bathymetric contour (IMCRA Technical Group, 1998). Inside this contour there is a series of limestone islands (South and North Muiron, Serrurier, Bessieres, Thevenard, Rosily, Barrow and the Montebello islands); with fringing coral reefs typically occurring on the seaward side of most of these islands (IMCRA Technical Group, 1998).

Further offshore from the continental slope is the Exmouth Plateau, within which the Offshore Project Area lies. The Exmouth Plateau is a deepwater plateau, with a narrow, steep southern slope and a wider, less steep northern slope. The Montebello Trough along the south-east edge of this plateau drains into the Cape Range Canyon; while the northern portion of the plateau comprises the Dampier Ridge and Swan Canyon.

Physical Characteristics of the Project Area

The seafloor of the Offshore Project Area is generally flat and uniform with water depths ranging from 900 m to 970 m. The Trunkline Project Area extends from the Offshore Project Area across the continental slope to the inner continental shelf, in waters approximately 30 m deep. The Borrow

Ground Project Area lies in shallow waters (less than 100 m), where the seabed in generally flat and uniform with no important subsea features.

The predominant seabed type at the Offshore Project Area is mud and calcareous clay, and along the Trunkline Project Area is calcareous gravel, sand and silt. The Borrow Ground Project Area is characterised by calcium carbonate seabed deposits.

Currents, waves and winds, tides, water temperature and salinity in the Project Area, as well as water and air quality, and underwater noise and ambient light conditions, are expected to be typical of the North-west Marine Bioregion's tropical offshore environment.

Marine Fauna of Conservation Significance

Primary productivity of the NWMR is generally low. Distribution of pelagic fauna is primarily concentrated in waters closer to shore with species presence more likely along the export trunkline corridor than within the Permit Area. Many species however have known distribution which extends to within the deeper waters of the Project Area. Demersal species are generally concentrated around areas containing hard substrate habitats of which none are present within close proximity to the Project Area. The benthic environment within the Project Area is homogenous and widely spread with no sensitive species present.

Within the Offshore Project Area, a total of 25 conservation significant species may be present during the project, with the addition of one BIA for the Pygmy blue whale. Within the Trunkline Project Area, a total of 46 conservation significant species may be present with an additional ten BIAs intersecting the corridor. Within the Borrow Ground Project Area, a total of 35 conservation significant species may be present with an additional nine BIAs intersecting the area. Across the entire EMBA, 92 conservation significant species may be present, covering 12 BIAs. Neither the Project Area nor EMBA intersect any Threatened Ecological Communities.

Key Ecological Features

Key ecological features (KEFs) are not matters of NES and have no legal status in their own right; however, they are considered as components of a Commonwealth marine area. KEFs are parts of the marine ecosystem that are considered to be important for a marine region's biodiversity or ecosystem function and integrity. KEFs have been identified by the Australian Government based on advice from scientists identifying regions with important attributes associated with ecosystem function and biodiversity.

The Project Area intersects the following three KEFs (Figure 5.32):

- Exmouth Plateau (Permit Area and trunkline corridor)
- Ancient coastline at 125 m depth contour (trunkline corridor)
- Continental slope demersal fish communities (trunkline corridor).

Additional KEFs within the EMBA include:

- Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula (~175 km from Permit Area and ~21 km from the trunkline corridor)
- Commonwealth waters adjacent to Ningaloo Reef (~20 km from the Permit Area and 22 km from the trunkline corridor)
- Glomar Shoals (~6 km from the trunkline corridor and ~34 km from the Permit Area).

All KEFs are solely within Commonwealth waters.

Protected Places

Protected places of the NWMR and adjacent State waters which either overlap with the Project Area or the EMBA are listed below:

- World Heritage Properties
  - Ningaloo Coast (186 km from Project Area; within the EMBA)
- National Heritage Properties
  - Ningaloo Coast (natural) (186 km from Project Area; within the EMBA)
  - Dampier Archipelago (indigenous) (13 km from Project Area; within the EMBA)
- Commonwealth-managed Australian Marine Parks (AMPs)
  - Montebello (intersects Trunkline Project Area; within the EMBA)
  - Dampier (33 km from Project Area; within the EMBA)
  - Gascoyne (87 km from Project Area; within the EMBA)
  - Ningaloo (186 km from Project Area; within the EMBA)
  - Carnarvon Canyon (405 km from Project Area; within the EMBA)
  - Shark Bay (475 km from Project Area; within the EMBA)
- State-managed Marine Parks (MPs)
  - Montebello Islands (25 km from Project Area; within the EMBA)
  - Barrow Island (73 km from Project Area; within the EMBA)
  - Ningaloo (186 km from Project Area; within the EMBA)
  - Shark Bay (550 km from Project Area, within the EMBA)
- State-managed Marine Management Areas (MMAs)
  - Barrow Island (73 km from Project Area, within the EMBA)
  - Muiron Islands (177 km from Project Area; within the EMBA)
- Nationally important wetlands.
  - Exmouth Gulf East (outside Project Area; within the EMBA)
  - Hamelin Pools (outside Project Area; within the EMBA)
  - Learmonth Saline Coastal Flats (outside Project Area; within the EMBA)
  - Shark Bay East (outside Project Area; within the EMBA).

There are no Wetland of International Significance within the Project Area or EMBA.

Socio-Economic Values

Socio-economic values in the NWMR of relevance to the Project Area and EMBA include:

- Five Commonwealth-managed commercial fisheries, overlapping the Project Area
- Seven State-managed commercial fisheries overlapping the Project Area, and three additional fisheries overlapping the EMBA
- Recreation and tourism activities overlapping the EMBA, including charter fishing, other recreational fishing, diving, snorkelling, whale, Whale shark, marine turtle and dolphin watching, cruise ship stop overs and yachting.

- Commercial shipping, overlapping the Project Area, although mainly restricted to waters to the east and south of the Offshore Project Area and along the Trunkline Project Area.
- Oil and Gas exploration and operation, overlapping the EMBA (closest project is located 70 km east of the Project Area).
- The Australian Defence Force have a Defence Training Area that intersects with the Offshore Project Area and Trunkline Project Area.

ES6. IMPACT AND RISK ASSESSMENT METHODOLOGY

Under the OPGGS (Environment) Regulations, a titleholder is required to detail and evaluate all the environmental impacts and risks associated with the proposed project, and to demonstrate that the project can be undertaken in such a way that the environmental impacts and risks will be managed to an acceptable level.

An assessment of the impacts and risks associated with the proposed development of Scarborough has been undertaken in accordance with Woodside's Environment Impact Assessment Guideline and Risk Assessment Procedure, following the systematic approach below:

1. **CONTEXT SETTING**
    a. Establishing the context based on the proposed activities
    b. Establishing the context for the environment in which the proposal is to take place
    c. Review of the significance/sensitivity of receptors and levels of protection
    d. Environmental legislation and other requirements
    e. External requirements
    f. Internal requirements
2. **IMPACT AND RISK ASSESSMENT**
    a. Impact and Risk Identification
    b. Impact and Risk analysis
    c. Impact and Risk evaluation
    d. Determining Acceptability
3. **IMPACT AND RISK TREATMENT**
    a. Identifying Controls

The other key steps of the Woodside Risk Management Process including implementation (which includes the steps to monitor, review and report) and stakeholder consultation.

A total of 19 EPOs have been set for Scarborough.

ES7. EVALUATION OF ENVIRONMENTAL IMPACTS AND RISKS

The OPP has identified the impacts and risks associated with the proposed development of Scarborough. This will inform the subsequent EPs that must include an implementation strategy to demonstrate that the impacts and risks can be managed to ALARP and an acceptable level and to describe appropriate environmental performance outcomes, standards and measurement criteria.

The residual impacts and risks associated with each aspect of Scarborough were determined to be acceptable following implementation of the key management controls, as outlined in Table ES-0.1

Table ES-0.1 Summary of Environmental Impacts and Risks associated with the proposed development of Scarborough – Planned Activities

Aspect	Source of aspect (Activities)	Receptor	Impact	Environmental Performance Outcome	Adopted Control(s)	Receptor sensitivity	Magnitude	Impact significance level	Acceptability
Routine Light Emissions	Vessel operations FPU operations MODU operations Hydrocarbon processing.	Ambient light	Change in ambient light	**EPO1:** 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.	**CM1:** Lighting will be limited the minimum required for navigational and safety requirements, with the exception of emergency events.	Low value (open water)	Slight	Negligible (F)	Acceptable
		Seabirds and migratory shorebirds	Change in fauna behaviour	**EPO10:** To not have a substantial adverse effect on a population of seabirds or shorebirds, or the spatial distribution of the population. **EPO8:** To not substantially modify, destroy or isolate an area of important habitat for a migratory species. **EPO9:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.		High value species (e.g. wedge-tailed shearwater)	No lasting effect	Slight (E)	Acceptable
		Marine reptiles		**EPO11:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population. **EPO1:** 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. **EPO9:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.		High value species (e.g. flatback turtle)	No lasting effect	Slight (E)	Acceptable
Routine Atmospheric and Greenhouse Gas Emissions	FPU operations MODU operations Vessel operations Well flowback Hydrocarbon processing.	Air quality	Change in air quality	**EPO5:** To not result in a substantial change in air quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM2:** Vessel and MODU compliance with Marine Order 97 (Marine Pollution Prevention – Air Pollution), including: • International Air Pollution Prevention (IAPP) Certificate, required by vessel class • use of low sulphur fuel when available • Ship Energy Efficiency Management Plan (SEEMP), where required by vessel class • onboard incinerator to comply with Marine Order 97. **CM3:** Optimisation of flaring to allow the safe and economically efficient operation of the facility.	Low value (open water)	Slight	Negligible (F)	Acceptable
		Climate	Climate change	**EPO19:** Optimise efficiencies in air emissions and reduce greenhouse emissions to ALARP and Acceptable Levels.	**CM4:** Facilities will be designed and operated to optimise resource efficiency. **CM5:** Reporting of GHG emissions as per regulatory requirements.	Low value	Slight	Negligible (F)	Acceptable
Routine Acoustic Emissions	Vertical seismic profiling Pre-lay surveys Drilling operations (including MODU operations) Installation of FPU – piling FPU operations Hydrocarbon extraction	Ambient noise	Change in ambient noise	**EPO1:** 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.	**CM6:** Woodside VSP Procedure implemented while VSP operations are undertaken to prevent prolonged exposure to marine fauna. **CM7:** For impact piling activities, Woodside will implement the soft start procedure at the commencement of piling activities and shut down zones during the activity. **CM8:** EPBC Regulations 2000 Part 8 Division 8.1 Interacting with cetaceans.	Low value (open water)	No lasting effect	Negligible (F)	Acceptable
		Fish	Change in fauna behaviour Injury/mortality to marine fauna	**EPO7:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population		High value species (MNES species known to be present.)	No lasting effect	Slight (E)	Acceptable

Aspect	Source of aspect (Activities)	Receptor	Impact	Environmental Performance Outcome	Adopted Control(s)	Receptor sensitivity	Magnitude	Impact significance level	Acceptability
	Vessel operations (including trunkline installation vessels) Helicopter operations Removal of subsea infrastructure.	Marine reptiles	Change in fauna behaviour Injury/mortality to marine fauna	**EPO11:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population. **EPO1:** 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. **EPO9:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.		High value species (i.e. flatback turtle)	No lasting effect	Slight (E)	Acceptable
		Marine mammals	Change in fauna behaviour Injury/mortality to fauna	**EPO12:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **EPO1:** 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. **EPO9:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.		High value species (i.e. pygmy blue whale)	No lasting effect	Slight (E)	Acceptable
Physical Presence – Displacement of Other Users	Surveys Vessel operations MODU operations FPU operations Helicopter operations Trunkline installation Installation of the FPU and subsea infrastructure. Removal of subsea infrastructure	Commonwealth managed fisheries	Changes to the function interests or activities of others	**EPO15:** To not have a substantial adverse effect on the sustainability of commercial fishing. **EPO14:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.	**CM9:** Vessels to adhere to the navigation safety requirements including the Navigation Act 2012 and any subsequent Marine Orders. **CM10:** Notify Australian Hydrographic Service (AHS) of activities and movements prior to activity commencing. **CM11:** Notify representatives of State and Commonwealth fisheries of activities.	High value marine user	Slight	Minor (D)	Acceptable
		State managed fisheries				High value marine user	Slight	Minor (D)	Acceptable
		Shipping				Medium value marine user	Slight	Slight (E)	Acceptable
		Industry				Medium value marine user	Slight	Slight (E)	Acceptable
Physical Presence – Seabed Disturbance	Pre-lay surveys Drilling operations Installation of the FPU and subsea infrastructure Trunkline installation and stabilisation Removal of subsea infrastructure MODU operations Vessel operations ROV operations.	Water quality	Change in water quality	**EPO2:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM12:** Infrastructure will be positioned on the seabed within design footprint to reduce seabed disturbance.	Low value	Slight	Negligible (F)	Acceptable
		Epifauna and infauna	Change in habitat	**EPO1:** 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.		Low value	Slight	Negligible (F)	Acceptable
		KEFs	Change in habitat Change in water quality Injury or mortality	**EPO16:** 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 results.		High value	Slight	Minor (D)	Acceptable
		AMPs	Change in habitat Change in water quality	**EPO1:** 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.		High value	Slight	Minor (D)	Acceptable

Aspect	Source of aspect (Activities)	Receptor	Impact	Environmental Performance Outcome	Adopted Control(s)	Receptor sensitivity	Magnitude	Impact significance level	Acceptability
Routine and Non-Routine Discharges: Sewage and Greywater	Vessel operations MODU operations FPU operations	Water quality	Change in water quality	**EPO2:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM13:** Compliance with relevant MARPOL, Commonwealth requirements and subsequent Marine Order requirements for sewage management.	Low value (open water)	Slight	Negligible (F)	Acceptable
Routine and Non-Routine Discharges: Food Waste	Vessel operations MODU operations FPU operations	Water quality	Change in water quality	**EPO2:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM14:** Compliance with relevant MARPOL, Commonwealth requirements and subsequent Marine Order requirements for waste discharges. **CM15:** Implementation of waste management procedures which provide for safe handling and transportation, segregation and storage and appropriate classification of all waste generated.	Low value (open water)	No lasting effect	Negligible (F)	Acceptable
Routine and Non-Routine Discharges: Chemicals and Deck Drainage	Vessel operations MODU operations FPU operations	Water quality	Change in water quality	**EPO2:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM14:** Compliance with relevant MARPOL, Commonwealth requirements and subsequent Marine Order requirements for waste discharges. **CM15:** Implementation of waste management procedures which provide for safe handling and transportation, segregation and storage and appropriate classification of all waste generated.	Low value (open water)	No lasting effect	Negligible (F)	Acceptable
Routine and Non-Routine Discharges: Brine and Cooling Water	Vessel operations MODU operations FPU operations	Water quality	Change in water quality	**EPO2:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM16:** Chemicals will be selected with the lowest practicable environmental impacts and risks subject to technical constraints.	Low value (open water)	No lasting effect	Negligible (F)	Acceptable
		Sediment quality	Change in sediment quality	**EPO3:** To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		Low value (open water)	No lasting effect	Negligible (F)	Acceptable
		Plankton	Injury/ mortality to fauna	**EPO6:** To not have a substantial adverse effect on a population of plankton including its life cycle and spatial distribution.		Low value (open water)	No lasting effect	Negligible (F)	Acceptable
		Epifauna and Infauna	Injury/ mortality to fauna	**EPO1:** 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.		Low value (open water)	No lasting effect	Negligible (F)	Acceptable
Routine and Non-Routine Discharges: Operational Fluids	Hydrocarbon extraction Hydrocarbon processing.	Water quality	Change in water quality	**EPO2:** To not result in a substantial change in water quality (including temperature) which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM16:** Chemicals will be selected with the lowest practicable environmental impacts and risks subject to technical constraints. **CM18:** Development of a management framework for produced formation discharges.	Low value (open water)	Slight	Negligible (F)	Acceptable
		Sediment quality	Change in sediment quality	**EPO3:** To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		Low value (open water)	No lasting effect	Negligible (F)	Acceptable
		Plankton	Injury/ mortality to fauna Injury/ mortality to fauna	**EPO6:** To not have a substantial adverse effect on a population of plankton including its life cycle and spatial distribution.		Low value (open water)	No lasting effect	Negligible (F)	Acceptable
		Epifauna and Infauna		**EPO1:** 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.		Low value (open water)	No lasting effect	Negligible (F)	Acceptable

Aspect	Source of aspect (Activities)	Receptor	Impact	Environmental Performance Outcome	Adopted Control(s)	Receptor sensitivity	Magnitude	Impact significance level	Acceptability
		KEFs	Change in habitat	**EPO16:** 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.		High value	No lasting effect	Slight (E)	Acceptable
Routine and Non-Routine Discharges: Subsea Installation and Commissioning	Installation of the FPU Installation of subsea infrastructure Commissioning.	Water quality	Change in water quality	**EPO2:** To not result in a substantial change in water quality (including temperature) which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM16:** Chemicals will be selected with the lowest practicable environmental impacts and risks subject to technical constraints.	Low value (open water)	Slight	Negligible (F)	Acceptable
		Sediment quality	Change in sediment quality	**EPO3:** To not substantially change sediment quality, which may adversely impact biodiversity, ecological integrity, social amenity or human. **EPO4**: To not result in persistent organics 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.		Low value (open water)	Slight	Negligible (F)	Acceptable
		Plankton	Injury/ mortality to fauna	**EPO6:** To not have a substantial adverse effect on a population of plankton including its life cycle and spatial distribution.		Low value (open water)	No lasting effect	Negligible (F)	Acceptable
		Epifauna and Infauna	Injury/ mortality to fauna	**EPO1:** 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.		Low value (open water)	No lasting effect	Negligible (F)	Acceptable
		KEFs	Change in habitat	**EPO16:** 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.		Medium value habitat	Slight	Negligible (F)	Acceptable
Routine and Non-Routine Discharge: Drilling	Drilling operations Well abandonment. Well intervention	Water quality	Change in water quality	**EPO2:** To not result in a substantial change in water quality (including temperature) which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM19:** WBM will be used during drilling activities as the first preference. Where WBM cannot meet required technical specifications, NWBM may be used following technical justification. **CM20:** Bulk overboard discharge of NWBM is prohibited. **CM21:** Drill cuttings returned to the MODU will be processed to reduce oil on cuttings to < 6.9% by weight on wet cuttings (measured as a well average only including sections drilled with NWBM) prior to discharge. **CM22:** Drill cuttings returned to the MODU will be discharged below the waterline.	Low value (open water)	Slight	Negligible (F)	Acceptable
		Sediment quality	Change in sediment quality	**EPO3:** To not substantially change sediment quality, which may adversely impact biodiversity, ecological integrity, social amenity or human.		Low value (open water)	Slight	Negligible (F)	Acceptable
		Plankton	Injury/ mortality to fauna	**EPO6:** To not have a substantial adverse effect on a population of plankton including its life cycle and spatial distribution.		Low value (open water)	No lasting effect	Negligible (F)	Acceptable
		Epifauna and Infauna	Injury/ mortality to fauna	**EPO1:** 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.		Low value (open water)	No lasting effect	Negligible (F)	Acceptable
		KEFs	Change in habitat	**EPO16:** 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.		Medium value habitat	Slight	Negligible (F)	Acceptable

Table ES-0.2 Summary of Environmental Impacts and Risks associated with the proposed development of Scarborough – Unplanned Activities

Aspect	Source of aspect (Activities)	Receptor	Impact	Environmental Performance Outcome	Adopted Control(s)	Receptor sensitivity	Risk Consequence	Likelihood	Risk Rating	Acceptability
Unplanned Discharge: Chemicals	Drilling operations FPU operations. Vessel operations MODU operations ROV operations Helicopter operations	Water quality	Change in water quality	**EPO2:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM16:** Chemicals will be selected with the lowest practicable environmental impacts and risks subject to technical constraints. **CM15:** Implementation of waste management procedures which provide for safe handling and transportation, segregation and storage and appropriate classification of all waste generated.	Low value (open water)	Negligible (F)	Highly Unlikely	Low	Acceptable
Unplanned Discharge: Solid Waste	Vessel operations MODU operations FPU operations	Water quality	Change in water quality	**EPO2:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM23:** Project vessels compliant with Marine Order 95 (pollution prevention – Garbage). **CM15:** Implementation of waste management procedures which provide for safe handling and transportation, segregation and storage and appropriate classification of all waste generated.	Low value (open water)	Negligible (F)	Remote	Low	Acceptable
		Migratory shorebirds and seabirds	Injury/mortality to fauna	**EPO10:** To not have a substantial adverse effect on a population of seabirds or shorebirds, or the spatial distribution of the population. **EPO7:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **EPO12:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **EPO1:** 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. **EPO11:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population. **EPO8:** To not substantially modify, destroy or isolate an area of important habitat for a migratory species. **EPO9:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.		High value species	Minor (D)	Remote	Low	Acceptable
		Fish				High value species	Minor (D)	Remote	Low	Acceptable
		Marine mammals				High value species	Minor (D)	Remote	Low	Acceptable
		Marine reptiles				High value species	Minor (D)	Remote	Low	Acceptable
Physical Presence (Unplanned): Seabed Disturbance	Vessel operations MODU operations FPU operations Trunkline installation	Epifauna and infauna	Change in habitat Injury/ mortality to fauna	**EPO1:** 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.	**CM12:** Infrastructure will be positioned on the seabed within design footprint to reduce seabed disturbance.	Low value	Negligible (F)	Highly Unlikely	Low	Acceptable
		KEFs	Change in habitat	**EPO16**: 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 results.		High Value	Minor (D)	Highly Unlikely	Moderate	Acceptable
Physical Presence (Unplanned): IMS	Installation of FPU Installation of subsea infrastructure Trunkline Installation MODU operations Vessel operations.	Epifauna and infauna	Change in ecosystem dynamics	**EPO18:** To not result in a known or potential pest species (IMS) becoming established. **EPO1:** 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.	**CM24:** Compliance with the Woodside Invasive Marine Species Management Plan. **CM25:** Requirements of the Australian Ballast Water Management to be met.	Low value habitat (homogenous)	Negligible (F)	Remote	Low	Acceptable
		Coral				High value	Minor (D)	Remote	Low	Acceptable
		Seagrass				High value	Minor (D)	Remote	Low	Acceptable
		Macroalgae				Low value	Negligible (F)	Remote	Low	Acceptable

Aspect	Source of aspect (Activities)	Receptor	Impact	Environmental Performance Outcome	Adopted Control(s)	Receptor sensitivity	Risk Consequence	Likelihood	Risk Rating	Acceptability
		Industry, Shipping, Defence	Changes to the functions, interests or activities of other users	**EPO18:** To not result in a known or potential pest species (IMS) becoming established. **EPO13:** To not have a substantial adverse effect on water quality such that an adverse impact on industry use occurs. **EPO14:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.		Medium value	Minor (D)	Remote	Low	Acceptable
Physical Presence (Unplanned): Collision with Marine Fauna	Vessel operations	Marine Mammals; Marine reptiles	Injury to/ mortality of fauna	**EPO7:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **EPO12:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **EPO11:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population. **EPO1:** 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. **EPO9:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	**CM8:** EPBC Regulations 2000 Part 8 Division 8.1 Interacting with cetaceans. **CM32**: Marine fauna interaction mitigation measures to be considered and implemented as appropriate during the EP process.	High value species	Slight (E)	Highly Unlikely	Low	Acceptable
Unplanned Hydrocarbon Release	Drilling operations Commissioning FPU operations Hydrocarbon extraction Hydrocarbon processing Gas export Decommissioning.	Sediment quality	Change in sediment quality	**EPO3**: To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM26:** All vessels and facilities (appropriate to class) will comply with MARPOL 73/78, the Navigation Act 2012, the Protection of the Sea (Prevention of Pollution from Ships Act 1983 and subsequent Marine Orders including: • waste management requirements • management of spills aboard • emergency drills. **CM27:** Relevant Stakeholders will be notified of activities prior to commencement. **CM28:** Vessels will have in place a valid and appropriate Shipboard Oil Pollution Emergency Plan and/or Shipboard Marine Pollution Emergency Plan. Emergency response activities will be implemented in accordance with the SOPEP/SMPEP. **CM29:** Environment Plans and Oil Pollution Emergency Plans will be accepted and in place, appropriate to the credible hydrocarbon spill scenario associated with activities during the development of Scarborough. Emergency response activities will be implemented in accordance with the OPEP. **CM30:** Emergency response capability will be maintained in accordance with EP, OPEP and related documentation. **CM31:** Well Operations Management Plan accepted and in place for all wells, in accordance with the Offshore Petroleum and Greenhouse Gas Storage Act requirements, which include:	Low value (open water)	Negligible (F)	Highly Unlikely	Low	Acceptable
		Water quality	Change in water quality	**EPO2**: To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		Low value (open water)	Negligible (F)	Highly Unlikely	Low	Acceptable
		Plankton	Injury/ mortality to fauna	**EPO6**: To not have a substantial adverse effect on a population of plankton including its life cycle and spatial distribution.		Low value (open water)	Negligible (F)	Highly Unlikely	Low	Acceptable
		Fish	Change in fauna behaviour	**EPO7**: To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **EPO8**: To not substantially modify, destroy or isolate an area of important habitat for a migratory species. **EPO9**: To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.		High value species	Minor (D)	Highly Unlikely	Moderate	Acceptable
			Injury/ mortality to fauna			High value species	Minor (D)	Highly Unlikely	Moderate	Acceptable

Aspect	Source of aspect (Activities)	Receptor	Impact	Environmental Performance Outcome	Adopted Control(s)	Receptor sensitivity	Risk Consequence	Likelihood	Risk Rating	Acceptability
		Marine mammals	Change in fauna behaviour	**EPO12**: To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **EPO1:** 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. **EPO9:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	• Blowout Preventer (BOP) installation during drilling operations • regular testing of BOP.	High value species	Minor (D)	Highly Unlikely	Moderate	Acceptable
			Injury/ mortality to fauna			High value species	Minor (D)	Highly Unlikely	Moderate	Acceptable
		Marine Reptiles	Change in fauna behaviour	**EPO11**: To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population. **EPO1**: 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. **EPO9**: To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.		High value species	Slight (E)	Highly Unlikely	Low	Acceptable
			Injury/ mortality to fauna			High value species	Minor (D)	Highly Unlikely	Moderate	Acceptable
		Seabirds and migratory shorebirds	Change in fauna behaviour	**EPO10**: To not have a substantial adverse effect on a population of seabirds or shorebirds, or the spatial distribution of the population. **EPO8**: To not substantially modify, destroy or isolate an area of important habitat for a migratory species. **EPO9**: To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.		High value species	Slight (E)	Highly Unlikely	Low	Acceptable
			Injury/ mortality to fauna			High value species	Minor (D)	Highly Unlikely	Moderate	Acceptable
		Coral	Change in habitat	**EPO1:** 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.		High value habitat	Major (B)	Highly Unlikely	Moderate	Acceptable
		Seagrass				High value habitat	Slight (E)	Highly Unlikely	Low	Acceptable
		Macroalgae				Low value habitat (homogenous)	Negligible (F)	Highly Unlikely	Low	Acceptable

Aspect	Source of aspect (Activities)	Receptor	Impact	Environmental Performance Outcome	Adopted Control(s)	Receptor sensitivity	Risk Consequence	Likelihood	Risk Rating	Acceptability
		Mangroves				High value habitat	Slight (E)	Highly Unlikely	Low	Acceptable
		Shoreline habitats				Low value habitat	Negligible (F)	Highly Unlikely	Low	Acceptable
		Saltmarsh				High value habitat	Slight (E)	Highly Unlikely	Low	Acceptable
		KEFs	Change in habitat	**EPO16**: 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		High value	Minor (D)	Highly Unlikely	Modera te	Acceptable
		AMPs	Change in habitat	**EPO1:** 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.		High value	Minor (D)	Highly Unlikely	Modera te	Acceptable
		Protected Places				Medium value	Slight (E)	Highly Unlikely	Low	Acceptable
		Commonwealth and state managed fisheries	Changes to the functions, interests or activities of other users	**EPO15**: To not have a substantial adverse effect on the sustainability of commercial fishing. **EPO14**: To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.		High value marine user	Slight (E)	Highly Unlikely	Low	Acceptable
		Tourism and recreation	Changes to the functions, interests or activities of other users	**EPO14**: To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.		Medium value users	Slight (E)	Highly Unlikely	Low	Acceptable
			Change in aesthetic value			Medium value users	Slight (E)	Highly Unlikely	Low	Acceptable

Aspect	Source of aspect (Activities)	Receptor	Impact	Environmental Performance Outcome	Adopted Control(s)	Receptor sensitivity	Risk Consequence	Likelihood	Risk Rating	Acceptability
		Settlements	Changes to the functions, interests or activities of other users	**EPO17**: To protect social surroundings from significant harm.		Medium value users	Slight (E)	Highly Unlikely	Low	Acceptable
			Change in aesthetic value			Medium value users	Slight (E)	Highly Unlikely	Low	Acceptable
		Industry	Changes to the functions, interests or activities of other users	**EPO13**: To not have a substantial adverse effect on water quality such that an adverse impact on industry use occurs. **EPO14:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.		Medium value	Slight (E)	Highly Unlikely	Low	Acceptable
		Defence	Changes to the functions, interests or activities of other users	**EPO14**: To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.		Medium value	Slight (E)	Highly Unlikely	Low	Acceptable

ES8. CUMULATIVE IMPACTS AND RISKS

Cumulative effects of other marine users, proposed developments, as well as all key stages and aspects of the proposed development of Scarborough have been considered as part of this OPP process ensuring a holistic/lifecycle assessment of impacts.

Cumulative impacts and risks from the proposed development of Scarborough may occur in two ways:

- Aspect-based – Cumulative or combination effects may arise from other activities/projects resulting in the same aspects as those identified in this OPP.
- Receptor-based – Cumulative or combination effects on a receptor may arise, both from multiple aspects of Scarborough and similar/multiple aspects resulting from other activities/projects.

Aspects arising from the proposed development of Scarborough may compound with similar aspects caused by other activities/developments, to result in a cumulative impact. Other activities/developments include:

- Pluto LNG Project
- Equus Field Development
- Commonwealth and State managed fisheries
- Commercial shipping.

All other activities/developments are located outside of the EMBA.

The aspects identified which were common to these activities/developments and the proposed development of Scarborough are those typically related to vessel movements, which include:

- Physical presence (routine): displacement of other users
- Light emissions
- Routine and non-routine discharges: project vessels.

As a large development within an already busy marine area, there was wide-ranging potential for cumulative impacts to occur as a result of Scarborough. However, the cumulative impact assessment has shown that there is little cross-over in spatial extent of aspects, both within Scarborough itself and when considering aspects in combination with other activities/developments. The majority of emissions and discharges, particularly those which will occur during the full lifecycle of Scarborough, will be made within the Permit Area, which is remote and unlikely to result in interactions with other activities/developments.

When considering potential cumulative impacts on receptors, it is clear that in most cases the phased approach of development proposed for Scarborough will alleviate the potential for cumulative pressure on receptors, allowing recovery/return to baseline conditions between impact events. It is still possible that individuals will experience combination effects from multiple impact events in the vicinity of the Offshore Project Area, however this is not predicted to occur on a population level for any receptors. Where cumulative impacts are predicted, i.e. light emissions on marine reptiles, the assessment concludes that no significant impacts will occur, and any cumulative impacts will be acceptable.

ES9. ENVIRONMENTAL PERFORMANCE FRAMEWORK

Overview

The proposed development of Scarborough will be undertaken in accordance with the OPP. This will be implemented by ensuring that all petroleum activities are within the scope of the accepted OPP, and the adoption of controls and EPOs specified in the OPP in any future petroleum activity EPs.

Woodside, as Operator, has developed the Environmental Management Implementation Approach for Scarborough, which consists of:

- Managing activities in accordance with existing fit-for purpose systems, practices and procedures under the Woodside WMS
- Identifying key roles and responsibilities for Woodside and Contractor personnel in relation to the implementation and management of EPOs for Scarborough
- Developing plans and procedures for emergency preparedness and response for all future petroleum activities
- Monitoring of EPO implementation through successful implementation of controls, environmental performance standards and associated measurement criteria specific to the activity for which an EP is being developed.
- Undertaking environmental performance audits
- Reporting on the environmental performance of the project to NOPSEMA
- Managing changes to the OPP concerning changes to activity scope, changes in understanding of the environment, and potential new advice from external stakeholders.

Implementing Requirements of the OPP in Future EPs

The OPP provides guidance on how the different elements of Scarborough which are petroleum activities will be reflected within Environment Plans. Key Management Controls and Environmental Performance Outcomes for each aspect of the project have also been presented, as follows:

- Aspects related to drilling activities
- Aspects related to installation and commissioning activities
- Aspects related to operational activities
- Aspects related to decommissioning activities
- Aspects related to installation, maintenance and repair activities

ES10. CONSULTATION

Stakeholder consultation and engagement is an integral component of the environmental impact assessment and environmental authorisation process for OPPs.

The objectives of the stakeholder consultation process are to:

- Provide stakeholders with opportunities to obtain information about the development of Scarborough including 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.
- Work with stakeholders to understand the key environmental and social factors associated with the development of Scarborough and potential impacts.

- Gain feedback from stakeholders on their concerns in relation to the development of Scarborough and where possible, address stakeholder concerns through further activities, or by implementing additional mitigation measures.

The stakeholder consultation for Scarborough is a component of Woodside's broader consultation program for all Burrup Hub opportunities including the Browse Development, NWS Extension, Pluto Expansion, Pluto-NWS Interconnector and activities to integrate industrial-scale solar power generation with gas-fired generation and battery storage for our future Burrup Hub LNG operations.

Specific to Scarborough, Woodside is undertaking a phased program of consultation:

- **Phase 1:** Preliminary consultation proposed to take place during the impact assessment process and preparation of the OPP.
- **Phase 2**: Formal consultation under the public review process of the draft OPP by NOPSEMA.
- **Phase 3**: Ongoing consultation during project planning and execution.

Phase 1 – Preliminary consultation commenced in 2018 and is built on the broader consultation and engagement process that Woodside has in place for the region. It will continue up until the point of formal consultation under the OPP process. To date, Phase 1 consultation activities have included:

- Developing a dedicated project website https://www.woodside.com.au/our-business/burrup-hub/scarborough-to-pluto which includes a detailed video explaining key characteristics of the proposal, information regarding the approvals, up-to-date fact sheets and point of contact.
- Preparing a Scarborough fact sheet uploaded to the website and provided directly to key stakeholders via email.
- Preparing fact sheets describing some of the key issues associated with the development of Scarborough for upload to the website.
- Holding community forums and group meetings including information sessions which were undertaken in May 2019 in Karratha and Roebourne. These sessions were to address the environmental issues associated with the development of Scarborough in preparation for the release of the draft OPP and formal public consultation process (Phase 2).
- Holding one-on-one meetings between environment, stakeholder and project management representatives.
- Emailing information directly to key stakeholders, including details of Scarborough and key milestones including approval submissions.

Phase 2 – Formal consultation under the public review of the Scarborough OPP will take place in 2019 and will be for a period of 4 – 12 weeks, as determined by NOPSEMA.

Phase 3 – Ongoing consultation will continue on acceptance of the OPP, to engage with stakeholders during the preparation of EPs and execution of Scarborough.

1 INTRODUCTION

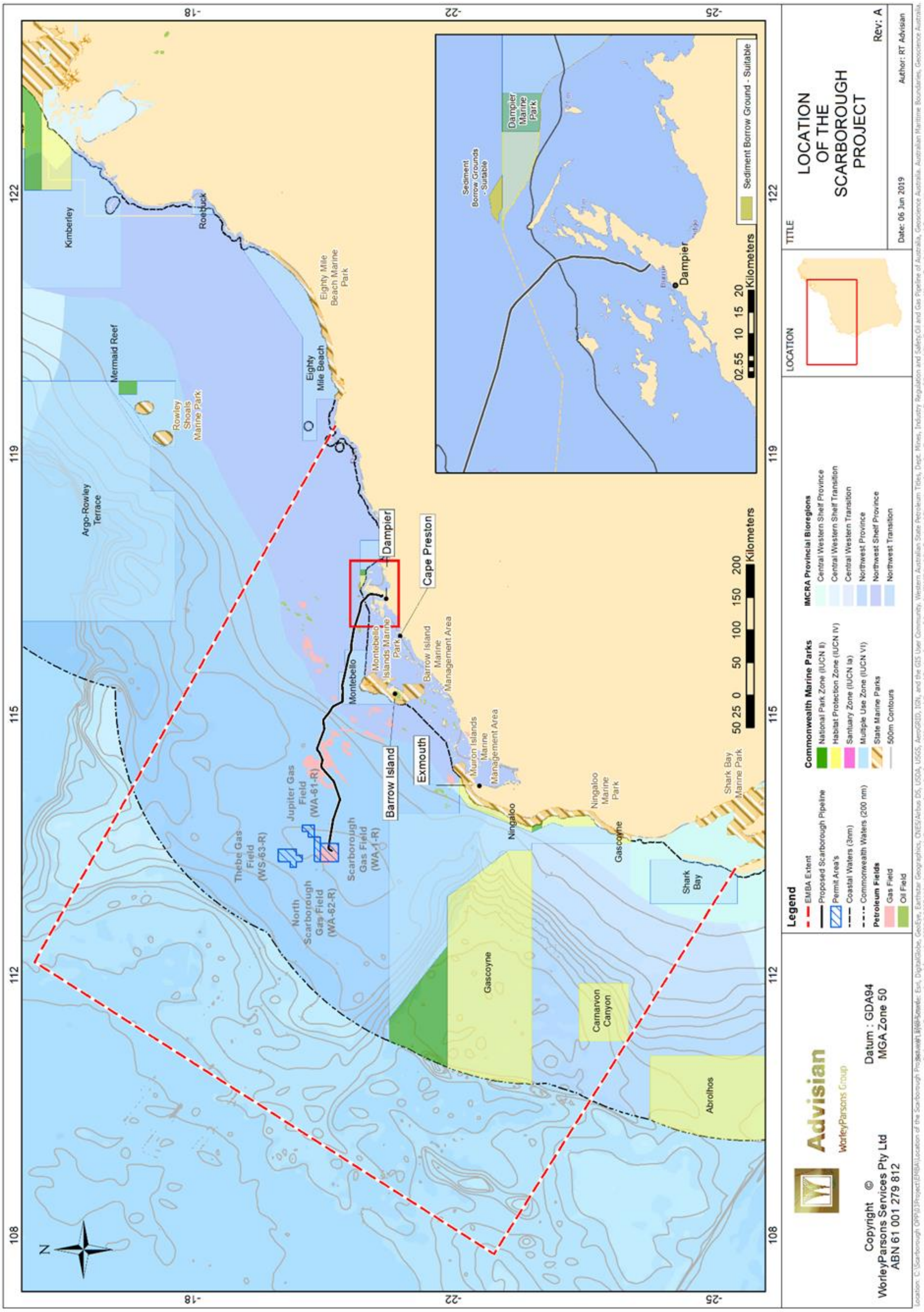
The Scarborough gas resource, located in Commonwealth waters approximately 375 km off Western Australia's Burrup Peninsula, forms part of the Greater Scarborough gas fields, comprising the Scarborough, North Scarborough, Thebe and Jupiter gas fields. The Scarborough gas resource is estimated to hold 7.3 Tcf (100%, 2C) of dry gas.

Woodside Energy Limited (Woodside), is proposing to develop the gas resource through new offshore facilities. These facilities are proposed to be connected to the mainland through an approximately 430 km trunkline to an onshore facility. Woodside's preferred concept is to process Scarborough gas through a brownfield expansion of the existing Pluto LNG onshore facility (Pluto Train 2) (Figure 1.1).

The proposed offshore development, referred to as the development of Scarborough, targets the commercialisation of the Scarborough and North Scarborough gas fields, through the construction of a number of subsea, high-rate gas wells, tied back to a semi-submersible Floating Production Unit (FPU) moored in about 900 metres of water close to the Scarborough field (Figure 1.2).

The proposed development of Scarborough is an integral part of Woodside's Burrup Hub vision for a regional gas hub which will secure economic growth and local employment opportunities for Western Australia for years to come. In addition to the development of the Scarborough and North Scarborough fields, the 1.4 Tcf (100%, 2C) Thebe and 0.5 Tcf (100%, 2C) Jupiter gas fields provide opportunities for future tieback to Scarborough infrastructure. As the proposed export trunkline route crosses the Carnarvon Basin, in close proximity to other undeveloped fields, Woodside is also engaging with other resource owners to explore opportunities for future development.

Woodside propose to commence front end engineering design activities in 2019 targeting a final investment decision (FID) in 2020 to be ready for start-up (RFSU) in 2023. Achieving these milestones is subject to all necessary joint venture approvals, regulatory approvals and appropriate commercial arrangements being finalised.



Note: Refer to Section 7 for definition of Environment that may be Affected (EMBA)

Figure 1.1: Location of Scarborough

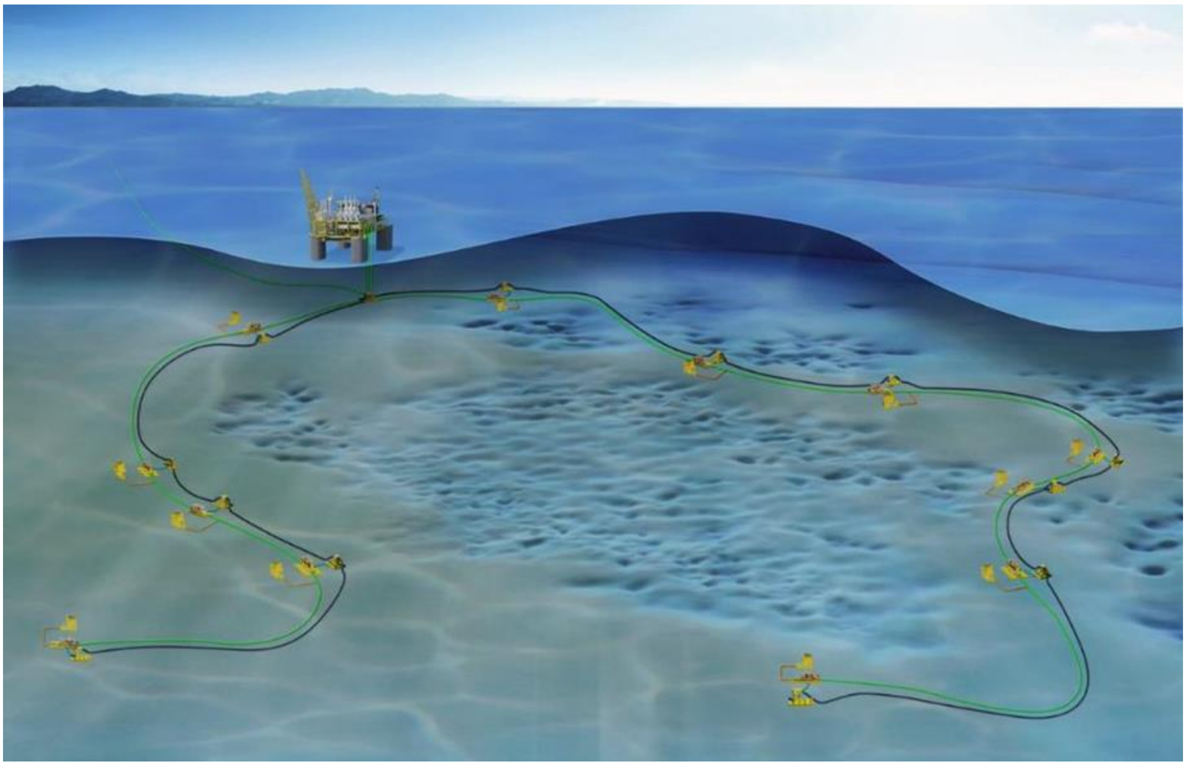


Figure 1.2: Schematic of the upstream components of the proposed development of Scarborough (note schematic not to scale)

1.1 Proponent

Woodside is Operator of the various joint ventures relating to the Scarborough, North Scarborough, Thebe and Jupiter fields., which comprise both Woodside and BHP Billiton Petroleum (North West Shelf) Pty Ltd (**"BHP"**). Current equity participation of the joint venture is as described in Table 1.1.

Table 1.1: Scarborough Equity Participants

Gas Fields	Woodside Interest	BHP Interest
Scarborough (WA-1-R)	75%	25%
North Scarborough (WA-62-R)	50%	50%
Thebe (WA-63-R)	50%	50%
Jupiter (WA-61-R)	50%	50%

Woodside is the largest Australian natural gas producer. The company operates Australia's biggest resource development, the North West Shelf Project (NWS Project) in Western Australia.

The Woodside-operated producing LNG assets in the north-west of Australia are among the world's best facilities. The NWS Project has been operating for more than 30 years, delivering one-third of Australia's oil and gas production from one of the world's largest LNG facilities. Pluto LNG also forms part of Woodside's outstanding base business, and since commissioning in 2012, has delivered over 400 LNG cargoes.

Woodside recognises that strong environmental performance is essential to success and continued growth. Woodside has an established methodology to identify impacts and risks and assess potential consequences of activities. Strong partnerships, sound research and transparency are the key elements of Woodside's approach to the environment.

1.2 Proponent Contact Details

Woodside, as proponent of Scarborough, can be contacted at:

Scarborough
Mia Yellagonga
11 Mount Street, Perth, WA, 6000
Email: feedback@woodside.com.au
Phone: 1800 442 977

A dedicated Project Website is available at address:

https://www.woodside.com.au/our-business/burrup-hub/scarborough-to-pluto

1.3 Project Overview and Location

1.3.1 Project Overview

The upstream development concept for Scarborough comprises a number of subsea gas wells drilled to target petroleum resources of the Scarborough and North Scarborough fields tied back to an FPU moored in about 900 m of water, over the Scarborough field. Woodside proposes that the FPU topsides have processing facilities for gas dehydration and compression. Once processed, it is proposed that the gas will be transported through an approximate 430 km trunkline to onshore. The Thebe and Jupiter fields provide opportunities for future tie-backs to Scarborough infrastructure. Woodside's preferred development option for the processing of Scarborough gas is a trunkline to the Woodside-operated Pluto LNG Facility, which will require brownfield expansion under existing approvals to process the Scarborough gas.

The Scarborough gas resource has been appraised and determined to be dry gas, with only trace levels or no condensate expected. The gas has no detectable hydrogen sulphide (H_2S) and only trace levels of carbon dioxide.

The key components of Scarborough are:

- drilling of the Scarborough and North Scarborough gas fields, with potential for future fields (including Thebe and Jupiter gas fields) to be tied back to the facility
- installation of subsea infield infrastructure, including wells, drill centres, manifolds, flowlines, umbilicals, risers and moorings
- installation of an FPU over the Scarborough field
- installation of an approximately 430 km long trunkline from the FPU to the Burrup Peninsula
- commissioning of the trunkline and production facilities
- operation of the facilities for their lifetime (designed for approximately 30 years[2])
- maintenance of all infrastructure over the life of the project
- decommissioning after economic life is reached
- extraction of offshore sediments to be used for stabilisation of the export trunkline.

[2] While the design life for the Scarborough Project is 30 years, it is possible that this may be extended through various engineering redesign options that may be contemplated in the future.

1.3.2 Project Location

The Scarborough and North Scarborough fields are located 375 km west-north-west of the Burrup Peninsula in the north-west of Australia, within offshore petroleum permits WA-1-R and WA-62-R. The Thebe and Jupiter fields are located to the north and north-east of the Scarborough and North Scarborough fields, within offshore petroleum permits WA-63-R and WA-61-R respectively (; the commercialisation of these fields provide potential opportunity for future expansion of Scarborough.

In Commonwealth waters, the Scarborough area comprises the areas outlined in Figure 1.1, encompassing the extent of the retention lease areas for WA-1-R, WA-62-R, WA-63-R and WA-61-R, defined as the Offshore Project Area, as well as the gas export trunkline, which lies within the Trunkline Project Area, extending from the location of the FPU to the State water limits (from which point environmental approvals are required under the *Environment Protection Act* (EP Act) and *Environment Protection and Biodiversity Conservation Act* (EPBC Act)). Additionally, potential borrow ground areas have been identified for sourcing sediments to be used to stabilise some of the sections of the trunkline in both State and Commonwealth waters and are termed the Borrow Grounds Project Area.

For the purpose of this OPP, the area comprising the Offshore Project Area, Trunkline Project Area and Borrow Grounds Project Area is collectively defined as the Project Area.

1.4 Document Purpose and Scope

1.4.1 Background to the OPP

This OPP has been prepared in accordance with the requirements of the *Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009,* and associated guidelines.

In 2014, NOPSEMA became the sole Commonwealth regulator for environmental management of offshore petroleum activities following streamlining of regulatory processes under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (OPGGS Act) and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The effect of streamlining is that offshore petroleum activities only require approval by NOPSEMA under the OPGGS Act, and no longer require separate approval by the Minister for the Environment under the EPBC Act.

To allow streamlining to occur, several changes were made to the Environment Regulations administered by NOPSEMA. This included introducing the requirement that a proponent submits an offshore project proposal (OPP), for all offshore projects, to NOPSEMA for approval. The OPP process involves the proponent’s consideration and NOPSEMA’s assessment of the potential environmental impacts and risks of petroleum activities conducted over the life of an offshore project. The process includes a public comment period prior to approval and requires a proponent to ensure environmental impacts and risks will be managed to acceptable levels.

Unlike the previous EPBC Act process, the requirement for an OPP applies to all offshore projects regardless of the potential level of impact or risk to the environment that the project may present. An OPP for a project must be accepted by NOPSEMA before the proponent can submit Environment Plans (EPs) for activities that make up the project.

More information can be found on the OPP process on NOPSEMA’s website https://www.nopsema.gov.au/environmental-management/assessment-process/offshore-project-proposals/.

Once the OPP is accepted, EPs will be developed and submitted to NOPSEMA for acceptance prior to the commencement on any petroleum activities within the scope of this OPP (Section 3.2.1).

1.4.2 Purpose

This OPP has been prepared by Woodside as Operator of WA-1-R, WA 62-R, WA 61-R and WA-63-R to present the assessment of the potential environmental impacts and risks associated with the development of Scarborough. It is an early stage project assessment which, subject to acceptance by NOPSEMA, will form the basis for future activity-specific EPs that will be prepared and submitted to NOPSEMA, and will be required to be assessed and accepted prior to any activity related to Scarborough to commence.

As required under the OPGGS (Environment) Regulations, the content of this OPP includes:

- a description of the project, including location and proposed timetable
- a description of the environment that may be affected by the project, including details of relevant environmental values and sensitivities
- environmental performance outcomes for the project
- a description of any feasible alternative to the project, or alternative activity to that forming part of the project
- a description of legislative and other requirements that applies to the project
- a description and evaluation of the environmental impacts and risks of the project, appropriate to the nature and scale of each impact or risk
- a summary of any public comments made and how they were evaluated and addressed
- a demonstration of any changes made to the proposal as a result of public comment.

The contents of this OPP are in accordance with the requirements of the OPGGS (Environment) Regulations and align with current OPP content guidelines (N-04790-GN-1663) and NOPSEMA Policy of OPP Assessment (N-04790-PL-1650), as shown in Table 1.2.

Table 1.2: Concordance of OPGGS (Environment) Regulations with OPP

OPGGS (E) Regulations	Requirements	Relevant Section of OPP
Regulation 5A Submission of an Offshore Project Proposal		
5A (5) (a)	Include the proponent's name and contact details.	Section 1.2
5A (5) (b)	Include a summary of the project, including the following: (i) a description of each activity that is part of the project (ii) the location or locations of each activity (iii) a proposed timetable for carrying out the project (iv) a description of the facilities that are proposed to be used to undertake each activity (v) a description of the actions proposed to be taken, following completion of the project, in relation to those facilities.	Section 4
5A (5) (c)	Describe the existing environment that may be affected by the project.	Section 5
5A (5) (d)	Include details of the particular relevant values and sensitivities (if any) of that environment.	Section 5
5A (5) (e)	Set out the environmental performance outcomes for the project.	Sections 6 and 7
5A (5) (f)	Describe any feasible alternative to the project, or an activity that is part of the project, including: (i) a comparison of the environmental impacts and risks arising from the project or activity and the alternative	Section 4

OPGGS (E) Regulations	Requirements	Relevant Section of OPP
	(ii) an explanation, in adequate detail, of why the alternative was not preferred.	
5A (6)	Requirement to address particular relevant values and sensitivities [as defined in the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)].	Section 5
5A (7)	The proposal must: a) describe the requirements, including legislative requirements, that apply to the project and are relevant to the environmental management of the project b) describe how those requirements will be met.	Sections 2 and 3
5A (8)	The proposal must include: a) details of the environmental impacts and risks for the project b) an evaluation of all the impacts and risks, appropriate to the nature and scale of each impact or risk.	Sections 7 and 8
Regulation 11A Consultation with relevant authorities, persons and organisations, etc		
11A	Consultation with relevant authorities, persons and organisations.	Section 10

1.4.3 Scope

For the purpose of the OPP, the scope of the activity is limited to construction and operation of Scarborough concept in Commonwealth waters only. This includes:

- site preparation surveys (geophysical and geotechnical surveys) at the FPU site and the well locations
- drilling of development wells
- installation of subsea infrastructure, including umbilicals, risers and flowlines from wells to an FPU
- installation, commissioning and operation of a new FPU, with the ability for gas dehydration and compression to transport the gas to shore
- maintenance of all infrastructure for the life of the project
- installation, commissioning and operation of a new approximately 430 km export trunkline transporting Scarborough gas from the FPU to shore – the scope of the OPP will be limited to the Commonwealth jurisdiction and as such cover installation and operation activities up to the State water limits (for approximately 400 km of the trunkline) at which point jurisdiction is under the EP Act and EPBC Act
- decommissioning activities at the end of the Scarborough resource life
- the sourcing of marine sediments from a borrow ground located in Commonwealth waters to be used in trunkline stabilisation activities (in both Commonwealth and State waters).

The development of Scarborough will also require both vessel and helicopter-based support activities for all phases of the offshore development.

The State waters and onshore components of the Project are assessed and approved under other regulatory mechanisms (via the EP Act and EPBC Act), and are not in scope of this OPP.

1.4.4 Structure of the OPP

The structure of this OPP is summarised as follows:

- **Section 0** introduces Scarborough, and outlines the purpose and structure of the OPP.
- **Section 2** describes the Woodside Management System which provides the framework for management, governance and assurance to implement commitments made in the OPP.
- **Section 3** summarises legislative requirements, standards and guidelines relevant to the development of Scarborough.
- **Section 4** describes Scarborough and details key activities (from development drilling through to decommissioning) relevant to environmental impact and risk assessment. This section also provides an assessment of the alternative development concepts and key activities considered in the project development process.
- **Section 5** describes the existing environment for key physical, ecological and socioeconomic values and sensitivities of the Project Area.
- **Section 6** describes the criteria Woodside have used to evaluate the acceptability of the impacts and risks and summarises the EPOs and justifications for the acceptability limits for each receptor.
- **Section 7** evaluates in detail all impacts and risks associated with Scarborough, from both planned and unplanned activities.
- **Section 8** provides an assessment of cumulative impacts.
- **Section 9** outlines the environmental performance framework for the development of Scarborough and describes how commitments made in the OPP will be implemented.
- **Section 10** summarises Woodside's stakeholder consultation methodology, including identification of stakeholders, preliminary engagement undertaken to date, and proposed approach to address feedback received during the public comment process and other future consultation.
- **Section 11** provides citations for all the references used throughout the OPP.

2 WOODSIDE HEALTH, SAFETY AND ENVIRONMENTAL MANAGEMENT SYSTEM

2.1 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, framework of authorities and standards required, that when applied, provides management, governance and assurance. Environmental management is one of the components of the overall WMS.

2.1.1 Environment Policy

Within the WMS, the overall direction for Environment is set through Woodside's corporate Health Safety, Environment and Quality Policy (Figure 2.1). 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 employees, contractors and Joint Venture partners engaging in activities under Woodside operational control.

In addition, Woodside Climate Change Policy Figure 2.2 demonstrates a commitment to be part of a solution to climate change. This includes promoting and pursuing a culture of energy efficiency and improve resources use in designs and operation.

WOODSIDE POLICY

Woodside

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 by the Woodside Petroleum Ltd Board on 7 December 2018

Figure 2.1: Woodside’s corporate Health Safety, Environment and Quality Policy

WOODSIDE POLICY

Woodside

Climate Change Policy

OBJECTIVE

Woodside recognises the scientific consensus on climate change and the challenge of providing safe, clean, affordable and reliable energy whilst reducing emissions. Woodside is committed to being part of the solution.

We believe hydrocarbons will continue to be vital in meeting the world's energy needs and that the benefits of natural gas, in particular, will see it play an increasingly important role globally both in the energy mix and in reducing greenhouse gas emissions.

PRINCIPLES

Woodside will achieve the objective by:

- Promoting natural gas in the global energy mix as a means to reduce greenhouse gas emissions, support renewable energy and improve local air quality
- Promoting and pursuing a culture of energy efficiency and improved resource use in designs and operations
- Supporting our host countries in their endeavours to set emission reduction targets in accordance with internationally accepted science and to achieve these targets using efficient and stable policies
- Supporting lowest cost abatement through global carbon pricing
- Evaluating the resilience of our portfolio and investment decisions to potential changes in global climate policy
- Setting and publishing targets to encourage innovation and drive reductions in our carbon footprint and energy use
- Pursuing greenhouse gas emission reduction technologies with our peers and scientific institutions

APPLICABILITY

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.

Approved by the Woodside Petroleum Ltd. Board on 21 February 2017

Figure 2.2: Woodside's Climate Change Policy

2.2 Woodside HSEMS Standard

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 comprises of four elements: Compass & Policies; Expectations; Processes & Procedures; and Guidelines outlined below (and illustrated in Figure 2.3):

- **Compass & Policies**. Set the enterprise-wide direction for Woodside by governing behaviours, actions and business decisions and ensuring Woodside meet their 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 are required to carry out an activity or a process; and
- **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.

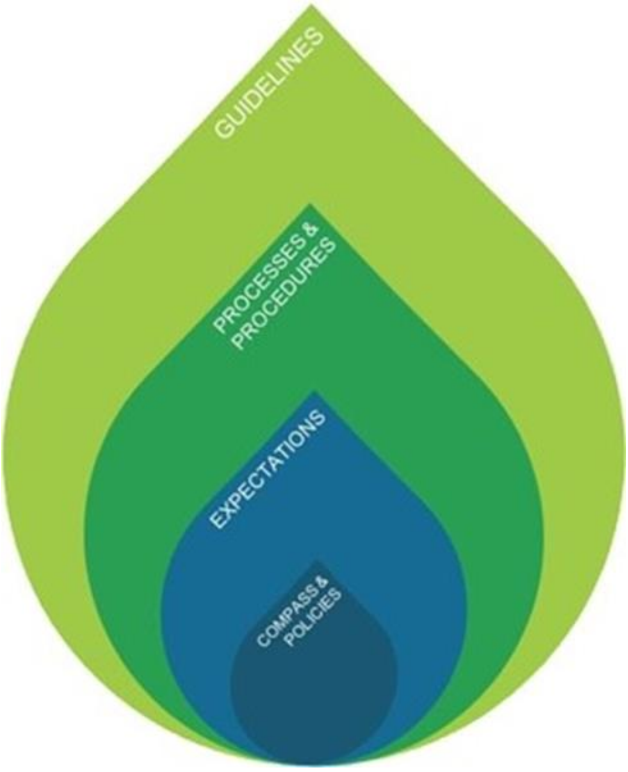


Figure 2.3: The four major elements of the WMS Seed

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 wherever required. These Key Business Activities are grouped into Management, Support and Value Stream activities as shown in Figure 2.4. The Value Stream activities capture, generate and deliver value through the exploration and production (E&P) lifecycle. The management activities influence all areas of the business, while support activities may influence one or more value stream activities.

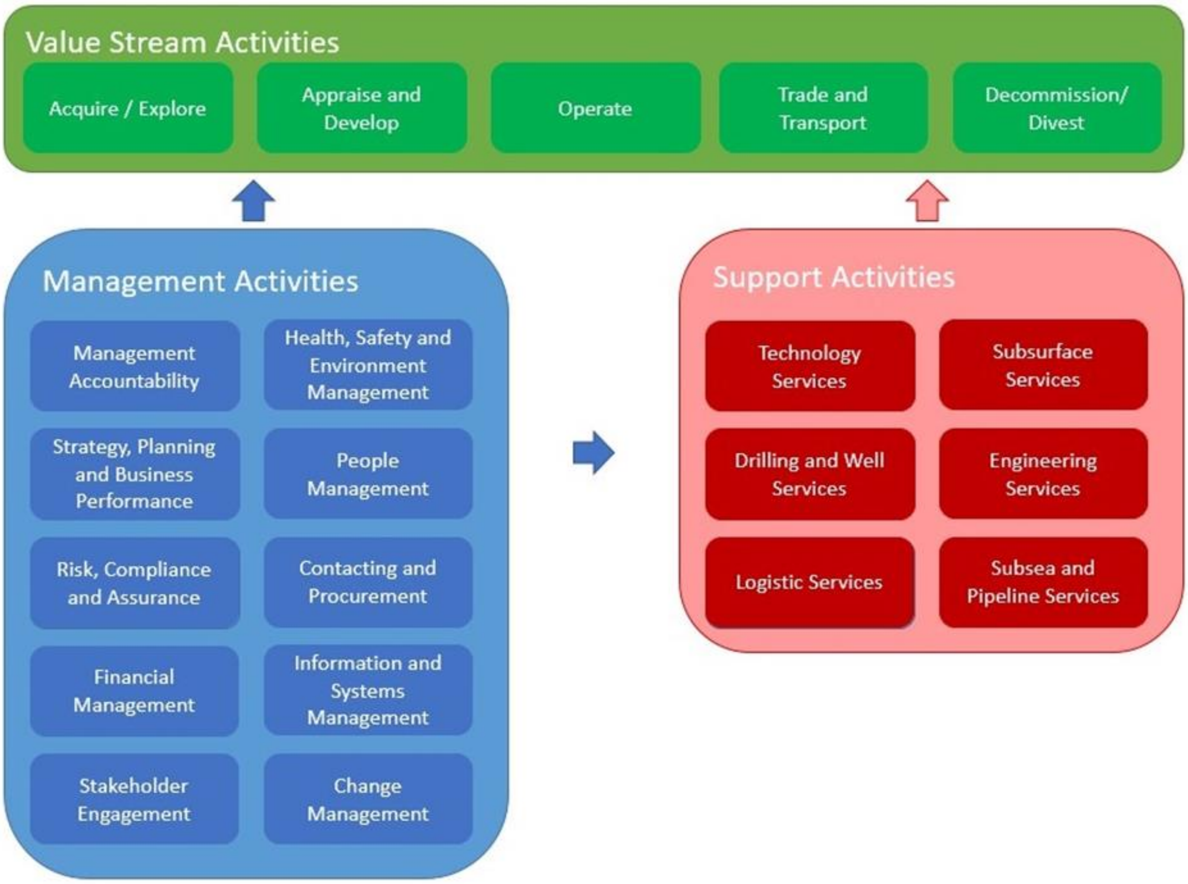


Figure 2.4: The WMS business process hierarchy

2.3 Relationship of the WMS to the OPP

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 the Scarborough OPP and subsequent EPs, will be implemented through a management framework specific to Scarborough, but integrated into the WMS.

3 ENVIRONMENTAL LEGISLATION AND OTHER ENVIRONMENTAL MANAGEMENT REQUIREMENTS

Scarborough is located in Commonwealth waters and therefore falls under Commonwealth jurisdiction. As an offshore petroleum activity being undertaken in Commonwealth waters, Scarborough triggers both the Commonwealth *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (OPGGS Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

3.1 EPBC Act

The EPBC Act is the Commonwealth Government's primary environmental legislation. This is the principal statute for the protection and management of Matters of National Environmental Significance (MNES).

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

Assessment under the EPBC Act, administered by the Department of Environment and Energy (DEE) includes an assessment of the impacts of a proposal on matters of NES listed under Part 3 of the EPBC Act.

However, in 2014, NOPSEMA became the sole Commonwealth regulator for environmental management of offshore petroleum activities following streamlining of regulatory processes under the OPGGS Act (see Section 3.2) and the EPBC Act. The effect of streamlining is that offshore petroleum activities are no longer required to be subject to separate authorisation processes under the OPGGS Act and the EPBC Act.

To allow for streamlining to occur, several changes to the Environment Regulations administered by NOPSEMA were made. This included introducing the Offshore Project Proposal (OPP) authorisation process to allow for public scrutiny and comment on offshore petroleum developments early in the project lifecycle. The OPP process reflects the level of transparency and opportunity for public comment that is provided for as part of the 'Environmental Impact Statement/Public Environmental Review' assessment process under the EPBC Act.

Unlike the EPBC Act assessment process previously applicable to offshore petroleum activities, the OPP assessment process applies to all offshore petroleum activities regardless of the potential level of impact or risk to the environment that the proposal may present.

3.2 OPGGS Act

The OPGGS Act is the principal Act governing offshore petroleum exploration and production in Commonwealth waters. Specific environmental, resource management and safety obligations are set out in associated Regulations:

- Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009
- Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011
- Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Environment Regulations).

Assessment under the OPGGS Act, administered by NOPSEMA, aims to ensure all impacts and risks of a petroleum activity are acceptable and as low as reasonably practicable.

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

Assessment of Scarborough has identified the potential for interaction with whales and other marine fauna. This policy encourages the goal of minimising the likelihood of injury or hearing impairment of whales, based on current scientific understanding. The aim of the policy is to:

- provide practical standards to minimise the risk of acoustic injury to whales in the vicinity of seismic survey operations
- provide 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
- provide guidance to both proponents of seismic surveys and operators conducting seismic surveys about their legal responsibilities under the EPBC Act.

While this policy is applicable to the control of exploration seismic activities, it can be used to control noise from other sources.

3.2.2 Environment Plans

Beyond the OPP, other approvals required under the OPGGS Act and associated regulations include Environment Plans (EPs) and Oil Pollution Emergency Plans (OPEPs).

Under the Environment Regulations, a titleholder is required to have in place an accepted EP before commencing a petroleum activity. The EP 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 EP must include an implementation strategy to demonstrate that the impacts and risks can be managed to ALARP and an acceptable level and to describe how appropriate environmental performance outcomes, standards and measurement criteria outlined in the EP will be met. The EP must also provide a summary of all consultation undertaken with relevant persons. The EPs required in support of Scarborough will address activities related to:

- drilling development wells
- installing subsea infrastructure
- installing, commissioning and operating the FPU
- installing, commissioning and operating a new export trunkline from the FPU to the State water limits
- decommissioning activities at the end of Scarborough resource life.

EPs will be supported with appropriate OPEPs and OSMPs, which are required as a part of an EP's implementation strategy, noting that these may be developed to support a range of activities or phases of a project. The EPs will be submitted and accepted by NOPSEMA before the activities listed above can commence.

Unless an offshore petroleum activity has prior approval under the EPBC Act (pre-2014), an OPP must be accepted by NOPSEMA before the proponent can submit EPs, and other related approvals for activities that make up the project.

3.2.3 Other Petroleum Activity Approvals

In addition to environmental approvals as discussed, the Resource Management and Administration Regulations also require that a Safety Case and a Well Operations Management Plan (WOMP) are assessed and accepted by NOPSEMA for petroleum facilities, along with any relevant licences to support pipelines, infrastructure and production.

Woodside will prepare and submit the required permit applications, Safety Cases and WOMPs to NOPSEMA as the project is developed.

3.3 Other Relevant Commonwealth Legislation

Other Commonwealth legislation that may applicable to the environmental management of the project is outlined in Table 3.1.

Table 3.1: Other relevant Commonwealth legislation

Commonwealth Legislation	Legislation Summary	Relevance to Scarborough
Air Navigation Act 1920 • *Air Navigation Regulations 1947* • *Air Navigation (Aerodrome Flight Corridors) Regulations 1994* • *Air Navigation (Aircraft Engine Emissions) Regulations 1995* • *Air Navigation (Aircraft Noise) Regulations 1984* • *Air Navigation (Fuel Spillage) Regulations 1999*	This Act relates to the management of air navigation.	Applies to helicopter activities undertaken during all phases of the project. Not linked to the control of any impacts and risks under this OPP.
Australian Radiation Protection and Nuclear Safety Act 1998	This Act relates to the protection of the health and safety of people, and the protection of the environment from the harmful effects of radiation.	Radioactive traces may be used during formation evaluation. These sealed radioactive sources are lowered into the well as a part of the well logging tools and removed. Any use of radioactive materials must comply with this Act. Not linked to the control of any impacts and risks under this OPP.
Environment Protection (Sea Dumping) Act 1981 *Environment Protection (Sea Dumping) Regulations 1983*	This Act and associated regulations provide for the protection of the environment by regulating dumping matter into the sea, incineration of waste at sea and placement of artificial reefs.	Sea Dumping Permits will be in place where required. Sea dumping activities will be undertaken in accordance with the act and under permit as required.
Industrial Chemicals (Notification and Assessment Act) 1989	This Act creates a national register of industrial chemicals. The Act also provides for restrictions on the use of certain chemicals which could have harmful effects on the environment or health.	All chemicals used in association with this project will consider the requirements of this act. Not linked to the control of any impacts and risks under this OPP.
National Greenhouse and Energy Reporting Act 2007 (NGER Act)	This Act requires Operators to report on GHG emissions from activities which are under their operational control.	GHG emissions and energy use from offshore facilities will be reported in accordance with the requirements of the NGER Act.

Commonwealth Legislation	Legislation Summary	Relevance to Scarborough
National Environment Protection Measures (Implementation) Act 1998 *National Environment Protection Measures (Implementation) Regulations 1999*	This Act and associated Regulations provide for the implementation of National Environment Protection Measures (NEPMs) to protect, restore and enhance the quality of the environment in Australia and ensure that the community has access to relevant and meaningful information about pollution. The National Environment Protection Council has made NEPMs relating to ambient air quality, the movement of controlled waste between states and territories, the national pollutant inventory, and used packaging materials.	Woodside will meet any requirements of this Act including submission of a greenhouse and energy report as required. Not linked to the control of any impacts and risks under this OPP.
Navigation Act 2012	This Act regulates navigation and shipping including Safety of Life at Sea (SOLAS). Although the Act does not apply to the operation of petroleum facilities, it may apply to some activities of operations support vessels.	Vessel operations undertaken as a part of this activity will adhere to MARPOL and the various Marine Orders (as appropriate to vessel class) enacted under this Act. Applicable requirements are specified as controls to relevant impacts and risks.
Ozone Protection and Synthetic Greenhouse Gas Management Act 1989 *Ozone Protection and Synthetic Greenhouse Gas Management Regulations 1995*	This Act and associated regulations provide for measures to protect ozone in the atmosphere by controlling and ultimately reducing the manufacture, import and export of ozone depleting substances (ODS) and synthetic greenhouse gases, and replacing them with suitable alternatives. The Act will only apply to Woodside if it manufactures, imports or exports ozone depleting substances.	Activities undertaken as a part of this project will adhere to the requirements of this Act including restrictions on import and use of Ozone Depleting Substances (ODS) (in refrigeration and air conditioning equipment) through control measures in procurement. Applicable requirements are specified as controls to relevant impacts and risks.
Protection of the Sea (Prevention of Pollution from Ships) Act 1983 (MARPOL) *Protection of the Sea (Prevention of Pollution from Ships) (Orders) Regulations 1994* • *Marine Orders – Marine Pollution Prevention (Oil)* • *Marine Orders – Marine Pollution Prevention (Noxious liquid substances)* • *Marine Orders – Marine Pollution Prevention (Packaged harmful substances)* • *Marine Orders – Marine Pollution Prevention (Sewage)* • *Marine Orders – Marine Pollution Prevention (Garbage)*	This Act implements into Australian law Australia's obligations under the International Convention for the Prevention of Pollution from Ships (MARPOL Convention). This Act and associated Regulations relate to the protection of the sea from pollution by oil and other harmful substances discharged from ships. Under this Act, discharge of oil or other harmful substances from ships into the sea is an offence. There is also a requirement to keep records of the ships dealing with such substances. The Act applies to all Australian ships, regardless of their location. It applies to foreign ships operating between 3 nautical miles (nm) off the coast out to the end of the Australian Exclusive Economic Zone (200 nm). It also applies within the 3 nm of the coast where the State/Northern Territory does not have complementary legislation.	Vessel operations undertaken as a part of this activity will adhere to MARPOL and associated Marine Orders (as appropriate to vessel class) enacted under this Act. Applicable requirements are specified as controls to relevant impacts and risks.

Commonwealth Legislation	Legislation Summary	Relevance to Scarborough
Protection of the Sea (Harmful Antifouling Systems) Act 2006	This Act implements Australia's obligations under the International Convention on the Control of Harmful Anti-Fouling Systems on Ships (Harmful Anti-Fouling Systems Convention) This Act relates to the protection of the sea from the effects of harmful anti-fouling systems. It prohibits the application or reapplication of harmful anti-fouling compounds on Australian ships or foreign ships that are in an Australian shipping facility.	Vessel operations undertaken as a part of this project will comply with anti-fouling system requirements in accordance with this Act. Applicable requirements are specified as controls to relevant impacts and risks.
Biosecurity Act 2015 *Quarantine Regulations 2000*	This Act provides the Commonwealth with powers to take measures of quarantine, and implement related programs as are necessary, to prevent the introduction of any plant, animal, organism or matter that could contain anything that could threaten Australia's native flora and fauna or natural environment. The Commonwealth's powers include powers of entry, seizure, detention and disposal. This Act includes mandatory controls on the use of seawater as ballast in ships and the declaration of sea vessels voyaging out of and into Commonwealth waters. The Regulations stipulate that all information regarding the voyage of the vessel and the ballast water is declared correctly to the quarantine officers.	The project will comply with biosecurity requirements in accordance with this Act. This will include biofouling and ballast water requirements for vessels, offshore facilities and associated in-water equipment. Applicable requirements are specified as controls to relevant impacts and risks.
Australian Heritage Council Act 2003	This Act identifies areas of heritage value, including those listed on the World Heritage List, National Heritage List and the Commonwealth Heritage List. The Act also establishes the Australian Heritage Council and its functions.	The project will take into consideration any heritage values in the area.
Historic Shipwrecks Act 1976 and Historic Shipwrecks Regulations 1978	This Act protects shipwrecks that have lain in territorial waters for 75 years or more. It is an offence to interfere with any shipwreck covered by the Act.	There are no planned activities associated with this project which will result in any interference with a shipwreck.
Hazardous Waste (Regulation of Exports and Imports) Act 1989	This Act regulates the export and import of hazardous waste to ensure that hazardous waste is disposed of safely so human beings and the environment, both within and outside Australia, are protected from the harmful effects of the waste.	Project will comply with the requirements of this act with regard to export of hazardous waste.

3.4 Commonwealth Policies and Guidelines

The following are Commonwealth Government policies and guidelines that are relevant to petroleum activities in Commonwealth waters.

3.4.1 Australian Offshore Petroleum Development Policy

This 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. 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, as described in Section 3.2.

3.4.2 Australia's Ocean Policy

Australia's Oceans Policy, introduced in 1998, is a framework for integrated and ecosystem-based planning and management for Australia's marine jurisdictions. Building on the existing effective sectoral and jurisdictional mechanisms, the policy promotes ecologically sustainable development (ESD) of the resources of our oceans and the encouragement of 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 to:

- exercise and protect Australia's rights over its marine jurisdictions
- meet its obligations under the United Nations Convention on the Law of the Sea 1982 (UNCLOS)
- understand and protect the marine environment.

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

3.4.3 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. The Plans provide information on conservation values and the current and emerging pressures within each region, as well as describing conservation priorities and measures for the region. The Marine Bioregional Plans are a source of information for Government and industry to improve the way the marine environment is managed and protected (Commonwealth of Australia 2012b). The Marine Bioregional Plans:

- 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.

The Marine Bioregional Plans improve the understanding of Australian oceans by providing a consolidated picture of the biophysical characteristics and the diversity of marine life (Commonwealth of Australia 2012b). The four Marine Bioregional Plans that have been developed are South-west, North-west, North and Temperate East. Scarborough lies within the North-west Marine Region. The Minister will take into consideration the Marine Bioregional Plans in making an approval decision, with particular focus on Key Ecological Features (KEFs) identified within Section 5.

3.4.4 Australian Ballast Water Management Requirements 2017

Scarborough will make use of vessels deployed from both Australian and international ports. The Australian Ballast Water Management Requirements (DAWR, 2017, version 7), provide guidance on how vessel operators should manage ballast water when operating within Australian seas in order to comply with the Biosecurity Act 2015. They also align to the International Convention for the Control and Management of Ships' Ballast Water and Sediments 2004 (the Ballast Water

Management Convention), which entered into force internationally on 8 September 2017. 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 favour of other approved methods of ballast water management, 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 fresh water 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.

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

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

3.4.6 Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000

These Guidelines are intended to provide Government, industry, consultants and community groups with a comprehensive set of tools that will enable the assessment and management of 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.

3.5 EPBC Management Plans

3.5.1 Listed Threatened Species Management/Recovery Plans and Conservation Advices

While unlikely to be significant, the development of Scarborough may trigger risks 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 OPP. Recovery plans are enacted under the EPBC Act and remain in force until the species is removed from the threatened species list. Conservation advice provides guidance on immediate recovery and threat abatement activities that can be undertaken to facilitate the conservation of a listed species or ecological community.

Table 3.2 outlines the management/recovery plans and conservation advices relevant to those species identified as potentially occurring or having habitat within the Scarborough Project Area. The table also summarises the key threats to those species, as described in relevant management/recovery plans and conservation advices.

The management/recovery plans and conservation advices have been taken into consideration in assessing the impacts and risks associated with the project (Section 7) and will be further incorporated into implementation planning in activity-specific EPs.

Table 3.2: Summary of EPBC management/recovery plans and conservation advices relevant to the project

Species/ Sensitivity	Recovery plan/ conservation advice (date issued)	Key threats identified in the recovery plan/ conservation advice	Relevant Conservation Actions
All Vertebrate Fauna			
All Vertebrate Fauna	Threat abatement plan for the impacts of marine debris on vertebrate marine life (DEWHA, 2009)	Marine debris	No explicit management actions for non-fisheries related industries (note that management actions in the plan relate largely to management of fishing waste (e.g. "ghost" gear), and state and Commonwealth management through regulation).
Marine Mammals			
Sei Whale	Conservation advice *Balaenoptera borealis* sei whale (TSSC, 2015a)	Noise interference	Once the spatial and temporal distribution (including biologically important areas) of sei whales is further defined an assessment of the impacts of increasing anthropogenic noise (including from seismic surveys, port expansion, and coastal development) should be undertaken on this species
		Vessel disturbance	Ensure all vessel strike incidents are reported in the National Vessel Strike Database.
Blue Whale	Conservation management plan for the blue whale: *A recovery plan under the Environment Protection and Biodiversity Conservation Act 1999* 2015–2025 (Commonwealth of Australia, 2015a)	Noise interference	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.
			EPBC Act Policy Statement 2.1—Interaction between offshore seismic exploration and whales is applied to all seismic surveys.
		Vessel disturbance	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
Fin Whale	Conservation advice *Balaenoptera physalus* fin whale (TSSC, 2015b)	Noise interference	Once the spatial and temporal distribution (including biologically important areas) of fin whales is further defined, assess the impacts of increasing anthropogenic noise (including seismic surveys, port expansion, and coastal development).
		Vessel disturbance	Develop a national vessel strike strategy that investigates the risk of vessel strikes on fin whales and identifies potential mitigation measures.

Species/ Sensitivity	Recovery plan/ conservation advice (date issued)	Key threats identified in the recovery plan/ conservation advice	Relevant Conservation Actions
			Ensure all vessel strike incidents are reported in the National Vessel Strike Database.
Humpback Whale	Approved Conservation Advice for *Megaptera novaeangliae* (humpback whale) (TSSC, 2015c)	Noise interference	For actions involving acoustic impacts (example pile driving, explosives) on humpback whale calving, resting, feeding areas, or confined migratory pathways, undertake site-specific acoustic modelling (including cumulative noise impacts).
		Vessel disturbance	Ensure the risk of vessel strike on Humpback Whales is considered when assessing actions that increase vessel traffic in areas where humpback whales occur and, if required appropriate mitigation measures are implemented to reduce the risk of vessel strike.
Reptiles			
Loggerhead Turtle, Hawksbill Turtle, Green Turtle, Olive Ridley Turtle, Flatback Turtle and Leatherback Turtle	Recovery plan for marine turtles in Australia (DoEE, 2017)	Vessel disturbance	Vessel interactions identified as a threat; no specific management actions in relation to vessels prescribed in the plan.
		Light pollution	Minimise light pollution.
			Identify the cumulative impact on turtles from multiple sources of onshore and offshore light pollution.
		Acute chemical discharge (oil pollution)	Ensure spill risk strategies and response programs include management for turtles and their habitats.
Leatherback Turtle	Approved conservation advice for *Dermochelys coriacea* (Leatherback Turtle) (TSSC, 2008a)	Vessel disturbance	No explicit relevant management actions; vessel strikes identified as a threat.
Short-nosed Seasnake	Approved Conservation Advice for *Aipysurus apraefrontalis* (Short-nosed Seasnake) (DSEWPaC, 2011).	Habitat loss, disturbance and modification	Monitor known populations to identify key threats. Ensure there is no anthropogenic disturbance in areas where the species occurs, excluding necessary actions to manage the conservation of the species.
Sharks and Rays			
Great White Shark	Recovery plan for the White Shark (*Carcharodon carcharias*) (DSEWPaC 2013a)	No additional threats identified (ex. marine debris)	None applicable.

Species/ Sensitivity	Recovery plan/ conservation advice (date issued)	Key threats identified in the recovery plan/ conservation advice	Relevant Conservation Actions
Dwarf Sawfish, Queensland Sawfish	Approved conservation advice for *Pristis clavata* (Dwarf Sawfish) (TSSC, 2009)	Habitat degradation/ modification	No explicit relevant management actions; habitat loss, disturbance and modification identified as threats.
	Sawfish and river shark multispecies recovery plan (Commonwealth of Australia, 2015b)		Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks.
Green Sawfish, Dindagubba, Narrowsnout Sawfish	Approved conservation advice for Green Sawfish (TSSC, 2008b)	Habitat degradation/ modification	No explicit relevant management actions; habitat loss, disturbance and modification identified as threats.
	Sawfish and river shark multispecies recovery plan (Commonwealth of Australia, 2015c)		Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks.
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish	Approved Conservation Advice for *Pristis* (Largetooth Sawfish) (DoE, 2014).	Habitat degradation/ modification	Implement measures to reduce adverse impacts of habitat degradation and/or modification.
Whale Shark	Conservation advice *Rhincodon typus* (Whale Shark) (TSSC, 2015d)	Vessel disturbance	Minimise offshore developments and transit time of large vessels in areas close to marine features likely to correlate with Whale shark aggregations and along the northward migration route that follows the northern Western Australian coastline along the 200 m isobath.
	Whale Shark (*Rhyncodon typus*) recovery plan 2005–2010 (DEH, 2005)	Habitat degradation/ modification	No explicit relevant management actions; seasonal aggregations of Ningaloo recognised as important habitat.
Grey Nurse Shark (west coast population)	Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (DoEE, 2014)	No additional threats identified (ex. marine debris)	None applicable.
Seabirds			
Red Knot	Conservation advice *Calidris canutus* (Red Knot) (TSSC, 2016a)	Habitat degradation/ modification	No explicit relevant management actions; oil pollutions recognised as a threat.
Curlew Sandpiper	Conservation advice *Calidris ferruginea* (Curlew Sandpiper) (TSSC, 2015f)	Habitat degradation/ modification (oil pollution)	No explicit relevant management actions; oil pollutions recognised as a threat.
Bar-tailed Godwit (Western Alaskan)	Conservation advice *Limosa lapponica baueri* (Bar-tailed Godwit (Western Alaskan)) (TSSC, 2016b)	Habitat degradation/ modification	No explicit relevant management actions; oil pollutions recognised as a threat.

Species/ Sensitivity	Recovery plan/ conservation advice (date issued)	Key threats identified in the recovery plan/ conservation advice	Relevant Conservation Actions
Bar-tailed Godwit (Northern Siberian)	Conservation advice *Limosa lapponica menzbieri* (Bar-tailed Godwit (Northern Siberian)) (TSSC, 2016c)	Habitat degradation/ modification	No explicit relevant management actions; oil spills recognised as a threat.
Australian Fairy Tern	Conservation advice for *Sterna nereis* (Fairy Tern) (TSSC, 2011)	Habitat degradation/ modification (oil pollution)	Ensure appropriate oil-spill contingency plans are in place for the subspecies' breeding sites which are vulnerable to oil spills.
Eastern Curlew, Far Eastern Curlew	Conservation Advice for *Numenius madagascariensis* (Eastern Curlew) (DotE, 2015)	Habitat loss, disturbance and modification	Manage disturbance at important sites when the species is present.
Australian Painted Snipe	Approved Conservation Advice for *Rostratula australis* (Australian Painted Snipe). (DSEWPaC, 2013a)	Habitat loss, disturbance and modification	Ensure there is no disturbance in areas where the species is known to breed.
Greater Sand Plover, Large Sand Plover	Conservation Advice for *Charadrius leschenaultii* (Greater Sand Plover). (TSSC, 2016e)	Habitat loss and degradation Pollution and contamination impacts	Manage disturbance at important sites which are subject to anthropogenic disturbance when the species is present.
Great Knot	Conservation Advice for *Calidris tenuirostriss* (Great Knot) (TSSC, 2016d)	Habitat loss, disturbance and modification	Manage disturbance at important sites which are subject to anthropogenic disturbance when the species is present.
Common Sandpiper, Red Knot, Oriental Plover, Oriental Pratincole, Bar-tailed Godwit, Common Greenshank	Wildlife conservation plan for migratory shorebirds (DoEE, 2015a)	Habitat degradation/ modification (oil pollution)	No explicit relevant management actions; oil spills recognised as a threat.

3.5.2 Australian Marine Parks

Under the EPBC Act, Australian Marine Parks (AMPs), formally known as Commonwealth Marine Reserves, 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, include those listed in Table 3.3.

Table 3.3: Marine Parks that occur within or near the Project Area

Marine Park	Distance from Project Area (km)	IUCN Protected Area Category
Montebello	Overlap	VI (Multiple Use Zone)

Dampier[3]	Adjacent to Borrow Ground Project Area	II (National Park Zone), IV (Habitat Protection Zone) & VI (Multiple use Zone)
Gascoyne	87	II (National Park Zone), IV (Habitat Protection Zone) & VI (Multiple use Zone)
Ningaloo	186	IV (Habitat Protection Zone)

Scarborough will include construction of approximately 80 km of pipeline through the Montebello Marine Park Multiple Use Zone, as well as inspection maintenance and repair (IMR) activities along the pipeline once operational. Mining operations may be undertaken in the Montebello Multi Use Zone (MUZ) (VI) if authorised by a policy, plan or program endorsed under Part 10 of the EPBC Act ("strategic assessment") and conducted in accordance with that authorisation and a class approval issued under the North-West Marine Parks Network Management Plan (Plan). A class approval permitting mining operations and greenhouse gas activities was issued specifically under this Plan dated 28 June 2018 https://parksaustralia.gov.au/marine/pub/class-approvals/North-west_Marine_Parks_Network.pdf, which includes the Montebello Marine Park MUZ as an Approved Zone.

As these activities will be covered within a future environment plan(s), they do not require any further assessment by the Director of National Parks (DNP). However, the DNP will still be a relevant person for consultation under an OPP/EP with regard to activities in a marine park.

In addition to the identified Management Principles, activities must be undertaken in a manner that is consistent with the objectives of the zone, 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.

Australian IUCN Reserve Management Principles for each category are set out in the Environment Protection and Biodiversity Conservation (EPBC) Regulations and are summarised in Table 3.4.

The values of the marine parks are described in Section 5.6.

[3] Currently included to support option to use adjacent borrow ground. Reference to this AMP will be removed if option is not carried forward.

Table 3.4: Australian IUCN reserve management principles

Category II: National Park: Protected Area managed mainly for ecosystem conservation and recreation	Category IV: Habitat/Species Management Area: Protected Area managed mainly for conservation through management intervention	Category VI: Managed Resource Protected Areas: Protected Area managed mainly for the sustainable use of natural ecosystems
3.01 The reserve or zone should be protected and managed to preserve its natural condition according to the following principles. 3.02 Natural and scenic areas of national and international significance should be protected for spiritual, scientific, educational, recreational or tourist purposes. 3.03 Representative examples of physiographic regions, biotic communities, genetic resources, and native species should be perpetuated in as natural a state as possible to provide ecological stability and diversity. 3.04 Visitor use should be managed for inspirational, educational, cultural and recreational purposes at a level that will maintain the reserve or zone in a natural or near natural state. 3.05 Management should seek to ensure that exploitation or occupation inconsistent with these principles does not occur. 3.06 Respect should be maintained for the ecological, geomorphologic, sacred and aesthetic attributes for which the reserve or zone was assigned to this category. 3.07 The needs of indigenous people should be taken into account, including subsistence resource use, to the extent that they do not conflict with these principles. 3.08 The aspirations of traditional owners of land within the reserve or zone, their continuing land management practices, the protection and maintenance of cultural heritage and the benefit the traditional owners derive from enterprises, established in the reserve or zone, consistent with these principles should be recognised and taken into account.	5.01 The reserve or zone should be managed primarily, including (if necessary) through active intervention, to ensure the maintenance of habitats or to meet the requirements of collections or specific species based on the following principles. 5.02 Habitat conditions necessary to protect significant species, groups or collections of species, biotic communities or physical features of the environment should be secured and maintained, if necessary, through specific human manipulation. 5.03 Scientific research and environmental monitoring that contribute to reserve management should be facilitated as primary activities associated with sustainable resource management. 5.04 The reserve or zone may be developed for public education and appreciation of the characteristics of habitats, species or collections and of the work of wildlife management. 5.05 Management should seek to ensure that exploitation or occupation inconsistent with these principles does not occur. 5.06 People with rights or interests in the reserve or zone should be entitled to benefits derived from activities in the reserve or zone that are consistent with these principles. 5.07 If the reserve or zone is declared for the purpose of a botanic garden, it should also be managed for the increase of knowledge, appreciation and enjoyment of Australia's plant heritage by establishing, as an integrated resource, a collection of living and herbarium specimens of Australian and related plants for study, interpretation, conservation and display.	7.01 The reserve or zone should be managed mainly for the sustainable use of natural ecosystems based on the following principles. 7.02 The biological diversity and other natural values of the reserve or zone should be protected and maintained in the long term. 7.03 Management practices should be applied to ensure ecologically sustainable use of the reserve or zone. 7.04 Management of the reserve or zone should contribute to regional and national development to the extent that this is consistent with these principles.

3.6 International Agreements

Australia is a signatory to several international conventions and agreements relevant to environmental protection. Those relevant to Commonwealth legislation that may apply to Scarborough 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 or 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 Organisation 1948
- International Convention for the Prevention of Pollution from Ships, London, 1973/1978 (commonly known as MARPOL 73/78)
- International Convention on Harmful Anti Fouling Systems 2001 (AFS Convention)
- 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 or 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)
- Rotterdam Convention a multilateral treaty to promote shared responsibilities in relation to importation of hazardous chemicals
- 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 or ROKAMBA)
- The Convention on the International Regulations for Preventing Collisions at Sea 1972 (COLREGS)
- UNCLOS
- United Nations Framework Convention on Climate Change 1992.

4 DESCRIPTION OF THE PROJECT AND ALTERNATIVES ANALYSIS

4.1 Project Overview

The Scarborough and North Scarborough gas fields are located 375 km west-north-west of the Burrup Peninsula in the northwest of Australia within offshore petroleum permits WA-1-R and WA-62-R. The Thebe and Jupiter fields, which may provide opportunities for future tie-back options, are located to the north and north-east of the Scarborough and North Scarborough gas fields, within offshore permits WA-63-R and WA-61-R respectively (Figure 4.1). These potential future field tie-back options are included as part of the overall Scarborough Offshore Project Proposal. As the proposed export trunkline route crosses the Carnarvon Basin, in close proximity to other undeveloped fields, Woodside is also engaging with other resource owners to explore opportunities for future development. Any future development opportunities will be undertaken in accordance with the environmental legislative requirements in force at that time.

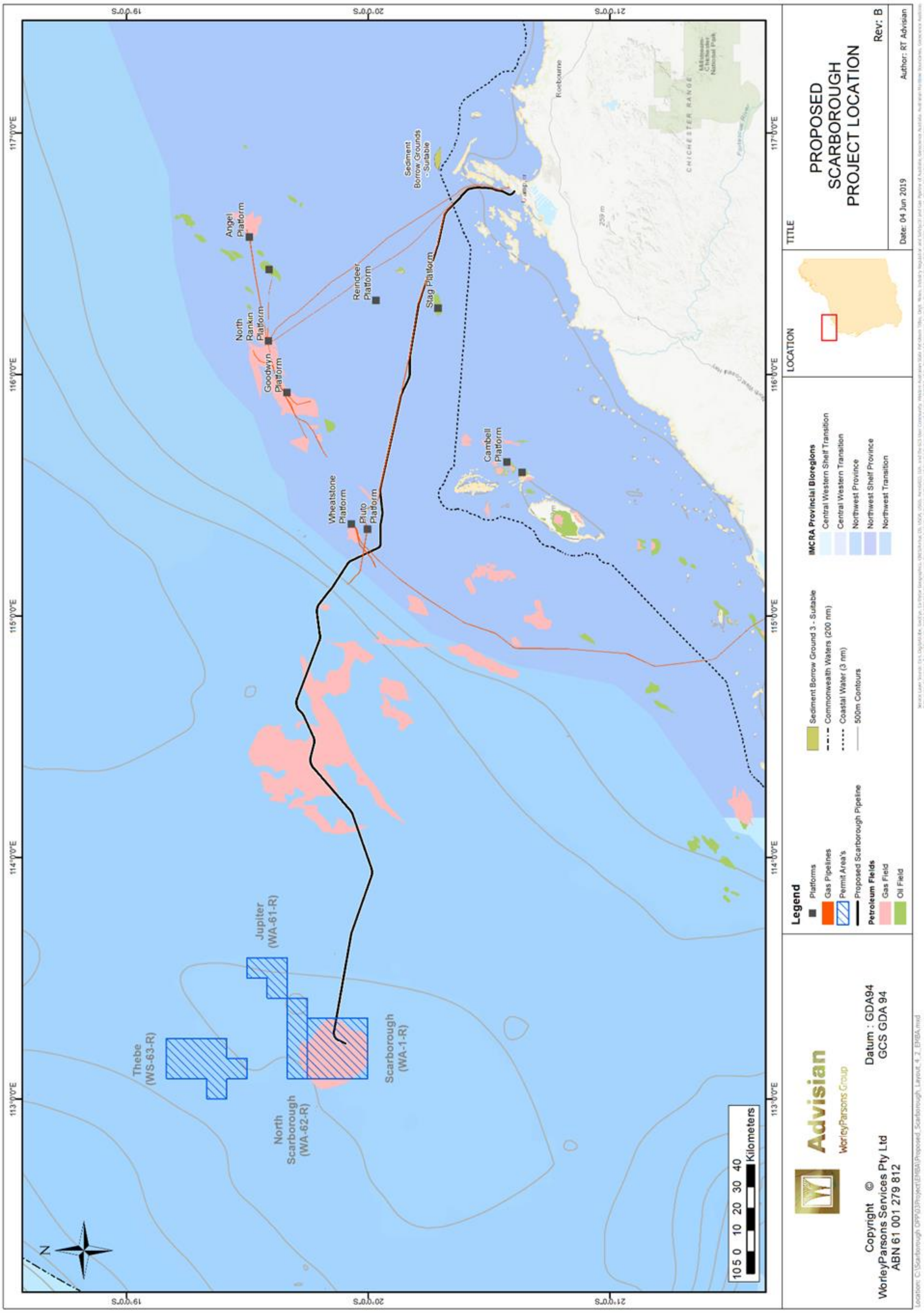


Figure 4.1: Proposed Scarborough and trunkline location

The proposed development of Scarborough includes drilling of multiple subsea gas wells (which includes wells in the Scarborough, North Scarborough, Thebe and Jupiter gas fields). Wells will be tied back to an FPU moored in about 900 m of water, over the Scarborough field. Woodside proposed that the FPU topsides has processing facilities for gas dehydration and compression to transport the gas through an approximately 430 km long trunkline to a proposed brownfield expansion of the existing Pluto LNG onshore facility (Pluto Train 2) (outside the scope of this Proposal).

The key characteristics of Scarborough are outlined in Table 4.1.

Table 4.1: Key project characteristics for Scarborough

Criteria	Key Characteristics of the Development
Proponent	Woodside Energy Ltd (Woodside) for and on behalf of the Scarborough Joint Venture (SJV) consisting of Woodside and BHP Billiton Petroleum (North West Shelf) Pty Ltd (BHP NWS)
Field Location	375 km WNW of the Burrup Peninsula in the North West of Australia
Offshore Permits	WA-1-R (Scarborough field) WA-62-R (North Scarborough field) WA-63-R (Thebe field) WA-61-R (Jupiter field) With potential for other future tie-ins in the vicinity of these permits
Anticipated Hydrocarbon	Dry gas (i.e. trace or no condensate expected) No detectable hydrogen sulphide (H_2S) and extremely low reservoir CO_2 (~0.1 mol%) compared with other oil and gas reservoirs.
Key Project Phases	Development and infill drilling Subsea infield infrastructure installation FPU and installation Trunkline installation (including crossing of existing trunklines) Commissioning activities Operation Decommissioning
Proposed Number of Wells	Anticipated that a number of wells will be drilled in two phases in the Scarborough reservoir. As an estimate only, this may include up to 20 wells: • proposed seven wells at start up • up to 13 future wells (including wells for subsequent tiebacks of other reservoirs including Thebe (8 wells) and Jupiter (2 wells). • While not currently planned, the assessment carries a contingency of 10 additional wells should this be requirement for the development.
Subsea Infrastructure	Infield infrastructure, including; wellheads, manifolds, flowlines and umbilicals, export trunkline and communications lines.
Surface Infrastructure	Minimally manned FPU in approximately 900 m of water to the southeast of the WA-1-R permit area
Trunkline Installation Techniques	Trenching and backfill
Final Investment Decision – Woodside target	2020
Ready for Start Up – Woodside target	2023
Project life[1]	2055

[1] If additional or third-party reservoirs have been tied into Scarborough infrastructure, this could increase the project's economic life.

4.1.1 Project Schedule

Woodside is proposing to conduct FEED activities in 2019 to support the Operator's targeted Final Investment Decision (FID) in 2020, as well as obtaining all primary approvals. Woodside's target schedule for Scarborough is included in Table 4.2.

Table 4.2: Woodside's target preliminary schedule

Phase	Timing
Select/Definition (Pre-FEED)	2018
Primary Environmental Approvals	End of 2019
Front End Engineering Design (FEED)	FEED activities will be conducted in 2019 to be ready for FID in 2020
Final Investment Decision (FID)	2020
Drilling	2020 Phase 1 2025 Phase 2 (potentially including Thebe and Jupiter) ***Note that timing will be dependent on reservoir performance***
FPU Installation	2023
Trunkline Installation	2022
Ready for Start-Up (RFSU)	2023
Decommissioning[1]	2055 (estimation only)

[1] Note decommissioning may occur in stages, and if additional or third-party reservoirs have been tied into Scarborough infrastructure, this could increase the project's economic life and thus postpone decommissioning.

4.2 Project Location

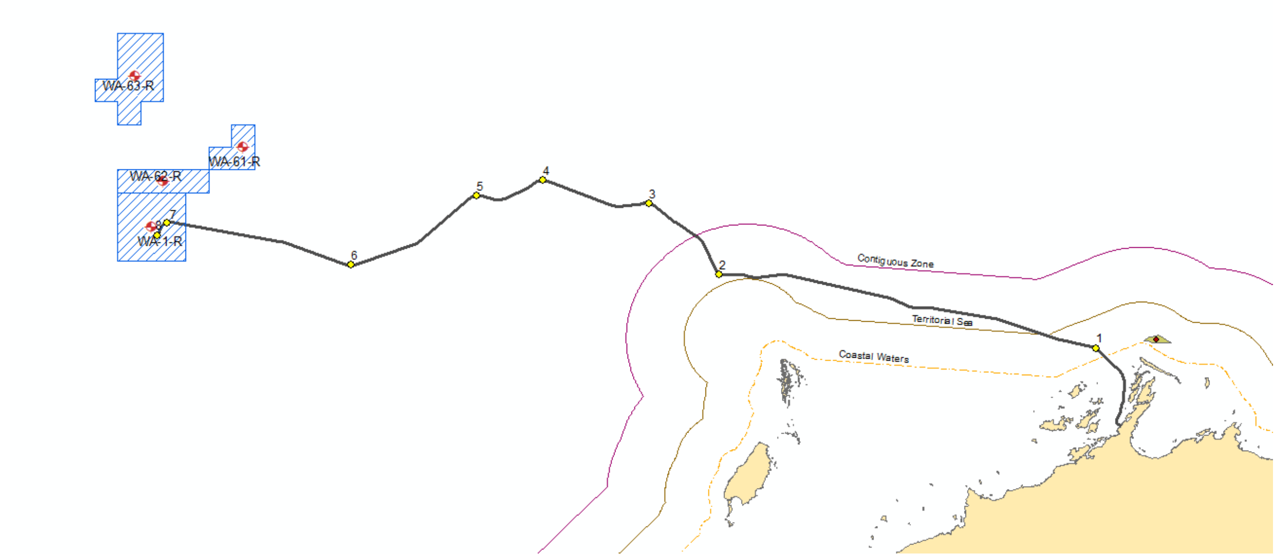
The proposed Scarborough and North Scarborough fields are located in permit area WA-1-R and WA-62-R, in Commonwealth waters approximately 375 km north west off the Burrup Peninsula in the North West of Australia. Water depths within WA-1-R range between 900 m to 1000 m. Wells may also be drilled and tied back to the FPU from the Thebe and Jupiter fields, located in petroleum permits WA-63-R and WA-61-R respectively.

All subsea and subsurface infield infrastructure and wells are located in Commonwealth waters. The trunkline from the FPU to shore will be the only part of the proposed development which traverse into State waters. The proposed trunkline route is shown in Figure 4.1. The location at which the trunkline will cross into State waters is about 20 km north-west from the shore and in water depths of 31 m.

Table 4.3 presents the location of the key Scarborough infrastructure.

Table 4.3: Approximate location details for key infrastructure

Site/Location	Coordinates (MGA94(50))	
	Longitude	***Latitude***
FPU	113.242°E	-19.926°S
WA-1-R Centre point	113.210°E	-19.874°S
WA-61-R Centre point	113.543°E	-19.582°S
WA-62-R Centre point	113.251°E	-19.707°S
WA-63-R Centre point	113.147°E	-19.322°S
Trunkline Point 1	116.669°E	-20.321°S
Trunkline Point 2	115.291°E	-20.050°S
Trunkline Point 3	115.034°E	-19.789°S
Trunkline Point 4	114.642°E	-19.704°S
Trunkline Point 5	114.399°E	-19.761°S
Trunkline Point 6	113.939°E	-20.016°S
Trunkline Point 7	113.264°E	-19.860°S
Trunkline Point 8	113.230°E	-19.906°S
Sediment Borrow Grounds - Suitable	116.769°E	-20.468°S



4.2.1 Definition of Project Area

For the purpose of this OPP, the Project Area has been defined to consist of the Offshore Project Area (for the Scarborough, North Scarborough, Thebe and Jupiter fields), the Trunkline Project Area to the State water limits and the Borrow Ground Project Area, as shown in Figure 4.3. This Project Area has been considered to include the extent of all planned activities described in this proposal with sufficient buffer.

The Project Area will accommodate the movement of vessels around the offshore facilities during installation, commissioning and operation. However, the OPP does not include the transit of vessels to or from the offshore locations. These activities are undertaken in accordance with maritime legislation including the Commonwealth *Navigation Act 2012*.

The OPP does not consider any activities undertaken in State waters or onshore. These activities will be assessed under the relevant State and Commonwealth legislation.

4.3 Hydrocarbon Characteristics

The Scarborough gas resource contains about 9 trillion cubic feet (Tcf) of gas which is classified as 'dry' with only trace levels of condensate, and 'sweet' with no detectable H_2S and <0.01 mol% of CO_2.

Understanding of the Scarborough gas composition was supported by information collected from reservoir samples and well tests obtained from the SC-4 and SC-5 appraisal wells, and compositional analysis undertaken in 2018. The Scarborough gas composition is provided in Table 4.4.

Table 4.4: Scarborough gas composition

Component	Composition Range (mol%)
Carbon dioxide	0.01 to 0.06
Nitrogen	4.3 to 5.6
Methane	94.2 to 95.5
Ethane	0.06 to 0.1
Propane +	0.002 to 0.01

Table 4.5: Scarborough contaminants [S1, S4, S8]

Contaminant	Maximum Concentration	Units
BTEX	<1	ppm
Hydrogen Sulphide (H_2S)	<0.2	ppm
Mercaptans	<0.2	ppm
Mercury (Hg)	30	ug/m³
Arsenic (As)	<0.005	mg/m³
Helium (He)	0.025	mol %
Hydrogen (H_2)	0.018	mol %
Radon (Rn)	300	Bq/m³

The development of Scarborough considers future tie-in to adjacent fields including the Thebe and Jupiter fields. These fields are expected to be of a similar composition to the Scarborough gas resource.

4.4 Development Infrastructure

The key infrastructure components of Scarborough include wells, subsea infrastructure, the FPU and export trunkline. These are discussed in Section 4.4.2.

4.4.1 Future Development

The project is designed to accommodate future tie-back opportunities including Thebe and Jupiter gas fields and potentially other resources owned either by Woodside or other resource owners. Any future development opportunities will be undertaken in accordance with the environmental legislative requirements in force at that time.

Provision for tie-in to the FPU, such as spare riser slots and preinstalled tees in the export pipeline, is part of the current design of Scarborough. The infrastructure to support Thebe and Jupiter field development is likely to comprise development wells and subsea infrastructure such as manifolds, possibly subsea compression and flowlines. While the design of these facilities is not yet matured, consideration of the activities is within the scope of the assessment in this OPP.

4.4.2 Current Infrastructure Design

4.4.2.1 Wells

It is anticipated that Scarborough will require a number of development wells to be drilled in the target reservoirs over the life of the project. The number and location of these wells will depend on reservoir target areas, seabed bathymetry and features to optimise reservoir recovery. Pressure and saturation changes in the reservoir will be monitored over the life of the Project. Data will be used to inform decisions regarding reservoir management.

Each well will be topped by a wellhead, which provides means of hanging the production well casing, and installing the christmas tree and well flow control facilities. Each well is then fitted with a christmas tree which enables reservoir fluids to flow from the well to the flowlines. Christmas trees are used to:

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

Wells will be grouped into drill centres, thereby optimising the layout of wells. For future tie-ins of the Thebe and Jupiter gas fields, it is likely that one drill centre for each field will be required. While the exact location of the wells has not yet been determined, they are proposed be located with the permit areas as identified in Figure 4.1.

4.4.2.2 Subsea Infrastructure

The drill centres are connected to manifolds by well jumpers to allow reservoir fluids to be carried. Connection between the flowlines and the FPU is achieved using flexible risers through a riser base manifold.

Subsea infrastructure is powered, monitored and controlled from the FPU facilities using a network of electro-hydraulic control umbilicals and subsea distribution units (SDUs). Wells are serviced by static umbilicals likely to follow the same route as the infield flowlines, the static umbilicals are tied back to the FPU using a dynamic umbilical. A telecommunications fibre optic cable will connect the FPU and associated subsea infrastructure to shore. This line would most likely follow the path of the Export Trunkline, though details regarding installation and operation will be determined during detailed engineering design.

Other subsea infrastructure includes FPU mooring anchors and the riser base manifold.

All subsea infrastructure types described above will be located in Commonwealth waters.

The total extent of seabed required for the installation of subsea infrastructure for Scarborough is estimated at about 0.234 km^2. This total area is subject to refinement during the design process, but a 50% contingency has been added to represent a conservative maximum extent (Table 4.6).

Table 4.6: Approximate extent of seabed disturbance for infield subsurface disturbance[4]

Infrastructure	Area (km²)
Scarborough Field	
FPU and infield infrastructure (flowlines, umbilicals, in-line tees (ILTs), risers and anchors, flowlines)	0.038
Jupiter and Thebe Field	
Flowlines and interfield lines	0.090
Total Disturbance	***0.156***
Total Disturbance with 50% contingency	***0.234***

4.4.2.3 Floating Production Unit

The FPU will be a semi-submersible platform installed over the Scarborough field, in approximately 900 m water depth. Table 4.7 presents preliminary main characteristic of the FPU. The FPU will provide all necessary systems and utilities to support gas compression and exporting to shore. MEG will be continuously injected into the subsea gathering system to prevent hydrate formation. The MEG will be regenerated and stored on the FPU and pumped to the subsea and topsides injection points as required.

The Scarborough FPU is currently being designed so that the facility would be manned by the minimum number of personnel required to operate safely, with the ability for remote control operations. If required, additional personnel would be transferred to the FPU to complete maintenance on the facility.

The FPU is envisaged as a production hub for other resources in the area. The Thebe and Jupiter gas fields provide opportunities for future tie backs via subsea flowlines to the Scarborough FPU.

Table 4.7: Floating Production Unit (FPU) preliminary main characteristics[5]

Characteristic	Unit	Value
Hull type		Conventional semi-submersible
Deck Dimensions (L x W x H)	m-m-m	2 @ 70 x 70 x 13
Draft	m	28
Mooring radius	m	1,400
Maximum POB	persons	75

The FPU will be maintained on location by a semi-taut mooring system. The mooring lines will be preferentially secured to the seabed by suction piles. The suction piles will typically be 6 to 10 m in diameter and about 30 m in length, with each weighing about 400 tonnes. It is anticipated that up to 20 piles may be required. While the base case is for the use of suction piles, the option to use driven piles will be carried depending on seabed conditions.

The topsides process configuration has been selected in line with the current minimum manning and remote control of FPU operation philosophies. The FPU topsides process functionality will include:

- inlet reception facilities for wet well fluids
- gas/liquid separation

[4] Note that this will be subject to change during FEED

[5] Note these may be subject to change during FEED

- gas conditioning (dehydration and hydrocarbon dew-pointing)
- dry gas export compression
- MEG Recovery Unit including regeneration and reclamation, storage and pumping
- MEG solids treatment and disposal
- produced water treatment and disposal
- contaminants removal and disposal – sand, mercury, oil
- gas back flow from the export trunkline
- production flowline re-pressurisation
- process support utilities (including power generation and flare)
- temporary flowline pigging facilities.

The topsides will be designed to be operated remotely from shore, including shut-down, start-up and steady state operation with minimal manning requirements.

4.4.2.4 Export Trunkline

Woodside proposes that gas will be exported from the FPU via a 32-inch carbon steel trunkline that runs approximately 430 km from the FPU to a proposed and approved brownfield expansion of the existing Pluto LNG onshore facility (Pluto Train 2). Under this proposal the trunkline will extend from the FPU site to the Pluto platform and then run parallel to the existing Pluto trunkline, within the existing trunkline corridor and come ashore on the Burrup Peninsula adjacent to the existing Pluto trunkline shore crossing. Trunkline construction is anticipated to begin in 2022.

4.4.2.5 Onshore Development (out of scope)

Woodside's preferred development for Scarborough proposes to transport feed gas to the existing Woodside-operated Pluto LNG facility on the Burrup Peninsula for processing, where a second LNG train will be built (known as Pluto Expansion). However, Pluto Expansion is subject to separate State and Commonwealth environmental approval mechanisms, and is out of scope of this OPP.

4.4.3 Drilling Activities

The proposed production wells will be drilled using a moored or semi-moored MODU, or dynamically positioned (DP) MODU or drill ship.

The location of wells and associated subsea facilities will be influenced by reservoir targets, general bathymetry, seabed features and hydraulic performance of subsea production systems.

A phased development drilling program is proposed with infill drilling as required. While the final number and location of operating wells is not yet known, it is anticipated that seven wells will be available at ready for start-up (RFSU) in 2023, and up to 13 wells (including eight wells in the Thebe field and two wells in the Jupiter field) during a potential second future phase, that may begin in 2025. An additional 10 wells are proposed to be carried in this assessment as contingency. While the exact location of the wells has not yet been determined, they are proposed be located with the permit areas as identified in Figure 4.1.

Each operating well is anticipated to take approximately 2-3 months from the start of drilling to completions. Table 4.8 provides an estimate of Scarborough operating wells, noting that this is an estimate only.

Table 4.8: Estimates for the Scarborough wells

Drilling Phase	Anticipated Timeframes	Reservoir	Anticipated number of wells
1	2020	Scarborough (Phase 1)	7
2	2025	Scarborough (Phase 2)	3
		Thebe	8
		Jupiter	2
Contingency wells (50%)			10
TOTAL			**30**

4.4.3.1 Drilling Method Overview

Several vessel types will be required to complete production drilling, including:

- semi-submersible moored MODU or DP MODU
- support vessels, required for activities such as to run and set anchors and support the MODU, during operations.

Development wells will be drilled to depths of about 3000 m beneath sea level to intersect the reservoirs. Wells will be spaced out optimising the layout of subsea infrastructure and bottom hole targets.

Typically, the drilling process starts 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 an intermediate casing will be run in and cemented. Intermediate casings provide structural support for the hole walls, isolate geological formations and allow pressure management that may be experienced during drilling.

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

Once drilling and completion of the well is completed, the well is then flowed to the MODU. Once stable flow is achieved the produced fluids are sent to tanks for separation onboard the MODU. The produced hydrocarbons are flared while the water is treated to meet regulatory requirements and then discharged overboard. This first production to the MODU is known as unloading and typically lasts approximately 12 hours per well. Once unloading activities are completed, the wells are then isolated until they are connected to the FPU.

Well construction activities are conducted in the stages described below. Detailed well designs will be submitted to the Well Integrity department of NOPSEMA as part of the Approval to Drill and the accepted Well Operation Management Plan (WOMP) as required under the *Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011*.

4.4.3.2 Top Hole Section Drilling

Drilling commences with the top-hole section of the well as follows:

1. The MODU arrives and establishes position over the well site.
2. A pilot hole or holes may be drilled close to the intended well location. Pilot holes are used when confirmation of geology and shallow hazards or further understanding of the structural integrity of the rock is required. Pilot holes are drilled riserless, as described below, and result in additional cuttings, sweeps and potentially deposition to seabed.

3. Top hole sections are drilled riserless using seawater with pre-hydrated bentonite sweeps/ (XC) Polymer sweeps or *drilling* fluids to circulate drill cuttings from the wellbore.
4. Once each of the top-hole sections are drilled, steel casings are inserted into the wellbore to form the surface casing and secured in place by pumping cement into the annular space back to about 300 m above the casing shoe, which may involve a discharge of excess cement at the seabed.

Cuttings generated during drilling of the top-hole sections are discharged at the seabed. Discharged volumes for each well have been estimated in Table 7.37.

4.4.3.3 Blowout Preventer and Marine Riser Installation

After setting the surface casing, a BOP is installed on the wellhead to provide a means for sealing, controlling and monitoring the well during drilling activities. The BOP components are operated using open hydraulic systems (utilising water-based BOP control fluids). Each time the BOP is operated, the maximum volume of BOP control fluid released to the marine environment per well is 1320 – 2250 L of water-based fluid containing about 40 – 68 L of control fluid additive. BOP operation includes pressure testing approximately every 21 days and a function test approximately every seven days, excluding the week a pressure test is conducted.

Following installation of the BOP, a marine riser is installed to provide a physical connection between the well and MODU. This enables a closed circulation system to be maintained, where weighted water-based muds (WBM) and cuttings can be circulated from the wellbore back to the MODU via the riser.

4.4.3.4 Bottom Hole Section Drilling

Bottom hole drilling involves drilling of the lower section of the well. Bottom hole drilling requires a bottom hole assembly (BHA) that provides the force for the drill bit to break the rock in what can be a more challenging mechanical environment.

Bottom-hole section drilling uses a closed system (post installation of marine riser) to the planned wellbore total depth (TD). Bottom hole sections may be drilled using a combination of water-based and non-water-based drilling fluids.

Protective steel tubulars (casings and liners) are inserted as required. After a string of casing/liner has been installed into the wellbore and the cement holding it in place has hardened, the casing/liner is pressure-tested.

Cementing operations are also undertaken to:

- maintain well control and structural support of the casing as required
- set a plug in an existing well in order to sidetrack
- plug a well so it can be abandoned.

Cements are transported as dry bulk to the MODU by support vessels, mixed as required by the cementing unit on the MODU and are pumped by high pressure pumps to the surface cementing head then directed down the well.

Once well operations are completed, excess cement (dry bulk), is either held on-board and used for subsequent wells; provided to the next operator at the end of the program; or discharged to the marine environment along with cement that does not meet technical requirements (least likely option).

Cuttings and drilling fluids circulated back to the MODU are separated from the drilling fluids by the solids control equipment (SCE). The SCE comprises shale shakers to remove coarse cuttings from the drilling fluid. After processing by the shale shakers, the recovered fluids from the cuttings may be directed to centrifuges, which are used to remove the finer solids (4.5 to 6 µm). The cuttings are usually discharged below the water line and the fluids are recirculated into the fluid system. Volumes of drill cuttings and fluids discharged per well are summarised in Table 7.37.

4.4.3.5 Well Clean-up

Prior to installing the drill stem test (DST) string, wells will generally be displaced from the drilling fluid system to brine. A chemical cleanout fluids train will be circulated between the two fluids, then seawater or brine circulated until operational cleanliness specifications are met. This will be in line with Woodside's Reservoir, Drilling and Completions Fluids Guideline. Brine is typically a filtered brine with <70 NTU and/or <0.05% total suspended solids (TSS). This results in a brine and seawater discharge after this operation. Should there be clean-up brine contaminated with base oil, it will be captured and stored on the MODU for treatment prior to discharge or returned to shore if treatment is not possible.

4.4.3.6 Well Flow-back

Upon successfully drilling the production wells, Woodside may conduct well testing or well flowback activities. The types of tasks associated with well testing and flowback may include:

- reservoir gas flaring
- reservoir gas venting.

During flowback, initial unloading of the well displaces the suspension fluids. These are discharged overboard – the gas content makes it too dangerous to filter or treat them. Once the suspension fluids are unloaded, the gas stream is sent to flare via the production separator.

After the objectives of the well testing and flowback are achieved, the flow is stopped and the well may be cleaned using a brine that can include several chemicals, such as biocide and surfactant.

4.4.3.7 Completion

Once a well has been drilled, well completion activities will be undertaken including installation of sand control screens, production tubing and the christmas tree, followed by well suspension. Lower completions will require down-hole sand control to manage the potential for formation failure during operation.

Installation of well infrastructure will consist of deploying the horizontal christmas tree and lock it to the wellhead, followed by verification testing of the connector, flowline connector and subsea control module (SCM) as required. The installation will be supported by remotely operated vehicles (ROVs) with installation by wire from the MODU or vessel.

4.4.3.8 Subsea Equipment Preservation Chemicals

Following well completion activities, the wells may be left with subsea equipment (such as christmas trees) installed, awaiting connection to the FPU. All subsea equipment will contain preservation fluids to prevent corrosion and any other deterioration of the equipment before production. Such fluids will be flushed back to the FPU when production from the well commences.

Prior to leaving the subsea equipment flooded and ready for start-up, pre-commissioning and final hydrotests of the subsea infrastructure will result in discharge of treated seawater.

4.4.3.9 Drilling Fluids

Drilling fluids are used to lubricate the drill string, resist any pressure from the well stream and return cuttings to surface. They are 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 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 more confirmed.

All wells will be drilled using Water Based Muds (WBMs) for the top-hole sections and either WBMs or Non-Water Based Muds (NWBMs) for the lower sections. The selection of mud types is dependent on technical aspects of the drilling program that will not be known until completion of detailed design:

- WBM is typically used as the first preference when planning to drill a well, consistent with the requirements of Woodside's Environmental Performance Standard. WBM is mainly comprised of water (salt or fresh). Some basic additives such bentonite/guar gum may be added to the water. All WBM chemicals selected for use will be assessed under the Woodside Chemical Selection and Assessment Environment Guideline.
- NWBM may also be used subject to the development of a "business case deviation" that details environment, technical, health and waste management considerations. The requirement to use NWBM is typically based on a need for improved management of the technical and safety aspects of drilling technically complex wells. All NWBM chemicals selected for use will be assessed under the Woodside Chemical Selection and Assessment Environment Guideline.

Given the shallow depth of the target reservoir in the Scarborough, Thebe and Jupiter reservoirs, a combination of horizontal and high angle wells are required with maximum well lengths of approximately 2000 m.

4.4.3.10 Vertical Seismic Profiling

As a part of ongoing field evaluation, Woodside may undertake vertical seismic profiling (VSP) once total depth is reached.

VSP is used to generate a high-resolution seismic image of the geology in the well's immediate vicinity. It uses a small airgun array, typically comprising either a system of three 250 inch^3 airguns with a total volume of 750 inch^3 of compressed nitrogen at about 1800 psi (12,410 kPa) or two 250 inch^3 airguns with a total volume of 500 inches^3. During VSP operations, four to five receivers may be positioned in a section of the wellbore (station) and the airgun array is discharged approximately five times at 20 second intervals. The generated sound pulses are reflected through the seabed and are recorded by the receivers to generate a profile along 60 to 75 m section of the wellbore. This process is repeated as required for different stations in the wellbore and it may take up to 24 hours to complete, depending on the wellbore's depth and number of stations being profiled.

4.4.4 Installation of Subsea Infrastructure

Subsea infrastructure required for start-up will be installed prior to the installation of the FPU, with further infrastructure, including temporary infrastructure to support commissioning activities, installed throughout the life of the project as required (e.g. for wells drilled in Phase 2 and in the Thebe and Jupiter fields). Subsea infrastructure such as riser-based manifolds, risers, flowlines, umbilicals and mooring system will be transported to site by a combination of installation vessels and cargo barges. Subsea installation of equipment will be performed by subsea installation vessels (ISV). These will be equipped with submersible ROVs, which will aid in the installation, hook-up and commissioning processes.

With the riser based manifolds in place, the subsea well jumpers, infield flowlines and umbilicals will be installed on the seabed. The infield flowlines will be installed progressively within a defined corridor using a pipe-lay vessel, whereby each flowline is lowered to the seabed as the vessel moves forward. The flowlines and MEG lines will be laid directly on the seabed following seabed preparation (if required) and umbilicals will be laid alongside the flowlines.

Compression facilities are likely to be installed at a later stage (four to ten years after operation commences) to maintain the gas production rate as reservoir pressure declines. There are a number of possible options for future compression facilities, the most likely being installation of a second platform to house the compression facilities. Alternative options being considered include the installation of compression facilities on the riser platform or subsea. Additional utilities and systems similar to those needed for the riser platform may be required to support the compression facilities.

4.4.5 Installation of Flexible Risers

The flexible risers will be installed using an ISV. Each of the flexible risers will be installed, already filled with MEG or freshwater/seawater. To achieve the final riser design configuration, buoyancy modules will be installed directly onto the riser during the installation. Once each riser has been laid, the subsea end will be installed to the riser base manifold. Diverless connectors are likely to be used to connect each riser to the manifold. The installation of the flexible umbilical risers will follow the same methodology; however, the umbilicals will be connected to the Subsea Distribution Unit (SDU).

4.4.6 Installation of FPU

The FPU components will be assembled and pre-commissioned as much as reasonably possible at onshore fabrication/pre-assembly sites before transportation to its final offshore location.

The anchor piles and mooring legs will be installed in advance and laid on the seabed.

The FPU will most likely be dry towed to a sheltered location for offloading and wet towed to site. Once at site, the mooring lines will be connected to the FPU.

Riser connection and offshore commissioning will then be completed. A marine spread will be at site supporting anchor and riser connection.

Where suction piling is to be used, piles will be installed by gently lowering the pile onto the seabed and using gravity to lower the pile into the soft substrate. The preferred installation method is to pump out the entrapped water inside the pile, with the resulting differential pressure drawing the pile deeper into the seabed. Should driven piling be required, current options being assessed are drilling and cementing or impact piling, which involves the application of force to drive the pile into the seabed.

4.4.6.1 FPU Utilities

The FPU will likely include utilities as described below.

Power Generation and Distribution: Power generation is likely to be supplied by gas turbine driven generators that have the capacity to use diesel if gas is not available (such as during start-up operations). The need for separate emergency power generation equipment will be determined during FEED.

Fuel Gas Treatment: Gas would be the main source of fuel for power generation. A fuel gas treatment system usually consists of pressure reduction, filtering, dew pointing and metering equipment prior to use by turbines and other fuel gas users.

Diesel System: A diesel storage and distribution system may be required to provide a fuel source for emergency power generation systems, materials handling cranes, firewater pumps, and as a back-up fuel source for the main power generation system. Diesel would be transported to the FPU by supply vessel.

Emergency Flare System: An emergency depressuring (flare) system, also referred to as a 'safety flare system', will be installed on the FPU. The safety flare will be designed to provide a safe means of rapidly disposing pressurised gas from process equipment in the event of an emergency or process upset. The flare system is also required during commissioning, initial production, process shutdowns and restarts, maintenance, and equipment downtime. A pilot flare will keep the emergency flare lit.

Chemical Storage and Injection Facilities: Chemicals may need to be stored on the FPU for injection into the subsea systems (flowlines/wellheads/manifolds) and export trunkline and for production purposes. A wide variety of chemicals and other materials may be stored and used on the FPU, including:

- acids and solvents
- hydrate and corrosion inhibitors
- surface active agents
- lubricating fluids and greases
- hydraulic oils and fluids
- paints
- specialised cleaning fluids
- seawater system treatment chemicals.

MEG will be continuously injected into the subsea gathering system to prevent hydrate formation. The MEG will be regenerated and stored on the FPU and pumped to the subsea and topsides injection points as required. Produced and condensed water extracted from the reservoir and separated from the MEG during regeneration will be treated to acceptable quality and routinely disposed of overboard, with volumes expected to be below 100 m^3/day.

Subsea Controls Support System: The subsea equipment will be controlled by an electro-hydraulic system. The hydraulic fluid, power and controls communications functions will be transported to the manifolds via an umbilical. This umbilical may also transport some of the production chemicals required at the field. The FPU will house all the equipment needed to support these functions, including a hydraulic pressure maintenance system, power supply and uninterrupted power supply system, a master controls station and the umbilical initiation point.

Seawater Treatment: Seawater may be required for various purposes, including cooling of wellstream fluids, process equipment, fire protection systems, and freshwater production. Seawater treatment systems may include coarse filters to strain debris from the seawater and injection of hypochlorite (or similar biocide) to prevent the build-up of marine fouling growth on the internal surfaces of the system. Hypochlorite is the most widely used material and is normally produced onboard by electrolysis of seawater.

Seawater used for cooling purposes will be routinely discharged overboard from either the surface or at a point below sea level (depending on final FPU design) at a temperature less than 60^{o}C and rates up to 175,000 m^3/d.

Accommodation Facilities: A project objective is to design the FPU to achieve minimally manned operation. Accommodation facilities will be provided for core crew as well as increased manning during maintenance or other activities.

Safety Systems: Safety systems will include escape equipment, fire/gas/smoke detection and protection systems, and back-up power systems. The fire protection system will consist of passive systems (such as equipment coatings) and active systems possibly including deluge, water, foam, CO^2 and extinguishers. The most appropriate system for each area will be selected based on detailed risk assessments. Ozone-depleting substances will not be used for these systems. Safety equipment including fire pumps, emergency lighting and communications equipment, are generally designed to be completely independent and with appropriate levels of redundancy. Independent fuel or energy sources, such as diesel, may be used.

Communication Systems: Standard offshore communications systems will be in place. Additional safeguards will also be implemented such as the gazetting of the platform onto navigational charts and the creation of a safety exclusion zone.

Flowline and Export Trunkline Pigging Facilities: For operational and inspection reasons, it may be necessary to run 'pigs' through the flowlines and/or export trunkline. The FPU may include launchers/receivers for these activities.

Drains: The FPU drainage and disposal systems will include closed drains, open drains and liquid hydrocarbon recovery systems. Deck drainage consists mainly of deck washdown water and rainwater.

4.4.7 Gas Export Trunkline

The base case design is a dry gas export trunkline between the FPU and the shore. The nominal size is 32-inch with a total route length of approximately 430 km.

The proposed route for the export trunkline between the FPU and Pluto Gas is shown in Figure 4.1.

In deep water, the key routing drivers for the export trunkline are:

- minimising environmental impact
- avoiding any identified geohazards
- finding an optimum route up the continental slope (1000 m to 300 m water depth) which minimises intervention requirements and long-term integrity issues
- minimising the number of third-party trunkline crossings.

Figure 4.1 shows the preliminary export trunkline route. At KP 200, about 20 km north-west of the Pluto Riser Platform, the export trunkline deviates to the south to avoid the existing facilities and manage environment, technical and safety risks. From KP 160, about 20 km south-east of the platform, the export trunkline will be routed alongside the existing Pluto gas trunkline, within the same corridor as the Pluto trunkline (about 100 m to the south) until it reaches Mermaid Sound.

4.4.7.1 Pre-lay Survey

A pre-lay survey of the export trunkline will be undertaken prior to commencement of the trunkline installation. This survey is aimed to identify debris and other hazards prior to laying the trunkline and is not considered a full geophysical/geotechnical survey.

The pre-lay survey will be performed by a dedicated pre-lay survey vessel (which is typically similar in size to support vessels) or potentially the ISV. The survey usually utilises a side scan sonar fish towed behind the pre-lay survey vessel. The survey methods are non-intrusive and the equipment, under planned operation, will not disturb the seabed. Information is transferred to the survey vessel via an umbilical. The pre-lay survey may also be undertaken with ROV or autonomous underwater vehicle (AUV) using side scan sonar.

A multi-beam echo sounder, a common survey tool for offshore surveys, may also be deployed to establish the profile of the seabed, using sound pulses.

Geotechnical surveys typically involve in-situ testing and piston/push sampling. Following sampling, all equipment is withdrawn from the seabed. A small hole (<1 m^2) will remain, which will eventually collapse and infill with the movement of surface sediments in ocean current

4.4.7.2 Trunkline Installation

The export trunkline will be installed from a conventional pipelay vessel (Figure 4.2). The pipelay vessel may be required to temporarily moor on location, which may require the use of pile driving to install the necessary moorings. This however is dependent on geotechnical information and further engineering and design.

The export trunkline is built up from pipe lengths, each being welded to the previous section. Following completion of each weld, a Non-Destructive Examination (NDE) technique will be employed to inspect the weld, and weld repairs will be performed if required. An anti-corrosion heat shrink sleeve or cold tape will then be applied to the weld area, and the void between adjacent concrete coatings may then be filled with a suitable infill. Upon completion of this process, the pipe is laid over a pipe support ramp (stinger) on the stern of the lay barge and laid onto the seabed.

Laying the export trunkline near existing trunklines (e.g. the Pluto trunkline, TSEP trunkline, etc.) will need to be considered, and appropriate measures established to protect these trunklines.

Figure 4.2: Conventional pipelay vessel

4.4.7.3 Trunkline Stabilisation

During FEED, the trunkline dredging, protection and stabilisation design will be refined to provide an optimum solution in terms of environmental impact, safety, cost and schedule. However, it is anticipated that stabilisation is generally required in water depths shallower than 40 m, which corresponds to a location about 50 km offshore. Accordingly, it is anticipated that for the section of export trunkline from shore to approximately KP 34 out to KP 50 (Figure 4.3), there may be a requirement for some trenching and back fill to stabilise the export trunkline in both state and Commonwealth waters.

The pre-lay dredging works associated with the export trunkline installation involves the dredging of an approximately 2.5–3.5 m deep trench along the trunkline route within a Trunkline Project Area (corridor) of 30 m.

Trailing suction hopper dredgers (TSHD) have been proposed for the pre-lay dredging works in Commonwealth waters. Material will be dredged, placed alongside the export trunkline route and potentially used as backfill to stabilise the export trunkline once it has been flooded and tested. This stabilisation will be done using coarse sand and crushed calcareous rock (CCR). Where the dredged material is not used to backfill the trench, it will be disposed at existing spoil grounds within the region and alternative backfill will be sourced from one of the pre-identified borrow ground locations. Estimated maximum volumes for trenching and backfill activities are presented in Table 4.9.

Table 4.9: Estimated maximum dredge and backfill volumes

Activity	Estimated maximum volumes
Commonwealth waters trenching	1.2 Mm^3
Commonwealth waters backfill	1.5 Mm^3

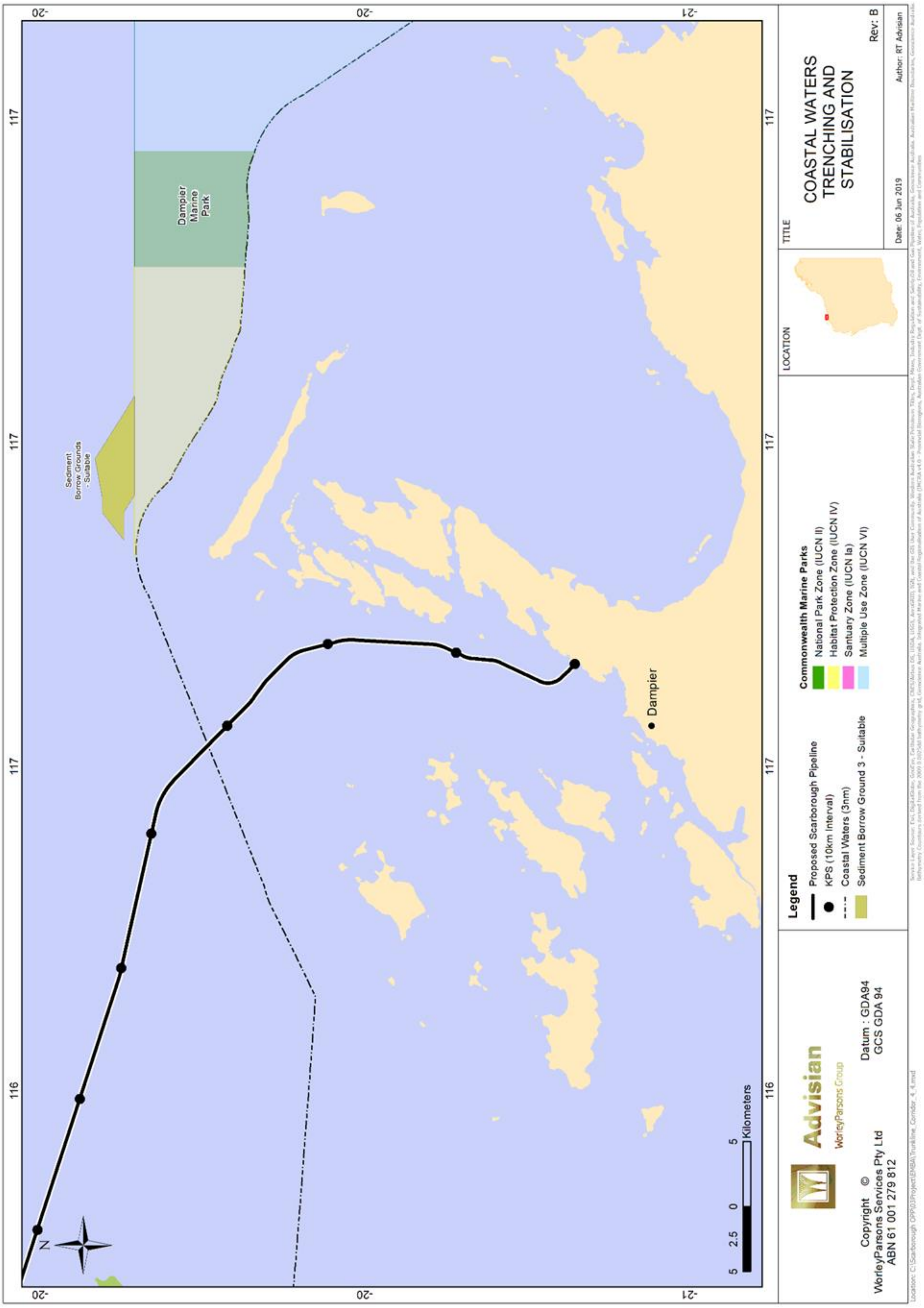


Figure 4.3: Trunkline Corridor within Commonwealth Waters and Potential Borrow Ground Project Area

At KP 210 about 2500 m³ to 15,000 m³ of material may be displaced to allow safe pipelay operations to be conducted as the Export Trunkline crosses the scarp in approximately 580 m water depth. This seabed material relocation will be completed using a potential combination of Mass Flow Excavation, subsea equipment based material relocation/intervention, ROV based material relocation or a grader. Any displaced material would not be recovered to the surface.

4.4.7.4 Borrow Ground

Sand may be required to assist with export trunkline stabilisation in some of the trunkline sections in shallower water. This sand is proposed to be obtained from borrow ground locations in either State or Commonwealth waters. The location of the pre-identified borrow ground in Commonwealth waters is shown in Figure 4.3.

The sand would be dredged from the borrow ground using a TSHD. The volumes required, and duration of the dredging activities is to be confirmed during detailed engineering design.

Consideration was given to the potential re-use of materials from existing Spoil Grounds to negate the requirement to use a new borrow ground, however the geotechnical properties of the materials in existing spoil grounds are not suitable for pipeline stabilisation (refer to Section 4.5 for additional discussion regarding borrow ground selection).

4.4.8 Commissioning

Once installation and hook up of subsea infrastructure are complete, the subsea infrastructure, including the subsea umbilicals, risers and flowlines (SURF) and the export trunkline will be subject to pre-commissioning activities, required to test the integrity of the subsea infrastructure. For SURF, this will be conducted using hydrotest fluids, whereby the pipeline 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, at which time hydrotest fluids will be discharged. The likely volume of hydrotest fluids used for SURF commissioning is 5300 m³ with a 10% contingency, resulting in a maximum likely volume of 5800 m³.

The preferred option for trunkline commissioning does not involve the use of hydrotest fluids. “Dry commissioning” relies on data gathered during fabrication and installation to provide assurance of trunkline integrity. There is a possibility, however, that hydrotesting may still be required and as such this has been included in the scope of activities under the OPP. Potential volume of pre-commissioning fluid for the trunkline is 190,000 m³ of chemically treated seawater with a 20% contingency, resulting in a maximum likely volume of 223,000 m³.

The location and timing of the pre-commissioning fluid discharge is unknown; however, it is assumed it will be discharged from a single point on the seabed in the vicinity of the proposed location of the FPU at any time of the year. For the purpose of undertaking this assessment, the discharge rate is estimated at around 1500 m³/hr for the trunkline and 85 m³/hr for SURF. Residual biocide may be present in the hydrotest water at the time it is discharged at concentrations in the order of 500 to 1500 ppm.

FPU will be pre-commissioned at the fabrication site prior to transportation to the offshore location. Commissioning will include checking, inspection, cleaning, tightness testing, drying and inerting and first fill of process chemicals and adsorbents for the gas treatment system.

Commissioning of the overall production system will be conducted from the FPU once on location. Commissioning will include testing, adjusting and monitoring of all systems.

4.4.9 Operations

4.4.9.1 Hydrocarbon Extraction

Hydrocarbons from the reservoir will flow via the subsea infrastructure to the FPU for processing.

Control of the subsea system is via the umbilical which transports electrical power, control fluids and chemicals to the required subsea locations. Other chemicals including MEG will be injected into the gas at the wellhead to prevent the formation of gas hydrate in the flowlines and risers and to assist in corrosion inhibition.

4.4.9.2 Processing

Well fluids are processed on the FPU to meet the export trunkline gas specification. MEG, water and any salt, sand and scale are removed for further processing and disposal. The gas will then be compressed to meet the requirements of the trunkline and metered prior to export via the export trunkline.

Due to the temperature difference between the reservoir fluids and the FPU process, mercury contained in reservoir fluids is expected to condense and collect in the topside process. The mercury will be removed from the FPU process for onshore treatment and disposal.

Condensed water, resulting from the vapour in the gas stream which condenses out during gas processing, will be produced throughout the life of the project at rates of about 285 bbl/day. This water will be treated and discharged from the FPU to the marine environment.

Wells are not expected to produce formation water until they start to water out toward the end of well life. Once they start to water out, about 200 bbl/day of formation water may be produced. At that time, daily discharge of up to approximately 485 bbl/day (combined condensed water and formation water) will be generated for a limited duration prior to watering out, at which point the well will be shut-in.

The condensed water and produced formation water will also contain residual salt, MEG, scale, corrosion inhibitors and sands. The condensed water and produced formation water will be separated by distillation in the MEG unit and will contain a small amount of residual MEG and corrosion inhibitors but no salt, scale, or fines. These streams will be directed to the produced water treatment system for processing prior to discharge overboard either from the surface, or from a point below the surface depending on the final design of the FPU.

Any solids will be recovered, dissolvable salts may be re-dissolved or slurried using treated water and discharged overboard. Other solids will be recovered and transported to shore for treatment and disposal.

4.4.9.3 Gas Export

Gas is to be exported from the FPU to shore via the 430 km long export trunkline. The export trunkline will operate dry and liquids free. Any future hydrocarbon liquids from future field tie-backs will be exported separately to the gas to avoid export trunkline liquid management issues.

Processing of the gas onshore is outside the scope of this document.

4.4.10 Decommissioning

At the end of Scarborough's 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 Scarborough, North Scarborough, Thebe and Jupiter fields have reached the end of their economic life and may occur in stages. If additional or third-party reservoirs have been tied into Scarborough infrastructure, this could increase the project's economic life and thus postpone decommissioning.

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". However, this obligation is subject to other provisions of the Act and allows titleholders to identify and seek approval for alternative arrangements. Subsequently, decommissioning may include:

- plugging of production wells and removal of christmas trees and wellheads down to 5 m below the seabed
- removal of manifolds
- removal of umbilicals
- cut off mooring and remove the FPU
- anchor piles and mooring legs remain at location, within the seabed
- removal of subsea infrastructure (subject to other provisions of the OPGGS Act).

Given the expected life of the project, the decommissioning of Scarborough is not likely for many years. While it is not possible to fully scope the decommissioning strategy that will be employed at that time, and given the possible improvements in technology that may occur between now and the time of decommissioning, it is intended within this OPP to identify the broad environmental performance outcomes for decommissioning, and demonstrate how these will be met through activity-specific Environment Plans to be developed closer to the time.

4.4.10.1 Well Abandonment

Once no longer required for use, wells must be abandoned in accordance with the requirements of the OPGGS Act and industry best practice.

On abandonment, the surface casing, conductor, and wellhead may be cut off below the seabed and recovered.

Well plug and abandonment include activities such as:

- install and pressure test BOP
- bullhead the well
- isolate the reservoir (deep set slick line plug)
- cut/perforate casing/production tubing
- install permanent reservoir barrier
- perforate the well casing/tubing
- install permanent surface barrier
- Remove BOP stack
- sever and remove surface casing and wellhead
- conduct post operation ROV survey.

4.4.11 Inspection, Maintenance and Repair Activities

All facilities supporting Scarborough, both subsea and topsides, will be subject to Inspection, maintenance and repair activities. For the FPU this will be undertaken during campaign maintenance periods to reduce the number of personnel onboard during normal production periods. For the subsea systems activities will be conducted using ROVs.

Inspection, maintenance and repair activities may need to occur during the operational life of the field to:

- prevent deterioration and/or failure of infrastructure
- maintain reliability and performance of infrastructure.

4.4.11.1 Inspections

For Scarborough, wellheads, pipelines, export trunkline umbilicals and subsea structures will be inspected by an ROV from a vessel. Inspections may monitor:

- anode wastage
- coating damage
- cathodic protection measurements
- non-destructive testing
- external corrosion
- lack of integrity (missing components, broken loose or damaged appurtenances)
- marine growth
- damage (impact, environment or third party)
- scour
- variation of inspected components or operating conditions
- leaks (gas or liquid).

The frequency and duration of inspections is dependent in the issue however could take place at any time of the year for a duration of a few hours to a few days.

4.4.11.2 Maintenance and Repair

Maintenance and repair activities may need to occur during the operational life of the field to:

- prevent deterioration and/or failure of infrastructure
- maintain reliability and performance of infrastructure.

Maintenance and repair activities are typically conducted in response to inspection findings, engineering analyses, and/or external events. The activities are typically performed by ROV from a vessel or may be undertaken by divers from a dive support vessel in shallower sections of the trunkline.

Typical maintenance and repair activities include:

- cathodic protection system maintenance
- leak testing
- marine growth and hard deposit removal
- removal of debris or fishing net
- rectification of electrical or hydraulic fault
- pipeline/trunkline repair
- pipeline/trunkline stabilisation
- general subsea infrastructure servicing

- general topsides servicing.

4.4.11.3 Well Intervention

Well intervention generally occurs within the wellbore and includes activities such as:

- slickline/wireline/coil-tubing operations
- well testing and flowback
- well workovers (mechanical or hydraulic).

The frequency of well intervention activities depends on well performance.

During intervention activities, local control of the Christmas trees may be required. Valve actuation of the trees may be required, which will result in small releases of subsea control fluids to be released to the environment. Intervention activities also include removing marine fouling by mechanical or acid soaking, resulting in the release of marine-fouling debris and small amounts of acid to the environment. When retrieving intervention tooling, small volumes of wellbore fluids may be displaced back into the well.

In addition, various other activities (described in Section 4.4.3 Drilling Activities) may also be conducted during well intervention activities.

4.4.12 Support Activities

Support Vessels

The drilling, installation, commissioning and operation phases of the project will be supported by a variety of vessels including barges, tugs, heavy lift vessels, accommodation support vessels, survey vessels and supply vessels (thereafter referred to as support vessels) and installation (ISV) and pipelay vessels. Vessels used during these phases may be sourced from international or Australian based location, depending on the time of vessel needed and availability. Regional ports such as Dampier and Exmouth are proposed for use during different phases of the project (including but not limited to mobilisation/resupply/equipment transfer activities). Port based activities associated with these vessels, are subject to all applicable maritime regulations and other requirements (including Woodside's *Marine Operations Operating Procedure (WM0000PG10120467)*.

While in the Project Area, support vessels will be required for transporting stores and equipment. Support vessels also backload materials and segregated waste for transportation back to shore, as well as carrying out standby duties where required. Standby duties may include but are not limited to periods of helicopter operations and working over the side activities while in the field. During the operations phase supply vessels will travel between the supply chain and logistics support facility (or facilities) and the FPU.

During drilling activities, several different materials required for the campaign will be transferred from vessels to the MODU in bulk. Cement, barite and bentonite are transported as dry bulk to the MODU by support vessels and pneumatically blown to the MODU storage tanks using compressed air.

Vessels may also be employed to undertake various inspection, maintenance and repair activities, both in-field of the subsea facilities, and along the trunkline.

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.

Helicopter Operations

Helicopters are the primary means of transporting passengers and/or urgent freight to/from during drilling, installation, commissioning and operation phases of the project. They are also the preferred means of evacuating personnel in an emergency. Helicopter support is principally supplied from the Karratha and Exmouth Airports.

Remotely Operated Vehicles

All phases may be supported by remotely operated vehicles (ROV). These may be used during drilling operations, inspection and maintenance and in decommissioning

The ROV can be fitted with various tools and camera systems that can be used to capture permanent records (both still images and video) of the operations and immediate surrounding environment.

The ROV may also be used in the event of an incident to deploy the Subsea First Response Toolkit.

4.4.13 Key Aspects Associated with the Project

A summary of the project stages, the activities and identified environmental aspects based on the activity as described in this section is provided in Table 4.10. This forms the framework for the impact assessment undertaken in Section 7 of this OPP.

Table 4.10: Relationship between the project phases, activities and aspects

Aspect Name	Drilling			Installation and Commissioning							Operations				Decommissioning			Inspection, Maintenance and Repair			Support Operations			
	Drilling Operations	Well flow-back	Completion	Vertical Seismic Profiling	Pre-Lay Survey	Installation of FPU	Installation of subsea infrastructure	Trunkline installation	Trunkline stabilisation	Commissioning	FPU Operations	Hydrocarbon extraction	Hydrocarbon processing	Gas Export	Removal of subsea infrastructure	Leaving flowlines in place	Well Abandonment	Inspection	Maintenance and Repair	Well Intervention	MODU Operations	Vessel Operations	ROV Operations	Helicopter Operations
Planned																								
Routine light emissions											✓		✓								✓	✓		
Routine atmospheric emissions		✓									✓		✓								✓	✓		
Routine acoustic emissions	✓			✓	✓	✓					✓	✓			✓						✓	✓		✓
Physical presence (routine): Displacement of Other Users					✓	✓	✓	✓			✓				✓						✓	✓		✓
Physical presence (routine): Seabed disturbance	✓				✓	✓	✓	✓	✓						✓						✓	✓	✓	
Routine and non-routine discharges: Sewage and Greywater											✓										✓	✓		
Routine and non-routine discharges: Food Waste											✓										✓	✓		
Routine and non-routine discharges: Chemicals and Deck Drainage											✓										✓	✓		
Routine and non-routine discharges: Brine and Cooling Water											✓										✓	✓		
Routine and non-routine discharges: Operational Fluids												✓	✓											
Routine and non-routine discharges: Subsea installation, and commissioning						✓	✓			✓														
Routine and non-routine discharges: Drilling	✓																✓			✓				
Unplanned																								
Unplanned Discharges: Chemicals	✓										✓										✓	✓	✓	✓
Unplanned Discharges: Solid Waste											✓										✓	✓		
Physical presence (unplanned): Seabed disturbance								✓			✓										✓	✓		
Physical presence (unplanned): IMS						✓	✓	✓													✓	✓		
Physical presence (unplanned): Collision with Marine Fauna																						✓		
Unplanned hydrocarbon release	✓									✓	✓	✓	✓	✓	✓		✓				✓	✓		✓

4.5 Assessment of Alternatives

4.5.1 Background

In 2018, Woodside acquired an additional 50% interest in WA-1-R containing the majority of the Scarborough field, taking the Company's interest to 75% in WA-1-R and a 50% interest in WA-61-R, WA-62-R and WA-63-R. Prior to this acquisition, the previous Operator had evaluated and selected as a concept the development of the Scarborough field via Floating Liquefied Natural Gas (FLNG) technology. This Proposal was referred under the EPBC Act (reference no. 2013/6811) by ExxonMobil to the Commonwealth in 2013 and was set a level of assessment as “assessed by preliminary documentation”. The Proposal was approved the same year with conditions and varied in 2015 to allow for changes resulting from the streamlining arrangements set in place for the assessment of petroleum activities under the OPGGS Act and EPBC Act. Woodside is proposing to bring Scarborough gas onshore to existing LNG facilities through an approximately 430 km export trunkline.

4.5.2 Proposal Need and Alternatives Considered

The Scarborough field was discovered in 1979 with the drilling of the Scarborough-1 well. Since discovery, various development options have been considered.

The previous Operator evaluated two concept themes, a tieback to a shore-based LNG site and Floating LNG (FLNG). Given high costs for developing a greenfield LNG site and the limited commercial solutions for expanding existing LNG facilities at the time, the previous Operator selected FLNG as the preferred development concept. The FLNG concept included proprietary technologies of the previous Operator. Woodside’s view of the concept was that it would take several years to fully mature the technology prior to being ready for deployment.

Woodside has further considered development options and undertaken a comparative assessment (including a ‘no development’ option) to identify the benefits, risks and impacts of each. A summary of the evaluation outcome is presented in Table 4.11, with environmental aspects potentially resulting from different activities undertaken for each concept summarised in Table 4.12. A more detailed evaluation against the key drivers of the concepts one to four is provided in Table 4.13.

Table 4.11: Woodside assessment of alternative concepts for the development of Scarborough

Concept	Summary of Woodside evaluation
1. Semi-submersible to Pluto LNG Semi-submersible platform with trunkline to Pluto LNG. Includes infield processing and compression at ready for start-up (RFSU).	*Preferred approach* – Pre-investment made during construction of Pluto LNG (including the trunkline corridor, tanks and jetty infrastructure) for future expansion, and existing primary environmental approvals for a second LNG train, has provided cost benefits and reduced risk. Processing Scarborough gas through Pluto LNG will maximise use of existing infrastructure, extend the life of the facility and supply domestic and export markets from mid-2020 for decades. Lower environmental impact as area has previously been developed and no additional onshore clearing or significant dredging required.
2. Subsea Tieback to Shore Various subsea focussed development options with initial free flow and later installation of floating or subsea compression facilities.	There is negligible difference in environmental impacts/risks between this option and the preferred option (i.e. both have an infrastructure footprint, and both require an export pipeline from the field site to the onshore location). Weakness in the concept are complexity in delivering design rate, technology development risk and complex liquids management in the export trunkline.
3. Subsea Tieback via Pluto Upstream Subsea development tieback to existing offshore Pluto Platform.	Carries similar weaknesses to the above Subsea Tieback to Shore option and presents higher technical risks and value impacts associated with the offshore brownfield integration (i.e. integration of new platform with existing riser platform, complex liquids management in the export trunkline, shut-down implications during offshore installation and integration).
4. FLNG Concept As proposed by previous Operator, includes immature proprietary gas processing, storage and cryogenic offloading technology.	Higher technical risk including unproven technology in Scarborough conditions. Higher cost, longer schedule and risks to predictable delivery. Does not support use of existing onshore LNG infrastructure
5. No Development	Titleholder is required to undertake certain petroleum exploration and production related activities towards commercialising the Scarborough gas resource.

Table 4.12: Environmental Aspects related to Activities associated with each Concept

Activity	Related Concept	Ecological Services Impacts		IMS Risk	Emissions and Discharge Impacts				
		Physical Presence	Vessel movements	IMS	Underwater noise emissions	Atmospheric emissions	Light emissions	Planned liquid and solid discharges and waste	Unplanned Discharges
Installation and Commissioning									
Pre-lay survey	1, 2, 3, 4		✓	✓	✓				
Installation of semi-submersible platform (FPU)	1, (2)	✓	✓	✓	✓				
Installation of moorings for FLNG	4	✓	✓	✓					
Installation of subsea infrastructure	1, 2, 3, 4	✓	✓	✓					
Trunkline installation	1, 2, 3	✓	✓	✓					
Trunkline stabilisation	1, 2, 3	✓	✓	✓					
Installation of floating or subsea compression facilities	(2), 3	✓	✓	✓					
Commissioning	1, 2, 3, 4							✓	✓
Operations									
FPU Operations	1, (2)	✓	✓	✓		✓	✓	✓	✓
FLNG Operations	4	✓	✓	✓	✓	✓	✓	✓	✓
Infield hydrocarbon processing	1, 4					✓		✓	
Subsea Compression Facilities	(2), 3				✓				
Production via FLNG	4		✓	✓		✓			
Gas Export	1, 2, 3, 4								x
Support Operations									
Vessel Operations	1, 2, 3, 4		✓	✓	✓	✓	✓	✓	✓

Note – Concept 2 may involve either floating or subsea compression facilities. Potentially related activities are marked (2).

4.5.3 Comparative Assessment Process

To provide a broad comparison of the merit of the different alternative concepts that were determined to be feasible for Scarborough, a qualitative assessment is presented in Table 4.15. This reflects key considerations of safety, environment, technical and economic drivers and stakeholder/society expectations. Specific details regarding the assessment criteria has been provided in Table 4.13. These criteria were considered by Woodside as part of the decision-making process to identify the optimal concept for the development of the Scarborough gas resource.

Criteria have been assessed against a rating system relevant to each of the options. Environmental drivers and criteria described in Table 4.13 refer to relevant environmental aspects triggered by activities undertaken for each concept. Where an environmental aspect is not triggered, low or no risk is determined.

Table 4.13: Key criteria used in the assessment of alternatives (as relevant)

Driver		Criteria
ECONOMIC DRIVERS	Schedule Risk	• Ability to meet the development timeline
	Cost Risk	• Economic viability
	Future Flexibility Risk	• Ability to accommodate future development including ties-ins of other fields
TECHNICAL FEASIBILITY AND SAFETY DRIVERS	Safety Risk	• In line with industry standards and good practice
	Operability Risk	• Technically feasible to meet the field life requirements
	Technical Readiness	• Project considers an acceptable technology readiness level (TRL). TRL is a method of estimating technology maturity of Critical Technology Elements (CTE)
ENVIRONMENTAL DRIVERS	Ecological Services Impacts	• Physical presence (i.e. seabed disturbance) • Vessel movements
	IMS Risk	• IMS
	Emissions and Discharge Impacts	• Underwater noise emissions • Atmospheric emissions • Light emissions • Planned liquid and solid discharges and waste • Unplanned discharges
SOCIAL DRIVERS	Socioeconomic Impacts	• Avoidance/minimisation of impacts to other industry • Avoidance/minimisation of impacts to fishery resources

Table 4.14: Ranking scale for comparative assessment of the options

Preference	Risk/Impact/Significance Ranking			
	Technical, Economic, Safety and Environment (Risk) [1]	Environment (Impact) [2]	Socioeconomic Risk (Significance) [2]	
Least preferred	Severe	Catastrophic	-	6
	Very High	Major	Major	5
	High	Moderate	Moderate	4
	Moderate	Minor	Minor	3
	Low	Slight	Slight	2
	-	Negligible	-	1
Most preferred	No risk	No impact	No risk	0

Notes:

1. Woodside's risk levels defined in Figure 6.3
2. Woodside's impact significance levels defined in Section 6.4.2.1

Table 4.15: Woodside assessment against key drivers of alternative concepts for the development of Scarborough

Driver		Criteria	Evaluated Concepts							
			1. Semi-submersible to Pluto LNG		*2. Subsea Tiebacks to Shore*		*3. Subsea Tieback via Pluto Upstream*		*4. FLNG Concept*	
			Ranking	*Risk/Impact*	*Ranking*	*Risk/Impact*	*Ranking*	*Risk/Impact*	*Ranking*	*Risk/Impact*
ECONOMIC DRIVERS	Schedule Risk	Ability to meet the development timeline	2	Able to meet development timeframe based on greater schedule certainty due to low technology risks.	3	Risks to meeting schedule as higher technical risks introduces risks of schedule slippage.	3	Risks to meeting schedule based on the technical risks associated with the offshore brownfield component.	4	High risk to meeting schedule due to technical uncertainties.
	Cost Risk	Economic viability	2	Economically viable as offshore gas processing and compression improves trunkline efficiency (such as flow rate and assurance).	3	Higher costs associated with the requirements for installation of late subsea compression and the lower production rates.	2	Reduced costs due to there being no requirement for shallow water trunkline, and in any other opportunities to share infrastructure/ activities with Pluto.	3	Higher costs associated with new technology.
	Future Flexibility Risk	Ability to accommodate future development including ties-ins of other fields	1	Able to provide future risers and adjust for low reservoir pressure with compression facilities.	2	Able to adjust subsea compression but likely that this will be costlier to implement in a subsea environment.	3	Low reservoir pressure support would compromise capacity.	3	High degree of complexity and higher costs associated with future tie backs to the FLNG facility.

Driver		Criteria	Evaluated Concepts							
			1. Semi-submersible to Pluto LNG		***2. Subsea Tiebacks to Shore***		***3. Subsea Tieback via Pluto Upstream***		***4. FLNG Concept***	
			Ranking	*Risk/Impact*	*Ranking*	*Risk/Impact*	*Ranking*	*Risk/Impact*	*Ranking*	*Risk/Impact*
TECHNICAL FEASIBILITY AND SAFETY DRIVERS	Safety Risk	In line with industry standards and good practice	3	Simple topsides processing and compression. Minimal manned and presents a moderate risk due to POB.	1	Safest option given unmanned, however there is still potential requirements for subsea intervention which would contribute to safety risks.	3	Comparable POB to Semi-sub option. Additional safety risks during Brownfield construction and integration.	4	High manning and new technology introduce safety risks. Challenging metocean conditions for FLNG design.
	Operability	Technically feasible to meet the field life requirements	1	Known operation, i.e. topsides compression and gas dehydration.	3	Complex liquids management in the trunkline.	3	Complex liquids management in the trunkline. Uncertain shutdown implications during offshore brownfield integration.	3	Unproven technology in Scarborough conditions
	Technical Readiness	Technology readiness levels (TRL) (Note TRL are a method of estimating technology maturity of Critical Technology Elements (CTE) of a program.	1	Proven facility concept, trunkline operation, multiple suppliers available.	4	Novel subsea compression and power, 1 or 2 suppliers of the technology, uncertain trunkline capacity.	4	Some novel subsea elements, uncertain trunkline capacity, Pluto brownfield modifications.	4	Many novel design components which are not ready for full field application. No line of sight to technology deployment ahead of potential Scarborough use.
ENVIRONMENTAL DRIVERS	Ecological services	Physical Presence (i.e. seabed disturbance)	3	Seabed disturbance is greatest based on subsea infrastructure, FPU moorings and export trunkline to shore.	2	Seabed disturbance is slightly lower given no moored FPU, however other infrastructure including trunkline remains.	2	Low level of seabed disturbance as gas is exported to Pluto over the further shoreline options.	1	Lowest level of seabed disturbance as gas is not transferred but processed closer to the location.

Driver	Criteria	Evaluated Concepts							
		1. Semi-submersible to Pluto LNG		***2. Subsea Tiebacks to Shore***		***3. Subsea Tieback via Pluto Upstream***		***4. FLNG Concept***	
		Ranking	*Risk/Impact*	*Ranking*	*Risk/Impact*	*Ranking*	*Risk/Impact*	*Ranking*	*Risk/Impact*
	Vessel movements	2	Moderate level of vessel movements due to minimally manned status during operation.	1	Low level of vessel movements due to subsea infrastructure. Limited to construction and inspection activities.	1	Low level of vessel movements due to subsea infrastructure. Limited to construction and inspection activities.	2	Moderate level of vessel movements due to manned status during operation.
IMS risk	IMS	3	Risk of invasive marine species is likely to be similar for all options, noting that water depths are not favourable for introduction to region. Although noting that the mobilisation of the FPU to the region introduces an additional potential pathway.	2	Risk of invasive marine species is likely to be similar for all options, noting that water depths are not favourable for introduction to region.	2	Risk of invasive marine species is likely to be similar for all options, noting that water depths are not favourable for introduction to region.	3	Risk level may be slightly higher due to vessel movements to support the manned offshore facility.
Emissions and discharges	Underwater noise emissions	2	Underwater noise may be slightly higher during construction phase only due to requirement for piling during mooring of the FPU.	2	Underwater noise is likely to be lowest, however there are some technical uncertainties with noise emissions associated with subsea compression (if undertaken).	2	Underwater noise is likely to be lowest, however there are some technical uncertainties with noise emissions associated with subsea compression (if undertaken).	2	Underwater noise may be higher due to operation of the FLNG and presence of offtake vessels.

Driver		Criteria	Evaluated Concepts							
			1. Semi-submersible to Pluto LNG		*2. Subsea Tiebacks to Shore*		*3. Subsea Tieback via Pluto Upstream*		*4. FLNG Concept*	
			Ranking	Risk/Impact	Ranking	Risk/Impact	Ranking	Risk/Impact	Ranking	Risk/Impact
		Atmospheric emissions	2	Emission levels slightly higher due to topside machinery/plant and vessel movements.	1	Emissions lowest due to subsea infrastructure and minimal surface activities.	1	Emissions lowest due to subsea infrastructure and minimal surface activities.	3	Emission levels highest due to topside machinery/plant and vessel movements.
		Light emissions	2	Moderate light levels to support the topsides. Noting all offshore facilities and vessels must meet minimum requirements for navigation and safety.	1	Minimal lighting due to lower surface infrastructure. Noting all offshore facilities and vessels must meet minimum requirements for navigation and safety.	1	Minimal lighting due to lower surface infrastructure. Noting all offshore facilities and vessels must meet minimum requirements for navigation and safety.	2	Highest level of light emissions to support the FLNG. Noting all offshore facilities and vessels must meet minimum requirements for navigation and safety.
		Planned liquid and solid discharges and wastes	2	Moderate level of discharges based on domestic discharges from minimally manned facility, and cooling water/PW discharge.	1	Lowest level of discharge based given subsea infrastructure.	1	Lowest level of discharge based given subsea infrastructure.	3	Highest levels of discharge based on domestic wastes, cooling waters, etc.

Driver		Criteria	Evaluated Concepts							
			1. Semi-submersible to Pluto LNG		***2. Subsea Tiebacks to Shore***		***3. Subsea Tieback via Pluto Upstream***		***4. FLNG Concept***	
			Ranking	*Risk/Impact*	*Ranking*	*Risk/Impact*	*Ranking*	*Risk/Impact*	*Ranking*	*Risk/Impact*
		Unplanned discharges	3	Credible spill risk highest due to topside inventories. Credible spill risk from the loss of well control will be similar across the options.	2	Lowest risk of spill risk due to no surface infrastructure and associated chemical/hydrocarbon inventories. Credible spill risk from the loss of well control will be similar across the options.	2	Lowest risk of spill risk due to no surface infrastructure and associated chemical/hydrocarbon inventories. Credible spill risk from the loss of well control will be similar across the options.	3	Credible spill risk highest due to topside inventories. Credible spill risk from the loss of well control will be similar across the options.
SOCAL DRIVERS	Socio-economic Impacts	• Avoidance/ minimisation of impacts to other oil and gas activities • Avoidance/ minimisation of impacts to fishery resources	1	Processing Scarborough through Pluto LNG will extend the life of the facility and the supply of gas for domestic and export markets.	1	Processing Scarborough through Pluto LNG will extend the life of the facility and the supply of gas for domestic and export markets.	3	Processing Scarborough through Pluto upstream and LNG will extend the life of the facility and the supply of gas for domestic and export markets. Noting that production capacity and expansion options will be more limited in the initial phases of operation.	3	Does not support extension of the life of the Pluto LNG Facility.

In consideration of all the assessment drivers listed in Table 4.15, Concept 1 is Woodside's preferred development option, whereby Scarborough gas would be processed through a brownfield expansion of Pluto LNG, where additional LNG processing capacity and domestic gas infrastructure will be installed. The composition of Scarborough gas is well suited to the Pluto LNG Facility, which is designed for lean gas and nitrogen removal.

In the context of the environmental impacts and risks associated with each of the options, the following conclusions have been drawn:

- Option 1, based on FPU and export trunkline to shore, results in additional seabed disturbance; however, for onshore development (outside the scope of the OPP) there are benefits in the use of the existing brownfield site and the promotion of the Pluto LNG hub.
- Although Options 2 and 3 would result in lower discharges and potential for unplanned events, due to the lack of surface infrastructure and minimal vessel movements during the operations phase, there are significant technical and economic disadvantages to these options.
- For Option 4, FLNG would result in less seabed disturbance, technical uncertainties and lower opportunities for social benefits (contribution to the domestic gas market), making this option less favourable.

4.5.4 Design/Activity Alternatives

As part of Woodside's preferred concept of a brownfield expansion of the existing Woodside-operated Pluto LNG Facility to process Scarborough gas, Woodside is considering and assessing a range of options for facilities, activities, installation and construction methods. Elements of the project that may have potential impacts and risks on the environment, depending on the concept selected include:

- mooring of construction vessels
- manning of FPU
- drilling fluids
- piling techniques
- compression facilities
- trunkline route
- post-lay stabilisation and protection
- energy efficiencies
- produced water reinjection
- MODU design.

The following sections set out the alternatives for these key elements where they are evident at the current phase of engineering maturity, with each alternative assessed against the criteria for the respective drivers (Table 4-12). The criteria that are used for each decision are those that demonstrate a material difference between the options under consideration.

4.5.4.1 *Mooring of Construction Vessels*

Three options for the mooring of construction vessels were considered:

- Option 1: Anchoring (drag anchors)
- Option 2: Mooring at location – using suction piles
- Option 3: Mooring at location – using driven piles
- Option 4: Dynamically positioned vessels.

The criteria considered when reviewing the type of mooring for construction vessels for the development of Scarborough were as shown in Table 4.16. Evaluation of the applicable environment drivers is provided in Table 4.17.

Table 4.16: Criteria considered when reviewing the type of mooring for construction vessels

Driver Category	Criteria
Economic	• Economic viability
Technical feasibility and safety	• In line with industry standards and good practice
Environment	• Physical presence: Seabed disturbance
Socioeconomic	• Avoidance/minimisation of impacts to other industry • Avoidance/minimisation of impacts to fishery resources • Avoidance/minimisation of risk to public health and safety

Table 4.17 Woodside assessment against key environment drivers of alternatives mooring of construction vessels

Criteria	Evaluated Concepts							
	1. Anchoring (drag anchors)		*2. Mooring at location – using suction piles*		*3. Mooring at location – using driven piles*		*4. Dynamically positioned vessels*	
	Ranking	*Risk/Impact*	*Ranking*	*Risk/Impact*	*Ranking*	*Risk/Impact*	*Ranking*	*Risk/Impact*
Physical Presence: Seabed disturbance	2	Slightly higher level of impact due to the potential number of anchors during construction, noting that this is the least feasible option due to water depth.	1	There will be seabed disturbance at the Project Area where the piles are installed, however as area does not intersect environmentally sensitive habitats, this impact is low.	1	There will be seabed disturbance at the Project Area where the piles are driven, however as area does not intersect environmentally sensitive habitats, this impact is low.	0	No impact to the seabed. Lowest level of seabed disturbance

Other than the export trunkline installation, activities will occur offshore in waters of about 900 m, and as such anchoring at this depth is unlikely to be suitable for construction vessels. There will potentially be installed mooring facilities in the Offshore Project Area, while other vessels may use dynamic positioning systems. For vessels being used to support the export trunkline installation, there will be a need for temporary moorings at various locations within the Trunkline Project Area.

The final decision for mooring will be determined during the FEED phase of the project. Although DP vessels provided the lowest environmental impact / risk ranking, given that the Project Area does not intersect environmentally sensitive habitats, the decision will be based mainly on technical feasibility and economic criteria. The environmental impact assessment however considers the worst-case impacts associated with each of the options. For example, driven piles for installing moorings offshore are assessed in terms of the potential underwater noise impacts (note that the alternatives of suctions versus driven piles is considered further in the following sections).

4.5.4.2 Manning of FPU

Three options for the manning the FPU were considered:

- Option 1: Manned FPU
- Option 2: Minimally manned FPU
- Option 3: Unmanned facilities.

The criteria considered when reviewing the manning philosophy for the FPU as part of the development of Scarborough were as shown in Table 4.18.

Table 4.18: Criteria considered when reviewing the manning philosophy for the FPU

Driver Category	Criteria
Technical feasibility and safety	• In line with industry standards and good practice • Technically feasible to meet the field life requirements

Environmental criteria have not been considered in the decision of manning the FPU as the location of the FPU is at a sufficient distance offshore and from areas of environmental sensitivity that the environmental impacts associated with domestic discharges and activities is minimal.

The key drivers for the manning philosophy are technical feasibility and safety criteria. Unmanned facilities are viable for the subsea focused development options; however, these options were not selected in the concept evaluation based on the technical feasibility and readiness of such options. Offshore manning will be minimised through design of the facilities for minimal offshore maintenance and remote control and operation.

As such Option 2: Minimally manned FPU is the preferred option, and it is a project objective to design the Scarborough FPU so a minimally manned operation (aiming for potential future unmanned activities) with campaign maintenance strategy can be achieved.

The final decision for manning will be determined during the FEED phase of the project. Given the Project Area does not intersect environmentally sensitive habitats, the decision will be based mainly on the technical feasibility and safety criteria. The environmental impact assessment however considers the worst-case impacts associated with a manned option – i.e. to assess the potential domestic discharges associated with up to 75 persons on board.

4.5.4.3 *Drilling Fluids*

Two options for drilling fluids were considered:

- Option 1: Water Based Mud (WBM)
- Option 2: Non-Water Based Mud (NWBM).

The criteria considered when reviewing the type of drilling fluids for the development of Scarborough were as shown in Table 4.19.

Table 4.19: Criteria considered when reviewing the type of drilling fluids

Driver Category	Criteria
Technical feasibility and safety	• In line with industry standards and good practice • Technically feasible to meet the field life requirements

The selection of drilling fluid types is dependent on technical aspects of the drilling program that will not be known until completion of detailed design. WBM drilling fluids systems are used as the first preference when planning to drill a well, consistent with the requirements of Woodside's Environmental Performance Standard. NWBM may also be used subject to the development of a "business case deviation" that details environment, technical, health and waste management considerations. The requirement to use NWBM is typically based on a need for improved management of the technical and safety aspects of drilling technically complex wells.

Where NWBMs are used these will be selected in accordance with the Woodside Chemical Selection and Assessment Environment Guideline. Therefore, the key criterion for selection is technical feasibility and safety and as such both Option 1: WBM and Option 2: NWBM are being progressed.

4.5.4.4 Piling Techniques

Two options for the installation of the FPU are under consideration:

- Option 1: Suction piles
- Option 2: Driven piles.

The criteria considered when reviewing the piling techniques for the installation of the FPU for the development of Scarborough were as shown in Table 4.20. Evaluation of the applicable environment drivers is provided in Table 4.21.

Table 4.20: Criteria considered when reviewing the piling techniques for installing the FPU

Driver Category	Criteria
Economic	• Ability to meet the development timeline • Economic viability • Ability to accommodate future development including ties-ins of other fields
Technical feasibility and safety	• In line with industry standards and good practice • Technically feasible to meet the field life requirements
Environment	• Underwater noise emissions

Table 4.21: Woodside assessment against key environment drivers of alternatives for piling techniques

Criteria	Evaluated Concepts			
	1. Suction piles		***2. Driven piles***	
	Ranking	*Risk/Impact*	*Ranking*	*Risk/Impact*
Underwater noise emissions	1	Some noise during construction however this will be comparable to typical vessel driven noise.	3	Piling is likely to generate underwater noise during the construction period that will have the potential for minor short term impacts up to approximately 40 km from the Project Area (Marshall Day Acoustics, 2019).

The preferred option for piling is Option 1 given the associated costs, safety and environmental impacts are likely to be much less. However, there are potentially technical constraints for this option based on the geotechnical conditions at the location of the FPU. On this basis, Woodside are carrying both options until further investigative studies are undertaken including geophysical and geotechnical assessment at the FPU location.

When compared on environmental drivers, suction piling presents the lowest potential impact and risk to receptors. However, given final decisions will be determined in the FEED phase of the project, the environmental impact assessment considers the worst-case impacts associated with each of the options. For example, driven piles for installing moorings offshore are assessed in terms of the potential underwater noise impacts.

4.5.4.5 *Compression Facilities*

Three options for the compression facilities were considered:

- Option 1: Conventional compression on a floating semi-submersible
- Option 2: Subsea compression at RFSU
- Option 3: Future platform or subsea compression.

The criteria considered when reviewing the type of compression facilities for the development of Scarborough were as shown in Table 4.22.

Table 4.22: Criteria considered when reviewing the type of compression facilities

Driver Category	Criteria
Economic	• Ability to meet the development timeline • Economic viability • Ability to accommodate future development including ties-ins of other fields
Technical feasibility and safety	• In line with industry standards and good practice • Technically feasible to meet the field life requirements • Project considers an acceptable technology readiness levels (TRL)

Option 1 is a known mode of operation. Woodside is experienced with the use of topsides for compression facilities, and this option provides schedule certainty.

Subsea compression (Option 2) is a novel technology. The adoption of this option would incur significant schedule risk and costs to pursue.

Option 3 would not support the required production capacity at commencement, and as such does not meet the project requirements.

4.5.4.6 Trunkline Route

An assessment of options associated with the Scarborough trunkline route have been divided into two sections. The deepwater trunkline route (ie West of the existing Pluto platform) and the shallower water trunkline route (ie East of the existing Pluto platform). The criteria considered when reviewing the export trunkline route for the development of Scarborough were as shown in Table 4-23.

Table 4-23: Criteria considered when reviewing the export trunkline route

Driver Category	Criteria
Economic	• Ability to meet the development timeline • Not impact economics of other projects • Economic viability
Technical feasibility and safety	• In line with industry standards and good practice • Technically feasible to meet the field life requirements • Crossing angle of other pipelines • Avoidance of challenging seabed features such as rocky outcrops

	• Approach angle to bathymetric features such as sand waves
Environment	• Physical presence: Seabed disturbance
Socio economic	• Avoidance/minimisation of impacts to other industry (including future development)

Deepwater trunkline route (ie West of the existing Pluto platform)

A summary of the evaluation of the applicable environment drivers for the base case and three alternative deepwater trunkline routes is provided in Table 4-24.

Table 4-24: Woodside assessment against key environment drivers of alternatives for the deepwater trunkline route

Criteria	Evaluated Concepts							
	1. Base case		*2. Alternative 1*		*3. Alternative 2*		*4. Alternative 3*	
	Ranking	*Risk/Impact*	*Ranking*	*Risk/Impact*	*Ranking*	*Risk/Impact*	*Ranking*	*Risk/Impact*
Physical Presence: Seabed disturbance	2	Pipeline length of 430km. Lower seabed intervention given the location of the scarp crossing. While the route traverses the Marine park surveys show sand waves at this location with little habitat.	3	Greatest pipeline length at 455km. Limited crossing with other infrastructure however, the increased pipeline length and seabed intervention required for scarp crossing results in greatest area of seabed disturbance.	2	Lowest pipeline length at 415km. However additional crossings with infrastructure which increases the potential risks.	2	425km pipeline length however there are unknowns with respect to environmental sensitivities and increases in crossings with infrastructure

The base case for the export trunkline has an overall length of about 430 km. It traverses from the Offshore Project Area to the north of the existing Io/Jansz subsea infrastructure before approaching the continental slope to the north of the Pluto field.

A key driver for trunkline routes is to minimise risks associated with geohazards and abrupt bathymetry features such as submarine landslide deposits, debris flows, turbidite flows, sand waves and steep sections. Previous work undertaken by Woodside has identified an area of the continental scarp that can be crossed without significant slope crossing construction (including deepwater trenching and rock dumping) and avoidance of intolerable pipe spans and geohazards and as such this is preferred for the base case. The route does not follow the same corridor as the Pluto flowlines up the slope because there is no space for the Scarborough trunkline to pass through a narrow 'choke' area between canyon features at the Pluto flowline crossing. It also ensures that the trunkline runs parallel to the sand wave features in this location which is important for a rigid trunkline (relative to the more flexible Pluto flowline). This is depicted on Figure 4.5. Crossing the scarp in this location places the trunkline within the far north-western corner of the Montebello Multiple Use Zone.

The base case route brings the trunkline to the south of the Pluto Platform and Pluto trunkline and avoids an area of rocky outcrops to the south of Pluto Platform, as depicted on Figure 4.5. This is also on the same side as the shore crossing (which is restricted due to spatial constraints). If the route took the Scarborough trunkline to the north of the Pluto trunkline, it would require a crossing to bring it to the south side, a challenging sharp turn at the top of the scarp and an additional crossing of the Pluto flowline. No alternative sites at which the trunkline could safely cross the continental scarp further to the north of the Pluto Platform were identified.

Once at the top of the slope, the pipeline will follow existing Woodside infrastructure before heading into the south-easterly direction and crossing the Pluto, Julimar and Wheatstone pipeline and umbilical systems. All route options have to cross existing pipelines, and since crossings present technical challenge and safety/environment risk associated with damage to the existing pipelines, the number of pipelines to be crossed is a key differentiator between the options. The base case route is then located to the south of the Pluto platform comes into close proximity to the existing Pluto trunkline (within about 100 m) and then follows the it to shore.

Alternative Route 1 with the greatest route length of 455 km, follows the base case route from the Offshore Project Area for the first 190 km, before deviating southwards, avoiding areas proposed for future development, and limiting the number of pipeline crossings. This option however presents some challenges for scarp crossing, which would require significant engineering and construction based on industry experience for this area. The seabed intervention required for this crossing would increase physical disturbance in the area (including generation of turbidity from dredging and stabilisation), and associated presence of deepwater construction vessels. As such and based on the potential implications to schedule and cost, this option was not considered further.

Alternative Route 2 has a total length of 415 km and follows the base case route from the Offshore Project Area for the first 75 km. It then deviates in an easterly direction and crosses the continental slope at the same location as the base case route. The main point of difference is that this alternative saves around 15 km of pipeline length by crossing the Io/Jansz pipeline system in waters approximately 1200 m deep. Other crossings are in much shallower areas (120 to 150 m) and this crossing therefore carries more technical risk. There is also a potential for other deepwater developments at some time in the future, and therefore based on the uncertainty and risks surrounding this deepwater crossing, this route was not considered further, despite having an overall route slightly shorter than the base case.

Alternative Route 3 has a total route length of 425 km and follows the base case route from the Offshore Project Area for the first 75 km. It then deviates in a south-easterly direction and crosses the continental slope in an area for which high quality survey data is not available. For example, it is unknown as to whether there are environmental sensitivities (i.e. deepwater sponges or corals) on the slope in this area. The route will also result in a number of pipeline crossings including the possible future developments and the existing Io/Jansz pipelines. Even though this alternative offers some savings in total length (5 km), based on the above factors, it has not been considered further.

The option selected by Woodside is the base case route, as shown in Figure 4.4, for the deepwater section of the export trunkline.

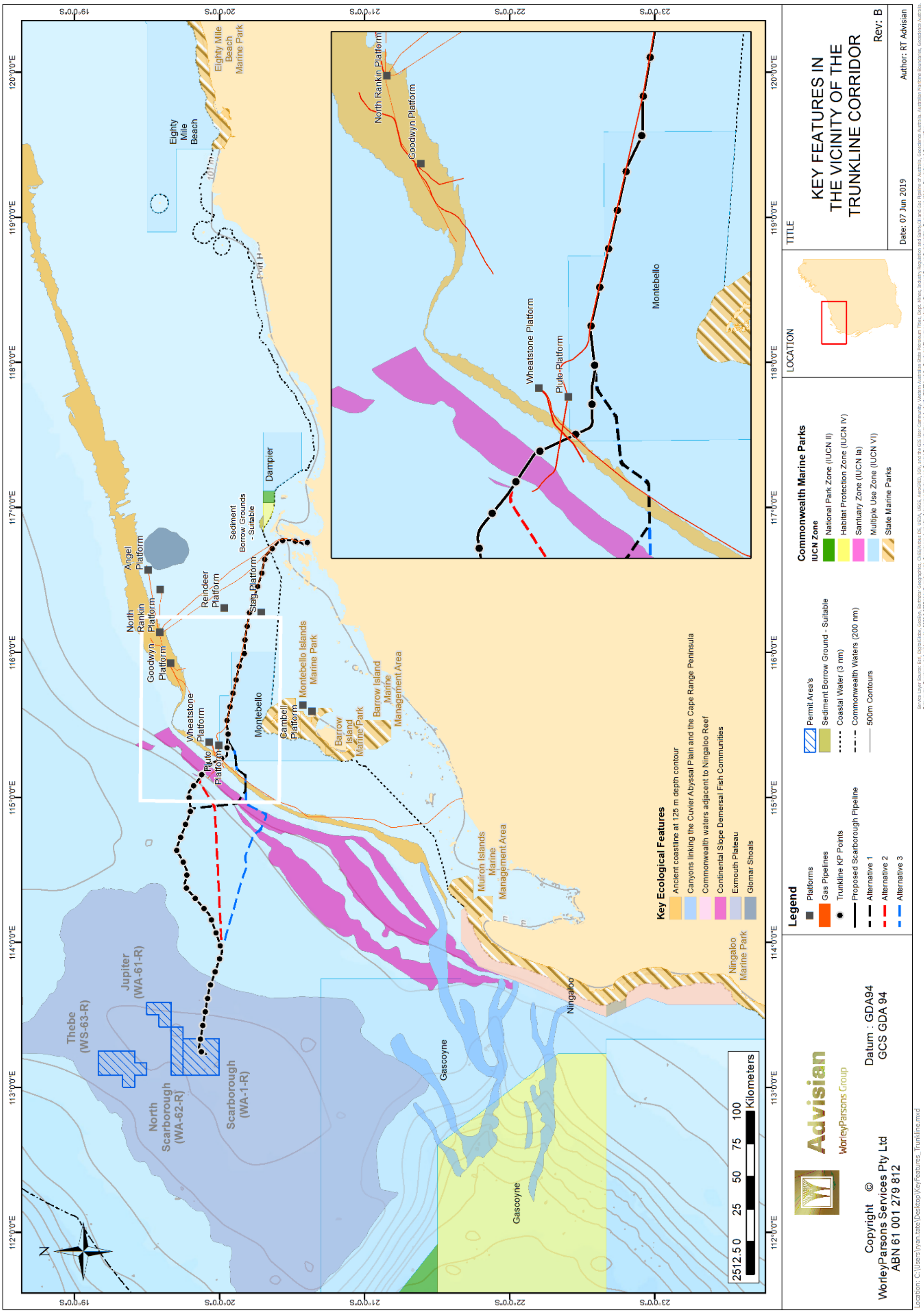


Figure 4.4: Alternative alignments for the deepwater export trunkline

Shallow water trunkline route (ie East of the existing Pluto platform)

A summary of the evaluation of the applicable environment drivers (Table 4.25) for the proposed option and alternatives for the Trunkline route east of the Pluto platform.

Table 4.25: Woodside assessment against key environment drivers of alternatives for the trunkline route east of the Pluto platform

Criteria	Evaluated Concepts							
	1. Base Case - Along existing Pluto trunkline from shore then deviate to the South.		***2. Alternative A - Along existing Pluto trunkline from shore for longer period then deviate to the North prior to Pluto platform.***		***3. Alternative B - Use of Existing Pluto Trunkline and then extension past platform in deeper waters.***		***4. Alternative C – New Route to North which completely avoids Montebello AMP.***	
	Ranking	*Risk/Impact*	*Ranking*	*Risk/Impact*	*Ranking*	*Risk/Impact*	*Ranking*	*Risk/Impact*
Physical Presence: Seabed disturbance	3	Level of seabed disturbance equivalent to other trunkline options. Route avoids rocky outcrop features to the north. Route allows trunkline to align at optimum angle to traverse sand waves and other pipelines.	3	Risky scarp crossing location. Level of seabed disturbance equivalent to other trunkline options. This was not a preferred alternative for the Scarborough export trunkline as this would have required further crossings of existing infrastructure (including the existing Pluto trunkline) that introduces additional technical and integrity risk and costs.	2	Risky scarp crossing location. Not preferred due to differences in fluid composition between Pluto and Scarborough, flow on impacts (processing complexity) for the onshore facilities and as capacity of that line is already accounted for with existing and planned future projects.	3	Risky scarp crossing location. Not preferred as going to the north would require crossing the existing Pluto trunkline due to the configuration of the existing shore crossing. A new trunkline route in this location would be traversing through less understood bathymetry and seabed data. Seabed disturbance not within a pre-disturbed footprint and is of a longer distance (ie greater seabed disturbance.

When considering Woodside's preferred Scarborough trunkline route and Alternative Route A, following the existing Pluto trunkline corridor within the northern extent of the AMP Multiple Use Zone provides technical benefits including using well understood bathymetry and seabed data. This approach of following an existing disturbance corridor also reduces the cumulative physical footprint impacts a result of multiple trunkline corridors and related seabed preparation (where required).

Deviating to the North around the Pluto Platform (ie outside the Montebello AMP Multiple Use Zone) before meeting the Pluto trunkline (ie Alternative Route A) was considered, however this route would have required further crossings of existing infrastructure (including the existing Pluto trunkline) that introduces additional technical and integrity risk and costs. In addition, this route is less technically feasible as it would involve traversing an area of large sand wave features found on the continental slope at a less than optimal traversing angle which would reduce stability and increase span risk in this section. Crossing the sand waves on this different angle would have also required seabed intervention and stabilisation that was not required for the Pluto flowlines due to its greater pipe inherent flexibility when compared with a trunkline. As highlighted within the deepwater section above, this alternative route would have been traversing the scarp through less understood bathymetry and seabed data (ie similar to Alternative Route C). At present no alternative sites at which the trunkline could safely cross the continental scarp further to the north of the Pluto Platform have been identified.

Meeting the Pluto trunkline offshore on the southern side avoids an additional crossing which is particularly sensitive for the Pluto trunkline due to the chemical supply pipe which is located on top of the main Pluto trunkline. Since crossing risks are reduced by perpendicular approach angles, a crossing of the Pluto trunkline would also require a loop to be introduced to achieve this and therefore result in additional seabed disturbance. In addition, seabed surveys (Keesing, 2019) indicate that seabed sensitivity is likely higher in the Trawl Fishery Area to the North/West of the Montebello AMP Multiple Use Zone than within it. This includes a biomass of habitat forming filter feeders 5.5 times greater than that within the Montebello AMP Multiple Use Zone.

Tie in to the existing Pluto trunkline (i.e. Alternative Route B on Figure 4.5) does not meet the economic drivers listed in Table 4-23. The existing Pluto project and trunkline is expected to continue operating at full capacity for a number of years. Therefore, use of this trunkline for Scarborough would either mean significant delay to project start up (potentially making it non-viable), or limiting production from existing Pluto wells to create space in the trunkline which impacts the economics of the Pluto project. Additionally, due to different reservoir pressures significant infrastructure would be required on either the Scarborough or Pluto platforms to reduce Scarborough pressure and allow tie in at the Pluto platform. This is not considered feasible due to space and weight constraints on both facilities.

Construction of a separate dry gas pipeline for Scarborough rather than co-mingling with the “wet” Pluto trunkline also allows a simpler onshore gas plant design which does not have to separate liquids, MEG condensate and heavy hydrocarbon gases. This represents both a cost saving and reduction of onshore physical footprint

An option was also considered where the new Scarborough trunkline route avoids the Montebello AMP Multiple Use Zone completely and extends to the north (Alternative Route C on Figure 4.5). A new trunkline route in this location would be traversing through less understood bathymetry and seabed data with the same challenges related to scarp crossing described above. In addition this route would be longer overall compared to other options causing a greater overall increase of seabed disturbance. As described above spatial constraints at the shore crossing location mean that the Scarborough trunkline must cross the coastline on the southern side of the existing Pluto trunkline, so use of this route would require an additional pipeline crossing to bring it back to the south side of the Pluto trunkline. Seabed surveys (described above) also indicate that seabed sensitivity to the North/West of the Montebello AMP Multiple Use Zone (Keesing, 2019) is also higher, suggesting greater potential for disturbance to habitats from this route.

Trunkline shallower waters

In shallow water (east of the Pluto Platform beyond the Montebello AMP Multiple Use Zone) it is preferred that the export trunkline follows the alignment of the Pluto trunkline to the entrance of Mermaid Sound. Justifications regarding this selection are similar to the Base Case above where following the existing Pluto trunkline corridor provides technical benefits including well understood bathymetry and seabed data, but also reduces the cumulative physical footprint impacts a result of multiple trunkline corridors. In addition, when the route gets closer to Mermaid South this course also provides the advantage of known environment and geology, and the availability for use of the pre-investment work (dredging and seabed preparation) undertaken for Pluto LNG.

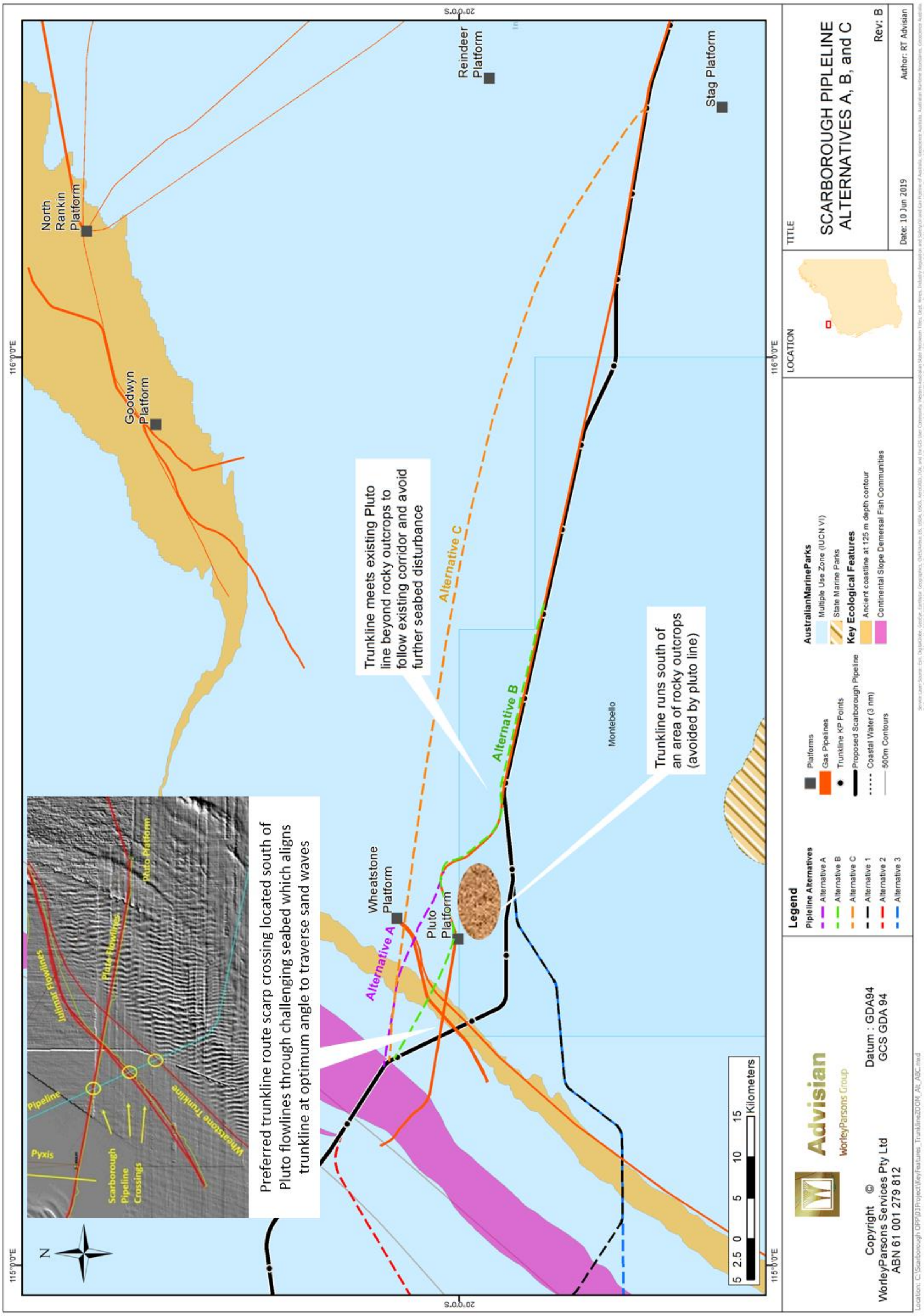


Figure 4.5: Shows the location of key features that influenced the preferred trunkline corridor adjacent to the Pluto platform.

4.5.4.7 Post Lay Stabilisation and Protection

Considerations when assessing trunkline stabilisation in Commonwealth Waters included:

- Necessity to stabilise the trunkline
- Use of rock dumping or sand to stabilise the trunkline
- Source of rock or sand used to stabilise the trunkline

The criteria considered when assessing these options are summarised in Table 4.26.

Table 4.26: Criteria considered when reviewing the trunkline post lay stabilisation and protection

Driver Category	Criteria
Economic	• Economic viability • Proximity of borrow ground to pipeline
Technical feasibility and safety	• In line with industry standards and good practice • Stabilisation performance and protection
Environment	• Physical presence: Seabed disturbance

As described in Section 4.4.7.3, it is anticipated that trunkline stabilisation will be required in water depth shallower than 40 m. Use of rock for stabilisation may be required in some areas, however sand is preferentially used due to its local availability which reduces cost and risk associated with bringing rock from onshore locations. Woodside considered a range of stabilisation options as presented in Table 4.27.

Table 4.27: Summary of assessment of stabilisation options

Stabilisation Option	Feasible?	Justification
Use of Sand Material Sourced from Borrow Ground >250 m from the Commonwealth Marine Park	**Woodside's Preferred Option**	Location contains substantial amounts of highly suitable material of a quality and quantity to undertake stabilisation activities for the Scarborough Scope. A 250 m buffer will be maintained from the Dampier Marine Park.
Use of Sand Material Sourced from Borrow Ground adjacent to Commonwealth Marine Park	Feasible	Location contains substantial amounts of highly suitable material of a quality and quantity to undertake stabilisation activities for the Scarborough Scope.
Use of Rock Material for whole trunkline (no sand stabilisation)	Feasible	While this option is feasible, trench and backfill is valued as a superior solution over stabilisation rock berms (no cover over the pipeline) for the following reasons: • Higher Health and Safety Exposure associated with rock handling (onshore quarrying, transport over public roads, stockpiling, load out to vessel) compared to the TSHD only option. • Costs impact associated with only using rock for trunkline stabilisation would be significant compared to a combination of rock and sand. • Vessel time would be significantly increased over TSHD trench and backfill option
Use of Sand Material Sourced from within Dampier Commonwealth Marine Park	Not Feasible	Commonwealth Marine Park Area – Marine Habitat Protected Area. There is a higher potential impact to the values of the marine park, and as such Woodside's preferred position is to focus on areas adjacent to the Marine Park where suitable sediment is located.

Stabilisation Option	Feasible?	Justification
Use of Sand Material Sourced from Borrow Ground within Mermaid Sound	Unknown	Additional work would need to be undertaken to prove material suitability and quantity. Location is expected to contain only marginally suitable material of a quality to undertake stabilisation activities for the Scarborough Scope. The areas with of acceptable material are thin and spread across the area making dredging potentially inefficient. Given the overlap with the PPA approved anchorages on the west and the new Scarborough pipeline on the eastern side, the practical access to the areas and the actual available volume may be less than required.
Use of Sand Material Sourced from existing Spoil Grounds	Not Feasible	Testing of this material undertaken during Pluto LNG demonstrated that the material is of inconsistent quality with a majority of the volume not meeting minimum backfill requirements. Not suitable.
Use of Sand Material Sourced from Onshore	Not Feasible	Suitable backfill sand is only available in limited quantities and from a significant distance away from the point of load out. The cost associated with using onshore quarried sand would be significant due and likely impacting the local sand (and concrete) trade.
Use of Sand Material Sourced from TSEP Borrow Ground	Not Feasible	Borrow Ground was used during TSEP and subsequently for the Pluto Foundation Project. As a result, it no longer contains adequate suitable material to undertake stabilisation activities for the Scarborough Scope.

For the assessment of stabilisation options, consideration was given to the suitability of stabilisation material, proximity to the pipeline and proposed backfill and the environmental sensitivity of the borrow ground and surrounding area when selecting suitable borrow ground locations.

A geotechnical survey was conducted in four distinct areas for the TSEP project to characterise potential suitable borrow grounds. These surveys identified the most suitable location as that identified in Figure 4.3.

Consideration was given to the potential re-use of materials from existing Spoil Grounds to negate the requirement to use a new borrow ground, however the geotechnical properties of the materials in existing spoil grounds are not suitable for pipeline stabilisation (refer to Section 4.5 for additional discussion regarding borrow ground selection).

A benthic habitat survey of the potential borrow ground and surrounding areas within the Dampier Marine Park was commissioned (Advisian, 2019c) to support the assessment of the suitability of the borrow ground. Evaluation of the applicable environment drivers for the technically feasible options is provided in Table 4.28.

Table 4.28: Woodside assessment against key environment drivers of feasible alternatives for trunkline stabilisation

Criteria	Evaluated Concepts					
	1. Borrow ground >250 m from Dampier Marine Park		***2. Only rock material used for stabilisation***		***3. Borrow ground within Mermaid Sound***	
	Ranking	Risk/Impact	Ranking	Risk/Impact	Ranking	Risk/Impact
Physical Presence: Seabed disturbance	2	Options presents some potential for seabed disturbance however a buffer from the Dampier Marine Park will be maintained, and the area was surveyed to show that bare sandy substrate dominates the area identified for suitable borrow.	2	Options presents less seabed disturbance as the rock is likely to be sourced onshore. However, there is additional onshore impacts, including clearance, transport and additional vessel movements required.	2	Area has had prior disturbance, as such the impacts may be less, however there are increased technical challenges and the potential for impacts to social receptors within the Port.

Bare sandy substrate dominated most of the locations where towed/drop camera transects were conducted. Where biota was observed, it typically consisted of invertebrates such as anemones and crinoids at densities no greater than 10% and typically less than 5% cover. Of the 24 survey locations within the potential borrow ground, sparse invertebrate cover was observed at only two locations. Of the 51 survey locations within the habitat protection zone of the Dampier Marine Park immediately adjacent to the proposed borrow ground, sparse invertebrate cover was observed at 12 locations.

Additional survey work completed by CSIRO shows that benthic cover in the habitat protection zone of the Dampier AMP, adjacent to the proposed borrow ground, is not regionally significant and that benthic cover in the habitat protection zone of the Dampier AMP, adjacent to the proposed borrow ground, is lower than that identified regionally (Keesing, J.K. (Ed.) 2019).

Based on an assessment of the existing environment at and surrounding the borrow ground and the geotechnical properties of the regional seabed the borrow ground identified in Figure 4.3 is considered the most suitable for the project.

4.5.4.8 Energy Efficiencies

While the majority of decisions that will influence the energy efficiency of the development will be made during the design phase of the project, a number of alternatives which will benefit energy efficiency have been included in the development base case as preferred options. These include:

- Allowance in design for future installation of a battery energy storage system (BESS) to reduce the fuel gas consumption (and emissions) for power generation in steady state operation, in the event additional design work and collection of operational data determines that a BESS is ALARP for the facility.
- Selection of a minimally manned concept which provides benefits in the form of reduced electrical load for the living quarters, reduced helicopter and vessel use and associated philosophy of simplifying topsides process as much as possible. This enables the facility to be operated with fewer personnel, but also reduces electrical load associated with ancillary systems
- Use of waste heat from turbine exhaust to provide heating duty on the FPU, removing the need for fired boilers
- Providing pre-cooling of incoming gas using a gas-gas heat exchanger rather than refrigeration
- Internally flow coated trunkline which reduces pressure drop along the length and therefore requires lower compression on the FPU, and
- Turbine and equipment selection

Alternatives that have not been selected include:

- Alternative power sources such as offshore renewables or a cable from shore. These options were not selected for implementation due to technical constraints associated with the infrastructure and significant cost which was considered grossly disproportionate to the emissions reduction
- Free flow to shore. This concept involves removing the hydrocarbon dewpointing process on the FPU, and therefore the necessity to recompress the gas before export using gas powered turbines. It was not considered technically feasible to implement this option due to risk of liquid build-up in sections of the export trunkline

A FEED phase energy efficiency workshop has been held to identify additional opportunities which can be investigated during design. The workshop was facilitated by specialist consultants and was attended by key discipline engineers to enable comprehensive opportunity identification. Opportunities will be screened and implemented according to ALARP principles and in alignment with the framework defined by the WMS including expected benefit, economic, technical and health, safety and environment drivers.

4.5.4.9 Produced Water Disposal

Two options were considered for disposal of produced water:

- Option 1: Reinjection into the reservoir
- Option 2: Treatment and overboard disposal

The criteria considered in this decision are summarised in Table 4.29. Evaluation of the applicable environment drivers for the options is provided in Table 4.30.

Table 4.29: Criteria considered when reviewing the disposal of produced water

Driver Category	Criteria
Economic	• Economic viability • Impact on reservoir performance • Maintenance requirements (in minimum manning philosophy)
Technical feasibility and safety	• In line with industry standards and good practice
Environment	• Planned liquid and solid discharges and wastes

Table 4.30: Woodside assessment against key environment drivers of alternatives for produced water disposal

Criteria	Evaluated Concepts			
	1. Reinjection into the reservoir		*2. Treatment and overboard disposal*	
	Ranking	Risk/Impact	Ranking	Risk/Impact
Planned liquid and solid discharges and wastes	2	Would require drilling of an additional well, with potential for additional impacts.	2	Low volumes for disposal anticipated. Modelling demonstrated that impacts are localised and will not result in any significant impact.

The volume of water expected to be produced from Scarborough, Thebe and Jupiter is expected to be very low in comparison with other offshore facilities where treated produced water is discharged overboard, up to a maximum of 600 bbl/day (see Section 7.1.10). Reinjection of this water into a reservoir would require drilling of an additional well, additional subsea and topsides infrastructure and has considerations for reservoir performance. This not only incurs significant additional cost (estimated $300 million) but carries associated health and safety risk and environment impact. Since modelling indicates that suitably treated produced water can be discharged with acceptable environmental impact (see Section 4.4.9.2) the decision has been made to progress treatment and overboard disposal of produced water.

4.5.4.10 MODU Design

Three options were considered for MODU design:

- Option 1: Jack-up MODU
- Option 2: Anchored floating MODU
- Option 3: DP floating MODU.

The criteria considered in this decision are summarised in Table 4.31. Evaluation of the applicable environment drivers for the options is provided in Table 4.30.

Table 4.31: Criteria considered when reviewing MODU design options

Driver Category	Criteria
Economic	• Ability to meet the development timeline • Economic viability
Technical feasibility and safety	• In line with industry standards and good practice
Environment	• Physical presence: Seabed Disturbance • Underwater noise emissions

Table 4.32: Woodside assessment against key environment drivers of alternatives for MODU design

Criteria	Evaluated Concepts					
	1. Jack-up MODU		*2. Anchored floating MODU*		*3. DP floating MODU*	
	Ranking	*Risk/Impact*	*Ranking*	*Risk/Impact*	*Ranking*	*Risk/Impact*
Physical presence: Seabed disturbance	-	Option not technically feasible.	3	Seabed disturbance footprint dependent on anchor spread. Anchor handling required.	1	Footprint minimised due to lack of anchor spread. No anchor handling required.
Underwater noise emissions	-	Option not technically feasible.	0	No underwater noise emissions generated from positioning.	2	Thrusters generate underwater noise emissions.

Due to the water depth in the Scarborough Project area, it is not technically feasible to use a jack-up MODU. Option 1 was therefore screened out, with no further consideration undertaken.

The use of a DP MODU (Option 3) is considered the best option as it does not require the subsea layout to accommodate mooring locations for anchors and provides lower risk as no anchor handling is required, minimizing the potential to damage the infrastructure being laid on location if an anchor is dropped. Having no anchors also minimises the potential environmental impact on the seabed. The more mobile nature of using a DP MODU allows for more dynamic and efficient well sequencing, reducing the total duration of the drilling activity.

Although the DP MODU (Option 3) is favourable with regards to minimising seabed impact and well sequence flexibility, they generate more underwater noise when compared to an anchored MODU. Additionally, DP MODUs generate more atmospheric emission due to the additional fuel consumption associated with the use of DP thrusters.

Although Option 3 is the currently preferred option, Option 2 (Anchored MODU) has not been ruled out as it is still a potential option and will depend on regional and local rig availability.

5 DESCRIPTION OF THE ENVIRONMENT

5.1 Overview

Scarborough occurs in Commonwealth waters off the northwest coast of Western Australia (WA) (Figure 5.1), located in the North West Marine Bioregion (NWMR) (IMCRA 4.0). The target fields occur within the Northern Carnarvon Basin on the Exmouth Plateau, and are about 375 km offshore from Dampier, in water depths of 900–970 m, with the proposed trunkline ultimately crossing into State waters along the same alignment as the Pluto Gas Export Pipeline (Figure 5.1).

For the purpose of describing the environmental context relevant to the development of Scarborough, two zones have been developed:

- The Project Area, which is divided further into the Offshore Project Area (the area covered by WA-1-R, WA-62-R, WA-61-R and WA-63-R), the Trunkline Project Area (the proposed trunkline route with a 1 km buffer either side) and the Borrow Grounds Project Area (the proposed location for the borrow grounds). The EMBA with the largest spatial extent was chosen as the outer limits where unplanned events could have an environmental consequence.
- The environment that may be affected (EMBA) by Scarborough, which is the largest spatial extent where unplanned events could have an environmental consequence on the surrounding environment (Figure 5.2). 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 spill scenario. (i.e. a 2,000 m^3 vessel fuel tank rupture; refer to Section 7.2.6). 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 scenario. While the EMBA considers all hydrocarbon phases, it is characterised by the low exposure zone for entrained hydrocarbons. The EMBA has been set with some buffer (approximately a minimum of 50 km) to accommodate exposure below these levels (noting that below these levels any biological impacts are not expected to occur). The EMBA also extended inshore to accommodate for a spill scenario occurring anywhere along the trunkline route and simplified to a rectangular shape for ease of use. The modelling that was used to derive the EMBA is detailed in the report provide in Appendix I.

For planned and unplanned emissions and discharges, numerical modelling was undertaken as outlined in Section 5.2.

This EMBA forms the basis of the EPBC Protected Matters search and Woodside has undertaken an assessment of all the environmental values and sensitivities within this EMBA. Noting that the thresholds at which impacts to biological and social impacts will vary, the level of detail provided on each of the receptor will reflect this difference.

The key characteristics of the environment for these areas have been summarised in the sections below.

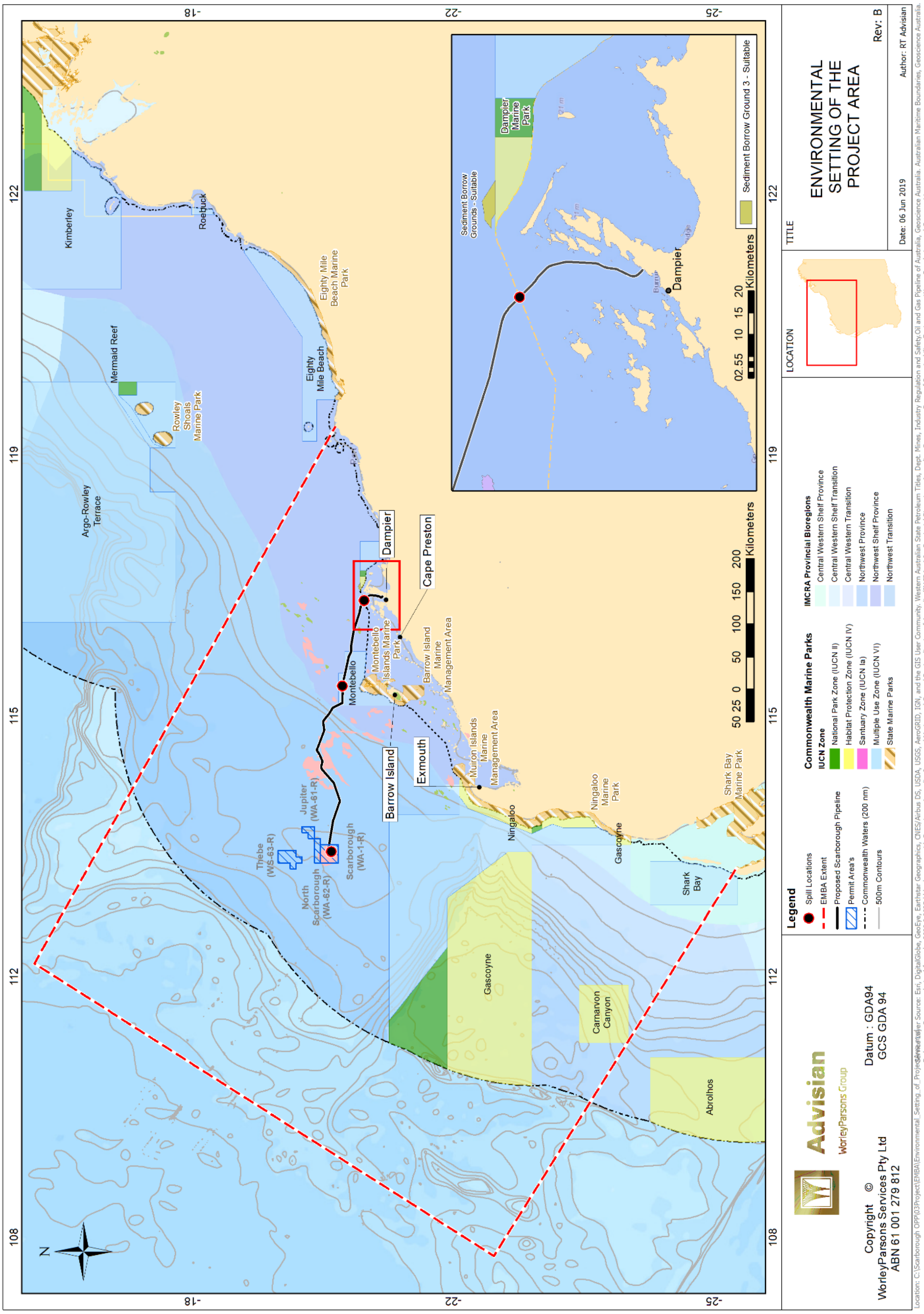


Figure 5.1: Environmental setting of the Project Area

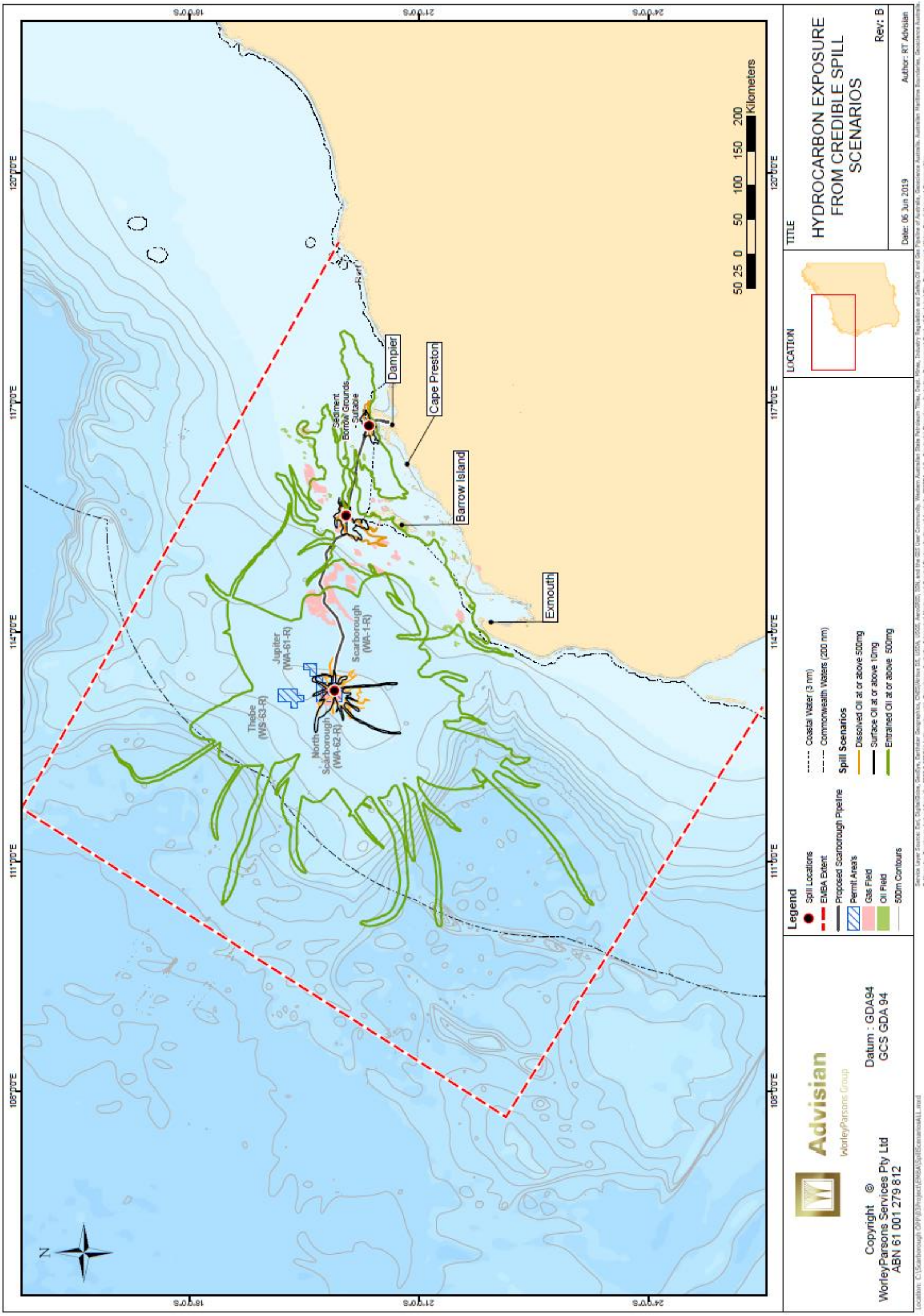


Figure 5.2: Results from stochastic hydrocarbon spill modelling used to define the EMBA

5.2 Studies and Information Sources

5.2.1 Overview

Studies and reviews of the Exmouth Plateau and North West Shelf have been compiled and/or undertaken to provide an understanding of the physical, biological and socio-economic environmental conditions within the Scarborough Project area.

These studies contribute to long-term datasets for the region and the majority have been made available in the public domain. Information on the existing environment gathered through these studies has been supplemented by information from:

- peer reviewed journals
- industry and government technical reports
- standards and guidelines
- Department of the Environment and Energy (DoEE) resources and published literature including the Species Profile and Threats (SPRAT) database
- search tools such as the Department of Parks and Wildlife (DPaW) NatureMap and an EPBC Act Protected Matters database search to identify listed species and communities potentially occurring in the vicinity of Scarborough.

Baseline databases available for searching and accessing studies and scientific literature for the NWS region include:

- Industry-Government Environmental Meta-database (IGEM): http://www.igem.com.au
- CSIRO MarLIN Metadata System: http://www.marlin.csiro.au
- CSIRO Data Access Portal (DAP): https://data.csiro.au
- WAMSI research access, Pawsey Data Portal: https://data.pawsey.org.au/
- Australian Ocean Data Network (AODN): https://catalogue.aodn.org.au
- AIMS Data Centre: https://www.aims.gov.au/docs/data/data.html
- North West Access: https://maps.northwestatlas.org/.

5.2.2 Completed Studies

In the broader NWMR, many studies have been conducted by both petroleum titleholders (e.g. studies undertaken by Woodside for the Pluto LNG development) and independent research agencies (e.g. Brewer et al. (2007) reviewed trophic systems of the Northwest Marine Region). Existing specialist studies that have been completed specifically for and have been made available to support the assessment and management of the development of Scarborough include those presented in Table 5.1.

Table 5.1: Studies undertaken to support Scarborough

Organisation	Study
Sinclair Knight Merz	Pluto LNG Development Offshore Marine Environmental Survey (2006) (and other associated technical studies). Available from: http://www.epa.wa.gov.au/sites/default/files/PER_documentation/1632-PER-Technical%20Report%20-%20combined.pdf
Woodside Energy Limited	Pluto LNG Development: Draft Public Environment Report/Public Environment Review (2006), and associated studies. Available from: http://www.epa.wa.gov.au/sites/default/files/PER_documentation/1632-PER-PLUTO%20LNG%20PER.pdf
	Advisian. 2019a. Scarborough Offshore Benthic Marine Habitat Assessment. Prepared for Woodside Energy Ltd. Advisian WorleyParsons Group. (Appendix A)
	Advisian. 2019b. Montebello Marine Park Benthic Habitat Survey. Prepared for Woodside Energy Ltd. Advisian WorleyParsons Group. (Appendix C)
	Advisian. 2019c. Dampier Marine Park Benthic Habitat Survey. Prepared for Woodside Energy Ltd. Advisian WorleyParsons Group. (Appendix B)
Marshall Day Acoustics	Underwater noise modelling for the Scarborough Project (Marshall Day, 2019; Appendix E)
RPS/APASA	Scarborough Gas Development Cooling Water Discharge Modelling Study (RPS, 2019a; Appendix F)
	Scarborough Gas Development Produced Water Discharge Modelling Study (RPS, 2019b; Appendix G
	Scarborough Gas Development Hydrotest Discharge Modelling Study (RPS, 2019c; Appendix H)
	Scarborough Gas Development Quantitative Spill Risk Modelling (RPS, 2019d; Appendix I)
	Scarborough Dredge Dispersion Modelling – Offshore Borrow Ground (RPS, 2019e; Appendix J)

5.3 Marine Regional Characteristics

5.3.1 Introduction

The Project area and EMBA occur within the North-West Marine Region (NWMR), which encompasses waters from the WA/Northern Territory (NT) border to Kalbarri (Figure 5.1). The NWMR covers a large area of continental shelf and slope, with a range of bathymetric features such as canyons, plateaus, terraces, ridges, reefs, banks and shoals.

The Offshore Project Area, and the western part of the Trunkline Project Area, is in the Northwest IMCRA Province. As the trunkline traverses the continental shelf it crosses into the Northwest Shelf IMCRA Province (Figure 5.1). These provinces are the start of a transition between tropical and temperate marine areas; and include migration routes and breeding locations for some important whale and bird species (DEWHA, 2008a). The provinces are known to be important areas for the petroleum and commercial fishing industries (DEWHA, 2008a). No additional IMCRA Provinces occur in the EMBA.

The continental shelf in the vicinity of the Project Area is wide, with a change of slope at about the 20 m bathymetric contour (IMCRA Technical Group, 1998). Inside this contour there is a series of limestone islands (South and North Muiron, Serrurier, Bessieres, Thevenard, Rosily, Barrow and the Montebello islands); with fringing coral reefs typically occurring on the seaward side of most of these islands (IMCRA Technical Group, 1998).

Further offshore from the continental slope is the Exmouth Plateau. The Exmouth Plateau is a deep-water plateau, with a narrow, steep southern slope and a wider, less steep northern slope. The

Montebello Trough along the south-east edge of this plateau drains into the Cape Range Canyon; while the northern portion of the plateau comprises the Dampier Ridge and Swan Canyon.

5.3.2 Oceanographic Environment and Coastal Processes

5.3.2.1 Currents

The NWMR is influenced by a complex system of ocean currents that can change between seasons and between years. The major surface currents in the region flow away from the equator, and include the Indonesian Throughflow, Leeuwin Current, South Equatorial Current and the Eastern Gyral Current. These surface currents are typically warm, low salinity and oligotrophic (DEWHA, 2008a). There are also a series of subsurface currents that influence the area, the most important of which are the Leeuwin Undercurrent and the West Australian Current (Figure 5.3). These subsurface currents are typically cooler, with higher salinity and dissolved oxygen content (DEWHA, 2008a).

The Exmouth Plateau is known to influence the region's currents due to its topography. The plateau obstructs the flow of the warm surface currents and forces upwelling of the cold nutrient-rich waters underneath, influencing the physical and biological properties of the environment.

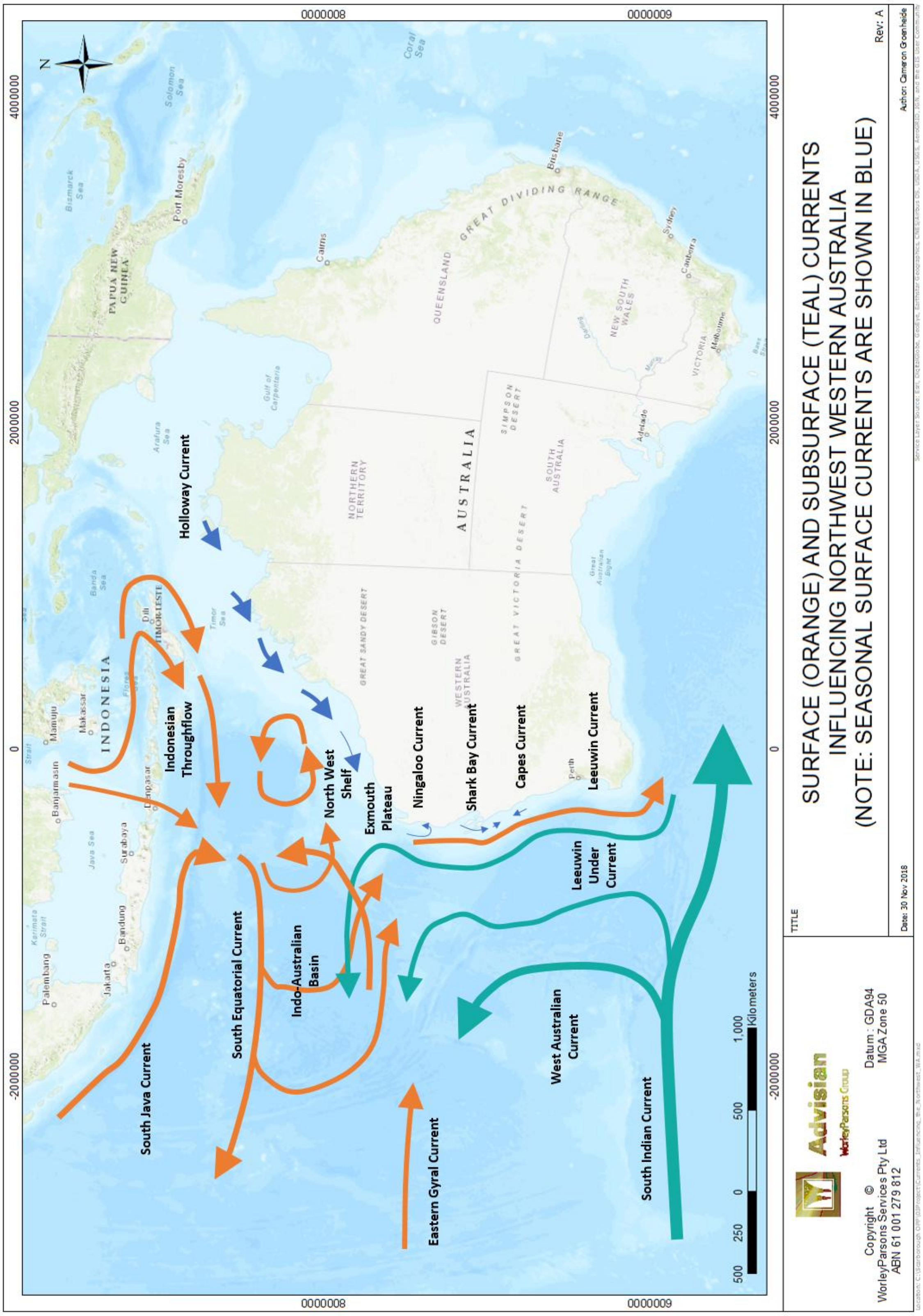


Figure 5.3: Surface (orange) and subsurface (teal) currents influencing the northwest Western Australia (Note: seasonal surface currents are shown in blue)

5.3.2.2 Tides

The NWMR experiences highly variable tidal regimes but can be broadly categorised as semi-diurnal (two highs and two lows per day) with a diurnal inequality (difference between successive highs and successive lows). Tides and winds strongly influence water flow in the coastal zone and over the inner to mid shelf, whereas flows over the outer shelf, slope, rise and deeper waters are influenced by large-scale regional circulation (DEWHA, 2008a). The interaction of the semi-diurnal tides with the Exmouth Plateau generates internal tides, also known as barotropic tides (Holloway, 1988). These internal tides can subsequently generate internal waves, which are dynamic, episodic events strongly influenced by topography and caused by pronounced temperature differences in the water column and the interaction between currents and the seafloor (DEWHA, 2008a). Internal waves are large in amplitude (up to 75 m high) and encourage the mixing of surface waters with deeper, more nutrient-rich waters, which is important for biological productivity in the region (DEWHA, 2008a). Internal waves are considered to occur more frequently and to be stronger during the wet season than the dry season when the water column is more stratified (Brewer et al., 2007; DEWHA, 2008a).

5.3.2.3 Waves and Wind

The wave climate of open waters of the NWMR is influenced by locally generated wind waves (seas) and remotely generated swells. Swell directions can vary widely in the region, depending on wind direction, locations of major storms, and local bathymetric effects. Fugro (2012) measured wave height in the Offshore Project Area throughout the year and recorded a maximum of 9.2 m in December.

Winds vary seasonally, with a tendency for winds from the south-west quadrant during summer months (September–March) and the north-east quadrant in autumn and winter months (April–August). The summer south-westerly winds are driven by high pressure cells that pass from west to east over the Australian continent. During winter months, the relative position of the high-pressure cells moves further north, leading to prevailing south-easterly winds blowing from the mainland (Pearce et al., 2003). Winds typically weaken and are more variable during the transitional period between the summer and winter regimes, generally between April and August.

5.3.2.4 Tropical Cyclones

Tropical cyclones are relatively frequent in the NWMR, with the Pilbara coast experiencing more cyclonic activity than any other region of the Australian mainland coast (Bureau of Meteorology, n.d.). Tropical cyclone activity can occur between November and April and is most frequent during December to March (i.e. considered the peak period), with an annual average of about one storm per month. Cyclones are less frequent in the months of November and April. Based on 47 years of historical weather data from 1970 until 2016, 34 tropical cyclones have occurred in the region of the Offshore Project Area (Bureau of Meteorology, n.d.). The likelihood of a tropical cyclone during the first 28 days of November is far less than could be expected for the remainder of tropical cyclone season.

5.3.2.5 Water Temperature and Salinity

Variation in surface salinity along the North West Shelf (NWS) (in the vicinity of the Trunkline Project Area) throughout the year is minimal (between 35.2 and 35.7 Practical Salinity Units), with slight increases occurring during the summer months due to intense coastal evaporation (Pearce et al., 2003; James et al., 2004). This small increase in salinity during summer is countered by the arrival of the lower salinity waters of the Leeuwin Current and Indonesian Throughflow in autumn and winter (James et al., 2004). Across Dampier Archipelago waters, surface salinity closer to the mainland coast is higher than outer archipelago waters throughout the year. In winter, denser (cooler and more saline) water forms within the archipelago and wedges seaward beneath open shelf waters. In summer, salinity increases in shallow coastal waters due to the localised effects of evaporation (Pearce et al., 2003).

In the Offshore Project Area, temperatures of about 25°C and salinity of about 35 ppt were recorded in surface waters; while deeper waters recorded temperatures of about 5°C and salinity of about 34.5 ppt (ERM, 2013a). Presence of both a thermocline and halocline were recorded; the level of these varied by about 50 m seasonally.

5.3.3 Seabed Characteristics

5.3.3.1 Region and EMBA

The EMBA overlaps both the Northwest Shelf IMCRA Province and the Northwest IMCRA Province.

The Northwest Shelf IMCRA Province is located almost entirely on the continental shelf. The shelf slopes gradually from the coast to the shelf break with a number of banks, shoals and valleys, examples including Rankin Bank (Section 5.3.13) and Glomar Shoals (Section 5.5.6).

The Northwest Province occurs entirely on the continental slope and comprises muddy sediments. There are many distinguishable topographic features, such as the Exmouth Plateau (Section 5.5.1), as well as deep holes and valleys on the inner slope. The Montebello Trough occurs on the eastern side of the Exmouth Plateau and represents more than 90 per cent of the area of troughs in the NWMR (Baker et al., 2008).

The seafloor of the EMBA is strongly affected by cyclonic storms, long-period swells and large internal tides, which can resuspend sediments within the water column as well as move sediment across the shelf (Margvelashvili et al., 2006). The North West marine bioregion includes a variety of geomorphological features (Figure 5-3).

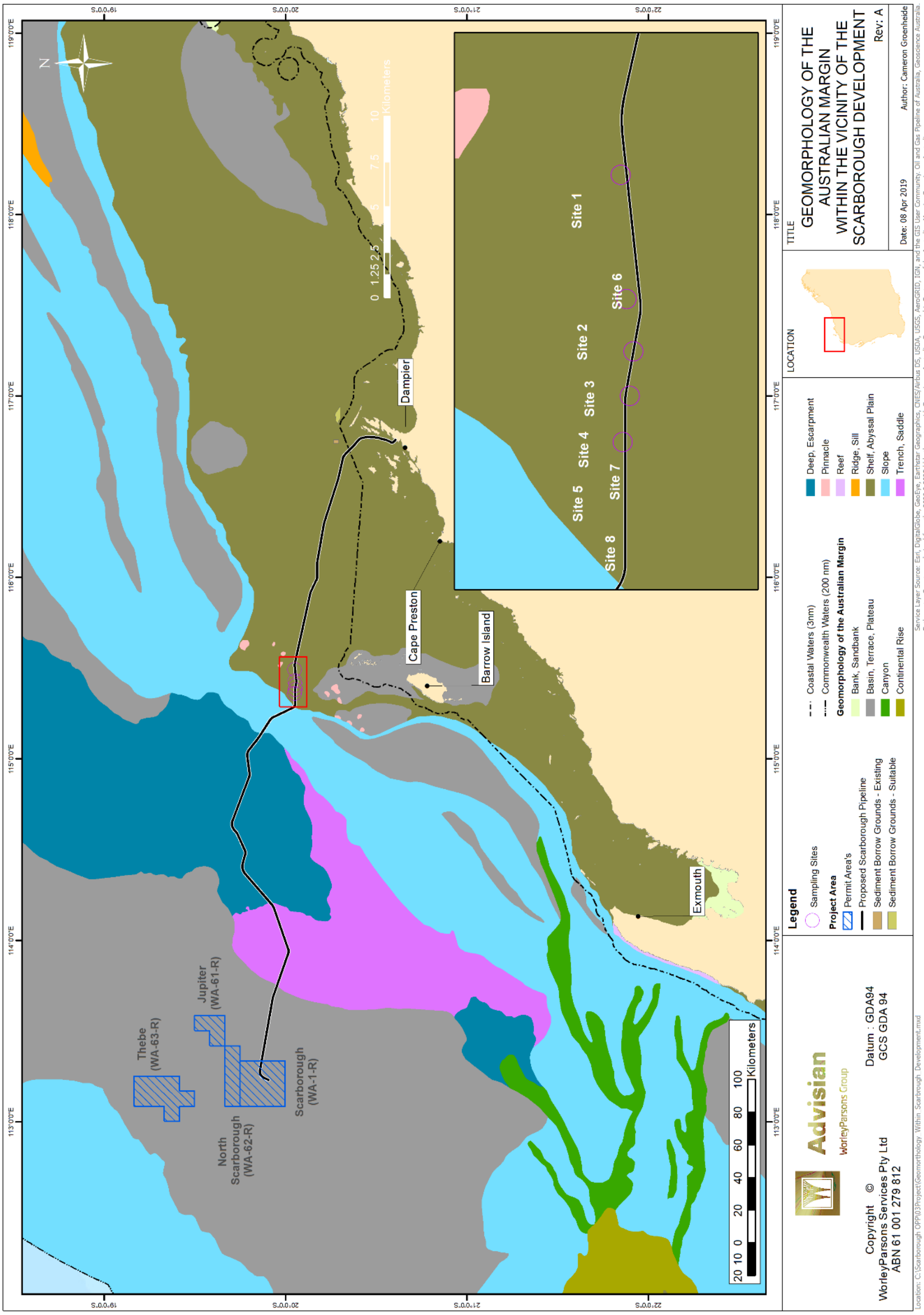


Figure 5.4: Geomorphology of the Australian margin within the vicinity of the development of Scarborough

5.3.3.2 Trunkline Project Area

The Trunkline Project Area, in the context of this OPP, extends from the State-Commonwealth boundary on the inner continental shelf, onto the continental slope where it traverses the continental slope westwards to the Offshore Project Area on the Exmouth Plateau. The eastern half of the Trunkline Project Area is adjacent to the existing Pluto trunkline.

The inner continental shelf is the area from the coast to about 30 m water depth, and the middle continental shelf is the area between 30 and 120 m water depth. At about 120 m depth, a terrace (start of the outer shelf) of gradients of between 5° and 20° represents a paleo-shoreline and marks an important divide between the continental shelf and the continental slope (SKM, 2006).

The continental slope in proximity of the Pluto field is the narrowest part of the continental slope in the NWS. Assessment of geophysical and ROV data of this area confirmed that it is traversed by several canyon systems where water depth ranges from 160 m to 1220 m (Geoconsult, 2005). The continental slope can be characterised into three sub-divisions, namely:

- dendritic channel areas
- channel areas
- continental slope areas (between channels).

A total of six major and nine minor dendritic channel areas were recorded that are up to 200 m deep and with gradients of 1:1. Major channels were well spaced through the site: in 300 m to 750 m water depth: between 500 m to 1500 m wide and up to 5 km in length.

The minor channels are prevalent in 320 m to 550 m water depths: 500 m to 900 m wide and up to 2.4 km in length. They are formed by the gradual erosion of the continental slope as numerous small, localised slumps, which trigger turbidity currents. It is suspected that dendritic channel areas act as a focus for seafloor currents (Advisian, 2019a).

5.3.3.3 Offshore Project Area

The Offshore Project Area is situated on the Exmouth Plateau. The seascapes of the Exmouth Plateau are not considered unique (Falkner et al. 2009), and consistent with the seascape of the broader area at this depth range.

The seafloor is generally flat and uniform with water depths ranging from 900 m to 970 m within the Scarborough permit, with a gradual increase from the north/north-west to the south/south-east of the area (Figure 5.5 and Figure 5.7; Fugro, 2010). Water depths in the North Scarborough and Jupiter fields are similar to Scarborough; however, Thebe is slightly deeper (1,000 m to 1,400 m) with a south-east to north-west gradient.

To the south-west of the Offshore Project Area, craters (up to 400 m across and 10 m deep) and smaller pockmarks (metres to tens of metres across) have been identified through geophysical surveys (Fugro, 2010). The seafloor exhibits gradients less than 1° but extends to about 15° on the edge of craters (Fugro, 2010). These crater and pockmark formations may be associated with hydrocarbon seeps and associated authigenic carbonate formations (Fugro, 2010).

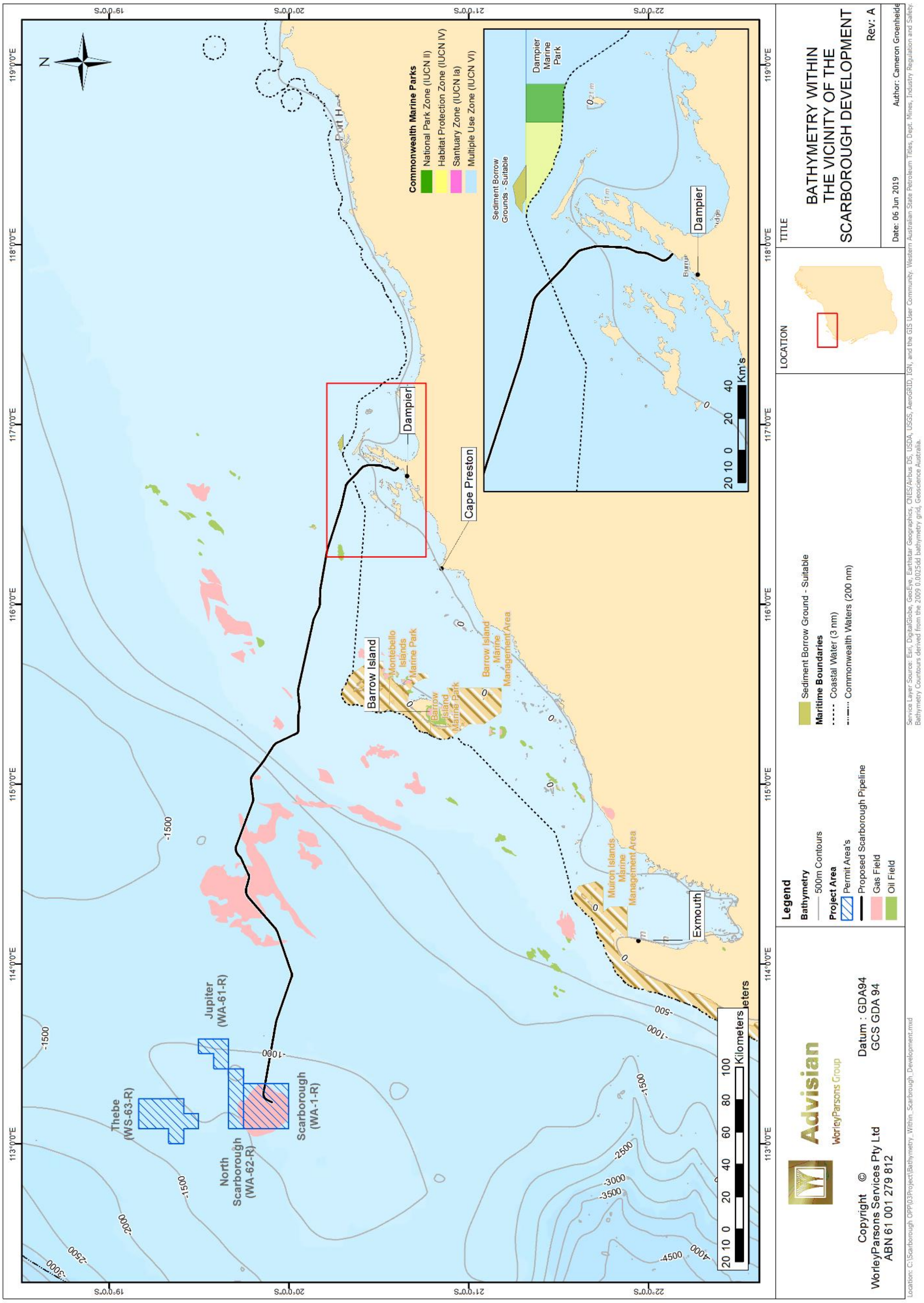


Figure 5.5: Bathymetry showing the 500 m depth contour in the vicinity of Scarborough

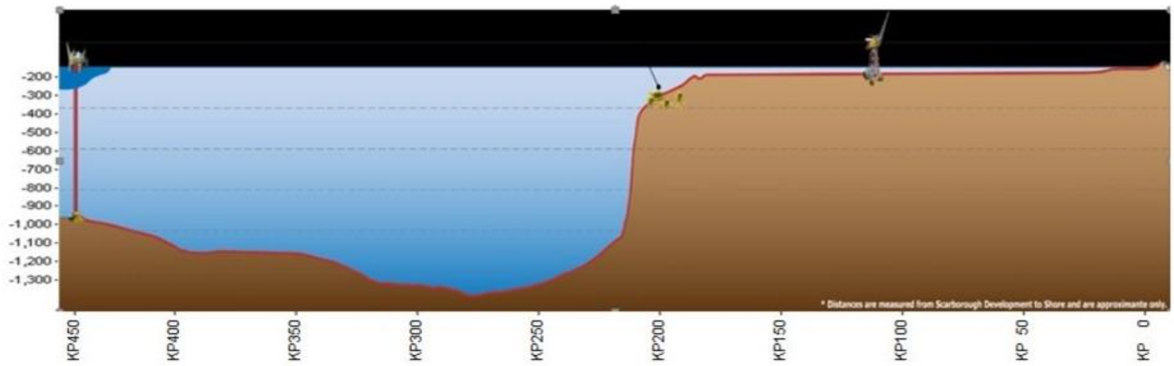


Figure 5.6: Depth profile along the proposed Scarborough deep water trunkline route

5.3.3.4 Borrow Ground Project Area

The Borrow Ground Project Area lies just outside the State marine boundary to the NNE of the damper Archipelago (~15 km). Water depths in this area are shallow (~100 m), increasing gradually in a N/ NW direction. The Borrow Grounds Project Area lies within the continental shelf and is characterised by a generally flat/ undulating and uniform seabed with no important submerged features (i.e. pinnacles).

5.3.4 Marine Sediments

5.3.4.1 Region and EMBA

Marine sediments are the deposits of insoluble material found on the sea floor. These deposits can include rock and soil particles originating from adjacent land masses (terrigenous) or the remains of marine organisms (pelagic). They can also originate from volcanic sources beneath the surface of the ocean or from chemical precipitation processes that occur in the water column.

The composition, distribution and movement of marine sediments is an important component of a marine ecosystem. These sediments can influence the primary biological production in the water column as well as the evolution and distribution of marine habitats.

Sediments in the outer NWS are relatively homogenous and are typically dominated by sands and a small portion of gravel (Baker et al., 2008). Fine sediment size classes (e.g. muds) increase with proximity to the shoreline and the shelf break but are less prominent on the continental shelf (Baker et al., 2008). Carbonate sediments typically account for the bulk of sediment composition, with both biogenic and precipitated sediments present on the outer shelf (Dix et al., 2005). Beyond the shelf break, the proportion of fine sediments increases along the continental slope towards the Exmouth Plateau and the abyssal plain (Baker et al., 2008). The predominant seabed type at the Offshore Project Area is mud and calcareous clay, and along the Trunkline Project Area is calcareous gravel, sand and silt (Figure 5.7).

Hard substrates occur in the region and can host more diverse benthic communities. Hard substrate may be associated with the Ancient coastline at 125 m depth contour KEF (Section 5.5.2).

The NWMR comprises bio-clastic, calcareous and organogenic sediments deposited from relatively slow and uniform sedimentation rates (Baker et al., 2008). Sediments in the region generally become finer with increasing water depth, ranging from sand and gravels on the continental shelf to mud on the continental slope and abyssal plain (Brewer et al., 2007).

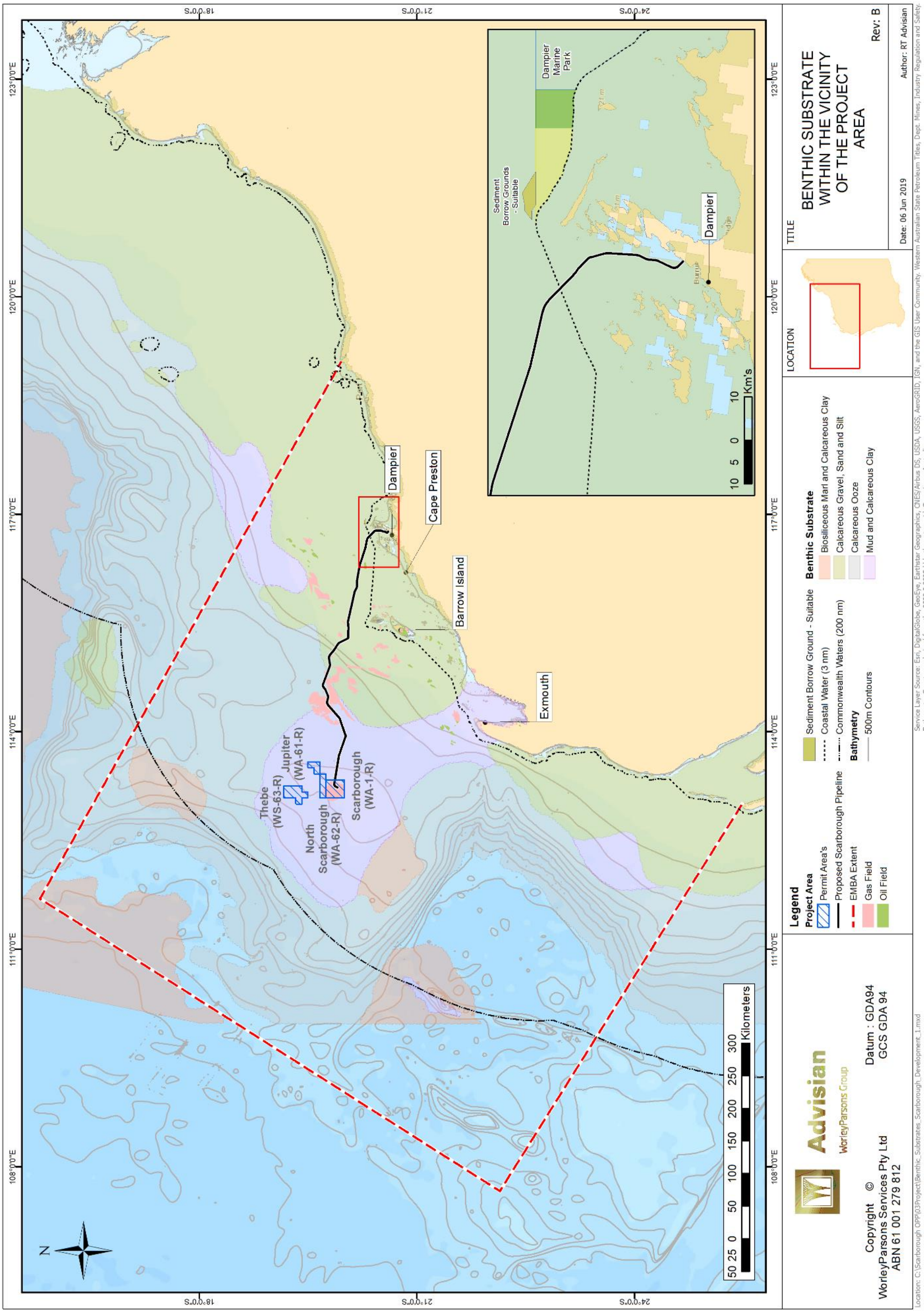


Figure 5.7: Benthic substrate within the vicinity of Scarborough

5.3.4.2 Trunkline Project Area

Sediments along the Trunkline Project Area are expected to be dominated by sand as is typical of the continental slope in the Northwest Transition bioregion (DEWHA, 2008a). These sediments will be further characterised during the baseline survey of the Trunkline Project Area. Sediments on the continental slope are expected to comprise very soft sandy clay/silt.

Six major and nine minor complete channels were identified on an area of the continental slope traversed by the Trunkline Project Area (SKM, 2006). The presence of sand in the channels was confirmed by drop cores and within the channel base current driven bedforms or erosive “back stepping” of bedding planes were observed. ROV stills show current driven bedforms and rounded cobble sized clasts and sediment clumps in the channel base. Channels are not only developed by seafloor currents but have in the past been conduits for large scale turbidity currents. Present day sedimentary processes are observed to be significant, with active seafloor currents. The area of continental slope between channels undulates and deepens from the SE to the NW over a series of linear and steep scarps from water depths of approximately 250 m to 1100 m (SKM, 2006).

5.3.4.3 Offshore Project Area

The Offshore Project Area is located on the Exmouth Plateau which is characterised by a thick Triassic sequence overlain by a Jurassic, Cretaceous and Cainozoic sediment sequence; and fine-grained carbonate ooze (Fugro, 2010). Sediment transport on the outer shelf/slope of the Exmouth Plateau is influenced by a combination of slope processes and large ocean currents.

Marine sediment quality surveys within the Scarborough (WA-1-R) permit were undertaken during the 2012/2013 wet and dry seasons (ERM, 2013). The ERM marine investigation included sampling at a number of sampling sites, as shown in Figure 5.8, to:

- provide a broad characterisation of the habitats within WA-1-R
- achieve spatial coverage across WA-1-R
- provide a representative selection of the various topographic features and corresponding benthic habitats (i.e. crater/pockmark versus non-crater areas).

While no specific sediment sampling was undertaken within the North Scarborough, Thebe or Jupiter permit areas, given the relatively close distance (<50 km), similar water depths, and exposure to similar oceanographic conditions, the sediment characteristics of the Scarborough field are considered to be representative of the Offshore Project Area.

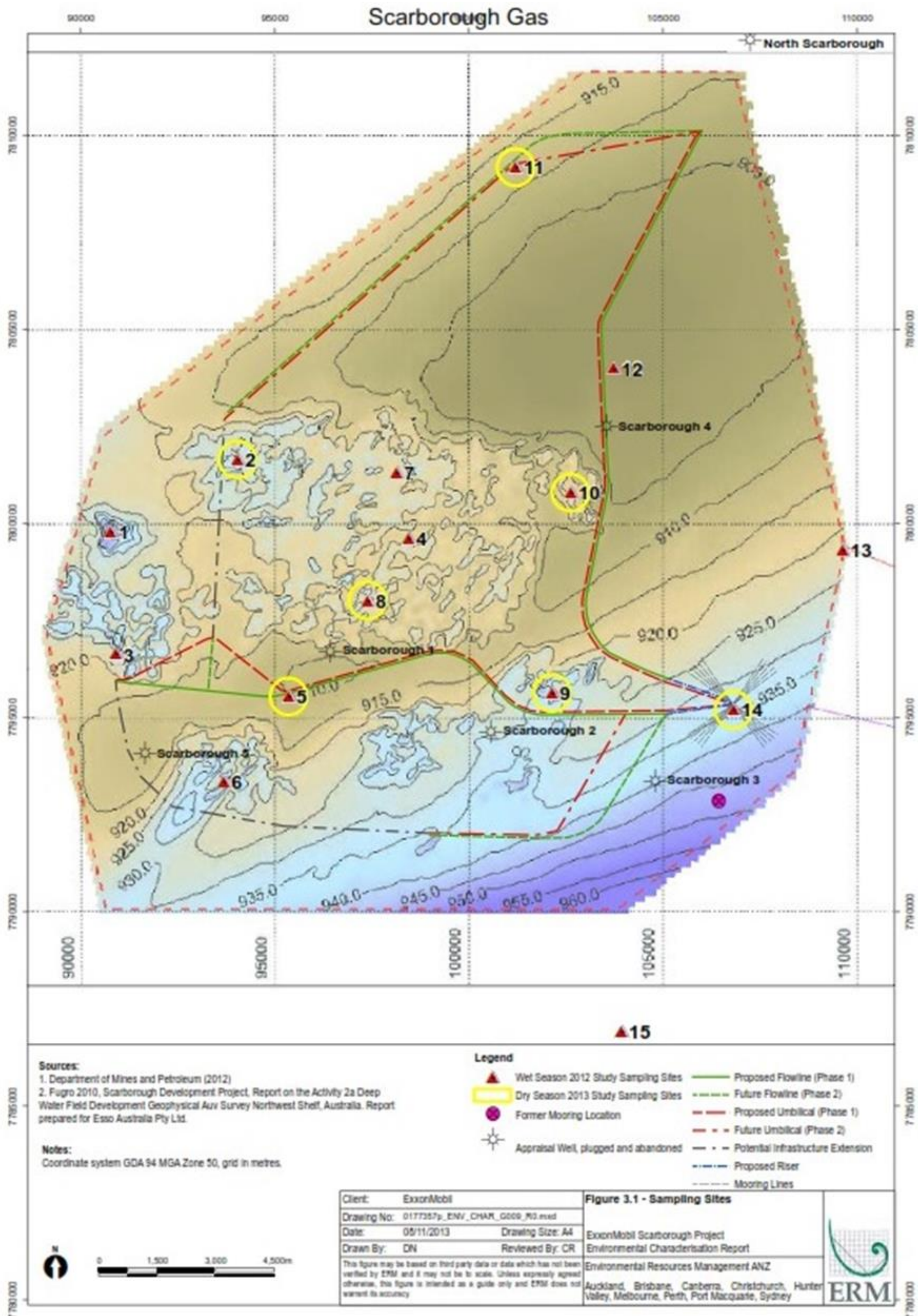


Figure 5.8: Sampling sites in the Permit Area WA-1-R on the Exmouth Plateau, undertaken by ERM in the wet and dry seasons of 2012/2013 (Source: ERM, 2013)

Key results included:

- All the sediment samples collected were predominantly (≥97% w/w) composed of clay and silt; and only small amounts (1–3% w/w) of sand and shell were detected (Figure 5.9).
- Generally, low concentrations of metals and nutrients were detected.
- No hydrocarbons were detected.

Although crater and pockmark formations have been identified in the Offshore Project Area, which have been associated with hydrocarbon seeps and authigenic carbonate formations (Fugro, 2010), the absence of hydrocarbons in sediment samples indicates the lack of recent hydrocarbon seep activity in the locations sampled (ERM, 2013).

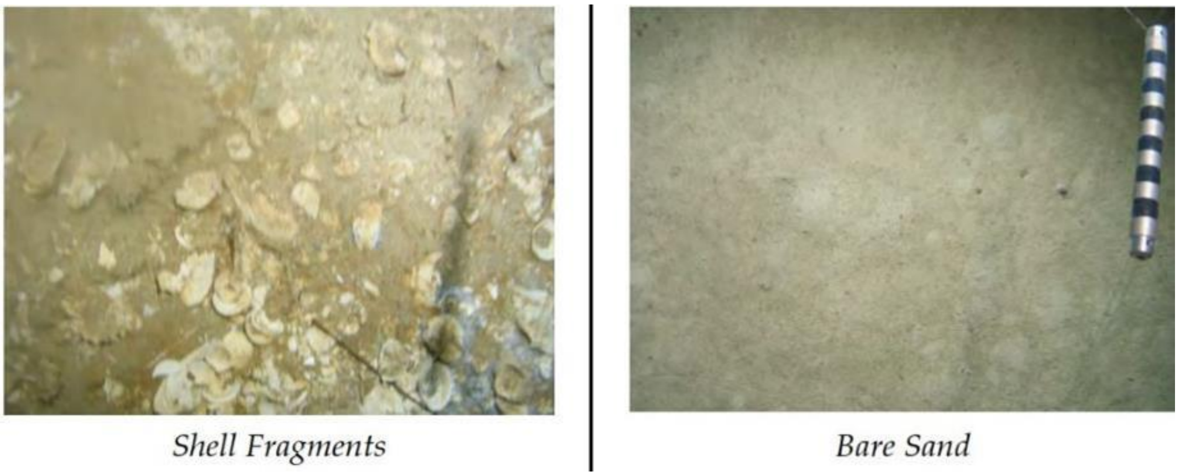


Figure 5.9: Sediment types of Permit Area WA-1-R collected as still imagery during Habitat Characterisation Survey (ERM, 2013)

5.3.4.4 Borrow Ground Project Area

The Borrow Ground Project Area lies within close proximity to the Dampier Archipelago (~15 km to the NNE) within the Lampert Shelf. The Lampert Shelf is dominantly comprised of Cretaceous-Cenozoic sedimentary rocks of up to 2000 m thick. The sediment formation of the offshore area surrounding the Archipelago, including the Borrow Grounds is known as the Delambre Formation which predominantly comprises of calcium carbonate skeletal remains or marine organisms ranging in particle size from millimetres to a few microns.

5.3.5 Water Quality

5.3.5.1 Region and EMBA

Marine water quality considers chemical, physical and biological characteristics with respect to its suitability to support marine life, or for a purpose such as swimming or fishing. Marine water quality can be measured by several factors, such as the concentration of dissolved oxygen, the salinity, the amount of material suspended in the water (turbidity or total suspended solids) as well as the concentration of contaminants such as hydrocarbons and heavy metals.

In the NWMR, water quality is regulated by the Indonesian Throughflow, which plays a key role in initiating the Leeuwin Current and brings warm, low-nutrient, low-salinity water to the NWMR. It is the primary driver of the oceanographic and ecological processes in Western Australia. Water quality is expected to reflect the offshore oceanic conditions of the Western Australian coast wider region which has high water quality, with the exception of water quality in ports and harbours that can be locally influenced by industry effluent.

Coastal waters of the Pilbara are turbid due to a combination of high tidal ranges and terrestrial run-off from rainwater, peaking during summer months (Human and McDonald 2009). Cyclones are a prevalent meteorological feature during summer that adds to the turbidity (DEWHA, 2008a).

The water quality is influenced by tidal conditions and pre-existing disturbances that cause increased turbidity levels (MScience, 2018b). Karratha is a major hub with existing infrastructure including the Port of Dampier, Karratha Gas Plant and Pluto Trunkline. Mermaid Sound off Dampier was exposed to elevated turbidity conditions during the Mermaid Sound dredging projects in 2004, and dredging of Woodside Pluto Trunkline in 2009 (MScience, 2018a, 2018b). Increased turbidity and reduced water quality were restricted to the dredging sites. Increased turbidity has been recorded within 500 m of the dredge site and turbidity outside 500 m of the dredge site was below the 80th percentile of turbidity at two reference sites (MScience, 2018a).

In coastal waters off Dampier, dissolved concentrations of a range of heavy metals (e.g. cadmium, copper, and mercury) and organic chemicals (e.g. petroleum hydrocarbons) are generally of very high quality with little or no organic chemical detected in any of the samples and heavy metal levels approaching those in the open ocean (DEWHA, 2008). Sediment quality in nearshore waters of the NWMR is regarded as very good. Studies showed slight elevations of some metals in inner Dampier port (DoE, 2006).

5.3.5.2 Trunkline Project Area and Borrow Ground Project Area

Water quality along the Trunkline Project Area portion of the Project area and the Borrow Grounds Project Area is expected to be typical of an unpolluted tropical offshore environment. The nearshore coastal waters of the Pilbara are turbid due to a combination of high tidal ranges and terrestrial runoff from rainwater, peaking during summer months (Human and McDonald, 2009). Cyclones are a prevalent meteorological feature during summer that adds to the turbidity (DEWHA, 2008a). Off Dampier Archipelago, dissolved concentrations of a range of heavy metals (e.g. cadmium, copper, and mercury) and organic chemicals (e.g. petroleum hydrocarbons) are generally of very high quality with little or no organic chemical detected in any of the samples and heavy metal levels approaching those in the open ocean (DEWHA, 2008a).

5.3.5.3 Offshore Project Area

Water quality in the Offshore Project Area is typical of an unpolluted tropical offshore environment. Much of the surface water in this area is nutrient poor, transported from the Indonesian Throughflow and has low primary productivity.

The marine water quality of the offshore environment of the Exmouth Plateau was measured by collecting triplicate water samples at three stations per 15 sampling sites (across two seasons) (ERM, 2013a). Key results from the water profiling and water quality sampling undertaken in the 2012/2013 wet and dry seasons are summarised in Figure 5.10 and Figure 5.11. Key results include:

- The deeper waters had significantly lower dissolved oxygen concentrations (about 23%) compared to the oxygen-saturated (≥100%) surface waters.
- Generally low concentrations of metals, nutrients and chlorophyll-a were detected.
- Total suspended solid mean concentrations were higher during the wet season (22,450 µg/L) than the dry season study (4000 µg/L) and showed variability across sites and throughout the water column.
- No hydrocarbons were detected.

Results from the studies indicated that the water quality within the WA-1-R permit area is generally typical of the North-west Marine Bioregion’s tropical deep-water environment (ERM, 2013a).

Depth	Season Study	Temperature (°C)	Conductivity (mS/cm)	Turbidity (FTU)	pH	DO (%SAT)
Full Water Column	Wet	12.7 (5.0 – 26.1)	41.0 (32.3 – 54.0)	5.2 (0.0 – 124.3)	8.0 (7.8 – 8.6)	52.9 (22.1 – 106.7)
	Dry	11.8 (5.0 – 25.2)	40.0 (33.6 – 52.6)	0.0 (0.0 – 1.8)	8.0 (7.7 – 8.3)	53.9 (21.8 – 104.2)
Surface (Top 10 m)	Wet	25.6 (23.1 – 25.9)	53.6 (0 – 54.0)	5.7 (0.0 – 120.0)	8.2 (8.0 – 8.8)	113.0 (96.5 – 128.7)
	Dry	24.8 (24.7 – 25.2)	52.1 (51.6 – 52.6)	0.2 (0.1 – 0.8)	8.2 (8.2 – 8.3)	101.6 (100.8 – 104.2)
Bottom (Bottom 10 m)	Wet	5.1 (5.0 – 5.2)	33.8 (33.6 – 34.0)	5.0 (4.6 – 6.8)	7.8 (7.8 – 7.9)	22.7 (22.2 – 23.8)
	Dry	5.1 (5.0 – 5.3)	33.7 (33.6 – 33.8)	0.3 (0.0 – 1.7)	7.8 (7.7 – 7.9)	23.0 (22.4 – 25.1)

Parameter readings are shown as mean with total range in brackets.

Figure 5.10: Water profiling results summary from marine surveys undertaken in permit area WA-15-R (ERM, 2013)

Depth	Season Study	Ammonia	Nitrate (as NO3−)	Nitrogen (total oxidised)	Total Nitrogen	Phosphorus	Reactive Phosphorus (as P)
Full Water Column	Wet	12 (<5- 73)	711 (<50-2400)	160 (<5-530)	251 (<50-650)	40 (<10-130)	27 (<5-86)
	Dry	11 (<5-18)	680 (<50-2400)	153 (<5-<550)	367 (210-750)	28 (<10-90)	28 (<5-91)
Surface (Top 10 m)	Wet	11 (<5-49)	25 (<50-<50)	2.50 (<5-<5)	86 (<50-190)	13 (<10-80)	2.50 (<5-<5)
	Dry	15 (12-17)	25 (<50-<50)	5.30 (<5-11)	240 (210-260)	5 (<10-<10)	5.50 (<5-7)
50 m	Wet	8.20 (<5- 30)	56 (<50-490)	9.70 (<5-110)	114 (<50-340)	13 (<10-30)	3.50 (<5-17)
	Dry	7.70 (<5-18)	53 (<50-110)	13 (<5-24)	230 (210-250)	6.70 (<10-10)	4.80 (<5-6)
150 m	Wet	9 (<5- 34)	436 (<50-600)	103 (<5-140)	201 (80-420)	40 (<10-130)	16 (<5-21)
	Dry	11 (<5-17)	243 (120-440)	55 (28-99)	270 (240-310)	12 (<10-20)	12 (7-19)
Bottom (Bottom 10 m)	Wet	18 (<5-73)	2,307 (2,100-2,400)	523 (470-530)	601 (530-650)	95 (70-120)	85 (83-86)
	Dry	11 (<5-16)	2,400 (2,400-2,400)	540 (530-550)	727 (710-750)	87 (80-90)	89 (86-91)

Parameter readings are shown as mean with total range in brackets.
Nitrite was not detected in the samples.

Figure 5.11: Water quality nutrients key results summary (µg/L) from marine surveys undertaken in permit area WA-15-R (ERM, 2013)

5.3.6 Air Quality

There is a lack of air quality data for the NWP and greater offshore NWMR air shed. However, the area is very remote relative to other areas of Australia and globally and therefore air quality in nearshore and offshore waters of the Pilbara area is considered high.

While vessels and industry developments contribute to emissions in the area, results from previous monitoring (e.g. DEP, 2002; CSIRO, 2008) around the Burrup Peninsula suggest that concentrations of measured air quality parameters remain low (ERM, 2012). For example, nitrogen dioxide (NO_2) concentrations during the early Pilbara air quality study were below NEPM standards (DEP, 2002; ERM, 2012). Similarly, during the rock art air quality studies, concentrations of NO_2 were higher at sites closer to industrial sources (e.g. monthly average of 3.5–3.8 ppb) but was still considered as a low concentration (CSIRO, 2008).

Due to the extent of the open ocean area and the activities that are currently undertaken within the NWS, it is considered the ambient air quality in the EMBA and wider offshore NWMR will be high.

5.3.7 Ambient Light

The Project Area is offshore and remote from urban or industrial areas; as such local light emissions via anthropogenic sources are limited to occasional vessels, particularly in the eastern sections of the Trunkline Project Area.

5.3.8 Ambient Noise

Physical and biological processes contribute to natural background sound. Physical processes include that of wind and waves while biological noise sources include vocalisations of marine mammals and other marine species.

Underwater noise surveys in the region detected fauna noise (Antarctic blue whales; pygmy blue whales; dwarf minke whales; Bryde's whales; sperm whales; humpback whales; Antarctic minke whales; dolphins; and one fish chorus) and artificial noise (vessel noise; seismic survey signals; mooring noise artefacts) (McCauley, 2011).

5.3.9 Planktonic Communities and productivity

EMBA

Plankton within the EMBA is expected to reflect the conditions of the NWMR. Primary productivity of the NWMR is generally low and appears to be largely driven by offshore influences (Brewer et al., 2007), with periodic upwelling events and cyclonic influences driving coastal productivity with nutrient recycling and advection.

Seasonal weather patterns also influence the delivery of nutrients from deep-water to shallow water. Cyclones and north-westerly winds during the north-west monsoon (approximately November–March) and the strong offshore winds of the south-east monsoon (approximately April–September) facilitate the upwelling and mixing of nutrients from deep-water to shallow water environments (Brewer et al., 2007). Aggregations of marine life, high primary productivity and species richness on the reefs are likely due to the steep rise of the reef from the seabed. On the shelf within the nearshore waters, the plankton abundance and diversity are considered relatively low.

Zooplankton and may include organisms that complete their lifecycle as plankton (e.g. copepods, euphausiids) as well as larval stages of other taxa such as fishes, corals and molluscs. Peaks in zooplankton such as mass coral spawning events (typically in March and April) (Rosser and Gilmour, 2008; Simpson et al., 1993) and fish larvae abundance (Department of Conservation and Land Management, 2005) can occur throughout the year.

Within the region, peak primary productivity occurs in late summer/early autumn, along the shelf edge of the Ningaloo Reef. It also links to a larger biologically productive period in the area that includes mass coral spawning events, peaks in zooplankton and fish larvae abundance (Department of Conservation and Land Management, 2005) with periodic upwelling throughout the year.

Trunkline Project Area and Borrow Ground Project Area

Primary productivity in the NWMR is generally low, with boom and bust cycles driven by monsoonal seasonality. Seasonal weather patterns also influence the delivery of nutrients from deep water to shallow water. Cyclones and north-westerly winds during the north-west monsoon (approximately November–March) and the strong offshore winds of the south-east monsoon (approximately April–September) facilitate the upwelling and mixing of nutrients from deep-water to shallow water environments (Brewer et al., 2007). Aggregations of marine life, high primary productivity and species richness on the reefs and in the surrounding Commonwealth waters are likely due to the steep rise of the reef from the seabed. This causes nutrient-rich waters from below the thermocline (about 100 metres) to mix with the warmer, relatively nutrient-poor tropical surface waters via the action of internal waves and from mixing and higher productivity in the lee of emergent reefs (Brewer et al., 2007). For this reason, in general, within the NWMR shallower, nearshore environments are more productive, decreasing l productivity with increasing depth.

Offshore Project Area

Productivity is generally considered to be low in the region and on the Exmouth Plateau, with upwelling events and peaks in primary productivity occurring during both the wet and dry seasons (Brewer et al., 2007; DEWHA, 2008a). Satellite observations indicate that productivity is enhanced along the northern and southern boundaries of the plateau and along the shelf edge (Figure 5.12). This in turn suggests that despite the region's productivity being low, the plateau is a significant contributor to that productivity (Brewer et al., 2007).

Sampling within the Offshore Project Area returned low phytoplankton densities (ERM, 2013). Seasonal variation was observed in the samples with total recorded taxa, species richness and species diversity (Shannon-Weiner) being significantly greater in the dry season than in the wet season (ERM, 2013). Dinoflagellates were the most abundant group within wet season study, and diatoms were generally the most abundant group in dry season study (ERM, 2013).

Similarly, greater species abundance and diversity was recorded in zooplankton samples during the dry season compared to the wet season (ERM, 2013). Copepods were the most dominant taxonomic group during both studies in terms of abundance and concentrations, with other zooplankton including ostracods, molluscs (pterepods), euphausiids (krill) and larvaceans also being identified in relatively abundant amounts (ERM, 2013).

Concentrations of fish larvae were similar in both wet and dry season samples. For both seasons ichthyoplankton communities largely comprised the larvae of meso-pelagic fishes (Myctophidae (lantern fishes) and Gonostomatidae (bristlemouths)) (ERM, 2013).

It is noted that these survey findings do not reflect the productivity trends reported in scientific literature for the region (DEWHA, 2008a; Brewer et al., 2007), whereby productivity is typically greater during the wet season when the weakening of surface currents allows for increased upwelling. However, the findings do indicate that productivity remains low across the seasons and that while seasonal variations in plankton species composition potentially occurs, variations in abundance are likely to be overall minor (ERM, 2013).

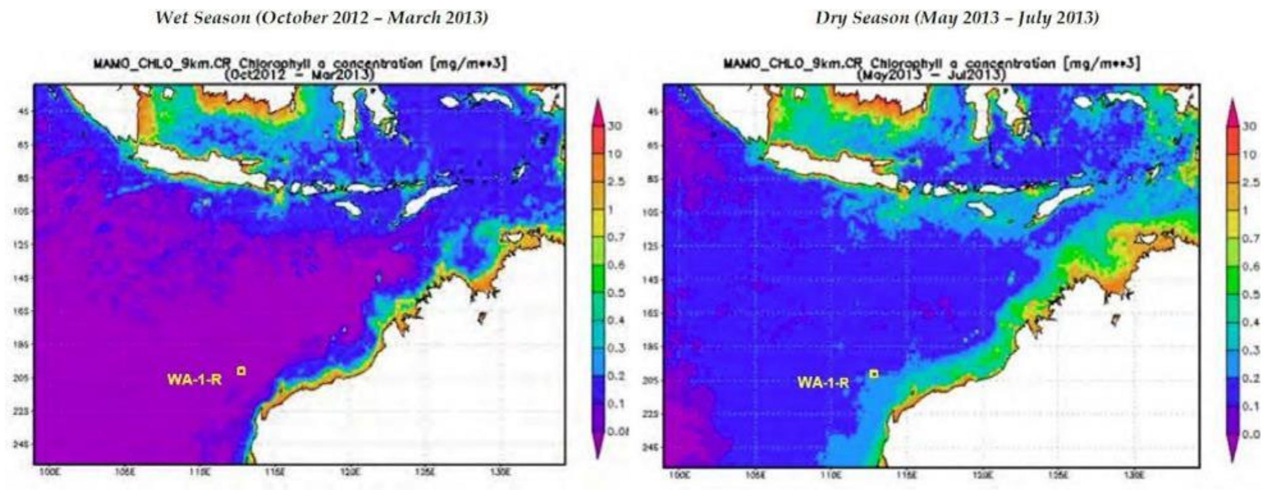


Figure 5.12: Seasonal satellite primary productivity imagery (Source: ERM, 2013a)

5.3.10 Epifauna and Infauna

Region and EMBA

Studies completed within the region indicate that benthic composition in deep water habitats is generally lower in abundance than shallow water habitats of the region (DEWHA, 2008a; Brewer et al., 2007). Gage (1996) reported that the density of benthic fauna tends to be lower in deep water sediments (>200 m) than in shallower coastal sediments, but the diversity of communities may be similar.

The area of shallower waters between Dampier and Port Hedland is a hotspot for sponge biodiversity. There is a high species richness of sponges within the region. A total of 275 species have been recorded through three studies (Fromont, 2004, 2017) that looked at the biodiversity (distribution and habitat) of sponges in the Damper Archipelago. This biodiversity in the Dampier AMP (see Section 5.6.1.4) may reflect short pelagic stages for sponge larvae, resulting in minimal larval exchange and high population differentiations between sponge communities (Director of National Parks, 2018).

Trunkline Project Area

A desktop study was undertaken summarising all known information on benthic habitats from the offshore slope and deeper development area which the trunkline will pass through and is based on survey work previously completed in the Offshore Project Area (>950 m water depth), on the escarpment of the continental shelf (i.e. slope) (300 to 950 m water depth) and on the shelf (<300 m water depth) (Advisian, 2019a). This included a review of recent marine surveys, including geophysical and ROV surveys that filmed the proposed trunkline route from the Scarborough field such as the Base Case Slope ROV Investigation Field Report Scarborough Development Export Pipeline Route Survey (Ocean Affinity, 2018) that conducted ROV inspections along the slope section of the trunkline route between Scarborough and Pluto. An ROV survey of benthic habitats within the Montebello Marine Park was also undertaken and results have been described in Sections 5.5.2 and 5.6.1.3.

Regional and site-specific studies reviewed indicate that seabed material along the proposed Trunkline Project Area (and around the gas field) is predominantly flat and featureless and comprises thick, unconsolidated fine-grained sands (Geoconsult, 2005, SKM, 2006, ERM, 2013).

Where the trunkline would be located within the deeper waters beyond the slope, epifauna and infauna communities would be similar to those described for the Offshore Project Area. The low energy, soft bottom seafloor around Scarborough supports sparse marine fauna as reported for the

Exmouth Plateau. Sediments are calcareous, fine-grained and low in nutrients. Benthic communities are dominated by motile organisms, including shrimp, sea cucumbers, demersal fish and small, burrowing worms and crustaceans. No threatened species/ecological communities or migratory species were identified in the previous studies (as defined under the EPBC Act).

The infauna of the continental slope, (as based on data collected from the Pluto field) was very sparse with a maximum density of 167 individuals per m² from a sample collected in 400 m water depth. Infauna was generally more abundant in sites located in shallow water, although this trend with depth was somewhat obscured because three samples contained no infauna, both samples from 800 m and one sample from 1000 m. A total of 47 individuals, representing 32 nominal species, were collected from the 12 samples. The fauna was dominated by polychaetes, which comprised 79% of the fauna by abundance and 75% of the fauna by species richness. Some crustaceans, sipunculids and nemerteans were also recorded but no molluscs or echinoderms were collected in any of the box core samples. The infauna recorded was sparse but highly diverse (given the limited number of individuals collected). While a number of epifaunal species had not been recorded previously in Australia, Western Australia or the NWS region, this is attributed to the limited number of previous studies of the continental slope rather than the rarity of the fauna (SKM, 2006).

The greatest proportion of images analysed from around the Pluto field survey consisted of soft sediments supporting a typically sparse deep-water fauna. The fauna was typical of the fauna expected on the North-West Shelf (NWS) and slope. A total of 231 epifaunal species a species was identified during the SKM (2006) survey. The only natural habitat on the continental slope that is not classified as soft sediment is the rock pinnacle field that lies in about 300 m water depth. The pinnacle field covers an area about 1 km long x 4 km wide, but the pinnacles are isolated forms and do not constitute continuous reef. It remains unclear what the rock pinnacles are constructed from, however the structures provide habitat for a diverse range of epifaunal and demersal species that commonly occur elsewhere in the NWS. Many tens of fish were observed gathered around these pinnacles, most probably belonging to either the Glaucosomidae or Pricanthidae families. Crinoids, hydroids and ophiuroids were also common. Other species visible on the mounds include anemones, soft corals, small crustacean like shrimp and some larger brachyurans, possibly *Cyrtomaia suhmii (*Advisian, 2019a).

Epifauna was most abundant on the continental shelf compared to the slope and the abundance of the fauna appeared to be inversely associated with depth, with distinct differences in the fauna on the shelf and slope. The assessment of the offshore habitats that occur on the continental shelf (<300 m water depth), have been based on ROV footage collected as part of subsea facility inspections around the Pluto field within Permit Area WA-34-L and WA-48-L. While the Pluto platform itself is located within WA-48-L, in 83 m water depth, much of the subsea infrastructure including pipelines and wellheads are in WA-34-L in ~190 m water depth. The seabed composition through these areas has been previously described as being predominantly flat and featureless and comprises thick, unconsolidated fine-grained sands. The sediments support soft sediment benthic communities dominated by infauna (including molluscs, crustaceans and worms) and isolated larger fauna (free swimming cnidarian, demersal fish and benthic crustaceans). Interestingly, the habitats containing the greatest biodiversity in these offshore environments are the habitats formed by colonising invertebrates on oil and gas subsea infrastructure including the well heads and pipelines. These habitats and the species present on these structures in the NWS of Western Australia have been recently subject to detailed quantitative and qualitative assessment (McLean et al., 2017, 2018, Bond et al., 2018a, b).

Offshore Project Area

Habitat characterisation studies undertaken in the Offshore Project Area included benthic habitat assessment using towed video and stills. At each of the 15 sites, a minimum of 15 minutes of video and 25 stills at three stations were collected (ERM, 2013).

The seafloor composition within the Offshore Project Area is expected to primarily be mud and clay material (Figure 5.7; see also Section 5.3.3). The seafloor in the Offshore Project Area is characterised by sparse marine life dominated by motile organisms (ERM, 2013). Such motile organisms included shrimp, sea cucumbers, demersal fish and small, burrowing worms and crustaceans. This soft bottom habitat also supports patchy distributions of mobile epibenthos, such as sea cucumbers, ophiuroids, echinoderms, polychaetes and sea-pens (DEWHA, 2008). The dominant types of epifauna were arthropods and echinoderms (especially shrimp and sea cucumbers, respectively), while the dominant infauna groups were crustaceans and polychaetes (ERM, 2013). Bioturbation traces are common in the Offshore Project Area (Figure 5.13) and represent presence of benthic infauna including echinoderms and biota including foraminiferans, echiurans and annelids (ERM, 2013).

Benthic communities in the Offshore Project Area are representative of the Exmouth Plateau and of deep-water soft sediment habitats reported in the region (e.g. BHP Billiton, 2004; Woodside, 2005; Woodside, 2006; Brewer et al., 2007; RPS, 2011; Woodside, 2013; Apache, 2013). No organisms identified to species level for the ERM (2013) studies were listed as Threatened or Migratory under the EPBC Act according to the Species Profile and Threats (SPRAT) database.

Figure 5.13: Example of typical benthic habitat and bioturbation traces observed in Permit Area WA-1-R (ERM, 2013)

Hydrocarbon Seep-Associated Benthic Communities

Hydrocarbon seeps are the seeping of gaseous or liquid hydrocarbons (including oil and methane) to the surface of the seabed from fractures and fissures in the underlying rock, resulting in possible hydrocarbons and other chemicals in the water column (DEWHA, 2008). It is possible that these formations may host thiotrophic (sulphur-based metabolism) or methanotrophic (methane-based metabolism) benthic communities and chemosymbiotic benthic fauna reliant on methane-oxidising bacteria, which usually aggregate in the form of mats over the seafloor (Barry et al., 1996).

Naturally occurring hydrocarbon seeps are known to be present in the region; however, no indication of active seeps was observed during marine surveys (ERM, 2013). Bivalve shell debris and bacterial mats (both with low percent cover, Figure 5.14) were the only identified features that may be indicative of historic hydrocarbon seep activity. The benthic infauna analysis provided no evidence of the presence of unique hydrocarbon seep chemosynthetic benthic communities, which are typically characterised by species from the family Dorvilleidae (ERM, 2013; Thornhill et al., 2012).

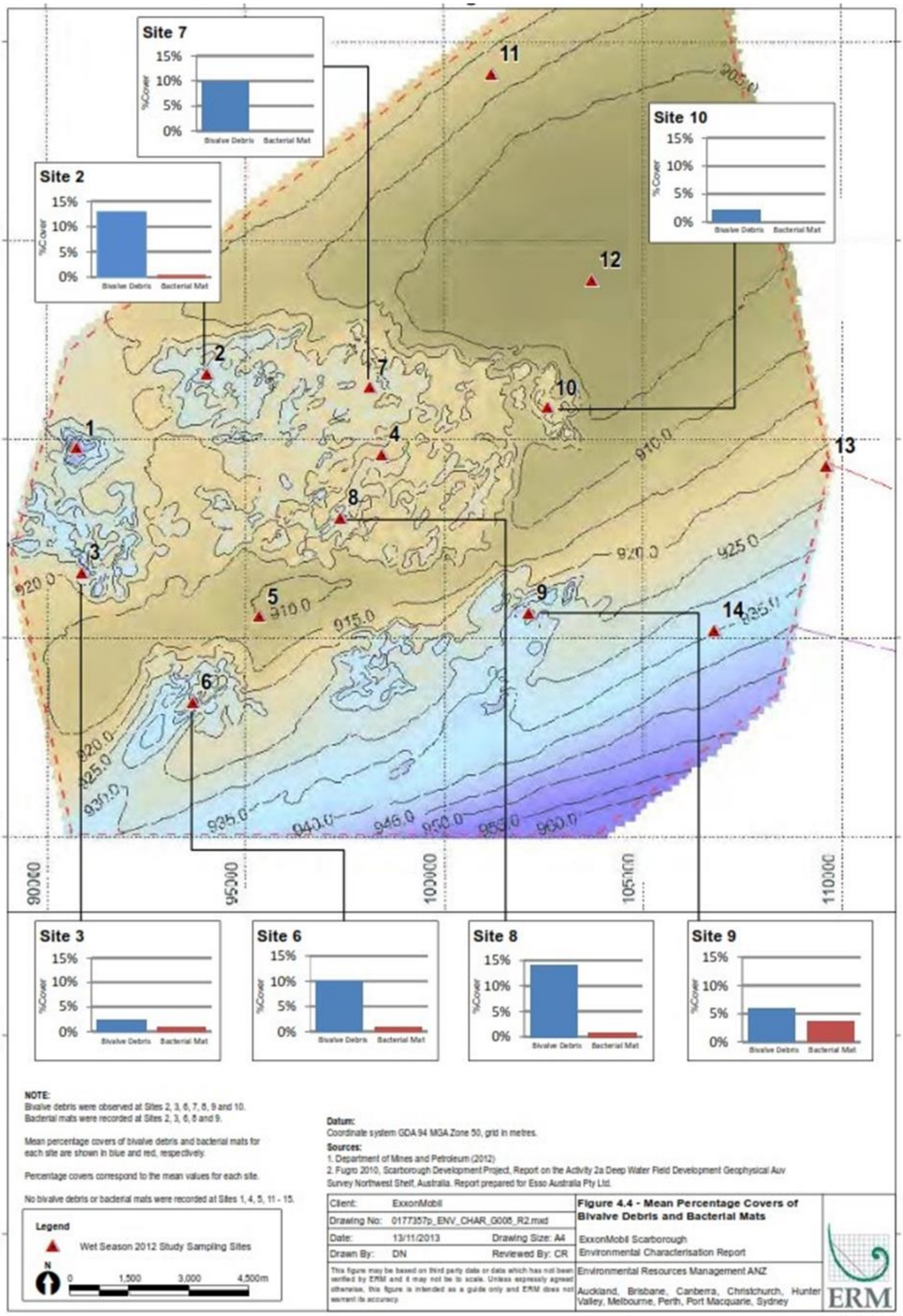


Figure 5.14: Mean percentage cover of bivalve debris and bacterial mats at study sites samples in the permit area WA-15-R (source: ERM, 2013)

Borrow Ground Project Area

Preliminary findings from the benthic habitat survey completed in the Borrow Ground Project Area and adjacent areas of the Dampier AMP suggest that the benthic habitat is dominated by sandy bottom and with little to no biota (Advisian, 2019c). Data captured included high resolution still images and video footage at 24 drop camera locations outside the marine park and 51 drop camera locations within the marine park. Within and outside the marine park little or no invertebrates were observed (<10% coverage) (Figure 5.15 and Figure 5.16).

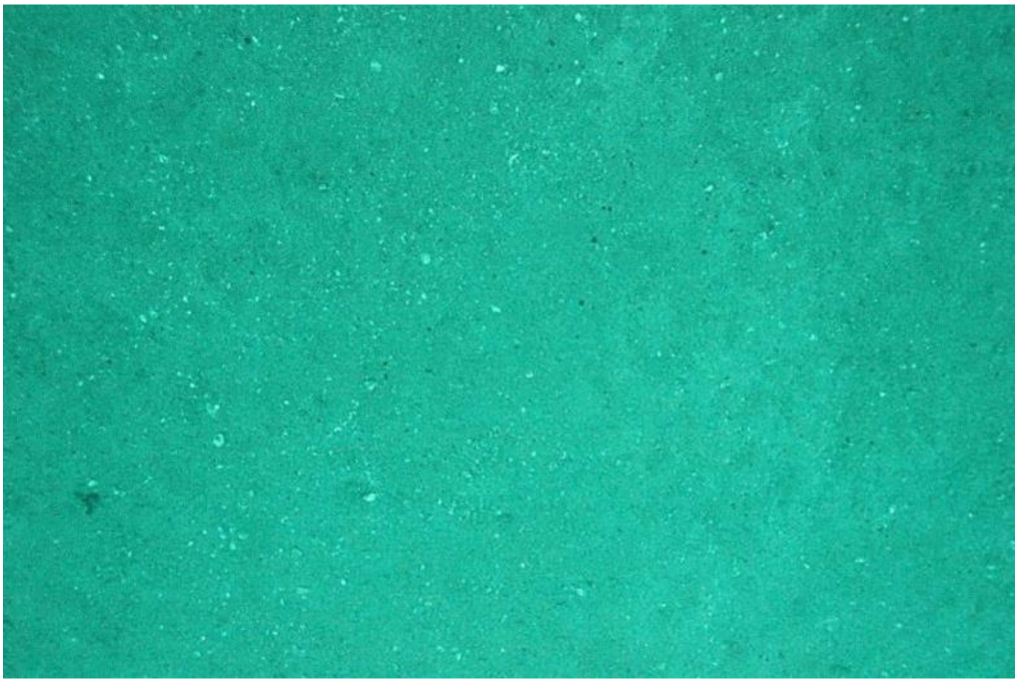


Figure 5.15: Example image of typical sand habitat with no biota observed within the Dampier Marine Park area of interest

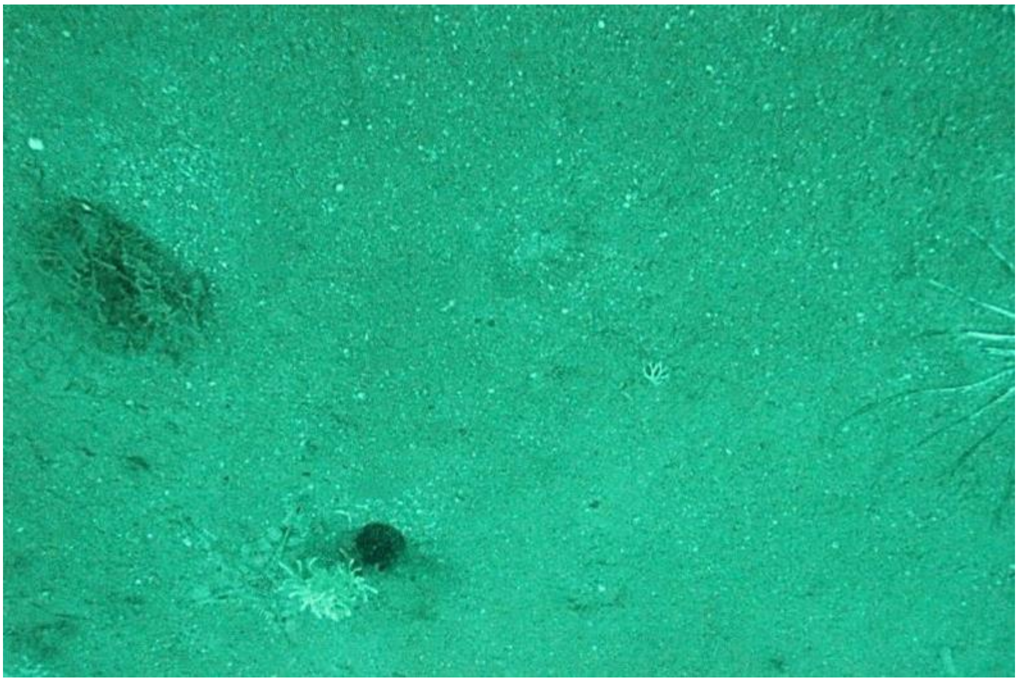


Figure 5.16: Example image of sand habitat with sparse invertebrates (<10%) observed within the Dampier Marine Park area of interest

5.3.11 Coral

EMBA

Corals are generally divided into two broad groups: the zooxanthellate ('reef-building', 'hermatypic' or 'hard') corals, which contain symbiotic microalgae (zooxanthellae) that enhance growth and allow the coral to secrete large amounts of calcium carbonate; and the azooxanthellate ('ahermatypic' or 'soft') corals, which are generally smaller and often solitary (Tzioumis and Keable, 2007). Hard corals are generally found in shallower (<50 m) waters while the soft corals are found at most depths, particularly those below 50 m (Tzioumis and Keable, 2007).

Both zooxanthellate and azooxanthellate corals are found throughout the Dampier Archipelago, including a total of 229 species from 57 hermatypic coral genera (Woodside, 2006; Griffith, 2004), representing a large proportion of the 318 hermatypic species from 70 genera known to occur in Western Australia (URS, 2004). The most diverse coral assemblages of the Dampier Archipelago are on the seaward slopes of outer islands such as Delambre Island, Legendre Island, Rosemary Island and Kendrew Island (Jones, 2004; CALM, 2005). Areas supporting a broad variety of corals are also found at Hamersley Shoal, Sailfish Reef and north-west Enderby Island (Woodside, 2006).

The coral communities along the mainland Burrup Peninsula coast show little evidence of reef development; rather they grow by encrusting solid substrata such as Precambrian rock (URS, 2004; Jones, 2004). Coral reefs have been recorded near King Bay, between Phillip Point and the Dampier Public Wharf; however, water conditions in this area are extremely turbid and the reef is patchy (Water Corporation, 2000). URS (2003) has recorded various species of coral along the western coast of the Burrup Peninsula, with the most dominant genera being *Favities*, *Favia*, *Platygyra*, *Goniastrea* and *Caulastrea*, as well as *Turbinaria* colonies. Other common corals recorded include *Porites*, *Pavona*, *Acropora*, *Lobophyllia*, *Symphyllia*, *Goniopora*, *Montipora* and *Pectinia* species (URS, 2003).

Other significant areas of coral reef in the EMBA include Ningaloo Reef, and those fringing the Muiron Islands, Barrow Island and Montebello Islands.

Trunkline Project Area

Due to the water depths of the majority of the Trunkline Project Area in Commonwealth waters, no zooxanthellate corals are expected to occur. However, free-living soft solitary corals were an abundant phylum observed during sled tow sampling (SKM, 2006). The only natural habitat within the Offshore Project Area and Trunkline Project Area that is not classified as soft sediment is the rock pinnacle field that lies in about 300 m water depth, on the continental slope (Figure 5.17). The pinnacle field covers an area about 1 km long x 4 km wide, but the pinnacles are isolated forms and do not constitute continuous reef. It remains unclear what the rock pinnacles are constructed from, however the structures provide habitat for a diverse range of epifaunal and demersal species that commonly occur elsewhere in the NWS, including a very low percentage cover of live coral with only a few live specimens of coral observed growing on top of the pinnacles. Professor Murray Roberts (University of Edinburgh) was provided footage of ROV surveys of the rock pinnacles and determined the coral species was "at first glance *Dendrophyllia cornigera* (well known in the Mediterranean Sea), but perhaps more likely a Leptosammia species (same family: Dendrophylliidae)" *(*Advisian, 2019a).

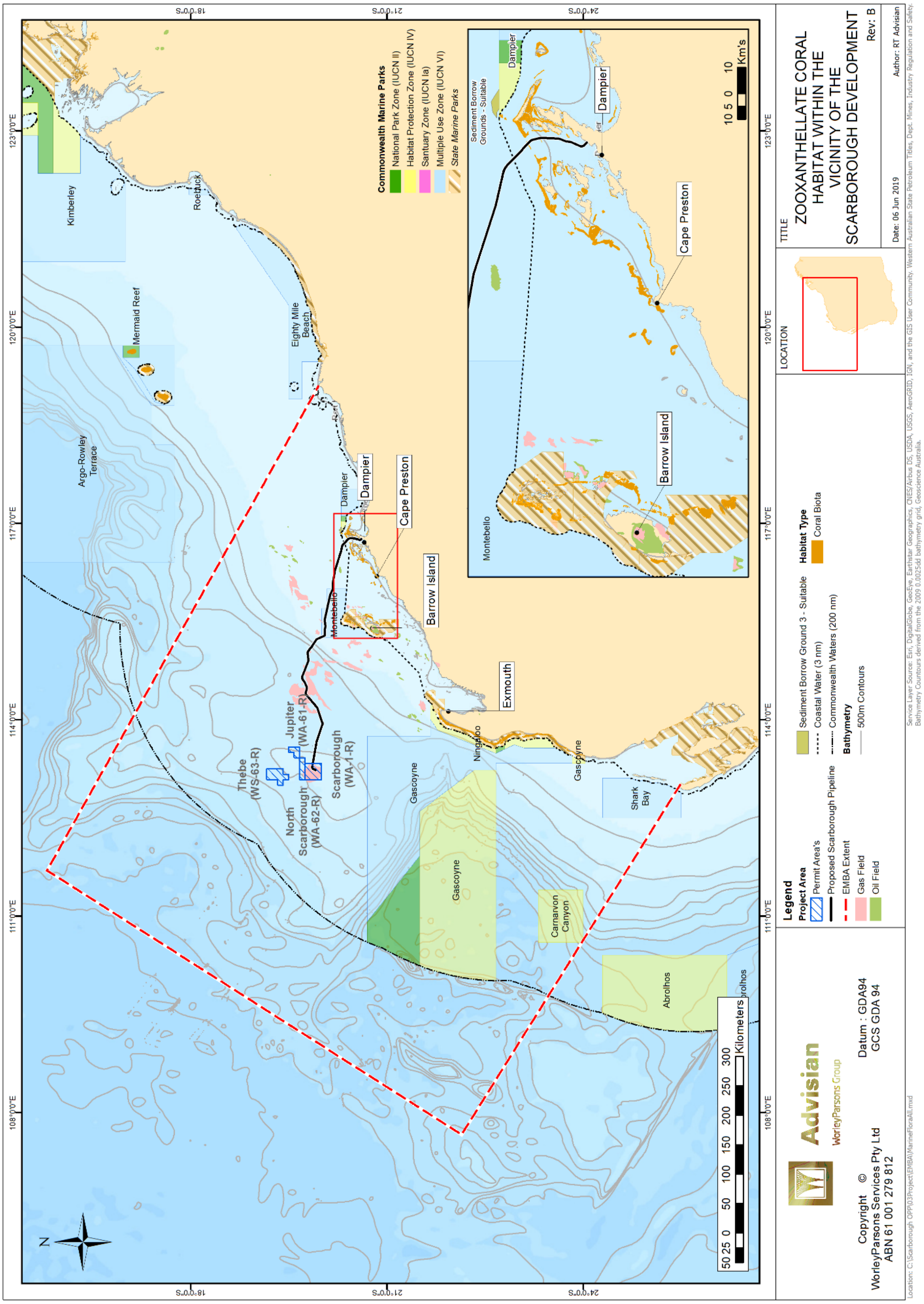


Figure 5.17: Zooxanthellate coral habitat within the vicinity of Scarborough

Offshore Project Area

Given the water depths of the Offshore Project Area, no zooxanthellate corals are expected to occur in this region. Soft corals were observed during surveys in the Offshore Project Area, though were not dominant. Most sites where soft coral was identified were found outside of the seafloor crater areas (ERM, 2013) (see 'Epifauna and Infauna').

Borrow Ground Project Area

As outlined above for epifauna and infauna, preliminary findings from the benthic habitat survey completed in the Borrow Ground Project Area and adjacent areas of the Dampier AMP found that benthic habitat within the Borrow Grounds Project Area consisted of sand with little to no biota throughout the area. No Coral species were identified.

5.3.12 Seagrass and Macroalgae

EMBA

Seagrass beds and benthic macroalgae reefs are a main food source and provide key habitats and nursery grounds for many marine species (Heck Jr. et al., 2003; Wilson et al., 2010). In the northern half of Western Australia, these habitats are restricted to sheltered and shallow waters due to large tidal movement, high turbidity, large seasonal freshwater run-off and cyclones.

Within the EMBA, significant seagrass and macroalgae communities are found in waters surrounding islands of the Dampier Archipelago, Barrow Island and the Montebello Islands.

Seagrasses in the Dampier Archipelago are generally sparse, occurring in low abundance on shallow sandy sediments in sheltered areas such as flats and larger bays (CALM, 2005; Jones, 2004). Surveys in the region have identified the following nine species: *Cymodocea angustata*, *Enhalus acoroides*, *Halophila decipiens*, *Halophila minor*, *Halophila ovalis*, *Halophila spinulosa*, *Halodule uninervis*, *Thalassia hemprichii,* and *Syringodium isoetifolium* (Woodside, 2006). Recorded occurrences of *Halophila* species in the Dampier Archipelago fluctuate depending on a variety of factors such as salinity, success of seed set and colonisation, temperature and grazing by dugongs (Woodside, 2006).

Macroalgae are most commonly found on shallow limestone pavements located throughout the Dampier Archipelago (Figure 5.18). Large expanses of macroalgae are prevalent along the seaward side of West Intercourse Island, extending south-west along the coast to Cape Preston and beyond. Large macroalgal platforms are also evident at Rosemary Island, Nelson Rocks, Legendre Island, West Lewis and East Lewis Islands, Enderby Island, Gidley Island, Eaglehawk Island, Malus Island and Angel Island; these platforms generally occur on the northern and western sides of the islands (Woodside, 2006). The most abundant group of algae in the region is brown algae; species from the genus *Sargassum*, *Dictyopteris* and *Padina* are very common (Woodside, 2006). The most common species of green algae in the Dampier Archipelago include *Caulerpa* species and calcareous *Halimeda* species (CALM, 2005; Jones, 2004). A variety of red algae are also found in the Dampier Archipelago including corallines, calcified red algae and algal turf (Jones, 2004).

In waters surrounding Barrow Island and the Montebello Islands, extensive subtidal macroalgal and seagrass communities are important primary producers and refuge areas for fishes and invertebrates. Macroalgae communities are most commonly found on shallow limestone pavement in depths of 5 to 10 m. The macroalgal assemblage is typically dominated by species of brown algae, particularly of the genera *Sargassum*, *Turbinaria* and *Pandina*. Green algae from the genera *Caulerpa*, *Cladophora* and *Rhodophyta* are also quite common. Other abundant taxa include *Halimeda*, *Dictyopterus*, *Dictyota*, *Cystoseira*, *Codium* and *Laurencia*.

In the vicinity of the Montebello Islands, seagrasses do not appear to form extensive meadows but instead are sparsely interspersed between the macroalgae assemblages. Seagrasses typically extend from the intertidal zone to approximately 15 m water depth. A total of seven seagrass species have been recorded to date, these being *Cymodocea angustata*, *Halophila ovalis*, *Halophila spinulosa*, *Halodule uninervis*, *Thalassia hemprichi*, *Thalassodendron ciliatum* and *Syringodium isoetifolium*.

Offshore Project Area/Trunkline Project Area/Borrow Ground Project Area

Seagrasses and macroalgae are generally found in coastal waters at depths of <10 m, although they have been recorded at 50 m in some Australian waters. Therefore, it is highly unlikely that seagrasses are present within the Offshore Project Area (900 – 970 m depth) or Borrow Grounds Project Area (~100 m depth).

The shallowest water depths in Trunkline Project Area are 35 m. Seagrasses may occur in areas of the Trunkline Project Area where water depths are less than 50 m. However, extensive areas of seagrass are not expected given distribution is typically limited to water depths shallower than the Trunkline Project Area.

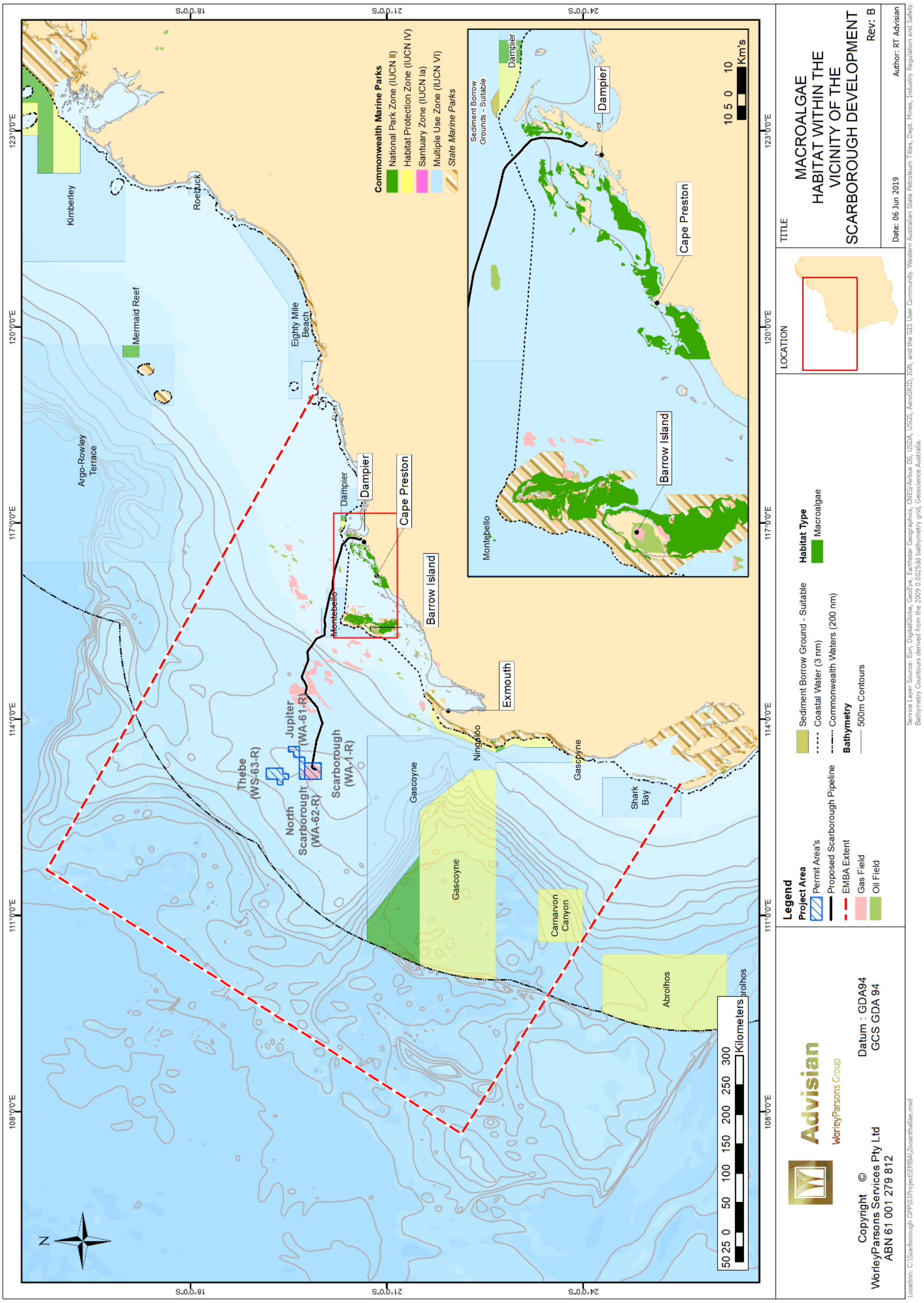


Figure 5.18: Macroalgae habitat within the vicinity of Scarborough

5.3.13 Regionally Important Shoals and Banks

As outlined in Section 5.3.3, no shoals or banks occur in the Project Area. However, regionally important shoals occur within the EMBA, namely Glomar shoals and Rankin Bank. Glomar Shoals is a designated Key Ecological Feature (KEF) and is described further in Section 5.5.6.

Rankin Bank is on the continental shelf, about 40 km from the Project Area. While Rankin Bank is not protected and is not a KEF, it is the only large, complex bathymetrical feature on the outer western shelf of the West Pilbara and represents habitats that are likely to play an important role in the productivity of the Pilbara region (AIMS, 2014). Rankin Bank consists of three submerged shoals delineated by the 50 m depth contour with water depths of about 18–30.5 m (AIMS, 2014).

Rankin Bank was surveyed by AIMS in 2013 as part of a co-investment project between Woodside and AIMS to better understand the habitats and complexity of the submerged shoal ecosystems. 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). 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). Indeed, in a comparison between Glomar Shoals and Rankin Bank, Rankin Bank had both higher cover of hard corals, and higher abundance of fish compared to Glomar Shoals (Abdul Wahab et al., 2018).

Rankin Bank has 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).

5.3.14 Coastal Habitats

Given the offshore location of the Project Area, coastal habitats occur in neither the Offshore Project Area nor Trunkline Project Area. However, coastal habitats may occur within the EMBA and are discussed below.

The coastline within the northwest of Western Australia is varied, but predominantly includes tidal flats with smaller areas of rocky shores and sandy beaches (described in Section 5.3.15). Tidal flats are shorelines exposed to high tidal variation; includes both sandy and muddy sediments. This shoreline type can often be associated with mangrove or saltmarsh environments.

5.3.14.1 Saltmarshes

Saltmarshes are terrestrial halophytic (salt-adapted) ecosystems that mostly occur in the upper-intertidal zone. They are typically dominated by dense stands of halophytic plants such as herbs, grasses and low shrubs. The diversity of saltmarsh plant species increases with increasing latitude (in contrast to mangroves). The vegetation in these environments is essential to the stability of the saltmarsh, as they trap and bind sediments. The sediments are generally sandy silts and clays and can often have high organic material content. Saltmarshes provide a habitat for a wide range of both marine and terrestrial fauna, including infauna and epifaunal invertebrates, fish and birds.

There are no saltmarshes within the Project Area. However, saltmarshes are known to occur at locations along the Pilbara coast and islands of the Dampier Archipelago as shown in Figure 5.19.

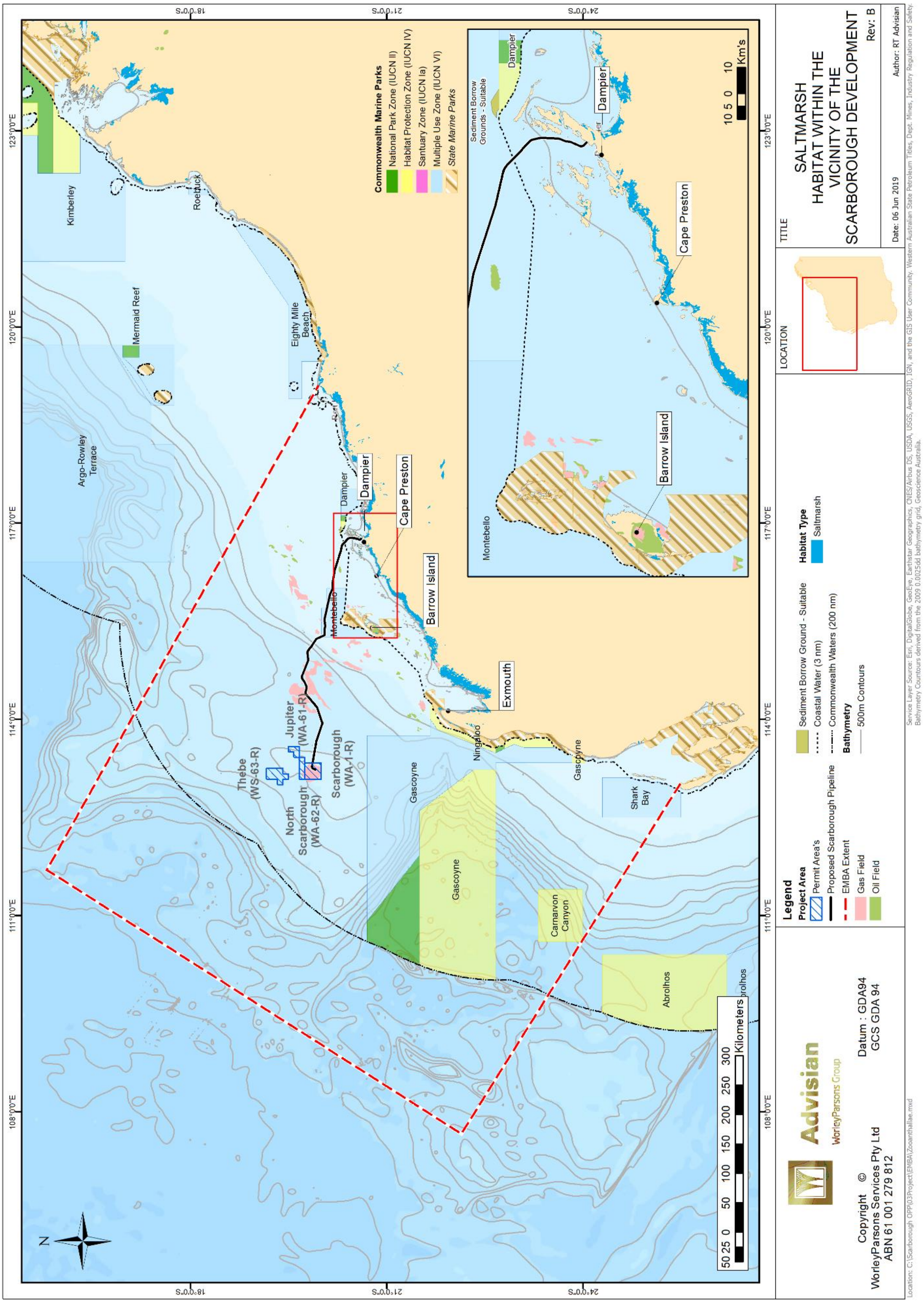


Figure 5.19: Saltmarsh habitat within the vicinity of Scarborough

5.3.14.2 Mangroves

Mangroves grow in intertidal mud and sand, with specially adapted aerial roots (pneumatophores) that provide for gas exchange during low tide (McClatchie et al., 2006). Mangrove forests can help stabilise coastal sediments, provide a nursery ground for many species of fish and crustacean, and provide shelter or nesting areas for seabirds (McClatchie et al., 2006).

There are no mangroves within the Project Area. However, mangrove presence is known at locations along the Pilbara coast and islands of the Dampier Archipelago as shown in Figure 5.20.

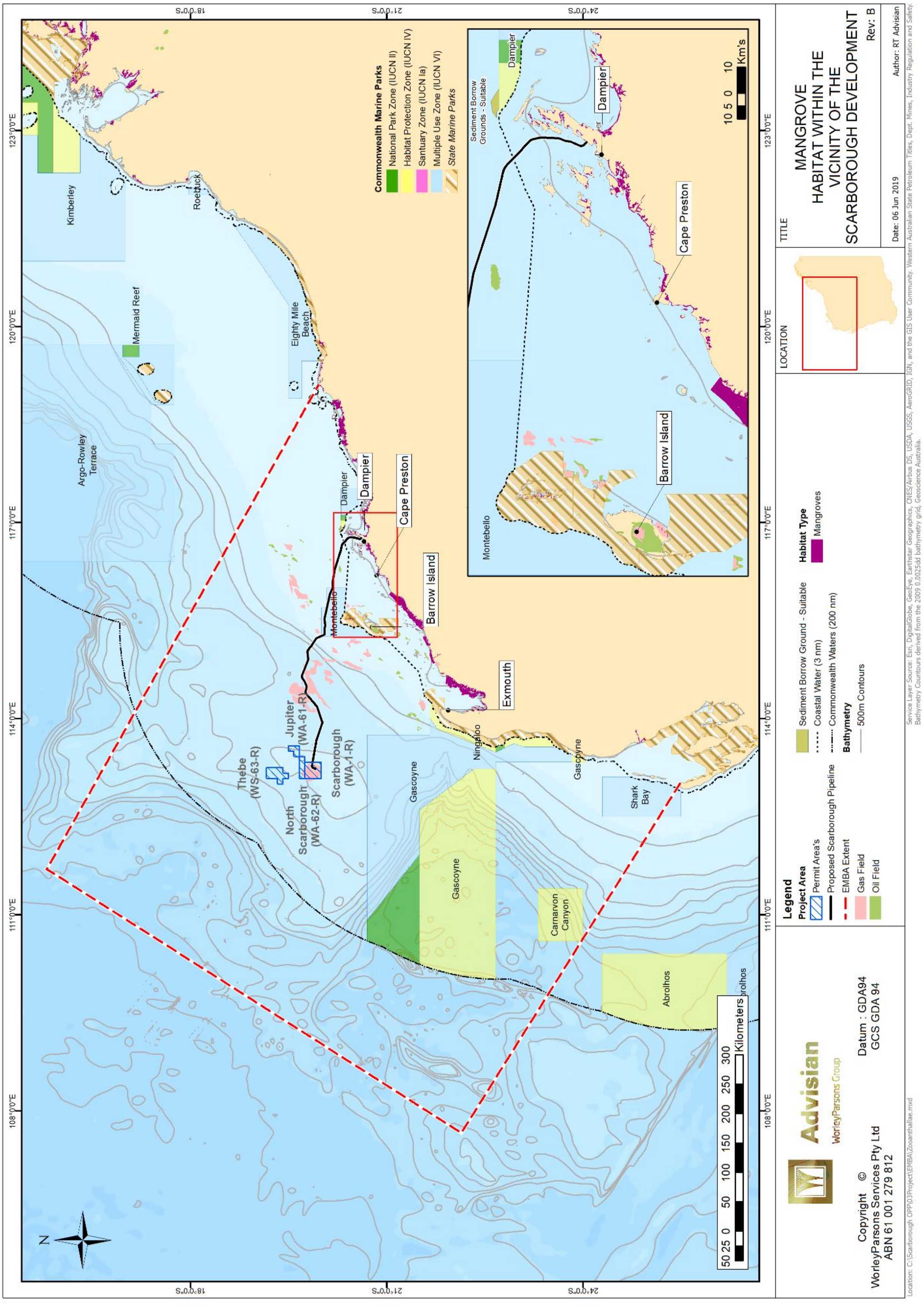


Figure 5.20: Mangrove habitat within the vicinity of Scarborough

5.3.15 Shoreline Habitats

Given the offshore location of the Project Area, shoreline habitats occur in neither the Offshore Project Area nor Trunkline Project Area. However, shoreline habitats may occur within the EMBA and are discussed below.

The shoreline within the northwest of Western Australia is varied, but predominantly includes tidal flats (described in Section 5.3.14) with smaller areas of rocky shores and sandy beaches (Table 5.2). Each of these shoreline types has the potential to support different flora and fauna assemblage due to the different physical factors (e.g. waves, tides, light, etc.) influencing the habitat.

Table 5.2: Description of shoreline types

Shoreline Type	Description
Rocky	Hard and soft rocky shores, including bedrock outcrops, platforms, low cliffs (less than five metres), and scarps. Depending on exposure, rocky shores can be host to a diverse range of flora and fauna, including barnacles, mussels, sea anemones, sponges, sea snails, starfish and algae. Australian fur-seals are also known to use rocky shores for haul-out and/breeding.
Sandy	Beaches dominated by sand-sized (0.063–2 mm) particles; also includes mixed sandy beaches (i.e. sediments may include muds or gravel, but sand is the dominant particle size). Sandy beaches are dynamic environments, naturally fluctuating in response to external forcing factors (e.g. waves, currents, etc). Sandy beaches can support a variety of infauna and provide nesting and/or foraging habitat to shorebirds and seabirds and pinnipeds. Sand particles vary in size, structure and mineral content; this in turn affects the shape, colour and inhabitants, of the beach.

5.3.16 Listed Threatened Ecological Communities

The Project Area does not intersect any Threatened Ecological Communities (TEC) as designated under Section 181 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). However, the EMBA intersects with the Subtropical and Temperate Coastal Saltmarsh TEC.

5.3.16.1 Subtropical and Temperate Coastal Saltmarsh

The Subtropical and Temperate Coastal Saltmarsh is listed as a vulnerable TEC under the EPBC Act. The TEC is predominantly distributed in southern Australia, however an area in the vicinity of Carnarvon is known to occur (Figure 5.21).

The Subtropical and Temperate Coastal Saltmarsh ecological community occurs within a relatively narrow margin along the coast, within the subtropical and temperate climatic zones; and includes coastal saltmarsh occurring on islands within these climatic zones (DSEWPaC, 2013b). The physical environment for the ecological community is coastal areas under regular or intermittent tidal influence (DESWPaC, 2013b).

The ecological community consists mainly of salt-tolerant vegetation (halophytes) including grasses, herbs, sedges, rushes and shrubs (DESWPaC, 2013b). Many species of non-vascular plants are also found in saltmarsh, including epiphytic algae, diatoms and cyanobacterial mats (TSSC, 2013a). The ecological community is inhabited by a wide range of infaunal and epifaunal invertebrates, and temporary inhabitants such as prawns, fish and birds (and can often constitute important nursery habitat for fish and prawn species) (DESWPaC, 2013b). Insects are also abundant and an important food source for other fauna, with some species being important pollinators (DESWPaC, 2013b). The dominant marine residents are benthic invertebrates, including molluscs and crabs that rely on the sediments, vascular plants, and algae, as providers of food and habitat across the intertidal landscape (DESWPaC, 2013b).

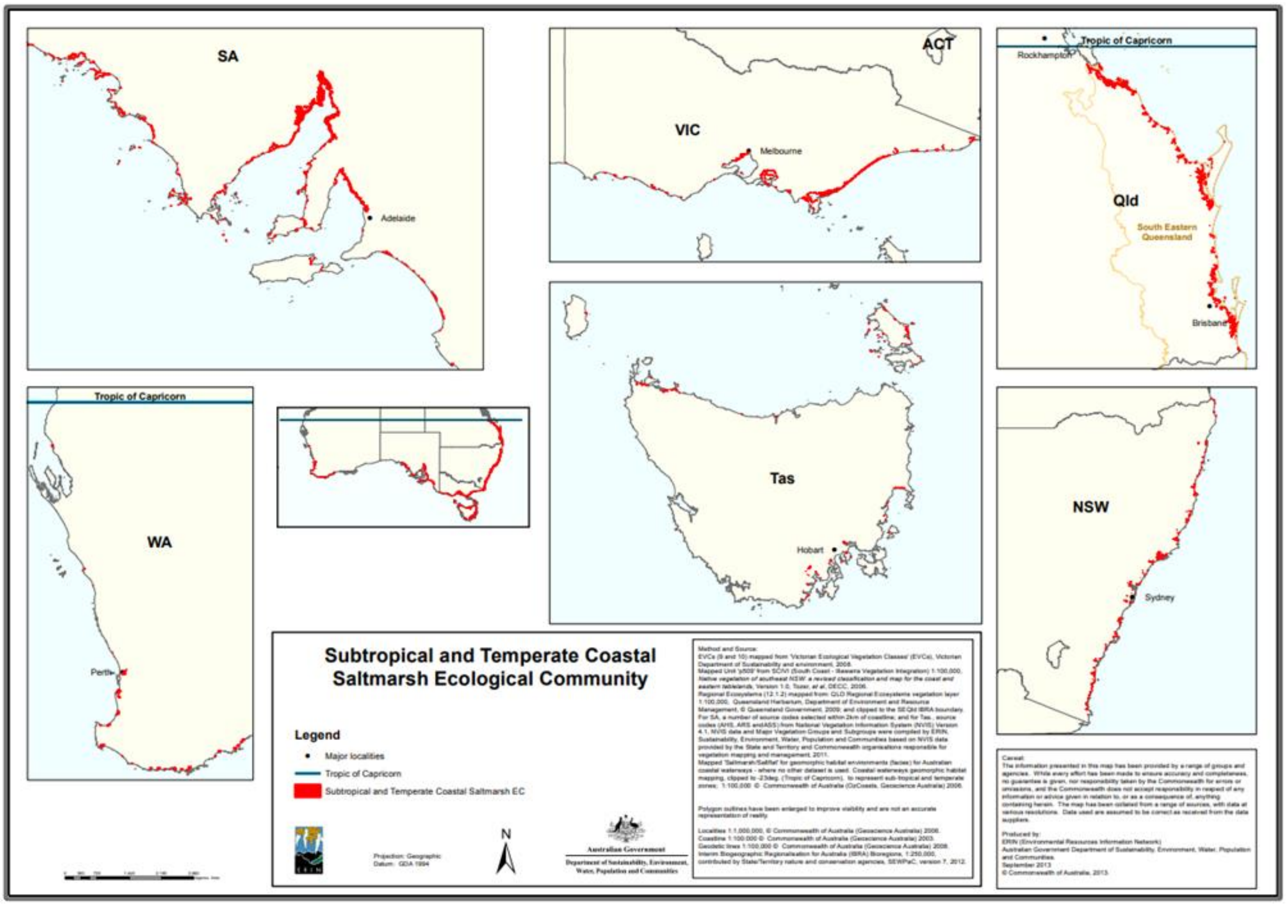


Figure 5.21: Distribution of Subtropical and Temperate Coastal Saltmarsh TEC

5.4 Marine Fauna of Conservation Significance

Under Part 13 of the EPBC Act, species can be listed as one, or a combination, of the following protection designations:

- threatened (further divided into categories; extinct, extinct in the wild, critically endangered, endangered, vulnerable, conservation-dependent)
- migratory
- whale or other cetaceans
- marine.

Additionally, the *Western Australia Wildlife Conservation Act 1950* (WA Wildlife Conservation Act) provides for species or subspecies of native animals (fauna) to be specially protected and listed as 'threatened' in Western Australia because they are:

- under identifiable threat of extinction
- rare
- otherwise in need of special protection.

The EPBC Act Protected Matters Search Tool was used to identify protected species that may occur within the Project Area and EMBA. Four separate EPBC Act Protected Matters Reports were generated for the Offshore Project Area, Trunkline Project Area, Borrow Grounds Project Area and EMBA.

Details of listed fauna and their likely presence in the Project Area and EMBA are provided in the following sections and appendices. Results of the EPBC Act Protected Matters Search Tool were cross-checked against the Threatened and Priority Fauna List, downloaded from the Department of Biodiversity, Conservation and Attractions website.

For the purpose of the OPP, only species listed as threatened or migratory under the EPBC Act likely to occur in the Project Area are considered to have conservation significance warranting further discussion. Likely occurrence was determined by the EPBC Act Protected Matters Reports or through designation of important habitat (e.g. BIA).

5.4.1 Biologically Important Areas and Critical Habitat to the Survival of a Species

Biologically Important Areas (BIAs) are areas that are particularly important for the conservation of protected species and where aggregations of individuals display biologically important behaviour such as breeding, foraging, resting or migration. Their designation is based on expert scientific knowledge about species' distribution, abundance and behaviour. The presence of the observed behaviour is assumed to indicate that the habitat required for the behaviour is also present.

BIAs and critical habitat for survival of a species which overlap the Project Area and EMBA have been identified for the following EPBC Act listed species using the Conservation Values Atlas and are summarised in Table 5.3. Further details about the BIAs and critical habitat are included in the relevant species sections below.

Table 5.3: Designated biologically important areas and critical habitat for the survival of a species for protected species occurring in the Project Area and EMBA

Receptor		Distance/overlap with BIA				Type	Description
		Offshore Project Area	*Trunkline Project Area*	*Borrow Ground Project Area*	*EMBA*		
Seabirds and shorebirds	Australian Fairy tern	>216 km	Overlap	Overlap	Overlap	Breeding	Birds from South West Marine Region (SWMR) dispersing northwards in winter – July to late September. BIA located around islands of Dampier Archipelago, Barrow Island, Montebello Islands and Pilbara coast
	Brown booby	>525 km	>215 km	>200 km	Overlap	Breeding	Breeding February to October (but mainly in autumn). BIA located around Bedout Island.
	Lesser crested tern	>211 km	>34 km	114 km	Overlap	Breeding	Breeding March to June. BIA located around Lowendal Islands
	Roseate tern	>206 km	>25 km	Overlap	Overlap	Breeding	Breeding from mid-March to July, birds from SWMR dispersing north in winter. BIAs located around Lowendal Islands, Pilbara islands and Dampier Archipelago
	Wedge-tailed shearwater	>106 km	Overlap	Overlap	Overlap	Breeding	Breeding visitor arriving in mid-August and leaving in April. Large BIA covering large proportions of Commonwealth and State waters

Receptor		Distance/overlap with BIA				Type	Description
		Offshore Project Area	*Trunkline Project Area*	*Borrow Ground Project Area*	*EMBA*		
Marine mammals	Humpback whale	>153 km	Overlap	Overlap	Overlap	Migration	Migration routes, including timing, provided in Section 5.4.4
		>198 km	>198 km	>198 km	Overlap	Resting	Resting area in Exmouth Gulf
	Pygmy blue whale	>35 km	Overlap	>160 km	Overlap	Migration	Migration routes, including timing, provided in Section 5.4.4
		Overlap	Overlap	Overlap	Overlap	Distribution	Large BIA for presence of species, could occur year-round
		>186 km	>186 km	>344 km	Overlap	Foraging	Relatively small area off Ningaloo Reef, activity could occur year-round
	Dugong	>198 km	>198 km	>284 km	Overlap	Nursing and foraging	BIA for year-round breeding, nursing and foraging in proximity to Ningaloo reef and Exmouth Gulf
Marine turtles	Flatback turtle	>164 km	Overlap	Overlap	Overlap	Inter-nesting	80 km buffer around nesting beaches, including Montebello Islands, Barrow Island, Dampier Archipelago and the Pilbara coast, October to March
		>222 km	>63 km	>8 km	Overlap	Nesting	Smaller BIA restricted to a few kilometres from key nesting beaches at the Montebello Islands, Barrow Island and Dampier Archipelago, October to March
		>200 km	>80 km	>18 km	Overlap	Foraging	Inshore of Barrow Island, observations during July, no evidence of turtle activity October to November
		>224 km	>10 km	>10 km	Overlap	Mating	Nearshore waters surround Montebello Islands, Barrow Island and Dampier Archipelago, October to March
		>165 km	Overlap	Overlap	Overlap	Critical habitat for survival of a species	Barrow Island, Montebello Islands, 6 km inter-nesting buffer, October to March
	Green turtle	>188 km	Overlap	Overlap	Overlap	Inter-nesting	20 km buffer around nesting beaches, including Muiron Islands, North West Cape, Montebello Islands, Barrow Island and Dampier Archipelago, November to March

Receptor		Distance/overlap with BIA				Type	Description
		Offshore Project Area	*Trunkline Project Area*	*Borrow Ground Project Area*	*EMBA*		
		>226 km	>10 km	>8 km	Overlap	Nesting	Smaller BIA restricted to a few kilometres from key nesting beaches at the Montebello Islands, west coast of Barrow Island, Muiron Islands and North West Cape and Dampier Archipelago, November to March
		>200 km	>80 km	>42 km	Overlap	Foraging	Inshore of Barrow Island, observations during July, no evidence of turtle activity October to November
		>188 km	Overlap	Overlap	Overlap	Critical habitat for survival of a species	Nearshore waters surround Montebello Islands, Barrow Island and Dampier Archipelago, November to March
	Hawksbill turtle	>203 km	Overlap	Overlap	Overlap	Inter-nesting	20 km buffer around nesting beaches, including North West Cape, Ningaloo Reef, Montebello Islands, Barrow Island, Serrurier Island and the Dampier Archipelago, October to February
		>222 km	>9 km	>6 km	Overlap	Nesting	Smaller BIA restricted to a few kilometres from key nesting beaches at the North West Cape, Ningaloo Reef, Montebello Islands, Barrow Island, Serrurier Island and the Dampier Archipelago, October to February
		>200 km	>80 km	>36 km	Overlap	Foraging	Inshore of Barrow Island, observations during July, no evidence of turtle activity October to November
		>203 km	Overlap	Overlap	Overlap	Critical habitat for survival of a species	Dampier Archipelago (particularly Rosemary Island), Montebello Islands and Lowendal Islands. 2 km inter-nesting buffer, October to February
	Loggerhead turtle	>192 km	Overlap	Overlap	Overlap	Inter-nesting	20 km buffer around nesting beaches, including North West Cape, Ningaloo Reef, Muiron Islands, Montebello Islands and the Dampier Archipelago, November to March
		>192 km	>172 km	>172 km	Overlap	Critical habitat for	Exmouth Gulf and Ningaloo coast; 2 km inter-nesting buffer; November to May

Receptor		Distance/overlap with BIA				Type	Description
		Offshore Project Area	Trunkline Project Area	Borrow Ground Project Area	EMBA		
						survival of a species	
Fish	Whale shark	>165 km	Overlap	>20 km	Overlap	Foraging	Broad BIA encompassing migration and foraging post aggregation at Ningaloo Reef (see below) May to November
		>208 km	>193 km	>193 km	Overlap	Foraging (high density prey)	Upwelling of nutrients result in high primary production, mass spawning of corals also brings about increased zooplankton production in April to June. BIA smaller that Foraging BIA

5.4.2 Listed Threatened Species Recovery Plans

Listed threatened species recovery plans (Recovery plans) and Conservation advices may be in place for species of marine fauna of conservation significance. Recovery plans are enacted under the EPBC Act and remain in force until the species is removed from the threatened list. Conservation advice provides guidance on immediate recovery and threat abatement activities that can be undertaken to facilitate the conservation of a listed species or ecological community.

Table 3.2 outlines the recovery plans and conservation advices relevant to those species identified as potentially occurring within or utilising habitat in the Project Area and EMBA and summarises the key threats to those species, as described in relevant recovery plans and conservation advices.

5.4.3 Seabirds and Migratory Shorebirds

5.4.3.1 Overview

Birds in the marine environment can include seabirds and shorebirds. Seabirds refers to those species of bird whose normal habitat and food sources are derived from the ocean (both coastal and pelagic); pelagic seabirds include such species as shearwaters and petrels, coastal seabirds include species such as cormorants. Shorebirds (sometimes referred to as wading birds) refers to those species of bird commonly found along sandy or rocky shorelines, mudflats, and shallow waters; shorebirds include such species as plovers and sandpipers

Seabirds spend most of their lives at sea, ranging over large distances to forage over the open ocean. Many of these species also breed in and adjacent to the NWMR, including populations of terns and shearwaters (DEWHA, 2008). Based on the results of two survey cruises and other unpublished records, Dunlop et al. (1988) recorded the occurrence of 18 species of seabirds over the NWS. Seabird distributions were generally patchy, except near islands (Dunlop et al., 1988).

Migratory shorebirds may be present in or fly through the region between July and December and again between March and April as they migrate between Australia and offshore locations (Bamford et al., 2008; DoE, 2015a). During their migration, shorebirds use several staging areas, typically wetland habitat, as intermediate feeding sites to rest and restore energy reserves. Where wetland habitat has been assessed as provided significant ecological value, including utilisation by shorebirds, they are designated ‘Ramsar wetlands of international importance’. As outlined in

Section 5.6.5.1, there are no Ramsar wetlands of international importance located in the Project Area or EMBA.

There are numerous important habitats for seabirds and migratory shorebirds including key breeding/nesting areas, roosting areas and surrounding waters important foraging and resting areas within the NWMR. These include:

- Muiron Islands (186 km from Project Area)
- Montebello/Barrow/Lowendal Islands group (41 km from Project Area)
- Pilbara Islands (North, Middle and South groups) (>50 km from Project Area)
- Rowley Shoals (420 km from Project Area)
- Ashmore Reef (>1000 km from Project Area)
- Kimberley coast (>1000 km from Project Area)
- Shark Bay (607 km from Project Area)
- Houtman Abrolhos Islands (>1000 km from Project Area).

Other species may also utilise the marine environment, and are listed as marine under the EPBC Act, but have distributions that also extend into freshwater or terrestrial environments. Such species include passerines or raptors.

There are 19 seabird and shorebird species (or species habitat) that may occur within the Project Area and an additional 60 seabirds or shorebirds that could occur in the EMBA. These include species classified as threatened, migratory and marine under the EPBC Act (Table 5.4); however no additional species are protected under the WA Wildlife Conservation Act. The type of presence varies between species and location and includes important behaviours (e.g. breeding, foraging) for a small number of species within the Trunkline Project Area (Table 5.4).

Breeding BIAs for seabirds and shorebirds are primarily restricted to within tens of kilometres of emergent features, except the wedge tailed shearwater, as described in Table 5.3.

Table 5.4: Bird species or species habitat that may occur within the Project Area and EMBA

Species		Specially Protected Fauna	Threatened Species	Migratory Species	Listed Marine Species	Biologically Important Area	Offshore Project Area	Trunkline Project Area	Borrow Grounds Project Area	EMBA
Seabirds										
Anous stolidus	Common noddy			✓(M)	✓		MO	MO	MO	LO
Ardenna carneipes	Flesh-footed shearwater			✓(M)	✓					LO
Ardenna pacifica	Wedge-tailed shearwater			✓(M)	✓	✓(b)				BKO
Calonectris leucomelas	Streaked shearwater			✓(M)	✓			LO	LO	LO
Catharacta skua	Great skua				✓					MO
Diomedea amsterdamensis	Amsterdam albatross		E	✓(M)	✓					MO
Diomedea exulans	Wandering albatross		V	✓(M)	✓					MO
Fregata ariel	Lesser frigatebird			✓(M)	✓		MO	LO	LO	KO
Fregata minor	Great frigatebird			✓(M)	✓					MO
Larus novaehollandiae	Silver gull				✓					BKO
Larus pacificus	Pacific gull				✓					BKO
Macronectes giganteus	Southern giant petrel		E	✓(M)	✓		MO	MO	MO	MO
Macronectes halli	Northern giant petrel		V	✓(M)	✓					MO
Onychoprion anaethetus	Bridled tern			✓(M)	✓					BKO
Papasula abbotti	Abbott's booby		E		✓					MO
Pterodroma mollis	Soft-plumaged petrel		V		✓					FLO
Sterna caspia	Caspian tern			✓(M)	✓					BKO
Sterna dougallii	Roseate tern			✓(M)	✓	✓(b)		FLO	BKO	BKO
Sterna fuscata	Sooty tern				✓					BKO
Sterna nereis	Fairy tern				✓					BKO
Sternula nereis	Australian fairy tern		V			✓(b)		FLO	BKO	BKO
Sula leucogaster	Brown booby				✓	✓(b)				BKO

Species		Specially Protected Fauna	Threatened Species	Migratory Species	Listed Marine Species	Biologically Important Area	Offshore Project Area	Trunkline Project Area	Borrow Grounds Project Area	EMBA
Thalassarche carteri	Indian yellow-nosed albatross		V	✓(M)	✓					FMO
Thalassarche cauta	Tasmanian shy albatross		V	✓(M)	✓					MO
Thalassarche impavida	Campbell albatross		V	✓(M)	✓					MO
Thalassarche melanophris	Black-browed albatross		V	✓(M)	✓					MO
Thalassarche	White-capped albatross		V	✓(M)	✓					FLO
Thalasseus bengalensis	Lesser crested tern				✓	✓(b)				BKO
Thalasseus bergii	Crested tern				✓					BKO
Shorebirds										
Actitis hypoleucos	Common sandpiper			✓(W)	✓		MO	MO	MO	KO
Ardea alba	Great egret				✓					BKO
Ardea ibis	Cattle egret				✓					MO
Arenaria interpres	Ruddy turnstone			✓(W)	✓					KO
Calidris acuminata	Sharp-tailed sandpiper			✓(W)	✓		MO	MO	MO	KO
Calidris alba	Sanderling			✓(W)	✓					KO
Calidris canutus	Red knot		E	✓(W)	✓		MO	MO	MO	KO
Calidris ferruginea	Curlew sandpiper		CE	✓(W)	✓			MO	MO	KO
Calidris melanotos	Pectoral sandpiper			✓(W)	✓		MO	MO	MO	KO
Calidris ruficollis	Red-necked stint			✓(W)	✓					KO
Calidris subminuta	Long-toed stint			✓(W)	✓					KO
Calidris tenuirostris	Great knot		CE	✓(W)	✓					KO
Charadrius leschenaultii	Greater sand plover		V	✓(W)	✓					KO
Charadrius mongolus	Lesser sand plover		E	✓(W)	✓					KO
Charadrius ruficapillus	Red-capped plover				✓					KO

Species		Specially Protected Fauna	Threatened Species	Migratory Species	Listed Marine Species	Biologically Important Area	Offshore Project Area	Trunkline Project Area	Borrow Grounds Project Area	EMBA
Charadrius veredus	Oriental plover			✓(W)	✓					KO
Gallinago megala	Swinhoe's snipe			✓(W)	✓					RLO
Gallinago stenuar	Pin-tailed snipe			✓(W)	✓					RLO
Glareola maldivarum	Oriental pratincole			✓(W)	✓					KO
Himantopus	Pied stilt				✓					KO
Limicola falcinellus	Broad-billed sandpiper			✓(W)	✓					KO
Limosa lapponica	Bar-tailed godwit	IA		✓(W)	✓					KO
Limosa lapponica baueri	Bar-tailed godwit (baueri)		V							KO
Limosa lapponica menzbieri	Northern Siberian bar-tailed godwit		CE							LO
Limosa	Black-tailed godwit			✓(W)	✓					KO
Numenius madagascariensis	Eastern curlew		CE	✓(W)	✓			MO	MO	KO
Numenius minutus	Little curlew			✓(W)	✓					KO
Numenius phaeopus	Whimbrel			✓(W)	✓					KO
Phalaropus lobatus	Red-necked phalarope			✓(W)	✓					KO
Pluvialis fulva	Pacific golden plover			✓(W)	✓					KO
Pluvialis squatarola	Grey plover			✓(W)	✓					RKO
Recurvirostra novaehollandiae	Red-necked avocet				✓					RKO
Rostratula australis	Australian painted snipe		E		✓					MO
Rostratula benghalensis (sensu lato)	Painted snipe		E		✓					MO
Stiltia isabella	Australian pratincole				✓					KO
Thinornis rubricollis	Hooded plover				✓					KO
Tringa brevipes	Grey-tailed tattler			✓(W)	✓					KO

Species		Specially Protected Fauna	Threatened Species	Migratory Species	Listed Marine Species	Biologically Important Area	Offshore Project Area	Trunkline Project Area	Borrow Grounds Project Area	EMBA
Tringa glareola	Wood sandpiper				✓					RKO
Tringa nebularia	Common greenshank			✓(W)	✓					KO
Tringa stagnatilis	Marsh sandpiper			✓(W)	✓					KO
Tringa totanus	Common redshank			✓(W)	✓					KO
Xenus cinereus	Terek sandpiper			✓(W)	✓					KO
Other Species										
Apus pacificus	Fork-tailed swift			✓(M)	✓			LO	LO	LO
Chrysococcyx osculans	Black-eared Cuckoo			✓(M)	✓			LO		KO
Haliaeetus leucogaster	White-bellied sea-eagle				✓					BKO
Hirundo rustica	Barn swallow			✓(T)	✓			MO		KO
Merops ornatus	Rainbow bee-eater				✓			MO		MO
Motacilla cinerea	Grey wagtail			✓(T)	✓			MO		MO
Motacilla flava	Yellow wagtail			✓(T)	✓			MO		KO
Pandion haliaetus	Osprey			✓(W)	✓			MO	MO	BKO

Specially Protected Fauna:

IA Migratory birds protected under an international agreement

Threatened Species:

V Vulnerable

E Endangered

CE Critically Endangered

Migratory Species:

M Marine

W Wetland

T Terrestrial

Biologically Important Area:

(b) Breeding

(f) Foraging

Type of Presence:

MO	Species or species habitat may occur within area
LO	Species or species habitat likely to occur within area
KO	Species or species habitat known to occur within area
FMO	Foraging may occur within the area
FLO	Foraging likely to occur within the area
BKO	Breeding known to occur within area
RLO	Roosting likely to occur within area

Species	Specially Protected Fauna	Threatened Species	Migratory Species	Listed Marine Species	Biologically Important Area	Offshore Project Area	Trunkline Project Area	Borrow Grounds Project Area	EMBA
		RKO	Roosting known to occur within area						

EMBA

A total of 61 seabirds or shorebirds (or habitat) of conservation significance may occur in the EMBA (Table 5.4). Furthermore, five breeding BIAs (Australian Fairy tern, Brown booby, Lesser crested tern, Roseate tern and Wedge-tailed shearwater) overlap the EMBA (Table 5.3, Figure 5.22).

Given the presence of emergent features and coastlines within the EMBA, seabirds and shorebirds are likely to occur. Significant areas for seabirds and shorebirds in the EMBA include the Montebello Islands, Barrow Island and the islands of the Dampier Archipelago (see Section 5.6.1.4 for further details). Although some species may be resident year-round, peak occurrence of many species will be associated with breeding and nesting, the timing of which will vary between species. Species may breed in the area or be non-breeding visitors.

Trunkline Project Area and Borrow Ground Project Area

A total of 18 conservation significant seabirds or shorebirds (or habitat) occur in the Trunkline Project Area (Table 5.4). In addition, two BIAs also overlap the Trunkline Project Area; a breeding BIA for the Australian fairy tern, and breeding BIA for the wedge-tailed shearwater (Table 5.3, Figure 5.22). A total of 14 conservation significant seabirds or shorebirds (or habitat) may occur in the Borrow Ground Project Area (Table 5.4). Within the Borrow Ground Project Area, three breeding BIAs (Australian Fairy tern, Roseate tern and Wedge-tailed shearwater) overlap the Borrow Grounds Project Area (Table 5.3,Figure 5.22). Since the BIAs are associated with breeding, the designated areas will not represent important habitat for the species year-round.

Since the majority of species identified in Table 5.4 are migratory, their presence would only be expected in the Trunkline Project Area and Borrow Grounds Project Area during part of the year. Breeding sites are often associated with conditions of prey availability nearby. For seabirds, which are further constrained by the need to provision their young with whole or macerated prey, parents would be expected to forage as near to the colony as prey conditions and energetic requirements allow (McLeay et al., 2010).

Offshore Project Area

A total of seven conservation significant seabirds or shorebirds (or habitat) may occur in the Offshore Project Area (Table 5.4). Given the offshore location and distance from emergent habitats (e.g. Montebello Islands, 230 km; Dampier Archipelago, 330 km), coastal seabirds or migratory shorebirds are unlikely to occur, other than transitory individuals during migration.

Pelagic seabirds may occur more frequently given the wide-ranging distribution of these species. However, no critical habitats (including feeding) for any species are known to occur and therefore high numbers of individuals are unlikely.

5.4.3.2 Conservation-Significant Birds in the Project Area

Seabirds

Wedge-tailed Shearwater

The wedge-tailed shearwater (*Ardenna pacifica*, previously known as *Puffinus pacificus*) is listed Migratory under the EPBC Act. The species is common off the Western Australian coast from August to April (DEWHA, 2012a). Known breeding locations in the NWMR include Dampier Archipelago and the Montebello, Lowendal and Barrow islands. During chick provision, the chick is fed approximately every one to two days, though longer periods have been recorded. Diet is variable but commonly consists of squid, fish and crustaceans (DEWHA, 2012a).

A BIA for breeding extends throughout the NWMR (Figure 5.22), overlapping with the Trunkline Project Area. Although the species has a large pelagic distribution, individuals are likely to occur in the Trunkline Project Area rather than the Offshore Project Area, particularly in the vicinity of breeding colonies during incubation and chick rearing.

Streaked Shearwater

The Streaked shearwater (*Calonectris leucomelas,* previously known as *Puffinus leucomelas)* is listed as Migratory under the EPBC Act. Following its winter migration from the northern hemisphere, the Streaked shearwater occurs frequently in northern Australia from October to March, with some records as early as August and as late as May (Marchant & Higgins, 1990). While it does not breed in Australia, it is known to forage in the North Marine Region (NMR), in particular north-west of the Wellesley Islands (over 1000 km south-east of the Offshore Project Area) (DSEWPaC, 2012a). In Australia, its distribution ranges from the North West Cape across to North Queensland. Streaked shearwaters feed mainly on fish and squid which are caught by surface-seizing and shallow plunges (DSEWPaC, 2012b).

Considering the distribution for this species, individuals are not expected to occur in the Offshore Project Area, although presence is likely in the eastern portions of the Trunkline Project Area. While presence in the Trunkline Project Area is likely, the lack of known habitat for foraging or breeding in Trunkline Project Area suggests that large numbers or aggregations are unlikely.

Lesser Frigatebird

The Lesser frigatebird (*Fregata ariel)* is listed as Migratory under the EPBC Act. They are usually observed in tropical waters around the coast of northern Western Australia, Northern Territory, Queensland and New South Wales (DSEWPaC, 2012a). Breeding typically occurs on remote offshore islands, such as Bedout island, Ashmore Reef, Lacepede Islands and Adele Island in the NWMR, between March and November. They are often found foraging far offshore, especially during the non-breeding season where some large movements have been recorded (DSEWPaC, 2012a). During the breeding season (March–November), the Lesser frigatebird's range remains close to the breeding colonies (DSEWPaC, 2012a).

Due to the large distances potentially travelled, individuals may occur across the Project Area, however, are only likely to occur within the Trunkline Project Area. No important breeding or forging areas have been identified in the Project Area. Furthermore, breeding sites are remote to the Project Area meaning that aggregations of foraging birds are unlikely to occur.

Australian Fairy Tern

The Australian fairy tern (*Sternula nereis nereis*) is listed vulnerable under the EPBC Act. It is a widely distributed coastal seabird and occurs mainly on sandy beaches within sheltered coasts of New South Wales, Victoria, Tasmania, South Australia and Western Australia (TSSC, 2011a). In

Western Australia, the species occurs along the coast as far north as the Dampier Archipelago and offshore islands Barrow/Montebello/Lowendal Islands Group (TSSC, 2011b, 2011a). The Australian fairy tern is listed as vulnerable under the EPBC Act and occurs. Dampier Archipelago is the northern extent of known habitat for the species (DEWHA, 2012a). Australian fairy terns nest above the high-water mark in sandy substrates where vegetation is low (TSSC, 2011a). Breeding in the region is typically July to September (Johnstone and Storr, 1998). Fairy terns will feed predominantly on fish, foraged in inshore waters around island archipelagos and on the Australian mainland (DEWHA, 2012a).

Due to the preferences for coastal habitats, presence in the Offshore Project Area is not expected. However, the proximity of the Trunkline Project Area to breeding sites at the Montebello, Lowendal and Barrow islands, and the Dampier Archipelago suggest occurrence is likely. Indeed, BIAs for breeding at around the Dampier Archipelago are overlapped by the Trunkline Project Area (Figure 5.22). Additional BIAs are located around the Montebello, Lowendal and Barrow Island, although these do not overlap the Trunkline Project Area. Usage of these BIAs is seasonal, with the species typically found in the region during July, August and September (Department of Conservation and Land Management, 2005; Environment Australia, 2002).

<u>*Roseate Tern*</u>

The Roseate tern (*Sterna dougalii*) is listed Migratory under the EPBC Act. It is common in waters off northern Australia. Northern populations of the Roseate tern breed on offshore islands, cays and banks; breeding populations are known to occur within the Dampier Archipelago (DEWHA, 2012a). Throughout the year the species often rests and forages in sheltered estuaries, creeks, inshore waters. They have been found to feed primarily in the open sea and at a greater distance from the colony than other similar species of inshore terns (DSEWPaC, 2012a). For the northern population, breeding has been observed between April and June–July, but most between September and December–January (DSEWPaC, 2012a). Roseate terns predominantly eat small pelagic fish; although are also known to consume insects and marine invertebrates such as crustaceans (DEWHA, 2012a).

Although Roseate terns forage at greater distances from land compared to other tern species, presence in the Offshore Project Area is not expected given the distance offshore. Presence in the Trunkline Project Area is likely, particularly during the breeding season in the area closest to Dampier Archipelago where the Trunkline Project Area overlaps the BIA (Figure 5.22).

<u>*Caspian Tern*</u>

The Caspian tern (*Sterna caspia*) is listed as Migratory under the EPBC Act. It has a widespread occurrence in coastal and inland habitat. Within Western Australia, breeding is known to occur from the Recherche Archipelago to Dirk Hartog Island and Faure Island in Shark Bay, and in the Pilbara region from around Point Cloates to North Turtle Island, and more rarely, in the Kimberley (DoE, 2018a). The main breeding period in the southern hemisphere is September to December. The Caspian tern forages in open wetlands, including lakes and rivers, but can also be found in open coastal waters (Higgins & Davies, 1996). Diet predominantly comprises small fish species, with aquatic invertebrates, insects and carrion also occurring.

Due to the preferences for coastal habitats, presence in the Offshore Project Area is not expected. Although no BIAs have been designated in the vicinity of the Project Area, breeding is expected in proximity to the Trunkline Project Area and therefore presence in expected.

5.4.3.3 Shorebirds

Since shorebird presence is strongly associated with coastal habitat, occurrence of any shorebird species listed in Table 5.4 in the Offshore Project Area is unlikely. Occurrence in the Trunkline Project Area is more likely, given the relative proximity of this area to emergent features with coastal habitats. The following sections provide details of shorebirds which are likely to occur in the Trunkline Project Area. However, no BIAs, Ramsar sites or other protected areas for shorebirds occur in the Trunkline Project Area, which is located 13 km from the nearest shoreline, and as such, large numbers of individuals are not expected. Any individuals encountered will most likely be flying through the area as they move between foraging or roosting areas.

Bar-tailed Godwit

The Bar-tailed godwit (*Limosa lapponica*) is listed as Migratory under the EPBC Act. In addition, the Western Alaskan bar-tailed godwit (*L. lapponica bauera*), a subspecies of *L. lapponica* is listed Vulnerable under the EPBC Act.

The Bar-tailed godwit, including subspecies, are found in all states of Australia, preferring coastal habitats such as intertidal sandflats, banks, mudflats, estuaries and bays. They are known to forage near the edge of tidal estuaries and harbours, feeding mainly on worms, molluscs, crustaceans, insects and some plant material. The large waders commonly roost on sandy beaches, sandbars, spits and in near-coastal saltmarsh. In hotter environments, waders may choose roost sites where a damper substrate lowers the local temperature (DoE, 2018b).

Eastern Curlew

The Eastern curlew (*Numenius madagascariensis*) is listed as Migratory and Critically Endangered under the EPBC Act. The bulk of the global population spend non-breeding periods, between September and November, in Australia (Bamford et al., 2008). Within Australia, it has a primarily coastal distribution. It does not breed in Australia and is found foraging on soft sheltered intertidal sandflats or mudflats, open and without vegetation or covered with seagrass, often near mangroves, on salt flats and in saltmarsh, rockpools and among rubble on coral reefs, and on ocean beaches near the tideline (DoEE, 2015).

Common Greenshank

The Common greenshank (*Tringa nebularia*) is listed as Migratory under the EPBC Act. This wader does not breed within Australia; however, the species is widely distributed in wetland habitats of varying salinities throughout Australia, arriving from breeding grounds in August. Northward migration back to breeding sites occurs predominantly in April. These carnivorous birds commonly forage at the edges of wetlands, in soft mudflats, in channels, or in shallows around mangroves (DoE, 2018c).

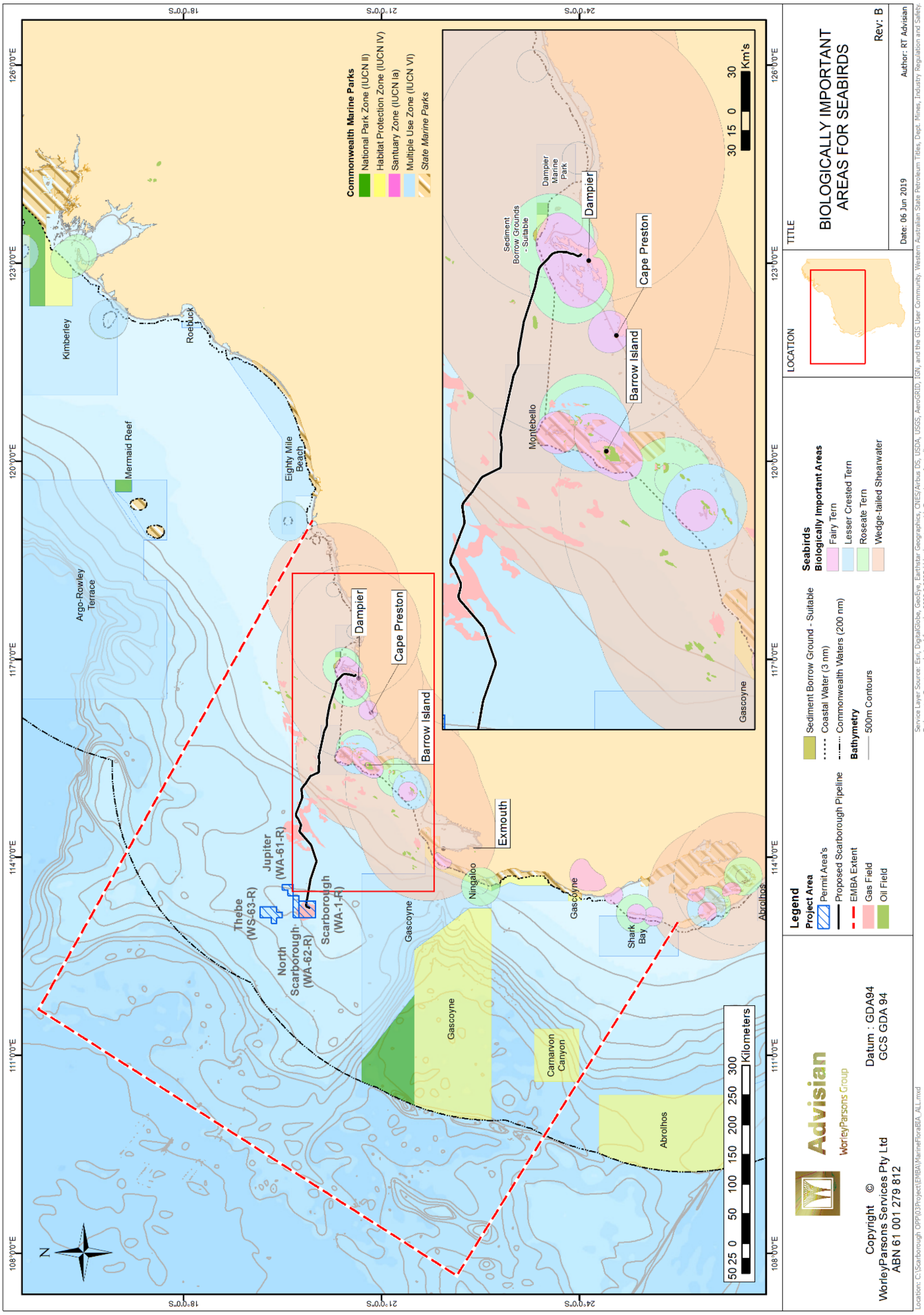


Figure 5.22: Biologically important areas (breeding) for the Fairy tern, Lesser crested tern, Roseate tern, Wedge-tailed shearwater and Brown booby

5.4.4 Fish

5.4.4.1 Overview

The NWMR supports a diversity of fish species. For the purpose of this OPP, fish species have been split into the following groups:

- sharks, sawfish and rays
- syngnathids (seahorses and pipefish)
- pelagic and demersal fish.

Habitat preferences and distribution of sharks and rays can vary depending on the species; from large pelagic distributions, to coastal habitat preferences, and can be migratory. Sawfish, however, are generally restricted to inshore coastal, estuarine and riverine environments.

Within the NWMR, Syngnathids may be encountered in a wide variety of shallow habitats, including seagrass meadows, reefs and sandy substrates around coastal islands and shallow reef areas. They are uncommon in deeper continental shelf waters (50–200 m). Data collected using Baited Remote Underwater Video Stations (BRUVS) at Rankin Bank and Glomar Shoals did not record any Syngnathids (Australian Institute of Marine Science, 2014).

Both demersal and pelagic fish communities of the NWMR appear to be closely associated with different depth ranges (DEWHA, 2008a), with fish assemblage species richness decreasing with depth (Last et al., 2005) as well as being positively correlated with habitat complexity (Gratwicke & Speight, 2005). Subsea oil and gas infrastructure in the NWMR (see Section 0) provide areas of hard substrate in an otherwise predominantly soft sediment habitat (see Sections 5.3.3 and 5.3.4). Accordingly, the presence of oil and gas infrastructure may artificially increase habitat complexity, resulting in higher species richness and abundance of fish species associated with infrastructure compared to adjacent natural habitats (McLean et al., 2018; McLean et al., 2017; Bond et al., 2018).

The NWMR supports both large and small pelagic fish species. Small pelagic fish inhabit a range of marine habitats, including inshore and continental shelf waters. They feed on pelagic phytoplankton and zooplankton and represent a food source for a wide variety of predators including large pelagic fish, sharks, seabirds and marine mammals (Mackie et al., 2007). Large pelagic fish include commercially targeted species such as mackerel, wahoo, tuna, swordfish and marlin. Large pelagic fish are typically widespread, found mainly in offshore waters (occasionally on the shelf) and often travel extensively.

High levels of endemism in demersal fish communities on the continental slope are known to occur within the region. The North West Cape region is cited as a transition between tropical and temperate demersal and continental slope fish assemblages (Last et al., 2005). Demersal fish are associated with more complex habitats; the Continental Slope Demersal Fish Communities KEF (see Section 5.5.3), has been identified as one of the most diverse slope assemblages in Australian waters. Additionally, the Ancient Coastline at 125 m Depth Contour (‘Ancient Coastline’) KEF (see Section 5.5.2) provides areas of hard substrate in an area of predominantly soft sediment, providing sites for higher diversity and species richness for epifauna, and consequently, demersal and pelagic fish. The Montebello Australian Marine Park (AMP) (see Section 5.6.1) also supports high demersal fish richness and abundance, despite their isolated location.

On the Exmouth Plateau, also a designated KEF (see Section 5.5.1), strong tidal activity and internal waves cause upwellings of deep-water and increased productivity, as observed from satellite images of chlorophyll concentrations (Brewer et al., 2007). As a result, these areas have been shown to support high catch rates of pelagic and demersal commercial fish, although evidence suggests these high production events are sporadic (Brewer et al., 2007).

There are35 Syngnathids, five sharks, three sawfish and two ray species (or species habitat) that may occur within the Project Area and an additional 4 Syngnathids, one shark and one sawfish that could occur in the EMBA. These includes species classified as Threatened or Migratory under the EPBC Act (Table 5.5). The type of behaviour is predominantly a presence (i.e. may, likely or known to occur), with a foraging BIA identified for a single species, the Whale shark, within the Trunkline Project Area (Table 5.3).

Table 5.5: Fish species or species habitat that may occur within the Project Area and EMBA

Species		Specially Protected Fauna	Threatened Species	Migratory Species	Listed Marine Species	Biologically Important Area	Offshore Project Area	Trunkline Project Area	Borrow Grounds Project Area	EMBA
Sharks										
Carcharias taurus (west coast population)	Grey nurse shark (west coast population)		V					LO	LO	KO
Carcharodon carcharias	Great white shark		V	✓			MO	MO	MO	KO
Isurus oxyrinchus	Shortfin mako			✓			LO	LO		LO
Isurus paucus	Longfin mako			✓			LO	LO		LO
Lamna nasus	Porbeagle shark			✓						MO
Rhincodon typus	Whale shark		V	✓		✓(f)		FKO	MO	FKO
Sawfish										
Anoxypristis cuspidata	Narrow sawfish			✓				LO	LO	KO
Pristis clavata	Dwarf sawfish		V	✓				KO	KO	KO
Psristis pristis	Freshwater sawfish		V	✓						LO
Pristis zijsron	Green sawfish		V	✓				KO	KO	KO
Rays										
Manta alfredi	Reef manta ray			✓				KO	KO	KO
Manta birostris	Giant manta ray			✓			MO	LO	LO	KO
Seahorse and Pipefish										
Acentronura larsonae	Helen's pygmy pipehorse				✓			MO	MO	MO
Bulbonaricus brauni	Braun's pughead pipehorse				✓			MO	MO	MO
Campichthys galei	Gale's pipefish				✓					MO

Species		Specially Protected Fauna	Threatened Species	Migratory Species	Listed Marine Species	Biologically Important Area	Offshore Project Area	Trunkline Project Area	Borrow Grounds Project Area	EMBA
Campichthys tricarinatus	Three-keel pipehorse				✓			MO	MO	MO
Choeroichthys brachysoma	Pacific short-pipehorse				✓			MO	MO	MO
Choeroichthys latispinosus	Muiron Island pipehorse				✓			MO	MO	MO
Choeroichthys suillus	Pig-snouted pipehorse				✓			MO	MO	MO
Corythoichthys flavofasciatus	Reticulate pipehorse				✓			MO		MO
Cosmocampus banneri	Roughridge pipehorse				✓			MO		MO
Doryrhamphus dactyliophorus	Banded pipehorse				✓			MO	MO	MO
Doryrhamphus excisus	Bluestripe pipehorse				✓			MO		MO
Doryrhamphus janssi	Cleaner pipehorse				✓			MO	MO	MO
Doryrhamphus multiannulatus	Many-banded pipehorse				✓			MO	MO	MO
Doryrhamphus negrosensis	Flagtail pipehorse				✓			MO	MO	MO
Festucalex scalaris	Ladder pipehorse				✓			MO	MO	MO
Filicampus tigris	Tiger pipehorse				✓			MO	MO	MO
Halicampus brocki	Brock's pipehorse				✓			MO	MO	MO
Halicampus grayi	Mud pipehorse				✓			MO	MO	MO
Halicampus nitidus	Glittering pipehorse				✓			MO	MO	MO
Halicampus spinirostris	Spiny-snout pipehorse				✓			MO	MO	MO
Haliichthys taeniophorus	Ribboned pipehorse				✓			MO	MO	MO
Hippichthys penicillus	Beady pipehorse				✓			MO	MO	MO
Hippocampus angustus	Western spiny seahorse				✓			MO	MO	MO

Species		Specially Protected Fauna	Threatened Species	Migratory Species	Listed Marine Species	Biologically Important Area	Offshore Project Area	Trunkline Project Area	Borrow Grounds Project Area	EMBA
Hippocampus histrix	Spiny seahorse				✓			MO	MO	MO
Hippocampus kuda	Spotted seahorse				✓			MO	MO	MO
Hippocampus planifrons	Flat-face seahorse				✓			MO	MO	MO
Hippocampus spinosissimus	Hedgehog seahorse				✓			MO		MO
Hippocampus trimaculatus	Three-spot seahorse				✓			MO	MO	MO
Lissocampus fatiloquus	Prophet’s pipefish				✓					MO
Micrognathus micronotopterus	Tidepool pipefish				✓			MO	MO	MO
Nannocampus subosseus	Bonyhead pipefish				✓					MO
Phoxocampus belcheri	Black rock pipefish				✓			MO	MO	MO
Solegnathus hardwickii	Pallid pipehorse				✓			MO	MO	MO
Solegnathus lettiensis	Gunther's pipehorse				✓			MO	MO	MO
Solenostomus cyanopterus	Robust ghostpipefish				✓			MO	MO	MO
Stigmatopora argus	Spotted pipefish				✓					MO
Syngnathoides biaculeatus	Double-end pipehorse				✓			MO	MO	MO
Trachyrhamphus bicoarctatus	Bentstick pipefish				✓			MO	MO	MO
Trachyrhamphus longirostris	Straightstick pipefish				✓			MO	MO	MO

Threatened Species:
V Vulnerable
Biologically Important Area:
(f) Foraging

Type of Presence:

MO	Species or species habitat may occur within area
LO	Species or species habitat likely to occur within area
KO	Species or species habitat known to occur within area

Species	Specially Protected Fauna	Threatened Species	Migratory Species	Listed Marine Species	Biologically Important Area	Offshore Project Area	Trunkline Project Area	Borrow Grounds Project Area	EMBA
		FKO	Foraging known to occur within area						

5.4.4.2 EMBA

A total of 12 conservation significant species (or habitat) may occur in the EMBA. Foraging (including high density prey) BIAs for the Whale Shark overlap with the EMBA. Areas where increased biodiversity may occur include:

- Dampier AMP (see Section 5.6.1.4): presence of various habitats, particularly coral reefs and seagrasses, provide habitat for a variety of fish fauna, including Syngnathids.
- Gascoyne AMP (see Section 5.6.2.4): diverse continental slope habitats, evidenced by the presence of three KEFs (described below)
- Ningaloo AMP (see Section 5.6.2.2): diverse continental slope habitats, evidenced by the presence of three KEFs (described below)
- Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula (KEF) (see Section 5.5.4): aggregations of whale sharks, manta rays, sharks and large predatory fish are known to occur in this area, the hard substrates of the canyons' sides provide habitat for deepwater snappers and other species
- Commonwealth waters adjacent to Ningaloo Reef (KEF) (see Section 5.5.5): benthic and pelagic habitats create high productivity and aggregations of marine species, including fish fauna
- Glomar Shoals (KEF) (see Section 5.5.6): known to be an important area for a number of commercial and recreational fish species
- Rankin Bank (see Section 5.3.13): varied marine environment supporting a diverse fish assemblage.

5.4.4.3 Trunkline Project Area

A total of ten conservation significant fish species (or habitat) may occur in the Trunkline Project Area: five sharks, three sawfish and two rays. A designated BIA for Whale Shark foraging traverses the Trunkline Project Area, where seasonal peaks in whale shark presence is likely.

In addition to habitat for conservation significant species, the Trunkline Project Area overlaps other significant area for fish habitat, namely the Continental Slope Demersal Fish Communities KEF (see Section 5.5.3), Ancient Coastline KEF (see Section 5.5.2) and the Montebello AMP (see Section 5.6.1.3) which support higher demersal fish richness and abundance.

5.4.4.4 Offshore Project Area

Four conservation-significant fish species (or habitat) may occur in the Offshore Project Area: the Longfin mako, Shortfin mako, Great white shark and Giant manta ray. No threatened or migratory rays or sawfish are likely to occur in the Offshore Project Area, due to the absence of key habitat for these species.

The deep water and predominantly featureless, flat soft sediment seabed of low complexity (see Section 5.3.3) in the Offshore Project Area reduces the species diversity and richness of Syngnathids, pelagic and demersal fish species. Although sporadic upwelling events associated with the Exmouth Plateau and associated KEF, may temporarily increase fish diversity, overall, fish fauna is not expected to be abundant in the Offshore Project Area.

5.4.4.5 Borrow ground Project Area

A total of eight conservation significant fish species may be present within the Borrow Grounds project Area: three sharks, three sawfish species and two ray species. No BIAs overlap the Borrow Ground Project Area, however a foraging BIA for whale sharks lies ~20km to the north, extending from west to east (Figure 5.23).

Sharks, Sawfish and Rays

<u>Whale Shark</u>

The Whale shark (*Rhincodon typus*) is listed as Vulnerable and Migratory under the EPBC Act (TSSC, 2015j). The species is widely distributed in Australian waters, most commonly aggregating at Ningaloo Marine Park in WA (between March and July), and to a lesser extent at Christmas Island in the Coral Sea. The seasonal aggregation of Whale sharks at Ningaloo Reef is estimated at 300–500 individuals, although the status of the population is unknown (DEWHA, 2012d). The species is generally encountered close to or at the surface, although whale sharks are known to dive to depths of at least 980 m (Wilson et al., 2006), and as single individuals or occasionally in schools or aggregations of up to hundreds of sharks. Aggregations around Ningaloo Reef are generally greatest during La Niña years rather than El Niño years due to an intensification of the Leeuwin current (DEWHA, 2008a).

The NWMR is considered important to Whale sharks for foraging. Key foraging areas include: (1) the Ningaloo Marine Park and adjacent commonwealth waters (depths of 60–100 m) in March to July; and (2) northward from Ningaloo Marine Park along the 200 m isobath in July to November (DEWHA, 2012d). Satellite tracking of whale sharks from the Ningaloo Reef area have shown movement in a northerly, north-easterly and north-westerly direction towards or into Indonesian waters (Wilson et al., 2006). 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.

Two foraging BIAs have been identified in the NWMR, one for high prey density at Ningaloo Reef, and the other along the continental shelf for post aggregation foraging and migration, with the latter overlapping the Trunkline Project Area (Figure 5.23). Whale sharks are likely to be present in the Trunkline Project Area, particularly during the months of July to November, as they migrate north east within the BIA. Whale sharks are unlikely to occur in the Offshore Project Area.

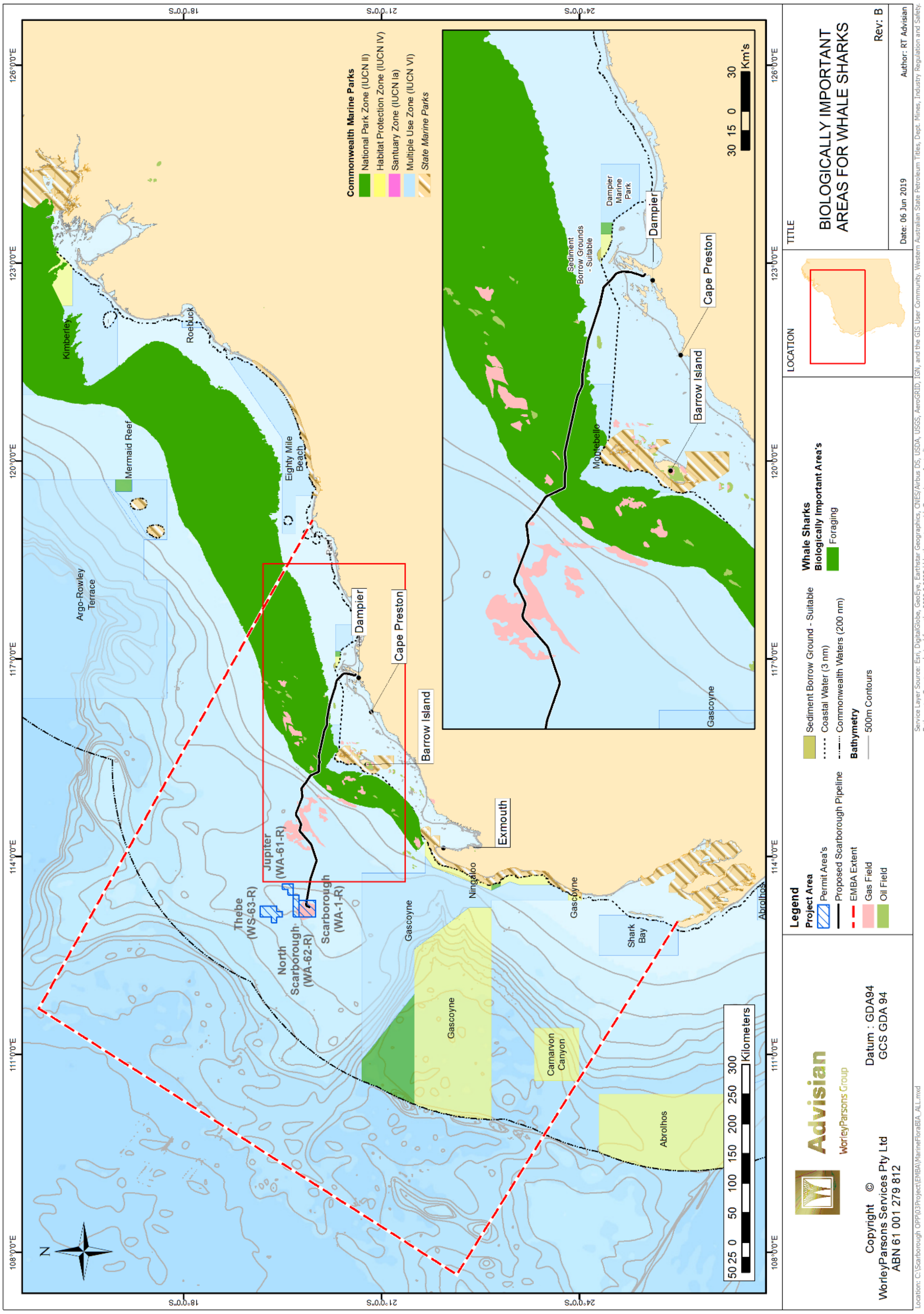


Figure 5.23: Biologically important area for whale sharks

Grey Nurse Shark (West Coast Population)

The Grey nurse shark (*Carcharus taurus*) is listed Vulnerable under the EPBC Act and has a broad distribution in inner continental shelf waters, primarily in sub-tropical to cool temperate waters (DoE, 2014). The species occurs primarily in south-west coastal waters between 20 and 140 m depth off Western Australia (Chidlow et al., 2006). Grey nurse sharks have been documented as aggregating in specific areas (typically reefs), however no clear aggregation sites have been identified off WA (Chidlow et al., 2006).

Given the species' preference for relatively shallow temperate waters, Grey nurse sharks are not expected to occur in the Offshore Project Area. Although at the northern most limit of their distribution, individuals may be present in the Trunkline Project Area, particularly where it crosses the continental shelf. No BIAs have been identified for this species.

Shortfin Mako

The Shortfin mako (*Isurus oxyrinchus*) is listed as Migratory under the EPBC Act (TSSC, 2014). It is a pelagic species with a circumglobal, wide-ranging oceanic distribution in tropical and temperate seas (Mollet et al., 2000). Little is known about the population size and distribution of Shortfin mako sharks in WA; however, the species is commonly found in water with temperatures greater than 16 °C and can grow to almost 4 m. The Shortfin mako shark is an apex and generalist predator that feeds on a variety of prey, such as teleost fish, other sharks, marine mammals and marine turtles (Campana et al., 2005). Tagging studies indicate Shortfin mako sharks spend most of their time in water less than 50 m deep but with occasional dives up to 880 m (Abascal et al., 2011; Stevens et al., 2010).

Although tagging has indicated a preference for shallower waters, their migratory nature and oceanic distribution suggest they could occur in the Project Area and EMBA in low numbers. No BIAs have been identified for this species in the NWMR.

Longfin Mako

The Longfin mako (*Isurus paucus*) is listed as Migratory under the EPBC Act. It is a widely distributed, but rarely encountered, oceanic shark species. The species can grow to just over 4 m long and is found in northern Australian waters, from Geraldton in Western Australia to at least Port Stephens in New South Wales and is uncommon in Australian waters relative to the shortfin mako (Bruce, 2013; DEWHA, 2010). There is very little information about these sharks in Australia, with no available population estimates or distribution trends. A study from southern California, documented juvenile longfin mako sharks remaining near surface waters, while larger adults were frequently observed at greater maximum depths of about 200 m (Sepulveda et al., 2004).

Given its large distribution oceanic distribution, the longfin mako may occur in the Project Area and EMBA, but in low numbers. No BIAs have been identified for this species in the NWMR.

Narrow Sawfish

The Narrow sawfish (*Anoxypristis cuspidate*) is listed Migratory under the EPBC Act. It occurs from the northern Arabian Gulf to Australia and north to Japan. The species inhabits inshore and estuarine waters and offshore waters up to depths of 100 m (IUCN 2015) and are most commonly found in sheltered bays with sandy bottoms. They are not currently listed as Threatened but are commonly caught as bycatch and constituted over half of sawfish bycatch in the Northern Prawn Fishery in 2013 (DoEE, 2015c; Morgan et al., 2010).

They are unlikely to occur in the Offshore Project Area but may be present one the shallower waters of the Trunkline Project Area and EMBA. No BIAs for this species occur in the NWMR.

Dwarf Sawfish

The Dwarf sawfish (*Pristis clavata)* is listed Vulnerable and Migratory under the EPBC Act. They are found in Australian coastal waters extending north from Cairns around the Cape York Peninsula in Queensland to the Pilbara coast (DotE, 2013b). Dwarf sawfish typically inhabit shallow (2 to 3 m) silty coastal waters and estuarine habitats, occupying relatively restricted areas and moving only small distances (Stevens et al., 2008). Juvenile Dwarf sawfish utilise estuarine habitats in north-western Western Australia as nursery areas (Thorburn et al., 2008; TSSC, 2009) and migrate to deeper waters as adults. Most capture locations for the species in Western Australian waters have occurred within King Sound (>1000 km from the Project Area) and the lower reaches of the major rivers that enter the sound, including the Fitzroy, Mary and Robinson rivers (Morgan et al., 2010). Individuals have also been recorded at Eighty Mile Beach, and occasional individuals have also been taken from considerably deeper water from trawl fishing (Morgan et al., 2010). Coastal waters around Eighty Mile Beach have been identified as a possible pupping area for this species, with a BIA designated accordingly.

The Dwarf sawfish is not expected to occur in the Offshore Project Area due to the deep, offshore environment. They may occur infrequently in the shallower waters of the Trunkline Project Area, and in coastal habitats of the EMBA. No BIAs for this species occur in the Project Area or EMBA.

Green Sawfish

The Green sawfish (*Pristis zijsron*) is listed as Vulnerable and Migratory under the EPBC Act. They were once widely distributed in coastal waters along the northern Indian Ocean, although it is believed that northern Australia may be the last region where significant populations exist (Stevens et al., 2005). Within Australia, Green sawfish are currently distributed from about the Whitsundays in Queensland across northern Australian waters to Shark Bay in Western Australia (DoEE, 2015a). Green sawfish are present in coastal waters, tidal creeks, the north eastern parts of the Ashburton Lagoon (Chevron Australia Pty Ltd, 2014). Despite records of the species in deeper offshore waters, Green sawfish typically occur in the inshore fringe with a strong associated with mangroves and adjacent mudflat habitats (Commonwealth of Australia, 2015b; Stevens et al., 2005). Movements within these preferred habitats is correlated with tidal movements (Stevens et al., 2008).

The species is known to occur in offshore waters of the NWS, with known pupping areas in coastal waters north of Port Hedland to Roebuck Bay; pupping is likely to occur south of Port Hedland, Exmouth Gulf and North West Cape (Commonwealth of Australia, 2015b; DoEE, 2017f). However, BIAs for pupping, nursing and foraging have only been designated in coastal waters of Eighty Mile Beach.

The Green sawfish is not expected to occur in the Offshore Project Area due to the deep, offshore environment. They may occur infrequently in the shallower waters of the Trunkline Project Area, and in coastal habitats of the EMBA. No BIAs for this species occur in the Project Area or EMBA.

Reef Manta Ray

The Reef manta ray (*Manta alfredi)* is listed as Migratory under the EPBC Act. The species is commonly sighted inshore, but also found around offshore coral reefs, rocky reefs and seamounts (Marshall et al., 2009). In contrast to the giant manta ray, long-term sighting records of the reef manta ray at established aggregation sites suggest that this species is more resident in tropical waters and may exhibit smaller home ranges, philopatric movement patterns and shorter seasonal migrations than the giant manta ray (Deakos et al., 2011; Marshall et al., 2009). A resident population of reef manta rays has been recorded at Ningaloo Reef, and the species has been shown to have both resident and migratory tendencies in eastern Australia (Couturier et al., 2011).

Given the lack of coral reef habitat within and in the vicinity of the Offshore Project Area, reef manta rays are not expected to occur in the Offshore Project Area. Presence in the Trunkline Project Area and EMBA is more likely given the water depths and proximity to preferred habitat. No BIAs for this species occur in the NWMR.

Giant Manta Ray

The Giant manta ray (*Manta birostris*) is listed as Migratory under the EPBC Act and is broadly distributed in tropical waters of Australia. The species primarily inhabits nearshore environments along productive coastlines with regular upwelling, but they appear to be seasonal visitors to coastal or offshore sites including offshore island groups, offshore pinnacles and seamounts (Marshall et al., 2011). Ningaloo Reef is an important area for Giant manta rays in autumn and winter (Environment Australia, 2002; Preen et al., 1997).

Occurrence of Giant manta rays in the Offshore Project Area is unlikely given the deep offshore waters and featureless seafloor. Presence in the Trunkline Project Area is more likely as they migrate through the area, but aggregations are unlikely. The species is known to forage within the EMBA, at Ningaloo Reef, however no BIAs have been identified for this species in the NWMR.

5.4.5 Marine Mammals

5.4.5.1 Overview

Marine mammals in the NWMR can include cetacean (whales and dolphins) and dugongs. The NWMR is thought to be an important migratory pathway for large truly pelagic whales (such as humpback whale and pygmy blue whale) between feeding grounds in the Southern Ocean and breeding grounds in tropical waters (DEWHA, 2012b). In addition, foraging whales have been observed in areas of upwelling in NWMR. Dolphins and dugongs are typically found in nearshore waters.

There are 15 whale, 14 dolphin and one dugong species (or species habitat) that may occur within the Project Area, and an additional three whales could occur in the EMBA; this includes species classified as Threatened and Migratory under the EPBC Act or specially protected under the WA Wildlife Conservation Act (Table 5.6). The type of behaviour is predominantly a presence (may, likely or known to occur), with some important behaviours (e.g. migrating) for a small number of species within the Trunkline Project Area (Table 5.3).

Two species, the Pygmy blue whale and Humpback whale, have BIAs for migration overlapping the Project Area (Table 5.3, Figure 5.26). Although foraging BIAs for Pygmy blue whales, and foraging and nursing BIAs for Dugongs, are present in the EMBA, these do not overlap the Project Area (Table 5.3).

Table 5.6: Mammal species or species habitat that may occur within Project Area and EMBA

Species		Specially Protected Fauna	Threatened Species	Migratory Species	Listed Cetacean Species	Biologically Important Area	Offshore Project Area	Trunkline Project Area	Borrow Ground Project Area	EMBA
Whale										
Balaenoptera acutorostrata	Minke whale				✓		MO	MO	MO	MO
Balaenoptera bonaerensis	Antarctic minke whale			✓	✓		LO	LO		LO
Balaenoptera borealis	Sei whale		V	✓	✓		LO	LO		FLO
Balaenoptera edeni	Bryde's whale			✓	✓		LO	LO	MO	LO
Balaenoptera musculus brevicauda	Pygmy blue whale		E	✓	✓	✓(m,d)	LO	MrK		MrK
Balaenoptera musculus intermedia	Blue whale		E	✓	✓	✓(m,d)	LO	MrK	LO	MrK
Balaenoptera physalus	Fin whale		V	✓	✓		LO	LO		FLO
Eubalaena australis	Southern right whale		E	✓	✓					LO
Globicephala macrorhynchus	Short-finned pilot whale				✓		MO	MO		MO
Indopacetus pacificus	Longman's beaked whale				✓					MO
Kogia breviceps	Pygmy sperm whale				✓		MO	MO		MO
Kogia simus	Dwarf sperm whale				✓		MO	MO		MO
Megaptera novaeangliae	Humpback whale	S	V	✓	✓	✓(m)	MO	KO	KO	AKO
Mesoplodon densirostris	Blainville's beaked whale				✓		MO	MO		MO
Mesoplodon ginkgodens	Gingko-toothed beaked whale									MO

Species		Specially Protected Fauna	Threatened Species	Migratory Species	Listed Cetacean Species	Biologically Important Area	Offshore Project Area	Trunkline Project Area	Borrow Ground Project Area	EMBA
Peponocephala electra	Melon-headed whale				✓		MO	MO		MO
Physeter macrocephalus	Sperm whale			✓	✓		MO	MO		MO
Ziphius cavirostris	Cuvier's beaked whale				✓		MO	MO		MO
Dolphin										
Delphinus delphis	Common dolphin				✓		MO	MO	MO	MO
Feresa attenuata	Pygmy killer whale				✓		MO	MO		MO
Grampus griseus	Risso's dolphin				✓		MO	MO	MO	MO
Lagenodelphis hosei	Fraser's dolphin				✓		MO	MO		MO
Orcinus orca	Killer whale			✓	✓		MO	MO	MO	MO
Pseudorca crassidens	False killer whale				✓		LO	LO		LO
Sousa chinensis	Indo-Pacific humpback dolphin			✓	✓			MO	MO	KO
Stenella attenuata	Spotted dolphin				✓		MO	MO	MO	MO
Stenella coeruleoalba	Striped dolphin				✓		MO	MO		MO
Stenella longirostris	Long-snouted spinner dolphin				✓		MO	MO		MO
Steno bredanensis	Rough-toothed dolphin				✓		MO	MO		MO
Tursiops aduncus	Indian Ocean bottlenose dolphin				✓			MO	LO	LO
Tursiops aduncus (Arafura/Timor Sea populations)	Spotted bottlenose dolphin (Arafura/Timor Sea populations)			✓	✓			LO	LO	KO
Tursiops truncatus s. str.	Bottlenose dolphin				✓		MO	MO	MO	MO

Species		Specially Protected Fauna	Threatened Species	Migratory Species	Listed Cetacean Species	Biologically Important Area	Offshore Project Area	Trunkline Project Area	Borrow Ground Project Area	EMBA
Dugong										
Dugong	Dugong	S		✓	✓			LO	LO	BKO

Specially Protected Fauna:
S Other specially protected fauna
Threatened Species:
V Vulnerable
E Endangered
Biologically Important Area:
(d) Distribution
(m) Migration

Type of Presence:

MO	Species or species habitat may occur within area
LO	Species or species habitat likely to occur within area
KO	Species or species habitat known to occur within area
FLO	Foraging likely to occur within area
AKO	Congregatin or aggregation known to occur
BKO	Breeding known to occur within area
MrK	Migration route known to occur within area

EMBA

A total of 13 conservation significant marine mammals (or habitat) may occur in the EMBA (Table 5.4). BIAs for three significant marine mammals overlap the EMBA: Humpback whale migration and resting; Pygmy blue whale migration, distribution and foraging; and Dugong nursing and foraging (Table 5.3).

Since the EMBA covers offshore, continental shelf and coastal habitats, the presence of whales, dolphins and dugongs may occur.

Shallower waters in proximity to shorelines of the mainland and islands provide habitat for a number of dolphin species. Additionally, seagrass habitat around the Montebello, Lowendal and Barrow islands, Dampier Archipelago and the Exmouth Gulf provides foraging habitat for dugongs. Upwelling off the Ningaloo coast may provide foraging habitat for the Pygmy blue whale in addition to other whale species.

Trunkline Project Area and Borrow Ground Project Area

A total of 12 conservation significant marine mammals (or habitat) may occur in the Trunkline Project Area and seven conservation significant species within the Borrow Ground project Area (Table 5.4). In addition, BIAs for two significant marine mammals overlap the Trunkline Project Area and Borrow ground Project Area: Humpback whale migration and Pygmy blue whale distribution and migration (Table 5.3, Figure 5.22). Numbers of migrating individuals in the Trunkline Project Area and Borrow ground Project Area will be higher during peak migration periods which differs between species.

Nevertheless, these BIAs will only represent important habitat for Humpback and Pygmy blue whales for discreet periods of the year.

Since the Trunkline Project Area and Borrow ground Project Area traverses the continental shelf and is in relative proximity to shorelines, dolphins are more likely to occur in the Trunkline Project Area compared to the Offshore Project Area, although no BIAs or other significant habitat or aggregations were identified. The Dugong is also more likely to occur in shallower waters of the Trunkline Project Area.

Offshore Project Area

A total of nine conservation significant marine mammals (or habitat) may occur in the Offshore Project Area (Table 5.6). Although some dolphin species may have distributions that extend into offshore waters, their presence is not considered likely given their preference for coastal or continental shelf waters. The exception is the False killer whale, which is more likely to occur in the Offshore Project Area.

Only one BIA, for the Pygmy blue whale, overlaps the Offshore Project Area. However, this BIA is designated for distribution only, rather than more sensitive behaviours such as foraging and migration.

5.4.5.2 Conservation Significant Marine Mammals in the Project Area

Whales

<u>*Blue Whale and Pygmy Blue Whale*</u>

Blue whales are listed as Endangered and Migratory under the EPBC Act. There are two subspecies of blue whales found in the southern hemisphere and known to occur in Australian waters: the Antarctic blue whale (or "true" blue whale, *Balaenoptera musculus intermedia*) and the pygmy blue whale (*Balaenoptera musculus brevicauda*). Antarctic blue whales are uncommon north of 60°S (DotE, 2019), while pygmy blue whales have been recorded in northern waters of the Kimberley region and are assumed to breed in the tropical north.

Blue whales are generally associated with deep water beyond continental shelves, though can be found in shallow-water regions with narrow continental shelves (Branch et al., 2007). Pygmy blue whales are found along the western and southern coasts of Australia, from as far north as Indonesia down to SW Australia and east across the Great Australian Bight and Bonney Upwelling, and into waters as far east as Tasmania (Gill et al., 2011; McCauley, 2011; Double et al., 2014; Möller et al., 2015). They have been found to aggregate reliably and have shown longer periods of occupancy within certain regions (Commonwealth of Australia (2015), Figure 5.24).

Seasonally important areas in Australia include the Peth Canyon and the Bonny Upwelling, which represent two distinct feeding areas (Gill, 2002b; Rennie et al., 2009). In the Bonny Upwelling, pygmy blue whales have been sighted in this region from November to June (Gill, 2002; Gill et al., 2011, 2015; Möller et al., 2015) and acoustically detected off Portland from November, though predominantly from March to June (Tripovich et al., 2015). In the Perth Canyon, visual and acoustic surveys have shown pygmy blue whales arriving as early as November and numbers increasing to a peak in the following March to May (McCauley et al., 2000, 2004; Balcazar et al., 2015). Satellite tracking of these whales as they migrate north has indicated lower rates of travel and relatively longer occupancy within the Perth Canyon/Naturaliste Plateau region (Double et al., 2014). The number of pygmy blue whales present at any one time in this region is highly variable throughout the season and between years (Balcazar et al., 2015). 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). Most whales leave by late June, although a small number of acoustic detections have still been made into July (McCauley et al., 2004; Balcazar et al., 2015).

Outside of these recognised aggregation areas, satellite tracking has indicated rates of relatively higher occupancy around North West cape/Ningaloo Reef region in WA (Double et al., 2014; Möller et al., 2015). At this location, primary production rates are equal to those recorded in upwelling systems (Furnas, 2007) and is therefore likely to support blue whale feeding.

Limited and currently unpublished observations suggest areas of relatively higher occupancy may include Scott Reef to the far NW of Australia during October (Commonwealth of Australia, 2015). Further research is needed to confirm blue whale occupancy within these areas.

Branch et al. (2007b) hypothesised that pygmy blue whales occurring in Australian waters migrate between Australia and Indonesia along the Australian west coast. Acoustic data collected in December 2014–January 2015 on the Exmouth Plateau was used to evaluate the corridor of the southbound migration of pygmy blue whales of the eastern Indian Ocean population (Gavrilov and McCauley, 2018). The study reported pygmy blue whale travel southward much further away from the Western Australian coast than expected from data on their northbound migration, at distances of up to 400 km from shore.

Acoustic recordings collected from south-west Australia (McCauley et al., 2004; Stafford et al., 2004, 2011; Gavrilov and McCauley, 2013) showed whale detections increasing from November to June and peaking between February and March. These migration patterns are also supported by satellite telemetry data for pygmy blue whales, which indicates that whales feeding at both the Perth canyon (Gales et al., 2010; Double et al., 2014) and Bonney Upwelling (Möller et al., 2015) travel north along the west Australian coast into Indonesian waters. Assuming these tagged individuals are representative of the animals that feed off Australia as a whole, these data suggest whales feeding of the Perth Canyon migrate north in March–May reaching Indonesia by June–July where they remain until at least September (Double et al., 2014; Möller et al., 2015). They may then migrate south from Indonesia from September, reaching the subtropical frontal zone in December before returning to the Perth Canyon the following March (Double et al., 2014). A single tagged whale travelling north along southwest Australia over the course of a week was found to make consistently shallow dives while migrating, on average to a depth of 14 m for 5.2 min, unrelated to local bathymetry (Owen et al., 2016).

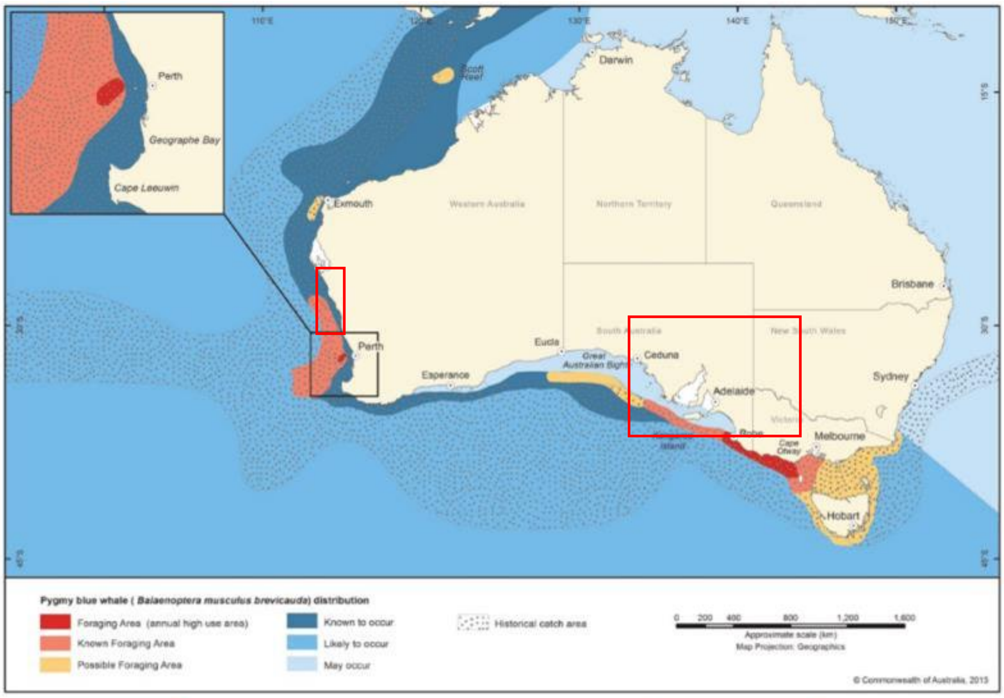
Acoustic detections of Indo-Australian pygmy blue whales around Scott Reef in the far north-west have shown that at least some migrating whales transit in the vicinity of the reef, and an increase in detections was found between 2007–2009 (McCauley, 2011). South-bound migrating whales were detected from October to January with a peak in November, and those travelling north were detected from April to August (McCauley, 2011). Preferred transit routes were west of Scott reef, though whales were also found to pass to the east. Approximately half of the blue whales detected around Scott Reef were estimated to pass through the channel separating the north and south lagoons, but few ventured far into the southern lagoon. Overall, it is estimated that between 6-40% of whales passing by Exmouth pass by Scott Reef (McCauley, 2011).

Indo-Australian type calls have also been recorded far to the west in the SW Indian Ocean subtropical frontal zone between January and June (Samaran et al., 2010; 2013), and two detections have been made in the Prydz Bay region during the austral summer representing the farthest south this population has been recorded (Gedamke and Robinson, 2010). This suggests plasticity in migratory behaviour or multiple migration routes, with some longitudinal movements from east to west in the Indian Ocean. Varying migration paths have also been suggested by McCauley and Jenner (2010) due to the large interannual variation in vocal activity detected off south-west Australia

Based on acoustic data, pygmy blue whales are likely to travel alone or in small groups. Typically, solitary whales have been recorded calling on noise loggers, although larger groups of calling animals were occasionally detected (McCauley & Duncan, 2011). For example, 78% of pygmy blue whale calls recorded around Scott Reef between 2006 and 2009 were from lone whales, 18% were from two whales and 4% were from three or more whales (McCauley & Duncan, 2011). The maximum number of individuals calling at one time was five (McCauley & Duncan, 2011).

Two BIAs for the pygmy blue whale overlap the Project Area (Figure 5.25); a BIA for distribution overlaps the Offshore Project Area and Trunkline Project Area, and a BIA for migration overlaps the Trunkline Project Area only. Although the migration BIA doesn't overlap the Offshore Project Area, based on recent findings (Gavrilov and McCauley, 2018), it is possible that migrating individuals will also traverse the Offshore Project Area.

Therefore, it is likely that individuals will occur in both the Offshore Project Area and Trunkline Project Area, with a peak in numbers during the migration season; May and June for northbound, and October and December for southbound.



Foraging Area (Annual high use area)	Blue whales are regularly observed feeding on a seasonal basis	Known to occur	Blue whales are known to occur based on direct observations, satellite tagged whales or based on acoustic detections
Known Foraging Area	Known foraging occurs in these areas but is highly variable both between and within seasons	Likely to occur	Blue whales are likely to occur based on occasional observations in the area and nearby areas
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	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 5.24: An overview of the distribution of pygmy blue whales around Australia (Commonwealth of Australia, 2015)

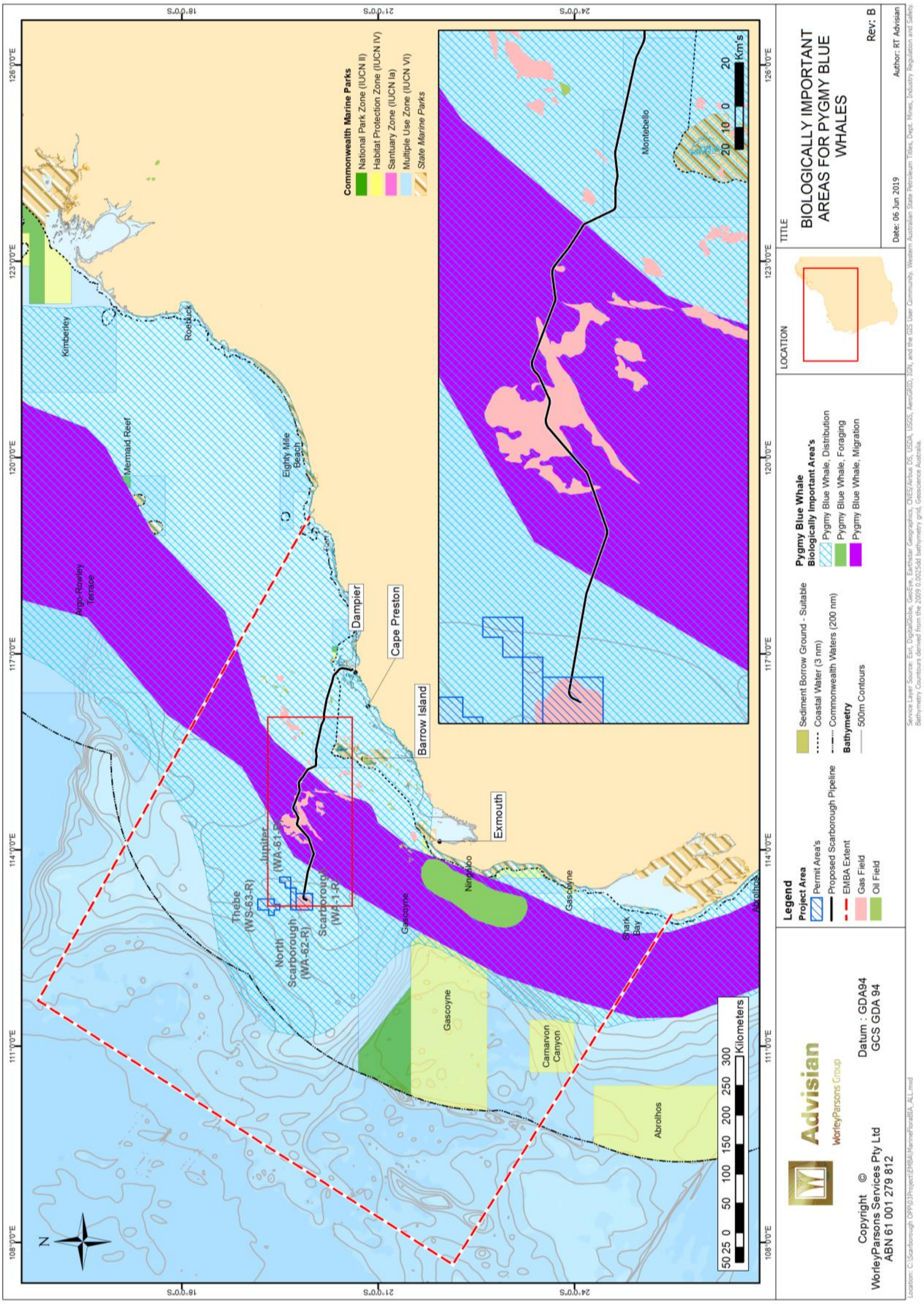


Figure 5.25: Biologically important areas for pygmy blue whales

Humpback Whale

The humpback whale (*Megaptera novaeangliae*) is listed as Vulnerable and Migratory under the EPBC Act, and specially protected under the WA Wildlife Conservation Act. Humpback whales occur throughout Australia, with two genetically distinct east and west subpopulations. The distributions of both subpopulations are influenced by migratory pathways and aggregation areas for resting, breeding and calving. The western subpopulation of Humpback whale was estimated to be as large as 33,300 in 2008 (Bejder et al., 2016). Previous estimates of the Western Australian population of humpback whales saw an increase from ~7000 individuals in 2000 to ~26,000 in 2008 (Salgado Kent et al., 2012).

Humpback whales of the west coast subpopulation migrate north from their Antarctic feeding grounds between May and November each year, to calving grounds which extend south from Camden Sound in the Kimberley (15°S) to at least North West Cape (22°43′S) (Irvine et al., 2018).

Young adults and lactating females arrive first in the mating and calving grounds, followed by non-pregnant mature females and adult males, with pregnant females arriving last (DEWHA, 2012b). The exact timing of the migration period can vary from year to year dependent upon water temperature, sea ice, predation risk, prey abundance and the location of the feeding ground last used (DEWR, 2007). Breeding and calving typically occurs between August and September (DEWHA, 2012b).

From the North West Cape, northbound Humpback whales travel along the edge of the continental shelf passing to the west of the Muiron, Barrow and Montebello Islands, peaking in late July (Jenner et al., 2001). The southern migratory route follows a relatively narrow track between the Dampier Archipelago and Montebello Islands. Southbound migration is more diffuse and irregular, lacking an obvious peak. An increase in migrating individuals may be observed between the North West Cape and the Montebello Islands between August and November (Jenner et al., 2001). Exmouth Gulf and Shark Bay are known resting/aggregation areas for southbound Humpback whales. Cow/calf pairs may stay in Exmouth Gulf for up to two weeks during September (Jenner et al., 2001).

Woodside has conducted marine megafauna aerial surveys that have confirmed that the temporal distribution of migrating Humpback whales off the North West Cape have remained consistent since baseline surveys were first conducted in 2000 to 2001 (RPS, 2010). Most Humpback whales occurred in depths less than 500 m, with the greatest density of whales concentrated in water depths of 200 to 300 m. Only a small proportion of the population were observed to occur in the deeper offshore waters (RPS, 2010). These survey results are consistent with satellite tagging studies (Double et al., 2010, 2012a).

One BIA for migration overlaps the Trunkline Project Area only (Figure 5.26). While individuals may occur in the Offshore Project Area, presence is much likely in the Trunkline Project Area, particularly during peak migration in the area. Presence is expected to be highest during the northbound migration peak in mid-July, and to a lesser extent between August and November for southbound migrating individuals.

No foraging or resting areas occur within the Project Area or EMBA, with the closest resting BIAs located in the Exmouth Gulf 198 km from the Project Area at the closest point.

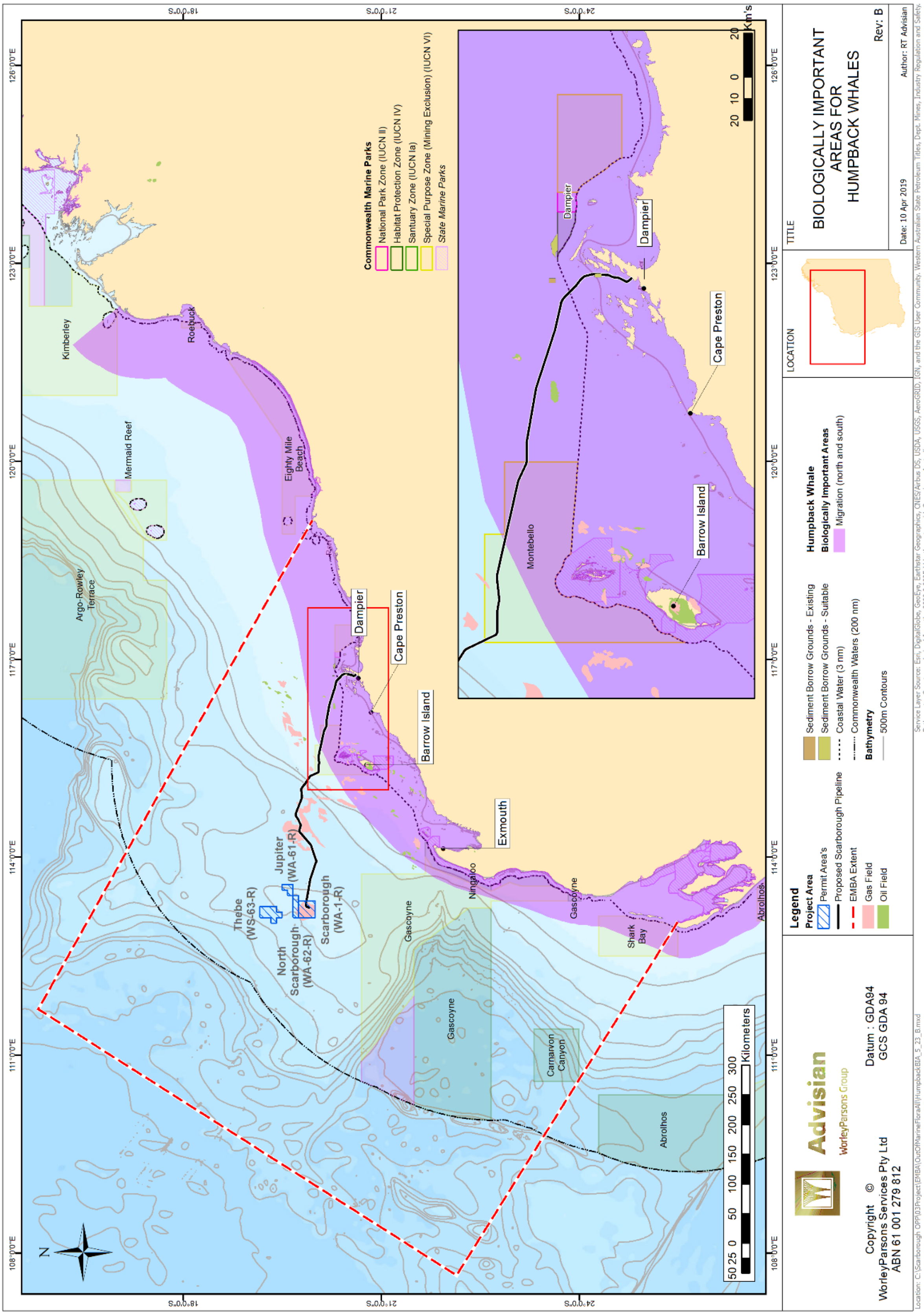


Figure 5.26: Biologically important areas for humpback whales

Antarctic Minke Whale

The Antarctic minke whale (*Balaenoptera bonaerenis*) is listed Migratory under the EPBC Act. It has a global distribution and inhabits all oceans in the Southern Hemisphere. Their summer range is close to Antarctica, but they move further north in winter, including along the Australian east and west coasts (Bannister et al., 1996). Antarctic minke whales have only been observed as far north as 21°S along the east coast of Australia (equivalent to Karratha on the west coast) and it is thought the species follows a similar migration on the Western Australian coast, migrating up to about 20 °S to feed and possibly breed (Bannister et al., 1996). However, detailed information on timing and location of migrations and breeding grounds in Western Australia is not well known.

Antarctic minke whale calls were recorded near Scott Reef on a logger deployed to the south-east of South Scott Reef. Calls were detected for a few days each year in 2006 to 2008 between July and October (McCauley & Duncan, 2011). No calls from this species were identified on other loggers set inside and outside of the reef.

Given the large, oceanic distribution of Antarctic minke whale, and the absence of defined migration pathways, the Project Area is unlikely to represent an important habitat for this species. While individuals may occur, they are unlikely to do so in large numbers, or be undertaking a behaviour critical to their survival. There are no known BIAs for Antarctic minke whales in the NWMR.

Sei Whale

The Sei whale (*Balaenoptera borealis*) is listed Vulnerable and Migratory under the EPBC Act. Like many baleen whale species, the population of Sei whales was significantly reduced in numbers by commercial whaling operations. The species has a worldwide oceanic distribution and is expected to undertake seasonal migrations between low latitude wintering areas and high latitude summer feeding grounds (Bannister et al., 1996; Prieto et al., 2012). Sei whales have been infrequently recorded in Australian waters (Bannister et al., 1996) which could be due to the similarity in appearance of Sei whales and Bryde’s whales leading to incorrect recordings. There are no known mating or calving areas in Australian waters (DoE, 2016a). The species prefers deep waters, and typically occurs in oceanic basins and continental slopes (Prieto et al., 2012); records of the species occurring on the continental shelf (<200 m water depth) are uncommon in Australian waters (Bannister et al., 1996).

Given the large, oceanic distribution of the Sei whale, and the absence of defined migration pathways or foraging areas, the Project Area is unlikely to represent an important habitat for this species. Occurrence within the Offshore Project Area is more likely than the Trunkline Project Area given their preference for deep water habitats, however, they are unlikely to do so in large numbers. There are no known BIAs for Sei whales in the NWMR.

Bryde's Whale

The Bryde’s whale (*Balaenoptera edeni*) is listed Migratory under the EPBC Act, with a wide distribution throughout tropical, sub-tropical and temperate waters from the equator to about 40 °S (Bannister et al., 1996; DoE, 2015a). Bryde’s whales have been identified as occurring in both oceanic and inshore waters, with the only key localities recognised in Western Australia being in the Abrolhos Islands and Shark Bay (Bannister et al., 1996). Data suggests offshore whales may migrate seasonally through a broad area of the continental shelf, heading towards warmer tropical waters during the winter, however, information on migration is not well known (McCauley & Duncan, 2011; RPS Environment and Planning, 2012). This species has been detected on the North West Shelf from mid-December to mid-June, peaking in late February to mid-April (RPS Environment and Planning, 2012).

In 2008, Bryde’s whales were recorded in low numbers across a large survey area between the mainland and Scott Reef (Woodside, 2014b). During aerial and vessel-based surveys in 2009, one

Bryde's whale was recorded 10 km west of Coulomb Point on the Kimberley coast (Woodside, 2014b). Calls attributed to Bryde's whales have been recorded year-round in low numbers on sea noise loggers deployed inside and outside of Scott Reef, between September 2006 and June 2008 (outside the Region) (McCauley, 2009). In Shark Bay, Bryde's whales are present foraging between November and April (Department of Environmental Protection, 2001).

Due to the large, oceanic distribution of Bryde's whale, the Project Area is unlikely to represent an important habitat for this species. Foraging areas have been identified in Shark Bay, 607 km from the Project Area and outside the EMBA. Since they have been observed in offshore and nearshore waters (Bannister et al., 1996), individuals may occur in the Offshore Project Area and Trunkline Project Area, however, they are unlikely to do so in large numbers. There are no known BIAs for Bryde's whales in the NWMR.

Fin Whale

The Fin whale (*Balaenoptera physalus*) is listed Vulnerable and Migratory under the EPBC Act. Fin whales have a cosmopolitan distribution in all ocean basis between 20 and 75 °S (Department of the Environment and Heritage, 2005a). Fin whales have been recorded off all states in Australia except New South Wales and the Northern Territory (Bannister et al., 1996). The global population of Fin whales was reduced significantly by commercial whaling, with the species being targeted due to its large size and broad distribution.

Like other baleen whales, Fin whales undertake annual migrations between high latitude summer feeding grounds and lower latitude over-wintering areas (Bannister et al., 1996). Fin whales are thought to follow oceanic migration paths and are uncommonly encountered in coastal or continental shelf waters. The Australian Antarctic waters are important feeding grounds for Fin whales, however there are no known mating or calving areas in Australian waters (Morrice et al., 2004).

Due to the large, oceanic distribution of the Fin whale, like other large baleen whales, the Project Area is unlikely to represent an important habitat for this species. Given they are uncommonly observed in coastal or continental shelf waters, they are more likely to occur in the Offshore Project Area compared to the Trunkline Project Area, however, they are unlikely to occur in the Offshore Project Area in large numbers. There are no known BIAs for Fin whales in the NWMR.

Dolphins

Spotted Bottlenose Dolphin (Arafura/Timor Sea Population)

The spotted bottlenose dolphin (*Tursiops aduncus*) is listed as Migratory under the EPBC Act. It is generally considered to be a warm water subspecies of the common bottlenose dolphin and its distribution is primarily inshore waters, often in depths of less than 10 m (Bannister et al., 1996). They are known to occur from Shark Bay, north to the western edge of the Gulf of Carpentaria.

Given the distribution of Spotted bottlenose dolphins and their preference for shallow coastal waters they are not expected to occur in the Offshore Project Area. Occurrence in the Trunkline Project Area is more likely, given the relative proximity to shorelines; however, the Trunkline Project Area is still 375 km from the shoreline and therefore unlikely to represent an important habitat for this species. BIAs overlap neither the Project Area nor EMBA.

Dugong

The Dugong (*Dugong dugong*) is listed Migratory under the EPBC Act. The species is distributed along the Western Australian coast throughout the Gascoyne, Pilbara and Kimberley, with notable populations in Ningaloo Reef, Exmouth Gulf and Shark Bay. Dugong distribution is correlated with seagrass habitats which Dugong feed on, although water temperature has also been correlated with

Dugong movements and distribution (Preen et al., 1997; Preen, 2004). Dugongs are known to migrate between seagrass habitats (hundreds of kilometres) (Sheppard et al., 2006).

Given the lack of seagrass habitat in the Project Area, Dugong are not expected to occur, particularly in the Offshore Project Area when considering the distance offshore. Presence is more likely in the Trunkline Project Area given the shallower water depths; however, individuals would be limited to a very low number potentially transiting the area on migration between areas of seagrass habitat. No BIAs overlap the Project Area. A BIA for foraging and nursing occur in the Exmouth Gulf, however this is outside the EMBA.

5.4.6 Marine Reptiles

5.4.6.1 Overview

Marine reptiles of the NWMR include turtles and seasnakes. Six of the seven marine turtle species are present in Australia, predominantly occurring in the waters off Queensland, Northern Territory and north Western Australia. Marine turtles are highly migratory during some life phases, but during others show high site fidelity. They require both terrestrial and marine habitats to fulfil different life history stages (DoEE, 2017x).

The waters of the NWMR provides marine turtle habitat or a variety of behaviours including; foraging, mating and inter-nesting. Additionally, a number of important nesting beaches occur, including:

- Ningaloo coast
- Muiron Islands
- Montebello, Lowendal and Barrow islands
- Pilbara island chain, including Serrurier Islands
- Dampier Archipelago
- locations along the Pilbara mainland coast.

Many of these locations have been identified as BIAs or habitat critical to the survival of a species (Table 5.3).

Seasnakes occur along the North West Shelf and are reported to occur in offshore and nearshore waters. They occupy diverse habitats including coral reefs, turbid water habitats and deeper water (Guinea et al., 2004). Species exhibit habitat preferences depending on water depth, benthic habitat, turbidity and season (Heatwole & Cogger, 1993). The majority of information on the occurrence of seasnakes has been sourced from by-catch logs maintained by the Northern Prawn Fishery (DEWHA, 2008a).

A total of five marine turtles and 17 seasnakes species (or species habitat) may occur within the Project Area and an additional seasnake species that could occur within the EMBA. Species include those that are classified as Threatened and Migratory under the EPBC Act, or specially protected under the WA Wildlife Conservation Act (Table 5.7).

Seasnake presence is not expected to be linked to a particular behaviour. However, of the five marine turtle species expected to occur, four (flatback, green, loggerhead and hawksbill turtle) have BIAs or Critical Habitat for breeding (nesting, inter-nesting or mating) overlapping the Project Area. Additional foraging BIAs for those four species also occur within the EMBA.

Table 5.7: Marine reptile species or species habitat that may occur within the Project Area and EMBA

Species		Specially Protected Fauna	Threatened Species	Migratory Species	Listed Marine Species	Biologically Important Area	Offshore Project Area	Trunkline Project Area	Borrow Grounds Project Area	EMBA
Turtles										
Caretta	Loggerhead Turtle		E	✓	✓	✓(i)	LO	AKO	KO	BKO
Chelonia mydas	Green Turtle		V	✓	✓	✓(i,n,m, f,mr)	LO	AKO	KO	BKO
Dermochelys coriacea	Leatherback Turtle		E	✓	✓		LO	LO	LO	FKO
Eretmochelys imbricata	Hawksbill Turtle		V	✓	✓	✓(i,n,m, f,mr)	LO	AKO	KO	BKO
Natator depressus	Flatback Turtle		V	✓	✓	✓(i,n,m, f,mr)	LO	AKO	AKO	BKO
Seasnakes										
Acalyptophis peronii	Horned seasnake				✓			MO	MO	MO
Aipysurus apraefrontalis	Short-nosed seasnake		CE		✓			LO	MO	KO
Aipysurus duboisii	Dubois' seasnake				✓			MO	MO	MO
Aipysurus eydouxii	Spine-tailed seasnake				✓			MO	MO	MO
Aipysurus laevis	Olive seasnake				✓		MO	MO	MO	MO
Aipysurus pooleorum	Shark Bay seasnake				✓					MO
Aipysurus tenuis	Brown-lined seasnake				✓			MO	MO	MO
Astrotia stokesii	Stokes' seasnake				✓			MO	MO	MO
Disteira kingii	Spectacled seasnake				✓		MO	MO	MO	MO
Disteira major	Olive-headed seasnake				✓			MO	MO	MO
Emydocephalus annulatus	Turtle-headed seasnake				✓			MO	MO	MO
Ephalophis greyi	North-western mangrove seasnake				✓			MO	MO	MO

Species		Specially Protected Fauna	Threatened Species	Migratory Species	Listed Marine Species	Biologically Important Area	Offshore Project Area	Trunkline Project Area	Borrow Grounds Project Area	EMBA
Hydrelaps darwiniensis	Black-ringed seasnake				✓			MO	MO	MO
Hydrophis czeblukovi	Fine-spined seasnake				✓			MO	MO	MO
Hydrophis elegans	Elegant seasnake				✓			MO	MO	MO
Hydrophis mcdowelli	(unnamed)				✓			MO	MO	MO
Hydrophis ornatus	Spotted seasnake				✓			MO	MO	MO
Pelamis platurus	Yellow-bellied seasnake				✓		MO	MO	MO	MO

Threatened Species:
V Vulnerable
E Endangered
Biologically Important Area:
(i) Inter-nesting
(n) Nesting
(m) Mating
(f) Foraging
(mr) Migration

Type of Presence:

MO	Species or species habitat may occur within area
LO	Species or species habitat likely to occur within area
KO	Species or species habitat known to occur within area
FKO	Foraging known to occur within area
AKO	Congregatin or aggregation known to occur
BKO	Breeding known to occur within area

5.4.6.2 EMBA

Six conservation significant marine reptile species (or habitat) may occur in the EMBA; five marine turtles and one seasnake (Table 5.4). BIAs for the Flatback turtle, Green turtle, Hawksbill turtle and Loggerhead turtle overlap with the EMBA as described in (Table 5-7).

The shallower waters and shorelines of the EMBA are likely to provide more significant inter-nesting, mating and nesting habitat for the marine turtle species compared to the Project Area. Greater presence of primary producers in the EMBA compared to the Project Area, such as coral reefs or seagrasses, provide additional foraging areas for marine turtles and habitat for a wider range of seasnake species.

5.4.6.3 Trunkline Project Area and Borrow Ground Project Area

A total of six conservation significant marine reptile species (or habitat) may occur in both the Trunkline Project Area and Borrow Ground Project Area; five marine turtles and one seasnake.

In addition, overlapping the Trunkline Project Area and Borrow Grounds Project Area are BIAs for inter-nesting hawksbill, flatback, loggerhead and green turtles, and critical habitat for inter-nesting hawksbill, flatback, loggerhead and green turtles. These areas are associated with nesting beaches at the North West Cape, Muiron Islands, Montebello, Lowendal and Barrow islands, and the islands of the Dampier Archipelago (Commonwealth of Australia, 2017; Environment Australia, 2003; Limpus, 2007, 2008a, 2008b, 2009). Significant nesting and aggregation areas for marine turtles within the Dampier Archipelago were reported by CALM (2005). Presence of marine turtles in the Trunkline Project Area are expected to peak during breeding periods.

5.4.6.4 Offshore Project Area

A total of five conservation significant marine turtle species (or habitat) may occur in the Offshore Project Area (Table 5.7). Since the Offshore Project Area is located in deep offshore waters, and is devoid of primary producers and emergent features, the area does not represent important habitat, such as foraging or breeding for marine reptiles. However, given the large distribution of marine turtles, particularly the Leatherback turtle, transient individuals may occur infrequently.

No conservation significant seasnake species are likely to occur in the Offshore Project Area (Table 5.7). While some seasnake species inhabit deep offshore habitats, none of the species listed in the EPBC Protected Matters report (Table 5.7) are listed Threatened or Migratory under the EPBC Act, or likely to occur in the Offshore Project Area.

Marine Turtles

Leatherback Turtle

Leatherback turtles (*Dermochelys coriacea*) are listed Endangered and Migratory under the EPBC Act. They have a broad distribution worldwide but are uncommon within their Australian range, particularly within the NWMR (DoEE, 2017c). Leatherback turtles are rarely recorded breeding within Australia with no large recorded rookeries, however they are known to regularly forage within tropical and temperate continental shelf waters. The leatherback turtle is an oceanic, pelagic species that feeds primarily on jellyfish, sea squirts and other soft-bodied invertebrates (DEWHA, 2012c).

Given their broad distribution the leatherback turtle could occur in the Offshore Project Area and Trunkline Project Area, but in low numbers. No BIAs for this species have been identified in the NWMR.

Flatback Turtle

Flatback turtles (*Natator depressus*) are listed Vulnerable and Migratory under the EPBC Act. They are endemic to the northern Australia/southern New Guinea continental shelf. Flatback turtles differ from other marine turtles in that they do not have a pelagic phase to their lifecycle; instead, hatchlings grow to maturity in shallow coastal waters thought to be close to their natal beaches. They also prefer soft bottom habitats away from rock and reef systems, feeding on jellyfish, coral and sea cucumbers. There are two breeding stocks within the NWMR, one of which (the North West Shelf stock) has significant rookeries on Thevenard Island, Barrow Island, the Montebello Islands, Varanus Island, the Lowendal Islands, islands of the Dampier Archipelago, and coastal areas around Port Hedland or along the Kimberley coast where suitable beaches occur (DoEE, 2017a). Nesting begins in late November–December, peaks in January, and finishes by February–March.

Both BIAs and critical habitat for the survival of flatback turtles have been identified within the Trunkline Project Area around the Montebello, Lowendal and Barrow islands and the Dampier Archipelago (Table 5.3). Compared to other turtles identified in the NWMR, inter-nesting behaviours exhibited by flatback turtles extend further offshore, with the BIA and critical habitat extending 80 km and 60 km from nesting beaches respectively (Figure 5.27). However, tracking data indicates that flatback turtles in the NWMR travel and forage in relatively shallow coastal waters less than 70 m deep (Chevron Australia Pty Ltd, 2015). Furthermore, while inter-nesting distances of up to 70 km have been recorded, these were either in a longshore direction or from islands to mainland, rather out into open water. A number of individuals, from four different rookeries, remained within 10 km of the nesting site (Whittock, Pendoley and Hamann, 2014). These distances are less than previous studies which showed flatback turtles travelled at least 26 km and up to 48 km in all directions from nesting beaches on the Lacepede Islands, during internesting (Waayers et al. 2011), although water depths are not reported.

It is likely that flatback turtles will occur in the Project Area. Although individuals may transit through the Offshore Project Area, the distance offshore, water depths, and lack of primary producers and nesting beaches, prevents the Offshore Project Area from providing habitat that encourages aggregation of this species. The proximity of the Trunkline Project Area to known nesting sites, and the overlap with areas designated as inter-nesting habitat (BIAs and habitat critical to survival of a species), increases the likely presence of flatback turtles in the Trunkline Project Area compared to within the Offshore Project Area. Nevertheless, given the water depths and distance from the Trunkline Project Area to known nesting beaches at the Montebello, Lowendal and Barrow islands, and islands of the Dampier Archipelago, the number of inter-nesting females potentially occurring is unlikely to comprise a significant portion of the Western Australian population. Within the EMBA, the inter-nesting BIA is expected to be utilised more frequently as distance to nesting sites decreases. Additional breeding BIAs for mating and nesting also occur in the EMBA. No foraging areas were identified in the Project Area, although a foraging BIA overlaps the EMBA.

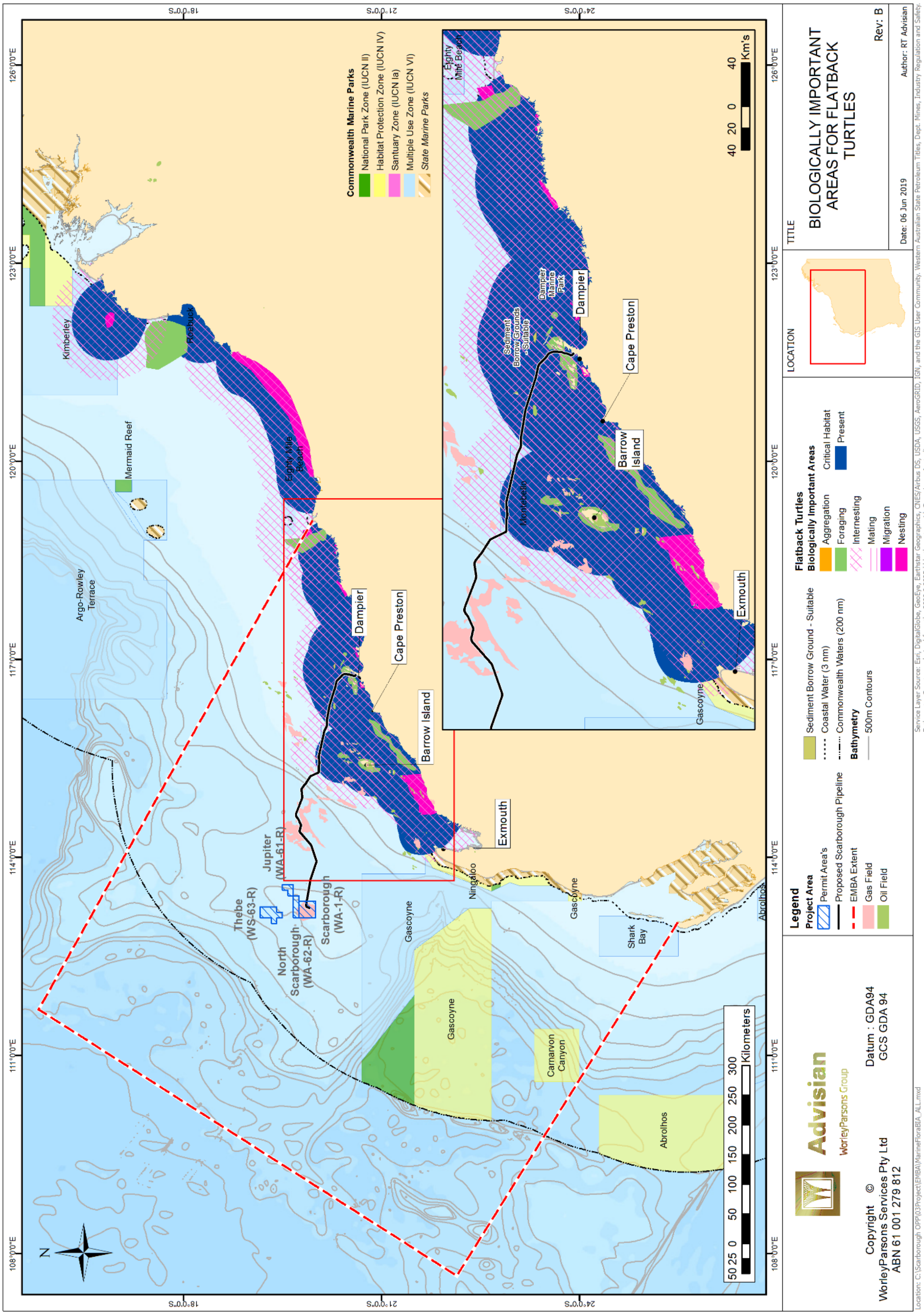


Figure 5.27: Biologically important area and critical habitat for flatback turtles

Green Turtle

Green turtles (*Chelonia mydas*) are listed as Vulnerable and Migratory under the EPBC Act. They are the most common marine turtle breeding in the NWMR (DEWHA, 2012c). Three distinct breeding stocks of green turtles occur in the region: the North West Shelf (NWS) stock, the Scott Reef stock and the Ashmore stock. Locations of key nesting beaches for the NWS stock include the Montebello Islands, west coast of Barrow Island, Muiron Islands and North West Cape and Dampier Archipelago (Table 5.3).

Habitat distribution of the species varies depending on their life stage, with general distribution from the ages of five to ten within offshore pelagic environments, followed by a retreat to shallow nearshore tropical – subtropical benthic habitats including seagrass pastures, rocky reef and coral reef systems. The nesting period for the NWS stock is expected to begin in November, peak in January-February, and end in April (DoEE, 2017c).

Both BIAs and critical habitat for the survival of green turtles have been identified overlapping the Trunkline Project Area around the Dampier Archipelago (Figure 5.28). However, while information on inter-nesting turtle movement in Western Australia is limited, tracking data has shown that during nesting periods, female green turtles typically inter-nest in shallow, nearshore waters between 0 and 10 m deep (Pendoley, 2005) and remain <5 km nesting beaches on Barrow Island, Varanus Island, and Rosemary Island (Pendoley, 2005) and within 10 km of nesting beaches on the Lacepede Islands (Waayers et al. 2011). These conclusions for green turtles inter-nesting are also supported by other international scientific studies that suggest inter-nesting grounds are located close to nesting beaches, in 10–18 m of water (Stoneburner, 1982; Mortimer & Portier, 1989; Maylan, 1995; Tucker et al., 1995; Starbird & Hills, 1992).

It is likely that green turtles will occur in the Project Area. Although individuals may transit through the Offshore Project Area, large numbers are not expected given the distance offshore, water depths, and lack of primary producers and nesting beaches. The proximity of the Trunkline Project Area to known nesting sites, and the overlap with areas designated as inter-nesting habitat (BIAs and habitat critical to survival of a species), increases the likely presence of green turtles compared to the Offshore Project Area. However, given the water depths and distance from the Trunkline Project Area to known nesting beaches at the Montebello, Lowendal and Barrow islands, and islands of the Dampier Archipelago, the number of inter-nesting females potentially occurring is expected to be a small proportion of the NWS stock. Within the EMBA, the inter-nesting BIA is expected to be utilised more frequently as distance to nesting sites decreases. Additional breeding BIAs for nesting also occur in the EMBA. No foraging areas were identified in the Project Area, although a foraging BIA overlaps the EMBA.

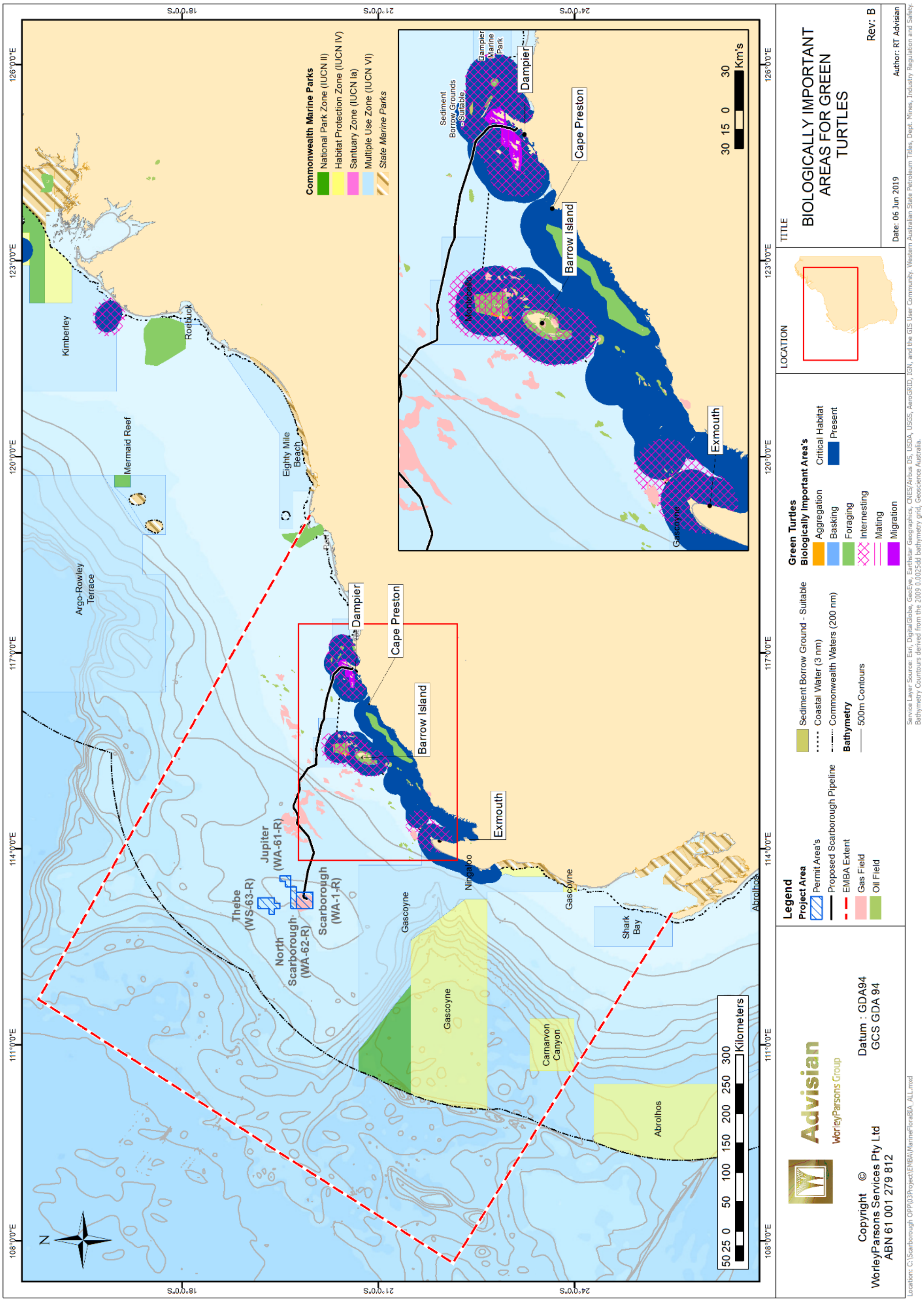


Figure 5.28: Biologically important area and critical habitat for green turtles

Hawksbill Turtle

Hawksbill turtles (*Eretmochelys imbricate*) are listed Vulnerable and Migratory under the EPBC Act. They typically occupy tidal and subtidal tropical to warm temperate waters around the northern coast Australia from New South Wales to Shark Bay. This species is generally associated with rocky and coral reef habitats, foraging on algae, sponges and soft coral (DoEE, 2017g).

There is a single breeding stock in the region, the Western Australian stock, which is centred on the Dampier Archipelago and is one of the largest stocks in the world. The most significant breeding areas of the species within the NWMR include Rosemary Island in the Dampier Archipelago, Varanus Island in the Lowendal group, Barrow Island and some islands in the Montebello group (DEWHA, 2012c). Nesting in the region can occur year-round, but with a peak between October and January (DoEE, 2017g).

Inter-nesting BIAs and critical habitat for the survival of hawksbill turtles have been identified within the Trunkline Project Area around the Dampier Archipelago (Figure 5.29). Information on hawksbill turtles nesting on Varanus and Rosemary Islands suggests females remain within several (less than ten) kilometres of their nesting beaches on Varanus Island and within 1 km of nesting beaches on Rosemary Island (Pendoley, 2005).

It is likely that hawksbill turtles will occur in the Project Area. Although individuals may transit through the Offshore Project Area, large numbers are not expected given the distance offshore and lack of coral reef or rocky shore and nesting beaches. The proximity of the Trunkline Project Area to known nesting sites, and the overlap with areas designated as inter-nesting habitat (BIAs and habitat critical to survival of a species), increases the likely presence of hawksbill turtles compared to the Offshore Project Area. However, given the distance from the Trunkline Project Area to known nesting beaches at the Montebello, Lowendal and Barrow islands, and islands of the Dampier Archipelago, the number of inter-nesting females potentially occurring is expected to be a small proportion of the Western Australian stock. Within the EMBA, the inter-nesting BIA is expected to be utilised more frequently as distance to nesting sites decreases. Additional breeding BIAs for nesting also occur in the EMBA. No foraging areas were identified in the Project Area, although a foraging BIA overlaps the EMBA.

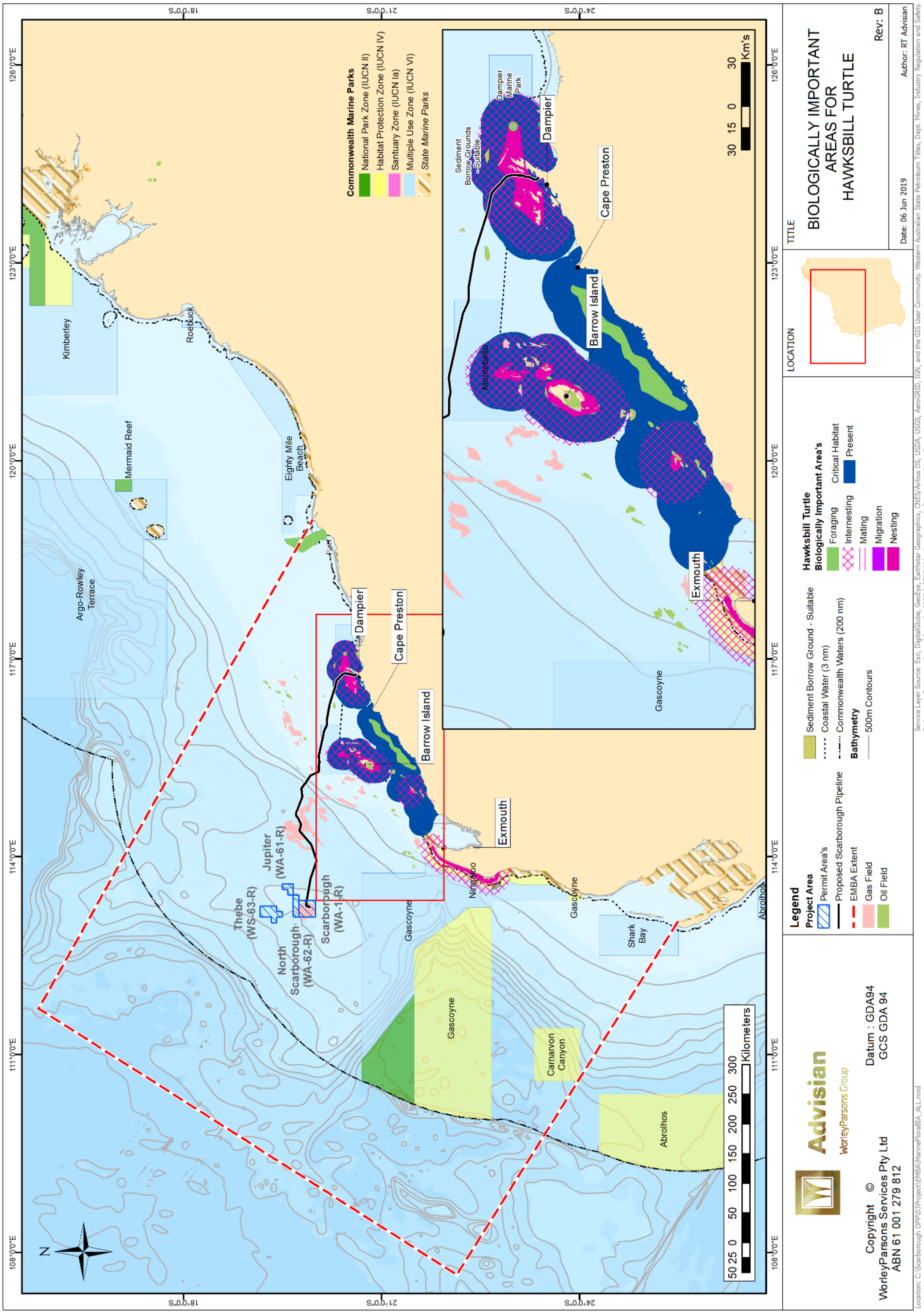


Figure 5.29: Biologically important area and critical habitat for hawksbill turtles

Loggerhead Turtle

Loggerhead turtles (*Caretta caretta*) are listed Endangered and Migratory under the EPBC Act. Within Australia two breeding stocks exist, with the western breeding stock being the larger of the two stocks. Loggerhead turtles occur throughout the NWMR and forage across a wide range of habitats including rocky and coral reefs, seagrass pastures, estuaries, muddy bays and open ocean environments (DoEE, 2017b).

In the NWMR, loggerhead turtles breed from November to March and require sandy beaches to nest. Nesting occurs principally from Shark Bay to the North West Cape with Dirk Hartog Island in the south being a major nesting site for the species (typically 800–1500 breeding females annually). Other key breeding spots include Gnaraloo bay, Murion Island and beaches along the North West Cape; with occasional records from Varanus and Rosemary islands, Barrow Island, Lowendal Islands (WA DEC, 2009) and Ashmore Reef (Guinea, 1995).

An inter-nesting BIA for loggerhead turtles overlaps the Trunkline Project Area; critical habitat for the survival of loggerhead turtles occurs within the EMBA but does not intersect with the Trunkline Project Area (Table 5.3; Figure 5.30). During inter-nesting periods, female loggerhead turtles generally remain within 10 km of nesting beaches (DoEE, 2017b). Movement patterns during inter-nesting are generally short forays of 4 to 8 km, with distance increasing towards the end of the inter-nesting period. Larger movements (~10 km) were mainly longshore, rather than directed offshore, and confined to water depths of less than 15 m (Tucker et al., 1995).

It is likely that loggerhead turtles will occur in the Project Area. Although individuals may transit through the Offshore Project Area, large numbers are not expected given the lack of habitats that would promote aggregating behaviours, such as breeding or foraging. The proximity of the Trunkline Project Area to known nesting sites, and the overlap with an inter-nesting BIA, increases the likely presence of hawksbill turtles compared to within the Offshore Project Area. However, given the distance from the Trunkline Project Area to known nesting beaches at the North West Cape, Ningaloo Reef, Muiron Islands, Montebello Islands and the Dampier Archipelago, the number of inter-nesting females potentially occurring is expected to be a small proportion of the western breeding stock. Within the EMBA, the inter-nesting BIA is expected to be utilised more frequently as distance to nesting sites decreases. Additional inter-nesting BIAs and habitat critical to the survival of loggerhead turtles occurs around Ningaloo Reef and the North West Cape within the EMBA. No foraging areas were identified in the Project Area or EMBA.

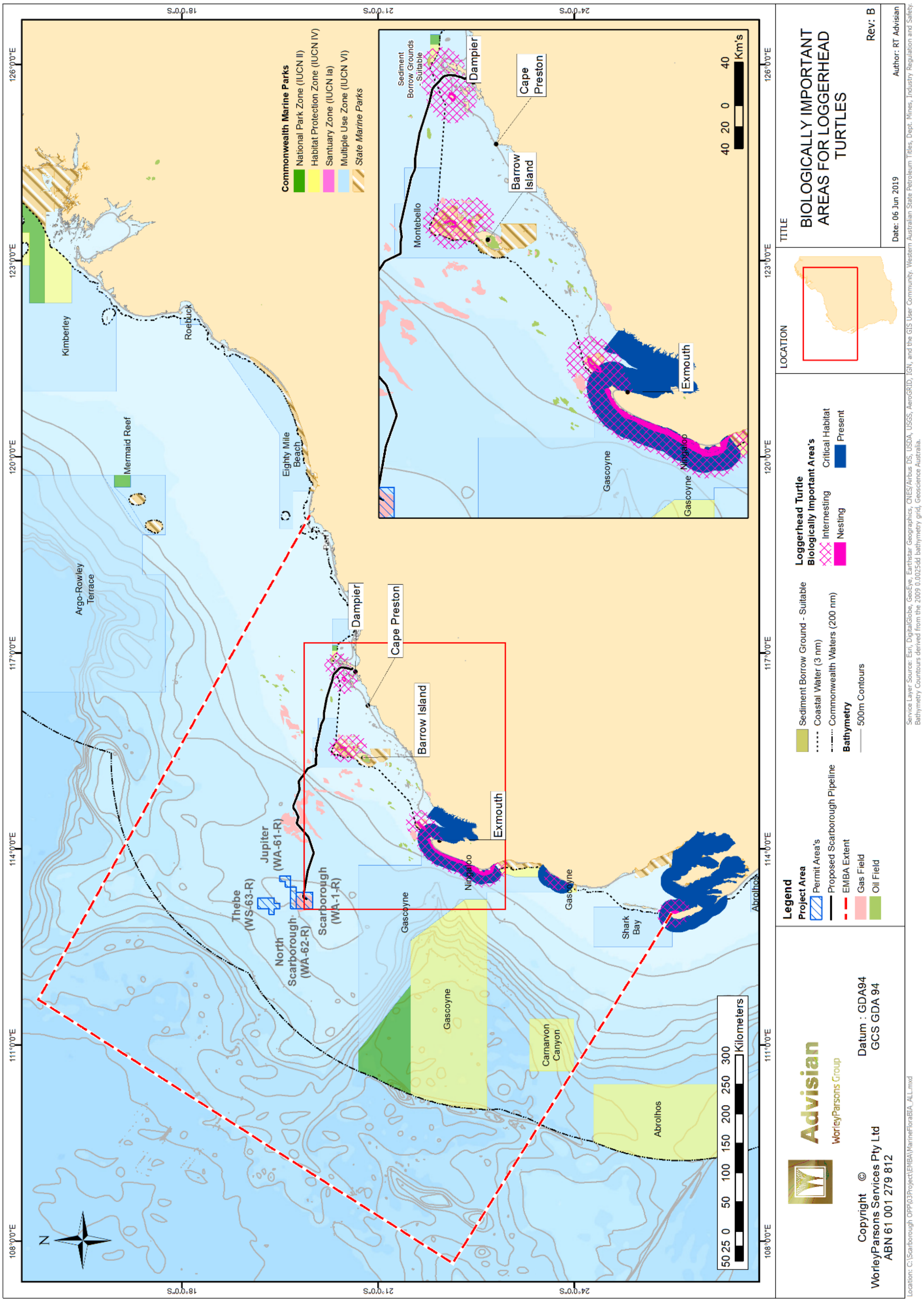


Figure 5.30: Biologically important area and critical habitat for loggerhead turtles

Seasnakes

Short-nosed Seasnake

The short-nosed seasnake (*Aipysurus apraefrontalis*) is listed as Critically Endangered under the EPBC Act. With the NWMR, it has been recorded at Ashmore and Hibernia reefs. However, despite a fivefold increase in survey effort, the species has not been identified at Ashmore since the late 1990s (DoEE, 2017e). Guinea and Whiting (2005) reported that very few short-nosed sea snakes moved as far as 50 m from the reef flat.

Given the coral reef habitat preferences for this species, it does not occur in Offshore Project Area. Although the Trunkline Project Area passes in closer proximity to coral reefs, for example, fringing the Montebello Islands or islands of the Dampier Archipelago, no corals are expected to occur in the Trunkline Project Area. Given the small distances that Short-nosed seasnakes have been observed straying from reef habitat, likely presence in the Trunkline Project Area is limited. It is possible that the Short-nosed seasnake would occur in coral reefs found in the EMBA. No BIAs have been identified for this species in the NWMR.

5.5 Key Ecological Features

Key ecological features (KEFs) are not MNES and have no legal status in their own right; however, they are considered as components of a Commonwealth marine area. KEFs are parts of the marine ecosystem that are considered to be important for a marine region's biodiversity or ecosystem function and integrity. KEFs have been identified by the Australian Government based on advice from scientists identifying regions with important attributes associated with ecosystem function and biodiversity.

The Project Area intersects with the following three KEFs (Figure 5.32):

- Exmouth Plateau (Offshore Project Area and Trunkline Project Area)
- ancient coastline at 125 m depth contour (Trunkline Project Area)
- continental slope demersal fish communities (Trunkline Project Area).

Additional KEFs within the EMBA include:

- canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula (~175 km from Offshore Project Area and ~21 km from the Trunkline Project Area)
- Commonwealth waters adjacent to Ningaloo Reef (~20 km from the Offshore Project Area and 22 km from the Trunkline Project Area)
- Glomar Shoals (~6 km from the Trunkline Project Area and ~34 km from the Offshore Project Area).

All KEFs are distributed in offshore areas within Commonwealth waters. Details of the above KEFs are outlined below.

5.5.1 Exmouth Plateau (Offshore Project Area and Trunkline Project Area)

The Exmouth Plateau is a large, mid-slope, continental margin plateau that lies off the north-west coast of Australia. It ranges in depth from about 500 to more than 5000 m and is a major structural element of the Carnarvon Basin (DNP, 2013; Miyazaki and Stagg, 2013). The plateau is bordered by the Rankin Platform and the Exmouth sub-basin of the Northern Carnarvon Basin to the east, the Argo Abyssal Plain to the north, and the Gascoyne and Cuvier Abyssal Plains to the north-west and south-west.

The Exmouth Plateau is defined as a KEF as it is a unique seafloor feature with ecological properties of regional significance, which apply to both the benthic and pelagic habitats within the feature (Figure 5.32; DoEE, 2018b). The KEF lies offshore within Commonwealth waters, starting at about 110 km and extending to as far as about 370 km from the shore, occupying an area of 49,310 km² within water depths of 800–4000 m (Exon & Willcox, 1980, cited in Falkner et al., 2009; Heap & Harris, 2008).

Although the seascapes of this plateau are not unique (Falkner et al., 2009), it is believed that the large size of the Exmouth Plateau and its expansive surface may modify deep water flow and be associated with the generation of internal tides; both of which may subsequently contribute to the upwelling of deeper, nutrient-rich waters closer to the surface (Brewer et al., 2007). Satellite observations suggest that productivity is enhanced along the northern and southern boundaries of the plateau and along the shelf edge (Brewer et al., 2007). The waters of the Exmouth Plateau are a mixture of waters from the Indonesian Throughflow and the Indian Ocean Central Water; and therefore, can display significant temporal variations due to the fluctuations in the Indonesian Throughflow (and other climatic factors). Internal tides are known to be strongest during January–March (Brewer et al., 2007).

The topography of the plateau (with valleys and channels), in addition to potentially providing a range of benthic environments, may provide conduits for the movement of sediment and other material from the plateau surface through the deeper slope to the abyss. The northern margin is steep and intersected by large canyons (e.g. Montebello and Swan canyons); whereas the western margin is moderately steep and smooth, and the southern margin is gently sloping and virtually free of canyons (Falkner et al., 2009). Sediments on the plateau suggest that biological communities include scavengers, benthic filter feeders and epifauna (DotE, 2018b). Fauna in the pelagic waters above the plateau are likely to include small pelagic species and nekton (Brewer et al., 2007). Protected and migratory species are also known to pass through the region including Whale sharks and cetaceans.

No pressures were assessed as ‘of concern’ for this KEF; one pressure, ocean acidification as a result of climate change, was assessed as ‘of potential concern’ (DotE, 2018b).

The Offshore Project Area lies entirely within the Exmouth Plateau KEF. Additionally, the Trunkline Project Area partially overlaps the KEF. The Trunkline Project Area enters the KEF at the eastern boundary ~208 km offshore (north of the North West Cape) and extends ~45 km west from the KEF boundary before reaching the Offshore Project Area. The Trunkline Project Area and Offshore Project Area occupy a relatively small portion of the entire KEF (<1.7%).

5.5.2 Ancient Coastline at 125 m Depth Contour (Trunkline Project Area)

The ancient coastline at 125 m depth contour is defined as a KEF (“Ancient Coastline”) as it is a unique seafloor feature with ecological properties of regional significance (Figure 5.32; DotE, 2018b). The feature is defined by a depth range of between 115–135 m. This KEF extends along the NW coast from the North West Cape to within the offshore Kimberley region occupying an area of 16,190 km², spanning approximately 2,910 km end-to-end.

The ancient submerged coastline provides a hard benthic substrate, and therefore may provide sites for higher diversity and species richness relative to surrounding areas of predominantly soft sediment (DotE, 2018b). Little is known about fauna associated with the hard substrate of the escarpment, but it is expected to include sponges, corals, crinoids, molluscs, echinoderms and other benthic invertebrates representative of hard substrate fauna in the North West Shelf bioregion (DotE, 2018b).

The submerged coastline may also facilitate increased availability of nutrients off the Pilbara by interacting with internal waves and enhancing vertical mixing of water layers. Enhanced productivity associated with the sessile communities and increased nutrient availability may attract larger marine life such as whale sharks and large pelagic fish (DEWHA, 2008b). It has been suggested that humpback whales, whale sharks and other migratory pelagic species may use the rocky escarpment as a guide to navigate through the region (DNP, 2013).

No pressures[6] were assessed as 'of concern' for this KEF; one pressure, ocean acidification as a result of climate change, was assessed as 'of potential concern' (DotE, 2018b).

There is no overlap between the Ancient Coastline KEF and the Offshore Project Area. Only a very small portion (5 km² or <0.03%) of this KEF transects the Trunkline Project Area, approximately 132 km offshore, 46 km north-northwest of the Montebello Islands. A benthic habitat survey along the trunkline through this KEF area did not identify the potential features of the KEF (i.e. areas of hard substrate with high biodiversity) (Advisian, 2019b). The area was observed to be predominantly bare sand habitat (Figure 5.31). While no hard substrate or rocky features were identified, the soft sediment habitat was observed to support sparse (<15%) coverage of benthic organisms including epifauna, sponges and soft corals (Advisian, 2019b).

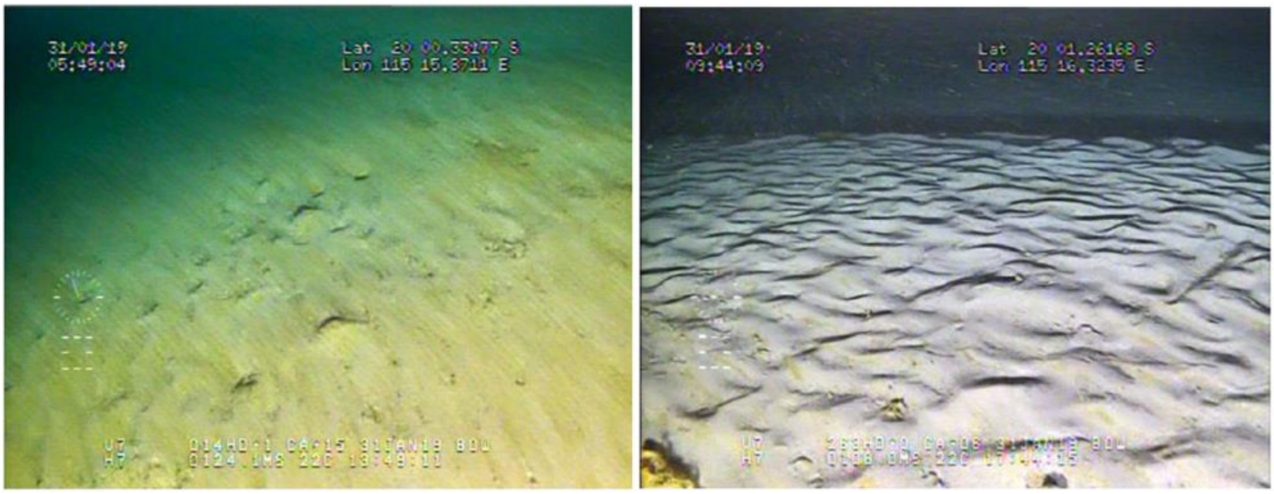


Figure 5.31: Example of ROV footage from benthic habitat survey within trunkline corridor within the ancient coastline at 125 m depth KEF

5.5.3 Continental Slope Demersal Fish Communities (Trunkline Project Area)

This species assemblage is recognised as a KEF because of its biodiversity values, including high levels of endemism (Figure 5.32; DotE, 2018b).

The diversity of demersal fish assemblages on the continental slope in the Timor Province, the Northwest Transition and the Northwest Province is high compared to elsewhere along the Australian continental slope (DotE, 2018b). The continental slope between North West Cape and the Montebello Trough has more than 500 fish species, 76 of which are endemic, which makes it the most diverse slope bioregion in Australia (Last et al., 2005). The slope of the Timor Province and the Northwest Transition also contains more than 500 species of demersal fish of which 64 are considered endemic (Last et al., 2005), making it the second richest area for demersal fish throughout the whole continental slope. The demersal fish species occupy two distinct demersal biomes associated with the upper slope (225–500 m water depths) and the mid-slope (750–1000 m). Although poorly known, it is suggested that the demersal-slope communities rely on bacteria and detritus-based systems comprised of infauna and epifauna, which in turn become prey for a range of teleost fish, molluscs and crustaceans (Brewer et al., 2007). Higher-order consumers may include carnivorous fish, deepwater sharks, large squid and toothed whales (Brewer et al., 2007). Pelagic

[6] During the development of marine bioregional plans, pressures (defined as human-driven processes or events) that do or could detrimentally impact conservation values were identified for each KEF.

production is phytoplankton based, with hot spots around oceanic reefs and islands (Brewer et al., 2007).

No pressures were assessed as of concern for this KEF; three pressures, (i) changes in sea temperature and ocean acidification as a result of climate change, and (ii) physical habitat modification, and (iii) bycatch were assessed as of potential concern (DotE, 2018b).

The Trunkline Project Area intersects a small, narrow portion of the KEF near its northwest-most extent. The KEF mostly lies further south extending about 300 km from the Trunkline Project Area past the North West Cape, splitting from a single corridor into three. Only a small extent (16 km^2 or <0.05%) of this KEF transects the Trunkline Project Area.

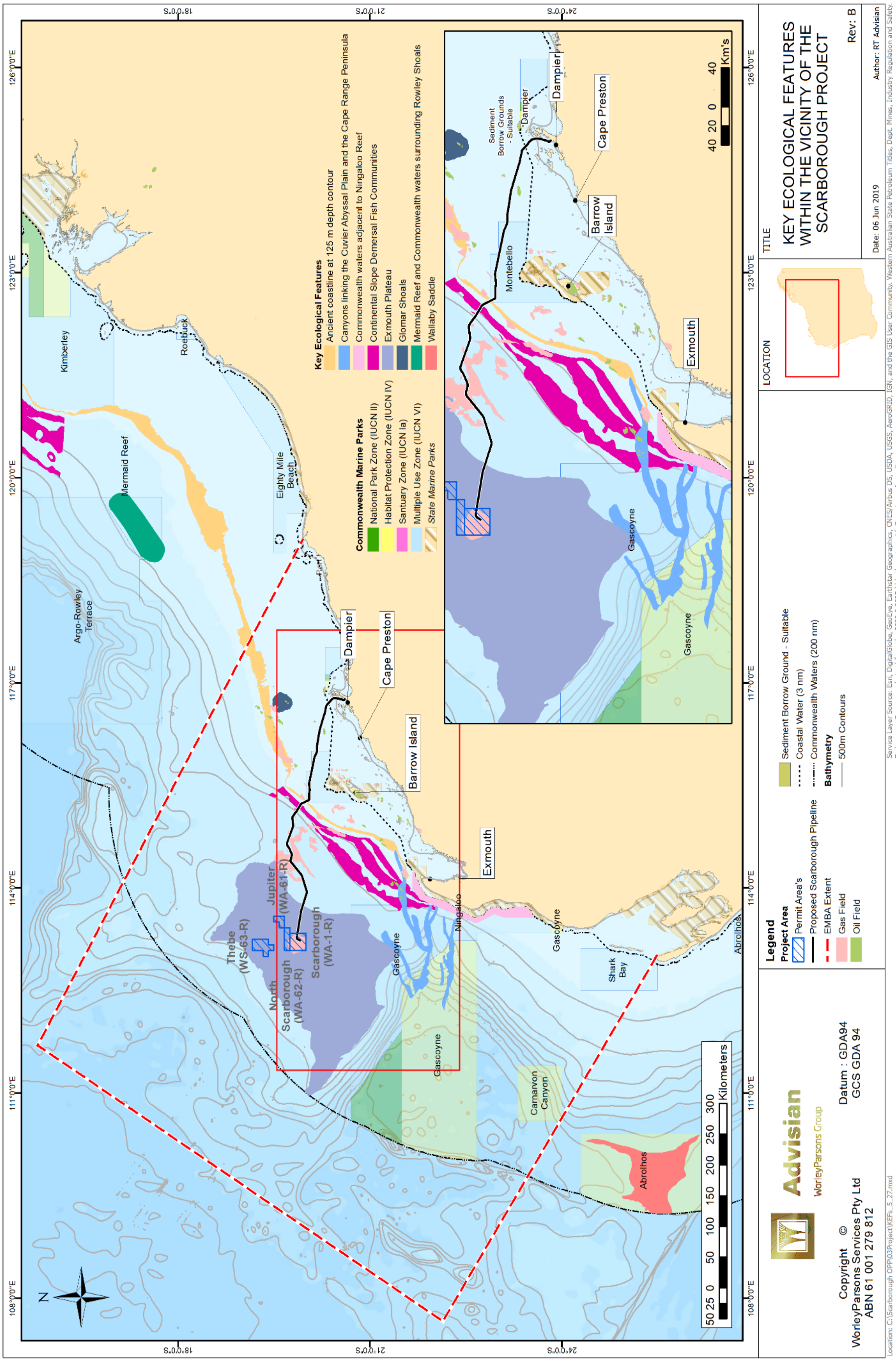


Figure 5.32: Key Ecological Features within the vicinity of Scarborough

5.5.4 Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula Key Ecological Feature (EMBA)

The canyons that link the Cuvier Abyssal Plain with the Cape Range Peninsula KEF ('Canyons KEF') lie off the northwest coast of Australia and are believed to support the productivity and species richness of Ningaloo Reef (DSEWPaC, 2012a). In relation to the Project Area, the Canyons KEF is about 130 km south of the Offshore Project Area at its nearest point. Interactions with the Leeuwin current and strong internal tides are thought to result in upwelling at the canyon heads, thus creating conditions for enhanced productivity in the region (Brewer et al., 2007). As a result, aggregations of Whale sharks, Manta rays, Humpback whales, sea snakes, sharks, predatory fish and seabirds are known to occur in the area due to its enhanced productivity (Sleeman et al., 2007).

Woodside commissioned a literature review of the Cape Range Canyon, supported by an environmental survey of the Enfield Canyon (BMT Oceanica, 2016). This survey examined several sections of the canyon (approximately 365–870 m water depth) and sampled a range of physical and biological parameters, including water, sediments, epifauna and mobile invertebrates, infauna and fish assemblages. Benthic habitats within and surrounding the canyon surveyed were similar in nature to those observed elsewhere in the NWMR and were characterised by flat unconsolidated sediments composed of sand- and mud-sized particles (BMT Oceanica, 2016; Falkner et al., 2009). Epifauna and mobile invertebrate communities associated with these habitats were considered to be similar to those observed elsewhere in the region, as well as other continental slopes in the Indo-Pacific region (BMT Oceanica, 2016, Heyward et al., 2010). The fish assemblages associated with the canyon observed during the survey were considered to be high, and consistent with data recorded during other investigations (Last et al., 2005; Williams et al., 2001). The fish assemblage at the foot of the canyon (the deepest area surveyed) was more diverse than those observed in higher sections of the canyon, with Angulliform (eels) and Scorpaeniform (*Paraliparis* spp.) species present that were not observed in the main section of the canyon.

In reviewing KEFs in the NWMR, Falkner et al. (2009) concluded that the canyons occurring in the region exhibited habitat heterogeneity (although noted that such habitat was not restricted to canyon features) and were representative of the region. These conclusions were based on a review of existing physical and biological data from a range of sources. The observations made during the survey of the Enfield Canyon were not consistent with these conclusions, finding that the habitat at different locations within the canyon comprised flat unconsolidated sediments composed of sand- and mud-sized particles (BMT Oceanica, 2016).

5.5.5 Commonwealth Waters Adjacent to Ningaloo Reef (EMBA)

The spatial boundary of this KEF, as defined in the Conservation Values Atlas, is defined as the waters contained in the existing Ningaloo AMP, provided in Section 5.6.2.

5.5.6 Glomar Shoals (EMBA)

The Glomar Shoals are a submerged littoral feature located about 150 km north of Dampier and about 56 km east of the Trunkline Project Area on the Rowley shelf at depths of 33–77 metres (Falkner et al., 2009). The shoals consist of a high percentage of marine-derived sediments with high carbonate content and gravels of weathered coralline algae and shells (McLoughlin & Young, 1985). The area's higher concentrations of coarse material in comparison to surrounding areas are indicative of a high-energy environment subject to strong seafloor currents (Falkner et al., 2009). Cyclones are also frequent in this area of the north-west and stimulate periodic bursts of productivity because of increased vertical mixing. Studies by Abdul Wahab et al. (2018) found a number of hard coral and sponge species in water depths less than 40 m. 170 different species of fish were detected with greatest species richness and abundance in shallow habitats (Abdul Wahab et al., 2018). Fish species present include 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 & Santoro, 2009). These species have recorded high catch rates associated with the Glomar Shoals, indicating that the shoals are likely to be an area of high productivity. The Glomar Shoals are defined as a KEF for their high productivity and aggregations of marine life.

5.6 Protected Places

Protected places of the NWMR and adjacent State waters include:

- World Heritage Properties
- National Heritage Properties
- Commonwealth-managed Australian Marine Parks (AMPs)
- State-managed Marine Parks (MPs)
- State-managed Marine Management Areas (MMAs)
- Ramsar wetlands of international importance
- Nationally important wetlands.

Distances between these protected places and the Project Area are provided in Table 5.8 (for those with any overlap with the EMBA) and shown in Figure 5.33 and Figure 5.34. Further details are provided in sections that follow. AMPs in north western Australia are managed under the Australian Marine Parks North-west Marine Parks Network Management Plan 2018 (Director of National Parks, 2018).

Table 5.8: Protected places in the EMBA

	Distance from Project Area to Values/Sensitivity boundaries (km)	IUCN Protected Area Category	Section Ref.	
Australian Marine Parks (Commonwealth-managed)				
Montebello	Overlap	VI	Montebello and Barrow Islands	5.6.1
Dampier	<1^	II, IV & VI	Dampier Coast	5.6.1
Gascoyne	77	II, IV & VI	Ningaloo Coast and Gascoyne	5.6.2
Ningaloo	182	IV	Ningaloo Coast and Gascoyne	5.6.2
Carnarvon Canyon	405	IV	Shark Bay	5.6.3
Shark Bay	475	VI	Shark Bay	5.6.3
Marine Parks (State managed)				
Montebello Islands	25	IA, II & IV	Montebello and Barrow Islands	5.6.1
Barrow Island	73	IA & VI	Montebello and Barrow Islands	5.6.1
Ningaloo	186	IA, II & IV	Ningaloo Coast and Gascoyne	5.6.2
Shark Bay	550	IA, II, IV	Shark Bay	5.6.3
Marine Management Areas (State managed)				
Barrow Island	40	1A & VI	Montebello and Barrow Islands	5.6.1
Muiron Islands	177	1A & VI	Ningaloo Coast and Gascoyne	5.6.2
World Heritage Properties				
Ningaloo Coast	186	N/A	Ningaloo Coast and Gascoyne	5.6.2
Shark Bay	525	N/A	Shark Bay	5.6.3
National Heritage Properties				
Ningaloo Coast (natural)	186	N/A	Ningaloo Coast and Gascoyne	5.6.2
Dampier Archipelago (indigenous)	13	N/A	Dampier Coast	5.6.1
Shark Bay (natural)	525	N/A	Shark Bay	5.6.3
Dirk Hartog Landing - Cape Inscription (historic)	615	N/A	Shark Bay	5.6.3
Ramsar Wetlands of International Importance				
-	-	-	Protected Wetlands	5.6.5
Nationally Important Wetlands				
Exmouth Gulf East	160	N/A	Protected Wetlands	5.6.5
Hamelin Pool	635	N/A	Protected Wetlands	5.6.5
Learmonth Saline Coastal Flats	255	N/A	Protected Wetlands	5.6.5

	Distance from Project Area to Values/Sensitivity boundaries (km)	IUCN Protected Area Category	Section Ref.	
Shark Bay East.	545	N/A	Protected Wetlands	5.6.5

**Conservation objectives for IUCN categories include:*

- *IA: Strict nature reserve – Area of land and/or sea possessing some outstanding or representative ecosystems, geological or physiological features and/or species, available primarily for scientific research and/or environmental monitoring.*
- *II: National park – Natural area of land and/or sea, designated to (a) protect the ecological integrity of one or more ecosystems for this and future generations, (b) exclude exploitation or occupation inimical to the purposes of designation of the area, and (c) provide a foundation for spiritual, scientific, educational, recreational and visitor opportunities, all of which must be environmentally and culturally compatible.*
- *IV: Habitat/species management area – Area of land and/or sea subject to active intervention for management purposes so as to ensure the maintenance of habitats and/or to meet the requirements of specific species.*
- *VI: Protected area with sustainable use of natural resources – Area containing predominantly unmodified natural systems, managed to ensure long term protection and maintenance of biological diversity, while providing at the same time a sustainable flow of natural products and services to meet community needs.*

^ The proposed sediment borrow ground is immediately adjacent to (north of) Dampier Marine Park's Habitat Protection Zone (IUCN IV).

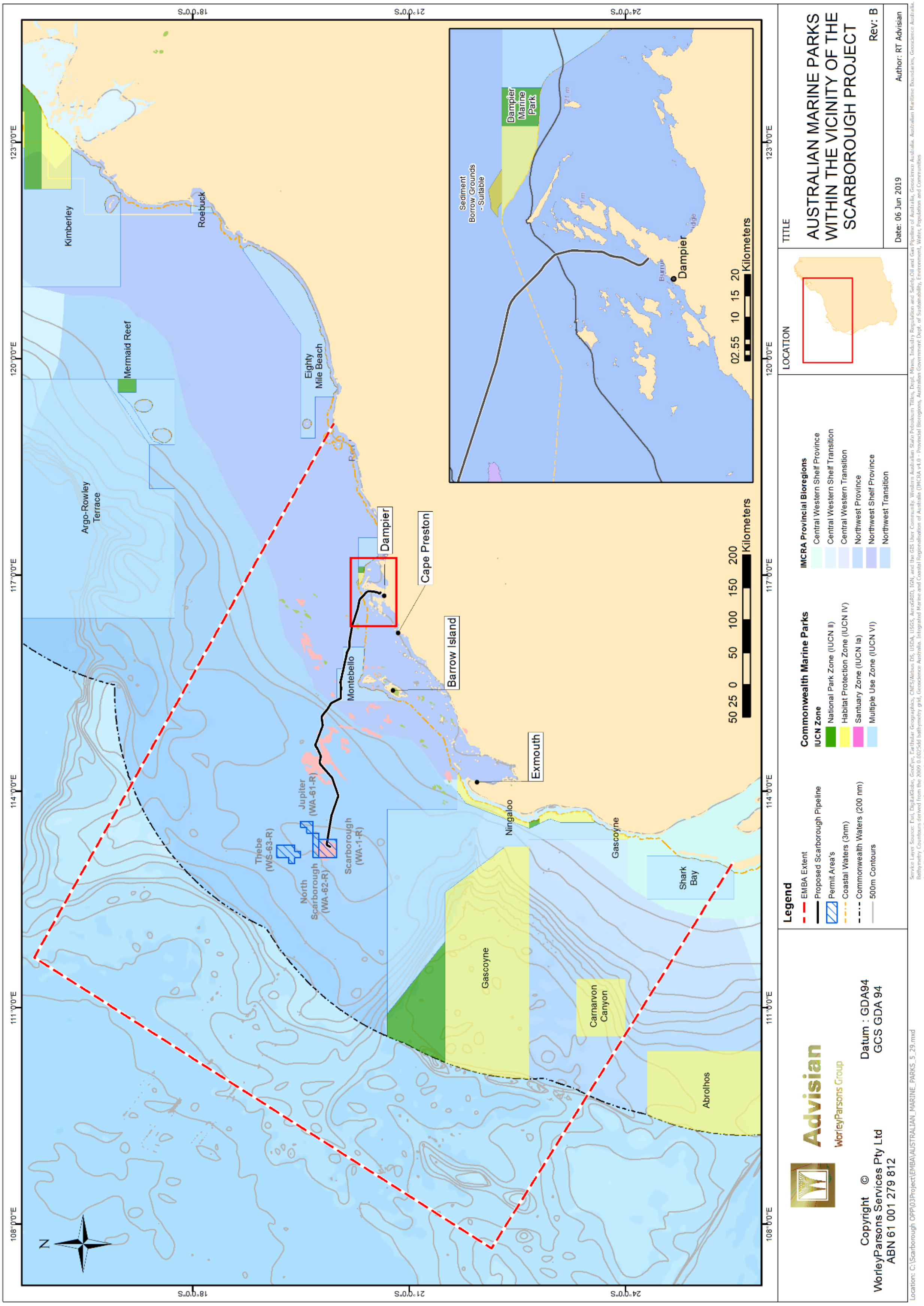


Figure 5.33: Australian Marine Parks within the vicinity of Scarborough

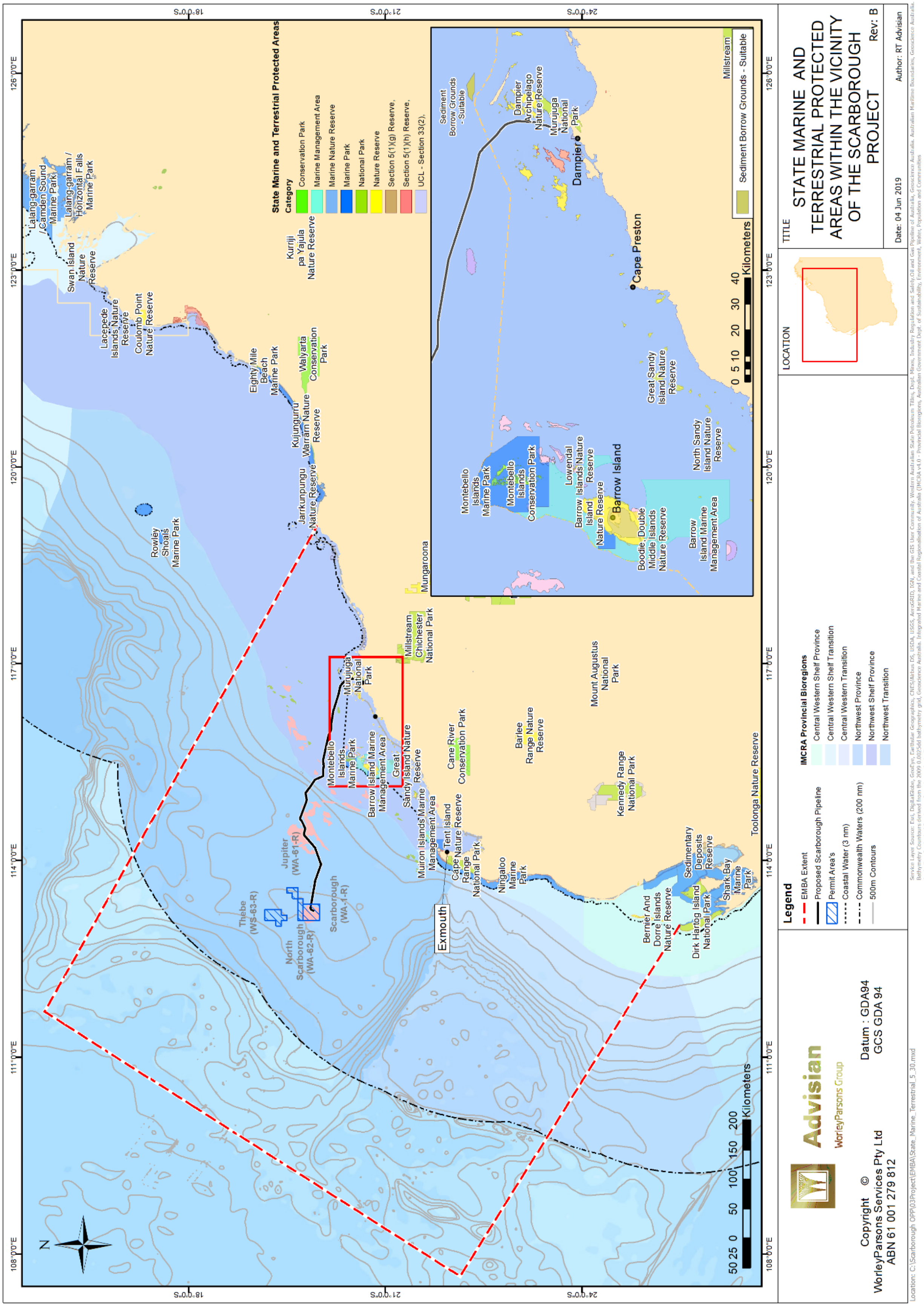


Figure 5.34: State marine and terrestrial protected areas within the vicinity of Scarborough

5.6.1 Montebello and Barrow Islands

5.6.1.1 Montebello Marine Park/Barrow Island Marine Park/Barrow Island Marine Management Area

The marine and coastal environments of the Montebello/Barrow Islands region 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, 2007; Director of National Parks, 2018).

The Montebello Islands Marine Park, Barrow Island Marine Park and Barrow Island Marine Management Area are jointly managed and cover a combined area of 1770 km², located about 25 km south of the Project Area at the closest point. A sanctuary zone covers the entire 4100 ha Barrow Island Marine Park. The Barrow Island Marine Management Area covers 114,500 ha and includes most of the waters surrounding Barrow Island and Lowendal Islands, except for the port areas around Barrow and Varanus Islands. Key conservation and environmental values within the protected areas include (DEC, 2007; Director of National Parks, 2018):

- a complex seabed and island topography consisting of subtidal and intertidal reefs, sheltered lagoons, channels, beaches, cliffs and rocky shores
- pristine sediment and water quality, supporting a healthy marine ecosystem
- undisturbed intertidal and subtidal coral reefs and bommies with a high diversity of hard corals
- important mangrove communities, particularly along the Montebello Islands, which are considered globally unique as they occur in offshore lagoons
- extensive subtidal macroalgal and seagrass communities
- important habitat for cetaceans and dugongs
- nesting habitat for marine turtles
- important feeding, staging and nesting areas for seabirds and migratory shorebirds
- rich finfish fauna with at least 456 species
- culture of the pearl oyster (*Pinctada maxima*) in the area produces some of the highest quality pearls in the world.

These islands support significant colonies of Wedge-tailed shearwaters and Bridled terns. The Montebello Islands support the biggest 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. Barrow Island is ranked equal tenth among 147 sites in Australia that are important for migratory shorebirds. Barrow, Lowendal and Montebello islands are internationally significant sites for six species of migratory shorebirds, supporting more than 1% of the East Asian-Australasian Flyway population of these species (DSEWPaC, 2012a).

The Montebello Islands Marine Park/Barrow Island Marine Park/Barrow Island Marine Management Area are contiguous with the Montebello Australian Marine Park. The intertidal habitats of the Montebello/Barrow/Lowendal Islands region are influenced by the passage of tropical cyclones that shape sandy beaches (RPS Bowman Bishaw Gorham, 2007). The dominant habitats on the exposed west coasts of islands in the area are sandy beaches, rocky shores and cliffs. The predominant physical habitats of the sheltered east coasts of islands are sand flats, mud flats, rocky pavements and platforms (RPS Bowman Bishaw Gorham, 2007).

5.6.1.2 Barrow Island Nature Reserve

The Barrow Island Nature Reserve is a Class A Nature Reserve covering about 235 km² and extends to the low water mark adjacent to the Montebello Islands/Barrow Island Marine Parks. It is about 73 km from the Project Area at the closest point. The islands surrounding Barrow Island including Boodie, Double, and Middle Islands make up the Boodie, Double, and Middle Islands Nature Reserve, covering 587 ha (DPaW, 2015; Director of National Parks, 2018). Together, these two nature reserves are commonly referred to as the Barrow Group Nature Reserves (DPaW, 2015).

The Barrow Island coastline consists of dry creek beds, beaches, clay and salt flats, mangroves, intertidal flats and reefs and is bordered by high cliffs on the western side. Key conservation values within the reserves include (DPaW 2015; Director of National Parks, 2018):

- the second largest island off the WA coast
- important biological refuge site because of isolation from certain threatening processes on the mainland
- contains flora that are restricted in distribution and at or near the limit of their range
- high number of fauna species with high conservation value
- extensive hydrogeological karst system that supports a subterranean community of high conservation significance
- regionally and nationally significant rookeries for green and flatback turtles
- important habitat for migratory shorebirds and also used by these species as a staging and destination terminus
- significant habitat values, such as intertidal mudflats, rock platforms, mangroves, rock piles and cliffs, clay pans and caves
- a significant fossil record that indicates local historical biodiversity and evolution
- a history of Aboriginal and other Australian use including 13 registered Aboriginal cultural heritage sites.

5.6.1.3 Montebello Australian Marine Park

The Trunkline Project Area traverses the northern border of the Montebello Marine Park (Multiple Use Zone). Approximately 80 km of pipeline will extend into the park, equating to approximately 2.4 km^2 overlap (allowing for a 30 m disturbance area on the trunkline). This conservative disturbance area would result in approximately 0.07% of the Montebello Marine Park, including the area intersecting the Ancient Coastline KEF.

An ROV survey of the trunkline route within the Montebello AMP was undertaken in 2019 (Advisian, 2019b). This survey predominantly targeted areas where the Scarborough trunkline deviates from the existing Pluto trunkline (i.e. the northwestern extent). Bathymetry data was analysed to select areas that could be expected to support benthic communities, including areas of potential harder substrate, the ancient coastline KEF (see also Section 4.5.4.6), areas of sub-cropping calcarenite with shallow sediment cover, and areas of potential turtle foraging habitat. Video imagery was collected from between one and three transects from five separate sites along the trunkline route through the Montebello Marine Park (Figure 5.35). Area 1 was located in the vicinity of the ancient coastline KEF; and Areas 4 and 5 were in the vicinity of the existing Pluto trunkline. Benthic habitat from the videos was described and classified in accordance with the CATAMI Classification System.

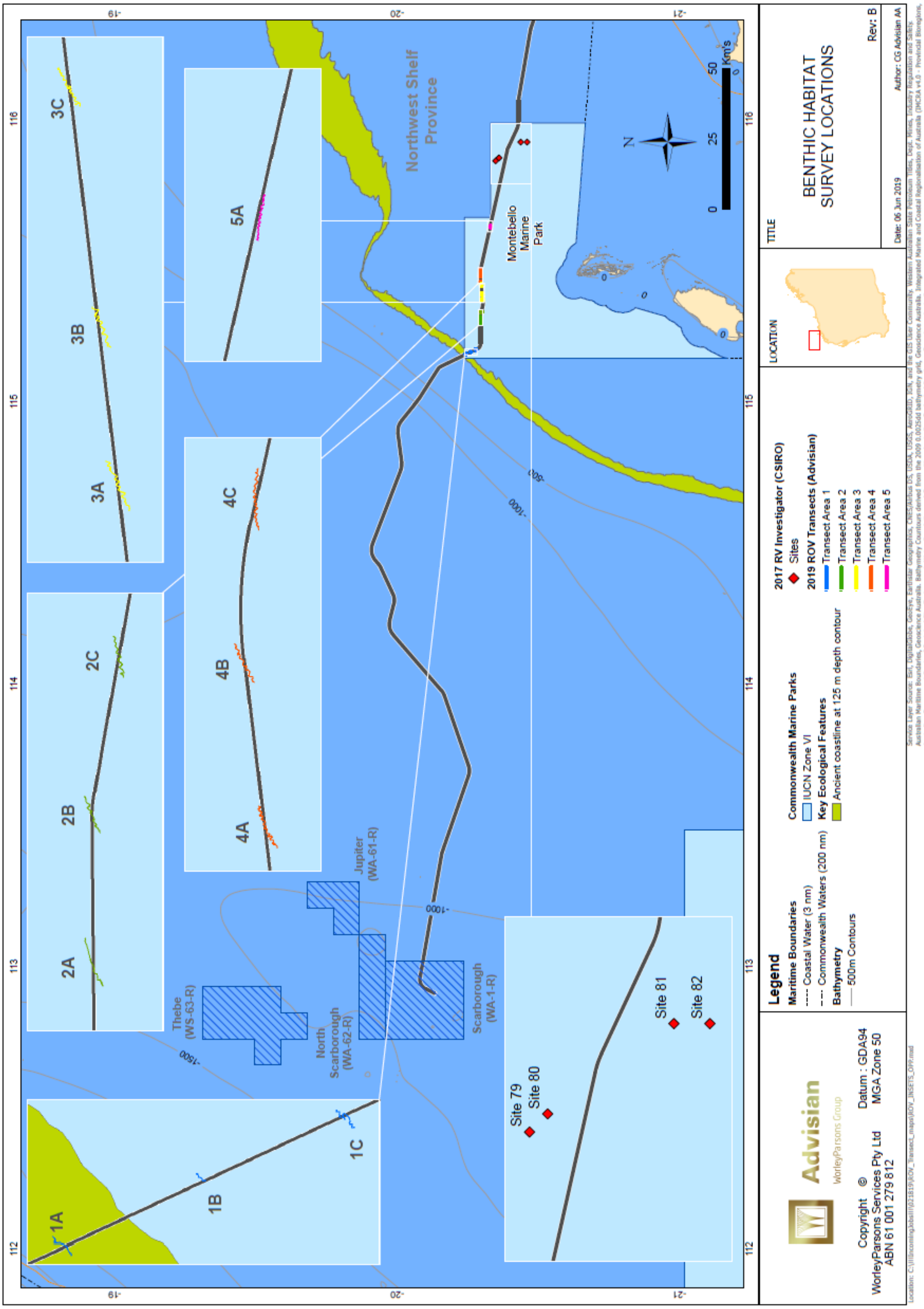


Figure 5.35: Location of survey areas and transects from the trunkline benthic habitat survey within the Montebello AMP

Analysis of the high definition ROV video data (Advisian, 2019b) found that the area in which the trunkline intersects the Montebello AMP is characterised by bare sandy sediments, interspersed with predominantly sparse benthic communities and epifauna (Table 5.9, Figure 5.36). Denser areas of sponges were observed in areas identified from the bathymetry as having a more complex seabed structure.

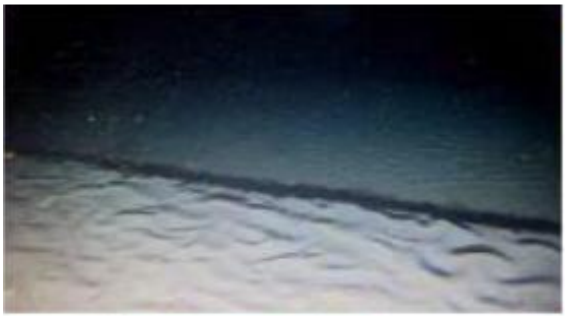
Area 1 which was the deepest and located in the vicinity of the KEF was most different, with a much lower cover of benthic organisms than Areas 2 to 5 (Advisian, 2019b). Transects which were centred on the ancient coastline KEF and surrounding area at the 125 m depth contour did not identify any areas of rocky escarpments, thought to provide biologically important habitat in areas otherwise dominated by soft sediments (Table 5.9; see also Section 5.5.2). Areas 2 to 5 were quite similar in depth (typically 70–80 m) and in nature, with some small differences in the density and occurrence of benthic organisms and in substrate type (e.g. variants of soft sediment bedforms and cover of biologenic gavel) (Table 5.9; Advisian, 2019b).

Table 5.9: Summary of benthic habitat analysis of ROV footage within the Montebello AMP

Survey Area	Summary
1	• Transect 1a was located within the KEF; Transects 1b and 1c were not. No potential features of the KEF (i.e. areas of hard substrate with high biodiversity) were seen along any of the transects surveyed. • Benthic habitat along all transects were typically bare sand with various bedforms including flat bare sand, small ripples (of 2D and 3D forms) and small 'steps' (<50 cm). • Some areas of seafloor were bare, while others were covered in a light bacterial mat and others were seen to have a cover of biologenic gravel (of unidentified origin). The cover of biologenic gravel changed continuously over the course of the transects. • No moderate or high relief features or areas of consolidated hard substrate were present within any transect. • Benthic organisms (including sponges and soft corals) were present on occasion and generally occurred as single or low density aggregations of individuals. The cover of benthic organisms in ranged from 0% to ~15% (highest in Transect 1c). • Bioturbation of the seafloor was evident in all three transects indicating the presence of mobile organisms living on and within the seabed. Mobile organisms including fish, echinoderms and jellies, were also noted on the video.
2	• The seafloor was relatively flat and sandy with a light to high cover of unconsolidated biologenic gravel and/or organic material. Small undulations of the seabed were seen but no other regular bedforms such as sand ripples or sand waves were apparent. • No significant high relief habitat features, or areas of consolidated hard substrate, were observed in any transect. • Some areas of seafloor were relatively bare while others included a low (~5%) to high (~80%) density cover of benthic organisms. This benthic cover changed continually and often (within m's) over each transect. Benthic fauna comprised a diverse array of sponges and corals with varying forms, sizes and colours. Hydroids and cnidarians were also apparent on occasion. • Bioturbation of the seafloor in the form of small cones, craters, burrows, small and large trails was also apparent. Mobile organisms including fish, echinoderms and jellies, were also noted on the videos.
3	• The seafloor in Area 3 was relatively flat and sandy with a light to high cover of biologenic gravel and/or organic material over its entire length (continually changing). Small undulations of the seabed and some small sand waves were present on occasion, but no other regular bedforms such as sand ripples or sand waves were apparent. • No significant moderate or high relief habitat features were observed on the video or can be seen on the transect maps with detailed bathymetry. Any features seen are in the order of ~1 m and occur over relatively large scales. • The seabed was a mosaic of bare substrate and low (~5%) to high (~75%) density cover of benthic organisms (e.g. sponges, corals). Benthic fauna comprised a diverse array of sponges and corals with varying forms, sizes and colours. Hydroids and cnidarians were also apparent on occasion along the transect length.

Survey Area	Summary
	• Bioturbation of the seafloor in the form of small cones, craters, burrows and small and large trails was apparent. Mobile organisms including fish, echinoderms and jellies, were also noted on the videos. Fish fauna diversity was quite high, and varying sizes of fish were seen amongst the aggregations of corals and sponges and also over bare sandy seafloor.
4	• The seafloor within Area 4 was typically flat sand with a high level of biologenic gravel of unknown origin. Small mounds, waves and undulations all < 50 cm in height were seen on occasion and mainly occurred around aggregations of benthic epifauna (i.e. sponges and corals). • No significant moderate or high relief features, or significant areas of consolidated hard substrate, were present in Area 4 as could be seen on the video or transect maps. • The seafloor in Area 4 was scattered with sponges and corals of varying forms and sizes; occurring as individuals with a low-density cover (~5%) up to more dense clusters (~50%). Other benthic epifauna included echinoderms (e.g. feather stars) and cnidaria (e.g. seapens). Mobile fauna (mainly small bony fishes) were most common around the larger clusters of sponges and corals. • Areas of bare sand were present amongst the patches of epifauna; and the switch between bare sand to benthic cover changed constantly and over short distances. • Bioturbation of the seafloor in the form of small mounds and craters was evident along the entire transect length.
5	• The seafloor consisted of flat sand, often with an organic cover (likely bacterial or algae) or a biologenic gravel component. The seafloor showed some slight undulation in places and scour marks commonly occurred around small ‘clusters’ of benthic epifauna (i.e. sponges and corals). No regular bedforms such as sand ripples or sand waves were present. • No significant moderate or high relief features were present. • Benthic epifauna occurred sporadically along the entire transect length and generally occurred as diverse ‘clusters’ of sponges and corals. These organisms were often large and were very diverse in form. The percentage cover of benthic organisms ranged from 5% to ~40%. • Mobile fauna were common around these clumps of sponges and corals; including echinoderms (e.g. sea stars, feather stars and sea cucumbers) and small bony fishes. • Bioturbation of the seafloor was common over the entire transect length and usually occurred in the form of thin trails, small mounds or craters.

Area 1

Area 2


Area 3


Area 4


Area 5 (note: transect does not cross the trunkline)

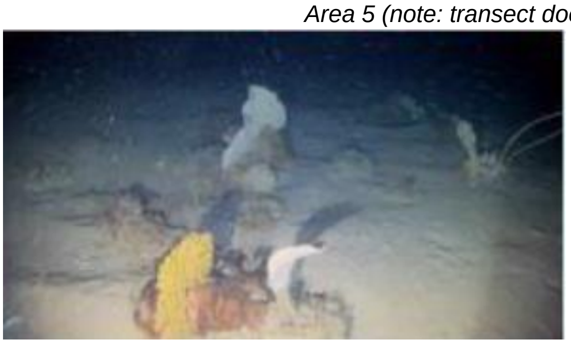
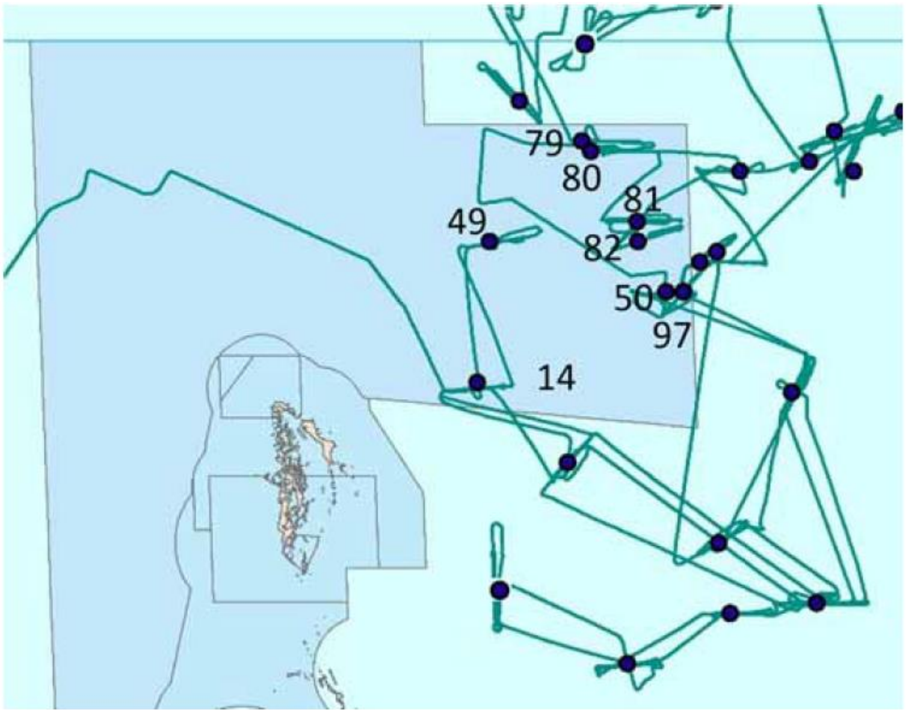



Figure 5.36: Example of ROV footage from the benthic habitat survey of the trunkline corridor within the Montebello Marine Park (photos selected from near the trunkline route)

Relatively recent previous surveys of benthic habitat data from areas on the North West Shelf (including the Montebello AMP) include the 2017 CSIRO *RV Investigator* voyage (Keesing, 2019) and the 2013 Pilbara Marine Conservation Partnership (PMCP) surveys (Pitcher et al., 2016). General findings of these studies are provided below.

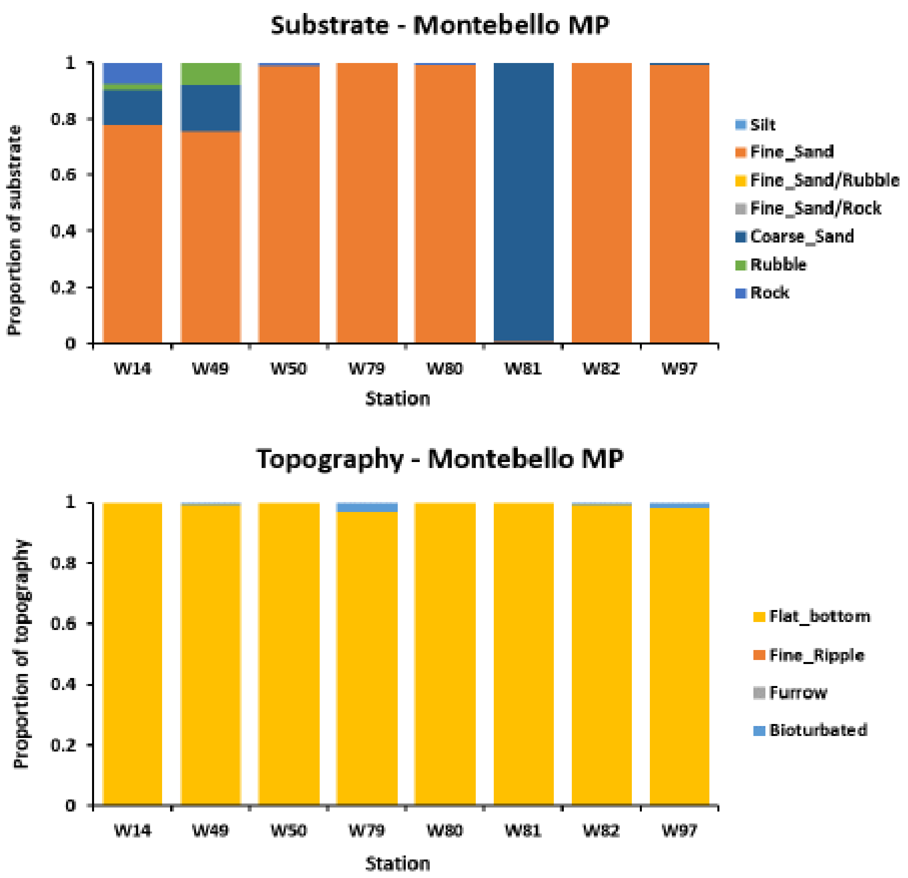
Data used to describe benthic substrates and biota from the 2017 CSIRO *RV Investigator* voyage were principally derived from still camera images. This study was predominantly undertaken in the eastern region of the AMP (Figure 5.37); with sites 79, 80, 81 and 82 being the closest to the Scarborough trunkline route (Figure 5.35). This study showed that topography in the vicinity of the Scarborough trunkline was predominantly flat bottom with some occasional bioturbated areas, and that the substrate was typically fine sands although site 81 was predominantly rock (Figure 5.38). These sites within the vicinity of the Scarborough trunkline had low numbers of sponges, whips and gorgonians (Figure 5.39) and as a result, complex benthic filter feeder communities were largely absent. The dominant filter feeders were hydroids, seapens and crinoids. The most commonly recorded crinoid was *Comatula rotalaria* which is free living on sand rather than associated with other filter feeders like gorgonians. Only site (81) had more than 50% of images with no biota however most sites had large areas characterised by soft sediment dwelling crinoids or hydroids and seapens.

The Keesing (2019) report did note that no imagery or biological samples had been collected in the northwestern part of the Montebello AMP as part of their study (or the previous 2013 PMCP study). Acoustic data was collected on a single swath path through part of the northwest region of the AMP (Figure 5.37), which did indicate rocky bottomed areas. However, this swath path is located south of the Scarborough trunkline. The substrate type and benthic habitat results from the Advisian (2019b) survey work towards filling this gap in data and are considered representative of habitats expected to be encountered by the Scarborough trunkline through the northwestern part of the Montebello AMP.



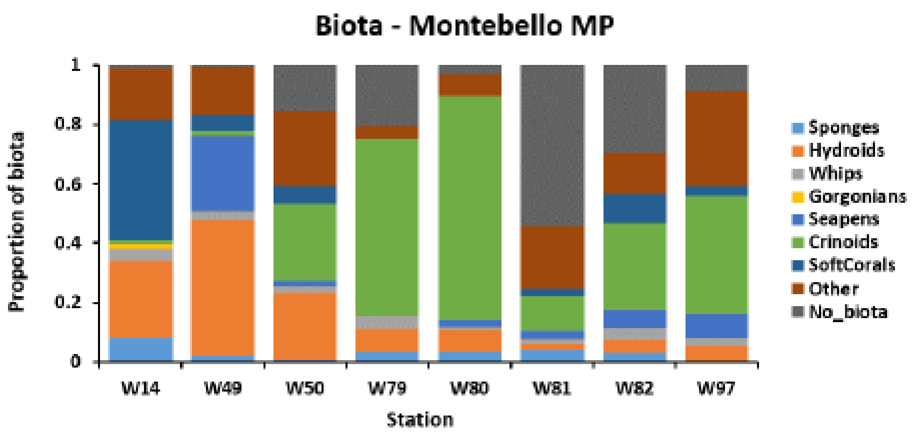
(Source: Keesing, 2019)

Figure 5.37: Location of sites surveyed swath mapping within the Montebello AMP during the 2017 study



(Source: Keesing, 2019)

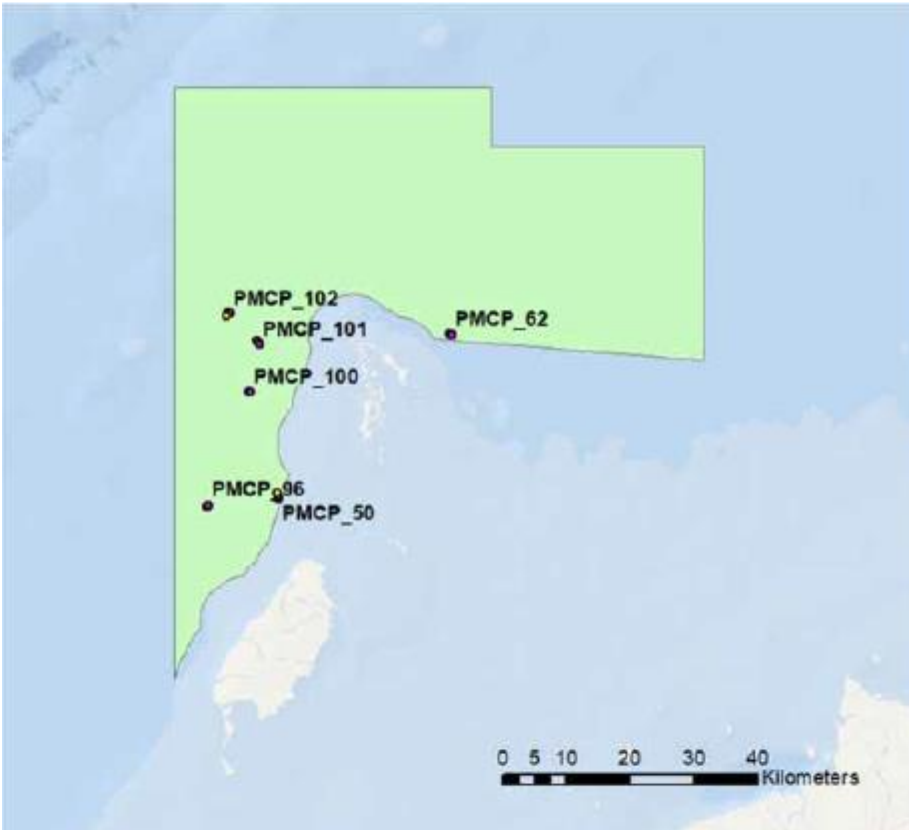
Figure 5.38: Proportion of substrate and topography types in seabed images from the RV Investigator survey



(Source: Keesing, 2019)

Figure 5.39: Proportion of benthic biota types in seabed images from the 2017 RV Investigator survey

The 2013 PMCP project included habitat and biodiversity mapping in the region between North West Cape and Barrow Island and the Montebello Islands; one of the studies included sites in what is now the Montebello AMP (Pitcher et al., 2016). All sites in the PMCP study were located much further south within the Montebello AMP than the Scarborough trunkline (Figure 5.40). Substrate type recorded by video at the 2013 survey sites was either fine or coarse sand at four sites and rippled at two sites located in the south-western section of the AMP. The towed video sites surveyed in the south-western part of the AMP had large proportions of video transects where no biota was evident. Dense sponges occurred at shallower sites on the central southern and south western section of the MP, west of the islands and a site also in the south-western section had a large proportion of gorgonian habitat.



(Source: Keesing, 2019)

Figure 5.40: Location of sites surveyed within the Montebello AMP during the 2013 study

The results of previous benthic studies in the Montebello AMP are largely in alignment with the findings of the current study in terms of the benthic habitat recorded (i.e. typically low relief sandy seafloor (with various bedforms) with occasional rubbly areas increasing at sites more inshore) and dominant benthic organisms identified (which varied in diversity and density within and between survey areas, but typically included a wide variety of sponges and soft corals including whips and gorgonians, hydroids, seapens and crinoids) (Advisian, 2019b). While the presence of benthic biota (e.g. sponge and soft corals) may provide a food source for marine turtles, given the variation in cover, the water depth, and lack of any significant high relief habitat features, the region in proximity to the Scarborough trunkline route is not considered to be representative of a significant turtle foraging habitat.

Details of the Montebello Marine Park values are provided below. These are taken directly from the North-west Marine Parks Network Management Plan 2018 (Director of National Parks, 2018).

The Montebello Marine Park is located offshore of Barrow Island and 80 km west of Dampier extending from the Western Australian state water boundary and is adjacent to the Western Australian Barrow Island and Montebello Islands Marine Parks (refer to Section 5.6.1). The Marine Park covers an area of 3413 km² and water depths from less than 15 m to 150 m.

The Marine Park was proclaimed under the EPBC Act on 14 December 2013 and renamed Montebello Marine Park on 9 October 2017. The Marine Park is assigned IUCN category VI and includes one zone assigned under this plan: Multiple Use Zone (VI).

The Montebello Marine Park is significant because it contains habitats, species and ecological communities associated with the Northwest Shelf Province. It includes one key ecological feature: the ancient coastline at the 125 m depth contour (valued as a unique seafloor feature with ecological properties of regional significance).

The Marine Park provides connectivity between deeper waters of the shelf and slope, and the adjacent Barrow Island and Montebello Islands Marine Parks. A prominent seafloor feature in the Marine Park is Trial Rocks consisting of two close coral reefs. The reefs are emergent at low tide.

Comparison of Montebello AMP and the adjacent Trawl Fishery Area

The Keesing (2019) report also completed a comparison between the Montebello AMP and the adjacent Trawl Fishery area as part of their study. This study notes that both the Pilbara Fish Trawl Fishery (PFTF) Area 1 and the Montebello AMP had a similar history of fishing effort up until about 1985, however there has been little or no trawling in the area that is now the Montebello AMP since that time.

Substrate type and topography of the seabed were similar between the two areas with predominantly flat bottom with fine sand substrate. Similar biota types (sponges, gorgonians, whips and other soft corals, hydroids, crinoids and sea pens) were present in the two areas. The exception to this was that sponge and whips were more abundant in PFTF Area 1, making up more than 50% of biota scored in images from 6 sites, while only one site in the Montebello AMP had more than 10% of biota scored as sponges or whips. The biomass of habitat forming filter feeder communities was also much greater (5.5 times higher) at sites in the PFTF Area 1 than in the Montebello MP.

Fish species diversity also differed between PFTF Area 1 sites and Montebello AMP sites and it was concluded that this could probably be attributable to the lesser availability of complex benthic filter feeder habitat in the AMP. There was also found to be a strong association between habitat forming benthic filter feeder biomass and fish biomass for most families of fish. In general fish biomass was much greater at stations within the PFTA Area 1 than in the Montebello AMP.

Natural Values

The Marine Park includes examples of ecosystems representative of the Northwest Shelf Province – a dynamic environment influenced by strong tides, cyclonic storms, long-period swells and internal tides. The bioregion includes diverse benthic and pelagic fish communities, and ancient coastline thought to be an important seafloor feature and migratory pathway for humpback whales. A key ecological feature of the Marine Park is the ancient coastline at the 125 m depth contour where rocky escarpments are thought to provide biologically important habitat in areas otherwise dominated by soft sediments.

The Marine Park supports a range of species including species listed as threatened, migratory, marine or cetacean under the EPBC Act. Biologically important areas within the Marine Park include breeding habitat for seabirds, internesting, foraging, mating, and nesting habitat for marine turtles, a migratory pathway for humpback whales and foraging habitat for whale sharks.

Cultural Values

Sea country is valued for Indigenous cultural identity, health and wellbeing. Across Australia, Indigenous people have been sustainably using and managing their sea country for tens of thousands of years. At the commencement of the North-west Marine Parks Network Management Plan 2018 (Director of National Parks, 2018), there is limited information about the cultural significance of this Marine Park. The Yamatji Marlpa Aboriginal Corporation is the Native Title Representative Body for the Pilbara region.

Heritage Values

No international, Commonwealth or national listings apply to the Marine Park at commencement of the North-west Marine Parks Network Management Plan 2018 (Director of National Parks, 2018), however the Marine Park is adjacent to the Western Australia Barrow Island and the

Montebello-Barrow Island Marine Conservation Reserves which have been nominated for national heritage listing (Director of National Parks, 2018).

The Marine Park contains two known shipwrecks listed under the Historic Shipwrecks Act 1976: Trial (wrecked in 1622), the earliest known shipwreck in Australian waters and Tanami (unknown date) (Director of National Parks, 2018).

Social and economic values

Tourism, commercial fishing, mining and recreation are important activities in the Marine Park. These activities contribute to the wellbeing of regional communities and the prosperity of the nation (Director of National Parks, 2018).

5.6.1.4 Dampier Archipelago National Heritage Property

The Dampier Archipelago (including Burrup Peninsula) is an indigenous class feature on the National Heritage List. The place comprises of parts of the Burrup Peninsula, Islands of the Dampier Archipelago and Dampier Coast. The Dampier Archipelago is sacred and home to Indigenous Australians. 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 Indigenous stone features, camp sites, quarries and shell middens which show a rich cultural and spiritual history dating back tens of thousands of years. Indigenous 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).

5.6.2 Ningaloo Coast and Gascoyne

5.6.2.1 Ningaloo Coast World and National Heritage Area

The Ningaloo Coast World Heritage Area (WHA) includes North West Cape and the Muiron Islands, and was inscribed, under criteria (vii) and criteria (x) by the World Heritage Committee onto the World Heritage Register in June 2011. The statement of Outstanding Universal Value for the Ningaloo coast was based on the natural criteria and recognised the following (UNESCO, 2011):

- **Criterion (vii)**: The landscapes and seascapes of the Ningaloo Coast WHA are comprised of mostly intact and large-scale marine, coastal and terrestrial environments. The lush and colourful underwater scenery provides a stark and spectacular contrast with the arid and rugged land. The property supports rare and large aggregations of Whale sharks (*Rhincodon typus*) along with important aggregations of other fish species and marine mammals. The aggregations in Ningaloo following the mass coral spawning and seasonal nutrient upwelling cause a peak in productivity that leads about 300–500 Whale sharks to gather, making this the largest documented aggregation in the world.
- **Criterion (x):** In addition to the remarkable aggregations of Whale sharks, the Ningaloo Reef harbours a high marine diversity of more than 300 documented coral species, over 700 reef fish species, roughly 650 mollusc species, as well as around 600 crustacean species and more than 1000 species of marine algae. The high numbers of 155 sponge species and 25 new species of echinoderms add to the significance of the area. On the ecotone, between tropical and temperate waters, the Ningaloo Coast hosts an unusual diversity of marine turtle species with an estimated 10,000 nests deposited along the coast annually.

The Ningaloo Coast WHA is recognised as being of outstanding conservation value, supporting a rich array of habitats and a diverse and abundant marine life (DoEE, n.d.). The region has a high diversity of marine habitats including coastal mangrove systems, lagoons, coral reef, open ocean, continental slope and the continental shelf (CALM, 2005). The dominant feature of the Ningaloo Coast WHA is Ningaloo Reef, the largest fringing reef in Australia. Ningaloo Reef supports both tropical and temperate species of marine fauna and flora and more than 300 species of coral (CALM, 2005).

The Ningaloo Coast WHA provides important nesting habitat for four species of marine turtle found in Western Australia. The North West Cape and Muiron Islands are major nesting sites for Loggerhead turtles, with about 400 and 600 females nesting annually on the Ningaloo Coast (particularly, North West Cape area) and Muiron Islands, respectively (Department of Environmental Protection, 2001). The North West Cape is also a major nesting habitat for Hawksbill and Green turtles, with an estimated 1000–1500 Green turtles nesting in the area annually (DEC, 2009). The Muiron Islands are minor nesting sites for Flatback and Hawksbill turtles (DEC, 2009).

It is these natural heritage values, iconic wilderness, seascapes, wildlife and biodiversity which are major attractions of the WHA and therefore the main driver for tourism on the North West Cape. All properties inscribed on the World Heritage List must have adequate management to ensure their protection, thus the Ningaloo WHA is managed via the Australian Marine Park and State marine park (see subsections below).

5.6.2.2 Ningaloo Australian Marine Park

The Ningaloo Marine Park is located 186 km from the Project Area. Details of the Ningaloo Marine Park values are provided below. These are taken directly from the North-west Marine Parks Network Management Plan 2018 (Director of National Parks, 2018).

The Ningaloo Marine Park stretches about 300 km along the west coast of the Cape Range Peninsula and is adjacent to the Western Australian Ningaloo Marine Park and Gascoyne Marine Park. The Marine Park covers an area of 2435 km^2 and a water depth range of 30 m to more than 500 m.

The Marine Park was originally proclaimed under the National Parks and Wildlife Conservation Act 1975 on 20 May 1987 as the Ningaloo Marine Park (Commonwealth Waters) and proclaimed under the EPBC Act on 14 December 2013 and renamed Ningaloo Marine Park on 9 October 2017. The Marine Park is assigned IUCN category IV and includes two zones assigned under this plan: National Park Zone (II) and Recreational Use Zone (IV).

The Ningaloo Marine Park is significant because it contains habitats, species and ecological communities associated with the Central Western Shelf Transition, Central Western Transition, Northwest Province, and Northwest Shelf Province. It includes three key ecological features: canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula (valued for unique seafloor features with ecological properties of regional significance); Commonwealth waters adjacent to Ningaloo Reef (valued for high productivity and aggregations of marine life); and continental slope demersal fish communities (valued for high levels of endemism and diversity).

The Marine Park provides connectivity between deeper offshore waters of the shelf break and coastal waters of the adjacent Western Australian Ningaloo Marine Park. It includes some of the most diverse continental slope habitats in Australia, in particular, the continental slope area between North West Cape and the Montebello Trough. Canyons in the Marine Park are important for their role in sustaining the nutrient conditions that support the high diversity of Ningaloo Reef.

The Marine Park is located in a transition zone between tropical and temperate waters and sustains tropical and temperate plants and animals, with many species at the limits of their distributions.

Natural Values

The Marine Park includes examples of ecosystems representative of:

- Central Western Shelf Transition – continental shelf of water depths up to 100 m, and a significant transition zone between tropical and temperate species
- Central Western Transition – characterised by large areas of continental slope, a range of topographic features such as terraces, rises and canyons, seasonal and sporadic upwelling, and benthic slope communities comprising tropical and temperate species
- Northwest Province – an area of continental slope comprising diverse and endemic fish communities
- Northwest Shelf Province – a dynamic environment, influenced by strong tides, cyclonic storms, long-period swells and internal tides. The bioregion includes diverse benthic and pelagic fish communities, and ancient coastline thought to be an important seafloor feature and migratory pathway for humpback whales.

Key ecological features of the Marine Park are:

- canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula –an area resulting in upwelling of nutrient rich water and aggregations of marine life
- Commonwealth waters adjacent to Ningaloo Reef – an area where the Leeuwin and Ningaloo currents interact, resulting in enhanced productivity and aggregations of marine life
- continental slope demersal fish communities – an area of high diversity among demersal fish assemblages on the continental slope.

Ecosystems represented in the Marine Park are influenced by interaction of the Leeuwin Current, Leeuwin Undercurrent and the Ningaloo Current.

The Marine Park supports a range of species including species listed as threatened, migratory, marine or cetacean under the EPBC Act. Biologically important areas within the Marine Park include breeding and or foraging habitat for seabirds, internesting habitat for marine turtles, a migratory pathway for humpback whales, foraging habitat and migratory pathway for pygmy blue whales, breeding, calving, foraging and nursing habitat for dugong and foraging habitat for whale sharks.

Cultural Values

Sea country is valued for Indigenous cultural identity, health and wellbeing. Across Australia, Indigenous people have been sustainably using and managing their sea country for tens of thousands of years. The Gnulli people have responsibilities for sea country in the Marine Park.

The Yamatji Marlpa Aboriginal Corporation is the Native Title Representative Body for the Yamatji region.

Heritage Values

World Heritage

The Marine Park is within the Ningaloo Coast World Heritage Property, recognised for its outstanding universal heritage values, meeting world heritage listing criteria vii and x. In addition to the Marine Park, the world heritage area includes the Western Australian Ningaloo Marine Park, the Muiron Islands, the Western Australian Cape Range National Park and other terrestrial areas. The area is valued for high terrestrial species endemism, marine species diversity and abundance, and the interconnectedness of large-scale marine, coastal and terrestrial environments. The area connects the limestone karst system and fossil reefs of the ancient Cape Range to the nearshore reef system of Ningaloo Reef, to the continental slope and shelf in Commonwealth waters.

National Heritage

The Ningaloo Coast overlaps the Marine Park and was established on the National Heritage List in 2010, meeting the national heritage listing criteria A, B, C, D and F.

Commonwealth Heritage

The Ningaloo Marine Area (Commonwealth waters) was established on the Commonwealth Heritage List in 2004, meeting Commonwealth heritage listing criteria A, B and C. The Ningaloo Marine Area overlaps the Marine Park.

Historic Shipwrecks

The Marine Park contains more than 15 known shipwrecks listed under the Historic Shipwrecks Act 1976.

Social and Economic Values

Tourism and recreation, including fishing, are important activities in the Marine Park. These activities contribute to the wellbeing of regional communities and the prosperity of the nation.

5.6.2.3 Ningaloo Marine Park and Muiron Islands Marine Management Area

The Ningaloo Marine Park (State waters) was established in 1987 and stretches 300 km from the North West Cape to Red Bluff. It encompasses the State waters covering the Ningaloo Reef system and a 40 m strip along the upper shore. The Muiron Islands Marine Management Area is managed under the same management plan as for the Ningaloo State Marine Park (CALM, 2005). The Ningaloo Marine Park is part of the Ningaloo Coast WHA. Whalebone is located within the Muiron Islands Marine Management Area

Ecological and conservation values of the Ningaloo Marine Park and Muiron Islands are summarised below. Generally, all ecological values are presumed to be in an undisturbed condition except for some localised high use areas (CALM, 2005). The ecological and conservation values include:

- Unique geomorphology has resulted in a high habitat and species diversity.
- There is high sediment and water quality.
- Subtidal and intertidal coral reef communities provide food, settlement substrate and shelter for marine flora and fauna.
- Filter feeding communities (sponge gardens) exist in the northern part of the North West Cape and the Muiron and Sunday Islands.
- Shoreline intertidal reef communities provide feeding habitat for larger fish and other marine animals during high tide.
- Soft sediment communities are found in deeper waters, characterised by a surface film of microorganisms that provide a rich source of food for invertebrates.
- Macroalgae and seagrass communities are an important primary producer providing habitat for vertebrate and invertebrate fauna.
- Mangrove communities occur only in the northern part of the Ningaloo Marine Park and are important for reef fish communities (Cassata and Collins, 2008) and support a high diversity of infauna, particularly, molluscs (600 mollusc species).

- There is diverse fish fauna (about 460 species).
- Foreshores and nearshore reefs of the Ningaloo coast and Muiron/Sunday islands provide inter-nesting, nesting and hatchling habitat for several species of marine turtles including the loggerhead, green, flatback and hawksbill turtles.
- Whale sharks aggregate annually to feed in the waters around Ningaloo Reef, from March to July, with the largest numbers being recorded around April and May (Sleeman et al., 2010). The season can be variable, with individual Whale sharks being recorded at other times of the year. Timing of the whale sharks' migration to and from Ningaloo coincides with the mass coral spawning period when there is an abundance of food (krill, planktonic larvae and schools of small fish) in the waters adjacent to Ningaloo Reef.
- Seasonal shark aggregations and Manta rays are commonly found in the area with a permanent population of manta rays (*Manta alfredi*) inhabiting the Ningaloo Reef. Numbers are boosted periodically by roaming and seasonal animals. Small aggregations coincide with small pulses of target prey and the spawning events of many reef inhabitants, while larger aggregations coincide with major seasonal spawning events. The number of species in the Ningaloo Reef area peaks during autumn, which corresponds to coral spawning, and during spring which corresponds with the crab spawning event (McGregor, 2008).
- Annual mass coral spawning on Ningaloo Reef. Synchronous, multi-specific spawning of tropical reef corals occurs during a brief predictable period in late summer/early autumn generally seven to nine nights after a full moon on neap, nocturnal ebb tides March/April each year (Rosser and Gilmour, 2008; Taylor and Pearce, 1999).
- Large coral slicks generally form over shallow reef areas in calm conditions. It is noted that there are minor spawning activities on the same nights after the February and April full moons, and in some years the mass spawning event occurs after the April full moon (Simpson et al., 1993a).
- Marine mammals such as dugong and small cetacean populations frequent or reside in nearshore waters. Dugong numbers in Ningaloo Marine Park are considered to be in the order of around 1000 individuals, with a similar number in Exmouth Gulf (CALM, 2005). The Ningaloo/Exmouth Gulf region supports a significant population of dugongs which is interconnected with the Shark Bay resident population (which represents less than 10% of the world's dugongs).
- Nesting and foraging habitat is present for seabirds and shorebirds. About 33 species of seabirds are recorded in the Ningaloo Marine Park (13 resident and 20 migratory) and there are five known rookeries as well isolated rookeries on the Muiron and Sunday Islands.

In addition to the ecological and conservation values, the Ningaloo Marine Park has a number of social values including culture heritage and marine based tourism and recreation (water-sports and fishing) (Section 0). The Ningaloo Marine Park (State waters) is contiguous with the Ningaloo Australian Marine Park.

Ningaloo Shoreline, Shallow Subtidal Reef and Intertidal Habitats

The Ningaloo Reef and lagoonal systems comprise a variety of shallow subtidal and intertidal communities that comprise shallow outer reef slope (spur and groove habitat), reef crest (emergent at low tide), reef flat (coralline algae and high cover tabular *Acropora* spp. coral communities), back reef lagoon (coral, soft sediment and macro-algal communities), sublittoral limestone platform (turf algae/molluscs/echinoderm community), and intertidal mangrove, mud flat and salt marsh communities (Cassata and Collins, 2008).

The area seaward of the reef crest is characterised by a coralline algae/coral community (spur and groove reef slope). The area has a series of perpendicular spur and grooves from 5 to 40 m depth range consisting of narrow, deep channels filled with sand and coral rubble and rock spurs with diverse hard coral communities (with dominant tabular *Acropora* spp. growing in small, compact colonies), together with soft corals, *Millepora* (fire coral), sponges and macroalgae. Coralline algae encrust dead corals, rocks and coral rubble. Coral growth is most prolific between 5 and 10 m depth.

On the landward side of the reef crest is a reef flat habitat and back reef lagoon with a number of subtidal and intertidal habitats (Cassata and Collins, 2008) as follows:

- Outer reef flat (very shallow, <1 m depth) at the back of the reef crest: Coralline algae/coral community (spur and groove). Similar morphology to the reef slope.
- Rocky middle/inner reef flat (approximately 1 m depth): Tabular *Acropora* spp. Community.
- Back reef lagoon (>2 m depth): Patchy staghorn, massive and sub-massive coral community.
- Lagoonal sand flat (1–2 m depth): Sparse corals and algae community. This habitat is characterised by sheltered areas of limestone pavement with a veneer of sand and small outcrops of corals (*Porites* spp., *Acropora* spp.) with scattered patches of macroalgae (*Sargassum* spp., *Halimeda* spp., *Caulerpa* spp.) or seagrass (*Halophila* spp.).
- Lagoonal and inter-reef sandy depressions (3–15 m depth): Coral 'bommies' and algal patch community. A distinctive habitat type composed of sandy depressions either found as large deep regions within the lagoon or small depressions/channels inside the reef flat.
- Lagoon, shoreward reef channels (shallow): Macroalgal community. Fleshy algae colonising subtidal limestone pavement that is covered in sand with *Sargassum* spp. up to 0.5 m high and other red and green algal species. There are also small patches of hard and soft corals, sponges and ascidians.
- Sublittoral limestone platform: Turf algae/mollusc/echinoderm community. This habitat is composed of a flat limestone pavement often contiguous with the rocky shoreline and supports intertidal and subtidal fauna comprising molluscs (limpets, chitons, small mussels, cowries and giant clams) and echinoderms (sea cucumbers, starfish and sea urchins) with isolated hard and soft coral colonies. The limestone pavement also has a ubiquitous coverage of turf algae.
- Mangrove coastal swamps: Although not a common habitat type within Ningaloo Marine Park, there are mangrove stands in the upper intertidal zone on a muddy substrate of carbonate silt and lay. The mangrove communities are located within the Mangrove Sanctuary Zone (where they occupy a large section of coast between Low Point and Mangrove Bay) and sporadically within the Osprey Sanctuary Zone on the Yardie Creek banks. There are three species of mangrove: *Avicennia marina*, *Rhizophora stylosa* and *Bruguiera exaristata*. *Avicennia marina* is most common and widespread. This habitat supports a diverse community of invertebrate fauna including gastropods, crabs and burrowing worms and is also a nursery area for the juveniles of many species of reef fish.
- Intertidal mud flats: Mud flats occur in the lower intertidal zone of the lagoon, formed from the deposition of mud in the sheltered tidal waters.

- Salt marshes: The salt marsh habitat is seaward of the mangroves and is represented by salt tolerant vegetation and sandy patches.

Muiron Islands Subtidal, Intertidal and Shoreline Habitats

Coastal sensitivity mapping identified the onshore sensitivities to be turtle rookeries and turtle nesting occurring from October to April (Joint Carnarvon Basin Operators, 2012). Most of the western coast consists of limestone coastal cliffs interspersed with sandy beaches and intertidal rock platforms. The nearshore sensitivities include the intertidal/nearshore reef (Joint Carnarvon Basin Operators, 2012). Soft coral communities dominate the reefs on the western side of the Muiron Islands. Habitats on the eastern side of the Muiron Islands are more sheltered, consisting of sandy beaches and shallow lagoons with diverse soft and hard coral communities (Cassata and Collins, 2008; Kobryn et al., 2013).

5.6.2.4 Gascoyne Australian Marine Park

The Gascoyne Marine Park is located 87 km from the Project Area. Details of the Gascoyne Marine Park values are provided below. These are taken directly from the North-west Marine Parks Network Management Plan 2018 (Director of National Parks, 2018).

The Gascoyne Marine Park is located approximately 20 km off the west coast of the Cape Range Peninsula, adjacent to the Ningaloo Reef Marine Park and the Western Australian Ningaloo Marine Park and extends to the limit of Australia's exclusive economic zone. The Marine Park covers an area of 81,766 km² and water depths between 15 m and 6000 m.

The Marine Park was proclaimed under the EPBC Act on 14 December 2013 and renamed Gascoyne Marine Park on 9 October 2017. The Marine Park is assigned IUCN category IV and includes three zones assigned under this plan: National Park Zone (II), Habitat Protection Zone (IV) and Multiple Use Zone (VI).

- The Gascoyne Marine Park is significant because it contains habitats, species and ecological communities associated with the Central Western Shelf Transition, Central Western Transition, and Northwest Province. It includes four key ecological features: Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula (valued for unique seafloor features with ecological properties of regional significance); Commonwealth waters adjacent to Ningaloo Reef (valued for high productivity and aggregations of marine life); continental slope demersal fish communities (valued for high levels of endemism and diversity); and the Exmouth Plateau (valued as a unique seafloor feature with ecological properties of regional significance).

The Gascoyne Marine Park includes some of the most diverse continental slope habitats in Australia, in particular the continental slope area between North West Cape and the Montebello Trough. Canyons in the Marine Park link the Cuvier Abyssal Plain to the Cape Range Peninsula and are important for their role in sustaining the nutrient conditions that support the high diversity of Ningaloo Reef.

<u>Natural Values</u>

The Marine Park includes examples of ecosystems representative of:

- Central Western Shelf Transition – continental shelf with water depths up to 100 m, and a significant transition zone between tropical and temperate species
- Central Western Transition – characterised by large areas of continental slope, a range of topographic features such as terraces, rises and canyons, seasonal and sporadic upwelling, and benthic slope communities comprising tropical and temperate species

- Northwest Province – an area of continental slope comprising diverse and endemic fish communities.

Key ecological features of the Marine Park are:

- canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula – an area resulting in upwelling of nutrient rich water and aggregations of marine life
- Commonwealth waters adjacent to Ningaloo Reef – an area where the Leeuwin and Ningaloo currents interact resulting in enhanced productivity and aggregations of marine life
- continental slope demersal fish communities – an area of high diversity of demersal fish assemblages on the continental slope
- Exmouth Plateau – a regionally and nationally unique deep-sea plateau in tropical waters.

Ecosystems represented in the Marine Park are influenced by the interaction of the Leeuwin Current, Leeuwin Undercurrent and the Ningaloo Current.

The Marine Park supports a range of species including species listed as threatened, migratory, marine or cetacean under the EPBC Act. Biologically important areas within the Marine Park include breeding habitat for seabirds, internesting habitat for marine turtles, a migratory pathway for humpback whales, and foraging habitat and migratory pathway for pygmy blue whales.

Cultural Values

Sea country is valued for Indigenous cultural identity, health and wellbeing. Across Australia, Indigenous people have been sustainably using and managing their sea country for tens of thousands of years. The Gnulli people have responsibilities for sea country in the Marine Park.

The Yamatji Marlpa Aboriginal Corporation is the Native Title Representative Body for the Yamatji region.

Heritage Values

World Heritage

The Ningaloo Coast was listed as an area of outstanding universal value under the World Heritage Convention in 2011, meeting world heritage listing criteria vii and x. The Ningaloo Coast World Heritage Property is adjacent to the Marine Park.

Commonwealth Heritage

The Ningaloo Marine Area (Commonwealth waters) was established on the Commonwealth Heritage List in 2004, meeting the Commonwealth heritage listing criteria A, B and C. The Ningaloo Marine Area is adjacent to the Marine Park.

National Heritage

The Ningaloo Coast was established on the National Heritage List in 2010, meeting the national heritage listing criteria A, B, C, D, and F and is adjacent to the Marine Park.

Historic Shipwrecks

The Marine Park contains more than five known shipwrecks listed under the Historic Shipwrecks Act 1976.

<u>Social and Economic Values</u>

Commercial fishing, mining and recreation are important activities in the Marine Park. These activities contribute to the wellbeing of regional communities and the prosperity of the nation.

5.6.3 Shark Bay

5.6.3.1 Shark Bay World and National Heritage Areas

Shark Bay is a natural class feature on the World and National Heritage List.

Shark Bay is a large, shallow bay with associated peninsulas and islands on the coast of WA. The place, which has a total area of 22,000 km^2, includes the marine and estuarine areas of the bay, together with the peninsulas and islands projecting into it and adjacent areas of the mainland including the coastal strip along the eastern coast and the region immediately to the south.

Shark Bay has three exceptional natural features: its vast sea-grass beds, which are the largest (4,800 km^2) and richest in the world; its dugong population; and its stromatolites (colonies of algae which form hard, dome-shaped deposits and are among the oldest forms of life on earth). Shark Bay is also home to five species of endangered mammals.

The Shark Bay World Heritage Area (WHA) was inscribed, under criteria (vii), (viii), (ix) and (x) by the World Heritage Committee onto the World Heritage Register in 1991. The statement of Outstanding Universal Value for the Ningaloo coast was based on the natural criteria and recognised the following (UNESCO, 1991):

- **Criterion (vii):** One of the superlative natural phenomena present in this property is its stromatolites, which represent the oldest form of life on Earth and are comparable to living fossils. Shark Bay is also one of the few marine areas in the world dominated by carbonates not associated with reef-building corals. This has led to the development of the Wooramel Seagrass Bank within Shark Bay, one of the largest seagrass meadows in the world with the most seagrass species recorded from one area. These values are supplemented by marine fauna such as dugong, dolphins, sharks, rays, turtles and fish, which occur in great numbers. The hydrologic structure of Shark Bay, altered by the formation of the Faure Sill and a high evaporation, has produced a basin where marine waters are hypersaline (almost twice that of seawater) and contributed to extensive beaches consisting entirely of shells. The profusion of peninsulas, islands and bays create a diversity of landscapes and exceptional coastal scenery.
- **Criterion (viii):** Shark Bay contains, in the hypersaline Hamelin Pool, the most diverse and abundant examples of stromatolites in the world. Analogous structures dominated marine ecosystems on Earth for more than 3,000 million years. The stromatolites of Hamelin Pool were the first modern, living examples to be recognised that have a morphological diversity and abundance comparable to those that inhabited Proterozoic seas. As such, they are one of the world's best examples of a living analogue for the study of the nature and evolution of the earth's biosphere up until the early Cambrian. The Wooramel Seagrass Bank is also of great geological interest due to the extensive deposit of limestone sands associated with the bank, formed by the precipitation of calcium carbonate from hypersaline waters.
- **Criterion (ix):** Shark Bay provides outstanding examples of processes of biological and geomorphic evolution taking place in a largely unmodified environment. These include the evolution of the Bay's hydrological system, the hypersaline environment of Hamelin Pool and the biological processes of ongoing speciation, succession and the creation of refugia. One of the exceptional features of Shark Bay is the steep gradient in salinities, creating three biotic zones that have a marked effect on the

distribution and abundance of marine organisms. Hypersaline conditions in Hamelin Pool have led to the development of a number of significant geological and biological features including the 'living fossil' stromatolites. The unusual features of Shark Bay have also created the Wooramel Seagrass Bank. Covering 103,000 ha, it is the largest structure of its type in the world.

- **Criterion (x):** Shark Bay is a refuge for many globally threatened species of plants and animals. The property is located at the transition zone between two of Western Australia's main botanical provinces, the arid Eremaean, dominated by Acacia species and the temperate South West, dominated by Eucalyptus species, and thus contains a mixture of two biotas, many at the limit of their southern or northern range. The property contains either the only or major populations of five globally threatened mammals, including the Burrowing Bettong (now classified as Near Threatened), Rufous Hare Wallaby, Banded Hare Wallaby, the Shark Bay Mouse and the Western Barred Bandicoot. A number of globally threatened plant and reptile species also occur in the terrestrial part of the property. Shark Bay's sheltered coves and lush seagrass beds are a haven for marine species, including Green Turtle and Loggerhead Turtle (both Endangered, and the property provides one of Australia's most important nesting areas for this second species). Shark Bay is one of the world's most significant and secure strongholds for the protection of Dugong, with a population of around 11,000. Increasing numbers of Humpback Whales and Southern Right Whales use Shark Bay as a migratory staging post, and a famous population of Bottlenose Dolphin lives in the Bay. Large numbers of sharks and rays are readily observed, including the Manta Ray which is now considered globally threatened.

5.6.3.2 Dirk Hartog Landing – Cape Inscription National Heritage Area

The Dirk Hartog Landing is a historic class feature on the National Heritage List.

Cape Inscription is the site of the oldest known landings of Europeans on the Western Australian coast and is associated with a series of landings and surveys by notable explorers over a 250-year period. The first known European landing on the west coast of Australia was by Dirk Hartog of the Dutch East India Company's ship the Eendracht at Cape Inscription on 25 October 1616. Hartog left a pewter plate, inscribed with a record of his visit and nailed to a post left standing upright in a rock cleft on top of the cliff. This plate is the oldest extant record of a European landing in Australia.

5.6.3.3 Carnarvon Canyon Australian Marine Park

The Carnarvon Canyon Marine Park is located 405 km from the Project Area. Details of the Carnarvon Canyon Marine Park values are provided below. These are taken directly from the North-west Marine Parks Network Management Plan 2018 (Director of National Parks, 2018).

The Carnarvon Canyon Marine Park is located approximately 300 km north-west of Carnarvon. It covers an area of 6177 km^2 and a water depth range of 1500–6000 m.

The Marine Park was proclaimed under the EPBC Act on 14 December 2013 and renamed Carnarvon Canyon Marine Park on 9 October 2017. The Marine Park is assigned IUCN category IV and includes one zone assigned under this plan: Habitat Protection Zone (IV).

The Carnarvon Canyon Marine Park is significant because it contains habitats, species and ecological communities associated with the Central Western Transition. This includes deep-water ecosystems associated with the Carnarvon Canyon. The Marine Park lies within a transition zone between tropical and temperate species and is an area of high biotic productivity.

Natural values

The Marine Park includes examples of ecosystems representative of the Central Western Transition—a bioregion characterised by large areas of continental slope, a range of topographic features such as terraces, rises and canyons, seasonal and sporadic upwelling, and benthic slope communities comprising tropical and temperate species. It includes the Carnarvon Canyon, a single-channel canyon covering the entire depth range of the Marine Park.

Ecosystems of the Marine Park are influenced by tropical and temperate currents, deep-water environments and proximity to the continental slope and shelf. The soft-bottom environment at the base of the Carnarvon Canyon is likely to support species that are typical of the deep seafloor (e.g. holothurians, polychaetes and sea-pens).

The Marine Park supports a range of species, including species listed as threatened, migratory, marine or cetacean under the EPBC Act. There is limited information about species' use of this Marine Park.

Cultural values

Sea country is valued for Indigenous cultural identity, health and wellbeing. Across Australia, Indigenous people have been sustainably using and managing their sea country for tens of thousands of years.

Heritage values

No international, Commonwealth or national heritage listings apply to the Marine Park at commencement of this plan.

Social and economic values

Commercial fishing is an important activity in the Marine Park. These activities contribute to the wellbeing of regional communities and the prosperity of the nation.

5.6.3.4 Shark Bay Australian Marine Park

The Shark Bay Marine Park is located 475 km from the Project Area. Details of the Shark Bay Marine Park values are provided below. These are taken directly from the North-west Marine Parks Network Management Plan 2018 (Director of National Parks, 2018).

The Shark Bay Marine Park is located approximately 60 km offshore of Carnarvon, adjacent to the Shark Bay world heritage property and national heritage place. The Marine Park covers an area of 7443 km², extending from the Western Australian state water boundary, and a water depth range between 15 m and 220 m.

The Marine Park was proclaimed under the EPBC Act on 14 December 2013 and renamed Shark Bay Marine Park on 9 October 2017. The Marine Park is assigned IUCN category VI and includes one zone assigned under this plan: Multiple Use Zone (VI).

The Shark Bay Marine Park is significant because it contains habitats, species and ecological communities associated with the Central Western Shelf Province and Central Western Transition. The Marine Park provides connectivity between deeper Commonwealth waters and the inshore waters of the Shark Bay world heritage property.

Natural values

The Marine Park includes examples of ecosystems representative of:

• Central Western Shelf—a predominantly flat, sandy and low-nutrient area, in water depths 50–100 m. The bioregion is a transitional zone between tropical and temperate species; and

• Central Western Transition—characterised by large areas of continental slope, a range of topographic features such as terraces, rises and canyons, seasonal and sporadic upwelling, and benthic slope communities comprising tropical and temperate species.

Ecosystems represented in the Marine Park are influenced by the Leeuwin, Ningaloo and Capes currents.

The Marine Park supports a range of species including species listed as threatened, migratory, marine or cetacean under the EPBC Act. Biologically important areas within the Marine Park include breeding habitat for seabirds, internesting habitat for marine turtles, and a migratory pathway for humpback whales. The Marine Park and adjacent coastal areas are also important for shallow-water snapper.

Cultural values

Sea country is valued for Indigenous cultural identity, health and wellbeing. Across Australia, Indigenous people have been sustainably using and managing their sea country for tens of thousands of years. The Gnulli and Malgana people have responsibilities for sea country in the Marine Park.

The Yamatji Marlpa Aboriginal Corporation is the Native Title Representative Body for the Yamatji region.

Heritage values

No international, Commonwealth or national heritage listings apply to the Marine Park at commencement of this plan, but the Marine Park is adjacent to the Shark Bay, Western Australia World Heritage Property and Shark Bay, Western Australia National Heritage Place.

Historic shipwrecks

The Marine Park contains approximately 20 known shipwrecks listed under the Historic Shipwrecks Act 1976.

Social and economic values

Tourism, commercial fishing, mining and recreation, including fishing, are important activities in the Marine Park. These activities contribute to the wellbeing of regional communities and the prosperity of the nation.

5.6.3.5 Shark Bay Marine Park

The Shark Bay Marine Park was gazetted on 30 November 1990 as A-Class Marine Park Reserve No. 7 and vested in the National Park and Nature Conservation Authority (NPNCA) under the CALM Act. The State Marine Park encompassing an area of 748,725 ha.

Shark Bay is of international significance, having been inscribed on the World Heritage List in 1991 in recognition of the area's outstanding universal natural values (Section 5.6.3.1).

The region contains an outstanding example of Earth's evolutionary history in the stromatolites and hypersaline environment of Hamelin Pool. There are significant ongoing geological and biological processes in both the marine and terrestrial environments of Shark Bay. The Faure Sill and Wooramel Seagrass Bank are examples of the many superlative natural phenomena or features to be found in the World Heritage Area. The World Heritage Area provides the habitat of a number of rare and threatened species with many others at the limit of their range. Shark Bay is also noted for its natural beauty and in particular the diversity of its land and seascapes.

Shark Bay is renowned for its marine fauna, including the dugong which is estimated to be one of the largest populations in the world. Humpback whales use the Bay as a staging area in their migration along the coast. Green and loggerhead turtles occur in the Bay with Dirk Hartog Island providing an important nesting site for loggerheads in Western Australia.

5.6.4 Pilbara Inshore Islands Nature Reserve

The Pilbara Inshore Islands Nature Reserves are mostly small, remote islands that are important breeding and resting places for migratory shorebirds, seabirds and marine turtles. Several threatened species rely on the islands as a refuge protected from disturbance or threats like introduced predators, light/noise pollution, wildfire and vehicles on beaches.

Four species of marine turtle (green, loggerhead, hawksbill and flatback) nest on inshore islands with major nesting beaches on the Muiron, Locker, Thevenard, Serrurier and Sholl Islands.

Around one million wedge-tailed shearwaters migrate to the area each year. They visit the islands (particularly the Muiron and Serrurier) from July onwards in order to prepare a burrow for nesting in when November arrives. During the day the adult birds are out feeding and return to their burrows every evening. Bird species that live on the islands all year round include the Beach Stone-curlew, Pied and Sooty Oystercatcher and Fairy Tern.

5.6.5 Protected Wetlands

5.6.5.1 Ramsar Wetlands of International Importance

The Project Area does not intersect with any wetlands of international importance.

The closest RAMSAR site is Eighty Mile Beach (Site number 480) located about 240 km east of the Project Area and outside the EMBA. Eighty Mile Beach provides continuous intertidal mudflat in excellent condition which supports feeding and stop-over for migratory shorebirds. It also supports the Flatback turtle, which is an IUCN listed species.

5.6.5.2 Nationally Important Wetlands

The Project Area does not intersect with any wetlands of national importance. However, the EMBA overlaps the following Nationally Important Wetlands:

- Exmouth Gulf East
- Hamelin Pool
- Learmonth Saline Coastal Flats
- Shark Bay East.

Exmouth Gulf East is classified as a marine and coastal zone wetland, and occurs within the eastern part of Exmouth Gulf, from Giralia Bay to Urala Creek Locker Point. The wetland has been identified as an outstanding example of tidal wetland systems of low coast of north-west Australia, with well-developed tidal creeks, extensive mangrove swamps and broad saline coastal flats. The site is one of the major population centres for dugongs in Western Australia, and its seagrass beds and extensive mangroves provide nursery and feeding areas for marine fishes and crustaceans in the Gulf (DOEE 2019).

Hamelin Pool is classified as a marine and coastal zone wetland and occurs in the far south-east part of Shark Bay. The wetland has been identified as an outstanding example of a hypersaline marine embayment. Hamelin Pool supports extensive microbialite (subtidal stromatolite or 'layered' and intertidal thrombolite or 'clotted') formations, which are the most abundant and diverse examples of growing marine microbialites in the world. There is no emergent vegetation below the usual high-water mark, though the surrounding land supports tall shrubland.

Very little is known about the Learmonth Saline Coastal Flats site, except that it represents typical saline coastal flats subject to inundation and ponding. This vegetation type typically has low species richness, but its floristic composition and structure is highly distinctive and supports habitat specific fauna.

Shark Bay East is classified as a marine and coastal zone wetland, and occurs on the east arm of Shark Bay, from the mouth of the Gascoyne River south to Hamelin Pool. The wetland is considered to be an outstanding example of a very large, shallow marine embayment, with particularly extensive occurrence of seagrass beds and substantial areas of intertidal mud/sand-flats and mangrove swamp. The site supports what is probably the world's largest discrete population of *Dugong dugon*; it is also a major nursery and/or feeding area for turtles, rays, sharks, other fishes, prawns and other marine fauna; and is a major migration stop-over area for shorebirds. Plant structural formations: Mangrove in low closed-forest, closed-scrub and open-scrub form in periform arrangement on the Carnarvon to Bush Bay coast, at Faure Island and at Guichenault Point; low shrubland (samphire) occurs behind mangroves and in areas not occupied by mangroves, especially in the north-east of the site (DOEE 2019).

5.6.6 Cultural Heritage

5.6.6.1 World Heritage Properties

No World Heritage Properties occur within the Project Area. Ningaloo Coast and Shark Bay World Heritage Area occurs in the EMBA and is described in Section 5.6.2 and 5.6.3.

5.6.6.2 National Heritage Places

No National Heritage Places occur within the Project Area. The Dampier Archipelago, Ningaloo Coast, Shark Bay and Dirk Hartog/Cape Inscription National Heritage Areas occur in the EMBA and is described in Sections 5.6.1, 5.6.2 and 5.6.3 respectively.

5.7 Socio-Economic Values

Socio-economic values in the NWMR include:

- Commercial Fisheries (Commonwealth and State)
- Recreation and Tourism
- Shipping
- Oil and Gas exploration and operation
- Defence.

Potential socio-economic receptors occurring the Project Area and EMBA are detailed in the following sections.

5.7.1 Commonwealth Managed Fisheries

The Australian Fisheries Management Authority (AFMA) manages the Commonwealth-managed commercial fisheries under the Fisheries Management Act 1991. Fisheries typically operate within 3 nm to 200 nm offshore (i.e. to the extent of the Australian Fishing Zone). Commonwealth fisheries generated an estimated gross value of production (GVP) of $403 million in 2016–17, accounting for 23% of wild-catch fisheries GVP in Australia ($1.75 billion) (Patterson et al., 2018).

There are five Commonwealth-managed commercial fisheries that have management areas within the Project Area. No additional Commonwealth fisheries overlap the EMBA. However, one of these fisheries is currently not active (Western Skipjack) and three have actual fishing efforts that have only occurred beyond the Project Area in recent years (Southern Bluefin Tuna, Western Tuna and Billfish and Western Deepwater Trawl) (Patterson et al., 2018). The Northwest Slope Trawl Fishery is likely to be the only fishery that may have active fishing areas intersecting with the Project Area given recent fishing records.

The following commercial fisheries may overlap with the Project Area and are discussed below in further detail:

- Western Skipjack Tuna Fishery (Offshore Project Area and Trunkline Project Area)
- Southern Bluefin Tuna Fishery (Offshore Project Area and Trunkline Project Area)
- Western Deepwater Trawl Fishery (Offshore Project Area and Trunkline Project Area)
- Western Tuna and Billfish Fishery (Trunkline Project Area)
- Northwest slope trawl fishery (Trunkline Project Area).

5.7.1.1 Western Skipjack Tuna Fishery (Offshore Project Area/Trunkline Project Area/Borrow Grounds Project Area)

The Western Skipjack Tuna Fishery (WSTF) extends around the whole of Australia in waters out to 200 nm, using mainly purse seine fishing gear (98%) and some pole-and-line effort (Patterson et al., 2018). There has been no fishing effort in the WSTF since the 2008–09 fishing season (Patterson et al., 2018).

Given the lack of fishing effort across the whole fishery, activity within the Project Area is not expected.

5.7.1.2 Southern Bluefin Tuna Fishery (Offshore Project Area/Trunkline Project Area/Borrow Grounds Project Area)

The southern Bluefin Tuna Fishery (SBTF) extends around the whole of Australia in waters out to 200 nm. The fishery typically uses a mix of purse seine and pelagic longline fishing gear, although since 1992, most of the Australian catch has been taken by purse seine in the Great Australian Bight. The catch, comprising juvenile bluefin tuna, is transferred to aquaculture farming operations off the coast of Port Lincoln, South Australia (SA), where the fish are grown to a larger size to achieve higher market prices (Patterson et al., 2018). A smaller proportion of catch is taken by longline along the east coast of Australia (Patterson et al., 2018).

Although the fishery boundaries encompass the Project Area, the lack of effort outside the Great Australian Bight and the east coast of Australia, activity within the Project Area is not expected.

5.7.1.3 Western Deepwater Trawl Fishery (Offshore Project Area/Trunkline Project Area/Borrow Grounds Project Area)

The Western Deepwater Trawl Fishery (WDTF) operates in Commonwealth waters off the coast of WA with the northern boundary of the fishery adjacent to the western boundary of the North West Slope Trawl Fishery (NWSTF) (see below). Using demersal trawl methods, fishers catch more than 50 species in habitats ranging from temperate–subtropical in the south to tropical in the north (Patterson et al., 2018). Catches in the WDTF were historically dominated by six commercial finfish species or species groups: Orange roughy (*Hoplostethus atlanticus*), Oreos (*Oreosomatidae*), Boarfish (Pentacerotidae), Eteline snapper (Lutjanidae: Etelinae), Apsiline snapper (Lutjanidae: Apsilinae) and Sea bream (*Lethrinidae*). Between 2000 and 2005, deepwater bugs (*Ibacus* spp.) were the most important target species (Patterson et al., 2018). Total fishing effort has been comparatively low since 2005–06; a single vessel was active in the 2016–17 fishing season, resulting in low catches, following two years of no effort (Patterson et al., 2018).

Given the low fishing effort reported for the fishery as a whole, activity within the Project Area is not expected.

5.7.1.4 Western Tuna and Billfish Fishery (Offshore Project Area/Trunkline Project Area/Borrow Grounds Project Area)

The Western Tuna and Billfish Fishery (WTBF) has a wide area of operation, extending from the tip of Cape York around Western Australia to the border of Victoria and South Australia within both the Australian Fishing Zone and further ashore within the high seas, with major landing ports for the fishery being in Fremantle and Geraldton (Patterson et al., 2018). The WTBF targets a range of species including; Bigeye tuna (*Thunnus obesus*), Yellowfin tuna (*Thunnus albacares*), Swordfish (*Xiphias gladius*) and Striped marlin (*Kajikia audax*) using mainly pelagic longline fishing methods and some use of minor-line fishing methods (Patterson et al., 2018). Economic details of the fishery are not available due to confidentiality.

Although the fishery boundaries encompass the Project Area, in recent years, effort has concentrated off south-west WA and SA and therefore activity within the Project Area is not expected.

5.7.1.5 Northwest Slope Trawl Fishery (Offshore Project Area/Trunkline Project Area/Borrow Grounds Project Area)

The Northwest Slope Trawl Fishery (NWSTF) operates off north-western Australia in deep water from the coast of the Prince Regent National Park to Exmouth, roughly between the 200 m depth contour to the outer limit of the Australian Fishing Zone (AFZ). The default fishing season is 12 months, commencing on 1 July each year. Fishers use demersal trawl methods; with major landing ports in Darwin and Point Samson. The NWSTF is managed by limited entry and operators must hold permits to fish. Active vessels are typically one to two each year (Patterson et al., 2018). Recent economic data for this fishery is not available (Patterson et al., 2018).

The NWSTF has predominantly been a scampi fishery in recent years, with the key species being Australian scampi (*Metanephrops australiensis*), with smaller quantities of Velvet scampi (*Metanephrops velutinus)* and Boshma's scampi (*Metanephrops boschmai*). Deepwater prawns, including the Red prawn (*Aristaeomorpha foliacea*), were previously targeted in this fishery. Between 2015 and 2016, total catch of scampi species was 33 tonnes (Patterson et al., 2018).

During 2016–2017, active fishing occurred in two sub-areas of the NWSTF management area; the Trunkline Project Area may intersect with the most southern of these areas (Figure 5.41). In the same period, two fishing vessels were active over 114 days (Patterson et al., 2018).

Given the Trunkline Project Area overlaps with an area of known activity, fishing vessels may occur in the Trunkline Project Area. Fishing effort for the NWSTF does not extend into the Borrow Ground Project Area or the Offshore Project Area.

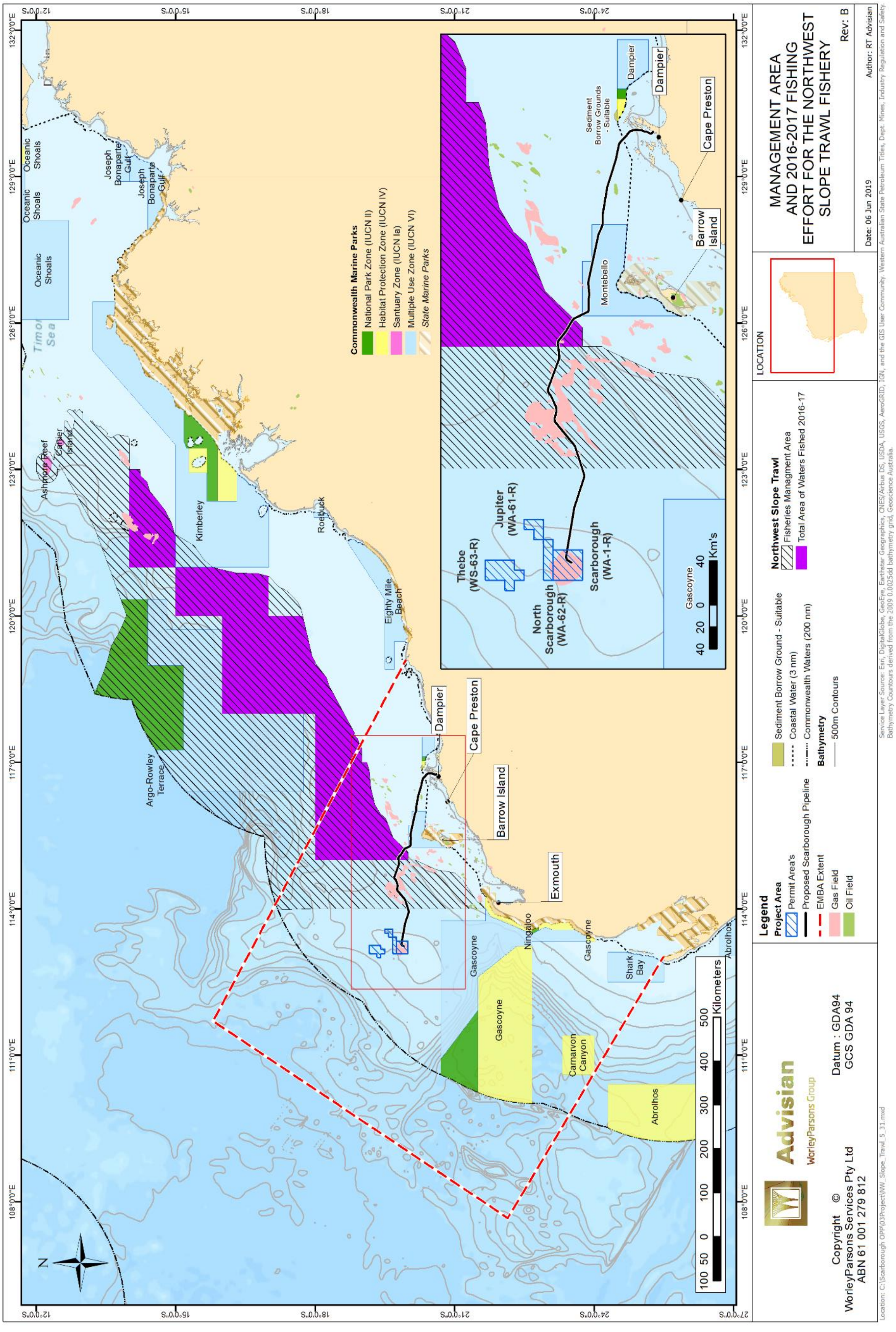


Figure 5.41: Management area and 2016–2017 fishing effort for the Northwest Slope Trawl Fishery

5.7.2 State Managed Fisheries

The WA Department of Fisheries (DoF) manages the State commercial fisheries under the *Fish Resources Management Act 1994*, Fisheries Resources Management Regulations 1995, relevant gazetted notices and licence conditions and applicable Fishery Management Plans.

The principal State commercial fisheries focus on tropical finfish, particularly the high-value emperors, snappers and cods that are taken by the Pilbara Trap and Trawl Fishery and the Northern Demersal Scalefish Fishery (Gaughan & Santoro, 2018). Other fisheries present within the NWMR also target mollusc, crustacean and echinoderm species. The Project Area lies within the following two defined bioregions:

- Gascoyne Coast
- North Coast.

The Gascoyne Coast bioregion is dominated mainly by invertebrate stock resources, with three fisheries (Shark Bay Prawn, Exmouth Gulf and Shark Bay Scallop fisheries) making an average annual combined value of $40–$50 million. Of the approximately 1400 known species within the bioregion, only a small portion of species are targeted including; scallops, penaeid prawns, blue swimmer crabs and deep-sea crabs. The North Coast bioregion has 15 operating fisheries within its waters targeting a range of organisms including crustaceans, finfish, echinoderms and molluscs.

Of the 15 fisheries that operate within these bioregions in the North Coast bioregion, seven state managed fisheries have the potential to undertake fishing activities within the Project Area. These fisheries include the:

- West Coast Deep Sea Crustacean Managed Fishery (Offshore Project Area and Trunkline Project Area)
- South West Coast Salmon Fishery (Offshore Project Area and Trunkline Project Area)
- Mackerel Managed Fishery (Offshore Project Area and Trunkline Project Area)
- Pilbara Demersal Scalefish Fisheries (Trunkline Project Area)
- Pearl Oyster Managed Fishery (Trunkline Project Area)
- Onslow Prawn Fishery (North Coast Prawn Managed Fisheries) (Trunkline Project Area)
- West Coast Roe’s Abalone Resource (Trunkline Project Area)
- Marine Aquarium Managed Fishery (Trunkline Project Area)
- Specimen Shell Fishery (Trunkline Project Area).

Additional state-managed fisheries which overlap the EMBA include:

- Exmouth Gulf Prawn Managed Fishery
- Nickol Bay Prawn Fishery (North Coast Prawn Managed Fisheries)
- West Coast Rock Lobster Fishery.

5.7.2.1 West Coast Deep Sea Crustacean Managed Fishery (Offshore Project Area/Trunkline Project Area/Borrow Grounds Project Area)

The West Coast Deep Sea Crustacean Managed Fishery (WCDSC) operates along the coast of Western Australia within the Gascoyne Coast bioregion in Commonwealth waters, north of latitude 34° 24' S within water depths >150 m. Fishing is generally concentrated in deeper waters on the continental slope within water depths of 500–800 m (How and Nardi, 2014). Crystal (snow) crab

(*Chaceon albus*) stocks support the bulk of this fishery with other species including Giant (king) crabs (*Pseudocarcinus gigas*) and Champagne (Spiny) crabs (*Hypothalassia acerba*) also targeted (How et al., 2015). Fishing methods used for these species are restricted to baited pots on the seafloor (Fletcher and Santoro, 2013). The total landings in 2016 was 153.3 t (Fletcher and Santoro, 2018).

The Project Area is located within the fishery boundaries (Figure 5.42). Furthermore, the Offshore Project Area and deeper waters of the Trunkline Project Area occur in water depths known to be fished (500–800 m). Therefore, fishing effort may occur within the Project Area.

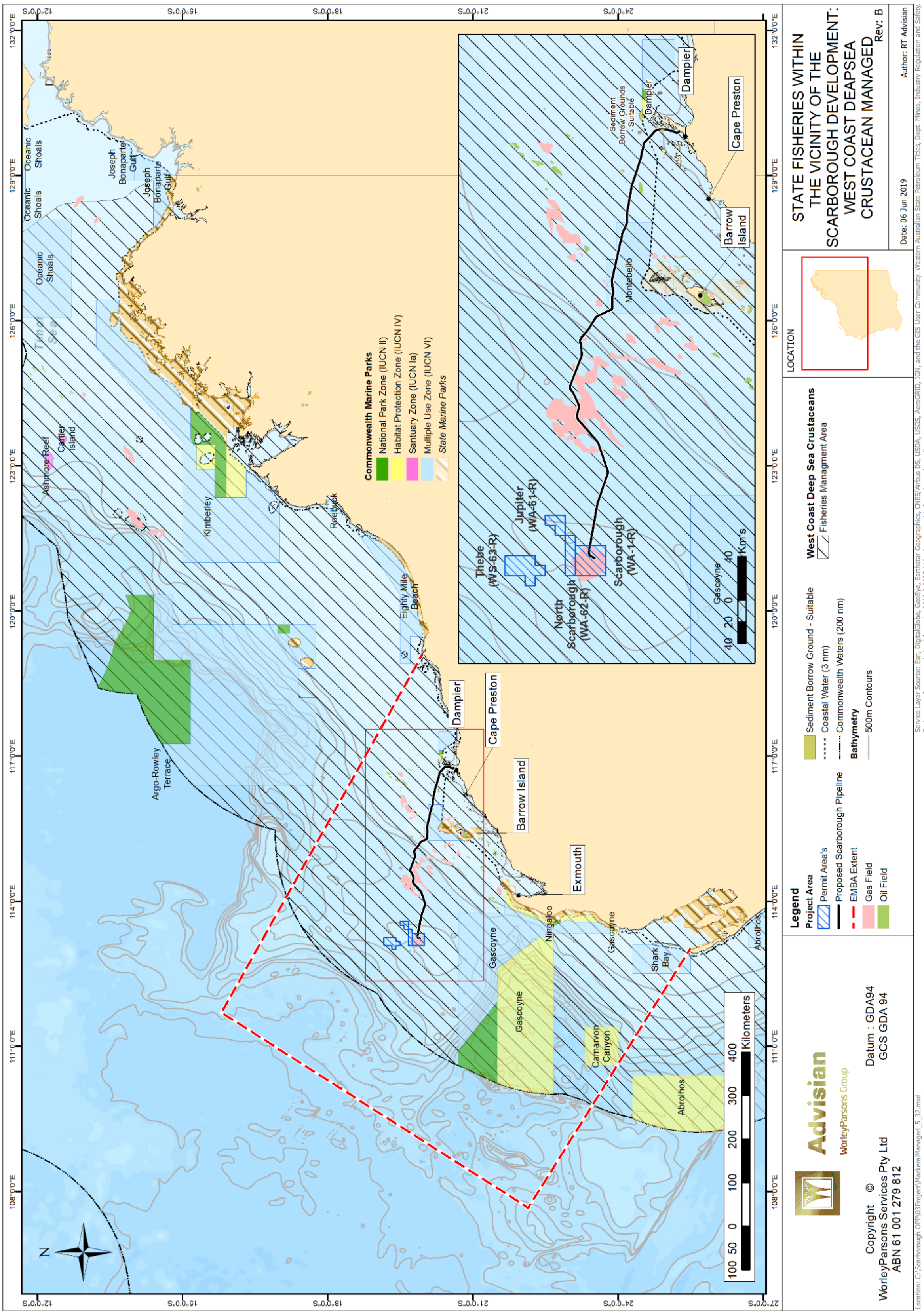


Figure 5.42: West Coast Deep Sea Crustacean Managed Fishery operating area within the vicinity of Scarborough

5.7.2.2 West Coast Salmon Fishery (Offshore Project Area/Trunkline Project Area/Borrow Grounds Project Area)

The South West Coast Salmon Managed Fishery includes all WA waters north of Cape Beaufort (WA/Northern Territory (NT) border) except Geographe Bay. This fishery uses beach seine nets to take salmon (*Arripis truttaceus*). No fishing takes place north of the Perth metropolitan area (Fletcher and Santoro, 2018), and therefore, fishing activities in the Project Area are not expected.

5.7.2.3 Mackerel Managed Fishery (Offshore Project Area/Trunkline Project Area/Borrow Grounds Project Area)

The Mackerel Managed Fishery (MMF) covers much of the WA coast within both Commonwealth and State waters between the Northern Territory border to the north of Augusta with most fishing efforts focused north of Geraldton in Pilbara and Kimberley waters (Fletcher and Santoro, 2018). The MMF mainly relies on near-surface trolling and jig fishing around coastal reefs, shoals and headlands targeting mackerel species including Spanish mackerel (*Scomberomorus commerson*), Grey mackerel (*Scomberomorus semifasciatus*) and other species from the genera Scomberomorus, Grammatorcynus and Acanthocybium (Fletcher and Santoro, 2018).

The Project Area is located within the fishery boundaries (Figure 5.43). Considering the habitats and features that the fishery targets (reefs, shoals and headlands) are absent from the Offshore Project Area, activity is not expected in this part of the Project Area. Fishing effort is likely to be higher in the Trunkline Project Area and borrow Grounds Project Area, particularly in areas close to shorelines and reefs. However, considering the area of overlap in context of the total area available for fishing, interactions with fishing vessels in the Trunkline Project Area are expected to be infrequent.

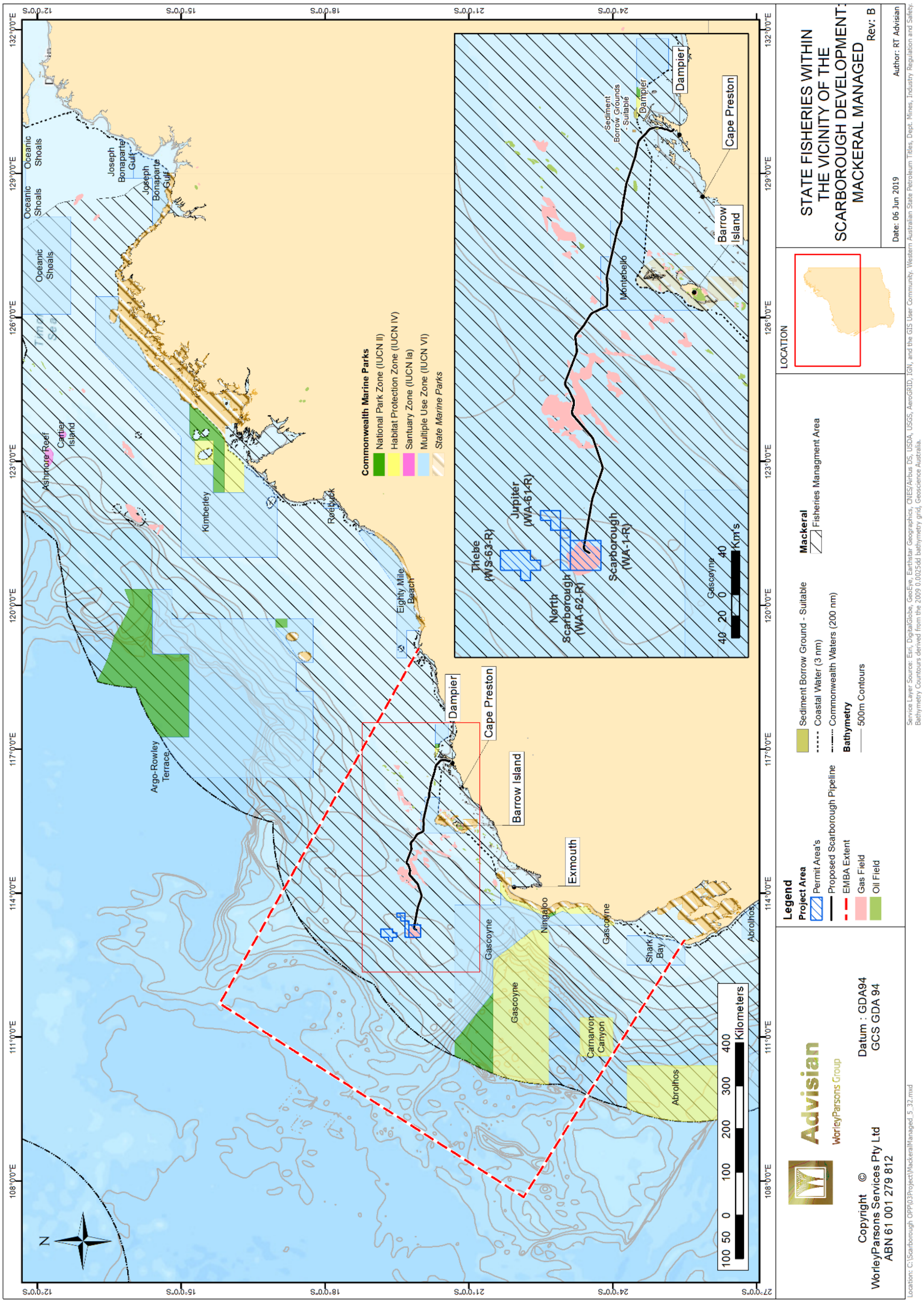


Figure 5.43: Mackerel Managed Fishery operating area within the vicinity of Scarborough

5.7.2.4 Pilbara Demersal Scalefish Fisheries (Trunkline Project Area and Borrow Ground Project Area)

The Pilbara Demersal Scalefish Fisheries include the Pilbara Fish Trawl (Interim) Managed Fishery, the Pilbara Trap Managed Fishery and the Pilbara Line Fishery (Newman et al., 2016). Target species include Goldband snapper (*Pristipomoides multidens*), Crimson snapper (*Lutjanus erythropterus*), Red emperor (*Lutjanus sebae*), Bluespotted emperor (*Lethrinus punctulatus*), Saddletail snapper (*Lutjanus malabaricus*), Rankin cod (*Epinephelus multinotatus*), Brownstripe snapper (*Lutjanus vitta*), Rosy threadfin bream (*Nemipterus furcosus*), Spangled emperor (*Lethrinus nebulosus*) and Moses' snapper (*Lutjanus russelli*). The trawl fishery contributes more than 50 species of scalefish, and the trap and line fisheries contribute 40-50 species, with the line fishery providing additional offshore species such as Ruby snapper (*Etelis carbunculus*) and Eightbar grouper (*Hyporthodus octofasciatus*) (Fletcher and Santoro, 2018).

In 2016, 71% (1,529 t) of the total commercial catches of demersal scalefish in the Pilbara (2,150 t) were landed by the trawl sector, with 23% (495 t) taken by the trap sector and 6% (126 t) taken by the line sector.

The Pilbara Trawl Fishery is of high intensity and is prohibited from certain areas of the fishery, according to Schedules. The Trunkline Project Area traverses Schedule 5 where trawling is permanently prohibited and is immediately south of the border of the Schedule 3 Area 1 which is currently open to trawling (Figure 5.44).

The Pilbara Trap Fishery covers the area from Exmouth northwards and eastwards to the 120° line of longitude, and offshore as far as the 200 m isobath. Like the trawl fishery, the trap fishery is also managed by using input controls in the form of individual transferable effort allocations, monitored with a satellite-based vessel monitoring system (VMS). The fishery operates primarily from Onslow and Schedule 3 of the fishery has been closed to trapping since 1998 (Newman et al., 2015b) (Figure 5.45). Traps are limited in number with the greatest effort in waters less than 50 m depth. This fishery targets high value species such as Red emperor (which spawn October to March) and Goldband snapper (which spawn January to April) (Fletcher and Santoro, 2018).

The Pilbara Line Fishery encompasses all of the 'Pilbara waters' targeting tropical demersal scalefish (Figure 5.46). The Line Fishery is managed under the Prohibition on Fishing by Line from Fishing Boats (Pilbara Waters) Order 2006 with the exemption of nine fishing vessels for any nominated five-month block period within the year (Fletcher and Santoro, 2018).

The Trunkline Project Area overlaps areas open to trap, trawl and line fishing whilst the Borrow Grounds Project Area lies predominantly within the Trap line managed fishery with a small portion entering the line managed fishery. Trap and line fishing are relatively low intensity and therefore interaction with fishing vessels in the Trunkline Project Area and Borrow Ground Project Area is expected to be low. While trawl fishing is of higher intensity, much of the area traversed by the Trunkline Project Area is closed to fishing. Of the areas open to trawling (Schedule 3, Area 1), the Trunkline Project Area traverses a limited area only [HOLD: GIS for actual area], reducing the potential for interaction with trawling vessels. Trap, trawl or line fishing may occur within the Project Area.

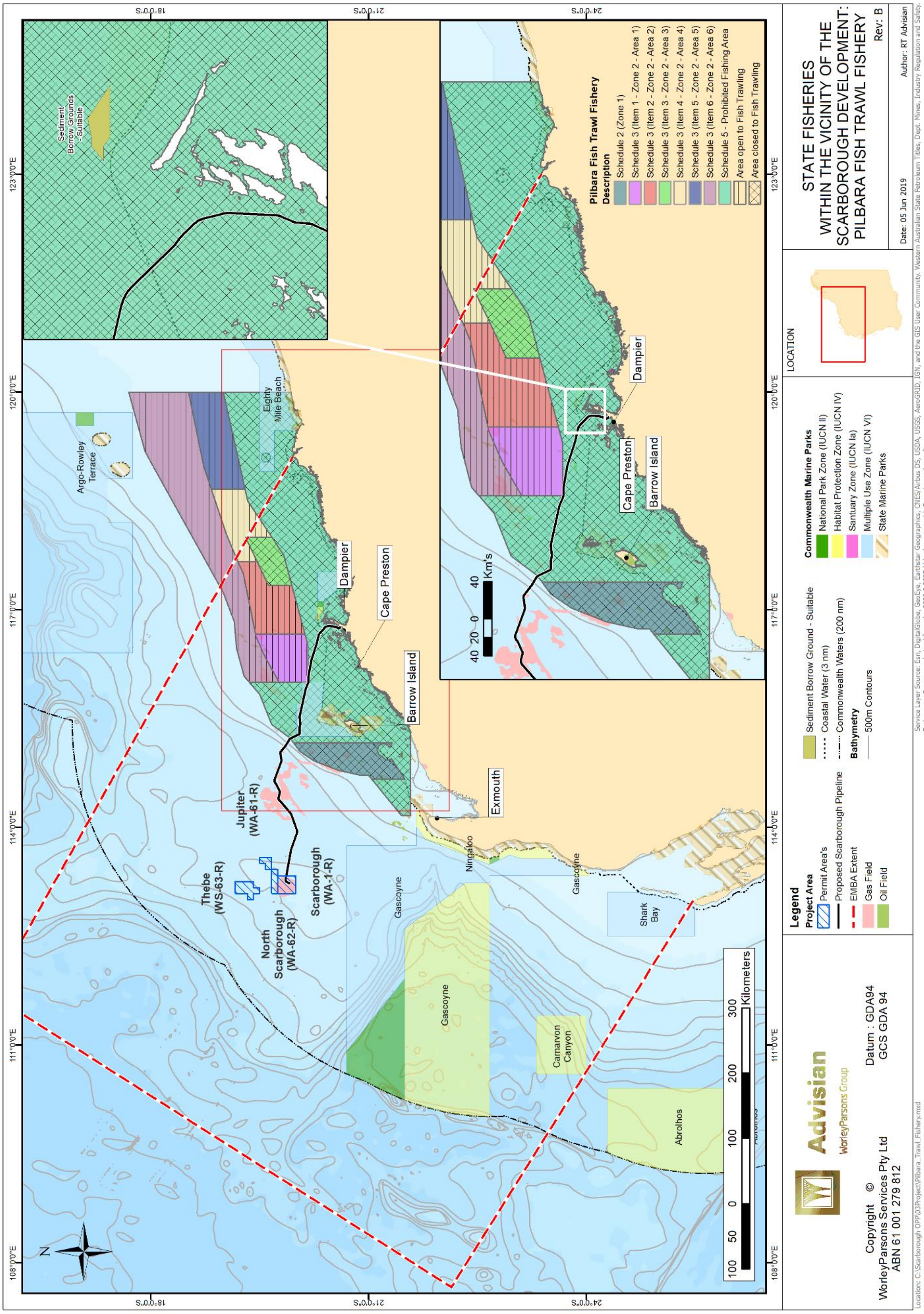


Figure 5.44: Pilbara Trawl Fishery operating within the vicinity of Scarborough

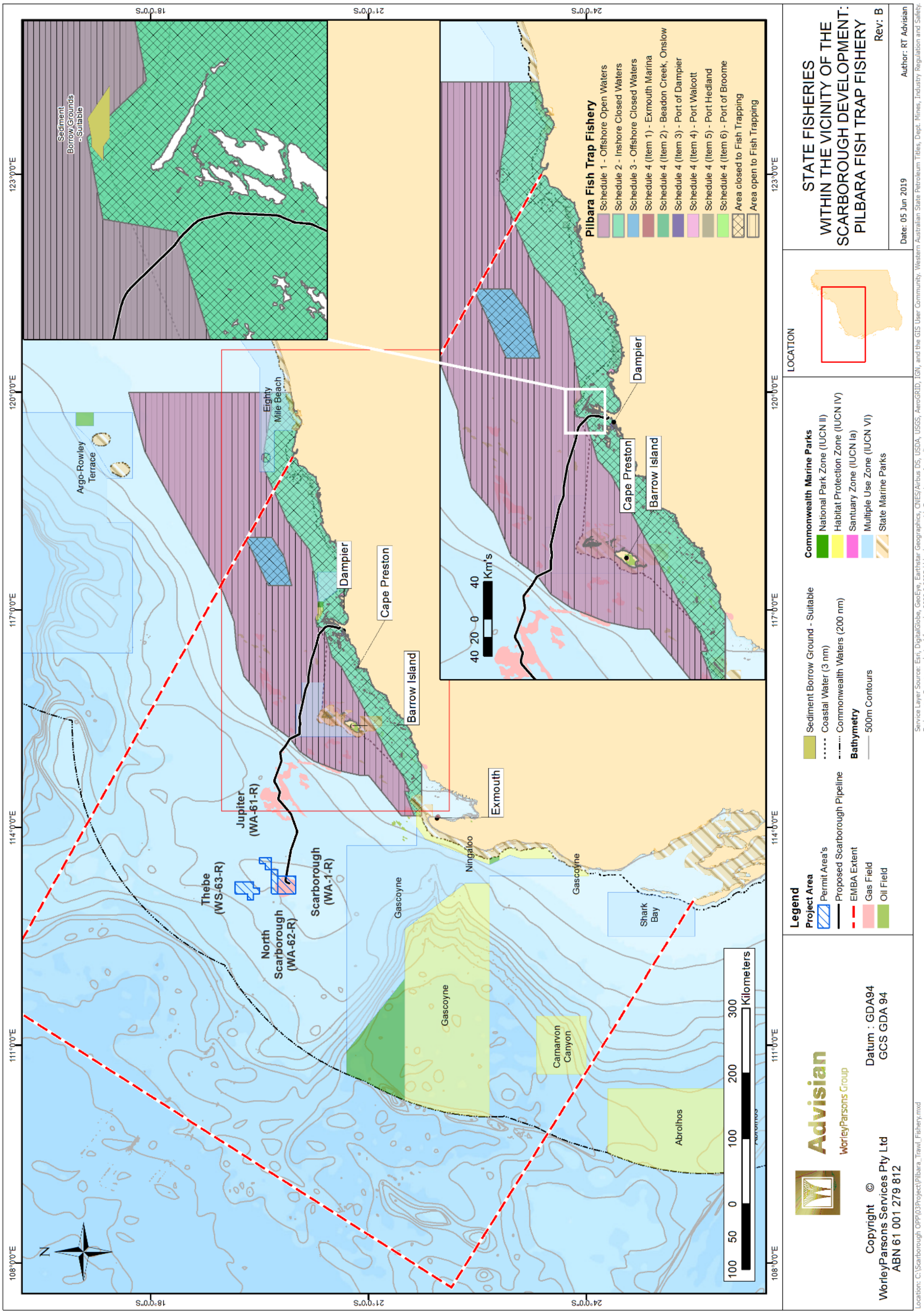


Figure 5.45: Pilbara Trap Fishery operating within the vicinity of Scarborough

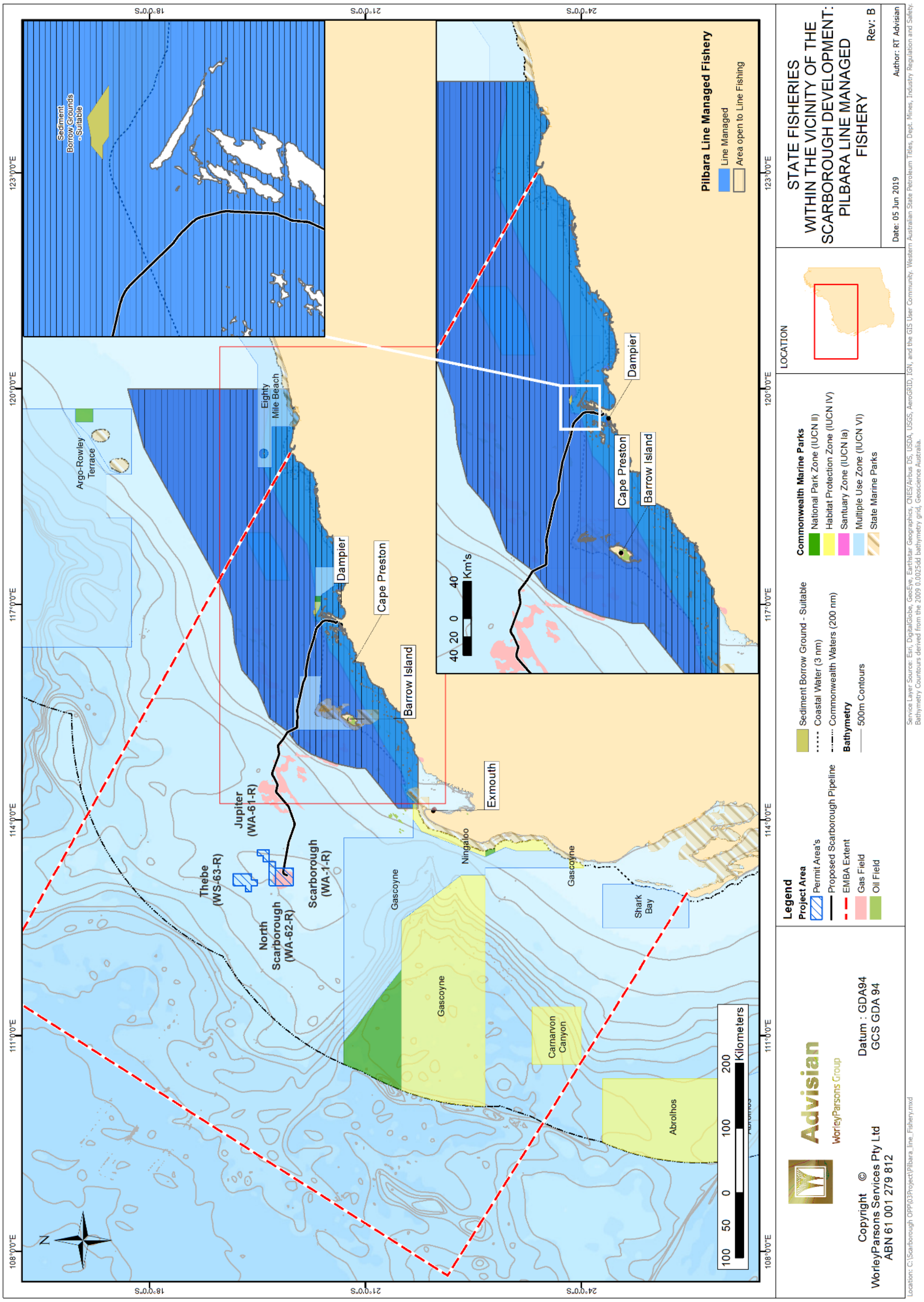


Figure 5.46: Pilbara Line Fishery operating within the vicinity of Scarborough

5.7.2.5 Pearl Oyster Managed Fishery (Trunkline Project Area and Borrow Ground Project Area)

The Pearl Oyster Managed Fishery (POMF) operates in the North Coast bioregion and is the only significant wild stock pearl fishery in the world, using drift diving methods within shallow coastal waters along the NWS (Fletcher and Santoro, 2018). This fishery is separated into four zones, of which the Zone 1 fishing area, running from the North West Cape and Exmouth Gulf to longitude 119°30´ E, lies within the Trunkline Project Area. Although fishing areas extend far offshore from state to Commonwealth waters, fishing effort is focused predominantly close to shore (Fletcher and Santoro, 2018). Other fishing zones located further north may lie within the EMBA. The POMF targets the Indo-Pacific silver-lipped pearl oyster (*Pinctada maxima*) and had an estimated value of $71 million in 2017 (Fletcher and Santoro, 2018).

Although the Trunkline Project Area and Borrow Ground Project Area overlaps the POMF boundaries (Figure 5.47), diving methods of the fishery restrict operations to shallow waters. It is possible fishing activities could occur in the shallowest regions of the Project Area, though effort here is not expected to be high.

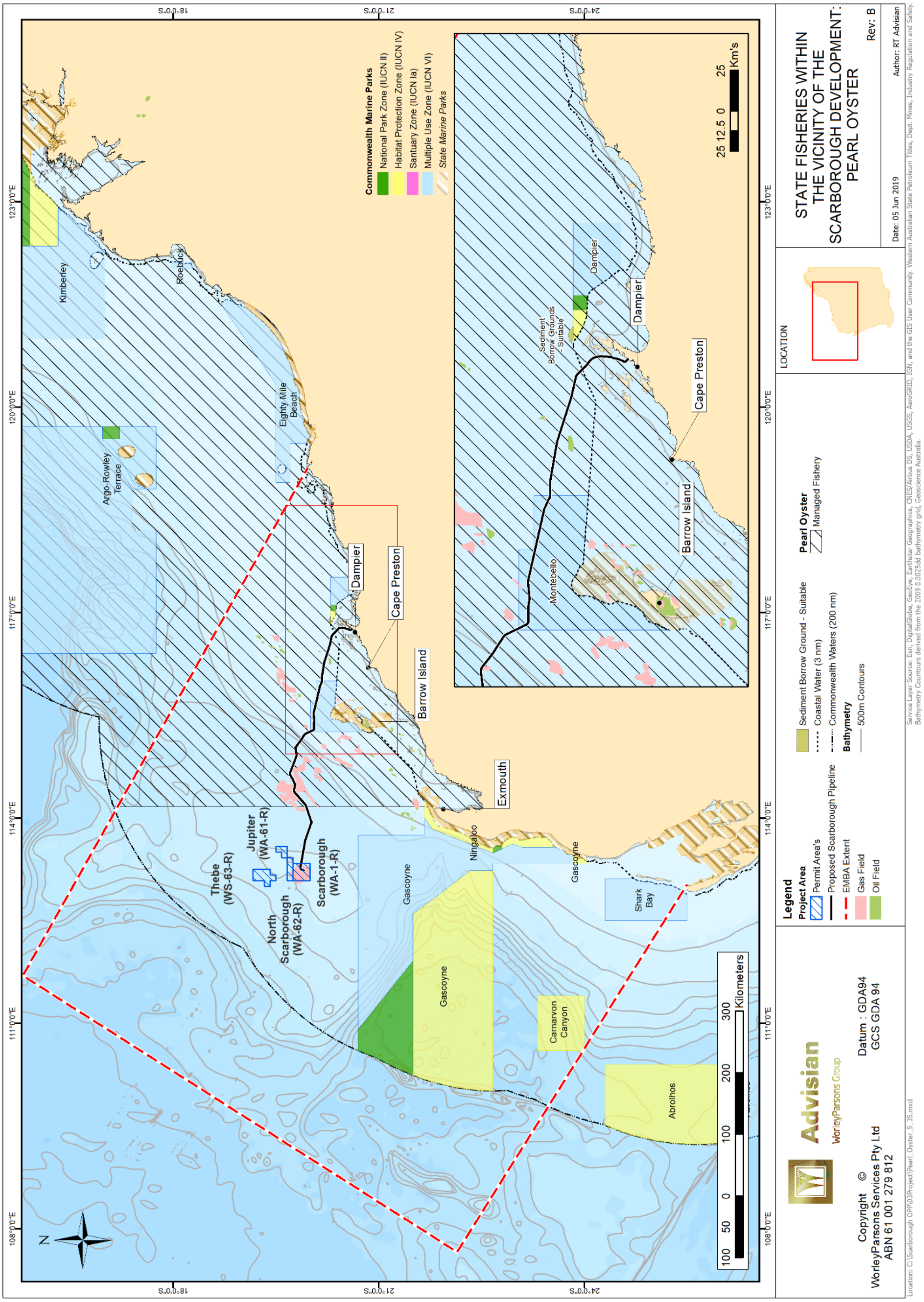


Figure 5.47: Pearl Oyster Managed Fishery operating area within the vicinity of Scarborough

5.7.2.6 North Coast Prawn Managed Fisheries (Offshore Project Area/Trunkline Project Area/Borrow Grounds Project Area)

The North Coast Prawn Managed Fisheries (NCPMF) include the Onslow, Nickol Bay, Broome and Kimberly Prawn Managed Fisheries and operate within the North Coast bioregion on the landward side of the 200 m isobath, east of 114º39.9' within both Commonwealth and State waters. Of the above four prawn fisheries in the North Coast bioregion, the Onslow Prawn Managed Fishery (OPMF) is the only fishery which is transected by the Trunkline Project Area; while the Nickol Bay Prawn Managed Fishery (NBPMF) occurs within the EMBA. The Broome and Kimberley Prawn Managed Fisheries are outside the EMBA.

These fisheries target Western king prawns (*Penaeus latisulcatus*), Endeavour prawns (*Metapenaeus* spp.), Brown tiger prawns (*Penaeus esculentus*) and Banana prawns (*Penaeus merguiensis*) using otter trawl systems (Fletcher and Santoro, 2018).

Effort and catch in the OPMF was minimal for the 2016 season, resulting in 3 t of the 60–180 t Total Allowable Catch (TAC) limit landed. Further, total landings of the NBPMF for the 2016 season were 17 t, the second lowest catch since 1966 (Fletcher and Santoro, 2018).

The Offshore Project Area does not overlap the NCPMF, therefore interactions between planned activities in the permit area and this fishery will not occur. However, the Trunkline Project Area and Borrow Ground Project Area traverses and lies within the OPMF, and fishing activity may occur in the area (Figure 5.48).

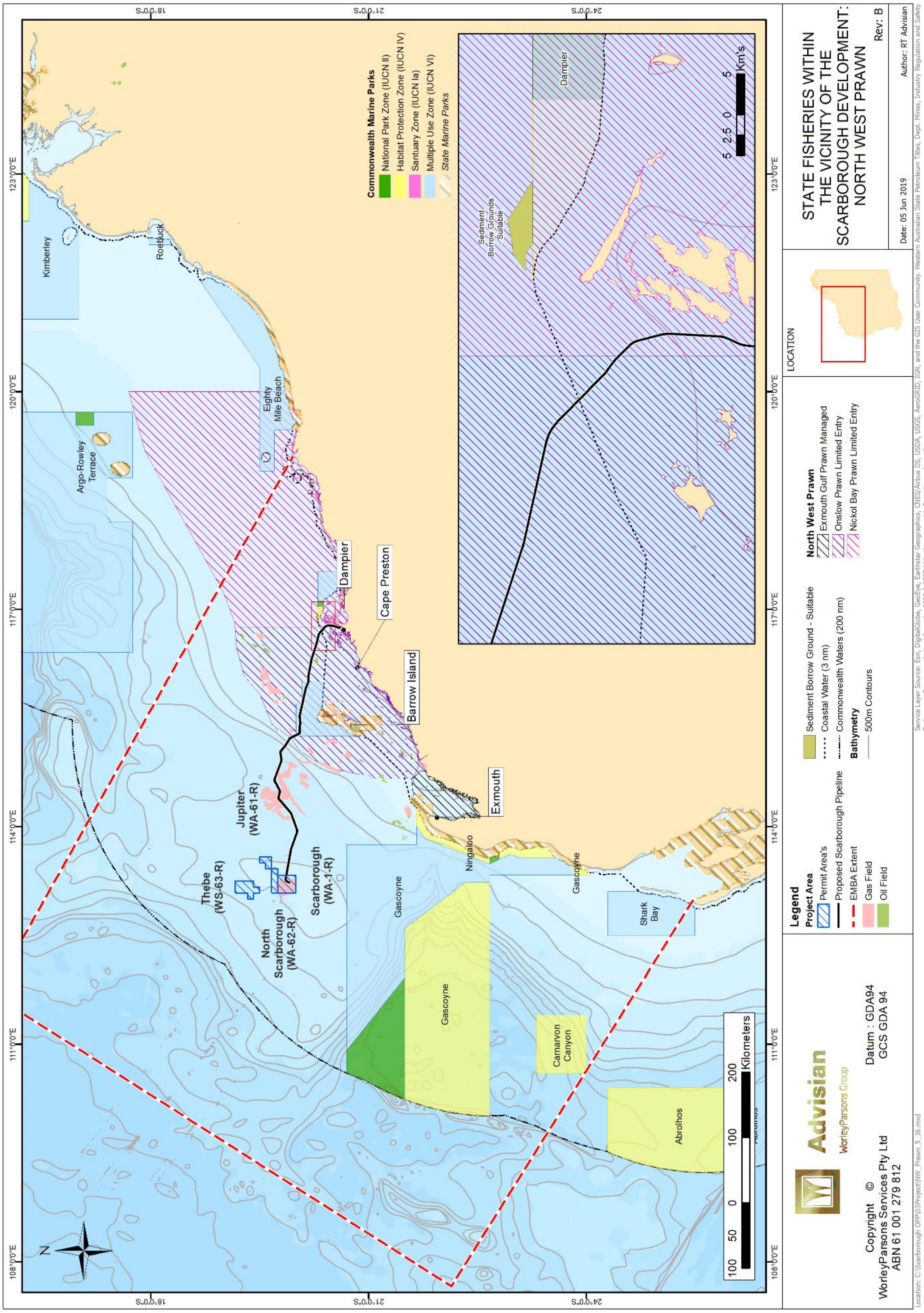


Figure 5.48: North Coast Prawn Managed Fisheries operating area within the vicinity of Scarborough

5.7.2.7 West Coast Roe's Abalone Resource (Trunkline Project Area and Borrow Grounds Project Area)

The WA Abalone Managed fishery boundaries include all waters from the SA border to the NT border. Fishing effort from the dive-based fishery is restricted to shallow coastal waters off the south-west and south coasts of WA, particularly around the Perth metropolitan area (Fletcher and Santoro, 2018). Abalone is harvested by divers, limiting the fishery to shallow waters.

Although the fishery is overlapped by the Project Area, fishing effort is concentrated around the Perth Metropolitan Area and Shark Bay is considered the northern range limit for Roe's abalone. As such, interactions this fishery are not expected in the Project Area.

5.7.2.8 Marine Aquarium Managed Fishery (Trunkline Project Area and Borrow Grounds Project Area)

The Marine Aquarium Fish Managed Fishery operates within all WA State waters. The majority of effort within the fishery occurs in waters between Esperance and Broome, particularly in waters around the Cape region, Perth, Geraldton, Exmouth and Dampier (DoF, 2017). The fishery is diver based, which typically restricts effort to safe diving depths (<30 m).

The Trunkline Project Area traverses the fishery and occurs in water depths where diving can occur. It is possible that fishing effort may occur in the shallowest part of the Trunkline Project Area near Dampier; however, water depths are at the upper limit of safe diving depths and therefore activity is expected to be infrequent.

5.7.2.9 Specimen Shell Fishery (Trunkline Project Area)

The Specimen Shell Managed Fishery (SSF) occurs in all WA State waters. The SSF targets the collection of specimen shells for display, collection, cataloguing and sale. Over 18,000 shells were reported for the fishery for the 2014–15 season (DoF, 2017). Collection is predominantly by hand when diving or wading in shallow, coastal waters though a deeper water collection aspect to the fishery has been initiated with the employment of ROVs operating at depths up to 300 m (Hart and Crowe, 2015). Although the SSF encompasses the entire WA coastline but effort is concentrated in area adjacent to the largest population centres such as: Broome, Karratha, Shark Bay, Mandurah, Exmouth, Cape region, Albany and Perth (Hart and Crowe, 2015).

Although the Trunkline Project Area traverses the fishery, activity is restricted to the shallowest portion of the Trunkline Project Area where the water depths are within safe diving limits. However, high effort in the around Dampier is not expected, and therefore, interactions with this fishery are expected to be infrequent.

5.7.2.10 Western Rock Lobster Fishery (EMBA)

The West Coast Rock Lobster Fishery targets the Western rock lobster (*Panulirus cygnus*) from Shark Bay south to Cape Leeuwin using baited traps (pots) (Fletcher and Santoro, 2018). Although the fishery boundaries fall within the EMBA, the reported northern most limit of the fishery is outside the EMBA and therefore interactions of this fishery with either planned or unplanned events are not expected.

5.7.2.11 Exmouth Gulf Prawn Managed Fishery (EMBA)

The Exmouth Gulf Prawn Managed Fishery (EGPMF) targets Western king prawns (*Penaeus latisulcatus*), Brown tiger prawns (*Penaeus esculentus*), Endeavour prawns (*Metapenaeus endeavouri*) and Banana prawns (*Penaeus merguiensis*) with low opening, otter prawn trawl systems within sheltered waters of Exmouth Gulf (Fletcher and Santoro, 2018). Fishing effort has been in decline since the 1970s but was higher in 2016 compared to the previous four years (Fletcher and Santoro, 2018).

The fishery is not overlapped by the EMBA and therefore interactions with planned activities will not occur.

5.7.3 Aquaculture

As above for state managed fisheries, aquaculture development in the north west is split into two regions; the Gascoyne Coast bioregion and the North Coast bioregion. Aquaculture development in the North Coast region is dominated by the production of pearls (Section 0). A large number of pearl oysters for seeding are obtained from wild stocks and supplemented by hatchery-produced oysters, with major hatcheries operating at Broome and around the Dampier Peninsula (Gaughan & Santoro, 2018). Aquaculture pearling in the Gascoyne Coast bioregion focuses on predominantly the Blacklip oyster (*Pinctada margaritifera*) and Akoya pearl oyster (*Pinctada imbricate*) which complements the pearling industry which has historically focused on the silver lip pearl (Fletcher and Santoro, 2018).

Other aquaculture developments in the North Coast bioregion include emerging producers of coral and live rock species for aquariums in the Gascoyne Coast bioregion as well as barramundi (*Lates calcarifer*) farms and microalgae culturing for omega-3, biofuels and protein biomass in the North Coast bioregion (Fletcher and Santoro, 2018).

The Project Area does not intersect with any known aquaculture areas (Figure 5.49). The closest is the West Lewis Island (Dampier Archipelago) licence, about 27 km from the Trunkline Project Area.

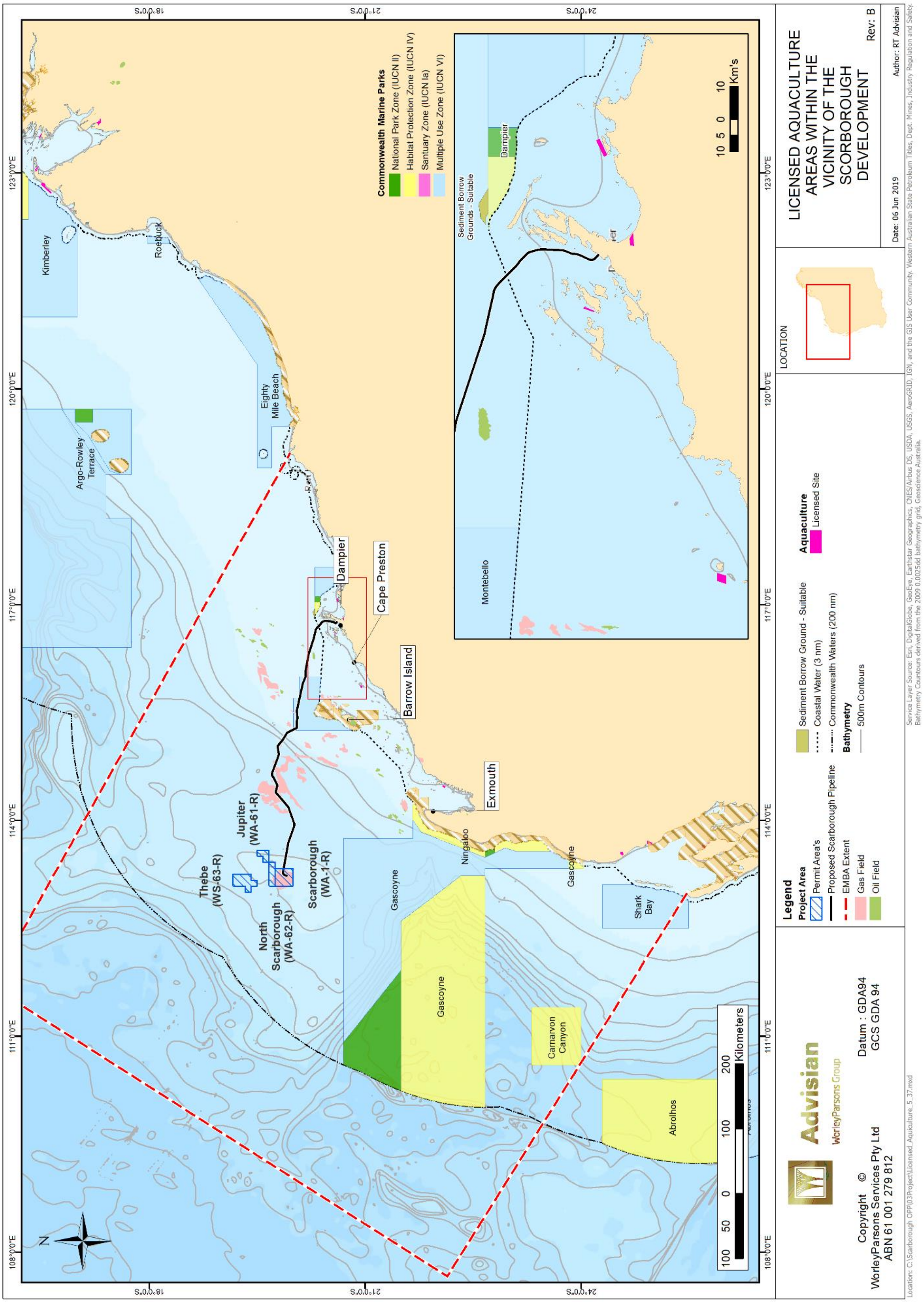


Figure 5.49: Licensed aquaculture areas within the vicinity of Scarborough

5.7.4 Recreation and Tourism

Recreation and tourism activities within the NWMR are of high social value. Recreational and tourism activities include; charter fishing, other recreational fishing, diving, snorkelling, whale, Whale shark, marine turtle and dolphin watching, cruise ship stop overs and yachting.

On a broad scale, recreational fishing within the NWMR tends to be concentrated in State waters adjacent to population centres, with highest records typically in areas such as Point Samson (about 340 km from the Offshore Project Area and 180 km from the Trunkline Project Area), Coral Bay (about 280 km from the Offshore Project Area and 260 km from the Trunkline Project Area) Exmouth (about 255 km from the Offshore Project Area and 225 km from the Trunkline Project Area) and Carnarvon (about 420 km from the Offshore Project Area and 400 km from the Trunkline Project Area) with the addition of charter fishing boats are known to fish further ashore within Commonwealth waters (DEWHA, 2008a). Recreational fishing is known to occur around the Dampier Archipelago with boats launched from boat ramps around Dampier and Karratha (Williamson et al., 2006). Once at sea, charter vessels may also frequent the waters surrounding the Montebello Islands.

Primary dive locations include the State-managed Ningaloo Marine Park (about 400 km from the Offshore Project Area and 120 km from the Trunkline Project Area), the Montebello State Marine Park (25 km from the Trunkline Project Area), the Rowley Shoals, including the Commonwealth marine reserve at Mermaid Reef (about 520 km from the Offshore Project Area and 360 km from the Trunkline Project Area), Scott Reef (approximately 1000 km from the Offshore Project Area and Trunkline Project Area), Seringapatam Reef (about 1000 km from the Offshore Project Area and Trunkline Project Area), Ashmore Reef Australian Marine Park and Cartier Island (about 1500 km from the Offshore Project Area and Trunkline Project Area). The Muiron Islands (about 160 km from the Offshore Project Area and 120 km from the Trunkline Project Area), which are in State waters, are the destination for most of the dive charters operating out of Exmouth.

Whale shark, dolphin and turtle watching tours in the NWMR generally do not extend far ashore. Fauna observation tours often occur around island and reef systems such as Ningaloo Reef (about 160 km from the Offshore Project Area and 120 km from the Trunkline Project Area) and the Dampier Archipelago (about 300 km from the Offshore Project Area and 160 km from the Trunkline Project Area). A range of companies operate in the area specialising in a range of tours that may vary depending on the time of year and/or weather conditions.

Cruise ships that operate in the area, frequently include visits to Exmouth as their primary stop within the NWMR, bringing an added value of $0.7 million to the area (Tourism WA, 2017). Cruise ships are expected to operate within standard shipping lanes and more within State waters and are therefore not discussed further.

Potential presence of these activities within the Scarborough Project Area are outlined below.

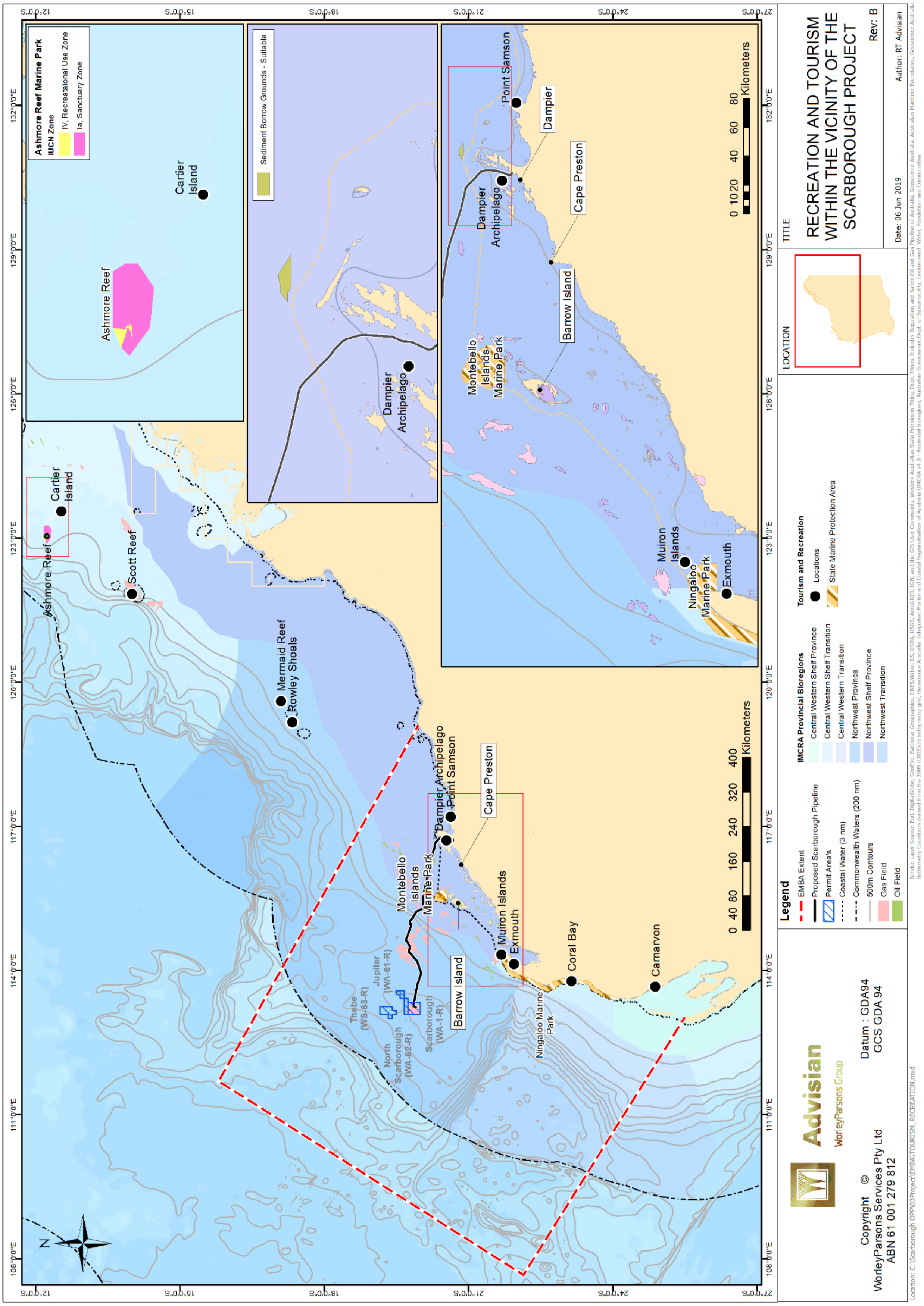


Figure 5.50: Known locations of recreation and tourism activities

5.7.4.1 EMBA

A number of more popular tourism locations occur within the EMBA, including:

- Ningaloo Reef
- Muiron Islands
- Montebello and Barrow islands
- Dampier Archipelago.

Activities within these areas include recreational fishing (including charter fishing), snorkelling, diving and fauna watching, as described in further detail below.

5.7.4.2 Trunkline Project Area and Borrow Ground Project Area

Of the most popular recreational fishing sites outlined above, none lie within the Trunkline Project Area or Borrow Ground Project Area. Trunklines are often popular sites for recreational fishing therefore charter fishing may occur within the Trunkline Project Area within defined fishing areas; however, fish aggregation areas, where charter fishing would be expected to occur, are limited to small areas of increased habitat complexity, such as the Ancient Coastline KEF (Section 5.5.2) or Montebello AMP (see Section 5.6.1). It is possible that interaction with charter vessels could occur within the Montebello AMP; however, given the relative lack of fish aggregation areas (in comparison to other areas in the wider NWMR) and distance offshore from the shoreline and population centres, the level of interaction is considered low.

Subsea infrastructure, such as trunklines, can provide areas of hard substrate which attract a higher species richness and abundance of fish (Bond et al., 2018; Ajemian et al., 2015; Pears and Williams, 2005; Grossman et al., 1997). Anglers visiting offshore oil and gas infrastructure frequently report high catch rates (Grossman et al., 1997). Increased recreational fishing along the Pluto export trunkline, which is located adjacent to the continental shelf portion of the Trunkline Project Area, may be observed.

Fauna observation tours generally occur within State waters around areas of high species aggregation. For fauna watching, cetacean species are usually the targeted for viewings. Although not as popular as tours operating out of Exmouth, whale watching tours operate out of Dampier. The Humpback whale migration BIA and Pygmy blue whale distribution BIA (Section 5.4.5, Table 5.3) are transected by the Trunkline Project Area, about 33 km from Dampier. Therefore, it is possible that whale watching tours could occur in the Trunkline Project Area; however, given the distance offshore, frequency is expected to be low.

There are no popular dive or snorkelling sites within the Trunkline Project Area or Borrow Ground Project Area, and given the distance offshore, water depths and lack of coastal habitats, snorkelling and diving is not expected.

In summary, recreational and tourism activities within the Trunkline Project Area and Borrow Ground Project Area will be more common than that experienced in the Offshore Project Area, particularly activities such as whale watching and charter fishing. However, given the water depths and distance offshore and from population centres, interaction with recreational and tourism activities are expected to be infrequent.

5.7.4.3 Offshore Project Area

Recreational and tourism activities within the Offshore Project Area are limited due to its distance offshore. Charter fishing is known to occur within waters very far ashore; however, due to the water depth and lack of hard substrate or habitats promoting fish aggregations, the Offshore Project Area is unlikely to be a consistently preferred area for charter fishing (see Section 5.4.4).

5.7.5 Shipping

Commercial shipping traffic is high within the NWMR (Figure 5.51) with vessel activities including commercial fisheries, tourism such as cruises, international shipping and oil and gas operations. There are 12 ports adjacent to the NWMR, including the major ports of Dampier, Port Hedland and Broome, which are operated by their respective port authorities. These ports handle large tonnages of iron ore and petroleum exports in addition to salt, manganese, feldspar chromite and copper (DEWHA, 2008a).

The State waters adjacent to the easternmost point of the Trunkline Project Area fall within the boundaries of the Pilbara Ports Authority, within which the ports of Dampier and Port Hedland lie. Between 2017 and 2018, annual revenue within the Pilbara Port Authority was $511.9 million with the port of Port Hedland receiving a total of 519.5 Mt of goods and the port of Dampier receiving 177.3 Mt (PPA, 2018).

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 (AMSA, 2012).

Although the Offshore Project Area is located west of a busy shipping fairway (Figure 5.51), vessel traffic within the Offshore Project Area is relatively low. The majority of vessel movement occurs to the south-east of the Offshore Project Area within the Trunkline Project Area.

In addition to high vessel traffic within the shipping fairway, vessel traffic is high towards the east of the Trunkline Project Area where increased vessel traffic will be associated with ports servicing the resource industry at Barrow Island, Onslow and Dampier.

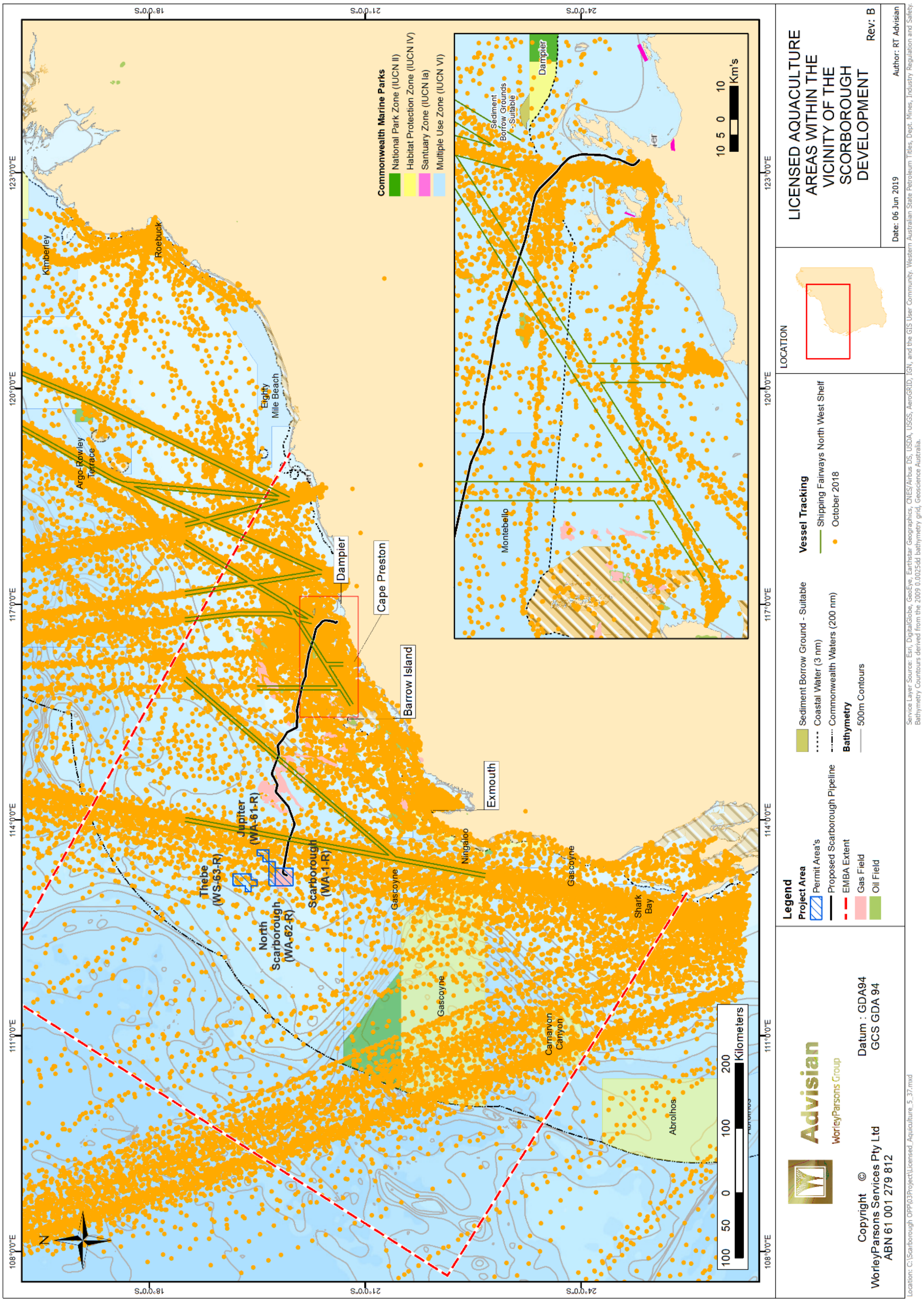


Figure 5.51: Vessel tracking information within the vicinity of Scarborough

5.7.6 Industry

The oil and gas industry is Australia's largest source of energy (gas: 24% and oil: 38%), contributing $34 billion to the Australian economy within the financial year between 2014 and 2015 (APPEA, 2017). Within the NWMR there are seven sedimentary petroleum basins: 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 (DEWHA, 2008a), which is reflected by the level of development in the area.

The Project Area is located in the Rankin Platform/Exmouth Plateau area of the Northern Carnarvon Basin. In addition to Scarborough there is currently another development project within the Rankin Platform/Exmouth Plateau area, the Equus Development Project located about 70 km east of the Project Area.

Oil and gas infrastructure in proximity to the Project Area include that associated with the main producing hubs of the Pluto LNG project, the Wheatstone LNG project and the Greater Gorgon LNG project. As shown in

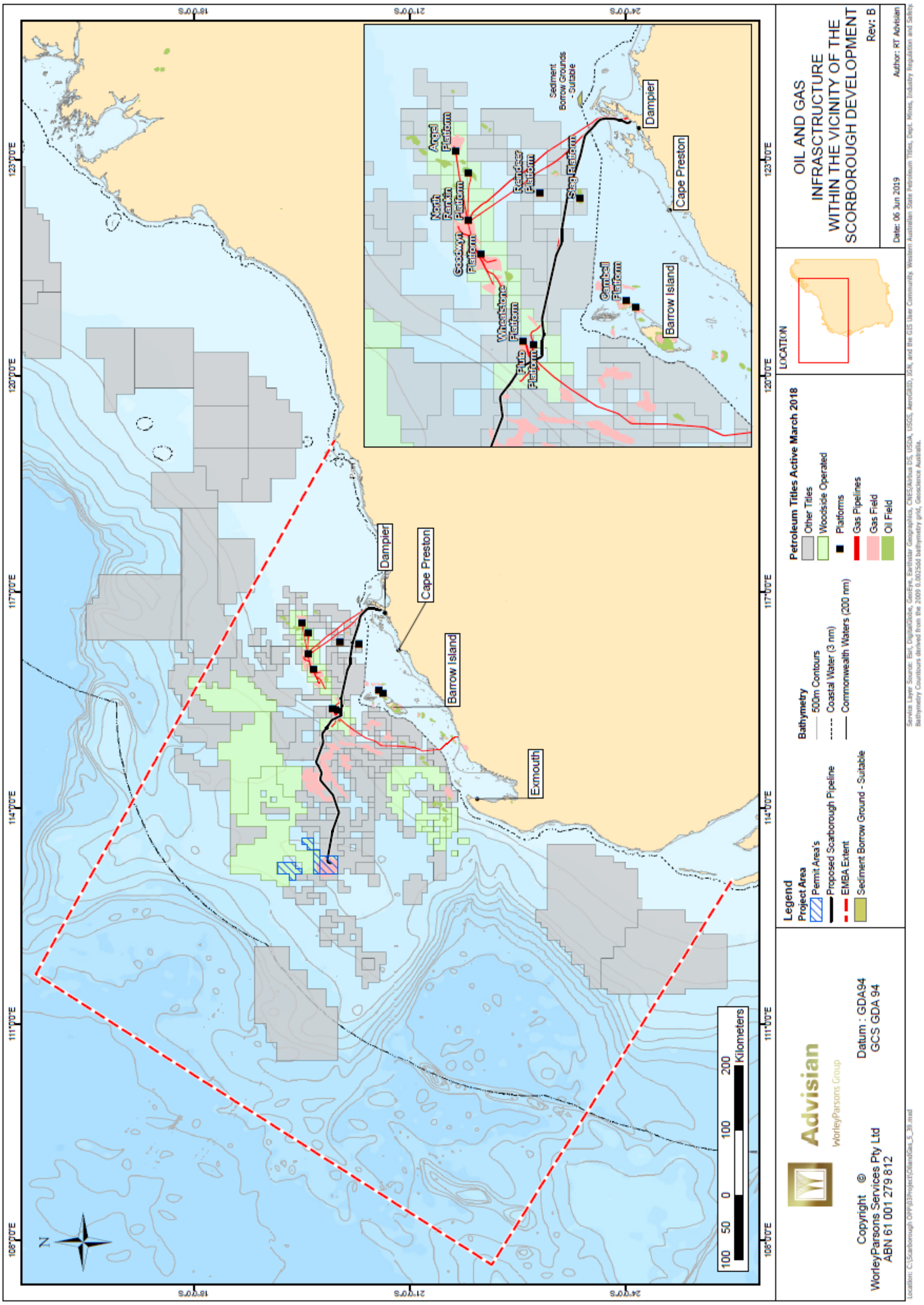


Figure 5.52, the Trunkline Project Area is adjacent to the existing Pluto trunkline and intersects existing subsea infrastructure including:

- Julimar flowlines/pipelines (Woodside)
- Wheatstone flowlines and trunkline (Chevron)
- Reindeer offshore gas supply pipeline (Santos).

Production facilities within the EMBA are provided in Table 5.10 and shown in

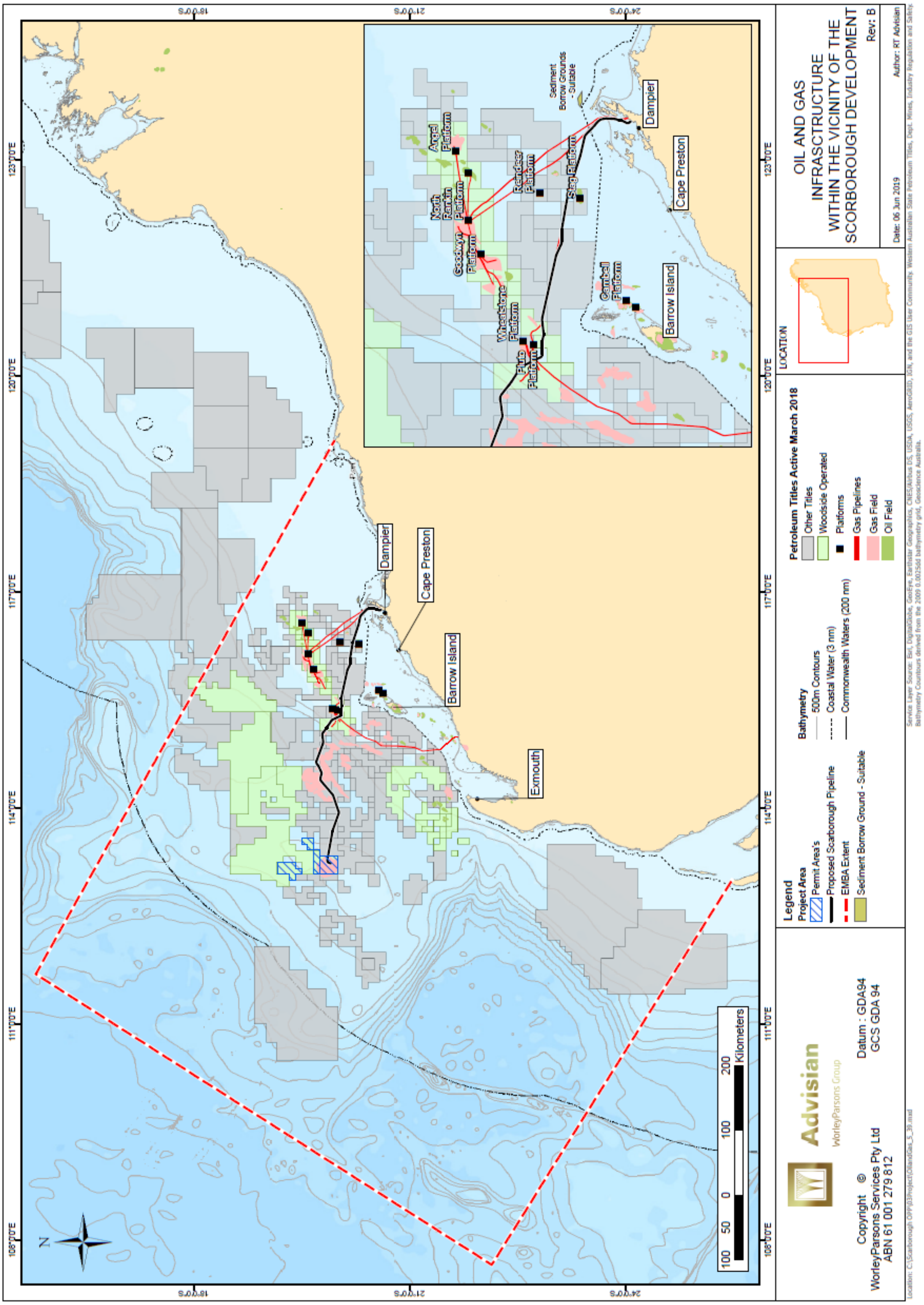


Figure 5.52.

The oil and gas industry is the predominant industry that uses the offshore marine environment in the Project Area for their day-to-day operations. However, other land-based industries depend upon the marine environment in the nearshore area. These include ports (refer to Section 5.7.5), salt mines such as Karratha and Onslow, LNG onshore processing facilities such as Burrup Hub, Thevenard Island, Barrow Island, Varanus Island, and small-scale desalination plants at Barrow Island, Burrup, Cape Preston and Onslow.

Table 5.10: Oil and gas facilities in the vicinity of the Project Area

Facility name and Operator	Approximate distance from Project Area (km)
Pluto (Woodside)	5
Stag (Jadestone)	9
Reindeer (Santos)	19
Goodwyn (Woodside)	51
North Rankin Complex (Woodside)	64

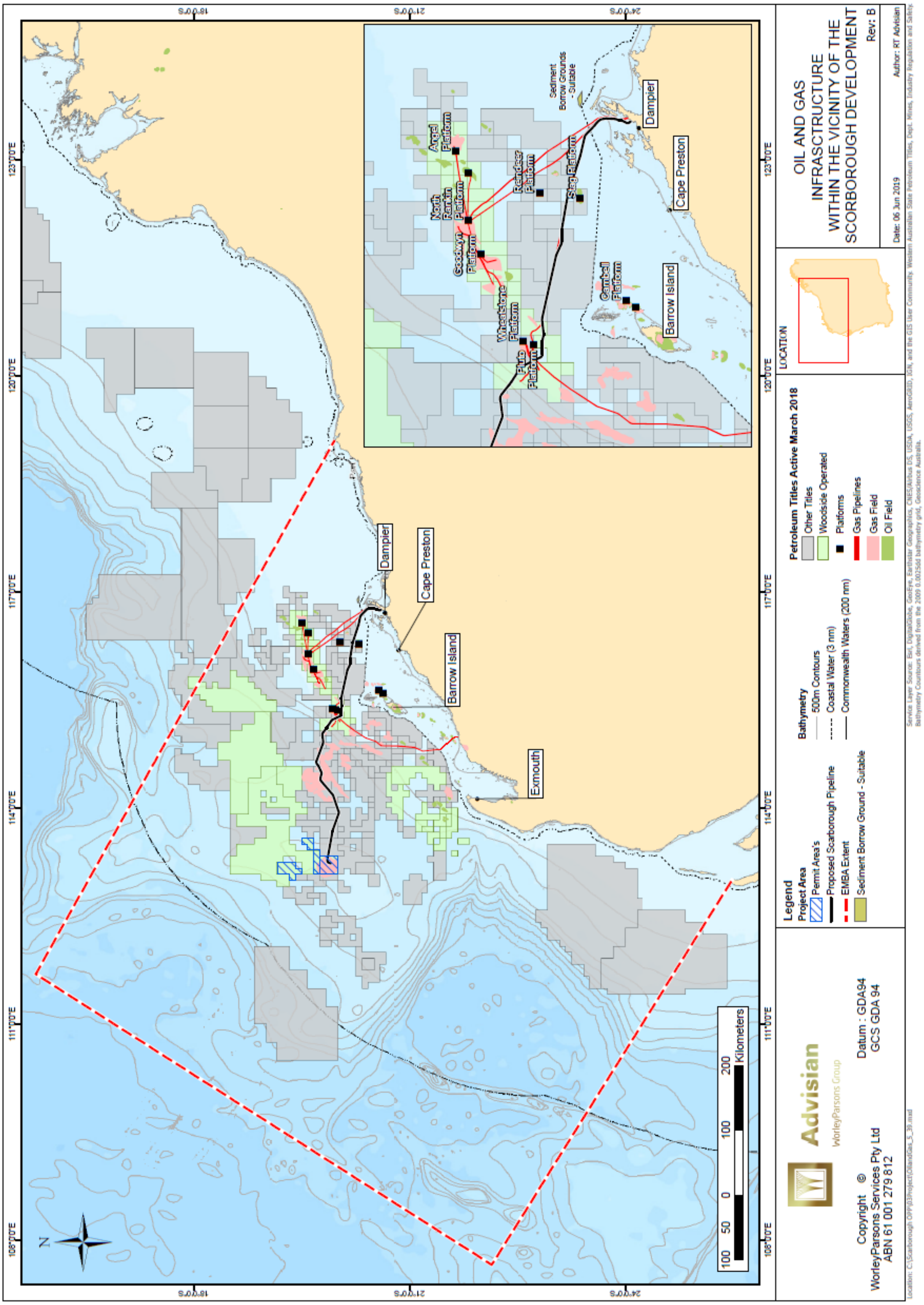


Figure 5.52: Oil and gas infrastructure within the vicinity of Scarborough

5.7.7 Defence

The Australian Defence Forces utilise areas within and adjacent to the NWMR for a range of training and operational activities. These include:

- An operating logistics base has been established in Dampier to support vessels patrolling the waters around offshore oil and gas facilities in the NWMR. A dedicated navy administrative support facility is also being constructed at the nearby township of Karratha.
- The Royal Australian Air Force currently maintains two 'bare bases' in remote areas of Western Australia which are used for military exercises. One of these is the Royal Australian Air Force Base in Learmonth. The Royal Australian Air Force maintains the Commonwealth Heritage listed Learmonth Air Weapons Range Facility, which is located between Ningaloo Station and the Cape Range National Park. The air training area associated with the Learmonth base extends over part of the Project Area (Figure 5.53).
- The Naval Communications Station Harold E. Holt is located ~6 km north of in Exmouth. The main role of the station is to communicate at very low frequencies (19.8 kHz) with Australian and United States submarines and ships in the eastern Indian Ocean and the western Pacific Ocean.

The Offshore Project Area and Trunkline Project Area both intersect Defence Training Areas (Figure 5.53).

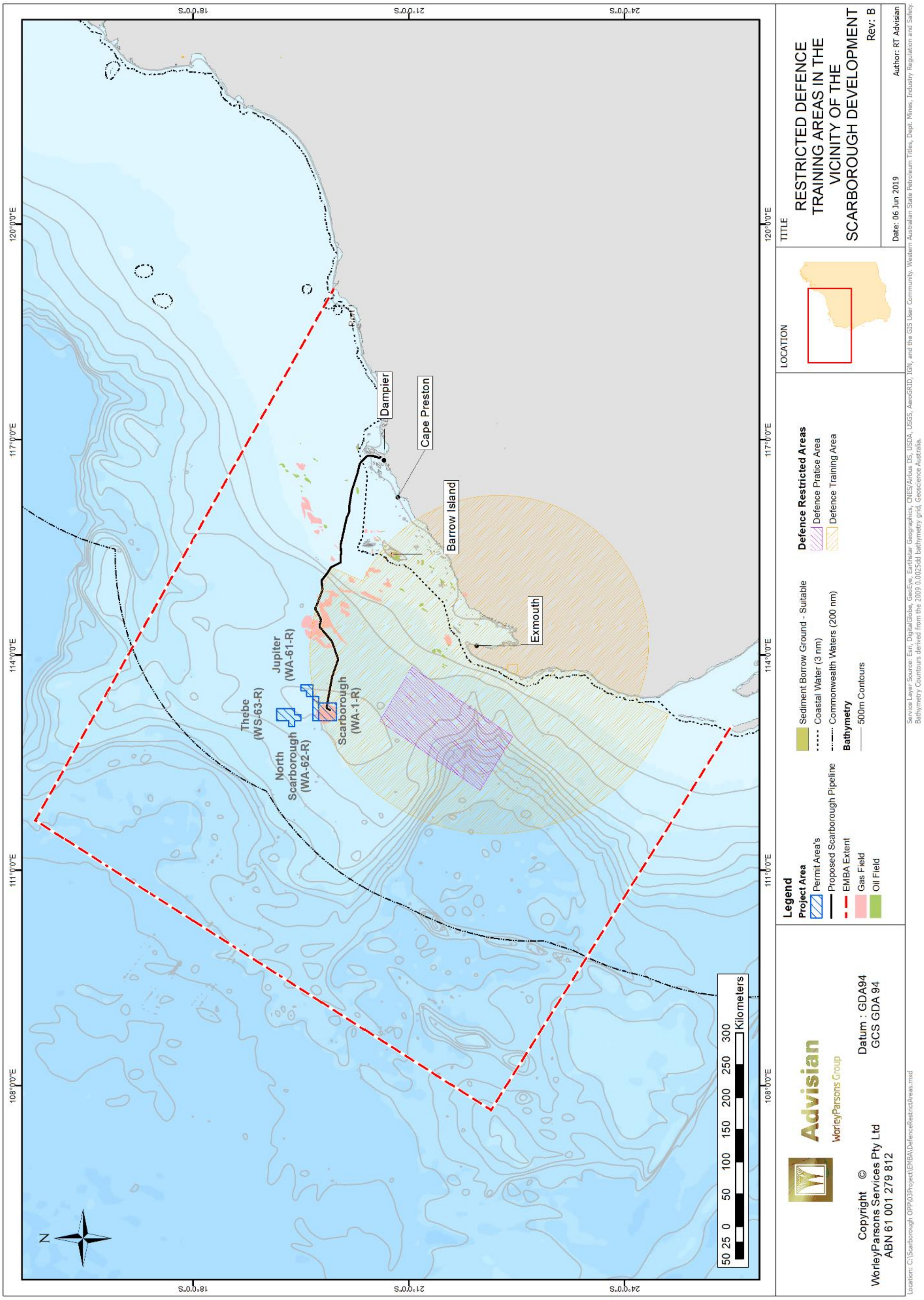


Figure 5.53: Defence training areas

5.7.8 Coastal Settlements

There are no coastal settlements in the Project Area, however the EMBA includes areas of coastline which includes coastal settlements, which are described here.

Coastal settlements in the north-west region range from small towns to larger regional centres such as Exmouth, Onslow, Karratha, Port Hedland and Broome, where the population is concentrated. Smaller towns typically service specific industries, such as mining, fishing and tourism. The population in these larger regional centres are typically transient, with a heavy influence from the mining and offshore sectors where fly-in-fly-out work is common. In the last census, Karratha was the largest centre with a population of 21,473, followed by Port Hedland is 14,469.

6 IMPACT AND RISK ASSESSMENT METHODOLOGY

Under the OPGGS (Environment) Regulations, a titleholder is required to detail and evaluate all the environmental impacts and risks associated with the proposed project, and to demonstrate that the project can be undertaken in such a way that the environmental impacts and risks will be managed to an acceptable level.

An assessment of the impacts and risks associated with Scarborough has been undertaken in accordance with Woodside's Environment Impact Assessment Guideline and Risk Assessment Procedure. This guideline and procedure set out the broad principles and high-level steps for assessing environmental impacts across the lifecycle of Woodside's activities and managing these during project execution.

The key steps of the Woodside impact and risk management process are comprised of:

- the environmental impact and risk assessment
- the communication and consultation that informs the assessment and ongoing performance, and
- the steps required during implementation of the activity including to monitor, review and report.

These steps are shown in Figure 6.1.

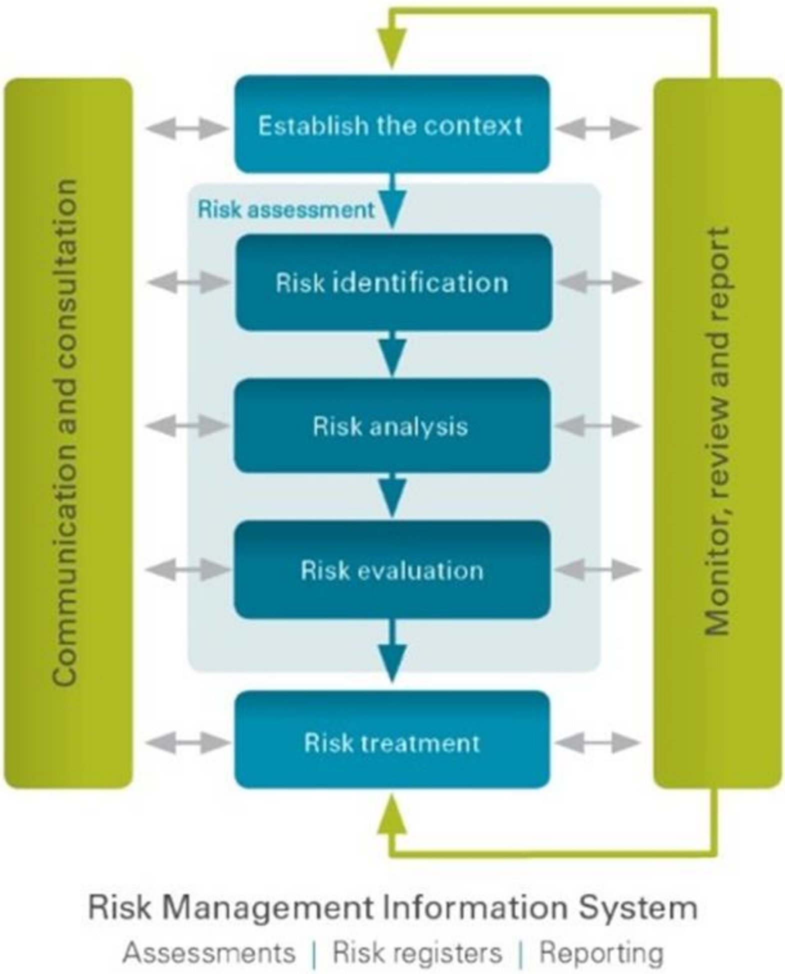


Figure 6.1: Woodside's risk management process

For the impact and risk assessment stage of the management process, Woodside's approach to undertaking assessments include the following steps:

4. **CONTEXT SETTING**
    a. Establishing the context based on the proposed activities
    b. Establishing the context for the environment in which the proposal is to take place
    c. Review of the significance/sensitivity of receptors and levels of protection
    d. Environmental legislation and other requirements
    e. External requirements
    f. Internal requirements
5. **IMPACT AND RISK ASSESSMENT**
    a. Impact and Risk Identification
    b. Impact and Risk analysis
    c. Impact and Risk evaluation
    d. Determining Acceptability
6. **IMPACT AND RISK TREATMENT**
    a. Identifying Controls

The Impact and Risk Assessment process as implemented for Scarborough is described in more detail in the following sections. The other key steps of the Woodside Risk Management Process including implementation (which includes the steps to monitor, review and report) and stakeholder consultation, are addressed in Section 9 and 10 respectively.

6.1 Establish the Context

Context is established by considering the proposed activities associated with a project, and the environment in which the project is planned to take place.

6.1.1 Activity Description

This is achieved by describing the key activities associated with the proposal and identifying 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). It is important that there is a sufficient level of detail provided for each activity, such that the associated aspects can be adequately quantified and assessed. Information about the activity which does not aid in the assessment of the environmental aspect may be included for context but is not necessary for the assessment.

Section 4 describes all components of the project proposal which are relevant to this assessment. This includes all phases of Scarborough, and activities that will be undertaken under the relevant Petroleum Titles. This section also details the aspects triggered by each activity (Table 4.10).

6.2 Risk Assessment of Key Environmental Impacts and Risks

In accordance with Regulation 5 of the OPGGS Regulations, the potential environmental impacts and risks associated with Scarborough have been identified and evaluated and summarised in this section. The impact and risk evaluations have been conducted as per the methodology described in Section 6. The scoping matrices in Section 6.3 identifies the aspects and impacts/risks to receptors associated with the proposed activities.

This section has been structured so:

- Sections 7.1.1 to 7.1.9.2 describe potential impacts from planned activities (i.e. routine and non-routine aspects)
- Sections 7.2.1 to 7.2.6 describe potential risks from unplanned activities (i.e. unplanned aspects).

Table 6.1 describes the content and purpose of this Section 7.

Table 6.1: Structure of this section

Content	Purpose
Source of the Aspect	Description of the aspect relative to Scarborough.
Impact or Risk	Description of how this aspect of Scarborough t has the potential to impact/presents a risk on the environment.
Receptors Potentially Impacted	Provides a summary of the receptors potentially impacted which were identified within the Impact or Risk Section. The Receptor/impact matrix which has been provided after the impact/risk evaluation of context contains ticks for receptors which are carried forward to detailed impact evaluation and crosses for those receptors which have not been evaluated further.
Detailed Impact Evaluation	For receptors which have a higher level of impact/risk of being impacted as a result of Scarborough a more details impact evaluation is undertaken. These are also the receptors for which a specific Environmental Performance Objectivise (EPO) have been developed.
Consequence Evaluation and review against acceptability criteria	Provides commentary to the overall consequence of the described aspect, and whether acceptability criteria have been met.
Summary of Impact Assessment	Section provides a summary of impacts, management controls, impact significance ratings and EPOs for the aspect.

6.2.1 Environment Description

This requires a description of the Project Area, and the Environment that May Be Affected (EMBA) by the aspects identified. The description includes all physical, ecological and socioeconomic receptors that may be present, with sufficient detail to inform the impact assessment. Where the impacts and risks are greatest, it is expected that there is more detail and certainty provided in the receptor description.

Section 5 describes the receiving environment. This section addresses the Project Area, which is comprised of the Offshore Project Area, the Trunkline Project Area and Borrow Ground Project Area. It also extends to the broader area that may be impacted in the event of unplanned events such as a hydrocarbon spill.

6.2.2 Review of the 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 sensitivity/vulnerability/importance of the receptor) as either high, medium or low value, and by stating the **Environmental Performance Outcomes (EPO)** for each receptor in the Project Area and EMBA, and the criteria for determining whether impacts and risks are **acceptable**.

Table 6-3 identifies the sensitivity of each of the receptors, which was determined to be either low, medium or high based on qualitative expert judgement. Key considerations for this determination included:

- **Quality** – Is the receptor considered to be relatively high quality, or is it damaged/degraded?
- **Sensitive 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?

To determine overall sensitivity, each receptor has been assessed against each of these considerations, and determined to be of high, medium or low sensitivity in accordance with the following:

- **Low**: Highly degraded, low biodiversity value ecosystems or those with a high recovery capacity.
- **Medium**: Natural ecosystem, species, habitat including ecosystems with slight disturbance/ degradation or those with a moderate recovery capacity.
- **High**: Highly valued ecosystems, species, habitats or physical or biological attributes or those with a low recovery capacity

Where one consideration was shown to have a higher level of sensitivity than others, for example where a receptor is of low importance and quality in a region but has a medium sensitivity to change, the highest sensitivity rating has been selected as the overall sensitivity.

Sensitivity considerations should also take into account any relevant legal protection, government policy, stakeholder views or ecosystem service value, and be reflected in the EPOs and acceptability criteria.

6.2.3 Environmental legislation and other requirements.

As part of establishing the context, it is important to know what environment legislation or other requirements are to be considered. This may include legislation that identifies the manner in which specific activities should be undertaken (such as vessel activities), for particular impacts and risks (e.g. biosecurity legislation) or management plans, guidelines, or advices that are issued to aid in the protection of significant receptors.

In preparing this OPP, Woodside has ensured 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 significant impact guidelines for MNES).

This has included developing the project in accordance with all applicable legislation as identified in Section 3, and ensuring the requirements of the species recovery plans and conservation advices have been considered to identify any requirements that may be applicable to the risk assessment.

Recovery plans are enacted under the EPBC Act and remain in force until the species is removed from the threatened list. Conservation advice provides guidance on immediate recovery and threat abatement activities that can be undertaken to facilitate the conservation of a listed species or ecological community. Recovery plans and conservation advices relevant to those species identified as potentially utilising habitat in the Scarborough Project Area by the EPBC Protected Matters search (Appendix D) have been considered in the determination of acceptable levels.

The OPP has also considered the significant impact guidelines for MNES. The MNES potentially impacted or at risk included:

- critically endangered and endangered species
- vulnerable species
- migratory species

- Wetlands of International Importance
- Commonwealth Marine Environment.

The relevant significant impact criteria were identified for each receptor and are reflected in the Environmental Performance Outcomes (EPOs) set for each of the receptors potential impacted or at risk from activities associated with Scarborough.

6.2.4 External requirements

In addition to legal or other requirements, to establish the context for a proposal there is a need to understand stakeholder expectations for the area in which the proposal is to take place. These expectations may be well understood and based on previous experience, consultation or general advice made available by stakeholders. Alternatively, they may be identified during project 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. Consequently, over the years Woodside has establish strong stakeholder relationships and an appreciation for 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 this into decision for the level of potential impact and risk of activities.

Woodside has commenced preliminary consultation with identified relevant stakeholders (Section 10) incorporating outcomes into the OPP where applicable and will continue to consider the views of stakeholders who provide comment on the Scarborough OPP through the formal consultation process and other means of ongoing consultation.

Consideration of the stakeholder views received via the public review process will be incorporated into the revised Scarborough OPP that will be submitted to NOPSEMA for their assessment following the public comment period.

6.2.5 Internal requirements

As well as legal and external, there are also internal requirements of the proponent that must be implemented when undertaking activities. These may be focussed on the manner in which particular activities are undertaken (for example VSP), for particular impacts or risks (IMS) or in order to protect certain receptors and may be captured under the proponents HSE Management System.

The Woodside Management System (WMS) (described in Section 2) defines how Woodside will deliver 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 area of responsibilities. Where relevant, Woodside internal requirements have been identified as controls (Section 7).

6.3 Impact and Risk Assessment - Scoping

6.3.1 Impact and Risk Identification

Terminology used for this impact and risk assessment has been taken from the Woodside impact and risk management process, which is aligned with ISO 13001:2018 and the requirements of the OPGGS Regulations.

Environmental impacts and risks include those directly and indirectly associated with the proposed activities and include potential emergency and accidental events.

Planned (routine and non-routine) activities have the potential for inherent changes to the environment, termed environmental ‘impacts’.

An environmental risk is an unplanned event which has the potential to result in a change to the environment, positive, negative or neutral. Risks are expressed in terms of the risk source, the event, the consequence of the risk, and the likelihood. In the instance where an environmental risk source leads to an unplanned event, the term ‘risk’ is used to describe the potential for impact (i.e. changes to the environment) which may affect receptor(s) (should the risk be realised). Risks include an assessment of both likelihood of the impact, and consequence of the change, which is called ‘risk consequence’ when discussed in terms of a risk.

All impacts and risks of the project are 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 are established. This sets up the framework for the more detailed impact and risk analysis and evaluation and helps to identify the knowledge gaps which may trigger specific studies and surveys required.

Based upon the context of the project, and known environmental aspects, all relevant risks and impacts were identified in the scoping phase. This was undertaken by considering the receptors identified (Section 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). All impacts and risks identified during the scoping phase are summarised in Table 6.2, which shows two categories of impacts or risks:

- Impacts/risks considered, but not considered credible (shown in grey)
- Impacts/risks considered credible, that are carried through into the environmental risk and impact assessment in Section 7.0 for a detailed evaluation (shown in green).

Section 7.0 provides justification for impacts or risks where application of an EPO for management purposes is warranted (shown in green), and describes the detailed assessment of all identified impacts and risks.

Table 6.2: Scoping of relationships between Aspects, Associated Impacts and Risks, and Receptors

Key	✓	Detailed Impact / Risk Assessment	✓	Impact / Risk Considered

Aspect	Impact/Risk[7]	Physical						Ecological												Socioeconomic									
		Marine Sediments	Water quality	Air Quality	Climate	Ambient Light	Ambient Noise	Plankton	Epifauna and Infauna	Coral	Seagrass	Macroalgae	Saltmarsh	Mangroves	Shoreline Habitats	Seabirds and Migratory Shorebirds	Fish	Marine Mammals	Marine Reptiles	KEFs	AMPs	Protected Places	Commonwealth Managed Fisheries	State Management Fisheries	Tourism and Recreation	Shipping	Industry	Defence	Coastal Settlements
Planned																													
Routine light emissions	Change in ambient light					✓																							
	Change in fauna behaviour															✓	✓		✓										
	Changes to the functions, interests or activities of other users																						✓	✓	✓				
Routine atmospheric and greenhouse gas emissions	Change in air quality			✓																									
	Injury/mortality to fauna															✓													
	Climate change				✓																								
	Change in aesthetic value																								✓				✓
Routine acoustic emissions	Change in ambient noise						✓																					✓	
	Change in fauna behaviour								✓								✓	✓	✓				✓	✓					
	Injury/mortality to fauna							✓	✓								✓	✓	✓										
	Changes to the functions, interests or activities of other users																						✓	✓				✓	
Physical presence: Displacement of other users	Changes to the functions, interests or activities of other users																						✓	✓	✓	✓	✓	✓	
Physical presence: Seabed disturbance	Change in habitat								✓								✓			✓	✓								
	Change in water quality		✓																	✓	✓								
	Injury/mortality to fauna							✓	✓								✓			✓									
Routine and non-routine discharges: Sewage and greywater	Change in water quality		✓																	✓									
	Injury/mortality to marine fauna							✓									✓	✓	✓	✓									
	Change in aesthetic value																								✓				✓
	Change to the functions, interests or activities of other users																								✓				✓
Routine discharges: Food waste	Change in water quality		✓																	✓									
	Change in fauna behaviour															✓	✓												
Routine and non-routine	Change in water quality		✓																	✓									
	Change in sediment quality	✓																											

[7] Note that there is a variation in the identified impacts and risks for each aspect. The basis for the selection of the relevant impacts and risks is provided in Section 7

Aspect	Impact/Risk[7]	Physical						Ecological													Socioeconomic								
		Marine Sediments	Water quality	Air Quality	Climate	Ambient Light	Ambient Noise	Plankton	Epifauna and Infauna	Coral	Seagrass	Macroalgae	Saltmarsh	Mangroves	Shoreline Habitats	Seabirds and Migratory Shorebirds	Fish	Marine Mammals	Marine Reptiles	KEFs	AMPs	Protected Places	Commonwealth Managed Fisheries	State Management Fisheries	Tourism and Recreation	Shipping	Industry	Defence	Coastal Settlements
discharges: Chemicals and deck drainage	Injury/mortality to fauna							✓									✓	✓	✓										
Routine and non-routine discharges: Brine and cooling water	Change in water quality		✓																	✓									
	Change in sediment quality	✓							✓											✓									
	Injury/mortality to fauna							✓	✓								✓	✓	✓										
Routine and non-routine discharges: operational fluids	Change in water quality		✓																	✓									
	Change in sediment quality	✓																											
	Injury/mortality to fauna							✓	✓								✓	✓	✓										
	Change in habitat																			✓									
	Changes to the functions, interests or activities of other users																						✓	✓					
Routine and non-routine discharges: Subsea installation and commissioning	Change in water quality		✓																	✓									
	Change in sediment quality	✓																		✓									
	Injury/mortality to fauna							✓	✓								✓												
	Changes to the functions, interests or activities of other users																						✓	✓					
Routine and non-routine discharges: Drilling	Change in habitat																			✓									
	Change in water quality		✓																										
	Change in sediment quality	✓																											
	Injury/mortality to fauna							✓	✓								✓	✓	✓										
Unplanned																													
Unpanned discharges: Chemicals	Change in water quality		✓																										
	Change in sediment quality	✓																											
	Injury/mortality to fauna							✓									✓	✓	✓										
Unplanned discharges: Solid waste	Change in water quality		✓																										
	Injury/mortality to fauna															✓	✓	✓	✓										
	Change in aesthetic values																								✓				✓
Physical presence (unplanned): Seabed disturbance	Change in water quality		✓																										
	Change in habitat								✓								✓			✓									
	Injury/mortality to fauna							✓	✓								✓			✓									
Physical presence (unplanned): IMS	Change in ecosystem dynamics								✓	✓	✓	✓																	
	Changes to the functions, interests or activities of other users																						✓	✓		✓	✓	✓	

Aspect	Impact/Risk[7]	Physical						Ecological												Socioeconomic									
		Marine Sediments	Water quality	Air Quality	Climate	Ambient Light	Ambient Noise	Plankton	Epifauna and Infauna	Coral	Seagrass	Macroalgae	Saltmarsh	Mangroves	Shoreline Habitats	Seabirds and Migratory Shorebirds	Fish	Marine Mammals	Marine Reptiles	KEFs	AMPs	Protected Places	Commonwealth Managed Fisheries	State Management Fisheries	Tourism and Recreation	Shipping	Industry	Defence	Coastal Settlements
Physical presence (unplanned): Collision with marine fauna	Injury/mortality to fauna																✓	✓	✓										
Unplanned hydrocarbon release	Change in water quality		✓																										
	Change in sediment quality	✓																											
	Change in habitat									✓	✓	✓	✓	✓	✓					✓	✓	✓							
	Change in fauna behaviour															✓	✓	✓	✓		✓	✓	✓	✓	✓				
	Injury/mortality to fauna							✓								✓	✓	✓	✓		✓	✓	✓	✓	✓				
	Changes to the functions, interests or activities of other users																						✓	✓	✓	✓	✓	✓	✓
	Change in aesthetic value																								✓				✓

6.4 Detailed Impact and Risk Analysis and Evaluation

Following the identification of impacts and risks, analysis and evaluation is undertaken to determine the extent of the impacts and risks, whether they are acceptable or not and to identify any impact and risk treatment (or controls) to be implemented.

6.4.1 Impact and Risk Analysis

Once pathways for impacts or risks on receptors are identified as credible, a more detailed analysis is undertaken to support further evaluation. This may involve detailed consideration of the receptors present, and the exposure levels and impact or risk pathways for each of the environmental aspects.

For Scarborough, the impact and risk analysis were informed by previous experience, literature and expert judgement, but also by project specific surveys and studies of key environmental features (including benthic habitat) and quantitative modelling of discharges and emissions. Where impacts and risks are greatest, the level of detail and certainty of the analysis increased.

6.4.2 Impact and Risk Evaluation

Impact and risk evaluation are undertaken by assessing the **magnitude** (i.e. no lasting effect, slight, minor, moderate, major or catastrophic) of the credible environmental impacts from each aspect based on extent, duration, frequency and scale, and then either

- assigning an **impact significance level** to each credible environmental impact based on the receptor sensitivity and the magnitude of the impact, OR
- assigning an **environmental risk consequence** to each environmental risk based on the receptor sensitivity, magnitude of the impact, and the **likelihood** of occurrence.

6.4.2.1 Impact Evaluation

This process involves determining the magnitude of an impact on the environmental receptor. This is an assessment of the impact in terms of the extent, duration frequency and scale of the impact as follows:

- Extent: The spatial extent of the impact ranges from limited to the location of the activity (e.g. FPU location), local (e.g. Offshore Project Area, width of Trunkline Project Area), regional (e.g. NW marine region) or widespread (>state-wide up to international).
- Duration: Timeframe of the impact; i.e. if it is short, medium or long term. Linked to duration of the aspect. E.g. pile driving over a few hours results in sound emissions that will stop once piling is finished. Based on sound levels emitted (high/low), impact (e.g. effects on marine mammals – behavioural or physical) may be lasting beyond the duration of the aspect.
- Frequency: The rate at which an event occurs over a period of time.
- Scale: The degree to which existing environmental conditions are modified as a result of the impact. This could be positive or negative. (e.g. physical disturbance to seabed from presence of subsea infrastructure – small footprint compared to rest of seabed available – but duration would be long-term).

The impact assessment then determines the impact significance of the potential impacts, based on the magnitude and the receptor sensitivity (Figure 6.2). 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.

	Receptor 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
Catastrophic (A)
Major (B)
Moderate (C)
Minor (D)
Slight (E)
Negligible (F)

Figure 6.2: Impact significance level

6.4.2.2 Risk Evaluation

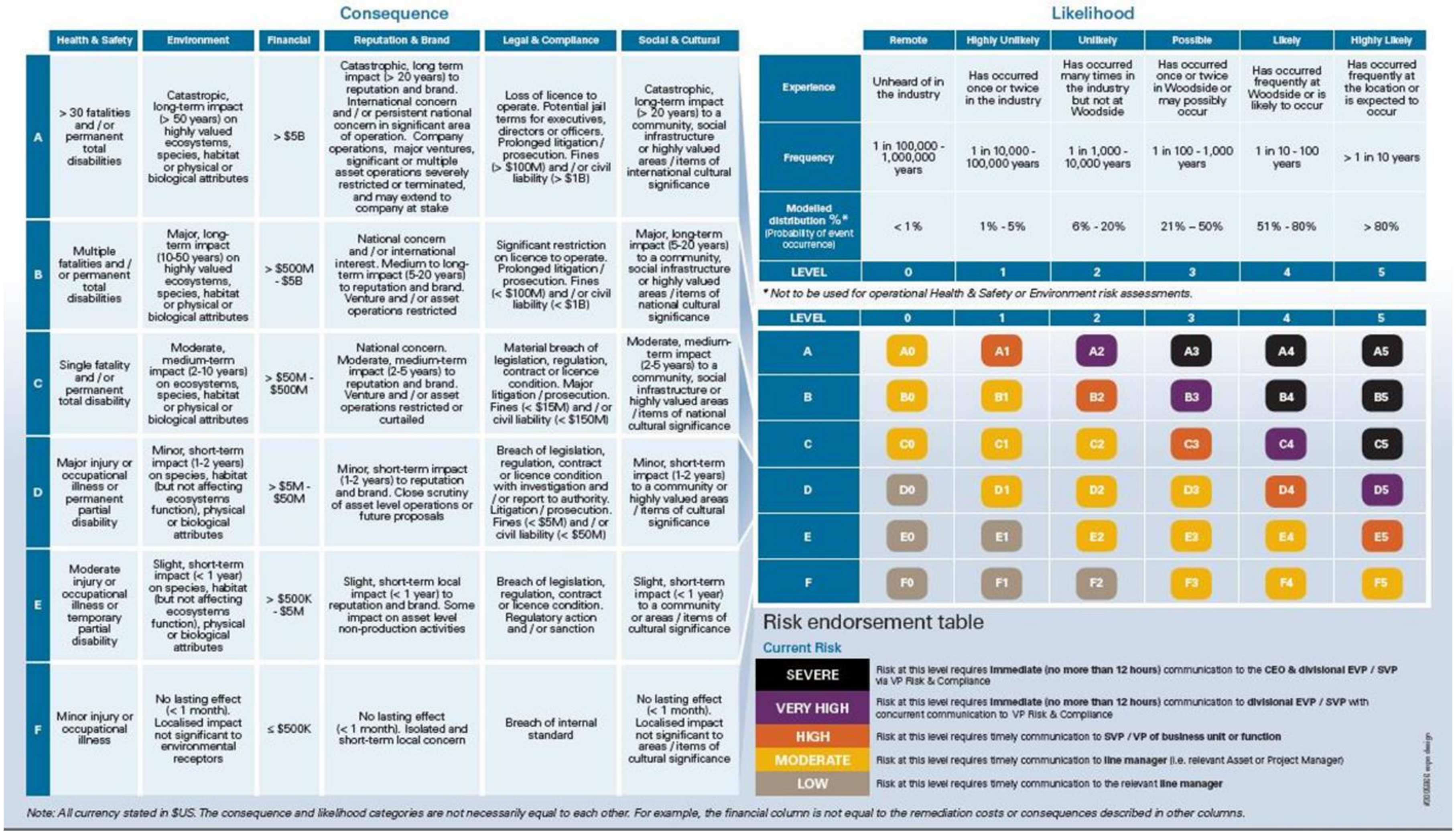
Environment risk levels are determined slightly differently than impact levels due to the requirement to consider the likelihood that the risk source(s) lead to the event or incident occurring. The likelihood of a risk occurring can be considered remote (0), highly unlikely (1), unlikely (2), possible (3), likely (4) or highly likely (5). Risk consequence, i.e. the consequence of any impacts realised by the risk source leading to an event, is determined using the methodology described in the Impact Evaluation (Section 6.4.2.1), i.e. magnitude and receptor sensitivity are combined to determine the overall consequence of the impact associated with the risk. The likelihood is combined with the risk consequence, to determine the risk level. The following risk levels may be assigned for the environmental risks:

- Severe
- Very High
- High

- Moderate
- Low.

Where consideration of the context, including the nature and scale of the activity and subsequent magnitude of impact, or the sensitivity or value of the receptor resulted in impacts that were either negligible or not credible, this is detailed and that impact or risk on the particular receptor not evaluated further.

For all other impacts and risks, detailed evaluations were undertaken to determine whether or not these were acceptable based on the criteria set in Section 6.4.4. Where the acceptability was contingent on applying particular controls, these were also described in the summary of residual risks, EPOs, etc.



Consequence

	Health & Safety	Environment	Financial	Reputation & Brand	Legal & Compliance	Social & Cultural
A	> 30 fatalities and / or permanent total disabilities	Catastropic, 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**

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 6.3: Environmental risk levels

6.4.3 Impact and Risk Treatment

In the process of evaluating impacts and risks, any **adopted controls** required to manage the impacts and risks to acceptable levels are identified and captured as commitments to be implemented for the project.

At the OPP phase, the adopted controls reflect the commitments that are required to be implemented in order to meet the criteria for acceptance. This includes any practices that will reduce the impacts and risks in order to meet the identified EPOs, any relevant legal requirements (related specifically to the impact/risk), internal company requirements, and any requirements that are identified through the community consultation process.

Further review and potential adoption of additional controls will be undertaken in subsequent phases of the project, such as during the preparation of EP for activities under the scope of this OPP. While the overarching EPOs will be carried through to the EP, the controls and corresponding environmental performance standards will be implemented to reduce risks to as low as reasonably practicable (ALARP).

6.4.4 Acceptability

In accordance with Regulation 5A, the Scarborough OPP describes the existing environment that may be affected by the project, and the details of the particular relevant values and sensitivities of that environment. It also aims, in accordance with 5D(6), to demonstrate that the proposal meets the criteria for acceptance of the OPP including that it:

(*d) sets out appropriate environmental performance outcomes that:*

(i) are consistent with the principles of ecologically sustainable development; and

(ii) demonstrate that the environmental impacts and risks of the project will be managed to an acceptable level.

Once the impacts and risks are evaluated, it can be determined whether the residual impacts and risks for each of the receptors present are consistent with the EPOs and meet all the criteria for acceptability.

Woodside has determined whether the impacts and risks of Scarborough are acceptable by considering the following evaluation criteria:

- Principles of Ecologically Sustainable Development (ESD) as defined under the EPBC Act (Section 6.4.4.1)
- internal context – the proposed impacts and risk levels are consistent with Woodside policies, procedures and standards (Section 6.2.5)
- external context – consideration of the environment consequence and stakeholder acceptability (Section 6.2.4)
- other requirements – the proposed controls and impact and risk levels are consistent with national and international standards, laws, policies and Woodside Standards (including applicable plans for management and conservation advices, and significant impact guidelines for MNES) (Section 0).

6.4.4.1 Principles of ESD

To define acceptable limits for identified impacts and risks, Woodside has given consideration of the principles of ESD as defined in Section 3A of the EPBC Act. This includes:

- decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations

- 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
- the principle of inter-generational equity – that the present generation should ensure the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations
- the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making
- improved valuation, pricing and incentive mechanisms should be promoted.

These principles are reflected in the Environmental Performance Outcomes set for the project, which have been set to align with the definitions provided in the *Matters of National Environmental Significance – Significant impact guidelines 1.1* (DotE, 2013).

6.5 Environmental Performance Outcomes and Acceptable Levels

The OPGGS Environment Regulations define EPOs to mean: "*a measurable level of performance required for the management of environmental aspects of an activity to ensure that environmental impacts and risks will be of an acceptable level*". As such, the process of defining an appropriate EPO, has relied on the required levels of performance set either in legislation (such as the OPGGS Act), regulator guidance notes such as the Matters of National Environmental Significance– Significant Impact Guidelines (DotE, 2013) or may be the result of specific agreements or expectations with other relevant stakeholders (e.g. fishers or other marine users).

In the assessment of Scarborough, impacts and risks have been demonstrated to be at an acceptable level if they do not result in a 'significant impact' as described in the Matters of National Environmental Significance – Significant Impact Guidelines (DotE, 2013). As described in the Guidelines, whether a not an activity is likely to have a significant impact depends on the sensitivity, value and quality of the environment which is impacted (as described in Section 4) and upon the intensity, duration, magnitude and geographic extent of the impacts (as described in detail for all impacts and risks in Section 7).

The EPO will be specific to the receptor (although may rely on common terminology used in the legislation or guidance to which they relate) and will be determined by whether the receptor species present are listed as an MNES or exist within an area of value.

For the physical and biological receptors present within the Scarborough EMBA, Woodside has identified EPOs that are consistent with the *Matters of National Environmental Significance – Significant impact guidelines 1.1* (DotE, 2013). These are defined in Table 6.3, and reflect the definitions as provided in the Significant Impact Guidelines.

For social receptors, including fishing and other commercial activities, the EPOs that have been set reflect the requirements in the OPGGS Act Section 280(2) in that the activities undertaken as a part of the development of Scarborough should not interfere with other marine users, to a greater extent than is necessary for the exercise of right conferred by the titles granted.

Based on the criteria described in Section 6.4.4, and the identified EPOs for each receptor, the acceptable levels of impacts and risks from Scarborough have been identified and are summarised in Table 6.3. Note that for each of the receptor-based EPOs, the source aspect is also referenced in the table.

Table 6.3: Receptor EPOs, regional context and consideration for determination of acceptability and justification for acceptable limits

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
Ambient light	**Low value (open water)** Ambient light is typical of an open water environment, with low sensitivity to change.	**EPO1:** 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.[9]	The Offshore Project Area is located 375 km from shore where there are no existing significant sources of artificial light. Existing lighting is limited to transient vessels. The Trunkline Corridor extends from the offshore location, pasting through remote waters where existing lighting sources are limited to transient vessels, other than the point where the corridor passes the Pluto facility (km distance). As the trunkline gets closer to State waters existing sources of light increase, especially around the islands, shipping channels and on approach to the mermaid sound.	Routine Light Emissions	**To meet the principles of ESD** Changes to ambient light would be acceptable providing EPO is met. This includes 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.
					Internal context There are no specific Woodside internal requirements, including policies, procedures and standards regarding ambient light at the Project Area. Matters relating to potentially impacted / at risk receptors are discussed for the respective receptor.
					External context To this point there have been no specific matters raised by stakeholders, regarding ambient light at the Project Area. Matters relating to potentially impacted / at risk receptors are discussed for the respective receptor.
					Other requirements There are no Management Plans, Recovery Plans or Conservation Advice related to ambient light. Vessel operations undertaken as a part of this activity will adhere to the *Navigation Act 2012*, MARPOL and the various Marine Orders (as appropriate to vessel class) enacted under this Act.

[8] The applicable impacts and risks of this aspect on the receptor are described in Section 7.

[9] Source of EPO: 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* (DotE, 2013).

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
					This Act regulates navigation and shipping including Safety of Life at Sea (SOLAS), which includes specific requirements for navigational lighting. Although the Act does not apply to the operation of petroleum facilities, it may apply to some activities of operations support vessels. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered as per the North-west Marine Parks Network Management Plan (DNP, 2018).
Ambient noise	**Low value (open water)** Ambient noise is typical of an open water environment, with low sensitivity to change. Anthropogenic noise exists in the region, lowering quality.	**EPO1:** 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.[10]	Large fluctuations in ambient noise levels in the Project Area are expected due to changes in weather systems and seasons, biological events such as whale migrations, and presence of shipping and other industrial activities. Ambient noise is expected to be greater in areas of the Trunkline Project Area which intercept areas of high vessel traffic.	Routine Acoustic Emissions	**To meet the principles of ESD** Changes to ambient noise would be acceptable providing EPO is met. This includes 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 a Commonwealth marine area results.
					Internal context The following Woodside internal requirements, including policies, procedures and standards, relate to ambient noise in the Project Area: • VSP Procedure. Matters relating to potentially impacted / at risk receptors are discussed for the respective receptor.
					External context To this point there have been no specific matters raised by stakeholders, regarding ambient noise in the Project Area. Matters relating to potentially impacted / at risk receptors are discussed for the respective receptor.

[10] Source of EPO: 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* (DotE, 2013).

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
					Other requirements No other requirements are identified for ambient noise. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered as per the North-west Marine Parks Network Management Plan (DNP, 2018). Other requirements relating to potentially impacted / at risk receptors are discussed for the respective receptor.
Water quality	**Low value (open water)** Ambient water quality is typical of an open water environment, with low sensitivity to change.	**EPO2:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.[11]	Water quality within the Project Area is typical of an unpolluted tropical offshore environment. Turbidity levels increase during the wet season, especially closer to shore, due to increased runoff, high tidal ranges and increased cyclonic activity. Concentrations of heavy metals and organic chemicals throughout the Project Area are low with concentrations in the Offshore Project Area environment generally lower. Surface water in the Offshore Project Area is nutrient poor. Deeper water has significantly lower concentrations of	Physical Presence – Seabed Disturbance Routine and Non-Routine Discharges: Sewage and Greywater Routine and Non-Routine Discharges: Food Waste Routine and Non-Routine Discharges: Chemicals and Deck Drainage Routine and Non-Routine Discharges: Brine and Cooling Water	**To meet the principles of ESD** Changes to water quality would be acceptable providing EPO is met. This includes to not result in a substantial change in water quality (including temperature) which may adversely impact on biodiversity, ecological integrity, social amenity or human health.
					Internal context Woodside will be compliant with the following requirements during activities that may impact on water quality: • Chemicals must be selected with the lowest practicable environmental impacts and risks subject to technical constraints.
					External context To this point there have been no specific matters raised by stakeholders, regarding water quality in the Project Area. Matters relating to potentially impacted / at risk receptors are discussed for the respective receptor.

[11] Source of EPO: 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* (DotE, 2013).

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
			dissolved oxygen than that of shallower waters, with no detected hydrocarbons.	Routine and Non-Routine Discharges: Operational Fluids Routine and Non-Routine Discharges: Subsea Installation and Commissioning Routine and Non-Routine Discharge: Drilling Unplanned Discharge: Chemicals Unplanned Discharge: Solid Waste Physical Presence (Unplanned): Seabed Disturbance Unplanned Hydrocarbon Release	**Other requirements** There are no Management Plans, Recovery Plans or Conservation Advice directly related to water quality. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered as per the North-west Marine Parks Network Management Plan (DNP, 2018). Vessel operations undertaken as a part of this activity will adhere to MARPOL and the various Marine Orders (as appropriate to vessel class) enacted under the *Navigation Act 2012*. This Act implements into Australian law Australia's obligations under the International Convention for the Prevention of Pollution from Ships (MARPOL Convention), which includes specific requirements for the discharge of wastes into the marine environment. Other requirements relating to potentially impacted / at risk receptors are discussed for the respective receptor.
Sediment quality	**Low value** Sediment quality is typical of the surrounding environment, with low sensitivity to change and	**EPO3:** To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.[12]	Sediments in the Offshore Project Area are currently of high quality, with low concentrations of metals and nutrients and no hydrocarbons detected during marine sediment quality surveys.	Routine and Non-Routine Discharges: Subsea Installation and Commissioning Routine and Non-Routine Discharge: Drilling Unplanned Hydrocarbon Release	**To meet the principles of ESD** Changes to sediment quality would be acceptable providing EPO is met. This includes: • to not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health • to not result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that

[12] Source of EPO: 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* (DotE, 2013).

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
	no features or species of conservation value.	**EPO4:** 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.[13]	Sediments along the Trunkline Project Area are expected to be dominated by sand as is typical of the continental slope in the Northwest Transition bioregion.		biodiversity, ecological integrity, social amenity or human health may be adversely affected. **Internal context** There are no specific Woodside internal requirements, including policies, procedures and standards regarding sediment quality at the Project Area. Matters relating to potentially impacted / at risk receptors are discussed for the respective receptor. **External context** To this point there have been no specific matters raised by stakeholders, regarding sediment quality at the Project Area. Matters relating to potentially impacted / at risk receptors are discussed for the respective receptor. **Other requirements** There are no Management Plans, Recovery Plans or Conservation Advice related to sediment quality. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered as per the North-west Marine Parks Network Management Plan (DNP, 2018). Sea Dumping Permits under the *Environment Protection (Sea Dumping) Act 1981* will be in place where required. Sea dumping activities will be undertaken in accordance with the act and under permit as required. Other requirements relating to potentially impacted / at risk receptors are discussed for the respective receptor.

[13] Source of EPO: 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* (DotE, 2013).

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
Air quality	**Low value (open water)** Air quality is typical of an open water environment, with low sensitivity to change.	**EPO5:** To not result in a substantial change in air quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.[14]	Due to the extent of the open ocean area and the activities that are currently undertaken within the NWS, it is considered the ambient air quality in the EMBA and wider offshore NWMR will be high.	Routine Atmospheric Emissions	**To meet the principles of ESD** Changes to air quality would be acceptable providing EPO is met. This includes to not result in a substantial change in air quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.
					Internal context The following Woodside internal requirements relate to air quality in the Project Area: • Facilities must be designed and operated to optimise resource efficiency.
					External context To this point there have been no specific matters raised by stakeholders, regarding air quality at the Project Area. Matters relating to potentially impacted / at risk receptors are discussed for the respective receptor.
					Other requirements There are no Management Plans, Recovery Plans or Conservation Advice related to air quality. Activities undertaken as a part of this project will adhere to the requirements of the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* Act including restrictions on import and use of Ozone Depleting Substances (ODS) (in refrigeration and air conditioning equipment) through control measures in procurement. This Act and associated regulations provide for measures to protect ozone in the atmosphere by controlling and ultimately reducing the manufacture, import and export of ozone depleting substances (ODS) and synthetic greenhouse gases, and replacing them with suitable alternatives. The Act

[14] Source of EPO: 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* (DotE, 2013).

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
					will only apply to Woodside if it manufactures, imports or exports ozone depleting substances. Other requirements relating to potentially impacted / at risk receptors are discussed for the respective receptor.
Climate	**Low sensitivity (at location)** Climate is typical of an open water environment, with low sensitivity to change.	**EPO19:** Optimise efficiencies in air emissions and reduce greenhouse emissions to ALARP and Acceptable Levels.	Climate in the Project Area is typical of the offshore environment in the North West Marine Region. The wave climate of open waters of the NWMR is influenced by locally generated wind waves (seas) and remotely generated swells. Winds vary seasonally, with a tendency for winds from the south-west quadrant during summer months (September–March) and the north-east quadrant in autumn and winter months (April–August). Tropical cyclones are relatively frequent in the NWMR, with the Pilbara coast experiencing more cyclonic activity than any other region of the Australian mainland coast. Tropical cyclone activity can occur between November and April and is most frequent during December to March (i.e. considered the peak period), with an annual average of about one storm per month.	Routine Atmospheric Emissions	**To meet the principles of ESD** Changes to climate would be acceptable providing EPO is met. This includes to minimise GHG emissions contributing to climate change. **Internal context** The following Woodside internal policy relates to climate in the Project Area: • Woodside Climate Change Policy **External context** To this point there have been no specific matters raised by stakeholders, regarding air quality at the Project Area. Matters relating to potentially impacted / at risk receptors are discussed for the respective receptor. **Other requirements** There are no Management Plans, Recovery Plans or Conservation Advice related to climate. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered as per the North-west Marine Parks Network Management Plan (DNP, 2018). Activities undertaken as a part of this project will adhere to the requirements of the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* Act including restrictions on import and use of Ozone Depleting Substances (ODS) (in refrigeration and air conditioning equipment) through control measures in procurement.

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
					This Act and associated regulations provide for measures to protect ozone in the atmosphere by controlling and ultimately reducing the manufacture, import and export of ozone depleting substances (ODS) and synthetic greenhouse gases, and replacing them with suitable alternatives. The Act will only apply to Woodside if it manufactures, imports or exports ozone depleting substances. The Paris Agreement has established a framework for managing global climate change that relies on nations setting Nationally Determined Contributions and establishing domestic policies to meet them. As such, Scarborough will be subject to domestic laws that reflect Australia's commitment under the Paris Agreement. Beyond complying with these laws, Scarborough is subject to Woodside's Climate Change Policy, which includes promoting a culture of energy efficiency and improved resource use in designs and operations. Other requirements relating to potentially impacted / at risk receptors are discussed for the respective receptor.
Plankton	**Low value (open water)** Plankton are typical of an open water environment, with low sensitivity to change and no species of high importance or quality.	**EPO6:** To not have a substantial adverse effect on a population of plankton including its life cycle and spatial distribution.[15]	Plankton communities have a naturally patchy distribution in both space and time, noting that the NWMR is typically characterised by low planktonic productivity.	Routine and Non-Routine Discharges: Brine and Cooling Water Routine and Non-Routine Discharges: Operational Fluids Unplanned Hydrocarbon Release	**To meet the principles of ESD** Impacts or risks to plankton are considered to be acceptable providing that the EPO is met. This includes to not have a substantial adverse effect on a population of plankton including its life cycle and spatial distribution. **Internal context** There are no specific Woodside internal requirements, including policies, procedures and standards regarding plankton in the Project Area. **External context** To this point there have been no specific matters raised by stakeholders, regarding plankton at the Project Area.

[15] Source of EPO: 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* (DotE, 2013).

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
					Other requirements No other requirements have been identified for plankton. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered as per the North-west Marine Parks Network Management Plan (DNP, 2018).
Fish	**High value species** MNES species known to be present.	**EPO7:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population.[16] **EPO8:** To not substantially modify, destroy or isolate an area of important habitat for a migratory species.[17] **EPO9:** To not seriously disrupt the lifecycle (breeding, feeding, migration or	Generally, within the NWMR, fish assemblage and species richness decrease with increasing depth and is positively correlated with habitat complexity. The Offshore Project Area is deep and predominantly featureless resulting in a low abundance of fish fauna. Fish species presence is more likely along the trunkline corridor which overlaps significant fish habitat areas that support higher demersal fish richness and abundance.	Unplanned Discharge: Solid Waste Unplanned Hydrocarbon Release	**To meet the principles of ESD** Impacts or risks to fish are considered to be acceptable providing that the EPO is met. This includes: • to not have a substantial adverse effect on a population of fish, or the spatial distribution of the population • to not substantially modify, destroy or isolate an area of important habitat for a migratory species • to not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.
					Internal context There are no specific Woodside internal requirements, including policies, procedures and standards regarding fish in the Project Area.

[16] Source of EPO: 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* (DotE, 2013).

[17] Source of EPO: Significant impact criteria for an impact on the environment on a migratory species as defined in the *Matters of National Environmental Significance – Significant impact guidelines 1.1* (DotE, 2013).

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
		resting behaviour) of an ecologically significant proportion of the population of a migratory species.[18]			**External context** To this point there have been no specific matters raised by stakeholders, regarding plankton at the Project Area.
					Other requirements Impacts to specific species of fish and sharks that may be present are to be managed in accordance with the specific conservation advices. These advices identify habitat degradation / modification and vessel disturbance as the key threats. While generally no explicit management actions are identified, for some species there are specific requirements. Sawfish and river sharks: • Identify risks to important sawfish and river shark habitat and measures needed to reduce those risks. • Implement measures to reduce adverse impacts of habitat degradation and/or modification. (Freshwater sawfish only) Whale shark: • Minimise offshore developments and transit time of large vessels in areas close to marine features likely to correlate with Whale Shark aggregations and along the northward migration route that follows the northern Western Australian coastline along the 200 m isobath. As activities will take place within or adjacent to AMPs, there are also principles, objectives and values to be considered. **Montebello Marine Park** The objective of the Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species. Natural values of

[18] Source of EPO: Significant impact criteria for an impact on the environment on a migratory species as defined in the *Matters of National Environmental Significance – Significant impact guidelines 1.1* (DotE, 2013).

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
					the marine park include diverse fish communities, and Biologically Important Areas for foraging habitat for whale sharks. **Dampier Marine Park** 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 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. Natural values of the marine park include diverse fish communities. **Gascoyne Marine Park** 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 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 Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species. Natural values of the marine park include diverse fish communities, specifically within the Continental slope demersal fish communities KEF. **Ningaloo Marine Park** 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. Natural values of the marine park include diverse fish communities, specifically within the Continental slope demersal fish communities KEF, and Biologically Important Areas for foraging habitat for whale sharks.

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
Seabirds and Shorebirds	**High value species** MNES species known to be present.	**EPO10:** To not have a substantial adverse effect on a population of seabirds or shorebirds, or the spatial distribution of the population.[19] **EPO8:** To not substantially modify, destroy or isolate an area of important habitat for a migratory species.[20] **EPO9:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.[21]	A range of seabirds and shorebirds are likely to occur with the Project Area and broader region. Breeding BIAs for seabirds and shorebirds are primarily restricted to within tens of kilometres of emergent features however pelagic seabird presence is still likely to occur within the Offshore Project Area. Since the majority of species which have distribution within the Trunkline Project Area are migratory, their presence would only be expected during part of the year. It is expected that species presence in the Trunkline Project Area will be greatest in proximity to emergent features.	Routine Light Emissions Unplanned Discharge: Solid Waste Unplanned Hydrocarbon Release	**To meet the principles of ESD** Impacts or risks to seabirds and shorebirds are considered to be acceptable providing that the EPO is met. This includes: • to not have a substantial adverse effect on a population of seabirds or shorebirds, or the spatial distribution of the population • 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 • to not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species. **Internal context** There are no specific Woodside internal requirements, including policies, procedures and standards regarding seabirds or shorebirds for the Project Area. **External context** To this point there have been no specific matters raised by stakeholders, regarding seabirds or shorebirds in the Project Area.

[19] Source of EPO: 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* (DotE, 2013).

[20] Source of EPO: Significant impact criteria for an impact on the environment on a migratory species as defined in the *Matters of National Environmental Significance – Significant impact guidelines 1.1* (DotE, 2013).

[21] Source of EPO: Significant impact criteria for an impact on the environment on a migratory species as defined in the *Matters of National Environmental Significance – Significant impact guidelines 1.1* (DotE, 2013).

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
					Other requirements Impacts to specific species of seabirds and shorebirds that may be present are to be managed in accordance with the specific conservation advices. These advices identify habitat degradation as the key threats. While generally no explicit management actions are identified, for some of the species including the Greater Sand Plover, Large Sand Plover, Great Knot, Eastern Curlew and Far Eastern Curlew, there is a general requirement to: • manage disturbance at important sites which are subject to anthropogenic disturbance when the species is present. In addition, there is a specific requirement for the Australian Painted Snipe to: • ensure there is no disturbance in areas where the species is known to breed. There is also a specific requirement for Australian Fairy Tern to: • ensure appropriate oil-spill contingency plans are in place for the subspecies' breeding sites which are vulnerable to oil spills. As activities will take place within or adjacent to AMPs, there are also principles, objectives and values to be considered. **Montebello Marine Park** The objective of the Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species. Natural values of the marine park include biologically important areas for breeding habitat for seabirds. **Dampier Marine Park** 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

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
					habitats. 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. Natural values of the marine park include biologically important areas for breeding and foraging habitat for seabirds. **Gascoyne Marine Park** 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 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 Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species. Natural values of the marine park include biologically important areas for breeding habitat for seabirds. **Ningaloo Marine Park** 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. Natural values of the marine park include biologically important areas for breeding and foraging habitat for seabirds.
Marine Reptiles	**High value species** MNES species known to be present.	**EPO11:** To not have a substantial adverse effect on a population of marine reptiles, or the	There are no sensitive marine turtle habitats near the offshore location for Scarborough. The closest known turtle nesting beach are the islands of the Dampier Archipelago, about 375 km from the Offshore Project Areas associated with Scarborough.	Routine Light Emissions Routine Acoustic Emissions Unplanned Discharge: Solid Waste Physical Presence (Unplanned):	**To meet the principles of ESD** Impacts or risks to marine reptiles are considered to be acceptable providing that the EPO is met. This includes: • to not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population • 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	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
		spatial distribution of the population.[22] **EPO1:** 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.[23] **EPO9:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.[24]	The Trunkline Project Area does intercept with BIAs for flatback, green, hawksbill and loggerhead turtles. BIAs and critical habitats for marine turtles are identified for internesting and foraging.	Collision with Marine Fauna Unplanned Hydrocarbon Release	• to not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species. **Internal context** There are no specific Woodside internal requirements, including policies, procedures and standards regarding marine reptiles for the Project Area. **External context** To this point there have been no specific matters raised by stakeholders, regarding marine reptiles in the Project Area. **Other requirements** Impacts to turtles are to be managed in accordance with the Recovery plan for marine turtles in Australia (DoEE, 2017). Identified conservation actions include: *Vessel Disturbance* • Vessel interactions identified as a threat; no specific management actions in relation to vessels prescribed in the plan. *Light Pollution* • Minimise light pollution.

[22] Source of EPO: 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* (DotE, 2013).

[23] Source of EPO: Significant impact criteria for an impact on the environment on a migratory species as defined in the *Matters of National Environmental Significance – Significant impact guidelines 1.1* (DotE, 2013).

[24] Source of EPO: Significant impact criteria for an impact on the environment on a migratory species as defined in the *Matters of National Environmental Significance – Significant impact guidelines 1.1* (DotE, 2013).

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
					• Identify the cumulative impact on turtles from multiple sources of onshore and offshore light pollution. *Acute chemical discharge (oil pollution)* • Ensure spill risk strategies and response programs include management for turtles and their habitats. • The Recovery plan identifies darkness strategies to reduce as far as practicable lights or light glow interfering with nesting female turtles and hatchlings. In addition, there is in place approved Conservation Advice for the Short-nosed Seasnake (DSEWPaC, 2011). This advice includes to: • Monitor known populations to identify key threats. Ensure there is no anthropogenic disturbance in areas where the species occurs, excluding necessary actions to manage the conservation of the species. As activities will take place within or adjacent to AMPs, there are also principles, objectives and values to be considered. **Montebello Marine Park** The objective of the Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species. Natural values of the marine park include biologically important areas for internesting, foraging, mating and nesting habitat for marine turtles. **Dampier Marine Park** 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 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.

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
					Natural values of the marine park include biologically important areas for internesting for marine turtles. **Gascoyne Marine Park** 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 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 Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species. Natural values of the marine park include biologically important areas for internesting for marine turtles. **Ningaloo Marine Park** 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. Natural values of the marine park include biologically important areas for internesting for marine turtles.
Marine mammals	**High value species** MNES species known to be present.	**EPO12:** To not have a substantial adverse effect on a population of marine mammals, or the	The NWMR is thought to be an important migratory pathway for large truly pelagic whales. Foraging whales have been observed in areas of upwelling in NWMR. Dolphins and dugongs are typically found in nearshore waters. Numbers of migrating individuals in the Project Area will be higher during peak migration periods which differs between species.	Routine Acoustic Emissions Unplanned Discharge: Solid Waste Physical Presence (Unplanned): Collision with Marine Fauna Unplanned Hydrocarbon Release	**To meet the principles of ESD** Impacts or risks to marine mammals are considered to be acceptable providing that the EPO is met. This includes: • to not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population • 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 • to not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
		spatial distribution of the population.[25] **EPO1:** 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.[26] **EPO9:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the	Nevertheless, these BIAs will only represent important habitat for Humpback and Pygmy blue whale. Since the Trunkline Project Area traverses the continental shelf and is in relative proximity to shorelines, dolphins are more likely to occur in the Trunkline Project Area compared to the Offshore Project Area, although no BIAs or other significant habitat or aggregations were identified. The Dugong is also more likely to occur in shallower waters of the Trunkline Project Area. Distribution of cetaceans in the Offshore Project Area are less likely than that experienced along the trunkline corridor, with one BIA for distribution in the area.		ecologically significant proportion of the population of a migratory species. **Internal context** The following Woodside internal requirements, including policies, procedures and standards, relate to marine mammals in the Project Area: • VSP Procedure. **External context** To this point there have been no specific matters raised by stakeholders, regarding marine mammals in the Project Area. **Other requirements** Impacts to specific species of marine mammals that may be present are to be managed in accordance with the specific conservation advices. These advices identify noise interference and vessel disturbance as the key threats. Activities will be conducted in line with the management

[25] Source of EPO: 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* (DotE, 2013).

[26] Source of EPO: Significant impact criteria for an impact on the environment on a migratory species as defined in the *Matters of National Environmental Significance – Significant impact guidelines 1.1* (DotE, 2013).

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
		population of a migratory species.[27]			measures and conservation advice relevant to each species, as provided below. Sei whale: • Assess and manage acoustic disturbance. • Assess and manage physical disturbance and development activities. Blue whale: • Assess and address anthropogenic noise. • Minimise vessel collision. Fin whale: • Once the spatial and temporal distribution (including biologically important areas) of Fin Whales is further defined, assess the impacts of increasing anthropogenic noise (including seismic surveys, port expansion, and coastal development). • Develop a national vessel strike strategy that investigates the risk of vessel strikes on Fin Whales and identifies potential mitigation measures • Ensure all vessel strike incidents are reported in the National Vessel Strike Database. Humpback whale: • For actions involving acoustic impacts (example pile driving, explosives) on Humpback Whale calving, resting, feeding areas, or confined migratory pathways, undertake site-specific acoustic modelling (including cumulative noise impacts). • Ensure the risk of vessel strike on Humpback Whales is considered when assessing actions that increase vessel traffic in areas where Humpback

[27] Source of EPO: Significant impact criteria for an impact on the environment on a migratory species as defined in the *Matters of National Environmental Significance – Significant impact guidelines 1.1* (DotE, 2013).

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
					Whales occur and, if required appropriate mitigation measures are implemented to reduce the risk of vessel strike. All relevant activities will be conducted in line with the *EPBC Act Policy Statement 2.1 – Interaction between Offshore Seismic Exploration and Whales.* As activities will take place within or adjacent to AMPs, there are also principles, objectives and values to be considered. **Montebello Marine Park** The objective of the Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species. Natural values of the marine park include biologically important areas for migratory pathways for humpback whales. **Dampier Marine Park** 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 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. Natural values of the marine park include biologically important areas for migratory pathways for humpback whales. **Gascoyne Marine Park** 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 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 Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species. Natural values of

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
					the marine park include biologically important areas for migratory pathways for humpback whales and foraging habitat and migratory pathways for pygmy blue whales. **Ningaloo Marine Park** 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. Natural values of the marine park include biologically important areas for migratory pathways for humpback whales, foraging habitat and migratory pathways for pygmy blue whales, and foraging and nursing habitat for dugong.
Epifauna and infauna	**Low value** Epifauna and infauna are typical of the surrounding environment, with no species of high importance or quality.	**EPO1:** 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.[28]	Benthic composition in deep water habitats is generally lower in abundance than shallow water habitats of the region. Density of benthic fauna tends to be lower in deep water sediments (>200 m) than in shallower coastal sediments, but the diversity of communities may be similar. The area of shallower waters between Dampier and Port Hedland is a hotspot for sponge biodiversity.	Physical Presence – Seabed Disturbance Physical Presence (Unplanned): Seabed Disturbance Physical Presence (Unplanned): IMS	**To meet the principles of ESD** Impacts or risks to epifauna and infauna are considered to be acceptable providing that the EPO is met. This includes 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. **Internal context** The following Woodside internal requirements, including policies, procedures and standards, relate to epifauna and infauna in the Project Area: • IMS Procedure. **External context** To this point there have been no specific matters raised by stakeholders, regarding epifauna and infauna in the Project Area.

[28] Source of EPO: 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* (DotE, 2013).

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
					Other requirements There are no Management Plans, Recovery Plans or Conservation Advice related to epifauna and infauna. Vessel operations undertaken as a part of this project will comply with anti-fouling system requirements in accordance with the *Protection of the Sea (Harmful Antifouling Systems) Act 2006*. This Act implements Australia's obligations under the International Convention on the Control of Harmful Anti-Fouling Systems on Ships (Harmful Anti-Fouling Systems Convention). The project will comply with biosecurity requirements in accordance with the *Biosecurity Act 2015*. This will include biofouling and ballast water requirements for vessels, offshore facilities and associated in-water equipment. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. Natural values of the marine park relating to epifauna and infauna occur in Dampier Marine Park, but not in Montebello, Gascoyne or Ningaloo Marine Parks. **Dampier Marine Park** 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 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. Dampier Marine Park is a hotspot for sponge diversity.

<table>
<tr><th>Receptor</th><th>Receptor Sensitivity Level</th><th>EPO</th><th>Regional Context</th><th>Environmental Aspects Relevant to the OPP[8]</th><th>Considerations to determine whether impacts and risks are acceptable</th></tr>
<tr><td rowspan="4">Coral</td><td rowspan="4">High value habitat
High sensitivity to change.</td><td rowspan="4">EPO1: 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.[29]</td><td rowspan="4">Both hard corals and sofa corals are found throughout the Dampier Archipelago, with the species diversity representing a large proportion of the genera known to occur in WA. Other significant areas of coral reef in the EMBA include Ningaloo Reef, and those fringing the Muiron Islands, Barrow Island and Montebello Islands.
Due to the water depths of the majority of the Trunkline Project Area in Commonwealth waters, no hard corals are expected to occur, however surveys have shown the presence of soft corals, however they are not a dominant species.</td><td rowspan="4">Physical Presence (Unplanned): IMS
Unplanned Hydrocarbon Release</td><td>To meet the principles of ESD
Impacts or risks to coral are considered to be acceptable providing that the EPO is met. This includes 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.</td></tr>
<tr><td>Internal context
The following Woodside internal requirements, including policies, procedures and standards, relate to coral in the Project Area:
• IMS Procedure.</td></tr>
<tr><td>External context
To this point there have been no specific matters raised by stakeholders, regarding coral in the Project Area.</td></tr>
<tr><td>Other requirements
There are no Management Plans, Recovery Plans or Conservation Advice related to coral.
Vessel operations undertaken as a part of this project will comply with anti-fouling system requirements in accordance with the Protection of the Sea (Harmful Antifouling Systems) Act 2006. This Act implements Australia's obligations under the International Convention on the Control of Harmful Anti-Fouling Systems on Ships (Harmful Anti-Fouling Systems Convention).
The project will comply with biosecurity requirements in accordance with the Biosecurity Act 2015. This will include biofouling and ballast water requirements for vessels, offshore facilities and associated in-water equipment.</td></tr>
</table>

[29] Source of EPO: 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* (DotE, 2013).

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
					As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. Natural values of the marine park relating to coral occur in Dampier Marine Park, but not in Montebello, Gascoyne or Ningaloo Marine Parks. **Dampier Marine Park** 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 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. Dampier Marine Park includes several submerged coral reefs and shoals including Delambre Reef and Tessa Shoals.
Seagrass	**High value habitat** High sensitivity to change.	**EPO1:** 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.[30]	Within the EMBA, significant seagrass and macroalgae communities are found in waters surrounding islands. Seagrasses and are generally found in coastal waters at depths of <10 m, although they have been recorded at 50 m in some Australian waters. Therefore, it is highly unlikely that seagrasses are present within the Offshore Project Area. The shallowest water depths in Trunkline Project Area are 35 m. Seagrasses may occur	Physical Presence (Unplanned): IMS Unplanned Hydrocarbon Release	**To meet the principles of ESD** Impacts or risks to seagrass are considered to be acceptable providing that the EPO is met. This includes 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.
					Internal context The following Woodside internal requirements, including policies, procedures and standards, relate to seagrass in the Project Area: • IMS Procedure.
					External context To this point there have been no specific matters raised by stakeholders, regarding seagrass in the Project Area.

[30] Source of EPO: 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* (DotE, 2013).

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
			in areas of the Trunkline Project Area where water depths are less than 50 m. However, extensive areas of seagrass are not expected given distribution is typically limited to water depths shallower than the Trunkline Project Area.		**Other requirements** There are no Management Plans, Recovery Plans or Conservation Advice related to seagrass. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. There are no specified natural values related to seagrass in the Dampier, Gascoyne, Ningaloo or Montebello Marine Parks.
Macroalgae	**Low value habitat** Macroalgae are homogenous, and therefore have a low sensitivity to change.	**EPO1:** 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.[31]	Macroalgae are most commonly found on shallow limestone pavements. Macroalgae are generally found in coastal waters at depths of <10 m, although they have been recorded at 50 m in some Australian waters. Therefore, it is highly unlikely that seagrasses are present within the Offshore Project Area.	Physical Presence (Unplanned): IMS Unplanned Hydrocarbon Release	**To meet the principles of ESD** Impacts or risks to macroalgae are considered to be acceptable providing that the EPO is met. This includes 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.
					Internal context The following Woodside internal requirements, including policies, procedures and standards, relate to macroalgae in the Project Area: • IMS Procedure.
					External context To this point there have been no specific matters raised by stakeholders, regarding macroalgae in the Project Area.
					Other requirements There are no Management Plans, Recovery Plans or Conservation Advice related to macroalgae. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered as per

[31] Source of EPO: 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* (DotE, 2013).

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
					the North-west Marine Parks Network Management Plan (DNP, 2018).
Coastal habitats	**High value habitat** Habitats with high sensitivity to change, such as mangroves.	**EPO1:** 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.[32]	Given the offshore location of the Project Area, coastal habitats occur in neither the Offshore Project Area nor Trunkline 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 Release	**To meet the principles of ESD** Impacts or risks to shoreline habitats are considered to be acceptable providing that the EPO is met. This includes 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.
					Internal context The following Woodside internal requirements, including policies, procedures and standards, relate to coastal habitats in the Project Area: • IMS Procedure.
					External context To this point there have been no specific matters raised by stakeholders, regarding coastal habitats.
					Other requirements There are no Management Plans, Recovery Plans or Conservation Advice related to shoreline habitats. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered as per the North-west Marine Parks Network Management Plan (DNP, 2018).

[32] Source of EPO: 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* (DotE, 2013).

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
Industry	**Low value** The Project Area is not of extensive use by other Industry.	**EPO13:** To not have a substantial adverse effect on water quality such that an adverse impact on industry use occurs.[33] **EPO14:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.[34]	Industry includes oil and gas activities, and defence activities. Oil and gas infrastructure in proximity to the Project Area include that associated with the main producing hubs of the Pluto LNG project, the Wheatstone LNG project and the Greater Gorgon LNG project. There are designated Department of Defence practice areas operating out of the Royal Australian Air Force base located at Learmonth, on North West Cape.	Physical Presence – Displacement of Other Users Physical Presence (Unplanned): IMS Unplanned Hydrocarbon Release	**To meet the principles of ESD** Impacts or risks to industry are considered to be acceptable providing that the EPO is met. This includes: • to not have a substantial adverse effect on water quality such that an adverse impact on industry use occurs • to not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted. **Internal context** There are no specific Woodside internal requirements, including policies, procedures and standards regarding industry in the Project Area. **External context** To this point there have been no specific matters raised by stakeholders, regarding industry in the Project Area. **Other requirements** Vessel operations undertaken as a part of this activity will adhere to MARPOL and the various Marine Orders (as appropriate to vessel class) enacted under the *Navigation Act 2012*. This Act regulates navigation and shipping including Safety of Life at Sea (SOLAS). Although the Act does not apply to the operation of petroleum facilities, it may apply to some activities of operations support vessels. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. Social

[33] Source of EPO: 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* (DotE, 2013).

[34] Source of EPO: OPGGS Act Section 280(2)

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
					values of the marine park relating to industry occur in Montebello and Gascoyne Marine Parks, but not in Ningaloo or Dampier Marine Parks. **Montebello Marine Park** The objective of the Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species. Mining is listed as an important activity for social and economic values of the Marine Park. **Gascoyne Marine Park** 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 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 Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species. Mining is listed as an important activity for social and economic values of the Marine Park.
Commonwealth and State Managed Fisheries	**High value marine user** Key fishing area, with high importance to stakeholders.	**EPO15:** To not have a substantial adverse effect on the sustainability of commercial fishing. **EPO14:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right	Commonwealth and State managed fisheries are present within the EMBA and Trunkline Project Area. The only Commonwealth managed fisheries likely to have active fishing areas intersecting with the Project Area is the Northwest Slope Trawl Fishery. There are seven State-managed fisheries which may	Physical Presence – Displacement of Other Users Unplanned Hydrocarbon Release	**To meet the principles of ESD** Impacts or risks to fishing are considered to be acceptable providing that the EPO is met. This includes: • to not have a substantial adverse effect on the sustainability of commercial fishing • to not interfere with other marine users, including recreational and commercial fishers to a greater extent than is necessary for the exercise of right conferred by the titles granted. **Internal context**

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
		conferred by the titles granted.[35]	undertake fishing activities within the Project Area.		The following Woodside internal requirements, including policies, procedures and standards, relate to fishing in the Project Area: • IMS Procedure.
					External context To this point there have been no specific matters raised by stakeholders, regarding fishing in the Project Area.
					Other requirements Vessel operations undertaken as a part of this activity will adhere to MARPOL and the various Marine Orders (as appropriate to vessel class) enacted under the *Navigation Act 2012*. This Act regulates navigation and shipping including Safety of Life at Sea (SOLAS). Although the Act does not apply to the operation of petroleum facilities, it may apply to some activities of operations support vessels. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. **Montebello Marine Park** The objective of the Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species. Fishing is listed as an important activity for social and economic values of the Marine Park **Dampier Marine Park** 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 National Park Zone (II) is to

[35] Source of EPO: OPGGS Act Section 280(2)

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
					provide for the protection and conservation of ecosystems, habitats and native species in as natural a state as possible. Fishing is listed as an important activity for social and economic values of the Marine Park **Gascoyne Marine Park** 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 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 Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species. Fishing is listed as an important activity for social and economic values of the Marine Park **Ningaloo Marine Park** 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. Fishing is listed as an important activity for social and economic values of the Marine Park.
Australia Marine Parks	**High value** Designated sensitive area. Values protected by legislation.	**EPO1:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem	The following AMPs are relevant to the Project Area: • Montebello (Overlaps the Project Area) • Dampier (Adjacent to Borrow Ground Project Area) • Gascoyne (87km from Project Area)	Physical Presence – Seabed Disturbance Unplanned Hydrocarbon Release	**To meet the principles of ESD** Impacts or risks to AMPs are considered to be acceptable providing that the EPO is met. This includes 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.
					Internal context There are no specific Woodside internal requirements, including policies, procedures and standards regarding AMPs in the Project Area.

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
		functioning or integrity results.[36]	• Ningaloo (186km from Project Area)		**External context** To this point there have been no specific matters raised by stakeholders, regarding AMPs in the Project Area. **Other requirements** Impacts to AMPs are to be managed in accordance with the North-west Marine Parks Management Plan 2018 (Director of Parks, 2018) and the IUCN Protected Area Category and relevant Management Principles, as outlined in Section 3.5.2. Other requirements relating to potentially impacted / at risk receptors are discussed for the respective receptor.
KEFs	**High value** Designated sensitive area. Values protected by legislation.	**EPO16:** 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.[37]	The Project Area intersects with the following three KEFs: • Exmouth Plateau • ancient coastline at 125 m depth contour • continental slope demersal fish communities Additional KEFs within the EMBA include: • canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	Physical Presence – Seabed Disturbance Routine and Non-Routine Discharges: Subsea Installation and Commissioning Routine and Non-Routine Discharge: Drilling Physical Presence (Unplanned): Seabed Disturbance Unplanned Hydrocarbon Release	**To meet the principles of ESD** Impacts or risks to KEFs are considered to be acceptable providing that the EPO is met. This includes 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. **Internal context** There are no specific Woodside internal requirements, including policies, procedures and standards regarding KEFs in the Project Area. **External context** To this point there have been no specific matters raised by stakeholders, regarding KEFs in the Project Area.

[36] Source of EPO: 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* (DotE, 2013).

[37] Source of EPO: 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* (DotE, 2013).

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
			• Commonwealth waters adjacent to Ningaloo Reef • Glomar Shoals.		**Other requirements** As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. KEFs form an essential part of the Marine Park network. There are no KEFs in the Dampier Marine Park. **Montebello Marine Park** 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 Marine Park contains one KEF: ancient coastline at 125 m depth contour. **Gascoyne Marine Park** 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 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 Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species. The Marine Park contains four KEFs: • canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula • Commonwealth waters adjacent to Ningaloo Reef • continental slope demersal fish communities • Exmouth Plateau. **Ningaloo Marine Park** 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 Marine Park contains three KEFs:

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
					• canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula • Commonwealth waters adjacent to Ningaloo Reef • continental slope demersal fish communities.
Shipping	**Medium/high value users** Busy shipping area is located outside of Project Area, but shipping traffic still likely to be high.	**EPO14:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.[38]	Commercial shipping traffic is high within the NWMR with vessel activities including commercial fisheries, tourism such as cruises, international shipping and oil and gas operations. Although the Offshore Project Area is located west of a busy shipping fairway, vessel traffic within the Offshore Project Area is relatively low. The majority of vessel movement occurs to the south-east of the Offshore Project Area within the Trunkline Project Area. In addition to high vessel traffic within the shipping fairway, vessel traffic is high towards the east of the Trunkline Project Area where increased vessel traffic will be associated with ports servicing the resource industry at Barrow Island, Onslow and Dampier.	Physical Presence – Displacement of Other Users Unplanned Hydrocarbon Release	**To meet the principles of ESD** Impacts or risks to shipping are considered to be acceptable providing that the EPO is met. This includes to not interfere with other marine users, including shipping to a greater extent than is necessary for the exercise of right conferred by the titles granted. **Internal context** There are no specific Woodside internal requirements, including policies, procedures and standards regarding shipping in the Project Area. **External context** AMSA have provided comment on the placement of the moorings and cross referenced them with Traffic data. Shows trunkline crosses charted shipping fairways where vessel traffic is heavy. Woodside to provide Marine Safety Information as per AMSA's request. **Other requirements** Vessel operations undertaken as a part of this activity will adhere to MARPOL and the various Marine Orders (as appropriate to vessel class) enacted under the *Navigation Act 2012*. This Act regulates navigation and shipping including Safety of Life at Sea (SOLAS). Although the Act does not apply to the operation of petroleum facilities, it may apply to some activities of operations support vessels. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered.

[38] Source of EPO: OPGGS Act Section 280(2)

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
					Shipping is listed as a social and economic value for Dampier Marine Park (Port Activities), but not for Ningaloo, Montebello or Gascoyne Marine Parks. **Dampier Marine Park** 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 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. Port activities are listed as a social and economic value of the Marine Park as they contribute to the wellbeing of regional communities and prosperity of the nation.
Tourism and recreation	**Medium/high value users** Seasonally important, unlikely to have activities focused within the Project Area.	**EPO14:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.[39]	A number of popular tourism locations occur within the EMBA: • Ningaloo Reef • Muiron Islands • Montebello and Barrow islands • Dampier Archipelago. Activities within these areas include recreational fishing (including charter fishing), snorkelling, diving and fauna watching. Of the most popular recreational fishing sites	Unplanned Hydrocarbon Release	**To meet the principles of ESD** Impacts or risks to tourism and recreation are considered to be acceptable providing that the EPO is met. This includes to not interfere with other marine users, including tourism and recreational users to a greater extent than is necessary for the exercise of right conferred by the titles granted.
					Internal context There are no specific Woodside internal requirements, including policies, procedures and standards regarding tourism and recreation in the Project Area.
					External context To this point there have been no specific matters raised by stakeholders, regarding tourism and recreation in the Project Area.
					Other requirements

[39] Source of EPO: OPGGS Act Section 280(2)

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
			outlined above, none lie within the Trunkline Project Area.		As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. **Montebello Marine Park** The objective of the Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species. Tourism and recreation are listed as a social and economic value of the Marine Park. **Dampier Marine Park** 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 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. Recreation is listed as a social and economic value of the Marine Park. **Gascoyne Marine Park** 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 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 Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species. Recreation is listed as a social and economic value of the Marine Park. **Ningaloo Marine Park** 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

Receptor	Receptor Sensitivity Level	EPO	Regional Context	Environmental Aspects Relevant to the OPP[8]	Considerations to determine whether impacts and risks are acceptable
					habitats. Tourism and recreation are listed as a social and economic value of the Marine Park.
Settlements	**Medium value users** Regionally important, low sensitivity to change.	**EPO17:** To protect social surroundings from significant harm.	There are no coastal settlements in the Project Area, however the EMBA includes areas of coastline which includes coastal settlements. Coastal settlements in the north-west region range from small towns to larger regional centres such as Exmouth, Onslow, Karratha, Port Hedland and Broome, where the population is concentrated.	Unplanned Hydrocarbon Release	**To meet the principles of ESD** Impacts or risks to settlements are considered to be acceptable providing that the EPO is met. This includes to protect social surroundings from significant harm.
					Internal context There are no specific Woodside internal requirements, including policies, procedures and standards regarding settlements in the Project Area.
					External context To this point there have been no specific matters raised by stakeholders, regarding settlements in the Project Area.
					Other requirements No other requirements are identified for settlements. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. There are no social or economic values related to settlements listed for the Ningaloo, Montebello, Dampier or Gascoyne Marine Parks.

7 EVALUATION OF ENVIRONMENTAL IMPACTS AND RISKS

7.1 Planned Aspects

7.1.1 Routine Light Emissions

Routine light emissions include light sources that alter the ambient light conditions in an environment.

7.1.1.1 Sources of the Aspect

Activities and facilities associated with Scarborough will require lighting for operational and safety reasons. Light emissions will be produced during:

- vessel operations
- FPU operations
- MODU operations
- hydrocarbon processing.

Vessel, FPU and MODU Operations

Vessels, and facilities including the FPU and MODU will have external lighting to support safe navigation and safe operations at night. 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. Lighting is considered standard and is restricted to safe operations and navigational requirements.

While light emissions from MODU operations will be short term (about two to three months per well), the lighting from the FPU operations will be long term, that is over the life of the project. The intermittent and transient lighting from vessels supporting Scarborough will be greatest during the construction phase of the project but remain ongoing as vessels will provide ongoing support functions for the life of Scarborough.

Woodside (2014) undertook a line-of-sight assessment to determine the maximum distance that light associated with offshore activities may be visible (irrespective of the light source intensity). This study focused on lighting from a MODU which is considered conservative for vessel operations and appropriate for the FPU operations, given the height above sea level for the FPU is similar to that of the MODU used for this study. It showed that the maximum distance direct light may be visible extended up to:

- 20 km for main deck lights
- 35 km for topside modules/cranes lights
- 50 km for the flare (at about 150 m above sea level).

Hydrocarbon Processing

During hydrocarbon processing, flare stacks are used for burning off flammable gas released by pressure release valves (referred to as flaring). Flaring most often takes place during start-ups and shutdowns or in emergency events. The flare tip however may remain lit at all times via the pilot flame, which results in continued emission of light from the FPU.

Flaring will occur during commissioning and operations. During normal operations, intensity will be low comprising of small gas streams and the pilot light (resulting in flame approximately 2 m high). During blowdown events, the intensity will be much higher, and the flame could be as high as 50 m, at which time the light emissions will be greatest (Woodside, 2011). These events are however infrequent at around ten events per year, and will be of a relatively short duration, about 15 minutes depending on the inventory of hydrocarbons to be discharged.

A line of sight assessment was undertaken to support the Browse FLNG Development to identify the maximum distance that light associated with project activities (including a flare stack at 154 m above sea level) was visible (Woodside, 2014). In this assessment, it was determined that under routine operation the flare at the FLNG would be visible at a maximum distance of 47.7 km from the source. In an earlier study, Woodside estimated that a 2 m high flare would be reach a maximum distance of 45.2 km from source, when the flare stack was 137 m, above sea level (Woodside, 2011). These studies are considered comparable to the flare stack proposed on the Scarborough FPU.

7.1.1.2 Impact or Risk

Routine light emissions generated by offshore activities has the potential to result in the following impact(s):

- a change in ambient light.

As a result of a change in ambient light, further impacts may occur, which include:

- a change in fauna behaviour
- a change to the functions, interests or activities of other users.

<u>*Change in Ambient Light*</u>

The extent of this potential impact for Scarborough is restricted to the line of sight for each activity emitting light (Table 7.1), which based on the previous work undertaken by Woodside is about 30 km from the MODU during drilling activities and 30 km from support vessels. For hydrocarbon operations, specifically flaring, the distance at which the flare will be visible is expected to be less than 50 km from the source, and potentially around 10 km further during emergency flaring (Woodside 2011, 2014).

Table 7.1: Extent of potential impact from light sources associated with Scarborough

Activity	Estimated visual line of sight	Project stage	Reference
Vessel operations	30 km	Commissioning, operations, decommissioning	Woodside, 2014
FPU operations	30 km	Commissioning and operations	Woodside, 2014
MODU operations	30 km	Commissioning and operations	Woodside, 2014
Hydrocarbon processing (flaring)	50 km (+ 10 km during emergency flaring)	Commissioning and operations	Woodside, 2011

While the line of sight may extend tens of kilometres from the source, the light density (measured in Lux – which represents the intensity of light that arrives at or leaves a surface, as perceived by the human eye) rapidly decreases as distance increases from the source of the light. Monitoring undertaken as a part of Woodside's 2014 study indicated that light density (from navigational lighting) attenuated to below 1.00 Lux and 0.03 Lux at distances of 300 m and 1.4 km, respectively, from the source (a MODU). Light densities of 1.00 and 0.03 Lux are comparable to natural light densities experienced during deep twilight and during a quarter moon. Navigational lighting from vessels is less than lighting on a MODU. Therefore, light emissions from the MODU and vessels are expected to be below 1.00 Lux within 300 m from the source.

Change in Fauna Behaviour

Routine light emissions have the potential to disrupt ecological processes that rely on natural light for visual cues. The fauna potentially impacted include shorebirds and migratory seabirds, fish and marine reptiles.

Change to the Functions, Interests or Activities of Other Users

Light emissions can result in changes to the ambience of an area, which can potentially impact on values for tourism and recreation. Given the distance from shore of the Offshore Project Area (375 km), and the high vessel traffic already offshore from Dampier, the impact from routine light emissions on changes to the functions, interest or activities of others is likely to be negligible. Therefore, the potential impact from changes to the functions interest of activities of other users, such as Commonwealth and State managed fisheries and tourism and recreation is not evaluated further.

Receptors Potentially Impacted

Routine light emissions have the potential to disrupt ecological processes that rely on natural light for visual cues. Marine fauna receptors that are known to either rely on light for ecological functions or have a sensitivity to light include:

- fish
- seabirds and migratory shorebirds
- marine reptiles.

Fish

Experiments using light traps have found that some fish and zooplankton species are attracted to light sources (Meekan et al., 2001). The concentration of organisms attracted to light may result in an increase in food source for predatory species and marine predators may subsequently aggregate in these areas (e.g. Shaw et al., 2002).

The BIA for whale sharks is about 180 km away from the Offshore Project Area and no whale sharks are expected to be present within the Offshore Project Area. Whilst the trunkline overlaps with the whale shark BIA, potential light disturbance is restricted to vessels during the trunkline construction phase. Presence of other threatened fish species within the Offshore Project Area or pipeline route is expected to be of a transient nature only.

Within the Offshore Project Area, the temporary attraction of transient fish to light emissions will be localised around the source, and not result in a substantial adverse effect on a population of species or its lifecycle. Outside of the Offshore Project Area, vessels undertaking trunkline installation activities will be transient and present for short periods only, and although operating within the BIA will not seriously disrupt the lifecycle of an ecologically significant proportion of whale sharks. Additionally, light emissions from these activities are comparable to other activities in the region. On this basis, the impacts to fish, from light emissions during activities associated with Scarborough, is likely to be negligible. Therefore, the potential impact from lighting to fish is not evaluated further.

Table 7.2 outlines the potential impacts to receptors associated with light emissions.

Table 7.2: Receptor/impact matrix after evaluation of context

Impacts	Receptors: Ambient Light	Seabird and Migratory Shorebirds	Fish	Marine Reptiles
Change in ambient light	✓			
Change in fauna behaviour		✓	X	✓

Detailed Impact Evaluation

For each of the receptors identified for detailed evaluation, the criteria for acceptability as defined in Table 6.3 have been considered and addressed in the following sections. This includes to meet the principles of ESD, internal and external context and any other requirements.

Ambient Light

The introduction of light emissions from activities associated with Scarborough can result in a change to ambient light, by adding temporary lights from vessels as well as ongoing source of light from the FPU which may be visible up to 60 km away during emergency flaring activities.

The area of operation is at a significant distance from coastal sources of light emissions. However, there are existing activities in the region which also currently generate light including offshore facilities and supporting activities, as well as shipping traffic.

The contribution of light emissions from the development of Scarborough will be comparable with existing vessels and facilities on the North West Shelf and will not result in a notable increase.

The environmental performance outcome for ambient light is 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. Given the distance from shore, low sensitivity of receptors offshore (and low likelihood of presence of nesting or hatchling marine turtles) and the negligible contribution of light emissions to the environment from Scarborough, habitat or ecosystem function or integrity of the marine area will not be impacted.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to ambient light. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. Matters relating to potentially impacted receptors from a change in ambient light are discussed for the specific receptors.

Based on the detailed impact evaluation, the potential impact of a change in ambient light is considered **acceptable**.

Seabirds and Migratory Shorebirds

High levels of marine lighting can attract and disorient seabird species resulting in species behavioural changes (e.g. circling light sources or disrupted foraging), injury or mortality near the light source (e.g. Longcore and Rich, 2004; Gaston et al. 2014; Rich and Longcore, 2006).

Light emission from Scarborough will be greatest in the Offshore Project Area due to MODU presence and FPU operations. The Offshore Project Area is about 375 km offshore and outside known BIAs for seabirds. Threatened bird species are not expected to be encountered within the Offshore Project Area. The Scarborough Project Area overlaps with BIAs for four seabird species in the Dampier Archipelago, along the pipeline route in Commonwealth waters. Australian fairy terns occupy offshore islands including the Montebello and Lowendal Islands groups and have seasonal presence in the region during July–September (Johnstone & Storr 1998). The lesser crested tern occupies coastal areas, islands and estuary environments. They are short-ranging seabirds with foraging likely to occur near nesting sites. Roseate terns are common in the region and have known breeding sites on islands of the Dampier Archipelago (Higgins & Davies 1996). Throughout the year the species often rests and forages in sheltered estuaries, creeks and inshore waters. Similarly, wedge-tailed shearwaters BIA overlaps with the Trunkline Project Area and are also known to breed on islands of the Dampier Archipelago and forage in nearby coastal waters (Marchant & Higgins 1990). As most of the Project Area, including the trunkline route in Commonwealth waters, is offshore and away from islands or other emergent features, any presence of seabirds or shorebirds is considered likely to be of a transient nature only.

Within the Project Area, the environmental performance outcomes for migratory birds include to:

- not have a substantial adverse effect on a population of seabirds or shorebirds, or the spatial distribution of the population
- not substantially modify, destroy or isolate an area of important habitat for a migratory species
- not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

Behavioural disturbance to birds from light in the Offshore Project Area is expected to be localised to within the vicinity of the FPU (Figure 7.1) and/or MODU and vessels within the permit areas (Figure 7.2). While the FPU light source is continuous, the interaction with seabirds is expected to be low given the distance offshore and lack of known aggregation areas. The light source from the MODU and vessels within the Offshore Project Area will be temporary and only when operations are occurring; and similar to the FPU source, interaction with seabirds is expected to be low. Therefore impacts, if they did occur, are predicted to be at an individual level and not a population level. Behavioural disturbance to birds from light sources within the Trunkline Project Area are expected to be localised (Figure 7.2) and temporary. These light sources are associated with particular activities and will not occur for the life of the project. The temporary behavioural disturbance of birds will be localised around the light sources, and not result in a substantial adverse effect on a population of species or its lifecycle. Additionally, light emissions will not seriously disrupt the lifecycle of an ecologically significant proportion any migratory birds.

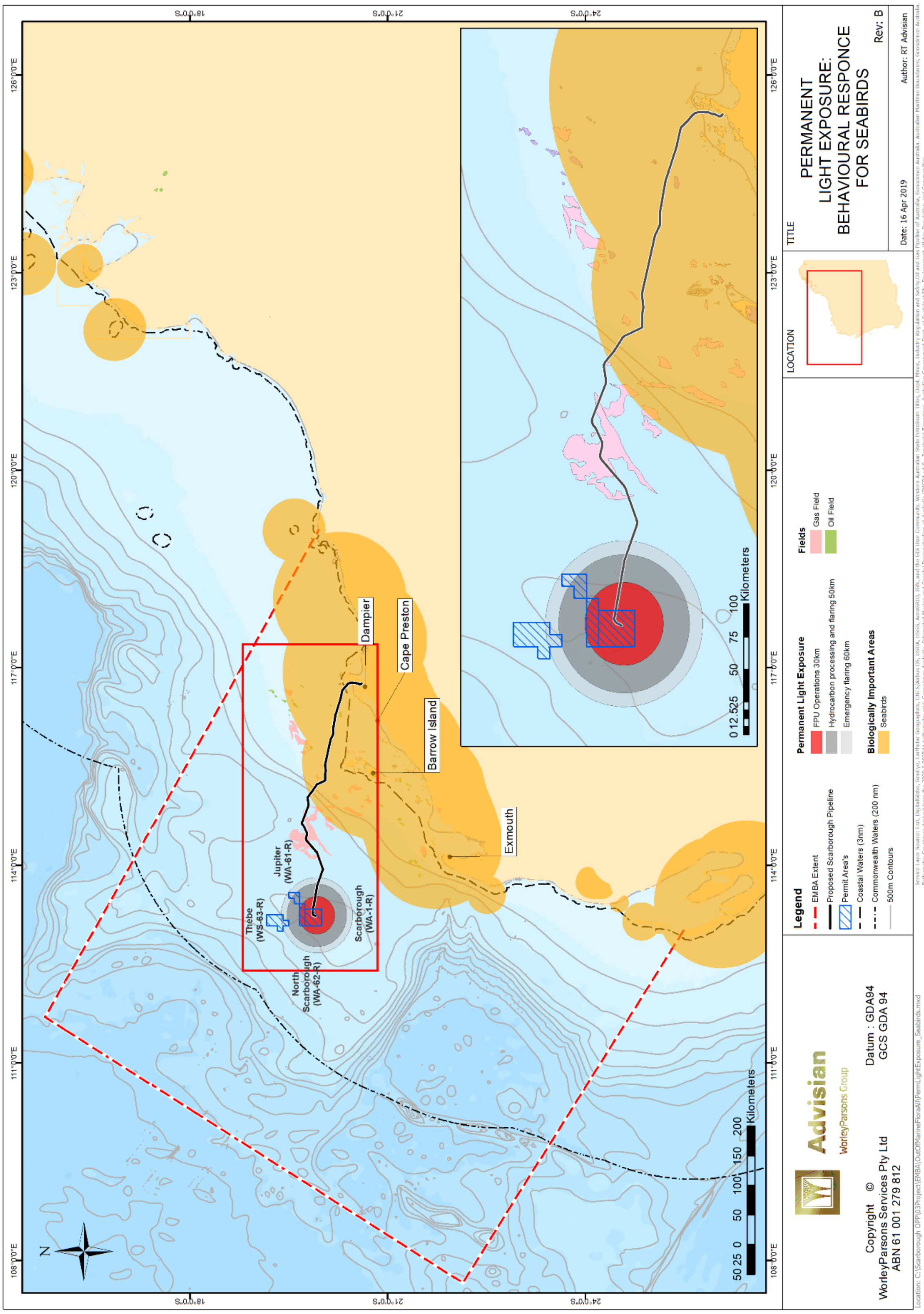
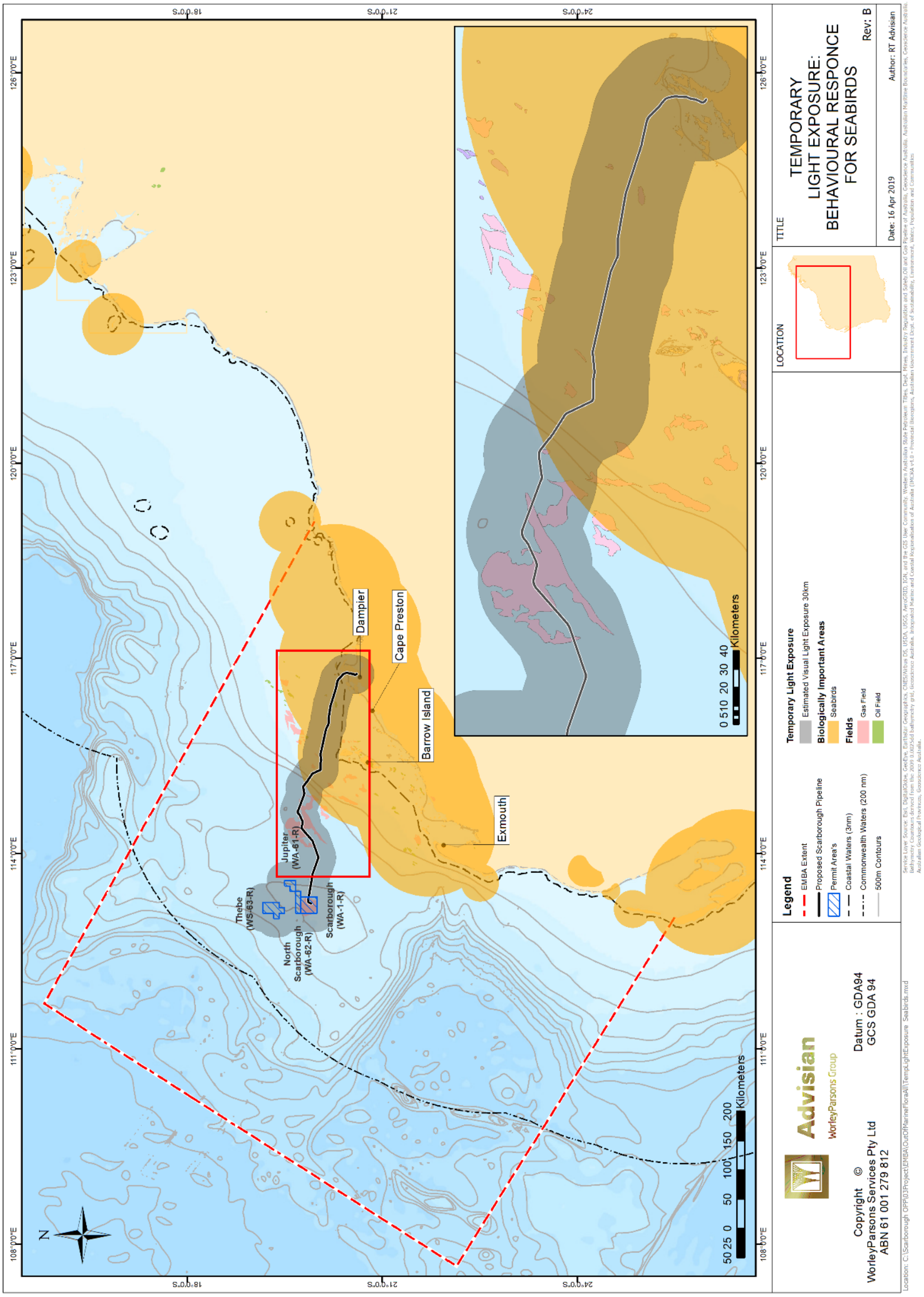


Figure 7.1: Predicted exposure area from continuous (red shading) and intermittent (grey shading) light sources associated with FPU operations and known biologically important areas for seabirds



Note: Light exposure from MODU and vessel operations would not occur within all these areas simultaneously.

Figure 7.2: Predicted exposure area from temporary light sources associated with MODU and vessel operations and known biologically important areas for seabirds

There are no Recovery plans for seabirds and shorebirds in this location, however there are a number of Conservation advices that relate to ensuring protection where certain listed species are known to breed. These are however at significant distance from the Project Area where impacts from lighting are limited.

For construction and IMR activities occurring within the Montebello Marine Park, and adjacent to the Dampier Marine Park, the short term and transient nature of vessel lighting will not be 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, or for the Habitat Protection Zone (IV) 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 values identified for both these AMPs including for breeding and foraging birds will not be impacted given the significant distance from sensitive locations and transient nature of activities.

Based on the detailed evaluation, the impacts to birds from light emissions during activities associated with Scarborough is evaluated to be **acceptable**.

Marine Reptiles

Exposure of marine turtles to artificial light can result in changes to their natural behaviour. Witherington and Martin (2003) state that light pollution on nesting beaches is detrimental to marine turtles because it alters critical nocturnal behaviours, namely, how turtles choose nesting sites, how they return to the sea after nesting, and how hatchlings find the sea after emerging from their nests.

There are no sensitive marine turtle habitats near the Offshore Project Area. The closest known turtle nesting beach are the islands of the Dampier Archipelago, about 375 km from the Offshore Project Area. The marine turtle BIAs are predominantly in State waters with some overlap in Commonwealth waters. At the Offshore Project Area, marine turtles are unlikely to occur due to the deep waters (>950 m) and limited habitat for marine turtle foraging. However, they may occur offshore in small numbers. Marine turtles generally have a pelagic life stage as juveniles, before returning to nearshore coastal habitats as adults to forage and breed. Leatherback turtles are an oceanic, pelagic species known to regularly forage within continental shelf waters. No breeding sites for leatherback turtles occur in the Project Area. Whilst leatherback turtles may occur in the offshore Project Area in small numbers, there distribution is widespread in Australia and their presence is unlikely. No turtles were observed during the winter or summer offshore marine surveys in the Project Area (ERM, 2013).

The Trunkline Project Area does intercept with BIAs for flatback, green, hawksbill and loggerhead turtles. BIAs and critical habitats for marine turtles are identified for internesting and foraging. Marine turtles are abundant in the Dampier Archipelago and they may occur in the area all year round. Breeding and nesting areas in the Dampier region include: Rosemary Island (5.5 km from trunkline route), Varanus Island in the Lowendal group (>100 km from the trunkline), and some islands in the Montebello group (>100 km from the trunkline) (DEWHA, 2012c). In the vicinity of the Trunkline Project Area of the Project Area, sea turtles predominantly nest on Rosemary and Legendre Islands, and to a lesser extent on Enderby and Mawby Island and northern Angel Island. There are no nesting beaches identified in Commonwealth waters. The closest nesting beach to the trunkline route in Commonwealth waters is Rosemary Island approximately 5.5 km away from the Trunkline Project Area at the closest distance.

Turtles passing through the Project Area may temporarily alter their normal behaviour if attracted to the light spill from infrastructure. This impact could extend up to tens of kilometres away from the FPU which will be visible for up to 50 km during flaring and less than 30 km during routine operations. In such instances, the turtles would likely return to their normal behaviour once they have moved away from the area. There are no sensitive locations within 50 km therefore the impact from this source would be minor and short term. Given the wide migratory distribution (i.e. several hundred kilometres) of adult turtles outside of nesting season and their low-density presence within the

Project Area, the attraction from direct lighting is expected to be minor and a temporary disruption to a small portion of the adult turtle population.

Turtles in breeding or foraging habitat in BIAs around offshore islands may temporarily alter their normal behaviour if attracted to light spill from vessels. Vessels will be present in the Project Area during trunkline installation and provide support to the offshore development during operation. Given the temporary nature of vessels in the area and the low levels of light emitted from project vessels, the impact to turtles from vessel light will be minor. Light density from navigational lights on vessels is predicted to be less than 1.00 and 0.03 Lux at distances of 300 m and 1.4 km, respectively, from source, which is comparable to the light level between a moonless clear night sky and a quarter moon. At this level, light is not expected to be sufficient to alter hatchling behaviour leaving the nesting site. The trunkline in Commonwealth waters is greater than 5.5 km from the closest nesting beach and therefore, the impact to nesting behaviour or hatchlings from light emission is not expected.

For listed species of marine turtle, the environmental performance outcomes include to:

- not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population
- 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
- not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

Behavioural disturbance to turtles from light in the Offshore Project Area is expected to be localised to within the vicinity of the FPU (Figure 7.3) and/or MODU and vessels within the permit areas (Figure 7.4). While the FPU light source is continuous, the interaction with turtles is expected to be low given the distance offshore and lack of known aggregation areas. The light source from the MODU and vessels within the Offshore Project Area will be temporary and only when operations are occurring; and similar to the FPU source, interaction with turtles is expected to be low. Therefore impacts, if they did occur, are predicted to be at an individual level and not a population level. Behavioural disturbance to turtles from lights within the Trunkline Project Area are expected to be localised (Figure 7.4) and temporary. These light sources are associated with particular activities and will not occur for the life of the project. Impacts will not occur to significant proportions of the populations of the species, nor result in the decrease of the quality of the habitat such that the extent of these species is likely to decline.

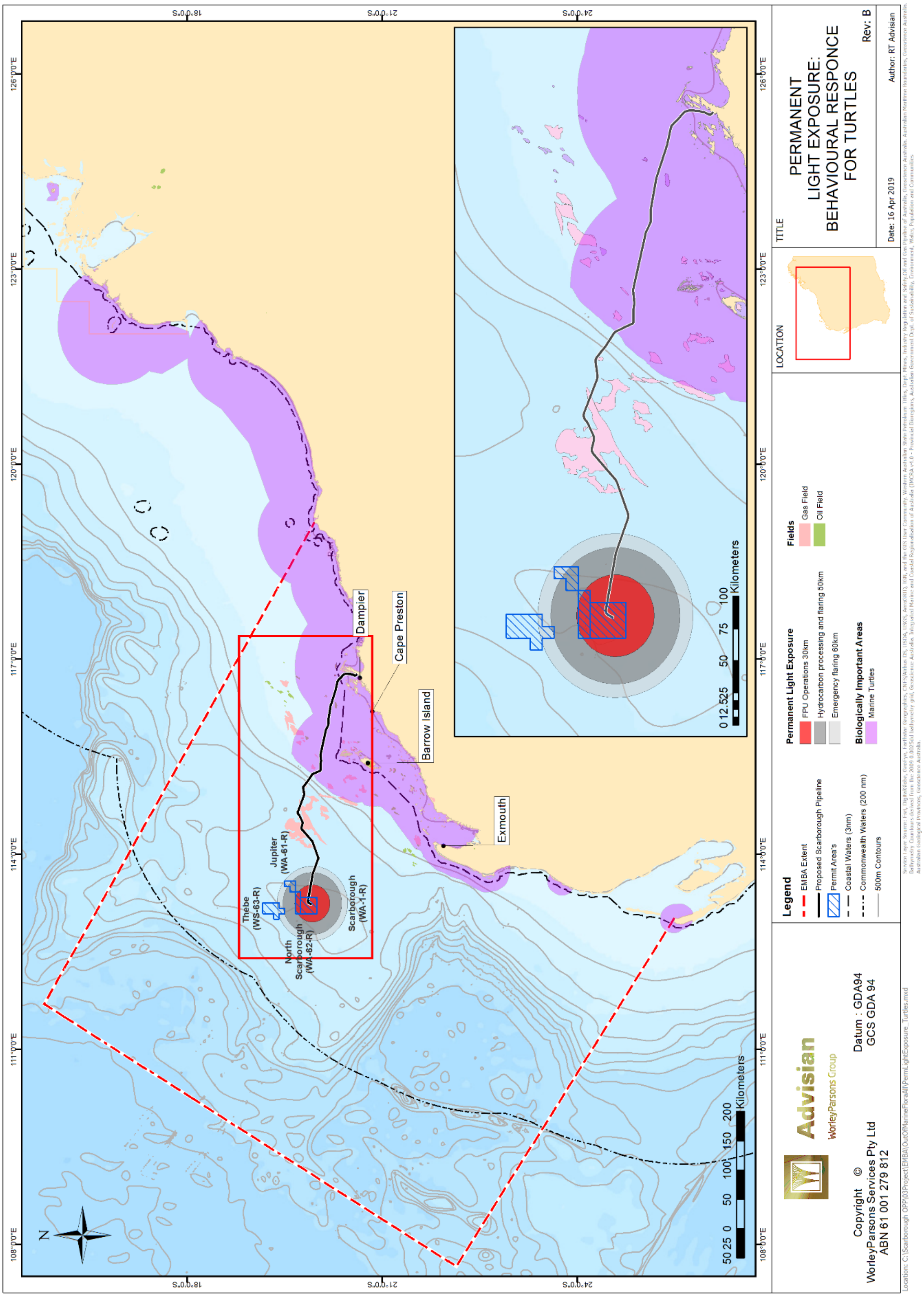
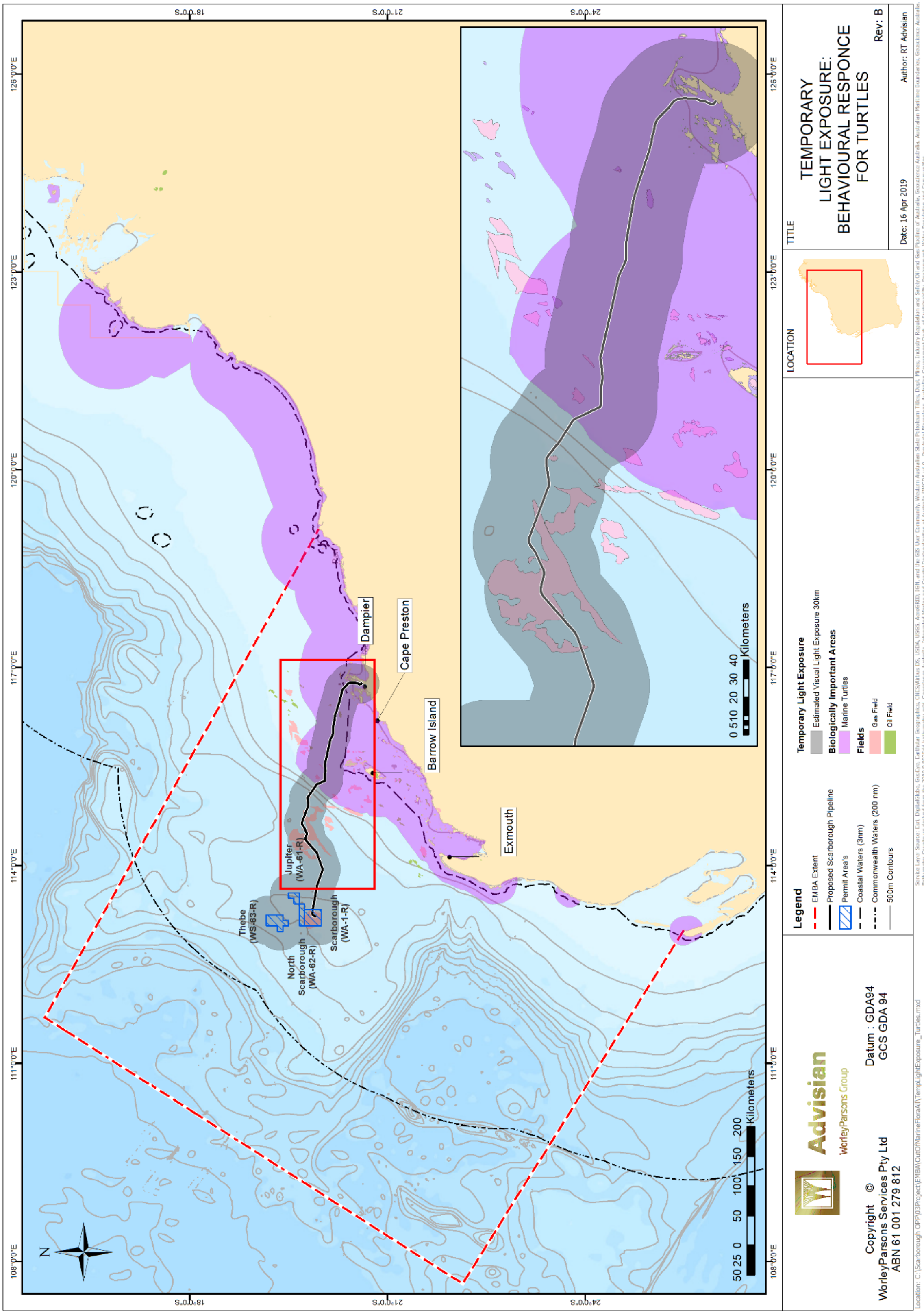


Figure 7.3: Predicted exposure area from continuous (red shading) and intermittent (grey shading) light sources associated with FPU operations and known biologically important areas for turtles



Note: Light exposure from MODU and vessel operations would not occur within all these areas simultaneously.

Figure 7.4: Predicted exposure area from temporary light sources associated with MODU and vessel operations and known biologically important areas for turtles

Impacts to turtles from artificial light are to be managed in accordance with the Recovery Plan for marine turtles in Australia (DoEE, 2017). The Recovery Plan identifies minimising light pollution and considering cumulative impacts on turtles from multiple sources of onshore and offshore light pollution (see Section 8).

For construction and IMR activities occurring within the Montebello Marine Park, and adjacent to the Dampier Marine Park, the short term and transient nature of vessel lighting will not be 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, or for the Habitat Protection Zone (IV) 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 values identified for both these AMPs including internesting areas for turtles will not be impacted given the significant distance from sensitive locations.

Based on the detailed evaluation, the impacts to marine turtles from light emissions during activities associated with Scarborough is evaluated to be **acceptable**.

7.1.1.3 Impact Significance Evaluation

Impacts from routine light emissions will have slight to no lasting effect, as the extent, duration, frequency and scale of the impact are all sufficiently small. When considered with receptor sensitivity, Impact Significance Level of light emissions from Scarborough has been evaluated as **Negligible (F)** for ambient light, and **Slight (E)** for seabirds and shorebirds and marine reptiles. The impacts overall have been determined to be **acceptable** based on an evaluation against the criteria:

To meet the principles of ESD

- The contribution of light emissions from Scarborough will be comparable with existing vessels and facilities on the North West Shelf, and not result in a notable change to the ambient light of the wider area.
- Behavioural disturbance to birds from light is expected to be localised and temporary, occurring on an individual level only given the transient nature of birds within the Project Area, and distance from sensitive areas.
- Given the wide migratory distribution of adult turtles outside of nesting season and their low-density presence within the Project Area, the attraction from direct lighting is expected to be minor and a temporary disruption to a small portion of the adult turtle population.

Internal context

- There are no specific Woodside internal requirements with respect to light emissions, or potentially impacted receptors.

External context

- No stakeholder concerns have been raised with respect to light emissions or potentially impacted receptors.

Other requirements

- Lighting will be limited the minimum required for navigational and safety requirements, with the exception of emergency events.
- Requirements of the Recovery plan for marine turtles in Australia (DoEE, 2017) and the relevant conservation advices for seabirds / shorebirds have been met.
- With respect to light emissions, activities associated with Scarborough 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.

7.1.1.4 Summary of the Impact Assessment

Table 7.3 provides a summary of the risk assessment and acceptability for impacts from routine light emissions on receptors.

Table 7.3: Summary of impacts, management controls, impact significance ratings and EPOs for routine light emissions

Receptor	Impact	Environmental Performance Outcome	Adopted Control(s)	Receptor sensitivity level	Magnitude	Impact significance level	Acceptability
Ambient light	Change in ambient light	**EPO1:** 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.	**CM1:** Lighting will be limited the minimum required for navigational and safety requirements, with the exception of emergency events.	Low value (open water)	Slight	Negligible (F)	Acceptable
Seabirds and migratory shorebirds	Change in fauna behaviour	**EPO10:** To not have a substantial adverse effect on a population of seabirds or shorebirds, or the spatial distribution of the population. **EPO8:** To not substantially modify, destroy or isolate an area of important habitat for a migratory species. **EPO9:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.		High value species (e.g. wedge-tailed shearwater)	No lasting effect	Slight (E)	Acceptable
Marine reptiles		**EPO11:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population. **EPO1:** 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. **EPO9:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.		High value species (e.g. flatback turtle)	No lasting effect	Slight (E)	Acceptable

7.1.2 Routine Atmospheric and Greenhouse Gas Emissions

Atmospheric emissions refer to the discharges to the atmosphere of gases and particulates from an activity or from a facility or piece of machinery which have a recognised adverse effect on human health and/or flora and fauna. The main emissions responsible for these effects include carbon monoxide (CO), oxides of nitrogen (NO_x), sulphur dioxide (SO_2), particulate matter less than 10 microns (PM10), non-methane volatile organic compounds (VOCs), BTEX (benzene, toluene, ethylbenzene and xylenes), which are specific VOCs of interest.

Greenhouse gas (GHG) emissions are defined as those gases within the atmosphere that absorb long-wave radiation, and thus trap heat reflected from the Earth's surface. The main gases responsible for this effect include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Other greenhouse gases include perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF_6).

7.1.2.1 Sources of the Aspect

Atmospheric and greenhouse gas (GHG) emissions will be produced in all phases of the development of Scarborough, as a result of:

- FPU operations
- MODU operations
- vessel operations
- well flowback
- hydrocarbon processing.

FPU, MODU and Vessel Operations

<u>*Atmospheric Emissions*</u>

MODUs, FPUs and vessels are powered via the use of on-board generators. Operations require the use of diesel to undertake daily activities functions such as transport, desalination, sewage treatment, etc. Emissions produced during vessel, FPU and MODU operations will be emitted to the atmosphere during all project phases.

Atmospheric emissions generated during these operations will include SOx, NOx, particulates and Volatile Organic Compounds (VOCs). SOx and particulate matter emissions are heavily influenced by the fuel used and its relative sulphur content, MGO having a lower sulphite content than marine diesel oil (MDO) or heavy fuel oil (HFO).

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 is 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/m³ (0.001 ppm) within 10 km of the source and 0.1 µg/m³ (0.0001 ppm) within 40 km of the source. This represents an increase of 2% over typical background concentrations within 40 km, with air quality remaining well below the WHO air quality guideline for NO_2 of 40 µg/m³ 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.

Due to the similar functions performed by the production platforms compared to FPUs, the use of this study to predict NO_2 emission attenuation for FPU and MODU operations associated with the development of Scarborough is considered appropriate. MODU and FPU operations will be limited to the Offshore Project Area. Vessels will operate within the Offshore Project Area, the Borrow Grounds Project Area and the Trunkline Project Area although emissions produced from such sources will be substantially less than that of the MODU or FPU.

GHG Emissions – Direct (Scope 1)

As with other gas developments, such as Pluto, Gorgon, Browse and Ichthys, Scarborough direct GHG emissions will be made up almost entirely of CO_2 as opposed to methane and nitrous oxide. Significant emissions of hydrofluorocarbons, perfluorocarbons or sulphur hexafluoride are unlikely to be emitted. The GHG emissions of the upstream components (i.e. the scope of this OPP) constitute a relatively small proportion of the overall development of Scarborough.

Direct greenhouse emissions from the FPU are estimated to average approximately 500 ktCO_2e/yr. During steady state operations, this is comprised of 87% combustion of fuel gas in turbines driving export compressors, 11% combustion of fuel for power generation and 2% from flaring.

Measures to improve energy efficiency and reduce GHG emissions are described in Section 4.5.4.8. This includes alternatives that have been selected for implementation as preferred options in the development base case, and a description of the energy efficiency opportunity identification and implementation process to be implemented during the remainder of the design process.

Related Processing Emissions (Onshore)

Gas from the development of Scarborough will be processed at the onshore Pluto Gas Plant, which Woodside intends to expand within the existing cleared footprint to include a second processing train. Greenhouse gas emissions associated with the two trains at the Pluto Gas Plant were assessed and approved under the Western Australian Environment Protection Act 1986 and Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC 2006/2968 and Ministerial Statement 757). The total approved greenhouse gas emissions were 4.1 MMtCO2e/yr, and the Pluto Gas Plant currently emits approximately 2 MM tCO2e/yr. Additional emissions attributed to expansion will fall within the remaining 2.1 MMtCO2e/yr. It is important to note that Scarborough feed gas will be a lower CO_2 concentration than Pluto due to the lower reservoir CO_2 content. The Scarborough feed gas composition is not expected to have any other material impacts on Pluto operations. The Pluto Public Environment Review (PER) is available for review on the WA EPA website:

http://www.epa.wa.gov.au/sites/default/files/PER_documentation/1632-PER-PLUTO%20LNG%20PER.pdf

GHG Emissions – Indirect

Scope three emissions (i.e. those related to transport and consumption of LNG product by customers) for a two-train development have been assessed and approved as part of the above PER process. The facility is approved to export 12Mtpa of LNG to international markets and currently only exports approximately half this capacity. As outlined in the Pluto PER life cycle analysis, LNG has the potential to play a key role in displacing higher carbon intensity fossil fuels and complementing renewables.

Comparison with Other Inventories

The National Inventory Report 2016 (Department of Environment and Energy 2018) indicates that during steady state operations:

- Direct emissions from the Scarborough FPU (i.e. scope of the OPP) will contribute approximately 0.1% of Australia's annual greenhouse emissions

- Maximum related onshore processing emissions will contribute approximately 0.4% of Australia's annual greenhouse emissions, or 2.5% of Western Australia's annual greenhouse emissions

Well Flowback and Hydrocarbon Processing

Atmospheric Emissions

Wellbore flowback will occur following wellbore clean-up and will result in the venting and/or flaring of hydrocarbons. During wellbore flowback, initial unloading of the well displaces the well fluids (i.e. suspension/completion brine). These are discharged overboard as the gas content makes it too dangerous to filter or treat. Once the brines are unloaded, the gas stream is sent to flare via the production separator. Well flowback activities will be undertaken during drilling operations at the beginning of the proposed development of Scarborough, and for future phases. Well flowback may occur at any time throughout the drilling of wells.

In addition to flowback activities, flaring may occur during hydrocarbon processing, where flare stacks are used for burning off flammable gas released by pressure release valves. Flaring most often takes place during start-ups and shutdowns or in emergency events. If flow rate is not sufficient to sustain a flare for MODU operations, venting will occur. Depending on the process selected (venting or flaring) the emissions may vary from methane to carbon dioxide, NO_x, etc. Flaring activities may take place anytime during the drilling and production phase of the project.

During the study undertaken by (BP 2013), NO_2 emissions from flaring were modelled for clean-up flaring on MODUs at a rate of 250 MMscfd for up to two days and emergency flaring on FPUs at full load for up to an hour. This model showed that short term concentrations of NO_2 from MODU flaring increased by up to about 60 µg/m³ (0.06 ppm) within 10 km of the source and increase of up to 20 µg/m³ (0.02 ppm) at about 40 km from the source. For emergency flaring, modelling showed that NO_x concentrations may increase by up to 10 µg/m³ (0.01 ppm) at 10 km from the source and 4 µg/m³ (0.0004 ppm) at about 40 km from the source. These levels are intermittent and temporary and do not result in exceedances above the WHO air quality guideline for NO_2 of 40 µg/m³ annual mean.

Planned flaring during wellbore clean-up and flowback and hydrocarbon processing will occur at a at typical levels per flaring event therefore the study undertaken by BP (2013) is an appropriately conservative indicator of attenuation of flaring emissions. As stated above, studies into the attenuation of other gasses is not discussed due to the nature of potential impacts of NO_2 to receptors.

GHG Emissions

As explained above, GHG emissions of the upstream component of Scarborough will be produced almost exclusively during the operations phase from power generation and compression with only a small proportion from the flaring.

7.1.2.2 Greenhouse Gas Emission and Energy Efficiency Reporting

Reporting of GHG emissions is required on an annual basis under the following legislation.

National Greenhouse and Energy Reporting Act 2007 (NGER Act)

The National Greenhouse and Energy Reporting System (NGERS) require Woodside to report on GHG emissions from activities which are under its operational control. Woodside will report GHG emissions and energy use from the offshore facilities in accordance with its requirements under the NGER Act.

7.1.2.3 Impact or Risk

Routine atmospheric and greenhouse gas emissions from the sources described above have the potential to result in the following impact(s):

- change in air quality.

As a result of a change in air quality, further impacts may occur, which include:

- injury/mortality to fauna
- climate change
- change in aesthetic value.

Change in Air Quality

Atmospheric and greenhouse gas emissions may result in a decline in local air quality, within the immediate vicinity of the emissions source. As described above, produced emissions throughout the project will include SO_2, NOx, ozone depleting substances, CO_2, particulates and Volatile Organic Compounds (VOCs). Emissions from engines, generators and deck equipment may be toxic, odoriferous or aesthetically unpleasing, and will result in a reduction in air quality.

Injury/Mortality to Fauna

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 atmospheric emissions will be typical of other operating facilities and equipment, and that fauna numbers will be low at the point of discharge. Injury or mortality to fauna a result of atmospheric discharges is negligible and has not been evaluated further.

Climate Change

While the upstream component of the Scarborough LNG project results in a small fraction of emissions relative to the overall project, and in particular the downstream component, emissions of GHG from Scarborough will cause also contribute to GHG concentrations in the earth's atmosphere. Where Scarborough's products, including LNG, displace more emissions intensive fuels, the net impact will be a decrease in global GHG concentrations.

Change in Aesthetic Value

Atmospheric emissions have the potential to introduce odour and visual amenity issues which can result in changes to the aesthetic value of an area.

Scarborough is located in the open ocean and is well-removed from nearest residential or sensitive populations of the WA coast, with limited interaction with the regional airshed.

Given the distance from shore of the Offshore Project Area (375 km), the potential for a change in air quality from atmospheric emissions associated with Scarborough resulting in a change to aesthetic value for tourism/recreation or settlements is not considered to be credible. As the Offshore Project Area is not directly visible from the nearest landfall, the flare and potential smoke resulting from emissions will not impact visual amenity, and no impacts to visual amenity for settlements are expected. Therefore, a change in aesthetic value from atmospheric emissions associated with Scarborough is negligible and has not been evaluated further.

Receptors Potentially Impacted

Routine atmospheric emissions have the potential to change the local air quality as shown in Table 7.4.

Table 7.4: Receptor/impact matrix after evaluation of context

Impacts	Receptor: Air Quality	Receptor: Climate
Change in air quality	✓	
Climate change		✓

Detailed Impact Evaluation

For each of the receptors identified for detailed evaluation, the criteria for acceptability as defined in Table 6-3 have been considered and addressed in the following sections. This includes to meet the principles of ESD, internal and external context and any other requirements.

Air Quality

The air quality within Scarborough Area is typical of an unpolluted tropical offshore environment and the ambient air quality in the offshore NWMR will be of high quality. Atmospheric emissions from Scarborough have the potential to result in a localised reduction in air quality in the immediate vicinity of the release point.

Within the Project Area, where routine atmospheric emissions are to occur, the environmental performance outcome for air quality is to not result in a substantial change in air quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. Given the offshore location of Scarborough offshore facilities, and the low volumes of atmospheric emission which will be generated, biodiversity, ecological integrity, social amenities and human health will not be impacted.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to air quality.

Based on the detailed impact evaluation, the potential impact of a change in air quality is considered **acceptable**.

Climate

GHG emissions from Scarborough will contribute to GHG concentrations in the earth's atmosphere. The contribution from the upstream component is low compared to the overall project. However, Woodside is committed to minimising greenhouse gas emissions from the company's production of energy products. Woodside achieves this through improvements in technology, efficiency and market measures. For the upstream component, reduction opportunities have been considered at all stages of the development.

Within the Project Area, where routine atmospheric emissions are to occur, the environmental performance outcome for climate is to optimise efficiencies in air emissions and reduce greenhouse emissions to ALARP.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to climate. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered, noting there is nothing specific in these relating to climate.

Activities undertaken as a part of this project will adhere to the requirements of the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989 Act* including restrictions on import and use of Ozone Depleting Substances (ODS) and hydrofluorocarbons (HFCs) which have a low ODS, but high Global Warming Potential (GWP) (in refrigeration and air conditioning equipment) through control measures in procurement. This Act and associated regulations provide for measures to protect ozone in the atmosphere by controlling and ultimately reducing the manufacture, import and export of ozone depleting substances (ODS) and synthetic greenhouse gases, and replacing them with suitable alternatives. The ODS elements of the Act will only apply to Woodside if it manufactures, imports or exports ozone depleting substances. The elements of the Act relating to HFCs will apply if Woodside imports HFCs that aren't already pre-charged in other equipment.

As demonstrated in Section 7.1.2.1, the direct greenhouse emissions are not substantial on a Western Australian or Australian scale, and indirect emissions are assessed under different legislation. Direct emissions of greenhouse gases from Scarborough will be minimised and managed in accordance with relevant legislation.

Based on the detailed evaluation, the impacts to climate from routine atmospheric emissions during activities associated with Scarborough is evaluated to be **acceptable**.

7.1.2.4 Impact Significance Evaluation

Impacts from routine atmospheric emissions will have a slight effect on receptors, as the extent, duration, frequency and scale of the impact are all sufficiently small. When considered with receptor sensitivity, Impact Significance Level of routine atmospheric emissions and greenhouse gas emissions from Scarborough has been evaluated as **Negligible (F)** for all receptors. The impacts overall have been determined to be **acceptable** based on an evaluation against the criteria:

To meet the principles of ESD

- The volumes of routine atmospheric emissions from Scarborough will be relatively low in comparison to existing vessels and facilities on the North West Shelf.
- There are currently very low background levels of pollutants in the existing environment.
- The location of Scarborough offshore facilities is at a significant distance from sensitive receptors.
- The possible GHG emissions from Scarborough upstream activities represent a small portion of the total emissions for Scarborough overall project.

Internal Context

- With respect to atmospheric emissions and greenhouse gas emissions, Woodside will implement internal requirement that align with the Woodside Climate Change Policy. This includes to ensure that:
  - facilities must be designed and operated to optimise resource efficiency.

External Context

- No stakeholder concerns have been raised with respect to routine atmospheric emissions and greenhouse gas emissions, or potentially impacted receptors.

Other Requirements

- There are no Management Plans, Recovery Plans or Conservation Advice related to air quality or climate.

- Activities undertaken as a part of Scarborough will adhere to the requirements of the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989 Act* including restrictions on import and use of Ozone Depleting Substances (ODS) (in refrigeration and air conditioning equipment) through control measures in procurement.
- The Paris Agreement has established a framework for managing global climate change that relies on nations setting Nationally Determined Contributions and establishing domestic policies to meet them. As such, Scarborough will be subject to domestic laws that reflect Australia's commitment under the Paris Agreement. Beyond complying with these laws, Scarborough is subject to Woodside's Climate Change Policy, which includes promoting a culture of energy efficiency and improved resource use in designs and operations.
- Reporting of GHG emissions will be undertaken as required by the NGER Act.
- With respect to routine atmospheric emissions and greenhouse gas emissions, activities associated with Scarborough 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.

7.1.2.5 Summary of the Impact Assessment

Table 7.5 provides a summary of the risk assessment and acceptability for impacts from atmospheric and greenhouse gas emissions on receptors.

Table 7.5: Summary of impacts, management controls, impact significance ratings and EPOs for Atmospheric Emissions

Receptor	Impact	Environmental Performance Outcome	Adopted Control(s)	Receptor sensitivity level	Magnitude	Impact significance level	Acceptability
Air quality	Change in air quality	**EPO5:** To not result in a substantial change in air quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM2:** Vessel and MODU compliance with Marine Order 97 (Marine Pollution Prevention – Air Pollution), including: • International Air Pollution Prevention (IAPP) Certificate, required by vessel class • use of low sulphur fuel when available • Ship Energy Efficiency Management Plan (SEEMP), where required by vessel class • onboard incinerator to comply with Marine Order 97. **CM3:** Optimisation of flaring to allow the safe and economically efficient operation of the facility.	Low value (open water)	Slight	Negligible (F)	Acceptable
Climate	Climate change	**EPO19:** Optimise efficiencies in air emissions and reduce greenhouse emissions to ALARP and Acceptable Levels.	**CM4:** Facilities will be designed and operated to optimise resource efficiency. **CM5:** Reporting of GHG emissions as per regulatory requirements.	Low sensitivity (at location)	Slight	Negligible (F)	Acceptable

7.1.3 Routine Acoustic Emissions

Routine acoustic emissions refer to noise generated during an activity.

Activities conducted during Scarborough may produce noise and associated vibrations in the air, underwater and beneath the earth's surface.

Given the multiple metrics commonly used to express sound levels and assess potential impacts to marine fauna, it is important to ensure any comparisons between specific sound level values are made using the same measures. For example, peak Sound Pressure Level (SPL) compared with peak SPL, or root mean square (RMS) SPL with RMS SPL, rather than peak SPL compared to Sound Exposure Level (SEL). Also, care must be taken when comparing decibel sound levels in air with sound levels underwater. The information below describes how underwater sound is measured and referenced.

The decibel (dB) scale is a logarithmic scale that expresses the ratio of two values of a physical quantity. It is used to measure the amplitude or 'loudness' of a sound. As the dB scale is a ratio, it is denoted relative to some reference level, which must be included with dB values if they are to be meaningful. The reference pressure level in underwater acoustics is 1 micropascal (µPa). Whereas the reference pressure level used in air is 20 µPa, which was selected to match human hearing sensitivity.

Underwater sound is typically measured in terms of instantaneous pressure (sound pressure level – SPL), in dB re 1µPa (Richardson et al., 2005). SPL for an impulsive sound is typically expressed in terms of peak or peak-to-peak SPL. SPL can also be expressed as an RMS measure, which is an average pressure over a duration of time. The RMS SPL measure is commonly associated with continuous sounds; however it is also used to characterise pulse sounds where the time duration is related to pulse duration or a percentage of energy of the pulse signal.

RMS SPL has historically been used to assess potential impacts to marine life, although SEL and peak SPL are increasingly used. SEL accounts for the duration of a sound exposure and enables comparison between sound from different sound signals (and therefore sound sources) with different characteristics.

SEL is a metric used to describe the amount of acoustic energy that may be received by a receptor (such as a marine animal) from an event. SEL is the dB level of the time-integrated, squared sound pressure normalised to a one second period, and is expressed as dB re 1 $\mu Pa^2.s$.

Metric terminology used in this section are based on the metrics in the ISO 18405 Underwater Acoustics – Terminology (ISO 2017) (Table 7.6). However, previously used metrics are also provided where they are used in literature published prior to 2017.

Table 7.6: Metric terminology for underwater sound

Metric	Previously used	ISO 18405:2017	
		Main text	Tables/equations
Sound pressure level	SPL_{rms}, SPL_{RMS}	SPL	SPL (L_p)
Peak pressure	SPL_{pk}	PK	PK (L_{pk})
Sound exposure level	SEL_{cum}	SEL_{24h}	SEL_{24h} ($L_{E,24h}$)

Underwater noise is distinguished as two different sound categories: (1) impulsive; and (2) continuous (non-pulsed). Note that impulsive sounds (such as pile driving) are typically characterised using different measures or metrics compared to continuous sound (such as the FPU/vessel and ambient 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.

Continuous Noise

Continuous noise is a category of sound that is described by a continual non-pulsed sound. Continuous sound can be tonal, broadband, or both. Some of these non-pulse sounds can be transient signals of short duration but without the essential properties of pulses (e.g. rapid rise-time) (Southall et al., 2007).

Due to the continuous non-pulsed properties of continuous noise, the risk and severity of potential impact to marine fauna is lower than that of impulsive noise. Activities which may produce continuous noise sound include vessels, drilling, FPU operation and Remotely Operated Underwater Vehicles (ROVs).

Impulsive Noise

Impulsive noise is a category of sound that is described by a series of pulsed sound events, defined as brief, broadband, atonal and transient. Impulsive noise is most common in industrial construction or exploration, including seismic acquisition, vertical seismic profiling (VSP), pile driving, blasting (single pulse), multibeam echo sounder and sonar.

These sounds are all characterised by a relatively rapid rise from ambient pressure to a maximal pressure value followed by a decay period that may include a period of diminishing, oscillating maximal and minimal pressures. The rapid rise-time characteristic of these sounds ensures that they are also broadband in nature, with the higher-frequency components being related to the rapidity of the risetime (Southall et al. 2007). Pulses, either as isolated events or repeated in some succession, generally have an increased capacity to induce physical injury as compared with sounds that lack these features.

7.1.3.1 Sources of the Aspect

Activities and facilities associated with Scarborough will generate routine acoustic emissions during drilling, installation & commissioning and operations. Source level is a measure of sound at a nominal distance of 1 m from the source. It is denoted in dB re 1 µPa@ 1 m and will differ depending upon the activities being undertaken. Furthermore, whether impulsive or continuous noise emission are discharged will also depend upon the activity. A summary of source level and type of noise emission is provided in Table 7.7. Acoustic emissions will be produced during:

- vertical seismic profiling
- pre-lay surveys

- drilling operations (including MODU operations)
- installation of FPU – piling
- FPU operations
- hydrocarbon extraction
- vessel operations (including trunkline installation vessels)
- helicopter operations
- removal of subsea infrastructure.

Vertical Seismic Profiling

VSP may be required to confirm well location during the drilling phase of Scarborough. The duration of VSP is short, up to 24 hours for the well, and utilises relatively small airguns that generate low sound energy levels and are a pulsed noise source. VSP operations are typically of short duration, normally taking no more than a day to complete.

The VSP source (typically 750 cubic inches (cui) and comprising of three 250 cui airguns) is expected to generate a noise level around 216 dB re 1 µPa (SPL) @ 1 m, with most noise concentrated at low (<100 Hz) frequencies. Empirical measurements of an equivalent small sized airgun array (440 cui) undertaken by Curtin University of Marine Science and Technology (CMST, 2013) demonstrated that the source would attenuate to 160 dB re 1 µPa^2.s (SEL) within 500 m, equating to a total of 56 dB attenuation over 500 m. VSP activities associated with Scarborough are expected to reach 160 dB re 1 µPa (SPL) at about 590 m. Matthews (2012) indicates that airguns with a 250 cui source that is discharged about five times at 20 second intervals, sound levels of approximately 238 dB re 1 µPa (PK) are generated at 1 m (Matthews, 2012), with frequencies less than 200 Hz. Sound levels are expected to attenuate rapidly to about 180 dB re 1 µPa (PK) within 100 m (Matthews, 2012).

Pre-lay Survey

The pre-lay survey utilises a side scan sonar towed behind a project supply vessel, or a multi-beam echo sounder (MBES). Most modern MBES systems work by transmitting a broad acoustic pulse from a hull or pole mounted transducer. Transponders will be placed on the seabed to assist in correct flowline placement, acoustic metrology and long baseline (LBL)/ultra-short baseline (USBL). Pre-lay survey may be used during the construction phase of the Project.

Typical frequency and source levels (Jimenez-Arranz et al., 2017) are:

- MBES – 210–245 dB re 1 µPa @ 1 m (PK); 221 dB re 1 µPa @ 1 m (SPL) at 12 to 700 kHz
- USBL – 184–206 dB re 1 µPa @ 1 m (PK) at 18 to 36 kHz.

Side scan survey and MBES emit high frequency impulsive noise between 12 and 700 kHz. High frequency sound attenuates rapidly in water and the area of exposure will be within the immediate vicinity of the activity.

Drilling Operations

During drilling operations, the MODU will produce low-intensity continuous sound. Sound produced from an active MODU is predominantly below 2 kHz, with peak frequencies below 500 hertz (Hz). Broadband source sound levels ranging between 157 and 162 dB re 1 µPa (SPL) have been recorded for semisubmersible drilling rigs (Hannay et al., 2004; McCauley, 1998, 2002). The MODU will emit routine acoustic emissions during the drilling and operational phase of Scarborough.

An acoustic monitoring program commissioned by Santos was conducted during an exploratory drilling program in 2003, which indicated that the drilling operation was not audible between 8 and 28 km from the MODU (or beyond) (McCauley, 2004).

Noise associated with a moored MODU will be restricted to drilling activities, such as drill pipe operations and on-board machinery. A range of broadband values (59 to 185 dB re 1 μPa at 1 m (SPL)) have been quoted for various MODUs (Oceans of Noise, 2004), where noise is likely to be between 100 to 190 dB re 1 μPa at 1 m (SPL) during drilling, and between 85 to 135 dB re 1 μPa at 1 m (SPL) when not actively drilling. McCauley (1998) recorded received noise levels of about 117 dB re 1 μPa at 1 m (SPL) at 125 m from a moored MODU while actively drilling (with activity support vessel on anchor).

FPU Operations

Production platforms have machinery mounted on decks raised above the sea, hence, most noise is transmitted to the marine environment from air (i.e. power generation and operational flaring). Continuous machinery noise on-board the FPU may be radiated into the underwater environment via the mooring lines and risers, which may act as transducers. Monitoring programs have indicated that underwater noise from platforms is typically very low or not detectable (Jiménez-Arranz et al., 2017; McCauley, 2002).

Gales (1982) assessed noise from 18 oil and gas platforms and found the strongest noise levels were relatively low frequency (<100 Hz, and mostly between 4 and 38 Hz), with sound levels of 110 to 130 dB re 1 μPa (unspecified unit) @100 feet (30 m) (Gales, 1982). Noise from the platforms was found to be lower than levels recorded from support vessels, with a cumulative increase in overall underwater noise of 20 to 30 dB from the noise produced by a support vessel operating near an operations platform (Gales, 1982).

Acoustic emissions within 1 m from the FPU during operations are expected to be 180 dB re 1µPa SPL, reducing to 120 dB re 1µPa SPL within 4.55 km (Marshall Day Acoustics, 2019).

Hydrocarbon Extraction

Noise will also be generated during hydrocarbon extraction as a result of the operation of the wellheads and subsea infrastructure.

The continuous noise produced by an operational wellhead was measured by McCauley (2002). At 113 dB re 1 m Pa, broadband noise level was very low and only marginally above rough sea condition ambient noise. For a number of nearby wellheads, the sources would have to be in very close proximity (<50 m apart) before their signals summed to increase the total noise field (with two adjacent sources only increasing the total noise field by 3 dB). Hence, for multiple wellheads in an area, the broadband noise level in the vicinity of the wellheads would be expected to be of the order of 113 dB re 1 m Pa and are expected to drop to background levels within <200 m from the wellhead.

Based on the measurements of wellhead noise discussed in McCauley (2002), which included flow noise in flowlines, noise produced along a flowline or the export pipeline may be expected to be similar to that described for wellheads, with the radiated noise field falling to ambient levels within a hundred metres of the flowline. Woodside has undertaken acoustic measurements on noise generated by the operation of choke valves associated with the Angel facility (JASCO, 2015). These measurements indicated choke valve noise is continuous, and the frequency and intensity of noise emitted is dependent on the rate of production from the well. Noise intensity at low production rates (16% and 30% choke positions) were approximately 154–155 dB re 1 m Pa, with higher production rates (85% and 74% choke positions) resulting in lower noise levels (141–144 dB re 1 m Pa). Noise from choke valve operation was broadband in nature, with the majority of noise energy concentrated above 1 kHz.

Installation of FPU

FPU station keeping will be maintained by moorings. The preferred installation technique for FPU moorings is through suction piling of moorings given the associated costs, safety and environmental impacts are likely to be much less. Should suction piling be undertaken, the resulting noise will be associated with the pump and is expected to be similar to continuous operational noise of other machinery described above for FPU operation. There are potentially technical constraints for this option based on the geotechnical conditions at the FPU location which may require driven piling.

Approximately 20 piles would be required in the Offshore Project Area, with each taking one day (24 hours) to install in water depths of approximately 900 m. Pile driving would generate low frequency impulsive sound. The noise emanating from a pile during pile-driving is a function of its material type, its size, the force applied to it and the characteristics of the substrate into which it is being driven. The frequency bandwidth for most of the energy in pile driving sounds is typically below 1000 Hz. Given the substrate characteristics in the Offshore Project Area, 5 m diameter steel piles may be required.

Predicted sound levels within 1 m of the piling location during pile driving is 235 dB re 1µPa SPL. reducing to 160 dB re 1µPa SPL within 38.25 km (Marshall Day Acoustics, 2019).

Vessel and MODU Operations

Vessels generate underwater sound from their propellers and thrusters. Vessels, including the MODU, used in deeper water or the pipelay vessel during trunkline installation, may use Dynamic Positioning (DP) where propellers and thrusters are used to hold position, rather than anchoring.

Excluding DP, marine vessels produce low frequency sound (i.e. below 1 kHz) from the operation of machinery, hydrodynamic flow sound around the hull and from propeller cavitation, which is typically the dominant source of sound (Ross, 1987, 1993). Tugboats, crew boats, supply ships and many research vessels in the 50–100 m size class typically have broadband source levels in the 165–180 dB re 1 µPa SPL range (Gotz et al., 2009). In comparison, underwater sound levels generated by large ships can produce levels exceeding 190 dB re 1 µPa (Gotz et al., 2009) and vessels up to 20 m size class typically 151 to 156 dB re 1µPa (Richardson et al., 1995).

DP MODU underwater noise measurements were taken for the MAERSK Discoverer drill rig used on the North West Shelf (Woodside, 2011). They showed the system emitted tonal signals between 200 Hz and 1.2 kHz, which is within the auditory bandwidth for cetaceans. The measured source level was between 176 and 185 dB re 1 µPa SPL @ 1 m. A noise assessment for the Deepwater Millennium (McPherson et al., 2013) DP drillship, drilling off the Northwest Cape, estimated the broadband source level for drilling operations at 196 dB re 1 µPa SPL @ 1 m, with all six thrusters working at 100%. This is a worst-case scenario as standard operation uses thrusters at 60% capacity or less, depending on weather conditions.

Measured source levels of the pipelay vessel Deep Orient under DP (length 135 m, breadth – 27 m, draft 6.85 m) showed a source level of 168 SPL @1 m (dB re 1 µPa). The source level of a support vessel with DP of 186 dB re 1 µPa (SPL) @1 m was derived from measured levels of the Setouchi Surveyor (Hannay et al., 2004; McCauley, 2005).

Noise modelling has shown that, assuming a source level of 186 dB re 1µPa SPL @ 1 m (Hannay et al. 2004), sound levels will be reduced to 120 dB re 1µPa SPL within 4.903 km (Marshall Day Acoustics, 2019). Given the size of the vessel (length 135 m, breadth 27 m and draft 6.85 m (Marshall Day Acoustics (2019)), acoustic emissions do not originate form a single point source (as is assumed in the modelling) and therefore, the modelled near field sound levels are exaggerated and considered highly conservative. Although SEL_{24h} is modelled for the pipelay and support vessel, in reality marine fauna will not be within close proximity of the vessels for a 24-hour duration, given that the relevant marine fauna are mobile, and that the vessels will be continually moving. As such, SEL_{24h} is not applied in the impact assessment of this activity.

ROV Operations

An ROV is a tethered underwater vehicle equipped with at least a video camera and lights. Additional equipment may include sonars, magnetometers, a still camera, a manipulator or cutting arm, water samplers, and instruments that measure water clarity, water temperature, water density, sound velocity, light penetration and temperature. ROVs may be used during Scarborough for assessing the FPU or trunkline.

ROVs may be fitted with measurement devices such as sonar, that emit a pulse of sound (often called a 'ping') and then listens for reflections (echo) of that pulse. ROVs may be used during construction, operation and decommissioning phases of the Project.

Typical frequency and sound source levels for ROV mounted sonar is (Jimenez-Arranz et al., 2017):

- frequency range between 3k Hz–200 kHz
- source level 150–235 dB re 1 uPa SPL @ 1 m.

Helicopter Operations

Helicopter noise is emitted to the atmosphere during routine helicopter flights. Helicopter trips will occur regularly during construction and less frequently during operation of Scarborough. Sound emitted from helicopter operations is typically below 500 Hz (Richardson et al., 1985). The peak-received level diminishes with increasing helicopter altitude, but the duration of audibility often increases with increasing altitude. Richardson et al. (1995) reports that helicopter sound is 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 reported for a Bell 212 helicopter during fly-over was reported at 162 dB re 1 µPa and for Sikorsky-61 is 108 dB re 1 µPa at 305 m (Simmonds et al., 2004).

Removal of Subsea Infrastructure

Removal of subsea infrastructure and trunkline will be evaluated at end of field life. Options of leave in-situ, removal or part removal of the infrastructure will be part of a future comparative assessment, which will assess the costs and benefits of the options. If subsea infrastructure is removed, acoustic emissions may be caused by methods such as mechanical cutting.

Table 7.7: Sources of aspect and the operating frequency and noise levels

Source of aspect	Operating frequency (kHz)	Source Level (@1 m)		Sound category^	Reference
		SPL (L_p)	*PK (L_{pk})*		
VSP	<0.1	216	238	I	CMST, 2013 Matthews, 2012
ROV	3–200	150–235	-	C	Jimenez-Arranz et al., 2017
Pre-lay survey: • MBES • USBL	 12–700 18–36	 221 -	 210–245 184–206	 I I	 Jimenez-Arranz et al., 2017
Drilling operations	<2	<190	-	C	Hannay et al., 2004; McCauley, 1998, 2002; Oceans of Noise, 2004
FPU operations		180		C	Erbe et al., (2013)
FPU installation – Pile driving*		235	-	I	Marshall Day Acoustics (2019)
Vessel operations: • Support vessel • Pipelay vessel	 0.2–1 0.2–1	 186 168	 -	 C C	 Hanney et al., 2004 McCauley, 2005 Marshall Day Acoustics, 2019
Helicopter operations	0.5	162	-	C	Simmonds et al., 2004

^ Sound category: I = impulsive; C = continuous
* Suction piling techniques are expected to generate similar, continuous noise emissions to FPU operations

7.1.3.2 Impact or Risk

Routine acoustic emissions produced by offshore activities has the potential to result in the following impact(s):

- a change in ambient noise.

As a result of a change in ambient noise, further impacts may occur, which include:

- a change in fauna behaviour
- injury/ mortality to fauna
- changes to the functions, interest or activities of other users.

To inform the assessment of potential impacts to marine fauna from underwater noise associated with Scarborough, Marshall Day Acoustics were contracted to undertake underwater noise modelling to inform the Scarborough Project OPP. The full report is presented as a technical appendix (Appendix) (Marshall Day Acoustics, 2019). Modelling was undertaken using the dBSea software to predict underwater noise levels using dBSea model solvers: dBSea Parabolic Equation (PE), dBSeaRay and dBSeaModes. Model parameters included noise level spectra, source locations and depths, bathymetry, sound speed profile and seabed properties.

Three key noise generating activities associated with Scarborough were modelled:

- FPU installation (pile driving)
- vessel operation of pipelay vessel with DP thrusters
- FPU and subsea infrastructure operation.

<u>Modelling Methodology</u>

1. FPU Installation – Impact piling

For driven piling of 5 m diameter steel piles, a source level of 225 dB re 1 µPa^2.s for a single pulse with a frequency between 31.5 Hz – 20k Hz was applied. The source level was based on maximum levels reported by the South Australia Pile Driving Guidelines (DPTI, 2012). The source depth is based on 0 m pile penetration on the basis that this would represent a worst-case scenario in terms of noise propagation. Model solvers dBSeaPE and dBSeaRay were used to model sound levels from FPU operations.

2. FPU Operations – FPU with offload tanker and support vessel with DP

Noise source levels for FPU operations include 180 SPL @1 m (dB re 1 µPa) for a stationary moored, typical FPU topside equipment operating, as derived from Erbe et al., 2014 (50th percentile data used). For the support vessel under DP, source levels were predicted using data derived from measured levels of the Setouchi Surveyor (Hannay et al., 2004) of 186 SPL @1 m (dB re 1 µPa). A frequency range of 31.5 Hz to 2.5 kHz was used. The modelling source depth was 5 m below the surface and the source location was in 980 m water depth in the Offshore Project Area. Model solvers dBSeaPE and dBSeaRay were used to model sound levels from FPU operations.

3. Vessel Operations

Broadband source levels within the frequency range of 31.5 Hz to 10 kHz were used to predict sound levels for vessel operations. For the pipelay vessel, a source level of 168 SPL @1 m (dB re 1 µPa) was used, based on measured levels Deep Orient: length 135 m, breadth – 27 m, draft 6.85 m, source data based on DP in calm seas. As described above for FPU installation, the source level for support vessel with DP of 186 SPL @1 m (dB re 1 µPa) was derived from measured levels of the Setouchi Surveyor (Hannay et al., 2004; McCauley, 2005). The model source location was at 5 m source depth, in a water depth of 20 m. The source location is on the State and Commonwealth boundary 3 nm offshore from Dampier. Evaluation of pipelay vessel operation noise has been conducted using dBSeaModes normal mode solver, verified to be appropriate for use in shallow water environments with homogenous bathymetry and sediment composition.

<u>Change in Ambient Noise</u>

Ambient noise levels are influenced by natural variables including wave action, wind, rain, seismic events, marine fauna communication (including both vocalisations and other behaviours such as whale breaching), and anthropogenic sources including shipping, military practices (i.e. sonar), recreational boat use and industrial development.

Underwater ambient noise levels have been recorded at 90 dB re 1 µPa (SPL) under very calm, low wind conditions, to 120 dB re 1 µPa (SPL) under windy conditions (McCauley, 2005). Large fluctuations in ambient noise levels in the Project Area are expected due to changes in weather systems and seasons, biological events such as whale migrations, and presence of shipping and other industrial activities.

Changes in ambient noise have the potential to impact marine fauna as discussed below.

Change in Fauna Behaviour

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.

Thresholds, where appropriate, for behavioural response of different species to noise are discussed in the sections that follow.

Injury/Mortality to Fauna

In some cases, injury or morality to marine fauna can occur due to elevated noise levels by causing direct physical effects on hearing or other organs, including (Richardson et al., 1995):

- potential for mortality/mortal injury resulting from exposure to noise (considered negligible given the noise sources associated with the Petroleum Activities Program, with the exception of plankton)
- Permanent Threshold Shift (PTS) – permanent reduction in the ability to perceive sound after being exposed to noise
- Temporary Threshold Shift (TTS) – temporary reduction in the ability to perceive sound after being exposed to noise, with hearing returning to normal.

Exposure to sufficiently intense sound may lead to an increased hearing threshold. If this shift is reversed and the hearing threshold returns to normal, the effect is called a temporary threshold shift (TTS). Southall et al., 2007 defined TTS as a threshold shift of 6 dB above the normal hearing threshold. If the threshold shift does not return to normal, permanent threshold shift (PTS) has occurred. Threshold shifts can be caused by acoustic trauma from a very intense sound of short duration, as well as from exposure to lower level sounds over longer time periods (Houser et al., 2017).

Changes to the Functions, Interest or Activities of Other Users

Where the functions, interests or activities of other marine users involve marine fauna, any effect to fauna presence or abundance will indirectly impact on the functions, interests or activities of other users. The potential impact may occur for the duration of the noise emission; however, following cessation of the activity, long term changes in fauna abundance or distribution are not expected. Given the location, short term nature of the more significant noise generating activities, and that the impacts to fish populations will be negligible, changes to the functions, interests or activities of other users, such as commercial fisheries, from acoustic emissions are not notable and have not been evaluated further.

A change in noise can potentially impact on the functions, interests or activities of other marine users that are dependent on underwater communications (e.g. Defence).

Receptors Potentially Impacted

Routine acoustic emissions have the potential to disrupt ecological processes that are sensitive to under water noise. As described for changes in behaviour above, vulnerability of individuals to injury or mortality varies between species. Receptors for which impacts have been determined to be negligible have been discussed below.

Plankton (Zooplankton)

Few studies have reported negative impacts of impulsive noise on zooplankton (including meroplankton or temporary members of the plankton such as fish eggs and larvae, and invertebrate and coral larvae), and none from more than 10 m away from an airgun. This suggests the range of chronic effects on fish eggs and larvae due to seismic discharges is likely to be restricted to <10 m (Table 7.8). Popper et al., (2014) presented a threshold of >210 dB re 1 µPa^2.s (SEL) or 207 dB re 1 µPa (PK) for mortality and potential mortal injury, which is lower (and therefore more conservative) than the observed effects provided in Table 7.8.

Table 7.8: Summary of impulsive noise impacts on fish eggs and larvae

Species	Source	Source level (dB re 1 µPa @ 1 m)	Distance from source (m)	Exposure level (dB re 1 µPa)	Observed effect	Reference
Cod (larvae 5 days)	Single airgun	250	1	250	Delamination of the retina	Matishov (1992)
Cod (larvae 2–10 days)	Single airgun	222	1	222	No injuries detected	Dalen and Knutsen (1986)
			10	202	No injuries detected	
Fish eggs (Anchovy)	Single airgun	230 (estimated)	1	230	7.8% of eggs injured relative to control	Kostyvchenko (1973)
Fish eggs (Red Mullet)			10	210	No injuries detected	
			1	230	No injuries detected	
			10	210	No injuries detected	
Dungeness Crab (larvae)	Seven airgun array	244 (estimated)	1	233.5	No significant difference in survival rate relative to controls	Pearson et al., (1994)

Applying sound exposure guidelines for eggs and larvae (SEL_{24h} >210 dB re 1 µPa^2.s) (Popper et al., 2014) indicates that mortality or potential permanent injury may occur within 2.39 km of the largest acoustic source (Marshall Day Acoustics, 2019). A study by McCauley (1994) calculated the impact in a seismic survey area assuming plankton mortality of 100% within 10 m of an airgun. It argued that the total mortality due to seismic testing would be <1% of plankton in the surveyed area. A more recent study undertaken by McCauley et al. (2017) showed potential for noise impulses discharged from a single 150 cui airgun resulted in zooplankton mortality and reduction in abundance out to more extended ranges (1.2 km), at levels up to 178 dB re 1 µPa PK-PK Pressure.

Furthermore, Richardson et al. (2017) modelled the effect proposed by McCauley et al. (2017) in the context of ocean ecosystem dynamic and zooplankton population dynamic. The report concluded that even if the full effect reported by McCauley et al., (2017) did exist, plankton abundance would not be adversely affected, due to extensive movement of water masses carrying plankton through survey areas, and the rapid reproductive cycle and high reproductive potential characteristics of planktonic organisms.

The literature and acoustic modelling results suggest that a reduction in plankton may occur within 2.39 km or the acoustic source, representing a small proportion of the plankton stock in the NWMR. Rapid recovery and repopulation are expected and the overall impact to plankton abundance is likely to be negligible, and not evaluated further.

Epifauna and Infauna

Although sparsely distributed, epifauna and infauna in the Project Area consists of invertebrates including small burrowing worms and crustaceans. These invertebrate species are permanently in contact with the bottom substrate and accordingly it is important to also consider the propagation of vibration through the ground, particularly for an acoustic emission from piling activities. For benthic epifauna and infauna, this type of vibration is likely of similar or greater importance than water-borne vibration or even the compressional component of a sound (Roberts and Elliott, 2017). However, the published scientific information on vibration sensitivity in marine invertebrates is extremely scarce (Roberts et al., 2015; Roberts et al., 2016; Popper and Hawkins, 2018). Only a small number of studies have indicated reception of vibration and behavioural responses in bivalve molluscs (Mosher, 1972; Ellers, 1995; Kastelein et al., 2008), which, although they may occur in the Project Area, were not dominant. To date, there is no convincing evidence for any significant effects induced by non-impulsive noise in benthic invertebrates.

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 (McCauley, 1994). 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., 2004).

Studies have indicated that offshore marine seismic survey activity has no effect on catch rates of crustaceans in the surrounding area (Andriguetto-Filho et al., 2005; Parry and Gason, 2006). In addition, Wardle et al. (2001) observed little effect on invertebrate (crustaceans, echinoderms and molluscs) populations inhabiting a reef that was exposed to airgun noise. Furthermore, Christian et al. (2004) conducted a behavioural investigation during which caged snow crabs were positioned 50 m below a seven-gun array. Observations on the crabs’ responses to seismic survey pulses were recorded by remote underwater camera. No obvious startle behaviours were observed.

More recently, field experiments were undertaken in water depths of 10–12 m, to understand the impacts of seismic surveys, an anthropogenic impulsive sounds source (Day et al., 2016). Researchers suggested the findings were broadly applicable to scallop and spiny lobster fisheries throughout the world, and bivalve and crustaceans in general. The exposure levels measured in the study were compared to levels of a hypothetical source modelled and are considered equivalent to a commercial ~3100 in^3 seismic source. Key findings from these experiments showed:

- seismic exposure did not result in any lobster mortality, but some temporary and permanent sub- lethal effects (for example reflexes – tail extension and righting, and damage to the sensory hairs of the statocyst) were observed
- lobsters collected from a site subject to high levels of anthropogenic aquatic noise were shown to already have some sub-lethal damage (significant damage to the statocyst hairs) prior to the study; however, the damage resulting from the study was less than that of other lobsters

- seismic exposure did not cause immediate mass mortality of scallops; however, it did increase the risk of mortality, and result in significant changes in behaviour (reduction in classic behaviours and air gun signals eliciting a novel velar flinch behaviour) and reflexes (faster recessing times and indications of slowed righting times) during and following seismic exposure.

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 Project Area, and the short-term nature of the impulsive noise, impacts are likely to be negligible and have not been evaluated further.

Defence

There is a Naval Communications Station located just north of Exmouth that utilises very low frequency (19.8 kHz) transmissions to communicate with vessels and submarines. This type of function is not expected to be a consistent requirement in the area. The Defence communication frequency doesn't overlap with that predicted for noise emissions from ongoing activities (e.g. MODU, FPU), but may for some temporary (e.g. pre-lay survey, ROV operations) activities. Given the temporary nature of these Project activities, and the inconsistent nature of communication emissions, impacts are likely to be negligible and have not been evaluated further.

Marine receptors that may be impacted by routine acoustic emissions are outlined in Table 7.9.

Table 7.9: Receptor/impact matrix after evaluation of context

	Receptor						
Impacts	*Ambient Noise*	*Plankton*	*Epifauna and Infauna*	*Fish*	*Marine Mammals*	*Marine Reptiles*	**Defence**
Change in ambient noise	✓						X
Change in fauna behaviour			X	✓	✓	✓	
Injury/mortality to fauna		X	X	✓	✓	✓	

Detailed Impact Evaluation

For each of the receptors identified for detailed evaluation, the criteria for acceptability as defined in Table 6.3 have been considered and addressed in the following sections. This includes to meet the principles of ESD, internal and external context and any other requirements.

Ambient Noise

Ambient noise levels in the Project Area may be elevated during all phases of the project. Underwater noise surveys in the region detected marine fauna vocalisations and anthropogenic sources including vessel noise; seismic survey signals; mooring noise artefacts (McCauley, 2011). Although ambient noise levels in the Project Area have not been recorded, they are expected to be towards the upper limit of published ambient noise levels given the presence of shipping fairways and high vessel traffic in the Trunkline Project Area and adjacent to the Offshore Project Area.

As shown in Table 7.7, activities emitting the greatest source levels are associated with temporary activities including geotechnical surveys and installation of facilities. Longer term activities, such as operation of the FPU, have much lower source levels and smaller EMBA.

The environmental performance outcome for ambient noise is 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. Given the extent of the EMBA, and the temporary nature of the largest source levels, adverse impacts to a substantial area of habitat are not expected.

In order to minimise impacts from acoustic emissions, Woodside will implement internal requirements, specifically the VSP Procedure.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to ambient noise. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. Matters relating to potentially impacted receptors from a change in ambient noise are discussed for the specific receptors.

Based on the detailed impact evaluation, the magnitude of potential impact of a change in ambient noise is no lasting effect and considered **acceptable**.

Change in Fauna Behaviour and Injury/Mortality to Fauna

Fish

Sound is perceived by fish through the ears and the lateral line which are sensitive to vibration. Some species of teleost or bony fish (e.g. herring) have a structure linking the gas-filled swim bladder and ear. These species usually have increased hearing sensitivity. These species are considered to be more sensitive to anthropogenic underwater noise sources than species such as cod (*Gadus sp.*) which do not possess a structure linking the swim bladder and inner ear. Fish species that either do not have a swim bladder (e.g. elasmobranchs and scombrid fish (sharks, mackerel and tunas)) or have a much-reduced swim bladder (e.g. flat fish), tend to have a relatively low auditory sensitivity. Considering these differences in fish physiology, Popper et al., (2014) developed sound exposure guidelines for fish for impulsive noise. These are presented in Table 7.10. Data on exposure or received levels to provide similar thresholds in response to continuous noise are lacking (Popper et al., 2014), as described below.

Table 7.10: Threshold for impulsive exposure to fish (Popper et al., 2014)

Type of Fish	Mortality and potential mortal injury	Impairment	
		Recoverable Injury (PTS)	***Temporary Threshold Shift (TTS)***
Type 1 – No swim bladder (particle motion detector)	>219 dB re 1 μPa^{2}s (SEL) Or >207 dB re 1 μPa (PK)	>216 dB re 1 μPa^{2}s (SEL) Or >213 dB re 1 μPa (PK)	>186 dB re 1 μPa^{2}s (SEL)
Type 2 – Swim bladder is not involved in hearing (particle motion detector)	>210 dB re 1 μPa^{2}s (SEL) Or >207 dB re 1 μPa (PK)	>207 dB re 1 μPa^{2}s (SEL) Or >203 dB re 1 μPa (PK)	>186 dB re 1 μPa^{2}s (SEL)
Type 3 – Swim bladder involved in hearing (primary pressure detection)	>207 dB re 1 μPa^{2}s (SEL) Or >207 dB re 1 μPa (PK)	>207 dB re 1 μPa^{2}s (SEL) Or >203 dB re 1 μPa (PK)	>186 dB re 1 μPa^{2}s (SEL)

Underwater continuous noise has been shown to result in recoverable injury or TTS in sound pressure sensitive species, including the goldfish (*Carassius auratus*), at 170 dB re 1 μPa (SPL) over 48 hours (Smith et al., 2006), and the catfish (*Pimelodus pictus*) at 158 dB re 1 μPa (SPL) over 12 hours (Amoser and Ladich, 2003). However, the data for several species of fish lacking sound pressure specialisations showed no TTS in response to long term noise exposure, including tilapia (*Oreochromis niloticus*) (Smith et al., 2004), bluegill sunfish (*Lepomis macrochirus*) (Scholik and Yan, 2002) and rainbow trout (*Oncorhynchus mykiss*) (Wysocki et al., 2007). Rainbow trout exposed to continuous noise levels of up to up to 150 dB re 1 μPa (SPL) for nine months in an aquaculture facility showed no hearing loss nor any negative effects on fish health (Wysocki et al., 2007).

Guideline noise levels criteria from Popper et al., 2014 provide impact threshold for shipping and other continuous noise sources to Type 3 fish (swim bladder involved in hearing) at 170 dB re 1 μPa (SPL) over 48 hours for recoverable injury, and 158 dB re 1 μPa (SPL) over 12 hours for TTS. In absence of more conclusive studies, these impact thresholds have been applied for conservatism.

Underwater impulsive sound such as pile driving may have negative impacts on fish species ranging from behavioural disturbance to physical injury/mortality. The hearing system of most fishes is sensitive to sound pressures between 50 hertz and 500 hertz (Ladich and Fay, 2013), which overlaps the predominant frequency ranges of pile driving activities.

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.

The Scombroid fishes such as tuna, billfish and marlin are considered hearing generalists with poor hearing sensitivity, based on the physiology of the inner structure (as documented for the bluefin tuna, Song et al., 2006). Pelagic finfish species, which are not hearing specialists, inhabit seabed areas and can exhibit avoidance behaviour when experiencing impulsive noise levels that lead to low-level behavioural effects.

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 (Type 1 fish without swim ladder) and therefore, unlikely to be impacted by impulsive noise unless at close distances to the source location (Popper et al., 2014). Underwater sound emissions are not listed as a threat in the IUCN Red List listing (Pierce and Norman, 2016) or the Conservation advice *Rhincodon typus* (Whale Shark) (TSSC, 2015d).

Applying impact thresholds detailed in Table 7.10 for Type 1 fish (no swim bladder), mortality or lethal injury could occur up to 0.75 km (R_{max}) from the piling location during piling. For Type 2 fish (swim is not involved in hearing) and Type 3 fish (swim bladder involved in hearing), mortality or lethal injury could occur at 2.39 km and 3.5 km (R_{max}) from the piling location during piling, respectively. For all fish types, TTS could occur if exposed to SEL_{24h} at ranges up to 34.06 km from source.

During FPU operation, recoverable injury and TTS to Type 3 fish (swim bladder involved in hearing) may occur within 0.36 km and 0.78 km (R_{max}) from the FPU respectively. TTS due to continuous acoustic emissions from the pipelay and support vessel in the Trunkline Project Area is not considered credible (see Section 7.1.3.1).

Although there is some evidence of impacts to fish a result of acoustic emissions, the potential for mortality, lethal or recoverable injury is restricted to within close distances of the acoustic sources (<3.5 km). Although TTS could occur at greater distances (up to 34.06 km for piling in the Offshore Project Area), given the temporary nature of this activity, impacts may occur to a small proportion of the resident or transient fish populations, and are temporary in nature. Whale sharks are not expected to occur in the Offshore Project Area (Section 5.4.4), with the closest areas of significant habitat (foraging BIAs) located >165 km form the piling location. Subsequently, impacts to whale sharks are not expected. Overall, the impacts to fish, including listed species such as the whale shark, is assessed as having no lasting effects and evaluated as **acceptable**.

Marine Mammals

The potential impacts of anthropogenic noise on marine mammals have been the subject of considerable research; reviews are provided by Richardson et al. (1995), Nowacek et al., (2007), Southall et al., (2007), Weilgart (2007) and Wright et al., (2007).

Southall et al., (2007), Finneran and Jenkins (2012) and Wood et al., (2012) reviewed available literature to determine exposure criterion for injury, referred to as the onset of non-recoverable permanent hearing loss (PTS) and temporary hearing threshold shift (TTS), in cetaceans.

In marine mammals, the onset level and growth of TTS is frequency specific, and depends on the temporal pattern, duty cycle, and the hearing test frequency of the fatiguing stimuli. Exposure to intense impulse noise might be more hazardous to hearing than non-impulsive noise. Sounds generated by seismic airguns, pile-driving and mid-frequency sonars have been tested directly and proven to cause noise-induced threshold shifts in marine mammals at high received levels. Finneran (2015) reviewed the current state of knowledge on TTS and PTS. TTS typically decreases in marine mammals relative to the logarithm of the increasing recovery time, although there is considerable individual difference in TTS-related parameters between species that have been tested.

PTS is considered injurious in marine mammals, but there are no published data on the sound levels that cause PTS in marine mammals. Onset levels of PTS are typically extrapolated from TTS onset levels and assumed growth functions (Southall et al., 2007). Only a few studies have investigated TTS in marine mammals in response to exposure to impulsive sounds. Lucke et al. (2009) tested the effect of a single airgun on a male harbour porpoise. They documented onset of TTS at received (unweighted) SEL of 164 dB re 1 $\mu Pa^2 s$. This equates to a high frequency cetacean weighted SEL_{24h} of 140 dB re 1 $\mu Pa^2 \cdot s$ (NOAA 2016). Kastelein et al. (1997) tested the auditory tolerance of a harbour porpoise to playbacks of broadband pile driving sounds. After one hour of exposure an unweighted SEL 146 dB re 1 $\mu Pa^2 \cdot s$ and a SEL_{24h} of 180 dB re 1 $\mu Pa^2.s$. They calculated an onset of TTS for this type of sound at a SEL_{24h} of approximately 175 dB re 1 $\mu Pa^2.s$. Kastelein et al. (2017) exposed a harbour porpoise to 10 and 20 consecutive airgun impulses at received SEL_{24h} of 188–191 dB re 1 $\mu Pa^2 \cdot s$ with a mean shot interval of around 17 seconds.

Finneran et al. (2015) tested the exposed three bottlenose dolphins to ten impulses produced by a seismic air gun. The highest exposures were conducted at peak sound pressure levels of 210 dB re 1 µPa (PK) and 212 dB re 1 µPa (PK-PK), and cumulative (unweighted) SEL_{24h} of 195 dB re 1 $\mu Pa^2.s$.

The NMFS (2018) criteria incorporate the best available science to estimate PTS and TTS onset in marine mammals from sound energy (SEL_{24h}) and sound pressure levels (PK) (Table 7.12).

Beyond the area in which injury may occur, the impact on marine mammal behaviour is the most important measure of a potential impact of underwater noise.

Behavioural reactions to acoustic exposure are generally more variable, context-dependent, and less predictable than the effects of noise exposure on hearing or physiology. This is because behavioural responses to anthropogenic sound depend upon operational and environmental variables, and on the physiological, sensory and psychological characteristics of exposed animals. It is important to note that the animal variables may differ (greatly in some cases) among individuals of a species, and even within individuals, depending on various factors (e.g. sex, age, previous history of exposure, season, animal activity). However, within certain similar conditions, there appears to be some relationship between the sound exposure level and the magnitude of behavioural response.

Southall et al. (2007) graded the severity of context-specific behavioural responses to noise exposure, as follows (refer to Table 7.11 for a detailed description):

- relatively minor and/or brief: score 0–3
- a higher potential to affect feeding, reproduction or survival: score 4–6
- considered likely to affect these life functions: score 7–9.

Table 7.11: Behavioural disturbance scale (Southall et al., 2007)

Response Score	Corresponding Behaviours in Free-ranging Subjects
0	No observable response.
1	Brief orientation response (investigation/visual orientation).
2	Moderate or multiple orientation behaviours. Brief or minor cessation/modification of vocal behaviour. Brief or minor change in respiration rates.
3	Prolonged orientation behaviour. Individual alert behaviour. Minor changes in locomotion speed, direction, and/or dive profile but no avoidance of sound source. Moderate change in respiration rate. Minor cessation or modification of vocal behaviour (duration <duration of source operation).
4	Moderate changes in locomotion speed, direction, and/or dive profile but no avoidance of sound source. Brief, minor shift in group distribution. Moderate cessation or modification of vocal behaviour (duration more or less equal to the duration of source operation).
5	Extensive or prolonged changes in locomotion speed, direction, and/or dive profile but no avoidance of sound source. Moderate shift in group distribution. Change in inter-animal distance and/or group size (aggregation or separation). Prolonged cessation or modification of vocal behaviour (duration >duration of source operation).
6	Minor or moderate individual and/or group avoidance of sound source. Brief or minor separation of females and dependent offspring. Aggressive behaviour related to sound exposure (e.g. tail/flipper slapping, fluke display, jaw clapping/gnashing teeth, abrupt directed movement, bubble clouds). Extended cessation or modification of vocal behaviour. Visible startle response. Brief cessation of reproductive behaviour.
7	Extensive or prolonged aggressive behaviour. Moderate separation of females and dependent offspring. Clear anti-predator response. Severe and/or sustained avoidance of sound source. Moderate cessation of reproductive behaviour.
8	Obvious aversion and/or progressive sensitisation. Prolonged or significant separation of females and dependent offspring with disruption of acoustic reunion mechanisms. Long-term avoidance of area (>source operation). Prolonged cessation of reproductive behaviour.
9	Outright panic, flight, stampede, attack of conspecifics, or stranding events. Avoidance behaviour related to predator detection.

The more severe the response on the scale, the lower the amount of time that the animals will tolerate it before there could be significant negative effects on life functions. This would constitute a disturbance under the relevant regulations.

Available data on marine mammal behavioural responses to pulsed sounds are highly variable and context-specific. Recent studies on the behavioural response to humpback whales to seismic airguns has demonstrated behavioural response to seismic airguns above received sound exposure levels of 140 dB re 1 μPa^2.s (SEL) (Dunlop et al., 2017). This study used the behavioural response of humpback whales to noise from two different moving air gun arrays (20 and 140 cubic inch air gun array) to determine whether a dose–response relationship existed. To do this, a measure of avoidance of the source was developed, and the magnitude (rather than probability) of this response was tested against dose. The proximity to the source, and the vessel itself, was included within the one-analysis model. Humpback whales were more likely to avoid the air gun arrays (but not the controls) within 3 km of the source at sound exposure levels over 140 dB re 1 μPa^2.s (SEL), meaning that both the proximity and the received level were important factors and the relationship between dose (received level) and therefore the 140 dB re 1 μPa^2.s (SEL) cannot be adopted as a stand-alone threshold if the source proximity is greater than 3 km. This study tested towing an airgun source directly into the incoming path of a southern humpback migration which included mother and calf humpback whales, therefore the context and applicability of these results may not be directly applicable to the behavioural response to all cetaceans in every context and has not been adopted for the assessment of potential behavioural impacts from VSP due to that fact that the source is stationary. It should be noted that Dunlop et. al. 2017 makes reference that their results are surprisingly consistent with previous studies with humpback whales in different behavioural contexts. For example, feeding humpback whales responded at ranges up to 3 km from the source, at levels of 150–169 dB re 1 μPa (SPL) (Malme et al., 1985), and resting female humpback whales with calves displayed avoidance reactions at 140 dB re 1 μPa (SPL), though other cohorts reacted at higher levels (157–164 dB re 1 μPa (SPL)) (McCauley et al., 2003).

NMFS (2013) sets the behavioural response threshold for marine mammals at 160 dB re 1 μPa (SPL) for impulsive noise and 120 dB re 1 μPa (SPL) for continuous noise. The value for impulsive sound sits in the upper-mid range for disturbance impacts identified in Southall et al. (2007) and consequently this criterion has been used (in lieu of more suitable up to date criteria) for assessing onset of potentially strong behavioural reaction in this assessment, although it should be borne in mind that this value is possibly over-pessimistic. The value for continuous sound sits roughly mid-way between the range of values identified in Southall et al. (2007) but is lower than the value at which most mammals responded at a response score of 6 (i.e. once the received SPL is greater than 140 dB re 1 μPa). Considering the paucity and high level of variation of data relating to onset of behavioural impacts due to continuous sound, it is recommended that any ranges predicted using this number are viewed as probabilistic and possibly over-precautionary.

The criteria for use in assessing the likelihood of injury as a result of Scarborough are summarised in **Table 7.12**.

Table 7.12: Noise exposure criteria for onset of TTS and PTS (NMFS 2018) and behavioural response (NMFS 2013)

Hearing group	PTS onset thresholds (received level)		TTS onset thresholds (received level)		Behavioural response
	Impulsive	*Non-impulsive*	*Impulsive*	*Non-impulsive*	
Low-frequency cetaceans	Lpk, flat: 219 dB LE, LF, 24h: 183 dB	LE, LF, 24h: 199 dB	Lpk, flat: 213 dB LE, LF, 24h: 168 dB	LE, LF, 24h: 179 dB	Lp 160 dB
Mid-frequency cetaceans	Lpk, flat: 230 dB LE, MF, 24h: 185 dB	LE, MF, 24h: 198 dB	Lpk, flat: 224 dB LE, MF, 24h: 170 dB	LE, MF, 24h: 178 dB	Lp 160 dB
High-frequency cetaceans	Lpk, flat: 202 dB LE, HF, 24h: 155 dB	LE, HF, 24h: 173 dB	Lpk, flat: 196 dB LE, HF, 24h: 140 dB	LE, HF, 24h: 153 dB	Lp 160 dB

Cumulative Sound Exposure Levels (SEL_{24h}) from driven piling in the Offshore Project Area are estimated to exceed threshold criteria for PTS and TTS for low frequency cetaceans at maximum depth distances of 34 km and 99 km (R_{max}), respectively (Figure 7.5, Figure 7.6). For high frequency cetaceans, such as dolphins, the equivalent distances where PTS and TTS could occur is 42.91 km and 17.49 km (R_{max}), respectively (Figure 7.5, Figure 7.6). The SEL_{24h} assumes that a whale is exposed to the SEL_{24hr} over a 24hr period, which is considered unlikely as the whale would be expected to be transient through the area and move away from the sound source.

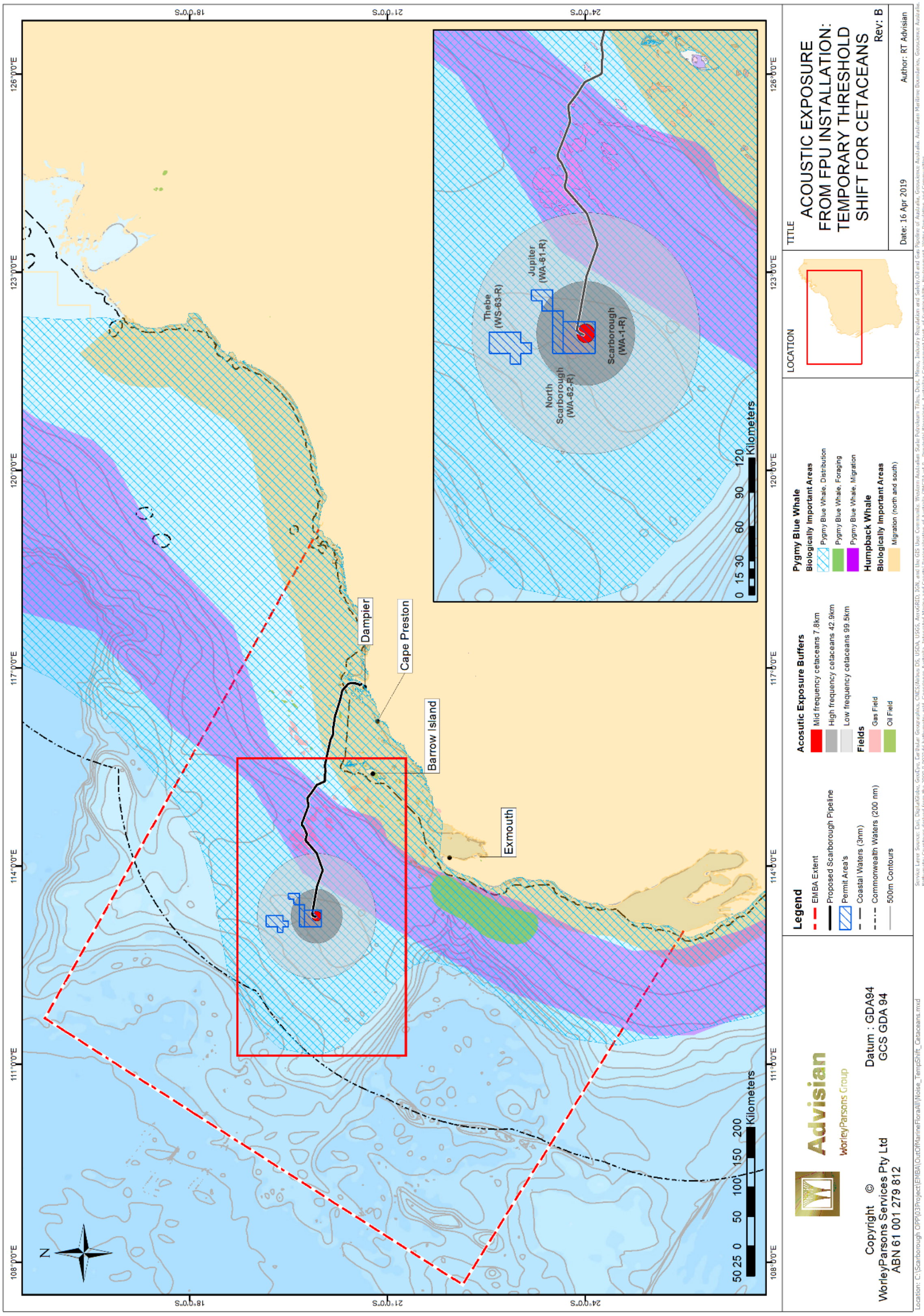


Figure 7.5: Predicted exposure area from impulsive noise from FPU installation activities that may cause a temporary threshold shift in cetaceans

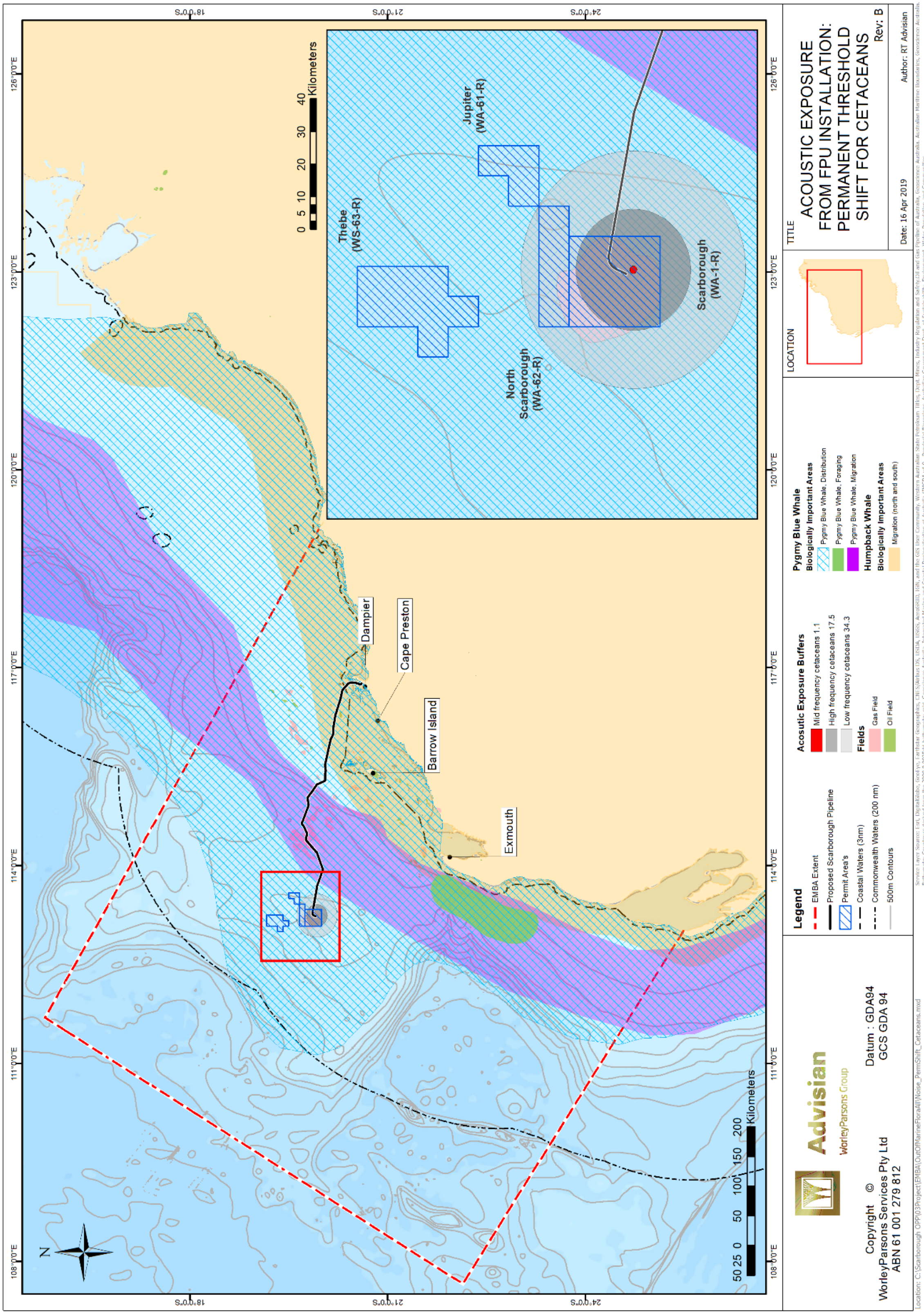


Figure 7.6: Predicted exposure area from impulsive noise from FPU installation activities that may cause a permanent threshold shift in cetaceans

Sound levels (PK) would exceed threshold criteria for PTS and TTS for low frequency cetaceans at maximum distances of 0.59 km and 0.75 km (R_{max}), respectively. For high frequency cetaceans, PTS and TTS thresholds would be exceed at 0.88 km and 1.5 km (R_{max}), respectively. Behavioural response thresholds for marine mammals would be reached at a maximum distance of 38 km from the piling location during pile driving.

Continuous acoustic emissions (SEL_{24h}) associated with FPU operation may cause PTS and TTS to low frequency cetaceans within 0.73 km and 1.4 km (R_{max}) if exposed over a 24hr duration. For high frequency cetaceans PTS and TTS thresholds may be exceed within <0.01 km and 0.34 km (R_{max}) respectively. Based on SPL behavioural response thresholds, behavioural disturbance of marine mammals from FPU operations may occur up to 4.6 km from source (Figure 7.7).

In the Trunkline Project Area, underwater noise generated by vessel operations could result in behavioral response of marine mammals up to 4.903 km from the vessel (Figure 7.8). It is not considered credible for TTS or PTS to occur due to vessel noise.

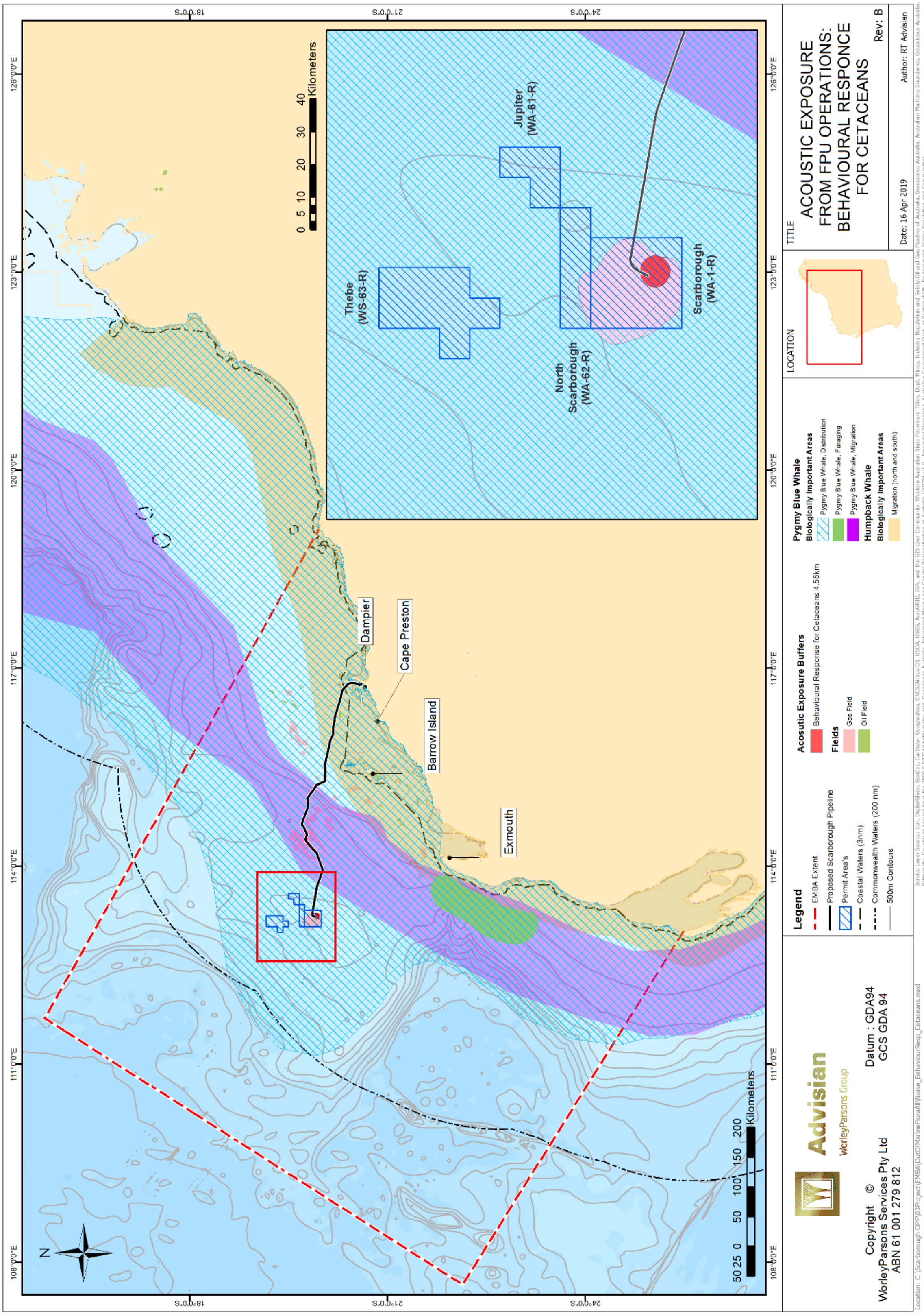


Figure 7.7: Predicted exposure area from continuous noise from FPU operations that may cause a behavioural response in cetaceans

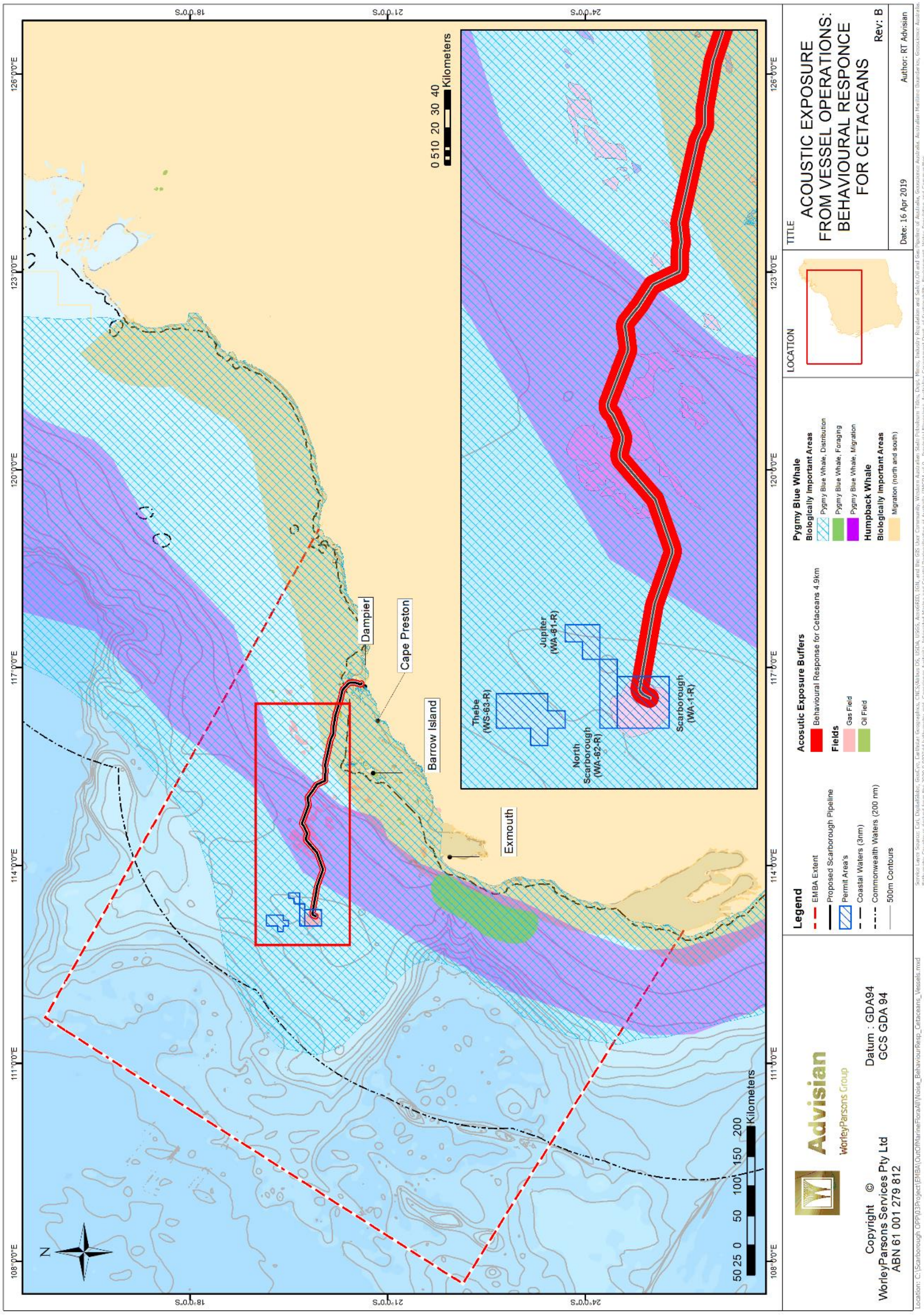


Figure 7.8: Predicted exposure area from continuous noise from vessel operations that may cause a behavioural response in cetaceans

The FPU location is within the distribution BIA, and within 36 km of a migration BIA, for pygmy blue whales. Furthermore, recent findings (Gavrilov and McCauley, 2018), suggest that migrating individuals may also traverse the Offshore Project Area. Pygmy blue whales migrate past Exmouth and the Montebello Islands from April and August during their northern migration and October to December during their southbound migration. If piling activities were to occur during these months, pygmy blue whales may be exposed to noise levels that could cause physical impact (PTS) from a single pile strike within 590 m and from cumulative exposure over 24 hours up to a max distance of 34 km, and TTS from a single strike within 750 m and from cumulative exposure over 24 hours at max distance of 99 km. Behavioural disturbance may occur at distances up to 38 km from the source, and would therefore intercept with the distribution and migration BIA. During FPU operations, potential impacts are restricted to within 4.6 km (behavioural disturbance), with no overlap on the migration BIA. Such behavioural responses are expected to be restricted to localized avoidance. Operation of the FPU is unlikely to displace a significant number of pygmy blue whales or disrupt migration of individuals migrating outside the BIA boundaries.

The migration BIA for humpback whales is >150 km from the FPU and therefore, impacts to migrating humpback whales rom piling noise or FPU operation are not expected.

Migrating humpback and pygmy blue whales are more likely to occur in the Trunkline Project Area. Behavioural responses may occur within 5 km of the pipelay vessel during installation activities. Such behavioural responses will be restricted to within 5 km of the vessel, which will be continually moving at a slow speed. Given the width of the migration BIAs of both pygmy blue and humpback whales, the operation of the pipelay vessel is unlikely to present a barrier to migration. Any disturbance is likely to be temporary and localised at the individual level.

Dugongs are not expected to be resident in the Project Area given the lack of significant seagrass habitat (Section 5.4.4). Transient individuals may traverse the Trunkline Project Area as they migrate between foraging habitats. Any individuals that are encountered may display behavioural responses to acoustic emissions form the pipelay vessel. However, since dugong encounters are expected to be infrequent, the number of individuals that may be affected is not expected to represent a significant proportion of the regional population.

Within the Project Area, the environmental performance outcomes for marine mammals include to:

- not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population
- 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
- not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

The greatest noise source is driven piling in the Offshore Project Area. This activity is temporary and therefore any impacts to marine mammals will only occur to a small proportion of the regional populations preventing population level effects. Acoustic emissions from activities in the Trunkline Project Area are also temporary. Although FPU operation will result in long-term acoustic emissions, the EMBA is restricted to within close proximity of the FPU which has not been identified as important for resting, foraging or breeding.

In order to minimise impacts to marine mammals, Woodside will implement internal requirements, specifically the VSP Procedure.

All relevant activities associated with routine acoustic emissions will be conducted in line with the *EPBC Act Policy Statement 2.1 – Interaction between Offshore Seismic Exploration and Whales.*

For construction and IMR activities occurring within the Montebello Marine Park, and adjacent to the Dampier Marine Park, the short term and transient nature of activities associated with acoustic emissions will not be 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, or for the Habitat Protection Zone (IV) 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 values identified for both these AMPs including BIAs for migratory pathways will not be impacted given the significant distance from sensitive locations.

Based on the detailed evaluation, the magnitude of potential impacts to marine mammals from acoustic emissions during activities associated with Scarborough is assessed as no lasting effects and evaluated as **acceptable**.

Marine Reptiles

There is a paucity of data regarding responses of marine turtles to underwater noise. Electro-physical studies have indicated that the best hearing range for marine turtles is in the 100 to 700 Hz range (Popper et al., 2014). Because of their rigid external anatomy, it is possible that sea turtles are highly protected from impulsive sound (Popper et al., 2014).

Popper et al., (2014) provided injury thresholds for turtles (>207 dB PK) however no thresholds were provided for behavioural disturbance. McCauley (2000) noted that sea turtles exhibit increased swimming activity in response to impulsive noise exposure at 166 dB re 1 uPa (SPL). McCauley et al., (2003), Popper et al., (2014) and O'Hara and Wilcox (1990), however, reference behavioural exposure thresholds for impulsive noise sources on caged green and loggerhead turtles and turtle injury thresholds specific to pile driving (Table 7.13).

For continuous noise sources, such as vessel operations, marine turtles have been shown to avoid low-frequency sounds (Lenhardt, 1994). Further, playback study of diamondback terrapins (*Malaclemys terrapin terrapin*) using boat noise, some animals were observed to increase or decrease swimming speed while others did not alter their behaviour at all (Lester et al., 2013).

Table 7.13: Impulsive noise exposure for marine turtles

Species	Received Level			Effect	Source
	SPL (L_p)	***PK (L_{pk})***	***SEL (L_E)***		
Sea turtles	-	>207	210	Injury	Popper et al., 2014
Loggerhead turtle	175-176	-	-	Avoidance response	O'Hara and Wilcox, 1990
One green and one loggerhead turtle	166	-	-	Noticeable increase in swimming behaviour, presumed avoidance response	McCauley et al., 2003
One green and one loggerhead turtle	175	-	-	Behaviour becomes increasingly erratic, presumed alarm response	McCauley et al., 2003

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 that may result in PTS or TTS; 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. Typical startle responses occur at relatively short ranges (tens of metres) (Hazel et al., 2007) and as such, startle responses during typical helicopter flight profiles are considered to be remote. In the event of a behavioural response to the presence of a helicopter, turtles are expected to exhibit diving behaviour, which is of no lasting effect.

Acoustic emissions form pile driving may exceed marine turtle impact thresholds for mortality/lethal injury and behavioural response at 2.395 km and 24.6 km (R_{max}), respectively. For the continuous noise emissions associated with the FPU operation and pipelay vessels, the distance at which the behavioural response threshold is exceeded is lower, at 0.48 km and 0.46 km (R_{max}) respectively.

Marine turtles are expected to occur in the Offshore Project Area infrequently. Significant or critical habitat is not known to occur for any turtle species in the Offshore Project Area, with the closest BIA located >150 km away. Although the Trunkline Project Area overlaps areas identified as potential critical breeding habitat for loggerhead, hawksbill, flatback and green turtles, the area of impact from acoustic sources in these habitats are restricted to within 0.46 km of the pipelay vessel (Figure 7.9), preventing displacement of a significant proportion of the breeding population. Furthermore, trunkline installation activities will be temporary and the vessel continually moving, further reducing the potential for impact at the individual and population level.

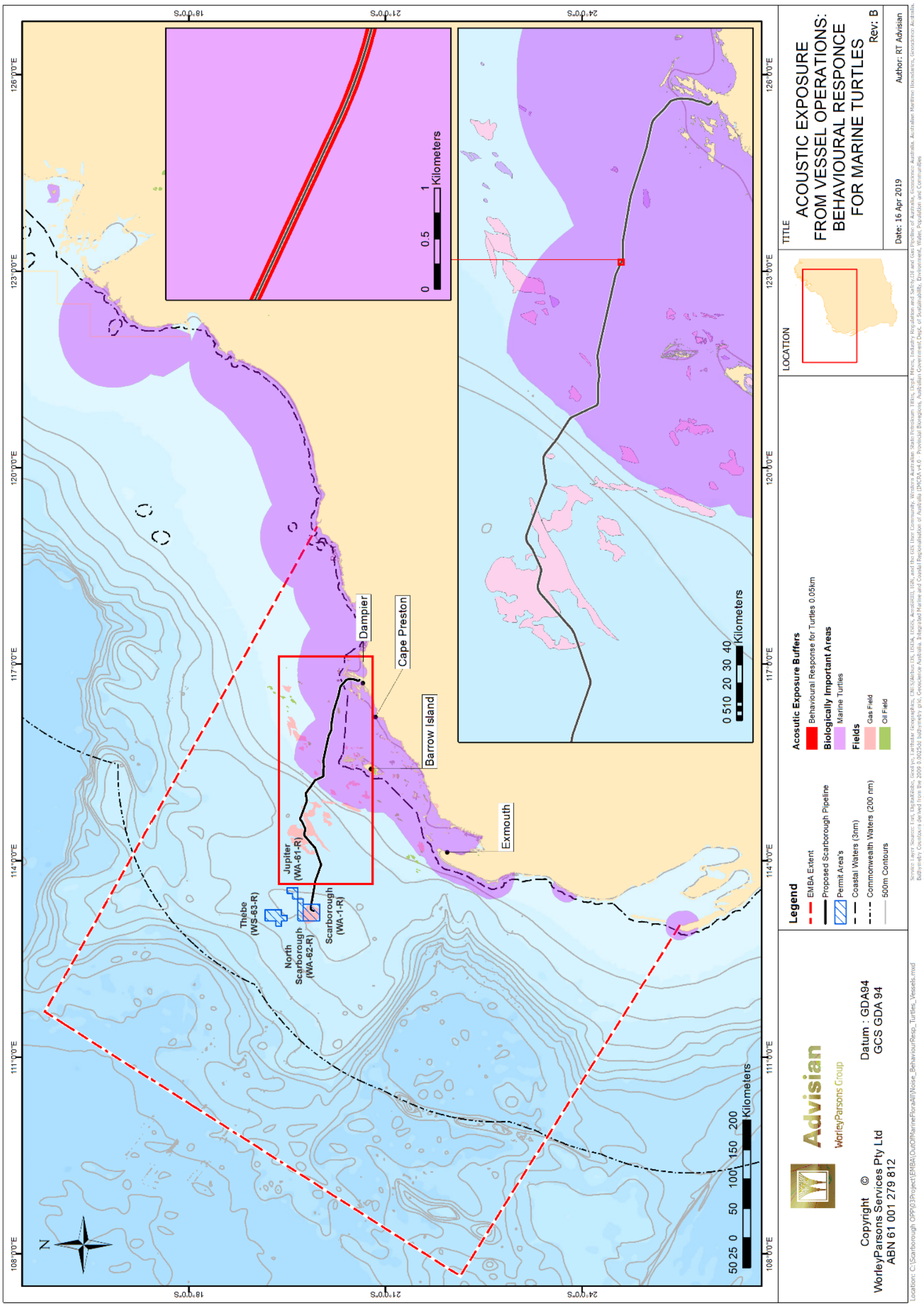


Figure 7.9: Predicted exposure area from continuous noise from vessel operations that may cause a behavioural response in turtles

Impacts of acoustic signals on sea snakes have not be researched in great depth. Guinea and Whiting (2005) reported that very few short-nosed sea snakes moved as far as 50 m from the reef flat and are therefore unlikely to be encountered in high numbers in the Project Area.

Within the Project Area, the environmental performance outcomes for marine reptiles include to:

- not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population
- 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
- not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

The greatest noise source is driven piling in the Offshore Project Area, where marine reptiles are not expected to occur in large numbers. This piling activity is temporary, further reducing the number of individuals that could be present within the area where noise levels exceed impact thresholds. Although individuals are more likely to occur in the Trunkline Project Area, particular in areas that overlap BIAs and (draft) critical habitat, routine acoustic emissions from activities in the Trunkline Project Area are also temporary and restricted to behavioural responses in close proximity to the vessel.

In order to minimise impacts to ambient noise, Woodside will implement internal requirements, specifically the VSP Procedure. Woodside VSP Procedure sets out the manner in which VSP operations are to be carried out. This procedure contains measures that are consistent with industry standards, and includes requirements for:

- Pre-start visual observations
- Soft start procedures
- Operating procedures
- Low visibility operating procedures

The procedure reduces the potential for impacts to marine fauna from acoustic emissions by ensuring that there is no prolonged exposure of acoustic emissions from VSP activities to marine fauna once they are detected.

Impacts to sea snakes from routine acoustic emissions are to be managed in accordance with approved Conservation Advice for the Short-nosed Sea snake (DSEWPaC, 2011). The Conservation advice outlines the monitoring of known populations to identify key threats and ensure there are no anthropogenic disturbance in areas where the species occurs, excluding necessary actions to manage the conservation of the species.

For construction and IMR activities occurring within the Montebello Marine Park, and adjacent to the Dampier Marine Park, the short term and transient nature of activities associated with acoustic emissions will not be 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, or for the Habitat Protection Zone (IV) 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 values identified for both these AMPs including BIAs for internesting, foraging, mating and nesting habitat for marine turtles will not be impacted given the significant distance from sensitive locations.

Based on the detailed evaluation, the magnitude of potential impacts to marine reptiles from acoustic emissions during activities associated with Scarborough is assessed as no lasting effects and evaluated as **acceptable**.

7.1.3.3 Impact Significance Evaluation

Impacts from routine atmospheric emissions will have no lasting effect on receptors. When considered with receptor sensitivity, Impact Significance Level of routine acoustic emissions from Scarborough have been evaluated as **Slight (E)**. The impacts overall have been determined to be **acceptable** based on an evaluation against the criteria:

To meet the principles of ESD

- Acoustic emissions associated with Scarborough are, in general, restricted to within close proximity of the source, with the exception of pile driving which is a relatively short-term activity (~20 days).
- Long term acoustic emissions (i.e. FPU operation) are not expected to disrupt population dynamics or function of marine fauna.
- Activities within the Trunkline Project Area are temporary and acoustic emissions restricted to within close proximity of the pipelay vessel, which will be continually moving, preventing reduction in the area of occupancy of important marine fauna populations.
- The potential for mortality and lethal injury to marine fauna to occur is restricted within close proximity of the piling locations in the Offshore Project Area which lacks significant habitat for marine fauna.
- Recoverable injury and behavioural responses may occur at greater distances from the piling locations, however, are note expected to result in displacement of a large proportion of the regional population.

Internal context

- With respect to acoustic emissions, Woodside will implement its internal requirement:
  - VSP Procedure.

External context

- No stakeholder concerns have been raised with respect to acoustic emissions or potentially impacted receptors.

Other requirements

- All relevant activities associated with routine acoustic emissions will be conducted in line with the EPBC Act Policy Statement 2.1 – Interaction between Offshore Seismic Exploration and Whales.
- Adherence to conservation advice for whales and sea snakes.
- With respect to acoustic emissions, activities associated with Scarborough 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.

7.1.3.4 Summary of the Impact Assessment

Table 7.14 provides a summary of the risk assessment and acceptability for impacts from routine acoustic emissions on receptors.

Table 7.14: Summary of impacts, management controls, impact significance ratings and EPOs for Routine Acoustic Emissions.

Receptor	Impact	Environmental Performance Outcome	Adopted Control(s)	Receptor sensitivity level	Magnitude	Impact significance level	Acceptability
Ambient Noise	Change in ambient noise	**EPO1:** 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.	**CM6:** Woodside VSP Procedure implemented while VSP operations are undertaken to prevent prolonged exposure to marine fauna. **CM7:** For impact piling activities, Woodside will implement the soft start procedure at the commencement of piling activities and shut down zones during the activity. **CM8:** EPBC Regulations 2000 Part 8 Division 8.1 Interacting with cetaceans.	Low value (open water)	No lasting effect	Negligible (F)	Acceptable
Fish	Change in fauna behaviour Injury/mortality to marine fauna	**EPO7:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population.		High value species (MNES species known to be present.)	No lasting effect	Slight (E)	Acceptable
Marine Reptiles	Change in fauna behaviour Injury/mortality to marine fauna	**EPO11:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population **EPO1:** 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 **EPO9:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.		High value species (i.e. flatback turtle)	No lasting effect	Slight (E)	Acceptable

Receptor	Impact	Environmental Performance Outcome	Adopted Control(s)	Receptor sensitivity level	Magnitude	Impact significance level	Acceptability
Marine Mammals	Change in fauna behaviour Injury/mortality to fauna	**EPO12:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **EPO1:** 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. **EPO9:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.		High value species (i.e. pygmy blue whale)	No lasting effect	Slight (E)	Acceptable

7.1.4 Physical Presence – Displacement of Other Users

Displacement of other marine users can include temporary or long-term disruption to activities of commercial fishers, shipping, tourism and recreation or other industry.

7.1.4.1 Sources of the Aspect

Activities and facilities associated with Scarborough will displace other marine users during:

- surveys
- vessel operations
- MODU operations
- FPU operations
- helicopter operations
- trunkline installation
- installation of the FPU and subsea infrastructure.
- removal of subsea infrastructure

Vessel, FPU and MODU Operations

The movement of survey, installation and support vessels within the Project Area, and the physical presence of the vessels, MODU and FPU, have the potential to displace other marine users. Types of vessels may include moored or semi-moored MODU or dynamically positioned MODU or drill ship, subsea installation vessels (ISV), pipelay vessels, survey vessels, dredging vessels and support vessels. The type and number of vessels in 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. trunkline installation) in the Trunkline Project Area or drilling activities in the Offshore Project Area. Fewer vessels will typically be required during the long-term operational project phase.

MODUs and FPUs will only be present in the Offshore Project Area 375 km from shore in approximately 900 m water depth, whereas the pipelay vessel will traverse the length of the Trunkline Project Area. Support vessels will operate in both the Offshore Project Area and Trunkline Project Area. The FPU and MODU will have a 500 m safety exclusion zone surrounding their location within the Offshore Project Area for the duration of the operational project phase.

Trunkline Installation

The base case design is a 32-inch dry gas trunkline from the Scarborough FPU to shore, with a total route length of approximately 430 km. The trunkline installation and ongoing physical presence could displace other marine users. The physical presence of the trunkline will remain for the duration of field life.

It is anticipated that trunkline stabilisation is required in water depths shallower than 40 m, which corresponds to a location about 50 km offshore from the Pluto LNG Plant. The seabed is proposed to be trenched and the trunkline buried in this water depth. The material dredged during trenching will be used to backfill the trench, covering the trunkline.

The risk of marine users interacting with the trunkline is limited to potential snagging of fishing gear with the trunkline on the seafloor. Where the trunkline is backfilled, a reduced snagging risk will occur as the pipeline will be buried below the seabed.

Installation of the FPU and Subsea Infrastructure

Subsea infrastructure including wellheads, flowlines, manifolds will be located within the Offshore Project Area. The physical presence of this infrastructure will remain for the duration of field life. Wellheads and manifolds take up a small area on the seabed, however, may rise several metres above the seabed. The risk of marine users interacting with the subsea infrastructure is negligible within the Offshore Project Area due to the water depths (approximately 900 m).

Helicopter Operations

Helicopters will be used to transport personnel on/offshore during drilling and during periods of FPU manning in the Offshore Project Area and during trunkline installation in the Trunkline Project Area. The risk of marine users interacting with helicopter operations is restricted to temporary displacement due to increased air traffic in the area.

7.1.4.2 Impact or Risk

Displacement of other marine users due to physical presence of vessels, helicopters and trunkline and subsea infrastructure may result in the following impact:

- changes to the functions, interests or activities of other users.

Changes to the Functions, Interests or Activities of Other Users

Physical presence of vessels, trunkline, MODU and FPU 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 FPU, trunkline and subsea infrastructure presence, the change will be permanent for the duration of the field life.

Receptors Potentially Impacted

Tourism and Recreation

Tourism and recreation activities in the region include recreational fishing, diving and snorkelling, yachting and wildlife watching. Most of these activities occur within shallow waters close to shore or within fauna aggregation areas. Tourism and recreation within the Offshore Project Area are expected to be limited by the distance offshore and water depths. Although recreational fishing may occur at greater distances from shore, these activities are usually associated with areas of elevated biodiversity, such as offshore shoals or reefs. Since the Offshore Project Area does not contain such habitat, it is not considered an area frequented by recreational fishers.

Tourism and recreation activities may be more common in the Trunkline Project Area, particularly in proximity to the Montebello Islands. However, given the location, and the short-term nature of activities in this area, impacts to tourism and recreational activities are unlikely, and have not been evaluated further.

Defence

Defence activities in the vicinity of the Offshore and Trunkline Project Areas may include Naval vessel traffic and Air Force training exercises. Neither of these types of activities are expected to be a consistent presence in the area. The MODU and FPU (i.e. above-sea infrastructure) are also on the outer extent of the training area (Figure 5.53) associated with the Learmonth Air Force Base. As such, any potential interaction is expected to be minimal and not significantly different from interaction with other facilities within the northwest region, and therefore impacts have not been evaluated further. Any potential impact to Naval vessel operations are considered as similar to the 'Shipping' impact evaluation presented below.

Table 7.15 outlines the potential impacts to receptors associated with displacing other marine users.

Table 7.15: Receptor/impact matrix after evaluation of context

	Receptor					
Impacts	***Commonwealth Managed Fisheries***	***State Managed Fisheries***	***Tourism and Recreation***	***Shipping***	***Industry***	***Defence***
Changes to the functions, interests or activities of other users	✓	✓	X	✓	✓	X

Detailed Impact Evaluation

For each of the receptors identified for detailed evaluation, the criteria for acceptability as defined in Table 6-3 have been considered and addressed in the following sections. This includes to meet the principles of ESD, internal and external context and any other requirements.

Commonwealth and State Managed Fisheries

Five Commonwealth managed fisheries (one of which is inactive) and seven State managed fisheries overlap the Project Area. Potential impacts to commercial fishers depend on the use of the area by fishers, in addition to the temporal and spatial extent of the presence of vessels and facilities/infrastructure.

Potential impacts to commercial fisheries include damage to fishing and loss of commercial catch due to displacement from fishing grounds. Damage to trawl nets could occur if they catch or snag on subsea infrastructure. The Northwest Slope Trawl Fishery (Commonwealth) and the Pilbara Trawl Fishery (State) overlap the Trunkline Project Area. No trawl fisheries overlap the Offshore Project Area. Subsea infrastructure presenting the greatest snag hazard, such as wellheads and manifold, are located in the Offshore Project Area only where trawl fishing does not occur. The trunkline will be buried at depths <40 m, which correlates to about 50 km offshore, this area corresponds to the higher area of fish trawling activity. Burying the trunkline negates the snagging risk within the Trunkline Project Area.

During installation of the FPU and other subsea infrastructure, and during surveys and drilling, the presence of vessels (and MODU) in the Offshore Project Area will present a surface hazard to fishing vessels. During drilling a 500 m safety exclusion zone will be required around the MODU and, once operational, the FPU 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 Offshore Project Area is not an area of high commercial fishing activity. Furthermore, the 500 m safety exclusion zone around the MODU and/or FPU comprises a relatively small area when compared to the extent of the individual fishery boundaries that overlap. As such, displacement of commercial fisheries due to activities in the Offshore Project Area are not expected to impact commercial fishing activities or the economic viability of the fisheries.

Fishing activity is expected to be higher in the shallower waters of the Trunkline Project Area. Here, fishers will be temporarily displaced from parts of the Trunkline Project Area during activities associated with the trunkline such as installation or surveys. Additionally, fishers may be temporarily displaced from the Borrow Grounds Project Area during dredging. As with the FPU, a requested 500 m safety exclusion zone will be present around the pipelay vessel. During trunkline installation, the pipelay vessel has low manoeuvrability, meaning that fishing vessels will be required to avoid the vessel. However, the trunkline installation activity will take place over a short period comparative to Scarborough and therefore any displacement will be temporary. Furthermore, the pipelay vessel is continually moving and only operating within a small spatial footprint at any one time. Therefore, fishing vessels will not be excluded from the entire Trunkline Project Area for the total duration of trunkline installation, further reducing the timeframe within which displacement could occur. Once installation activities have occurred, the trunkline remains in situ and is buried at water depths <40 m, negating snagging risk from trawling vessels. Considering the temporary and localised displacement potential for commercial fisheries due to installation activities in the Trunkline Project Area and Borrow Grounds Project Area, and that the trunkline is buried below the seabed in waters depths <40 m, impacts to the fishing activities is not expected.

Within the Project Area, the environmental performance outcomes for commercial fisheries include:

- to not have a substantial adverse effect on the sustainability of commercial fishing
- to not interfere with other marine users, including recreational and commercial fishers to a greater extent than is necessary for the exercise of right conferred by the titles granted.

Vessel operations undertaken as a part of this activity will adhere to MARPOL and the various Marine Orders (as appropriate to vessel class) enacted under the *Navigation Act 2012*. This Act regulates navigation and shipping including Safety of Life at Sea (SOLAS).

For construction and IMR activities occurring within the Montebello Marine Park, and adjacent to the Dampier Marine Park, the short term and transient use of vessels will not be 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, or for the Habitat Protection Zone (IV) 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 values identified for both these AMPs including fishing as an important activity.

The presence of commercial fisheries in the Offshore Project Area is low. The trunkline installation phase of Scarborough, when vessel use will be highest, is a comparatively short phase. Therefore, any displacement of fishing activities will be temporary. Once installation activities have ceased, the trunkline remains in situ and is buried at water depths <40 m, negating snagging risk from trawling vessels in these waters. The magnitude of potential impacts to commercial fisheries from Scarborough are assessed as slight, given the impact is potentially notable, but well within applicable standards, and considered **acceptable**.

Shipping

Commercial shipping in the Project Area is high, particularly in areas where the Trunkline Project Area traverses shipping fairways and as it approaches the state water boundary where the ports of Dampier and Port Hedland are in located. In comparison to the Trunkline Project Area, shipping activity in the Offshore Project Area is relatively low. As such, activities associated with the Offshore Project Area (e.g. drilling, FPU installation and operation, subsea infrastructure installation) are less likely to impact commercial shipping compared to activities associated with the Trunkline Project Area.

During trunkline installation, the pipelay vessel will have limited manoeuvrability, meaning that commercial shipping vessels will be required to alter course to avoid the vessel and its 500 m safety exclusion zone. This may result in minor delays or increased fuel use due to a less direct route. However, the presence of the pipelay vessel will be temporary throughout the trunkline installation activities only. Furthermore, the pipelay vessel will be continuously moving, albeit at a slow speed, so that it will not be present in a single location (e.g. a shipping fairway) for more than a few weeks at most. Once the trunkline is installed, the presence and operation of the trunkline will not impact on commercial shipping activities.

Within the Project Area, the environmental performance outcome for commercial shipping is to not interfere with other marine users, including shipping to a greater extent than is necessary for the exercise of right conferred by the titles granted.

AMSA have provided comment on the placement of the moorings and cross referenced them with Traffic data. Shows trunkline crosses charted shipping fairways where vessel traffic is heavy. Woodside to provide Marine Safety Information as per AMSA's request.

Vessel operations undertaken as a part of this activity will adhere to MARPOL and the various Marine Orders (as appropriate to vessel class) enacted under the *Navigation Act 2012*. This Act regulates navigation and shipping including Safety of Life at Sea (SOLAS).

For construction and IMR activities occurring within the Montebello Marine Park, and adjacent to the Dampier Marine Park, the short term and transient use of vessels will not be 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, or for the Habitat Protection Zone (IV) 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. Shipping is not listed as a social value for the Montebello Marine Park, however port activities related to shipping is identified as an important activity for the Dampier Marine Park.

Impact to commercial shipping is limited to the temporary presence of vessels throughout the trunkline installation activities. The trunkline installation will present short term disruption to commercial shipping who may need to avoid the installation vessels. The installation phase of Scarborough, when vessel use will be highest, is comparatively short. Therefore, displacement will be temporary and limited to minor course alteration. The magnitude of potential impacts to commercial shipping from Scarborough are assessed as slight and considered **acceptable**.

Industry

The NWS is an area of active oil and gas exploration and production. The closest facility to the Offshore Project Area is the Woodside Pluto facility (160 km to the west). The closest facilities to the Trunkline Project Area are the Woodside Pluto facility (5 km) and the Jadestone Stag facility (9 km). The Trunkline Project Area passes through several exploration and production permits with a variety of titleholders. In addition, the Trunkline Project Area also crosses existing trunklines including the Reindeer and Wheatstone export trunklines.

Displacement of, or interference with, other oil and gas activities are not expected within the Offshore Project Area (given the lack of other activities), however activities associated with the trunkline, such as trunkline installation, may result in short term interference. However, as previously described, the pipelay vessel will be continuously moving so that it will not be present in a single location for more than a few weeks at most. Once installed, the presence and operation of the trunkline will not result in significant interference with other petroleum activities.

Within the Project Area, the environmental performance outcome for industry is to not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.

Vessel operations undertaken as a part of this activity will adhere to MARPOL and the various Marine Orders (as appropriate to vessel class) enacted under the *Navigation Act 2012*. This Act regulates navigation and shipping including Safety of Life at Sea (SOLAS).

For construction and IMR activities occurring within the Montebello Marine Park, and adjacent to the Dampier Marine Park, the short term and transient use of vessels will not be 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, or for the Habitat Protection Zone (IV) 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. Industry is not listed as a social value for the Dampier Marine Park; however, mining is identified as an important activity for the Montebello Marine Park.

Activities associated with the trunkline, such as trunkline installation, may result in localised, short term interference to industry vessels required minor course alteration. Once the trunkline is installed this interference will be greatly reduced as the interference with other oil and gas activities are not expected within the Offshore Project Area given its distance from other facilities. The magnitude of potential impact to industry from Scarborough is assessed as slight and considered **acceptable**.

7.1.4.3 Impact Significance Evaluation

Impacts from displacement of other users will have a slight effect on receptors, as the extent, duration, frequency and scale of the impact are all sufficiently small. When considered with receptor sensitivity, Impact Significance Level of displacing other users from Scarborough have been evaluated as **Minor (D)** for Commonwealth and State Managed Fisheries, and **Slight (E)** for Shipping and Industry. The impacts overall have been determined to be **acceptable** based on an evaluation against the criteria:

To meet the principles of ESD

- The presence of other marine users in the Offshore Project Area is low; the area does not represent important fishing grounds or areas of high vessel traffic (such as shipping fairways), is remote from other oil and gas activities, and is too far offshore for notable tourism and recreational uses.
- Activities occurring in the Offshore Project Area, including the long-term operation of the FPU, are not expected to change or impact the interests or functions of other users.
- The installation phase of Scarborough, when vessel use will be highest is a comparatively short phase of Scarborough. Once the installation phase of Scarborough is completed (trunkline installation, FPU and subsea infrastructure), vessel presence will be significantly reduced in the Project Area.
- The area covered by the Trunkline Project Area includes areas of increased activity such as shipping fairways, known fishing grounds and petroleum export pipelines.
- Trunkline installation will be limited to approximately one year of activity, following which its presence and operation is unlikely to present a hazard to other users.

Internal context

- There are no specific Woodside internal requirements with respect to physical presence – displacement of other users, or potentially impacted receptors.

External context

- AMSA have provided comment on the placement of the moorings and cross referenced them with Traffic data. Shows trunkline crosses charted shipping fairways where vessel traffic is heavy. Woodside to provide Marine Safety Information as per AMSA's request.

Other requirements

- Vessel operations undertaken as a part of this activity will adhere to the *Navigation Act 2012*, MARPOL and the various Marine Orders (as appropriate to vessel class) enacted under this Act. This Act regulates navigation and shipping including Safety of Life at Sea (SOLAS), which includes specific requirements for navigational lighting. Although the Act does not apply to the operation of petroleum facilities, it may apply to some support vessels. Woodside will notify AHS and representative of Commercial and State fisheries of all activities.

- With respect to physical presence – disturbance to other users, activities associated with Scarborough 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.

7.1.4.4 Summary of the Impact Assessment

Table 7.16 provides a summary of the risk assessment and acceptability for impacts from displacement of other marine users to receptors.

Table 7.16: Summary of impacts, management controls, impact significance ratings and EPOs for displacement of other marine users

Receptor	Impact	Environmental Performance Outcome	Adopted Control(s)	Receptor sensitivity level	Magnitude	Impact significance level	Acceptability
Commonwealth Managed Fisheries	Changes to the function interests or activities of others	**EPO15:** To not have a substantial adverse effect on the sustainability of commercial fishing. **EPO14:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.	**CM9:** Vessels to adhere to the navigation safety requirements including the Navigation Act 2012 and any subsequent Marine Orders. **CM10:** Notify Australian Hydrographic Service (AHS) of activities and movements prior to activity commencing. **CM11:** Notify representatives of State and Commonwealth fisheries of activities.	High value marine user	Slight	Minor (D)	Acceptable
State Managed Fisheries				High value marine user	Slight	Minor (D)	Acceptable
Shipping				Medium value marine user	Slight	Slight (E)	Acceptable
Industry				Medium value marine user	Slight	Slight (E)	Acceptable

7.1.5 Physical Presence – Seabed Disturbance

Seabed disturbance includes changes to the existing physical (e.g. substrate) and biological (e.g. habitat) values of the environment.

7.1.5.1 Sources of the Aspect

Throughout the development of Scarborough, disturbance to the seabed will occur during:

- pre-lay surveys
- drilling operations
- installation of the FPU and subsea infrastructure
- trunkline installation and stabilisation
- removal of subsea infrastructure
- MODU operations
- vessel operations
- ROV operations.

Pre-lay Surveys

Geotechnical surveys may be required to collect data to inform installation activities, in order to confirm the seabed sediments. Seabed disturbance can result from placing survey equipment on the seafloor, or when collecting seabed samples.

Geotechnical surveys typically involve in-situ testing and piston/push sampling. Following sampling, all equipment is withdrawn from the seabed. A small hole (<1 m^2) will remain, which will eventually collapse and infill with the movement of surface sediments in ocean current.

An Ultra Short Base Line (USBL) system will be used during geotechnical surveys to accurately monitor survey equipment deployed from the survey vessel. USBL is an underwater positioning system that uses a vessel-mounted transceiver to detect the range and bearing to a sampling target.

To ensure the USBL system is functioning correctly, the system will be calibrated using a USBL beacon. This involves deploying a USBL beacon complete with acoustic release, float and weight to the seabed for a period of one to two hours. Once the calibration is complete, the beacon is released from the seabed and ascends to the surface where it is recovered to the survey vessel. The weight will remain on the seabed. Seabed disturbance will be localised to the area of the weight (about 0.1 m^2).

Drilling and MODU Operations

The proposed production wells will be drilled using a moored or semi-moored MODU or dynamically positioned drill ship.

Seabed disturbance will result from the anchor holding testing and MODU anchor mooring system, including placement of anchors and chain/wire on the seabed, potential dragging during tensioning, and recovery of anchors. Mooring may require a 12-point pre-laid mooring system at each well location, depending on the time of year. Although the exact anchoring configurations are currently unknown, a semi-submersible MODU with an 8 to 12-point anchoring system could disturb up to 13 km^2 per well, allowing for anchor footprint and disturbance from anchor chains (NERA, 2018). For the 30 proposed wells, this gives a total footprint of 390 km^2.

Dynamic positioning of the MODU uses satellite navigation and radio transponders in conjunction with thrusters to maintain the position of the MODU at the required location. Information about the position of the MODU is provided via seabed transponders, which are replaced on the seabed and emit signals that are detected by receivers on the MODU and used to calculate position. The transponders are typically deployed in an array on the seabed, using clump weights comprising concrete, for the duration of the drilling at each well. They are recovered at the end, generally by ROV. Clump weights are recovered if practicable to do so or may be left in-situ on the seafloor. Clump weights generally consist of a clumped group of four 20 kg weights covering an area less than 1 m². A total seabed disturbance area of 20 m² per well is anticipated, giving a total 0.6 km² for the proposed 30 wells.

Installation of the FPU and Infield Subsurface Infrastructure

The FPU will be moored in place by 20 permanent piles. The piles will be installed either by suction piling (preferred) or driven piling. Where suction piling is used, suction piles will typically be 6 m to 8 m in diameter, and about 30 m in length, with each weighing about 180 tonnes. Based on these dimensions, 20 piles will result in a seabed disturbance area of 1000 m².

The infield subsea infrastructure required for Scarborough along with the disturbance area is expected to disturb an area of approximately 0.234 km² (this includes a 50% contingency as the figure is subject to refinement during the design process).

Table 7.17: Extent of seabed disturbance for the FPU and infield subsurface disturbance

Infrastructure	Area (km²)
Scarborough Field	
FPU and infield infrastructure (flowlines, umbilicals, ILT's, risers and anchors, flowlines)	0.038
Jupiter and Thebe fields (flowlines and interfield lines)	0.027
Jupiter and Thebe Field	
Flowlines and interfield lines	0.090
Total Disturbance	0.156
Total Disturbance with 50% contingency	0.234

Flowline and umbilical installation may require jetting or trenching techniques for burial. Jetting uses high pressure water and air or water to create a trench by fluidising the seabed, which is then dispersed into the water column. In areas of harder soil materials, the jetting equipment will be substituted by a mechanical cutter.

Trenching techniques involve a mechanical cutter, which is used to cut a trench about 1 m wide and 0.5 m deep below the seabed. The umbilical then falls within the trench which is backfilled over time by sediment deposition.

The installation of subsea infrastructure required for the project will generate turbidity when placed on the seafloor. Once placed, seabed sediments will be disturbed and enter the water column, increasing local turbidity for a short period.

The base case design is a 32-inch dry gas trunkline between the Scarborough FPU and the Pluto Gas Plant, with a total route length of about 430 km. The pre-lay dredging works associated with the trunkline development involves dredging of an approximately 2.5–3.5 m deep trench along the trunkline route within a Trunkline Project Area (corridor) of 30 m.

It is anticipated that trunkline stabilisation is required in water depths shallower than 40 m, which corresponds to a location about 50 km offshore. Where the dredged material is not used to backfill the trench, it will be disposed at existing spoil grounds within the region. Trenching and backfill activities would result in seabed disturbance between approximately KP 34 to KP 50 in Commonwealth waters and at the proposed Borrow Ground (Figure 7.10). Sea Dumping Permits under the *Environment Protection (Sea Dumping) Act 1981* will be in place where required to support this activity. Sea dumping activities will be undertaken in accordance with the act and under permit as required.

For a length of trunkline around approx. KP210 (Figure 7.10) seabed material (2,500–15,000m3) may be mobilised and/or displaced to allow safe pipelay operations to be conducted in approximately 580 m water depth. This seabed material relocation will be completed using a potential combination of Mass Flow Excavation, subsea equipment based material relocation/intervention, ROV based material relocation or a grader. Any displaced material would not be recovered to the surface. Seabed disturbance from installing and stabilising the trunkline is anticipated to be 12.9 km^2 based a Trunkline Project Area of 30 m encompassing the trunkline for the entire 430 km.

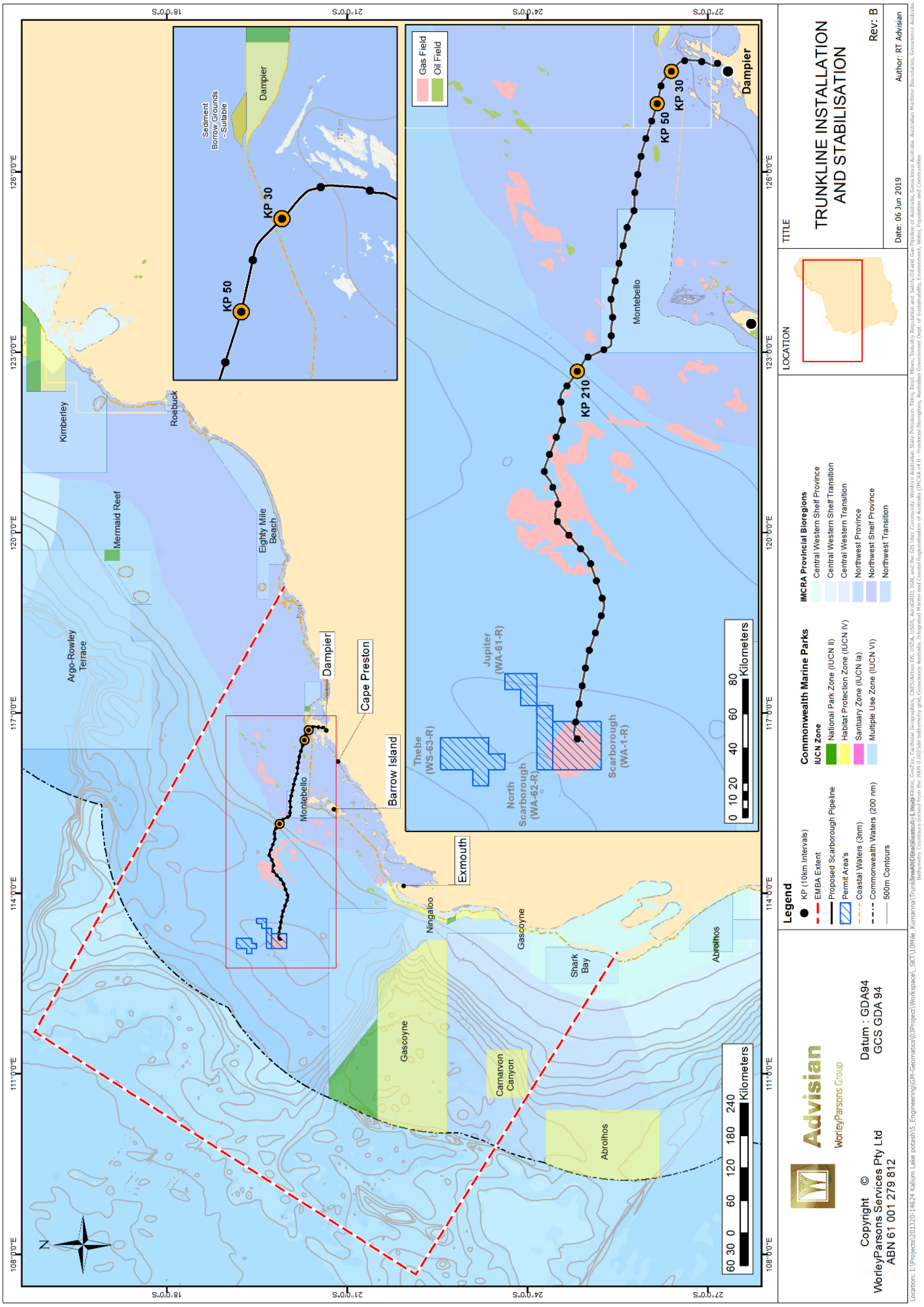


Figure 7.10: Proposed borrow ground and trunkline stabilisation areas

Removal of Subsea Infrastructure

Removal of subsea infrastructure and trunkline will be evaluated at end of field life. Options of leave in-situ, removal or part removal of the infrastructure will be part of a future comparative assessment, which will assess the costs and benefits of the options.

If all subsea infrastructure is removed at the end of field life, the total seabed disturbance will equate to the same or similar to that of the infield subsea infrastructure and trunkline installation and be within the same area previous seabed disturbance took place.

Vessel and ROV Operations.

The use of an ROV during activities as described may result in temporary seabed disturbance and suspension of sediment as a result of working close to, or occasionally on, the seabed. ROV use close to or on the seabed is limited to that required for effective and safe subsea activities. The footprint of a typical ROV is about 2.5 m × 1.7 m (4.25 m²).

While vessel anchoring in deeper waters is unlikely, there may be occasions where support vessels anchor in shallower waters, while working on the trunkline route. Should this be required, the level of seabed disturbance is dependent on the anchoring, however, use of a single anchor could result in a total disturbance area of up to 1300 m².

7.1.5.2 Impact or Risk

Routine physical presence resulting in a disturbance to the seabed from the sources described above will result in the following impacts:

- change in habitat
- change in water quality.

Which may have the following further impacts:

- injury/mortality to fauna.

Change in Habitat

Installation of subsea infrastructure and the trunkline on the seabed are likely to result in localised sedimentation and permanent modification of seabed habitat in the vicinity of the infrastructure. A total area of 12.9 km² of habitat modification is anticipated from permanent placement of infrastructure on the seabed.

The trunkline stabilisation and burial may result in coarser seabed sediments within the pipeline corridor. Where the pipeline remains exposed the predominantly soft benthos would be replaced with the hard-outer coating of the pipeline.

The mooring of the MODU, vessel anchoring, ROV use and geotechnical surveys will result in localised, small scale seabed disturbance, sedimentation and habitat modification.

Change in Water Quality

Trunkline dredging, seabed material relocation, sourcing of material from the borrow ground, spoil disposal activities and trunkline installation have the potential to cause temporary increases in suspended sediments and turbidity levels in marine waters.

Injury and/or Mortality to Marine Fauna

As a result of a change in water quality and change in habitat, further impacts to receptors may occur, which include injury or mortality to marine fauna resulting from an increase in turbidity, or physical contact with equipment or infrastructure being installed.

Temporary increases in suspended sediments and turbidity levels can potentially result in the following impacts to marine water fauna:

- adversely affect marine biota by reducing light penetration through the water column, thereby temporarily reducing productivity and growth rates in shallow waters close to the state waters boundary
- cause clogging and damage to the feeding and breathing apparatus of filter feeding organisms (Parr et al., 1998)
- cause localised and temporary reduction in oxygen levels due to the release of potentially organic rich sediments into the water column
- increase organic matter and nutrient availability to marine organisms subsequently resulting in eutrophic waters with knock-on effects for the productivity of marine ecosystems
- cause toxicological effects to marine organisms associated with the potential re-suspension of previously contaminated sediments.

Receptors Potentially Impacted

The receptors most at risk in this location are:

- plankton
- epifauna and infauna
- fish
- KEFs.

Plankton

Plankton are widely dispersed throughout the water column. Injury/mortality to planktonic 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 planktonic 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, and have not been evaluated further.

Fish

The presence of subsea infrastructure has the potential to act as artificial habitat or hard substrate for the settlement of marine organisms that would not otherwise be successful in colonising the area. Over time, the colonisation of subsea infrastructure can lead to the development of a community, which subsequently provides predator or prey refuges, foraging resources for pelagic fish species, and artificial reefs potentially supporting fish aggregations (Gallaway et al., 1981) (Bond et al., 2018).

Addition of subsea infrastructure on the seabed can provide more habitat and refuge for some fish species. Negative impact to fish species is not anticipated, and as such this has not been evaluated further.

Table 7.18: Receptor/impact matrix after evaluation of context

Impacts	Receptor: Water Quality	Epifauna and Infauna	Plankton	Fish	KEFs	AMPs
Change in water quality	✓				✓	✓
Change in habitat		✓		X	✓	✓
Injury or mortality to fauna		✓	X	X	✓	

Detailed Impact Evaluation

For each of the receptors identified for detailed evaluation, the criteria for acceptability as defined in Table 6.3 have been considered and addressed in the following sections. This includes to meet the principles of ESD, internal and external context and any other requirements.

Sediment dispersion modelling

Sediment dispersion modelling was undertaken to assess the potential impacts to water quality from dredging of the offshore borrow ground and associated placement for the stabilisation on specific sections of the trunkline (Section 4.4.7.3; Figure 4.3).

Three-dimensional numerical modelling was used to simulate the distribution of sediments suspended by dredging operations during the full duration of the dredging program. The modelling relied upon specification of sediment discharges over time for each of the expected sources of sediment suspension and predicted the evolution of the combined sediment plumes via current transport, dispersion, sinking and sedimentation. The model also allowed for the subsequent resuspension of settling sediments due to the erosive effects of currents and waves.

Modelling of the potential sediment dispersion from the dredging required temporal and spatial representation of the hydrodynamic (e.g. currents) and waves conditions within the project area. A hydrodynamic and wave model framework for the Mermaid Sound area had previously been constructed, calibrated and validated for a past marine modelling study of dredge spoil stability and navigation for WEL (RPS, 2016); this existing model framework was adopted and further refined for this activity. The configuration of the current and wave models is in line with best practice for sediment dispersion modelling in Western Australia as outlined by WAMSI Dredging Science Node guidance (Sun et al., 2016).

There are inherent limitations to the accuracy of any numerical model study (RPS, 2019e; Appendix J). These limitations have been minimised during this modelling scope by incorporating actual data where available, aligning with best practice guidance, and utilising extensive past project experience from both a modelling and dredging perspective.

Model Scenarios

The provisional schedule for the dredging works indicates a December 2021 start for dredging of the offshore borrow ground. Analysis of wind data in the region from 1993–2017 has shown that the period of 2016-2017 is likely to be representative of typical conditions. The dredge modelling simulations were conducted using hydrodynamic and wave data drawn from this period, with nominal start dates for model simulation purposes being chosen as 1 December 2016 (summer) and 1 June 2017 (winter). A summary of the scenarios that were modelled is as follows:

- **Scenario 1**: Dredging of the offshore borrow ground commencing on 1 December 2016 (summer start). TSHD dredging operations were programmed to occur between 1 December 2016 and 9 February 2017. A simulation run-on period was assumed to occur between 9 February 2017 and 10 April 2017. Sediments suspended in the water column during previous operations were subject to settlement and progressively reducing levels of resuspension during this time.
- **Scenario 2**: Dredging of the offshore borrow ground commencing on 1 June 2017 (winter start). TSHD dredging operations were programmed to occur between 1 June 2017 and 10 August 2017. A simulation run-on period was assumed to occur between 31 August 2017 and 31 October 2017. Sediments suspended in the water column during previous operations were subject to settlement and progressively reducing levels of resuspension during this time.

Modelled quantities and sediment properties

While actual volumes of material required from the offshore borrow ground is not yet confirmed, up to 2 Mm^3 of sandy sediments with a low proportion of fines has been modelled. The critical geotechnical information required as input to the modelling is PSD data for the sediments to be dredged from the borrow ground. This data has been specified (WEL, 2018b) for each pipeline section. The resultant PSDs have been redistributed to match the material size classes used in the model. For the offshore borrow ground, it has been assumed that the measured PSDs between KP30 and KP50 were applicable. The PSD data for these sections is characterised mainly as coarse sand, with 15% of the total mass existing as fines.

Thresholds

Modelling of activities at the Borrow Ground considered thresholds that describe potential environmental impacts to the benthic communities of Mermaid Sound and also considered the conservation values of the adjacent Dampier AMP.

Model outputs were interrogated by a series of water quality thresholds to predict the extent of impacts in a series of zones as recommended by Technical Guidance Environmental Impact Assessment of Marine Dredging Proposals (EPA 2016). Thresholds have been developed based on the definitions of management zones suggested within the guidance document. Thresholds were selected for benthic habitats on the basis of past and present mapping of the communities surrounding the Borrow Ground and Mermaid Sound and technical justification from the work of the Western Australian Marine Science Institute's Dredging Node (WAMSI: https://www.wamsi.org.au/dredging-science-node). Thresholds for three management zones – a Zone of Influence (ZoI), a Zone of Moderate Impact (ZoMI) and a Zone of High Impact (ZoHI) – were defined. The definition of the zones applied to the modelling to assess impacts to the benthic values of the Dampier Marine Park are presented in Table 7.19.

Table 7.19: Impact Zone Definitions

Impact Zone[40]	Definition of Zone
Zone of High Impact	Is the area where impacts on benthic communities or habitats are predicted to be irreversible. The term irreversible means 'lacking a capacity to return or recover to a state resembling that prior to being impacted within a timeframe of five years or less'. Areas within and immediately adjacent to proposed dredge and disposal sites are typically within zones of high impact.
Zone of Moderate Impact	The area within which predicted impacts on benthic organisms are recoverable within a period of five years following completion of the dredging activities. This zone abuts, and

[40] As per Technical Guidance Environmental Impact Assessment of Marine Dredging Proposals (EPA 2016)

	lies immediately outside of, the zone of high impact. Proponents should clearly explain what would be protected and what would be impacted within this zone, and present an appraisal of the potential implications for ecological integrity of the impacts over the timeframe from impact to recovery (e.g. through loss of productivity, food resources, shelter). Where recovery from the impact predicted in this zone is likely to result in an 'alternate state' compared with that present prior to development, then this outcome should be clearly stated in environmental assessment documents, along with justification as to why the predicted impacts should be included within this zone (rather than the Zone of High Impact) and an appraisal of the potential consequences for ecological integrity and biological diversity.
Zone of Influence	The area within which changes in water quality associated with dredge plumes are predicted and anticipated during the dredging operations, but where these changes would not result in a detectible impact on benthic biota. These areas can be large, but at any point in time the dredge plumes are likely to be restricted to a relatively small portion of the Zone of Influence. The outer boundary of the Zone of Influence bounds the composite of all of the predicted maximum extents of dredge plumes and represents the point beyond which dredge-generated plumes should not be discernible from background conditions at any stage during the dredging campaign.

In recognition that different species may display very different degrees of tolerance and susceptibility to the same level of sediment-related pressure, it is appropriate to generate different predictions for identified management zones for different groups of benthic organisms or community/habitat types.

The criteria associated with each management zone varied across three ecological zones, which were broadly defined based on past studies of these areas. The ecological zones are named as follows, with reference to the pipeline chainages, and with the spatial extents set for this study as shown in Figure 7.11:

- **Offshore**: the trunkline area beyond KP25, and generally all areas north of a boundary line containing Rosemary Island, Legendre Island and Delambre Island.
- **Zone B**: the trunkline area between KP8 and KP25, adjacent coral and macroalgae habitats within Mermaid Sound, and generally all coral, macroalgae and mixed community habitats between Dolphin Island and Bezout Island.
- **Zone A**: the trunkline area between the shoreline and KP8, adjacent macroalgae and mangrove habitats within Mermaid Sound, and generally all mangrove, marsh and seagrass habitats between Nickol Bay and Point Samson.

The offshore ecological zone is within the scope of activities for this OPP.

The thresholds applicable to this zone considered that benthic communities in Commonwealth waters and the Dampier Marine Park adjacent to the proposed Borrow Ground are predominantly bare substrate with sparse coverage of biota made up largely of sponges and filter feeders. This assumption of benthic community type was confirmed in recent surveys of the Dampier Marine Park and Borrow Ground (Advisian 2019c; Appendix B). As such, impact thresholds for filter feeder-sponge habitat were developed by MScience (2019) based on studies undertaken as part of the WAMSI Dredging Node (Pineda et al. 2017). Thresholds based on coral, seagrass or macroalgae were not considered for the offshore zone as they are not known to form significant communities in the area. The adopted thresholds for the ZoMI an ZoHI were based on effect concentrations (LC_{10} for ZoMI and LC_{50} for ZoHI derived for *Carteriospongia foliascens*) over a 28-day exposure period as suggested within Pineda et al. 2017. The thresholds were based on laboratory experiments using sponge species of different morphologies (encrusting, cup and fan) and nutritional modes (phototrophic and heterotrophic), and therefore considered representative of the variety of sponge biology. Of these species, one (*Carteriospongia foliascens*) was determined to be sensitive to suspended sediment concentrations; and another (*Cliona orientalis*) as sensitive but with potential for recovery (Abdul Wahab et al. 2018).

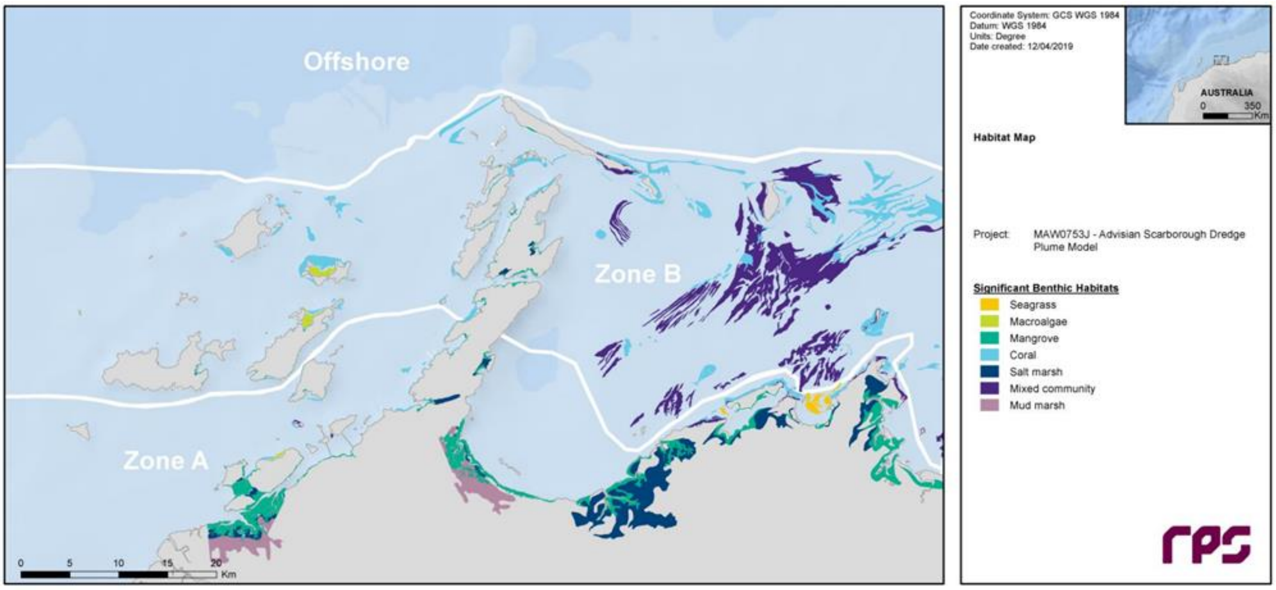


Figure 7.11: Delineation of the proposed ecological zones (Zone A, Zone B and Offshore)

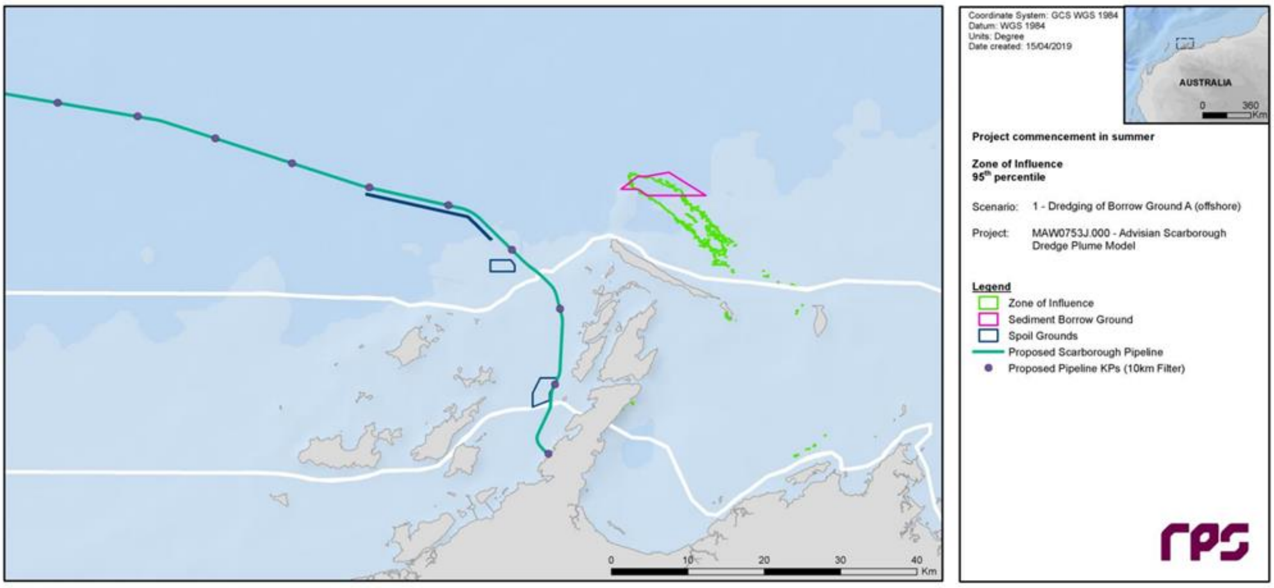
Model outcomes

The modelling showed that there was no exceedance of the ZoHI or ZoMI thresholds predicted from activities associated with the Borrow Ground. The modelling results show that turbidity levels remain below the intensity-duration thresholds predicted to cause an impact to benthic communities.

Figure 7.12 and Figure 7.13 illustrate the predicted extents of the defined ZoI management zone over the entire programme of offshore borrow ground dredging activity for each scenario. No exceedances of any ZoMI or ZoHI threshold are predicted, so no figures are presented in relation to these thresholds.

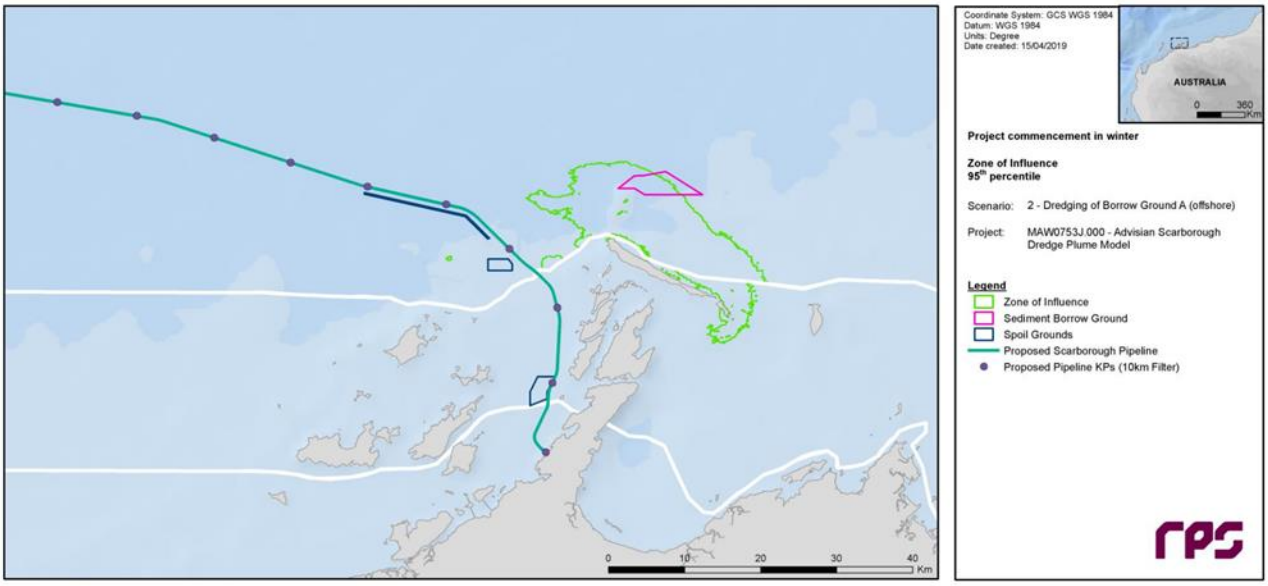
It should be noted that the indicated management zone extent represents a cumulative measure of exceedances of the relevant thresholds over a four-month period. That is, they do not represent an instantaneous sediment plume footprint at any point in time (ie this is not a depiction of the visual plume produced on a single day of the activity, this would be significantly less). The indicated areas of threshold exceedances are largely a reflection of the areas of sediment confluence due to the proximity to the key activity area, where there is a sustained input of suspended sediments over periods of several months, and the influence of local metocean conditions acting to inhibit rates of settling and increase rates of resuspension.

The larger ZoI for dredging works commencing in winter is largely a consequence of the lower thresholds applicable during this period, and consequently the lower levels of dredge-excess suspended sediment concentrations (SSC) required to cause exceedances.



Note: The ZoI presented is a cumulative measure of exceedances over a four-month period (i.e. this is not representative of the visual plume produced on a single day of the activity). There was no ZoMI or ZoHI exceedances for sensitive receptors.

Figure 7.12: Predicted 95th percentile Zone of Influence for summer-start scenario (1 December 2016 to 10 April 2017).



Note: The ZoI presented is a cumulative measure of exceedances over a four-month period (i.e. this is not representative of the visual plume produced on a single day of the activity). There was no ZoMI or ZoHI exceedances for sensitive receptors.

Figure 7.13: Predicted 95th percentile Zone of Influence for winter-start scenario (1 June 2017 to 9 October 2017).

Water Quality

Water quality change occurs when seabed sediments enter the water column (turbidity). After a period, the suspended sediments settle and the turbidity in the water column returns to pre-disturbance levels.

Trenching and backfill activities would result in seabed disturbance between approximately KP 34 to KP 50 in Commonwealth waters and at the proposed Borrow Ground. Where the dredged material is not used to backfill the trench, it will be disposed at existing spoil grounds within the region.

Both the relatively short period of trunkline dredging, and daily movement of the dredge mean the potential for elevated turbidity at any site, is expected to be of short duration (i.e. likely less than five days).

Backfill operations involve the placement of coarser materials for trunkline stabilisation. As such the fines component is expected to be less than the dredging of the seabed. Given the lower fines component, suspended sediments are expected to settle more rapidly limiting the temporal and spatial scale of any elevated turbidity. Additionally, the backfill operations are expected to progress rapidly along the trunkline route maintaining the duration and frequency terms of any intensity-duration-frequency threshold of turbidity elevation below that currently predicted as required to generate material levels of stress to ecological communities. Where rock dumping is required for pipeline stabilisation purposes elevated turbidity is expected prior to placement of the rock on the seabed, however this is expected to be temporally and spatially confined such that any water quality impacts are not expected to cause an impact to any sensitive receptors.

The fines component of the material at the potential Commonwealth borrow ground is minimal. The borrow ground was selected based on the material having a higher component of coarse sands.

Sediment mobilisation and/or displacement along the trunkline at KP 210 are expected to result in temporary elevations in turbidity. Due to the methods being used (e.g. Mass Flow Excavator), any increase in turbidity will only occur in bottom waters. Both the increased turbidity, and the associated sediment deposition, is expected to be restricted to the vicinity of the activity which is estimated to be over a distance of a few hundred metres, and within an area of predominately bare sand habitat.

For dredged material that is not used as backfill material, it will be disposed of at existing spoil grounds. This will be an intermittent activity only completed on an as-needed basis, and therefore no extended periods of sediment disturbance are expected to occur around the spoil grounds.

The environmental performance outcome for water quality is to not substantially change water quality which may adversely impact biodiversity, ecological integrity, social amenity or human health. The change in water quality will be localised around the placement of infrastructure on the seabed and is temporary in nature, returning to normal rapidly after the disturbed sediments settle. On this basis, there is a high level of certainty that the proposed Scarborough trunkline is unlikely to have a significant impact on water quality from routine seabed disturbance, during activities associated with Scarborough.

In addition, modelling has shown that the elevations in turbidity as a result of operations at the borrow ground, adjacent to the Dampier Marine Park will remain below the intensity-duration thresholds predicted to cause an impact to benthic communities.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to water quality. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. It is considered that although the ZoI extends into the Dampier AMP, the nature of the change is temporary only, and not at levels which will result in impacts to values of the AMP. Matters relating to potentially impacted receptors are discussed for the specific receptors.

Based on the detailed impact evaluation, the magnitude of potential impact of a change in water quality is slight and is considered **acceptable**.

<u>Epifauna and Infauna</u>

Epifauna and infauna may be impacted from the permanent placement of infrastructure (identified in Table 7.17) and the trunkline, or placement of temporary infrastructure (anchors, ROV, geotechnical equipment) on the seabed. Disturbance to the seabed can alter the physical seabed habitat conditions, resulting in epifauna and infauna community changes (Newell et al., 1998). Trunkline and subsea infrastructure installation are permanent for the duration of field life and will result in the displacement and/or permanent loss of some epifauna and infauna over the infrastructure and trunkline footprint.

The seafloor in the Offshore Project Area is characterised by sparse marine life dominated by motile organisms (ERM, 2013) including shrimp, sea cucumbers, demersal fish and small, burrowing worms and crustaceans. Benthic communities in the Offshore Project Area are representative of the Exmouth Plateau and of deepwater soft sediment habitats reported in the region (e.g. BHP Billiton, 2004; Woodside, 2005; Woodside, 2006; Brewer et al., 2007; RPS, 2011; Woodside, 2013; Apache, 2013).

The infauna recorded along the trunkline route is sparse but highly diverse. The abundance of the fauna is inversely associated with depth, with distinct differences in the fauna on the shelf and slope. Benthic fauna assessments in the Pluto field, which overlaps a portion of the Trunkline Project Area on the continental shelf, determined that epifauna is most abundant on the continental shelf (150–200 m) (SKM, 2006). SKM (2006) also identified polychaetes as dominant, which comprised 79% of the fauna by abundance and 75% of the fauna by species richness. Although epifauna and infauna of the Trunkline Project Area is expected to be more abundant when compared to the Offshore Project Area, species present are expected to be well represented in the wider NWMR.

ROV surveys and geophysical surveys of the continental shelf show that the area is generally devoid of hard substrate with the exception of two areas. The main area of exposed hard substrate occurs in about 1000 m depth where the continental slope meets the abyssal plain. The bottom of the rocky cliffs is situated in about 1050 m water depths with an almost vertical wall extending 20 m up to about 1030 m at the surveyed location. The rock appears to be sedimentary with clear bands or layers occurring in the rock profile. No epifauna was observed on the exposed rock (SKM, 2006).

The second area of harder substrate comprises a series of rock pinnacles located at about 300 m water depth. Results from the geotechnical studies indicated that there was potential for rock pinnacles to be spread over a 4 x 1 km area of seabed along the 300 m contour. The SKM 2006 survey identified that the pinnacles contain a very low percentage cover of live coral with only a few live specimens of coral observed growing on top of the pinnacles.

Additional survey work was completed in 2018 to collect higher resolution imagery of the pinnacles. This confirmed that the pinnacles were confined to a small area approximately 350 m from the pipeline route alignment and that they are not widespread across the continental shelf. The pinnacles provide structure for a diversity of fauna including fish and invertebrates. Many tens of fish were observed gathered around these pinnacles, most probably belonging to either the Glaucosomidae or Pricanthidae families. Crinoids, hydroids and ophiuroids were also common. Other species visible on the mounds include anemones, soft corals, small crustacean like shrimp and some larger brachyurans, possibly *Cyrtomaia suhmii.* Imagery was sent to Professor Murray Roberts (University of Edinburgh) for expert assessment. It was confirmed that the yellow corals which were originally identified as *Lophelia* were “at first glance *Dendrophyllia cornigera* (well known in the Mediterranean Sea), but perhaps more likely a Leptosammia species (same family: Dendrophylliidae)”. It was also confirmed that there was no evidence of *Lophelia* sp. in the imagery that was reviewed (M. Roberts, pers. comm).

Given that any seabed material displacement is likely to result in highly localised turbidity for short periods of time and that the rock pinnacles observed are approximately 350 m from the trunkline alignment, water quality impacts associated with the seabed material displacement are not expected to pose a risk to the surrounding epifauna and infauna communities on the continental shelf.

Sediment mobilisation and/or displacement along the trunkline at KP 210 are expected to result in temporary elevations in turbidity. Due to the methods being used (e.g. Mass Flow Excavator), any increase in turbidity will only occur in bottom waters. Both the increased turbidity, and the associated sediment deposition, is expected to be restricted to the vicinity of the activity. Based on an ROV transect undertaken in the northwest corner of the Montebello Marine Park (Advisian, 2019b; Appendix C), approx. 20 km away, the seabed within the KP210 area is expected to be predominantly bare sand habitat with a sparse coverage of benthic organisms, such as epifauna, sponges or soft corals. As for the trunkline trenching and stabilisation, water quality impacts associated with the seabed material displacement are not expected to pose a risk to the surrounding epifauna and infauna communities.

Surveys have been completed at the Borrow Ground Project Area (Advisian, 2019c) to determine the suitability of the proposed area as a source of trunkline stabilisation material. Towed video and drop camera surveys of both the potential borrow ground and the DMP directly adjacent to the borrow ground, confirm that the seabed and its benthic composition are relatively uniform in structure and composition. Both locations are dominated by bare substrate with large areas of seabed that are apparently largely devoid of any epibenthic species. Where epibenthos is present, the percentage cover of species is comparatively low (in the order of 5%), with no transects recording greater than 10% coverage in the species present. Common species present were alcyonaceans (mainly solitary soft corals), pennatulaceans (sea pens), crinoids (feather stars), asteroids (sea stars) and hydroids. No benthic primary producer habitat in the form of hard corals, macroalgae or seagrass was recorded or observed along any of the survey transects. The benthic habitat observed is consistent with a broad scale characterisation of the Pilbara seabed undertaken by UWA and CSIRO (Pitcher et al 2016) and anecdotal results from a recent survey by CSIRO (Keesing, J.K. (Ed.) 2019) Based on the coarse sediment (with minimal fines) and the area being largely devoid of any epibenthic species, no important or substantial area of epifaunal or infaunal habitat is expected to be modified, destroyed, fragmented, isolated or disturbed as a result of works in the Borrow Ground Project Area.

Habitat within the Project Area may be reduced or altered, leading to a localised change in epifauna and infauna local communities. However, this will be limited to the offshore seabed infrastructure, and Trunkline Project Area, representing a small proportion of the total area, that is well represented in the region.

No threatened or migratory species, or ecological communities (as defined under the EPBC Act), were identified in the benthic communities during studies completed in the Offshore Project Area (ERM, 2013a) or the trunkline project area (Advisian, 2019a, Advisian, 2019b).

Within the Project Area, the environmental performance outcome for epifauna and infauna is 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. Generally sparse epifauna and infauna communities have been identified in the Project Area, no threatened or migratory species or ecological communities were identified. Those epifauna and infauna communities observed are likely to be well represented elsewhere in the region with impacts restricted to a localised proportion of benthic fauna communities. The Trunkline Project Area runs adjacent to the existing Pluto pipeline restricting impacts to previously disturbed areas inshore of the Pluto field. In addition, the trunkline route avoids areas of rock pinnacles which may provide more diverse habitats.

For construction and IMR activities occurring within the Montebello Marine Park, and adjacent to the Dampier Marine Park, the short term and transient nature of activities associated with seabed disturbance will not be 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, or for the Habitat Protection Zone (IV) 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.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to epifauna and infauna.

Based on the detailed evaluation, the magnitude of potential impacts to epifauna and infauna from seabed disturbance during activities associated with the development of Scarborough is minor and is considered to be **acceptable.**

AMPs

The Trunkline Project Area traverses the northern border of the Montebello Marine Park. Approximately 80 km of pipeline will extend into the park, equating to approximately 2.4 km^2 overlap (allowing for a 30 m disturbance area on the trunkline). This conservative disturbance area would result in approximately 0.07% of the Montebello Marine Park, including the area intersecting the Ancient Coastline KEF.

Relevant BIAs that intersect the Trunkline Project Area in the Montebello AMP include an internesting BIA for Flatback Turtles, migration corridor for Humpback Whales and foraging area for Whale Sharks.

Analysis of the high definition ROV video data (Advisian, 2019b) found that the area in which the trunkline intersects the Montebello AMP is characterised by bare sandy sediments, interspersed with predominantly sparse benthic communities and epifauna. Denser areas of sponges were observed in areas identified from the bathymetry as having a more complex seabed structure.

Trunkline installation activities are not expected to negatively impact the areas of bare sandy substrate. Recent research has also confirmed that habitats containing the greatest biodiversity in these offshore environments are the habitats formed by colonising invertebrates on oil and gas subsea infrastructure including pipelines. These habitats and the species present on these structures in the NWS of Western Australia have been subject to detailed assessment by McLean et al. (2018), Bond et al. (2018) and McLean et al. (2017). These habitats not only have structural complexity but also create habitat for a large diversity of fish species that commonly occur elsewhere in the NWS but do not occur over soft unconsolidated sediments.

The intersection of the trunkline with the area of denser sponges is not expected to fragment the community given that any loss of sponges will be localised to the trunkline footprint. Nor is it expected to result is substantial loss given the spatial extent of the community running perpendicular to the trunkline route.

Given the small footprint of the trunkline, and subsequent percentage disturbance to the Montebello AMP the project activities are not expected to destroy, fragment or isolate substantial areas of habitat important to Turtles, Whale Sharks or Whales in the Montebello AMP.

The magnitude of potential impacts to the Montebello AMP from routine seabed disturbance during activities associated with Scarborough are evaluated to be slight and **acceptable**.

The Borrow Grounds Project Area is located adjacent to the Dampier Marine Park. The Dampier Marine Park covers about 1252 km² and includes waters from less than 15 m to 70 m depth. Conservation values identified within the reserve (Director of National Parks, 2018) include:

- foraging areas adjacent to important breeding areas for migratory seabirds
- foraging areas adjacent to important nesting sites for marine turtles
- part of the migratory pathway of the protected Humpback whale
- high level protection for offshore shelf habitats adjacent to the Dampier Archipelago, and for the shallow shelf with depths ranging from 15 m to 70 m
- examples of the communities and seafloor habitats of the NWS province bioregion as well as the Pilbara (nearshore) and Pilbara (offshore) meso-scale bioregions
- part of a hotspot for sponge biodiversity (area between Dampier and Port Hedland).

Recent benthic habitat surveys of an area of the Dampier AMP adjacent to the Borrow Grounds Project Area (Advisian, 2019c) showed the seabed and benthic composition of the area surveyed was relatively uniform in structure and composition. The survey area was dominated by bare sandy substrate with large areas of seabed that are apparently largely devoid of any epibenthic species. Given the coarse nature of the sediments at the borrow ground, it is expected that the duration and frequency terms of any intensity-duration-frequency threshold of turbidity elevation would be maintained below that currently predicted as required to generate material levels of stress to ecological communities in areas of higher filter feeder abundance in the eastern end of the marine park. Sediment dispersion modelling for the dredging of the Borrow Grounds showed no exceedance of the ZoMI or ZoHI. A ZoI was defined (Figure 7.12 and Figure 7.13), which does extend into the boundary of the Dampier AMP. However, it is noted that the ZoI is defined as an area within which changes in water quality associated with dredge plumes are predicted but where these changes would not result in a detectible impact on benthic biota.

The environmental performance outcome for AMPs is 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 a Commonwealth marine protected area results. Given the temporary and localised nature of any water quality impacts to the Montebello and Dampier AMPs, and the low abundance of filter feeders adjacent to the proposed borrow ground in the Dampier AMP, activities are not expected to modify, destroy, fragment, isolate or disturb an important or substantial area of habitat.

Based on the detailed impact evaluation, the magnitude of potential impact of a change in water quality and change in habitat to AMPs is slight and is considered **acceptable**.

KEFs

Three KEFs overlap the Offshore Project Area and Trunkline Project Area: the Exmouth Plateau, Ancient Coastline at 125 m Depth and Continental Slope Demersal Fish Community. Seabed disturbance will occur within these KEFs and may lead to change in habitat and short-term water quality change.

The Trunkline Project Area and Offshore Project Area lie within the Exmouth Plateau KEF. The KEF occupies an area of 49,310 km² within water depths of 800 – 4000 m (Exon & Willcox, 1980, cited in Falkner et al., 2009; Heap & Harris, 2008). The Trunkline Project Area enters the KEF about 240 km offshore, extending about 60 km into the KEF before reaching the Offshore Project Area. The Trunkline Project Area and Offshore Project Area occupy a relatively small portion of the entire KEF. Physical habitat modification is not listed as a potential concern for this KEF. Based on this and the small area affected by the Trunkline Project Area and Offshore Project Area, no impact to the values of this KEF is anticipated.

A relatively small portion of the Ancient Coastline at 125 m Depth KEF overlaps the Trunkline Project Area. This intersect is located about 360 km offshore north-north-west of the Montebello Islands. While physical habitat modification is not listed as a potential concern for this KEF, any seabed disturbance will be a very small portion within the KEF. Impact will not occur to the hard substrates of the KEF, as the trunkline route will avoid hard substrates and associated increase in species richness.

An ROV survey of the trunkline route undertaken in 2019 (Advisian, 2019b) targeted areas of interest including the ancient coastline KEF. Bathymetry data was analysed to select sites that could be expected to support benthic communities, including areas of potential harder substrate. The survey found that the area in which the trunkline intersects the Montebello AMP is characterised by bare sandy sediments, interspersed with predominantly sparse benthic communities and epifauna.

The Continental Slope Demersal Fish Community is recognised as a KEF because of its biodiversity values, including high levels of endemism (DotE, 2018b). The Trunkline Project Area intersects a small portion of the KEF, across one of its thinnest points throughout its distribution. Most of the KEFs area lies further south, extending about 240 km from the Trunkline Project Area to just past the tip of the Exmouth Peninsula, splitting from a single corridor into three. Physical habitat modification is listed as a potential concern for this KEF (DotE, 2018b). However, any potential impact to the KEF from habitat disturbance is restricted to the overlap of the trunkline and impacts will be highly localised.

Within the Project Area, the environmental performance outcome for KEFs is to not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat, such that an adverse impact occurs to marine ecosystem functioning or integrity in an area defined as a KEF. The seabed disturbance within the KEF is highly localised and relatively small compared to the size of the KEF. There will be no substantial adverse effect on the KEF or the communities within it.

For construction and IMR activities occurring within the Montebello Marine Park, and adjacent to the Dampier Marine Park, the short term and transient nature of activities associated with seabed disturbance will not be 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, or for the Habitat Protection Zone (IV) 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. KEFs form an essential part of the Marine Park network. There are no KEFs in the Dampier Marine Park. The Montebello Marine Park contains one KEF: ancient coastline at 125 m depth contour. Any impacts to values of the KEF will be over a small area and will not affect the KEF as a whole.

On this basis, the magnitude of potential impacts to KEFs from routine seabed disturbance during activities associated with Scarborough is slight and is evaluated to be **acceptable**.

7.1.5.3 Impact Significance Evaluation

Impacts from seabed disturbance will have a slight effect on receptors, as the extent, duration, frequency and scale of the impact are all sufficiently small. When considered with receptor sensitivity, Impact Significance Level of seabed disturbance from Scarborough have been evaluated as **Minor (D)** for AMPs and KEFs, and **Negligible (F)** for water quality and epifauna and infauna. The impacts overall have been determined to be **acceptable** based on an evaluation against the criteria:

To meet the principles of ESD

- The contribution of routine seabed disturbance from the development of Scarborough will result in localised impacts or disturbance to benthic communities but is not expected to affect the population or local ecosystem function.
- No threatened or migratory species, or ecological communities were identified, and those epifauna and infauna communities observed are likely to be well represented elsewhere in the region.
- The seabed disturbance within the KEFs is highly localised and relatively small compared to the size of the KEF.
- The majority of seabed disturbance from installation activities will occur during a 12-month activity window, once installation activities have ceased seabed disturbance, and resulting change in habitat and water quality will be limited to drilling and MODU activities, ROV and vessel use and any removal of infrastructure at the end of field life.
- Elevations in turbidity a result of operations at the borrow ground, adjacent to the Dampier Marine Park will remain below the intensity-duration thresholds predicted to cause an impact to benthic communities.

Internal context

- There are no specific Woodside internal requirements with respect to seabed disturbance, or potentially impacted receptors.

External context

- No stakeholder concerns have been raised with respect to seabed disturbance or potentially impacted receptors.

Other requirements

- With respect to seabed disturbance, activities associated with Scarborough 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.
- Sea Dumping Permits under the *Environment Protection (Sea Dumping) Act 1981* will be in place where required. Sea dumping activities will be undertaken in accordance with the act and under permit as required.

7.1.5.4 Summary of the Impact Assessment

Table 7.20 provides a summary of the risk assessment and acceptability for impacts from routine seabed disturbance on receptors.

Table 7.20: Summary of impacts, management controls, impact significance ratings and EPOs for routine seabed disturbance

Receptor	Impact	Environmental Performance Outcome	Adopted Control(s)	Receptor sensitivity level	Magnitude	Impact significance level	Acceptability
Water quality	Change in water quality	**EPO2:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM12:** Infrastructure will be positioned on the seabed within design footprint to reduce seabed disturbance.	Low value	Slight	Negligible (F)	Acceptable
Epifauna and infauna	Change in habitat	**EPO1:** 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.		Low value	Slight	Negligible (F)	Acceptable
KEFs	Change in habitat Change in water quality Injury or mortality	**EPO16:** 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 results.		High value	Slight	Minor (D)	Acceptable
AMPs	Change in habitat Change in water quality	**EPO1:** 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.		High value	Slight	Minor (D)	Acceptable

7.1.6 Routine and Non-Routine Discharges: Sewage and Greywater

7.1.6.1 Sources of the Aspect

Vessels and facilities used in the oil and gas industry vary in size but often include accommodation facilities for crew and passengers. The use of these facilities will result in routine discharges of domestic wastes such as sewage and greywater. Activities and facilities associated with Scarborough will discharge sewage and greywater to the marine environment during:

- vessel operations
- MODU operations
- FPU operations.

Vessel, FPU and MODU Operations

The use of ablution, laundry and galley facilities by crew will result in the generation of sewage and greywater, which are treated and discharged to the marine environment. Depending on waste production rates and the specifications of sewage systems available, the total volume of this waste stream discharged typically ranges between 0.04 and 0.45 m^3 per day per person (EMSA, 2016).

Waste generation is dependent on the number of persons on board. A review of current petroleum activities shows that facilities such as FSPOs and platforms may discharge around 60 m^3 of waste water (consisting of sewage and greywater) per day; while vessels and MODUs typically generate around 5–15 m^3 of waste water per day (NERA, 2017). Support vessels for anchoring, towage, installation, commissioning, dredging and so on are expected to have between 20 and 60 persons on board (POB) each vessel. The largest construction vessel (used for trunkline installation) may have <700 POB. Vessel and POB numbers will peak during construction and commissioning; whereas during operations, the maximum manning for the FPU is <100 POB; with one support vessel.

Using a rate of 0.375 m^3/person/day as a guide (NERA, 2017), the maximum discharge volumes from the largest sources have been calculated for each phase. For installation and commissioning. the stationary facility with the largest discharge volume (FPU with a peak commissioning workforce of ~600) would discharge 225 m^3/day. The largest vessel with <700 POB would discharge 262 m^3/day. During operations, the FPU would discharge ~37.5 m^3/day at peak manning; and the support vessel ~9.4 m^3/day.

Facilities and MODUs generally discharge this waste stream over a longer term (extending from months to years), with the discharge point remaining relatively stationary; while vessels will typically discharge waste over a shorter period, and discharge while in transit.

7.1.6.2 Impact or Risk

Discharges of sewage and greywater from the sources described above has the potential to result in the following impacts:

- change in water quality
- injury/mortality to marine fauna
- change in aesthetic value
- changes to the functions, interest or activities of other marine users.

Change in Water Quality

Sewage and greywater contain nutrients (e.g. ammonia, nitrite, nitrate and orthophosphate), which when discharged can lead to nutrient loading and eutrophication. 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 such as phytoplankton and benthic algae which can deplete oxygen in the water column and result in changes in biological.

Chemicals within sewage and greywater 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.

While organics may degrade through bacterial action, oxidation and evaporation, there is the potential for some chemicals to persist (e.g. metals and chlorinated organics). These are likely to be most concentrated in the vicinity of the discharge.

Sewage and greywater 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.

Injury/Mortality to Marine Fauna

A change in water quality from the discharge of sewage and greywater could result in injury or mortality to marine fauna. This could be the result of oxygen depletion in the waters due to nutrient enrichment, or due to toxins and chemicals present in the discharged wastes.

Open marine waters are typically influenced by regional wind and large-scale current patterns resulting in the rapid mixing of surface and near surface waters where sewage discharges may occur. This means nutrients from the discharge of sewage will not accumulate or lead to eutrophication due to the highly dispersive environment. Therefore, the receptors with the greatest potential to be impacted are those in the immediate vicinity of the discharge (NERA, 2017). Given that sewage discharges from vessels and facilities are at or near the surface, and remain buoyant, the receptors with the potential to be impacted are also those within or on surface waters; i.e. plankton, fish and other marine fauna.

Change in Aesthetic Value

The composition of sewage and greywater may include physical particulate matter such as solids composed of floating, settle able, colloidal and dissolved matter. These substances can affect aspects of aesthetics such as ambient water colour, the presence of surface slicks/sheens and odour. The stationary facilities with the greatest discharge volumes (MODU and FPU) will be located >375 km from the closest shore. While the pipelay, dredging and support vessels will be closer to shore and in shallower waters during trunkline installation and dredging, these activities are of shorter duration, and most of these vessels are smaller and will generate less waste. Also, as vessels are moving during the discharge of sewage and greywater, this promotes mixing and dilution of the waste.

Given the distance of the project offshore, the proximity of water quality changes to the discharge source, the rapid consumption of matter by planktonic species and bacteria, and the spatial nature of tourism and recreation activities and coastal settlements (i.e. on or near the shoreline); impacts to receptors associated with changes in aesthetic values are not expected to occur and as such are not evaluated further.

Changes to the Functions, Interest or Activities of Other Marine Users

Significant discharges of sewage and greywater could result in water quality deterioration, including introduction of toxins and pathogens that could affect the activities of other marine users including commercial and recreational fishers. The largest expected discharge volumes from stationary facilities are ~375 km from shore, in a well-mixed marine environment. Although trunkline installation and dredging will occur in shallower waters closer to shore, these activities are of shorter duration, and discharges would be from moving vessels, promoting mixing and dilution. Therefore, this impact is not expected to occur and is not evaluated further.

Receptors Potentially Impacted

Routine discharges of sewage and greywater have the potential to impact on receptors which may be vulnerable to the toxicity. The receptors which have the potential to be impacted include:

- water quality
- plankton
- fish
- marine mammals
- marine reptiles
- KEFs.

Plankton

Plankton communities have a naturally patchy distribution in both space and time, and are known to have naturally high mortality rates, primarily through predation (ITOPF, 2011). However, in favourable conditions (e.g. supply of nutrients), plankton populations can rapidly increase. Once the favourable conditions cease, plankton populations will collapse and/or return to previous conditions. Plankton populations have evolved to respond to these environmental perturbations by copious production within short generation times (ITOPF, 2011). However, any potential change in phytoplankton or zooplankton abundance and composition is expected to be localised, typically returning to background conditions within tens to a few hundred metres of the discharge location (e.g. Abdellatif, 1993; Axelrad et al., 1981; Parnell, 2003).

The NWMR is typically characterised by low planktonic productivity. If a nutrient source was introduced, there is the potential for plankton productivity to increase, however due to the nature of the open ocean marine environment, eutrophication is not expected to occur due to rapid mixing.

Fish, Marine Mammals and Marine Reptiles

Other ecological receptors that may be present in surface waters that have the potential to be impacted by discharges of sewage and greywater include pelagic fish species, cetaceans and marine reptiles. These organisms could be exposed to toxins and other chemicals present in the waste stream which could potentially result in injury or mortality.

Studies indicate that direct impacts are only expected from prolonged exposure in waters with poor mixing (McKinley and Johnston, 2010). In addition, pelagic species are expected to be able to actively avoid discharge plumes and therefore evade impacts associated with toxic exposure. Less mobile organisms such as larval stage fish however may be subject to elevated levels of mortality due to inability to avoid discharge plume.

Bioaccumulation can occur as a result of toxins and chemicals passing through the food chain. As plankton impacts are expected to be restricted to the mixing zone, effects of bioaccumulation on receptors along the food chain, namely, fish, reptiles, birds and cetaceans are therefore not expected beyond the immediate vicinity of the discharge in deep open waters.

Fish species within the Project Area are transient, with no identified areas of significance within the Project Area, other than a section of the trunkline which does overlap the foraging BIA for whale sharks. While it is possible that some fish may be exposed to toxins and other chemicals in the sewage and grey water waste stream, this is only likely to occur close to the discharge point.

Some cetacean species may also be present within the Offshore Project Area and Trunkline Project Area that may be subject to ingestion of planktonic species which have been exposed to toxins from sewage and greywater discharges. A BIA for migration of Blue whale and Pygmy Blue whale populations as well as a BIA for known distribution of Humpback whales exist within the Offshore Project Area. Within the Trunkline Project Area, a BIA for Humpback migration is present.

Turtle presence of EPBC listed species includes the Loggerhead Turtle, Green Turtle, Leatherback Turtle, Hawksbill Turtle and Flatback Turtle within Commonwealth waters intersects with both the Offshore Project Area and pipeline corridor. Within the Offshore Project Area, where most discharges will be located, species presence is likely to occur. All species within the Trunkline Project Area have presences associated with known breeding activities other than the loggerhead turtle which is known to forage in the area.

Impacts to surface dwelling species including fish, cetaceans and reptiles via toxicity is not expected and due to the highly localised nature of impacts to planktonic species (prey), any impacts from sewage and greywater to ecological pelagic receptors are considered unlikely. and this impact has not been evaluated further.

KEFs

Given the impacts are restricted to surface waters in the immediate vicinity of the discharge, benthic species have not been considered. On this basis, the KEFs within the Project Area have not been identified at risk as the values associated with these KEFs related to the attributes of the demersal habitats and features.

Table 7.21 outlines the potential impacts to receptors associated with the routine and non-routine discharge of sewage and grey water.

Table 7.21: Receptor/impact matrix after evaluation of context

	Receptor					
Impacts	***Water Quality***	***Plankton***	***Fish***	***Marine Mammals***	***Marine Reptiles***	***KEF***
Change in water quality	✓					X
Injury/mortality to marine fauna		X	X	X	X	X

Detailed Impact Evaluation

For each of the receptors identified for detailed evaluation, the criteria for acceptability as defined in Table 6.3 have been considered and addressed in the following sections. This includes to meet the principles of ESD, internal and external context and any other requirements.

Water Quality

The mixing zone boundary of routine and non-routine discharges of sewage and greywater has been studied within the industry and for municipal sewage treatment plants. Monitoring of sewage discharges has demonstrated that a 10 m³ sewage discharge over 24 hours from a stationary source in shallow water, reduced to about 1% of its original concentration within 50 m of the discharge location (Woodside, 2008). In addition to this, monitoring at distances 50, 100 and 200 m downstream of the platform and at five different water depths confirmed that discharges were rapidly diluted or nutrients rapidly metabolised and no elevations in water quality monitoring parameters (e.g. total nitrogen, total phosphorous and selected metals) were recorded above background levels at any station.

The European Chemicals Bureau Chemical Hazard Assessment and Risk Management procedure (CIN, 2004) applies a worst-case default dilution factor of 1000 at a distance of 500 m for an offshore point source discharge. This same factor is also applied by the Australian National Industrial Chemicals Notification and Assessment Scheme (NICNAS, 2014).

For fixed discharge sources, the maximum discharge is expected to be ~225 m³/day, at peak workforce during FPU commissioning (expected to take about three months). NERA (2017) uses discharge volumes <150 m³/day; and states that it is expected to remain within the nominal mixing zone boundary of 500 m around fixed facilities. The defined mixing zone is suitably conservative when compared to metropolitan sewage treatment plants (STP) that routinely discharge much larger quantities of residential, industrial and commercial wastewater into the marine environment. For example, the Water Corporation discharges 100 million m³/year of treated wastewater from three STPs in Perth (NERA (2017)).

Generally, the impact is expected to be limited to within 500 m from discharge during FPU and MODU operations. For vessels, typically waste discharge is over a shorter term and discharged while in transit, therefore the potential for this impact is lower due to a more spread-out discharge over a spatial scale.

Within the Project Area, where discharges are to occur, the environmental performance outcome for water quality is to not result in a substantial change to water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. Given the offshore location of Scarborough offshore facilities, and the low volumes of routine and non-routine discharges of sewage and greywater which will be generated, biodiversity, ecological integrity, social amenities and human health will not be impacted.

Vessel operations undertaken as a part of this activity will adhere to the *Navigation Act 2012*, MARPOL and the various Marine Orders (as appropriate to vessel class) enacted under this Act. This Act implements into Australian law Australia's obligations under the International Convention for the Prevention of Pollution from Ships (MARPOL Convention).

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to water quality. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered.

Given the offshore location, the routine and non-routine discharges of sewage and greywater from activities associated with Scarborough may result in a slight change to water quality, and on this basis the impact is evaluated to be **acceptable**.

7.1.6.3 Consequence Evaluation

Impacts from routine and non-routine discharges of sewage and greywater will have a slight effect on receptors, as the extent, duration, frequency and scale of the impact are all sufficiently small. When considered with receptor sensitivity, Impact Significance Level of routine and non-routine discharges of sewage and greywater from Scarborough have been evaluated as **Negligible (F)**. The impacts overall have been determined as **acceptable** based on an evaluation against the criteria.

To meet the principles of ESD

- The contribution of sewage and greywater discharge from Scarborough will be comparable with existing vessels and facilities on the North West Shelf, and not result in a notable change to the water quality of the wider area.
- Impacts to surface dwelling species including fish, cetaceans and marine reptiles via toxicity is not expected, and does not pose any lasting effect. Due to the highly localised nature of impacts to planktonic species (prey), impacts from sewage and greywater to ecological pelagic receptors are not expected.

Internal context

- There are no specific Woodside internal requirements with respect to routine and non-routine discharges of sewage and greywater, or potentially impacted receptors.

External context

- No stakeholder concerns have been raised with respect to routine and non-routine discharges of sewage and greywater or potentially impacted receptors.

Other requirements

- Vessel operations undertaken as a part of this activity will adhere to the *Navigation Act 2012*, MARPOL and the various Marine Orders (as appropriate to vessel class) enacted under this Act. This Act implements into Australian law Australia's obligations under the International Convention for the Prevention of Pollution from Ships (MARPOL Convention).
- With respect to routine and non-routine discharges of sewage and greywater, activities associated with Scarborough 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.

7.1.6.4 Summary of the Impact Assessment

Table 7.22 provides a summary of the risk assessment and acceptability for impacts from sewage and greywater to receptors.

Table 7.22: Summary of key management controls, acceptability, EPOs and residual risk rating for sewage and greywater

Receptor	Impact	Environmental Performance Outcome	Adopted Control(s)	Receptor sensitivity level	Magnitude	Impact significance level	Acceptability
Water quality	Change in water quality	**EPO2:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM13:** Compliance with relevant MARPOL, Commonwealth requirements and subsequent Marine Order requirements for sewage management.	Low value (open water)	Slight	Negligible (F)	Acceptable

7.1.7 Routine and Non-Routine Discharges: Food Waste

Food waste will be generated on board the vessels and offshore facilities used during Scarborough. These will be discharged under controlled conditions to the marine environment.

7.1.7.1 Sources of the Aspect

Activities and facilities associated with Scarborough that will generate and discharge food waste to the marine environment include:

- FPU operations
- MODU operations
- vessel operations.

FPU, MODU and Vessel Operations

FPU, MODU and vessel operations used for Scarborough include accommodation facilities for crew and passengers. The crew and passengers will generate waste including food waste which will be discharged under controlled conditions to the marine environment. 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.

Food waste will be discharged throughout all phases of Scarborough. The FPU and MODU will discharge food 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.

Food waste will disperse and break up rapidly in the marine environment, with some of the waste being consumed by surface dwelling organisms upon discharge. Food 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.

7.1.7.2 Impact or Risk

The discharges of food waste from the identified sources has the potential to result in:

- change in water quality
- change in fauna behaviour.

Change in Water Quality

The presence of food waste within the water column can increase nutrient loads, resulting in potential reduction to biological oxygen demand (BOD). However, studies into the effects of nutrient enrichment indicate that the influence of nutrients in open marine areas such as the locations for Scarborough, is much less significant than that experienced in enclosed areas (McIntyre and Johnson, 1975). Black et al. (1994) state that biological oxygen demand BOD of treated effluent is not expected to lead to oxygen depletion in the receiving waters and food waste discharges are expected to result in the same outcome. Impacts to water quality relating to nutrient enrichment are thus not evaluated further.

Change in Fauna Behaviour

Discharge of food waste into the marine environment has the potential to attract some opportunistic marine fauna including fish and seabirds to the area in response to the increased food availability or, indirectly because of attraction of prey species. However, given the small quantities of food waste to be disposed, any attraction is likely to be minor, temporary and localised.

Receptors Potentially Impacted

Food wastes are discharged overboard and given they are typically buoyant they will initially remain at the surface or in the upper zone of the water column. The discharge will introduce an additional food source that has the potential to attract fish and birds that are present in the area. This change to behaviour will be for a short period and localised to the area immediately surrounding the point of discharge. It is not likely to affect the overall population or have a wider implication on the species potentially impacted.

Seabirds and Migratory Shorebirds

The Project Area may be occasionally visited by migratory and oceanic birds but does not contain any emergent land that could be utilised as roosting or nesting habitat and contains no known critical habitats (including feeding) for any species. As most of the area is offshore and away from islands or other emergent features, any presence of seabirds or shorebirds is considered likely to be of a transient nature only. For activities closer to shore, these are short term and not at a fixed location. Based on this the impacts from food discharge to birds has not been evaluated further.

Fish

Fish species within the Project area are expected to be transient, with no identified areas of significance within the Project Area, other than a section of the trunkline which does overlap the foraging BIA for whale sharks.

The temporary attraction of transient fish will be for a short period and localised around the point of discharge. There will be no lasting effect on high value species as a result of food waste discharge from Scarborough. Food waste is not identified as a threat in any EPBC listed threatened species recovery plans or conservation advice, including the Conservation advice for whale sharks (TSSC, 2015d). On this basis the impacts of the discharge of food waste on fish has not been evaluated further.

KEFs

Given the impacts are restricted to surface waters in the immediate vicinity of the discharge, benthic species have not been considered. On this basis, the KEFs within the Project Area have not been identified at risk as the values associated with these KEFs related to the attributes of the demersal habitats and features.

The receptors within the environment that may be affected by the discharge of food waste, that are potentially at risk from the identified impacts are outlined in Table 7.23.

Table 7.23: Receptor/impact matrix after evaluation of context

	Receptor			
Impacts	***Water Quality***	***Seabirds and Migratory Shorebirds***	***Fish***	***KEFs***
Change in water quality	✓			X
Change in fauna behaviour		X	X	

Detailed Impact Evaluation

For each of the receptors identified for detailed evaluation, the criteria for acceptability as defined in Table 6.3 have been considered and addressed in the following sections. This includes to meet the principles of ESD, internal and external context and any other requirements.

Water Quality

Discharges of food waste has the potential to change the local water quality for a short period through the addition of a temporary nutrient source. This nutrient loading would rapidly return to background conditions following dispersion through surface currents and wave action.

The extent of this potential impact for Scarborough is restricted to the immediate vicinity of the discharge location, this being the Offshore Project Area, and along the trunkline route during construction activities.

The environmental performance outcome for water quality is to not substantially change water quality (including temperature) which may adversely impact biodiversity, ecological integrity, social amenity or human health. The water quality within the Project Area is typical of an unpolluted tropical offshore environment. Within the Project Area, where discharges are to occur, the environmental performance outcome for water quality is to not result in a substantial change in water quality (including temperature) which may adversely impact on biodiversity, ecological integrity, social amenity or human health. Given the small volumes, and the offshore location for Scarborough, the change to water quality as a result of the discharge of food waste will not be substantial.

Vessel operations undertaken as a part of this activity will adhere to the Navigation Act 2012, MARPOL and the various Marine Orders (as appropriate to vessel class) enacted under this Act. This Act implements into Australian law Australia's obligations under the International Convention for the Prevention of Pollution from Ships (MARPOL Convention) and navigation and shipping including Safety of Life at Sea (SOLAS), which includes specific requirements for navigational lighting. Although the Act does not apply to the operation of petroleum facilities, it may apply to some activities of operations support vessels.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to water quality. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered.

Based on the detailed impact evaluation, the magnitude of potential impact of a change in water quality is no lasting effect and is considered **acceptable**.

7.1.7.3 Impact Significance Evaluation

Impacts from routine and non-routine discharges of food waste will have no lasting effect on receptors. When considered with receptor sensitivity, Impact Significance Level of routine and non-routine discharges of food waste from Scarborough have been evaluated as **Negligible (F)**. The impacts overall have been determined to be **acceptable** based on an evaluation against the criteria:

To meet the principles of ESD

- Volumes of food waste are small, and discharges occur in open offshore waters.
- There will be rapid dilution and consumption of food waste within the water column.
- The change in behaviour of marine fauna including birds and fish will be for a short period and localised to the area immediately surrounding the point of discharge.

Internal context

- There are no specific Woodside internal requirements with respect to food waste, or potentially impacted receptors.

External context

- No stakeholder concerns have been raised with respect to food waste or potentially impacted receptors.

Other requirements

- With respect to food waste, activities associated with Scarborough 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.

7.1.7.4 Summary of the Impact Assessment

Table 7.24 provides a summary of the risk assessment and acceptability for impacts from discharges of food waste on receptors.

Table 7.24: Summary of impacts, management controls, impact significance ratings and EPOs for discharges – food waste

Receptor	Impact	Environmental Performance Outcome	Adopted Control(s)	Receptor sensitivity level	Magnitude	Impact significance level	Acceptability
Water quality	Change in water quality	**EPO2:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM14:** Compliance with relevant MARPOL, Commonwealth requirements and subsequent Marine Order requirements for waste discharges. **CM15:** Implementation of waste management procedures which provide for safe handling and transportation, segregation and storage and appropriate classification of all waste generated.	Low value (open water)	No lasting effect	Negligible (F)	Acceptable

7.1.8 Routine and Non-Routine Discharges: Chemicals and Deck Drainage

7.1.8.1 Sources of the Aspect

Activities and facilities associated with Scarborough will routinely and non-routinely discharge chemicals and deck drainage. Discharges will be made during:

- FPU operations
- MODU operations
- vessel operations.

Vessel, FPU and MODU Operations

Chemicals are used during vessel, MODU, FPU and ROV activities for a variety of purposes within the Offshore Project Area and Trunkline Project Area. The FPU and vessels will be used during all phases of Scarborough, with the FPU only in the Offshore Project Area, and vessels also in the Trunkline Project Area. The MODU will only be used during drilling phases in the Offshore Project Area. Chemicals and hydrocarbons that will be used and discharged, or may be contained in the following types of discharges:

- deck drainage and bilge water
- non-process chemicals (maintenance and cleaning chemicals)
- fire suppressions systems (possibly including water, foam, CO^2 and extinguishers).

Usually a facility will have an open and closed drainage system. The open system collects deck drainage (firewater, stormwater, and washdown water), drip trays, and sample returns. Non-contaminated streams (such as rainwater from the roof of the living quarters) are sent directly to the open drains for discharge. Potentially contaminated streams will go to a bilge/slops tank for initial treatment first (such as an oil-water separator).

For high water flows beyond the capacity of the slops tank (e.g. firewater deluge or storm), the first flush is recovered to the slops tank, and the overflow goes directly to the open drain catchment (with this overflow considered to be uncontaminated drainage water).

The closed drain system collects hazardous wastes from the processing system and liquids from equipment and piping during maintenance and routes the hazardous waste to the closed drain collection tank/s. This collected water is disposed via the produced water system.

Facilities and MODUs generally discharge this waste stream over the life of the facility, with the discharge point remaining relatively stationary; while vessels will typically discharge waste over a shorter period, and discharge while in transit.

Deck Drainage and Treated Bilge

Deck drainage and treated bilge are generally similar in composition, although they are discharged via different pathways. Deck drainage can originate from rainfall, ocean spray or wash-down operations and is routinely discharged to the marine environment. Deck drainage typically contains particulate matter and residual chemicals such as cleaning chemicals, oil and grease in small volumes.

Bilge tanks receive wash water and waste liquids from all major process and machinery equipment and diesel/chemical storage areas on the FPU, MODU and project vessels. FPU, MODU and vessel decks are designed for deck drainage, however during washing or in the event of chemical or hydrocarbon leaks or spills to the deck, they may be plugged and diverted to bilge tanks.

The bilge system is designed to safely collect, contain and dispose of oily water from hazardous areas so that discharge of hydrocarbons to the marine environment is avoided. These fluids may contain contaminants such as oil, detergents, solvents, chemicals and solid waste, typically at low levels. Bilge water is then treated onboard using an oily water separator (OWS) to reduce any oily residue to below 15 ppm or where there are no visible signs of oil. The discharge of treated bilge is non-continuous and infrequent.

7.1.8.2 Impact or Risk

A discharge of deck drainage and treated bilge from the vessels, MODU or FPU to the marine environment has the potential to result in the following impacts to receptors:

- change in water quality
- change in sediment quality
- injury or mortality to marine fauna.

<u>*Change in Water Quality*</u>

As described above, deck drainage and treated bilge may contain a range of chemicals, oil, grease and solid material. These types of discharges are not dissimilar to other vessel and facility-based discharges occurring in the NWMR during petroleum and non-petroleum-based activities.

Shell (2010) undertook modelling for treated bilge discharges from a Floating LNG (FLNG) facility on the open marine environment, which predicted that concentrations of hydrocarbons and other chemicals rapidly dilute in the water column and fall below the predicted no effect concentration (PNEC) within a short time period and distance from the discharge source.

During maintenance, breaking containment of vessels, opening lines, high-pressure cleaning, and topping up and changing fluids may be performed, and can result in discharge of cleaning fluids, and similar contaminants, and low concentrations of sodium hypochlorite and corrosion inhibitor. These non-process chemicals are expected to be low in concentration and dilute rapidly within the water column.

There are several types of fire-fighting foams available, such as such as Aqueous Film Forming Foam (AFFF); Alcohol-Resistant AFFF; Protein Foams; Alcohol Resistant Protein Foams; Film-forming Fluoroprotein Foams (FFFP); Class A Foams; Medium and High Expansion Foams and Wetting Agents. They usually come in a concentrate that is diluted with water and agitated to form a foam solution.

Given the typically low levels of potential contaminants, relatively small and infrequent volumes of bilge and deck drainage water discharged, rapid mixing, changes in water quality due to discharge of bilge and deck drainage water from the FPU, MODU and vessels will be short term and highly localised to the discharge point.

<u>*Change in Sediment Quality*</u>

Impacts associated with routine and non-routine chemical and deck drainage discharges will be limited to the area surrounding the discharge source of the vessel, MODU or FPU. The stationary facilities and many of the support vessels will be concentrated around the well locations, which is ~930 m deep. Due to the dispersive nature of chemical discharges within the highly mixed offshore marine environment, toxins associated with surface discharges are not expected to reach marine sediments at concentrations that will result in notable changes to sediment quality. Therefore, impacts to sediment quality resulting from discharges of deck drainage and treated bilge is as such not discussed further; nor are any benthic receptors.

<u>*Injury/Mortality to Marine Fauna*</u>

As a result of a change in water quality, further impacts to receptors may occur, which include injury or mortality to marine fauna resulting from exposure to toxins in the chemicals and deck drainage discharge. Given that surface discharges are rapidly dispersed, the marine fauna at risk is limited to surface dwelling species.

For marine organisms including plankton, birds, fish and marine reptiles, OSPAR (2014) suggests that that the PNEC of dispersed oil is 70.5 ppb, which, given MARPOL requirements, is not expected, even within close proximity to the discharge point (Shell, 2010). Following discharge, concentration is expected to rapidly dilute further in the open ocean environment.

Biocides that may be present in discharges following maintenance of systems may pose a potential toxicity impact to marine fauna, in particular plankton and early life stages of fish (Walsh, 1978). However, the concentration at discharge and volumes would be very low, and rapidly disperse.

Firefighting foams such as AR-AFFF and FFFP contain organic and fluorinated surfactants, which can deplete dissolved oxygen in water (Schaefer 2013; ANSUL 2007; IFSEC Global 2014). However, in their diluted form (as applied in the event of a fire or test), these foams are generally considered to have a relatively low toxicity to aquatic species (Schaefer 2013; IFSEC Global 2014), and further dilution of the foam mixtures in dispersive aquatic environments may then occur before there is any substantial demand for dissolved oxygen (ANSUL 2007). The AR-AFFF and FFFP type foams are biodegradable and do not bioaccumulate (Mercury Firesafety 2013; Dafo Fomtec AB 2013).The use of AFFF foams is not banned in WA, however, the Commonwealth Government's National Industrial Chemicals Notification and Assessment Scheme (NICNAS) recommends that Australian industries should actively seek alternatives to – and phase out – PFAS and PFAS-related substances of concern, including AFFF. Alternative chemicals should be less toxic and not persist in the environment.

As discharges will be sporadic (i.e. no continuous flow), there is no potential for fluids to accumulate in the water column.

Although fish, marine mammals and marine reptiles may be present within receiving waters, it is unlikely that large numbers of individuals will occur within close proximity of the release point and therefore be exposed to PNEC. The expected volumes of discharges would not be significant enough to cause any notable impact to transient marine fauna, in the well-mixed marine environment.

Receptors Potentially Impacted

Routine and non-routine discharges of chemicals and deck drainage have the potential to impact on receptors which may be vulnerable to the toxicity. The receptors which have the potential to be impacted include:

- water quality
- plankton
- fish
- marine mammals
- marine reptiles.

<u>*Plankton, Fish and Marine Mammals and Reptiles*</u>

Plankton, including fish and coral larval, may be exposed to discharges exceeding 70.5 ppb within close proximity of the discharge point. However, given the small volumes released and rapid dilution within the mixing zone, the proportion of the plankton population exposed to PNEC is expected to be negligible when considering total plankton biomass in the Scarborough Project Area and wider environment.

Toxicological effects from firefighting foams is typically only associated with prolonged or frequent exposures, such as on land and in watercourses near firefighting training areas (McDonald et al., 1996; Moody and Field, 2000). Ongoing testing by the United States Fish and Wildlife Service (FWS) found that wetting agents and fluorine-free foams have a higher acute toxicity than AFFF agents but are still considered 'lightly to practically non-toxic' on the FWS scale (USDAFS, 2000).

Foam agents that do not contain fluorinated surfactants usually contain higher concentrations of hydrocarbon surfactants and solvents, in order to compensate for the lack of film formation; which are generally more toxic in aquatic systems (IFSEC Global, 2008). The AFFF agents were the least toxic of the foam concentrates tested (an order of magnitude lower in toxicity than the fluorine-free foams) and are considered practically non-toxic to relatively harmless, according to the FWS scale (USDAFS, 2000).

Early life stages of fish (embryos, larvae) and other plankton would be the most susceptible organisms to toxic exposure from chemicals and hydrocarbons present in the deck discharges, as they have limited mobility and are therefore likely to be exposed to the plume at the discharge points, if present. However, 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 (UNEP, 1985).

As discharges of chemicals and deck drainage are expected to be infrequent, of low volumes (~5 m^3 for fire system testing) and rapidly disperse, it is not expected that any impacts will occur to transient, EPBC-listed species. It is also expected that effects on planktonic communities, if any, would be very localised and of a short-term nature (i.e. negligible).

Due to the negligible proportion of plankton impacted, indirect impacts to higher trophic levels (e.g. through predation) are unlikely. On this basis the impact to these species from Scarborough is negligible, and not evaluated further.

KEFs

Given the impacts are restricted to surface waters in the immediate vicinity of the discharge, benthic species have not been considered. On this basis, the KEFs within the Project Area have not been identified at risk as the values associated with these KEFs related to the attributes of the demersal habitats and features.

Table 7.25 outlines the potential impacts to receptors associated with routine and non-routine discharges of deck drainage and treated bilge.

Table 7.25: Receptor/impact matrix after evaluation of context

	Receptor					
Impacts	*Water Quality*	*Plankton*	*Fish*	*Marine Mammals*	*Marine Reptiles*	*KEFs*
Change in water quality	✓					X
Injury/mortality to fauna		X	X	X	X	

Detailed Impact Evaluation

For each of the receptors identified for detailed evaluation, the criteria for acceptability as defined in Table 6.3 have been considered and addressed in the following sections. This includes to meet the principles of ESD, internal and external context and any other requirements.

Water Quality

Deck drainage and treated bilge may contain a range of chemicals, oil, grease and solid material. This particulate matter can cause an increase in the turbidity of the receiving waters close to the point of discharge. The additions of these substances into the marine environment will result in a change ambient water quality, however, as outlined above these discharges are expected to rapidly dilute in the water column (Shell, 2010). Discharges will disperse and dilute rapidly, with concentrations significantly dropping with distance from the discharge point.

Non-process chemicals (such as biocides, corrosion inhibitor and cleaning fluids) will be of low concentrations and volumes and are expected to disperse rapidly.

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.

The stationary facilities are located >375 km from the closest shore. While the pipelay, dredging and support vessels will be closer to shore and in shallower waters during trunkline installation and dredging, these activities are of shorter duration, and most of these vessels are smaller and will generate less deck drainage and bilge. Also, vessels are typically moving during the discharge of treated bilge, which promotes mixing and dilution.

Within the Project Area, where discharges are to occur, the environmental performance outcome for water quality is to not result in a substantial change to water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. Given the typically low levels of potential contaminants, relatively small and infrequent volumes of chemicals and deck drainage water discharged, and rapid mixing, biodiversity, ecological integrity, social amenities and human health will not be impacted.

Vessel operations undertaken as a part of this activity will adhere to the *Navigation Act 2012*, MARPOL and the various Marine Orders (as appropriate to vessel class) enacted under this Act. This Act implements into Australian law Australia's obligations under the International Convention for the Prevention of Pollution from Ships (MARPOL Convention).

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to water quality. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered.

Based on the detailed evaluation, the magnitude of potential impact of a change in water quality is no lasting effects and is evaluated to be **acceptable**.

7.1.8.3 Impact Significance Evaluation

Impacts from routine and non-routine chemicals and deck drainage will have no lasting effect on receptors. When considered with receptor sensitivity, Impact Significance Level of routine and non-routine chemicals and deck drainage discharges from Scarborough have been evaluated as **Negligible (F)**. The impacts overall have been determined as **acceptable** based on an evaluation against the criteria.

To meet the principles of ESD

- Discharges are non-continuous and infrequent, and due to the small volumes of discharge, high level of dispersion and rapid reduction in toxicity to below PNEC within close proximity to the discharge source, pose no lasting effect to receptors. Discharge plumes are not expected to accumulate in the water column or intersect with the benthic environment.
- The contribution of chemicals and deck drainage discharge from Scarborough will be comparable with existing vessels and facilities on the North West Shelf, and not result in a notable change to the water quality of the wider area.
- Impacts to surface dwelling species including fish, cetaceans and marine reptiles via toxicity is not expected, and does not pose any lasting effect. Due to the highly localised nature of impacts to planktonic species (prey), any impacts from chemicals and deck drainage bilge discharge to ecological pelagic receptors are considered unlikely.

Internal Context

- With respect to routine and non-routine discharges of brine and cooling water, Woodside will implement its internal requirement:

- Chemicals must be selected with the lowest practicable environmental impacts and risks subject to technical constraints.

External context

- No stakeholder concerns have been raised with respect to routine and non-routine discharges of chemicals and deck drainage or potentially impacted receptors.

Other requirements

- Vessel operations undertaken as a part of this activity will adhere to the *Navigation Act 2012*, MARPOL and the various Marine Orders (as appropriate to vessel class) enacted under this Act. This Act implements into Australian law Australia's obligations under the International Convention for the Prevention of Pollution from Ships (MARPOL Convention).
- With respect to routine and non-routine discharges of chemicals and deck drainage, activities associated with Scarborough 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.

7.1.8.4 Summary of the Impact Assessment

Table 7.26 provides a summary of the risk assessment and acceptability for impacts from deck drainage and treated bilge to receptors.

Table 7.26: Summary of impacts, management controls, impact significance ratings and EPOs for deck drainage and treated bilge

Receptor	Impact	Environmental Performance Outcome	Adopted control(s)	Receptor sensitivity level	Magnitude	Consequence	Acceptability
Water quality	Change in water quality	**EPO2:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM14:** Compliance with relevant MARPOL, Commonwealth requirements and subsequent Marine Order requirements for waste discharges. **CM15:** Implementation of waste management procedures which provide for safe handling and transportation, segregation and storage and appropriate classification of all waste generated.	Low value (open water)	No lasting effect	Negligible (F)	Acceptable

7.1.9 Routine and Non-Routine Discharges: Brine and Cooling Water

7.1.9.1 Sources of the Aspect

Activities and facilities associated with the development of Scarborough will routinely and non-routinely discharge brine and cooling water to the marine environment at the sea surface. Brine and cooling water will be discharged during:

- vessel operations
- MODU operations
- FPU operations.

Vessel, FPU and MODU Operations

<u>Brine</u>

Reverse osmosis (RO), distillation or desalination plants on board vessels, the MODU and FPU use seawater to produce potable and demineralised water; resulting in reject brine (i.e. hypersaline water) that is discharged to the marine environment. The potable water produced is stored in tanks on board.

During the distillation process, relatively small volumes of reject brine is produced and discharged. Reject brine discharge is typically 20 to 50 percent higher in salinity than the intake seawater (depending on the desalination process used) and may contain low concentrations of scale inhibitors and biocides, which are used to avoid fouling of pipework (Woodside, 2014).

Reject brine water will be discharged throughout all phases of Scarborough. Quantities, source and location will vary depending on the phase of the development. Models developed by the US EPA (Frick et al., 2001) for temporary brine discharges from vessels assuming no ocean current (i.e. 0 m/s) found that brine discharges from the surface dilute 40–fold at 4 m from the source. This modelling can be used as an indicator for predicting horizontal attenuation and diffusion of reject brine; and suggests that the salinity concentration drops below environmental impact thresholds within 4 m of the discharge point.

<u>Cooling Water</u>

The machinery systems fitted on board vessels, MODUs and FPUs are designed to work with maximum efficiency and run for long hours. Significant energy loss from machinery can be in the form of heat energy. This loss of heat energy must be reduced or carried away by a cooling media, such as central cooling water system, to avoid malfunctioning or breakdown of the machinery.

Seawater is used as a heat exchange medium for cooling machinery engines and other equipment. Seawater is drawn up from the ocean, where it is subsequently de-oxygenated and sterilised by electrolysis (by release of chlorine from the salt solution) and then circulated as coolant for various equipment through the heat exchangers (in the process transferring heat from the machinery), prior to being discharged to the ocean. Upon discharge, it will be warmer than the ambient water temperature. Cooling water is often treated with additives including scale inhibitors and biocide to avoid fouling of pipework. Scale inhibitors and biocide are usually used at low dosages, and are usually consumed in the inhibition process, so there is little or no residual chemical concentration remaining upon discharge.

In some instances, fresh water or central cooling systems may be fitted. In these systems, fresh water is used in a closed circuit to cool down the engine room machinery, and then further cooled by sea water in a seawater cooler.

Seawater used for cooling purposes from the FPU will be routinely discharged overboard from either the surface or at a point below sea level (depending on final design) at a temperature expected to be less than 70°C and rates less than 200,000 m^3. Discharge volumes from vessels and the MODU will be significantly smaller, in the order of ~50 m^3/d, depending on vessel size.

It should be noted that the actual discharge rates, temperatures and concentrations discussed in this section may vary, however these values have been selected as conservative indications for the purpose of modelling the potential impacts.

Cooling Water Modelling

Modelling of the cooling water discharge from the FPU was undertaken to predict the plume size, location, concentrations of residual chlorine present, and the distance where the plume temperatures approach ambient conditions (RPS, 2019a; Appendix E). Both near-field and far-field modelling was undertaken for cooling water discharges; these are used to describe different processes and scales of effect. The near-field zone ends where the discharged plume reaches the same density as the ambient water. 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 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 (VPLUMES) modelling package provided by the United States Environmental Protection Agency (Frick et al., 2003).

The far-field mixing and dispersion of the discharges was predicted using the three-dimensional discharge and plume behaviour model, MUDMAP (RPS, 2019a). 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.

Modelling included scenarios that considered dilution contours for summer, winter, and transitional and annualised conditions. Since engineering of the cooling water system is ongoing, the following conservative discharge scenarios were selected for modelling to cover the expected range of parameters:

- Cooling water discharge rate and temperature of 165,600 m^3/d (45°C), 64,800 m^3/d (57°C) and 82,800 m^3/d (60°C)
- Discharge depths of 0 m, 10 m, and 30 m (to allow for the final design of the FPU)
- Current strengths of weak, medium and strong
- Residual chlorine source concentration of 1,000 ppb.

Near-field modelling was undertaken for all the above scenarios; a sub-set of far-field modelling scenarios were selected based on the outcomes of the near-field modelling results.

Environmental, Health and Safety Guidelines (EHS guidelines) by International Finance Corporation (IFC) recommend temperature criteria for the effluent into seawater of a 3°C maximum temperature excess above ambient at the edge of the mixing zone (IFC, 2007).

The residual chlorine guideline value for protecting aquatic ecosystems in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ, 2000) is 3 ppb. This figure was adopted as a marine low reliability trigger value, to be used only as an indicative interim working level. Therefore, a conservative threshold value of 5 ppb was used in the modelling.

In order for the source chlorine and temperature values to drop below their associated threshold values, modelling was used to estimate the distance required to reach:

- a minimum of 200-fold dilution (based on chlorine thresholds);
- a minimum of 1.7-fold dilution (based on temperature differential for the 165,600 m^3/day discharge scenario);
- a minimum of 2.3-fold dilution (based on temperature differential for the 82,800 m^3/day discharge scenario);
- a minimum of 2.2-fold dilution (based on temperature differential for the 64,800 m^3/day discharge scenario).

Near-field modelling of the cooling water discharge predicted the following (RPS, 2019a; APPENDIX F):

- The surface discharges (at 0 m) increases the extent of the turbulent mixing zone and travels the shortest horizontal distance. Following the initial mixing, the positively-buoyant plumes are predicted to rise in the water column.
- The maximum plume depth is 14 m, 25 m and 43 m below the sea surface, for the 0 m, 10 m, and 30 m discharge depths respectively. This means that the seabed (at 930 m deep) won't be contacted by the plume.
- The diameter of the plume at the end of the near-field zone ranged from <1 m to 17 m. Increases in current speed result in a smaller plume diameter.
- For most combinations of season and discharge depth, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to plunge further and reach the trapping depth closer to the discharge point, which slows the rate of dilution. Increased current strengths increase the horizontal distance travelled by the plume.
- The required dilution factor of 200 (<5 ppb) for total chlorine was not achieved for any of the scenarios by the end of the near-field mixing zone. Some failures to reach the required threshold concentration and temperature are attributable to the plume rapidly breaking the surface (for surface discharges).
- The temperature differential of <3^o was achieved by all of the 30 m discharge depth scenarios, and by the 10 m scenario for the lowest temperature plume (45^o). The discharge at surface (0 m) did not achieve the temperature difference threshold in any of the plume temperatures modelled.

Based on these nearfield results, a subset of four scenarios were selected to run far-field modelling on, to cover the full range of discharge flows and depths:

- Cooling water discharge rate and temperature of 165,600 m^3/d (45^{o}C) and 64,800 m^3/d (57^{o}C)
- Discharge depths of 0 m and 30 m

Far-field modelling of the cooling water discharge predicted the following (RPS, 2019a; APPENDIX F):

- The discharge plume pooled under weak currents, which caused lower dilutions (higher concentrations) further from the discharge location.
- 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.

- The worst-case maximum horizontal distance, and the total area of coverage until dilution was achieved for chlorine was for the 165,600 m^3 scenario at a depth of 30 m; of 6.39 km (100th percentile); and a total area of coverage of 33.37 km^2.
- The maximum depth of the plume (from any scenario) from the discharge location was 38 m.
- The worst-case maximum horizontal distance until the △3°C temperature differential is met was 345 m (discharge of 165,600 m^3 at a depth of 30 m scenario).

Far-field modelling results for chlorine are summarised in Table 7.27 and for temperature in Table 7-29. 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 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.

Table 7.27: Far-field modelling estimates of distance required to reach dilution requirement for chlorine (RPS, 2019a)

Discharge Rate: 165,600 m^3/day; Temperature: 45°C; Depth: 0 m		
Percentile	**95th**	**99th**
Maximum horizontal distance till dilution is achieved (km)[1]	0.64	1.79
Total area of coverage till dilution is achieved (km^2)[1]	0.528	4.409
Maximum depth from discharge (m)	8	
Discharge Rate: 165,600 m^3/day; Temperature: 45°C; Depth 30 m		
Percentile	**95th**	**99th**
Maximum horizontal distance till dilution is achieved (km)[1]	0.77	2.47
Total area of coverage till dilution is achieved (km^2)[1]	0.70	5.48
Maximum depth from discharge (m)	38	
Discharge Rate: 64,800 m^3/day; Temperature: 57°C; Depth: 0 m		
Percentile	**95th**	**99th**
Maximum horizontal distance (m) till dilution is achieved (km)[1]	0.18	0.62
Total area of coverage till dilution is achieved (km^2)[1]	0.05	0.37
Maximum depth from discharge (m)	6	
Discharge Rate: 64,800 m^3/day; Temperature: 57°C; Depth: 30 m		
Percentile	**95th**	**99th**
Maximum horizontal distance till dilution is achieved (km)[1]	0.21	0.63
Total area of coverage till dilution is achieved (km^2)[1]	0.07	0.55
Maximum depth from discharge (m)	38	

[1] *Value shown is from the worst-case season*

Table 7.28: Far-field modelling estimates of distance required to reach dilution requirement for temperature (RPS, 2019a)

Discharge Rate: 165,600 m^3/day; Temperature: 45°C; Depth: 0 m		
Percentile	**95th**	**99th**
Maximum horizontal distance till dilution is achieved (km)[1]	<0.04	0.09
Discharge Rate: 165,600 m^3/day; Temperature: 45°C; Depth 30 m		
Percentile	**95th**	**99th**
Maximum horizontal distance till dilution is achieved (km)[1]	<0.04	0.12
Discharge Rate: 64,800 m^3/day; Temperature: 57°C; Depth: 0 m		
Percentile	**95th**	**99th**
Maximum horizontal distance (m) till dilution is achieved (km)[1]	<0.04	<0.04
Discharge Rate: 64,800 m^3/day; Temperature: 57°C; Depth: 30 m		
Percentile	**95th**	**99th**
Maximum horizontal distance till dilution is achieved (km)[1]	<0.04	0.09

[1] Value shown is from the worst-case season

7.1.9.2 Impact or Risk

Routine and non-routine discharges of brine and cooling water from the sources described above will result in the following impacts:

- change in water quality
- change in sediment quality
- injury/mortality to marine fauna.

Change in Water Quality

The key physicochemical stressors that are associated with reject brine and cooling water discharge include salinity, pH, temperature and chemical toxicity.

Water quality of the surrounding environment may be altered through the addition of chemicals and an increase in salinity. Scale inhibitors and biocides are commonly used within the systems described above to prevent fouling. Scale inhibitors are typically low molecular weight phosphorous compounds that are water-soluble, and only have acute toxicity to marine organisms about two orders of magnitude higher than typically used in the water phase (Black et al., 1994). The biocides typically used in the industry are highly reactive and degrade rapidly (Black et al., 1994).

The potential impacts on water quality due to cooling water discharge include chlorine toxicity and increased water temperatures.

As such, any potential impacts to water quality are expected to be limited to the source of the discharge where concentrations are highest.

Change in Sediment Quality

Increased salinity and other toxins from chemical additives in brine and cooling water discharges could potentially accumulate in benthic sediments, causing changes to sediment quality. Any potential impacts to sediment quality are expected to be limited to within the vicinity of the discharge source where concentrations of contaminants are highest.

Injury/Mortality to Marine Fauna

Changes in salinity as a product of routine discharges of cooling and brine water, can affect the ecophysiology of marine organisms. Most marine species can tolerate short-term fluctuations in salinity in the order of 20% to 30% (Walker and McComb, 1990) as well as temperature changes.

Receptors Potentially Impacted

Routine and non-routine discharges of brine and cooling water have the potential to impact on receptors which may be vulnerable to the changes in salinity or temperature, or toxicity of chemical additives. The receptors which have the potential to be impacted include:

- water quality
- sediment quality
- plankton
- epifauna and infauna
- fish
- marine mammals
- marine reptiles.

Fish, Marine Mammals and Marine Reptiles

As a result of a change in water quality, further impacts to receptors may occur, which include injury or mortality to marine fauna resulting from increases in salinity and changes in temperature, or exposure to toxins or chemicals in the reject brine or cooling water. Given surface discharges are rapidly dispersed, the marine fauna at risk is limited to surface-dwelling species.

The effect of chlorine on marine organisms is well known, given its 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. Lethal concentrations required for juvenile Atlantic fish (550 -650 ppb) would only be present in the immediate vicinity of the discharge point (Capuzzo et al. 1977). In addition, Abarno and Miossec (1992) suggest that mobile organisms such as fish and marine mammals and reptiles may detect and avoid areas with low levels of chlorine. The reactive compounds of chlorine do not persist long in the marine environment.

Elevated water temperatures have the potential to induce minor physical stress in marine fauna and may result in potential mortality for prolonged exposure.

The modelling of FPU cooling water discharge predicted the maximum horizontal distance from the source until the chlorine dilution factor was achieved is 6.39 km and a maximum plume depth was 38 m, therefore presenting a shallow field for individuals to transit through (RPS, 2019a).

Discharge plume temperature drops rapidly in the marine environment. For most discharge scenarios, the temperature differential (<3^{o}) is achieved within the near-field zone; and the worst-case for far-field is within 345 m. The plume is positively-buoyant, therefore demersal and pelagic species are unlikely to be exposed to worse than near-ambient temperatures.

Due to the relatively inert properties and low concentrations of scale inhibitors and biocides within the brine and cooling water discharge, the high level of dilution and mixing within the receiving offshore environment as well as the relatively resistant nature of pelagic species to increased temperatures and their expected avoidance of discharge plumes, impacts to pelagic species associated with injury or death are not expected.

Although fish, marine mammals and marine reptiles may be present within receiving waters, it is unlikely that large numbers of individuals will occur within close proximity of the release point and therefore be exposed to above exposure thresholds. The expected volumes of discharges would not be significant enough to cause any notable impact to transient marine fauna, in the well-mixed marine environment. As such impacts to fish, marine mammals and reptiles has not been evaluated further.

Key Ecological Features

The Offshore Project Area occurs within the Exmouth Plateau KEF. The Exmouth Plateau is defined as a KEF as it is a unique seafloor feature with ecological properties of regional significance, which apply to both the benthic and pelagic habitats within the feature. Therefore, as a result of a change in sediment quality and/or water quality, potential impacts to this KEF may occur.

There is no solids component in the brine and cooling water discharge, and therefore no smothering or alteration of the seabed is expected to occur.

Based on impact evaluations for water and sediment quality, the discharge of brine and cooling water is expected to result in a relatively small area of impact around the FPU or MODU. The change to water quality resulting from discharges will be temporary and habitat or ecosystem function or integrity will not be impacted. As such, no subsequent impacts to benthic or pelagic habitats are expected to occur and this has not been evaluated further.

Table 7.29 outlines the potential impacts to receptors associated with routine and non-routine discharges of brine and cooling water.

Table 7.29: Receptor/impact matrix after evaluation of context

	Receptor							
Impacts	Water Quality	Sediment Quality	Plankton	Epifauna and Infauna	Fish	Marine Mammals	Marine Reptiles	Key Ecological Features
Change in water quality	✓							X
Change in sediment quality		✓						X
Injury/mortality to fauna			✓	✓	X	X	X	

Detailed Impact Evaluation

For each of the receptors identified for detailed evaluation, the criteria for acceptability as defined in Table 6.3 have been considered and addressed in the following sections. This includes to meet the principles of ESD, internal and external context and any other requirements.

Water Quality

Reject brine water is typically 20–50% higher in salinity to the surrounding water and based on models developed by the US EPA (Frick et al., 2001), discharges of brine water will sink through the water column where it will be rapidly mixed with receiving waters and dispersed by ocean currents, decreasing in salinity rapidly as distance from source increases.

Generally, reject brine and cooling water containing chemical additives are inherently safe at the low dosages used. They are usually consumed in the inhibition process, so there is little or no residual chemical concentration remaining upon discharge.

The volume of brine discharged from vessel and FPU operations for Scarborough is orders of magnitude lower than that discharged for large commercial desalination plants. For example, the Water Corporation's Burrup Peninsula Desalinated Water and Seawater Supplies Project has conditional approval to discharge 208 ML/day (208,000 m^3) into King Bay; and the Southern Seawater Desalination Plant (SSDP) located south of Perth is licenced to discharge 170 GL/year.

Water quality monitoring at the SSDP found that salinity was within 1 ppt of background concentration at the boundary of the LEPA (Water Corporation, 2017). Monitoring at the Large desalination facilities in the Canary Islands and Spain found rapid dilution of salinity, temperature, pH and chemicals to near-ambient levels was generally recorded in the near-field region (i.e. 10 m to 20 m) around the outfalls. Models developed by the US EPA suggested that the salinity concentration drops below environmental impact thresholds within 4 m of the discharge point (Frick et al., 2001).

This prediction is supported by modelling undertaken by Woodside for its Torosa South-1 drilling program in the Scott Reef complex of continuous wastewater discharges (including cooling water) (Woodside, 2014). This study predicted that discharge water temperature decreases quickly as it mixes with the receiving waters, with the discharge water temperature being <1 °C above ambient within 100 m (horizontally) of the discharge point, and 10 m vertically (Woodside, 2014).

Modelling of the long-term routine cooling water discharge from the FPU predicted that the worst-case maximum horizontal extent until dilution factors were achieved was 6.39 km for chlorine (or 33.37 km^2), and 345 m for temperature.

As such, any potential impacts to water quality are expected to be limited to 6.39 km of the source of the discharge where concentrations are highest (Figure 7.14).

Within the Project Area, where discharges are to occur, the environmental performance outcomes are to not result in a substantial change to water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. Given the typically low levels of potential contaminants, rapid mixing, changes in water quality due to discharge of brine and cooling water from the FPU, MODU and vessels will not be inconsistent with this performance outcome.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to water quality. Activities are not proposed to take place within or adjacent to any AMPs.

Based on the detailed risk evaluation, the magnitude of the potential impact of a change in water quality from routine and non-routine brine and cooling water discharges is assessed as no lasting effect and is considered **acceptable**.

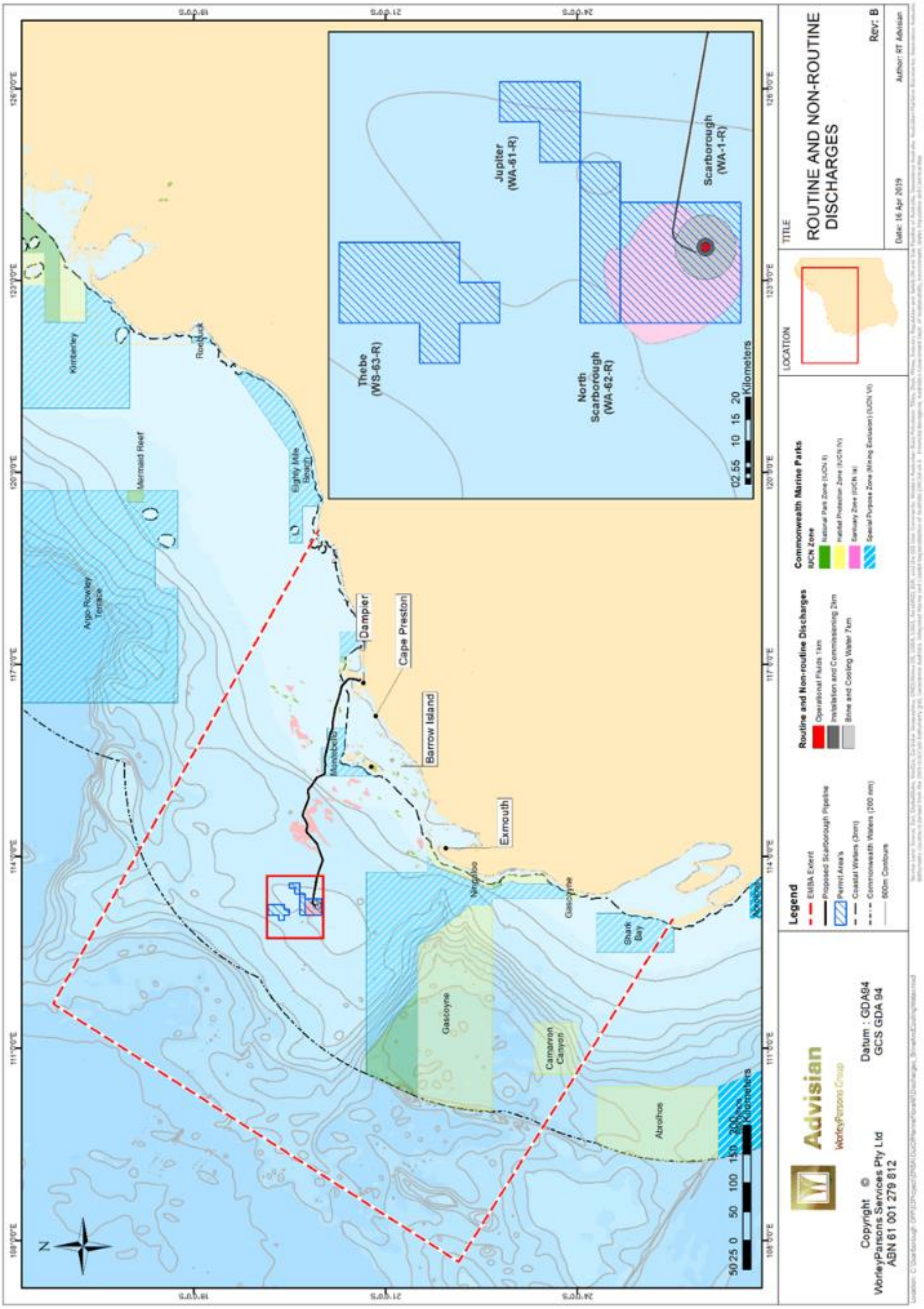


Figure 7.14: Predicted mixing zone for brine and cooling water discharge (light grey shading) associated with the FPU operations

Sediment Quality

Any potential impacts associated with routine brine and cooling water discharges will be limited to the area surrounding the discharge source of the vessel, MODU or FPU. The stationary facilities and many of the support vessels will be concentrated around the well locations, which is approximately 900 m deep and >375 km from shore.

Modelling suggests that cooling water plumes will not reach the seabed due to the water depth of which the FPU operates (approximately 930 m), as the maximum plume depth of the worst-case cooling water scenario modelled is predicted to be 38 m (RPS, 2019).

Due to the dispersive nature of chemical discharges within the highly mixed offshore marine environment, toxins associated with these surface discharges are not expected to reach marine sediments at concentrations that will result in notable changes to sediment quality.

The marine sediment within the Project Area bare sandy/silt and calcareous ooze and is reflective of the broader sediment found on the Exmouth Plateau and the deep-water environment of the NWMR. Within the Project Area, where discharges are to occur, the environmental performance outcome for marine sediment is to not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. Given the relatively small volumes and area of impact, the offshore location and the low sensitivity of marine sediment in the Project Area, biodiversity, ecological integrity, social amenities and human health will not be impacted.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to water quality. In addition, the activity is not proposed to take place in any AMPS, and as such there are no specific principles, objectives and values to be considered.

Based on the detailed risk evaluation, the magnitude of the potential impact of a change in sediment quality from routine and non-routine brine and cooling water discharges is assessed as negligible and is considered **acceptable**.

Plankton

Larval plankton stages are known to be more susceptible to impacts of increased salinity than that of most marine life (Neuparth, Costa & Costa, 2002). Early life stages of fish (embryos, larvae) and other plankton would also be most susceptible to toxic exposure from chemicals in the brine discharges, as they have limited mobility and are therefore likely to be exposed to the plume at the outfall, if present. However, 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 (UNEP, 1985).

Discharged brine sinks through the water column where its rapidly mixed with receiving waters and dispersed by ocean currents. In addition, brine discharges from vessels, particularly along the pipeline corridor, are expected to occur while in transit, therefore aiding in dispersion and reducing overall impacts to plankton populations. As such, any potential impacts are expected to be limited to the source of the discharge where concentrations are highest. Modelling described above suggests that the salinity falls below impact threshold levels (40-fold dilution) within 4 m of the discharge point. This is confirmed by studies that indicate effects from increased salinity on planktonic communities in areas of high mixing and dispersion are generally limited to the point of discharge only (Azis et.al., 2003).

Modelling of the long-term routine cooling water discharge from the FPU predicted that the worst-case maximum horizontal extent until the chlorine dilution factor was achieved was 6.39 km, for surface discharge scenarios. The worst-case extent for the 0 m discharge depth scenarios was estimated at 4.7 km; as the plume is positively buoyant, once it surfaces, dispersion is reduced. Therefore, for surface discharges, the potential to interact with plankton in the water column is reduced. Even for the 30 m discharge depths, the plume is only predicted to plunge to a maximum depth of 38 m, so the exposure to the 930 m deep water column at the FPU site is limited to only the surface extent.

Increased water temperatures are only expected to extend approximately 345 m for the worst-case discharge from the source. As discussed in Section 5, planktonic productivity in the NW region is low. Any reductions of existing populations are expected to rapidly recover once the activity ceases, given the high levels of natural mortality and a rapid replacement rate (UNEP, 1985). As such, exposure of planktonic communities is not considered to result in significant impacts on a population level nor would exposure affect ecological diversity or productivity within the Project Area. Impacts are therefore considered to result in undetectable or limited local degradation of the environment, rapidly returning to original state by natural action.

As plankton productivity in the Offshore Project Area is low (ERM, 2013), and due to the relatively small area of impact, exposure of planktonic communities to brine and cooling water is not considered to result in significant impacts on a population level, nor organisms that would affect ecological diversity or productivity within Commonwealth marine areas.

To better understand the impact of localized plankton mortality at larger spatial scales, CSIRO (Richardson et al., 2017) simulated the large-scale impact of zooplankton mortality assuming mortality rates associated with airgun exposure reported by McCauley et al. (2017). Richardson et al. (2017) simulated the impact over 35 days, across an area typical of a seismic survey (survey area of ~2900 km^2), and in 300 m to 800 m water depths. Zooplankton growth, movement by currents, and mixing of populations over the entire region were included in the model.

Richardson et al. (2017) reports a maximum decline of 22% and 14% in zooplankton populations in the survey area, and within 15 km of the survey area, respectively. However, impacts were not discernible over the entire Northwest Shelf Bioregion. Within the survey area (where decline was greatest) zooplankton populations recovered to pre-survey levels within three days, which was attributed to their fast growth rates, and the dispersal and mixing of zooplankton from both inside and outside of the impacted region.

Therefore, due to the likely undetectable or limited local degradation of the environment and expected rapid return to original state by natural action, the impacts to plankton from routine and non-routine discharges of brine and cooling water is assessed as no lasting effect Slight (E) and is considered **acceptable**.

Epifauna and Infauna

As a result of a change in sediment or water quality, further impacts to benthic habitat receptors may occur, which include injury or mortality to benthic epifauna and infauna resulting from the increased (water) or accumulation (sediment) of salinity or other toxins.

Any potential impacts associated with routine brine and cooling water discharges will be limited to the area surrounding the discharge source of the vessel, MODU or FPU. The stationary facilities and many of the support vessels will be concentrated around the well locations, which is approximately 900 m deep and >375 km from shore.

Modelling suggests that cooling water plumes will not reach the seabed due to the water depth of which the FPU operates (approximately 930 m), as the maximum plume depth of the worst-case cooling water scenario modelled is predicted to be 38 m (RPS, 2019).

Due to the dispersive nature of chemical discharges within the highly mixed offshore marine environment, toxins associated with these surface discharges are not expected to reach benthic waters or marine sediments.

Therefore, impacts to benthic habitats from routine and non-routine discharges of brine and cooling water are assessed as no lasting effect Slight (E) and is considered **acceptable**.

7.1.9.3 Impact Significance Evaluation

Impacts from routine and non-routine discharges or brine and cooling water will have no lasting effect on receptors. When considered with receptor sensitivity, Impact Significance Level of routine and non-routine discharges or brine and cooling water have been evaluated as **Negligible (F)**. The impacts overall have been determined as acceptable based on an evaluation against the criteria.

To meet the principles of ESD

- Monitoring of other projects predict that a near-ambient levels of salinity, temperature, pH and chemicals are likely to be achieved very close to the discharge points (Frick et. al, 2001; Woodside, 2014).
- Modelling of the FPU cooling water discharge predicted the worst-case maximum horizontal extent until threshold dilution factors were achieved was 6.39 km for chlorine, and 345 m for temperature. The plume is positively buoyant, and is not predicted to go deeper than 38
- Due to the rapid dispersion of brine; and the positively-buoyant nature of cooling water, the discharge plumes will remain shallow and will not interact with the bulk of the water column, nor reach the seabed (in particular, at the FPU location).
- The contribution of brine and cooling water from Scarborough will be comparable with existing vessels and facilities on the North West Shelf, and not result in a notable change to the water quality of the wider area.
- Given the typically low levels of potential contaminants, relatively rapid mixing for brine and for the deeper cooling water discharges, changes in water quality due to discharge of brine and cooling water from the FPU, MODU and vessels will not be inconsistent with environmental performance outcomes.
- Impacts to surface-dwelling species including fish, cetaceans and marine reptiles via toxicity is not expected, and does not pose any lasting effect. Due to the highly localised nature of impacts to planktonic species (prey), any impacts from routine brine and cooling water to ecological pelagic receptors are considered unlikely.
- Given the rapid dispersal of brine in deep-water environments, minimal intersection of the FPU cooling water plume with the water column, the rapid lowering of discharge plume temperature, and relatively quick recovery times of plankton, discharges of brine and cooling water from Scarborough are not expected to have a substantial adverse effect on plankton life cycle and spatial distribution, and will pose no lasting effect.

Internal context

- With respect to routine and non-routine discharges of brine and cooling water, Woodside will implement its internal requirement:
  - Given the typically low levels of potential contaminants, rapid mixing, changes in water quality due to discharge of brine and cooling water from the FPU, MODU and vessels will not be inconsistent with performance outcomes.
  - Chemicals must be selected with the lowest practicable environmental impacts and risks subject to technical constraints.

External context

- No stakeholder concerns have been raised with respect to routine and non-routine discharges from subsea installation and commissioning, or potentially impacted receptors.

Other requirements

- With respect to routine and non-routine discharges of brine and cooling water, activities associated with Scarborough 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.

7.1.9.4 Summary of the Impact Assessment

Table 7.30 provides a summary of the risk assessment and acceptability for impacts from discharges of brine water and cooling water on receptors.

Table 7.30: Summary of impacts, key management controls, acceptability, EPOs and residual risk rating for brine and cooling water

Receptor	Impact	Environmental Performance Outcome	Adopted Control(s)	Receptor sensitivity	Magnitude	Risk rating	Acceptability
Water quality	Change in water quality	**EPO2:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM16:** Chemicals will be selected with the lowest practicable environmental impacts and risks subject to technical constraints.	Low value (open water)	No lasting effect	Negligible (F)	Acceptable
Sediment quality	Change in sediment quality	**EPO3:** To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		Low value (open water)	No lasting effect	Negligible (F)	Acceptable
Plankton	Injury/ mortality to fauna	**EPO6:** To not have a substantial adverse effect on a population of plankton including its life cycle and spatial distribution.		Low value (open water)	No lasting effect	Negligible (F)	Acceptable
Epifauna and Infauna	Injury/ mortality to fauna	**EPO1:** 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.		Low value (open water)	No lasting effect	Negligible (F)	Acceptable

7.1.10 Routine and Non-Routine Discharges: Operational Fluids

7.1.10.1 Sources of the Aspect

Activities and facilities associated with Scarborough will routinely and non-routinely discharge operational fluids. Discharges will be made during:

- hydrocarbon extraction
- hydrocarbon processing.

Hydrocarbon Extraction

During operations, the flow rate of hydrocarbons through flowlines will be controlled at the wellhead. The wellheads and manifolds will be connected to umbilicals to support the operation. Subsea control fluids will be supplied through these umbilicals and used for the functioning of the choke valves by providing lubrication, corrosion protection, bacterial protection and stability with other chemicals. These fluids, including MEG, will be discharged throughout the operations phase to the marine environment at or near the seabed at volumes of about 2 L per actuation which may occur up to several times a day. It should be noted that these discharges are not continuous.

Hydrocarbon Processing

Following extraction, hydrocarbons will flow through the riser to the FPU for processing.

The liquids in the vapour phase will then be condensed to meet the requirements of the export trunkline specification, during which condensed water will be produced and discharged to the marine environment at a rate of up to approximately 285 bbl/day (45.3 m^3). Discharge will either be overboard from the surface, or from a point below the surface depending on the final design of the FPU.

Wells are not expected to produce formation water until they start to 'water out' towards the end of well life. Once they start to water out, up to approximately 200 bbl/day (31.7 m^3) of formation water may be produced. At this stage of the well life, the combined volume of condensed water and formation water (referred thereafter as produced water (PW)) is expected to be approximately 485 bbl/day (or 77 m^3). Such volume will only be generated for a limited duration, at which point the well will be shut-in. PW will be only be discharged during the operations phase of Scarborough.

The condensed water and produced formation water streams are treated onboard the FPU to remove, residual salt, MEG, mercury, scale, and fines. The PW that is discharged may contain residual amounts of MEG and corrosion inhibitor hydrocarbons (mainly dissolved), salts (soluble and precipitated) from the reservoir, fines and mercury. The discharge will dilute rapidly within the water column. Insoluble salts that may form on discharge and precipitate out will be of an inert nature and disperse rapidly in the water. Potential impacts from these chemicals are therefore expected to be lower than that predicted for residual hydrocarbons. On this basis residual hydrocarbons are the focus of the assessment of impacts from the discharge of operational fluids.

It should be noted that the actual discharge rates and concentrations discussed in this section may vary, however these values have been selected as conservative indications for the purpose of modelling the potential impacts.

Produced Water Modelling

PW discharges were modelled to quantify the likely extent of the discharge plume, and in particular the dilution of residual hydrocarbons in the water column (RPS, 2019b; APPENDIX G). Modelling included scenarios that considered near and far field modelling of dilution for summer, winter and transitional conditions, based on the following parameters:

- PW flow rate of 95 m^3/day (as a conservative level)
- Discharge depths of 0 m, 10 m, and 30 m (to allow for the final design of the FPU).
- Current strengths of weak, medium and strong
- Variety of plume temperatures and densities
- TPH source concentration of 29 mg/L[41].
- Impact threshold for TPH of 0.07 mg/L (set by the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ, 2000), and derived from Tsvetnenko (1998) using the USEPA methods (Stephan et al. 1985, USEPA 1994d)).

The modelling investigated specifically whether the dilution of the PW discharge would be sufficient to meet the ANZECC & ARMCANZ guideline value of 0.07 mg/L, thereby achieving dilution by a factor of 1:414.3.

Near-field modelling of the PW discharge predicted the following:

- The surface discharge increases the extent of the turbulent mixing zone, and the discharge travels the greatest lateral distance.
- Following the initial mixing, the plume is near neutrally-buoyant, and travels laterally in the water column.
- For most combinations of season and discharge depth, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to plunge further and reach the trapping depth closer to the discharge point, which slows the rate of dilution. Increased current strengths increase the horizontal distance travelled by the plume.
- The required dilution factor of 414.3 for TPH was not achieved for any of the scenarios by the end of the near-field mixing zone.
- Diameter of plume at the edge of the near-field mixing zone is in the order of a few meters, with the maximum diameter at the edge of the near-field mixing zone predicted to be approximately 4 m.
- Depth of the plume is generally between 0.1 m and 4.4 m, with the maximum plume depth predicted to be approximately 30 m.

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 0 m and 30 m scenarios were selected for far-field modelling, as the two depth extremes.

- Far-field modelling predicts the worst-case maximum exposure area is 0.7 km^2, and the maximum horizontal distance is 0.81 km.

Table 7.31: Summary of PW modelling

Discharge depth	Near-field	Far-field
0 m	• Depth of plume ranges between 0.1–4.4 m below the sea surface	• Maximum depth of the plume is 5 m below the surface.

[41] This concentration has been chosen to represent the maximum TPH concentration potentially present in the discharge stream given uncertainties around actual TPH concentration in future discharges. In implementing the activities, Woodside will however meet levels which are ALARP.

	• Maximum horizontal distance is 866 m • Diameter of plume at edge of near-field mixing zone ranges between 0.4–3.7 m • Average dilution factors are 1:1519 – 1:140	• Maximum horizontal distance is 543 m. • The maximum area of exposure is 0.48 km^2.
10 m	• Depth of plume is 9–11 m below the surface • Maximum horizontal distance is 123 m • Diameter of plume at end of near-field zone is 0.5–1.8 m • Average dilution factors 1:88–1:140	• N/A
30 m	• Depth of plume is 29–31 m below the surface • Maximum horizontal distance is 123 m • Diameter of plume at end of near-field zone is 0.6–1.7 m • Average dilution factors are 1:43–1:181	• Maximum depth of the plume is 33 m below the surface. • Maximum horizontal distance is 810 m. • The maximum area of exposure is 0.7 km^2.

[1] *Value shown is from the worst-case season*

7.1.10.2 Impact or Risk

Routine and non-routine discharges of operational fluids from the above activities to the marine environment has the potential to result in the following impacts to receptors:

- change in water quality
- change in sediment quality
- injury/mortality to fauna
- change in habitat
- changes to the functions, interests or activities of other users.

Change in Water Quality

A change in water quality may occur subsea around the well head during hydrocarbon extraction or at the surface during hydrocarbon processing. The key physio-chemical stressors associated with operational fluid discharges is toxicity.

Change in Sediment Quality

A change in sediment quality may occur subsea around the well head during hydrocarbon extraction. The key physio-chemical stressors associated with operational fluid discharges is toxicity.

Injury/Mortality to Fauna

As a result of a change in water quality, further impacts to receptors may occur, which include injury or mortality to marine fauna resulting from exposure to toxins or chemicals associated with the discharge of operational fluids.

Following a discharge of subsea control fluids, the marine fauna most at risk are expected to dwell at or near the seabed within both the water column and sediment. Due to the relatively small volumes of discharges per actuation (~2 L), control fluids are expected to disperse and dilute rapidly. As discharges will occur individually (no continuous flow) and based on the low toxic nature of the chemicals, it is likely that any impacts to marine fauna will be negligible.

As outlined above, PW contains some toxic components, which have the potential to result in injury or mortality of marine fauna. PW will be discharged at or relatively near the surface (0 – 30 m), therefore marine fauna most likely to be impacted by the plume are expected to dwell in surface waters. As previously discussed, modelling for PW indicates that the ANZECC & ARMCANZ guideline value of 0.07 mg/L for TPH will be reached at a maximum horizontal distance of 0.81 km from the discharge source, the plume being of a relatively narrow diameter and potentially extending to a maximum of 33 m below the surface. Impacts to fauna as a result of toxicity from hydrocarbons within the water column are therefore restricted within this range of the discharge source.

Change in habitat

As a result of a change in sediment quality and/or water quality, further impacts to receptors may occur, which include a change in habitat resulting from smothering and alteration of the seabed, or exposure to toxins or chemicals in the operational fluids discharges.

Change to the Functions, Interests or Activities of Other Users

As a result of impacts to fish species from routine and non-routine discharges of operational fluids, fisheries which operate in the area have the potential to be impacted via a reduction in fish stocks.

Receptors Potentially Impacted

Routine and non-routine discharges of operational fluids have the potential to impact on receptors which may be vulnerable to toxicity. The receptors which have the potential to be impacted include:

- water quality
- sediment quality
- plankton
- epifauna and infauna
- fish
- marine mammals
- marine reptiles
- Key Ecological Features
- Commonwealth and State managed fisheries.

Fish, Marine Mammals, Marine Reptiles

The routine and non-routine discharge of operational fluids, specifically produced water, will result in a narrow plume (1 - 4 m) with the potential for levels of TPH above the ANZECC & ARMCANZ guideline value of 0.07 mg/L extending to a maximum of around 0.81 km from the source of the discharge.

This exposure area however is conservative based on the assumptions made on maximum volume of oil in water on discharge and given the discharge rates and environmental conditions modelled. It should also be noted that ongoing discharges of PW are not anticipated, as wells are expected to only produce formation water between the time they start to water out toward the end of the well life and the well is shut in.

Pelagic fish, reptiles and marine mammals traversing waters within a 0.81 km radius around the discharge point may be exposed to TPH at concentrations above the ANZECC & ARMCANZ guideline value. Injury or death to fauna is only expected as a result of prolonged exposure to operational fluid discharges. Given the limited size of the plume, and that these species will be moving through the area and are unlikely to remain still on location for extended period of times, significant impacts are not anticipated.

Several pelagic species including Blue whale and Pygmy whales, Humpback whales, marine turtle species, fish species and bird species have distribution which extends to the Offshore Project Area and may be present during activities. However, no BIAs lie within the Offshore Project Area. Due to the mobile nature of pelagic species, if exposed to operational fluid discharges, they would be subjected to a change in water quality for a very short time only as they transit through the discharge plume. As transient species, they are not expected to experience any chronic or acute toxicity effects. For this reason, and due to the lack of species BIAs within the Offshore Project Area, prolonged exposure is unlikely.

Due to the limited periods of PW discharge, the high level of mixing and resulting dilution within the receiving offshore environment, the relatively small predicted EMBA, and the low concentrations TPHs and or chemicals within the PW discharge, the impacts to mammals, reptiles and fish from operational discharges is negligible and pose no lasting effect. Planktonic species (prey) may be impacted (as discussed below) however not at a significant scale to cause impact to higher order species.

On this basis the impacts to fish, cetaceans, marine reptiles from routine and non-routine discharges of operational fluids during activities have not been evaluated further.

Commonwealth and State Managed Fisheries

Where the functions, interests or activities of other marine users involve marine fauna, any effect to fauna presence or abundance will indirectly impact on the functions, interests or activities of other users. Given that the impacts to fish have been evaluated to be unlikely, the subsequent impact to fisheries is also unlikely and not evaluated further.

Table 7.32 summarises the potential impacts to receptors associated with routine and non-routine discharges of operational fluids.

Table 7.32: Receptor/impact matrix after evaluation of context

	Receptor									
Impacts	Water Quality	Sediment Quality	Plankton	Epifauna and Infauna	Fish	Marine Mammals	Marine Reptiles	Key Ecological Features	Commonwealth managed Fisheries	State Managed Fisheries
Change in water quality	✓							✓		
Change in sediment quality		✓								
Injury/mortality to fauna			✓	✓	X	X	X			
Change in habitat								✓		
Changes to the functions, interests or activities of other users									X	X

Detailed Impact Evaluation

For each of the receptors identified for detailed evaluation, the criteria for acceptability as defined in Table 6.3 have been considered and addressed in the following sections. This includes to meet the principles of ESD, internal and external context and any other requirements.

Water Quality

The subsea control fluid being used for Scarborough is not yet known. Due to the instantaneous nature and relatively small volumes of control fluid discharges throughout the operations phase of the project and the dynamic offshore marine environment, it is expected that fluids within the water column will disperse and dilute rapidly.

Toxic additives which may be present within the PW discharge stream include MEG, scale inhibitors, biocides, corrosion inhibitors and a range of other production chemicals. MEG is an organic compound which may be present in trace volumes within the PW discharge stream. In addition, scale inhibitors are typically low molecular weight phosphorous compounds that are water-soluble, and only have acute toxicity to marine organisms about two orders of magnitude higher than typically used in the water phase (Black et al., 1994). The biocides typically used in the industry are highly reactive and degrade rapidly (Black et al., 1994).

Residual hydrocarbons will be present within the discharge stream due to lack of ability to remove all hydrocarbons during processing. TPH within the PW discharge stream are expected to be low but have conservatively been estimated at up to 29 mg/L for the purpose of impact evaluation.

An ANZECC & ARMCANZ guideline value of 0.07 mg/L has been set for TPHs. Assuming a source concentration of 29 mg/L, the discharge would have to be diluted by a factor of 1:414.3 to return to this level.

Modelling of PW discharged from the FPU predicts that PNEC will be reached within a maximum horizontal distance of 0.81 km for all conditions (RPS, 2019b; APPENDIX G). The plume will be limited to a diameter of a 1-4 m and extend to a depth of up to 30 m below the surface. Far-field modelling predicts that the maximum area of exposure is 0.7 km^2, for the worst case modelled. As such, any potential impacts to water quality are expected to be limited to within relatively close proximity of the source of the discharge where concentrations are highest (Figure 7.15).

The environmental performance outcome for water quality is to not result in a substantial change in water quality (including temperature) which may adversely impact on biodiversity, ecological integrity, social amenity or human health.

Given discharges of operational fluids are expected to result in a relatively small area of impact around the FPU, the change to water quality resulting from routine discharges of operational fluids will be temporary and habitat or ecosystem function or integrity will not be impacted.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to water quality. According to the Marine Bioregional Plan for the North-west Marine Region, and the region is widely used by a range of industries including widescale and longstanding petroleum activities.

Based on the detailed risk evaluation, the magnitude of the potential impact of a change in water quality from routine and non-routine discharges of operational fluids is assessed as slight and is considered **acceptable**.

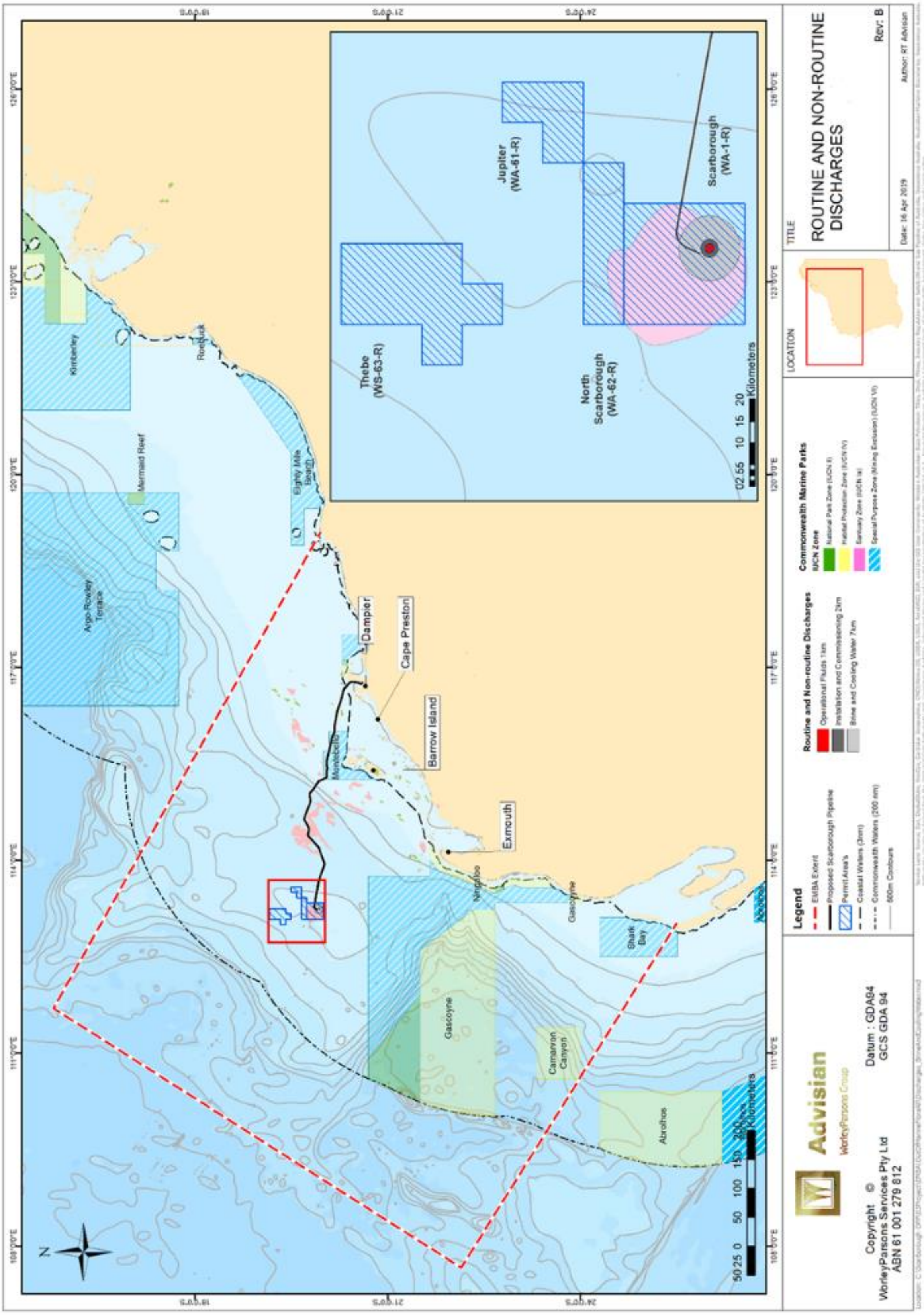


Figure 7.15: Predicted mixing zone for operational fluids (red shading) associated with the FPU operations

Sediment Quality

Modelling suggests that discharges of PW and associated toxins will not reach the seabed due to the water depth of which the FPU operates (approximately 930 m), and the dispersive nature of PW discharges in a high energy offshore marine environment such as the permit area. The maximum depth of the TPH plume is predicted to be approximately 33 m (RPS, 2019b; Appendix G).

Any solids present in the condensed water and produced formation water streams are separated out by distillation in the MEG unit and will either be discharged or collected and transported to shore for disposal (pending an ALARP analysis during Front End Engineering and Design (FEED). In addition, any residual insoluble MEG salts formed on discharge, will precipitate out of solution and are likely to be dispersed by the ocean currents. Given these salts will be inert they have not been considered further in terms of impacts to sediment quality.

A change in sediment quality has the potential to also occur due to a subsea release of control fluids during hydrocarbon extraction. Any persistent component of the control fluid may accumulate on or within the sediment profile, thus changing the chemical composition.

Subsea control fluids are discharged from the christmas trees close to the seabed. Subsea control fluids generally have inherently low toxicity, and at such intermittent, small volumes (~2 L), these fluids would disperse rapidly, and are not expected to accumulate and result in changes to the sediment quality.

The marine sediment within the Project Area bare sandy/silt and calcareous ooze and is reflective of the broader sediment found on the Exmouth Plateau and the deep-water environment of the NWMR. Within the Project Area, where discharges are to occur, the environmental performance outcome for marine sediment is to not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. Given the relatively small volumes and area of impact, the offshore location and the low sensitivity of marine sediment in the Project Area, biodiversity, ecological integrity, social amenities and human health will not be impacted.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to water quality. In addition, the activity is not proposed to take place in any AMPS, and as such there are no specific principles, objectives and values to be considered.

Based on the detailed risk evaluation, the magnitude of the potential impact of a change in sediment quality from routine and non-routine operational fluid discharges is assessed as no lasting effect and is considered **acceptable**.

Plankton

A change in water quality as a result of PW discharges has the potential to result in the injury or death of planktonic species within the water column through toxicity effects. As plankton are generally surface-dwelling organisms, subsea discharges during hydrocarbon extraction will not result in a detectable level of impact to plankton. 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 at the outfall, if present. However, 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 (UNEP, 1985).

Phytoplankton are typically not sensitive to the impacts of hydrocarbons, though they do bioaccumulate it rapidly (Hook et al., 2016). If phytoplankton are exposed to hydrocarbons, it may affect their ability to photosynthesize and therefore resulting in impacts to the next trophic level in the food chain (Hook et al., 2016). Hydrocarbons can also inhibit growth in phytoplankton, depending on the concentration range. For example, photosynthesis is stimulated by low concentrations of oil in the water column (10-30 ppb) but become progressively inhibited above 50 ppb. Conversely, photosynthesis can be stimulated below 100 ppb for exposure to weathered oil (Volkman et al., 2004). The threshold of 70 ppb (0.07 mg/L) used as the impact threshold for this assessment for TPH is therefore considered appropriate given the variability in the levels at which phytoplankton is impacted.

Zooplankton (microscopic animals such as rotifers, copepods and krill that feed on phytoplankton) are vulnerable to hydrocarbons (Hook et al., 2016). Water column organisms that come into contact with hydrocarbons risk exposure through ingestion, inhalation and dermal contact (NRDA, 2012), which can cause immediate mortality or decline in egg production and hatching rates along with a decline in swimming speeds (Hook et al., 2016).

Plankton is generally abundant in the upper layers of the water column and is the basis of the marine food web, so the presence of hydrocarbons in any one location is unlikely to have long-lasting impacts on plankton populations at a regional level. Reproduction by survivors or migration from unaffected areas is likely to rapidly replenish losses (Volkman et al., 2004). Oil spill field observations show minimal or transient effects on plankton (Volkman et al., 2004), therefore PW discharges are expected to have a lesser effect due to lower associated TPH concentrations. Once background water quality is re-established, plankton may take weeks to months to recover (ITOPF, 2011a).

Modelling predicts the threshold for TPH will be reached within approximately 0.81 km horizontally and 33 m vertically from the discharge point; and far-field modelling predicts the maximum area of exposure above the threshold is 0.7 km^2 (RPS, 2019b; Appendix G). Impacts associated with hydrocarbon exposure are therefore expected to be limited to within this range from the discharge source.

Once discharged, PW is expected to rapidly mix within receiving waters and dispersed by ocean currents. As such, any potential impacts associated with the low volumes of biocides, corrosion inhibitors and other chemical additives within the PW discharge stream are expected to be limited to the source of the discharge where concentrations are highest.

As plankton productivity in the Offshore Project Area is low (ERM, 2013), and due to the relatively small plume and rapid dispersal, exposure of planktonic communities to operational fluids is not considered to result in significant impacts on a population level, nor organisms that would affect ecological diversity or productivity within Commonwealth marine areas. Impacts are therefore considered to result in an undetectable or limited local degradation of the environment, rapidly returning to original state by natural action.

Based on the detailed risk evaluation, the magnitude of the potential impact of a change in plankton from the routine and non-routine discharges of operational fluids is assessed as slight Slight (E) and is considered **acceptable**.

Epifauna and Infauna

As a result of a change in sediment or water quality, further impacts to benthic habitat receptors may occur, which include injury or mortality to benthic epifauna and infauna resulting from the increased (water) or accumulation (sediment) of potential contaminants and toxins.

Any potential impacts associated with operational fluids discharges will be limited to the area surrounding the discharge source of the MODU or FPU. The stationary facilities will be concentrated around the well locations, which is approximately 900 m deep and >375 km from shore.

Modelling suggests that PW plumes will not reach the seabed due to the water depth of which the FPU or MODU operate (>900 m), as the maximum plume depth is predicted to be 33 m (RPS, 2019b).

Due to the dispersive nature of chemical discharges within the highly mixed offshore marine environment, toxins associated with these surface discharges are not expected to reach benthic waters or marine sediments.

Therefore, impacts to benthic habitats from routine and non-routine discharges of operational fluids is assessed as slight Slight (E) and is considered **acceptable**.

Key Ecological Features

The Offshore Project Area occurs within the Exmouth Plateau KEF. The Exmouth Plateau is defined as a KEF as it is a unique seafloor feature with ecological properties of regional significance, which apply to both the benthic and pelagic habitats within the feature. Therefore, as a result of a change in sediment quality and/or water quality, potential impacts to this KEF may occur.

There is no solids component in the operational fluids discharge, and therefore no smothering or alteration of the seabed is expected to occur.

Based on impact evaluations for water and sediment quality above, the discharge of operational fluids is expected to result in a relatively small area of impact around the FPU or MODU. The change to water quality resulting from discharges of operational fluids will be temporary and habitat or ecosystem function or integrity will not be impacted. Subsea fluids are expected to disperse rapidly and not expected to accumulate and result in changes to the sediment quality. As such, no subsequent impacts to benthic or pelagic habitats are expected to occur.

The environmental performance outcome for KEFs is 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. The only KEF which may be impacted is the Exmouth Plateau. Given the small amount of representative habitat within the KEF that will be impact from operational fluid discharges, no impacts to marine ecosystem functioning or integrity of the KEF are expected.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to KEFs. Physical habitat modification is recognised as a pressure ‘of less concern’ in the Marine Bioregional Plan for the NorthWest Marine Region (DSEWPC, 2012). In addition, the activity is not proposed to take place in any AMPS, and as such there are no specific principles, objectives and values to be considered.

Based on the detailed evaluation, the magnitude of the potential impact on the Exmouth Plateau KEF from routine and non-routine discharge of operational fluids is evaluated as no lasting effect and **acceptable.**

7.1.10.3 Impact Significance Evaluation

Impacts from routine and non-routine discharges of operational fluids will have a slight effect on receptors, as the extent, duration, frequency and scale of the impact are all sufficiently small. When considered with receptor sensitivity, Impact Significance Level of routine and non-routine discharges of operational fluids have been evaluated as **Negligible (F)**. The impacts overall have been determined as **acceptable** based on an evaluation against the acceptability criteria.

To meet the principles of ESD

- Near-field modelling of the PW discharge from the FPU predicted rapid dispersion to near-ambient levels within approximately 0.81 km, with an approximate plume diameter of 1-4 m and to a depth of 33 m. Far-field modelling predicts that the maximum area of exposure is 0.7 km^2, for the worst case modelled.
- Subsea control fluid discharge is of very small intermittent volumes and is likely to disperse almost instantaneously.

- Due to the rapid mixing and dilution of the PW discharge, and the near-neutrally buoyant nature of the plume, the maximum depth the plume reaches is approximately 33 m. As the FPU is in approximately 930m water, sediment and benthic receptors will not be impacted.
- The volumes of PW discharged from Scarborough will be comparable with existing facilities on the North West Shelf, and not result in a notable change to the water quality of the wider area.
- Given the typically low levels of potential contaminants and rapid mixing, changes in water quality due to discharge of operational fluids from the FPU will not be inconsistent with performance outcomes.
- Given the rapid dispersal of the PW in deep-water environments, the small plume diameter, rapid dispersal to below the impact threshold, and relatively quick recovery times of plankton, discharges of operational fluids from Scarborough are not expected to have a substantial adverse effect on plankton life cycle and spatial distribution, and will pose no lasting effect.

Internal Context

- With respect to discharges of operational fluids, Woodside will implement their internal requirements:
  - Chemicals will be selected with the lowest practicable environmental impacts and risks subject to technical constraints.
  - Development of a management framework for PW discharges. This framework will be implemented to understand the impacts from the discharge of PW from the FPU at the time these occur and inform if further actions are required to be implemented to meet the EPOs. This management framework may identify the requirement for in-situ monitoring of PW discharges and potentially Whole Effluent Toxicity (WET) testing to characterise the PW discharge composition when a suitably representative sample of PW can be obtained.

External Context

- No stakeholder concerns have been raised with respect to discharges of operational fluids, or potentially impacted receptors.

Other Requirements

- With respect to discharges of operational fluids, activities associated with Scarborough 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 and the values of the AMPs.
- The project will comply with the relevant MARPOL and Commonwealth requirements and subsequent Marine Order requirements for planned discharges.

7.1.10.4 Summary of the Impact Assessment

Table 7.33 provides a summary of the impact assessment and acceptability for impacts from operational fluid discharges to ecological and social receptors.

Table 7.33: Summary of impacts, management controls, impact significance ratings and EPOs for operational discharges

Receptor	Impact	Environmental Performance Outcome	Adopted control(s)	Receptor sensitivity	Magnitude	Consequence	Acceptability
Water quality	Change in water quality	**EPO2:** To not result in a substantial change in water quality (including temperature) which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM16:** Chemicals will be selected with the lowest practicable environmental impacts and risks subject to technical constraints. **CM18:** Development of a management framework for produced water discharges.	Low value (open water)	Slight	Negligible (F)	Acceptable
Sediment quality	Change in sediment quality	**EPO3:** To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		Low value (open water)	No lasting effect	Negligible (F)	Acceptable
Plankton	Injury/ mortality to fauna	**EPO6:** To not have a substantial adverse effect on a population of plankton including its life cycle and spatial distribution.		Low value (open water)	No lasting effect	Negligible (F)	Acceptable
Epifauna and Infauna	Injury/ mortality to fauna	**EPO1:** 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.		Low value (open water)	No lasting effect	Negligible (F)	Acceptable

Receptor	Impact	Environmental Performance Outcome	Adopted control(s)	Receptor sensitivity	Magnitude	Consequence	Acceptability
KEFs	Change in habitat	**EPO16:** 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.		High value	No lasting effect	Slight (E)	Acceptable

7.1.11 Routine and Non-Routine Discharges: Subsea Installation and Commissioning

Routine and non-routine discharges from subsea installation and commissioning activities include discharges of commissioning and hydrotest fluids into the marine environment.

7.1.11.1 Sources of the Aspect

Installation and commissioning of infrastructure for Scarborough will result in the discharge of commissioning and hydrotest fluids. Routine and non-routine discharges of commissioning and hydrotest fluids will occur during:

- installation of the FPU
- installation of subsea infrastructure
- commissioning.

Installation of FPU

During installation, the FPU will be hooked up to the SURF and trunkline infrastructure. Connection of the FPU to subsea infrastructure will result in the release of a small volume of commissioning fluids. Commissioning fluids will comprise of chemically treated and filtered seawater. Chemicals may consist of biocide, corrosion inhibitor and oxygen scavenger, scale inhibitor, MEG and fluorescein dye. Discharges associated with connection of the FPU to subsea infrastructure will occur during the installation of FPU. These discharges will only be during the installation of the FPU at the proposed offshore location.

Installation of Subsea Infrastructure

Subsea infrastructure (umbilicals, risers, flowlines, manifolds, well jumpers, MEG lines, export riser base) is required to transport gas from wells to the FPU. During installation the connection of subsea infrastructure will result in discharges of hydrotest fluid in small quantities. Hydrotest fluids may consist of biocide, corrosion inhibitor and oxygen scavenger, scale inhibitor, MEG and fluorescein dye.

Buckling is a risk that exists during installation of flowlines. If a buckle occurs, it could result in the rupture of the flowline and seawater entering the flowline. In the event preservation of the internals of a flowline is compromised, the line may require dewatering post commissioning activities. Contingency dewatering activities during construction (e.g. wet buckle) are possible but are considered non-routine. The requirement for contingency dewatering is determined by the technical design specifications and performance criteria of the line. 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 chemically-treated seawater that would be discharged in the event of a wet buckle depends on the location, extent and repair method. Worst case scenario would be complete dewatering of the compromised flowline.

Commissioning

Commissioning activities include testing the integrity of the subsea infrastructure by leak testing with hydrotest fluids. A pressure pump will be used to assess the pressure-volume relationship. Failure of testing equipment or integrity of the tested infrastructure may lead to a loss of hydrotest fluids. Where possible, the FPU components will be assembled and pre-commissioned at the onshore fabrication/pre-assembly sites. However, should it be required to be conducted in the Project Area there will be small localised discharges around each of the test locations as that infrastructure is tested and the flowlines are depressurised during pre-commissioning. There may also be small localised discharges at a connection points if they are not made correctly, however this will quickly be detected during pumping due to failure to reach test pressure. Pressure test mediums will match the contents of the system being tested.

Pre-commissioning

Once installation and hook up of subsea infrastructure are complete, the subsea infrastructure, including the SURF and the trunkline will be subject to pre-commissioning, required to test the integrity of the subsea infrastructure. This will be conducted using hydrotest fluids, whereby the pipeline 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, at which time they will be discharged at the offshore location.

Proposed volumes of commissioning fluids for the trunkline is 190,000 m^3 of chemically treated seawater with a 20% contingency, resulting in a maximum likely volume as 223,000 m^3, for the SURF the likely volume is 60,000 m^3 with a 10% contingency, resulting in a maximum likely volume as 66,000 m^3. The location and timing of the discharge is unknown; however, it is assumed it will be discharged from a single point on the seabed in the vicinity of the proposed location of the FPU at any time of the year. For this assessment, the discharge rate is estimated at around 1500 m^3/hr for the trunkline and 85 m^3/hr will be relatively short in duration. Residual biocide may be present in the hydrotest water at the time it is discharged at concentrations in the order of 500–1500 ppm.

Modelling results for discharges of 220, 000 m^3 of flooding fluid associated from dewatering activities of Wheatstone's trunkline and flowlines estimated any exceedance of the 48-hour median threshold is within 3.5 km of the point of discharge (Chevron, 2015). RPS conducted hydrotest discharge modelling, summarised below (RPS, 2019c; APPENDIX H).

7.1.11.2 Impact or Risk

Discharges during FPU and subsea installation and commissioning has the potential to result in the following impacts:

- change in water quality
- change in sediment quality
- injury/mortality to fauna
- changes to the functions, interests or activities of other users.

Change in Water and Sediment Quality

Modelling undertaken by Chevron determined the plume generated by the discharge of dewatering fluid. A total volume of 220,000 m^3 of treated seawater was modelled for discharge over a six to eight-day period, with an average discharge flowrate of 0.448 m^3 per second (1612.8 m^3/hr). Based on a median lethal concentration (LC_{50}) of 0.06 ppm (over 48 hours), it was predicted that the plume would dilute to below the threshold at 3.5 km from the discharge location (Chevron, 2015).

Hydrotest Discharge Modelling

Modelling was undertaken for Scarborough (RPS, 2019c; APPENDIX H) for discharges of hydrotest water from the FPU location. The modelling looked at scenarios where the discharge was made from the seabed, and from a location 10 m below the sea surface, for two flow rates (795 m^3/hr and 220 m^3/hr).

When discharged at the seabed, the plume remains close to the seabed, while for surface discharges the plume plunges to a depth of around 20 m before becoming neutrally buoyant and travelling laterally. The nearfield modelling shows that at the extent of the nearfield mixing zone in all cases, the biocide constituent of the hydrotest discharge is not expected to reach the required levels of dilution, and predicted a maximum horizontal distance of 0.152 km before reaching the trapping depth (APPENDIX H).

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. Two scenarios were selected for far-field modelling, as the two depth extremes. Far-field modelling predicted (Table 7.34):

- the maximum horizontal extent before dilution is achieved is 1.56 km; and the maximum area of exposure is 3.7 km^2 (both for the higher flow rate, 930 m depth scenario).

Table 7.34 Far-field modelling summary of Hydrotest Discharge modelling

Discharge Rate: 795 m^3/hr; Depth: 930 m			
Percentile	**95th**	**99th**	**100th**
Maximum horizontal distance till dilution is achieved (km)[1]	1.20	1.39	1.56
Total area of coverage till dilution is achieved (km^2)[1]	2.30	2.90	3.70
Maximum depth from discharge (m)	930		
Discharge Rate: 220 m^3/hr; Depth: 10 m			
Percentile	**95th**	**99th**	**100th**
Maximum horizontal distance till dilution is achieved (km)[1]	0.02	0.12	1.15
Total area of coverage till dilution is achieved (km^2)[1]	0.002	0.03	0.49
Maximum depth from discharge (m)	12		

[1] Value shown is from the worst-case season

The distance at which the dilution is met is less than predicted for the Chevron Wheatstone project (3 - 4 km), however the flow rate modelled was approximately double that of Scarborough (Chevron, 2015). This will be a factor of the current speed and direction at the time of the discharge. While the maximum diameter is not known (beyond the nearfield mixing zone), the diameter of the plume at the edge of this zone is up to around 25 m. The diameter will be affected by the current speed, with increases in current speed serving to restrict the diameter of the plume.

Other small volume chemical discharges, such as hydrotest chemicals from FPU hook-up and hydrotest activities, will disperse immediately on discharge to the environment. The potential impact from these small volume chemical discharges to marine environment is expected to be limited to localised and temporary change in water quality from the discharge point.

Injury/Mortality to Marine Fauna

A change in water/sediment quality may result in further impacts, such as injury/mortality to marine fauna. Marine fauna, including epifauna/infauna, plankton, and fish within close proximity to the discharge point, will be exposed to the discharged waters which may include biocides and other additives. Following discharge, concentration is expected to rapidly dilute further in the open ocean environment.

Changes to the Functions, Interests or Activities of Other Users

Fishing activities are typically focussed in coastal waters, and minimal fishing effort is known to be undertaken in the Offshore Project Area where discharges will occur. Given the distance of the discharge point and subsequent plume from shore (375 km), impacts from the discharge of commissioning fluids such as changes to the functions, interest or activities of Commonwealth and State managed fisheries are unlikely. Therefore, the potential impact from changes to Commonwealth and State managed fisheries is not assessed further.

Receptors Potentially Impacted

Routine and non-routine discharges of FPU and subsea installation and commissioning fluids have the potential to impact on receptors which may be vulnerable to toxicity. The receptors which have the potential to be impacted include:

- water quality
- sediment quality
- plankton
- epifauna and infauna
- fish
- KEFs.

Fish

WET test data estimated that the discharge of flooding fluid containing biocide has the potential to cause acute toxicity to fish at concentrations above 6.3–100.0 mg/L over 96 hours which is greater than the modelled threshold of 0.06 ppm over 48 hours (Chevron, 2015).

Potential impacts to pelagic fish species from dewatering are expected to be limited to avoidance of the plume in a localised area. Impacts to pelagic fish from small discharge volumes associated with leak testing is expected to be highly localised and negligible. 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.

No known breeding, feeding or aggregation areas are located within the discharge plume. Critical habitat for the survival of whale sharks in waters adjacent to Ningaloo Reef, >200 km from the Offshore Project Area, is identified in the Whale shark (*Rhyncodon typus*) recovery plan 2005–2010 (DEH, 2005). An additional BIA for the whale shark is located 165 km from the Offshore Project Area. While habitat degradation/modification is listed as a key threat in this habitat, the distance from the discharge point prevents any direct impacts to aggregating individuals. Fish are not expected to be abundant and diversity is expected to be limited due to depth and the lack of hard substrate/habitat complexity. Individual fish may pass through the area, however, are unlikely to come into contact with the discharge plume for significant periods of time. Exposure times of sufficient duration that may lead to toxic effects are not expected. The low likelihood of pelagic species being exposed to the discharge; and the ability of fish to move away from the discharge plume, the potential for toxic impacts to occur from dewatering discharge are considered to be localised, short-term and negligible at the population or bioregional scale.

The discharge during installation and commissioning will be restricted to a small area around the discharge point and will disperse rapidly in the environment. The extent of fish exposed at levels where impacts could occur will be small, and potential impacts are expected to be localised, temporary and negligible, as such impacts have not been evaluated further.

Table 7.35 outlines the potential impacts to receptors associated with discharges of inhibited seawater.

Table 7.35: Receptor/impact matrix after evaluation of context

	Receptor					
Impacts	***Marine Sediment***	***Water Quality***	***Plankton***	***Epifauna and Infauna***	***Fish***	***KEFs***
Change in water quality		✓				✓
Change in sediment quality	✓					✓
Injury/mortality to fauna			✓	✓	X	

Detailed Impact Evaluation

For each of the receptors identified for detailed evaluation, the criteria for acceptability as defined in Table 6.3 have been considered and addressed in the following sections. This includes to meet the principles of ESD, internal and external context and any other requirements.

Sediment and Water Quality

The release of commissioning and hydrotest fluids may alter water quality; and sediment quality, if it reaches the seabed. The discharge location is not determined, and may be at 10 m water depth, or at the seafloor (930 m). The 10 m release only reaches a maximum depth of 12 m and does not the reach the seabed, however for the seafloor release. The dewatering plume is expected to travel in close proximity to the seabed (RPS, 2019c; APPENDIX H), therefore dewatering may result in change in sediment quality. The maximum horizontal distance before dilution is achieved is predicted as 1.56 km, or a maximum area of exposure of 3.7 km^2.

Modelling has determined that hydrotest water will potentially extend to 1.56 km (Figure 7.16) from the discharge point, as a narrow neutrally buoyant plume.

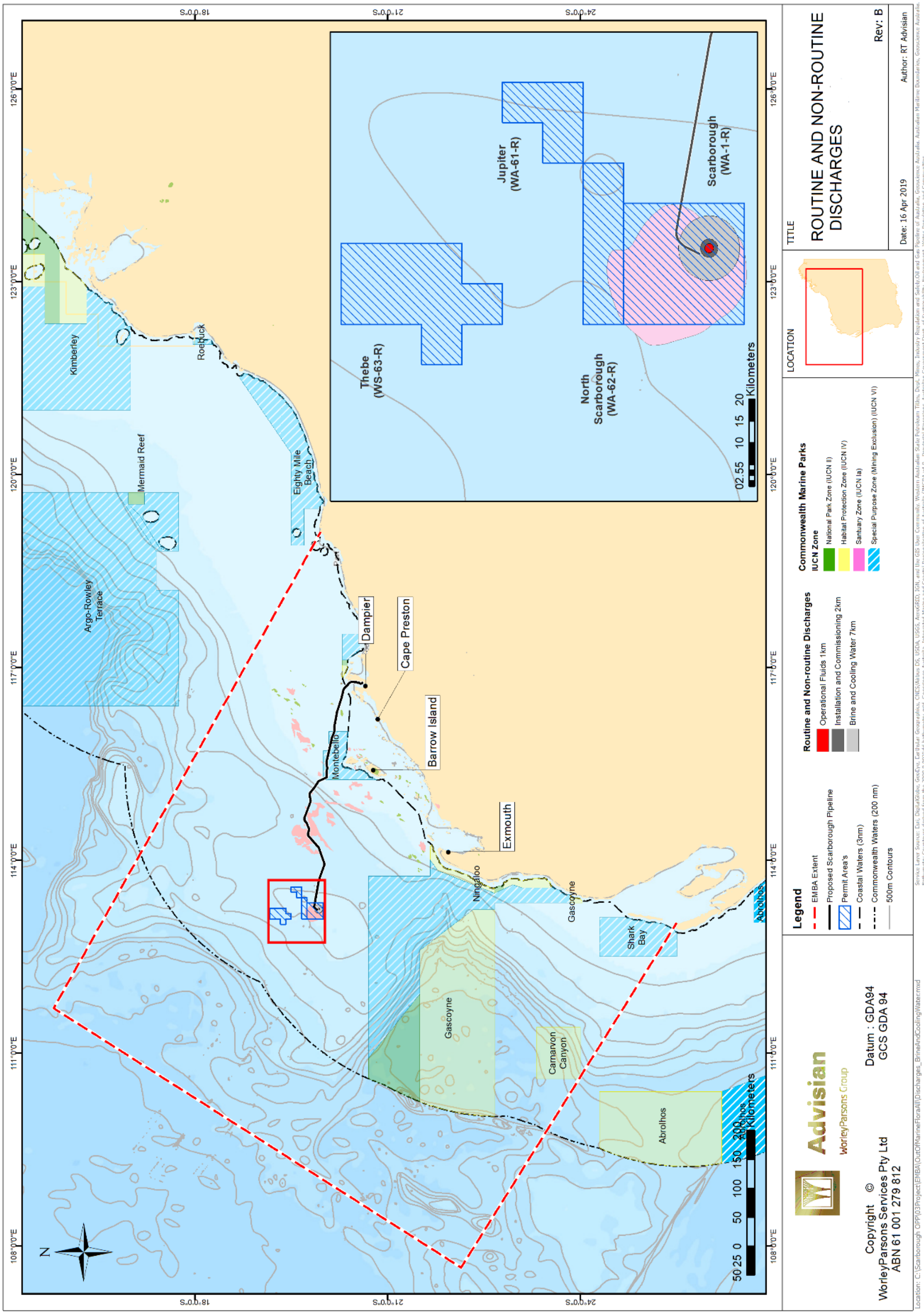


Figure 7.16: Predicted mixing zone for hydrotest discharges (dark grey shading) associated with the FPU operations

Biocide is considered to be the primary chemical in dewatering fluids to have the highest toxicity to marine receptors (Chevron, 2015). The biocides will however degrade rapidly and will not accumulate in the seabed sediments or remain within the water column.

Within the Project Area, where discharges are to occur, the environmental performance outcomes are:

- to not result in a substantial change to water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health
- to not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health
- 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.

Given low volumes of subsea installation and commissioning discharges associated with Scarborough, biodiversity, ecological integrity, social amenities and human health will not be impacted.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to water quality or sediment quality. Activities are not proposed to take place within or adjacent to any AMPs.

Based on the detailed evaluation, the magnitude of potential impacts to sediment and water quality from FPU and subsea installation and commissioning discharges are slight and have been evaluated as **acceptable**.

Plankton

Whole of Effluent Toxicity (WET) test data estimated that the discharge of flooding fluid containing biocide chemical Hydrosure 0-3670R (a type of biocide typically used in hydrotesting) has the potential to cause acute toxicity to marine organisms at concentrations above 0.06 ppm over 48 hours (Chevron, 2015). WET testing included the consideration of impacts to fish and pelagic invertebrate species.

Although planktonic productivity within the dewatering plume is considered low across the seasons, offshore plankton populations may be affected by dewatering discharges, but impacts are likely to occur in the immediate area of the discharge plume, within a few kilometres of the discharge point, and within a relatively small plume diameter.

Discharges during installation and commissioning will be restricted to a small area around the discharge point and will disperse rapidly in the environment. Given the fast population turnover of open water plankton populations (ITOPF, 2011), the potential impacts expected to be localised, temporary and are slight and have been evaluated as **acceptable**.

Epifauna and Infauna

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. Epifauna and infauna abundance within the discharge plume was characterised by sparse marine life dominated by motile organisms (ERM 2013a).

Modelling indicates the plume is initially a thin horizontal jet due to its large initial momentum, and then the plume begins a gradual rise/fall due to slight positive/negative buoyancy ending at a trapping depth or the seabed after it reaches neutral buoyancy (APPENDIX H). This suggests the plume may contact the seabed if it is more negatively buoyant, or where discharged from the seabed. Rapid dilution of the plume from deepwater flow and internal tides of the Exmouth Plateau may lower biocide concentration of the plume before seabed contact (when discharged at surface).

For discharges of hydrotest water at the seabed, the ecological consequences may include temporary and localised impact to epifauna and infauna populations with a temporary decline in abundance in the immediate area of the discharge, however, populations would recover rapidly by recolonisation by surrounding populations (Neff, 2005). The ecological integrity of epifauna and infauna communities will be maintained in the wider region. Impacts will be confined to a localised area not effecting the ecosystem function (DHI, 2014; APASA, 2012).

Discharges during installation and commissioning will be restricted to a relatively small area around the discharge point and will disperse rapidly in the environment. The extent of seabed exposed at levels where impacts could occur will be small, and potential impacts are expected to be localised, temporary and negligible, are slight and have been evaluated as **acceptable**.

KEFs

Values of the Exmouth Plateau with the potential to be affected by dewatering is limited to impacts to benthic environments containing low habitat heterogeneity within the plume.

The seafloor composition within the dewatering plume is expected to primarily be mud and clay material. Survey of the plume area identified the seafloor to contain sparse marine life dominated by motile taxa typical of deep-water soft substrates (ERM, 2013a; DEWHA, 2008a).

The hydrotest discharge depth is not yet determined, but if it is discharged from the surface (10 m), it will not contact the benthic environment. If it is discharged from the seafloor location (930 m), modelling predicts the maximum horizontal distance before dilution is achieved is 1.56 km, or a maximum area of exposure of 3.7 km^2 (RPS, 2019c; APPENDIX H). This footprint represents only 0.00007 of the Exmouth Plateau KEF (49310 km^2).

Impacts to the Exmouth Plateau would be limited to localised and temporary impacts to benthic fauna from dewatering. The extent of seabed exposed at levels where impacts could occur will be small, and potential impacts are expected to be negligible.

Within the Scarborough operation area, the environmental performance outcomes for KEFs include 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. Temporary and localised impacts to benthic fauna populations within the Exmouth Plateau is considered acceptable given no adverse impacts on marine ecosystem functioning or integrity are anticipated.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to the KEFs. Activities associated with this aspect will not take place within or adjacent to AMPs.

Based on a detailed evaluation, the magnitude of potential impacts to benthic fauna populations within the Exmouth Plateau from routine and non-routine discharges from FPU and subsea installation and commissioning associated with Scarborough are slight and is considered **acceptable**.

7.1.11.3 Impact Significance Evaluation

Impacts from routine and non-routine discharges from subsea installation and commissioning activities will have a slight effect on receptors, as the extent, duration, frequency and scale of the impact are all sufficiently small. When considered with receptor sensitivity, Impact Significance Level of routine and non-routine discharges from subsea installation and commissioning activities have been evaluated as **Negligible (F)**. The impacts overall have been determined as **acceptable** based on an evaluation against the criteria.

To meet the principles of ESD

- These discharges will result in localised and temporary changes in water quality, such as increased toxicity and turbidity, which can potentially impact marine fauna.
- The discharge plume would disperse below defined toxicity thresholds in a maximum horizontal distance of 1.56 km from the discharge site, or a maximum area of exposure of 3.7 km^2; which is located within the Offshore Project Area, 375 km from shore at the closest point.
- These discharges will result in localised but temporary increased toxicity, which can potentially impact sediment quality, epifauna and infauna and the Exmouth Plateau KEF.

Internal context

- With respect to routine and non-routine discharges of brine and cooling water, Woodside will implement its internal requirement:
  - Chemicals must be selected with the lowest practicable environmental impacts and risks subject to technical constraints.

External context

- No stakeholder concerns have been raised with respect to routine and non-routine discharges from subsea installation and commissioning, or potentially impacted receptors.

Other requirements

- With respect to routine and non-routine discharges from subsea installation and commissioning, activities associated with Scarborough 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.

7.1.11.4 Summary of the Impact Assessment

Table 7.36 provides a summary of the risk assessment and acceptability for impacts from routine and non-routine subsea installation and commissioning discharges on receptors.

Table 7.36: Summary of impacts, key management controls, acceptability, EPOs and residual risk rating for routine and non-routine discharges: subsea installation and commissioning.

Receptor	Impact	Environmental Performance Outcome	Adopted control(s)	Receptor sensitivity level	Likelihood	Risk rating	Acceptability
Sediment quality	Change in sediment quality	**EPO3:** To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. **EPO4:** 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.	**CM16:** Chemicals will be selected with the lowest practicable environmental impacts and risks subject to technical constraints.	Low value (open water)	Slight	Negligible (F)	Acceptable
Water quality	Change in water quality	**EPO2:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		Low value (open water)	Slight	Negligible (F)	Acceptable
Plankton	Injury/ mortality to fauna	**EPO6:** To not have a substantial adverse effect on a population of plankton including its life cycle and spatial distribution.		Low value (open water)	No lasting effect	Negligible (F)	Acceptable
Epifauna and Infauna	Injury/ mortality to fauna	**EPO1:** 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.		Low value (open water)	No lasting effect	Negligible (F)	Acceptable

Receptor	Impact	Environmental Performance Outcome	Adopted control(s)	Receptor sensitivity level	Likelihood	Risk rating	Acceptability
KEFs	Change in water quality Change in sediment quality	**EPO16:** 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.		Medium value habitat	Slight	Negligible (F)	Acceptable

7.1.12 Routine and Non-Routine Discharge: Drilling

7.1.12.1 Sources of the Aspect

Activities associated with Scarborough, that will generate drilling discharges include:

- drilling operations
- well abandonment.
- well intervention

Routine discharges will include:

- drilling fluids
- drill cuttings
- subsea control fluids
- cement
- completions fluids (including well clean-up fluids, suspension fluids).

Occasional bulk discharges of drilling fluids from the mud pits may also occur during the cleaning of equipment.

Drilling Operations

Around 20 wells with an additional 10 contingency wells are planned to be drilled during the proposed development of Scarborough, which will result in the same number of discharge locations. Each well is expected to take two to three months to drill.

Drilling activities generate drill cuttings, require cementing of the casing, and require the use of a range of fluids. Throughout the drilling program several different fluids are to be run through the closed circulation system including, but not limited to, drilling fluids (water-based muds and non-water-based muds), sea water, and kill-weight brine. During the displacement of one fluid to another, both fluids will mix. This mixture may be discharged to the environment, depending on its content.

Depending on the drilling phase and hole section, drill cuttings and fluids are discharged both subsurface and from surface waters. Non-routine bulk discharges of drilling fluids may also take place, these will be discharged to surface waters.

Each type of discharge is described further below.

Drilling Fluids

Drilling fluids (also termed drilling muds) serve a range of functions including aiding in cuttings transport to surface, maintaining bore stability and hydrostatic pressure, reducing friction and cleaning and cooling of the drill bit.

Water based muds (WBM) will be used during drilling activities and 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
- 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. 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.

WBM 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 solids control equipment (SCE) (bottom hole sections, drilled with riser in place)
- from the mud pits from a pipe below the sea surface, if the WBM cannot be re-circulated/ re-used through the drilling fluid system (due to deterioration/contamination), re-used on the well or on another well; or stored.

If WBM cannot be re-used due to bacterial deterioration or does not meet required drilling fluid properties, it is discharged to the marine environment, using seawater flushing.

Non-water-based muds (NWBM) refers to drill fluids that have a hydrocarbon rather than water base fluid. NWBM may be used, should the offset history, geohazards assessment and borehole stability studies indicate that NWBM is required to manage well stability to safe levels.

Like a WBM system, a range of standard solid and liquid additives may be added to alter specific mud properties for each section of the well, dependent on the conditions encountered while drilling. Discharge scenarios are much the same as that described for WBM, however NWBM will not be used for top hole section drilling (riserless); therefore, no direct seabed discharge of NWBM will occur. NWBM that cannot be re-used are recovered from the mud pits and transported to shore for recycling or disposal.

The mud pits and associated equipment are cleaned out at the completion of drilling operations. Should NWBM be used, mud pit residue and wash water will be treated onboard through Solid Control Equipment (SCE) and may be discharged to sea where the residue contains <1% oil volume. Where the mud pit residue exceeds 1% by volume, the residue will be retained and disposed onshore.

Drill Cuttings

Drilling generates drill cuttings due to the breakup of solid material from within the borehole. Cuttings are expected to range from very fine to very coarse (<1 cm diameter) after separation from the drilling fluid. Depending on the drilling phase and hole section, drill cuttings and fluids are discharged both subsurface and from surface waters.

Cuttings from drilling the top-hole section are discharged to the seabed at the well site. During top hole section drilling, based on a typical well profile, approximately 270 m^3 of drill cuttings will be produced per well.

Once the top-hole section is complete, installation of the riser and BOP provides a conduit back to the MODU, forming a closed circulating system. Solids control equipment (SCE) then removes cuttings from drilling fluids before being recycled and circulated back to the MODU.

The SCE uses shale shakers to remove coarse cuttings from the drilling mud. After processing by the shale shakers, the recovered mud from the cuttings may be directed to centrifuges, which are used to remove fine solids (~ 4.5 to 6 µm). The cuttings with retained fluids are discharged below the water line, and the mud is recirculated into the drill fluid system.

During bottom hole section drilling (for a typical well profile) approximately 110 m^3 of drill cuttings will be produced per well (actual volumes will depend on the final depth of the well).

If a NWBM system is required to drill a well section, the cuttings from the NWBM drilling fluid system will pass through a cuttings dryer to reduce the average residual oil on cuttings (OOC) to <6.9% for the well.

Cement

Once each of the top-hole sections are drilled, casing is 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).

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 m3 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. Also, in the rare event that the cement products become contaminated, the entire volume (~180 m^3 per well) may need to be discharged to sea.

Subsea Control Fluids

Pressure-control equipment (including Blow Out Preventers (BOP)) use hydraulics for operation. Subsea control fluids are water-based hydraulic control fluids used in control systems on the subsea trees, and BOPs.

Subsea control fluids will be discharged during:

- installation of the subsea trees (~10 L per well)
- function testing of the subsea tree (~30 L per test)
- function testing of the BOP control system includes pressure testing approximately every 21 days and a function test approximately every seven days, excluding the week a pressure test is conducted. The maximum volume of control fluid that will be released to the marine environment per well is 1320–2250 L of water-based fluid containing about ~3% active ingredient (40–68 L of control fluid additive).

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
- oxygen scavenger.

They are designed to have the proper density and flow characteristics to be compatible with the reservoir formation. Completion fluids are used to run well completions, and during wellbore clean-up and flowback during drilling.

Wellbore and casing clean-up are required at various stages of the drilling operations to ensure the contents of the well are free of contaminants before the next stage of drilling. A chemical wellbore cleanout fluid train may be used to remove residual fluids (including NWBM, 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 clean-up 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).

Kill-weight brine may also be used during well suspension or well abandonment, which is a brine (e.g. sodium chloride) of adequate density to control formation pressure.

Well Intervention

At some point in the life of all oil and gas wells, parts will require maintenance, repair or replacement. Well intervention activities generally occur within the wellbore and may include the following activities, as well as any other drilling activities described in Section 4.4.3:

- well logging activities (slickline, wireline, coil tubing)
- well testing and flowback
- well workovers.

Relevant discharge types generated from these activities may include the following:

- subsea control fluid (control of subsea tree)
- completions fluids
- well annular fluids.

These discharges are not expected to be different from those described above under the associated headings.

Well annular fluids may also be discharged during well intervention.

Well Annular Fluids

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.

Well Abandonment

The following well abandonment activities can result in discharges to the marine environment:

- install and pressure test BOP
- cutting/perforation of casing or production tubing
- install permanent reservoir and surface barrier (cementing).

Relevant discharge types generated from these activities may include the following:

- subsea control fluids
- well annular fluids (see below)
- cement.

Well Annular Fluids

WBM used during riserless drilling fluids 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. The non-instantaneous nature of the release of the well annular fluids is expected to result in rapid dilution within meters of the release location.

7.1.12.2 Impact or Risk

Routine and non-routine discharges of drilling-related fluids may result in the following impacts:

- change in water quality
- change in sediment quality
- change in habitat
- injury/mortality to marine fauna.

Some fluids are discharged at the sea surface (or just below); and some are discharged at the seabed. Due to water depth in the Offshore Project Area (approximately 900 m), this will determine the exposure pathway, and hence potential impacts and receptors.

Surface discharges include all those circulated to the MODU then discharged overboard, which include:

- drill cuttings, and drill fluids as fluid remaining on drill cuttings (bottom hole sections); consists of WBM and NWBM if used; or from clean out of mud pits.
- cement, from cleaning of cement systems
- completion fluid.

Subsea discharges from the subsea tree, wellhead or to the seabed during drilling, well intervention and abandonment that are likely to interface with the benthic environment include:

- drill fluids for top-hole drilling (riserless) – WBM only
- drill cuttings for top-hole drilling (riserless)
- cement
- subsea control fluids
- well annular fluids.

Change in Water Quality

The key physicochemical stressors that are associated with drilling discharges include turbidity and resulting sedimentation and chemical toxicity.

Discharges such as completion fluids and well annular fluids are typically inert and low-toxicity. These fluids are mostly brine, with a small proportion of chemical additives such as surfactants, biocide, corrosion inhibitor, oxygen scavenger, MEG, guar gum and so on. Well annular fluid may have some residual hydrocarbon from the reservoir, but in small amounts.

The main potential impact to water quality from drilling-related discharges is due to the following discharge types, which are described further below:

- drill cuttings and drill fluid
- cement
- completion fluids
- subsea control fluid
- well annular fluids.

Drill Cuttings and Fluid

A change in water quality because of drill cutting and fluid discharges may occur via a change in turbidity at the seabed or within the water column, increased chemical content in the water column and through oxygen depletion. Table 7.37 shows the expected volumes, mud types and discharge locations for an example well.

Table 7.37: Details of the drill cuttings and drilling fluids discharged for an example well[42]

Well Section	Interval Length (m)	Cuttings Volume (m^3)	Mud Type	Liquid Mud Volume (m^3)	Mud Solids Volume (m^3)	Discharge Duration (d)	Discharge Location
42” Conductor	60	53.6	WBM	266	8	0.3	Seabed
26” Surface Casing	627	214.8	WBM	1543	169	1.7	Seabed
13 5/8 ” Production Casing	289	44.8	NWBM/ WBM	632	0	0.8	Surface (-1 m MSL)
9 5/8” Production Liner	645	49.0	NWBM/ WBM	123	0	1.8	Surface (-1 m MSL)
9 5/8” Open Hole	300	14.8	NWBM/ WBM	37	25/64 (if WBM)	1.8	Surface (-1 m MSL)
Totals		**377.1**	**-**	**2601.1**	**202.6**	**6.4**	**-**

When cuttings are discharged from the surface, the larger particles, representing about 90% of the mass of the solids, form a plume that settles quickly to the bottom (or until the plume entrains enough seawater to reach neutral buoyancy) (Hinwood et al, 1994). About 10% of the mass of the solids form another plume in the upper water column that drifts with prevailing currents away from the platform and is diluted rapidly in the receiving waters (Neff, 2005; 2010). 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 drilling area), drilling mud is diluted by more than 100-fold within 10 m of the discharge.

[42] The volumes quoted in this table are estimates only for the purpose of undertaking as assessment of the environmental impacts. Detailed design will be undertaken further and the assessment updated in relevant activity EPs.

Drill cuttings and fluid from the bottom-hole sections will be smaller in volume and will be discharged from the surface, resulting in a wider area of deposition, but a much smaller cuttings pile depth (IOGP, 2016). Research has shown that volumes of bottom hole cuttings sharply decrease with distance from the discharge point; however, the distribution of these cuttings is generally very patchy (Nedwed, 2006; Balcom, 2012).

Dispersion of the cuttings plume is influenced by two factors: fluid type (i.e. particle size) and ocean current speed. The case studies described in Neff (2005) used WBMs and surface current speeds of 0.15–0.3 m/s. As currents in the Offshore Project Area are ~0.25 m/s at the surface (Section 5.3.2), and WBMs are expected to cause the largest turbidity risk for the drilling program, the dispersion extents in Neff (2005) are considered representative.

Using the widely-accepted dilution factor of 10,000 (Neff, 2005), cuttings (and adhered fluids) are expected to reach 100 mg/L within 100 m of the MODU. Using a conservative ocean current speed of 0.1 m/s (which is below average current speeds in the Offshore Project Area), these discharges are expected to disperse to 100 mg/L within ~16 minutes.

Cement

Cement operations during drilling and well abandonment involve routine and non-routine discharges that can result in increased toxicity and turbidity in the water column. Modelling of cement discharges for another offshore project (BP Azerbaijan, 2013) was used because it provides an appropriate, but conservative, comparison of the potential extent of exposure from this activity.

In this study, two hours after the start of discharge, plume concentrations were determined to be between 5 and 50 ppm with the horizontal and vertical extents of the plume ~150 m and 10 m, respectively (BP Azerbaijan, 2013). Five hours after ceasing the discharge, modelling indicates that the plume will have dispersed to concentrations <5 ppm.

Completion Fluids

Completion fluids are generally brine with additives that can have toxicity such as biocides, oxygen scavengers, and MEG.

The volume of one wellbore and subsequent discharge volume would be ~400 m^3 (based on the designs of the proposed production wells). The change to water quality is expected to be localised; drilling discharges have previously been identified to dissipate no more than 100 m from the drilling site (Kinhill, 1998; IRCE, 2003). As this is an intermittent batch discharge any change in water quality will be short term, due to rapid dilution from ocean currents.

Subsea Control Fluids

Subsea control fluids are water-based hydraulic fluids containing ~3% active ingredients. Modelling undertaken for another offshore drilling project indicates that a release of subsea control fluids during function testing is expected to reach a dilution of 3000 times within a maximum displacement plume of 98 m (BP Azerbaijan, 2013). Based on this information, it is expected concentrations of subsea control fluid would be ~10 ppm within 100 m of the BOP. Using a conservative ocean current speed of 0.1 m/s. fluids would be expected to travel 100 m (and thus reach concentrations of 10 ppm) in ~16 minutes.

Well Annular Fluids

The small volumes and non-instantaneous nature of the release of the well annular fluids is expected to result in rapid dilution to a no-effect concentration within meters of the release location.

Change in Sediment Quality

Toxins from chemical additives could potentially accumulate in benthic sediments, causing changes to sediment quality; and smothering and alteration of the seabed can impact physical characteristics of the seabed. Characteristics of sediment quality that may change include sediment structure, particle distribution, particle flow and chemical composition.

Impacts associated with routine and non-routine drilling discharges will be limited to the area surrounding the discharge source at the well locations and MODU, which are in approximately 900 m water and >375 km from shore.

Due to the dispersive nature of chemical discharges within the highly mixed offshore marine environment, toxins associated with surface discharges are not expected to reach marine sediments at concentrations that will result in notable changes to sediment quality.

Drill Cuttings and Fluids

The discharge of drill cuttings and unrecoverable fluids at the seabed during riserless top hole drilling results in a localised area of sediment deposition (known as a cuttings pile) near the well site. The dimensions of the cuttings pile depend on several factors, including volume and composition of cuttings, and oceanographic conditions at the discharge location. This seabed discharge has the greatest impact to sediment quality, as the solids tend to clump and settle rapidly around the discharge point (Neff, 2010). Accumulation of drill cuttings on the seafloor causes changes in physical properties and chemical composition of sediments and can include changes in sediment grain size and minerology, increase in concentrations of metals (e.g. barium), and forms of petroleum hydrocarbons (from the NWBM).

Several field studies are summarised in IAOGP (2016) for WBM discharged at the seafloor; and in all cases found that cuttings could be detected visually, or as elevated barium concentrations in benthic sediments within 10 – 150 m of the discharge, with a greater spread down-current. Maximum height of the cuttings pile was usually <50 cm. When cuttings were discharged from the MODU (i.e. at the surface), the increased depth allows small particles to disperse over greater distances, leaving thinner layers of cuttings near the well site – for example, WBM cuttings discharged from a single well in >300 m water may disperse so widely they may not be detectable in sediments at any distance from the MODU (IAOGP, 2016). However, when discharged to deeper water, NWBM cuttings may be deposited over a much larger area, to a horizontal distance of 500–1000 m from the discharge site (with concentrations decreasing with increasing distance) (IAOGP, 2016).

Therefore, a conservative exposure radius of 1000 m is assumed based on available research (IAOGP, 2016). This indicates there is the potential for smothering impacts and potential toxicity within an area of ~3.14 km^2 per well. For the proposed 20 wells plus 10 contingency wells, this gives a conservative total exposure area of approximately 90 km^2.

Other studies support these conclusions. Increases in turbidity at the seabed from drill cutting discharges during riserless drilling (i.e. direct discharge to the seabed) are expected to be highly localised and limited to within close proximity of the source (Neff, 2005).

Some components of NWBM are potentially bioaccumulative; though it is thought that the ability of organisms to oxidise and expel aromatics means that while hydrocarbons may be bioavailable, they are not expected to bioconcentrate (Melton et al. 2000). The physical and chemical persistence of drill cuttings on the seafloor depends on the energy of bottom waters and drilling substance reactivity and biodegradability. Most minerals in cuttings are stable and insoluble in water, and most of the organic chemicals in WBM and NWBM are biodegradable (IAOGP, 2016).

Cement

For cement discharges, the potential for toxicity is associated with the chemical additives that are added to cement mixtures; therefore, toxicity associated with the discharge of cement is limited to the subsurface release of cement (not discharge of dry cement).

Terrens et al. (1998) suggest that once the cement has hardened, the chemical constituents are locked into the hardened cement. Consequently, the extent of this hazard is limited to the waters directly adjacent to the displaced subsea cement (expected to be 10–50 m from the well) or pelagic waters within 150 m of the well (BP Azerbaijan, 2013).

Overspill of cement will permanently alter physical sediment properties, immediately adjacent to the well (within <50 m). The potential disturbance area is 0.007 km² per well; giving a total potential disturbance footprint of~0.21 km² for the proposed wells.

Change in Habitat

As a result of a change in sediment quality and/or water quality, further impacts to receptors may occur, which include a change in habitat resulting from smothering and alteration of the seabed, or exposure to toxins or chemicals in the drilling discharges.

Drill Cuttings and Fluids

Drill cuttings and cement discharges can physically smother seabed habitat and alter seabed substrate; and can also expose benthic habitats to chemical toxicity. Some components of WBM or NWBM are potentially bioaccumulative; though it's thought that the ability of organisms to oxidise and expel aromatics means that while hydrocarbons may be bioavailable, they are not expected to bioconcentrate (Melton et al., 2000).

An increase in NWBM in benthic sediments may lead to depletion of oxygen in surface layers, and potentially an increase in ammonia and sulphide leading to eutrophication. This can cause a change in or decrease in diversity of the benthic community (IAGOGP, 2016). Discharges of WBM and NWBM cuttings can affect mobile and sessile fauna mainly by burial, changes in bottom topography, or smothering by elevated water turbidity from suspended fine clay/barite particles.

The extent of the impact on the seafloor habitat depends on the type of cuttings and depth of water, but based on studies described above, a conservative impact radius of 1000 m is assumed. This indicates there is the potential for impacts to habitat over an area of ~3.14 km² per well.

Neff (2010) found that recolonisation of synthetic-based, mud-cuttings piles in cold-water marine environments began within one to two years of ceasing discharges, once the hydrocarbon component of the cutting piles biodegraded. Additional studies indicate that benthic infauna and epifauna recover relatively quickly, with substantial recovery in deepwater benthic communities within three to ten years (Jones, Gates and Lausen, 2012). Although these studies were associated with cold, deepwater environments, the recovery processes are expected to be similar. Although effectiveness and recovery time may differ, the species present in soft sediment are well adapted to changes in substrate, especially burrowing species (Kjeilen-Eilertsen, 2004); therefore, recovery is expected to be quicker.

Exposure duration is conservatively estimated at approximately 10 years. Consequently, a conservative recovery duration of ten years is used for evaluating the potential impacts and risks associated with this activity.

Cement

Most cement discharges that will occur during these activities will be at the seabed during cementing of the casing. The potential impacts of smothering from a surface release are expected to be significantly less, due to small volumes, intermittent nature of these discharges, and high potential for dispersal by ocean currents.

Once cement overspill from cementing activities hardens, the area directly adjacent to the well (10–50 m) will be altered, resulting in the destruction of seabed habitat within this area (Terrens et.al., 1998). This impact on soft sediment communities is not expected to affect the diversity or ecosystem function in this area and thus is only considered a localised impact.

<u>*Injury/Mortality to Marine Fauna*</u>

As a result of a change in water quality, further impacts to receptors may occur, which include injury or mortality to marine fauna resulting from an increase in turbidity or salinity, or exposure to toxins or chemicals in the drilling discharges.

Drill Cuttings and Fluids

The toxicity of widely used synthetic-based fluids (NWBM) is generally considered low, with WBMs inherently less toxic. Neff (2005) states that in well-mixed ocean waters (as is likely to be the case within the drilling area), drilling mud is diluted by more than 100-fold within 10 m of the discharge point, indicating that, following dilution, concentrations would be well below acute impact levels. This is further demonstrated by Melton *et al.* (2000), who used modelling to demonstrate that WBM and NWBM cuttings and solids within the water column fall below the United States Environment Protection Agency (USEPA) minimum 96-hour LC50 for drilling fluids within the first few metres of a surface discharge point.

Various other studies support the understanding that only organisms very close to the discharge point will be exposed to chemical concentrations above toxicity thresholds (Boehm et al., 2001; Kinhill, 1998; IRCE, 2003; SKM, 1996; Melton, 2000).

Although fish, marine mammals and marine reptiles may be present within receiving waters, it is unlikely that large numbers of individuals will occur within close proximity of the release point and therefore be exposed to PNEC. The expected volumes of discharges would not be significant enough to cause any notable impact to marine fauna, in the well-mixed marine environment.

Receptors Potentially Impacted

Routine and non-routine discharges of drilling fluids have the potential to impact on receptors which may be vulnerable to turbidity, toxicity and smothering. The receptors which have the potential to be impacted include:

- water quality
- sediment quality
- epifauna and infauna
- plankton
- fish
- marine mammals
- marine reptiles
- KEFs.

The presence of drill cuttings and fluids in the marine environment has the potential to disrupt ecological receptors that may be vulnerable to a physical and/or chemical change in water quality and sediment quality. The receptors at risk of impacts associated with the discharge of drilling-related fluids are those either in the water column for surface discharges, or in the benthic habitat where cuttings or other discharges are deposited directly on the seabed during riserless drilling or removal of the well cap.

Fish, Marine Reptiles and Marine Mammals

Any surface and subsurface drilling-related discharge types could impact plankton, as they are widely dispersed throughout the water column. The discharge types with the greatest potential to impact plankton are drill cuttings and fluids, cement, and completion fluid.

As discussed in Section 5, fish assemblage species richness and habitat complexity has been shown to decrease with increasing depth in the NWMR (Last et al., 2005). Due to the predominantly featureless, flat soft sediment of the Offshore Project Area and depth of water, it is expected that fish presence will be limited in the area and any impacts to fish habitat will occur on a local scale and will return to previous conditions relatively quickly. Any fish or mobile fauna that are present within 500 m of the well site are expected to actively avoid discharge plumes and avoid any impacts from toxicity and turbidity. As described above, impacts to prey sources such as plankton are expected to be limited and short term and are not expected to impact on pelagic fish species populations.

Drill Cuttings and Fluids

Jenkins and McKinnon (2006) reported that levels of suspended sediments >500 mg/L are likely to produce a measurable impact upon larvae of most fish species, and that levels of 100 mg/L will affect the larvae of some species if exposed for periods greater than 96 hours. This study also indicate that levels of 100 mg/L are likely to affect the larvae of several marine invertebrate species, and that fish eggs and larvae are more vulnerable to suspended sediments than older life stages.

Using the dilution assumptions described above (Neff, 2005; Melton et al. 2000), drilling cuttings and fluid discharge drops below the USEPA acute toxicity threshold of 10,000 ppm within 10 m of the discharge point; which is expected within 2 minutes, using conservative current speeds.

Therefore, fish larvae are not expected to be impacted. Any impact to fish larvae would be limited due to the small exposure footprint, high natural mortality of larvae, and dispersive characteristics of the open water in the Offshore Project Area.

Components of the WBM system generally have a low toxicity and are considered by OSPAR to pose little or no risk to the environment (PLONOR). If NWBM are used, returns will be treated to reduce OOC to <6.9%. The combination of low toxicity and rapid dilution of treated NWBMs discharged in association with drill cuttings are of little risk of direct toxicity to water-column biota (Neff et al., 2000).

There are no fish species with a BIA within the Offshore Project Area. Whale sharks are the closest to the Offshore Project Area at approximately 180 km away, therefore no impacts to the BIA are expected.

Therefore, only transient marine fauna would have the potential to be exposed to these discharges. Because no specific thresholds are available for the identified values and sensitivities, and because the concentrations of drilling fluid would fall below acute toxicity thresholds (10,000 ppm) for species even more sensitive to changes in water quality, any impact to values and sensitivities would be negligible. Even with the conservative impact area set for this discharge, exposures to transient individuals would be limited and are expected only for short durations. Consequently, any potential impact is expected to be limited to transient individuals, with recoverable concentrations resulting in localised, short-term impacts on species or a potential **Negligible (F)** consequence.

Summary

Due to the lack of hard substrate and depth of the Offshore Project Area, lack of sensitive species and the ability for any present fish species in the area during drilling activities to actively avoid drill cuttings and fluids discharge plumes, there is not likely to be a substantial adverse effect on a fish population. Additionally, given the short term and temporary nature of the discharge activities, there is not likely any impacts to the spatial distribution of fish or their larvae, or modification of habitat or disruption to lifecycle. On this basis the impacts to fish, from discharging drill cuttings and fluids during activities associated with Scarborough has not been evaluated further.

Table 7.38 outlines the potential impacts to receptors associated with routine and non-routine drilling discharges.

Table 7.38: Receptor/impact matrix after evaluation of context

	Receptor							
Impacts	***Water Quality***	***Sediment Quality***	***Plankton***	***Epifauna and Infauna***	***Fish***	***Marine Mammals***	***Marine Reptiles***	***KEFs***
Change in water quality	✓							
Change in sediment quality		✓						
Change in habitat								✓
Injury/mortality to fauna			✓	✓	X	X	X	

Detailed Impact Evaluation

For each of the receptors identified for detailed evaluation, the criteria for acceptability as defined in Table 6-3 have been considered and addressed in the following sections. This includes to meet the principles of ESD, internal and external context and any other requirements.

Water Quality

The potential impact to water quality from drilling-related discharges is due to drill cuttings and fluids, cement, completion fluids, well annular fluids and subsea control fluid.

Drill Cuttings and Fluids

The routine and non-routine discharge of cuttings and adhered fluids from the surface will occur intermittently during drilling. Neff (2005) states that although the total volumes of muds and cuttings discharged to the ocean during the drilling of a well are large, the impacts in the water column environment are minimal, because discharges of small amounts of materials are intermittent.

When cuttings are discharged to the ocean, the larger particles, which represent ~90% of the mass of the mud solids, form a plume that settles quickly to the bottom (or until the plume entrains enough sea water to reach neutral buoyancy). Hinwood et al. (1994) indicate that larger particles of cuttings and adhered muds (90–95%) fall to the seabed close to the release point.

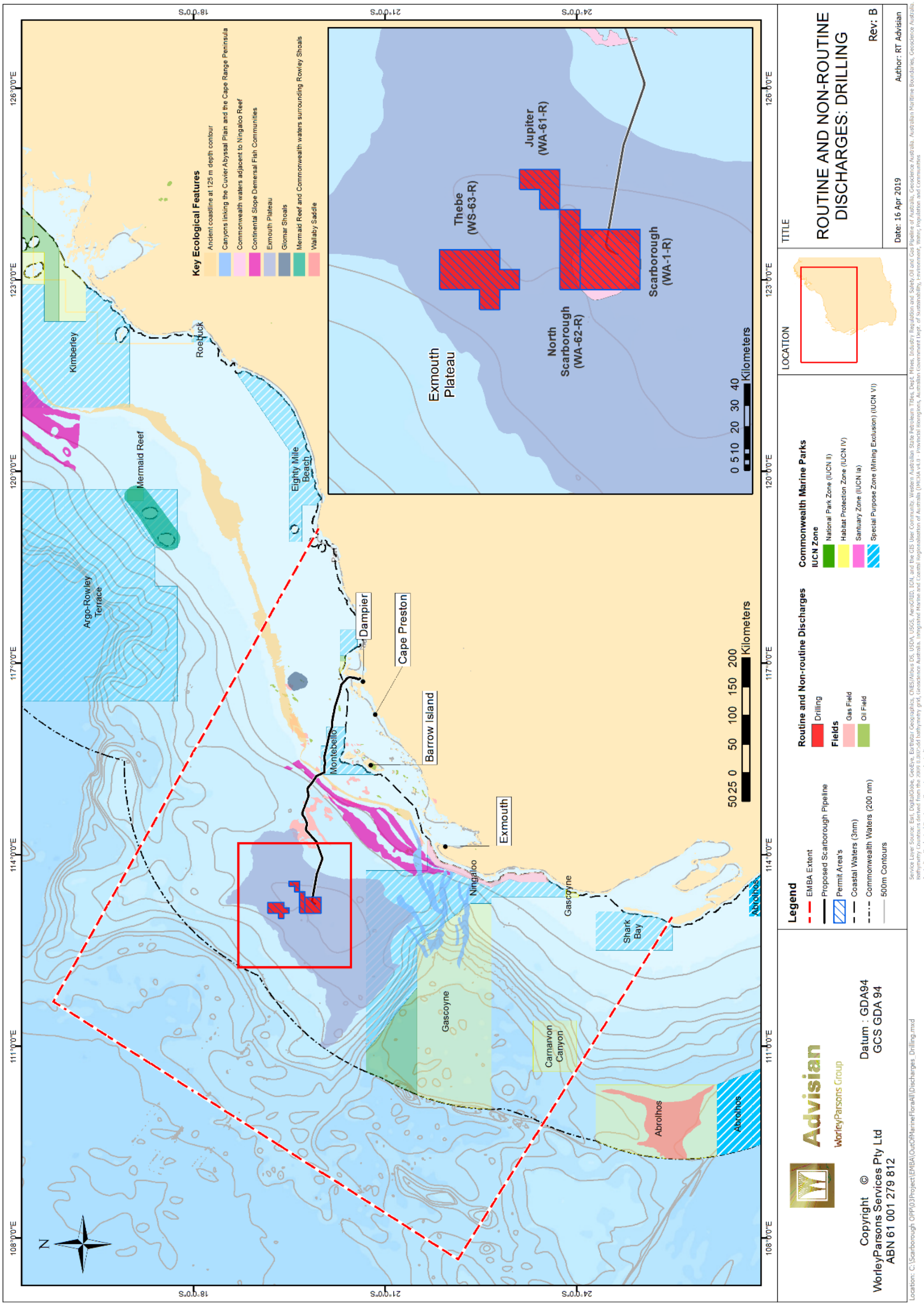
Other studies including Hinwood et. al (1994) and Neff (2005), which note that within 100 m of the discharge point, a drilling cuttings and fluid plume released at the surface will have diluted by a factor of at least 10,000; and that in well-mixed ocean waters (as is likely to be the case within the Project Area), drilling mud is diluted by more than 100-fold within 10 m of the discharge point.

Using the widely-accepted dilution factor of 10,000 (Neff, 2005), cuttings (and adhered fluids) are expected to reach 100 mg/L within 100 m of the MODU. Using a conservative ocean current speed of 0.1 m/s (which is well below average current speeds in the Offshore Project Area), these discharges are expected to disperse to 100 mg/L within ~16 minutes.

The area potentially impacted by turbidity was conservatively set at 1000 m from the MODU. That is, it is expected that 1000 m away from the MODU, turbidity concentrations are below impact thresholds (Figure 7.17).

Regarding toxicity, using the dilution assumptions described above (Neff, 2005; Melton et al., 2000), drilling cuttings and fluid discharge drops below the USEPA acute toxicity threshold of 10,000 ppm within 10 m of the discharge point; which is expected within two minutes, using conservative current speeds.

If NWBM are used, the cuttings tend to clump together in particles that rapidly settle to the seabed, suggesting that synthetic-based mud-coated cuttings tend to be less likely to increase water column turbidity (American Chemistry Council, 2006).



Note: MODU operations would not occur within all these areas simultaneously.

Figure 7.17: Predicted exposure area from drill cuttings and fluid discharges associated with MODU operations

Cement

Previous modelling (BP Azerbaijan, 2013) has shown low concentrations (<50 ppm) of cement particles within localised (~150 m horizontal and 10 m vertical) areas within two hours of discharge; and these concentrations reduce to <5 ppm approximately five hours after discharge ceases.

Because cement is expected to harden within a few hours, and because exposure to in-water concentrations are expected to be limited due to the rapid dispersion and dilution through the water column, the potential for acute or chronic effects on other receptors due to water quality is not discussed further.

Completion Fluids

The change to water quality due to discharges of completion fluid is expected to be localised; drilling discharges have previously been identified to dissipate no more than 100 m from the drilling site (Kinhill, 1998; IRCE, 2003).

Subsea Control Fluid

It is expected concentrations of subsea control fluid would be ~10 ppm within 100 m of the well heads (BP Azerbaijan, 2013). Using a conservative ocean current speed of 0.1 m/s, fluids would be expected to travel 100 m (and thus reach concentrations of 10 ppm) in ~16 minutes.

Given the small volumes associated with this discharge and limited exposure times due to rapid dilution, any potential impact to this aspect is expected to be localised and short term.

Well Annular Fluids

The small volumes and non-instantaneous nature of the release of the well annular fluids is expected to result in rapid dilution to a no-effect concentration within meters of the release location.

Summary

Studies have shown that subsea control fluid, completion fluid and well annular fluid have a predicted extent of <100 m (Kinhill, 1998; IRCE, 2003; BP Azerbaijan, 2013) which is less than that conservatively used to asses impact for drill cuttings and fluids (500 m). Therefore, these discharge types are not assessed separately for those receptors impacted by changes to water quality.

The water quality within the Project Area is typical of an unpolluted tropical offshore environment. Within the Project Area, where discharges are to occur, the environmental performance outcome for water quality is to not result in a substantial change to water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. Given the relatively small volumes, and the offshore location, biodiversity, ecological integrity, social amenities and human health will not be impacted.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to water quality. In addition, the activity is not proposed to take place in any AMPS, and as such there are no specific principles, objectives and values to be considered.

Based on the detailed evaluation, the magnitude of the potential impact of a change in water quality from drilling activities associated with Scarborough is slight and evaluated to be **acceptable**.

Sediment Quality

Subsea discharges that may affect sediment quality are drill cuttings and fluids, cement and subsea control fluids.

Drill Cuttings and Fluids

A change in sediment quality is an alteration in the condition of the sediment from its previous state which may occur due to discharges of both drilling cuttings and fluid. WBM has the potential to change sediment texture, in turn inhibiting the settlement of planktonic polychaete and mollusc larvae (Swan et al., 1994). The dilution of solid elements of the WBM into substrate largely depends on the energy level of the local environment and the 'mixing' that takes place but is expected to occur rapidly following release (especially with WBM).

Base fluids for NWBM (if required) are designed to be biodegradable in offshore marine sediments. Biodegradation can result in a low oxygen (anoxic) environment; however, this is dependent on the bioavailability of the base fluid. NWBM are designed to be low in toxicity and are not readily bioavailable.

Studies around the world also indicate biological effects from seabed communities associated with the deposition of NWBM cuttings are limited to ~500 m from a well site (Davis et.al., 1989; Daniels, 1998; Limia, 1996; Oliver and Fisher, 1999; Terrens et.al, 1998). Other studies found that in deeper water, NWBM may disperse horizontally from 500 -1000 m, therefore a conservative impact radius of 1000 m is assumed (Garcia et al. 2011; IAOGP, 2016). This indicates there is the potential for burial, smothering impacts and potential toxicity over an area of ~3.14 km^2 per well. For the proposed 20 plus 10 contingency wells, this gives a conservative total footprint of 94.2 km^2.

A study on the impacts of drilling in Bass Strait by Terrens et al. (1998) observed biological effects within 100 m of the drilling site shortly after drilling; recovery of seabed communities across the area were reported within four months. This study found that after 11 months NWBM was not detectable in sediments, indicating that recovery of the seabed is through a combination of dispersion and biodegradation. Neff (2010) found that recolonisation of synthetic-based, mud-cuttings piles in cold-water marine environments began within one to two years of ceasing discharges, once the hydrocarbon component of the cutting piles biodegraded. These studies were associated with cold, deepwater environments, but the recovery processes are expected to be similar.

In addition to degradation of drilling fluids, physical dispersion of drilling cuttings and fluids can be expected, given the influence of subsea currents in the area. Exposure duration is conservatively estimated at ~10 years. Consequently, a conservative recovery duration of ten years is used for evaluating the potential impacts and risks associated with this activity.

Cement

Overspill of cement will impact sediment quality immediately adjacent to the well once it hardens, permanently altering physical sediment properties. The potential disturbance area from discharge of cement is 0.007 km^2 per well; giving a total potential disturbance footprint of ~0.21 km^2 for the proposed wells.

Cement discharges may result in a localised alteration of seabed substrate within a habitat that is considered homogenous and not overly sensitive.

Subsea Control Fluids

Subsea control fluids have only ~3% active ingredients and are of relatively small volumes. Control fluids are expected to disperse rapidly throughout the water column adjacent to the seabed. Modelling for another offshore project indicates that subsea control fluid would dilute to below impact thresholds within 100 m from the BOP, and within 16 minutes (BP Azerbaijan, 2013). There is potential for some toxins in the control fluid to accumulate in the sediment, but due to small volumes and rapid dispersal, it is considered negligible.

Summary

The marine sediment within the Project Area bare sandy/silt and calcareous ooze and is reflective of the broader sediment found on the Exmouth Plateau and the deep-water environment of the NWMR. Within the Project Area, where discharges are to occur, the environmental performance outcome for marine sediment is to not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. Given the relatively small volumes and area of impact, the offshore location and the low sensitivity of marine sediment in the Project Area, biodiversity, ecological integrity, social amenities and human health will not be impacted.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to water quality. In addition, the activity is not proposed to take place in any AMPS, and as such there are no specific principles, objectives and values to be considered.

Based on the detailed evaluation, the magnitude of the potential impact of a change in sediment quality from drilling activities associated with Scarborough is slight and evaluated to be **acceptable**.

<u>Plankton</u>

Any surface and subsurface drilling-related discharge types could impact plankton, as they are widely dispersed throughout the water column. The discharge types with the greatest potential to impact plankton are drill cuttings and fluids and cement.

Drill Cuttings and Fluid

Injury/mortality to planktonic species may occur due to a change in water quality following discharges of drill cuttings and fluids. Impacts to these organisms can be as a product of both physical and/or chemical alterations of water quality, predominantly in the water column. Impacts to zooplankton from turbidity are associated with variations in predator prey dynamics which favours planktonic feeders over visual feeders (Gophen, 2015), while impacts to phytoplankton occur due to decreases in available light, therefore reducing productivity (Dokulil, 1994). Surveys completed by ERM (2013) during the wet and dry season within the Exmouth Plateau in the vicinity of the Offshore Project Area found that there is very low planktonic productivity in the region.

Jenkins and McKinnon (2006) reported that levels of suspended sediments greater than 500 mg/L are likely to produce a measurable impact upon larvae of most fish species, and that levels of 100 mg/L will affect the larvae of some species if exposed for periods greater than 96 hours. Jenkins and McKinnon (2006) also indicated that levels of 100 mg/L may affect the larvae of several marine invertebrate species, and that fish eggs and larvae are more vulnerable to suspended sediments than older life stages. Note, any impact to fish larvae is expected to be limited due to high natural mortality rates (McGurk, 1986), intermittent exposure, and the dispersive characteristics of the open water in the vicinity of the wells.

As dilution estimates (e.g. Hinwood et al., 1994; Neff, 2005) suggest suspended sediment concentrations caused by the discharge of drill cuttings will be well below the levels required to cause an effect on fish or invertebrate larvae (i.e. predicted levels are well below a 96-hour exposure at 100 mg/L, or instantaneous 500 mg/L exposure), minimal impact to larvae, or other marine fauna (pelagic fish, cetaceans, seabirds), is expected from the discharge of drill cuttings. Neff (2010) explains that the lack of toxicity and low bioaccumulation potential of the drilling muds means that the effects of the discharges are highly localised and are not expected to spread through the food web (of which planktonic species are the basis).

The toxicity of widely used NWBMs to zooplankton is considered low, with acute toxicity >10,000 ppm (Vik, Dempsey and Nesgård, 1996). As WBMs are inherently less toxic, the impact threshold for NADF was used for this evaluation. In well-mixed ocean waters (as is likely to be the case within the Project Area), drilling mud is diluted by more than 100-fold within 10 m of the discharge point, indicating that, following dilution, concentrations would be well below acute impact levels Neff (2005).

This is supported by Melton et al. (2000), who used modelling to demonstrate that WBM and NADF cuttings and solids within the water column fall below the United States Environment Protection Agency (USEPA) minimum 96-hour LC50 for drilling fluids within the first few metres of a surface discharge point (using a current speed of 0.17 m/s, which is slower than currents in the region).

Knowing that drilling fluids dilute 100-fold within 10 m of the discharge, and assuming the concentration of drilling fluids upon release is 100% (or 1,000,000 ppm), it is expected that concentrations of drilling fluid would fall below acute toxicity thresholds (10,000 ppm) within 10 m from the MODU. Using a conservative ocean current speed of 0.1 m/s, these discharges are expected to disperse to below acute toxicity thresholds within two minutes.

Therefore, only organisms very close to the discharge point would be exposed to chemical concentrations above the acute toxicity threshold, and only for a very short period.

Summary

Due to the lack of planktonic productivity in the offshore area, plankton populations on a regional scale are not expected to be affected by drilling operations. In addition, the open nature of the Scarborough Project Area and associated environmental conditions (i.e. windy, strong currents, etc.), the content of and dispersive nature of drilling muds within the marine environment (Hindwood, 1994; Neff, 2005) and the high population replenishment of these organisms, it is expected that impacts to plankton species will be limited to within 500 m of the discharge point and return to previous conditions within a relatively short period of time. On this basis the impacts to plankton, from routine and non-routine discharges during drilling activities is slight and evaluated to be **acceptable**.

Epifauna and Infauna

Subsea discharges that may affect epifauna and infauna are drill cuttings and fluids and cement.

Drill Cuttings and Fluids

The main environmental disturbance from discharging drilling cuttings and fluids is associated with the smothering and burial of sessile benthic and epibenthic fauna (Hinwood et al. 1994). Sessile benthic organisms located below the cuttings pile are likely to be smothered, while demersal species may be temporarily displaced from the area within which cuttings discharges accumulate. Ecological impacts are predicted when sediment deposition is equal to or greater than 6.5 mm (in thickness) (IOGP, 2016); confined to within a few hundred metres of the well location. Low levels of sediment deposition away from the immediate area of the well site may occur and would represent a thin layer of settled drill cuttings which will likely be naturally reworked into surface sediment layers through bioturbation (USEPA, 2000) and will not be of a significant impact.

Many studies have shown that the effects on seabed fauna and flora from the discharge of drilling cuttings with water based muds are subtle, although the presence of drill-fluids in the seabed close to the drilling location (<500 m) can usually be detected chemically (e.g. Cranmer, 1988; Neff et al., 1989; Hyland et al., 1994; Daan & Mulder, 1996; Currie & Isaacs, 2005; OSPAR, 2009; Bakke et al., 2013).

Ecological impacts are not expected for mobile benthic fauna such as crabs and shrimps or pelagic and demersal fish given their mobility (IOGP, 2016). Balcom et al. (2012) concluded that impacts associated with the discharge of cuttings and base fluids (including (NWBMs) are minimal, with impacts highly localised to the area of the discharge. Changes to benthic communities are normally not severe. 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, 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. (2006, 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.

Studies around the world also indicate biological effects from seabed communities associated with the deposition of NWBM cuttings are limited to ~500 m from a well site (Davis et.al., 1989; Daniels, 1998; Limia, 1996; Oliver and Fisher, 1999; Terrens et.al, 1998). Other studies found that in deeper water, NWBM may disperse horizontally from 500 -1000 m, therefore a conservative impact radius of 1000 m is assumed (Garcia et al. 2011; IAOGP, 2016). This indicates there is the potential for smothering impacts and potential toxicity over an area of ~3.14 km² per well.

Additional studies indicate that benthic infauna and epifauna recover relatively quickly, with substantial recovery in deepwater benthic communities within three to ten years (Jones, Gates and Lausen, 2012). These studies were associated with cold, deepwater environments, but the recovery processes are expected to be similar. Although effectiveness and recovery time may differ, the species present in soft sediment are well adapted to changes in substrate, especially burrowing species (Ref. 107); therefore, recovery is expected to be quicker. Within the Offshore Project Area and surrounding Exmouth Plateau environment, epifauna and infauna species dominate fauna abundance and are sparse and uniform in presence. Fauna include motile organisms such as shrimps, small burrowing worms, sea cucumbers, sea stars and crustaceans. There are no EPBC listed threatened benthic communities or species in the Offshore Project Area or within the footprint of the discharge location (ERM, 2013a).

The IAOGP paper (2016) found that the abundance and diversity of sessile and slow-moving megafauna could be reduced within the 50-100 m of cuttings discharge to the seafloor; and mobile megafauna were usually unaffected. Effects were the greatest at water depths >600 m. However, this study also found that in most cases, there is substantial recovery in benthic communities within one to a few years.

In general, research suggests that any smothering impacts within the Project Area will be limited to 1000 m from the well site, and full recovery is expected. Given the dispersive and inert nature of WBMs, the localised settling of NWBMs, the sparse and uniform nature of epifauna and infauna species in the Offshore Project Area and the lack of EPBC listed species, the impacts to epifauna and infauna species are expected to be limited.

Cement

Once cement overspill from cementing activities hardens, the area directly adjacent to the well (10–50 m) will be altered, resulting in the destruction of seabed habitat within this area; affecting any resident infauna and epifauna (Terrens et.al, 1998). The potential disturbance area is 0.007 km² per well. For the 20 proposed wells plus 10 contingency wells (estimate only) for Scarborough Project, results in a potential disturbance footprint of ~0.21 km².

The potential impacts of smothering from a surface release are expected to be significantly less, due to small volumes, intermittent nature of these discharges, and high potential for dispersal by ocean currents. This impact on soft sediment communities is not expected to affect the diversity or ecosystem function in this area and is only considered a localised impact with a **Negligible (F)** consequence.

Summary

Impacts to benthic species are predicted to be locally restricted, temporary during drilling activities, and localised to within a conservative radius of 1000 m of each proposed well (giving a potential disturbance footprint of ~3.14 km² per well; and a total 94.2 km² for the proposed 20 wells plus 10 contingency wells). On this basis, the impacts to benthic communities, from discharging of drilling-related fluids during activities is slight and evaluated to be **acceptable**.

<u>KEFs</u>

Discharges that may affect KEFs are drill cuttings and fluids and cement.

Although the Project Area lies within three KEFs, only one intersects with the Offshore Project Area where drilling activities will be undertaken, which is the Exmouth Plateau. Values associated with this KEF relate to attributes of demersal habitats and features, and it is likely to be an important area of biodiversity, as it provides an extended area offshore for communities adapted to depths of around 1000 m.

Drill Cuttings and Fluids

Drill cuttings and cement discharges can physically smother seabed habitat and alter seabed substrate; and can also expose benthic habitats to chemical toxicity. As described above, impacts associated with discharges of drilling fluid and cuttings will be limited to the area surrounding the discharge source. During riserless drilling, direct deposition of drilling fluids and cuttings on the seabed will impact a relatively small area of the KEF when compared to its overall size (49,310 km²).

A conservative impact radius of 1000 m is assumed indicating there is the potential for burial, smothering impacts and potential toxicity over an area of ~3.14 km² per well.

This gives a total footprint of 94.2 km² for approximately 20 proposed wells plus 10 as contingency. This represents a very small fraction of the Exmouth Plateau KEF (49310 km²).

During surface discharges, due to the dispersive nature of chemical discharges within the highly mixed offshore marine environment, fluids and cuttings are expected to disperse rapidly within the water column and settle on the seabed in low volumes and chemical concentrations. The magnitude of potential impacts to KEFs are therefore expected to be slight.

Cement

The proposed wells are located within a single KEF (Exmouth Plateau) and have the potential to be exposed to smothering and alteration of the seabed. Benthic habitat is expected to comprise soft sediment infauna communities that are widespread and homogenous in the region and is considered a unique seafloor feature with ecological properties of regional significance, which apply to both the benthic and pelagic habitats within the feature (DSEWPC, 2012).

Terrens et.al (1998) indicated that cement from upper-hole sections displaced to the seabed may affect the seabed around the well to a radius of ~10 m to 50 m from the well, resulting in the potential for disturbance of 0.007 km² per well. For the proposed wells for Scarborough Project, results in a potential disturbance footprint of 0.21 km²; which represents a very small fraction of the whole KEF.

Cement discharges may result in a localised alteration of seabed substrate within a habitat that is considered homogenous and not overly sensitive. Given the relatively small footprint associated with the subsea release of cement and very small proportion of the KEF potentially impacted, the magnitude of this impact is considered to result in localised impact to habitat with no lasting effect.

Summary

The environmental performance outcome for KEFs is 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. The only KEF which may be impacted is the Exmouth Plateau. Given the small amount of representative habitat within the KEF that will be impact from drilling discharges (0.0013% of the KEF), no impacts to marine ecosystem functioning or integrity of the KEF are expected.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to KEFs. Physical habitat modification is recognised as a pressure 'of less concern' in the Marine Bioregional Plan for the NorthWest Marine Region (DSEWPC, 2012). In addition, the activity is not proposed to take place in any AMPS, and as such there are no specific principles, objectives and values to be considered.

Based on the detailed evaluation, the magnitude of the potential impact on the Exmouth Plateau KEF from routine and non-routine discharge of drill-related fluids is evaluated as slight and **acceptable.**

7.1.12.3 Impact Significance Evaluation

Impacts from routine and non-routine discharges from drilling will have a slight effect on receptors, as the extent, duration, frequency and scale of the impact are all sufficiently small. When considered with receptor sensitivity, Impact Significance Level of drilling-related discharges from Scarborough have been evaluated as **Negligible (F)**. The impacts overall have been determined as **acceptable** based on an evaluation against the criteria.

To meet the principles of ESD

- These discharges will result in localised and temporary changes in water quality, such as increased toxicity and turbidity, which can potentially impact marine fauna.
- The predominantly dispersive and non-toxic nature of drilling-related discharges, the location of the Offshore Project Area in deep (~930 m), highly mixed and relatively sparse open water, and lack of sensitive receptors mean that the discharges are localised.
- These discharges will result in localised changes in sediment quality, including increased toxicity and smothering and alteration of the seabed, which can potentially impact sediment quality, epifauna and infauna and the Exmouth Plateau KEF.
- Multiple studies of drill cuttings and fluid discharges found that depending on mud type, water depth and current, water quality would fall below acute toxicity thresholds within 10 m of the discharge point; within about two minutes. Sediment quality was found to potentially be impacted by smothering and toxicity over a horizontal distance of <1000 m from the discharge. Therefore, a conservative radius of 1000 m has been set, and a conservative recovery duration of ten years has been used for evaluating the potential impacts and risks associated with this activity. This conservative disturbance footprint of ~3.14 km^2 per well gives a total of 94.2 km^2 for the proposed 20 wells plus 10 contingency wells.
- Cement overspill will permanently alter the seabed immediately adjacent (<50 m) to the wells, giving a total estimated disturbance footprint of 0.007 km^2 per well (or 0.21 km^2 for the proposed 20 wells plus 10 contingency wells). As benthic habitat is expected to comprise soft sediment infauna communities that are widespread and homogenous in the region, cement discharges are not expected to affect the diversity or ecosystem function in this region.

- Therefore, the total disturbance footprint of the worst-case drilling-related discharges type (drill cuttings and fluids) is 94.02 km^2; for the proposed wells. This represents a small fraction of the Exmouth Plateau KEF, which is the only KEF intersected by the Offshore Project Area.

Internal context

- With respect to routine and non-routine discharges of brine and cooling water, Woodside will implement its internal requirement:
  - Chemicals must be selected with the lowest practicable environmental impacts and risks subject to technical constraints.

External context

- No stakeholder concerns have been raised with respect to routine and non-routine discharges of drill-related fluids, or potentially impacted receptors.

Other requirements

- With respect to routine and non-routine discharges of drill-related fluids, activities associated with Scarborough 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.

7.1.12.4 Summary of the Impact Assessment

Table 7.39 provides a summary of the risk assessment and acceptability for impacts from drilling discharges on receptors.

Table 7.39: Summary of impacts, key management controls, acceptability, EPOs and residual risk rating for drilling discharges

Receptor	Impact	Environmental Performance Outcome	Adopted control(s)	Receptor sensitivity level	Magnitude	Impact Significance level	Acceptability
Sediment Quality	Change in sediment quality	**EPO3:** To not substantially change sediment quality, which may adversely impact biodiversity, ecological integrity, social amenity or human.	**CM16:** Chemicals will be selected with the lowest practicable environmental impacts and risks subject to technical constraints. **CM19:** WBM will be used during drilling activities as the first preference. Where WBM cannot meet required technical specifications, NWBM may be used following technical justification. **CM20:** Bulk overboard discharge of NWBM is prohibited. **CM21:** Drill cuttings returned to the MODU will be processed to reduce oil on cuttings to < 6.9% by weight on wet cuttings (measured as a well average only including sections drilled with NWBM) prior to discharge. **CM22:** Drill cuttings returned to the MODU will be discharged below the waterline.	Low value (open water)	Slight	Negligible (F)	Acceptable
Water Quality	Change in water quality	**EPO2:** To not result in a substantial change in water quality (including temperature) which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		Low value (open water)	Slight	Negligible (F)	Acceptable
Plankton	Injury/ mortality to fauna	**EPO6:** To not have a substantial adverse effect on a population of plankton including its life cycle and spatial distribution.		Low value (open water)	No lasting effect	Negligible (F)	Acceptable
Epifauna and Infauna	Injury/ mortality to fauna	**EPO1:** 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.		Low value (open water)	No lasting effect	Negligible (F)	Acceptable
KEFs	Change in habitat	**EPO16:** 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.		Medium value habitat	Slight	Negligible (F)	Acceptable

7.2 Unplanned Aspects

7.2.1 Unplanned Discharge: Chemicals

7.2.1.1 Sources of the Aspect

Activities and facilities associated with Scarborough may result in the unplanned discharge of chemicals to the marine environment during:

- drilling operations
- FPU operations.
- vessel operations
- MODU operations
- ROV operations
- helicopter operations

Vessel, MODU, FPU and ROV Operations

Chemicals are used during vessel, MODU, FPU and ROV activities for a variety of purposes within the Offshore Project Area and Trunkline Project Area. FPU, vessels and ROVs may be used during all phases of Scarborough in both the Offshore Project Area and Trunkline Project Area, whereas MODUs will only be used during drilling phases in the Offshore Project Area. Chemicals that will be used and may inadvertently be released may include:

- non-process chemicals (maintenance and cleaning chemicals)
- non-process hydrocarbons - i.e. hydraulic fluids used in machinery (including cranes, winches, ROVs), small volumes of fuel
- drilling fluids/muds/cement
- operational process chemicals.

Non-Process Chemicals

Non-process chemicals, such as wash chemicals, cleaning chemicals, maintenance and solvents are generally held onboard in low quantities (typically <50 L containers) and are located within chemical cabinets or bunded storage areas on the vessels and MODU. Spills of these chemicals may result from human error or damage to a chemical container during handling. Spills are generally captured by the drain system and routed to a holding tank for treatment or disposal onshore. In the event that a spill is not contained on deck or within a bunded area, there would be a release to the marine environment of up to 50 L.

Non-Process Hydrocarbons

Non-process hydrocarbons (hydraulic fluids) are used in hydraulic-powered machinery such as winches, cranes and ROVs, and are hydrocarbon-based with added chemical component additives. Unplanned discharges are predominantly due to failure of hydraulic hoses or minor leaks from process components, or spills during periodic refuelling of hydraulic hoses. Spills or leaks from hydraulic hoses are usually very small volumes (~1 L) and are typically contained within a bunded or drained area under the equipment mounted on deck. These small on-deck spills would be very unlikely to make it into the marine environment. A burst hydraulic hose on an extended crane could potentially result in hydraulic fluid being sprayed in a fine jet out over the water. However, this would only result in a small volume (~25 L) being released, due to the small capacity of hydraulic hoses.

ROVs are typically used during subsea works for surveying during drilling or production activities and during installation of the trunkline. ROVs may also be used for ongoing subsea inspection and maintenance activities of the wells and trunkline. ROV hydraulic lines are exposed to the marine environment and have the potential to be pinched through Operator error or may become caught resulting in minor hydraulic leaks (typically <20 L, based on capacity of hydraulic hoses).

Hydraulic fluids are medium oils of light to moderate viscosity and have a relatively rapid spreading rate and will dissipate quickly, particularly in high sea states. Lubricating oils may also be held onboard, typically stored with the non-process chemicals and held in low quantities. These hydrocarbons are more viscous, and so in the event of an unplanned discharge the spreading rate of a slick of these oils would be slightly slower.

Small volumes of MDO or aviation fuel could be released to the deck and/or the marine environment during bunkering, due to a partial or total failure of bulk transfer hoses. The credible volumes of such releases would be in the order of <200 L for MDO; and <100 L for aviation fuel (during helicopter refuelling).

Operational Process Chemicals

Operational process chemicals (such as MEG) stored on the FPU are generally kept in larger quantities compared to vessels or MODUs, subject to the requirement of the ongoing production from the wells. Typically, process chemicals are stored in dedicated tanks such as ISO tanks, which may be permanently plumbed in. Tank volumes for chemical storage can be up to 40 m^3. In the event of damage or corrosion of the tank, the worst-case credible chemical spill scenario could result in the entire tank volume being discharged and entering the marine environment.

Bulk transfer of process chemicals may occur via hoses directly from a supply vessel to the dedicated chemical storage on the FPU. Unplanned discharge may occur through Operator error or failure to follow procedures during bulk transfer. Typical spill volumes during transfer via hoses is less than 0.2 m^3, based on the volume of the transfer hose and the immediate shutoff of the pumps by personnel involved in the bulk transfer process. However, the worst-case credible spill scenario during transfer could result in up to 8 m^3 of discharge of chemical to the deck and/or into the marine environment, based on partial or total failure of a bulk transfer hose or fittings, combined with a failure in procedure to shutoff fuel pumps, for a period of up to five minutes. This unlikely scenario represents a complete failure of the bulk transfer hose combined with a failure to follow procedures (which require transfer activities to be monitored), coupled with a failure to immediately shut off pumps.

The behaviour of process chemicals when released in the marine environment is dependent on their physical and chemical properties, that is their tendency to evaporate, float, dissolve in the water column, or sink to the sea bed. The potential risk to receptors arises from the resulting ecotoxicity, bioaccumulation, and biodegradation of chemicals.

Drilling Operations

Drilling Fluids/Muds

Unplanned discharge of drilling muds or fluids may occur during events such as:

- bulk transfer of mud or base oil from the supply vessel to the MODU
- failure of the slip joint packer
- loss of chemical container during transfer from the supply vessel to the MODU.

A support vessel will undertake bulk transfer of mud or base oil to the MODU, if and when required. Failure of a transfer hose or fittings during a transfer or backload, as a result of an integrity or fatigue issue, could result in a spill of mud or base oil to either the bunded deck or into the marine environment.

The most likely spill volume of mud is likely to be less than 0.2 m^3 based on the volume of the transfer hose and the immediate shutoff of the pumps by personnel involved in the bulk transfer process. However, the worst-case credible spill scenario could result in up to 8 m^3 of mud being discharged. This scenario represents a complete failure of the bulk transfer hose combined with a failure to follow procedures requiring transfer activities to be monitored, coupled with a failure to immediately shut off pumps (e.g. mud pumped through a failed transfer hose for a period of about five minutes).

The slip joint packer enables compensation for the dynamic movement of the MODU (heave) in relation to the static location of the BOP. A partial or total failure of the slip joint packer could result in a loss of mud to the marine environment. The likely causes of this failure include a loss of pressure in the pneumatic (primary) system combined with loss of pressure in the back up (hydraulic) system.

Catastrophic sequential failure of both slip joint packers (pneumatic and hydraulic) would trigger the alarm and result in a loss of the volume of fluid above the slip joint (conservatively 1.5 m^3) plus the volume of fluid lost in the one minute (maximum) taken to shut down the pumps. At a flow rate of 1000 gallons per minute this volume would equate to an additional 3.8 m^3. In total, it is expected that this catastrophic failure would result in a loss of 5.3 m^3.

Failure of either of the slip joint packers at a rate not large enough to trigger the alarms could result in an undetected loss of 20 bbl (3 m^3) maximum assuming a loss rate of 10 bbl/hr and that MODU personnel would likely walk past the moon pool at least every two hours.

Loss of a drilling chemical container or drum during transfer from the supply vessel to the MODU may occur due to crane operator error or machinery failure. The maximum container that could be lost is an intermediate Bulk Container (IBC) which can hold 1 m^3 of chemicals. In the event that an IBC or drum is lost to the marine environment and cannot be recovered the contents will discharge, either immediately or over a period depending on the damage to the drum or container.

Cement

Bulk cement is transferred as powder from the supply vessel to the MODU prior to being mixed into a slurry in the cement unit. Additives are required to form a cement slurry; these are transferred to the MODU in drums from the supply vessel to the MODU. Unplanned discharge to the marine environment may occur due to crane operator error or machinery failure resulting in loss of a drum of cement additive, which cannot be recovered. Cement additives are typically stored in drums <100 litres.

7.2.1.2 Impact or Risk

Risk events resulting from unplanned chemical discharges have the potential to result in the following impacts:

- change in water quality
- change in sediment quality
- injury or mortality to marine fauna.

Change in Water Quality

Unplanned discharges of non-process chemicals and hydrocarbons may decrease the water quality in the immediate vicinity of the release and occur at all locations over Scarborough and throughout the life of the project. Only small volumes (<0.2 m^3) are anticipated, resulting in very short-term impacts to water quality, and limited to the immediate release location.

The worst-case scenario of an unplanned release of operational process chemicals during FPU operation is 8 m^3 during bulk transfer, or 40 m^3 for the loss of an entire ISO tank. The worst-case drilling fluid or cement unplanned discharge is 8 m^3 which could occur during bulk transfer from the supply vessel to the MODU during drilling. These discharges would be to the sea surface and would rapidly dilute through mixing by surface currents and wave action.

Change in Sediment Quality

Impacts associated with unplanned chemical releases will be limited to the area surrounding the discharge source of the vessel, MODU, FPU or ROV. Non-process chemicals or hydrocarbons may inadvertently be discharged by vessels or ROVS in shallower waters, closer to shorelines, however volumes would be <0.2 m^3.

Larger volumes of process chemicals could potentially be released from the FPU or MODU, however, while entrainment of some of the discharge may occur during the mixing by currents and wave action, flocculation and settlement of particles through approximately 900 m water depth is not expected to occur. Chemicals toxins associated with surface discharges are not expected to reach marine sediments at concentrations that will result in notable changes to sediment quality. Therefore, impacts to sediment quality resulting from unplanned discharges of chemicals are not evaluated further.

Injury or Mortality to Marine Fauna

As a result of a change in water quality, further impacts to receptors may occur, which include injury or mortality to marine fauna resulting from exposure to toxins in the released chemicals. Given that surface discharges are rapidly dispersed, and subsea discharges (from ROVs) would be of very small volumes, the marine fauna at risk is limited to surface dwelling species.

Receptors at Risk

Risk events resulting from unplanned discharge of chemicals has the potential to impact the following receptors:

- water quality
- plankton
- fish
- marine mammals
- marine reptiles.

Given the impacts are restricted to surface waters in the immediate vicinity of the discharge, benthic species have not been considered. On this basis, the KEFs within the Project Area have not been identified at risk as the values associated with these KEFs related to the attributes of the demersal habitats and features.

Plankton, Fish and Marine Mammals and Reptiles

Potential impacts to plankton from an accidental chemical discharge and the associated impact to water quality may include acute toxicity resulting in mortality of planktonic organisms. Given the rapid turnover of plankton communities (UNEP, 1985) and nature and scale of the credible releases, these impacts will be short-lived. Similarly, impacts to fish are expected to be of no lasting effect, as fish species are mobile and not restricted to the area affected by an unplanned chemical discharge. As such the impact to plankton and fish have not been evaluated further.

Other ecological receptors that may be present in surface waters that have the potential to be impacted by unplanned discharges of chemicals include transient marine mammals and marine reptiles. These organisms could be exposed to toxins and other chemicals present in the discharge which could potentially result in injury or mortality such as temporary irritation of sensitive membranes such as the eyes, mouth, and digestive system.

Physical coating of marine fauna by and sub-lethal or lethal effects from toxic chemicals, is considered unlikely given the expected low volumes of discharge, short exposure times and the rapid dilution and dispersion of the chemical discharge once entering the marine environment. Impacts to marine fauna will be limited to temporary irritation of sensitive membranes. The largest discharge volume potential (40 m^3) is from the FPU location, which is in a highly mixed, open water environment approximately 900 m deep.

Although distribution of some marine fauna species extends to the deeper, offshore waters of the Offshore Project Area, no known aggregation areas occur and therefore the likelihood of individuals being exposed to unplanned chemical releases at concentrations high enough to impact are considered negligible and not evaluated further.

Table 7.40 outlines the potential impacts to receptors associated with unplanned chemical releases.

Table 7.40: Receptor/impact matrix

	Receptor				
Impacts	***Water Quality***	***Plankton***	***Fish***	***Marine Mammal***	***Marine Reptiles***
Change in water quality	✓				
Injury/mortality to fauna		X	X	X	X

Detailed Risk Evaluation

For each of the receptors identified for detailed evaluation, the criteria for acceptability as defined in **Table 6-3** have been considered and addressed in the following sections. This includes to meet the principles of ESD, internal and external context and any other requirements.

Water Quality

The open water location and relatively small volumes of chemicals released will result in rapid dilution close to the source of discharge and is expected to have no lasting effects. Within the Project Area, where discharges are to occur, the environmental performance outcome for water quality is to not result in a substantial change to water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.

The environmental performance outcome for water quality is to not substantially change water quality (including temperature) which may adversely impact biodiversity, ecological integrity, social amenity or human health. Given the occasional nature of unplanned chemical discharge, the small volumes, and the offshore location for Scarborough, the change to water quality resulting from unplanned discharge of chemicals will not be substantial.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to water quality. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered.

Based on the detailed risk evaluation, the magnitude of potential impact of a change in water quality is slight and is considered **acceptable**.

7.2.1.3 Risk Evaluation

Risk events from unplanned chemical discharges can lead to impacts on receptors, which will be slight. Receptor sensitivity is low, leading to a **Negligible (F**) risk consequence, and likelihood of the risk event occurring is **Highly Unlikely**. The risk of unplanned chemical discharge from Scarborough have therefore been evaluated as **Low**. The impacts overall have been determined to be **acceptable** based on an evaluation against the criteria:

To meet the principles of ESD

- No lasting effect on any receptors are expected; and overall, the impacts of an unplanned chemical release are localised and temporary.
- Due to small volumes (<0.2 m³), impacts will be very localised to the discharge point, and not result in a substantial adverse effect on a population of the species.
- Physical coating of marine fauna by and sub-lethal or lethal effects from toxic chemicals is considered unlikely, given the expected low volumes of discharge, short exposure times and the rapid dilution and dispersion of the chemical discharge once entering the marine environment.
- Reduction in water quality will be localised and short-term.

Internal context

- With respect to routine and non-routine discharges of chemicals, Woodside will implement its internal requirement:
  - Chemicals must be selected with the lowest practicable environmental impacts and risks subject to technical constraints.

External context

- No stakeholder concerns have been raised with respect to unplanned chemical discharges or potentially impacted receptors.

Other requirements

- With respect to unplanned chemical discharges, activities associated with Scarborough 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.

7.2.1.4 Summary of the Risk Assessment

Table 7.41 provides a summary of the risk assessment and acceptability for impacts from unplanned chemical releases on receptors.

Table 7.41: Summary of risk assessment for unplanned chemical releases

Receptor	Risk	Environmental Performance Outcome	Adopted Control(s)	Receptor sensitivity	Risk Consequence	Likelihood	Risk rating	Acceptability
Water quality	Change in water quality	**EPO2:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM16:** Chemicals will be selected with the lowest practicable environmental impacts and risks subject to technical constraints. **CM15:** Implementation of waste management procedures which provide for safe handling and transportation, segregation and storage and appropriate classification of all waste generated.	Low value (open water)	Negligible (F)	Highly Unlikely	Low	Acceptable

7.2.2 Unplanned Discharge: Solid Waste

Non-hazardous solid wastes including paper, plastics and packaging, and hazardous solid wastes such as batteries, aerosols, contaminated materials and process wastes may be unintentionally released into the marine environment. Release of these waste streams may occur because of overfull and/or uncovered bins, incorrectly disposed items or spills during transfers of waste.

7.2.2.1 Sources of the Aspect

Activities and facilities associated with Scarborough may result in the accidental release of hazardous and non-hazardous waste into the marine environment. Unplanned discharges may occur during:

- vessel operations
- MODU operations
- FPU operations.

Vessel, MODU and FPU Operations

On board vessels, MODUs and FPUs, solid materials will be used, and waste created. These wastes are handled and stored onboard and are transported to shore to be disposed of at licensed onshore 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.

Material and waste onboard vessels, MODUs or FPUs may be hazardous or non-hazardous. 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. pipe dope, oily rags, oil filters)
- contaminated personal protective equipment (PPE)
- hazardous process waste.

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 materials and wastes will be disposed of onshore, however they could be accidentally dropped or lost overboard due to overfull bins or crane operator error. Non-hazardous materials and wastes include:

- paper and cardboard
- wooden pallets
- scrap steel, metal, aluminium, cans, etc
- glass
- plastics.

Unplanned release of hazardous and non-hazardous solid wastes could occur during general servicing and routine operations throughout all phases of Scarborough. Due to the potential for a wide range of hazardous and non-hazardous waste materials and substances, predicting exposure area is difficult. Solid waste dispersion varies and is dependent on the buoyancy of the material. For example, metal waste is likely to sink to the seafloor near the release site, whereas plastic items may float and disperse to greater distances away from the source. In general, incidents of accidental releases of waste are expected to be remote, and quantities small.

7.2.2.2 Impact or Risk

Risk events resulting from an accidental release of waste from vessels or facilities to the marine environment has the potential to result in the following impacts:

- change in water quality
- injury/mortality to fauna
- change in aesthetic values.

Change in Water Quality

Hazardous solid wastes such as paint cans, oily rags, etc., can cause localised contamination of the water through a release of toxins and chemicals.

Injury/Mortality to Fauna

The unplanned discharge of solid wastes can result in the mortality to fauna either through contamination or physical injury depending on the nature of the waste.

Change in Aesthetic Values

The accidental release of waste has the potential to result in unfavourable aesthetic conditions through the visual presence of waste within coastal or shoreline environments. The Project Area lies within Commonwealth waters between 5.5 km to 375 km from the coast. Any accidental release of waste has a low likelihood of reaching coastal and shoreline environments where tourism, recreation, settlements and indigenous sites are located. Aesthetic impacts to social receptors are therefore not expected and are not evaluated further.

Receptors at Risk

Risk events resulting from an unplanned discharge of hazardous/non-hazardous solid waste chemicals has the potential to impact the following receptors through contamination and physical injury:

- water quality
- fish
- seabirds and migratory shorebirds
- marine mammals
- marine reptiles.

The receptors within the environment that may be affected by the unplanned discharge of solid wastes are outlined in Table 7.42.

Table 7.42: Receptor/impact matrix

Impacts	Receptor: Water Quality	Fish	Seabirds and Migratory Shorebirds	Marine Mammals	Marine Reptiles
Change in water quality	✓				
Injury/mortality to fauna		✓	✓	✓	✓

Detailed Risk Evaluation

For each of the receptors identified for detailed evaluation, the criteria for acceptability as defined in Table 6.3 have been considered and addressed in the following sections. This includes to meet the principles of ESD, internal and external context and any other requirements.

Water Quality

Unplanned hazardous waste discharges, such as contaminated materials, may leach into the marine environment causing localised increases in toxicity. The level of impact to water quality will depend on the nature of the discharge, however the volumes of the hazardous components are generally low (such as residual paint in cans or oily rags). Modelling of small volumes of hydrocarbons such as this (e.g. Shell, 2010) indicate rapid dilution in the offshore marine environment, with impacts limited to the immediate vicinity of the contamination.

Given likely small volumes, and occasional nature of the event, these would result in temporary and highly localised changes to the water quality.

The water quality within the Project Area is typical of an unpolluted tropical offshore environment. Within the Project Area, where unplanned discharges may occur, the environmental performance outcome for water quality is to not result in a substantial change to water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health. Given the small volumes, occasional nature of the events and the offshore location, biodiversity, ecological integrity, social amenities and human health will not be impacted.

Vessel operations undertaken as part of the activity will adhere to various Marine Orders, as appropriate to vessel class, including Marine Order 95 – Garbage.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to water quality. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. Matters relating to potentially impacted receptors are discussed for the specific receptors.

Based on the detailed risk evaluation, the magnitude of potential impact of a change in water quality is slight and is considered **acceptable**.

Seabirds and Migratory Shorebirds, Fish, Marine Reptiles and Marine Mammals

Marine fauna, including fish, seabirds and shorebirds, marine mammals and marine reptiles may be impacted through ingestion or entanglement of waste or through exposure to toxic chemicals.

Ingestion or entanglement of marine fauna has the potential for physical harm which may limit feeding/foraging behaviours and thus can result in mortalities. Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris was listed as a key threatening process under the EPBC Act in August 2003 (DoEE, 2018). The Threat Abatement Plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans (DoEE, 2018) identifies EPBC Act-listed species for which there are scientifically documented adverse impacts resulting from marine debris. C&R Consulting (2009) reported that between 1974 and 2008, a total of 77 individuals of a variety of different species had been subject to impacts associated with entanglement in, or ingestion of, plastic debris within Australian waters. Of the reported species, humpback whales, marine turtles, Australian pelicans and a range of cormorant species dominate records. For these records, the sources of waste are unknown. Marine turtles and seabirds in particular may be at risk from plastics which may cause entanglement or be mistaken for food (e.g. DoEE, 2018; DoEE, 2017) and ingested causing damage to internal tissues and potentially preventing feeding activities. In the worst instance this could have a lethal affect to an individual. Marine debris has been identified as threat in the Recovery Plan for Marine Turtles in Australia (2017–2027).

Receptor presence in the Project Area is greatest within the Trunkline Project Area, however some species' distribution is known to extend to the Offshore Project Area approximately 375 km offshore. Seabirds and marine turtles, which are fauna susceptible to impacts from non-hazardous solid wastes, are found in greater densities and numbers in proximity to islands and shorelines where breeding, nesting and foraging habitat occurs. Therefore, it is considered unlikely that they will occupy the Offshore Project Area and if they do, it is likely to be in a temporary and transient nature. Fish, which are susceptible to impacts from minor volumes of hazardous contamination, are unlikely to be found in large numbers on the sea surface of the Offshore Project Area or the Trunkline Project Area. Activities in the Trunkline Project Area where solid wastes could be unintentionally released into the marine environmental will be limited to trunkline installation and survey activities, both of which are short term, reducing the likelihood of an interaction between solid waste and marine fauna occurring.

Within the Project Area, where discharges are to occur, the environmental performance outcome for listed species including fish, seabirds and shorebirds, marine mammals and marine reptiles include to:

- not have a substantial adverse effect on a population, or the spatial distribution of the population
- 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
- not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

Impacts to species including fish, birds, marine mammals and marine reptiles from the unplanned discharge of solid waste is unlikely given low occurrence of unplanned discharges and the location of the activities at significant distance from sensitive habitats. Significant impacts are unlikely to occur at an individual level and will not occur at a population level, nor result in the decrease of the quality of the habitat such that the extent of these species is likely to decline.

While, the threat abatement plan for impacts of marine debris on vertebrate marine life does not list explicit management actions for non-related industries (DEWHA, 2009), management controls outlined in Table 7.43 will reduce the risk of unplanned discharge of solid waste.

For construction and IMR activities occurring within the Montebello Marine Park, and adjacent to the Dampier Marine Park, the short term and transient nature of vessel movement will not be 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, or for the Habitat Protection Zone (IV) 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 values identified for both these AMPs includes biologically important areas for foraging habitat for whale sharks, breeding and foraging habitat for seabirds, internesting, foraging, mating and nesting habitat for marine turtles, and migratory pathways for humpback whales. These values will not be impacted given the significant distance from sensitive locations.

Based on the detailed risk evaluation, the magnitude of potential impacts to fish, birds, marine mammals and marine reptiles from injury/mortality to fauna is slight and is considered **acceptable**.

7.2.2.3 Risk Evaluation

Risk events from unplanned discharge of solid waste can lead to impacts on receptors, which will be slight. Receptor sensitivity is low for water quality and high for seabirds and migratory shorebirds, fish, marine reptiles and marine mammals, leading to a **Negligible (F)** risk consequence for water quality and a **Minor (D)** risk consequence for fauna. The likelihood of an event occurring is **Remote**, and the risk of an unplanned discharge of solid waste has therefore been evaluated as **Low** for all receptors.

The impacts overall have been determined as **acceptable** based on an evaluation against the criteria.

To meet the principles of ESD

- The location of the activity is at significant distance from sensitive habitats.
- Unplanned discharges will be occasional and of small volumes.
- Management controls will be in place to minimise the incidence of unplanned discharges.

Internal context

- There are no specific Woodside internal requirements with respect to unplanned discharges of solid waste, or potentially impacted receptors.

External context

- No stakeholder concerns have been raised with respect to unplanned discharges of solid waste, or potentially impacted receptors.

Other Requirements

- Vessel operations undertaken as a part of this activity will adhere to various Marine Orders, as appropriate to vessel class, including Marine Order 95 – Garbage.
- Requirements of the Threat Abatement Plan for the impacts of marine debris on vertebrates (DoEE, 2018) and the Recovery Plan for Marine Turtles in Australia (DoEE, 2017) have been met.
- With respect to unplanned discharges of solid waste, activities associated with Scarborough 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.

7.2.2.4 Summary of the Risk Assessment

Table 7.43 provides a summary of the risk assessment and acceptability for risks from unplanned discharge of solid waste to receptors.

Table 7.43: Summary of risk assessment for the unplanned discharge of solid waste

Receptor	Risk	Environmental Performance Outcome	Adopted Control(s)	Receptor sensitivity	Consequence	Likelihood	Risk rating	Acceptability
Water Quality	Change in water quality	**EPO2:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM23:** Project vessels compliant with Marine Order 95 (pollution prevention – Garbage). **CM15:** Implementation of waste management procedures which provide for safe handling and transportation, segregation and storage and appropriate classification of all waste generated.	Low value (open water)	Negligible (F)	Remote	Low	Acceptable
Migratory Shorebirds and Seabirds	Injury/mortality to fauna	**EPO10:** To not have a substantial adverse effect on a population of seabirds or shorebirds, or the spatial distribution of the population. **EPO7:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **EPO12:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **EPO1:** 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. **EPO11:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population. **EPO8:** To not substantially modify, destroy or isolate an area of important habitat for a migratory species.		High value species	Minor (D)	Remote	Low	Acceptable
Fish				High value species	Minor (D)	Remote	Low	Acceptable
Marine Mammals				High value species	Minor (D)	Remote	Low	Acceptable
Marine Reptiles				High value species	Minor (D)	Remote	Low	Acceptable

Receptor	Risk	Environmental Performance Outcome	Adopted Control(s)	Receptor sensitivity	Consequence	Likelihood	Risk rating	Acceptability
		EPO9: To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.						

7.2.3 Physical Presence (Unplanned): Seabed Disturbance

Unplanned seabed disturbance includes physical changes to the existing seabed substrate and any features that may be present such as benthic habitats.

7.2.3.1 Sources of the Aspect

Throughout the proposed offshore Scarborough Project, unplanned disturbance to the seabed may occur during:

- MODU operations
- vessel operations
- FPU operations
- Trunkline installation.

During these activities, the primary cause for unplanned seabed disturbance is through dropped objects from the FPU, MODU or vessels. Additional unplanned disturbance to the seabed may occur from anchor drag during MODU operations, or from placement of infrastructure, specifically the trunkline, outside of the proposed footprint.

Dropped Objects

While not intended, objects such as tools and equipment may be dropped from the MODU, FPU, support, survey and installation vessels. Operator error, bad weather events or failure of equipment may lead to the object loss. Potential dropped objects from during each of the key activities, along with the associated footprint, are identified in Table 7.44.

Table 7.44: Potential dropped objects from vessels, FPU or MODU during Scarborough activities

Activity	Dropped object	Maximum footprint (m²)
Geotechnical surveys	Survey/sampling equipment Small tools	15
Drilling operations	Casing Small tools/equipment Container/IBC	15
Installation of the FPU and subsea infrastructure	Subsea infrastructure lost during installation activities, such as: • manifold • anchor • umbilical termination assembly • riser • flowline end termination. Small tools/equipment	280
Trunkline installation and stabilisation	Small tools/equipment	10
Removal of subsea infrastructure	Subsea infrastructure lost during removal activities, such as: • manifold • anchor • umbilical termination assembly • riser • flowline end termination. Small tools/equipment	280
MODU operations	Small tools/equipment Container/IBC	10
Vessel operations	Small tools/equipment Container/IBC	10
FPU operations	Small tools/equipment Container/IBC	10

Anchor Drag

During drilling, the MODU will be secured on station by mooring lines, as designed by the mooring analysis, which are held in place by anchors deployed to the seabed. High energy weather events such as cyclones, occurring while the MODU is on station, can lead to excessive loads on the mooring lines, resulting in failure (either anchor(s) dragging or mooring lines parting). A failure of mooring integrity may lead to the mooring lines and anchors attached to the MODU being trailed across the seabed. If mooring failure is sufficient, the MODU may move off station, increasing the likelihood of anchor drag across the seafloor.

Industry statistics from the North Sea show that a single mooring line failure for MODUs is the most common failure mechanism (33 × 10-4 per line per year), followed by a double mooring line failure (11 × 10-4 per line per year) (Petroleumstilsynet, 2014). Note that single and double mooring line failures do not typically result in the loss of station keeping. If partial or complete mooring failures are sufficient to result in a loss of station keeping, industry experience indicates that MODUs may drift considerable distances from their initial position (Offshore: Risk & Technology Consulting Inc., 2002). Partial mooring failures leading to a loss of station keeping resulted in smaller MODU displacements, due to the remaining anchors dragging along the seabed when compared to complete mooring failures; complete mooring failures resulted in a freely drifting MODU (Offshore: Risk & Technology Consulting Inc., 2002).

Seabed disturbance area size from anchor drag will depend on the extent of the drag.

Positioning of trunkline outside proposed footprint

The identified route for the export trunkline, has been determined based on consideration of seabed features including sensitive environmental areas and existing infrastructure. During installation, the vessels will manage positioning.

7.2.3.2 Impact or Risk

Risk events resulting from unplanned disturbance to the seabed have the potential to result in the following impacts:

- change in habitat
- change in water quality.

Which may have the following further impacts:

- injury and/or mortality to fauna.

Change in Habitat

Dropped objects and anchor drag on the seabed are likely to result in localised sedimentation and modification of seabed habitat, which will be permanent if the object cannot be recovered or anchor drag has impacted hard bottom substrate.

Change in Water Quality

Change in water quality, through sediment disturbance and turbidity, is temporary and limited to when the dropped object touches down on the seabed or when the anchor is being dragged. After a period, the suspended sediments settle and the turbidity in the water column returns to pre-disturbance levels. Given the scenarios that would lead to unplanned seabed disturbance are unlikely to be of scale to cause resuspension of sediments, and the location of the activity, this impact has not been evaluated further.

Injury and/or Mortality to Marine Fauna

As a result of a change in water quality and change in habitat, further impacts to receptors may occur, which include injury or mortality to marine fauna resulting from an increase in turbidity, or physical contact with equipment or infrastructure being installed.

Given that a change to water quality is unlikely, the only receptors that would potentially be at risk of unplanned seabed disturbance are bottom dwelling species including epifauna and infauna. Risks to other marine fauna have not been evaluated further.

Receptors at Risk

Receptors at risk of events resulting from unplanned seabed disturbance are outlined in Table 7.45.

Table 7.45: Receptor/impact matrix

Impacts	Receptor: Water Quality	Epifauna and Infauna	Plankton	Fish	KEFs
Change in water quality	X				
Change in habitat		✓		X	✓
Injury or mortality		✓	X	X	✓

Detailed Risk Evaluation

For each of the receptors identified for detailed evaluation, the criteria for acceptability as defined in Table 6.3 have been considered and addressed in the following sections. This includes to meet the principles of ESD, internal and external context and any other requirements.

Epifauna and Infauna

Benthic communities, including epifauna and infauna may be impacted by the dropped objects (identified in Table 7.44), the drag of anchors on the seabed or the incorrect positioning of infrastructure specifically the trunkline. Disturbance to the seabed can alter the physical seabed habitat conditions, resulting in community changes. If not recovered, dropped objects may result in the permanent loss of a small area under the object.

The seafloor in the Offshore Project Area is characterised by sparse marine life dominated by motile organisms (ERM, 2013). Such motile organisms include shrimp, sea cucumbers, demersal fish and small, burrowing worms and crustaceans. Benthic communities in the Offshore Project Area are representative of the Exmouth Plateau and of deepwater soft sediment habitats reported in the region (e.g. BHP Billiton, 2004; Woodside, 2005; Woodside, 2006; Brewer et al., 2007; RPS, 2011; Woodside, 2013; Apache, 2013). No threatened or migratory species, or ecological communities (as defined under the EPBC Act), were identified in the benthic communities during studies completed in the Offshore Project Area (ERM, 2013a) or trunkline route (Advisian, 2019a, Advisian 2019b).

Dropped objects within the Offshore Project Area have a maximum footprint of 280 m^2. Habitat within the Offshore Project Area may be reduced to the extent of the dropped object's footprint. If anchor drag occurs, habitat impact will span the extent of the drag area. Both risks lead to a localised change in communities; however, substantial adverse effect is not anticipated, given the sparse marine life that are well represented elsewhere in the region.

The infauna recorded along the trunkline route is sparse. While most of the sampled seabed comprised soft sediments, geotechnical data indicated the presence of a rock pinnacle field in about 300 m depth. It is unclear what the rock pinnacles are constructed from. However, the structures provide habitat for a diverse suite of epifaunal species that are not usually found on the soft sediments. The proposed trunkline route avoids such features, and if it was positioned incorrectly, there is a risk of impact to these communities. This however is not anticipated due to controls in place to manage the trunkline positioning.

Within the Project Area, the environmental performance outcome for epifauna and infauna is 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. Given generally sparse benthic communities in the Project Area, no threatened or migratory species, or ecological communities were identified and those epifauna and infauna communities observed are likely to be well represented elsewhere in the region, impacts are expected to be restricted to a localised proportion of epifauna and infauna communities.

For construction and IMR activities occurring within the Montebello Marine Park, and adjacent to the Dampier Marine Park, the short term and transient nature of activities associated with unplanned seabed disturbance will not be 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, or for the Habitat Protection Zone (IV) 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. Dampier Marine Park is a hotspot for sponge diversity, however there are no identified values for epifauna and infauna related to the Montebello Marine Park.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to epifauna and infauna.

Based on the detailed evaluation, the magnitude of potential impacts to epifauna and infauna from seabed disturbance during activities associated with Scarborough is evaluated to be slight and is considered **acceptable.**

KEFs

Three KEFs overlap the Offshore Project Area and Trunkline Project Area; the Exmouth Plateau, Ancient Coastline at 125 m Depth and Continental Slope Demersal Fish Community. Non-routine seabed disturbance from dropped objects or anchor drag will occur within these KEFs and may lead to change in habitat.

The Trunkline Project Area and Offshore Project Area lie within the Exmouth Plateau KEF. The KEF occupies an area of 49,310 km² within water depths of 800–4000 m (Exon & Willcox, 1980, cited in Falkner et al., 2009; Heap & Harris, 2008). The Trunkline Project Area enters the KEF about 240 km offshore within water depths of ~1100 m, extending about 60 km into the KEF before reaching the Offshore Project Area. The Trunkline Project Area and Offshore Project Area occupy a relatively small portion of the entire KEF, and any unplanned seabed disturbance will be an even smaller portion within it. Physical habitat modification is not listed as a potential concern for this KEF.

A relatively small portion of the Ancient Coastline at 125 m Depth KEF overlaps the Trunkline Project Area. This intersect is located about 360 km offshore, north-north-west of the Montebello Islands. Any dropped object will be an even smaller portion within the KEF. Impact will not occur to the hard substrates of the KEF. Physical habitat modification is not listed as a potential concern for this KEF.

The Continental Slope Demersal Fish Community is recognised as a KEF because of its biodiversity values, including high levels of endemism (DotE, 2018b). The Trunkline Project Area intersects a small portion of the KEF, across one of its thinnest points throughout its distribution. Most of the KEF area lies further south, extending about 240 km from the Trunkline Project Area to just past the tip of the Exmouth Peninsula, splitting from a single corridor into three. Physical habitat modification is listed as a potential concern for this KEF (DotE, 2018b). However, any potential impact to the KEF from habitat disturbance is restricted to the footprint of the dropped object and will be highly localised.

Within the Project Area, the environmental performance outcome for KEFs is to not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat, such that an adverse impact occurs to marine ecosystem functioning or integrity in an area defined as a KEF. The non-routine seabed disturbance within the KEFs is highly localised and relatively small compared to the size of the KEFs. There will be no substantial adverse effect on the KEF or the communities within it.

For construction and IMR activities occurring within the Montebello Marine Park, and adjacent to the Dampier Marine Park, the short term and transient nature of activities associated with seabed disturbance will not be 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, or for the Habitat Protection Zone (IV) 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. KEFs form an essential part of the Marine Park network. There are no KEFs in the Dampier Marine Park. The Montebello Marine Park contains one KEF: ancient coastline at 125 m depth contour.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to ambient light.

On this basis, the magnitude of potential impacts to KEFs from unplanned seabed disturbance during activities associated with Scarborough is slight and evaluated to be **acceptable**.

7.2.3.3 Risk Evaluation

Risk events from unplanned seabed disturbance can lead to impacts on receptors, which will be slight. Receptor sensitivity for epifauna and infauna is low, leading to a **Negligible (F**) risk consequence, whilst receptor sensitivity for AMPs is high, leading to a Minor (D) risk consequence. As the likelihood of the risk event occurring is **Highly Unlikely**, the risk of unplanned seabed disturbance from Scarborough have been evaluated as **Low** for epifauna and infauna, and **Moderate** for KEFs. The risk overall has been determined to be **acceptable** based on an evaluation against the criteria:

To meet the principles of ESD

- Unplanned seabed disturbance from Scarborough will result in localised impacts or disturbance to benthic communities but is not expected to affect the population or local ecosystem function.
- No threatened or migratory species, or ecological communities were identified, and those epifauna and infauna communities observed are likely to be well represented elsewhere in the region.
- Unplanned seabed disturbance within the KEFs would be highly localised and relatively small compared to the size of the KEF.

Internal context

- There are no specific Woodside internal requirements with respect to unplanned seabed disturbance, or potentially impacted receptors.

External context

- No stakeholder concerns have been raised with respect to unplanned seabed disturbance or potentially impacted receptors.

Other requirements

- With respect to seabed disturbance, activities associated with Scarborough 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.

7.2.3.4 Summary of the Risk Assessment

Table 7.46 provides a summary of the risk assessment and acceptability for risks from unplanned seabed disturbance on receptors.

Table 7.46: Summary of risks, management controls, impact significance ratings and EPOs for unplanned seabed disturbance

Receptor	Risk	Environmental Performance Outcome	Adopted Control(s)	Receptor sensitivity	Risk Consequence	Likelihood	Risk rating	Acceptability
Epifauna and infauna	Change in habitat Injury/ mortality to fauna	**EPO1:** 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.	**CM12:** Infrastructure will be positioned on the seabed within design footprint to reduce seabed disturbance.	Low value	Negligible (F)	Highly Unlikely	Low	Acceptable
KEFs	Change in habitat	**EPO16:** 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 results.		High Value	Minor (D)	Highly Unlikely	Moderate	Acceptable

7.2.4 Physical Presence (Unplanned): IMS

Non-indigenous Marine Species (NIMS) are species which are translocated into a recipient environment where they are not historically found. Invasive marine species (IMS) 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 (DoF, 2016).

Example IMS could include a variety of different plants and animals such as: fish, seastars, crabs, molluscs, worms, sponges, microscopic dinoflagellates, shellfish, algae, bacteria and viruses.

7.2.4.1 Sources of the Aspect

Activities that have the potential to result in the unplanned establishment of IMS in the Project Area are:

- installation of FPU
- installation of subsea infrastructure
- trunkline installation
- MODU operations
- vessel operations.

Installation of FPU, Trunkline, Subsea Infrastructure, and MODU and Vessel Operations

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 Scarborough. Vessels used may be mobilised from within or outside Australian waters. Vessels has been identified as the single most important vector for the translocation of NIMS (DAFF 2010). 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 recent 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 could establish in the Project Area, and potentially become IMS, under several scenarios:

- NIMS could be present as biofouling on 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 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 Commonwealth marine environments beyond the Project Area (including ports)[43].

[43] While introduction of NIMS to ports has potential to lead to establishment of IMS in state waters, impacts to receptors in state waters are considered out of scope of this OPP.

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 bad 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 NIMS 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). 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 (DAWR 2017, version 7) 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 fresh water 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 undertake ballast water exchange within the Project Area. Should this be the case, ballast water exchange will only occur via the acceptable methods detailed in the Australian Ballast Water Management Requirements (DAWR 2017, version 7) and in accordance with the *Biosecurity Act 2015*.

Biofouling

The term biofouling refers to the accumulation and growth of aquatic organisms on submerged and/or wetted surfaces of marine vessels, facilities, infrastructure and equipment, including both external and internal surfaces.

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
- 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 FPU, trunkline and SURF over time. Vessels are required to antifoul regularly and should adhere to the National Biofouling Management Guidelines (petroleum production and exploration; and commercial vessels) (Commonwealth of Australia, 2009).

Establishment of IMS

Although there is a potential for NIMS to establish themselves in a foreign environment via ballast water and biofouling, not all NIMS that enter Australian waters and are released into the marine environment are successful in establishing a population and progressing to an IMS. 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. Biotic and abiotic factors can influence the survival probability of translocated NIMS and establish IMS.

Table 7.47: Biotic and Abiotic factors influencing the establishment of IMS

Biotic	Abiotic
Presence of natural predators	Water depth
Level physical disturbance	Environmental conditions (i.e. salinity, nutrient concentration, water temperature, light availability, etc.)
Dispersion rate	Transport conditions (i.e. vessel ballast water age, vessel speeds, etc.)
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)	

To manage the risk of IMS, Woodside has a comprehensive IMS Management Plan that has been developed in consultation with the relevant authorities.

7.2.4.2 Impact or Risk

Risk events resulting from the successful establishment of IMS in the Project Area has the potential to result in:

- changes in ecosystem dynamics
- changes to the functions, interests or activities of other users.

<u>Change in Ecosystem Dynamics</u>

Once an IMS is established, they have the potential to impact on native marine species diversity and abundance in a variety of ways. Table 7.48 describes the ways IMS can result in changes to ecosystem dynamics.

Table 7.48: Description of impacts from IMS causing changes to ecosystem dynamics

Factors driving changes to ecosystem dynamics from IMS	Description of impact
Competition for natural resources	IMS may decrease available resources for local species and, assuming they 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 utilise 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, if the IMS is predatory native prey species are more vulnerable to predation 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 itself, or may be vector to viruses, bacteria or pathogens. The introduction of disease through IMS could have devastating affects 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.

Despite the potential high consequence of the establishment of an IMS within a high value environment as a result of introduction, unlike coastal or sheltered nearshore waters, the deep offshore open waters of the Project Area are not conducive to the settlement and establishment of IMS (Geiling, 2014), due to the lack of light or suitable habitat to sustain growth or survival. The majority of activities associated with Scarborough will be undertaken in an open ocean, offshore location away from shorelines, with the majority of activities occurring in waters >900 m deep around the FPU, well locations and subsea infrastructure. Furthermore, during FPU operations vessels will be used only intermittently due to the FPU's minimally manned status.

Activities which may occur in more shallower waters (within Commonwealth Waters) along the export pipeline (up to 30 m water depth) will occur infrequently.

Current studies suggest that there are 429 introduced and cryptogenic species within Australian marine waters (DAFF, 2010). However, the IMS reported are typically restricted to nearshore environments within State waters, rather than offshore Commonwealth waters of the Project Area.

Surveying throughout Western Australian marine habitats indicated that there is a strong presence of marine NIMS (DAFF, 2010). Port Hedland, Shark Bay and other major ports and tourist destinations have been a focus for surveying of IMS. The Dampier Archipelago is subject to high amount of vessel traffic due to industrial activity and the presence of a large port structure. In addition, a paper by Huisman et al. (2008) gave an informative overview of introduced marine biota in Western Australian waters, including the Dampier region. The paper summarised findings from several intensive marine biodiversity surveys conducted within the Dampier region by the Western Australian Museum (1998–2002). Overall >4500 marine animal and plant species collected by the survey were identified to species level by expert taxonomists worldwide and a total of five species of introduced (NIMS) barnacles were identified. There was a predominant presence of Barnacles found throughout the surveys, most likely translocated by vectors moving through the area (DAFF, 2010).

Changes to the Functions, Interests or Activities of Other Users

The establishment of IMS has the potential to cause changes to the functions, interests or activities of other users through indirect impact such as changes to fisheries target species resulting in economic and social implications, or due to compromised reputation to the oil and gas industry.

Receptors Potentially at Risk

Risk events resulting from unplanned introduction of IMS has the potential to impact the following receptors:

- epifauna and infauna
- Commonwealth Managed Fisheries
- State Managed Fisheries
- shipping
- industry
- defence.

Commonwealth and State Managed Fisheries

The establishment of IMS may causes changes to the target prey abundance, distribution or behaviour, and in turn result in impacts to the activities of commercial Fisheries.

The Northwest Slope Trawl Fishery is likely to be the only Commonwealth fishery that may have active fishing areas intersecting with the Scarborough Project area. The Northwest Slope Trawl Fishery operates in deep water from the coast of the Prince Regent National Park to Exmouth between the 200 m depth contour to the outer limit of the Australian Fishing Zone (AFZ).

Given the low likelihood of IMS colonisation in this location i.e. due to distance from shore, activities associated with the Scarborough Project are unlikely to result in establishment of IMS, to negatively affect commercial fishing activities or greatly interfere with marine users in the region. On this basis the risk of introduction of IMS to fisheries has not been evaluated further.

The receptors at risk from IMS are listed in Table 7.49.

Table 7.49: Receptor/impact matrix

Impacts	Receptor: Epifauna and Infauna	Coral	Seagrass	Macroalgae	Cth Managed Fisheries	State Managed Fisheries	Shipping	Industry	Defence
Change in ecosystem dynamics	✓	✓	✓	✓					
Changes to the functions, interests or activities of other users					X	X	✓	✓	✓

Detailed Risk Evaluation

For each of the receptors identified for detailed evaluation, the criteria for acceptability as defined in Table 6-3 have been considered and addressed in the following sections. This includes to meet the principles of ESD, internal and external context and any other requirements.

Epifauna and Infauna, Coral, Seagrass and Macroalgae

Benthic communities including epifauna and infauna are susceptible to impacts from IMS due to the risk of changes to the ecosystem dynamics such as competition for resources and predation (Table 7.49).

Benthic productivity on the outer continental shelf and slope is low, and is a function of water depth, low nutrient availability, and the absence of hard substrates. Studies completed within the region indicate that benthic composition in deep-water habitats is generally lower in abundance than shallow water habitats of the region (DEWHA, 2008a; Brewer et al., 2007). The seafloor in the Offshore Project Area is characterised by sparse marine life dominated by motile organisms (ERM, 2013). Such motile organisms included shrimp, sea cucumbers, demersal fish and small, burrowing worms and crustaceans. This soft bottom habitat is also supporting patchy distributions of mobile epibenthos, such as sea cucumbers, ophiuroids, echinoderms, polychaetes and sea-pens (DEWHA, 2008). The dominant types of epifauna were arthropods and echinoderms (especially shrimp and sea cucumbers, respectively), while the dominant infauna groups were crustaceans and polychaetes (ERM, 2013). Benthic communities in the Offshore Project Area are representative of the Exmouth Plateau and of deep-water soft sediment habitats reported in the region.

Along the Trunkline Project Area in Commonwealth waters, the benthic habitat is also sparse; however, there may be potential for greater diversity and abundance in shallower water environment. Benthic species along the trunkline may include polychaetes, bryozoans, molluscs (bivalves and gastropods), cnidarians, echinoderms and porifera (Section 5.3.10). The benthic habitat is representative of the Exmouth plateau and broader NWMR (Brewer et al., 2007).

Marine primary producers such as coral, seagrass and macroalgae are absent from the Offshore Project Area. Hard coral, or zooxanthellate corals, are typically found in shallow waters and are unlikely to be found in the Scarborough area. Soft coral, or azooxanthellate coral, are known to be found at most depths, however, require hard substrate for attachment which is not found within the Scarborough area. It is possible that hard and soft corals exist along the Trunkline Project Area.

The potential for IMS to establish and impact benthic habitats in the Scarborough Project area decreases with water depth. The water depths, distance from shore and the open ocean environment of the Offshore Project Area and much of the Trunkline Project Area provides unfavourable environmental conditions for survival of IMS during translocation and establishment at the recipient location. As the Trunkline Project Area traverses the continental shelf towards the boundary with state waters, conditions become more favourable for IMS establishment. However, vessels, MODU and FPU transiting to the Scarborough Project area form international ports will travel in deep waters. In terms of ballast water exchange, all vessels will undertake ballast water exchanges in accordance with the Australian Ballast Water Management Requirements (version 7; DAWR, 2017). There is therefore a low likelihood of IMS being translocated to, and establishing in, the Project Area.

Within the Project Area, the environmental performance outcome applicable for this risk is to not result in a known or potential IMS becoming established. Specifically, for benthic communities is 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. Woodside's IMS risk assessment process will be applied to project vessels which enter the Project Area. Given the controls in place for IMS management, and the low likelihood of IMS translocation to, and colonisation of, this location, activities associated with Scarborough will not result in establishment of IMS, nor subsequently modify or disturb an important or substantial area of benthic habitat such that an adverse impact on marine ecosystem functioning results.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to water quality. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered.

Based on the detailed impact evaluation, the magnitude of potential impacts of a change in ecosystem dynamics is slight and has been evaluated as **acceptable**.

Industry, Shipping, Defence

The establishment of IMS has a potential to disturb the functions and activities of other marine users, including the oil and gas industry, shipping or Defence by increasing the risk of further translocation of IMS within and beyond the region.

The NWMR supports a number of industries including petroleum exploration and production. There are seven sedimentary petroleum basins in the NWMR. The closest productive fields to the Scarborough Project area would be Woodside's Pluto platform and subsea infrastructure (5 km), Jadestone's Stag platform (9 km) and Santos's Reindeer platform (19 km).

Environmental performance outcomes relevant to other marine users include:

- to not have a substantial adverse effect on water quality such that an adverse impact on industry use occurs
- to not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.

Given the controls in place for IMS management, and the low likelihood of IMS translocation to, and colonisation of, this location, activities associated with Scarborough will not result in establishment of IMS, and as such not adversely affect other marine user activities in the region. EPBC Listed threatened species recovery plans or conservation advice do not list IMS as a key threat to species recovery. Ballast water exchanges will be managed in accordance with the Australian Ballast Water Management Requirements (version 7; DAWR, 2017). Woodside's IMS risk assessment process will be applied to project vessels and MODU's which enter the Project Area. Based on the outcomes of each IMS risk assessment, management measures commensurate with the risk (such as the treatment of internal systems, IMS Inspections or cleaning) will be implemented to minimise the likelihood of IMS establishing.

Based on the detailed impact evaluation, the magnitude of potential impacts of a change to the functions, interests or activities of other users is slight and has been evaluated as **acceptable**.

7.2.4.3 Risk Evaluation

Risk events from unplanned introduction of IMS can lead to impacts on receptors, which will be slight. Receptor sensitivity for industry, shipping and defence is medium, leading to a **Slight (E)** risk consequence, whilst receptor sensitivity for epifauna and infauna and macroalgae is low leading to a **Negligible (F**) risk consequence, and receptor sensitivity for coral and seagrass is high leading to a **Minor (D)** risk consequence. The likelihood of the risk event occurring is **Remote**, therefore the risk has been assessed for all receptors as Low.

The impacts overall have been determined as **acceptable** based on an evaluation against the criteria.

To meet the principles of ESD

- The distance offshore and water depths of the majority of the Project Area are prohibitive to survival and establishment of IMS.
- In areas of the Project Area that are more favourable for IMS establishment (i.e. shallower waters of the Trunkline Project Area), controls in line with international legislation are in place to prevent translocation and establishment of IMS.

Internal context

- All activities will be undertaken in accordance with Woodside's IMS risk assessment process.

External context

- No stakeholder concerns have been raised with respect to IMS, or potentially impacted receptors.

Other requirements

- All vessels will undertake ballast water exchanges in accordance with the Australian Ballast Water Management Requirements (version 7; DAWR, 2017)
- With respect to IMS, activities associated with Scarborough 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.

7.2.4.4 Summary of the Risk Assessment

Table 7.50 provides a summary of the risk assessment and acceptability for impacts from IMS on receptors.

Table 7.50: Summary of risks, key management controls, acceptability, EPOs and residual risk rating for IMS

Receptor	Risk	Environmental Performance Outcome	Adopted control(s)	Receptor sensitivity	Risk Consequence	Likelihood	Risk rating	Acceptability
Epifauna and infauna	Change in ecosystem dynamics	**EPO18:** To not result in a known or potential pest species (IMS) becoming established. **EPO1:** 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.	**CM24:** Compliance with the Woodside Invasive Marine Species Management Plan. **CM25:** Requirements of the Australian Ballast Water Management to be met.	Low value habitat (homogenous)	Negligible (F)	Remote	Low	Acceptable
Coral				High value	Minor (D)	Remote	Low	Acceptable
Seagrass				High value	Minor (D)	Remote	Low	Acceptable
Macroalgae				Low value	Negligible (F)	Remote	Low	Acceptable
Industry, Shipping, Defence	Changes to the functions, interests or activities of other users	**EPO18:** To not result in a known or potential pest species (IMS) becoming established. **EPO13:** To not have a substantial adverse effect on water quality such that an adverse impact on industry use occurs. **EPO14:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.		Medium value	Minor (D)	Remote	Low	Acceptable

7.2.5 Physical Presence (Unplanned): Collision with Marine Fauna

Physical presence of vessels may result in unplanned collision with marine fauna including marine mammals, marine reptiles and fish.

7.2.5.1 Sources of the Aspect

Physical presence of vessels and unplanned collision with marine fauna has the potential to occur during:

- vessel operations.

Vessel Operations

Activities associated with Scarborough will require vessels for supply and transport. Types of vessels may include, but not be limited to, MODUs or drill ships, subsea installation vessels (ISV), pipelay vessels and support vessels. Vessels will be used across all phases of the project throughout the Scarborough including the Offshore Project Area and the Trunkline Project Area.

The type and number of vessels in 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. trunkline installation), with long term operational project phase requiring fewer vessels.

7.2.5.2 Impact or Risk

Risk events resulting from an unplanned collision between vessels and marine fauna has the potential to result in:

- injury to/mortality of fauna.

Injury to/Mortality of Fauna

Vessels operating in the Scarborough Project area may present a potential hazard to marine mammals, marine reptiles and fish. Vessel movements can result in collisions between the vessel (hull and propellers) and marine fauna, potentially resulting in superficial injury, serious injury that may affect life functions (e.g. movement and reproduction), or mortality. Although the risk of vessel strike to marine fauna is inherent to all vessel types, records of vessel collision with marine megafauna report a higher number of collisions with whale-watching boats, naval ships and container ships (DoEE, 2016). Further, the likelihood of vessel/marine fauna collision being lethal is influenced by vessel speed; the greater the speed at impact, the greater the risk of mortality (Jensen and Silber, 2004; Laist et al., 2001). Vanderlaan and Taggart (2007) found that the chance of lethally injuring a large whale due to a vessel strike increases from about 20% at 8.6 knots to 80% at 15 knots.

Receptors Potentially Impacted

Risk events resulting from an unplanned collision between vessels and marine fauna has the potential to impact the following receptors:

- fish
- marine mammals
- marine reptiles.

Fish (including Whale Sharks)

Fish species most vulnerable to collision with vessels include large sharks which frequent the upper portions of the water column. This is particularly relevant to the whale sharks which have been shown to 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 (Wilson et al., 2006; Gleiss et al., 2013). Conservation advice for the whale shark (TSSC, 2015) identifies boat strike form large vessels as a potential threat.

Due to the whale shark's broad distribution in Australian waters, individuals are likely to occur in the Offshore Project Area, though aggregation is not expected. The Trunkline Project Area traverses the BIA based on known foraging activity centred on the 200 m isobath from July to November, following peak aggregation at Ningaloo reef. It is likely that individual whale sharks would be encountered at greater frequency by project phases associated with the Trunkline Project Area (e.g. surveys, pipeline installation), should they occur in this timeframe.

Although there may be an increase in encounter rate in a section of the Trunkline Project Area within a restricted timeframe, the amount of overlap between the BIA and the Trunkline Project Area represents less than half of the overall Trunkline Project Area (including state waters), and a negligible proportion of the overall BIA. The trunkline installation is a relatively short-term activity, and the presence of vessels in this area will be transient and temporary. Thus, reducing the likelihood of a vessel collision occurring, which is further substantiated by the slow speed of vessels conducting activities.

Other species of shark, ray of fish is generally less vulnerable to vessel strike due to preferred habitat use. However, smaller fish are at risk of mortality through being caught in thrusters during station keeping operations (DP). However, noise emissions generated by DP operation will generally deter fish from the vicinity of the operating thrusters where lethal injury could occur.

The impact to fish from vessel strikes for Scarborough has been determined as negligible, and as such not evaluated further.

Table 7.51 outlines the potential impacts to receptors associated with unplanned vessel collisions.

Table 7.51: Receptor/risk matrix

	Receptor		
Impacts	***Fish***	***Marine Mammals***	***Marine Reptiles***
Injury/mortality to fauna	X	✓	✓

Detailed Risk Evaluation

For each of the receptors identified for detailed evaluation, the criteria for acceptability as defined in Table 6-3 have been considered and addressed in the following sections. This includes to meet the principles of ESD, internal and external context and any other requirements.

Marine Mammals

As described above, vessel speed influences the probability of a vessel collision with a cetacean occurring and also the chance that the collision will result in lethal injury (Vanderlaan and Taggart, 2007). Additionally, behaviour of individuals may also influence likelihood of collision occurring. Although large cetaceans are expected to show localised avoidance in response to vessel noise, studies have reported limited behavioural response to approaching ships (McKenna et al., 2015) individuals engaging in behaviours such as feeding, mating or nursing may be less aware of their surroundings and more susceptible to collision (Laist et al., 2001).

Fourteen species of whales, including four threatened species, may occur in the Offshore Project Area and Trunkline Project Area, although key foraging, breeding or other aggregations have not been identified. In general, large cetaceans tend to have wide-ranging oceanic distributions meaning that while occurrence in the Project Area is possible, the absence of aggregating behaviours reduces the likelihood that encounters will involve large numbers of individuals. The exception is during migration periods where numbers may be increased.

Two threatened and migratory species, the humpback whale and pygmy blue whale, have known migratory routes, which have been designated BIAs, that are intersected by the Trunkline Project Area. The Commonwealth Conservation Advice for the Humpback whales and the Conservation Management Plan for the Pygmy Blue Whale identify vessel disturbance and strike as a threat to the EPBC listed species (DoE, 2015a; DoE, 2015b). Overlap of BIAs with the Offshore Project Area are restricted to the distribution BIA for Pygmy Blue Whales. Migration (both northbound and southbound) of both species is confined to peak timeframes (Section 5.4.5.2). Migration timing for Humpback whales on the Western Australian coast is May-November with a northern migration past Dampier in June/July and southern migration occurring primarily in Oct/Nov. Pygmy Blue Whales migrate south from October/December and northern migration occurs from April/August, with peak abundance on the NWS in June and July. It is likely that a greater number of individuals would be encountered during project phases associated with trunkline activities (e.g. surveys, pipeline installation), should they occur in the migration periods. However, due to the slow speed of vessels conducting these activities, the likelihood of a collision occurring is low, and the risk of a collision result in lethal injury reduced further.

Smaller cetaceans, such as dolphins, comprise a lower proportion of vessel collision records (DoEE, 2016), though it is difficult to determine if this is due to a lower collision rate or lower detection rate of incidents. Dolphins often engage in bow riding which may make them more vulnerable to entanglement with propellers or thrusters compared to larger cetaceans.

Fourteen species of dolphin may occur in the Project Area, and eleven of these may occur in the Offshore Project Area. However, most dolphins, except the killer whale, show preference for coastal habitats over deep offshore waters. This reduces the likelihood of dolphin species being encountered in the Offshore Project Area and interacting with vessels associated with activities such as drilling or FPU installation and operation. However, as the Trunkline Project Area enters shallower, more coastal habitats, the frequency of occurrence may increase. As with larger cetaceans above, the likelihood of encountering individuals during project phases associated with Trunkline Project Area activities (e.g. surveys, pipeline installation) is expected to be higher than during activities in the Offshore Project Area. Nevertheless, in the absence of known aggregation or critical habitat along the Trunkline Project Area large numbers of individuals are not expected to be encountered. Furthermore, dolphin species are known to bow ride and have high agility around vessels, thus the risk of vessel strike is considered low.

Studies in Queensland showed that dugongs spend around 47% of their time within 1.5 m of the sea surface, with claves spending 13% of their time travelling or resting on their mother’s back (Hodgson, 2004). It has been postulated (Hodgson 2004) that vessel speed is the primary factor influencing collision risk between vessels and dugongs since evidence suggests that dugongs fail to flee or evade the approach of fast approaching vessels until an impact is unavoidable (Groom et al., 2004).

The correlation of dugong distribution and seagrass habitat suggests that dugongs will occur in the Offshore Project Area very rarely. As the Trunkline Project Area enters shallower waters, encounter rate is expected to increase. However, large expanses of seagrass habitat are absent (Advisian, 2019a) and therefore any dugongs encountered are likely to be restricted to few individuals migrating between foraging habitats. Overall, dugong encounters are not expected in the Project Area. This expectation is supported by the absence of BIAs for this species within 250 km of the Trunkline Project Area.

While the amount of time dugongs spend at the sea surface can increase vulnerability to vessel strike, this behaviour also increases detection of individuals enabling vessels to take evasive action. Furthermore, vessels operating in the vicinity of the Trunkline Project Area will be moving slowly, allowing individuals to take evasive action. This will reduce the likelihood of a collision with a vessel occurring and that such a collision will result in fatal injury.

Marine Reptiles

The Recovery Plan for Marine Turtles in Australia recognises vessel strikes as a key threat to EPBC listed turtle species. Marine turtles on the sea surface or in shallow coastal waters have been observed to avoid approaching vessels by typically moving away from the vessel's track (Hazel et al., 2007). Hazel et al. (2007) suggests this observed avoidance behaviour is based primarily on visual cues (although these 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 (rather than vessel type) and the prevailing water clarity. In a collision, the 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 of the vessel, and whether the animal is struck by the hull or propellers. 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).

Considering the offshore location, marine turtles are expected to be an infrequent visitor to the Offshore Project Area. As water depth decreases along the Trunkline Project Area the occurrence of marine turtles is expected to increase. The Trunkline Project Area intersects internesting BIAs for flatback, hawksbill, loggerhead and green turtles. These BIAs are based on distances that female turtles have been recorded as travelling from nesting beaches. Studies have shown that Flatback turtles predominantly remain within 10 km of the nesting beach, however they can also travel distances up to approximately 62 km during the internesting period (Whittock, Pendoley and Hamann, 2014). These interesting buffers have been defined as 60 km for flatback turtles and 20 km for hawksbill, loggerhead and green turtles within the Recovery Plan (DoEE, 2017). Within Commonwealth waters, it is acknowledged that an increased number of individuals may be encountered by vessels undertaking activities associated with the trunkline (e.g. pipelay, surveys) within the vicinity of offshore islands/archipelagos during breeding season (October to March). It is expected that individuals will respond to vessel presence by avoiding the immediate vicinity of the vessels, and combined with low vessel speed, will reduce the likelihood of a vessel-turtle collision.

Few sea snake species occur in deeper oceanic environments with inshore coral reef habitat being preferred. As such, the occurrence of sea snakes in the Offshore Project Area or the Trunkline Project Area in Commonwealth waters is considered rare, making any interactions with project vessels highly unlikely.

Marine Fauna Summary

The environmental performance outcomes for marine mammals and marine reptiles include to:

- not have a substantial adverse effect on a population, or the spatial distribution of the population
- 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
- not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

While there is a risk of collision with marine fauna with vessels associated with Scarborough, the implementation of controls measures will reduce the potential impact to low and will not result in substantial adverse effects on population or spatial distribution, modify, destroy, fragment, isolate or disturb important habitat, or disrupt the lifecycle of an ecologically significant portion of the population of a migratory species. Controls will include adhering to the requirements of the EPBC Regulations 2000 Part 8 Division 8.1 Interacting with cetaceans. These regulations include the following measures:

- activity support vessels will not travel greater than 6 knots within 300 m of a cetacean or turtle (caution zone) and not approach closer than 100 m from a whale;
- activity support vessels will not approach closer than 50 m for a dolphin or turtle and/or 100 m for a whale (with the exception of animals bow riding);
- if the cetacean or turtle shows signs of being disturbed, activity support vessels will immediately withdraw from the caution zone at a constant speed of less than 6 knots; and
- vessels will not travel greater than 8 knots within 250 m of a whale shark and not allow the vessel to approach closer than 30 m of a whale shark.

Implementing this control during vessel activities will help to reduce the risks of a collision with marine fauna which could result in an impact of injury or mortality.

Whilst vessel strike is identified as a threat in the Recovery Plan for Marine Turtles (DoEE, 2017), no explicit relevant management actions are recommended. There is reference to the National Strategy for Mitigating Vessel Strike of Marine Mega-fauna (DoEE, 2016) within the Recovery Plan; this strategy was released (and remains) in draft form. Based on available data (from NSW and Queensland) within the Strategy, the 'potential areas of concern' for turtles are typically associated with nearshore areas around port facilities; i.e. it is therefore considered that ‘potential areas of concern’ would not occur within the trunkline route through Commonwealth waters.

Within the Recovery Plan there is reference to undertaking dredging and trawling activities in interesting habitat outside peak nesting seasons. For the section of trunkline (i.e. KP 34 to KP 50) that may require trenching and backfilling, consideration will be given to fauna mitigation methods such as the seasonal timing of installation activities to limit disturbance to turtles within the development of Environment Plans.

The conservation management plan for the blue whale (Commonwealth of Australia, 2015a) recommends minimising vessel collision through speed reduction, and aligns with the control measures implemented by Woodside. Activities associated with Scarborough will be managed in accordance with all relevant management actions and recommendations.

For construction and IMR activities occurring within the Montebello Marine Park, and adjacent to the Dampier Marine Park, the short term and transient nature of vessel movement will not be 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, or for the Habitat Protection Zone (IV) 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 values identified for both these AMPs includes biologically important areas for internesting, foraging, mating and nesting habitat for marine turtles, and migratory pathways for humpback whales. These values will not be impacted given the significant distance from sensitive locations.

Potential impacts from collision with marine fauna will not result in a substantial adverse effect on a population or the spatial distribution of the population. No lasting effects to the population will occur. Additionally, no adverse impact on marine ecosystem functioning or integrity or impacts to life cycles of the population of migratory whales or fish will occur. Therefore, the potential impacts from collision with marine fauna from Scarborough are assessed as being **acceptable**.

7.2.5.3 Risk Evaluation

Risk events from an unplanned collision between vessel and marine fauna can lead to impacts on receptors, which will have no lasting effect. Receptor sensitivity is high, leading to a **Slight (E)** risk consequence, and likelihood of the event occurring is **Highly Unlikely**. The risk of unplanned collision between vessel and marine fauna from activities associated with Scarborough has therefore been evaluated as **Low**.

The impacts overall have been determined as **acceptable** based on an evaluation against the criteria.

To meet the principles of ESD

- Vessel movements associated with Scarborough will not significantly increase the current level of activity in the wider area.
- Wide migratory distribution of species potentially at risk and their low-density presence within the Scarborough area means that interactions are unlikely.
- Controls are in place to manage vessel movements.

Internal context

- There are no specific Woodside internal requirements with respect to vessel collision with marine fauna, or potentially impacted receptors.

External context

- No stakeholder concerns have been raised with respect to vessel collision with marine fauna, or potentially impacted receptors.

Other requirements

- Activities will be adhered to the requirements of the EPBC Regulations 2000 Part 8 Division 8.1 Interacting with cetaceans
- Requirements of the Conservation Management Plan for Blue Whales (Commonwealth of Australia, 2015a) have been met.
- Consideration of seasonal timing for trenching and backfill activities to be consistent with the guidance for dredging and trawling within the Recovery Plan for Marine Turtles (DoEE, 2017).
- With respect to vessel collision with marine fauna, activities associated with Scarborough 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.

7.2.5.4 Summary of the Risk Assessment

Table 7.52 provides a summary of the risk assessment and acceptability for impacts from vessel collision with marine fauna on receptors.

Table 7.52: Summary of risks, key management controls, acceptability, EPOs and residual risk rating for physical presence (unplanned): collision with marine fauna

Receptor	Risk	Environmental Performance Outcome	Adopted control(s)	Receptor sensitivity	Consequence	Likelihood	Risk rating	Acceptability
Marine Mammals Marine Reptiles	Injury to/ mortality of fauna	**EPO7:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population. **EPO12:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population. **EPO11:** To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population. **EPO1:** 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. **EPO9:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	**CM8:** EPBC Regulations 2000 Part 8 Division 8.1 Interacting with cetaceans **CM32**: Marine fauna interaction mitigation measures to be considered and implemented as appropriate during the EP process	High value species	Slight (E)	Highly Unlikely	Low	Acceptable

7.2.6 Unplanned Hydrocarbon Release

Unplanned hydrocarbon releases include both gas and liquid hydrocarbons that could unintentionally be released into the marine environment.

7.2.6.1 Sources of Aspect

Activities and facilities associated with Scarborough which may result in the unplanned discharge of gas hydrocarbons to the marine environment are:

- drilling operations
- commissioning
- FPU operations
- hydrocarbon extraction
- hydrocarbon processing
- gas export
- decommissioning.

A key difference between Scarborough and many other offshore developments is that the reservoirs contain no or only trace liquid hydrocarbons, which means there is no credible risk of hydrocarbon spill due to well blowout and only from fuel or non-process LOC.

Activities and facilities associated during the installation, commissioning, operations and decommissioning phases of Scarborough which may result in the unplanned discharge of liquid hydrocarbons to the marine environment are:

- vessel operations
- MODU operations
- helicopter operations.

Drilling Operations

During drilling operations, a loss of well control (LOWC) could result in an uncontrolled subsea release of hydrocarbons resulting from an over-pressurised reservoir. The major causes of a LOWC are identified as:

- well intervention
- dropped objects
- intersection with shallow gas
- human error.

Hydrocarbons of the Scarborough, Jupiter and Thebe reservoirs contain no measurable liquid condensate fraction so in a loss of containment there is expected to be no or negligible liquid component.

High pressure and low temperatures experienced at the depths in the development area are likely to cause released gas to combine with water to form hydrates. The hydrates will rise through the water column and upon reaching shallower water depths are likely to decompose into methane and water.

FPU Operations, Hydrocarbon Extraction and Hydrocarbon Processing, Hydrocarbons Export

During operations, hydrocarbons extracted from the reservoir will flow from the wellhead via the christmas trees and manifolds through the flowlines to the FPU. On the FPU, the gas is separated from the MEG and dehydrated further prior to export.

Extreme environmental conditions or other causes which result in an exceedance of the design criteria and a catastrophic failure of the facility and/or individual equipment (e.g. cranes, flare tower) could result in unplanned release of gas hydrocarbons. Topsides, this could be from process and non-process hydrocarbon inventories. Subsea, there is potential for a loss on containment from pipelines, flowlines or risers.

Causes of structural failure could include:

- internal corrosion
- external corrosion
- equipment failure
- extreme weather
- seismic events/seabed instability
- dropped objects
- fire/explosion event.

It is also possible that failure of down-well barriers or physical damage to a completed well could also result in a loss of control of a production well.

In addition to a loss of well control, a subsea loss of containment includes the potential loss of hydrocarbons from production flowlines and the export trunkline. Given the nature of the hydrocarbons, in the event of a subsea loss of containment there is unlikely to be any liquid hydrocarbons released.

Vessel and MODU Operations

Vessels will be used during all phases of Scarborough in both the Offshore Project Area and Trunkline Project Area. Types of vessels may include MODUs or drill ships, subsea installation vessels (SIV), deepwater pipelay vessels and support vessels. All project vessels (including MODUs and drill ships) will use marine diesel oil (MDO) or marine gas oil (MGO) as fuel.

The sources of unplanned MDO or MGO releases that could occur during vessel and MODU operations are:

- bunkering failure
- rupture of vessel fuel tank.

<u>Bunkering</u>

Bunkering of marine diesel between support vessel/s and the MODU or SIV may occur in the Offshore Project Area or Trunkline Project Area. Loss of containment of marine diesel during bunkering operations could occur due to:

- Partial or total failure of a bulk transfer hose or fittings during bunkering, due to operational stress or other integrity issues could spill marine diesel to the deck and/or into the marine environment. This would be in the order of less than 200 L, based on the likely volume of a bulk transfer hose (assuming a failure of the dry break coupling and complete loss of hose volume).

- 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, resulting in about 8 m³ MDO loss to the deck and/or into the marine environment.

Fuel Tank Rupture

During Scarborough, an unplanned release of MDO could occur if the fuel tank of any vessel is ruptured. This could eventuate from a collision between project vessels (e.g. support vessel with a MODU or pipelay vessel) 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 higher than the point of penetration.

The spill scenarios for the vessels are described in the sections below.

Deepwater Pipelay Vessel and Refuelling Vessel

The deep water pipelay vessels being considered for Scarborough have maximum tanks sizes of up to 1000 m³. However, the refuelling vessels that will be required to support these vessels may have a maximum single tank inventory of 2000 m³ of MDO. A rupture of the largest single tank of the refuelling vessel is considered as the worst-case credible release for this scenario.

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 heavy fuel oils (HFO), which have sulphur levels much higher than this cap, in use or stored onboard any of the contracted vessels.

Nearshore Pipelay Barge

The nearshore pipelay barges being considered for the Project have a maximum fuel inventory of less than 400 m³.

Note that a loss of vessel fuel tank integrity is also possible at locations closer to shore, therefore a potential scenario of 2000 m³ MDO also exists (Table 7.55).

MODU/FPU Bulk Fuel Tank

The worst-case credible non-process release from the FPU or MODU is a failure or rupture of the main diesel storage tank. MODUs typically have a total MDO capacity of about 966–1400 m³ that is distributed through a multiple isolated tank. MODU fuel tanks are located in the MODU pontoons, typically located on the inner sides of pontoons and can be over 10 m below the waterline.

A volume of 250 m³ of MDO is considered an appropriate worst case for a single fuel tank, based on existing facilities.

Note that a loss of vessel fuel tank integrity is also possible at the FPU location, therefore a potential scenario of 2000 m³ MDO also exists at this location (Table 7.55).

Summary of Credible Hydrocarbon Spill Scenarios

A summary of the credible hydrocarbon spill scenarios that could occur during Scarborough are provided in Table 7.53.

Note that minor spills to water have been assessed in Section 7.2 and minor spills to deck are included in Section 7.1.8.

Table 7.53: Credible hydrocarbon spill scenarios

Scenario	Hydrocarbon type	Maximum credible volume	Location
Loss of well control (LOWC)	Dry gas	No or negligible liquid hydrocarbon	FPU/MODU location
Facility failure	Dry gas	No or negligible liquid hydrocarbon	FPU location
Pipeline rupture	Dry gas	No or negligible liquid hydrocarbon	FPU location Trunkline route
Loss of containment during bunkering	MDO	8 m^3	FPU location Trunkline route
Topsides loss of containment from FPU/MODU	MDO	250 m^3	FPU/MODU location
Vessel fuel tank rupture	MDO/MGO	2000 m^3 (pipelay vessel)	Trunkline route FPU location

Hydrocarbon Characteristics

MDO is characterised by a large mixture of low- and semi- to low-volatile compounds (95%) and persistent hydrocarbons (5%). Additionally, MDO typically contains <3% aromatic hydrocarbons that could potentially dissolve in the water column.

MGO is typically a lighter fuel that contains about 60% aromatics, therefore, to be conservative, MDO has been used in in this risk assessment.

Table 7.54 summarises hydrocarbon characteristics of MDO.

Table 7.54: Characteristics of liquid hydrocarbons

Physical Properties	MDO
Density (kg/m^3)	829
American Petroleum Institute (API)	37.2
Dynamic viscosity (centipoises; cP)	4 (at 25 °C)
Pour Point (°C)	-7
Gas to condensate ratio (bbl/MMscf)	N/A
Oil Property Category	II
Oil Persistence Classification	Non-persistent

7.2.6.2 Impact or Risk

Risk events resulting from an unplanned hydrocarbon release have the potential to result in the following impacts:

- change in water quality
- change in sediment quality

- change in habitat.

As a result of these changes, further impacts may occur, which include:

- change in fauna behaviour
- injury or mortality to fauna
- change in aesthetic value
- change to the function, interests and activities of other users.

Quantitative Hydrocarbon Spill Modelling

In assessing the potential impacts of an unplanned hydrocarbon release, representative worst-case scenarios (in terms of volume and location) were assessed. For Scarborough, the worst-case scenario was identified to be an instantaneous surface release of 2000 m³ of MDO, representing loss of vessel fuel tank integrity. As the worst-case scenario, the following assessment of impacts will also address the potential impacts of other credible lesser releases.

To inform the impact assessment, quantitative hydrocarbon spill modelling was undertaken for the worst-case hydrocarbon release scenarios (RPS, 2019d; APPENDIX I). It is not practicable for spill modelling to be undertaken at every potential spill location within the Offshore Project Area. Release locations were selected by considering locations that would:

- have the greatest potential environmental consequence to the receiving environment (closest to sensitive receptors)
- be considered at greater risk of a spill event.

Accordingly, a spill of MDO was modelled at three representative locations; two along the trunkline at sensitive locations, and one at the FPU (Table 7.55).

Table 7.55: Spill release locations for 2000 m³ MDO spill

Location	Coordinates	Water Depth
Outside Mermaid Sound	19° 59' 46.476'' S 115° 22' 5.582''E	80 m
Within the Montebello Australian Marine Park	19° 53' 54.715'' S 113° 14' 19.561''E	74 m
FPU	19° 53'54.715'' S 113° 14' 19.561''E	930 m

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), which is designed to simulate the transport, spreading and weathering of specific hydrocarbon types under the influence of changing meteorological and oceanographic forces (RPS, 2019d; APPENDIX I).

<u>*Hydrocarbon Exposure Thresholds*</u>

The outputs of the quantitative hydrocarbon spill modelling are used to assess the extent of hydrocarbon exposure (which informs the EMBA and area described in Section 5) and the subsequent environmental risk by showing areas where specified impact thresholds for receptors are exceeded.

Woodside identifies exposure thresholds for floating (i.e. surface), entrained, dissolved and shoreline hydrocarbons (Table 7.56). These thresholds are used to support the assessment of the receptors present in the exposure area.

Table 7.56: Summary of environmental impact thresholds used to support impact assessment of a hydrocarbon spill

Parameter	Exposure Thresholds	Justification
Surface hydrocarbon	10 g/m²	The surface threshold of ≥10 g/m² is based on the relationship between film thickness and appearance and represents a ‘dull metallic colour’ (Bonn Agreement, 2015). Thresholds for registering biological impacts resulting from contact of surface slicks have been estimated by different researchers at about 10–25 g/m² (French et al., 1999; Koops et al., 2004; National Oceanic and Atmospheric Administration, 1996). 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/m² threshold is the reported level of oiling to instigate impacts to seabirds and is also applied to other wildlife, though 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, surface hydrocarbons will have a lower 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.
Entrained hydrocarbon[1] (ppb)	500 ppb	The threshold concentration of entrained hydrocarbons that could result in a biological impact cannot be determined directly using available ecotoxicity data for Water Accommodated Fractions (WAF) of hydrocarbons. It is also 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 will be a conservative approach. According to a review by IRC (2011) of Group II (MGO) hydrocarbons toxicity to the marine environment, a contact threshold of 500 ppb was found to be highly conservative for a range of species including crustaceans, molluscs, echinoderms and fish.
Dissolved aromatic hydrocarbon[1] (ppb)	500 ppb	Woodside has undertaken ecotoxological 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. The ecotoxicity tests were undertaken on a broad range of taxa of ecological relevance focusing on the early life stages of test organisms, when organisms are typically at their most sensitive. The ecotoxicology tests were conducted on six mainly tropical/subtropical species representatives from six major taxonomic groups. The laboratory-based ecotoxicology tests used a range of WAF 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. These results are consistent with other condensate ecotoxological testing undertaken by Woodside. Based on these ecotoxicology tests, a dissolved aromatic hydrocarbon threshold of 500 ppb has been adopted, which is significantly less than the lowest NOEC for the most sensitive organism tested. Therefore, it is considered that the 500 ppb dissolved aromatic threshold is a conservative threshold
Shoreline	100 g/m²	Owens and Sergy (1994) define accumulated hydrocarbon <100 g/m² to have an appearance of a stain on shorelines. French-McKay (2009) defines accumulated hydrocarbons ≥100 g/m² to be the threshold that could impact the survival and reproductive capacity of benthic epifaunal invertebrates living in intertidal habitat; therefore, ≥100 g/m² has been adopted as the threshold for shoreline accumulation.

[1] *these refer to instantaneous concentrations*

Summary of Predicted Hydrocarbon Exposure

Stochastic Spill Modelling

Stochastic modelling was carried out for this study, whereby SIMAP was applied to repeatedly simulate the defined credible spill scenarios using different randomly-selected conditions. These modelling simulations provide insight into the probable behaviour of a potential spill under the meteorological conditions expected to occur within the EMBA. They 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), 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. All scenarios were modelled for a duration of 42 days.

Key results from the stochastic modelling undertaken for the unplanned discharge of 2000 m^3 of MDO at the three release locations are summarised in Table 7.57 (RPS, 2019d; Appendix I).

Table 7.57: Summary of worst-case extent of stochastic spill modelling to be used in risk assessment

Scenario	Model Parameter	Summary

Outside Mermaid Sound	Floating	• Exposures above the threshold are predicted to occur within ~30 km of the source.
		• Exposures above the threshold are predicted to have a probability of intersecting the following key sensitive receptors:
		  • 3% probability to WA Coastline
		  • 2% probability to Dampier Marine Park
		  • 2% probability to Dampier Archipelago (including Legendre Island and Rosemary Island)
		  • <1% probability to Montebello Marine Park

	Entrained	• Exposures above the threshold are predicted to occur within ~163 km of the source.
		• Exposures above the threshold are predicted to have a probability of intersecting the following key sensitive receptors, at the associated maximum concentration in the worst-case simulation:
		  • 44% probability to Dampier Marine Park; 10,407 ppb
		  • 23% to Dampier Archipelago (including Legendre Island and Rosemary Island); 10,911 ppb
		  • 23% probability to WA Coastline; 6,832 ppb
		  • <1% probability to Montebello Marine Park.
		• Entrainment of MDO is only expected to occur under moderate wind conditions, within the upper water column.

	Dissolved	• Exposures above the threshold are predicted to occur within ~35 km of the source.
		• Exposures above the threshold are predicted to have a probability of intersecting the following key sensitive receptors, at the associated maximum concentration in the worst-case simulation:
		  • 2% probability to Dampier Marine Park; 635 ppb
		  • <1% probability to the Dampier Archipelago; 366 ppb.

	Shoreline	• The maximum local accumulated concentration ashore for the worst-case simulation was predicted to be 156 g/m^2 (at WA Coastline).
		• Exposures above the threshold are predicted to have a probability of intersecting the following key sensitive receptors, at the associated maximum accumulated volume in the worst-case simulation:
		  • 1% probability to Dampier Archipelago; 3 m^3
		  • 1% to WA Coastline; 3 m^3

Scenario	Model Parameter	Summary
		• Other shoreline receptors were <1%.

Within the Montebello Marine Park	Floating	• Exposures above the threshold are predicted to occur within ~40 km of the source.
		• Exposures above the threshold are predicted to have a probability of intersecting the following key sensitive receptors:
		  • 100% probability to Montebello Marine Park (as release location is inside Park)
		  • <1% probability of exposures above the threshold are predicted to any other receptor (including Montebello Islands, Barrow Island and other AMPs).

	Entrained	• Exposures above the threshold are predicted to occur within ~310 km of the source, with the greatest extent towards the south-west.
		• Exposures above the threshold are predicted to have a probability of intersecting the following key sensitive receptors, at the associated maximum concentration in the worst-case simulation:
		  • <70% probability to Montebello Marine Park; 156,954 ppb
		  • <4% probability to Montebello Islands Marine Park, Barrow Island; 4,577 ppb
		  • 7% to the Murion Islands Marine Management Area; 2,392 ppb
		  • <4% probability to Ningaloo Coast North World Heritage Area; 2,438
		• Entrainment of MDO is only expected to occur under moderate wind conditions, within the upper water column.

	Dissolved	• Exposures above the threshold are predicted to occur within ~85 km of the source, with the greatest extent towards the south-west.
		• Exposures above the threshold are predicted to have a probability of intersecting the following key sensitive receptors, at the associated maximum concentration in the worst-case simulation:
		  • 9% probability to Montebello Marine Park; 1,990 ppb.
		  • <1% probability for all other sensitive receptors. The worst-case maximum concentration for these receptors was only 200 ppb, which is below the exposure threshold.

	Shoreline	• There is <1% probability of any shoreline contact above the threshold. • The maximum local accumulated concentration ashore for the worst-case simulation was only 11 g/m^2 at Barrow Island and WA Coastline – which is not above the threshold of 100 g/m^2. • Barrow Island and WA Coastline were only predicted to accumulate a maximum of 1 m^3 for the worst-case simulation. • No other shoreline contact was predicted above the threshold.

FPU	Floating	• Exposures above the threshold are predicted to occur within ~113 km of the source, with the greatest extent predicted towards the south.
		• Exposures above the threshold are predicted to have a probability of intersecting the following key sensitive receptors:
		  • 1% probability to Gascoyne Marine Park.
		  • <1% for all other sensitive receptors.

	Entrained	• Exposures above the threshold are predicted to occur within ~476 km of the source, with the greatest extent towards the south-west.
		• Exposures above the threshold are predicted to have a probability of intersecting the following key sensitive receptors, at the associated maximum concentration in the worst-case simulation:
		  • 8% probability to Gascoyne Marine Park; 7,236 ppb
		  • <1% probability for all other sensitive receptors. The worst-case maximum concentration for these receptors was only 196 ppb, which is below the exposure threshold.

Scenario	Model Parameter	Summary
		• Entrainment of MDO is only expected to occur under moderate wind conditions, within the upper water column.
	Dissolved	• Exposures above the threshold are predicted to occur within ~74 km of the source, with the greatest extent towards the south-west. • No sensitive receptors are predicted to receive dissolved aromatic hydrocarbons at the 500 ppb threshold.
	Shoreline	• There is no shoreline contact above the exposure threshold predicted.

Deterministic Spill Modelling

Deterministic modelling (or single spill trajectory analysis) is used to predict the fate (transport and weathering behaviour) of spilled oil over time under predefined hydrodynamic and meteorological conditions. It was used to demonstrate the potential maximum extent of the area exposed to entrained hydrocarbons. The deterministic runs shown in Figure 7.18, Figure 7.19 and Figure 7.20 were for the three modelled release locations (of 2,000 m^3 MDO) and represent runs which showed the greatest extent of exposure to the south-west (with proximity to various sensitive environments) and to the shorelines.

While the stochastic figures may show a large extent of an area that could potentially be exposed at some point to hydrocarbons (in the event of a worst case spill) the worst-case deterministic runs indicate that the potential area exposed to entrained hydrocarbons is much smaller, at maximum over a 30 km^2 area and for only a small period of time.

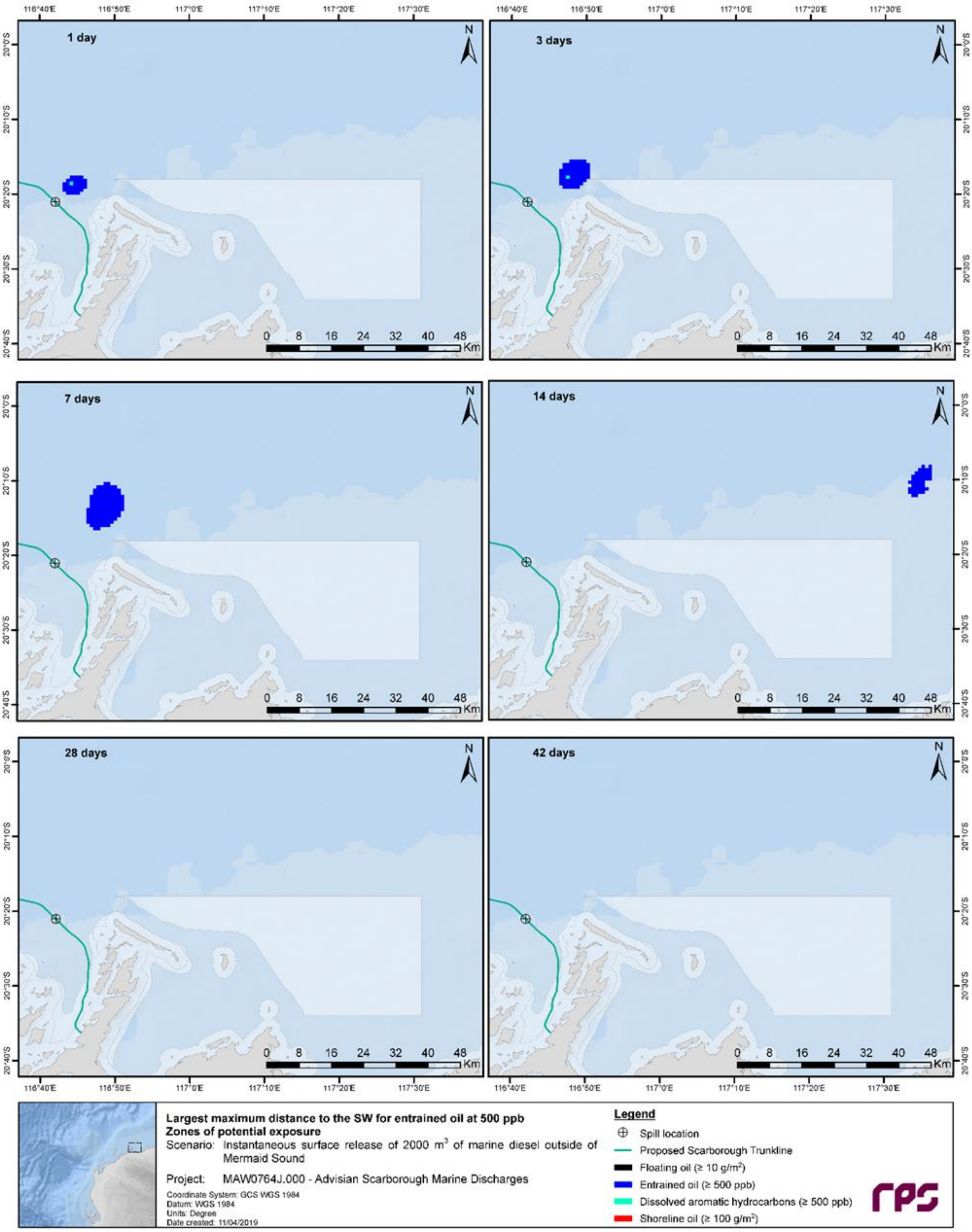


Figure 7.18: Time series from a single deterministic model run for an instantaneous release of 2000 m^3 of MDO from outside Mermaid Sound

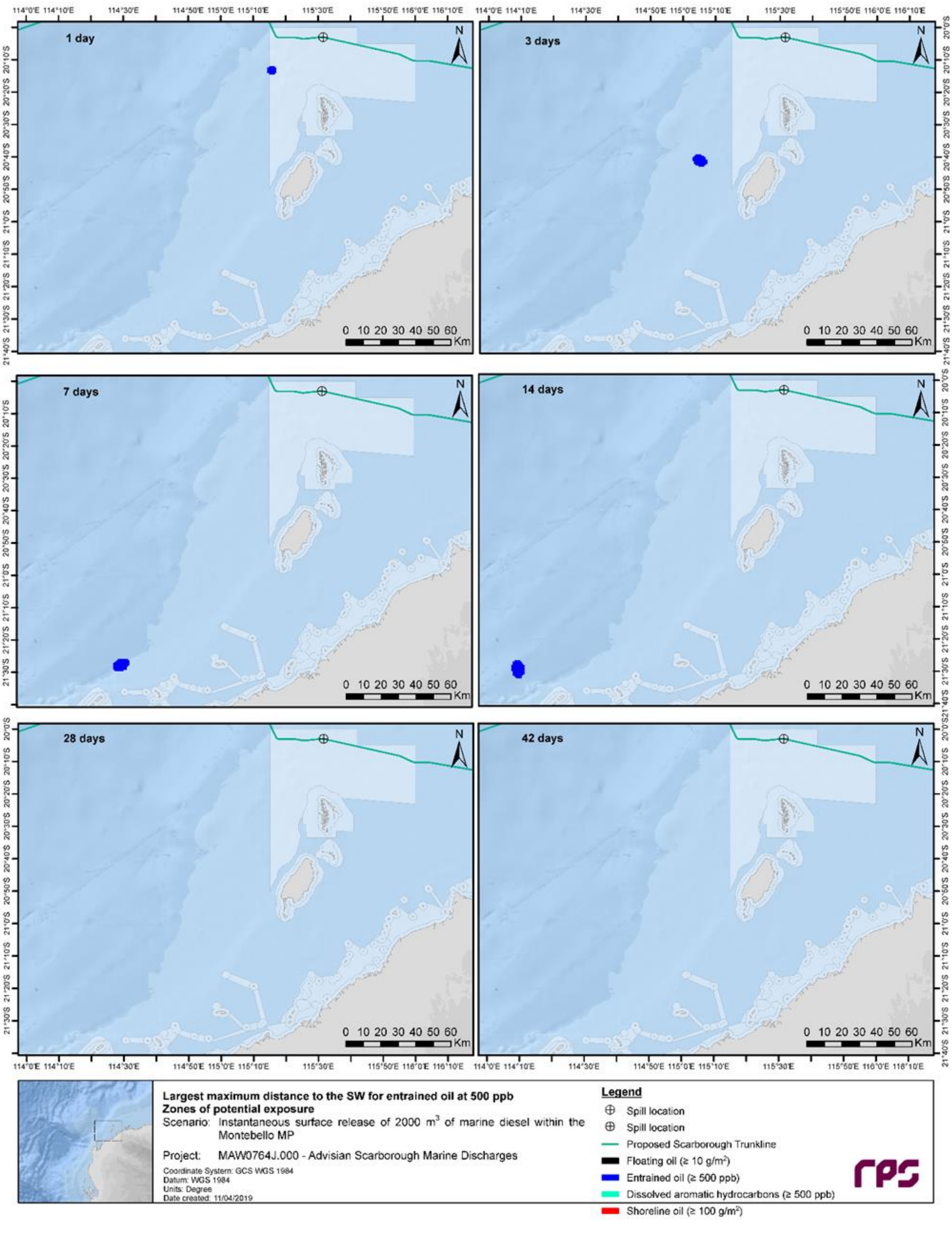


Figure 7.19: Time series from a single deterministic model run for an instantaneous release of 2000 m3 of MDO from within the Montebello Australian Marine Park

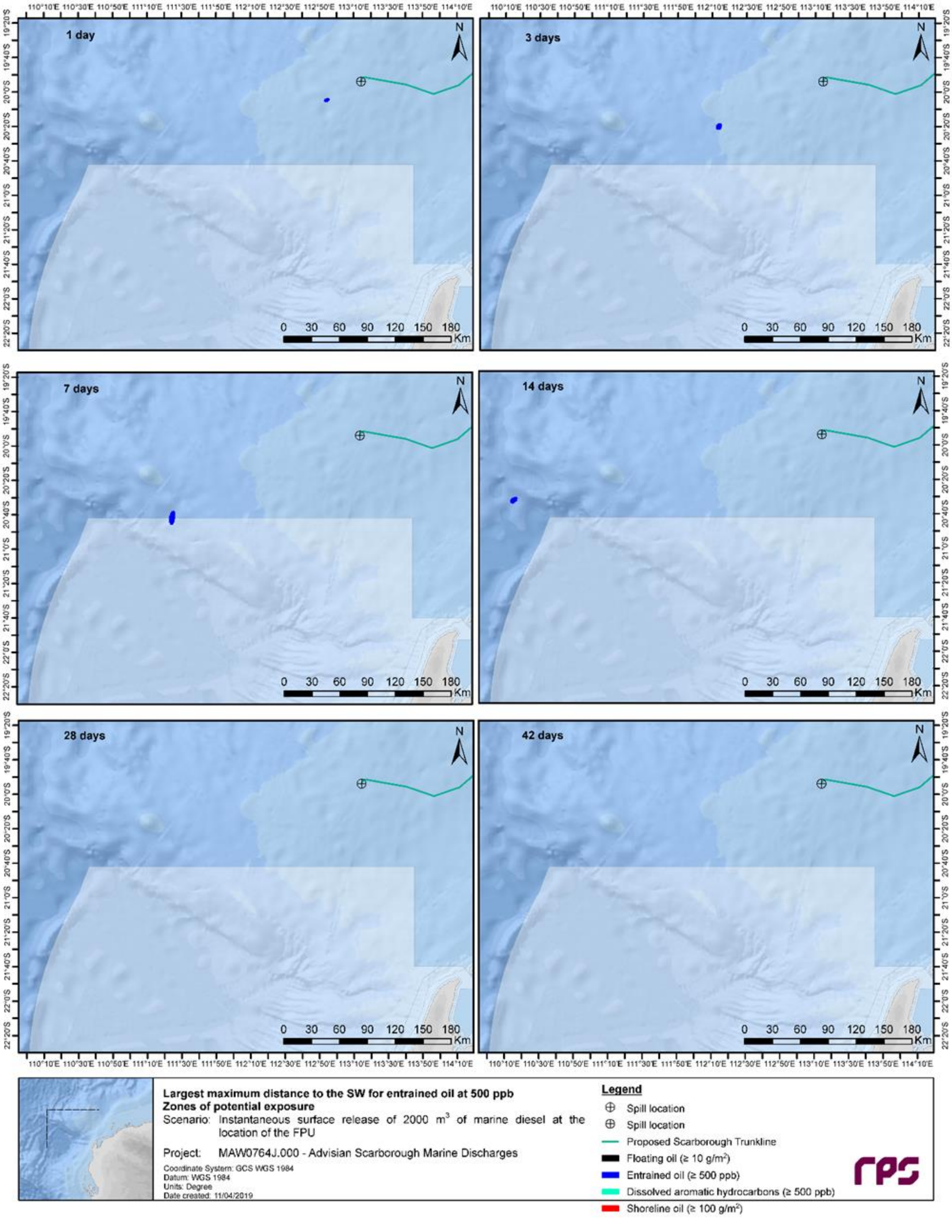


Figure 7.20: Time series from a single deterministic model run for an instantaneous release of 2000 m3 of MDO from the location of the FPU

Changes in Water Quality

In the event of a hydrocarbon release, water quality would be affected due to hydrocarbon exposure.

Dry Gas

In the event of a release of gas hydrocarbons from a loss of well control, the difference in density will mean gas bubbles will rise to the sea surface where it is released into the atmosphere.

Water depths encountered in Project Area (about 900 m), and associated high pressure and low temperature conditions, would result in any released gas to combine with water to form hydrates (Figure 7.21), a solid ice-like substance. Following formation, these hydrates would rise through the water column and, upon reaching shallower water depths (depths above the hydrate formation line as shown in (Figure 7.21)), decompose into methane and water. As methane is highly soluble in water, it would dissolve quickly into the water column after hydrate decomposition. The 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 will disperse within the water column.

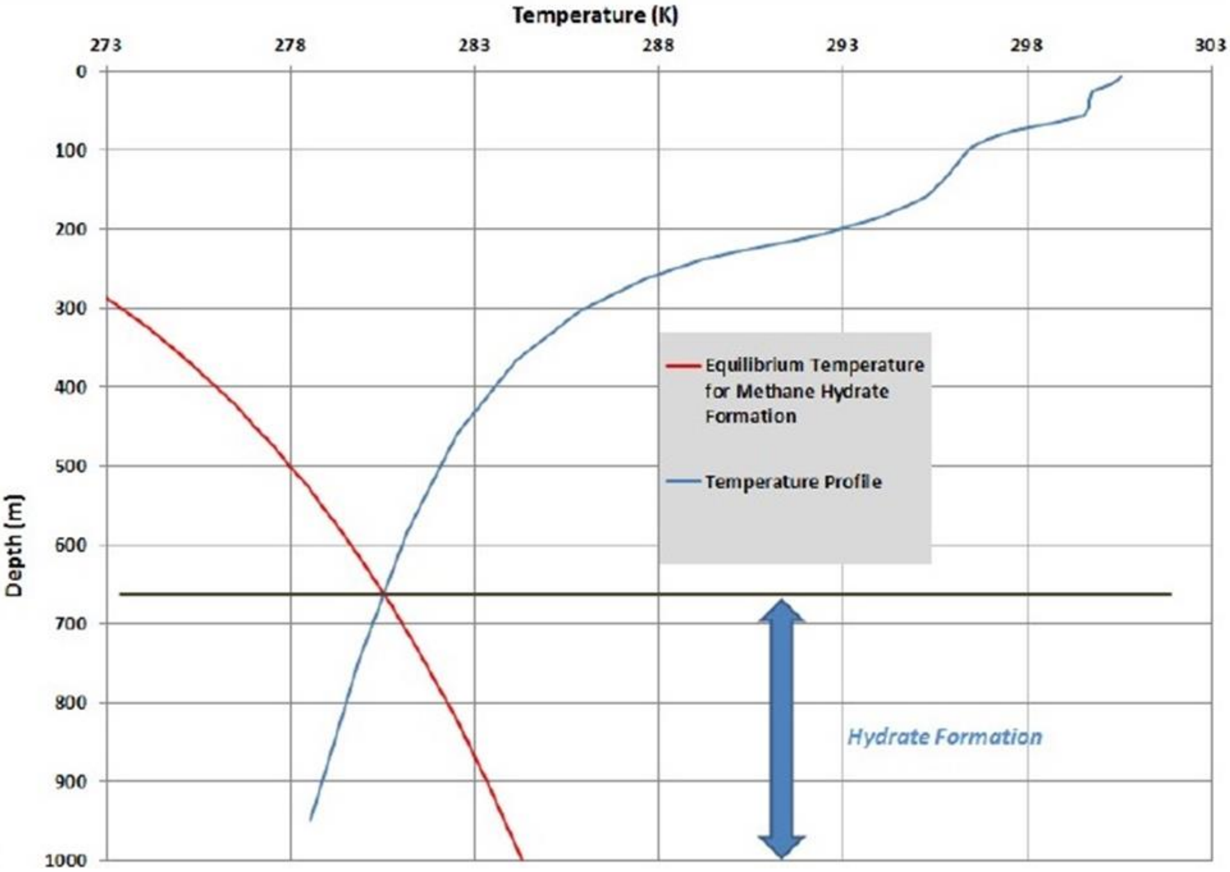


Figure 7.21: Hydrate formation for methane release during a well blow out scenario (Bishmnoi and Natarajan, 1996, cited in ERM, 2013)

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 this was in colder sea temperatures than is present at the project area, in general, as the temperature increases, the solubility of a gas decreases, meaning more gas will escape from solution. Therefore, potential impacts arising from a liquid hydrocarbon release are expected to exceed (in terms of impact pathway and spatial extent) that of a gas release.

Due to the pressure difference between the gas and surrounding water, contamination of the water column or sediment a result of a loss of well control and significant gas release is expected to be minimal and not evaluated further.

MDO

MDO is a non-persistent fuel oil and contains a small proportion of heavy components (or low-volatile components) that tend to physically entrain into the upper water column in the presence of moderate winds (i.e. >12 knots) and breaking waves but may re-float to the surface if these conditions abate. In the event of a substantial spill, the heavier components can remain entrained or remain on the sea surface for an extended period.

When spilt into the warm tropical and subtropical marine environment expected, MDO spreads rapidly and forms a very thin slick, with most of the volatile components typically evaporating in less than a day. Approximately 41% by mass of this oil is predicted to evaporate over the first couple of days depending on the prevailing wind conditions, with further evaporation slowing over time. The heavier (low volatility) components of the oil tend to entrain into the upper water column due to wind-generated waves, but can subsequently resurface depending on conditions (RPS, 2019d).

RPS conducted weathering simulations to illustrate the potential behaviour of MDO when exposed at the water's surface. Variable wind conditions were used (4-19 knots), as this is the worst-case scenario as the wind conditions generate entrainment of the hydrocarbon in the water column. Approximately 24 hours after the spill, around 45% of the oil mass is forecast to have entrained and a further 36% 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).

Variable wind does result in a higher percentage of biological and photochemical degradation, with an approximate rate of 1.8% per day. Whereas the constant wind scenario shows ~50% of the oil evaporates within 36 hours with negligible entrainment, but with a rate of only ~0.2% degradation per day.

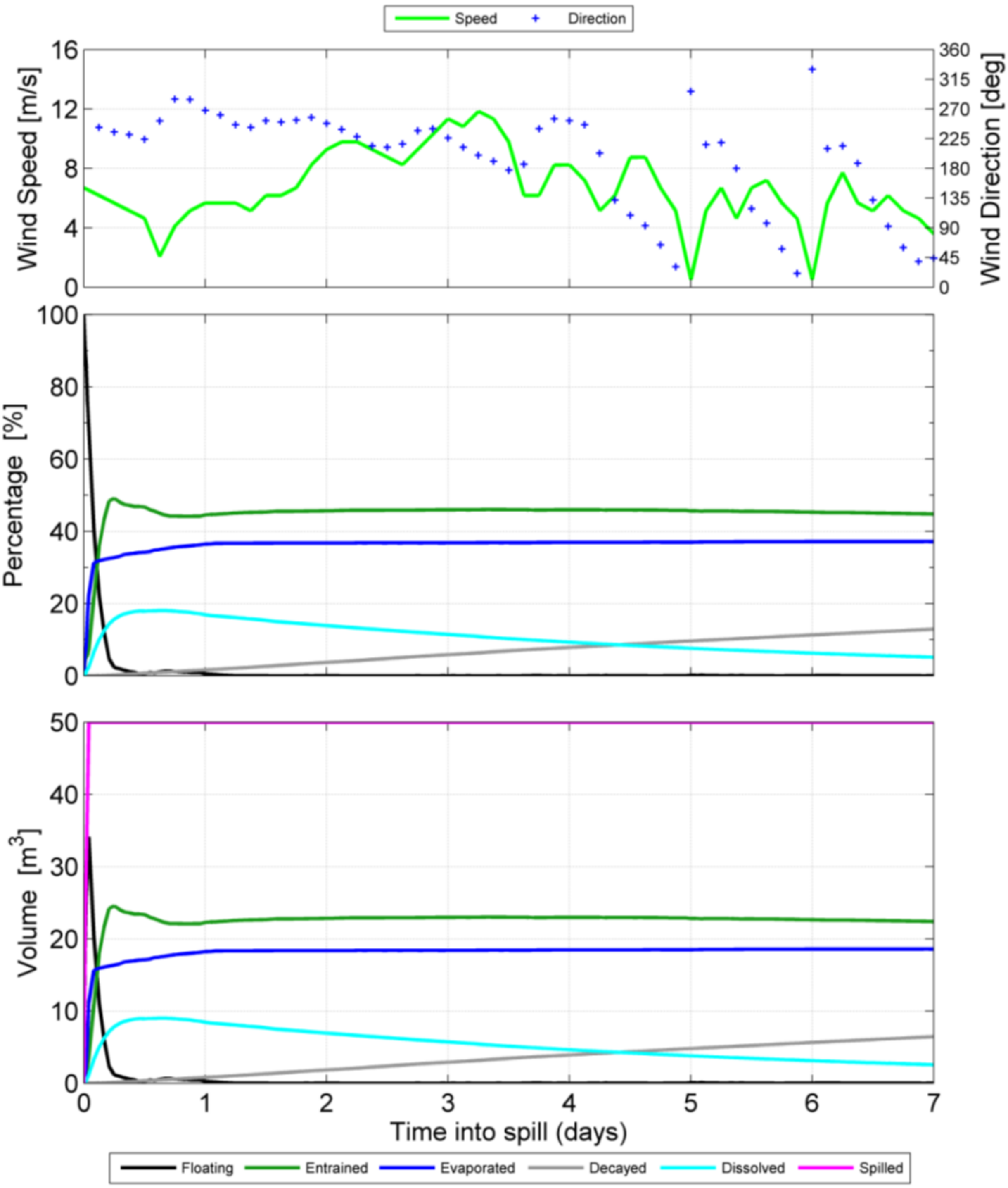


Figure 7.22: Mass balance plot representing, as a proportion (middle panel) and volume (bottom panel), the weathering of 50 m^3 MDO; subject to variable wind at 27 °C water temperature and 25 °C air temperature (RPS, 2019d)

Changes in Sediment Quality

In the event of a liquid hydrocarbon release, entrained hydrocarbons may be present at concentrations above biological impact thresholds (500 ppb). Such hydrocarbon contact may lead to reduced marine sediment quality by several processes, such as adherence to sediment and deposition shores or seabed habitat.

Typically, an MDO release would entrain into the top ~10 m of the water column. The water depth of the shallowest release point is 74 m, but entrained oil may contact benthic habitats in shallow water, or in intertidal zones.

The hydrocarbon properties of the dry gas and lack of any entrainment fraction means that adherence to sediments is not expected and is not evaluated further.

Change in Habitat

Because of a change in sediment quality and/or water quality, further impacts to receptors may occur, which include a change in habitat resulting from:

- exposure of benthic habitats to in-water concentrations of hydrocarbons
- exposure of intertidal and shoreline habitats to surface hydrocarbons
- exposure of shoreline habitats to shoreline exposure.

Habitats can refer to benthic habitats (including seagrass and macroalgae, KEFs and coral reefs), or shoreline habitats (including mangroves, saltmarsh and so on).

Different habitats types have a different sensitivity to hydrocarbon exposure, and different recovery rates, which is considered in the evaluation of impacts to the receptors.

Injury/Mortality to Marine Fauna

Because of a change in water quality, further impacts to receptors may occur, which include injury or mortality to marine fauna. There are three exposure pathways:

- in-water exposure to entrained or dissolved hydrocarbons for marine fauna present in the water column
- surface hydrocarbons exposure for those species that breathe, feed or are otherwise present on the sea surface
- shoreline exposure for species that forage, breed, nest or are otherwise are present on shorelines (for example marine turtles and shorebirds).

Several threatened, migratory and/or listed marine species have the potential to be present within the area predicted to be contacted by surface, in-water and shoreline hydrocarbons above the impact thresholds. Different species have a different sensitivity to hydrocarbon exposure which is considered in the evaluation of impacts to the receptors.

Surface exposures present the greatest risk to air-breathing marine fauna and seabirds, either through contact or inhalation of the VOCs, which can result in irritation to skin and eyes or damage respiratory systems (Etkins, 1997; Kirwan and Short, 2003); or fouling of marine avifauna feathers (O'Hara and Morandin, 2010). As such, the particular values and sensitivities with the potential to be affected by surface hydrocarbon exposures are:

- migratory marine mammals (specifically Humpback Whale and Pygmy Blue Whale)
- resident dolphin populations
- marine turtle foraging and internesting
- marine avifauna foraging.

Entrained hydrocarbons represent the dispersed insoluble oil droplets phase and pose a hazard to marine life that become entrained (i.e. juvenile fish, larvae, and plankton) with the hydrocarbon plume, via direct ingestion or the consumption of contaminated prey. Given the mobility of marine fauna (e.g. marine mammals, marine turtles) that may be present in the area at the time of the spill, no chronic impacts or risks are expected because these fauna are unlikely to undergo prolonged exposure.

Although the potential for acute exposure is widespread, the interaction of mobile marine fauna with surface hydrocarbons is expected to be limited because weathering will limit the duration of exposure. Therefore, exposures are expected to result in acute impacts to a small number of individuals but are unlikely to impact the viability of local populations.

Change in Fauna Behaviour

As a result of a change in water quality, further impacts to receptors may occur, which include a change in fauna behaviour to avoid hydrocarbon contact. This could include foraging, breeding, nesting, migrating and so on. Different species have a different sensitivity to hydrocarbon exposure which is considered in the evaluation of impacts to the receptors.

Change in Aesthetic Value

As a result of a change in water quality, further impact may occur. A visible sheen on the water surface may be observed, and residue may persist in nearshore areas. Shoreline accumulation over visible thresholds may also impact aesthetics.

This has the potential to reduce the visual amenity of the area for tourism and discourage recreational activities.

Change to the Functions, Interests or Activities of Other Users

As a result of a change in water quality or aesthetic value, further impacts may occur. The presence of a surface hydrocarbon slick can directly impact the activities of other marine users due to exclusion from the area.

Indirect impacts may also occur where a hydrocarbon release effects the presence, abundance or health of commercially targeted species for fisheries or aquaculture activities.

If a visible sheen or residue is observed, there is potential to reduce the visual amenity of the area for tourism and discourage recreational activities.

Receptors Potentially Impacted

Risk events resulting from unplanned hydrocarbon releases have the potential to impact several receptors including:

- water quality
- sediment quality
- habitats – coral, seagrasses, macroalgae, saltmarshes, mangroves and shoreline habitats
- marine fauna – plankton, fish, marine mammals, marine reptiles and seabirds and migratory shorebirds
- values of KEFs and protected areas such as AMPs
- functions, interests and activities of other marine users – commercial fisheries, tourism, shipping and other industries.

Table 7.58 outlines the potential impacts to receptors associated with hydrocarbon releases.

Table 7.58: Receptor/impact matrix

Impacts	Receptors: Water Quality	Sediment Quality	Plankton	Coral	Seagrass and	Macroalgae	Saltmarsh	Mangroves	Shoreline Habitats	Seabirds and Migratory Shorebirds	Fish	Marine Mammals	Marine Reptiles	KEFs	AMPs	Protected Place	Commonwealth Managed Fisheries	State Managed Fisheries	Tourism and Recreation	Shipping	Industry	Defence	Settlements
Change in water quality	✓																						
Change in sediment quality		✓																					
Change in habitat				✓	✓	✓	✓	✓	✓					✓	✓	✓							
Change in fauna behaviour										✓	✓	✓	✓		✓	✓	✓	✓	✓				
Injury/mortality to fauna			✓							✓	✓	✓	✓		✓	✓	✓	✓	✓				
Changes to functions, interests or activities of other users																	✓	✓	✓	✓	✓	✓	✓
Change in aesthetic value																			✓				✓

Detailed Risk Evaluation

For each of the receptors identified for detailed evaluation, the criteria for acceptability as defined in Table 6.3 have been considered and addressed in the following sections. This includes to meet the principles of ESD, internal and external context and any other requirements.

Water Quality

The highly-mixed, open water location and characteristics of hydrocarbons released will result in rapid evaporation and dispersion. However, MDO contains a small proportion of heavy components (or low-volatile components) that 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. If 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.

The hydrocarbon characteristics of MDO mean that in variable wind conditions, it is expected that approximately 24 hours after the spill, around 45% of the oil mass is forecast to have entrained and a further 36% is forecast to have evaporated, leaving only a small proportion of the oil floating on the water surface (<1%) (RPS, 2019d).

Entrained hydrocarbons that result from a potential spill at the FPU location or along the pipeline route could travel according to modelling up to 476 km from the location, which is the worst-case distance. The actual area or exposure will however be relatively small, and exposure is transient and temporary due to the influence of waves and currents.

The environmental performance outcome for water quality is to not substantially change water quality which may adversely impact biodiversity, ecological integrity, social amenity or human health. Given the control measures in place to prevent unplanned hydrocarbon releases, and the offshore location of Scarborough and hydrocarbon characteristics, the change to water quality resulting from unplanned hydrocarbon releases will be temporary and habitat or ecosystem function or integrity will not be impacted.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to water quality. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. Matters relating to potentially impacted receptors are discussed for the specific receptors.

Based on the detailed risk evaluation, the magnitude of potential impact of a change in water quality from unplanned hydrocarbon releases is assessed as slight and is considered **acceptable**.

Sediment Quality

Due to the depth of water at the FPU site, sediment quality in the Offshore Project Area is unlikely to be impacted by surface releases of hydrocarbons. A spill originating in the shallower waters of the Trunkline Project Area (>74 m) could potentially result in entrained hydrocarbons contacting marine sediment, although typically MDO is entrained in the top ~10 m of the water column, subject to wave and wind action.

However, if the plume moves towards shallower waters, the entrained hydrocarbons could potentially come into contact with benthic sediments, or intertidal and shoreline sediments. Shoreline contact is not predicted for spills from areas offshore, however there is potential that should a spill occur closer to state waters, there could be the potential for exposure to shallow waters and shorelines around islands and the mainland.

Where this occurs, toxins may accumulate within marine sediment.

The environmental performance outcomes for sediment quality are to:

- not substantially change sediment quality which may adversely impact biodiversity, ecological integrity, social amenity or human health
- 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.

While there is the potential for some shallow water and shoreline exposure, due to the hydrocarbon characteristics, water depths and expected dispersion of hydrocarbons in the water column, unplanned hydrocarbon releases from Scarborough are not expected over a large area and as such will not adversely impact biodiversity, ecological integrity, social amenity or human health.

There are no Management Plans, Recovery Plans or Conservation Advice related to sediment quality. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. Matters relating to potentially impacted receptors are discussed for the specific receptors.

Based on the detailed risk evaluation, the magnitude of potential impact of a change in sediment quality from unplanned hydrocarbon releases is assessed as slight and is considered **acceptable**.

Plankton

Injury/mortality to planktonic species may occur due to a change in water quality following an unplanned hydrocarbon release. Any surface and subsurface hydrocarbon release could impact plankton, as they are widely dispersed throughout the water column.

Primary production by plankton (supported by sporadic upwelling events in the offshore waters of the NWS) is an important component of the primary marine food web. Planktonic communities are generally mixed, including phytoplankton (cyanobacteria and other microalgae) and secondary consuming zooplankton, such as crustaceans (e.g. copepods), and the eggs and larvae of fish and invertebrates (meroplankton).

Exposure to hydrocarbons in the water column (entrained or dissolved) can change species composition, with declines or increases in one or more species or taxonomic groups (Batten et al., 1998). Phytoplankton may also experience decreased rates of photosynthesis (Tomajka, 1985). For zooplankton, such as fish, coral and 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. Impacts on plankton communities are likely to occur in areas where entrained or dissolved aromatic hydrocarbon threshold concentrations are exceeded, but communities are expected to recover relatively quickly (within weeks or months). This is due to high population turnover, with copious production within short generation times that also buffers the potential for long-term (i.e. years) population declines (International Tanker Owners Pollution Federation, 2011a).

When first released, MDO has a higher toxicity due to the presence of the volatile components. Plankton making contact close to the spill source at the time of the spill may be impacted, however, due to low planktonic productivity within the NW region it is unlikely that large populations of plankton will be affected at the sea surface above thresholds as this is only predicted for the first few days after the spill. MDO does not tend to have a high proportion that dissolves – all three release locations predict low probabilities and low concentration to intersect with sensitive receptors (Table 7.57).

The environmental performance outcome for plankton is to not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution.

Given hydrocarbon characteristics, expected rapid weathering and then degradation of the entrained component to below impact thresholds, and relatively quick recovery times of plankton, unplanned releases from Scarborough are not expected to have a substantial adverse effect on plankton life cycle and spatial distribution.

There are no Management Plans, Recovery Plans or Conservation Advice related to plankton. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered.

Based on the detailed risk evaluation, the magnitude of potential impact of a change in sediment quality from unplanned hydrocarbon releases is assessed as slight and is considered **acceptable**.

Fish

Injury/mortality to fish species may occur due to a change in water quality following an unplanned hydrocarbon release. Any surface and subsurface hydrocarbon release could impact fish, as they are widely dispersed throughout the water column.

Impacts to sharks and rays may occur through direct contact with hydrocarbons and contaminate the tissues and internal organs, either through direct contact or via the food chain (consumption of prey). As gill breathing organisms, 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). In the offshore environment, it is probable that pelagic shark species are able to detect and avoid hydrocarbons by swimming into deeper water or away from the affected areas.

Fish mortalities are rarely observed to occur as a result of hydrocarbon spills (International Tanker Owners Pollution Federation, 2011b). 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. 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). Where fish mortalities have been recorded, the spills (resulting from the groundings of the tankers Amoco Cadiz in 1978 and the Florida in 1969) have occurred in sheltered bays.

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). This suggests that juvenile and adult fish can avoid water contaminated with high concentrations of hydrocarbons.

The effects of exposure to oil on the metabolism of fish appear to vary according to the organs involved, exposure concentrations and route of exposure (waterborne or food intake). Oil 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 oil from the fish (Cohen et al., 2005).

Fish are perhaps most susceptible to the effects of spilled oil in their early life stages, particularly during egg and planktonic larval stages, which can become entrained in spilled oil. Contact with oil 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 because of exposure in early life stages to hydrocarbons 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).

Adult fish exposed to low hydrocarbon concentrations are likely to metabolise the hydrocarbons and excrete the derivatives, with studies showing that fish can metabolise petroleum hydrocarbons and that accumulated hydrocarbons are released from tissues when the fish is returned to hydrocarbon-free sea water. Several fish communities in these areas are demersal (i.e. living closer to the seabed) where concentrations of entrained hydrocarbons will be lower; any impacts are expected to be highly localised.

Marine fauna with gill-based respiratory systems are expected to have higher sensitivity to exposures of entrained contaminants. Therefore, the receptors most susceptible to dissolved hydrocarbons are fish and whale sharks. MDO does not tend to have a high proportion that dissolves – all three release locations predict low probabilities and low concentration to intersect with sensitive receptors.

When first released, MDO has a higher toxicity due to the presence of the volatile components. Individual fish making contact close to the spill source at the time of the spill may be impacted. Fish presence is generally concentrated in waters closer to shore, therefore spills within the Trunkline Project Area are more likely to have a greater level of impact than that of a spill in the Offshore Project Area. Although fish presence may occur throughout the entire Scarborough Project area and defined EMBA, it is unlikely that a large number of fish will be affected at the sea surface above thresholds, as this is only <1-15% remaining on the surface after 7 days.

Mobile transient fauna are not expected to remain within entrained hydrocarbon plumes for an extended time. Therefore, no acute impacts or risks associated with entrained exposures from an unplanned MDO release are expected. Any impacts from this exposure are expected to result in localised short-term effects to limited small numbers of juvenile fish and prey species (larvae and planktonic organisms), which are not expected to affect population viability and recruitment of fish. Consequently, diverse fish assemblages are not expected to be significantly impacted.

The environmental performance outcome for fish is to:

- not have a substantial adverse effect on a population of fish, or the spatial distribution of the population
- not substantially modify, destroy or isolate an area of important habitat for a migratory species
- not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

Although potential impacts could include mortality or sub-lethal injury/illness of pelagic fish, this would be expected to comprise a small proportion of the resident and transitory population. Given hydrocarbon characteristics, expected rapid weathering to below impact thresholds and degradation of entrained fractions, and the mobile transient nature of fish, unplanned releases from Scarborough are not expected to have a substantial adverse effect on the population, or spatial distribution of fish; or substantially modify, destroy or isolate an area of important habitat for migratory species. Additionally, unplanned releases will not seriously disrupt the lifecycle of an ecologically significant proportion of any migratory fish species (i.e. whale sharks).

There are specific conservation advices for some fish species which identify habitat degradation / modification as a key threat. While generally no explicit management actions are identified, for some species there are specific requirements:

- Sawfish and river sharks: Identify risks to important habitat and measures needed to reduce those risks and implement measures to reduce adverse impacts of habitat degradation and/or modification (freshwater sawfish only).
- Whale shark: Minimise offshore developments and transit time of large vessels in areas close to marine features likely to correlate with Whale Shark aggregations and along the northward migration route.

These focus on measures to reduce adverse impacts of habitat degradation, which could include from unplanned hydrocarbon releases, although this is not explicit.

As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. Natural values for the marine parks include:

- diverse fish communities for the Dampier, Gascoyne, Ningaloo or Montebello Marine Parks
- diverse fish communities specifically within the Continental slope demersal fish communities KEF for Gascoyne and Ningaloo Marine Parks
- whale shark foraging habitat BIAs for Montebello and Ningaloo Marine Parks.

The objective of the Habitat Protection Zone (IV) (Dampier, Gascoyne and Ningaloo Marine Parks) 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 National Park Zone (II) (Dampier and Gascoyne Marine Parks) 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 Multiple Use Zone (VI) is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species (refer to Section 3.5.2).

Modelling predicts that Dampier Marine Park is likely to be exposed to entrained, dissolved and surface hydrocarbons over the thresholds from the Mermaid Sound release location. The other two release locations are not predicted to expose Dampier Marine Park. The entrained fraction presents the worst-case, at a maximum concentration of 10,407 ppb (RPS, 2019d).

The Montebello Marine Park will be exposed to entrained, dissolved and surface hydrocarbons above exposure thresholds from the Montebello release scenario, which is to be expected, as the release point is inside the Marine Park. Ningaloo World Heritage Area and the Gascoyne Marine Park have a low probability of being intersected by entrained oil only (4% and 8% respectively).

Therefore, unplanned hydrocarbon releases that may result from Scarborough Project activities that may impact the Dampier, Gascoyne, Ningaloo or Montebello Marine Parks are not inconsistent with the objectives of the IUCN zones of the marine parks described above and in Section 3.5.2.

Based on the detailed risk evaluation, the magnitude of potential impacts to fish from unplanned hydrocarbon releases is assessed as slight and is considered **acceptable**.

Marine Mammals

A change in marine fauna behaviour or injury/mortality to marine mammals may occur due to a change in water quality following an unplanned hydrocarbon release.

Air-breathing fauna such as marine mammals are most at risk from surface exposures due to the high volatile components. Marine mammals that have direct physical contact with surface, entrained or dissolved aromatic hydrocarbons may suffer surface fouling, ingest hydrocarbons and inhale toxic vapours. 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 or neurological damage (Helm et al., 2015). If prey (fish and plankton) are contaminated, this can result in the absorption of toxic components of the hydrocarbons (PAHs).

In a review of cetacean observations in relation to a number of large-scale hydrocarbon spills, Geraci (1988) found little evidence of mortality associated with hydrocarbon spills. However, behavioural disturbance (i.e. avoiding spilled hydrocarbons) was observed in some instances for several species of cetaceans. This suggests that cetaceans are able to detect and avoid surface slicks. While this reduces the potential for physiological impacts from contact with hydrocarbons, active avoidance of an area may disrupt behaviours such as migration, or displace individuals from important habitat, such as foraging, resting or breeding.

Because of the potential extent of moderate surface exposures, there is the potential for widespread exposure to marine fauna (whales, turtles, whale sharks, and seabirds). Therefore, there is the potential for acute exposures to result in marine fauna casualties.

When first released, MDO has a higher toxicity due to the presence of the volatile components. Individual cetaceans making contact close to the spill source at the time of the spill may be impacted. Cetacean presence is generally more concentrated in waters closer to shore with the exception of false killer whales. Spills within the Trunkline Project Area are therefore more likely to have a greater level of impact than that of a spill in the Offshore Project Area. Migratory BIAs for humpback and pygmy blue whales occur along the Trunkline Project Area. Although cetacean presence may occur throughout the Scarborough Project area and defined EMBA, it is unlikely that a large number of cetaceans will be affected at the sea surface above thresholds, as dependant on wind conditions, weathering predicts that only <1 - 15% of hydrocarbon remains on the surface after ~7 days (RPS, 2019d).

The environmental performance outcomes for marine mammals are to:

- not have a substantial adverse effect on an endangered marine mammal species that results in a reduction to the area of occupancy of an important population
- 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 a Commonwealth marine area results
- not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

Although potential impacts could include mortality or sub-lethal injury/illness of marine mammals, this would be expected to comprise a small proportion of the resident and transitory population. Given hydrocarbon characteristics, expected rapid weathering of surface oil to below impact thresholds, and the mobile transient nature of marine mammals and potential avoidance behaviour, unplanned releases from Scarborough are not expected to have a substantial adverse effect on the population, or spatial distribution of marine mammals; or substantially modify, destroy or isolate an area of important habitat for migratory species. Additionally, unplanned releases will not seriously disrupt the lifecycle of an ecologically significant proportion of any migratory species.

There are specific conservation advices for some species which identify noise interference and vessel disturbance as key threats. While hydrocarbon spills are not explicitly identified as a threat, the sei whale conservation advice does include the management of physical disturbance and development activities. No explicit management actions are identified relevant to hydrocarbon spills.

As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. Natural values for the marine parks include:

- humpback whale migratory pathways BIAs for Montebello, Dampier and Gascoyne Marine Parks
- pygmy blue whale foraging habitat and migratory pathways BIAs for Gascoyne and Ningaloo Marine Parks
- dugong nursing habitat BIAs for Ningaloo Marine Park.

Modelling predicts that the Montebello Marine Park has 100% probability of surface oil above the threshold, which is to be expected, as one of the release points is inside the Marine Park. Surface oil weathers rapidly (depending on wind conditions), so this still presents a short-term change. The Dampier and Gascoyne Marine Parks have low probabilities of being intersected with surface oil over the threshold (RPS, 2019d). Ningaloo Marine Park is not predicted to be contacted with any surface hydrocarbon over the threshold.

Therefore, unplanned hydrocarbon releases that may result from Scarborough Project activities that may impact the Dampier, Gascoyne, Ningaloo or Montebello Marine Parks are not inconsistent with the objectives of the IUCN zones described for these marine parks in Section 3.5.2.

Potential impacts are unlikely to lead to mortality or sub-lethal injury/illness of an EPBC-listed protected species. Based on the detailed risk evaluation, the magnitude of potential impacts to marine mammals (focused on changes in behaviour) from unplanned hydrocarbon releases is assessed as slight and is considered **acceptable**.

Marine Reptiles

A change in marine fauna behaviour or injury/mortality to marine reptiles may occur due to a change in water or sediment quality following an unplanned hydrocarbon release.

Marine reptiles can be impacted by surface exposure when they surface to breathe, and by shoreline accumulation of hydrocarbons when breeding and nesting.

Hydrocarbons in surface waters may impact turtles when they surface to breathe and inhale toxic vapours. Their breathing pattern, involving large 'tidal' volumes and rapid inhalation before diving, results in direct exposure to petroleum vapours which are the most toxic component of the hydrocarbon spill (Milton and Lutz, 2003). This can lead to lung damage and congestion, interstitial emphysema, inhalant pneumonia and neurological impairment (National Oceanic and Atmospheric Administration, 2010). Contact with entrained hydrocarbons can result in hydrocarbon adherence to body surfaces, irritating mucous membranes in the nose, throat and eyes, leading to inflammation and infection (Gagnon and Rawson, 2010).

Adult sea turtles exhibit no avoidance behaviour when they encounter hydrocarbon spills (National Oceanic and Atmospheric Administration, 2010). Oiling can also irritate and injure skin, which is most evident on pliable areas such as the neck and flippers (Lutcavage et al., 1995). A stress response associated with this exposure pathway includes an increase in the production of white blood cells, and even a short exposure to hydrocarbons may affect the functioning of their salt gland (Lutcavage et al., 1995).

When first released, MDO has a higher toxicity due to the presence of the volatile components. Individual turtles making contact close to the spill source at the time of the spill may be impacted. Turtle presence is generally more concentrated in waters closer to shore with infrequent presence of turtles as far offshore at the Offshore Project Area. Spills within the Trunkline Project Area are therefore more likely to have a greater level of impact than that of a spill in the Offshore Project Area. Breeding, foraging and inter-nesting BIAs lie within the Trunkline Project Area and EMBA. Although turtle presence may occur throughout the Scarborough Project area and defined EMBA, it is unlikely that a large number of turtles will be affected at the sea surface above thresholds as weathering predicts that only <1 - 15% of hydrocarbon remains on the surface after ~7 days (RPS, 2019d).

Hydrocarbons accumulated on sandy beaches may also potentially impact nesting females, incubating eggs and emerging hatchlings through direct contact with the hydrocarbon. Conservative modelling predicts that there is 1% probability of shorelines being contacted over the exposure threshold, for any release location, at WA Coastline and Dampier Archipelago, with the maximum local volume predicted to accumulate of only 3 m^3. The FPU location does not predict any shoreline contact.

Several significant nesting areas for turtles occur across the EMBA, in particular at the Montebello/Barrow/Lowendal Islands group, Muiron Island, Pilbara islands, Dampier Archipelago which have been identified as BIAs or habitat critical to the survival of a species. Hence there is the potential to impact on nesting populations, which has the potential to affect species recruitment at a local population level. Therefore, there is the potential for long-term effects on species while local populations recover from interrupted recruitment, posing potential widespread long-term impacts to species.

The proximity of a potential spill from shore will determine how much hydrocarbons reach the shore, as MDO weathers rapidly, with only <15% remaining to reach the shore after the first ~7 days. The time of year can determine whether migratory species are present, and the type of activities being engaged in (i.e. nesting or hatching).

Impacts to sea snakes from direct contact with hydrocarbons are likely to result in similar physical effects to those recorded for marine turtles.

Impacts to sea snakes from direct contact with hydrocarbons are likely to result in similar physical effects to those recorded for marine turtles.

The environmental performance outcomes for marine reptiles are to:

- not have a substantial adverse effect on an endangered marine reptile species that results in a reduction to the area of occupancy of an important population
- 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
- not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

Potential impacts are unlikely to lead to mortality or sub-lethal injury/illness of an EPBC listed protected species. However, there is the potential for long-term effects on species while local populations recover from interrupted recruitment due to significant nesting areas potentially being impacted.

Although potential impacts could include mortality or sub-lethal injury/illness of marine reptiles, this would be expected to comprise a small proportion of the resident and transitory population. Given hydrocarbon characteristics, expected rapid weathering to below impact thresholds, and the mobile transient nature of individuals, unplanned releases from Scarborough are not expected to substantially modify, destroy or isolate an area of important habitat for migratory species.

However, it is not expected that unplanned releases will have a substantial adverse effect on the population, or spatial distribution of marine reptiles; or seriously disrupt the lifecycle of an ecologically significant proportion of any migratory species. The significant turtle nesting areas predicted to be contact by hydrocarbons above the shoreline exposure threshold include Legendre and Rosemary Island (in the Dampier Archipelago group), however of only a worst-case accumulated volume of 3 m^3. Barrow Island may be contacted, but not above the threshold (RPS, 2019d).

Impacts to turtles from unplanned hydrocarbon releases are to be managed in accordance with the Recovery Plan for marine turtles in Australia (DoEE, 2017). The Recovery Plan identifies ensuring spill risk strategies and response programs include management for turtles and their habitats. In addition, there is in place approved Conservation Advice for the Short-nosed Sea snake (DSEWPaC, 2011), which includes ensuring there is no anthropogenic disturbance in areas where the species occurs, excluding necessary actions to manage the conservation of the species.

As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. Natural values for the marine parks include:

- marine turtle interesting BIAS for Dampier, Gascoyne and Ningaloo Marine Parks
- marine turtle internesting, foraging, mating and nesting habitat BIAs for Montebello Marine Park.

Therefore, unplanned hydrocarbon releases that may result from Scarborough Project activities that may impact the Dampier, Gascoyne, Ningaloo or Montebello Marine Parks are not inconsistent with the objectives of the IUCN zones described for these marine parks in Section 3.5.2.

Based on the detailed risk evaluation, the magnitude of potential impacts to marine reptiles from unplanned hydrocarbon releases is assessed as no lasting effects (from change in fauna behaviour) and slight (from injury/mortality to fauna) and is considered **acceptable**.

Seabirds and Migratory Shorebirds

A change in marine fauna behaviour or injury/mortality to seabirds and migratory shorebirds may occur due to a change in water or sediment quality following an unplanned hydrocarbon release.

Seabirds and migratory birds are particularly vulnerable to contact with floating hydrocarbons, which may mat feathers. This may lead to hypothermia from loss of insulation and ingestion of hydrocarbons when preening to remove hydrocarbons. Both impacts may result in mortality (Hassan and Javed, 2011). Pathways of biological exposure that can result in impact may occur through ingesting contaminated fish (nearshore waters) or invertebrates (intertidal foraging grounds such as beaches, mudflats and reefs). Ingestion can also lead to internal injury to sensitive membranes and organs (International Petroleum Industry Environmental Conservation Association, 2004). Whether the toxicity of ingested hydrocarbons is lethal or sub-lethal will depend on the weathering stage and its inherent toxicity. Exposure to hydrocarbons may have longer term effects, with impacts to population numbers due to decline in reproductive performance and malformed eggs and chicks, affecting survivorship and losing adult birds.

When first released, MDO has a higher toxicity due to the presence of the volatile components. Individual birds making contact close to the spill source at the time of the spill may be impacted. Bird presence within the NW region is more concentrated in waters closer to shore with the potential for individual migratory birds within the Offshore Project Area. Spills within the Trunkline Project Area are therefore more likely to have a greater level of impact than that of a spill in the Offshore Project Area. Breeding and foraging BIAs for some bird species are present within the Trunkline Project Area and defined EMBA. Although bird presence may occur throughout the Scarborough Project area and defined EMBA, it is unlikely that a large number of birds will be affected at the sea surface above thresholds as this is only predicted for the first five days.

Offshore waters of the Project Area are potential foraging grounds for seabirds associated with the coastal roosting and nesting habitat, which includes the numerous islands along the Pilbara coast. Nearshore waters potentially impacted are utilised by seabirds and resident/non-breeding overwintering shorebirds for foraging and resting. Although breeding oceanic seabird species can travel large distances to forage in offshore waters, breeding seabirds tend to forage in nearshore waters near breeding colonies.

Shoreline hydrocarbons that may accumulate on beaches may also potentially impact nesting females, incubating eggs and emerging hatchlings through direct contact with the hydrocarbon. Conservative modelling predicts that there is 1% probability of shorelines being contacted over the exposure threshold, for any release location, at WA Coastline and Dampier Archipelago, with the maximum local volume predicted to accumulate of only 3 m^3. The FPU location does not predict any shoreline contact.

Several significant important habitats for seabirds and migratory shorebirds for key breeding/nesting areas, roosting areas and surrounding waters important foraging and resting areas nesting areas occur in the EMBA, in particular at Montebello/Barrow/Lowendal Islands group, Pilbara Islands, Muiron Islands and Rowley Shoals. Breeding BIAs for seabirds and shorebirds are primarily restricted to within tens of kilometres of emergent features. Hence there is the potential to impact on nesting populations, which has the potential to affect species recruitment at a local population level. The proximity of a potential spill from shore will determine how much hydrocarbons reach the shore, as MDO weathers rapidly, with only <1 - 15% of hydrocarbon predicted to remain on the surface after ~7 days (RPS, 2019d). The time of year can determine whether migratory species are present, and the type of activities birds are engaging in.

The environmental performance outcomes for seabirds and migratory shorebirds are to:

- not have a substantial adverse effect on a population of seabirds or shorebirds, or the spatial distribution of the population.
- not substantially modify, destroy or isolate an area of important habitat for a migratory species.
- not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

Potential impacts are unlikely to lead to mortality or sub-lethal injury/illness of an EPBC listed protected species. However, there is the potential for long-term effects on species while local populations recover from interrupted recruitment due to significant nesting areas potentially being impacted.

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. Given hydrocarbon characteristics, expected rapid weathering to below impact thresholds, and the mobile transient nature of individuals, unplanned releases from Scarborough are not expected to substantially modify, destroy or isolate an area of important habitat for migratory species.

However, it is not expected that unplanned releases will have a substantial adverse effect on the population, or spatial distribution of seabirds or migratory shorebirds; or seriously disrupt the lifecycle of an ecologically significant proportion of any migratory species. The significant shorebird nesting areas predicted to be contact by hydrocarbons above the shoreline exposure threshold include Legendre and Rosemary Island (in the Dampier Archipelago group), however of only a worst-case accumulated volume of 3 m^3. Barrow Island may be contacted, but not above the shoreline exposure threshold (RPS, 2019d).

There are specific conservation advices for some species which identify habitat degradation as the key threat. While generally no explicit management actions are identified, for some of the species, there is a general requirement to:

- manage disturbance at important sites which are subject to anthropogenic disturbance when the species is present (including the Greater Sand Plover, Large Sand Plover, Great Knot, Eastern Curlew, and Far Eastern Curlew)
- ensure there is no disturbance in areas where the species is known to breed (specific to the Australian Painted Snipe)
- ensure appropriate oil-spill contingency plans are in place for the subspecies' breeding sites which are vulnerable to oil spills (specific to the Australian Fairy Tern).

As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. Natural values for the marine parks include:

- seabird breeding habitat BIAs (Montebello, Dampier, Gascoyne and Ningaloo Marine Parks)
- seabird foraging habitat BIAs (Dampier and Ningaloo Marine Parks).

Therefore, unplanned hydrocarbon releases that may result from Scarborough Project activities that may impact the Dampier, Gascoyne, Ningaloo or Montebello Marine Parks are not inconsistent with the objectives of the IUCN zones for these marine parks described in Section 3.5.2.

Impacts have potential widespread long-term impacts to species. Based on the detailed risk evaluation, the magnitude of potential impact to seabirds and migratory shorebirds from unplanned hydrocarbon releases is assessed as having no lasting effects (from change in fauna behaviour) and slight (from injury/mortality to fauna) and is considered **acceptable**.

Coral

A change in habitat may occur due to a change in water or sediment quality following an unplanned hydrocarbon release.

Water soluble hydrocarbon fractions associated with surface slicks are also known to cause high coral mortality (Shigenaka, 2001) via direct physical contact of hydrocarbon droplets to sensitive coral species (such as the branching coral species). There is significant potential for lethal impacts due to the physical hydrocarbon coating of sessile benthos (e.g. by entrained hydrocarbons), with likely significant mortality of corals (adults, juveniles and established recruits) at the small spill-affected areas. This particularly applies to branching corals which are reported to be more sensitive than massive corals (Shigenaka, 2001).

Exposure to entrained hydrocarbons (≥500 ppb) 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 coral in early life stages to hydrocarbons (Negri and Heyward, 2000). Such impacts are likely to result in the failure of recruitment and settlement of new population cohorts. In addition to direct impacts to coral, species associated with coral reef habitat, such as fish, may also be impacted as described above.

The general behaviour of MDO is that it will typically remain on the sea surface but can entrain into the upper water column under moderate wind conditions; however, sedimentation of oil droplets is not expected to occur. As such, exposure of coral habitats to hydrocarbon would only be relevant in shallow nearshore and/or intertidal waters.

The environmental performance outcome for coral is 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.

Significant areas of coral are known to occur fringing the Montebello Islands, Barrow Island and the Muiron Islands, Dampier Archipelago (including Legendre and Rosemary Island) and Ningaloo Reef.

Montebello Marine Park has the highest probability of entrained hydrocarbon over the exposure threshold (70%), which is to be expected from the Montebello release location on the trunkline. The Dampier Archipelago is next most likely receptor impacted, and then Barrow and Muiron Islands and Ningaloo have <7% probability

The fraction of hydrocarbon entrained is very dependent on wind conditions, with stronger and variable wind conditions causing more entrainment. However, the entrained oil is subject to a greater degree of biological and photochemical degradation, with an accumulated total rate of ~13% after 7 days.

Given hydrocarbon characteristics and the expected rapid weathering to below impact thresholds, unplanned hydrocarbon releases from Scarborough are not expected to result in an adverse impact on marine ecosystem functioning or integrity.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to coral in the Project Area. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered.

In the event of a hydrocarbon spill, there is the potential for these coral reefs to be exposed to entrained and/or dissolved aromatic hydrocarbons concentrations that are considered to induce toxicity effects. Exposure to entrained hydrocarbons/dissolved aromatic hydrocarbons (≥500 ppb) has the potential to result in lethal or sublethal toxic effects to corals and other sensitive sessile benthos within the upper water column, including upper reef slopes (subtidal corals), reef flat (intertidal corals) and lagoonal (back reef) coral communities (with reference to Ningaloo Coast). As MDO can entrain into the upper water column under moderate wind conditions, this could result in impacts to the shallow water fringing coral communities/reefs of the offshore islands (e.g. Barrow/Montebello/Lowendal Islands) and also the mainland coast (e.g. Ningaloo Coast). Impacted coral reefs may experience long-term effects (ie recovery periods taking up to 10 years) due to their recovery relying on coral larvae from neighbouring coral communities that have either not been affected or only partially impacted. However, due to the short duration of the spill (ie instantaneous release, and short exposure time as documented by deterministic modelling), the confined spatial extent and the tendency of MDO to remain on the sea surface, the scale of potential consequences is limited.

Based on the detailed risk evaluation, the magnitude of potential impact to coral from unplanned hydrocarbon releases is assessed as Moderate (ie Medium-term impacts to ecosystem/habitat service on a far-field scale) and is considered **acceptable**.

Seagrass and Macroalgae

A change in habitat may occur due to a change in water or sediment quality following an unplanned hydrocarbon release.

Seagrass and macroalgal beds in the intertidal and subtidal zone may be susceptible to impacts from entrained hydrocarbons. Toxicity effects can also occur due to absorption of soluble fractions of hydrocarbons into tissues (Runcie et al., 2010). The potential for toxicity effects of entrained hydrocarbons may be reduced by weathering processes that should serve to 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 received and duration of exposure. Physical contact with entrained hydrocarbon droplets could cause sub-lethal stress, causing reduced growth rates and reduced tolerance to other stress factors (Zieman et al., 1984).

The general behaviour of MDO is that it will typically remain on the sea surface but can entrain into the upper water column under moderate wind conditions; however, sedimentation of oil droplets is not expected to occur. As such, exposure of seagrass or macroalgae to hydrocarbon would only be relevant in shallow nearshore and/or intertidal waters.

The environmental performance outcome for seagrass and macroalgae is 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.

Significant seagrass and macroalgae communities are found in waters surrounding islands of the Dampier Archipelago, Barrow Island and the Montebello Islands.

Modelling predicts that both Dampier Marine Park and Montebello Marine Park are predicted to be intersected with entrained hydrocarbons over the exposure thresholds (RPS, 2019d). In particular the Montebello Marine Park has a 70% probability, with high concentrations of entrained hydrocarbons. This is to be expected, as the release location modelled is within Park boundaries. The fraction of entrained hydrocarbon increases with winds, however, is then subject to a greater degree of biological and photochemical degradation.

Given hydrocarbon characteristics, expected rapid weathering to below impact thresholds, and the distance to areas of seagrass and macroalgae from the Project Area, unplanned hydrocarbon releases from Scarborough are not expected to result in an adverse impact on marine ecosystem functioning or integrity.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to seagrass and macroalgae in the Project Area. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered.

Based on the detailed risk evaluation, the magnitude of potential impacts to seagrass and macroalgae from unplanned hydrocarbon releases is assessed as no lasting effect and is considered **acceptable**.

<u>Mangroves</u>

A change in habitat may occur due to a change in water or sediment quality following an unplanned hydrocarbon release.

Mangroves are considered to have a high sensitivity to hydrocarbon exposure. Mangroves can be impacted by heavy or viscous oil, or emulsification, that covers the trees' breathing pores thereby asphyxiating the subsurface roots, which depend on the pores for oxygen (IPIECA, 1993). Hydrocarbons deposited on the aerial roots can block the pores used to breathe, or interfere with the trees' salt balance, resulting in sub-lethal and potentially lethal effects. Mangroves can also take up hydrocarbons from contact with leaves, roots or sediments, and it is suspected that this uptake causes defoliation through leaf damage and tree death (Wardrop et al., 1987). Acute impacts to mangroves can be observed within weeks of exposure, whereas chronic impacts may take months to years to detect. Mangroves can also be impacted by entrained/dissolved aromatic hydrocarbons that may adhere to the sediment particles. In low energy environments, such as in mangroves, deposited sediment-bound hydrocarbons are unlikely to be removed naturally by wave action and may be deposited in layers by successive tides (National Oceanic and Atmospheric Administration, 2014).

Entrained hydrocarbon impacts may also include sub-lethal stress and mortality to certain sensitive biota in these mangrove and mud flat habitats, including infauna and epifauna. Larval and juvenile fish, and invertebrates that depend on these shallow subtidal and intertidal habitats as nursery areas, may be directly impacted due to the loss of habitats and/or lethal and sub-lethal in-water toxic effects. This may result in mortality or impair growth, survival and reproduction (Heintz et al., 2000). In addition, there is the potential for secondary impacts on shorebirds, fish, sea turtles, rays, and crustaceans that use these intertidal habitat areas for breeding, feeding and nursery habitat.

Shoreline loading may occur along some of the offshore islands and mainland coast for some spill scenarios. Given potential spill locations are located away from shoreline habitats, and therefore there is a time period before exposure would occur, the volatile components (i.e. the components of the MDO that would coat and/or have other toxic effects) would already be reduced due to the natural rapid weathering characteristics of MDO.

Note also that literature (e.g. Lin and Mendelssohn, 1996) suggests that a threshold of 1000 g/m^2 is appropriate for hydrocarbon spill impacts on vegetation; which is a factor of 10 higher than the threshold criteria used for exposure in this assessment.

The environmental performance outcome for mangroves is 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.

The proximity of a potential spill from shore will determine how much hydrocarbons reach the shore, as MDO weathers rapidly, with only <1 - 15% of hydrocarbon predicted to remain on the surface after ~7 days.

Conservative modelling predicts that there is 1% probability of shorelines being contacted over the exposure threshold, for any release location, at WA Coastline and Dampier Archipelago, with the maximum local volume predicted to accumulate of only 3 m^3. The FPU location does not predict any shoreline contact. Entrained hydrocarbons are predicted to intersect Dampier Archipelago and WA Coastline, which includes some areas of mangroves (RPS, 2019d).

Mangroves do have a high sensitivity to hydrocarbon contamination however, and a longer recovery time than other types of coastal habitats.

Given hydrocarbon characteristics, rapid weathering and offshore location of the Project Area, the low predicted volume ashore (3 m^3), unplanned releases from Scarborough are not expected to have a substantial adverse impact on marine ecosystem functioning or integrity.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to mangroves. As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered.

Based on the detailed risk evaluation, the magnitude of potential impact to mangroves from unplanned hydrocarbon releases is assessed as no lasting effects and is considered **acceptable**.

Shoreline Habitats

A change in habitat may occur due to a change in water or sediment quality following an unplanned hydrocarbon release.

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. Hydrocarbon in the intertidal zone can adhere to sand particles however high tide may remove some or most of the hydrocarbon back of the sediments. Accumulated hydrocarbons ≥ 100 g/m^2 could impact the survival and reproductive capacity of benthic epifaunal invertebrates living in intertidal habitat (French-McCay, 2009).

The impact of hydrocarbon on rocky shores will be largely dependent on the incline and energy environment. On steep/vertical rock faces on wave exposed coasts there is likely to be no impact from a spill event. However, a gradually sloping boulder shore in calm water can potentially trap large amounts of hydrocarbon (International Petroleum Industry Environmental Conservation Association, 2000). The impact of the spill on marine organisms along the rocky coast will depend on the toxicity and weathering of the hydrocarbon. Like sandy shores, accumulated hydrocarbons ≥100 g/m^2 could affect the epifauna along rocky coasts and impact the reproductive capacity and survival.

Tidal flats are susceptible to potential impacts from hydrocarbons as they are typically low energy environments and therefore trap hydrocarbons. The extent of oiling 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 the flat at low tide. However, it is unlikely that hydrocarbon will penetrate the water-saturated sediments. Although, hydrocarbons can penetrate sediments through animal burrows and root pores.

The environmental performance outcome for shoreline habitats is 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.

The proximity of a potential spill from shore will determine how much hydrocarbons reach the shore, as MDO weathers rapidly, with only <1 - 15% of hydrocarbon predicted to remain on the surface after ~7 days. Conservative modelling predicts there is only 1% probability of shorelines being contacted over the exposure threshold, for any release location, at WA Coastline and Dampier Archipelago.

Given hydrocarbon characteristics, rapid weathering and offshore location of the Project Area, the low predicted volume ashore (3 m^3), unplanned releases from Scarborough are not expected to have a substantial adverse impact on marine ecosystem functioning or integrity.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to shoreline habitats.

Based on the detailed risk evaluation, the magnitude of potential impact to shoreline habitats from unplanned hydrocarbon releases is assessed as no lasting effects and is considered **acceptable**.

Saltmarsh

A change in habitat may occur due to a change in water or sediment quality following an unplanned hydrocarbon release.

Oil can enter saltmarsh systems during the tidal cycles, if the estuary/inlet is open to the ocean. Similar to mangroves, this can lead to a patchy distribution of the oil and its effects, because different places within the inlets are at different tidal heights. Oil (in liquid form) will readily adhere to the marshes, coating the stems from tidal height to sediment surface. Heavy oil coating will be restricted to the outer fringe of thick vegetation, although lighter oils can penetrate deeper, to the limit of tidal influence.

Saltmarsh is considered to have a high sensitivity to hydrocarbon exposure. Saltmarsh vegetation offers a large surface area for oil absorption and tends to trap oil. Evidence from case histories and experiments shows that the damage resulting from oiling, and recovery times of oiled marsh vegetation, are very variable. In areas of light to moderate oiling where oil is mainly on perennial vegetation with little penetration of sediment, the shoots of the plants may be killed but recovery can take place from the underground systems. Good recovery commonly occurs within one to two years (IPIECA, 1994).

Shoreline loading may occur along some of the offshore islands and mainland coast for some spill scenarios. Given potential spill locations are located away from shoreline habitats, and therefore there is a time period before exposure would occur, the volatile components (i.e. the components of the MDO that would coat and/or have other toxic effects) would already be reduced due to the natural rapid weathering characteristics of MDO. Note also that literature (e.g. Lin and Mendelssohn, 1996) suggests a threshold of 1000 g/m^2 is appropriate for hydrocarbon impacts on vegetation, which is a factor of 10 higher than the threshold criteria used for exposure in this assessment.

The environmental performance outcome for saltmarsh is 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.

The proximity of a potential spill from shore will determine how much hydrocarbons reach the shore, as MDO weathers rapidly, with only <1 - 15% of hydrocarbon predicted to remain on the surface after ~7 days.

Conservative modelling predicts that there is 1% probability of shorelines being contacted over the exposure threshold, for any release location, at WA Coastline and Dampier Archipelago, with the maximum local volume predicted to accumulate of only 3 m^3 (RPS, 2019d). Areas of saltmarsh are known within the Dampier Archipelago and WA Coastline.

Given hydrocarbon characteristics, rapid weathering and offshore location of the potential release scenarios, the small predicted volume ashore (3 m^3), unplanned releases from Scarborough are not expected to have a substantial adverse impact on marine ecosystem functioning or integrity.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to saltmarsh.

Based on the detailed risk evaluation, the magnitude of potential impact to saltmarshes from unplanned hydrocarbon releases is assessed as no lasting effects and is considered **acceptable**.

Key Ecological Features

A change in habitat may occur due to a change in water or sediment quality that could impact KEFs.

The Project Area intersects with three KEFs; and a further three KEFs have the potential to intersect with an unplanned release of hydrocarbons.

The values and sensitivities of these KEFs relate to seafloor features, and demersal fish species (i.e. that live close to the seafloor). Therefore, water depth can determine whether any in-water hydrocarbons can potentially interact with these values and sensitivities.

As MDO typically remains in the top ~10 m of the water column and rapidly weathers, in-water hydrocarbons are only likely to intersect with seafloor and demersal values in shallower waters. The water depths and potential impacts to the six relevant KEFs are summarised below:

- Exmouth Plateau KEF: intersects the Offshore Project Area. Values and sensitivities are related to seafloor features. Receptors on the seafloor are not expected to be impacted by a surface release of hydrocarbons, given the water depths in the Offshore Project Area (~930 m). However, these seafloor features may promote enhanced upwelling; potential impacts to plankton are discussed above.
- Ancient Coastline KEF: intersects the Trunkline Project Area. The KEF includes areas of hard substrate and higher diversity and species richness relative to surrounding areas of predominantly soft sediment . Given the minimum water depth in this KEF is 115 m, seafloor receptors are unlikely to be impacted by a surface hydrocarbon release. However, the submerged coastline may facilitate mixing of the water column enhancing productivity. Combined with greater diversity of sessile benthic organisms, this may increase abundance of pelagic species such as fish and cetaceans, impacts to which are discussed above.
- Continental Slope Demersal Fish Communities KEF: intersects the Trunkline Project Area. The KEF represents high levels of endemism of demersal fish species. Considering the minimum water depths of this KEF are 220–500 m and 750–1000 m, impacts to demersal fish are unlikely to occur. However, the values of the KEF may support higher order consumers, such as pelagic fish and shark species, impacts to which are discussed above.
- Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula KEF: is ~130 km south-west of the Project Area but is assumed to intersect the EMBA. Aggregations of whale sharks, manta rays, humpback whales, sea snakes, sharks, predatory fish and seabirds are known to occur in the area due to its enhanced productivity, which are assessed above.
- Commonwealth Waters Adjacent to Ningaloo KEF: The spatial boundary of this KEF, as defined in the Conservation Values Atlas, is defined as the waters contained in the existing Ningaloo AMP and is described below.
- Glomar Shoals: ~56 km east of the Project Area on the Rowley shelf at depths of 33 m to 77 m. The values of the KEF are high productivity and aggregations of marine life, impacts to which are discussed above.

The environmental performance outcome for KEFs is 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 identified as a KEF results.

Given the weathering characteristics of MDO, exposure would be restricted to surface (including the upper water column) and shoreline exposure; no interaction with benthic habitats in deep water areas is predicted. As such, for the potential release scenarios from Scarborough, there is unlikely to be substantial adverse impact on marine ecosystem functioning or integrity.

There are no Management Plans, Recovery Plans or Conservation Advice related specifically to KEFs, and given that the KEFs are not identified as values of the potential exposed marine parks, activities would not be inconsistent with the objectives of the IUCN zones of the relevant marine parks described in Section 3.5.2.

Based on the detailed risk evaluation, the magnitude of potential impact to KEFs from unplanned hydrocarbon releases is assessed as slight and is considered **acceptable**.

AMPs

Quantitative stochastic spill modelling predicts the following parameters and worst-case probabilities (for all release locations) above the relevant exposure threshold at the AMPs:

- Dampier Marine Park: surface (2%), entrained (44%), dissolved (2%), shoreline (2%)
- Montebello Marine Park: surface (100%), entrained (70%), dissolved (9%)
- Gascoyne Marine Park: surface (1%), entrained (8%)
- Shark Bay Marine Park: surface (<1%), entrained (<1%), dissolved (<1%), shoreline (<1%)
- Ningaloo Marine Park: surface (<1%), entrained (<1%), dissolved (<1%), shoreline (<1%)
- Carnarvon Canyon Marine Park: surface (<1%), entrained (<1%), dissolved (<1%).

The conservation values of these areas have been previously described but include foraging and migratory pathways for some species of seabird, whale shark, turtles and whales. As the conservation values of these protected marine areas are so varied, there are multiple potential impact pathways, including changes in water quality, injury/mortality to marine fauna, change in fauna behaviour, change in aesthetic value, and change to the functions, interests or activities of other users (for evaluation of impacts to specific fauna receptors refer to previous individual receptor assessments).

The environmental performance outcome for AMPs is 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 a Commonwealth marine area results. The values of the AMPs have been evaluated and it is determined that a spill is unlikely to result in significant impacts based on the nature of the spilled hydrocarbons.

Based on the detailed risk evaluation, the magnitude of potential impact to AMPs from unplanned hydrocarbon releases is assessed as slight and is considered **acceptable**.

Protected Places

Quantitative spill modelling predicts the following parameters and worst-case probabilities (for all release locations) above the relevant exposure threshold at the following protected places (RPS, 2019):

- Barrow Island: surface (<1%), entrained/dissolved (1%), shoreline (<1%)
- Murion Islands Marine Management Area-World Heritage Area: surface (<1%), entrained (7%), dissolved (<1%), shoreline (<1%)
- Montebello State Marine Park: surface (<1%), entrained (4%), dissolved (1%), shoreline (<1%).

The conservation values of these areas have been previously described but include foraging and migratory pathways for some species of seabird, whale shark, turtles and whales. As the conservation values of these protected marine areas are so varied, there are multiple potential impact pathways, including changes in water quality, injury/mortality to marine fauna, change in fauna behaviour, change in aesthetic value, and change to the functions, interests or activities of other users. (For evaluation of impacts to specific fauna receptors refer to previous individual receptor assessments).

The environmental performance outcome for protected places is 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. The values of the protected places have been evaluated and it is determined that a spill is unlikely to result in significant impacts based on the nature of the spilled hydrocarbons.

Based on the detailed risk evaluation, the magnitude of potential impact to protected places from unplanned hydrocarbon releases is assessed as slight and is considered **acceptable**.

Commonwealth and State Managed Fisheries

A change in marine fauna behaviour or injury or mortality to marine fauna – in particular to commercially targeted species, or their prey species (e.g. plankton) – can impact fisheries.

Fish exposure to hydrocarbon 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 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. Therefore, 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. There would be a temporary prohibition on fishing activities for a period and subsequent potential for economic impacts to affected commercial fishing operators. Additionally, hydrocarbon can foul fishing equipment such as traps and trawl nets, requiring cleaning or replacement.

MDO presence in the water would be restricted to the surface and upper water column only. Dissolved aromatics (i.e. the form that is bioavailable) are in such small concentrations in MDO that their effect in the marine environment is negligible; i.e. tainting from an MDO exposure is not considered likely to occur. Any exclusion zone established would be limited to the immediate vicinity of the release point, and due to the rapid weathering of MDO would only be in place days after release, therefore physical displacement to vessels is unlikely to be a significant impact.

The only Commonwealth Fishery expected to be active within the vicinity of the Project is the NWSTF. However, given the fishing method (i.e. trawl) and operations in deep water areas (>200 m) of this fishery, no significant impact from an MDO spill is predicted. Presence of hydrocarbon in areas used by State fisheries may occur, however given the type of hydrocarbon and duration of exposure, no significant impact from an MDO spill is expected to occur.

The environmental performance outcome for fisheries is to:

- not have a substantial adverse effect on the sustainability of commercial fishing
- not interfere with other marine users, including recreational and commercial fishers to a greater extent than is necessary for the exercise of right conferred by the titles granted.

Although potential impacts could include mortality or sub-lethal injury/illness of pelagic fish (described in the specific receptor evaluation), this would be expected to comprise a small proportion of the resident and transitory population. Given hydrocarbon characteristics, expected rapid weathering to below impact thresholds, and the offshore location of the Project Area and low fishing effort, unplanned releases from Scarborough are not expected to have a substantial adverse effect on the sustainability of commercial fishing; or to interfere with other marine users.

As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. Tourism and fishing are listed as an important activity for social and economic values of the Dampier, Gascoyne, Ningaloo or Montebello Marine Parks. Therefore, unplanned hydrocarbon releases that may result from Scarborough Project activities that may impact the Dampier, Gascoyne, Ningaloo or Montebello Marine Parks are not inconsistent with the objectives of the IUCN zones of the relevant marine parks described in Section 3.5.2.

Based on the detailed risk evaluation, the magnitude of potential impacts to commonwealth and state managed fisheries from unplanned hydrocarbon releases is assessed as having no lasting effect and is considered **acceptable**.

Tourism and Recreation

A change in marine fauna behaviour, injury or mortality to marine fauna, change in aesthetic value and change to the functions, interests or activities of other users would impact tourism and recreation following an unplanned hydrocarbon release. 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, with highest records typically of areas such as Point Samson, Coral Bay and Carnarvon (DEWHA, 2008a).

Offshore waters of the Scarborough Project Area are not expected to support tourism. However, should shoreline contact occur, restricted access to beaches for a period of days to weeks may occur until natural weathering or tides and currents remove the hydrocarbons. Tourists and recreational users may also avoid areas due to perceived impacts, including after the hydrocarbon spill has dispersed.

Depending on the location of the spill, areas used for recreation and tourism, including the nearshore and shoreline, may be exposed to hydrocarbon. Any impact to receptors that provide nature-based tourism features (e.g. whales) may cause a subsequent negative impact to recreation and tourism activities. However, the relatively rapid weathering of MDO suggests that any impacts would be short-term and localised.

If surface oil reaches towns, it may coat recreation areas and infrastructure such as jetties / boat ramps, beaches, and potentially impact on access due to any clean-up or decontamination activities.

The environmental performance outcome for tourism and recreation is to not interfere with other marine users, including tourism and recreational users to a greater extent than is necessary for the exercise of right conferred by the titles granted.

Conservative modelling predicts that there is only 1% probability of shorelines being contacted over the exposure threshold, for any release location, at WA Coastline and Dampier Archipelago, with the maximum local volume predicted to accumulate of only 3 m^3. Surface exposures have a low probability (<3%) of intersecting major tourism of industry (Dampier Archipelago, Barrow Island, WA Coastline).

Given hydrocarbon characteristics, expected rapid weathering to below impact thresholds, small volumes predicted ashore, and the offshore location of the Project Area, unplanned releases from Scarborough are not expected to interfere with other marine users than a greater extent than necessary.

As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered, which include:

- recreation is listed as a social and economic value of the Montebello, Dampier, Gascoyne and Ningaloo Marine Parks

- tourism is a social and economic value of the Montebello and Ningaloo Marine Parks.

Modelling predicts the main impact is to Montebello Marine Park, as the potential release location is within the Park boundaries. This has been considered in this assessment, specifically with regards to the values for recreation and tourism.

Therefore, unplanned hydrocarbon releases that may result from Scarborough Project activities that may impact the Dampier, Gascoyne, Ningaloo or Montebello Marine Parks are not inconsistent with the objectives of the IUCN zones of the relevant marine parks described in Section 3.5.2.

Based on the detailed risk evaluation, the magnitude of potential impacts to tourism and recreation from unplanned hydrocarbon releases is assessed as slight and is considered **acceptable**.

Settlements

A change in aesthetic value and change to the functions, interests or activities of other users may impact settlements following an unplanned hydrocarbon release.

Important coastal settlements in the EMBA include Exmouth, Karratha, Dampier, Onslow, Port Hedland and Broome. If surface oil reaches towns, it may coat infrastructure such as jetties / boat ramps, beaches, and potentially impact on access due to any clean-up or decontamination activities.

Modelling predicts that there is only 1% probability of shorelines being contacted over the exposure threshold, for any release location, at WA Coastline and Dampier Archipelago (RPS, 2019d), which may intersect with some settlements, such as Dampier and Karratha.

Given hydrocarbon characteristics, expected rapid weathering to below impact thresholds, small predicted volume ashore (approximately 3 m^3), and the offshore location of the Project Area, unplanned releases from Scarborough are not expected to cause significant harm to social surroundings.

The environmental performance outcome for settlements is to protect social surroundings from significant harm.

As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. However, there are no social or economic values related to settlements listed for the Ningaloo, Montebello, Dampier or Gascoyne Marine Parks.

Based on the detailed risk evaluation, the magnitude of potential impact to settlements from unplanned hydrocarbon releases is assessed as slight and is considered **acceptable**.

Defence

A change to the functions, interests or activities of other users may impact Defence following an unplanned hydrocarbon release.

In the event of a major spill, an exclusion zone may be established around the spill-affected area. This could impact Defence by restricting areas where training or exercises can be conducted, for a period of time. Any exclusion zone established would be limited to the immediate vicinity of the release point, and due to the rapid weathering of MDO would only be in place for days after release, therefore physical displacement to vessels is unlikely to be a significant impact.

If port areas are contacted by surface oil, it may coat infrastructure, and potentially impact Defence use of the port, due to any clean-up and decontamination activities.

The environmental performance outcome for Defence is to not interfere with other marine users, including Defence users to a greater extent than is necessary for the exercise of right conferred by the titles granted.

Given hydrocarbon characteristics, expected rapid weathering to below impact thresholds, small volumes ashore, short duration of displacement, and the offshore location of the Project Area, unplanned releases from Scarborough are not expected to interfere with other marine users to a greater extent than necessary.

As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. However, there are no social or economic values related to settlements listed for the Ningaloo, Montebello, Dampier or Gascoyne Marine Parks.

Based on the detailed risk evaluation, the magnitude of potential impact to defence from unplanned hydrocarbon releases is assessed as slight and is considered **acceptable**.

Shipping

A change to the functions, interests or activities of other users may impact shipping following an unplanned hydrocarbon release.

Shipping activity is widespread across the region, however main shipping channels appear to occur to the east of the offshore development area; and close to shore, are focused on the 12 ports in the North-West Marine Region.

In the 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 be limited to the immediate vicinity of the release point, and due to the rapid weathering of MDO would only be in place for days after release, therefore physical displacement to vessels is unlikely to be a significant impact.

If surface oil reaches active ports, it may coat infrastructure, and potentially impact port activities or access due to any clean-up and decontamination activities.

The environmental performance outcome for shipping is to not interfere with other marine users, including shipping to a greater extent than is necessary for the exercise of right conferred by the titles granted.

Modelling predicts that there is only 1% probability of shorelines being contacted over the exposure threshold, for any release location, at WA Coastline and Dampier Archipelago, with the maximum local volume predicted to accumulate of only 3 m^3. This could potentially intersect with the Ports of Dampier or Barrow Island, however, is of very low volumes and would be unlikely to foul infrastructure and equipment.

Given hydrocarbon characteristics, expected rapid weathering to below impact thresholds, small volumes ashore, short duration of displacement, and the offshore location of the Project Area, unplanned releases from Scarborough are not expected to interfere with other marine users to a greater extent than necessary.

As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. However, there are no social or economic values related to settlements listed for the Ningaloo, Montebello, Dampier or Gascoyne Marine Parks.

Based on the detailed risk evaluation, the magnitude of potential impact to settlements from unplanned hydrocarbon releases is assessed as slight and is considered **acceptable**.

Industry

A change in water quality and change to the functions, interests or activities of other users may impact industry following an unplanned hydrocarbon release.

Along the coastline, industries which depend upon marine water sources include ports, salt mines, LNG onshore processing facilities and desalination plants (Section 5.7.6). In the Project Area, industry is dominated by oil & gas activities.

The closest productive fields to Scarborough would be Chevron Australia's Jansz-Io fields, about 100 km to the east. However, all the infrastructure is subsea and is not expected to be impacted by an MDO spill.

In the 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 vessels used by the mining and petroleum industries.

Any exclusion zone established would be limited to the immediate vicinity of the release point, and due to the rapid weathering of MDO would only be in place days after release, therefore physical displacement to vessels is unlikely to be a significant impact.

If surface oil reaches active industry areas, such as causeways, Material Offloading Facilities, jetties, ports, it may coat infrastructure, and potentially impact activities or access due to any clean-up and decontamination activities. Hydrocarbons could also potentially contaminate seawater intakes for industries such as desalination plants, or Dampier Salt.

The environmental performance outcome for industry is to:

- not have a substantial adverse effect on water quality such that an adverse impact on industry use occurs
- not interfere with other marine users, including shipping to a greater extent than is necessary for the exercise of right conferred by the titles granted.

Surface exposures have a low probability (<3%) of intersecting major centres of industry (Dampier Archipelago, Barrow Island, WA Coastline). Modelling predicts that there is only 1% probability of shorelines being contacted over the exposure threshold, for any release location, at WA Coastline and Dampier Archipelago, with the maximum local volume predicted of only 3 m^3 (RPS, 2019d).

OPGGS(E) Regulations specify the requirement for an Oil Pollution Emergency Plan (OPEP) for petroleum activities. In the event of a spill, the OPEP will detail the response arrangements in order to reduce the potential consequence of the spill.

Response strategies detailed in the OPEP will be developed specific for the activities proposed in the EP but may include:

- **Source control**: In the event of a vessel collision resulting in a ruptured fuel tank, the most practical option involves the pumping of fuel into a secondary tank on board the same vessel.
- **Monitoring and evaluation**: Provides information on the fate, nature and weathering of hydrocarbons within the marine environment, which will aid in identifying potential risks to receptors and help to inform other response strategies, response priorities and ongoing response (if required).
- **Containment and recovery:** Boom and skimmer use during containment and recovery operations are an effective means of removing hydrocarbons from the surface layer, potentially reducing the overall impact. If used in conjunction with monitoring and modelling of spill trajectory, this method can be used to protect sensitive receptors.
- **Protection and deflection:** Booms or other physical barriers may be used to inhibit the flow of hydrocarbons and protect environmental sensitivities through targeted boom protection and specific oil deflection.
- **Shoreline:** In the event of a hydrocarbon spill resulting in shoreline contact, shoreline clean-up may be required, where accessible, to reduce shoreline loading's. Clean-up techniques may be manual and / or mechanical depending on the shoreline type and

accessibility to the affected area. Following the collection of spilled hydrocarbons, material will be appropriately disposed of at an onshore facility.

- **Oiled wildlife response:** In the event of a hydrocarbon spill at the surface, if deemed appropriate, oiled wildlife response may be implemented in order to either deter species from an area affected by a spill or to capture affected species for treatment and rehabilitation.

Given hydrocarbon characteristics, expected rapid weathering to below impact thresholds, small volumes predicted ashore, and the offshore location of the Project Area and distance to relevant industries, unplanned releases from Scarborough are not expected to interfere with other marine users than a greater extent than necessary. As modelling predicts the minimum time to shore is 53 hours, industry will have prior warning to close seawater intakes or potentially take other measures to prevent potential contamination.

As activities will take place within or adjacent to AMPs, there are principles, objectives and values to be considered. However, there are no social or economic values related to settlements listed for the Ningaloo, Montebello, Dampier or Gascoyne Marine Parks.

Based on the detailed risk evaluation, the magnitude of potential impact to settlements from unplanned hydrocarbon releases is assessed as slight and is considered **acceptable**.

7.2.6.3 Risk Evaluation

Industry data shows that vessel collisions are rare, with only 37 collisions reported from 1200 marine incidents in Australian waters from 2005-2012. Most vessel collisions involve damage to a forward tank which are generally double-lined and smaller than other tanks; therefore, the loss of the maximum credible scenario of 2,000 m^3 is conservative and unlikely. The probability of a loss of well control is very low, in the order of 0.0001% according to industry records (SINTEF, 2017).

Considering the rapid weathering of MDO and lack of any liquid hydrocarbon fraction in the dry gas, the inherent low likelihood of a collision occurring, and adopted controls, the likelihood of this event occurring was evaluated as **Highly Unlikely**.

Modelling of 2,000 m^3 of MDO at the three release locations at the FPU and along the trunkline was undertaken by RPS (RPS, 2019d). Depending on wind conditions, weathering predicts that only <1 - 15% of hydrocarbon remains on the surface after ~7 days (RPS, 2019d), with a greater proportion entraining into the water column under strong, variable wind conditions. The nature of MDO means that only a small proportion dissolves in the water column, and the greatest proportion is on the surface or entrained.

Modelling predicts that the likelihood of shoreline contact is only 1%, with only very small accumulated volumes predicted ashore (3 m^3). As one of the release locations modelled is inside the Montebello Marine Park boundaries, this AMP has the highest probability of exposure above thresholds to unplanned hydrocarbon releases.

An unplanned release will result in localised and temporary changes in water and sediment quality, such as increased toxicity, which can potentially impact marine fauna and habitats; though sediments would only be intersected by hydrocarbons in shallow water and intertidal areas. Mobile fauna such as plankton, fish and marine mammals could experience mortality or sub-lethal injury/illness, however this would be expected to comprise a small proportion of the resident and transitory population, and to not have a substantial adverse effect on a population or spatial distribution, lifecycle, or important habitat. Due to the high levels of receptor sensitivity amongst marine fauna, this impact has been evaluated as **Minor (D)**.

The Dampier Archipelago supports a diverse number of both scleractinian and non-scleractinian (soft) corals. There would be potential for entrained hydrocarbons above threshold concentrations to reach reef habitat in the Dampier Archipelago (particularly from the Outside Mermaid Sound Scenario). Additionally, shallow coral habitats may be vulnerable to hydrocarbon coating by direct contact with surface hydrocarbons during periods when corals are tidally-exposed. This could result in impacts to the shallow water fringing coral communities/reefs of the offshore islands (e.g. Barrow/Montebello/Lowendal Islands) and also the mainland coast (e.g. Ningaloo Coast). Impacted coral reefs may experience long-term effects (ie recovery periods taking up to 10 years) due to their recovery relying on coral larvae from neighbouring coral communities that have either not been affected or only partially impacted. However, due to the short duration of the spill (ie instantaneous release, and short exposure time as documented by deterministic modelling), the confined spatial extent and the tendency of MDO to remain on the sea surface, the scale of potential consequences is limited. Due to the high levels of receptor sensitivity amongst marine fauna, this impact has been evaluated as **Major (B).**

It is not expected that an unplanned hydrocarbon release would interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted, due to the rapid weathering of MDO. Socioeconomic receptors have medium value (i.e. medium Receptor Sensitivity), and the impacts been evaluated as **Slight (E).**

Shoreline accumulation of hydrocarbons could potentially impact the incubation success, nesting and hatching emergence of marine turtles and shorebirds. As there are significant nesting areas in the EMBA, this has the potential to impact species recruitment at a local population level; however it is not expected that the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species would be seriously disrupted, as only a maximum of $3m^3$ is predicted ashore, at only 1% probability. Therefore, the potential impacts to marine reptiles and seabirds and migratory shorebirds, both high sensitivity receptors, are **Minor (D).**

Therefore, the worst-case consequence of an unplanned hydrocarbon release has been evaluated as **Major (B)**; giving an overall risk rating of **Moderate (B1).**

The impacts overall have been determined as **acceptable** based on an evaluation against the criteria.

To meet the principles of ESD

- Overall, the worst-case impact magnitude to receptors from an unplanned hydrocarbon release are within applicable standards but is considered to have significance.
- Unplanned hydrocarbon releases that may result from Scarborough Project activities that may impact the Dampier, Gascoyne, Ningaloo or Montebello Marine Parks are not inconsistent with the objectives of the Marine Park Zones described above.
- Management controls will be in place to minimise the incidence of unplanned releases, with a focus on turtle and seabird and migratory shorebird nesting habitat, in accordance with the Recovery Plan for Marine Turtles in Australia (DoEE, 2017) and conservation advice for relevant bird species.

Internal Context

- Hydrocarbon spill prevention and response will be managed in accordance with regulatory requirements, including Environment Plans, Oil Pollution Emergency Plans 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 Shipboard Oil Pollution Emergency Plan and/or Shipboard Marine Pollution Emergency Plan.

External Context

- No stakeholder concerns have been raised with respect to unplanned hydrocarbon releases, or potentially impacted receptors.

Other Requirements

- Requirements of the Conservation Management Plans / Conservation Advice for the following species are met:
  - fish: sawfish and river sharks, whale sharks
  - seabirds and migratory shorebirds: Greater Sand Plover, Large Sand Plover, Great Knot, Eastern Curlew, Far Eastern Curlew, Australian Painted Snipe, Australian Fairy Tern
  - marine reptiles: short-nosed seasnake
  - marine mammals: sei whales,
- Requirements of the Recovery Plan for Marine Turtles in Australia (DoEE, 2017) have been met.
- Regulatory requirements for Environment Plans, Oil Pollution Emergency Plans and Well Operations Management plan are met.
- With respect to unplanned hydrocarbon releases, activities associated with Scarborough 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.

7.2.6.4 Summary of the Risk Assessment

Table 7.59 provides a summary of the risk assessment and acceptability for impacts from unplanned discharge of hydrocarbons to ecological receptors.

Table 7.59: Summary of risks, key management controls, acceptability, EPOs and residual risk rating for unplanned hydrocarbon releases

Receptor	Risk	Environmental Performance Outcome	Adopted control(s)	Receptor sensitivity	Consequence	Likelihood	Risk rating	Acceptability
Sediment quality	Change in sediment quality	**EPO3:** To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.	**CM26:** All vessels and facilities (appropriate to class) will comply with MARPOL 73/78, the Navigation Act 2012, the Protection of the Sea (Prevention of Pollution from Ships Act 1983 and subsequent Marine Orders including: • waste management requirements • management of spills aboard • emergency drills. **CM27:** Relevant Stakeholders will be notified of activities prior to commencement.	Low value (open water)	Negligible (F)	Highly Unlikely	Low	Acceptable
Water quality	Change in water quality	**EPO2:** To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.		Low value (open water)	Negligible (F)	Highly Unlikely	Low	Acceptable
Plankton	Injury/ mortality to fauna	**EPO6:** To not have a substantial adverse effect on a population of plankton including its life cycle and spatial distribution.		Low value (open water)	Negligible (F)	Highly Unlikely	Low	Acceptable
Fish	Change in fauna behaviour	**EPO7:** To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population.		High value species	Minor (D)	Highly Unlikely	Moderate	Acceptable

Receptor	Risk	Environmental Performance Outcome	Adopted control(s)	Receptor sensitivity	Consequence	Likelihood	Risk rating	Acceptability
	Injury/ mortality to fauna	**EPO8:** To not substantially modify, destroy or isolate an area of important habitat for a migratory species. **EPO9:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	**CM28:** Vessels will have in place a valid and appropriate Shipboard Oil Pollution Emergency Plan and/or Shipboard Marine Pollution Emergency Plan. Emergency response activities will be implemented in accordance with the SOPEP/SMPEP.	High value species	Minor (D)	Highly Unlikely	Moderate	Acceptable
Marine mammals	Change in fauna behaviour	**EPO12:** To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population.	**CM29:** Environment Plans and Oil Pollution Emergency Plans will be accepted and in place, appropriate to the credible hydrocarbon spill scenario associated with activities during Scarborough. Emergency response activities will be implemented in accordance with the OPEP.	High value species	Minor (D)	Highly Unlikely	Moderate	Acceptable
	Injury/ mortality to fauna	**EPO1:** 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. **EPO9:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	**CM30:** Emergency response capability will be maintained in accordance with EP, OPEP and related documentation. **CM31:** Well Operations Management Plan accepted and in place for all wells, in accordance with the Offshore Petroleum and	High value species	Minor (D)	Highly Unlikely	Moderate	Acceptable
Marine reptiles	Change in fauna behaviour	**EPO11:** To not have a substantial adverse effect on a population of marine		High value species	Slight (E)	Highly Unlikely	Low	Acceptable

Receptor	Risk	Environmental Performance Outcome	Adopted control(s)	Receptor sensitivity	Consequence	Likelihood	Risk rating	Acceptability
	Injury/ mortality to fauna	reptiles, or the spatial distribution of the population. **EPO1:** 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. **EPO9:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	Greenhouse Gas Storage Act requirements, which include: • Blowout Preventer (BOP) installation during drilling operations • regular testing of BOP.	High value species	Minor (D)	Highly Unlikely	Moderate	Acceptable
Seabirds and migratory shorebirds	Change in fauna behaviour	**EPO10:** To not have a substantial adverse effect on a population of seabirds or shorebirds, or the spatial distribution of the population. **EPO8:** To not substantially modify, destroy or isolate an area of important habitat for a migratory species. **EPO9:** To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.		High value species	Slight (E)	Highly Unlikely	Low	Acceptable
	Injury/ mortality to fauna			High value species	Minor (D)	Highly Unlikely	Moderate	Acceptable
Coral	Change in habitat	**EPO1:** To not modify, destroy, fragment, isolate or disturb an important or substantial area of habitat, such that an		High value habitat	Major (B)	Highly Unlikely	Moderate	Acceptable

Receptor	Risk	Environmental Performance Outcome	Adopted control(s)	Receptor sensitivity	Consequence	Likelihood	Risk rating	Acceptability
Seagrass	Change in habitat	adverse impact on marine ecosystem functioning or integrity results.		High value habitat	Slight (E)	Highly Unlikely	Low	Acceptable
Macroalgae	Change in habitat			Low value habitat (homogenous)	Negligible (F)	Highly Unlikely	Low	Acceptable
Mangroves	Change in habitat			High value habitat	Slight (E)	Highly Unlikely	Low	
Shoreline habitats	Change in habitat			Low value habitat	Negligible (F)	Highly Unlikely	Low	Acceptable
Saltmarsh	Change in habitat			High value habitat	Slight (E)	Highly Unlikely	Low	
KEFs	Change in habitat	**EPO16:** 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		High value	Minor (D)	Highly Unlikely	Moderate	Acceptable
AMPs	Change in habitat	**EPO1:** 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.		High value	Minor (D)	Highly Unlikely	Moderate	Acceptable

Receptor	Risk	Environmental Performance Outcome	Adopted control(s)	Receptor sensitivity	Consequence	Likelihood	Risk rating	Acceptability
Protected Places	Change in habitat	**EPO1:** 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.		Medium value	Slight (E)	Highly Unlikely	Low	Acceptable
Commonwealth and State Managed Fisheries	Changes to the functions, interests or activities of other users	**EPO15:** To not have a substantial adverse effect on the sustainability of commercial fishing. **EPO14:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.		High value marine user	Slight (E)	Highly Unlikely	Low	Acceptable
Tourism and recreation	Changes to the functions, interests or activities of other users	**EPO14**: To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.		Medium value users	Slight (E)	Highly Unlikely	Low	Acceptable
	Changes in aesthetic value			Medium value users	Slight (E)			
Settlements	Changes to the functions, interests or activities of other users	**EPO17:** To protect social surroundings from significant harm.		Medium value users	Slight (E)	Highly Unlikely	Low	Acceptable
	Change in aesthetic value			Medium value users		Highly Unlikely		

Receptor	Risk	Environmental Performance Outcome	Adopted control(s)	Receptor sensitivity	Consequence	Likelihood	Risk rating	Acceptability
Shipping	Changes to the functions, interests or activities of other users	**EPO14:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.		Medium value users	Slight (E)	Highly Unlikely	Low	Acceptable
Industry	Changes to the functions, interests or activities of other users	**EPO13:** To not have a substantial adverse effect on water quality such that an adverse impact on industry use occurs. **EPO14:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.		Medium value	Slight (E)	Highly Unlikely	Low	Acceptable
Defence	Changes to the functions, interests or activities of other users	**EPO14:** To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.		Medium value	Slight (E)	Highly Unlikely	Low	Acceptable

8 CUMULATIVE IMPACT ASSESSMENT

8.1 Context

So far, the assessment of impacts has focused on linear pathways from planned project activities and aspects to direct and indirect impacts on receptors. As described by the World Bank (IFC, 2013), effective impact and risk assessment should also 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.

This section provides a summary of cumulative impacts considered of relevance to Scarborough. Given the low likelihood of unplanned events (e.g. oil spills) arising during Scarborough, unplanned/non-routine events have not been considered in this assessment of cumulative impacts.

As described in Section 1.3, several large developments or proposed developments are located in close proximity to the Project Area. The Trunkline Project Area passes the Pluto LNG Platform (5 km), Stag Platform (9 km), Reindeer Platform (19 km), Goodwyn Platform (51 km) and North Rankin Complex (64 km). The Offshore Project Area is further offshore from these existing developments (about 170 km from Pluto LNG Platform); however, the Equus field (located 70 km east of the Project Area) is planned to be developed during the life of Scarborough. Impacts and aspects associated with nearshore and onshore activities, both from Scarborough and other activities/developments, are assessed under separate approval mechanisms and are not considered further here.

Aside from oil and gas activities, the North West Marine Region is a busy hub for both fishing and commercial shipping. As described in Section 5.7.5, the Offshore Project Area is located within an area of low vessel traffic. However, major shipping routes pass over the Trunkline Project Area. Similarly, vessels operating as part of Commonwealth and State managed fisheries are likely to be present in the water surrounding the Trunkline Project Area, with less fishing occurring in the deep waters surrounding the Offshore Project Area.

This assessment will consider cumulative effects of other marine users, proposed developments, as well as all key stages and aspects of Scarborough, ensuring a holistic/lifecycle assessment of impacts.

8.2 Identification and Evaluation of Impacts

Cumulative impacts from Scarborough may occur in two ways:

- Aspect-based – Cumulative or combination effects may arise from other activities/projects resulting in the same aspects as those identified in this OPP.
- Receptor-based – Cumulative or combination effects on a receptor may arise, both from multiple aspects of Scarborough and similar/multiple aspects resulting from other activities/projects.

8.2.1 Aspect-based Cumulative Impacts

This section considers how the aspects arising from Scarborough may compound with similar aspects caused by other activities/developments, to result in a cumulative impact. Other activities/developments include:

- Pluto LNG Project
- other Woodside and other operator activities currently under consideration
- Equus Field Development

- Commonwealth and State Managed Fisheries
- Commercial Shipping.

The aspects identified which were common to these activities/developments and Scarborough are those typically related to vessel movements, which include:

- physical presence (routine): displacement of other users
- light emissions
- routine and non-routine discharges: project vessels.

Atmospheric emissions resulting from Scarborough are very low, and the contribution towards greenhouse gas emissions is limited, therefore no cumulative impacts are expected.

Although seabed disturbance and planned discharges during export trunkline installation and commissioning will occur close to the Pluto LNG development, there will be no similar aspects resulting from Pluto activities during that time, and therefore no cumulative impacts are expected.

During the life of the project, operational fluids will be discharged within the Offshore Project Area on a near-continuous basis. Although other activities/developments in the area will not be close enough for these discharge streams to interact, the extended duration of the impact means that cumulative impacts could occur from Scarborough alone. This aspect has therefore also been assessed below.

8.2.1.1 Physical Presence (Routine): Displacement of Other Users

During installation and commissioning of Scarborough additional vessel traffic will result in an increased likelihood of displacement of other users. Impacts from Scarborough have been assessed as temporary and localised as vessels come and go from the Project Area. The Trunkline Project Area is located within an area of increased shipping and fishing traffic, and the combination of installation/commissioning vessels plus shipping and fishing vessels may lead to cumulative impacts. However, given the short time frame of the installation, and the required exclusion zone around the installation vessel due to its low manoeuvrability, any cumulative impacts will be limited.

Once the installation phase of Scarborough is completed (export trunkline installation, FPU and subsea infrastructure) vessel presence will be significantly reduced in the Project Area, reducing the potential for cumulative impacts to occur. During the operational phase of Scarborough, infrastructure such as the FPU and the export trunkline will be present on a long-term basis, however given the location of the FPU is in a low sensitivity area for other users and the export trunkline is buried at depths <40 m, cumulative impacts will be limited to the presence of subsea infrastructure including the trunkline in deep waters.

The consequence of cumulative impacts caused by displacement of other users has been evaluated as **Slight (E)** as the impact magnitude is sufficiently small. The impacts overall have been determined to be **acceptable** based on an evaluation against the criteria described in Section 7.1.1.3. No additional control measures are required.

8.2.1.2 Light Emissions

The light emitted during vessel operations, particularly during the construction phase has the potential to overlap with other light sources, including facilities and other vessels. However, given previous modelling suggests a 20 km visible light distance from vessels (Woodside, 2014), any interaction with existing light sources from offshore facilities is considered unlikely. If any overlap did occur, this will be a temporary increase given that the vessels will transit along the trunkline. Any cumulative impacts would be minimal and not result in an increased level of impact on receptors.

Impacts resulting from light emissions, such as change in fauna behaviour, are short-term, and cease once the light source is removed. As the phases of Scarborough will be undertaken separately, i.e. no concurrent vessel operations, no cumulative impacts are expected from within the Project Area.

8.2.1.3 Routine and Non-routine Discharges: Project Vessels

Routine and non-routine discharges from vessels include brine and cooling water, deck draining, treated bilge, food waste, and sewage and grey water. Particularly during installation and commissioning, Scarborough will result in an increase in vessel numbers and therefore an increase in vessel discharges.

Vessels associated with Scarborough will be mostly focused around the well/FPU location, >375 km from shore and significant distance from other activities/developments where existing vessel traffic is focused. Vessel discharges are controlled, and generally discharged when the vessel is moving to allow for the greatest dispersion rate and dissipation of any changes in water quality. As such, impacts are localised and temporary, and given the distance offshore and the low level of vessel traffic nearshore no cumulative impacts are expected.

8.2.1.4 Operational Fluids

Discharges of operational fluid includes subsea control fluids and PW. Any operational fluid discharged during hydrocarbon extraction and production, will contribute to other sources of waste within the region and may result in cumulative impacts to receptors. Discharges of subsea control fluids would be the most frequently discharged fluid at the well head site throughout operations and due to the small volumes, it is not expected that there will be cumulative impacts to receptors due to high levels of dispersion within the marine environment. For PW, there is the potential for a cumulative increase of impact to receptors within surface waters due to a range of other operational fluids that will be discharged throughout the life of the FPU. As values associated with the marine environment within the Offshore Project Area are low with no BIAs for protected species present, it is expected that the additional presence of PW within the water column will not result in an increased impact to receptors.

8.2.2 Receptor-based Cumulative Impacts

This section considers how receptors known to be impacted by individual aspects associated with Scarborough may be subject to additional impacts from alternate aspects (associated with Scarborough or other activities/developments), or which may be more sensitive to additional impacts due to a change in nature or state resulting from the initial aspect, leading to cumulative impacts to individual receptors/receptor groups. Other activities/developments include:

- Pluto LNG Project
- Equus Field Development
- Commonwealth and State Managed Fisheries
- Commercial Shipping.

All other activities/developments are located outside of the expected impact area.

8.2.2.1 Physical Environment

The physical environment within the Project Area is likely to be impacted throughout the project lifecycle. Other activities in the region (such as existing developments and other marine users) are well established, and their presence and impacts are included in the ambient or baseline environment considered in this assessment. Therefore, no cumulative impacts to the physical environment are expected from other activities/developments.

It is possible that cumulative impacts to the physical environment may occur from the different phases of Scarborough, especially impact to water quality and sediment quality. These are discussed further below. No cumulative impacts to ambient noise, air quality or light are expected from Scarborough.

Table 8.1 identifies aspects affecting receptors within the physical environment which may lead to cumulative impacts.

Table 8.1: Physical Environment which may be affected by Cumulative Impacts

Aspect	Sediments Quality	Water Quality
Physical presence (routine): Seabed disturbance		✓
Routine and non-routine discharges: Project vessels	✓	✓
Routine and non-routine discharges: Operational fluids	✓	✓
Routine and non-routine discharges: Subsea installation and commissioning	✓	✓
Routine and non-routine discharges: Drill cuttings and drilling fluids	✓	✓

Water Quality

Changes to water quality are likely from all stages in Scarborough, as the discharges and disturbances associated with the project phases vary the water composition at each impact location. Both surface and seabed discharges will result in changes, such as toxicity, temperature and salinity, however modelling and studies generally show that impacts are short term and localised (e.g. Shell, 2010; Frick et al., 2001; Woodside, 2014; Chevron, 2015), and the high-energy marine environment throughout the Project Area will lead to rapid mixing and reduce the extent of any impacts. Similarly, changes to water quality through increased sedimentation will be quick to recover, with particles settling quickly back to the seabed following disturbance events (Neff, 2005; 2010).

As the phases of Scarborough occur over a large temporal and spatial scale, and will not take place concurrently, cumulative impacts to water quality are not expected.

Sediment Quality

Similarly, changes to sediment quality are likely from all stages in Scarborough. Discharges at the seabed will result in changes in sediment quality, such as toxicity or changes to the sediment composition/granulometry. Modelling and studies show that impacts from planned/routine discharges are short term and localised (e.g. IAOGP, 2016; Neff, 2005; BP Azerbaijan, 2013), and that sediments will quickly return to their baseline condition following discharge (Terrens et al., 1998; Neff, 2010).

The only interaction in sediment quality impacts is between drilling discharges (i.e. drill cuttings and fluids discharged at the seabed from the riserless sections) and installation/commissioning within the Offshore Project Area (i.e. discharge of installation fluids). Subsea installation/FPU installation will not occur until drilling is complete. There will be a small area at each drill site (less than 500 m from the top-hole location) where sediment quality will be affected by drilling discharges, however given the time between drilling and scheduled installation/commissioning recovery of sediment quality will occur, and no cumulative impacts from these activities are expected.

8.2.2.2 Biological Environment

It is possible that cumulative impacts to the biological environment may occur from the different phases of Scarborough. To identify where cumulative impacts may occur, the full table of impacts to receptors was considered, in addition to aspects and impacts associated with other activities/developments. Where the location or timing of an impact coincides, or where impacts will affect a receptor in a short timeframe i.e. before recovery, the potential scope of cumulative impacts has been evaluation.

No cumulative impacts are expected to shoreline or nearshore habitats, such as seagrass and mangroves, or coral and macroalgae, plankton, fish or marine mammals. Impacts from the project will be limited, and other activities/developments are unlikely to result in the same/similar aspects for the duration of any impact effects. Similarly, impacts to seabirds and migratory shorebirds are limited, and are unlikely to affect protected species or sensitive life stages, therefore no cumulative impacts to birds are expected.

A section of the Scarborough trunkline is located within the Montebello AMP, and this AMP is therefore identified as an affected receptor to impacts related to seabed disturbance during installation and commissioning. A section of the existing Pluto trunkline is also located within the AMP, however the cumulative impact a result of the presence of a second trunkline has been minimised by locating it adjacent to the existing trunkline for much of the route that traverses the AMP. There will be no other activities/developments being undertaken in the same area and timeframe, therefore no cumulative impacts to Montebello AMP other than the addition of the second trunkline are expected.

Similarly, the proposed borrow ground is located adjacent to the Dampier AMP, however no impacts from seabed disturbance are expected to the area, and therefore no cumulative impacts to the Dampier AMP are expected.

Table 8.2 identified aspects affecting receptors within the biological environment which may lead to cumulative impacts.

Table 8.2: Biological Environment which may be affected by Cumulative Impacts

Aspect	Epifauna and Infauna	Marine Reptiles	KEFs
Routine light emissions		✓	
Routine acoustic emissions		✓	
Physical presence (routine): Seabed disturbance	✓		✓
Routine and non-routine discharges: Project vessels	✓		✓
Routine and non-routine discharges: Operational fluids	✓		✓
Routine and non-routine discharges: Subsea installation and commissioning			✓
Routine and non-routine discharges: Drilling			✓

Epifauna and Infauna

Epifauna and infauna are likely to be impacted throughout the drilling and installation and commissioning phases of Scarborough, primarily through seabed disturbance and subsea discharges during drilling operations. Once the facility is operational, there will be no impacts to epifauna and infauna from planned activities.

Any impacts from seabed disturbance and subsea discharge are separately assessed as being localised and short-term, with no population effects expected. A literature review undertaken by Bakke et al. (2013) confirmed this, indicating the ecosystem and population-level effects from numerous drilling operations are not expected. Given the low sensitivity of benthic communities in the Offshore Project Area and Trunkline Project Area, any combination of effects is not expected to have a long-term or population level impact on epifauna and infauna, therefore no cumulative impacts are expected.

Marine Reptiles

Marine reptiles will exhibit a change in behaviour from both light emissions and acoustic emissions.

Increased vessel activity during the installation and commissioning phase means that impacts associated with light and acoustic emissions from existing vessel traffic may be increased in intensity/severity as a result of the additional vessel movements. The Trunkline Project Area and Borrow Grounds Project Area intercepts with BIAs for inter-nesting hawksbill, flatback and green turtles, and critical habitat for inter-nesting hawksbill, flatback, loggerhead and green turtles. Presence of marine turtles in the Trunkline Project Area are expected to peak during breeding periods (described in detail in Section 5.4.6). The closest nesting beach to the export trunkline route in Commonwealth waters is Rosemary Island approximately 5.5 km away from the Trunkline Project Area at the closest distance.

Light density from navigational lights on vessels is predicted to be less than 1.00 and 0.03 Lux at distances of 300 m and 1.4 km, respectively, from source. During installation and commissioning activities along the Trunkline Project Area, vessels will maintain a 500 m exclusion zone, meaning that the light “pools” created by each vessel will not interact, ensuring that there is no large area of intense light cause by multiple vessels in the same location, leading to increased marine reptile disorientation.

Continuous acoustic emissions from vessel activity will result in changes in behaviour, such as avoidance and change in swimming direction and speed. Injury is not expected from vessel sound sources. It is possible that, with increased vessel traffic, there could be an overlap in the disturbance area from vessel based acoustic emissions.

Considering this, there is potential for an increased impact to marine reptiles from a combination of project vessels, and vessels associated with other activities/developments, specifically in the region close to turtle nesting sites. Total numbers of marine reptiles will peak during breeding periods, when individuals are potentially most vulnerable to impacts due to their dependence on natural cues and their reduced energy levels. Potential impacts generally have a low level of consequence and will likely result in minor behavioural changes which will revert once the individual is outside of the impact area. Therefore, any potential increased impact will be short-term and localised, with installation and commissioning activities limited to the initial stages of Scarborough. As such, any cumulative impacts to marine turtles from light emissions will occur on an individual level and are not expected to result in population level/significant effects and are therefore evaluated to be **acceptable**. No additional control measures are required.

Once Scarborough is operational, no further cumulative impacts are expected.

KEFs

The Project Area lies within three KEFs:

- Exmouth Plateau (Offshore Project Area and Trunkline Project Area)
- Continental Slope Demersal Fish Communities (Trunkline Project Area)

- Ancient Coastline at 125 m depth contour (Trunkline Project Area).

The primary impact to the values associated with KEFs will occur from seabed disturbance, particularly during installation of the Trunkline Project Area. Physical habitat modification is not listed as a potential concern for Exmouth Plateau KEF or Ancient Coastline at 125 m depth contour KEF and therefore impacts to the values of these KEFs are not anticipated. Physical habitat modification is listed as a potential concern for the Continental Slope Demersal Fish Communities KEF; however, the total impact area is small, and impacts will be highly localised to the Trunkline Project Area.

No secondary impacts are expected to the Exmouth Plateau KEF or Ancient Coastline at 125 m depth contour KEF from discharges and emissions, as the key values identified for these KEFs are physical environmental factors. There are no planned emissions or discharges within the Continental Slope Demersal Fish Communities KEF, as most discharges occur within the Offshore Project Area. Therefore, no cumulative impacts to KEFs are expected.

8.2.2.3 Socio-Economic Environment

The socio-economic environment in the North West Marine Region is of considerable importance to the local economy. Other marine users/activities within the region may be affected by the addition of Scarborough when considered in conjunction with other activities/developments in the area. These impacts are likely to be more severe in the nearshore area, and during high-intensity phases of Scarborough such as installation and commissioning, specifically trunkline installation. Once the project is operational, the additional vessel movements in the area will have limited impact on other marine users, and no cumulative impacts are expected for the remaining lifecycle of the project.

Potential impacts to socio-economic receptors have been identified throughout the Impact Assessment provided in Section 7. The assessment concludes that impacts from displacement of other users will be Slight (E) and acceptable, and no other aspects are expected to have impacts on social, economic or heritage receptors. On that basis, it has also been assumed that cumulative impacts to socio-economic receptors will not occur.

8.3 Summary

This cumulative impact assessment has shown that there is little cross-over in spatial extent of aspects, both within the project and between Scarborough and other activities/developments. The majority of emissions and discharges, particularly those which will occur during the full lifecycle of the project, will be made within the Offshore Project Area, which is remote and unlikely to result in interactions with other activities/developments.

When considering potential cumulative impacts on receptors, it is clear that in most cases the phased approach of development proposed for Scarborough will alleviate the potential for cumulative pressure on receptors, allowing recovery/return to baseline conditions between impact events. It is still possible that individuals will experience combination effects from multiple impact events in the vicinity of the Offshore Project Area, however this is not predicted to occur on a population level for any receptors. Where cumulative impacts are predicted, i.e. light emissions on marine reptiles, the assessment concludes that no significant impacts will occur, and any cumulative impacts will be acceptable.

9 ENVIRONMENTAL MANAGEMENT IMPLEMENTATION APPROACH

9.1 Overview

Scarborough will be undertaken in accordance with the OPP. This will be implemented by ensuring that all petroleum activities are within the scope of the accepted OPP, and the adoption of controls and EPOs specified in the OPP in any future petroleum activity EPs.

9.1.1 Woodside Management System

The Woodside Management System (WMS) described in Section 2 provides a structured framework of documentation to set common expectations governing how all activities will be undertaken.

The WMS comprises of four elements: Compass & Policies; Expectations; Processes & Procedures; and Guidelines. Procedures under the WMS will specify what steps, by whom and when are required to carry out an activity or a process. Further detail related to implementation of the OPP is provided in the following sections.

9.2 Roles and Responsibilities

Key roles and responsibilities for Woodside and Contractor personnel in relation to the implementation and management of EPOs identified in this OPP are described in **Table 9.1**.

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 9.1: Roles and responsibilities

Title (role)	Environmental Responsibilities
Office-based Personnel	
Woodside Project Manager	• Ensure implementation of the Environment Plans which will be produced to support the Scarborough OPP. • Ensure systems and procedures are in place to manage the activity so it is undertaken as per the relevant standards and commitments in this OPP • Ensure that contractors meet environmental related contractual obligations
Woodside Delivery Manager (FPU, SURF, Pipelay, Dredging)	• Ensure environment expectations are understood by team members in line with the commitments set out in this OPP • Communicate environment performance, relevant information and Lessons Learnt to team members and contractors • Ensure application of contractor's management of environment requirements, in accordance with the OPP
Woodside Environment Adviser	• Track compliance with environmental performance outcomes as per the requirements of this OPP • Prepare environmental component of relevant Induction Package • Provide advice to relevant Woodside personnel and contractors to assist them to understand their environment responsibilities
Woodside Drilling Superintendent	• Ensures the drilling program meets the requirements detailed in this OPP
Woodside Drilling and Subsea Engineers	• Ensure all chemicals and drill fluids proposed to be discharged are assessed and approved as per the requirements of the OPP and subsequent EPs
Woodside Corporate Affairs Adviser	• Prepare and implement the Stakeholder Consultation Plan for Petroleum Activities Program

Title (role)	Environmental Responsibilities
Woodside Marine Assurance Superintendent	• Conduct relevant audit and inspection to confirm vessels are compliant with relevant Marine Orders and Woodside Marine Charters Instructions requirements to meet safety, navigation and emergency response requirements
Offshore/Contractor Personnel	
MODU/FPU Offshore Installation Manager (OIM)	• Ensure the management system and procedures are implemented • Ensure personnel receive an environmental induction that meets the requirements specified in this OPP
Woodside Site Representative	• Ensure Scarborough Project scopes are undertaken as detailed in this OPP and subsequent EPs • Ensure the management measures detailed in this OPP are implemented on the MODU/FPU/Vessel
Offshore HSE Adviser /Vessel HSE Advisors	• Support Woodside Site Representatives to ensure that the controls detailed in this OPP relevant to offshore activities are implemented and assist in collection and recording of evidence of implementation (other controls are implemented, and evidence collected onshore) • Ensure periodic environmental inspections/reviews are completed and corrective actions from inspections are developed, tracked and closed out in a timely manner
Vessel Master	• Ensure the vessel management system and procedures are implemented • Ensure Scarborough Project scopes are undertaken as detailed in this OPP and subsequent EPs • Ensure personnel commencing work on the vessel receive an environmental induction that meets the requirements specified in this OPP
Vessel Logistics Coordinators	• Ensure waste is managed on the relevant support vessels and sent to shore as per the Contractor Waste Management Plan
Contractor Project Manager	• Ensure that activities are undertaken in accordance with this OPP, as detailed in the Woodside approved Contactor Environmental Management Plan • Ensure personnel commencing work on the project receive a relevant environmental induction that meets the requirements specified in this OPP

9.3 Emergency Preparedness and Response

Woodside will have an Emergency Response Plan (ERP) in place for all future petroleum activities. The ERP provides procedural guidance specific to the activity to control, coordinate and response to an emergency or incident including hydrocarbon spills.

Under Regulations 14(8) the Implementation Strategy for petroleum activity EPs must contain an oil pollution emergency plan (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.

A significant hydrocarbon spill during the petroleum activities proposed as a part of Scarborough is unlikely but should such an event occur it will be managed. Woodside has in place an overarching plan to manage oil spills from Woodside activities and facilities. This will be supported by specific plans that provide tactical response guidance to the activity/area.

9.4 Monitoring of EPO Implementation

The effective application of EPOs provided in this OPP will be demonstrated through the implementation of subsequent EPs. EPOs associated with planned impacts will generally be demonstrated through successful implementation of controls, environmental performance standards and associated measurement criteria specific to the activity for which an EP is being developed.

To ensure the requirements are met, Woodside and its contractors will undertake a program of monitoring during execution of the petroleum activities. The program of monitoring will be described in detail in the EPs for the specific activities and will make use of tools and systems that are appropriate to the activity, and the project teams.

Note that controls may include environmental monitoring programs, however these are not required where there is high confidence in the effectiveness of controls and the potential for environmental impact is low. Where an unplanned event (e.g. hydrocarbon spill or other discharge) results in the potential for environmental harm, the incident reporting and investigation process will identify if there is the potential for environmental impacts. This process will provide sufficient information to determine if the EPO has not been achieved.

9.4.1 Auditing

During the execution of project activities, environmental performance auditing will be undertaken to:

- Identify potential new, or changes to existing environmental impacts and risk, and methods for reducing these to ALARP,
- Confirm that any controls that are applied to ensure impacts and risks are acceptable are effective, and
- Confirm compliance with the controls and EPS detailed in future EPs.

Further details including the schedule for environmental performance auditing will be provided in future EPs for petroleum activities.

9.5 Reporting

In order to meet the environmental performance outcomes outlined in this OPP Woodside will undertake external reporting at a number of levels. These reporting arrangements are outlined below.

9.5.1 Environmental Performance Reporting

In accordance with applicable environmental legislation for the activity, Woodside is required to report information on environmental performance to NOPSEMA during the implementation of Environment Plans including:

- Monthly Recordable Incident Reports – submitted monthly to NOPSEMA, with details of recordable incidents that have occurred during the Petroleum Activity for the previous month (if any)
- Environmental Performance Report – submitted annually to NOPSEMA in accordance with the Environment Regulations. The report will address compliance with EPOs outlines in this EP, and controls and standards outlined in subsequent EPs.

9.5.2 Recordable Incidents

A recordable incident as defined under Regulation 4 of the Environment Regulations as an incident arising from the activity that:

- *'breaches an environmental performance outcome or environmental performance standard, in the EP that applies to the activity, that is not a reportable incident'.*

Any breach of the environmental performance outcomes will be raised as an incident and managed as per the notification and reporting requirements outlined below and the Woodside Health, Safety and Environment Event Reporting and Investigation Procedure.

NOPSEMA will be notified of all recordable incidents, according to the requirements of Regulation 26B (4), not later than 15 days after the end of the calendar month using the NOPSEMA Form – Recordable Environmental Incident Monthly Summary Report.

9.5.3 Reportable Incidents

A reportable incident as defined under Regulation 4 of the Environment Regulations as an incident relating to the activity that

- *'has caused, or has the potential to cause, moderate to significant environmental damage'.*

NOPSEMA will be notified of all reportable incidents, according to the requirements of Regulations 26, 26A and 26AA of the Environment Regulations:

- report all reportable incidents to the regulator (orally) as soon as practicable, but within two hours of the incident or of its detection by Woodside
- provide a written record of the reported incident to NOPSEMA, the National Offshore Petroleum Titles Administrator (NOPTA) and the Department of the responsible State Minister (DMIRS) as soon as practicable after the oral reporting of the incident
- complete a written report for all reportable incidents using a format consistent with the NOPSEMA Form FM0929 – Reportable Environment Incident which must be submitted to NOPSEMA as soon as practicable, but within three days of the incident or of its detection by Woodside
- provide a copy of the written report to NOPTA and DMIRS, within seven days of the written report being provided to NOPSEMA.

9.6 Management of Change

Management of changes relevant to this OPP, concerning the scope of the activity description (Section 4) including 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 EPBC Act and current requirements for Australian Marine Parks (Section 5) and potential new advice from external stakeholders (Section 10) will be managed in accordance with Woodside's Commonwealth Environmental Approvals Procedure (WM1050PF10239249).

Woodside's Commonwealth Environmental Approvals Procedure provides guidance on the Environment Regulations that may trigger a revision and resubmission of approvals. The procedure also provides guidance on what constitutes a significant new risk or increase in risk. A risk assessment will be conducted in accordance with the Environmental Risk Management Methodology (Section 6) to determine the significance of any potential new environmental impacts or risks not provided for in this OPP. Risk assessment outcomes are reviewed in compliance with Regulation 17 of the Environment Regulations.

Minor changes where a review of the activity and the environmental risks and impacts of the activity do not trigger a requirement for a revision, under Regulation 17 of the Environment Regulations, will be considered a 'minor revision'. Minor administrative changes to this OPP, where an assessment of the environmental risks and impacts is not required (e.g. document references, terminology, etc.), will also be considered a 'minor revision'. Minor revisions as defined above will be made to this OPP using Woodside's document control process.

9.7 Summary of EPOs

A total of 19 EPOs have been identified to manage the activities forming part of Scarborough. These are listed in Table 9.2.

Table 9.2: Environmental Performance Outcomes for Scarborough

EPO	Description
EPO1	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.
EPO2	To not result in a substantial change in water quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.
EPO3	To not result in a substantial change in sediment quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.
EPO4	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.
EPO5	To not result in a substantial change in air quality which may adversely impact on biodiversity, ecological integrity, social amenity or human health.
EPO6	To not have a substantial adverse effect on a population of plankton including its lifecycle and spatial distribution.
EPO7	To not have a substantial adverse effect on a population of fish, or the spatial distribution of the population.
EPO8	To not substantially modify, destroy or isolate an area of important habitat for a migratory species.
EPO9	To not seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.
EPO10	To not have a substantial adverse effect on a population of seabirds or shorebirds, or the spatial distribution of the population.
EPO11	To not have a substantial adverse effect on a population of marine reptiles, or the spatial distribution of the population.
EPO12	To not have a substantial adverse effect on a population of marine mammals, or the spatial distribution of the population.
EPO13	To not have a substantial adverse effect on water quality such that an adverse impact on industry use occurs.
EPO14	To not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted.
EPO15	To not have a substantial adverse effect on the sustainability of commercial fishing.
EPO16	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 Factor.
EPO17	To protect social surroundings from significant harm.
EPO18	To not result in a known or potential pest species (IMS) becoming established.
EPO19	Optimise efficiencies in air emissions and reduce greenhouse emissions to ALARP and Acceptable Levels.

9.8 Implementing Requirements of the OPP in Future EPs

Broadly, the purpose of an environment plan is for the titleholder to firstly identify the proposed petroleum activity's impacts on and risks to the receiving environment. Secondly, the titleholder must set out control measures to reduce the identified environmental impacts and risks of the activity and describe how and to what standard of performance will those measures will be implemented and throughout the life of the activity including emergency situations. Table 9.3, Table 9.4, Table 9.5, Table 9.6 and Table 9.7 provide a summary of Key Management Controls and Environmental Performance Outcomes relative to each aspect of the project.

Table 9.3: Drilling Key Management Controls and Environmental Performance Outcomes

Aspect	Receptor	EPO	Impact / Risk	Adopted control(s)
Routine atmospheric emissions	Air quality	EPO5	Change in air quality	**Well flow-back, Drilling** **CM2:** Vessel and MODU compliance with Marine Order 97 (Marine Pollution Prevention – Air Pollution), including: • International Air Pollution Prevention (IAPP) Certificate, required by vessel class • use of low sulphur fuel when available • Ship Energy Efficiency Management Plan (SEEMP), where required by vessel class • onboard incinerator to comply with Marine Order 97. **CM3:** Optimisation of flaring to allow the safe and economically efficient operation of the facility.
	Climate	EPO19	Climate change	**Well flow-back** **CM5:** Reporting of GHG emissions as per regulatory requirements.
Routine acoustic emissions	Ambient Noise	EPO1	Change in ambient noise	**VSP** **CM6:** Woodside VSP Procedure implemented while VSP operations are undertaken to prevent prolonged exposure to marine fauna.
	Fish	EPO7 EPO8 EPO9	Change in fauna behaviour Injury/mortality to marine fauna	
	Marine Reptiles	EPO11 EPO1 EPO9	Change in fauna behaviour Injury/mortality to marine fauna	
	Marine Mammals	EPO12 EPO1 EPO9	Change in fauna behaviour Injury/mortality to fauna	
Physical presence (routine): Seabed disturbance	Water quality	EPO2	Change in water quality	**Drilling Operations** **CM12:** Infrastructure will be positioned on the seabed within design footprint to reduce seabed disturbance.
	Epifauna and infauna	EPO1	Change in habitat	
	KEFs	EPO16	Change in habitat Change in water quality Injury or mortality	

Aspect	Receptor	EPO	Impact / Risk	Adopted control(s)
	AMPs	EPO1	Change in habitat Change in water quality	
Routine and non-routine discharges: Drilling	Sediment Quality	EPO3	Change in sediment quality	**<u>Drilling operations</u>** **CM16:** Chemicals will be selected with the lowest practicable environmental impacts and risks subject to technical constraints. **CM19:** WBM will be used during drilling activities as the first preference. Where WBM cannot meet required technical specifications, NWBM may be used following technical justification. **CM20:** Bulk overboard discharge of NWBM is prohibited. **CM21:** Drill cuttings returned to the MODU will be processed to reduce oil on cuttings to < 6.9% by weight on wet cuttings (measured as a well average only including sections drilled with NWBM) prior to discharge. **CM22:** Drill cuttings returned to the MODU will be discharged below the waterline.
	Water Quality	EPO2	Change in water quality	
	Plankton	EPO6	Injury/ mortality to fauna	
	Epifauna and infauna	EPO1	Injury/ mortality to fauna	
	KEFs	EPO16	Change in habitat	
Unplanned Discharge: Chemicals	Water quality	EPO2	Change in water quality	**<u>Drilling operations</u>** **CM16:** Chemicals will be selected with the lowest practicable environmental impacts and risks subject to technical constraints. **CM15:** Implementation of waste management procedures which provide for safe handling and transportation, segregation and storage and appropriate classification of all waste generated.
Unplanned hydrocarbon release	Sediment quality	EPO3	Change in sediment quality	**<u>Drilling Operations</u>** **CM26:** All vessels and facilities (appropriate to class) will comply with MARPOL 73/78, the Navigation Act 2012, the Protection of the Sea (Prevention of Pollution from Ships Act 1983 and subsequent Marine Orders including: • waste management requirements • management of spills aboard • emergency drills. **CM27:** Relevant Stakeholders will be notified of activities prior to commencement. **CM28:** Vessels will have in place a valid and appropriate Shipboard Oil Pollution Emergency Plan and/or Shipboard Marine Pollution
	Water quality	EPO2	Change in water quality	
	Plankton	EPO6	Injury/ mortality to fauna	
	Fish	EPO7 EPO8 EPO9	Change in fauna behaviour	
			Injury/ mortality to fauna	
	Marine mammals	EPO12 EPO1 EPO9	Change in fauna behaviour	
			Injury/ mortality to fauna	
	Marine reptiles	EPO11	Change in fauna behaviour	

Aspect	Receptor	EPO	Impact / Risk	Adopted control(s)
		EPO1 EPO9	Injury/ mortality to fauna	Emergency Plan. Emergency response activities will be implemented in accordance with the SOPEP/SMPEP. **CM29:** Environment Plans and Oil Pollution Emergency Plans will be accepted and in place, appropriate to the credible hydrocarbon spill scenario associated with activities during Scarborough. Emergency response activities will be implemented in accordance with the OPEP. **CM30:** Emergency response activities will be implemented in accordance with the OPEP the vessel SOPEP/SMPEP. **CM31:** Emergency response capability will be maintained in accordance with EP, OPEP and related documentation. Well Operations Management Plan accepted and in place for all wells, in accordance with the Offshore Petroleum and Greenhouse Gas Storage Act requirements, which include: • Blowout Preventer (BOP) installation during drilling operations • regular testing of BOP.
	Seabirds and migratory shorebirds	EPO10 EPO8 EPO9	Change in fauna behaviour	
			Injury/ mortality to fauna	
	Coral	EPO1	Change in habitat	
	Seagrass		Change in habitat	
	Macroalgae		Change in habitat	
	Mangroves		Change in habitat	
	Shoreline habitats		Change in habitat	
	Saltmarsh		Change in habitat	
	KEFs	EPO16	Change in habitat	
	AMPS	EPO1	Change in habitat	
	Protected Places		Change in habitat	
	Commonwealth and State Managed Fisheries	EPO15 EPO14	Changes to the functions, interests or activities of other users	
	Tourism and recreation	EPO14	Changes to the functions, interests or activities of other users	
			Changes in aesthetic value	
	Settlements	EPO17	Changes to the functions, interests or activities of other users	
			Changes in aesthetic value	
	Shipping	EPO14	Changes to the functions, interests or activities of other users	
	Industry	EPO13 EPO14	Changes to the functions, interests or activities of other users	

Aspect	Receptor	EPO	Impact / Risk	Adopted control(s)
	Defence	EPO14	Changes to the functions, interests or activities of other users	

Table 9.4: Installation and Commissioning Key Management Controls and Environmental Performance Outcomes

Aspect	Receptor	EPO	Impact	Adopted control(s)
Routine acoustic emissions	Ambient Noise	EPO1	Change in ambient noise	**<u>Installation of FPU</u>** **CM7:** For impact piling activities, Woodside will implement the soft start procedure at the commencement of piling activities and shut down zones during the activity. **CM8:** EPBC Regulations 2000 Part 8 Division 8.1 Interacting with cetaceans.
	Fish	EPO7 EPO8 EPO9	Change in fauna behaviour Injury/mortality to marine fauna	
	Marine Reptiles	EPO11 EPO1 EPO9	Change in fauna behaviour Injury/mortality to marine fauna	
	Marine Mammals	EPO12 EPO1 EPO9	Change in fauna behaviour Injury/mortality to fauna	
Physical presence (routine): Displacement of Other Users	Commonwealth Managed Fisheries	EPO15 EPO14	Changes to the function interests or activities of others	**<u>Pre-lay survey, Installation of FPU, Installation of subsea infrastructure, Trunkline installation</u>** **CM10:** Notify Australian Hydrographic Service (AHS) of activities and movements prior to activity commencing. **CM11:** Notify representatives of State and Commonwealth fisheries of activities.
	State Managed Fisheries			
	Shipping			
	Industry			
Physical presence (routine): Seabed disturbance	Water quality	EPO2	Change in water quality	**<u>Pre-lay survey, Installation of FPU, Installation of subsea infrastructure, Trunkline installation, Trunkline stabilisation</u>** **CM12:** Infrastructure will be positioned on the seabed within design footprint to reduce seabed disturbance.
	Epifauna and infauna	EPO1	Change in habitat	
	KEFs	EPO16	Change in habitat Change in water quality Injury or mortality	

Aspect	Receptor	EPO	Impact	Adopted control(s)
	AMPs	EPO1	Change in habitat Change in water quality	
Routine and non-routine discharges: Subsea installation, and commissioning	Sediment quality	EPO3 EPO4	Change in sediment quality	**<u>Installation of FPU, Installation of subsea infrastructure, Commissioning</u>** **CM16:** Chemicals will be selected with the lowest practicable environmental impacts and risks subject to technical constraints.
	Water quality	EPO2	Change in water quality	
	Plankton	EPO6	Injury/ mortality to fauna	
	Epifauna and infauna	EPO1	Injury/ mortality to fauna	
	KEFs	EPO16	Change in water quality Change in sediment quality	
Physical presence (unplanned) - Seabed disturbance	Epifauna and infauna	EPO1	Change in habitat Injury/ mortality to fauna	**<u>Trunkline installation</u>** **CM12:** Infrastructure will be positioned on the seabed within design footprint to reduce seabed disturbance.
	KEFs	EPO16	Change in habitat	
Physical presence (unplanned) - IMS	Epifauna and infauna Coral Macroalgae Seagrass	EPO18 EPO1	Change in ecosystem dynamics	**<u>Installation of FPU, installation of subsea infrastructure, trunkline installation</u>** **CM24:** Compliance with the Woodside Invasive Marine Species Management Plan. **CM25:** Requirements of the Australian Ballast Water Management to be met.
	Industry Shipping Defence	EPO18 EPO13 EPO14	Changes to the functions, interests or activities of other users	
Unplanned hydrocarbon release	Sediment quality	EPO3	Change in sediment quality	**<u>Commissioning</u>** **CM26:** All vessels and facilities (appropriate to class) will comply with MARPOL 73/78, the Navigation Act 2012, the Protection of the Sea (Prevention of Pollution from Ships Act 1983 and subsequent Marine Orders including: • waste management requirements • management of spills aboard • emergency drills.
	Water quality	EPO2	Change in water quality	
	Plankton	EPO6	Injury/ mortality to fauna	
	Fish	EPO7 EPO8 EPO9	Change in fauna behaviour Injury/ mortality to fauna	
	Marine mammals	EPO12 EPO1	Change in fauna behaviour Injury/ mortality to fauna	

Aspect	Receptor	EPO	Impact	Adopted control(s)
		EPO9		**CM27:** Relevant Stakeholders will be notified of activities prior to commencement. **CM28:** Vessels will have in place a valid and appropriate Shipboard Oil Pollution Emergency Plan and/or Shipboard Marine Pollution Emergency Plan. Emergency response activities will be implemented in accordance with the SOPEP/SMPEP. **CM29:** Environment Plans and Oil Pollution Emergency Plans will be accepted and in place, appropriate to the credible hydrocarbon spill scenario associated with activities during Scarborough. Emergency response activities will be implemented in accordance with the OPEP. **CM30:** Emergency response activities will be implemented in accordance with the OPEP the vessel SOPEP/SMPEP. **CM31:** Emergency response capability will be maintained in accordance with EP, OPEP and related documentation. Well Operations Management Plan accepted and in place for all wells, in accordance with the Offshore Petroleum and Greenhouse Gas Storage Act requirements, which include: • Blowout Preventer (BOP) installation during drilling operations • regular testing of BOP.
	Marine reptiles	EPO11 EPO1 EPO9	Change in fauna behaviour	
			Injury/ mortality to fauna	
	Seabirds and migratory shorebirds	EPO10 EPO8 EPO9	Change in fauna behaviour	
			Injury/ mortality to fauna	
	Coral	EPO1	Change in habitat	
	Seagrass		Change in habitat	
	Macroalgae		Change in habitat	
	Mangroves		Change in habitat	
	Shoreline habitats		Change in habitat	
	Saltmarsh		Change in habitat	
	KEFs	EPO16	Change in habitat	
	AMPS	EPO1	Change in habitat	
	Protected Places		Change in habitat	
	Commonwealth and State Managed Fisheries	EPO15 EPO14	Changes to the functions, interests or activities of other users	
	Tourism and recreation	EPO14	Changes to the functions, interests or activities of other users	
			Changes in aesthetic value	
	Shipping	EPO14	Changes to the functions, interests or activities of other users	
	Industry	EPO13 EPO14	Changes to the functions, interests or activities of other users	

Aspect	Receptor	EPO	Impact	Adopted control(s)
	Settlements	EPO17	Changes to the functions, interests or activities of other users	
			Change in aesthetic value	
	Defence	EPO14	Changes to the functions, interests or activities of other users	

Table 9.5:Operations Key Management Controls and Environmental Performance Outcomes

Aspect	Receptor	EPO	Impact	Adopted control(s)
Routine light emissions	Ambient light	EPO1	Change in ambient light	**FPU Operations** **CM1:** Lighting will be limited the minimum required for navigational and safety requirements, with the exception of emergency events.
	Seabirds and migratory shorebirds	EPO10 EPO8 EPO9	Change in fauna behaviour	
	Marine reptiles	EPO11 EPO1 EPO9		
Routine atmospheric emissions	Air quality	EPO5	Change in air quality	**FPU Operations** **CM2:** Vessel and MODU compliance with Marine Order 97 (Marine Pollution Prevention – Air Pollution), including: • International Air Pollution Prevention (IAPP) Certificate, required by vessel class • use of low sulphur fuel when available • Ship Energy Efficiency Management Plan (SEEMP), where required by vessel class • onboard incinerator to comply with Marine Order 97. **Hydrocarbon Processing** **CM3:** Optimisation of flaring to allow the safe and economically efficient operation of the facility.
	Climate	EPO19	Climate change	**FPU Operations, Hydrocarbon Processing** **CM4:** Facilities will be designed and operated to optimise resource efficiency. **CM5:** Reporting of GHG emissions as per regulatory requirements.
Routine acoustic emissions	Ambient Noise	EPO1	Change in ambient noise	**FPU Operations, Hydrocarbon Extraction** **CM8:** EPBC Regulations 2000 Part 8 Division 8.1 Interacting with cetaceans.
	Fish	EPO7 EPO8 EPO9	Change in fauna behaviour Injury/mortality to marine fauna	
	Marine Reptiles	EPO11	Change in fauna behaviour Injury/mortality to marine fauna	

Aspect	Receptor	EPO	Impact	Adopted control(s)
		EPO1 EPO9		
	Marine Mammals	EPO12 EPO1 EPO9	Change in fauna behaviour Injury/mortality to fauna	
Physical presence (routine): Displacement of Other Users	Commonwealth Managed Fisheries	EPO15 EPO14	Changes to the function interests or activities of others	**FPU Operations** **CM10:** Notify Australian Hydrographic Service (AHS) of activities and movements prior to activity commencing. **CM11:** Notify representatives of State and Commonwealth fisheries of activities.
	State Managed Fisheries			
	Shipping			
	Industry			
Routine Discharges: Sewage and Greywater	Water quality	EPO2	Change in water quality	**FPU Operations** **CM13:** Compliance with relevant MARPOL, Commonwealth requirements and subsequent Marine Order requirements for sewage management.
Routine Discharges: Food Waste	Water quality	EPO2	Change in water quality	**FPU Operations** **CM14:** Compliance with relevant MARPOL, Commonwealth requirements and subsequent Marine Order requirements for waste discharges. **CM15:** Implementation of waste management procedures which provides for safe handling and transportation, segregation and storage and appropriate classification of all waste generated during Scarborough.
Routine Discharges: Chemicals and Deck Drainage	Water quality	EPO2	Change in water quality	**FPU Operations** **CM17:** Compliance with relevant MARPOL, Commonwealth requirements and subsequent Marine Order requirements for planned discharges. **CM15:** Implementation of waste management procedures which provides for safe handling and transportation, segregation and storage and appropriate classification of all waste generated during Scarborough.

Aspect	Receptor	EPO	Impact	Adopted control(s)
Routine Discharges: Brine and Cooling Water	Water quality	EPO2	Change in water quality	**FPU Operations** **CM16:** Chemicals will be selected with the lowest practicable environmental impacts and risks subject to technical constraints.
	Plankton	EPO6	Injury/ mortality to fauna	
	Epifauna and infauna	EPO1	Injury/ mortality to fauna	
	Sediment quality	EPO3	Change in sediment quality	
Routine and non-routine discharges: Operational Fluids	Water quality	EPO2	Change in water quality	**Hydrocarbon extraction, Hydrocarbon processing** **CM16:** Chemicals will be selected with the lowest practicable environmental impacts and risks subject to technical constraints. **CM18:** Development of a management framework for produced formation discharges.
	Sediment quality	EPO3	Change in sediment quality	
	Plankton	EPO6	Injury/ mortality to fauna	
	Epifauna and infauna	EPO1	Injury/ mortality to fauna	
	KEFs	EPO16	Change in habitat	
Unplanned Discharges: Chemicals	Water quality	EPO2	Change in water quality	**FPU Operations** **CM16:** Chemicals will be selected with the lowest practicable environmental impacts and risks subject to technical constraints. **CM15:** Implementation of waste management procedures which provide for safe handling and transportation, segregation and storage and appropriate classification of all waste generated.
Unplanned Discharges: Solid Waste	Water Quality	EPO2	Change in water quality	**FPU Operations** **CM23:** Project vessels compliant with Marine Order 95 (pollution prevention – Garbage). **CM15:** Implementation of waste management procedures which provide for safe handling and transportation, segregation and storage and appropriate classification of all waste generated.
	Migratory Shorebirds and Seabirds Fish Marine Mammals Marine Reptiles	EPO10 EPO7 EPO12 EPO1 EPO11 EPO8 EPO9	Injury/mortality to fauna	
Unplanned hydrocarbon release	Sediment quality	EPO3	Change in sediment quality	**All activities** **CM26:** All vessels and facilities (appropriate to class) will comply with MARPOL 73/78, the Navigation Act 2012, the Protection of the Sea (Prevention of Pollution from Ships Act 1983 and subsequent Marine Orders including:
	Water quality	EPO2	Change in water quality	
	Plankton	EPO6	Injury/ mortality to fauna	
	Fish	EPO7	Change in fauna behaviour	

Aspect	Receptor	EPO	Impact	Adopted control(s)
		EPO8 EPO9	Injury/ mortality to fauna	• waste management requirements • management of spills aboard • emergency drills. **CM27:** Relevant Stakeholders will be notified of activities prior to commencement. **CM28:** Vessels will have in place a valid and appropriate Shipboard Oil Pollution Emergency Plan and/or Shipboard Marine Pollution Emergency Plan. Emergency response activities will be implemented in accordance with the SOPEP/SMPEP. **CM29:** Environment Plans and Oil Pollution Emergency Plans will be accepted and in place, appropriate to the credible hydrocarbon spill scenario associated with activities during Scarborough. Emergency response activities will be implemented in accordance with the OPEP. **CM30:** Emergency response activities will be implemented in accordance with the OPEP the vessel SOPEP/SMPEP. **CM31:** Emergency response capability will be maintained in accordance with EP, OPEP and related documentation. Well Operations Management Plan accepted and in place for all wells, in accordance with the Offshore Petroleum and Greenhouse Gas Storage Act requirements, which include: • Blowout Preventer (BOP) installation during drilling operations • regular testing of BOP
	Marine mammals	EPO12 EPO1 EPO9	Change in fauna behaviour	
			Injury/ mortality to fauna	
	Marine reptiles	EPO11 EPO1 EPO9	Change in fauna behaviour	
			Injury/ mortality to fauna	
	Seabirds and migratory shorebirds	EPO10 EPO8 EPO9	Change in fauna behaviour	
			Injury/ mortality to fauna	
	Coral	EPO1	Change in habitat	
	Seagrass			
	Macroalgae			
	Mangroves		Change in habitat	
	Shoreline habitats		Change in habitat	
	Saltmarsh		Change in habitat	
	KEFs	EPO16	Change in habitat	
	AMPS	EPO1	Change in habitat	
	Protected Places		Change in habitat	
	Commonwealth and State Managed Fisheries	EPO15 EPO14	Changes to the functions, interests or activities of other users	
	Tourism and recreation	EPO14	Changes to the functions, interests or activities of other users	
			Changes in aesthetic value	

Aspect	Receptor	EPO	Impact	Adopted control(s)
	Shipping	EPO14	Changes to the functions, interests or activities of other users	
	Industry	EPO13 EPO14	Changes to the functions, interests or activities of other users	
	Settlements	EPO17	Changes to the functions, interests or activities of other users	
			Change in aesthetic value	
	Defence	EPO14	Changes to the functions, interests or activities of other users	

Table 9.6: Decommissioning Key Management Controls and Environmental Performance Outcomes

Aspect	Receptor	EPO	Impact	Adopted control(s)
Physical presence (routine): Seabed disturbance	Water quality	EPO2	Change in water quality	**Removal of subsea infrastructure** **CM12:** Infrastructure will be positioned on the seabed within design footprint to reduce seabed disturbance.
	Epifauna and infauna	EPO1	Change in habitat	
	KEFs	EPO16	Change in habitat Change in water quality Injury or mortality	
	AMPs	EPO1	Change in habitat Change in water quality	
Routine and non-routine discharges: Drilling	Sediment Quality	EPO3	Change in sediment quality	**Well Abandonment** **CM16:** Chemicals will be selected with the lowest practicable environmental impacts and risks subject to technical constraints. **CM19:** WBM will be used during drilling activities as the first preference. Where WBM cannot meet required technical specifications, NWBM may be used following technical justification. **CM20:** Bulk overboard discharge of NWBM is prohibited. **CM21:** Drill cuttings returned to the MODU will be processed to reduce oil on cuttings to < 6.9% by weight on wet cuttings (measured
	Water Quality	EPO2	Change in water quality	
	Plankton	EPO6	Injury/ mortality to fauna	
	Epifauna and infauna	EPO1	Injury/ mortality to fauna	
	KEFs	EPO16	Change in habitat	

Aspect	Receptor	EPO	Impact	Adopted control(s)
				as a well average only including sections drilled with NWBM) prior to discharge. **CM22:** Drill cuttings returned to the MODU will be discharged below the waterline.
Unplanned hydrocarbon release	Sediment quality	EPO3	Change in sediment quality	**<u>All Activities</u>** **CM26:** All vessels and facilities (appropriate to class) will comply with MARPOL 73/78, the Navigation Act 2012, the Protection of the Sea (Prevention of Pollution from Ships Act 1983 and subsequent Marine Orders including: • waste management requirements • management of spills aboard • emergency drills. **CM27:** Relevant Stakeholders will be notified of activities prior to commencement. **CM28:** Vessels will have in place a valid and appropriate Shipboard Oil Pollution Emergency Plan and/or Shipboard Marine Pollution Emergency Plan. Emergency response activities will be implemented in accordance with the SOPEP/SMPEP. **CM29:** Environment Plans and Oil Pollution Emergency Plans will be accepted and in place, appropriate to the credible hydrocarbon spill scenario associated with activities during Scarborough. Emergency response activities will be implemented in accordance with the OPEP. **CM30:** Emergency response activities will be implemented in accordance with the OPEP the vessel SOPEP/SMPEP. **CM31:** Emergency response capability will be maintained in accordance with EP, OPEP and related documentation. Well Operations Management Plan accepted and in place for all wells, in accordance with the Offshore Petroleum and Greenhouse Gas Storage Act requirements, which include: • Blowout Preventer (BOP) installation during drilling operations
	Water quality	EPO2	Change in water quality	
	Plankton	EPO6	Injury/ mortality to fauna	
	Fish	EPO7 EPO8 EPO9	Change in fauna behaviour Injury/ mortality to fauna	
	Marine mammals	EPO12 EPO1 EPO9	Change in fauna behaviour Injury/ mortality to fauna	
	Marine reptiles	EPO11 EPO1 EPO9	Change in fauna behaviour Injury/ mortality to fauna	
	Seabirds and migratory shorebirds	EPO10 EPO8 EPO9	Change in fauna behaviour Injury/ mortality to fauna	
	Coral	EPO1	Change in habitat	
	Seagrass		Change in habitat	
	Macroalgae		Change in habitat	
	Mangroves		Change in habitat	
	Shoreline habitats		Change in habitat	
	Saltmarsh		Change in habitat	
	KEFs	EPO16	Change in habitat	

Aspect	Receptor	EPO	Impact	Adopted control(s)
	AMPS	EPO1	Change in habitat	• regular testing of BOP.
	Protected Places		Change in habitat	
	Commonwealth and State Managed Fisheries	EPO15 EPO14	Changes to the functions, interests or activities of other users	
	Tourism and recreation	EPO14	Changes to the functions, interests or activities of other users	
			Changes in aesthetic value	
	Shipping	EPO14	Changes to the functions, interests or activities of other users	
	Industry	EPO13 EPO14	Changes to the functions, interests or activities of other users	
	Settlements	EPO17	Changes to the functions, interests or activities of other users	
			Change in aesthetic value	
	Defence	EPO14	Changes to the functions, interests or activities of other users	

Table 9.7: Support Operations Key Management Controls and Environmental Performance Outcomes

Aspect	Receptor	EPO	Impact	Adopted control(s)
Routine light emissions	Ambient light	EPO1	Change in ambient light	**MODU, Vessel Operations** **CM1:** Lighting will be limited the minimum required for navigational and safety requirements, with the exception of emergency events.
	Seabirds and migratory shorebirds	EPO10 EPO8 EPO9	Change in fauna behaviour	
	Marine reptiles	EPO11 EPO1 EPO9		

Aspect	Receptor	EPO	Impact	Adopted control(s)
Routine atmospheric emissions	Air quality	EPO5	Change in air quality	**MODU, Vessel Operations** **CM2:** Vessel and MODU compliance with Marine Order 97 (Marine Pollution Prevention – Air Pollution), including: • International Air Pollution Prevention (IAPP) Certificate, required by vessel class • use of low sulphur fuel when available • Ship Energy Efficiency Management Plan (SEEMP), where required by vessel class • onboard incinerator to comply with Marine Order 97.
Routine acoustic emissions	Ambient Noise	EPO1	Change in ambient noise	**Vessel Operations** **CM8:** EPBC Regulations 2000 Part 8 Division 8.1 Interacting with cetaceans.
	Fish	EPO7 EPO8 EPO9	Change in fauna behaviour Injury/mortality to marine fauna	
	Marine Reptiles	EPO11 EPO1 EPO9	Change in fauna behaviour Injury/mortality to marine fauna	
	Marine Mammals	EPO12 EPO1 EPO9	Change in fauna behaviour Injury/mortality to fauna	
Physical presence (routine): Displacement of Other Users	Commonwealth Managed Fisheries	EPO15 EPO14	Changes to the function interests or activities of others	**MODU, Vessel and Helicopter Operations** **CM9:** Vessels to adhere to the navigation safety requirements including the Navigation Act 2012 and any subsequent Marine Orders. **CM10:** Notify Australian Hydrographic Service (AHS) of activities and movements prior to activity commencing. **CM11:** Notify representatives of State and Commonwealth fisheries of activities.
	State Managed Fisheries			
	Shipping			
	Industry			
Physical presence (routine): Seabed disturbance	Water quality	EPO2	Change in water quality	**MODU, Vessel and ROV Operations** **CM12:** Infrastructure will be positioned on the seabed within design footprint to reduce seabed disturbance.
	Epifauna and infauna	EPO1	Change in habitat	
	KEFs	EPO16	Change in habitat	

Aspect	Receptor	EPO	Impact	Adopted control(s)
			Change in water quality Injury or mortality	
	AMPs	EPO1	Change in habitat Change in water quality	
Routine Discharges: Sewage and Greywater	Water quality	EPO2	Change in water quality	**MODU, Vessel Operations** **CM13:** Compliance with relevant MARPOL, Commonwealth requirements and subsequent Marine Order requirements for sewage management.
Routine Discharges: Food Waste	Water quality	EPO2	Change in water quality	**MODU, Vessel Operations** **CM14:** Compliance with relevant MARPOL, Commonwealth requirements and subsequent Marine Order requirements for waste discharges. **CM15:** Implementation of waste management procedures which provide for safe handling and transportation, segregation and storage and appropriate classification of all waste generated.
Routine Discharges: Chemicals and Deck Drainage	Water quality	EPO2	Change in water quality	**MODU, Vessel Operations** **CM17:** Compliance with relevant MARPOL, Commonwealth requirements and subsequent Marine Order requirements for planned discharges. **CM15:** Implementation of waste management procedures which provide for safe handling and transportation, segregation and storage and appropriate classification of all waste generated.
Routine Discharges: Brine and Cooling Water	Water quality	EPO2	Change in water quality	**MODU, Vessel Operations** **CM16:** Chemicals will be selected with the lowest practicable environmental impacts and risks subject to technical constraints.
	Sediment quality	EPO3	Change in sediment quality	
	Plankton	EPO6	Injury/ mortality to fauna	
	Epifauna and infauna	EPO1	Injury/ mortality to fauna	
Unplanned Discharges: Chemicals	Water quality	EPO2	Change in water quality	**All Activities** **CM16:** Chemicals will be selected with the lowest practicable environmental impacts and risks subject to technical constraints. **CM15:** Implementation of waste management procedures which provide for safe handling and transportation, segregation and storage and appropriate classification of all waste generated.

Aspect	Receptor	EPO	Impact	Adopted control(s)
Unplanned Discharges: Solid Waste	Water Quality	EPO2	Change in water quality	**MODU, Vessel Operations** **CM23:** Project vessels compliant with Marine Order 95 (pollution prevention – Garbage). **CM15:** Implementation of waste management procedures which provide for safe handling and transportation, segregation and storage and appropriate classification of all waste generated.
	Migratory Shorebirds and Seabirds Fish Marine Mammals Marine Reptiles	EPO10 EPO7 EPO12 EPO1 EPO11 EPO8 EPO9	Injury/mortality to fauna	
Physical presence (unplanned) - Seabed disturbance	Epifauna and infauna	EPO1	Change in habitat Injury/ mortality to fauna	**MODU, Vessel Operations** **CM12:** Infrastructure will be positioned on the seabed within design footprint to reduce seabed disturbance.
	KEFs	EPO16	Change in habitat	
Physical presence (unplanned) - IMS	Epifauna and infauna Coral Seagrass Macroalgae	EPO18 EPO1	Change in ecosystem dynamics	**MODU, Vessel Operations** **CM24:** Compliance with the Woodside Invasive Marine Species Management Plan. **CM25:** Requirements of the Australian Ballast Water Management to be met.
	Industry Shipping Defence	EPO18 EPO13 EPO14	Changes to the functions, interests or activities of other users	
Physical presence (unplanned) - Collision with Marine Fauna	Marine Mammals Marine reptiles	EPO7 EPO12 EPO11 EPO1 EPO9	Injury to/ mortality of fauna	**Vessel Operations** **CM8:** EPBC Regulations 2000 Part 8 Division 8.1 Interacting with cetaceans. **CM32**: Marine fauna interaction mitigation measures to be considered and implemented as appropriate during the EP process.
Unplanned hydrocarbon release	Sediment quality	EPO3	Change in sediment quality	**MODU, Vessel, Helicopter Operations** **CM26:** All vessels and facilities (appropriate to class) will comply with MARPOL 73/78, the Navigation Act 2012, the Protection of the Sea (Prevention of Pollution from Ships Act 1983 and subsequent Marine Orders including:
	Water quality	EPO2	Change in water quality	
	Plankton	EPO6	Injury/ mortality to fauna	
	Fish	EPO7	Change in fauna behaviour	

Aspect	Receptor	EPO	Impact	Adopted control(s)
		EPO8 EPO9	Injury/ mortality to fauna	• waste management requirements • management of spills aboard • emergency drills. **CM27:** Relevant Stakeholders will be notified of activities prior to commencement. **CM28:** Vessels will have in place a valid and appropriate Shipboard Oil Pollution Emergency Plan and/or Shipboard Marine Pollution Emergency Plan. Emergency response activities will be implemented in accordance with the SOPEP/SMPEP. **CM29:** Environment Plans and Oil Pollution Emergency Plans will be accepted and in place, appropriate to the credible hydrocarbon spill scenario associated with activities during Scarborough. Emergency response activities will be implemented in accordance with the OPEP. **CM30:** Emergency response activities will be implemented in accordance with the OPEP the vessel SOPEP/SMPEP. **CM31:** Emergency response capability will be maintained in accordance with EP, OPEP and related documentation. Well Operations Management Plan accepted and in place for all wells, in accordance with the Offshore Petroleum and Greenhouse Gas Storage Act requirements, which include: • Blowout Preventer (BOP) installation during drilling operations • regular testing of BOP.
	Marine mammals	EPO12 EPO1 EPO9	Change in fauna behaviour Injury/ mortality to fauna	
	Marine reptiles	EPO11 EPO1 EPO9	Change in fauna behaviour Injury/ mortality to fauna	
	Seabirds and migratory shorebirds	EPO10 EPO8 EPO9	Change in fauna behaviour Injury/ mortality to fauna	
	Coral	EPO1	Change in habitat	
	Seagrass			
	Macroalgae			
	Mangroves		Change in habitat	
	Shoreline habitats		Change in habitat	
	Saltmarsh		Change in habitat	
	KEFs	EPO16	Change in habitat	
	AMPS	EPO1	Change in habitat	
	Protected Places		Change in habitat	
	Commonwealth and State Managed Fisheries	EPO15 EPO14	Changes to the functions, interests or activities of other users	
	Tourism and recreation	EPO14	Changes to the functions, interests or activities of other users Changes in aesthetic value	

Aspect	Receptor	EPO	Impact	Adopted control(s)
	Shipping	EPO14	Changes to the functions, interests or activities of other users	
	Industry	EPO13 EPO14	Changes to the functions, interests or activities of other users	
	Settlements	EPO17	Changes to the functions, interests or activities of other users	
			Change in aesthetic value	
	Defence	EPO14	Changes to the functions, interests or activities of other users	

10 CONSULTATION

10.1 Overview

Stakeholder consultation and engagement is an integral component of the environmental impact assessment and environmental authorisation process for OPPs.

This section describes Woodside's approach, as the Operator of Scarborough, to stakeholder consultation broadly, and for the development of Scarborough specifically. It will be updated in response to the formal OPP public review process to be undertaken in 2019.

Woodside's objectives for stakeholder consultation are to:

- improve stakeholder awareness and understanding of the development of Scarborough
- provide stakeholders with opportunities to obtain information about Scarborough including the physical, ecological and 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
- gain feedback from stakeholders on their concerns about the development of Scarborough and where possible, address stakeholder concerns through further activities, or by implementing additional mitigation measures.

Preliminary consultation commenced with interested and affected stakeholders in February 2018 as part of a planned, integrated and consistent approach to stakeholder engagement for of Woodside's proposed Burrup Hub opportunities (including the Browse to North West Shelf (NWS) Project, Scarborough, Pluto Train 2, NWS Project Extension and Pluto-NWS Interconnector). Consultation aims to be inclusive, transparent, voluntary, respectful and two-way. Consultation was completed by email, letter, phone call or meeting.

Consultation activities will continue to complement an overarching approach to stakeholder consultation for Woodside's Burrup Hub opportunities and will be phased throughout the OPP process. Concurrently, Woodside is completing a voluntary social impact assessment to assess the social opportunities and impacts arising from the proposed Burrup Hub projects. Woodside is employing a participatory approach, consulting stakeholders and gaining input into the identification and assessment of these impacts and opportunities.

10.2 Stakeholder Identification

The process for stakeholder consultation as undertaken by Woodside as the Operator of Scarborough included the identification of stakeholders and their relevance to the project. Table 10.1 presents a preliminary summary of stakeholders and stakeholder groups that are interested in, or likely to be affected by the development of Scarborough. This list is not exhaustive and additional stakeholders are expected to be identified as a part of the ongoing consultation which will include a formal comment period.

Stakeholders identified include stakeholders known as a result of Woodside's ongoing activities in Western Australia, as well as those identified through engagements with regulators, government agencies, desktop research and regional contacts.

Table 10.1: Identified stakeholders

Commonwealth Government	
Australian Customs Service – Border Protection Command	National Offshore Petroleum Titles Administrator (NOPTA)
Australian Hydrographic Service (AHS)	Office of Federal Minister for Resources and Northern Australia
Australian Maritime Safety Authority (AMSA)	Office of Shadow Minister for Environment
Department of Industry, Innovation and Science (DoIIS)	Office of Shadow Minister for Resources
National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA)	Senator Pat Dodson
Department of the Environment and Energy (DoEE)	Shadow Minister for Environment; Water
Federal Minister for Environment; Member for Durack	Parks Australia (a division of the Department of Environment and Energy)
Australian Fisheries Management Authority (AFMA)	Department of Agriculture and Water Resources – Biosecurity
State Government	
Australian Industry Participation Authority	Department of Health
Department of Primary Industries and Regional Development (DPIRD)	LandCorp
Department of Transport (DoT)	Environmental Protection Authority Services
Department of Water and Environmental Regulation (DWER)	Member for the Pilbara
Pilbara Ports Authority (PPA)	Office of State Minister for Mines and Petroleum
Department of Jobs, Tourism, Science and Innovation (DJTSI)	Office of the Leader of the Opposition, Public Sector Management, State Development, Jobs and Trade and Federal-State Relations
Department of Communities, Housing Division Pilbara	Office of the Minister for Fisheries
Department of Defence	Office of the Premier & Minister for State Development
Department of Education	Office of the State Minister for Environment
Department of Planning, Lands and Heritage	Office of the State Minister for Regional Development
Department of Primary Industries and Regional Development (DPIRD)	Office of the State Minister for Transport, Planning and Lands
Upper House Member for Mining and Pastoral	Office of the State Treasurer, Minister for Finance, Energy and Aboriginal Affairs
Department of Mines, Industry Regulation and Safety (DMIRS)	Western Australian Museum (Maritime Archaeology Department)
Department of Biodiversity, Conservation and Attractions (DBCA)	
Traditional Owner Groups, Local Government, Community, Educational Institutions and eNGOs	
Ngarluma Yindjibarndi Foundation	Wong-Goo-Tt-Oo
Murujuga Aboriginal Corporation (MAC)	Yaburara and Coastal Mardudhunera Aboriginal Corporation
City of Karratha	Australian Conservation Foundation
Conservation Council of Western Australia	Wilderness Society
World Wildlife Foundation – Australia	World Wildlife Fund (WWF)

International Fund for Animal Welfare (IFAW)	Friends of Australian Rock Art
Greenpeace	Market Forces
Australia Maritime and Fisheries Academy	Karratha Airport
Australian Conservation Foundation	Pilbara Development Commission
Karratha and Districts Chamber of Commerce and Industry	Karratha Visitors Centre
Karratha Community Liaison Group (includes Karratha Districts Chamber of Commerce and Industry, Dampier Community Association, Karratha Community Association, City of Karratha, Regional Development Australia, Pilbara Development Commission, Pilbara Ports Authority, Ngarluma Yindjibarndi Foundation Ltd and Yara Pilbara)	Karratha Heritage Group (includes Yindjibarndi Aboriginal Corporation, Yaburara and Coastal Mardudhunera Aboriginal Corporation, Wong-Goo-Tt-Oo, Ngarluma Aboriginal Corporation)
Tourism WA	
Industry	
Australian Petroleum Production and Exploration Association (APPEA)	Chamber of Minerals and Energy of Western Australia (CME)
Australian Marine Oil Spill Centre (AMOSC)	Oil and gas operators
Pilbara Ports Authority (PPA)	
Fisheries	
Commonwealth Fisheries Association (CFA)	Pearl Producers Association
Commonwealth commercial fisheries, including: • North West Slope Trawl • Western Tuna and Billfish Fishery • Southern Bluefin Tuna.	State commercial fisheries, including: • Pilbara Trap and Trawl Fishery • Nickol Bay and Onslow Prawn Fisheries.
Recfishwest	Australian Southern Bluefin Tuna Association (ASBTIA)
MG Kailis	Western Australian Indigenous Tourism Operators Council (WAITOC)
Dampier Island Tourism	Western Australia Fishing Industries Council (WAFIC)
Charter boat operators and recreational fishers	

10.3 Stakeholder Mapping to Scarborough Impacts and Risks

As a part of stakeholder consultation, the relevant stakeholders will be provided information relating to their specific functions, interests and activities. An initial assessment of the stakeholders' functions, interests and activities has been undertaken based on previous work with these stakeholders in the region and the preliminary impact assessment conducted for the project.

Functions, interests and activities have been mapped to the identified impacts and risks (as described in Section 7) in Table 10.2 and outlined by stakeholder group in Table 10.3. This will continue to be reviewed and updated as the assessment progresses and in response to the stakeholder feedback received.

Table 10.2: Stakeholder impact mapping

Receptor	Impact	Commonwealth Government	State Government	Traditional Owner Groups, Local Government, Organisations, Community, Educational Institutions and eNGOs	Industry/ Shipping/ Defence	Fisheries
Marine Sediments	Change in sediment quality	✓	✓			
Water Quality	Change in water quality	✓	✓			
Air Quality	Change in air quality	✓	✓	✓		
Climate	Change in climate	✓	✓	✓		
Ambient Light	Change in ambient light	✓	✓			
Ambient Noise	Change in ambient noise	✓	✓			
Plankton	Injury/mortality to fauna	✓	✓			
Epifauna and Infauna	Change in habitat	✓	✓	✓		
	Injury/mortality to fauna	✓	✓	✓		
	Change in ecosystem dynamics	✓	✓	✓		
Coral	Change in habitat	✓	✓	✓		
	Injury/mortality to fauna	✓	✓	✓		
	Change in ecosystem dynamics	✓	✓	✓		
Seagrass	Change in habitat	✓	✓	✓		
	Injury/mortality to fauna	✓	✓	✓		
	Change in ecosystem dynamics	✓	✓	✓		
Macroalgae	Change in habitat	✓	✓	✓		
	Injury/mortality to fauna	✓	✓	✓		
	Change in ecosystem dynamics	✓	✓	✓		

Receptor	Impact	Commonwealth Government	State Government	Traditional Owner Groups, Local Government, Organisations, Community, Educational Institutions and eNGOs	Industry/ Shipping/ Defence	Fisheries
Saltmarsh	Change in habitat	✓	✓	✓		
	Injury/mortality to fauna	✓	✓	✓		
	Change in ecosystem dynamics	✓	✓	✓		
Mangroves	Change in habitat	✓	✓	✓		
	Injury/mortality to fauna	✓	✓	✓		
	Change in ecosystem dynamics	✓	✓	✓		
Shoreline Habitats	Change in habitat	✓	✓	✓		
Seabirds and Migratory Shorebirds	Injury/mortality to fauna	✓	✓	✓		
	Change in fauna behaviour	✓	✓	✓		
Fish	Injury/mortality to fauna	✓	✓	✓		✓
	Change in fauna behaviour	✓	✓	✓		✓
Marine Mammals	Injury/mortality to fauna	✓	✓	✓		
	Change in fauna behaviour	✓	✓	✓		
Marine Reptiles	Injury/mortality to fauna	✓	✓	✓		
	Change in fauna behaviour	✓	✓	✓		
KEFs	Change in water quality	✓	✓	✓		
	Change in sediment quality	✓	✓	✓		
	Change in habitat	✓	✓	✓		
	Injury/mortality to fauna	✓	✓	✓		

Receptor	Impact	Commonwealth Government	State Government	Traditional Owner Groups, Local Government, Organisations, Community, Educational Institutions and eNGOs	Industry/ Shipping/ Defence	Fisheries
AMPs	Change in habitat	✓	✓	✓		
Commonwealth Managed Fisheries	Changes to the functions, interests or activities of other users	✓	✓	✓		✓
State Management Fisheries	Changes to the functions, interests or activities of other users	✓	✓	✓		✓
Tourism and Recreation	Changes to the functions, interests or activities of other users	✓	✓	✓		✓
	Change in aesthetic values	✓	✓	✓	✓	✓
Shipping	Changes to the functions, interests or activities of other users	✓	✓	✓	✓	
Defence	Changes to the functions, interests or activities of other users	✓	✓	✓	✓	
Industry	Changes to the functions, interests or activities of other users	✓	✓	✓	✓	
Settlements	Changes to the functions, interests or activities of other users	✓	✓	✓	✓	
	Change in aesthetic values	✓	✓	✓	✓	
Protected Places	Changes to the functions, interests or activities of other users	✓	✓	✓		

Table 10.3: Stakeholder Aspect mapping

Impact/Risk	Commonwealth Government	State Government	Traditional Owner Groups, Local Government, Organisations, Community, Educational Institutions and eNGOs	Industry/ Shipping/ Defence	Fisheries
Planned					
Routine light emissions	✓	✓	✓		
Routine atmospheric and greenhouse gas emissions	✓	✓	✓		
Routine acoustic emissions	✓	✓	✓		✓
Physical presence – Displacement of other users	✓	✓	✓	✓	✓
Physical presence – Seabed disturbance	✓	✓	✓		
Routine and non-routine discharges: Sewage and Greywater	✓	✓			
Routine discharges: Food wastes	✓	✓			
Routine and non-routine discharges: Chemicals and Deck Drainage	✓	✓			
Routine and non-routine discharges: Brine and Cooling water	✓	✓			
Routine and non-routine discharges: Operational Fluids	✓	✓	✓		
Routine and non-routine discharges: Subsea installation and commissioning	✓	✓	✓		
Routine and non-routine discharges: Drilling	✓	✓	✓		
Unplanned					
Unplanned discharges: Chemicals	✓	✓	✓		
Unplanned discharges: Solid waste	✓	✓	✓		
Physical presence (Unplanned) - Seabed disturbance	✓	✓	✓		
Physical presence (Unplanned) - IMS	✓	✓	✓	✓	
Physical presence (Unplanned) - Collision with Marine Fauna	✓	✓	✓		
Unplanned Hydrocarbon Release	✓	✓	✓	✓	✓

10.4 Stakeholder Consultation Approach

Woodside, as Operator of Scarborough is undertaking a phased program of consultation:

- **Phase 1:** Preliminary consultation proposed to take place during the impact assessment process and preparation of the OPP.
- **Phase 2**: Formal consultation under the public review process of the draft OPP by NOPSEMA.
- **Phase 3**: Ongoing consultation during project planning and execution.

10.4.1 Phase 1: Preliminary Consultation

Preliminary consultation is focused on key relevant stakeholders. It primarily aims to:

- introduce stakeholders to the development
- inform stakeholders of the work being undertaken to assess impacts relevant to their functions, interests and activities
- provide them with the opportunity to comment on the baseline assumptions made in relation to interactions with Scarborough and add new or different information
- inform them of the project timeframes and the mechanisms by which they can receive further updates or provide additional comment
- be provided with a point of contact or other information source for the project.

Preliminary consultation commenced in early 2018 and is built on the broader consultation and engagement process that Woodside has in place for the region. It will continue up until the point of formal consultation under the OPP process.

Phase 1 consultation activities include the following tasks:

- Develop a dedicated project website https://www.woodside.com.au/our-business/burrup-hub/scarborough-to-pluto which includes a detailed video explaining key characteristics of the proposal, information regarding the approvals, up-to-date fact sheets and point of contact.
- Have Scarborough fact sheets available on the project website and provided directly to key stakeholders via email or in person, including dedicated fact sheets on:
  - pipelay and dredging management
  - oil spill management and response
  - some of the key issues associated with Scarborough.
- Host community forums and group meetings including information sessions that were held on the 15th and 16th May 2019 in Karratha and Roebourne. These sessions allowed for broader engagement to validate initial data, obtain broader community input and allow for further identification of potential mitigation and management measures for Scarborough. The timing of these activities was intended to be prior to, the release of the draft OPP and formal public consultation process (Phase 2).
- Provide information to key stakeholders, including details of Scarborough and key milestones including approval submissions.

- Provide project updates on the project website and Woodside's social media channels, including key project updates provided by ASX Announcements, Media Releases, quarterly, half yearly and annual reporting as appropriate and required.

A summary of the Phase 1 consultation activities undertaken to date are provided in Table 10.4. This will be updated up until the point of formal public release of the OPP draft (Phase 1), and a complete stakeholder report of activities of consultation outcomes of Phase 1 and Phase 2 attached to the Final OPP.

Table 10.4: Table of stakeholder consultation activities to date

Date	Activity	Stakeholders Involved	Summary of Engagement
9 March 2018	Karratha Community Liaison Group	Attended by City of Karratha, LandCorp and Pilbara Development	Regular quarterly meeting, provided an overview of the Burrup Hub, including the Scarborough acquisition.
26 April 2018	Quarterly Karratha heritage meeting	Ngarluma Aboriginal Corporation, Yindjibarndi Aboriginal Corporation, Yaburara and Coastal Mardudhnuera Aboriginal Corporation, Wong-Goo-Tt-Oo	Regular quarterly meeting with Traditional Owner groups. Provided an update on approvals pathways and schedule for Burrup Hub projects including Scarborough.
8 June 2018	Karratha Community Liaison Group	Attended by City of Karratha, Karratha Districts Chamber of Commerce and Industry, Pilbara Ports Authority, Department of Environment, Ngarluma Yindjibarndi Foundation Ltd, Department of Local Government, Arts, Culture and Sport and WA Police.	Regular quarterly meeting, provided an update on the Burrup Hub, including Scarborough
12 June 2018	Burrup Hub meeting including Scarborough Project	Murujuga Aboriginal Corporation	Provided an update on the Burrup Hub, including Scarborough, heritage management and governance.
19 June 2018	Scarborough Project Update Meeting	Department of the Environment and Energy, Office of the Environmental Protection Authority and NOPSEMA.	Provided an overview of Scarborough.
27 July 2018	Scarborough Project Update Meeting	Department of the Environment and Energy	Provided an overview of Scarborough.
6 September 2018	Quarterly Karratha heritage meeting	Ngarluma Aboriginal Corporation, Yindjibarndi Aboriginal Corporation, Yaburara and Coastal Mardudhnuera Aboriginal Corporation, Wong-Goo-Tt-Oo	Regular quarterly meeting with Traditional Owner groups. Provided an update on approvals pathways and schedule for Burrup Hub projects including Scarborough.
7 September 2018	Karratha Community Liaison Group	Attended by City of Karratha, WA Police, Karratha Community	Provided an overview of the Burrup Hub activities and key environmental approvals required, including Scarborough.

Date	Activity	Stakeholders Involved	Summary of Engagement
		Association, Department of Education, Horizon Power, Pilbara Ports Authority, Pilbara Development Commission, Department of Sport and Recreation, Karratha Districts Chamber of Commerce and Industry	
11 September 2018	Burrup Hub meeting including Scarborough Project	Murujuga Aboriginal Corporation	Provided an update on the Burrup Hub, including Scarborough, approvals pathways, schedule and proposed engagement approach.
19 September 2018	Burrup Hub meeting including Scarborough Project	Office of the WA Minister for Environment	Provided an update on the Burrup Hub, including Scarborough, approvals pathways and schedule.
19 September 2018	Burrup Hub meeting including Scarborough Project	Office of the WA Premier and Minister for State Development	Provided an update on the Burrup Hub, including Scarborough.
20 September 2018	Burrup Hub meeting including Scarborough Project	Department of Industry, Innovation and Science	Provided an update on the Burrup Hub, including Scarborough.
20 September 2018	Burrup Hub meeting including Scarborough Project	Office of the Shadow Minister for Environment	Provided an update on the Burrup Hub, including Scarborough.
27 September 2018	Office of the Leader of the Opposition, Public Sector Management, State Development, Jobs and Trade and Federal-State Relations	Office of the Leader of the Opposition, Public Sector Management, State Development, Jobs and Trade and Federal-State Relations	Provided an update on the Burrup Hub, including Scarborough.
27 September 2018	Burrup Hub meeting including Scarborough Project	National Offshore Petroleum Titles Administrator	Provided an update on the Burrup Hub, including Scarborough
28 September 2018	Burrup Hub Update Meeting	Department of the Environment and Energy	Provided an update on approvals for Burrup Hub projects, including Scarborough.

Date	Activity	Stakeholders Involved	Summary of Engagement
28 September 2018	Burrup Hub meeting including Scarborough Project	Office of the Federal Minister for Resources and Northern Australia	Provided an update on approvals for Burrup Hub projects, including Scarborough.
2 October 2018	Burrup Hub meeting including Scarborough Project	Office of the State Treasurer, Minister for Finance, Energy and Aboriginal Affairs	Provided an update on the Burrup Hub, including Scarborough
2 October 2018	Burrup Hub meeting including Scarborough Project	Office of the State Minister for Transport, Planning and Lands	Provided an update on the Burrup Hub, including Scarborough
10 October 2018	Burrup Hub Update Meeting	Office of the Environmental Protection Authority	Provided an update on the Burrup Hub, including Scarborough, approvals pathway and schedule.
12 October 2018	Scarborough Project Update Meeting	Department of Jobs, Tourism, Science and Innovation	Provided an overview of Scarborough, including agreement with government.
12 October 2018	Burrup Hub meeting including Scarborough Project	Shadow Minister for Northern Australia	Provide update on approvals for Burrup Hub projects including Scarborough.
12 October 2018	Burrup Hub meeting including Scarborough Project	Senator for WA Patrick Dodson	Provided update on approvals for Burrup Hub projects including Scarborough.
12 October 2018	Burrup Hub meeting including Scarborough Project	Kimberley Land Council	Provided update on approvals for Burrup Hub projects including Scarborough
18 October 2018	Scarborough Project Update Meeting	Department of Jobs, Tourism, Science and Innovation	Consultation on the key components of Scarborough and details of the Scarborough Development Agreement.
18 October 2018	Scarborough Project Update Meeting	Member for Kimberley Josie Farrer	Provide update on approvals pathways and schedule for Burrup Hub projects including Scarborough
19 October 2018	Burrup Hub meeting including Scarborough Project	Office of the WA Minister for Regional Development	Provided update on approvals for Burrup Hub projects including Scarborough.
1 November 2018	Scarborough Project Update Meeting	Department of Jobs, Tourism, Science and Innovation	Consultation on the key components of Scarborough and details of the Scarborough Development Agreement.

Date	Activity	Stakeholders Involved	Summary of Engagement
9 November 2018	Scarborough Project Update Meeting	Ngarluma Yindjibarndi Foundation	Provide update on approvals for Burrup Hub projects.
12 November 2018	Scarborough Project Update Meeting	Nyamba Buru Yawuru	Discussion regarding Burrup Hub developments and environmental approvals information.
14 November 2018	Scarborough Project Update Meeting	Friends of Australian Rock Art	Burrup Hub environmental approvals briefing.
19 November 2018	Scarborough Project Update Meeting	Chamber of Minerals and Energy of Western Australia Inc NOPSEMA	Provided update on approvals for Burrup Hub projects.
19 November 2018	Scarborough Project Update Meeting	Pilbara Ports Authority	Provided an update on Scarborough, including the dredging and stabilisation scope.
23 November 2018	Scarborough Project Update Meeting	Member of Legislative Council- Mining and Pastoral Region	Provide update on approvals for Burrup Hub projects including Scarborough.
29 November 2018	Scarborough Project Update Meeting	Dampier Technical Advisory and Consultative Committee (TACC) (includes Pilbara Ports Authority, Department of Biodiversity Conservation and Attraction, Department of Transport, Rio Tinto, Department of Environment and Energy, Department of Planning Lands and Heritage, Department of Primary Industries and Regional Development, Toll, Water Corp, Department of Jobs, Tourism, Science and Innovation, Murujuga Land & Sea Unit)	Provided an update on Scarborough, including dredging and stabilisation scope.
29 November 2018	Quarterly Karratha heritage meeting	Ngarluma Aboriginal Corporation, Yindjibarndi Aboriginal Corporation, Yaburara and Coastal Mardudhnuera Aboriginal Corporation, Wong-Goo-Tt-Oo	Regular quarterly meeting with Traditional Owner groups. Provided an update on approvals pathways and schedule for Burrup Hub projects including Scarborough.
11 December 2019	Scarborough Project Update Meeting	Western Australian Marine Science Institution (WAMSI) Dredging Node	Provided an update on Scarborough, including dredging and stabilisation scope.

Date	Activity	Stakeholders Involved	Summary of Engagement
		(includes Australian Institute of Marine Science, WAMSI, Department of Water and Environmental Regulation)	
12 December 2018	Scarborough Project Update	Murujuga Aboriginal Corporation	Provided an update on Scarborough, proposed shore crossing activities and discussion on future engagement and opportunities to work together.
24 December 2018	Email notification to stakeholders of State Waters referral	Nyamba Buru Yawuru Wilderness Society Australian Government (Senator Dodson) Australian Fisheries Management Authority Western Australian Fishing Industry Council Ngarluma Yindjibarndi Foundation Department of Primary Industries and Regional Development Australian Conservation Foundation Department of Biodiversity, Conservation and Attractions - Parks and Wildlife Service World Wildlife Fund Greenpeace Friends of Australian Rock Art Recfishwest Australian Hydrographic Service WA Department of transport Member for Mining and Pastoral regions Member for Kimberley Australian Marine Oil Spill Centre (AMOSC)	Provided an update on Scarborough and advice of the referral of activities in State Waters to the EPA and DEE, and proposed submission of an OPP to NOPSEMA.

Date	Activity	Stakeholders Involved	Summary of Engagement
		Murujuga Aboriginal Corporation (MAC) Kimberley Land Council (KLC) Karratha and District Chamber of Commerce and Industry Dampier Community Association Karratha Community Association Regional Development Australia LandCorp Pilbara Ports Authority Yara Pilbara Fertilisers Pearl Producers Association Charter boat operators and recreational fishers	
9 January 2019	Burrup Hub meeting including Scarborough Project	Murujuga Aboriginal Corporation	Ongoing engagement and progress update on Woodside's Burrup Hub, including Scarborough.
11 January 2019	Email notification to stakeholders of State Waters referral	Australian Maritime Safety Authority	Provided an update on Scarborough and advice of the referral of activities in State Waters to the EPA and DEE, and proposed submission of an OPP to NOPSEMA. AMSA reviewed the placement of the moorings and cross referenced them with Traffic data. Shows trunkline crosses charted shipping fairways where vessel traffic is heavy. Woodside to provide Marine Safety Information as per AMSA's request.
21 January 2019	Marine Parks Studies Meeting	CSIRO	Provided an update on Scarborough. CSIRO discussed 2017 NWS survey and results from 11 sites in Australian Marine Parks (AMP) (3 in Dampier AMP and 8 in Montebello AMP) that have been analysed for a report soon to be released to Parks.
22 January 2019	Scarborough Project Update Meeting	Department of the Environment and Energy	Provide update on approvals for Burrup Hub projects and referral of activities in State Waters. Discussion around Sea Dumping Permits and dredging (State and Commonwealth Waters).
22 January 2019	Burrup Hub meeting including Scarborough Project	Department of Industry, Innovation and Science	Provided an update on the Burrup Hub projects, including Scarborough, schedule and environmental approvals.

Date	Activity	Stakeholders Involved	Summary of Engagement
24 January 2019	Burrup Hub meeting including Scarborough Project	Murujuga Aboriginal Corporation	Meeting to discuss ongoing engagement on the Burrup Hub, including Scarborough.
29 January 2019	Scarborough Project Update Meeting	Department of Primary Industries and Regional Development	Provided an overview of Scarborough, including environmental approvals and stakeholder engagement moving forward.
30 January 2019	Scarborough Project Update Meeting	Department of the Environment and Energy – Australian Marine Parks Division	A meeting was held with Parks Australia, where Woodside presented an overview of Scarborough with particular focus on activities relevant to Australian Marine Parks. Figures used in the presentation showed clearly the route of the proposed Scarborough Trunkline through the Montebello Marine Park Multiple Use Zone (MUZ), as well as proposed ROV video transects and sampling locations along the trunkline route to support a benthic habitat study. An overview was also provided of proposed dredging and spoil disposal locations associated with the trunkline preparation, with a figure clearly showing proximity to Dampier Marine Park. An associated towed/drop camera survey was discussed in relation to the potential Borrow Ground north of Dampier Marine Park, also accompanied by several figures supporting the methodology that had been used, in addition to transect locations and results from the survey. Further discussion re outcomes of the spill modelling is proposed for a meeting scheduled on the 11 April 2019. Parks Australia requested access to a copy of reports when they could become available. When asked what specific information Parks Australia would be looking to be presented within the OPP. Feedback was that consideration of relevant BIAs and KEFs, within discussion was important and an assessment against values (where they interact with the project). It was also recommended that details be provided regarding the representativeness of the area where the project area interacts with AMPs be discussed. Parks Australia summarised the objectives for each zone type, including the Multiuse zones (such as the area which the Scarborough Trunkline intersects) .[44] This feedback regarding BIA's, KEFs and AMP Objectives has been used within the OPP and during discussion of acceptable levels of impact (Table 6.3) for the Australian Marine Parks impacted by the project. Further discussion regarding outcomes of the spill modelling was proposed for a meeting scheduled on the 11 April 2019.

[44] *Feedback provided by Parks Australia during the meeting which has been presented within the OPP was endorsed by Parks Australia as an accurate record of consultation.*

Date	Activity	Stakeholders Involved	Summary of Engagement
5 February 2019	Burrup Hub meeting including Scarborough Project	Department of Transport	Provided an overview of the Burrup Hub, including Scarborough. Discussion regarding Scarborough, environmental approvals and approaches to marine oil pollution and maritime transport emergencies.
7 February 2019	Burrup Hub meeting including Scarborough Project	City of Karratha	Provided an update on Burrup Hub projects, including Scarborough, and environmental approvals.
8 March 2019	Karratha Community Liaison Group	Attended by Ngarluma Yindjibarndi Foundation Ltd, City of Karratha, Landcorp, WA Police, Dept Local Govt and Communities, Pilbara Ports, Karratha Districts Chamber of Commerce and Industry, Regional Development Australia, Pilbara Development Commission and Dampier Community Association	Provided a briefing on the environmental approvals process including the Scarborough Offshore Project Proposal and highlighted opportunities for public comment.
13 March 2019	Burrup Hub meeting including Scarborough Project	Office of the Environmental Protection Authority	Monthly update of Burrup Hub developments provided which included updates on Scarborough State and Commonwealth Waters approvals.
15 March 2019	Montebello Research Results Update	Department of the Environment and Energy – Australian Marine Parks Division	Secondary meeting with Department of Parks undertaken which presented preliminary findings of ROV video transects in Montebello AMP. No specific comments regarding ROV footage results were made.[45]
18 March 2019	Burrup Hub meeting including Scarborough Project	Department of the Environment and Energy	Update on progress towards environmental approvals which included updates on Scarborough State and Commonwealth Waters approvals.
28 March 2019	Scarborough Project Update Meeting	NOPTA	Quarterly Scarborough JV update.
5 April 2019	Scarborough Project Update Meeting	Dampier Technical Advisory and Consultative Committee (TACC) (includes Pilbara Ports Authority, Department of Biodiversity Conservation and Attraction,	Provided an update on Scarborough and progression of Environmental Approvals including the OPP and State Waters Referral.

[45] *Feedback provided by Parks Australia during the meeting which has been presented within the OPP was endorsed by Parks Australia as an accurate record of consultation.*

Date	Activity	Stakeholders Involved	Summary of Engagement
		Department of Transport, Rio Tinto, Department of Environment and Energy, Department of Planning Lands and Heritage, Department of Primary Industries and Regional Development, Toll, Water Corp, Department of Jobs, Tourism, Science and Innovation, Murujuga Land & Sea Unit)	
11 April 2019	Scarborough Project Update Meeting	Department of Environment and Energy – Australian Marine Parks Division	Update provided on Scarborough, environmental approvals and marine park studies. Particular focus was the presentation of plume modelling results and figures from proposed use of the offshore borrow ground, and the presentation of oil spill modelling result including EMBAs and Spill modelling outputs. Parks provided feedback regarding; - Presentation of figures and ensuring parks were accurately represented within the OPP (which has been addressed); - Asked questions regard the public consultation process/expected levels of interest in the OPP (which were discussed and satisfied at the time); and - Asked questions around entrained components of oil spill modelling and how this relates to environmental impacts (which was discussed and satisfied at the time). With the exception of the discussion points above no specific comments regarding modelling results were made.[46]
13 May 2019	Burrub Hub full council briefing, including Scarborough	City of Karratha councillors	Provided an update on woodside's Burrup Hub developments, including Scarborough.
15-16 May 2019	Burrup Hub public information sessions in Karratha and Roebourne	Various Karratha and Roebourne community members	Broad engagement with Karratha and Roebourne community members on issues and opportunities relevant to Burrup Hub developments, including Scarborough.
6 June 2019	Quarterly Karratha heritage meeting	Attended by Ngarluma Aboriginal Corporation, Yaburara and Coastal Mardudhnuera Aboriginal	Update on Scarborough and environmental approvals, including public comment periods.

[46] *Feedback provided by Parks Australia during the meeting which has been presented within the OPP was endorsed by Parks Australia as an accurate record of consultation.*

Date	Activity	Stakeholders Involved	Summary of Engagement
		Corporation and Wong-Goo-Tt-Oo Aboriginal Corporation.	
7 June 2019	Karratha Community Liaison Group meeting	Attended by the city of Karratha; Pilbara Development Commission; LandCorp; Regional Develop Australia; and Pilbara Port Authority.	Update on Scarborough and environmental approvals, including public comment periods for the OPP and DSDMP.

10.4.2 Phase 2 Formal OPP Consultation

The OPP assessment process includes the publication of the OPP on the NOPSEMA website and a period of public consultation which gives all relevant and interested stakeholders an opportunity to review and provide comment.

All public comment is provided to NOPSEMA who will provide a copy of the comments received to Woodside as Operator of Scarborough for their consideration in the update to the draft OPP. Following the public comment period, the proponent prepares a consultation report and final OPP for assessment by NOPSEMA. In the report, the proponent summarises the comments received with an assessment of the merits of each comment, a statement of their response to each comment, and an outline of any changes made to the OPP as a result of the comment.

Phase 2 engagement will capture those stakeholders that were not identified to be potentially impacted by the proposed development and as such consulted with in Phase 1.

The formal public review of Scarborough OPP will take place in 2019 and be for a period of 4–12 weeks, as determined by the Regulator. The process for assessment of the OPP, including the formal public review process, is summarised in Figure 10.1.

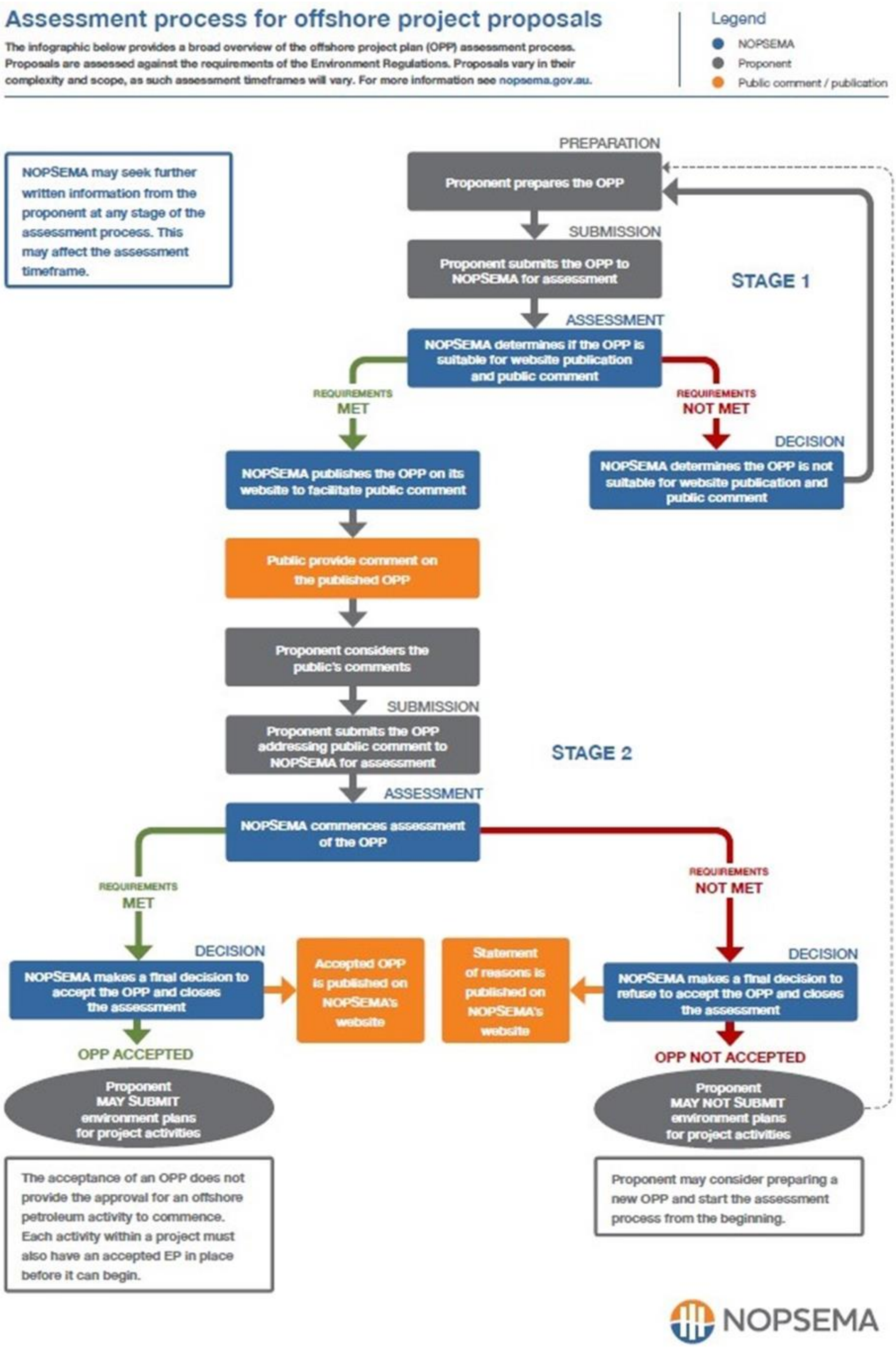


Figure 10.1: NOPSEMA assessment process for offshore project proposals

10.4.3 Phase 3: Ongoing Consultation

On acceptance of the OPP, Woodside as Operator will continue to consult with stakeholders during the preparation of EPs and execution of Scarborough.

Consultation is a formal requirement under Regulation 11A and 14(9) of the Environment Regulations. Accordingly, Woodside will conduct further stakeholder assessment and consultation with relevant stakeholders to inform decision-making and planning for the petroleum activities being undertaken as a part of this project.

Stakeholders identified for consultation in support of the Petroleum Activities Program will be monitored and updated as required, with any feedback from these stakeholders given consideration for future activities.

All proposed engagement and consultation will be planned for in a Stakeholder Engagement Plan, and outcomes of consultation will be tracked and recorded by Woodside.

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Appendix A

Scarborough Offshore Benthic Marine Habitat Assessment

Scarborough

Offshore Benthic Marine Habitat Assessment

1 February 2019

Level 4, 600 Murray St
West Perth WA 6005
Australia

-EN-REP-0001

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WorleyParsons Group

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Project No: REP-0001 – Scarborough: Offshore Benthic Marine Habitat Assessment

Rev	Description	Author	Review	WorleyParsons Approval	Date
A	Issued for Internal Review	C Steele	H Houridis	P Nichols	
B	Issued for Client Review	HH		PN	
0	Issued for use	HH	HH	PN	1 Feb 2019
1	Client comments addressed - issued for use	HH	HH	PN	13 Feb 2019
2	Client comments addressed - issued for use	pp. HH	PN	PN	18 Feb 2019

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Executive Summary

The Scarborough gas resource is located approximately 375 km west-north-west off the Burrup Peninsula and is part of the Greater Scarborough gas fields which are estimated to hold 9.2 Tcf (2C, 100%) of dry gas. Woodside is proposing to develop the Scarborough gas resource through new offshore facilities connected by an approximately 430 km pipeline onshore. The proposal is to initially develop the Scarborough gas field with wells, tied back to a semi-submersible floating production unit (FPU) moored in 900 m of water close to the Scarborough field. This report has been developed in support of environmental approvals associated with the Scarborough Project.

This report is a summary of relevant information on benthic habitats from the offshore slope and deeper development area and is based on survey work previously completed in the permit area (>950 m water depth), on the escarpment of the continental shelf (300-950m water depth) and on the shelf (<300 m water depth). The data used in the assessment is based on video recordings and still images collected from ROV footage obtained during industry operations at a range of locations from the offshore project area as well as project specific surveys for the Scarborough Development.

Regional and site specific studies reviewed indicate that seabed material along the proposed trunkline alignment (and around the gas field) is predominantly flat and featureless and comprises thick, unconsolidated fine grained sands. The sediments support soft sediment benthic communities dominated by infauna (including molluscs, crustaceans and worms) and isolated larger fauna (free swimming cnidarian, demersal fish and benthic crustaceans).

Sedimentary infauna associated with soft unconsolidated sediments of the general area is widespread and well represented throughout the North West Shelf (NWS) region. In the context of the broader extent of habitats across the region, benthic habitat along the proposed trunkline corridor and within the Scarborough field consists primarily of soft unconsolidated sediments and is considered to be of relatively low environmental sensitivity.

Benthic communities of filter feeders generally live in areas that have strong currents and hard substratum and are closely associated with substrate type, with areas of hard substrate typically supporting more diverse epibenthic communities. The only natural habitat within the offshore permit area and trunkline corridor that is not classified as soft sediment is the pinnacle field that lies in about 300m water depth, on the continental slope. The pinnacle field covers an area that is less than 3 km^2 in size and at its closest point is more than 350m away from the proposed trunkline. Furthermore, the pinnacles are isolated forms and do not constitute continuous reef. It remains unclear what the rock pinnacles are constructed from, however the structures provide habitat for a diverse range of epifaunal and demersal species that commonly occur elsewhere in the NWS.

Interestingly, the habitats containing the greatest biodiversity in these offshore environments are the habitats formed by colonising invertebrates on oil and gas subsea infrastructure including the well heads and pipelines. These habitats and the species present on these structures in the NWS of Western Australia have been recently subject to detailed quantitative and qualitative assessment

(McLean et al. (2018), McLean et al. (2017), Bond et al (2018)). These habitats not only have structural complexity but also create habitat for a large diversity of fish species that commonly occur elsewhere in the NWS but do not occur over soft unconsolidated sediments.

1 Introduction

1.1 Background

The Scarborough gas resource is located approximately 375 km west-north-west off the Burrup Peninsula and is part of the Greater Scarborough gas fields which are estimated to hold 9.2 Tcf (2C, 100%) of dry gas. Woodside is proposing to develop the Scarborough gas resource through new offshore facilities connected by an approximately 430 km pipeline onshore. The proposal is to initially develop the Scarborough gas field with wells, tied back to a semi-submersible floating production unit (FPU) moored in 900 m of water close to the Scarborough field.

WEL engaged Advisian to undertake an offshore marine habitat assessment to further the understanding of the environmental conditions of permit area WA-1-R. Findings from the marine studies will support the Scarborough Project environmental approvals.

The report is a summary of relevant information on benthic habitats from the offshore slope and deeper development area and is based on survey work previously completed in the permit area (>950 m water depth), on the escarpment of the continental shelf (300-950m water depth) and on the shelf (<300 m water depth).

1.2 Scope of Work

The objectives of the offshore marine habitat assessment were:

- To provide sufficiently detailed background information to enable the existing benthic habitat to be adequately described, particularly for benthic species and habitats of conservation significance, and
- To assess and interpret the available benthic habitat data which will be used to inform environmental approvals documentation for the Scarborough Development.

2 Method of Assessment

2.1 Review of Existing Literature

The offshore marine habitat assessment was undertaken by reviewing relevant literature from the areas of interest. This includes use of site specific environmental survey data that were commissioned to investigate the environmental conditions at both the Scarborough and Pluto field developments. Additional information was sourced from geophysical investigations, ROV surveys and sub-sea infrastructure inspections in the areas of interest.

An environmental characterisation report based on seasonal marine surveys was undertaken within Permit Area WA-1-R by ERM (2013). The surveys were completed in November 2012 (wet season) and July/August 2013 (dry season) and included sampling of water, sediment, plankton and infauna communities. Characterisation of seabed habitat was undertaken using multibeam.

The offshore marine environmental survey for the Pluto LNG development (SKM 2006) was also reviewed as the trunkline alignment from Scarborough will follow a similar route as that taken by the Pluto gas trunkline. The Pluto survey included infauna and epifauna sampling, sediment sampling for particle size analysis and sediment chemistry, ROV / video investigations of benthic habitats and anecdotal recordings of seabirds, cetaceans and other marine mammals, sea turtles and other reptiles. Detailed AUV and ROV survey data for Pluto were also reviewed as part of a comprehensive geophysical and geotechnical survey of the Pluto field (Geoconsult 2005).

The historical marine survey work was supplemented by a series of more recent marine surveys, including geophysical and ROV surveys that filmed the proposed trunkline route through the Scarborough field. These include the ROV survey of the export pipeline route (Ocean Affinity, July 2018) along a section of the continental slope between Scarborough and Pluto.

2.2 Report Layout

For the purpose of this report, the offshore marine habitat assessment has been divided into three sections according to water depth. These include describing habitats in the:

- Deeper Water (>950m depth), which includes the seabed where the Scarborough gas field is located;
- Continental Slope (300-950m water depth), which includes the section of seabed between the Scarborough gas field and the Pluto tieback;
- Continental Shelf (<300m water depth), which covers the seabed around the Pluto platform

For the purpose of this report, survey scopes that involved water quality, plankton and other surveys of the open water environment are not included in this report.

3 Deepwater Habitat

Much of the following section has been adapted from the Scarborough marine studies completed by ERM in 2013.

3.1 Background

The Scarborough Development is located on the Exmouth Plateau, within the North-west Marine Bioregion (Figure 3-1), as defined by DoE's framework for coordinating conservation and sustainable management (DoE 2013). The region comprises Commonwealth waters from the Western Australian/ Northern Territory border to Kalbarri, south of Shark Bay and covers 1.07 million square kilometres (km^2) of tropical and sub-tropical waters (DEWHA 2008). The Exmouth Plateau is located within the region's Northwest Province, which covers an area of 178,651 km^2 and is situated entirely on the continental slope (DEWHA 2008). The water depths of the North-west Province predominantly range between 1,000 m and 3,000 m reaching a maximum depth of 5,170 m.

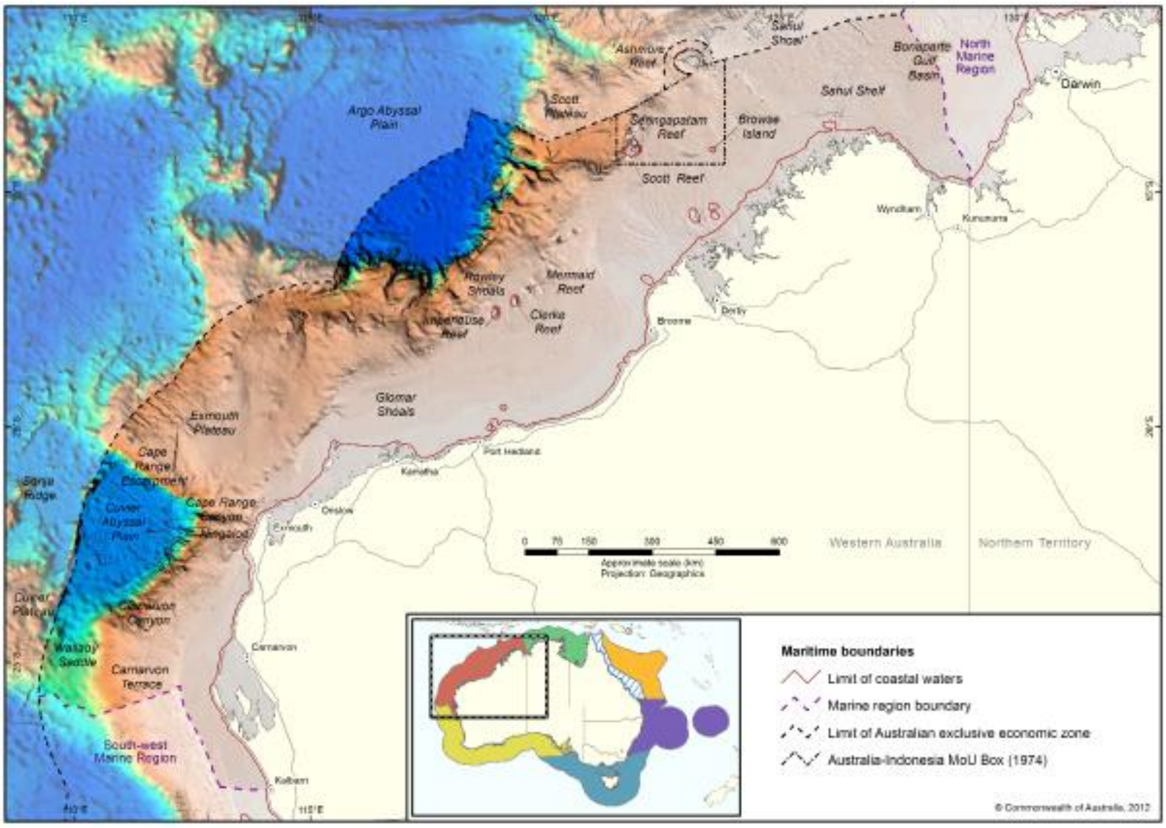


Figure 3-1 The North West Marine Bioregion, showing location of the Exmouth Plateau

The Exmouth Plateau, a deepwater plateau adjacent to the continental slope, is a dominant geomorphic feature of the region Figure 3-2. The Montebello Trough along the south-east edge of the plateau drains into the Cape Range Canyon, while the northern portion of the plateau comprises the Dampier Ridge and Swan Canyon. The Exmouth Plateau peaks at approximately 1,000 m deep with a narrow, steep southern slope and a wider, less steep northern slope. WA-1-R is located in the north-central section of the Exmouth Plateau in water depths of approximately 900 m to 970 m.

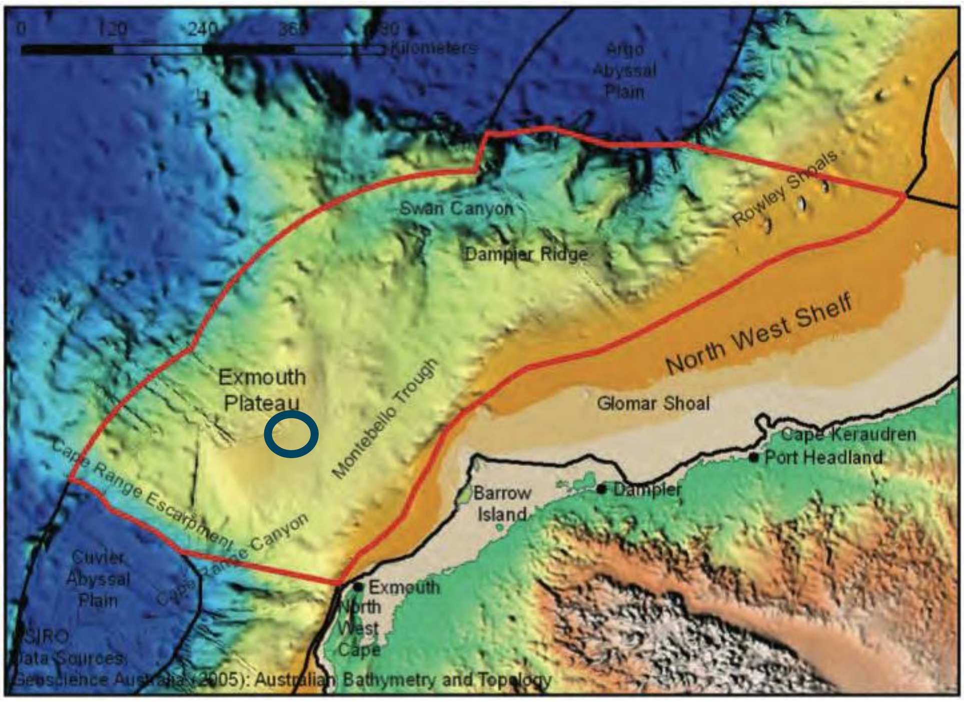


Figure 3-2 The Exmouth Plateau (showing location of Scarborough Development)

3.1.1 Seabed Characteristics

The region comprises bio-clastic, calcareous and organogenic sediments deposited from relatively slow and uniform sedimentation rates (Carrigy and Fairbridge 1954 in Baker *et al.* 2008 and Jones 1971 in Baker *et al.* 2008).

Sediments vary from sands and gravels on the shelf, to muds on the slope and abyssal plain/deep ocean floor (Baker *et al.* 2008). Calcium carbonate deposits are located on the inner shelf, middle shelf and outer shelf/ slope. The Exmouth Plateau is characterised by a thick Triassic sequence overlain by a Jurassic, Cretaceous and Cainozoic sediment sequence; and fine-grained carbonate ooze (Fugro 2010).

Sediment transport at WA-1-R on the outer shelf/ slope of the Exmouth Plateau is influenced by a combination of slope processes and large ocean currents.

The seafloor is generally flat and uniform with water depths ranging from 900 m to 970 m, with a gradual increase from the north/north-west to the south/ south-east of the area (*Figure 2.4*; Fugro 2010). To the south-west of WA-1-R, craters (up to 400 m across and depth of up to 10 m) and smaller pockmarks (metres to tens of metres across) have been identified through geophysical surveys (Fugro 2010). The seafloor exhibits gradients less than 1 degree (°) but extends to approximately 15 ° on the edge of craters (Fugro 2010). These crater and pockmark formations in WA-1-R may be associated with hydrocarbon seeps as well associated authigenic carbonate formations (Fugro 2010), and were a particular focus of the studies completed by ERM.

3.1.2 Benthic Communities

Studies completed within the region indicate that benthic composition in deepwater habitats is generally lower in abundance than shallow water habitats (DEWHA 2008, Brewer *et al.* 2007). Gage (1996) reported that the density of benthic fauna tends to be lower in deepwater sediments (>200 m) than in shallower coastal sediments, but the diversity of communities may be similar.

Information exists on the benthic communities of the Exmouth Plateau, although macrofaunal species diversity has been shown to be positively correlated to sediment diversity (Etter & Grassle, 1992). The mostly fine sediment environment of the Exmouth Plateau is expected to support scavengers, benthic filter feeders and epifauna, particularly at the intersection with the continental margin (Brewer *et al.* 2007). This soft bottom habitat is also likely to support patchy distributions of mobile epibenthos, such as sea cucumbers, ophiuroids, echinoderms, polychaetes and sea-pens (DEWHA 2008).

3.1.3 Hydrocarbon Seep-Associated Benthic Communities

Hydrocarbon seeps are the seeping of gaseous or liquid hydrocarbons (including oil and methane) to the surface of the seabed from fractures and fissures in the underlying rock, resulting in possible hydrocarbons and other chemicals in the water column (DEWHA 2008). It is possible that these formations may host thiotrophic (sulphur based metabolism) or methanotrophic (methane based metabolism) benthic communities and chemosymbiotic benthic fauna reliant on methane-oxidising bacteria, which usually aggregate in the form of mats over the seafloor (Barry *et al.* 1996).

These naturally occurring seeps are known to be present in the region, with an estimated 3,300 tonnes seepage of hydrocarbons annually (Fandry *et al.* 2006). Active hydrocarbon seeps have not been identified in WA-1-R. However, geophysical surveys conducted in 2010 identified crater and pockmark formations in WA-1-R, which may be associated with current or historic hydrocarbon seeps as well associated authigenic carbonate formations (Fugro 2010).

3.2 Survey Methods

The ERM marine investigation included sampling at 15 sampling sites as shown Figure 3-3 to:

- provide a broad characterisation of the habitats within WA-1-R;
- achieve spatial coverage across WA-1-R; and
- provide a representative selection of the various topographic features and corresponding benthic habitats (i.e. crater/pockmark versus non-crater areas).

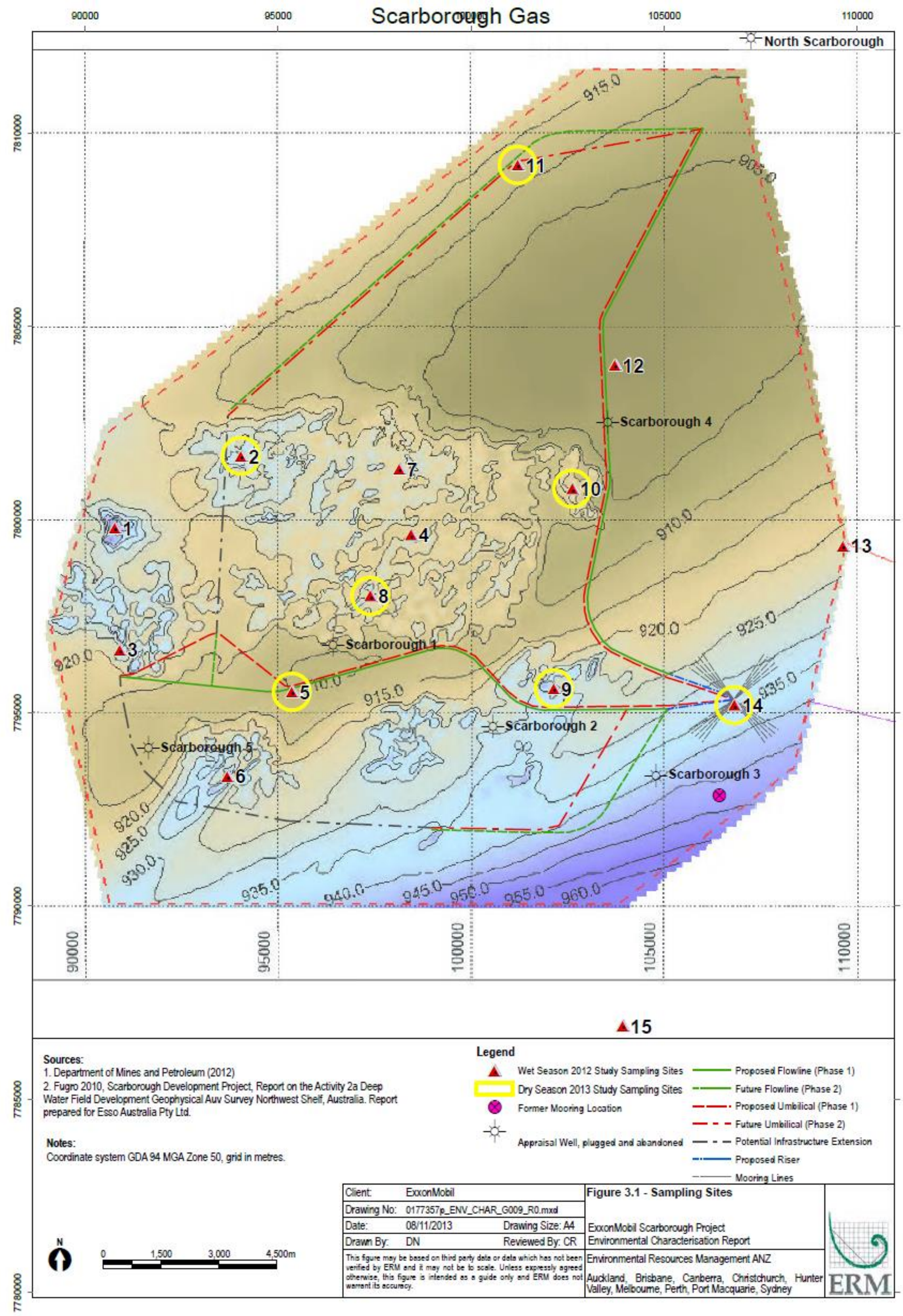


Figure 3-3 Sampling Sites used in the ERM Environmental Characterisation Report (ERM 2013)

3.2.1 Camera Study (Benthic Communities)

At each site, the camera was lowered to the seafloor of each sampling station. The vessel then drifted as slowly as possible across the station target area, capturing video footage. Video footage was collected for approximately 15 minutes at each of the three stations (45 minutes of footage per sampling site), with footage reviewed in real time. Video footage was acquired at all sites with the exception of Site 15 Stations 2 and 3 (due to bad weather).

Additionally, approximately 25 still images were captured opportunistically at each station sampled (75 images per sampling site). A total of 1,120 images were collected.

3.2.2 Infauna Study

Seafloor sediment was collected for physico-chemical analyses and identification of infauna. Sampling was undertaken using a box corer of the following dimensions: 0.49 x 0.52 x 0.55 m (length x width x height). The box corer was lowered to the seafloor for collection and recovered to the deck for inspection. The sample was split into quarters whereby one quarter was used for physicochemical subsamples and the other full quarters were sieved through a 0.5 mm mesh sieve.

3.3 Results

3.3.1 Benthic Communities

A total of 865 still images were quantitatively assessed by the South Australian Research and Development Institute (SARDI). A review of the benthic camera study recordings indicated a soft sediment seafloor across the area surveyed.

The quantitative assessment identified a total of 79 benthic taxa, consisting of the following phyla: echinoderms (28%), arthropods (24%), chordates (20%), cnidarians (19%), molluscs (4%) and poriferans (3%). In addition, there were 2% of taxa that appeared to be large protists (kingdom Chromista). Organisms were identified to the lowest recognisable taxonomic unit including species (5), genus (12), family (13), order (18), class (26), phylum (3) and kingdom (2).

The five species identified comprised a crab (*Eplumula* cf. *australiensis;)*, sea urchin (*Phormosoma* cf. *placenta)*, skate (*Insentiraja subtilispinosa)* and two fish species (*Bathypterois* cf *guentheri* and *Bathysaurus ferox*). Overall, a total of 605 individuals (including 54 unidentifiable organisms) were counted, dominated by arthropods (54.70%), followed by echinoderms (16.36**%**), cnidarians (10.41%), unidentified organisms (8.94%), chordates (7.44%), molluscs (0.99%), poriferans (0.83%) and the kingdom Chromista (0.33%).

The most abundant species were two shrimp species, of the genus *Nematocarcinus*. The next most abundant species were the gorgonian coral *Metallogorgia* sp. 1 (35 individuals) and the basket star *Gorgonocephalid* sp. 1 (29 individuals). Motile taxa such as shrimp, sea cucumbers and fish dominated the benthic fauna, comprising 75% of the species richness and 87% of the species.

Sessile taxa such as sea pens, corals, sponges, anemones and stalked crinoids made up the remainder of the contribution to overall species richness and abundance (25% and 13%, respectively).

The ERM (2013) study also noted bioturbation of the seabed in many of the images although most traces could not be confidently assigned to contributing taxa. Those that could be identified were considered potentially representative of echinoderms as well as biotic groups not identified in the still imagery such as foraminiferans, echiurans and annelids.

Bivalve shell debris was also recorded at several sites and was believed to be comprised of at least two species of the Vesicomyidae family. Aggregations of lithodid crabs were present in one occurrence of shell debris within one station. Small-scale bacterial mats that appear similar typical of *Beggiatoa* sp. were observed in a few of these bivalve shell debris occurrences. Shell debris and bacterial mats had mean percentage covers of 3.8% and 0.4%, respectively, across all the sites. For sites located in areas of coalescing seafloor craters, shell debris and bacterial mats had mean percentage covers of 6.3% and 0.7%, respectively.

3.3.2 Infauna

A total of 281 individuals and 43 different species were identified from the seven sediment samples collected from Sites 5, 8, and 14.

Of the 43-species identified, 33 were identified to family level, with the remainder identified to higher taxonomic levels. Crustaceans and polychaete worms were the dominant taxonomic groups, accounting for 89% and 86% of the individuals and species richness, respectively. The majority of crustaceans identified belonged to the Leptocheliidae and Apseudoidae families. The majority of polychaetes identified belonged to the Pilargidae family. Holothureans, molluscs, sponges, sipunculids and octocorals were recorded in relatively low abundances. The average density of infauna was estimated to be 214.1/m^2 (±43.3).

3.4 Discussion

No organisms identified to species level for the studies were listed as Threatened or Migratory under the EPBC Act according to the Species Profile and Threats (SPRAT) database (ERM 2013).

Benthic camera and sediment results indicated that the seafloor around the Scarborough Development is characterised by sparse marine life dominated by motile organisms. Such motile organisms included shrimp, sea cucumbers, demersal fish and small, burrowing worms and crustaceans (Figure 3-4, Figure 3-5 and Figure 3-6). Although these images were obtained from the original Pluto survey (Geoconsult 2005) and are closer to the Pluto slope, they are representative images of the deepwater habitat present at ~1,000m depth. The observed dominance by motile taxa is typical of deepwater soft substrates (DEWHA 2008), with sessile taxa more common on harder substrates (Ramirez-Llodra *et al.* 2010). Overall, observations made are representative of tropical deepwater soft sediment habitats reported in the region (BHP Billiton 2004; Woodside 2005; Woodside 2006; Brewer *et al.* 2007; RPS 2011; Apache 2013; Woodside 2013).

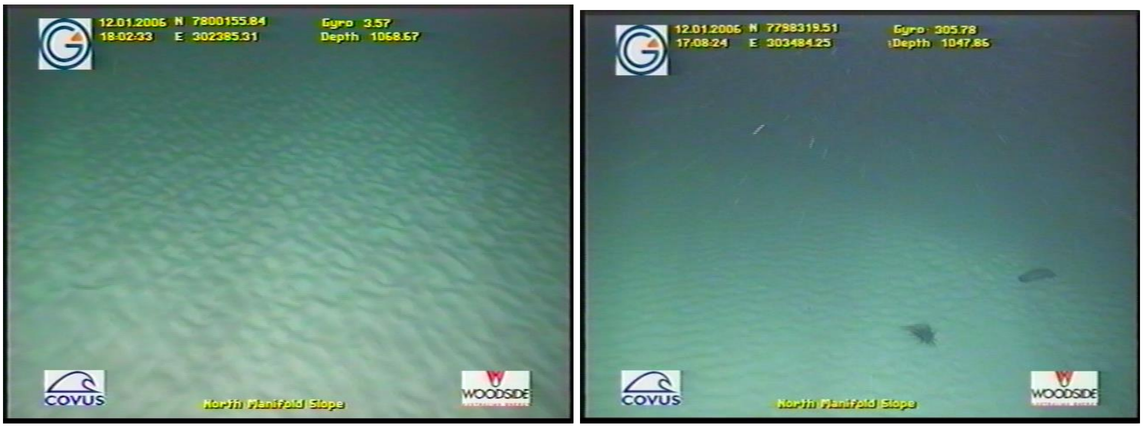


Figure 3-4 Deepwater soft bottom habitat (depths 1047-1068m), Tape 07 (January 2006)

Figure 3-5 Deepwater soft bottom habitat (depths 944-1025m), Tape 06 (January 2006)

Figure 3-6 Deepwater soft bottom habitat (depths 1029-1067m), Tape 07 (January 2006)

The majority of the 15 taxa that were identified to species or genus level in the benthic camera study are distributed worldwide. It is thought that offshore deepwater habitats of the NWS tend to support widespread Indo-pacific species, retaining extensive genetic connections over large distances (Heyward *et al.* 2006).

Four taxa were classified as Indo-pacific species, namely the carrier crab *Eplumula* cf. *australiensis* (typically in waters off southern Australia, New Zealand and New Caledonia (Poore 2004)), the velvet skate *Insentiraja subtilispinosa* (only in waters off north-west Australia and the Western Central Pacific (Last and Stevens 2009, Froese and Pauly 2011)), the halosaur fish *Aldrovandia* sp. 1 (previously recorded in the North West Province (Sorokin and Brock 2013)) and the tribute spiderfish *Bathypterois* cf. *guentheri* (Indo- West Pacific to the north east Indian Ocean and southern Japan (Froese and Pauly 2011)).

The demersal fish observed potentially reflects the community near the Exmouth Plateau. The upper and middle parts of the continental slope in the North-west Province have a high number of demersal fish species with high endemism (DEWHA 2008). This is especially so in the area between the North West Cape and the Montebello Trough (along the south-east edge of the plateau, *Figure 2.1*), which supports over 508 fish species of which 76 are endemic. It is noted that the demersal fish species identified for the benthic camera study did not correlate with the ichthyoplankton species identified in the zooplankton samples. This is attributed to the large depths at WA-1-R and general lack of vertical mixing between the surface and deeper layers (Sundby 1996).

The dominant types of epifauna were arthropods and echinoderms (especially shrimp and sea cucumbers, respectively), while the dominant infauna groups were crustaceans and polychaetes.

Benthic community composition was generally similar across sampling sites. There was not a strong correlation between bathymetric features and sessile or motile organisms. However, bathymetric features may have played a role in the abundance of certain organisms. The majority of sites where soft coral was identified were found outside of the coalescing seafloor crater areas. More than double the number of sea fans was identified in noncrater areas as opposed to coalescing seafloor craters.

The ERM (2013) study also noted that potential indicators of historic or localised ephemeral hydrocarbon seep activity were the most noticeable exception to a uniform benthic composition across WA-1-R. These indicators were in the form of bivalve shell debris and bacterial mats and they were only identified across the sites in the seafloor crater areas, where hydrocarbon seeps were considered to be potentially present (Fugro 2010). The shell debris and bacterial mats had low mean percentage covers of 6.3 % and 0.7 %, respectively, across the seafloor crater sites. The shell debris is considered to comprise at least two species of the Vesicomyidae family, which are common components of communities of sulphide-rich reducing environments such as hydrocarbon seeps (Krylova and Sahling 2010).

3.5 Summary

The low energy, soft bottom seafloor around the Scarborough Offshore Project Area supports sparse marine fauna as reported for the Exmouth Plateau. Sediments are calcareous, fine-grained and low in nutrients. Benthic communities are dominated by motile organisms, including shrimp, sea cucumbers, demersal fish and small, burrowing worms and crustaceans. No threatened species/ecological communities or migratory species were identified in the studies (as defined under the EPBC Act).

4 Continental Slope

Much of the following section has been adapted from the offshore marine environmental survey for the Pluto LNG development (SKM 2006) and supporting investigations such as the Pluto AUV/ROV survey conducted by Geoconsult (2005) and most recently by the ROV survey completed by the Ocean Affinity (2018).

4.1 Background

The Pluto field is located on the continental slope of the NWS, where the slope is at its narrowest.

Assessment of geophysical and ROV data confirmed that the Pluto field is traversed by several canyon systems as shown in Figure 4-1. The work area was located more than 200 km NW of Dampier off the NW coast of Australia and covered approximately 311 km^2 in water depths ranging from approximately 160m to 1220m.

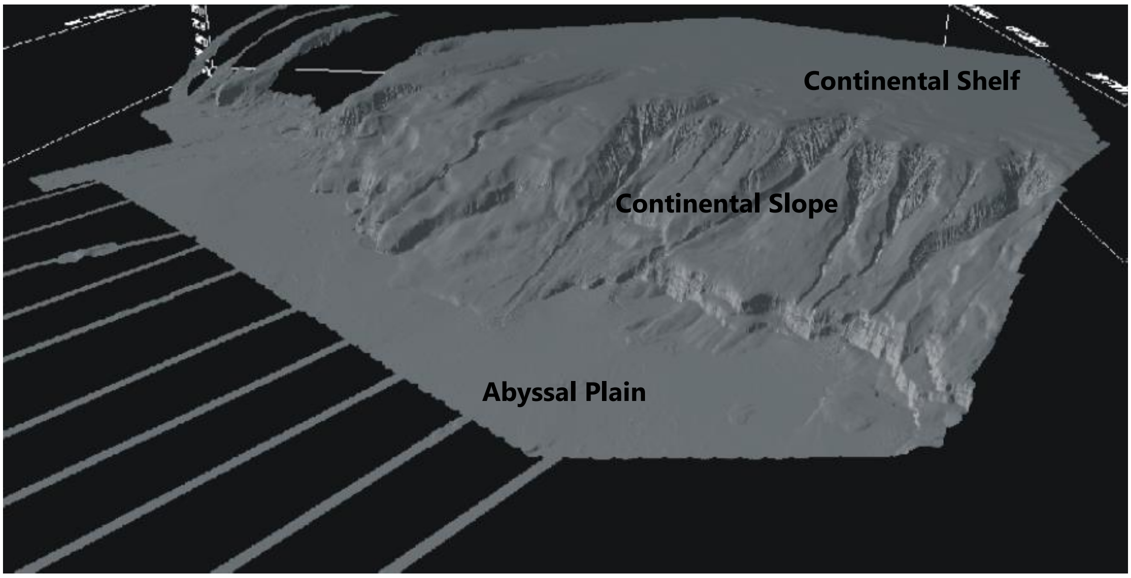


Figure 4-1 Continental slope adjacent to the existing Pluto field development

The Geoconsult (2005) report divides the Continental Slope into three sub-divisions, namely:

- Dendritic channel areas
- Channel areas
- Continental slope areas (between channels)

A total of six major and nine minor dendritic channel areas were recorded that are up to 200m deep and with gradients of 1:1. Major channels were well spaced through the site: in 300m to 750m water depth: between 500m to 1500m wide and up to 5km in length. The minor channels are prevalent in the southern half of the site: in 320m to 550m water depths: 500m to 900m wide and up to 2.4km in length. They are formed by the gradual erosion of the Continental Slope as numerous small, localised slumps, which trigger turbidity currents. It is suspected that dendritic channel areas act as a focus for seafloor currents. Sediments expected to comprise very soft sandy clay/silt.

Six major and nine minor complete channels were identified. Ten channels discharge sediment into the deeper water with the remaining minor channels discharging varying amounts of sediment on to the Continental Slope. Generally, they are between 15m and 300m wide, 5m to 150m deep with sidewall gradients of 1:1. The channels and their dendritic roots gradually erode the upper slope and transfer sediment to deeper water. Sediment is transported as local slumps and sediment flows and also as more extensive turbidity currents, which erode channel sidewalls and floors. Layered sediments in the base of channels document deposition following sediment flows. Plunge pools up to 230m wide and 20m deep have been observed. Channel sidewalls are susceptible to slumping and erosion.

The presence of sand in the channels has been confirmed by drop cores. Within the channel base current driven bedforms or erosive "back stepping" of bedding planes was observed. ROV stills show current driven bedforms and rounded cobble sized clasts and sediment clumps in the channel base. Channels are not only developed by seafloor currents but have in the past been conduits for large scale turbidity currents. Present day sedimentary processes are observed to be significant, with active seafloor currents.

The Continental Slope Area (between channels) undulates and deepens from the SE to the NW over a series of linear and steep scarps from water depths of ~250m to 1100m.

4.2 Survey Methods

4.2.1 SKM (2006) survey

The sampling programme was designed to collect representative biota across the outer shelf and slope habitats, to characterise species and habitat composition along a depth gradient down the slope (150 m, 200 m, 400 m, 600 m, 800 m and 1000 m). Sampling was conducted along two depth gradient transects, one transect orientate directly down a canyon system (referred to as canyon transect) and the second transect orientated down the continental slope outside of the canyon systems (referred to as slope transect).

The bathymetry of the canyon systems transecting the Pluto field include some very steep gradients, which suggests that the canyon systems could potentially contain some exposed hard substrate or cliff like structures. Surveys for the Vincent and Enfield fields, located near North West Cape, discovered rich and diverse epifaunal communities located on several rock outcroppings in 350–600 m water depth (Heyward and Rees 2001a and b; Heyward et al. 2001a and 2001b). In the absence of targeted geotechnical and geophysical data, the sampling strategy was focused on the seabed with the steepest gradients in the canyon systems. A total of twenty-eight sled tows were successfully completed by SKM (2006) across depths between 150 m and 800 m.

Over 40 hours of video of the seabed were collected by the ROV from depths ranging between 250 and 1050 m. While the majority of the seabed was composed of soft sediments, extensive video recording was collected of the steep cliffs located just below 1000 m and isolated pinnacles in the 300 m depth range.

4.2.2 Ocean Affinity (2018) survey

The purpose of this operation was to use a KD31 ROV to visually inspect points of interest (POI) along the base case route slope region that were identified during the geophysical survey and to revisit POI1 that was previously surveyed during the SKM (2006) ROV survey. The POI locations were identified following review of side scan sonar (SSS) and multi bean echo sounder (MBE) data collected during autonomous underwater vehicle (AUV) surveys as shown in Table 4-1.

Table 4-1 Positioning Details for Points of Interest Survey, (Ocean Affinity 2018)

POI	Easting	Northing	Depth (m)
1	310308	7798411	303
2	308721	7799862	454
3	309089	7800880	490
4	309498	7800578	422
5	309736	7800316	390
6	310145	7802325	450
7	311170.0	7796744	259

4.3 Results

4.3.1 Infauna

The infauna of the continental slope, (as based on data collected from the Pluto field) was very sparse with a maximum density of 167 individuals/m^2 from a sample collected in 400 m. Infauna was generally more abundant in sites located in shallow water, although this trend with depth was somewhat obscured because three samples contained no infauna, both samples from 800 m and one sample from 1000 m. A total of 47 individuals, representing 32 nominal species, were collected from the 12 samples. The fauna was dominated by polychaetes, which comprised 79% of the fauna by abundance and 75% of the fauna by species richness. Some crustaceans, sipunculids and nemerteans were also recorded but no molluscs or echinoderms were collected in any of the box core samples.

4.3.2 Epifauna

The sled catches varied between depths but were consistent across the two transects across the continental slope, inside and outside the canyon system.

Approximately 1200 specimens were collected from 25 sled shots. Cnidarians, mostly free-living deep water solitarily corals, were the most abundant phyla, followed by malacostracan crustaceans, mostly decapods, bony fish, and sponges. Together, these groups accounted for 70% of the fauna by abundance.

The fauna was most abundant along the 200 m contour but this was largely a result of the distribution of the free-living deep water, solitarily corals. Seventy percent of the corals collected occurred in samples collected from the 200 m sites. Crustaceans were most abundant at 400 m.

Commercial fishing for crustaceans (scampi, prawns) is concentrated between 200–400 m. Fish were most abundant in shallower water, particularly near the shelf break at 200 m depth. Sponges were most abundant in the deeper stations (600 m and 800 m). Ascidians were common in 150 m where one unidentified species was particularly abundant.

The Western Australian Museum (WAM) has identified the sponges, fish, molluscs, echinoderms, cnidarians and most of the crustaceans and made comparisons with existing deepwater collections. Five species of sponges, 45 species of fishes, 54 species of molluscs, 25 species of cnidarians, 34 species of echinoderms, and 50 species of crustaceans have been identified.

The WAM findings can be summarised as follows:

- Of the five species of sponges collected in the study, three belonged to the Class Demospongiae, which are shallow water sponges found at depths of 150 m or 200 m and two species belong to the Class Hexactinellida (glass sponges), which are deepwater species found at 600 m and 800 m. The glass sponges have a glass stalk holding the cup shaped sponge. The stalk is often covered in a cnidarian. No live sponges were collected from tows at 400 m.
- The fish species collected are typical of the area and depths with most of the taxa being deepwater representatives with tropical distribution.
- The echinoderm species belonged mainly to three classes, namely Asteroidea (seastars), Ophiuroidea (brittlestars) and Echinoidea (urchins), with only one species representing the class Holothuroidea (sea cucumbers). A number of animals could be identified to species level, with some of the identified species not previously recorded and many were not previously recorded in the area. Curiously, when compared to other recent sampling off the north west peninsula, several Asteriod genera found in similar water depths were absent in the Pluto samples. The Asteroid *Sidonaster waney* have not previously been recorded within Australian waters. Of the eleven Asteroid genera found, only 4 species could be identified to species level.
- The cnidarian species belonged mainly to the Family Nephtheidae and to a lesser extent the Family Alcyoniidae and Nephtheidae. Of the 41 cnidarian specimens, three specimens were black coral.
- The majority of the 50 crustacean species identified belonged to the Order Decapoda (48 decapods and two barnacles, Order Pedunculata). Most of the genera collected have been recorded previously from the deeper waters of Western Australia and all species were collected at depths typical for the species or genus. The material is mainly tropical with strong Indo-West Pacific affinities, particularly with the fauna of the Indo-Malayan sub-province, the area defined by the Indo-Malayan Archipelago, Australia and New Guinea to Japan. At the generic

level, the collection is comparable with material from similar depths in eastern Australian waters. The collection contains the first Australian records of *Raninoides hendersoni* Chopra, 1933 (Raninidae), *Mursia armata* de Haan, 1834 (Calappidae), *Polycheles coccifer* Galil, 2000 (Polychelidae), and *Eumunida (Eumunida) pacifica* Gordon, 1930 (Chyrostylidae). These species have known distributions in the Indo-Malayan sub-province of the Indo-west Pacific province. One species previously recorded in Australia from the east coast is recorded for the first time, *Conchoecetes artificiosus* (Dromiidae). A further two species, *Agonida* ? *eminens* and *A.* ? *incerta* (Galatheidae), are possible new records for WA but confirmation of their identifications is required. The specimens of the portunid crab *Charybdis (Charybdis) rufodactylus* represent the first record of the species outside of Queensland, Australia. The galitheid genus *Munidopsis* is also reported for first time from WA.

- Most of the 45 mollusc species had been previously recorded from western and northern Australian waters (WAM, January 2006), although some of the specimens in the collection belong to species that have been rarely collected for example, *Amoria diamantina*. Most molluscs occurred in depths of between 150 and 600 m. They represent 27 families, of which four are cephalopods, three are bivalves and the remaining 47 species are gastropods. The gastropods represented in this collection are mainly carnivores as would be expected from depths low in and below the photic zone. The broken shell of the sundial shell, *Discotectonica acutissima*, appears to be the first record for this species in Western Australian waters (WAM, January 2006). Of the cephalopods, those specimens identified as probably belonging to the genus *Mastigoteuthis* are the most noteworthy, being new to the collections of the Western Australian Museum. The actual depth at which the squids of the genera *Histioteuthis* and *Mastigoteuthis* were collected is doubtful as they swim in the water column, not on the substrate, and so must have been taken as the dredge was descending or ascending (Slack-Smith 2006).

4.3.3 ROV (SKM 2006)

The ROV recording was collected during December 2005 from five areas between 250 m and 1050 m depth (Figure 4-2). The soft sediments supported a very sparse coverage of epifauna overall but small areas supporting a higher density of epifaunal were also observed. The diversity of epifauna was far more limited overall than the diversity of fauna collected by the sled. Many tracks and marks were observed on the seabed through all depths but the fauna responsible for these tracks or living just below the sediment surface could not be identified. Only demersal species could be identified. The seafloor below about 800 m supported a similar fauna to that observed in shallow depths with mostly shrimps, batfish and holothurians observed. Glass sponges were noted to occur at high densities, particularly along the 750 m depth contour with an estimated density of 0.2 individuals/m^2.

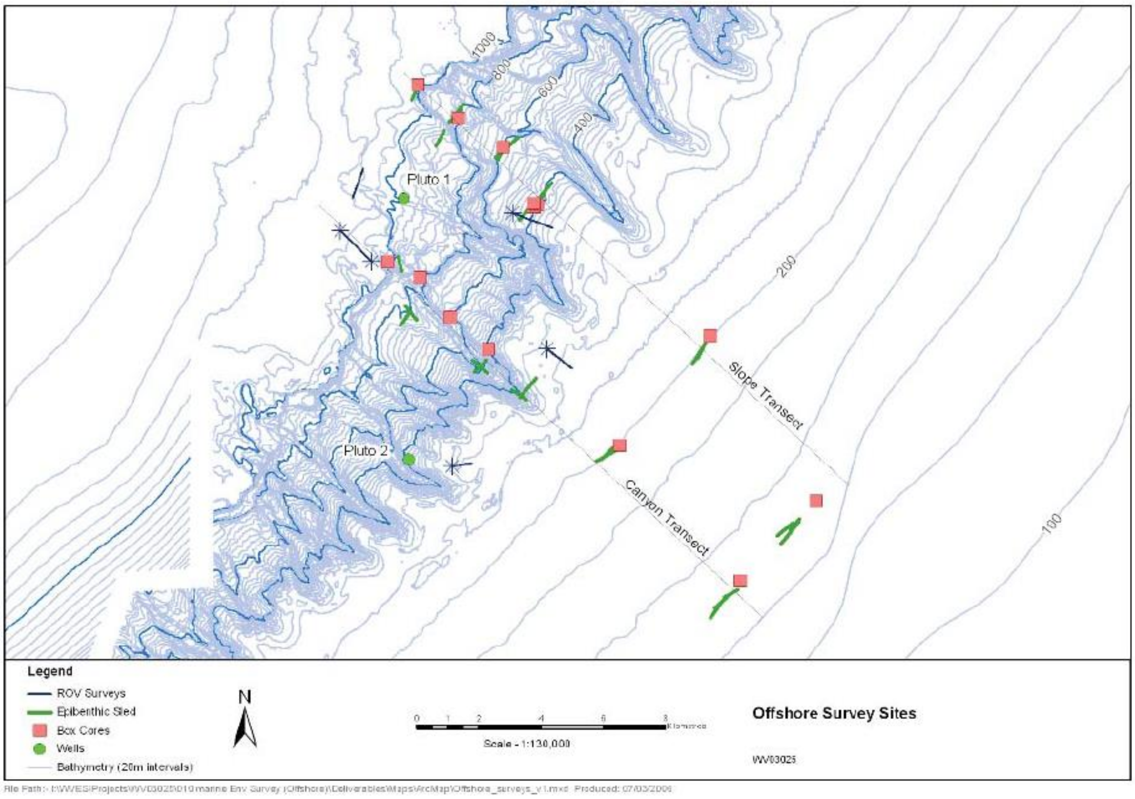


Figure 4-2 Location of Pluto field, showing ROV survey transects (from SKM (2006)

The majority of the substrate consisted of soft sediments, which were green, grey in colour below about 400 m and a light brown in shallower depths. Box core samples found the sediments to be silt below about 400 m and fine sand above this depth. Seabed gradients varied from flat to gradients in excess of 80°. Preliminary results from the geotechnical and geophysical survey of the Pluto field indicate that the seabed of the Pluto field is devoid of hard substrate except for two areas of seabed (M. Bowler [Woodside] 2006 *pers. comm*., January) which are particularly noteworthy.

Sea Cliffs

Preliminary results of the geotechnical and geophysical studies (completed during the Geoconsult 2006 survey), which commenced at the same time as the offshore environmental survey, indicate that the continental slope at the Pluto field is largely devoid of hard substrate exposed above the sedimentary seafloor. The main area of exposed hard substrate occurs in about 1000 m depth where the continental slope meets the abyssal plain (Figure 4-3).

Figure 4-3 Sea cliffs at the base of the continental slope where it meets the abyssal plain, (depth 1039-1045m)

The bottom of the rocky cliffs is situated in about 1050 m water depths with an almost vertical wall extending 20 m up to about 1030 m at the surveyed location. The rock appears to be sedimentary with clear bands or layers occurring in the rock profile. No epifauna was observed on the exposed rock. Where the seabed gradients are less steep, sediments accumulate and large anemones and batfish were observed. However, both the abundance and diversity of epifauna was limited in these rock areas, compared to the sedimentary seabed located above and below this area of rock cliffs. The size of the areas were not stated but were limited in size.

From about 1030 m to 880 m, rock and mud stone outcrops occur, interspersed with large areas of soft sediment which in places supported large numbers of glass sponges. Observations of the ROV's manipulator arm indicated that the mudstone was very soft, disintegrating very easily. The mudstone was quite flat in areas with limited vertical relief and the sediment build up on the exposed rock and mudstone minimal, which suggests that sediment movement down the slope is very limited and/or strong currents sweep away exposed sediments.

Rock Pinnacles

The only other exposed hard substrate known to occur in the Pluto field is a series of rock pinnacles located about 300 m water depth (Figure 4-4). Results from the geotechnical studies indicate that there are a number of these pinnacles present in a confined area along the 300 m depth contour. They are also described as "coral heads" as they up to 2.5 m in height and 6 m in diameter which often occur in over 10m deep scour depressions (Geoconsult 2005).

The pinnacles contain a very low percentage cover of live soft coral with only a few live specimens of soft coral observed growing on top of the pinnacles.

Figure 4-4 Rock Pinnacles, depth =297-299 m (Source: Geoconsult, 2006)

4.3.4 ROV (Ocean Affinity 2018)

A total of seven POIs were surveyed using ROV in July 2018 by Ocean Affinity. POIs 3, 4 and 5 were mostly flat, sandy seabed, whereas PO1 encountered some of the pinnacles previously described.

The original SKM (2006) survey incorrectly identified the the rock pinnacle structures as biogenic in origin having been created by the deep-water coral *Lophelia* (SKM 2005). The subsequent ROV survey, completed by Ocean Affinity (July 2018), collected much higher resolution imagery of the rock pinnacle field which were sent to Professor Murray Roberts (University of Edinburgh) for expert assessment. It was confirmed that the yellow corals which were originally identified as *Lophelia* were "at first glance *Dendrophyllia cornigera* (well known in the Mediterranean Sea), but perhaps more likely a Leptosammia species (same family: Dendrophylliidae)". It was also confirmed that there was no evidence of *Lophelia* sp. in the imagery that was reviewed (M. Roberts, pers. comm).

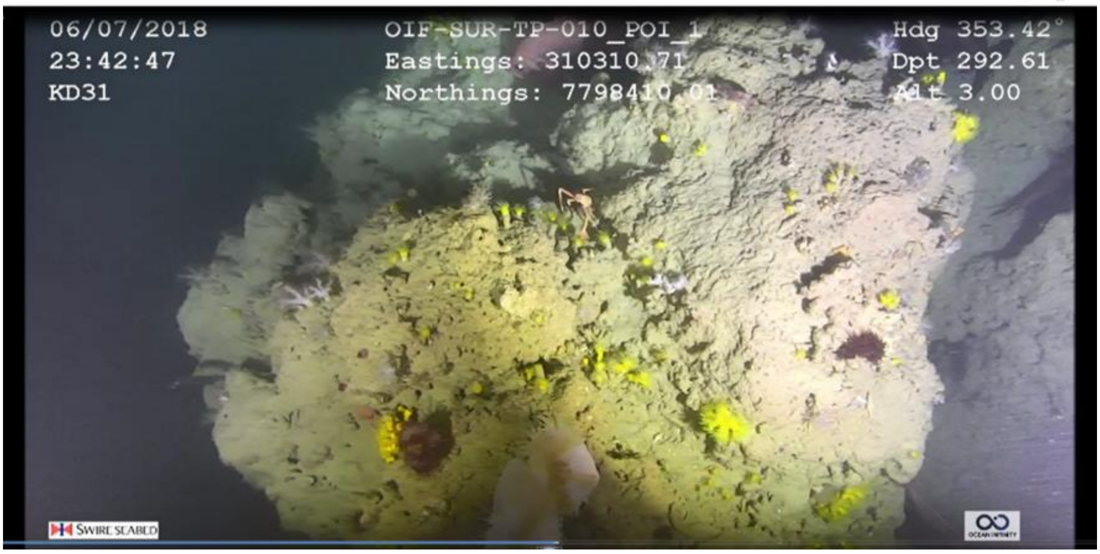


Figure 4-5 Rock Pinnacles at POI1, depth=292m, (Source: Ocean Affinity, 2018)

Figure 4-6 Dendrophyllids on rock pinnacles (POI1), depth = 295m, (Source: Ocean Affinity, 2018)

The pinnacles also provide structure for a diversity of fauna including fish and invertebrates. Many tens of fish were observed gathered around these pinnacles, most probably belonging to either the Glaucosomidae or Pricanthidae families. Crinoids, hydroids and ophiuroids were also common. Other species visible on the mounds include anemones, soft corals, small crustacean like shrimp and some larger brachyurans, possibly *Cyrtomaia suhmii* (Figure 4-7).

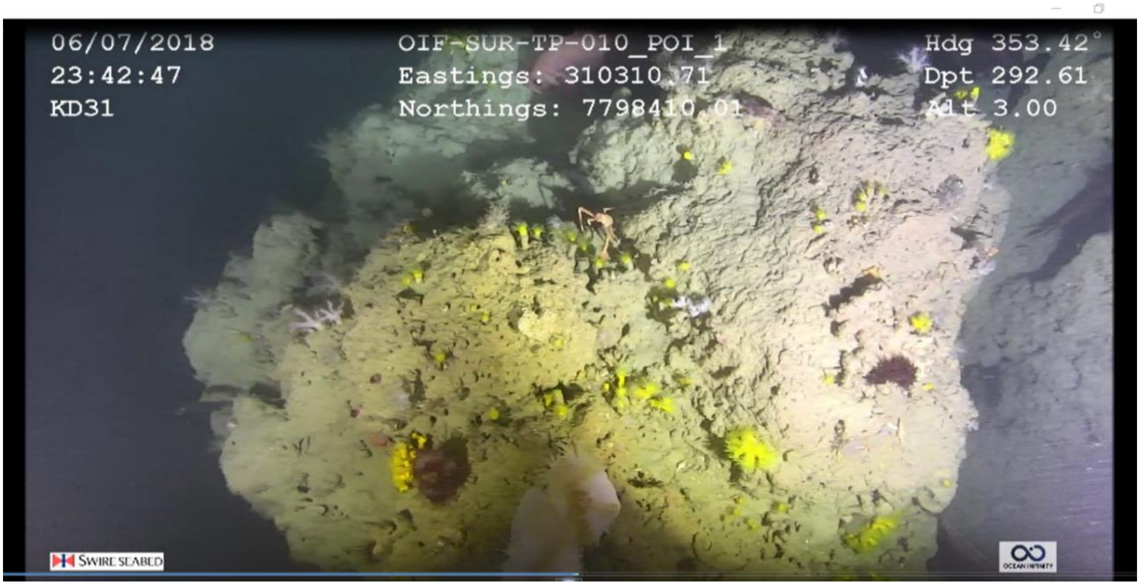
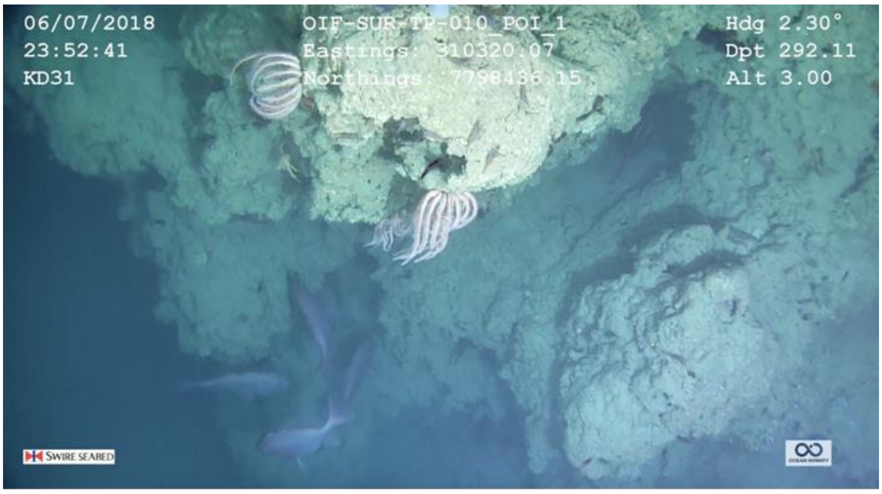
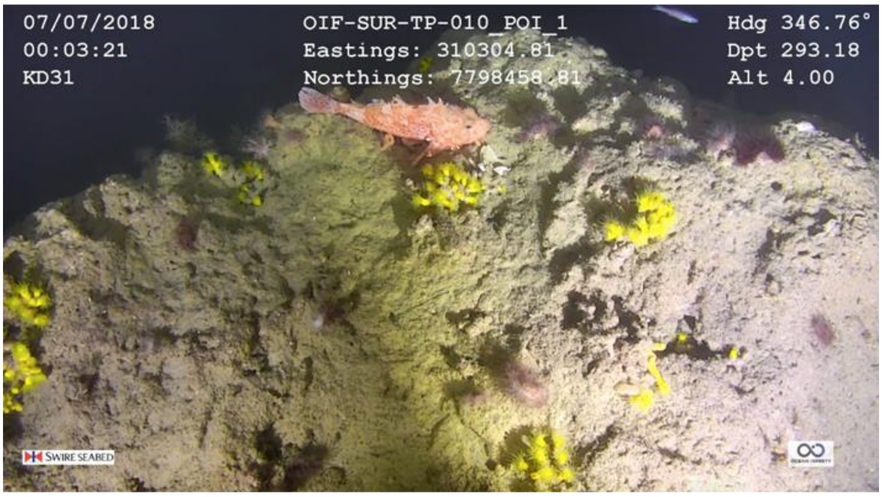


Figure 4-7 Rock Pinnacle (POI1), depth =292m, (Source: Ocean Affinity, 2018)





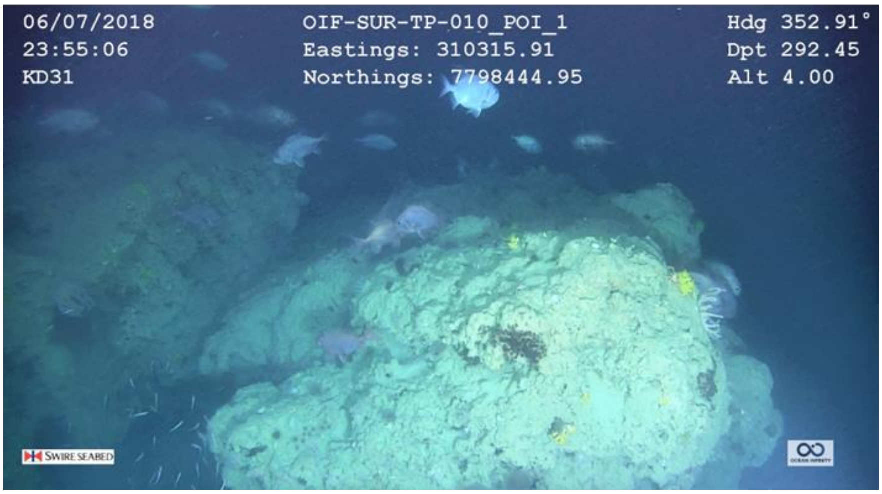


Figure 4-8 Rock Pinnacles from POI 1, showing fish depth =292m, (Source: Ocean Affinity, 2018)

Examples of the soft seabed from POI 3, 4 and 5 are shown in Figure 4-9.

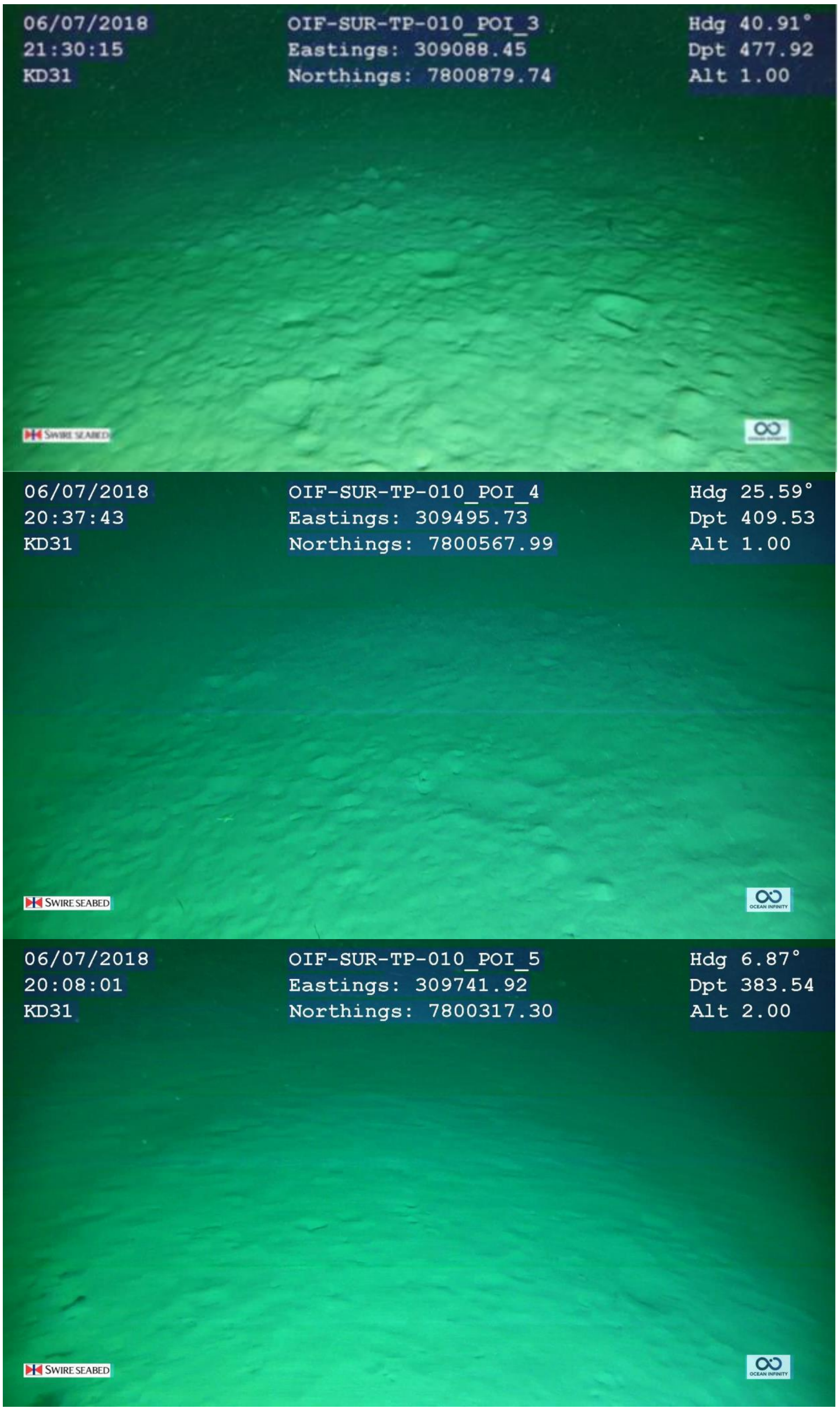


Figure 4-9 Soft sediment substrate at POI 3,4 and 5, depth 383-477m

The POI 2 was mostly soft sandy seabed, with one of the images capturing a solitary dory (Family Zeidae) close to the seabed (Figure 4-10). POI 6 was similar, with very little epifauna visible on the seabed. Species such as that shown in Figure 4-11 were uncommon.

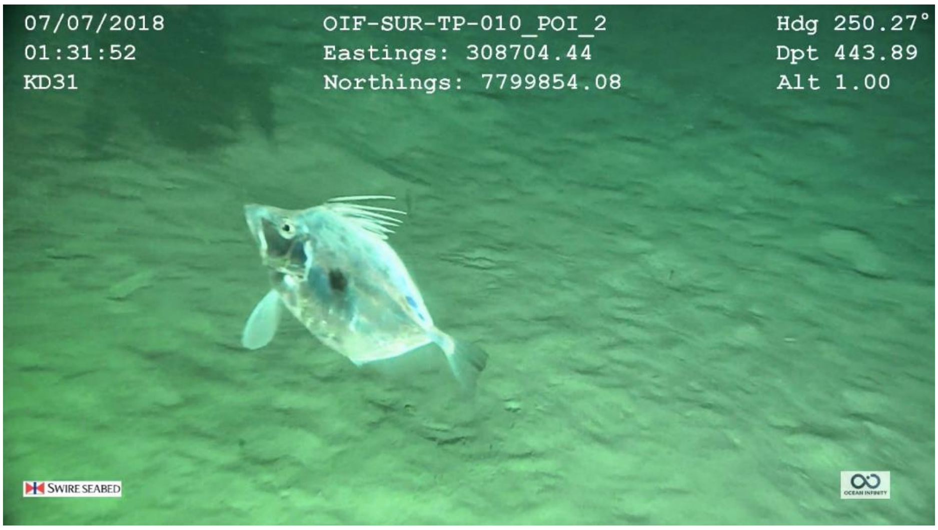


Figure 4-10 Dory, (Family Zeidae), depth 443m, POI2

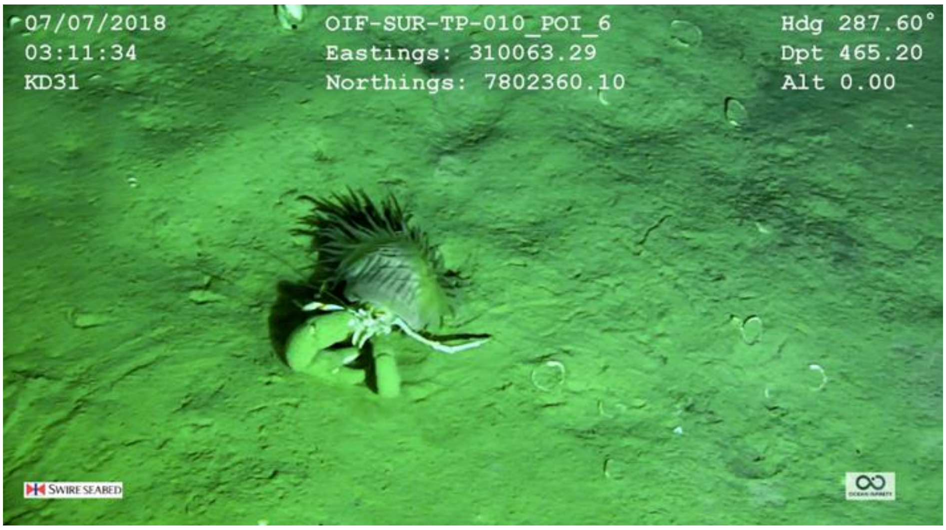


Figure 4-11 ?Opisthobranchia, depth=465m, POI6

All points of interest including the pinnacle field located at POI1 are shown in Figure 4-12. The ROV footage confirms that that the seabed along the trunkline alignment is entirely soft sediment benthos and that the pinnacles at their closest point are more than 350m away from the proposed trunkline alignment.

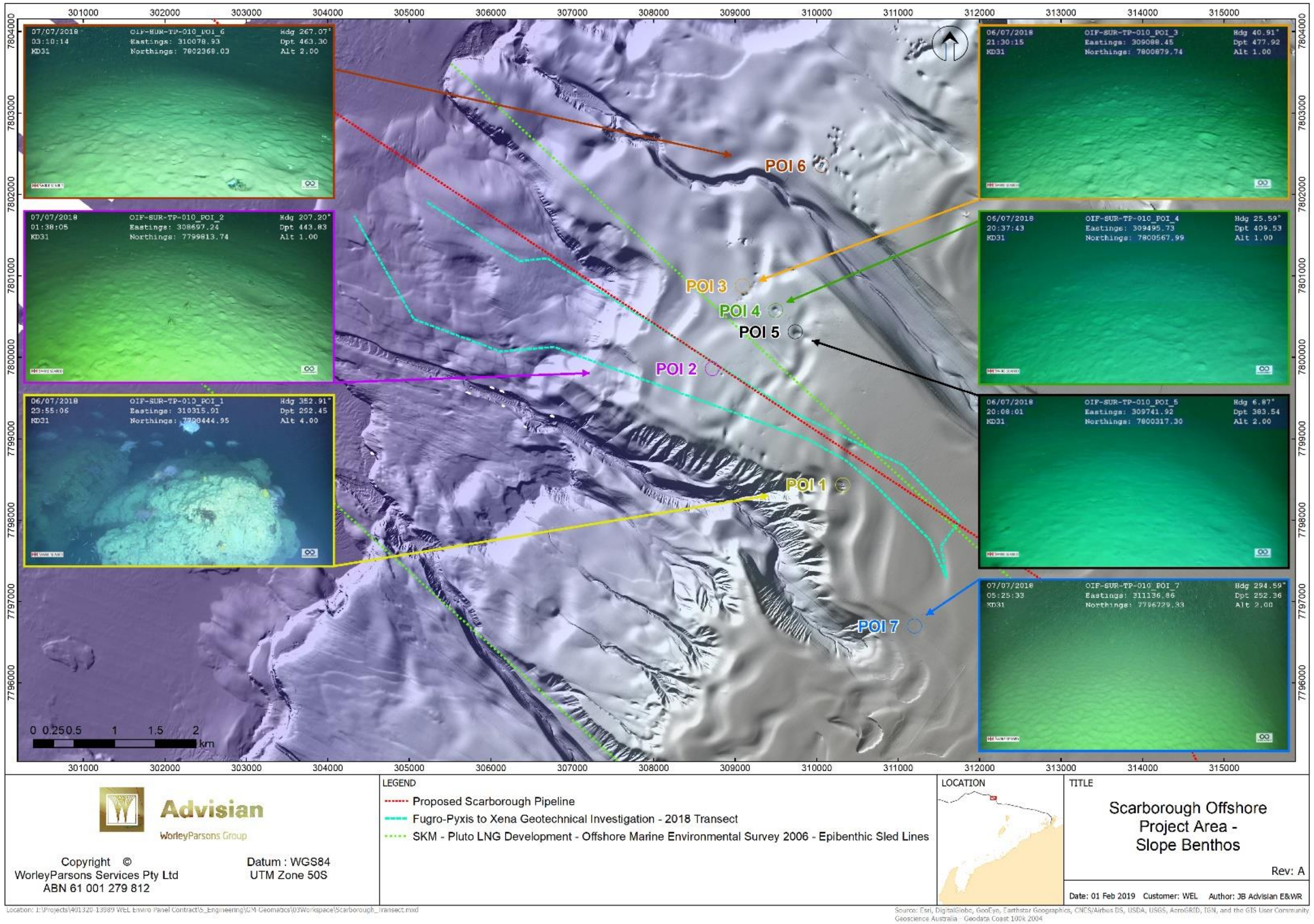


Figure 4-12 Points of Interest surveyed relative to proposed Scarborough trunkline, Continental Slope

4.4 Discussion

The greatest proportion of images analysed from around the Pluto field survey consist of soft sediments supporting a typically sparse deep-water fauna. The fauna was typical of the fauna expected on the North-West Shelf (NWS) and slope. A total of 231 epifaunal species and 32 infaunal species were identified during the SKM (2006) survey.

The infauna of the Pluto field was sparse but highly diverse (given the limited number of individuals collected). While a number of epifaunal species had not been recorded previously in Australia, Western Australia or the NWS region, this is attributed to the limited number of previous studies of the continental slope rather than the rarity of the fauna (SKM 2006).

Despite the limited distance between the Pluto and the Vincent and Enfield fields, the proportion of epibenthic species common to both fields was low. The distribution of fauna across the Pluto field differs to the patterns observed by AIMS during their recent studies around the Vincent and Enfield fields, where the fauna was patchily distributed and more strongly related to substrate type (rock outcrops *versus* soft sediments) than depth. The diversity of epifauna at Pluto was also lower than was observed in the AIMS studies off the North West Cape but this is largely attributable to the lack of rock outcrops in shallow water in the Pluto field.

While the majority of the Pluto field seabed was comprised of soft sediments, geotechnical data indicated the presence of a pinnacle field located in about 300 m depth. The pinnacle field covers an area that is less than $3km^2$ and consist of solitary outcrops rather than continuous reef. It remains unclear what the rock pinnacles are constructed from, however the structures provide habitat for a diverse suite of epifaunal and demersal species, including fish that are not usually found on the soft sediments.

4.5 Summary

The fauna observed was consistent with what would be expected to be found at the surveyed depths on the North West Shelf. The distribution of fauna across the Pluto field differs to the patterns observed by AIMS (Heyward and Rees 2001a and 2001b; Heyward et al. 2001 and 2001b) during historical studies around the Vincent and Enfield fields, off North West Cape. AIMS observed that the fauna was patchily distributed and more strongly related to substrate type (rock outcrops versus soft sediments) than depth. At Vincent and Enfield, the highest diversity of fauna was found on exposed rock outcrops. Preliminary geotechnical and geophysical data suggests that hard substrate is limited in the Pluto field. ROV recordings also indicate that the hard substrate located around 1000 m does not support a rich epifaunal community. The depth of water and sediment movement over the near vertical walls of the hard substrate may be the factors limiting the development of a rich epifaunal community (SKM 2006).

Despite the lack of similarities between the fauna in the collections made at Vincent-Enfield and the historical survey at the Pluto field, which are separated by less than 300 km, the Western Australian Museum researchers indicated that the species recorded from the Pluto field are representative of the area and collection depths with most species having been collected previously.

5 Continental Shelf

5.1 Background

The assessment of the offshore habitats that occur on the continental shelf (<300m water depth), have been based on ROV footage collected as part of subsea facility inspections around the Pluto field within Permit Area WA-34-L and WA-48-L. Whilst the Pluto platform itself is located within WA-48-L, in 83m water depth, much of the subsea infrastructure including pipelines and wellheads are in WA-34-L in ~190m water depth. The seabed composition through these areas has been previously described as being predominantly flat and featureless and comprises thick, unconsolidated fine grained sands. The sediments support soft sediment benthic communities dominated by infauna (including molluscs, crustaceans and worms) and isolated larger fauna (free swimming cnidarian, demersal fish and benthic crustaceans).

5.2 Survey Method

A total of 56 ROV video records from several subsea inspections were used as a basis for assessment. These included a review of footage from the following locations:

- Xeres-1A Well Head, (depth ~190m)
- Pluto Frond Mats (2015-2017), (depth ~170m)

5.3 Results

5.3.1 Xeres Well Head

The footage from the wellhead confirms that the seabed is comprised of soft unconsolidated sediments, possibly fine sand silts (Figure 5-1). The well head structure provides hard substrate for the colonisation by a range of invertebrates such as barnacles, hydroids and anemones. The structure in turn provides habitat for a range of fish species, as shown in Figure 5-1.

Figure 5-1 Schools of fish, Xeres Well Head, Depth 188m

5.3.2 Pluto Frond Mats

The footage from the annual surveys of the Pluto frond mats also confirms that the seabed surrounding the pipeline is comprised of soft unconsolidated sediments that is mainly fine sand (Figure 5-4, Figure 5-5, Figure 5-5).

Figure 5-2 Pipeline showing sandy substrate in the foreground, Pluto, depth =179m

5.1 Discussion

Epifauna was observed to be most abundant on the continental shelf (150–200 m) and the abundance of the fauna appeared to be inversely associated with depth, with distinct differences in the fauna on the Shelf and slope (SKM 2006). However additional analysis of the proposed trunkline route shows the pipelines and wellheads offer significant areas of hard bottom habitat in a region that is characterised by soft unconsolidated sediments. Figure 5-3 provides a snapshot of images from the ROV locations surveyed relative to the trunkline alignment. Due to the uniform nature of the seabed across much of this area of shelf (as also confirmed by regional geomorphological mapping, refer to IMCRA 4.0), the ROV locations are considered representative of the larger project area and have been used to confirm that the trunkline route over the entire section of seabed is likely to be dominated by sand and other sediment types.

It is the pipeline itself that provides hard substrate for the establishment of a habitat that supports a diversity of species that includes invertebrates and fish. The images within Figure 5-4 and Figure 5-5 show how cover by species can also vary. The most common forms present include barnacles, sea whips (Octocorals), anemones, hydroids and to a lesser extent sponges and crinoids. The type and number of fish present is also highly variable and also depends on the relative position of the pipeline above the seabed. Partially buried pipelines do not appear to provide the same habitat complexity and opportunity that suspended or resting pipelines provide (McLean *et al*. 2017).

Fish assemblages and colonising invertebrate habitats on these artificial hard substrates also vary with depth and age. Generally speaking, the structures that are located in shallower water (<135m) had a greater diversity of fish compared to habitats at 350m depth where the number of fish species and abundance declined markedly (McLean *et al*. 2018). The study by Bond (*et al*. 2018) also confirmed that compared to adjacent natural seabed habitats, pipeline fish fauna were characterised by higher relative abundance and biomass of commercially important species.

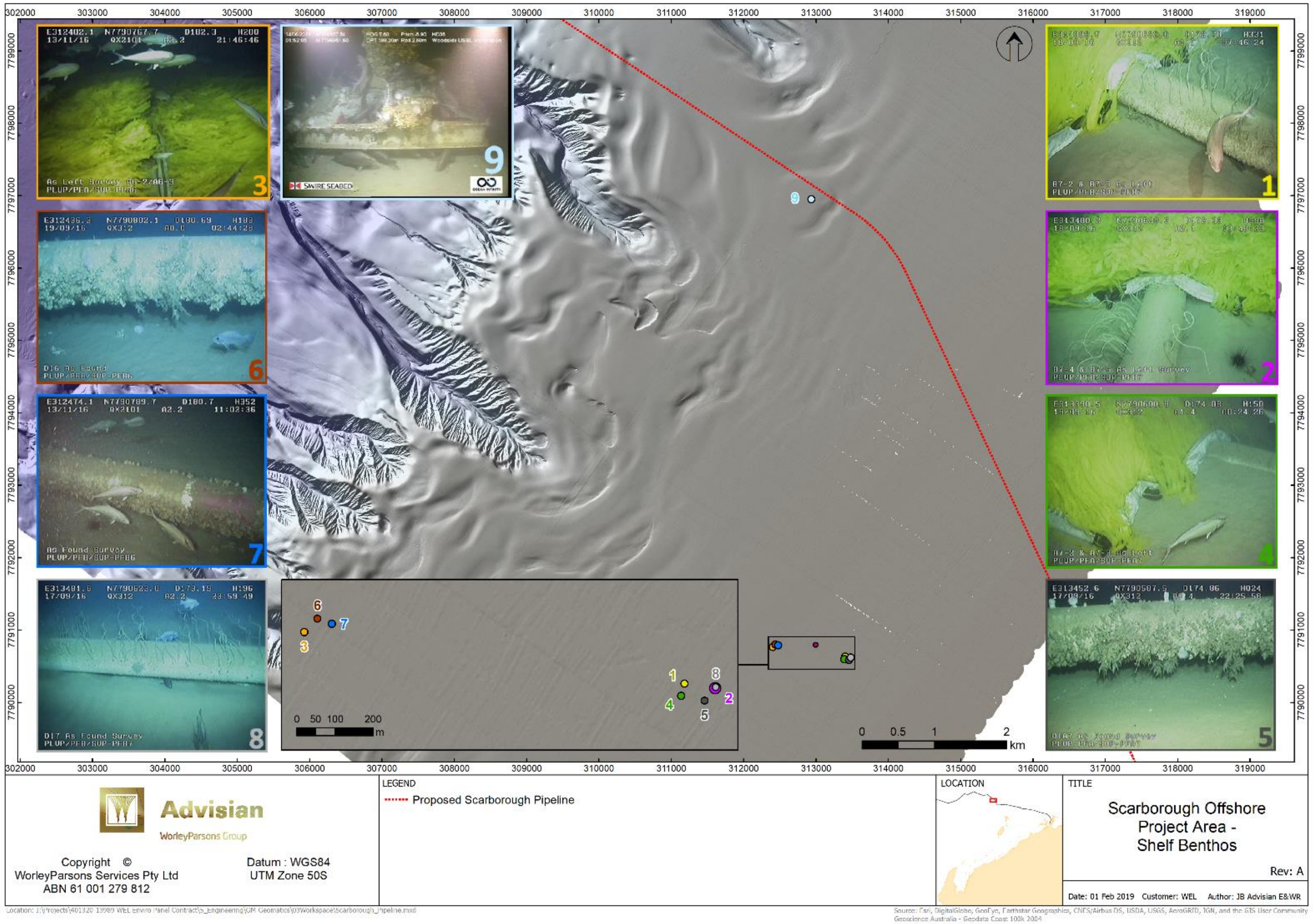


Figure 5-3 ROV survey locations, Continental Shelf

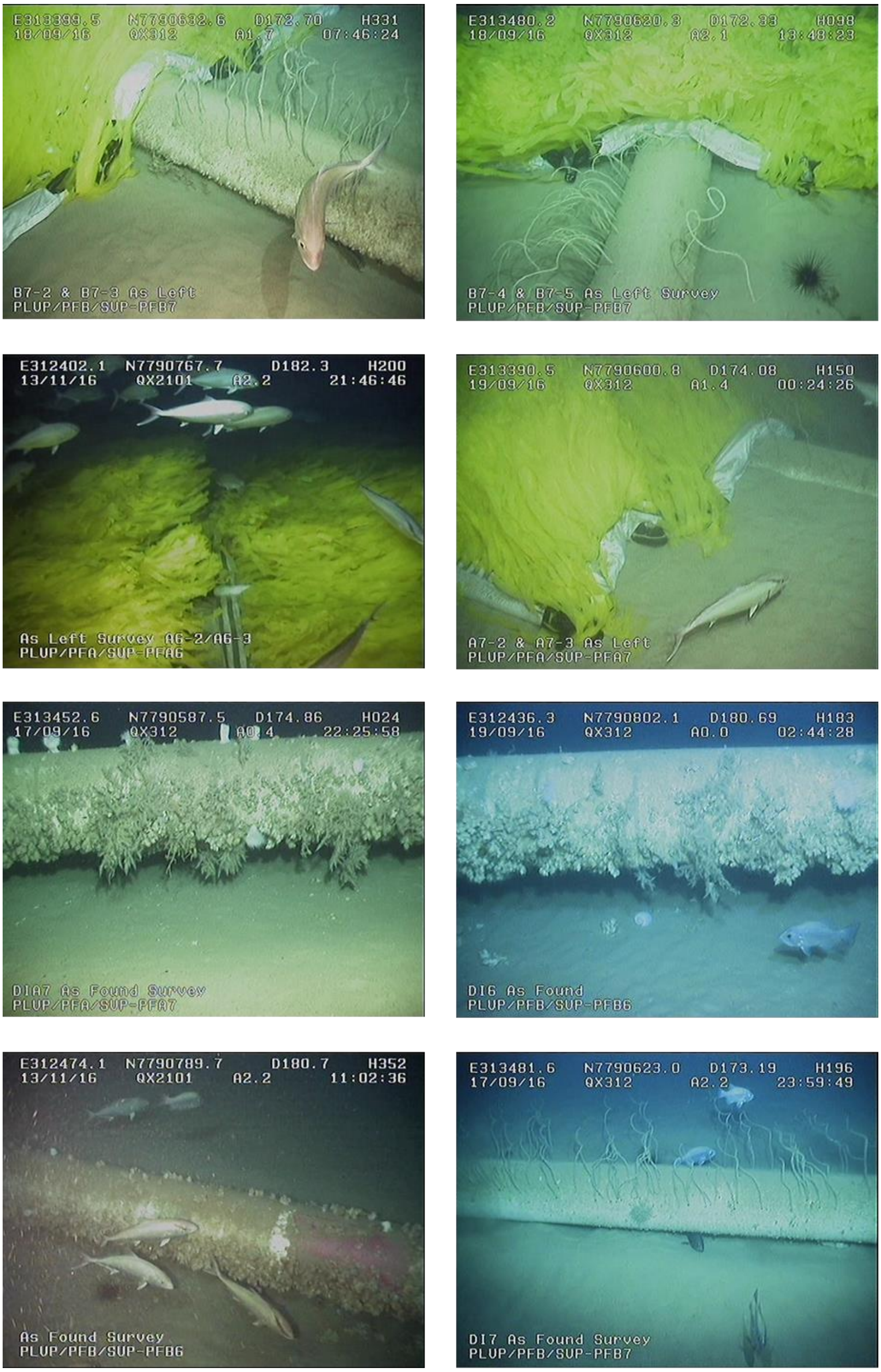


Figure 5-4 Pluto Frond Mats, 2016 Survey, Depth ~170m

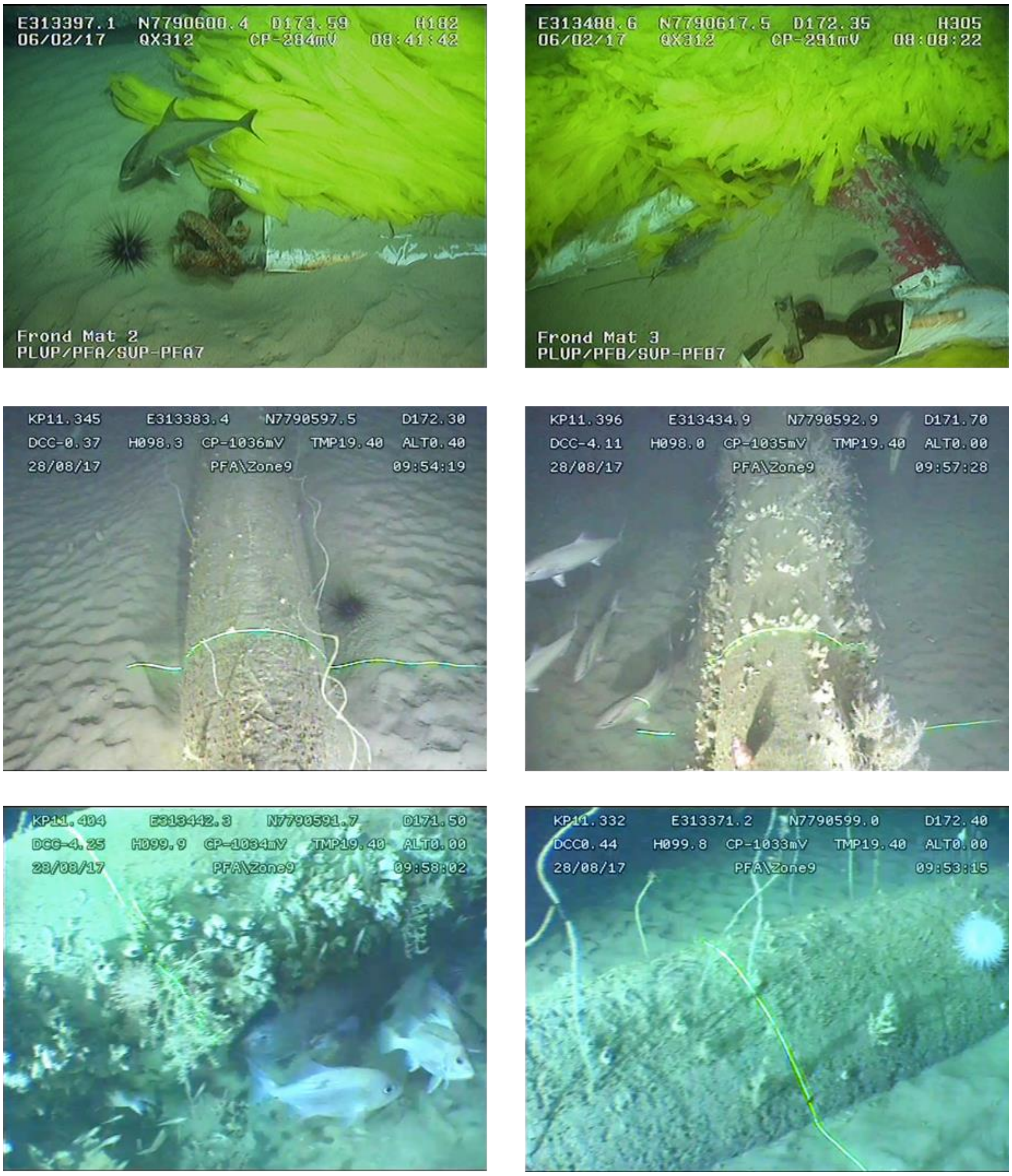


Figure 5-5 Pluto Frond Mats, 2017 Survey, Depth ~170m

6 Conclusions

Regional studies and the site specific studies reviewed indicate that seabed material along the proposed pipeline alignment (and around the gas field) is predominantly flat and featureless and comprises thick, unconsolidated fine grained sands. The sediments support soft sediment benthic communities dominated by infauna (including molluscs, crustaceans and worms) and isolated larger fauna (free swimming cnidarian, demersal fish and benthic crustaceans).

Sedimentary infauna associated with soft unconsolidated sediments of the general area is widespread and well represented along the continental shelf and upper slopes in the NWS region (Woodside 2004; SKM, 2007; Brewer *et al.,* 2007; RPS, 2011). Consequently, in the context of the contiguous extent of habitats across the region, benthic habitat along the proposed pipeline alignment consists primarily of soft unconsolidated sediments and is considered to be of relatively low environmental sensitivity.

Benthic communities of filter feeders generally live in areas that have strong currents and hard substratum (CALM, 2005) and are closely associated with substrate type, with areas of hard substrate typically supporting more diverse epibenthic communities (Heyward et al., 2001). The only natural habitat that is not classified as soft sediment is the pinnacle field that lies in about 300m water depth, on the continental slope. The pinnacle field covers an area less than $3km^2$ but the pinnacles are isolated forms and do not constitute continuous reef. It remains unclear what the pinnacles are constructed from, however the structures provide habitat for a diverse suite of epifaunal and demersal species that commonly occur elsewhere in the NWS.

Recent research has also confirmed that habitats containing the greatest biodiversity in these offshore environments are the habitats formed by colonising invertebrates on oil and gas subsea infrastructure including the well heads and pipelines. These habitats and the species present on these structures in the NWS of Western Australia have been subject to detailed assessment by McLean *et al.* (2018), Bond *et al*. (2018) and McLean *et al*. (2017). These habitats not only have structural complexity but also create habitat for a large diversity of fish species that commonly occur elsewhere in the NWS but do not occur over soft unconsolidated sediments.

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Appendix B

Dampier Archipelago Commonwealth Waters Marine Benthic Habitat Survey

Dampier Archipelago

Commonwealth Waters Marine Benthic Habitat Survey

18 January 2019

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Australia

401012-02612-EN-REP-0001

Advisian
WorleyParsons Group

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Disclaimer

Project No: SPA-ENG-00-EN-REP-0001 – Dampier Archipelago: Commonwealth Waters Marine Benthic Habitat Survey

Rev	Description	Author	Review	WorleyParsons Approval	Date
A	Issued for Client Review	A Lemmon	H Houridis	P Nichols	18/01/2019
0	Issued for use	A Lemmon	P Raitt	P Nichols	18/04/2019
1	Updated with client comments and issued for use	A Lemmon	P Nichols	P Nichols	13/02/2019
2	Further client comments addressed - issued for use			P Nichols	18/04/2019

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Executive Summary

The Scarborough gas resource is located approximately 375 km west-north-west off the Burrup Peninsula and is part of the Greater Scarborough gas fields which are estimated to hold 9.2 Tcf (2C, 100%) of dry gas. Woodside is proposing to develop the Scarborough gas resource through new offshore facilities connected by an approximately 430 km pipeline onshore. The proposal is to initially develop the Scarborough gas field with wells, tied back to a semi-submersible floating production unit (FPU) moored in 900 m of water close to the Scarborough field. This report has been developed in support of environmental approvals associated with the Scarborough Project.

As part of the trunkline installation, Woodside is assessing the feasibility of using backfill material from a potential borrow ground that has been identified in Commonwealth Waters. The potential borrow ground is located adjacent to the north-western extent of the habitat protection zone of the Dampier Marine Park. A benthic habitat survey of the potential borrow ground and surrounding areas within the Dampier Marine Park was commissioned (this study) to support the environmental impact assessment of the intended activities.

Surveys of marine benthic habitat of the potential borrow ground and nearby areas within the Dampier Marine Park were undertaken between 18th and 20th December 2018. This report presents the methodology and results from the survey.

Bare sandy substrate dominated most of the locations where towed/drop camera transects were conducted. Where biota was observed, it typically consisted of invertebrates such as anemones and crinoids at densities no greater than 10% and typically less than 5% cover. Of the 24 survey locations within the potential borrow ground, sparse invertebrate cover was observed at only two locations. Of the 51 survey locations within the habitat protection zone of the Dampier Marine Park, sparse invertebrate cover was observed at 12 locations.

1 Introduction

1.1 Project Background

Woodside is assessing the feasibility of using backfill material from a potential borrow ground in Commonwealth Waters. The potential borrow ground is adjacent to the north western extent of the Dampier Marine Park (DMP). The area of the DMP that is adjacent to the potential borrow ground is an International Union for Conservation of Nature (IUCN) Protected Area. It has been attributed Category IV status, which has the primary objective to maintain, conserve and restore species and habitats. An understanding of benthic communities at and surrounding the potential borrow ground is required to help inform the impact assessment for the intended activities associated with using the potential borrow ground.

This report presents the methodology and reports the findings of the benthic habitat survey that was undertaken in December 2018 at the potential borrow ground and adjacent areas within the DMP.

1.2 Scope of Work

The primary aim of the Commonwealth Waters survey was to gather information to support an environmental impact assessment of using the proposed borrow ground. The survey was completed to acquire qualitative data on species present, and to report on the presence of sensitive benthic biota or habitat near the proposed borrow ground and the adjacent DMP.

1.3 Survey Location

The potential borrow ground is located directly north of the western extent of the DMP, about 9 km north of the north-western extent of Legendre Island, outside the Dampier Archipelago (Figure 1-1).

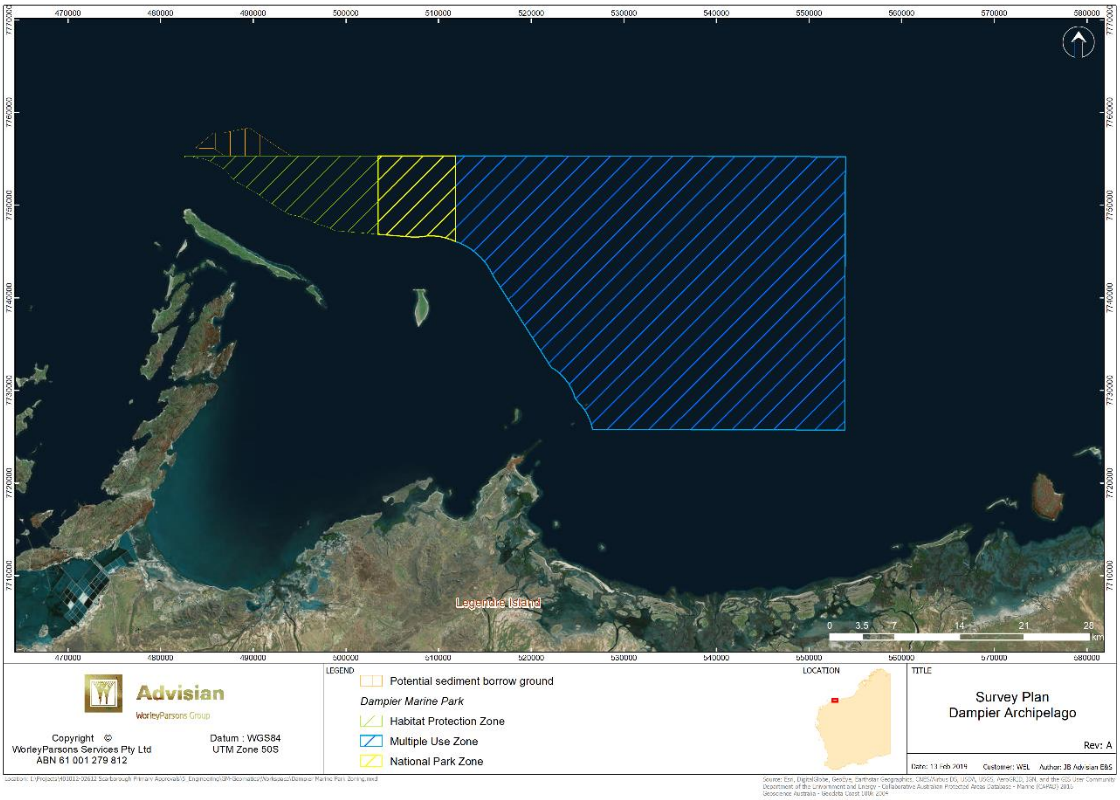

Figure 1-1: Survey location showing potential borrow ground and adjacent section of Dampier Marine Park

1.4 Previous Knowledge

The Marine Park was proclaimed in December 2013, though has been known as Dampier Marine Park since October 2017. DMP is significant because, as a whole, it provides protection for offshore shelf habitats adjacent to the Dampier Archipelago, the area between Dampier and Port Hedland and a seafloor rich with sponges (DNP, 2018). The habitat protection zone adjacent to the potential borrow ground is allocated Category IV Protection as it provides important habitat for benthic communities in the region. Previous knowledge of the benthic habitats and communities of the survey location includes a study by the CSIRO (Pitcher *et al* 2016), which covered an extensive area of the west Pilbara describing benthic habitats and categorizing the assemblages' present. The survey location appears to be on the outer fringes of the CSIRO study. Bathymetric information was limited to nautical charts of the region.

2 Methods

2.1 Survey Design

To optimise the field campaign, survey locations for video and still images were positioned to target the potential borrow ground and surrounding area (Figure 2-1). A 5km buffer was applied to the potential borrow ground to define the survey area in the Dampier Marine Park.

Existing historical data was not available to assist with directing survey effort. To maximise spatial coverage over this area in the available timeframe, a 1 km grid survey pattern was applied. Locations within the potential borrow ground and locations in the DMP closest to the potential borrow ground, were prioritised.

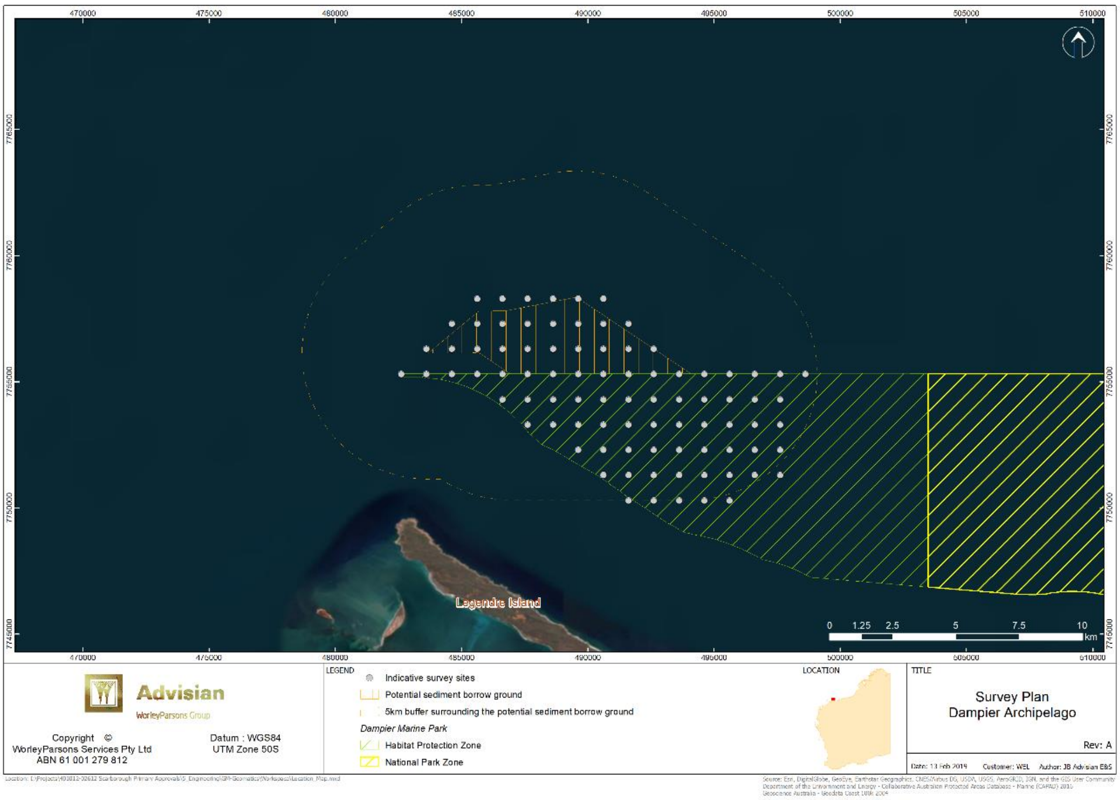

Figure 2-1: Survey sites planned in Commonwealth Waters at the potential borrow ground and Dampier Marine Park

2.2 Field Survey

The field survey was undertaken onboard the vessel *Kaelani*, operated by Bhagwan Marine, between 16th and 20th December 2018. A total of 24 transects were completed within the potential borrow ground and a further 51 transects were completed within the DMP during the survey. Transects varied in length from 30 m to about 230 m, though were typically around 100 m (Figure 2-2). The planned survey locations at the southern extent of the DMP were unable to be surveyed due to time constraints. Habitat data was obtained using a towed/drop camera array including digital recordings of high resolution still photographs and high definition video footage. When possible, real-time standard definition footage was observed by an attending marine scientist on the vessel. Preliminary qualitative habitat information was recorded into log sheets for subsequent review. Information recorded to the log sheet for each transect included:

- transect number (identifier)
- time of transect data collection (start/end) and observed changes of habitat
- dominant benthic habitat (substrate type and biota density)
- approximate depth (as measured by the vessel echo sounder)
- general comments relating to each transect.

Spatial positioning data was acquired using a Garmin GPSMap 62 and a Holux RCV-3000 located onboard the vessel. Two units were used for redundancy. The global positioning system (GPS) units recorded a tracklog for each day of operation and were time-synchronised with the laptops and cameras used to record habitat data.

At each survey location the camera array started recording on the deck of the vessel, where information about the transect and location was recorded before the array was deployed. Once the camera array reached the seabed, the vessel was allowed to drift for two to three minutes, depending on the rate of drift. When real-time viewing was available and more complex habitat was observed, or bathymetry was more variable, the transect/drift was allowed to proceed for a longer period but capped at around five minutes for operational efficacy. The typical drift speed was between 0.5 and 1.7 knots according to the vessel chart plotter.

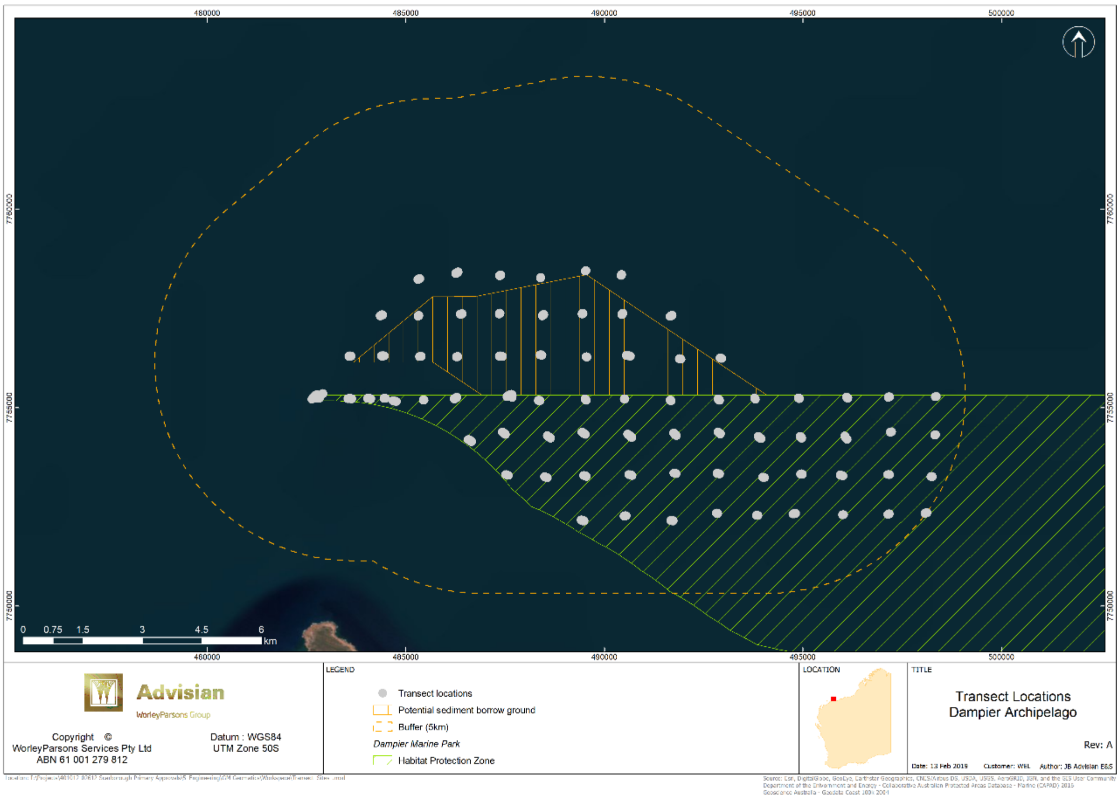

Figure 2-2: Benthic habitat transects conducted in Commonwealth Waters at the potential borrow ground and Dampier Marine Park, December 2018

2.3 Benthic Habitat Characterisation

High level habitat classes were derived from a benthic habitat map of the Dampier Archipelago by MScience (2018). These classes were refined based on habitats and biota observed during the survey (Table 2-1). The video footage and still imagery was reviewed after the field survey was complete, to confirm habitat classifications and to refine spatial data where necessary by improving time logs of habitat boundaries and transect start/end points. Where habitat boundaries or changes in epibenthic density were different to the initial logs, the elapsed time in the video was applied to determine the time and relative spatial position for the particular attribute and a new revision of the log was created.

Habitat information was georeferenced by relating the times recorded on the log sheets with the position logged by the GPS onboard the vessel. Position information was logged by the Holux GPS each second. For each spatial position received, the relative habitat information was attributed to create habitat point data of the areas surveyed.

Habitat point data was imported into ArcMap geographical information systems platform to create Esri shape files and to be displayed with other relevant spatial data for presentation in this report.

Table 2-1: Habitat classification scheme utilised for the survey

Habitat Class	Definition
Coral	Hard coral communities dominate and were present in ≥10% cover. Some minor biota may be present (i.e. ascidians, bryozoans and sponges); however, they are secondary in density and ecological function. No coral was observed along any of the survey transects.
Algae	Macroalgae were the dominant biota (≥10% cover) over a consolidated hard substrate that may contain sparse (≤10%) secondary biota (i.e. solitary corals or seagrasses). No macroalgae or seagrass was observed along any of the survey transects.
Invertebrates	Sessile and mobile benthic invertebrate biota (including crinoids, ascidians, hydroids and sponges) were present (≥3%) on sandy substrate with little or no other biota. Both sessile and mobile invertebrates were observed along survey transects. Example images are supplied in Figure 2-3.
Bare Sediment	Substrate is predominantly bare sand. Biota is very sparse (≤10% cover of macroalgae or coral and ≤3% invertebrates) or entirely absent. Bare sediment was the dominant habitat class in the survey transects. Example images are supplied in Figure 2-4.

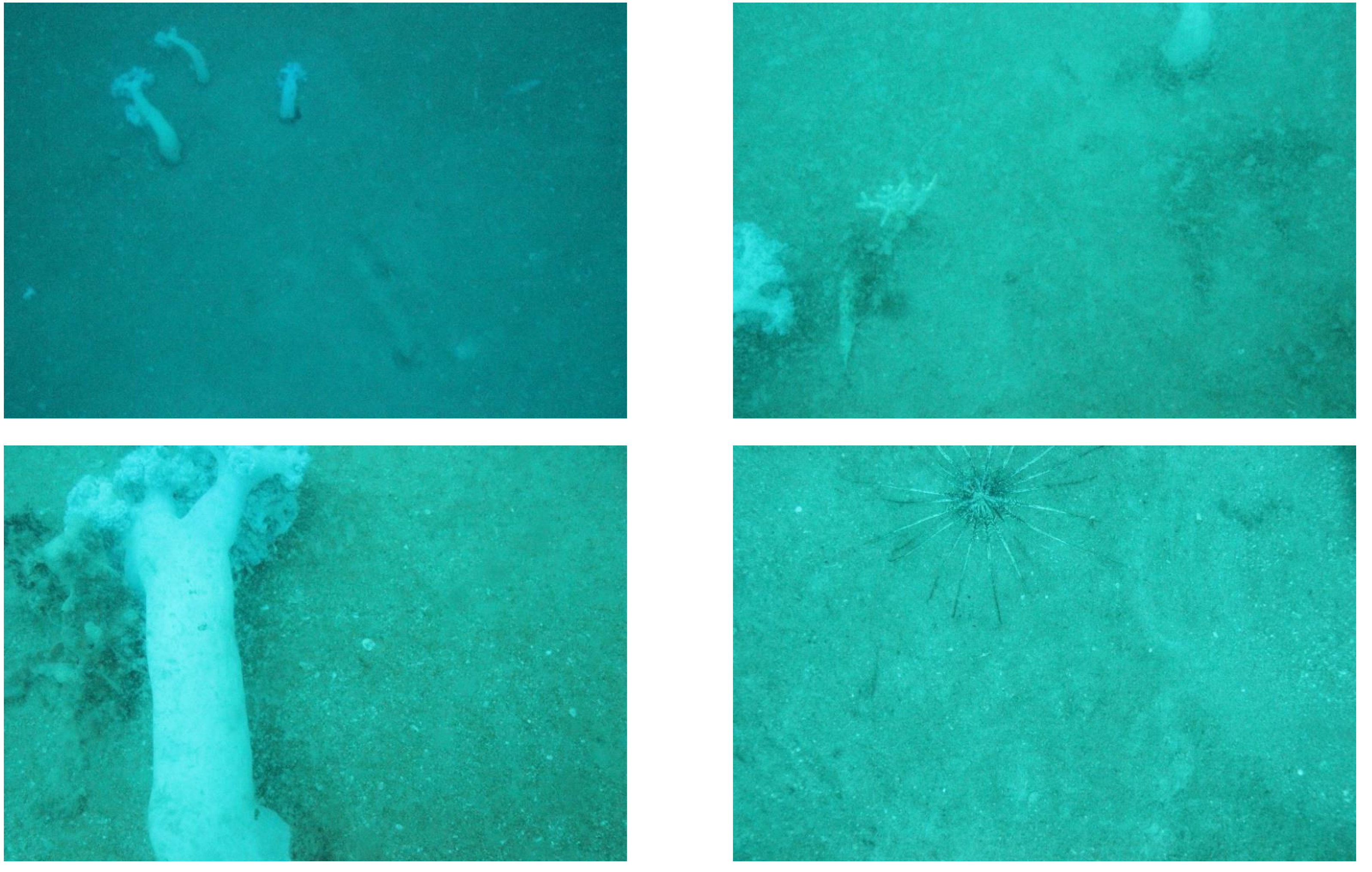

Figure 2-3: Examples of typical habitat classified as Invertebrates

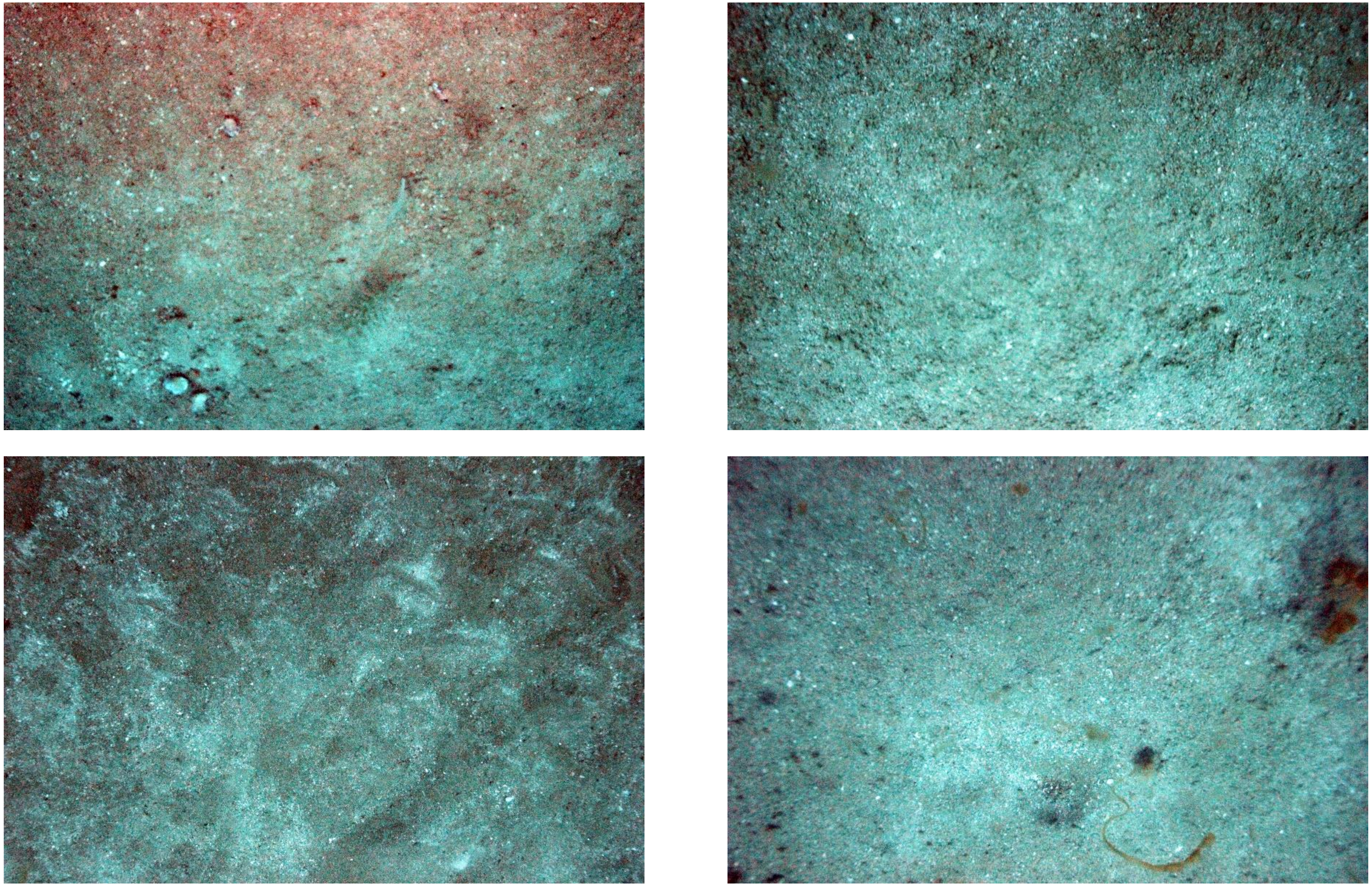

Figure 2-4: Examples of typical habitat classified as Bare Sediment

3 Results

3.1 Benthic Habitat

At the proposed borrow ground bare sandy substrate dominated areas where towed/drop camera transects were conducted. Where biota was observed, it typically consisted of invertebrates such as anemones and crinoids at densities no greater than 10%. Of the 24 survey locations, invertebrates were observed at only two (Figure 3-2 and Figure 3-3). Most transects were conducted in depths between 40 m and 42 m. Four transects were conducted in water depths between 37 and 40 m.

Like the potential borrow ground, bare sandy substrate dominated areas where towed/drop camera transects were conducted in the Dampier Marine Park. Where biota was observed, it typically consisted of invertebrates such as anemones and crinoids at densities no greater than 10%. Of the 51 survey locations, sparse invertebrate cover (3–10%) was observed at 12 of them (Figure 3-4, Figure 3-5 and Figure 3-6). Bathymetry was more variable within the marine park survey area, ranging from 31 m to 43 m. No particular association between habitat and depth is evident based on this data.

Figure 3-1 displays the general location of each the subsequent figures.

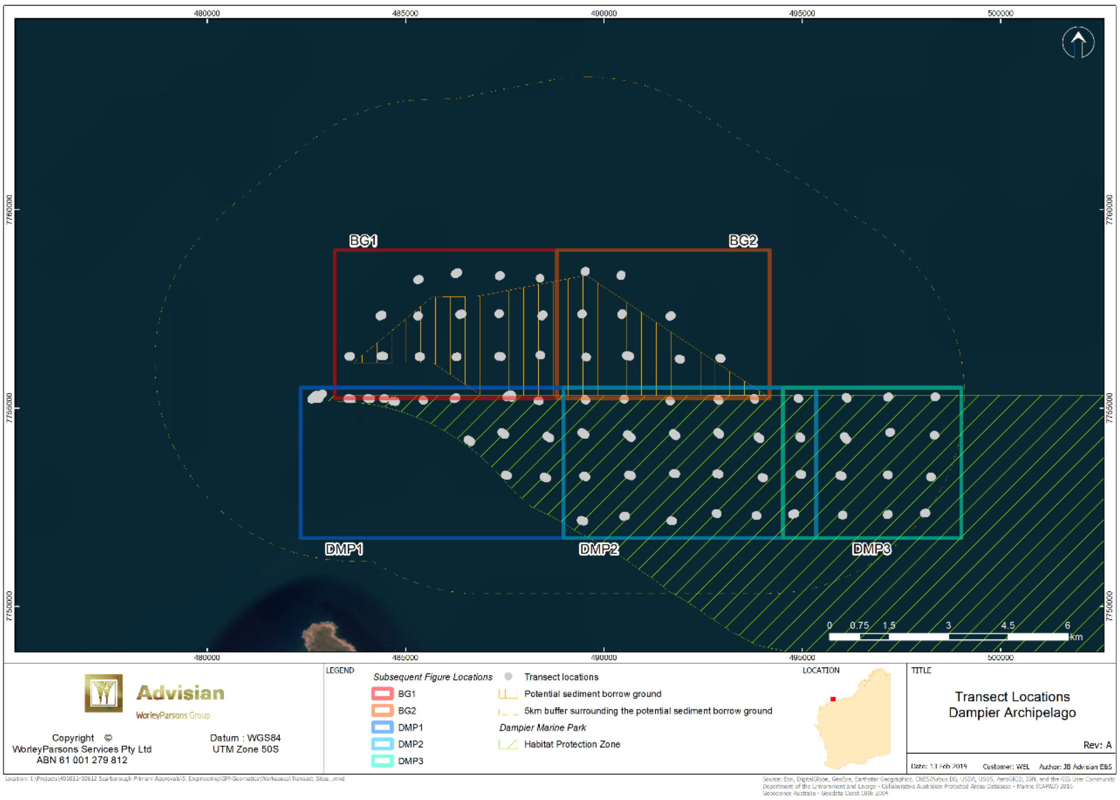

Figure 3-1: Transects with superimposed boxes indicating where subsequent figures presented are located

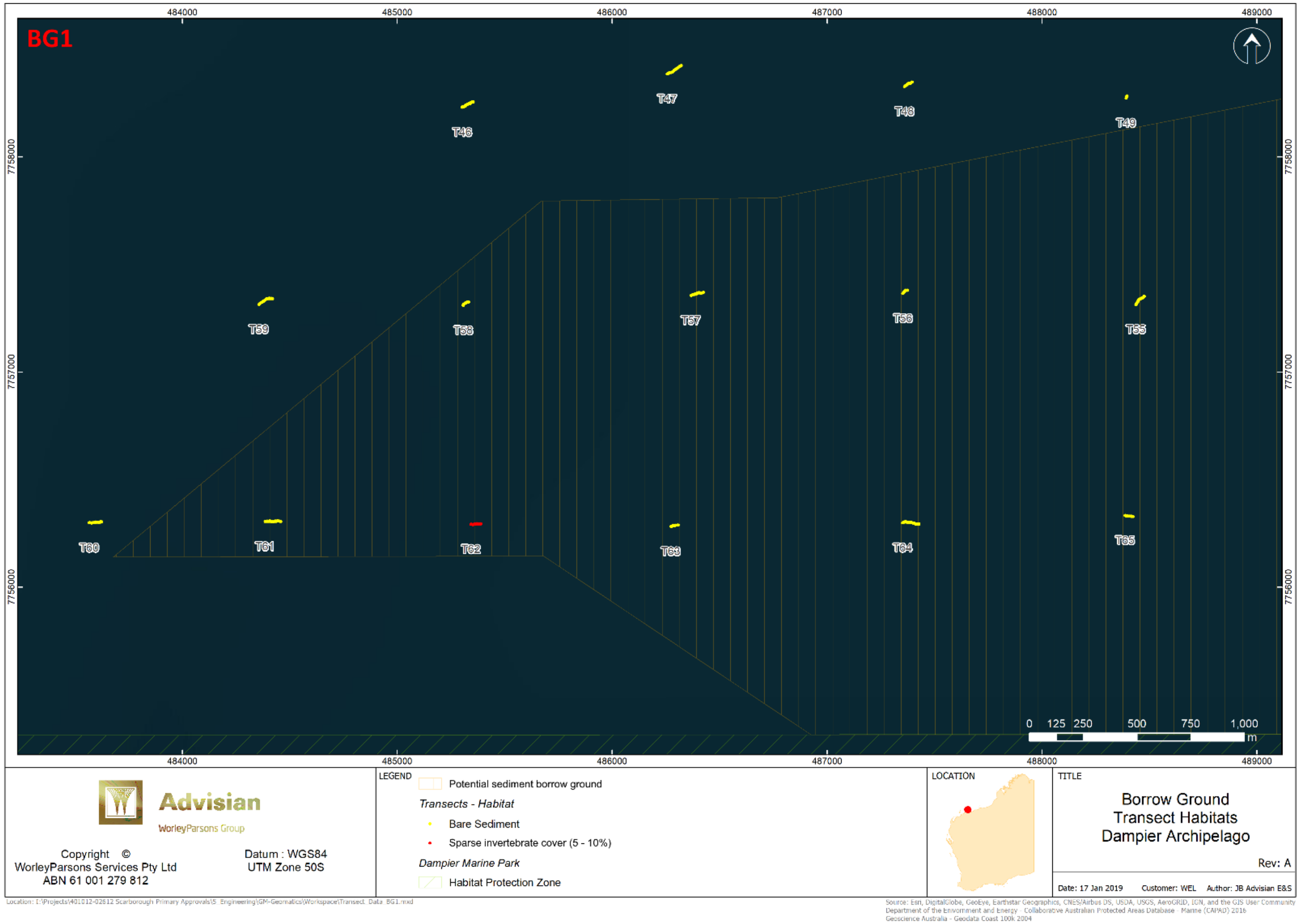

Figure 3-2: Benthic habitat in the western portion of the potential borrow ground

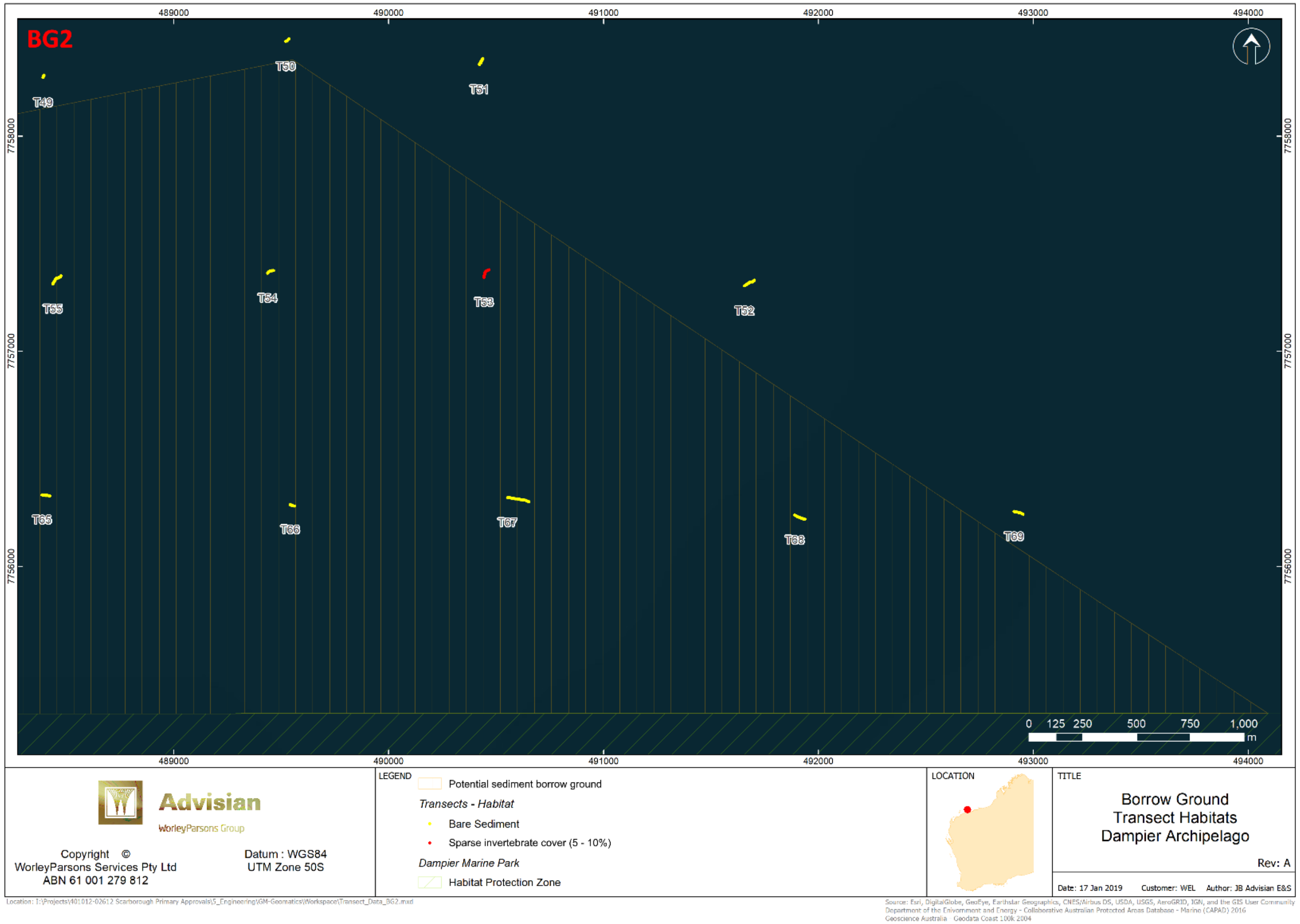

Figure 3-3: Benthic habitat in the eastern portion of the potential borrow ground

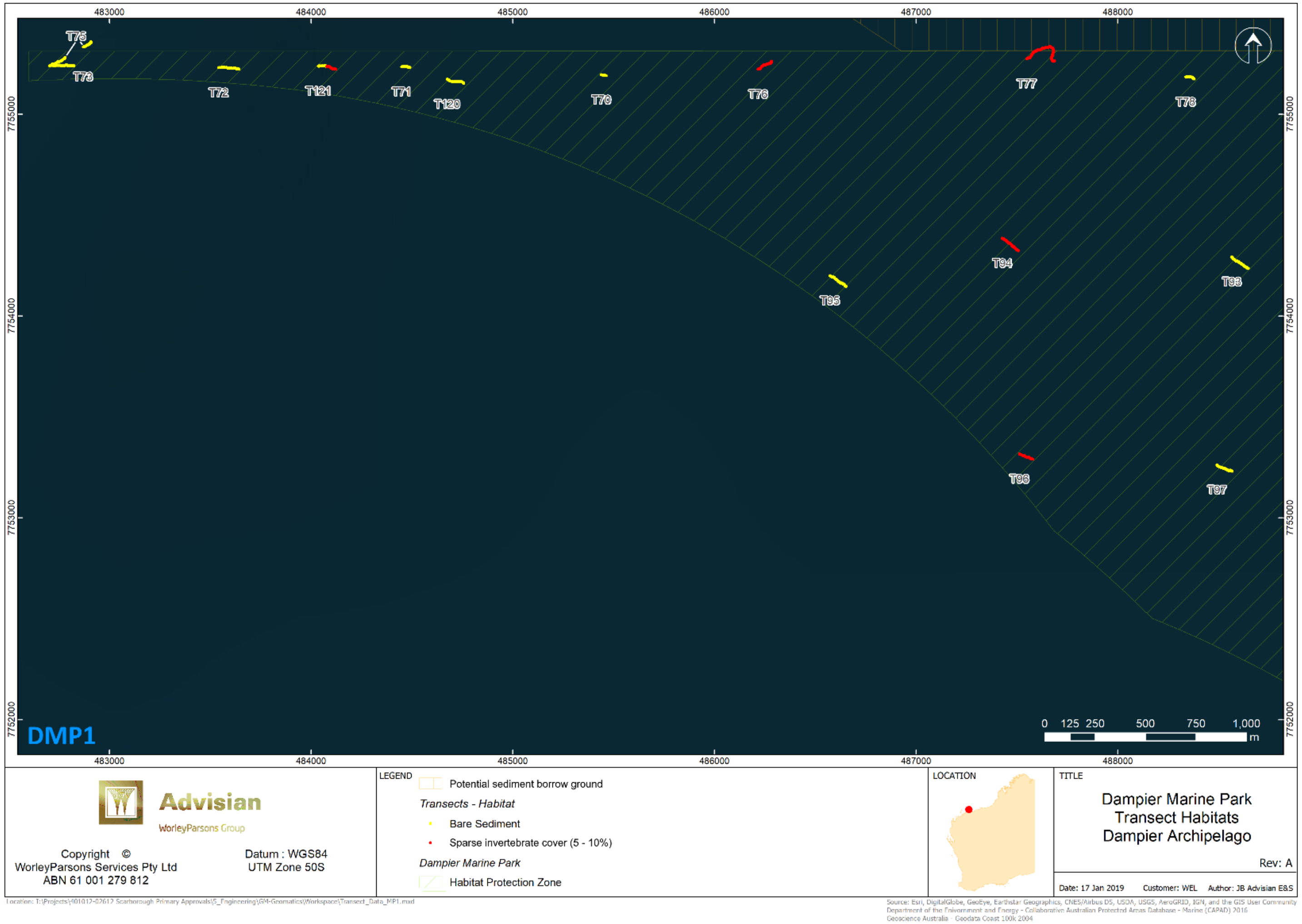

Figure 3-4: Benthic habitat in the western portion of the Dampier Marine Park

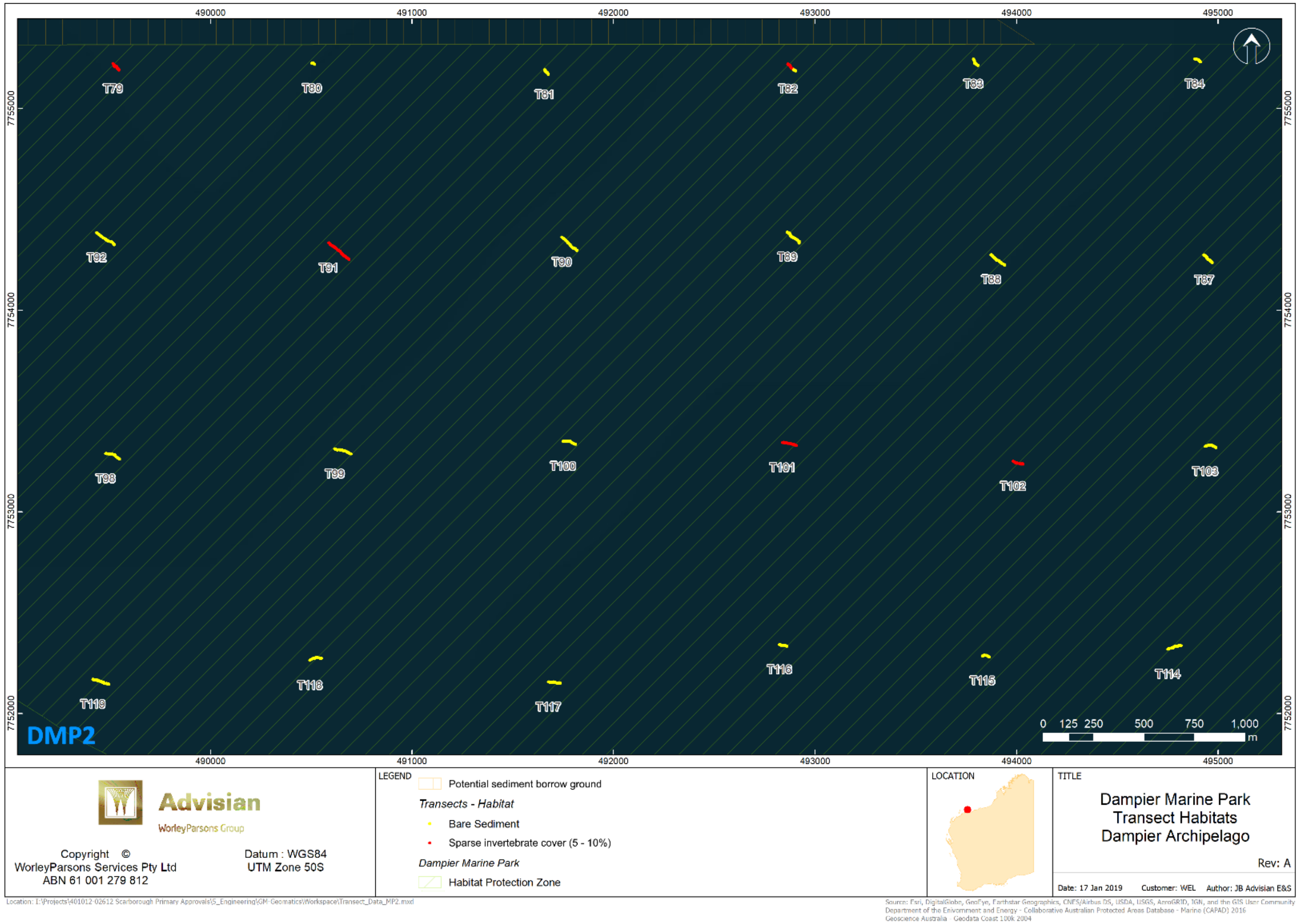

Figure 3-5: Benthic habitat in the middle of the Dampier Marine Park

Figure 3-6: Benthic habitat in the eastern portion of the Dampier Marine Park

4 Discussions and Conclusions

Towed video and drop camera survey of both the potential borrow ground and the DMP directly adjacent to the borrow ground confirm that the seabed and its benthic composition are relatively uniform in structure and composition. Both locations are dominated by bare substrate with large areas of seabed that are apparently largely devoid of any epibenthic species. Where epibenthos is present, the percentage cover of species is comparatively low (in the order of 5%), with no transects recording greater than 10% coverage in the species present.

Common species present were alcyonaceans (mainly solitary soft corals), pennatulaceans (sea pens), crinoids (feather stars), asteroids (sea stars), anemones and hydroids. No benthic primary producer habitat in the form of hard corals, macroalgae or seagrass was recorded or observed along any of the survey transects.

The benthic habitat observed during this survey appears to be consistent with a broad scale characterisation of the Pilbara seabed undertaken by UWA and CSIRO (Pitcher *et al* 2016), which categorises this area as "Assemblage 2" and describes it as "typically bare seabed interspersed with moderately high cover of whips (0– 95.6%), median gorgonians (0–12.4%) and median sponges (0–73.4%), some cover of algae (0 25%), and low cover of alcyonarians (0–2.2%), corals (0–6.8%), coral reef (0–5.4%), bioturbation (0– 13.4%) and halimeda (0–0.8%), and ~no cover of seagrass".

The similarity between benthic habitats observed within the potential borrow ground and habitat protection zone of the DMP during this survey, and those described above as Assemblage 2, indicates that the area surveyed is well represented in the regional context as opposed to more spatially discrete habitat features such as submerged coral reefs (Delambre Reef) and shoals (Tessa Shoals).

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Pitcher, C.R., Miller, M., Morello, E., Fry, G., Strzelecki, J., McLeod, I., Slawinski, D., Ellis, N., Thomson, D., Bearham, D., Keesing, J., Donovan, A., Mortimer, N. Babcock, R., Fromont, J, Gomez, O., Hosie, A., Hara, A., Moore, G., Morrison, S., Kirkendale, L., Whisson, C., Richards, Z., Bryce, M., Marsh, L., Naughton, K., O'Loughlin, M., O'Hara, T., Boddington, D., Huisman, J. (2016) Environmental Pressures: Regional Biodiversity — Pilbara Seabed Biodiversity Mapping & Characterisation. Final report, CSIRO Oceans & Atmosphere, Published Brisbane, March 2016, 62 pages.

Appendix C

Montebello Marine Park Benthic Habitat Survey

Montebello Marine Park Benthic Habitat Survey

ROV Analysis of the Scarborough Pipeline Route

18 April 2019

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Project No: 401012-02698- – Montebello Marine Park Benthic Habitat Survey: ROV Analysis of the Scarborough Pipeline Route

Rev	Description	Author	Review	Advisian Approval	Date
Rev1	Draft 1 submitted for internal review	K Newton / R Tate	P Nichols	NA	6 March 2019
Rev2	Draft 2 submitted for client review	K Newton / R Tate	Woodside	NA	AppDate4
Rev3	Draft 3 submitted for client review	K Newton / R Tate	Woodside	P Nichols	10 April 2019
Rev0	Final submitted to client	K Newton / R Tate	P Nichols	P Nichols	18 April 2019

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Executive Summary

The Scarborough gas resource is located approximately 375 km west-north-west off the Burrup Peninsula and is part of the Greater Scarborough gas fields. Woodside is proposing to develop the Scarborough gas resource through new offshore facilities connected by an approximately 430 km pipeline onshore. The proposal is to initially develop the Scarborough gas field with wells, tied back to a semi-submersible floating production unit (FPU) moored in 900 m of water close to the Scarborough field. This report has been developed in support of environmental approvals associated with the Scarborough Project.

This report provides the results of ROV surveys which were undertaken for the Scarborough project to characterise benthic habitat along the proposed trunkline route within the Montebello Australian Marine Park (AMP).

The objectives of this study were to:

- Confirm the environmental characteristics (physical and biological attributes) of the seabed along the pipeline route, including identification and qualitative descriptions of seabed habitat types and their general distribution;
- Provide spatial and habitat representation of the area of the Montebello AMP that the trunkline traverses; and
- Provide benthic habitat data at Key Ecological Features (KEFs) including the ancient coastline at the 125m depth contour KEF and potential turtle foraging habitat on hard substrate in the AMP where the trunkline overlaps.

Five areas within the Montebello AMP were surveyed, with three Remote Operated Vehicle (ROV) video transects undertaken within each area, except for Area 5 where only one transect was completed. The benthic habitat and epibenthic organisms within each area of the Montebello AMP were characterised through the assessment of the high definition (HD) video collected. Benthic habitat was described and classified in accordance with the CATAMI Classification Scheme for Scoring Marine Biota and Substrata in Underwater Imagery. Area 1, which was by far the deepest location, and which had one transect within the KEF, was most different with a much lower cover of benthic organisms than Areas 2 to 5. Areas 2 to 5 were quite similar in depth and in nature, with some small differences in the density and occurrence of benthic organisms and also in substrate type (e.g. variants of soft sediment bedforms and cover of biologenic gavel). A summary of findings for each area is provided below along with a discussion of the ROV results in relation to the published values for the Montebello AMP and 125m Depth Contour KEF.

Area 1 Summary

Area 1 was selected to assess the benthic habitat in the vicinity of the ancient coastline 125 m depth contour KEF and to provide spatial coverage of the AMP. One transect in Area 1 was located within the KEF (Transect 1A) and was 0.8 km from the eastern edge and 1.36 km from the north-western edge of the KEF. The most northern tip of this transect was located 0.45 km from the northern edge of the Montebello AMP and the south-western tip was 1.238 km from the western edge of the Montebello AMP. The depth at the midpoint of the transects surveyed in this area ranged from 103.2 m to 126.4 m. Benthic habitat was typically bare sand with various bedforms. Some areas of seafloor were covered in a light bacterial mat and others were seen to have a cover of biologenic gravel. No moderate or high relief features or areas of consolidated hard substrate were present. Benthic organisms (sponges and soft corals) typically occurred as single or in very low density aggregations. Mobile organisms including fish and echinoderms were also present on occasion.

The environmental values of the KEF refer to potential areas of hard substrate or rocky escarpments which may provide enhanced biodiversity or biologically important habitat in areas otherwise dominated by soft sediments. However, no potential features of the KEF described above were observed in any of the transects surveyed in Area 1.

Area 2 to 5

Areas 2 to 5 were selected to provide spatial coverage of the AMP, investigate areas of potentially high rugosity, areas that may include ancient coastline and areas of potential turtle foraging habitat. The depths in areas 2 to 5 were very similar with the midpoints depth of transects ranging from approximately 70 m to 78 m. The benthic habitats present along all transects in Areas 2 to 5 were very similar to each other. The seafloor in each area was relatively flat and sandy with a light to high cover of unconsolidated biologenic gravel and/or organic material. Small undulations of the seafloor were seen at times, as was scouring which typically occurred around large benthic organisms or aggregations of organisms. No significant high relief habitat features, or obvious areas of consolidated hard substrate, were observed in Areas 2 to 5. Benthic epifauna was present over the length of each transect, occurring in patches which varied from low (~5%) to high (~80%) density. Area 5 tended to have lower cover of organisms than areas 2 to 4. Benthic fauna in all of these areas comprised a diverse array of sponges and soft corals with varying forms, sizes and colours. Hydroids were also apparent. Mobile fauna including echinoderms (sea stars, feather stars) and Holothurians (sea cucumbers) and fish were common along most of the transects. Fish were especially abundant amongst the patches of sponges and corals. Bioturbation of the seafloor was common over the entire transect length and usually occurred in the form of thin trails, small mounds or craters.

For many transects a higher cover of benthic organisms was often seen in areas with higher amounts of biologenic gravel, however, benthic organisms were in no way limited to these areas, also being common in areas with fine sediment with little or no biologenic gravel. While at times the occurrence of benthic organisms could be loosely related to areas of high rugosity seen on detailed bathymetric mapping, this was not always apparent.

The high biodiversity of sessile and mobile organisms seen at depths of around 70 m – 78 m in Areas 2 to 5 of the Montebello AMO was in accordance with the natural values of the Montebello AMP in that the area surveyed ‘includes diverse benthic and pelagic fish communities’. These areas are all likely to provide foraging habitat for mobile (and potentially threatened) fauna such as marine turtles and other fish fauna that feed on soft bodied benthic organisms such as sponges and soft corals.

The benthic habitat descriptions in the current study are generally in alignment with the findings of previous (recent and historical) benthic habitat surveys undertaken in the Montebello AMP. These studies have also reported the typical benthic habitat in the AMP as low relief sandy seafloor (with various bedforms such as ripples and ridges) with occasional areas of rubble (often increasing at more inshore sites). Dominant benthic organisms recorded for the AMP (noted to vary in diversity and density between sites) typically include a wide variety of sponges, soft corals and crinoids.

1 Introduction

1.1 Project Background

The Scarborough gas resource is located approximately 375 km west-north-west off the Burrup Peninsula and is part of the Greater Scarborough gas fields which are estimated to hold 9.2 Tcf (2C, 100%) of dry gas. Woodside is proposing to develop the Scarborough gas resource through new offshore facilities connected by an approximately 430 km pipeline onshore. The proposal is to initially develop the Scarborough gas field with wells, tied back to a semi-submersible floating production unit (FPU) moored in 900 m of water close to the Scarborough field. This report has been developed in support of environmental approvals associated with the Scarborough Project.

Activities undertaken as a part of the Scarborough Project will include seabed preparation and trunkline installation activities, which will result in localised seabed disturbance and ongoing physical presence of the trunkline for the life of the project. The proposed pipeline is approximately 32 inch in diameter and the disturbance corridor is estimated at less than 30 m. The Scarborough trunkline is proposed to traverse through the northern section of the Montebello Australian Marine Park (AMP) as shown in Figure 1-1. This report provides the results of ROV surveys which were undertaken for the Scarborough Project to characterise benthic habitat along the proposed trunkline route within the Montebello AMP.

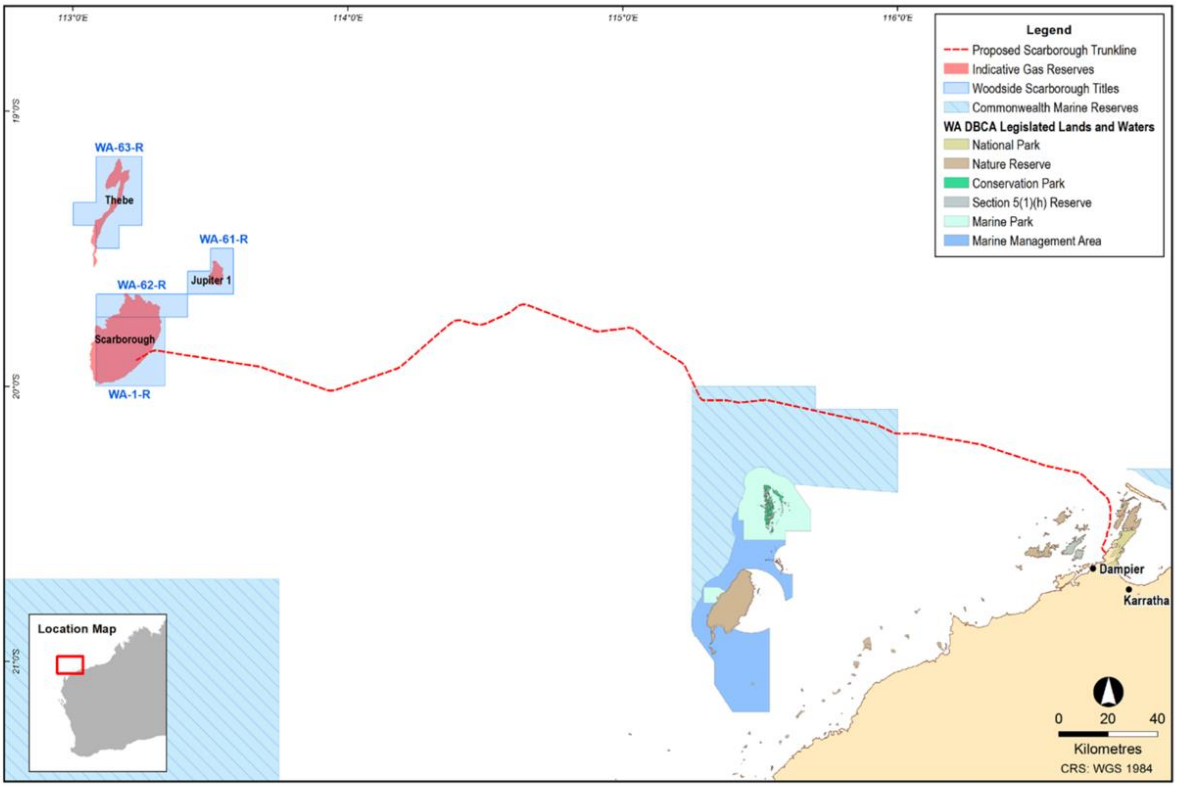

Figure 1-1 Location of the Scarborough Project and proposed trunkline (Image Source: Woodside 2019).

1.2 Environmental Setting of the Proposed Trunkline Route

The Scarborough Project occurs in Commonwealth waters off the northwest coast of Western Australia (WA) within the North-west Marine Region (NWMR) (Integrated Marine and Coastal Regionalisation of Australia (IMCRA) 4.0). The target fields occur within the Northern Carnarvon Basin on the Exmouth Plateau, and are about 380 km offshore from Dampier, in water depths of approximately 900 - 970 m, with the proposed trunkline ultimately crossing into State waters along the same alignment as the Pluto Gas Export Pipeline (Figure 1-2).

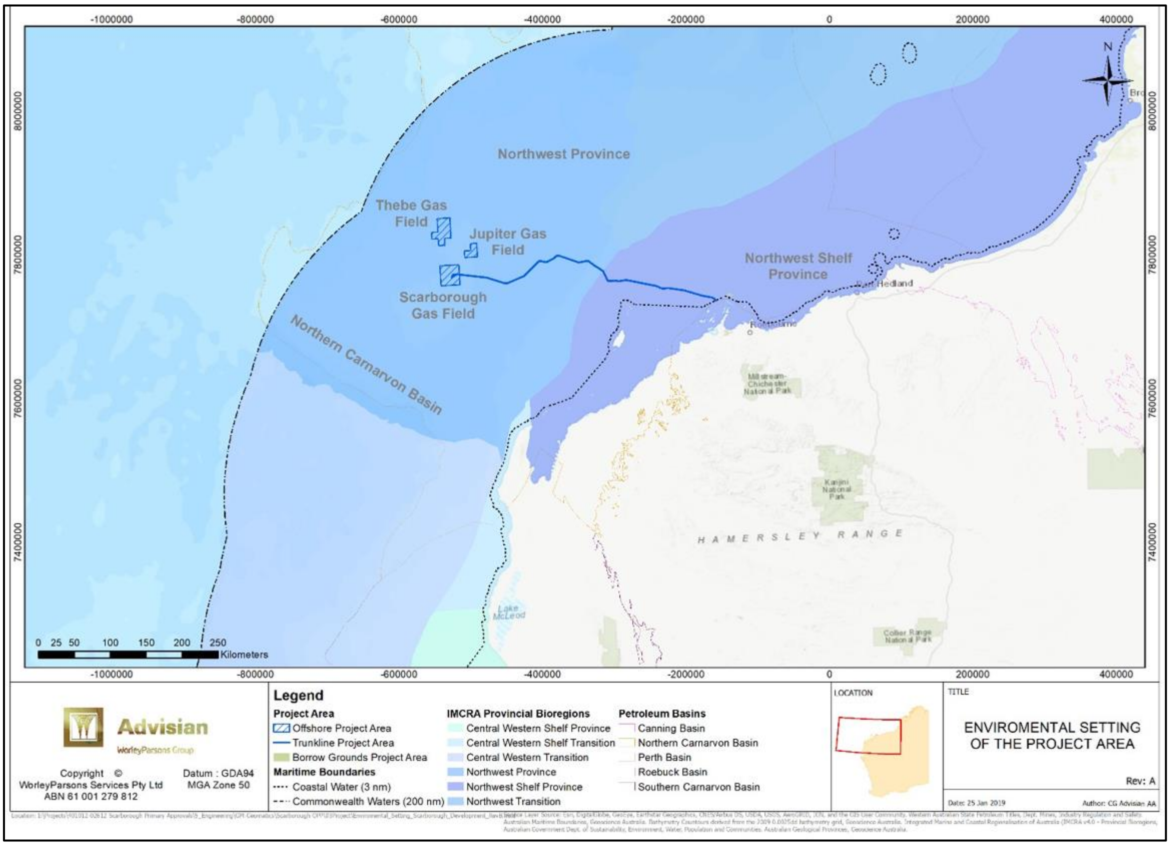

Figure 1-2 Environmental setting of the project area.

A number of studies and reviews of the Exmouth Plateau and North West Shelf have been compiled and/or undertaken to provide an understanding of the physical, biological and socio-economic environmental conditions within the Project Area. The majority of these have been made available in the public domain. The environmental values of the Montebello AMP and the ancient coastline KEF have been described in Sections 1.2.1 and 1.2.2 of this report.

The Trunkline Project Area extends from the State-Commonwealth boundary on the inner continental shelf, onto the continental slope where it traverses the continental slope westwards to the Offshore Project Area on the Exmouth Plateau. The eastern half of the Trunkline Project Area is adjacent to the existing Pluto trunkline. The inner continental shelf is the area from the coast to about 30 m water depth, and the middle continental shelf is the area between 30 m and 120 m water depth. At about 120 m depth, a terrace (start of the outer shelf) of gradients of between 5° and 20° represents a paleo-shoreline and marks an important divide between the continental shelf and continental slope (SKM, 2006). Sediments along the Trunkline Project Area are expected to be dominated by sand as is typical of the continental slope in the Northwest Transition bioregion (DEWHA, 2008a).

1.2.1 Natural Values of the Montebello AMP

Location

The Montebello Marine Park is located offshore of Barrow Island and 80 km west of Dampier extending from the Western Australian state water boundary and is adjacent to the Western Australian Barrow Island and Montebello Islands Marine Parks. The Marine Park covers an area of 3413 km^2 and water depths from less than 15 m to 150 m. The Marine Park was proclaimed under the EPBC Act on 14 December 2013 and renamed Montebello Marine Park on 9 October 2017 (Director of National Parks, 2018).

Statement of Significance

The Montebello AMP is significant because it contains habitats, species and ecological communities associated with the Northwest Shelf Province. It includes one KEF: the ancient coastline at the 125-m depth contour (valued as a unique seafloor feature with ecological properties of regional significance) (environmental values of the KEF are provided in Section 1.2.2). The Marine Park provides connectivity between deeper waters of the shelf and slope, and the adjacent Barrow Island and Montebello Islands Marine Parks. A prominent seafloor feature in the Marine Park is Trial Rocks consisting of two close coral reefs. The reefs are emergent at low tide (Director of National Parks, 2018).

Natural Values

The values of the Montebello AMP are outlined in the North-west Marine Parks Network Management Plan 2018 (Director of National Parks, 2018). The Marine Park includes examples of ecosystems representative of the Northwest Shelf Province, which is a dynamic environment influenced by strong tides, cyclonic storms, long-period swells and internal tides. The bioregion includes diverse benthic and pelagic fish communities, and ancient coastline thought to be an important seafloor feature and migratory pathway for humpback whales. A KEF of the Marine Park is the ancient coastline at the 125-m depth contour where rocky escarpments are thought to provide biologically important habitat in areas otherwise dominated by soft sediments (Director of National Parks, 2018).

The Marine Park supports a range of species including species listed as threatened, migratory, marine or cetacean under the EPBC Act 1999. Biologically important areas within the Marine Park include breeding habitat for seabirds, internesting, foraging, mating, and nesting habitat for marine turtles, a migratory pathway for humpback whales and foraging habitat for whale sharks (Director of National Parks, 2018).

1.2.2 Environmental Values of the Ancient Coastline at 125 m Depth Contour (KEF)

The shelf of the North-west Marine Region contains several terraces and steps which reflect changes in sea level that occurred over the last 100 000 years. The most prominent of these features occurs as an escarpment along the North West Shelf and Sahul Shelf at a depth of 125 m. The ancient coastline at 125 m depth contour is defined as a KEF as it is a unique seafloor feature with ecological properties of regional significance. The spatial boundary of this KEF, as defined in the Conservation Values Atlas, is defined by depth range 115-135 m in the Northwest Shelf Province and Northwest Shelf Transition provincial bioregions as defined in the Integrated Marine and Coastal Regionalisation of Australia (IMCRA v 4.0) (DSEWPaC, 2012). The boundary of the KEF in the study area is shown in Figure 2-1.

Environmental Values

The 'environmental values' of the 'ancient coastline at 125 m depth contour' KEF are described in the Marine Bioregional Plan for the North-west Marine Region (DSEWPaC, 2012). The ancient submerged coastline provides areas of hard substrate and therefore may provide sites for higher diversity and enhanced species richness relative to surrounding areas of predominantly soft sediment. Little is known about the fauna associated with the hard substrate of the escarpment, likely to include sponges, corals, crinoids, molluscs, echinoderms and other benthic invertebrates representative of hard substrate fauna in the North West Shelf bioregion (DSEWPaC, 2012).

The escarpment may also facilitate increased availability of nutrients off the Pilbara by interacting with internal waves and enhancing vertical mixing of water layers. Enhanced productivity associated with the sessile communities and increased nutrient availability may attract larger marine life such as whale sharks and large pelagic fish (DEWHA, 2008).

1.3 Objectives

The objectives of the current study were to:

- Characterise benthic habitat along the proposed trunkline route in the Montebello AMP;
- Confirm the environmental characteristics (physical and biological attributes) of the seabed along the pipeline route, including identification and qualitative descriptions of seabed habitat types and their general distribution;
- Provide spatial and habitat representation of the area of the Montebello AMP that the trunkline traverses; and
- Provide benthic habitat data at environmental sensitive locations including the ancient coastline at the 125m depth contour Key Ecological Feature (KEF) and potential turtle foraging habitat on hard substrate in the AMP where the trunkline overlaps.

2 Methods

Habitat characterisation was undertaken using a remotely operated underwater vehicle (ROV) to capture seabed imagery (video/stills) along pre-defined survey locations. Imagery was then used to describe the physical habitats and the presence/absence of benthic communities within the vicinity of the trunkline route in the section that traverses the Montebello AMP.

The survey was focused along the proposed trunkline route where it deviates from the existing Pluto pipeline route (located in the eastern area of the multi-use zone of the park). Survey sites reflected the potential variation in habitat, as determined by the geophysical data (e.g. bathymetry and interpreted seabed substrates) and general representativeness of the main seabed characteristics of the multi-use zone of the park, that the proposed trunkline route will traverse.

2.1 Survey Areas

Seafloor imagery was collected by Neptune, within five survey areas, which were sized approximately 4 km x 250 m, inside the Montebello AMP. The survey areas selected provide spatial coverage and representative habitat of the Montebello AMP. The locations of survey areas and transects, along with transect depths are provided in Table 2-1 and Figure 2-1. Figure 2-1 also provides the location of the ancient coastline 125 m depth contour KEF.

The five survey areas were selected for the following reasons:

- **Survey areas 1**: Was selected to assess benthic habitat in the vicinity of the ancient coastline 125 m depth contour KEF and to provide spatial coverage of the AMP (Figure 2-1 and Figure 2-2).

- **Survey areas 2 to 5**: Were selected to provide spatial coverage of the AMP, identify any outcropping / subcropping in rugose areas of seafloor (as seen on bathymetry) and assess the benthic habitat in areas which could provide potential turtle foraging habitat (Figure 2-1, Figure 2-3, Figure 2-4, Figure 2-5 and Figure 2-6).

The approximate distance between all adjacent transects from each other is shown in Table 2-2.

Within each survey area, there were three proposed sampling locations (Figure 2-1). At each location an ~500 m transect of trunkline was attempted to be surveyed. Transects were to provide a snake like path deviating from the proposed pipeline route by approximately 100 m each side of the pipeline and were to follow the pipeline route in a parallel direction (rather than running perpendicular). A kilometre buffer was allowed around each survey location, for flexibility given weather conditions etc. A minimum distance of 200 m between transects was to be maintained. Due to strong currents and the ROV tether management it was not possible to run the transect across the proposed pipeline route in Area 5 and the transect locations 5B and 5C were unable to be surveyed. Table 2-1 provides details for all transects.

Table 2-1 Location of the five survey areas and transect details.

Survey Area	Sampling Location	Position GDA94 Zone 50 (Midpoint) Latitude	Longitude	Potential Seafloor Features	Actual Midpoint Depth (m)
Survey Area 1	1A	318462.69	7787004.58	125m contour KEF	-126.4
	1B	319281.801	7785309.82	125m contour KEF	-110.2
	1C	320006.8476	7783542.972	125m contour KEF	-103.2
Survey Area 2	2A	328859.16	7781967.15	Outcrop/subcrop	-70.6
	2B	330692.8515	7781974.137	Outcrop/sand	-74.4
	2C	332650.32	7781636.45	Outcrop/sand	-74
Survey Area 3	3A	336633.23	7781316.65	Outcrop/subcrop	-73.8
	3B	338590.04	7781516.29	Sand	-72.5
	3C	341540.88	7781917.17	Outcrop/subcrop	-71.6
Survey Area 4	4A	342526.27	7782010.53	Sand	-75.3
	4B	344543.13	7782286.02	Sand/subcrop	-74.5
	4C	346553.46	7782136.72	Subcrop/outcrop	-78.2
Survey Area 5	5A	361146.91	7778773.61	Sand	-74.6
	5B	Not surveyed		Sand	NA
	5C	Not surveyed		Sand	NA

Table 2-2 Distances between adjacent transects (based on the approx. centre of each transect).

Transects	Distance
1A TO 1B	1.85 km
1B TO 1C	1.88 km
1C TO 2A	1.88 km
2A TO 2B	1.88 km
2B TO 2C	1.88 km
2C TO 3A	3.98 km
3A TO 3B	1.88 km
3B TO 3C	2.89 km
3C TO 4A	0.98 km
4A TO 4B	2.06 km
4B TO 4C	1.96 km
4C TO 5A	15 km

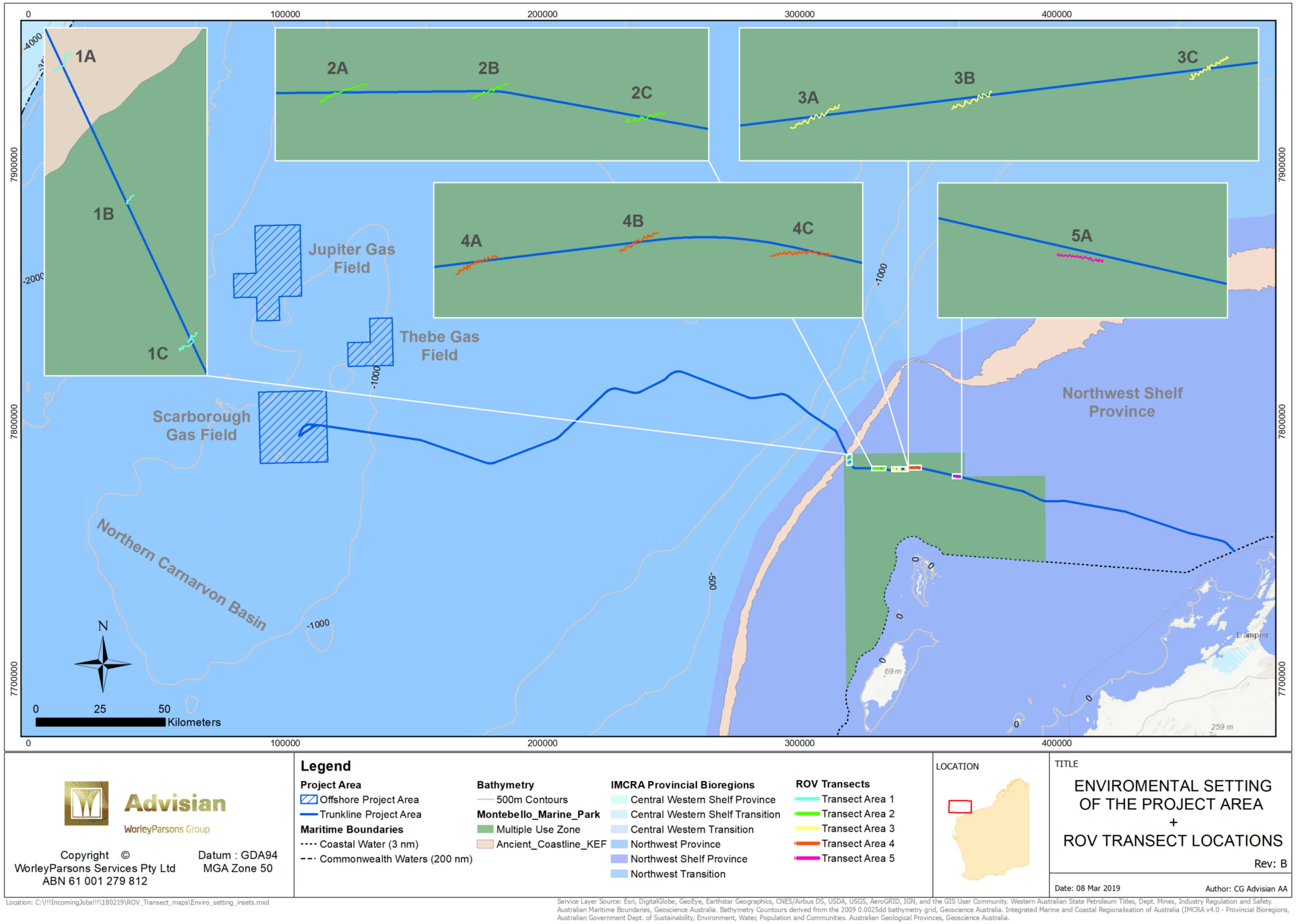

Figure 2-1 Location of the five survey areas and ROV transects.

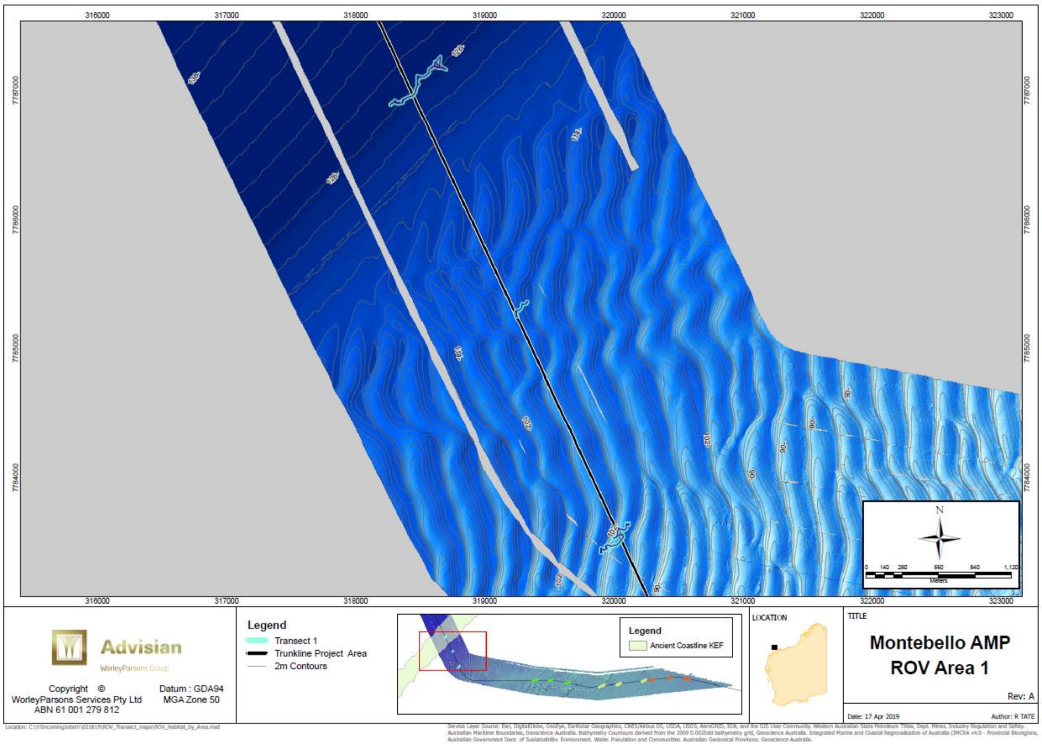

Figure 2-2 Transects 1A, 1B and 1C.

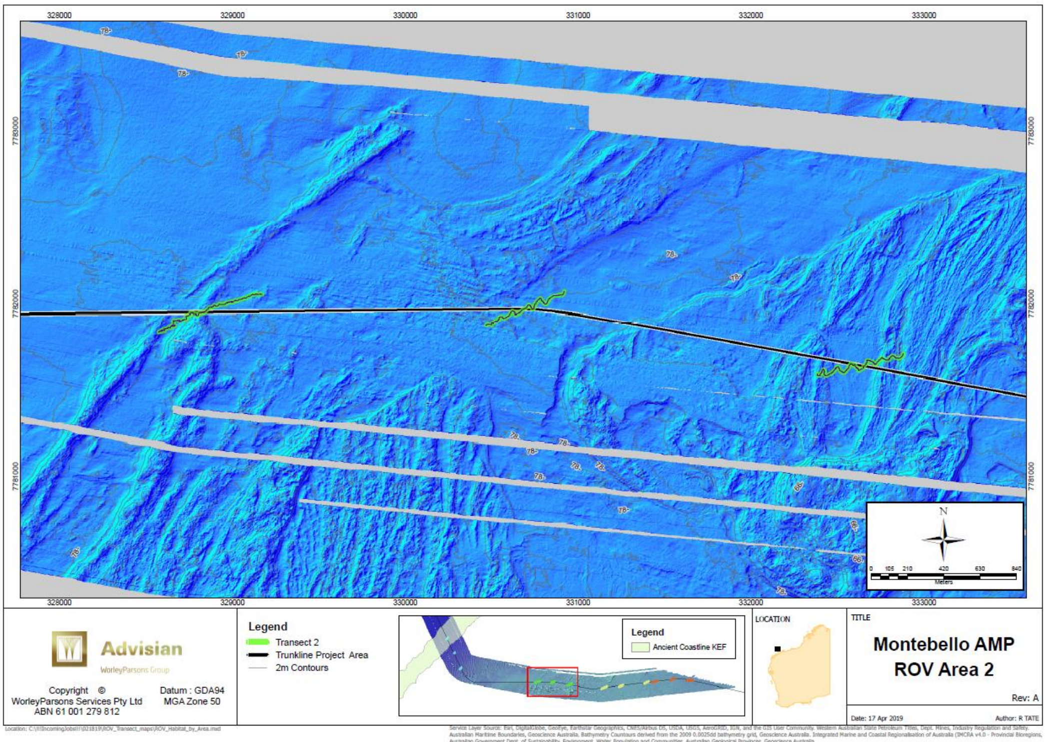

Figure 2-3 Transects 2A, 2B and 2C.

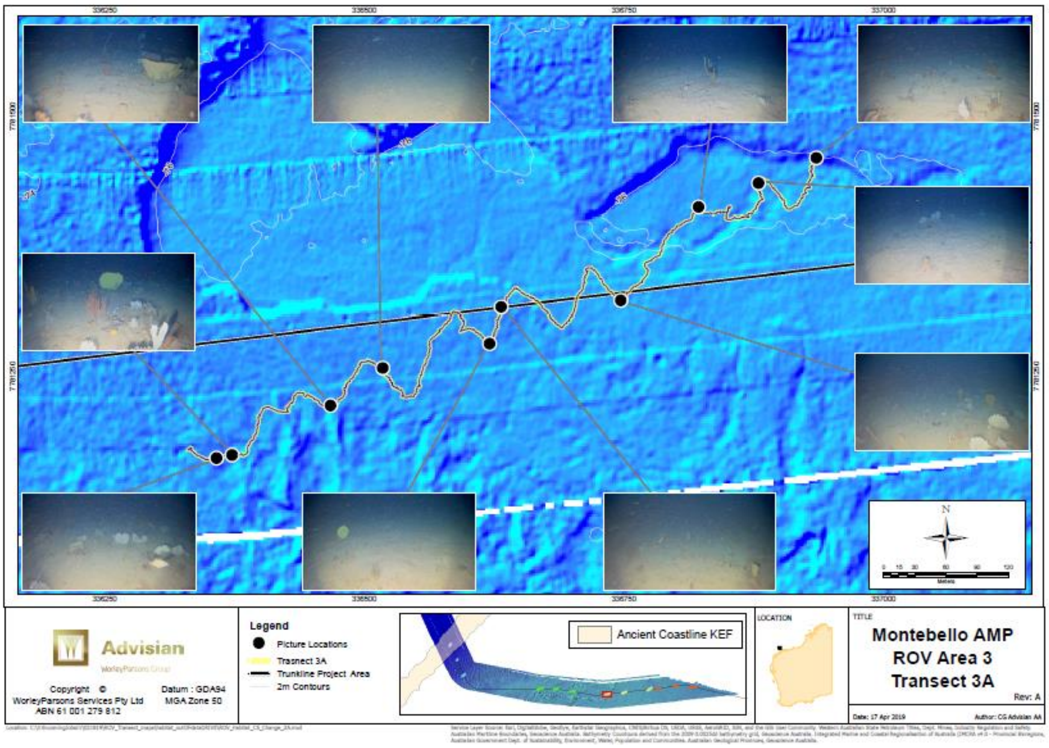

Figure 2-4 Transects 3A, 3B and 3C.

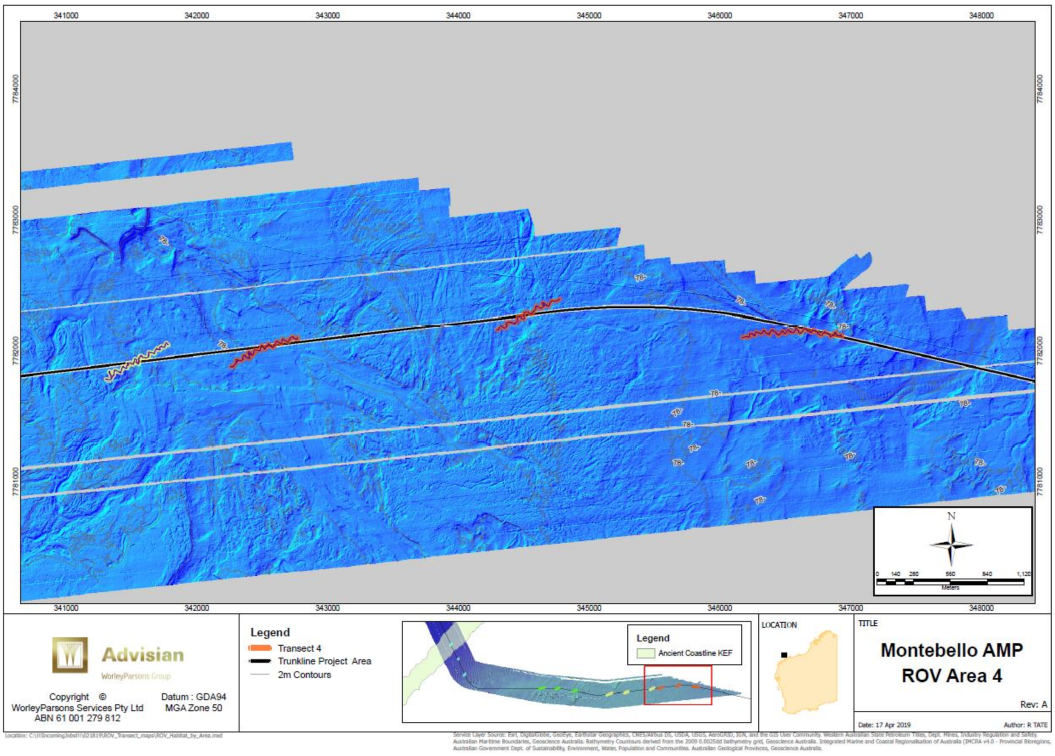

Figure 2-5 Transects 4A, 4B and 4C.

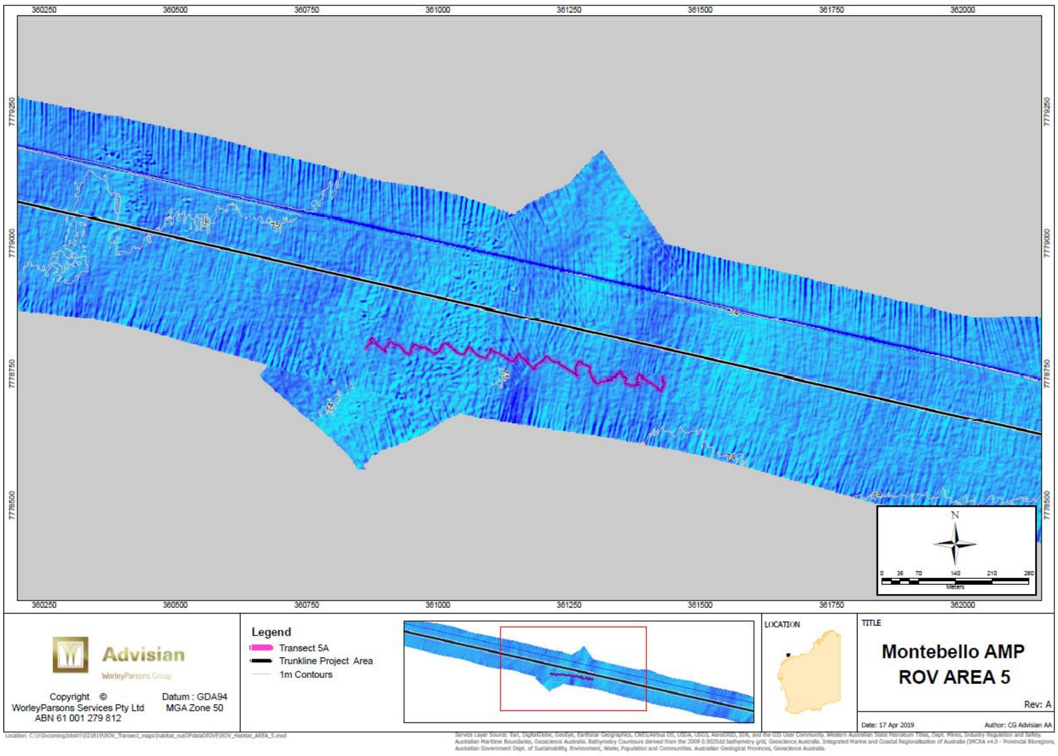

Figure 2-6 Transect 5A.

2.2 Remotely Operated Vehicle (ROV) Surveys

ROV surveys were undertaken by Neptune at each of the survey locations provided in Table 2-1 and shown in Figure 2-1. HD video was collected from a standardised height of approximately 1 m to 2 m. The camera was angled where possible to capture both the seabed and forward facing perspective of the general seascape. Depth and geospatial data of the ROV location was recorded at all sites. The depth and location of the midpoint of each transect is provided in Table 2-1.

2.3 Video Analysis

2.3.1 Technical Memos (Neptune)

Following the collection of the ROV video data, Neptune prepared a short technical memo for each transect which included the survey date, time, area of operations, location, brief seabed description, conclusions and recommendations and any issues encountered. All technical memos were reviewed and are provided in **Appendix A**.

2.3.2 Benthic Habitat Analysis

Prior to assessment of the benthic habitat, potential differences in seafloor bathymetry / rugosity were identified along each of the transect routes and five points of interest were selected for each. On video analysis, still images from each of these locations were captured.

High definition (HD) video data was viewed using VLC Media Player and the benthic habitat and sessile organisms present were classified in accordance with the CATAMI Classification Scheme for Scoring Marine Biota and Substrata in Underwater Imagery (http://CATAMI.github.io/) (Althaus et al. 2014). Data specifically collected and reported for each transect included:

- Substrate Type
- Bedform
- Relief
- Bioturbation
- Bacterial mats
- Flora
- Fauna

HD video assessment showed that the seafloor along all transects was low profile and no moderate or high profile features were present within any transect. For all transects surveyed, the seafloor habitat was found to be very similar along the entire transect length, or consisted of a mosaic of benthic habitat types / variations in habitat type which changed continually at small scales (typically a couple of m's) but represented the transect as a whole (e.g. area of bare sandy substrate, to area of sponges/corals on sandy substrate, back to bare substrate, or continually changing percentage cover of sponges and corals). For these reasons, and the qualitative nature of the assessment, an overall habitat classification was applied to each transect.

Still images of the various states of benthic habitat and the sessile benthic organisms seen along each transect were also taken from the HD video. Some of these were georeferenced and are overlaid on the transect maps. The report Appendices also include a greater number of images from each transect which are provided to demonstrate the small scale variability within a single general habitat type.

2.4 Transect and Habitat Mapping

Transects were created as line shapefiles from ROV derived X, Y point data. High resolution (2 m) bathymetry data was then used to generate the underlying raster surface as well as 2 m contour line data. All data was projected in GDA MGA Zone 50 coordinate system and processed in ArcMAP 10.4.

As the benthic habitat along each individual transect was generally the same and consisted of often very small scale (every few meters) and continual changes in substrate (e.g. sand ripple type) or the cover of benthic organisms (i.e. changes in density of benthic organisms), georeferenced 'habitat types' were not defined along the length of each transect. Each transect was mapped with detailed seafloor bathymetry and these transect maps were overlaid with georeferenced images of the benthic habitat along the transect.

3 Results

3.1 Area 1

Three transects (of varying length) were surveyed in Area 1 and are described in more detail below. The depth at the midpoint of these transects ranged from 103.2 m to 126.4 m. One transect in Area 1 (Transect 1a) was located within the KEF; located 0.8 km from the eastern edge and 1.36 km from the north-western edge of the KEF. The most northern tip of this transect was located 0.45 km from the northern edge of the Montebello AMP and the south-western tip was 1.238 km from the western edge of the Montebello AMP. While some representative images of each transect are provided in the Sections below, **Appendix B** provides additional images of the benthic habitat and organisms seen along each transect in Area 1.

3.1.1 Area 1a

Notes provided by Neptune for Area 1a included:

- The ROV transect crossed the pipeline route at E318445, N7786967 (time stamp 13:49:11).
- The ROV was on bottom at 13:49 and off bottom at 14:03.
- The seabed comprised a flat fine sandy seabed, with small isolated sand waves. There was a sparse benthic sand-dwelling habitat. Ripples had an organic/algae covering, particularly in the troughs. Isolated corals also occurred on the sand.
- No significant high relief habitat features were observed.
- Due to strong currents and the ROV tether management it was not possible to run the transect more along the proposed pipeline route.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in Area 1a are provided:

- The entire seafloor along the transect in Area 1a consisted of a low relief, flat and fine sandy seabed with bedforms alternating between small 2D and 3D ripples (< 10 cm) and some areas which had no ripples.
- No significant, or other, moderate or high relief features, or areas of hard substrate, were present. The transect ran almost entirely along the 126 m depth contour (Figure 3-2).
- Transect 1a was entirely located within the boundary of the ancient coastline KEF (refer to Figure 2-1 and Figure 3-2). However, no potential features of the KEF (i.e. areas of hard substrate with high biodiversity) were noted here, and the transect was comprised fully of soft sediment habitat.

- The seabed was generally bare sand (with very occasional benthic epifauna) and much of the transect area was noted to have a light covering of organic matter. This is very likely to be a bacterial mat considering the water depth and lack of light penetration in this location (refer to Figure 3-2 and **Appendix B** for images).

- No benthic flora (i.e. macroalgae or seagrass) was present in Area 1a.

- Benthic epifauna were present, although were quite uncommon. They generally occurred as single individuals (i.e. not in aggregations / clusters). Benthic epifauna included echinoderms (e.g. brittle stars and feather stars), sponges (erect simple, erect laminar, erect branching and cup like forms) and cnidarians (whip corals and quill corals (seapens) (refer to Table 3-1 for additional detail and CATAMI classification codes).

- The percentage cover of benthic organisms (within the entire video frame) in Area 1a ranged from 0% to ~5% (excluding any cover of biologenic gravel) over the entire transect length. No obvious bathymetric features could be seen on the transect maps or corresponded with the occurrence of different substrate types (e.g. sand ripples / flat sand / steps) or scattered benthic organisms. The benthic organisms recorded occurred on all different substrate types/bedforms.

- Occasional bioturbation of the seabed in the form of light trails, small mounds and craters was seen over the entire transect indicating the presence of various mobile fauna living on top of and within the seabed.

- Mobile fauna were seen on occasion but were also uncommon. They included small bony fishes (often quickly moving out of the field of view of the ROV) and jellies. Both types of fauna were unidentified.

- Due to currents affecting the stability of the ROV, along with a high level of suspended material in the water at times, visibility of the seabed was compromised in places. However, these less visible areas are very likely to be similar to the seafloor which could be seen based on the overall transect assessment.

A summary of the general benthic habitat characteristics, flora and fauna seen along the transect in Area 1a is provided in Table 3-1. This table also provides the CATAMI Species Codes for each seafloor feature and taxa that were identified.

The benthic habitat in the location where the transect crossed the pipeline route (as per the time stamp provided by Neptune) is shown in Figure 3-1 and consists of rippled bare sand.

A map showing the location of the transect in Area 1a in relation to seafloor bathymetry and the KEF, along with some georeferenced representative images of benthic habitat in this area, is provided in Figure 3-2. No correlation between the seafloor bathymetry / rugosity as evident on the transect map and the occurrence of benthic organisms was apparent for Transect 1a.

Additional seafloor images and images of some of the isolated benthic fauna recorded in Area 1a are provided in **Appendix B**.

Figure 3-1 Benthic habitat in the location of the pipeline crossing in Area 1a.

Table 3-1 Summary of habitat features in Area 1a.

Habitat Features	Description	CATAMI Species Code(s)	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm)	82001005	Entire Transect
Bedform	2D ripples (<10 cm height) 3D ripples (<10 cm height)	82002003 82002007	Alternating 2D and 3D ripples over transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Crawling traces: Thin trail Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone	81005001 81001003 81001012	Occasional sightings over entire transect
Bacterial mats	Bacterial mat	80000000	Around ½ transect
Flora	Nil	NA	NA
Fauna	Echinoderms: Ophiuroids: Brittle / snake stars Echinoderms: Feather stars Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Corals: Black & Octocorals: Whip Corals: Black & Octocorals: Quill (seapen) Jellies Fishes: Bony fishes	25160901 25000000 10000916 10000913 10000915 10000909 11168917 11168918 80600903 37990083	Occasional sightings over the entire transect length – most organisms occurred in isolation

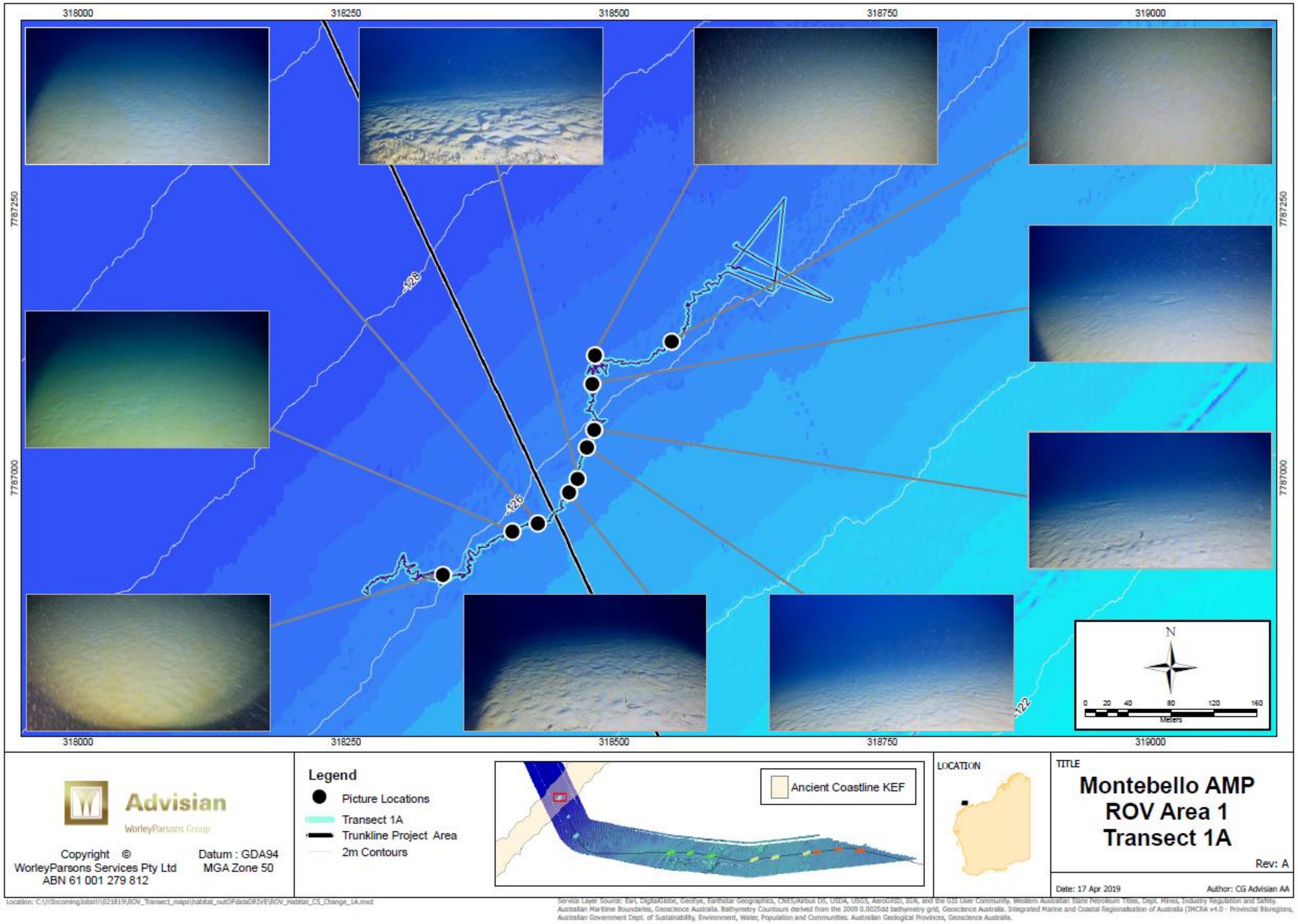

Figure 3-2 Typical benthic habitat and bathymetry in Area 1a.

3.1.2 Area 1b

Notes provided by Neptune for Area 1b included:

- The ROV crossed the proposed pipeline route at E 319248, N 7785254 at approximately 17:44:15.
- The ROV was on bottom at 17:43 and off bottom at 17:48.
- The seabed comprised a typically flat fine sandy seabed with ripples and larger sand waves. There was sparse benthic sand-dwelling habitat. Sand ripples had an organic/algae covering particularly in the troughs. The small sand wave crests (probably less than 0.5 m high) were cleaner and could be seen to prograde over the sediments burying isolated benthic fauna which typically occurred as soft corals and sponges.
- No significant high relief habitat features were observed.
- Due to strong currents and the ROV tether management it was not possible to run the transect more along the proposed pipeline route.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in Area 1b are provided:

- The seafloor along the transect in Area 1b was similar to that observed in Area 1a and was also similar along the entire transect length.
- Where the transect crossed the proposed pipeline route (as per the time stamp provided by Neptune), a flat sandy seafloor with 3D ripples was present (see image in Figure 3-3).
- Benthic habitat typically consisted of a low relief sandy seabed, with bedforms alternating between small 2D and 3D ripples and areas of flat sand. A series of small 'steps' / rises in the sand occurred over the entire length of the transect and these were generally <50 cm high. These 'steps' were identified as 'sand wave crests' by Neptune. Towards the end of the transect the small 2D and 3D sand ripples became slightly less common and the seafloor had a slightly flatter form. This area of flatter sand is not considered to be a separate habitat type, nor can it been identified on the transect map showing detailed bathymetry. Images of the variable types of sandy seafloor along Transect 1b are provided in Figure 3-4 and **Appendix B**.
- No significant, or other, moderate or high relief features, or areas of consolidated hard substrate, were present in Area 1b. However, some small areas of scattered biologenic rubble (perhaps shell, coral or small gravel) were noted along the transects length (see Figure 3-4 and **Appendix B)**. These areas cannot be seen on the transect maps with detailed bathymetry.
- Area 1b was located near to, but not within, the area mapped as the KEF (ancient coastline 125 m depth contour). The transect traversed an area of seabed which had a depth of

around 108 m to 113 m (refer to Figure 3-4). No potential features of the KEF (i.e. hard substrate with high biodiversity) were seen here.

- Some areas of sand were bare while others were covered in a light bacterial mat. This covering occurred over the entire transect however was more prevalent in the troughs of ripples and the base of each of the sand 'steps'. It was also common towards the end of the transect where sand ripples were less common.
- No benthic flora (i.e. macroalgae or seagrass) was present in Area 1b.
- Benthic epifauna were present, although were relatively uncommon and most often occurred as single organisms. Fauna included echinoderms (e.g. feather stars and sea cucumbers), cnidaria (e.g. seapens), soft corals and sponges (various erect forms). Some organisms were partially buried under the sand and could not be identified (refer to Table 3-2 for additional detail and CATAMI classification codes).
- The percentage cover of benthic organisms (within the entire video frame) in Area 1b ranged from 0% to ~10% (excluding cover of biologenic gravel) over the entire transect length. As for Transect 1a, no obvious bathymetric features were seen on the transect maps or corresponded with the occurrence of different substrate types (e.g. sand ripples / flat sand / steps) or these scattered benthic organisms. These organisms occurred on all different substrate 'types'.
- Small bony fishes were seen on occasion, usually quickly moving out of the field of view of the ROV but were not identified for this assessment.
- Bioturbation of the seafloor in the form of small mounds, craters and thin trails was seen along the entire length of the transect indicating the presence of mobile organisms living on and within the seabed.

A summary of the habitat characteristics, flora and fauna recorded in Area 1b is provided in Table 3-2. This table also provides the CATAMI Species Codes for each seafloor feature and taxa identified.

The benthic habitat in the location where the transect crossed the pipeline route (as per the time stamp provided by Neptune) is shown in Figure 3-3 and consists of 3D rippled sand with a small amount of biologenic gravel.

A map showing the location of the transect in Area 1b in relation to bathymetry and the KEF, along with some georeferenced representative images of benthic habitat, is provided in Figure 3-4. No correlation between the seafloor bathymetry / rugosity and occurrence of benthic organisms could be seen for Transect 1b. Less sand ripples were apparent in the north-eastern deeper portion of the transect but this could not be seen on the mapping.

Additional images of benthic habitat and organisms present are provided in **Appendix B**.

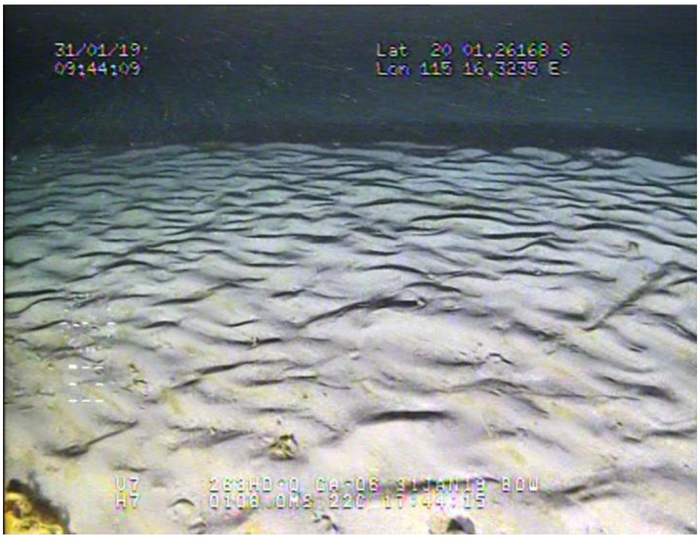

Figure 3-3 Benthic habitat in the location of the pipeline crossing in Area 1b.

Table 3-2 Summary of habitat features in Area 1b.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm)	82001005	Entire Transect
Bedform	2D ripples (<10 cm height) 3D ripples (<10 cm height)	82002003 82002007	Alternating 2D and 3D ripples over transect
Relief	Flat (with some small sand steps <50 cm)	82003001	Entire Transect
Bioturbation	Bioturbation: Crawling traces: Thin trail Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone	81005001 81001003 81001012	Occasional over entire transect
Bacterial mats	Bacterial mat	80000000	Around ½ transect
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Corals: Black & Octocorals: Quill (seapen) Corals (unidentified soft corals) Fishes: Bony fishes	25000000 25400901 10000916 10000913 10000915 10000909 11168918 11168000 37990083	Occasional sightings over the entire transect length – most organisms occurred in isolation

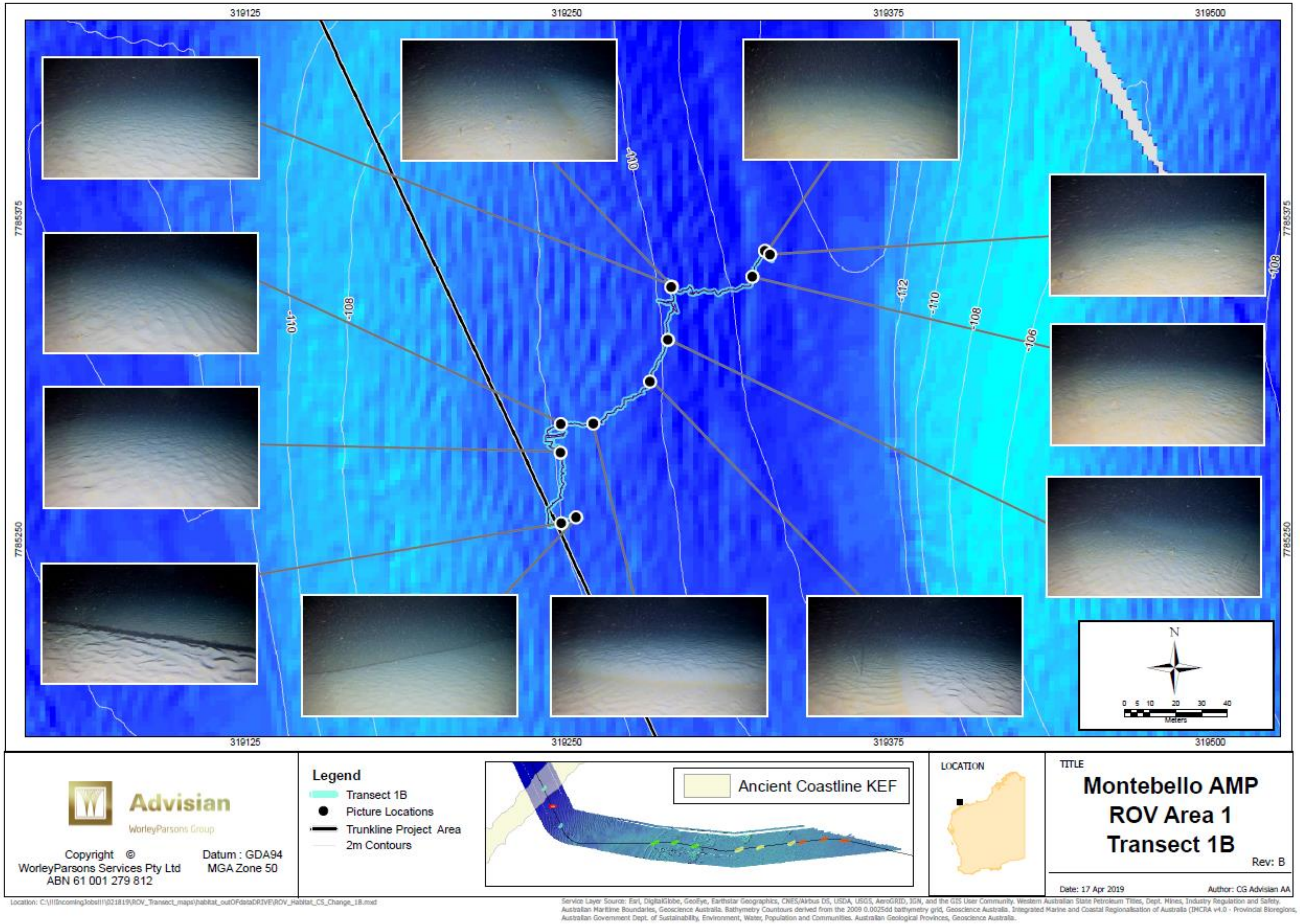

Figure 3-4 Typical benthic habitat and bathymetry in Area 1b.

3.1.3 Area 1c

Notes provided by Neptune for Area 1c included:

- The ROV crossed the proposed pipeline route at E320057, N7783523 at approximately 18:41:46.
- The ROV was on bottom at 18:34 and off bottom at 18:49.
- The south western margin of the track showed the seabed was flat comprising sand and larger gravel to small boulder sized carbonate debris which may be a localised hardpan formed from biological activity or sub-outcropping calcarenite.
- In the vicinity of the pipeline route the seabed was typically flat and had ripples associated with it. These typically had an organic/algae covering particularly in the troughs. Isolated soft corals also occurred.
- The seabed comprised a flat sandy seabed which had a sparse benthic habitat.
- No significant habitat features were observed.
- Due to strong currents and the ROV tether management it was not possible to run the transect more along the proposed pipeline route.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in this location are provided:

- The entire seafloor along the transect in Area 1c was flat and the bedforms alternated continually between flat bare sand to flat sand with small ripples (of both 2D and 3D forms) as for Area 1a and 1b. Some areas of seafloor had a higher cover of biologenic rubble (of unidentified origin) while others were bare (see Figure 3-6 and **Appendix 2**).
- In the vicinity of the pipeline route (as identified by the timestamp provided by Neptune), the seafloor was sandy with small ripples and occasional epifauna (see Figure 3-5).
- No moderate or high relief features or areas of consolidated hard substrate were present along the transect in Area 1c. However, some areas of biologenic rubble (perhaps shell, coral or small gravel but unidentifiable) were noted on the seafloor. However, the location of these areas could not be determined on the transect map with detailed bathymetry.
- Area 1c was located near to, but not within, the area mapped as the KEF (ancient coastline 125 m depth contour). The transect traversed an area of seabed which had a depth of around 95 to 100 m depth (see Figure 3-6). No potential features of the KEF (i.e. hard substrate with high biodiversity) were seen in Area 1c.

- Some areas of sand were bare while others were covered in a light bacterial mat. The bacterial mat was more prevalent in the troughs of ripples. This occurred over the length of the transect.

- Benthic epifauna were present on occasion and included echinoderms (e.g. feather stars and sea stars), cnidaria (e.g. seapens), soft corals (various forms) and sponges (various forms). Some organisms were buried under the sand and could not be identified (further detail and CATAMI classifications are provided in Table 3-3).

- The percentage cover of benthic organisms (within the entire video frame) in Area 1c ranged from 0% to ~ 15% and was typically greater in areas that had a higher cover of biologenic gravel. However, no obvious bathymetric features seen on the transect map corresponded with the occurrence of different substrate types (e.g. sand ripples / flat sand), areas with higher cover biologenic gravel or these scattered benthic organisms.

- Bioturbation of the seafloor in the form of small mounds, craters and thin trails was seen over the transect length, evidence of mobile organisms living within and on the seafloor.

- Sightings of mobile fauna were uncommon but included echinoderms (sea stars and sea cucumbers) and various small bony fishes (unidentified and usually quickly moving out of the field of view of the ROV).

A summary of the habitat characteristics, flora and fauna seen in Area 1c is provided in Table 3-3. This table also provides the CATAMI Species Codes for each seafloor feature and taxa identified.

The benthic habitat in the location of the pipeline crossing in Area 1c (as per the time stamp provided by Neptune) is shown in Figure 3-5 and includes a rippled sandy seabed with a low (<5%) cover of benthic organisms and some biologenic gravel.

A map showing the location of the transect in Area 1c in relation to bathymetry and the KEF, along with georeferenced representative images of benthic habitat is provided in Figure 3-6. No obvious correlation between the seafloor bathymetry / rugosity and occurrence of different habitat types or cover of benthic organisms could be seen for Transect 1c when looking at the transect map. However, video analysis noted that benthic cover was typically greater in areas which had a higher cover of biologenic gravel.

Additional images of the seafloor and benthic organisms in Area 1c are provided in **Appendix B**.

Figure 3-5 Benthic habitat in the location of the pipeline crossing in Area 1c.

Table 3-3 Summary of habitat features in Area 1c.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm)	82001005	Entire Transect
Bedform	2D ripples (<10 cm height) 3D ripples (<10 cm height)	82002003 82002007	Alternating between flat, 2D and 3D ripples over transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Crawling traces: Thin trail Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone	81005001 81001003 81001012	Occasional over entire transect
Bacterial mats	Bacterial mat	80000000	Around ½ transect
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Feather stars - Unstalked crinoids Echinoderms: Sea stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like	25000000 25001902 25102000 25400901 10000916 10000913 10000915 10000909	Occasional sightings over the entire transect length – most organisms occurred in isolation

Habitat Features	Description	CATAMI Species Code	Occurrence
	Sponges: Crusts: Creeping / ramose	10000917	
	Sponges: Massive forms – simple	10000904	
	Corals: Black & Octocorals: Quill (seapen)	11168918	
	Corals (unidentified soft corals)	11168000	
	Corals: Fleshy: Arborescent	11168911	
	Corals: Non-fleshy: Bushy	11168908	
	Fishes: Bony fishes	37990083	

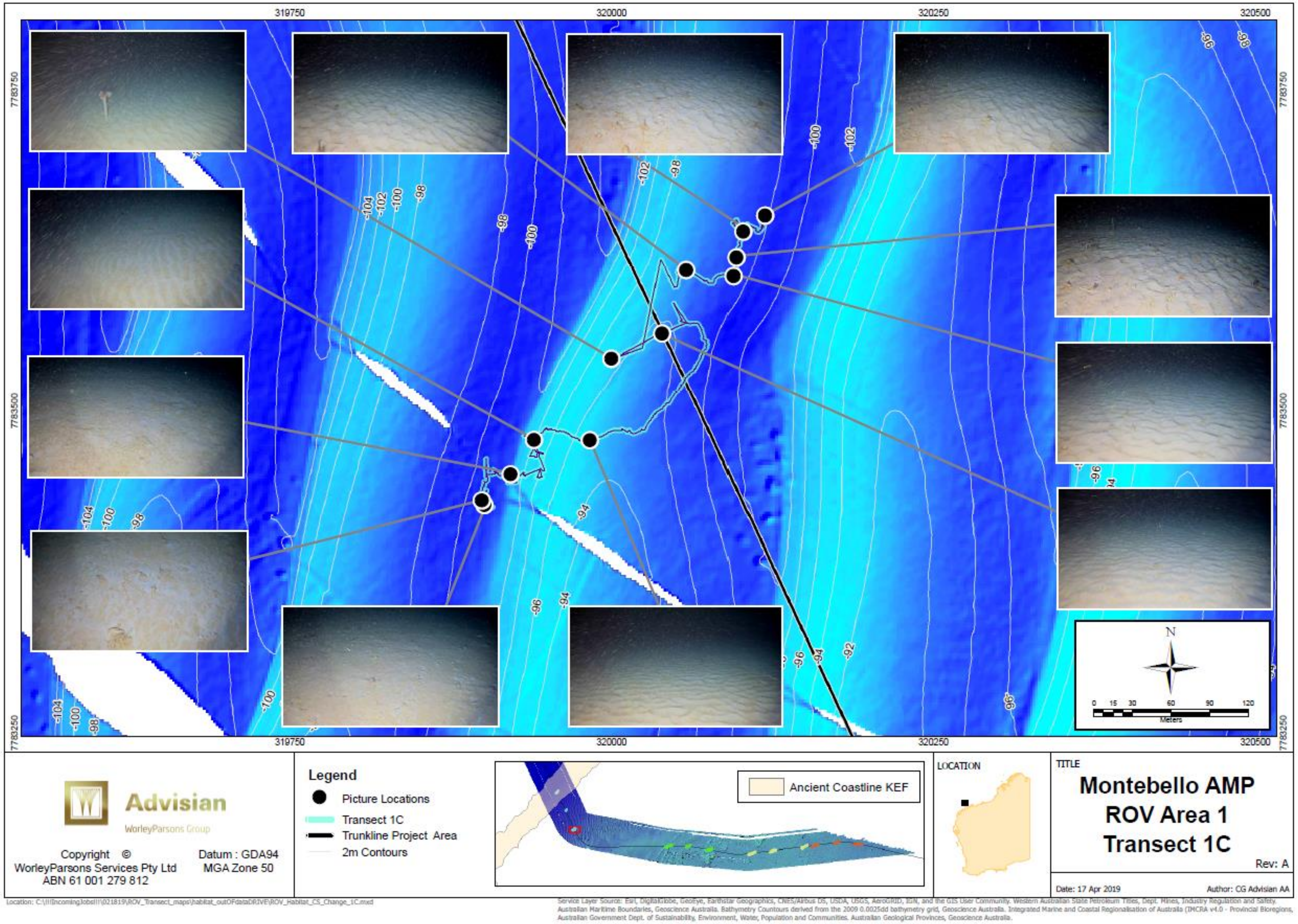

Figure 3-6 Typical benthic habitat and bathymetry in Area 1c.

3.2 Area 2

Three transects (of varying length) were surveyed in Area 2 and are described in more detail below. The depth at the midpoint of each of these transects ranged from 70.6 m to 74.4 m. While some representative images of each transect are provided in the Sections below, **Appendix C** provides additional images of benthic habitat and organisms seen along each transect in Area 2.

3.2.1 Area 2a

Notes provided by Neptune for Area 2a included:

- The ROV crossed the proposed pipeline route at E328839, N7781947 at approximately 06:48:04.
- The ROV was on bottom at 06:34 and off bottom at 06:59.
- The seabed was flat and comprised sand with subordinate bioclastic gravel. Benthic fauna included prolific soft corals, including large gorgonians and sponges.
- The seabed comprised a flat and predominantly sandy seabed which had considerable benthic habitat in the form of soft corals and sponges.
- No significant high relief habitat features were observed.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in this location are provided:

- The seafloor along Transect 2a was relatively flat and sandy with a light to high cover of biologenic gravel and/or organic material over its entire length. Some areas were relatively bare while others had a low (~5%) to high (~75%) density of benthic organisms. This benthic cover changed continually (within meters) over the transects length. Small undulations of the seabed were seen at times but no other bedforms such as sand ripples or sand waves were apparent (images are provided in Figure 3-8 and in **Appendix C**).
- The seafloor in the vicinity of the pipeline crossing (as per the timestamp provided by Neptune) was flat and sandy with a cover of ~30% of sponges and corals. This habitat types was similar to the rest of the transect (Figure 3-7).
- Bioturbation of the seafloor in the form of small cones, craters, burrows, small and large trails was apparent, evidence of mobile organisms living within and on the seabed.
- No significant high relief habitat features, or areas of consolidated hard substrate, were observed. The entire transect occurred in water depths ranging from around 72 m to 74 m (refer to Figure 3-8).

- Benthic epifauna were present along almost the entire transect, occurring in patches which varied from low (~5%) to high (~75%) density, and which changed continuously. High density aggregations were often found in areas which had a high cover of biologenic gravel, but were not limited to these areas, also being found where the sediment appeared to be quite fine and where no biologenic gravel was obvious. This benthic fauna comprised a diverse array of sponges and soft corals with varying forms, sizes and colours (refer to Figure 3-8 and **Appendix C**). Hydroids were also apparent on occasion along the transect length. Further details of taxa present and CATAMI codes are provided in Table 3-4.

- Fish fauna diversity was quite high, and varying sizes of fish were seen amongst the aggregations of corals and sponges and over bare sandy seafloor. Identification of fish fauna was not undertaken as part of this assessment.

A summary of the habitat characteristics, flora and fauna seen along the transect in Area 2a is provided in Table 3-4. This table also provides the CATAMI Species Codes for each seafloor feature and taxa that could be identified.

The benthic habitat in the location of the pipeline crossing in Area 2a (as per timestamp provided by Neptune) is shown in Figure 3-7. This area was flat and sandy with many sponges and corals present (~30% cover).

A map showing the location of the transect in Area 2a in relation to depth contours and detailed bathymetry, along with georeferenced representative images of benthic habitat is provided in Figure 3-8. There were no obvious differences in the cover of benthic organisms related to seafloor bathymetry / rugosity on the map which could be clearly differentiated by looking at the transect map, with a higher cover of organisms occurring in areas which appeared to be highly rugose and also in areas not as rugose. Similarly, areas with low cover of organisms occurred in more rugose and less rugose areas. Video analysis showed that sponges and corals occurred in low to high density along most of the transect length and occurred in varying density in areas of bare soft sediment and also those areas with higher levels of biologenic gravel.

Benthic habitat in the location of the pipeline crossing in Area 2a (as per the time stamp provided by Neptune) is shown in Figure 3-7. Additional images of the benthic habitat and fauna in Area 2a are provided in **Appendix C**.

Figure 3-7 Benthic habitat in the location of the pipeline crossing in Area 2a.

Table 3-4 Summary of habitat features in Area 2a.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm) Unconsolidated (soft): Pebble / gravel: Biologenic	82001005 82001007	Entire Transect Entire Transect
Bedform	Bioturbated	82002005	Entire transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Crawling traces: Thin trail Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone Bioturbation: Dwelling traces: Single burrow	81005001 81001003 81001012 81001006	Occasional over entire transect
Bacterial mats	Nil	NA	NA
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Sea stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Sponges: Cup-likes: Cups Sponges: Cups: Cup / goblet	25000000 25102000 25400901 10000916 10000913 10000915 10000909 10000910 10000919	Sponges and corals of high diversity were common and scattered over most of the seafloor in transect Area 2a. Patches of benthic epifauna changed

Habitat Features	Description	CATAMI Species Code	Occurrence
	Sponges: Cup-likes: Tubes and chimneys	10000911	continuously from low to high density.
	Sponges: Crusts: Creeping / ramose	10000917	
	Sponges: Massive forms – simple	10000904	
	Sponges: Massive forms: Cryptic	10000908	
	Corals: Black & Octocorals: Quill (seapen)	11168918	
	Corals (unidentified soft corals)	11168000	
	Corals: Fleshy: Arborescent	11168911	
	Corals: Non-fleshy: Bushy	11168908	
	Corals: Fern-frond: Complex	11168915	
	Corals: Black & Octocorals: Fan (2D)	11168912	
	Corals: Black & Octocorals: Whip	11168917	
	Cnidaria: Hydroids	11001000	
	Fishes: Bony fishes	37990083	

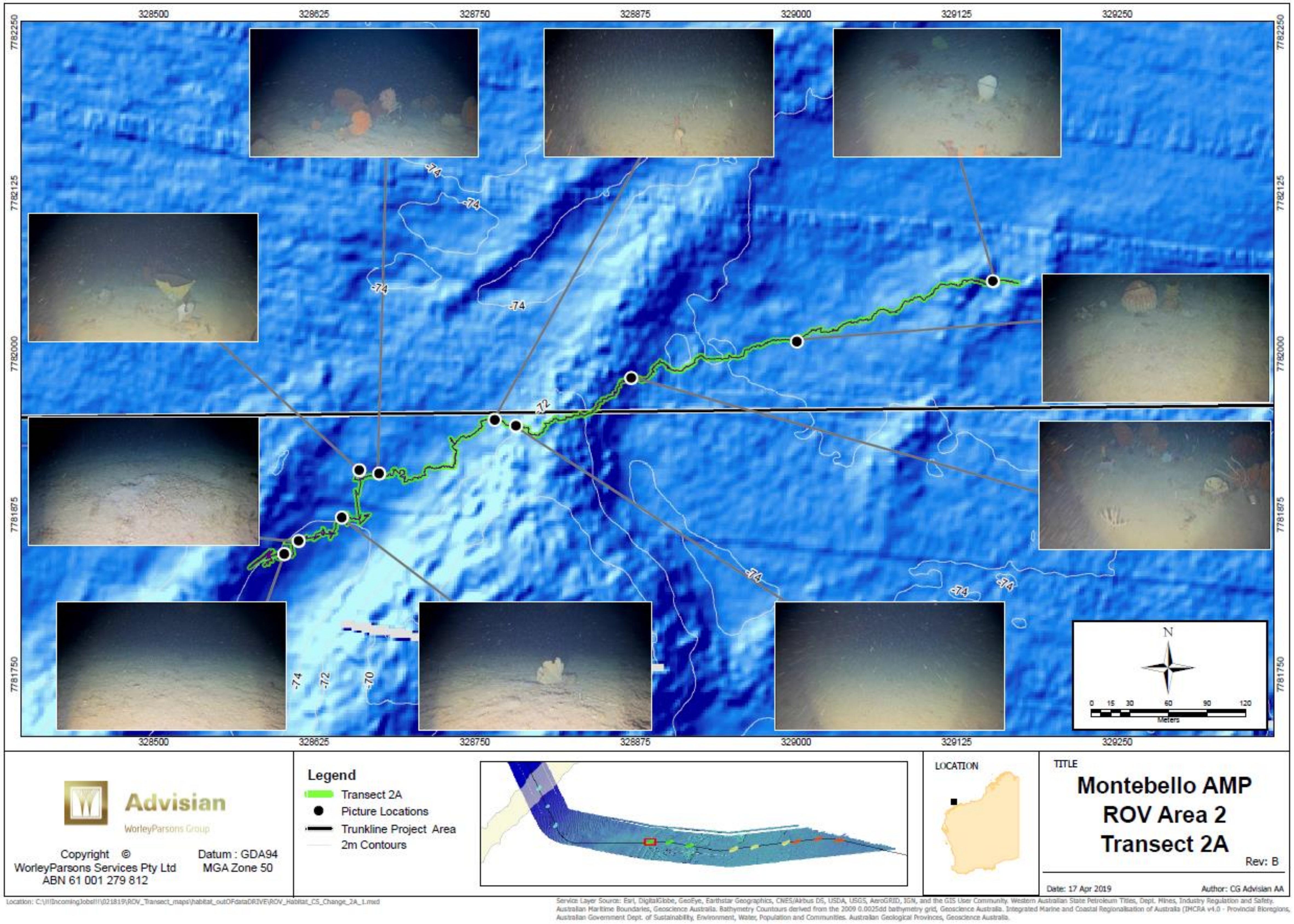

Figure 3-8 Typical benthic habitat and bathymetry in Area 2a.

3.2.2 Area 2b

Notes provided by Neptune for Area 2b included:

- The ROV crossed the proposed pipeline route in the vicinity of E330686, N7781970 at approximately 07:38:39.
- The ROV was on bottom at 07:29 and off bottom at 07:47.
- The seabed was flat and comprised sand with subordinate bioclastic gravel. Benthic fauna included soft corals, including large gorgonians and sponges.
- The seabed comprised a flat predominantly sandy seabed with considerable benthic habitat in the form of soft corals and sponges.
- No significant high relief habitat features were observed.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in this location are provided:

- The seafloor along Transect 2b was very similar to 2a. The seafloor was relatively flat and sandy with a light to high cover of biologenic gravel and/or organic material over its entire length. Some areas were relatively bare while others had a low (~5%) to high (~75%) density cover of benthic organisms. The cover of benthic organisms changed continually over the transect length. Small undulations of the seabed and some more pronounced scouring around larger sponges / soft corals was seen at times but no other formal bedforms such as sand ripples or sand waves were apparent. Images are provided in Figure 3-10 and **Appendix C**.
- The seafloor in the vicinity of the pipeline crossing was flat and sandy with many sponges and soft corals present (~50% cover). This habitat was similar to the rest of the transect (see Figure 3-9).
- Bioturbation of the seafloor in the form of small cones, craters, burrows, small and large trails was apparent providing evidence of mobile organisms within and on the seafloor.
- No significant moderate or high relief habitat features, or areas of consolidated hard substrate, were observed. Biologenic gravel was present and quite common. The transect occurred in water depths ranging from around 74 m to 76 m (refer to Figure 3-10)
- Benthic epifauna were present along almost the entire transect, occurring in aggregations which varied continually from low (~5%) to high (~75%) density. As for Transect 2a, high density aggregations were often found in areas which had a high cover of biologenic gravel, but were in no way limited to these areas, with dense aggregations also found in areas with less or no biologenic gravel and soft sediment.

- This benthic epifauna comprised a diverse array of sponges and corals with varying forms, sizes and colours. Hydroids were also apparent on occasion along the transect length. More detail on taxa and CATAMI codes are provided in
- Table 3-5.
- Fish fauna diversity was quite high, and varying sizes of fish were seen amongst the aggregations of corals and sponges and over bare sandy seafloor. Although, IDs of fish fauna were not undertaken for this assessment.
- A summary of the habitat characteristics, flora and fauna seen along the transect in Area 2b is provided in
- Table 3-5. This table also provides the CATAMI Species Codes for each seafloor feature and taxa that could be identified.

The benthic habitat in the location of the pipeline crossing in Area 2b (as per timestamp provided by Neptune) is shown in Figure 3-9. This area was flat and sandy with many sponges and corals present (around 50% cover).

A map showing the location of the transect in Area 2b in relation to depth contours, detailed bathymetry and with georeferenced representative images of benthic habitat is provided in Figure 3-10. Rugosity along the length of transect was quite similar and while some georeferenced images suggest that areas with slightly higher rugosity had a higher cover of organisms, other images show that some areas of higher rugosity also had a lower cover of benthic organisms. Similarly, high cover of organisms was also seen in relatively less rugose areas. However, the 'generally' rugose nature of the seabed as indicated by the transect image may provide some explanation for the generally common occurrence of benthic organisms in this location. Additional images of habitat and fauna are provided in **Appendix C**.

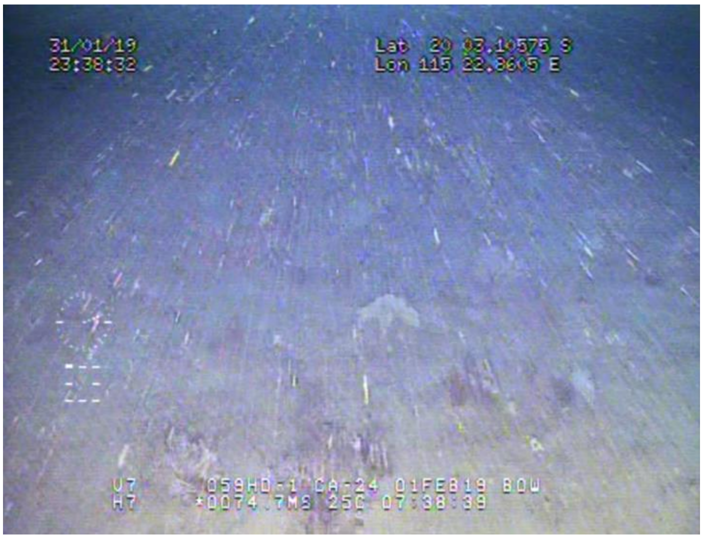

Figure 3-9 Benthic habitat in the location of the pipeline crossing in Area 2b.

Table 3-5 Summary of habitat features in Area 2b.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm) Unconsolidated (soft): Pebble / gravel: Biologenic	82001005 82001007	Entire Transect Entire Transect
Bedform	Bioturbated	82002005	Entire transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Crawling traces: Thin trail Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone Bioturbation: Dwelling traces: Single burrow	81005001 81001003 81001012 81001006	Occasional over entire transect
Bacterial mats	Nil	NA	NA
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Sea stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Sponges: Cup-likes: Cups Sponges: Cups: Cup / goblet Sponges: Cup-likes: Tubes and chimneys Sponges: Crusts: Creeping / ramose Sponges: Massive forms – simple Sponges: Massive forms: Cryptic Corals: Black & Octocorals: Quill (seapen) Corals (unidentified soft corals) Corals: Fleshy: Arborescent Corals: Non-fleshy: Bushy Corals: Fern-frond: Complex Corals: Black & Octocorals: Fan (2D) Corals: Black & Octocorals: Whip Cnidaria: Hydroids Fishes: Bony fishes	25000000 25102000 25400901 10000916 10000913 10000915 10000909 10000910 10000919 10000911 10000917 10000904 10000908 11168918 11168000 11168911 11168908 11168915 11168912 11168917 11001000 37990083	Sponges and corals of high diversity were common and scattered over most of the seafloor in transect Area 2b. Patches of benthic epifauna changed continuously from low to high density.

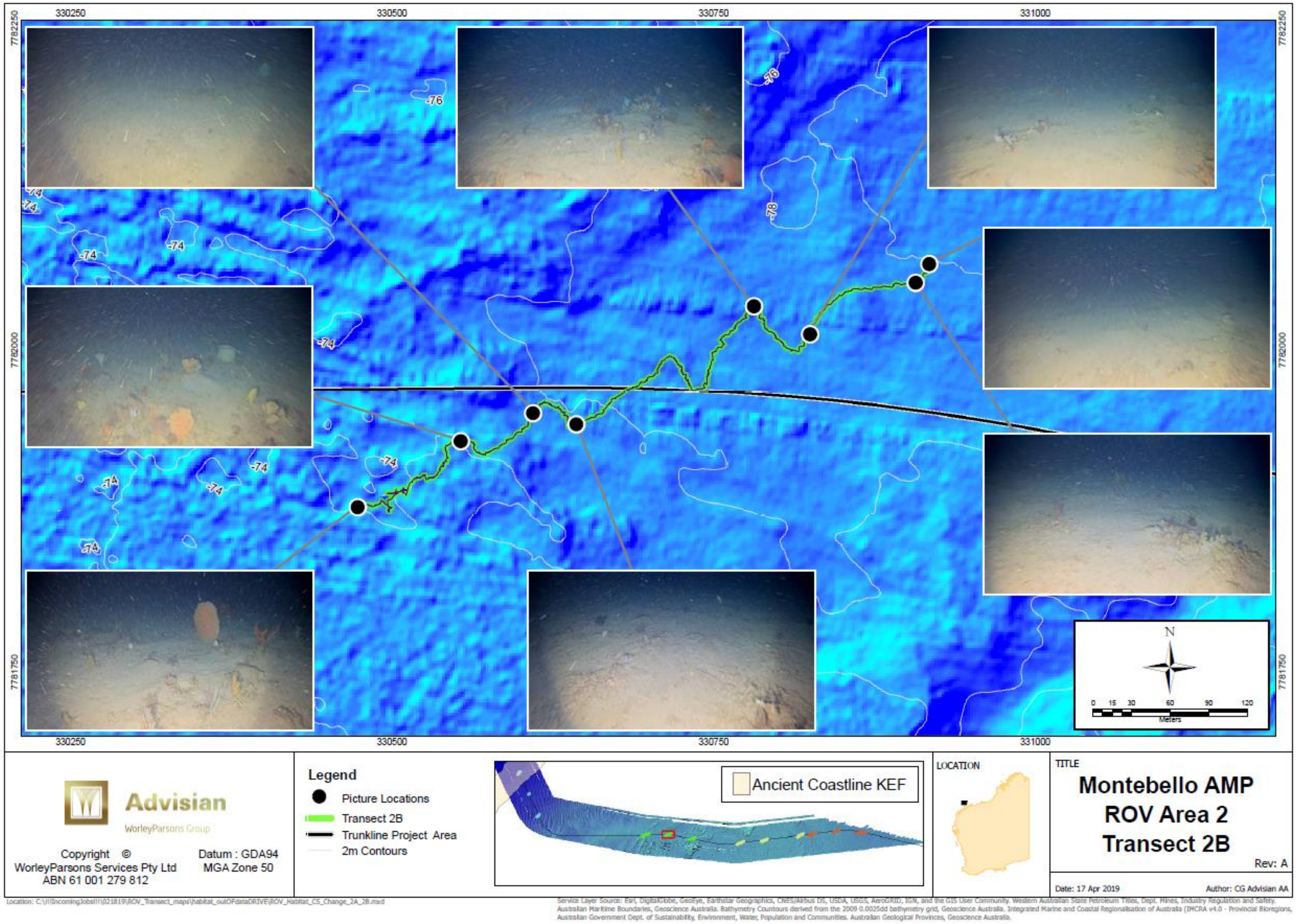

Figure 3-10 Typical benthic habitat and bathymetry in Area 2b.

3.2.3 Area 2c

Notes provided by Neptune for Area 2c included:

- The ROV crossed the proposed pipeline route in the vicinity of E332653, N7781637 at approximately 08:26:10.
- The ROV was on bottom at 08:16 and off bottom at 08:34.
- The seabed was flat and comprised sand with subordinate bioclastic gravel. Benthic fauna included areas of soft corals, including large gorgonians and sponges.
- The seabed comprised a flat predominantly sandy seabed with benthic habitat in the form of areas of soft corals and sponges.
- No significant high relief habitat features were observed.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in this location are provided:

- The seafloor along Transect 2c was again very similar to that in Area 2a and 2b. The seafloor was relatively flat and sandy (fine sand) with a light to high cover of biologenic gravel and/or organic material over most of its length. Some areas were relatively bare while others had a low (~5%) to high (~80%) density of benthic organisms. The benthic cover changed continually (and within meters) over the transects length. Small undulations of the seabed and some scouring around larger sponges / soft corals was seen, but no other formal bedforms such as sand ripples or sand waves were apparent. Images are provided in Figure 3-12 and **Appendix C**.
- The seafloor in the vicinity of the pipeline crossing (as per timestamp provided by Neptune) was flat and sandy with sponges and soft corals present (~20%) and the habitat was similar to the rest of the transect (see Figure 3-11).
- Bioturbation of the seafloor in the form of small cones, craters, burrows, small and large trails was apparent providing evidence of mobile organisms living on and within the seabed.
- No significant moderate or high relief habitat features, or areas of consolidated hard substrate, were observed on the video. Some areas of unconsolidated biologenic rubble of unknown origin were seen. The depth of the seafloor in Area 2c ranged from around 72 m to 74 m (refer to Figure 3-12). Figure 3-12 shows that the seafloor was slightly more rugose at the start and end of the transect with a flatter expanse in the middle.
- Benthic epifauna were present along almost the entire transect, occurring in patches which varied continually from low (~5%) to high (~80%) density. This benthic fauna comprised a diverse array of sponges and corals with varying forms, sizes and colours. Hydroids were also apparent on occasion along the transect length. Additional details and CATAMI

classifications are provided in Table 3-6. Video analysis (and georeferenced images to some degree) showed that benthic organisms were more common (and their cover was denser) at the start and end of the transect. This may be related to the reduced rugosity of the seafloor in the middle expanse seen in Figure 3-12. However, benthic organisms were in no way excluded from this less rugose area, they just tended to occur in lower densities when they did occur.

- Fish fauna diversity was quite high, and varying sizes of fish were seen amongst the aggregations of corals and sponges and over bare sandy seafloor. Although, IDs of fish fauna were not undertaken.

A summary of the habitat characteristics, flora and fauna seen along the transect in Area 2c is provided in Table 3-6. This table also provides the CATAMI Species Codes for each seafloor feature and taxa that could be identified.

The benthic habitat in the location of the pipeline crossing (as per timestamp provided by Neptune) is shown in Figure 3-11. This area was flat and sandy sponges and soft corals present, representing about 20% cover.

A map showing the location of the transect in Area 2c in relation to depth contours, along with representative images of benthic habitat, is provided in Figure 3-12. Area 2c showed some increased rugosity at either end of the transect with an expansive flatter area in the middle. The occurrence (and density) of benthic organisms was also generally greater at both ends of the transect and these bottom features may be related in this case. Notwithstanding this, benthic organisms were not excluded from the flatter mid section of Transect 2c.

Additional images of benthic habitat and fauna are provided in **Appendix C**.

Figure 3-11 Benthic habitat in the location of the pipeline crossing in Area 2c.

Table 3-6 Summary of habitat features in Area 2c.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm) Unconsolidated (soft): Pebble / gravel: Biologenic	82001005 82001007	Entire Transect Entire Transect
Bedform	Bioturbated	82002005	Entire transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Crawling traces: Thin trail Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone Bioturbation: Dwelling traces: Single burrow	81005001 81001003 81001012 81001006	Occasional over entire transect
Bacterial mats	Nil	NA	NA
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Sea stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Sponges: Cup-likes: Cups Sponges: Cups: Cup / goblet Sponges: Cup-likes: Tubes and chimneys Sponges: Crusts: Creeping / ramose Sponges: Massive forms – simple Sponges: Massive forms: Cryptic Corals: Black & Octocorals: Quill (seapen) Corals (unidentified soft corals) Corals: Fleshy: Arborescent Corals: Non-fleshy: Bushy Corals: Fern-frond: Complex Corals: Black & Octocorals: Fan (2D) Corals: Black & Octocorals: Whip Cnidaria: Hydroids Fishes: Bony fishes	25000000 25102000 25400901 10000916 10000913 10000915 10000909 10000910 10000919 10000911 10000917 10000904 10000908 11168918 11168000 11168911 11168908 11168915 11168912 11168917 11001000 37990083	Sponges and corals of high diversity were common and scattered over most of the seafloor in transect Area 2c. Patches of benthic epifauna changed continuously from low to high density.

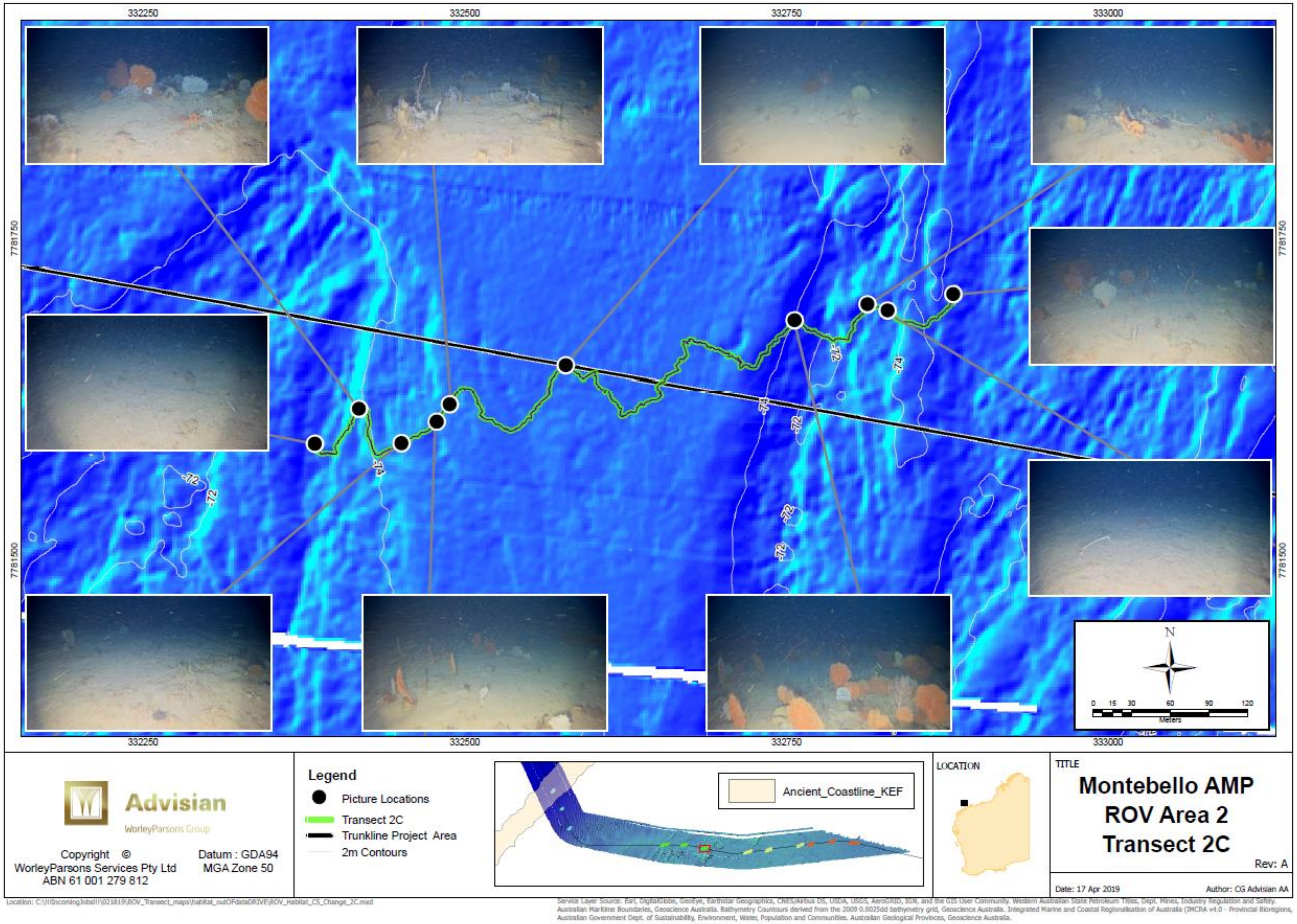

Figure 3-12 Typical benthic habitat and bathymetry in Area 2c.

3.3 Area 3

Three transects were completed in Area 3 and are described in more detail in the Sections below. The depth at the midpoint of these transects ranged from 71.6 m to 73.8 m. While some representative images of each transect are provided in the Sections below, **Appendix D** provides additional images of the benthic habitat and organisms seen along each transect in Area 3.

3.3.1 Area 3a

Notes provided by Neptune for Area 3a included:

- The ROV crossed the proposed pipeline route in the vicinity of E336608, N7781312 at approximately 09:35.
- The ROV was on bottom at 09:25 and off bottom at 09:51.
- The seabed was typically flat and comprised sand with subordinate bioclastic gravel. Benthic fauna included areas of soft corals, including large gorgonians and sponges as well as black 'whip' corals.
- The seabed comprised a flat predominantly sandy seabed with benthic habitat in the form of areas of soft corals and sponges.
- No significant high relief habitat features were observed.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in this location are provided:

- The seafloor along Transect 3a was relatively flat and sandy with a light to high cover of biologenic gravel and/or organic material over its entire length (continually changing). The seabed was a mosaic of bare substrate and low (~5%) to high (~75%) density cover of benthic organisms (e.g. sponges / soft corals), changing every few meters. This was very similar to Area 2. Small undulations of the seabed and some small sand waves were present on occasion, but no other regular bedforms such as sand ripples or sand waves were apparent. Images are provided in Figure 3-14 and **Appendix D**.
- The seafloor in the vicinity of the pipeline crossing (as identified by the time stamp provided by Neptune) was flat and sandy with a low-medium density cover (~20%) of sponges and soft corals and this habitat was typical of the rest of the transect (see Figure 3-13).
- Bioturbation of the seafloor in the form of small cones, craters, burrows and small and large trails was apparent. This occurred over the entire transect length and indicates the presence of mobile organisms living within and on top of the seabed.

- No significant moderate or high relief habitat features or areas which could clearly be defined as consolidated hard substrate were observed. Some potential very low profile outcropping was seen, although this was hard to clearly define with the often high cover of biologenic gravel and benthic organisms. The depth of the seafloor was between 75 m to 76 m along the entire transect (refer to Figure 3-14).

- Benthic epifauna were present along the entire transect and occurred in patches which changed continuously from low (~5%) to high (~75%) density. This benthic fauna comprised a diverse array of sponges and soft corals with varying forms, sizes and colours. Hydroids were also apparent on occasion along the transect length. Additional details and CATAMI classifications are provided in Table 3-7. High density benthic cover was seen in areas where biologenic gravel was high but also in areas of fine sediment. In addition, there were areas with a high cover of biologenic gravel which lacked any benthic organisms. The detailed bathymetry shown in Figure 3-14 did not differ significantly over the transect length. While there is some evidence of higher benthic cover in more rugose areas and less benthic cover in less rugose areas, this was not always the case as seen on the video.

- Fish fauna diversity was quite high, and varying sizes of fish were seen amongst the aggregations of corals and sponges and also over bare sandy seafloor. Identifications of fish were not undertaken as part of this assessment. Seastars and feather stars were both present.

A summary of the habitat characteristics, flora and fauna seen in Area 3a is provided in Table 3-7. This table also provides the CATAMI Species Codes for each seafloor feature and taxa that could be identified.

The benthic habitat in the location of the pipeline crossing (as per the timestamp provided by Neptune) is shown in Figure 3-13. The seafloor in this area was flat and sandy with a low-medium density cover (~20%) of sponges and soft corals. This habitat type was typical of the transect.

A map showing the location of the transect in Area 3a in relation to detailed bathymetry, along with georeferenced representative images of benthic habitat, is provided in Figure 3-14. While this mapping shows some evidence for higher benthic cover in areas of slightly higher rugosity, this was not always the case. In addition, the video analysis found that high benthic cover was not limited to particular substrate types (e.g. bare sand/soft sediment or areas with higher biologenic gravel).

Additional images of the seafloor habitat and epifauna in Area 3a are provided in **Appendix D**.

Figure 3-13 Benthic habitat in the location of the pipeline crossing in Area 3a.

Table 3-7 Summary of habitat features in Area 3a.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm) Unconsolidated (soft): Pebble / gravel: Biologenic	82001005 82001007	Entire Transect Entire Transect
Bedform	Bioturbated	82002005	Entire transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Crawling traces: Thin trail Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone Bioturbation: Dwelling traces: Single burrow	81005001 81001003 81001012 81001006	Occasional over entire transect
Bacterial mats	Nil	NA	NA
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Sea stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Sponges: Cup-likes: Cups Sponges: Cups: Cup / goblet	25000000 25102000 25400901 10000916 10000913 10000915 10000909 10000910 10000919	Sponges and corals of high diversity were common and scattered over

Habitat Features	Description	CATAMI Species Code	Occurrence
	Sponges: Cup-likes: Tubes and chimneys	10000911	most of the seafloor in transect Area 3a. Patches of benthic epifauna changed continuously from low to high density.
	Sponges: Crusts: Creeping / ramose	10000917	
	Sponges: Massive forms – simple	10000904	
	Sponges: Massive forms: Cryptic	10000908	
	Corals: Black & Octocorals: Quill (seapen)	11168918	
	Corals (unidentified soft corals)	11168000	
	Corals: Fleshy: Arborescent	11168911	
	Corals: Non-fleshy: Bushy	11168908	
	Corals: Fern-frond: Complex	11168915	
	Corals: Black & Octocorals: Fan (2D)	11168912	
	Corals: Black & Octocorals: Whip	11168917	
	Cnidaria: Hydroids	11001000	
	Fishes: Bony fishes	37990083	

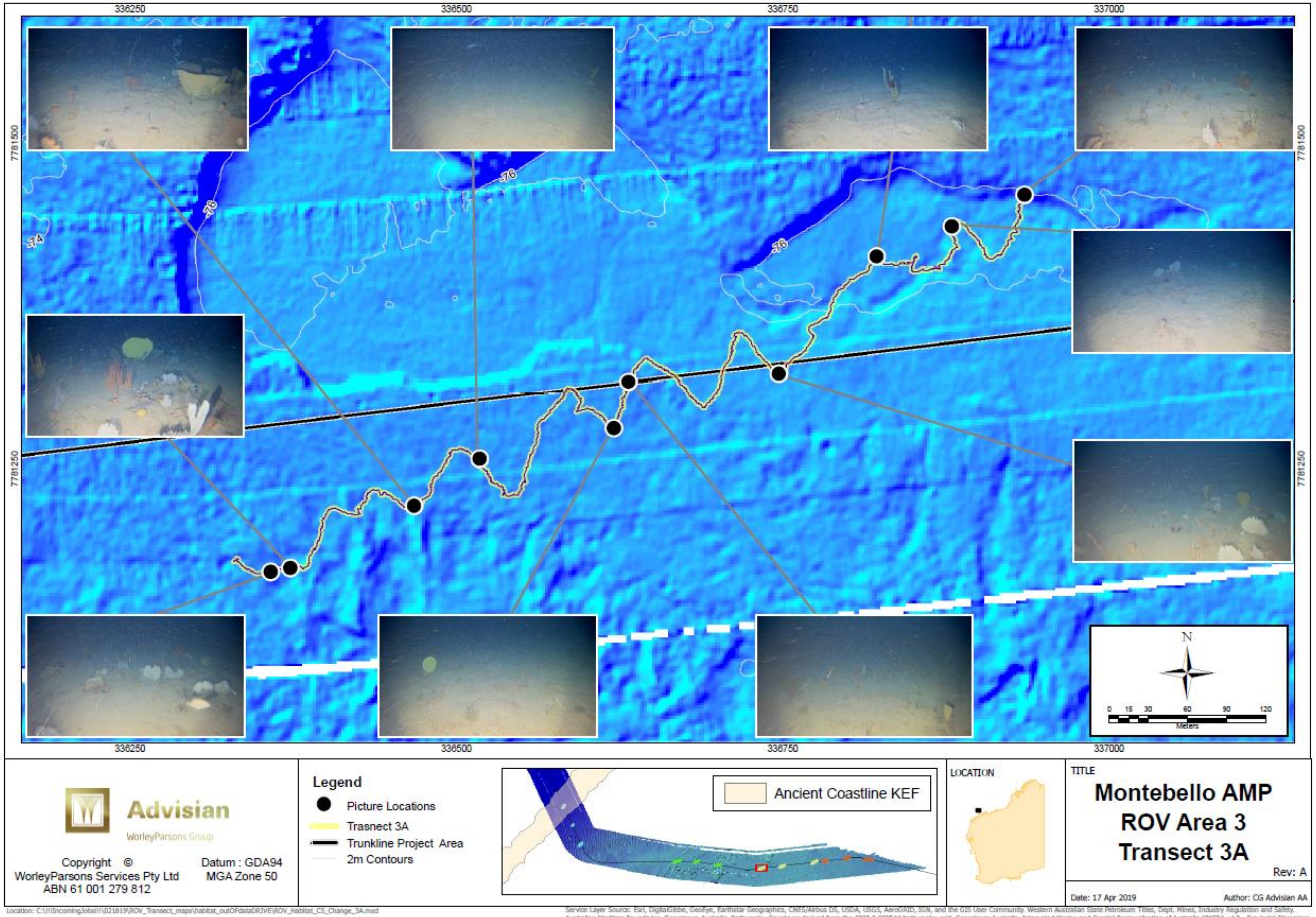

Figure 3-14 Typical benthic habitat and bathymetry in Area 3a.

3.3.2 Area 3b

Notes provided by Neptune for Area 3b included:

- The ROV crossed the proposed pipeline route in the vicinity of E338667, N7781567 at approximately 10:41.
- The ROV was on bottom at 10:25 and off bottom at 10:49.
- The seabed was typically flat and comprised sand with subordinate bioclastic gravel. Benthic fauna included areas of soft corals, including large gorgonians and sponges.
- The seabed comprised a flat and predominantly sandy seabed with benthic habitat in the form of areas of soft corals and sponges.
- No significant high relief habitat features were observed.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in this location are provided:

- The seafloor along Transect 3b was very similar to 3a. The seafloor was relatively flat and sandy with a light to high cover of biologenic gravel and/or organic material over its entire length (continually changing). Small undulations of the seabed and some small sand waves and scour pits (typically around larger organisms or aggregations of organisms) were present on occasion, but no other regular bedforms such as sand ripples or sand waves were apparent. The seabed was a mosaic of bare substrate and low (~5%) to medium (~50%) density cover of benthic organisms (e.g. sponges / soft corals), changing every few meters. Images are provided in Figure 3-16 and **Appendix D**.
- The seafloor in the vicinity of the pipeline crossing (as identified by the time stamp provided by Neptune) was flat and sandy with a low-medium density cover (~30%) of sponges and soft corals (see Figure 3-15).
- Bioturbation of the seafloor in the form of small cones, craters, burrows and small and large trails was apparent. This occurred over the entire transect length and provides evidence for mobile organisms living within and on the seafloor.
- No significant moderate or high relief habitat features, or significant areas of consolidated hard substrate, were present. Some potential small areas of outcropping were seen although this was hard to clearly define with the high cover of biologenic gravel and benthic organisms. The entire transect occurred in water depths of about 73 m to 74 m (refer to Figure 3-16). Rugosity was quite consistent over the transect length.
- Benthic epifauna were present along the entire transect and occurred in patches which changed continuously from low (~5%) to medium (~50%) density. Benthic fauna comprised a diverse array of sponges and soft corals with varying forms, sizes and colours. Hydroids were also apparent on occasion along the transect length. Additional

classification details and CATAMI codes are provided in Table 3-8. The transect map for Area 3b (Figure 3-16), overlaid with georeferenced images, shows that benthic organisms occurred along the entire transect length and were often of a medium density (~30-40% cover). Bare substrate was less common in Area 3b.

- Fish fauna diversity was quite high, as seen for transect 3a, and varying sizes of fish were seen amongst the aggregations of soft corals and sponges and over bare sandy seafloor. Identifications of fish were not undertaken as part of this assessment. Seastars and feather stars were both present.

A summary of the habitat characteristics, flora and fauna seen in Area 3b is provided in Table 3-8. This table also provides the CATAMI Species Codes for each seafloor feature and taxa that could be identified.

The benthic habitat in the location of the pipeline crossing in Area 3b is shown in Figure 3-15. This area was flat and sandy with a low-medium density cover (~30%) of sponges and soft corals.

A map showing the location of the transect in Area 3b in relation to bathymetry, along with representative images of benthic habitat, is provided in Figure 3-16. Benthic organisms were common along the entire length of the transect, which was quite similar in its rugosity.

Additional images of the seafloor habitat and epifauna in Area 3b are provided in **Appendix D**.

Figure 3-15 Benthic habitat in the location of the pipeline crossing in Area 3b.

Table 3-8 Summary of habitat features in Area 3b.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm) Unconsolidated (soft): Pebble / gravel: Biologenic	82001005 82001007	Entire Transect Entire Transect
Bedform	Bioturbated	82002005	Entire transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Crawling traces: Thin trail Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone Bioturbation: Dwelling traces: Single burrow	81005001 81001003 81001012 81001006	Occasional over entire transect
Bacterial mats	Nil	NA	NA
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Sea stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Sponges: Cup-likes: Cups Sponges: Cups: Cup / goblet Sponges: Cup-likes: Tubes and chimneys Sponges: Crusts: Creeping / ramose Sponges: Massive forms – simple Sponges: Massive forms: Cryptic Corals: Black & Octocorals: Quill (seapen) Corals (unidentified soft corals) Corals: Fleshy: Arborescent Corals: Non-fleshy: Bushy Corals: Fern-frond: Complex Corals: Black & Octocorals: Fan (2D) Corals: Black & Octocorals: Whip Cnidaria: Hydroids Fishes: Bony fishes	25000000 25102000 25400901 10000916 10000913 10000915 10000909 10000910 10000919 10000911 10000917 10000904 10000908 11168918 11168000 11168911 11168908 11168915 11168912 11168917 11001000 37990083	Sponges and corals of high diversity were common and scattered over most of the seafloor in transect Area 3b. Patches of benthic epifauna changed continuously from low to high density.

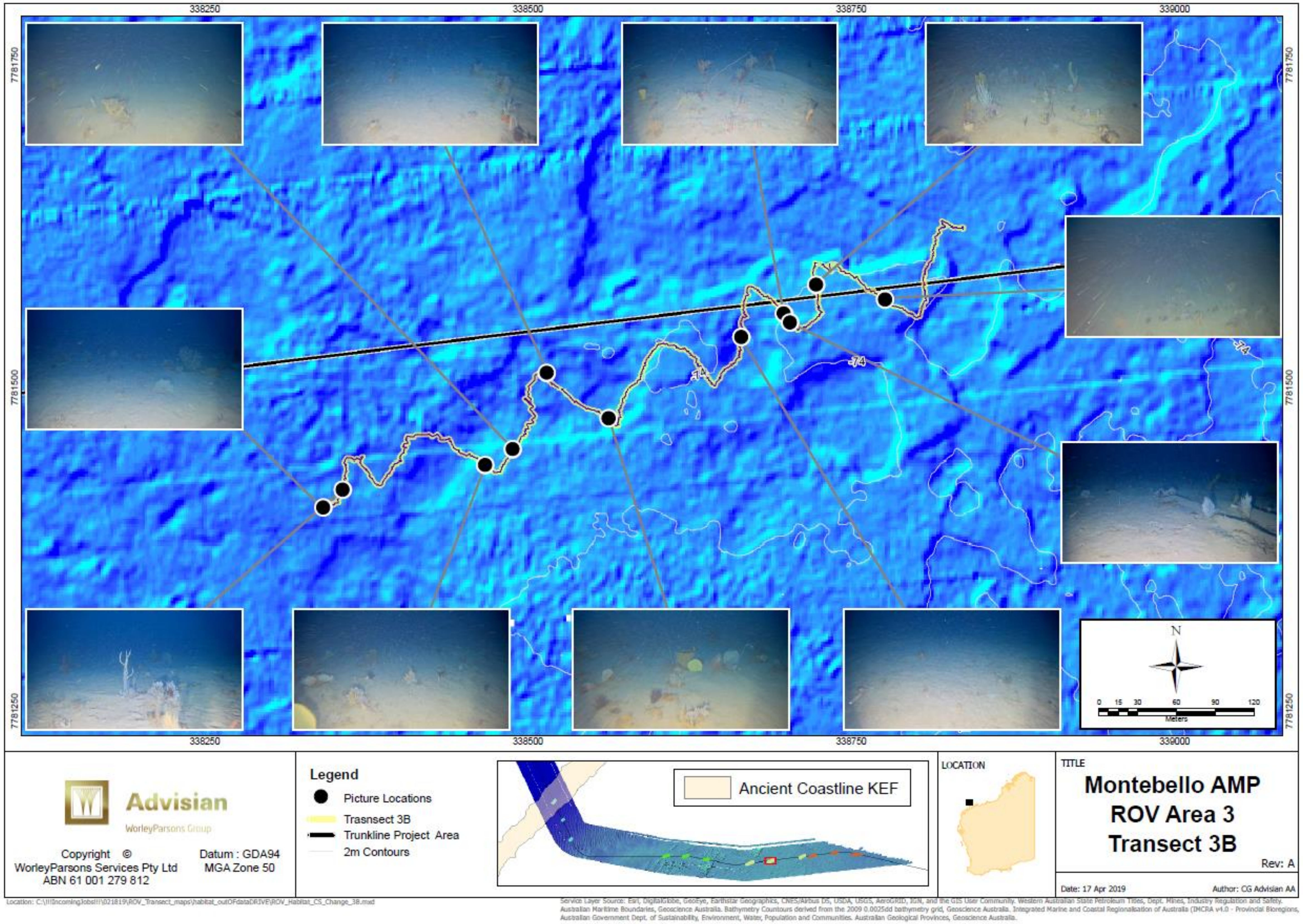

Figure 3-16 Typical benthic habitat and bathymetry in Area 3b.

3.3.3 Area 3c

Notes provided by Neptune for Area 3c included:

- The ROV crossed the proposed pipeline route in the vicinity of E341572, N7781919 at approximately 11:40.
- The ROV was on bottom at 11:28 and off bottom at 11:54.
- The seabed was typically flat to undulating and comprised sand with subordinate bioclastic gravel. Benthic fauna included sporadic areas of soft corals, including large gorgonians and sponges as well as black 'whip' corals. Current scour moats were noted around some of the sponges.
- The seabed comprised a flat predominantly sandy seabed with benthic habitat in the form of isolated areas of soft corals and sponges.
- No significant high relief habitat features were observed.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in this location are provided:

- The seafloor along Transect 3c was very similar to 3a and 3b. The seafloor was relatively flat and sandy with a light to high cover of biologenic gravel and/or organic material over its entire length (continually changing). Small undulations of the seabed and some small sand waves and scour pits were present on occasion, but no other regular bedforms such as sand ripples or sand waves were apparent. The seabed was a mosaic of bare substrate and low to high density cover of benthic organisms (e.g. sponges / soft corals), changing every few meters. Images are provided in Figure 3-18 and **Appendix D**.
- The seafloor in the vicinity of the pipeline crossing (as identified by the time stamp provided by Neptune) was flat and sandy with a low-medium density cover (~30%) of sponges and soft corals (see Figure 3-17).
- Bioturbation of the seafloor in the form of small cones, craters, burrows and small and large trails was apparent. This occurred over the entire transect length and provides evidence for mobile organisms living within and on the soft sediment.
- No significant moderate or high relief habitat features, or significant areas of consolidated hard substrate, were present. Some potential small areas of outcropping were seen on the video although this was hard to clearly define with the high cover of biologenic gravel and benthic organisms. The entire transect occurred in water depths between around 75 m and 76 m (refer to Figure 3-18). Rugosity was generally consistent over the transect length but was slightly higher in the south-western end of the transect.
- Benthic epifauna were present along the entire transect and occurred in patches which changed continuously from low (~5%) to medium (~50%) density, very similar to the other

transects in Area 3. Benthic fauna comprised a diverse array of sponges and soft corals with varying forms, sizes and colours. Hydroids were also apparent on occasion along the transect length. Additional classification details and CATAMI codes are provided in Table 3-9. While video analysis showed that benthic cover was often higher in areas which had a higher cover of biologenic gravel, and also occurred in higher densities in more rugose areas as shown in Figure 3-18, this was not always the case, with moderate benthic cover also seen in areas with little or no biologenic gravel and areas of the transect map which appear to be less rugose.

- Fish fauna diversity was again quite high with fish were seen amongst the aggregations of corals and sponges and also over areas of sandy seafloor. Identifications of fish were not undertaken as part of this assessment. Seastars and feather stars were both present.

A summary of the habitat characteristics, flora and fauna seen in Area 3c is provided in Table 3-9. This table also provides the CATAMI Species Codes for each seafloor feature and taxa that could be identified.

The seafloor in the area of the pipeline crossing is shown in Figure 3-17. This area was flat and sandy with a low-medium density cover of sponges and soft corals.

A map showing the location of the transect in Area 3c in relation to bathymetry, along with representative images of benthic habitat, is provided in Figure 3-18. While higher benthic cover could be related to a higher cover of biologenic gravel and/or rugosity on some occasions, this was not always the case. the detailed bathymetry / rugosity shown on the transect map cannot be used as an accurate predictor of the occurrence, or lack of, benthic organisms.

Additional images of the seafloor habitat and epifauna in Area 3c are provided in **Appendix D**.

Figure 3-17 Benthic habitat in the location of the pipeline crossing in Area 3c.

Table 3-9 Summary of habitat features in Area 3c.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm) Unconsolidated (soft): Pebble / gravel: Biologenic	82001005 82001007	Entire Transect Entire Transect
Bedform	Bioturbated	82002005	Entire transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Crawling traces: Thin trail Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone Bioturbation: Dwelling traces: Single burrow	81005001 81001003 81001012 81001006	Occasional over entire transect
Bacterial mats	Nil	NA	NA
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Sea stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Sponges: Cup-likes: Cups Sponges: Cups: Cup / goblet Sponges: Cup-likes: Tubes and chimneys Sponges: Crusts: Creeping / ramose Sponges: Massive forms – simple Sponges: Massive forms: Cryptic Corals: Black & Octocorals: Quill (seapen) Corals (unidentified soft corals) Corals: Fleshy: Arborescent Corals: Non-fleshy: Bushy Corals: Fern-frond: Complex Corals: Black & Octocorals: Fan (2D) Corals: Black & Octocorals: Whip Cnidaria: Hydroids Fishes: Bony fishes	25000000 25102000 25400901 10000916 10000913 10000915 10000909 10000910 10000919 10000911 10000917 10000904 10000908 11168918 11168000 11168911 11168908 11168915 11168912 11168917 11001000 37990083	Sponges and corals of high diversity were common and scattered over most of the seafloor in transect Area 3c. Patches of benthic epifauna changed continuously from low to high density.

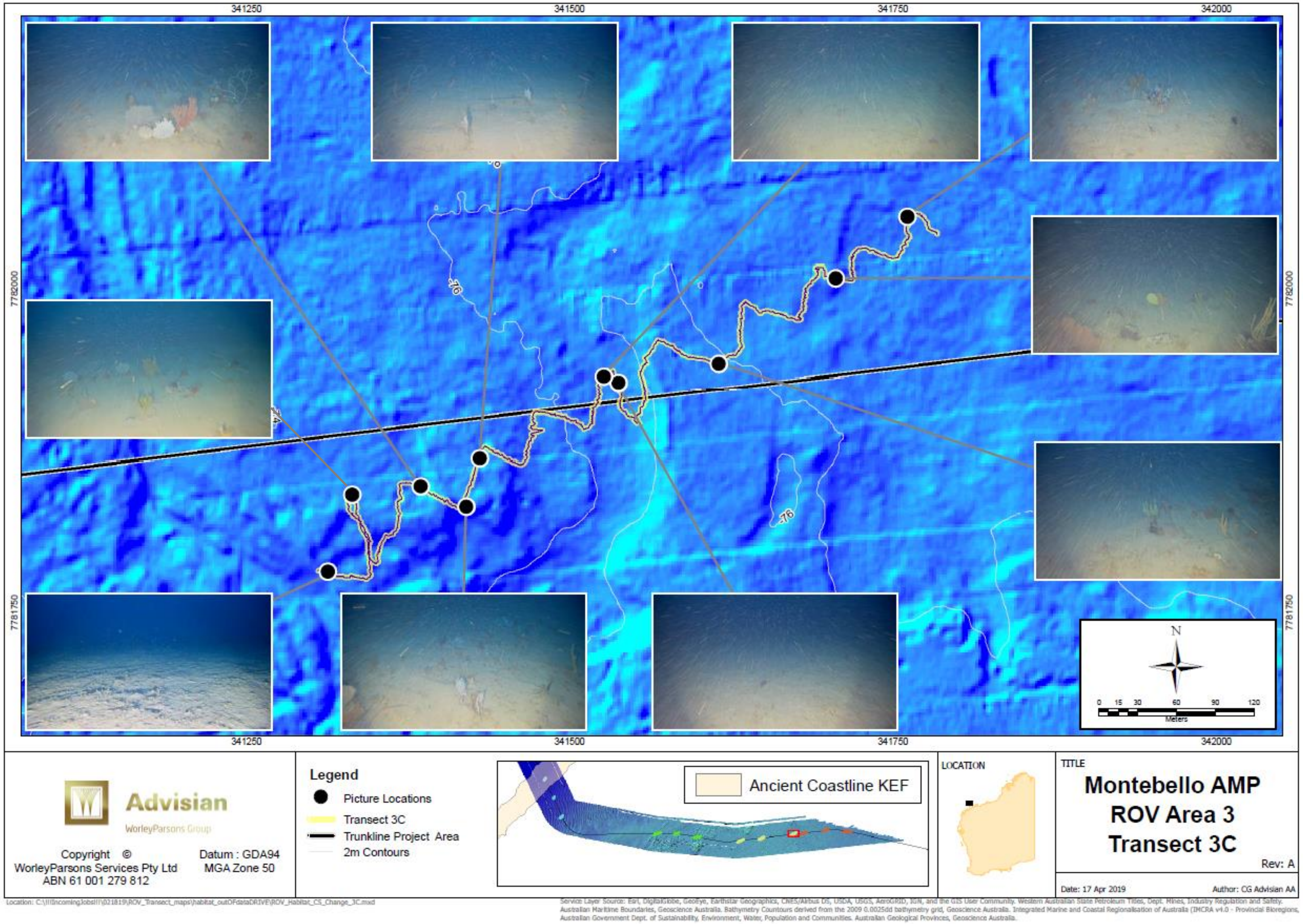

Figure 3-18 Typical benthic habitat and bathymetry in Area 3c.

3.4 Area 4

Three transects were completed in Area 4 and are described in more detail in the Sections below. The depth at the midpoint of these transects ranged from 74.5 m to 78.2 m (slightly deeper but similar to the depth in Area 2 and 3). **Appendix E** provides additional images of the benthic habitat and organisms seen along each transect in Area 4.

3.4.1 Area 4a

Notes provided by Neptune for Area 4a included:

- The ROV crossed the proposed pipeline route around E342566, N7782035 at approximately 13:15.
- The ROV was on bottom at 13:01 and off bottom at 13:29.
- The seabed was typically flat to undulating and comprised sand with subordinate bioclastic gravel. 'Starved' ripples occurred and typically had coarser gravel in their troughs. Benthic fauna includes sporadic areas of soft corals, including large gorgonians and sponges as well as black 'whip' corals. Current scour moats are noted around some of the sponges.
- The seabed comprised a flat predominantly sandy seabed which had a benthic habitat in the form of isolated areas of soft corals and sponges.
- No significant high relief habitat features were observed.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in Area 4a are provided:

- The seafloor within Area 4a was typically flat sand with a high level of biologenic gravel of unknown origin. Small mounds, waves and undulations all < 50 cm in height were seen on occasion and mainly occurred around aggregations of benthic epifauna (i.e. sponges and soft corals). Images are provided in Figure 3-20 and **Appendix E**.
- In the vicinity of the pipeline route (as identified by the time stamp provided by Neptune), the seafloor was typical of the area being flat and sandy with biologenic rubble and a medium density cover (~30%) of scattered sponges and soft corals (Figure 3-19).
- The vast majority of the seafloor along the transect in Area 4a was scattered with sponges and soft corals of varying forms and sizes. Some occurred as individuals and more dense clusters (up to ~50% cover) of these organisms were also common. Large areas of bare substrate were quite uncommon in Area 4a.
- No significant moderate or high relief features, or significant areas of consolidated hard substrate, were present along the transect in Area 4a (i.e. they were not seen on the video nor can be seen on the transect map). However, like in Area 2 and Area 3, much of the

seafloor was covered in a biologic gravel of unknown origin and this was quite dense at times. The depth along the Area 4a transect was around 76 m to 78 m (refer to Figure 3-20). This transect was in close proximity to the transect in Area 3c (which occurred in waters from 75 – 76 m).

- Benthic epifauna were common throughout the entire Area 4a, scattered in low to medium density clusters (5% - 30%) for the most part but also commonly occurring in larger more dense clusters (up to ~50% density). Soft corals (including gorgonians and seapens) and sponges were abundant and diverse in their form and size. Other benthic epifauna included echinoderms (e.g. feather stars which were often attached to sponges/corals). Additional details and CATAMI classifications are provided in Table 3-10. Like in other areas, the occurrence of benthic organisms could not be clearly predicted from any rugosity or other features shown on the detailed bathymetric map (Figure 3-20) nor were they always associated with a certain substrate type (e.g. high biologenic gravel).
- Mobile fauna (mainly small bony fishes) were most common around the larger clusters of sponges and soft corals. Fish were not identified as part of this assessment.
- Bioturbation of the seafloor in the form of small mounds and craters was evident along the entire transect length and provides evidence for the occurrence of mobile fauna (typically invertebrates) living within and on the soft sediment seafloor.

A summary of the habitat characteristics, flora and fauna seen along the transect in Area 4a is provided in Table 3-10. This table also provides the CATAMI Species Codes for each seafloor feature and taxa that could be identified.

The seafloor in the vicinity of the pipeline crossing in Area 4a (as identified by the timestamp provided by Neptune) is shown in Figure 3-19. This area was flat and sandy with biologenic rubble and a medium density cover (~30%) of sponges and soft corals.

A map showing the location of the transect in Area 4a in relation to bathymetry, along with representative images of benthic habitat, is provided in Figure 3-20. There were no clear or consistent relationships that could be seen between bathymetric features or rugosity in Area 4a with the occurrence or cover of benthic organisms.

Additional images of the seafloor habitat and epifauna in Area 4a are provided in **Appendix E**.

Figure 3-19 Benthic habitat in the location of the pipeline crossing in Area 4a.

Table 3-10 Summary of habitat features in Area 4a.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm) Unconsolidated (soft): Pebble / gravel: Biologenic	82001005 82001007	Entire Transect Entire Transect
Bedform	Bioturbated	82002005	Entire transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone	81001003 81001012	Occasional over entire transect
Bacterial mats	Bacterial mat	80000000	Occasional
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Sea stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Sponges: Cup-likes: Cups Sponges: Cups: Cup / goblet Sponges: Cup-likes: Tubes and chimneys Sponges: Crusts: Creeping / ramose	25000000 25102000 25400901 10000916 10000913 10000915 10000909 10000910 10000919 10000911 10000917	Sponges and corals of high diversity were common and scattered over most of the seafloor in transect Area 4a. Larger 'clumps' of sponges and corals were also seen on occasion along the entire transect.

Habitat Features	Description	CATAMI Species Code	Occurrence
	Sponges: Massive forms – simple	10000904	
	Sponges: Massive forms: Cryptic	10000908	
	Corals: Black & Octocorals: Quill (seapen)	11168918	
	Corals (unidentified soft corals)	11168000	
	Corals: Fleshy: Arborescent	11168911	
	Corals: Non-fleshy: Bushy	11168908	
	Corals: Fern-frond: Complex	11168915	
	Corals: Black & Octocorals: Fan (2D)	11168912	
	Corals: Black & Octocorals: Whip	11168917	
	Cnidaria: Hydroids	11001000	
	Fishes: Bony fishes	37990083	

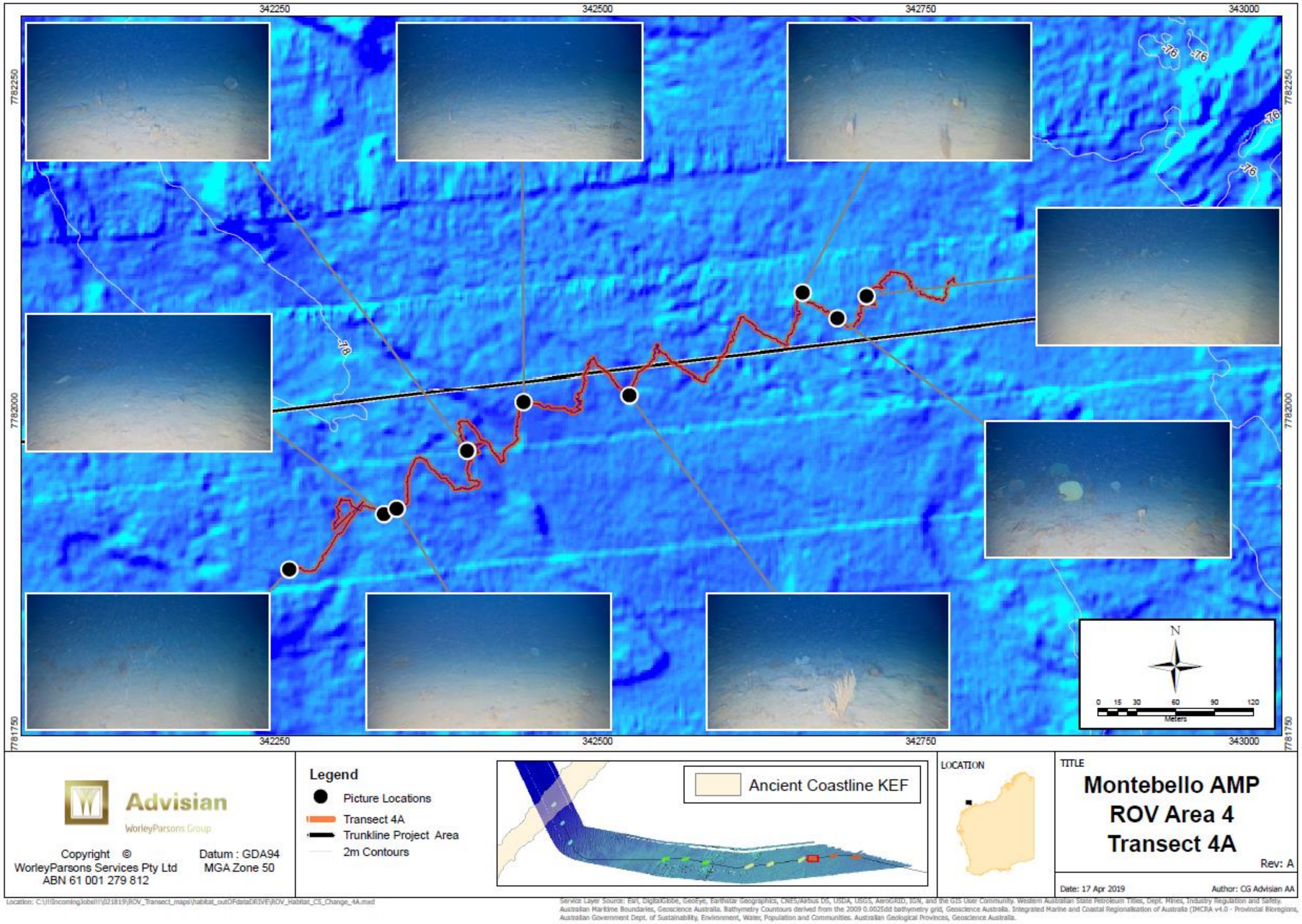

Figure 3-20 Typical benthic habitat and bathymetry in Area 4a.

3.4.2 Area 4b

Notes provided by Neptune for Area 4b included:

- The ROV crossed the proposed pipeline route around E344502, N7782269 at approximately 14:23.
- The ROV was on bottom at 14:15 and off bottom at 14:38.
- The seabed was typically flat to undulating and comprised sand with subordinate bioclastic gravel. 'Starved' ripples occurred and typically had coarser gravel in their troughs. Benthic fauna included sporadic areas of soft corals, including gorgonians and sponges as well as black 'whip' corals. Current scour moats were noted around some of the sponges.
- The seabed comprised a flat and predominantly sandy seabed which had a benthic habitat in the form of isolated areas of soft corals and sponges.
- No significant high relief habitat features were observed.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in Area 4b are provided:

- The seafloor within Area 4b was very similar to 4a, consisting of a typically flat and sandy seabed with a high level of biogenic gravel of unknown origin. Small mounds, waves and undulations all < 50 cm in height were seen on occasion and these mainly occurred around aggregations of benthic epifauna (i.e. sponges and soft corals). Images are provided in Figure 3-22 and **Appendix E**.
- The vast majority of the seafloor along the transect was scattered with a low to medium density cover (~5-30%) of sponges and soft corals of varying forms and sizes, although bare patches of sand were slightly more common than was seen in Area 4a. Medium density clusters of these organisms (up to ~40-50% cover) also occurred along the transects length. Images are provided in Figure 3-22 and **Appendix E**.
- In the vicinity of the pipeline route (as identified with the time stamp provided by Neptune), the seafloor was flat and sandy with biogenic rubble and a medium density cover of scattered sponges and soft corals (~30% cover). This habitat was consistent with the rest of the habitat in Area 4b (refer to Figure 3-21).
- No significant moderate or high relief features, or significant areas of consolidated hard substrate, were present along the transect in Area 4b (as seen on the video and on the detailed bathymetric mapping; Figure 3-22). However, much of the seafloor in this area was covered in a biologic gravel of unknown origin (with variable cover). The depth of the seafloor in Area 4b was around 74 m over the entire transect length. Rugosity along the transects length was relatively consistent and given the consistent depth, any small bathymetric features seen on the map would be of a very small scale (Figure 3-22).

- Benthic epifauna were common throughout the entire Area 4b, scattered for the most part in low density (ranging from ~5-20% cover), but also occurring in larger and more dense clusters of up to ~40-50% cover. Soft corals (including gorgonians and seapens) and sponges were abundant and diverse in their form and size. Other benthic epifauna included echinoderms (e.g. feather stars). Images are provided in Figure 3-22 and **Appendix E**. These shown that benthic organisms were common over most of the transect length regardless of small scale bathymetry / rugosity or substrate type (e.g. bare soft sediment or biologenic gravel).

- Mobile fauna (i.e. bony fishes) were most common around the larger clusters of sponges and soft corals in Area 4c. A high diversity of fish fauna was observed on the video however; these species were not identified as part of this assessment.

- Bioturbation of the seafloor in the form of small mounds and craters was evident along the entire transect length providing evidence for mobile fauna (typically invertebrates) living within and on the soft sediment seafloor.

A summary of the habitat characteristics, flora and fauna seen along the transect in Area 4b is provided in Table 3-11. This table also provides the CATAMI Species Codes for each seafloor feature and taxa that could be identified. The seafloor in the vicinity of the pipeline crossing in Area 4b (as per the timestamp provided by Neptune) is shown in Figure 3-21. This area was flat and sandy with biologenic rubble and scattered sponges and soft corals of about 30% cover.

The location of the transect in Area 4b in relation to detailed bathymetry, with georeferenced representative images of benthic habitat, is provided in Figure 3-22. There were no consistent patterns seen in the occurrence of benthic organisms or substrate type in relation to rugosity, nor were there significant changes in depth or rugosity. Additional images of seafloor habitat and epifauna in Area 4b are provided in **Appendix E**.

Figure 3-21 Benthic habitat in the location of the pipeline crossing in Area 4b.

Table 3-11 Summary of habitat features in Area 4b.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm) Unconsolidated (soft): Pebble / gravel: Biologenic	82001005 82001007	Entire Transect Entire Transect
Bedform	Bioturbated	82002005	Entire transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone	81001003 81001012	Occasional over entire transect
Bacterial mats	Bacterial mat	80000000	Occasional
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Sea stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Sponges: Cup-likes: Cups Sponges: Cups: Cup / goblet Sponges: Cup-likes: Tubes and chimneys Sponges: Crusts: Creeping / ramose Sponges: Massive forms – simple Sponges: Massive forms: Cryptic Corals: Black & Octocorals: Quill (seapen) Corals (unidentified soft corals) Corals: Fleshy: Arborescent Corals: Non-fleshy: Bushy Corals: Fern-frond: Complex Corals: Black & Octocorals: Fan (2D) Corals: Black & Octocorals: Whip Cnidaria: Hydroids Fishes: Bony fishes	25000000 25102000 25400901 10000916 10000913 10000915 10000909 10000910 10000919 10000911 10000917 10000904 10000908 11168918 11168000 11168911 11168908 11168915 11168912 11168917 11001000 37990083	Sponges and corals of high diversity were common and scattered over most of the seafloor in transect Area 4b. Larger 'clumps' of sponges and corals were also seen on occasion along the entire transect.

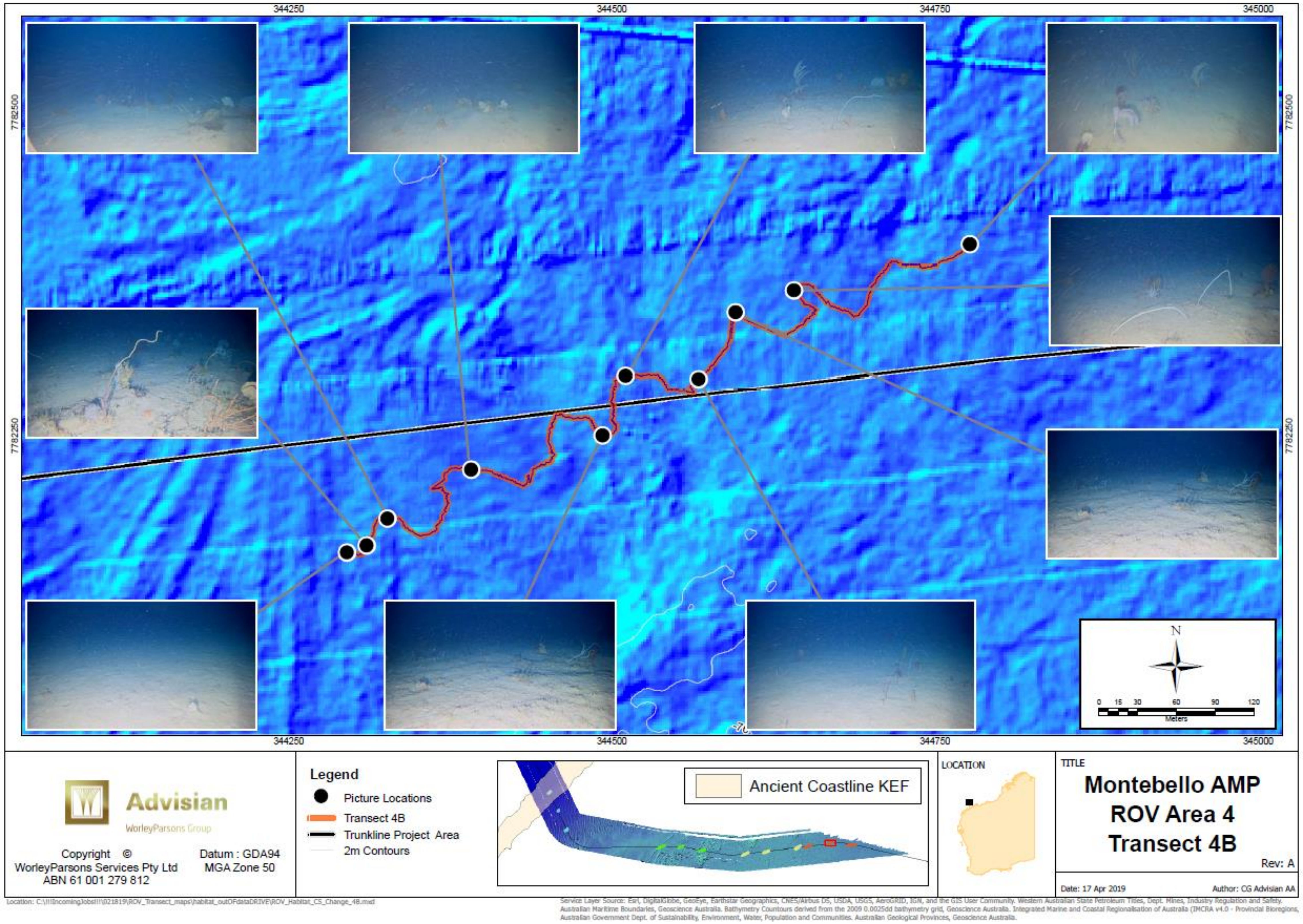

Figure 3-22 Typical benthic habitat and bathymetry in Area 4b.

3.4.3 Area 4c

Notes provided by Neptune for Area 4c included:

- The ROV crossed the proposed pipeline route at about E346650, N7782160 at approximately 15:34.
- The ROV was on bottom at 15:13 and off bottom at 15:47.
- The seabed was typically flat to undulating and comprised sand with subordinate bioclastic gravel. 'Starved' ripples occurred and typically had coarser gravel in their troughs. Benthic fauna included sporadic areas of soft corals, including gorgonians and sponges. Current scour moats were noted around some of the sponges.
- The seabed comprised a flat and predominantly sandy seabed which had a benthic habitat in the form of isolated areas of soft corals and sponges.
- No significant high relief habitat features were observed.

Analysis of video data by Advisian was undertaken and the following additional notes regarding benthic habitat in Area 4c are provided:

- The seafloor within Area 4c was very similar to 4a and 4b, consisting of typically flat fine sand with a generally high cover of biogenic gravel of unknown origin. Small mounds, waves and undulations all < 50 cm in height were seen on occasion, mainly around aggregations of benthic epifauna (sponges and soft corals). Images are provided in Figure 3-24 and **Appendix E**.
- The vast majority of the seafloor along the transect 4c was bare soft sediment, however, some areas were scattered with sponges and soft corals of varying forms and sizes. The majority of these were smaller in their form, however, larger forms tended to increase in occurrence towards the end of the transect. The density of benthic organisms in Area 4c was generally low (~5-15%) but some more dense clusters of these organisms also occurred towards the end of the transect (up to ~30% cover). The occurrence of sponges and corals in transect 4c was generally less than in Areas 4a and 4b. Bare sand was also more common in Area 4c than it was in 4b and 4a (while Area 4b also had more bare sand than Area 4a). Images are provided in Figure 3-24 and **Appendix E**.
- In the vicinity of the pipeline route (as identified by the time stamp provided by Neptune), the seafloor was flat and sandy with biogenic rubble and a low density of scattered sponges and soft corals (~5%). This is shown in in Figure 3-23.
- No significant moderate or high relief features or significant areas of consolidated hard substrate were present along the transect in Area 4c (as indicated on the video and the transect map with detailed bathymetry Figure 3-24). However, some of the seafloor was covered in a biologic gravel of unknown origin. The depth of the seafloor in Area 4c ranged between around 76 m to 78 m (refer to Figure 3-24). The eastern end of the

transect had a couple of smaller features relative to the rest of the transect which typically had low rugosity, however, these were only small scale (i.e. ~1 m).

- Benthic epifauna were diverse in Area 4c, as seen in Areas 4a and 4b, and were scattered throughout the entire Area 4c. Some larger clusters of epibenthic organisms occurred on occasion and these were mainly towards the eastern end of the transect. These areas of denser benthic fauna may be related to the small features which can be seen on the eastern half of the transect map. Soft corals (which included but were not limited to gorgonians and seapens) and sponges in this area were abundant and very diverse in their form and size. Other benthic epifauna included echinoderms (e.g. feather stars). Additional details and CATAMI classifications are shown in Table 3-12.
- Mobile fauna including bony fishes, sea stars and feather stars were most common around the larger clusters of sponges and corals. Sea cucumbers were also seen on occasion on the bare sand.
- Bioturbation of the seafloor in the form of small mounds, craters and large / small trails was evident over the entire transect length, again providing evidence for mobile fauna (typically invertebrates) living within and on the soft sediment seafloor.

A summary of the habitat characteristics, flora and fauna seen along the transect in Area 4c is provided in Table 3-12. This table also provides the CATAMI Species Codes for each seafloor feature and taxa that could be identified.

The benthic habitat in the vicinity of the pipeline crossing in Area 4c is shown in Figure 3-23. The seafloor was sandy and quite bare in this location which was consistent with much of the rest of this transect. There was ~5% cover of benthic organisms in this location.

A map showing the location of the transect in Area 4c in relation to bathymetry, along with georeferenced representative images of benthic habitat, is provided in Figure 3-24. The video analysis and transect map for Area 4c both provide some indication of a higher density of benthic organisms occurring in the eastern half of the transect, the location of a couple of bathymetric features on a relatively low rugosity seafloor. However, benthic organisms were not limited to this location and bare substrate was also seen in these locations.

Additional images of the seafloor habitat and epifauna in Area 4c are provided in **Appendix E**.

Figure 3-23 Benthic habitat in the location of the pipeline crossing in Area 4c.

Table 3-12 Summary of habitat features in Area 4c.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm) Unconsolidated (soft): Pebble / gravel: Biologenic	82001005 82001007	Entire Transect Entire Transect
Bedform	Bioturbated	82002005	Entire transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Crawling traces: Thin trail Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone	81005001 81001003 81001012	Occasional over entire transect
Bacterial mats	Bacterial mat	80000000	Occasional
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Sea stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Sponges: Cup-likes: Cups Sponges: Cups: Cup / goblet Sponges: Cup-likes: Tubes and chimneys	25000000 25102000 25400901 10000916 10000913 10000915 10000909 10000910 10000919 10000911	Sponges and corals of high diversity were scattered over the seafloor in transect Area 4c. Larger 'clumps' of sponges and corals were also seen on occasion along the entire transect, mainly in the

Habitat Features	Description	CATAMI Species Code	Occurrence
	Sponges: Crusts: Creeping / ramose	10000917	second half of the transect.
	Sponges: Massive forms – simple	10000904	
	Sponges: Massive forms: Cryptic	10000908	
	Corals: Black & Octocorals: Quill (seapen)	11168918	
	Corals (unidentified soft corals)	11168000	
	Corals: Fleshy: Arborescent	11168911	
	Corals: Non-fleshy: Bushy	11168908	
	Corals: Fern-frond: Complex	11168915	
	Corals: Black & Octocorals: Fan (2D)	11168912	
	Corals: Black & Octocorals: Whip	11168917	
	Cnidaria: Hydroids	11001000	
	Fishes: Bony fishes	37990083	

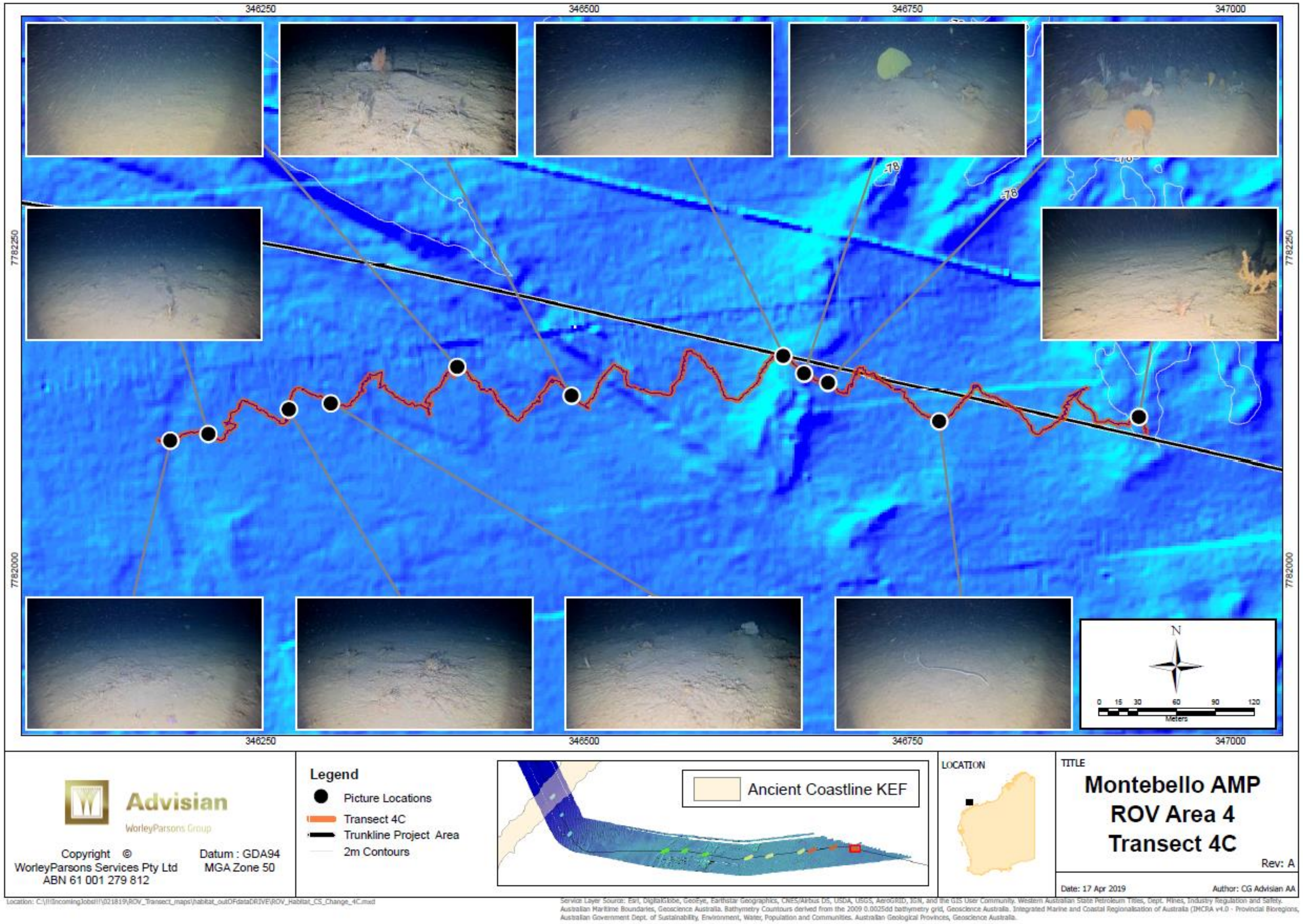

Figure 3-24 Typical benthic habitat and bathymetry in Area 4c.

3.5 Area 5

Only one transect was completed in Area 5. The depth at the midpoint of this transect was 74.6 m. This transect did not cross the pipeline route. **Appendix F** provides additional images of the benthic habitat and organisms seen in Area 5.

3.5.1 Area 5a

Notes provided by Neptune for Area 5a included:

- The ROV surveyed south of the proposed pipeline route round E361160, N7778778.
- The ROV was on bottom at 18:31 and off bottom at 19:00.
- The seabed was typically flat to undulating and comprised sand with subordinate bioclastic gravel. Where flat, the seabed had an algae cover. Where undulating, the seabed was characterised by starved ripples and scour moats, typically around sponges. Benthic fauna included sporadic areas of soft corals, including gorgonians and sponges.
- The seabed comprised a flat predominantly sandy seabed which had a benthic habitat in the form of isolated areas of soft corals and sponges.
- No significant high relief habitat features were observed.
- Due to strong currents and the ROV tether management it was not possible to run the transect across the proposed pipeline route. No image of the pipeline crossing area is shown for this reason.

Further analysis of video data by Advisian resulted in the following notes regarding benthic habitat in this location:

- The seafloor in Area 5a consisted of flat sand, often with an organic cover (likely bacterial or algae) or biologenic gravel component. The seafloor showed some slight undulation in places and scour marks commonly occurred around small ‘clusters’ of benthic epifauna (i.e. sponges and soft corals). No regular bedforms such as sand ripples or sand waves were present in this location. Images are provided in Figure 3-25 and **Appendix F**.
- No significant moderate or high relief features were present along the transect in Area 5a as identified during the video analysis or on the detailed bathymetric map (Figure 3-25). No areas of consolidated hard substrate were present. However, some small and more expansive areas of unconsolidated biologenic gravel resulted in the appearance of a partially-hard substrate. This gravel component was more common in the second half of the transect however cannot be identified on the transect map. The transect was located in water depths which ranged from around 74 m to 76 m (Figure 3-25). Rugosity was generally consistent over the entire transect length.

- While much of the seafloor was bare, benthic epifauna occurred sporadically along the entire transect length and sometimes occurred as small and diverse 'clusters' of sponges and soft corals. These organisms were often quite large and were very diverse in form. Isolated organisms also occurred and were more common in the second half of the transect where the seafloor tended to have a higher biologenic gravel component. Additional classification details and CATAMI codes are provided in Table 3-13. The percentage cover of benthic organisms (within the entire video frame) ranged from around 5% to 40% (excluding any cover of biologenic gravel). The location of georeferenced images with higher benthic cover on the transect map do correspond somewhat to areas with slightly increased rugosity, however, video analysis found they were not restricted to these areas. In addition, higher densities were found in areas with higher biologenic gravel cover and also areas without gravel and fine soft sediment.

- Mobile fauna was present and more common around these clumps of sponges and soft corals. They included echinoderms (e.g. sea stars, feather stars and sea cucumbers) and small bony fishes (unidentified and usually quickly moving out of the field of view of the ROV).

- Bioturbation of the seafloor was common over the entire transect length and usually occurred in the form of thin trails, small mounds or craters. These indicate that mobile fauna (typically invertebrates) live within and on the soft sediment seafloor.

- Due to strong currents and the ROV tether management it was not possible to run the transect across the proposed pipeline route. In addition, Area 5a was the only area which was surveyed within Area 5.

A summary of the habitat characteristics, flora and fauna seen in Area 5a is provided in Table 3-13. This table also provides the CATAMI Species Codes for each seafloor feature and taxa identified.

A map showing the location of the transect in Area 5a in relation to bathymetry, along with representative images of benthic habitat is provided in Figure 3-25. While some images with benthic cover do tend to occur in locations with slightly higher rugosity this variation in seafloor bathymetry is actually very small. No strong or consistent relationship between bathymetry / rugosity and the occurrence or density of benthic organisms could be inferred from the combined video and mapping analysis, with organisms occurring along the length of the transect and in areas with higher biologenic gravel and also areas with fine soft sediment and no gravel.

Additional images of benthic habitat and sessile organism in Area 5a are provided in **Appendix F**.

Table 3-13 Summary of habitat features in Area 5a.

Habitat Features	Description	CATAMI Species Code	Occurrence
Substrate Type	Unconsolidated (soft): Sand/mud (<2mm) Unconsolidated (soft): Pebble / gravel: Biologenic	82001005 82001007	Entire Transect Entire Transect
Bedform	Bioturbated	82002005	Entire transect
Relief	Flat	82003001	Entire Transect
Bioturbation	Bioturbation: Crawling traces: Thin trail Bioturbation: Dwelling traces: Small mound Bioturbation: Dwelling traces: Crater cone	81005001 81001003 81001012	Occasional bioturbation over entire transect
Bacterial mats	Bacterial mat	80000000	Around ½ transect
Flora	Nil	NA	NA
Fauna	Echinoderms: Feather stars Echinoderms: Sea stars Echinoderms: Sea cucumbers Sponges: Erect simple Sponges: Erect laminar Sponges: Erect branching Sponges: Cup like Sponges: Cup-likes: Cups Sponges: Cups: Cup / goblet Sponges: Cup-likes: Tubes and chimneys Sponges: Crusts: Creeping / ramose Sponges: Massive forms – simple Sponges: Massive forms: Cryptic - Corals: Black & Octocorals: Quill (seapen) Corals (unidentified soft corals) Corals: Fleshy: Arborescent Corals: Non-fleshy: Bushy Corals: Fern-frond: Complex Corals: Black & Octocorals: Fan (2D) Corals: Black & Octocorals: Whip Cnidaria: Hydroids Fishes: Bony fishes	25000000 25102000 25400901 10000916 10000913 10000915 10000909 10000910 10000919 10000911 10000917 10000904 10000908 11168918 11168000 11168911 11168908 11168915 11168912 11168917 11001000 37990083	Diverse 'clumps' of sponges and corals were seen on occasion along the entire transect in Area 5

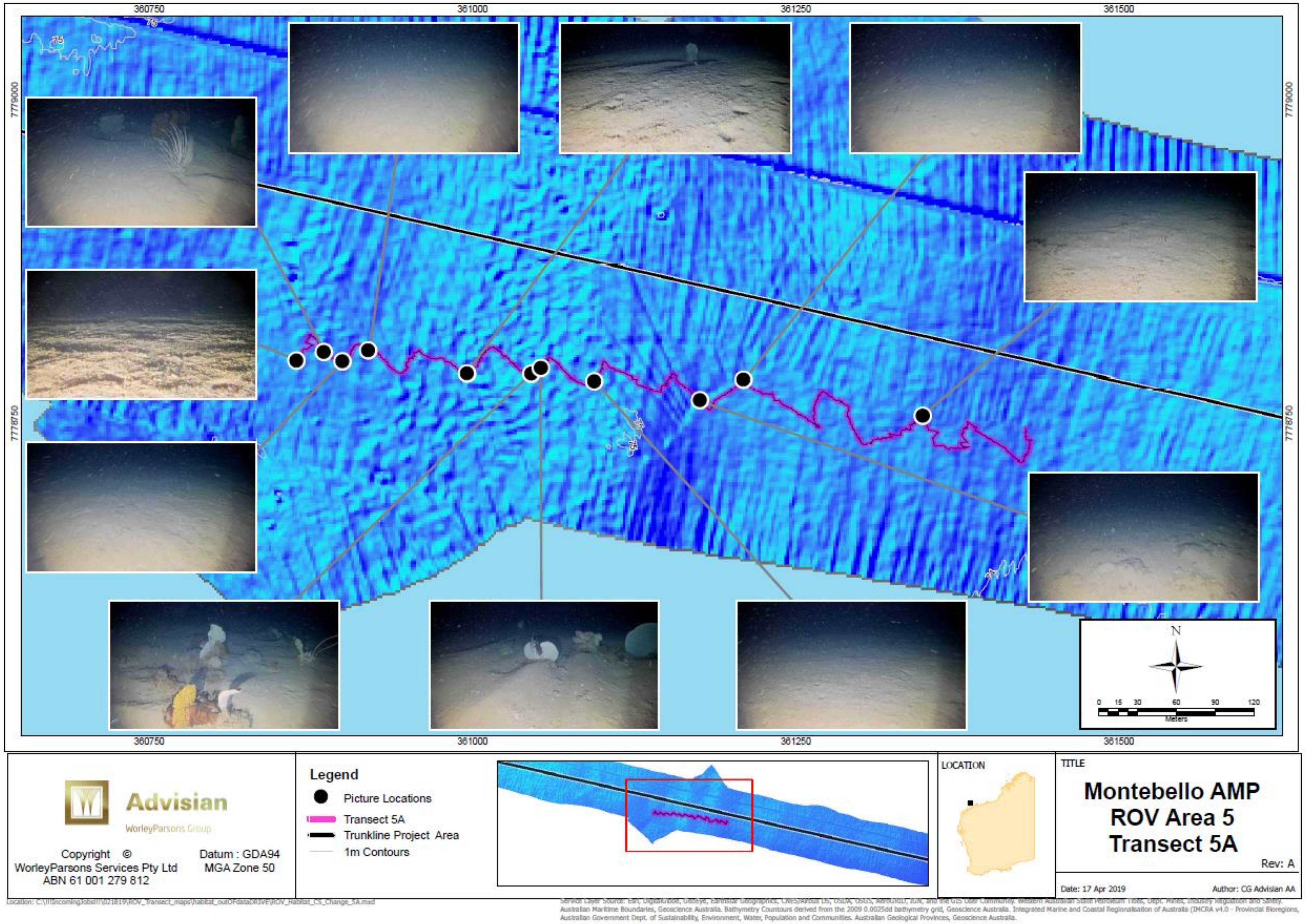

Figure 3-25 Typical benthic habitat in Area 5a.

4 Summary and Discussion

The benthic habitat within five areas of the Montebello AMP was characterised through assessment of video collected by ROV. This habitat has been described and classified in accordance with the CATAMI Classification System. Area 1 which was the deepest location and was located in the vicinity of the KEF was most different, with a much lower cover of benthic organisms than Areas 2 to 5. Areas 2 to 5 were quite similar in depth and in nature, with some small differences in the density and occurrence of benthic organisms and in substrate type (e.g. variants of soft sediment bedforms and cover of biologenic gavel). A summary of findings for each area surveyed is provided below along with a discussion of the results in relation to the published values for the Montebello AMP and 125m Depth Contour KEF.

4.1 Area 1

Area 1 was selected to assess the benthic habitat at the ancient coastline 125 m depth contour KEF and to provide spatial coverage of the AMP. Area 1a was located within the KEF, however Area 1b and 1c were not. No potential features of the KEF (i.e. areas of hard substrate with high biodiversity) were seen along any of the transects surveyed. The actual depth at the midpoint of the transects in Area 1 ranged from 103.2 m to 126.4 m. Benthic habitat along all transects surveyed in Area 1 were typically bare sand with various bedforms including flat bare sand, small ripples (of 2D and 3D forms) and small 'steps' (<50 cm). Some areas of seafloor were bare, while others were covered in a light bacterial mat and others were seen to have a cover of biologenic gravel (of unidentified origin). The cover of biologenic gravel changed continuously over the course of the transects. No moderate or high relief features or areas of consolidated hard substrate were present within any transect.

Benthic organisms (including sponges and soft corals) were present on occasion and generally occurred as single or low density aggregations of individuals. The cover of benthic organisms in Area 1 ranged from 0% to ~15% (being highest in Transect 1c). Slightly higher occurrences of benthic organisms were noted in areas with a higher cover of biologenic gravel (although were in no way limited to these areas and this feature could not be identified by looking at the transect maps). Furthermore, this relationship was not quantified. No relationship between bathymetry and different habitat 'types' or the cover of benthic organisms was seen along individual transects. The occurrence and cover of benthic organisms and the location of different substrate types could not be predicted from any obvious features on the bathymetric maps. Bioturbation of the seafloor was evident in all three transects in Area 1 indicating the presence of mobile organisms living on and within the seabed. Mobile organisms including fish, echinoderms and jellies, were also noted on the video.

The environmental values of the KEF refer to potential areas of hard substrate or rocky escarpments which may provide enhanced biodiversity or biologically important habitat in areas otherwise dominated by soft sediments. However, no hard substrate or rocky escarpments were recorded in Area 1 in the current study. Nonetheless, the soft sediment habitat did support a number of epibenthic and mobile fauna in the form of corals, sponges, echinoderms and fish.

4.2 Area 2

Area 2 was selected to provide spatial coverage of the AMP in an area which may include ancient coastline. The actual depth at the midpoint of each of the transects in Area 2 ranged from 70.6 m to 74.4 m. The benthic habitats present along all transects in Area 2 were very similar to each other. The seafloor in Area 2 was relatively flat and sandy with a light to high cover of unconsolidated biologenic gravel and/or organic material. Small undulations of the seabed were seen but no other regular bedforms such as sand ripples or sand waves were apparent. No significant high relief habitat features, or areas of consolidated hard substrate, were observed in any transect. Some areas of seafloor were relatively bare while others included a low (~5%) to high (~80%) density cover of benthic organisms. This was true for all three transects. This benthic cover changed continually and often (within m's) over each transect. Bioturbation of the seafloor in the form of small cones, craters, burrows, small and large trails was also apparent. Mobile organisms including fish, echinoderms and jellies, were also noted on the videos for Area 2.

Benthic epifauna was present over the length of each transect, occurring in patches which varied from low (~5%) to high (~80%) density, and which changed continuously. All three transects were quite similar. Benthic fauna comprised a diverse array of sponges and corals with varying forms, sizes and colours. Hydroids and cnidarians were also apparent on occasion along the transect length. Fish fauna were also common amongst the patches of sponges and corals. Higher cover of benthic organisms were often seen in areas which had higher amounts of visible biologenic gravel, however this was also seen in areas which seemed to comprise more fine sediment with less or no biologenic gravel. The generally common occurrence of benthic organisms in Area 2 may be related to the generally high rugosity which can be seen in all three transect maps. A decrease in benthic cover on some occasions could be related to more expansive areas of lower rugosity (e.g. in Transect 2c) however this was not always the case.

The high biodiversity of sessile and mobile organisms seen at depths of around 70 m – 76 m in Area 2 was in accordance with the natural values of the Montebello AMP in that the area surveyed 'includes diverse benthic and pelagic fish communities'. Area 2 may provide foraging habitat for mobile threatened fauna such as marine turtles and other fish fauna that feed on soft bodied benthic organisms such as sponges and soft corals.

4.3 Area 3

Area 3 was selected because it was identified as a point of interest in the AMP and along the trunkline corridor where there are likely to be outcropping / subcropping calcarenite with shallow sediment cover and sediment ponds, along with sections of sandy bottom (KP165-170). The actual depth at the midpoint of the transects in Area 3 ranged from 71.6 m to 73.8 m. The seafloor in Area 3 was relatively flat and sandy with a light to high cover of biologenic gravel and/or organic material over its entire length (continually changing). The seabed was a mosaic of bare substrate and low (~5%) to high (~75% - in Area 3a) density cover of benthic organisms (e.g. sponges / corals). Small undulations of the seabed and some small sand waves were present on occasion, but no other regular bedforms such as sand ripples or sand waves were apparent. No significant moderate or high relief habitat features were observed on the video or can be seen on the transect maps with detailed bathymetry. Any features seen are in the order of ~1 m and occur over relatively large scales. Some potential outcropping was seen, although this was hard to clearly define with the often high cover of unconsolidated biologenic gravel and cover of benthic organisms. Bioturbation of the seafloor in the form of small cones, craters, burrows and small and large trails was apparent. Mobile organisms including fish, echinoderms and jellies, were also noted on the videos for Area 3. Fish fauna diversity was quite high, and varying sizes of fish were seen amongst the aggregations of corals and sponges and also over bare sandy seafloor.

Benthic epifauna were present along the entire transect and occurred in patches which changed continuously from low (~5%) to high (~75%) density. Area 3a contained high density (~75%) aggregations on occasion, however, Area 3b and 3c only reached a medium density (~50%). Benthic fauna comprised a diverse array of sponges and corals with varying forms, sizes and colours. Hydroids and cnidarians were also apparent on occasion along the transect length. While some indication for higher benthic cover in areas containing a higher cover of biologenic gravel and/or areas which appeared slightly more rugose on the transect maps was seen, this relationship was not consistent and there were many occasions where a higher density of organisms was seen on soft sediment with little gravel cover and also on areas of the transect maps which appeared to be quite flat in relation to the rest of the transect.

The high biodiversity of sessile and mobile organisms seen at depths of around 73 m – 76 m in Area 3 was in accordance with the natural values of the Montebello AMP in that the area surveyed 'includes diverse benthic and pelagic fish communities'. Although no clear outcropping / subcropping of calcarenite was seen, areas of biologenic gravel with a medium cover of benthic organisms were common. Area 3, like Area 2, may provide foraging habitat for mobile threatened fauna such as marine turtles and other fish fauna that feed on soft bodied benthic organisms such as sponges and soft corals.

4.4 Area 4

Area 4 was included to provide data to assess the benthic habitat adjacent to the Pluto pipeline, in an area that could potentially provide turtle foraging on hard substrate / subcrops (KP160-164). The actual depth at the midpoint of the transects in Area 4 ranged from 74.5 m to 78.2 m. The seafloor within Area 4 was typically flat sand with a high level of biologenic gravel of unknown origin. Small mounds, waves and undulations all < 50 cm in height were seen on occasion and mainly occurred around aggregations of benthic epifauna (i.e. sponges and corals). The seafloor in Area 4 was scattered with sponges and corals of varying forms and sizes. Some occurred as individuals with a low density cover (~5%) and more dense clusters (up to about 50% cover) of organisms were also seen and were more common in some transects (namely 4a and 4b). Areas of bare sand were present amongst the patches of epifauna and were more common in Area 4c than 4b and again than in Area 4a. The switch between bare sand to benthic cover changed constantly and quickly however. Corals and sponges were abundant and diverse in their form and size. Other benthic epifauna included echinoderms (e.g. feather stars which were often attached to sponges/corals) and cnidaria (e.g. seapens). Mobile fauna (mainly small bony fishes) were most common around the larger clusters of sponges and corals. Bioturbation of the seafloor in the form of small mounds and craters was evident along the entire transect length.

No significant moderate or high relief features, or significant areas of consolidated hard substrate, were present in Area 4 as could be seen on the video or transect maps. However, much of the seafloor was covered in a biologic gravel of unknown origin and this was quite dense at times. While at times the bathymetric maps provided some indication of increased cover of benthic organisms in areas with higher rugosity, this was not always the case. In general, Area 4a and 4b were more rugose than 4c, and these two areas did appear to have a more consistent cover of benthic organisms. However, within individual transects, a medium - high density of benthic organisms could be seen in areas that were not necessarily highly rugose (as indicated on the bathymetric maps), and in some cases, density was high in areas with expansive biologenic gravel and at other times was high on areas of bare soft sediment.

The high biodiversity of sessile and mobile organisms seen at depths of around 74 m – 78 m in Area 4 was in accordance with the natural values of the Montebello AMP in that the area surveyed 'includes diverse benthic and pelagic fish communities'. Although no areas of consolidated hard substrate or subcrops were seen, the high epibenthic diversity, which included soft corals and sponges, could very well provide a foraging habitat for threatened marine turtles, along with other mobile fauna which are able to live at or travel to these depths.

4.5 Area 5

Area 5 was included for completeness to compare benthic habitat adjacent to the existing Pluto pipeline at the eastern end of the AMP. The actual depth at the midpoint of the only transect surveyed in Area 5 was 74.6 m. The seafloor in Area 5 consisted of flat sand, often with an organic cover (likely bacterial or algae) or a biologenic gravel component. The seafloor showed some slight undulation in places and scour marks commonly occurred around small 'clusters' of benthic epifauna (i.e. sponges and corals). No regular bedforms such as sand ripples or sand waves were present in this location. No significant moderate or high relief features were present along the transect in Area 5. No significant areas of consolidated hard substrate were seen. However, the biologenic gravel resulted in a partially-hard looking substrate.

Benthic epifauna occurred sporadically along the entire transect length and generally occurred as diverse 'clusters' of sponges and corals. These organisms were often large and were very diverse in form. The percentage cover of benthic organisms (within the entire video frame) ranged from 5% to ~40% (excluding any cover of biologenic gravel). No strong or consistent relationship between bathymetry / rugosity and the occurrence or density of benthic organisms could be inferred from the combined video and mapping analysis, with organisms occurring along the length of the transect and in areas with higher biologenic gravel and also areas with fine soft sediment and no gravel.

Mobile fauna were common around these clumps of sponges and corals. They included echinoderms (e.g. sea stars, feather stars and sea cucumbers) and small bony fishes. Bioturbation of the seafloor was common over the entire transect length and usually occurred in the form of thin trails, small mounds or craters.

The high biodiversity of sessile and mobile organisms seen at depths of around 74 m in Area 5 was in accordance with the natural values of the Montebello AMP in that the area surveyed 'includes diverse benthic and pelagic fish communities'. This area may provide foraging habitat for mobile threatened fauna such as marine turtles and other fish fauna that feed on soft bodied benthic organisms such as sponges and soft corals.

4.6 Previous Benthic Surveys

Benthic habitat data from the North-West Shelf including the Montebello AMP has been collected in several previous surveys including the 2017 RV Investigator voyage (Keesing, 2019), the 2013 Pilbara Marine Conservation Partnership (PMCP) surveys (Pitcher et al., 2016) and the 1982–1997 CSIRO North West Shelf (NWS) Effects of Trawling project (Sainsbury, 1988; 1991). General findings of these studies are provided below.

Data used to describe benthic substrates and biota from the 2017 RV Investigator voyage were principally derived from still camera images. This study showed that substrate and topography in the Montebello AMP was predominantly fine sand or a mix of fine and coarse sand. While deeper sites were often all coarse sand, some rubbly areas were observed at the shallowest sites. The general topography was predominantly flat bottom with occasional bioturbated areas. Apart from the most inshore site, most sites surveyed in the eastern section of the Montebello AMP had low numbers of sponges, whips and gorgonians. Complex benthic filter feeder communities were largely absent. The dominant filter feeders were hydroids, seapens and crinoids. The most commonly recorded crinoid was *Comatula rotalaria* which is free living on sand rather than associated with other filter feeders like gorgonians. One site surveyed was notable for the large numbers of seapens present and most sites had large areas characterised by soft sediment dwelling crinoids or hydroids and seapens rather than the complex sponge and soft coral communities observed in the Dampier MP.

The CSIRO Effects of Trawling Project conducted between 1982 and 1997 included 21 transects in the Montebello AMP. Substrate type was very similar across the whole of the AMP and similar to the 2017 surveys, being predominantly fine sand or a mix or fine and coarse sand, with some sites having rubbly areas. Topography was mostly fine sand or fine sand with ripples. Three sites had large proportions of ridges or large ripples or very large ripples. All of these sites were located at the far western side of the MP, two of these in the very south-western section of the MP. The biota recorded in the CSIRO studies varied notably from that during the 2017 RV Investigator surveys. In particular, the large proportion of sponges and small proportion of crinoids seen on the historical voyages. However, two historical sites located in the eastern part of the MP where the 2017 samples were taken also had a large proportion of images with no biota.

The Pilbara Marine Conservation Partnership (PMCP) project (Babcock et al. 2017) included habitat and biodiversity mapping in the region between North West Cape and Barrow Island and the Montebello Islands. One of the study components assessed benthic habitats and biodiversity in this region (Pitcher et al. 2016) and included sites in what is now the Montebello AMP. Substrate type recorded by video at the 2013 survey sites was either fine or coarse sand at four sites and rippled at two sites located in the south-western section of the AMP. The towed video sites surveyed in the south-western part of the AMP had large proportions of video transects where no biota was evident. Dense sponges occurred at shallower sites on the central southern and south-western section of the MP, west of the islands and a site also in the south-western section had a large proportion of gorgonian habitat.

The results of previous benthic studies in the Montebello AMP are largely in alignment with the findings of the current study in terms of the benthic habitat recorded (typically low relief sandy seafloor (with various bedforms) with occasional rubbly areas increasing at sites more inshore) as well as the dominant benthic organisms identified (which varied in diversity and density within and between survey areas, but typically included a wide variety of sponges and soft corals including whips and gorgonians, hydroids, seapens and crinoids).

5 References

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Appendix A: Transect Memos (Neptune)

SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018

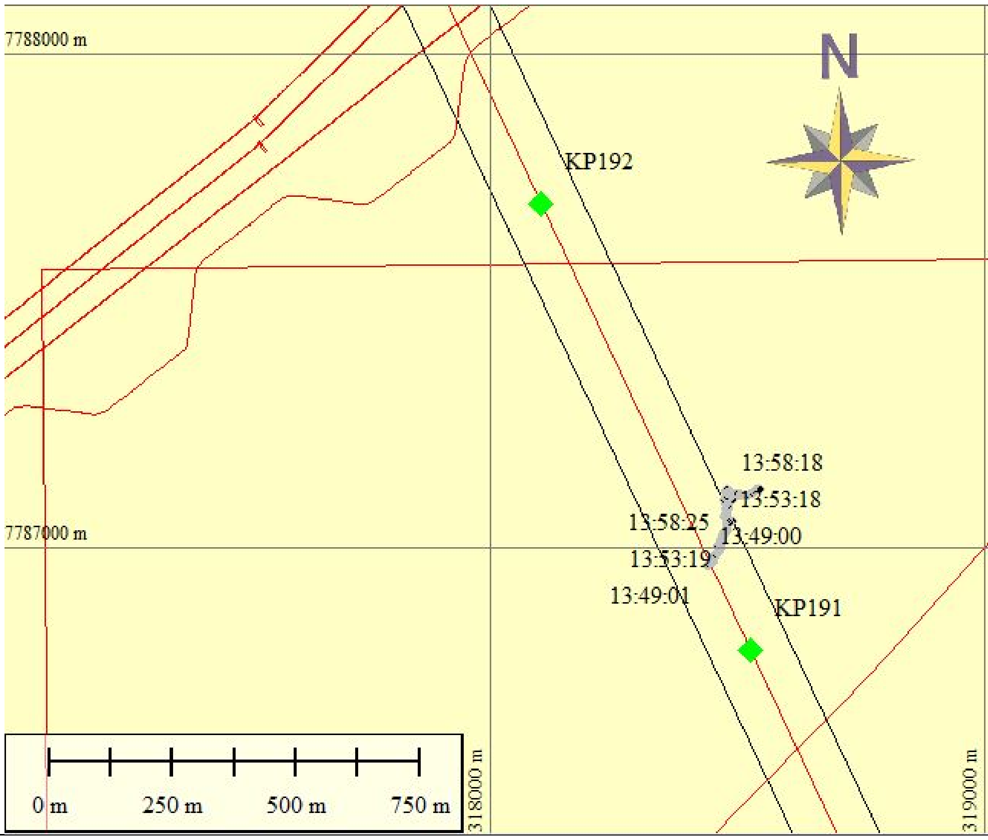
Technical Memo: No. 01	Date: 31/01/2019	Phase: Environmental	Area of Ops: Area 1A (KP191.5)	Rev.1

Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 1A

Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat.

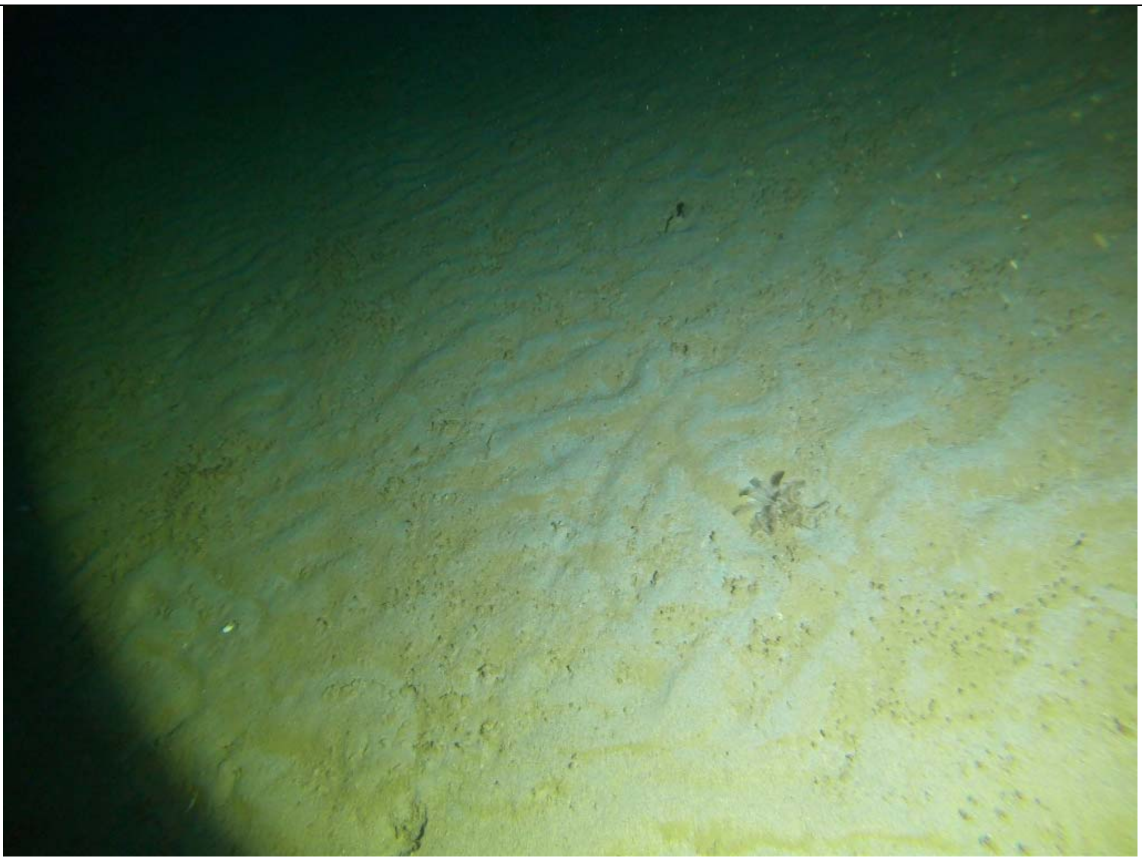
Aim: Report preliminary findings of ROV transect to office

Location: Proposed pipeline route in the vicinity of KP191.195, in the area of the AMP. The ROV transect crosses the PL route at E318445, N7786967 (time stamp 13:49:11). ROV on bottom at 13:49, off bottom at 14:03.



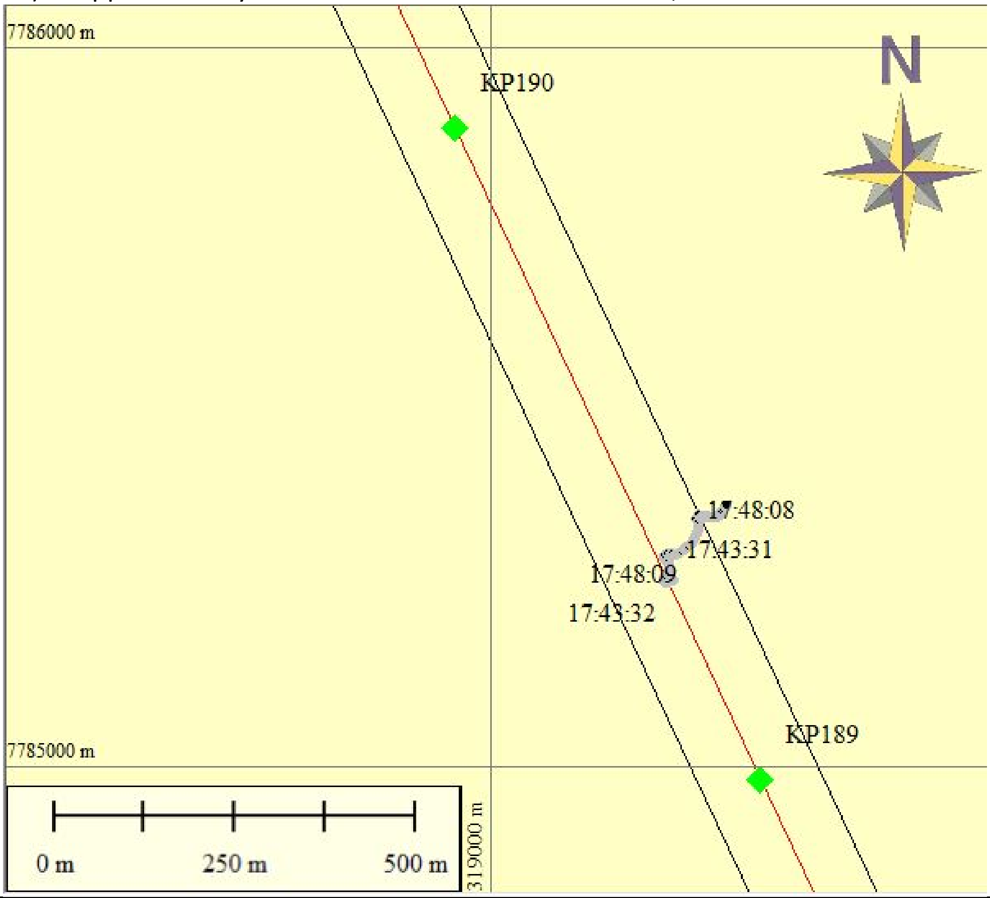
Description:

A flat rippled fine sandy seabed with small isolated sandwaves. Ripples have an organic/algae? covering particularly in the troughs. Isolated soft corals also occur on the sand.



Conclusions and recommendations: Seabed comprise a flat sandy seabed which has a sparse benthic sand-dwelling habitat. No significant high relief habitat features were observed. Due to strong currents and the ROV tether management it was not possible to run the transect more along the proposed pipeline route.	
Author: Ian Wright	Client Approval: Mike Varsanyi

SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018				
Technical Memo: No. 02	Date: 31/01/2019	Phase: Environmental	Area of Ops: Area 1B (KP189.5)	Rev.1
Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 1B				
Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat. **Aim:** Report preliminary findings of ROV transect to office				
Location: ROV crosses the proposed pipeline route in the vicinity of KP189.308 (E 319248, N7785254) at approximately 17:44:15. ROV on bottom at 17:43, off bottom at 17:48.				

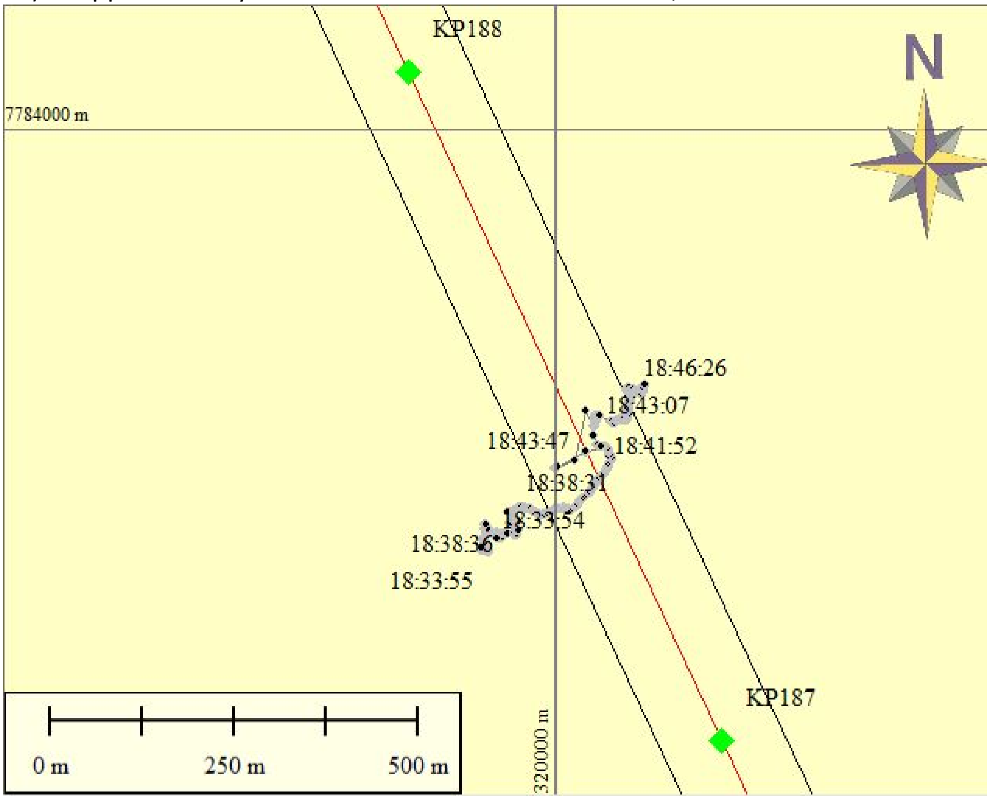


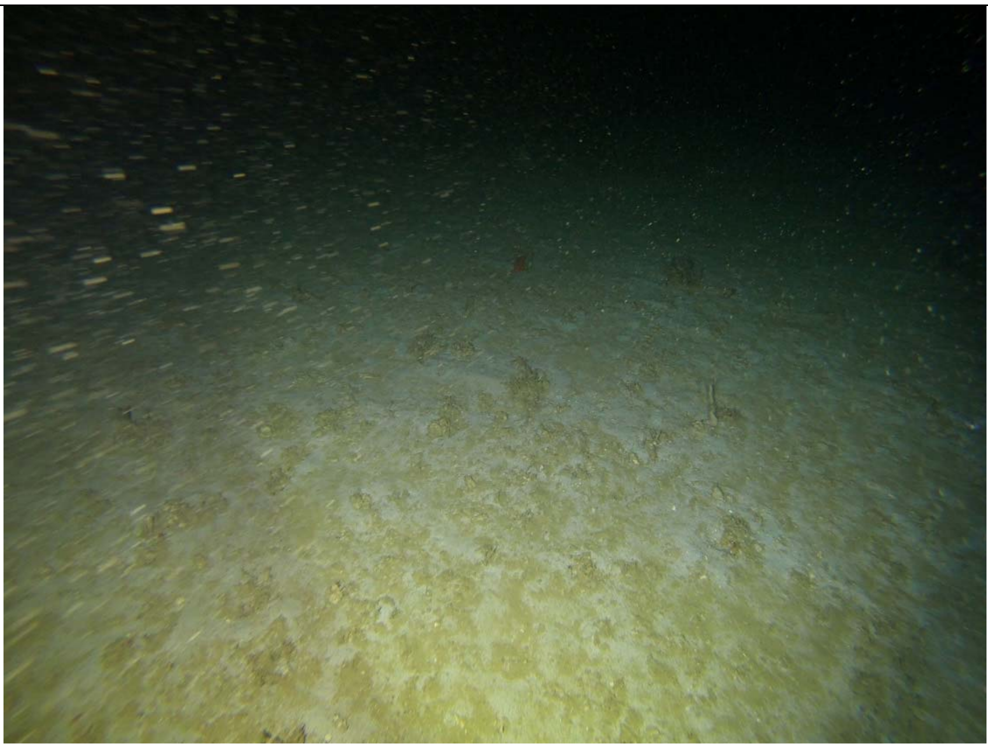
Description:
A typically flat fine sandy seabed which has ripples and larger sandwaves associated with it. Ripples have an organic/algae? covering particularly in the troughs. The small sandwave crests (probably less than 0.5m high) are cleaner and can be seen to prograde over the sediments burying isolated benthic fauna which typically occurs as soft corals and sponges

Conclusions and recommendations:
Seabed comprise a flat sandy seabed which has a sparse benthic sand-dwelling habitat. No significant high relief habitat features were observed.

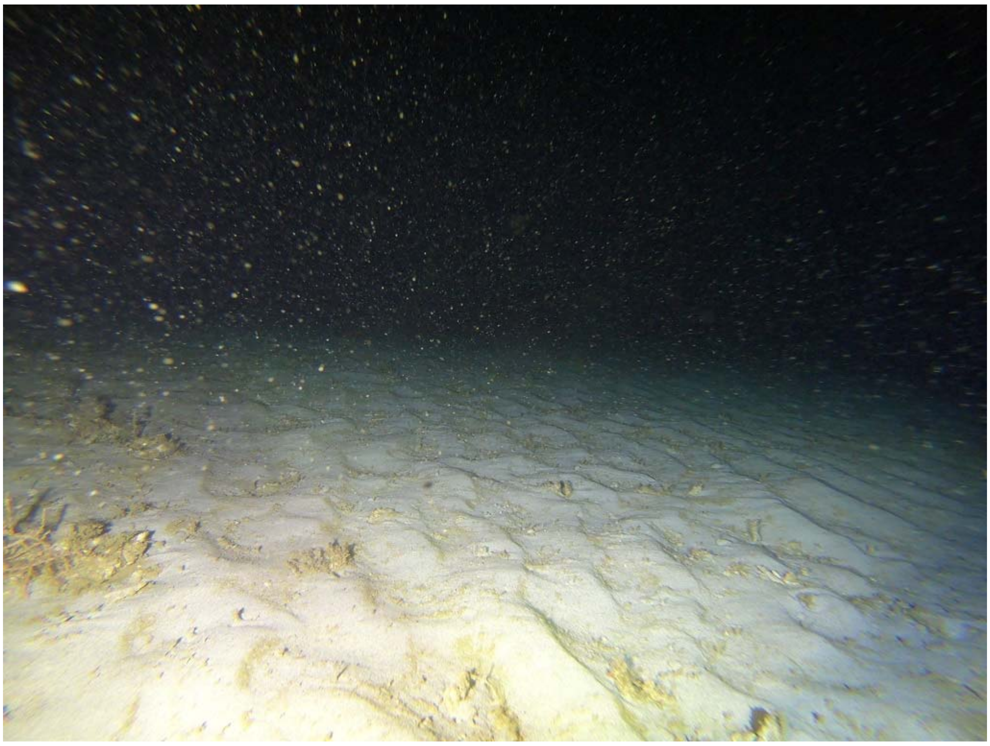
Due to strong currents and the ROV tether management it was not possible to run the transect more along the proposed pipeline route.

Author: Ian Wright	Client Approval: Mike Varsanyi

SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018				
Technical Memo: No. 03	Date: 31/01/2019	Phase: Environmental	Area of Ops: Area 1C (KP187.5)	Rev.1
Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 1C				
Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat. **Aim:** Report preliminary findings of ROV transect to office				
Location: ROV crosses the proposed pipeline route in the vicinity of KP187.392 (E320057, N7783523) at approximately 18:41:46. ROV on bottom at 18:34, off bottom at 18:49. 				
Description: The south western margin of the track shows the seabed is flat comprising sand and larger gravel to small boulder sized carbonate debris which may be a localised hardpan formed from biological activity or sub-outcropping calcarenite.				

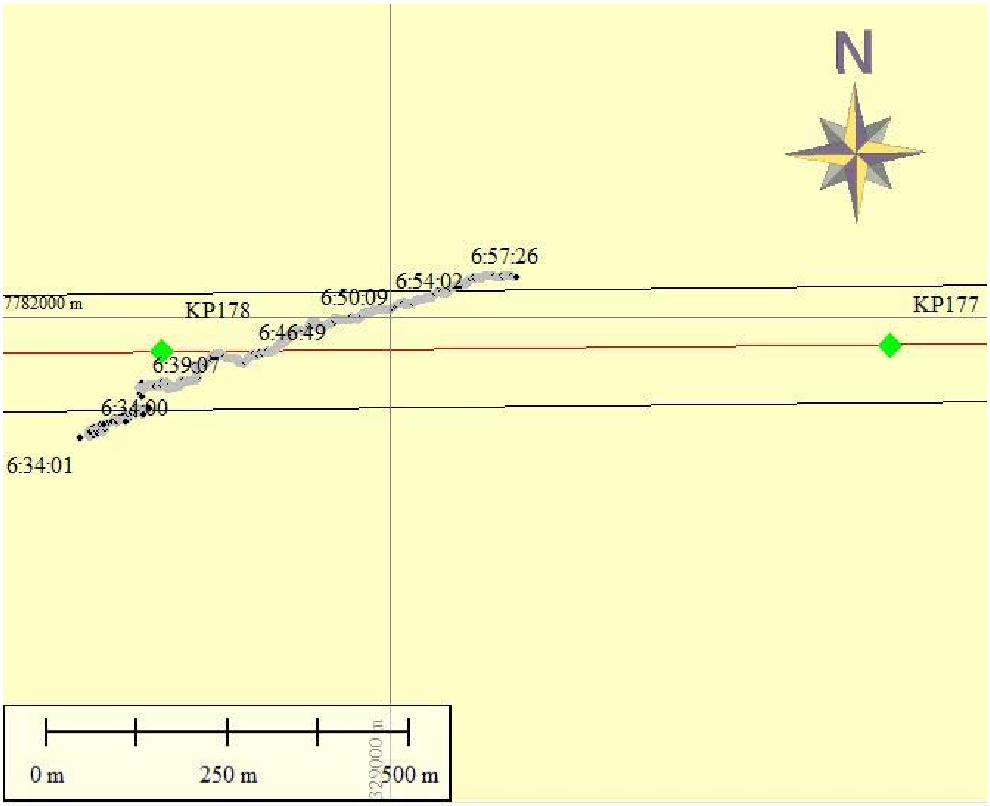


In the vicinity of the PL route (KP187.392, E320057, N7783520) the seabed is typically flat and has ripples associated with it. These typically have an organic/algae? covering particularly in the troughs. Isolated soft corals also occur.



Conclusions and recommendations: Seabed comprise a flat sandy seabed which has a sparse benthic habitat. No significant habitat features were observed. Due to strong currents and the ROV tether management it was not possible to run the transect more along the proposed pipeline route.	
Author: Ian Wright	Client Approval: Mike Varsanyi

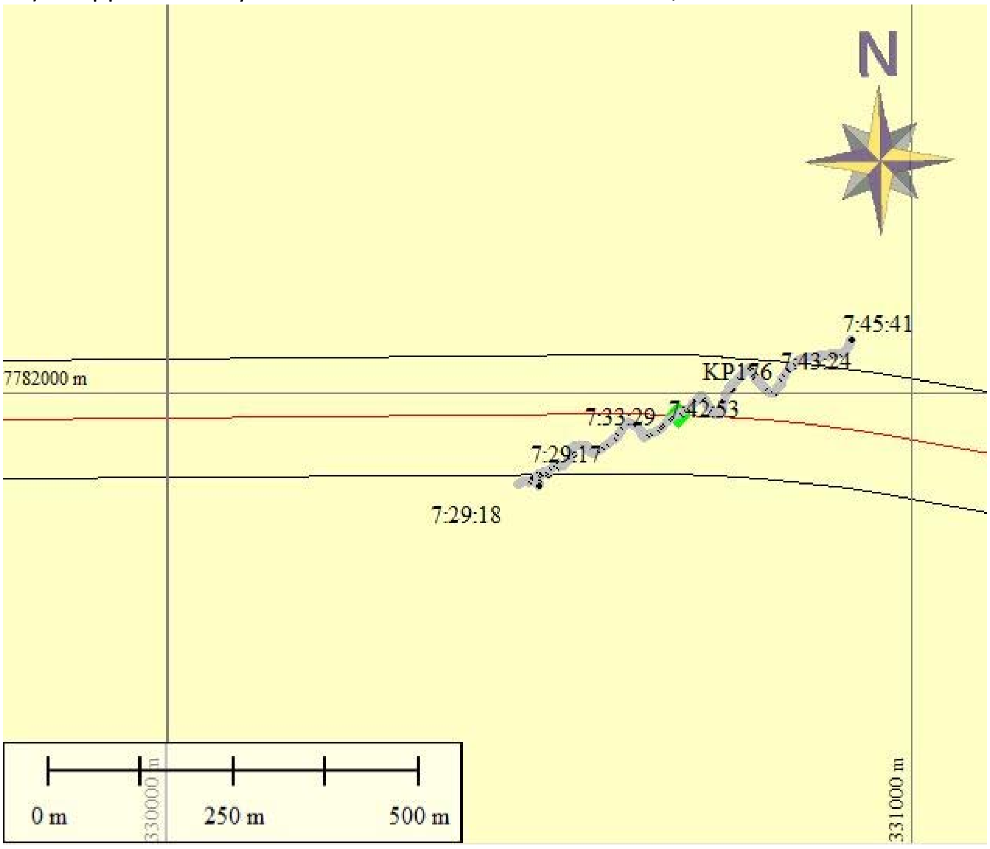
SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018				
Technical Memo: No. 04	Date: 01/02/2019	Phase: Environmental	Area of Ops: Area 2A (KP178)	Rev.0
Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 2A				
Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat. **Aim:** Report preliminary findings of ROV transect to office				
Location: ROV crosses the proposed pipeline route in the vicinity of KP177.8 (E328839, N7781947) at approximately 06:48:04. ROV on bottom at 06:34, off bottom at 06:59.				



Description: The seabed is flat and comprises sand with subordinate bioclastic gravel. Benthic fauna includes prolific soft corals, including large gorgonians and sponges				

Conclusions and recommendations:
Seabed comprise a flat predominantly sandy seabed which has a considerable benthic habitat in the form of soft corals and sponges. No significant high relief habitat features were observed.

Author: Ian Wright	Client Approval: Mike Varsanyi

SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018				
Technical Memo: No. 05	Date: 01/02/2019	Phase: Environmental	Area of Ops: Area 2B (KP176)	Rev.0
Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 2B				
Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat. **Aim:** Report preliminary findings of ROV transect to office				
Location: ROV crosses the proposed pipeline route in the vicinity of KP175.95 (E330686, N7781970) at approximately 07:38:39. ROV on bottom at 07:29, off bottom at 07:47. 				
Description: The seabed is flat and comprises sand with subordinate bioclastic gravel. Benthic fauna includes soft corals, including large gorgonians and sponges				

Conclusions and recommendations:
Seabed comprise a flat predominantly sandy seabed which has a benthic habitat in the form of soft corals and sponges. No significant high relief habitat features were observed.

Author: Ian Wright	Client Approval: Mike Varsanyi

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01/02/2019</td><td>Phase:
Environmental</td><td>Area of Ops: Area 2C
(KP174)</td><td>Rev.0</td></tr>
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<tr><td colspan="5">Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat.

Aim: Report preliminary findings of ROV transect to office</td></tr>
<tr><td colspan="5">Location: ROV crosses the proposed pipeline route in the vicinity of KP173.95 (E332653, N7781637) at approximately 08:26:10. ROV on bottom at 08:16, off bottom at 08:34.</td></tr>
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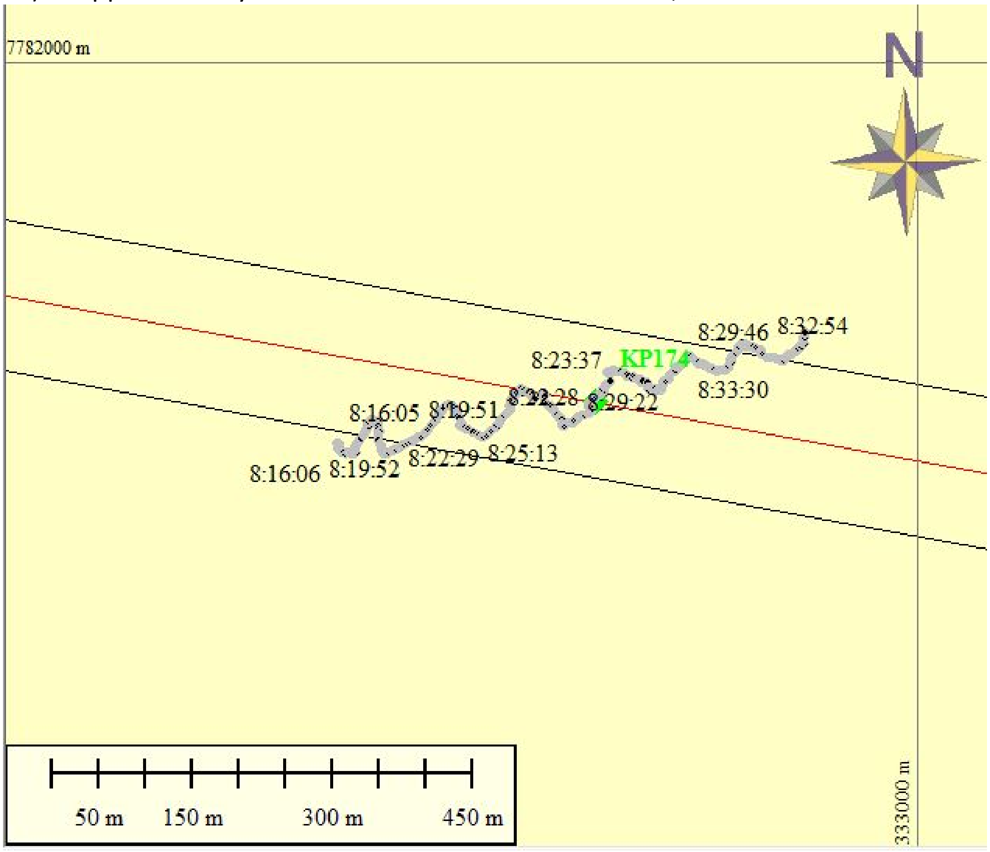

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<tr><td>Description: The seabed is flat and comprises sand with subordinate bioclastic gravel. Benthic fauna includes areas of soft corals, including large gorgonians and sponges.</td></tr>
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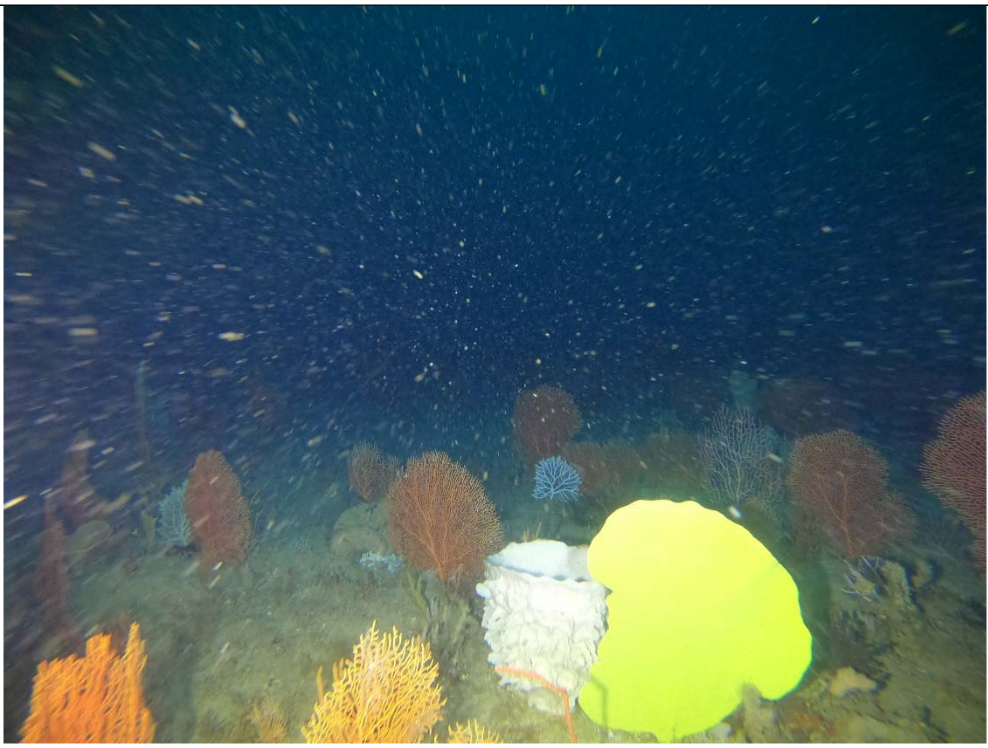
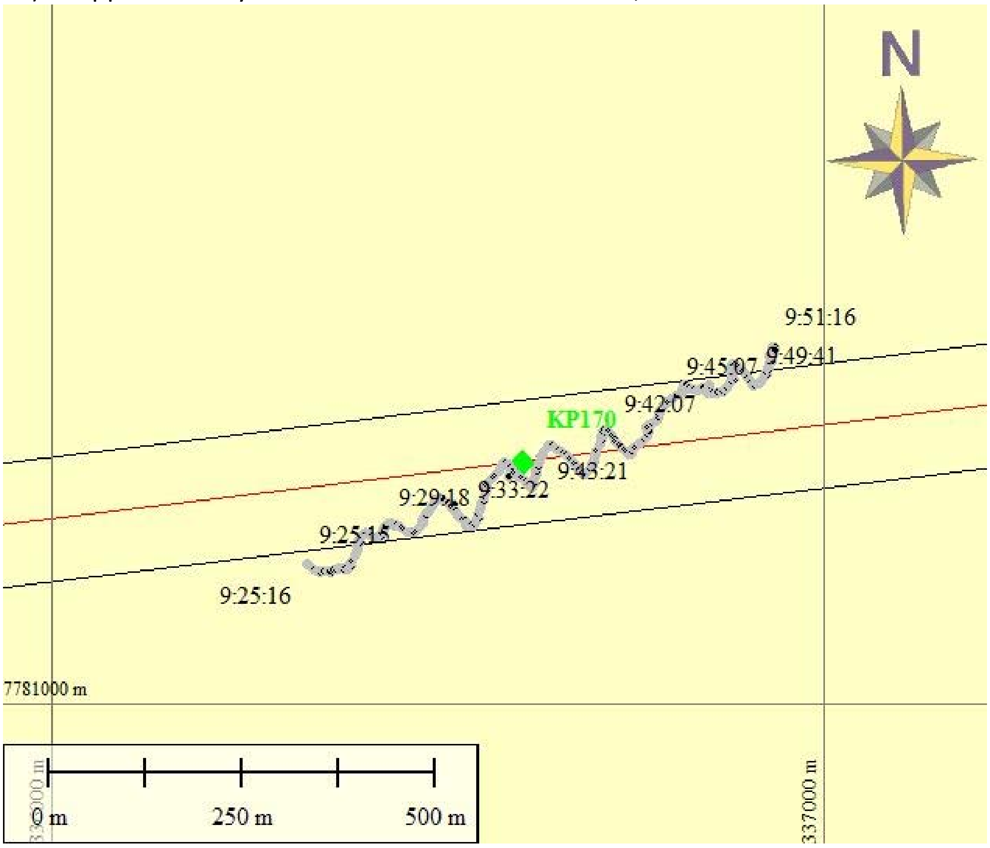


Conclusions and recommendations: Seabed comprise a flat predominantly sandy seabed which has a benthic habitat in the form of areas of soft corals and sponges. No significant high relief habitat features were observed.	
Author: Ian Wright	Client Approval: Mike Varsanyi

SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018				
Technical Memo: No. 07	Date: 01/02/2019	Phase: Environmental	Area of Ops: Area 3A (KP170)	Rev.0
Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 3A				
Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat. **Aim:** Report preliminary findings of ROV transect to office				
Location: ROV crosses the proposed pipeline route in the vicinity of KP169.05 (E336608, N7781312) at approximately 09:35. ROV on bottom at 09:25, off bottom at 09:51.				
Description: The seabed is typically flat and comprises sand with subordinate bioclastic gravel. Benthic fauna includes areas of soft corals, including large gorgonians and sponges as well as black 'whip' corals.				



Conclusions and recommendations: Seabed comprise a flat predominantly sandy seabed which has a benthic habitat in the form of areas of soft corals and sponges. No significant high relief habitat features were observed.	
Author: Ian Wright	Client Approval: Mike Varsanyi

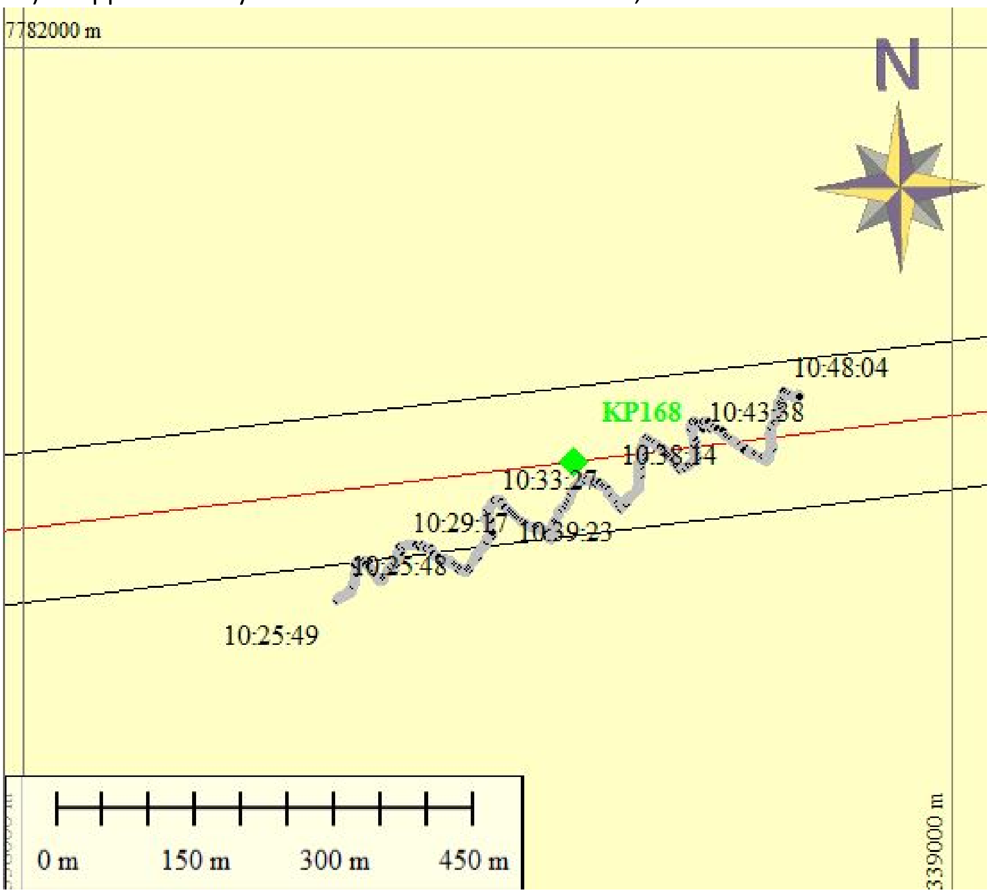
SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018				
Technical Memo: No. 08	Date: 01/02/2019	Phase: Environmental	Area of Ops: Area 3B (KP168)	Rev.0

Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 3B

Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat.

Aim: Report preliminary findings of ROV transect to office

Location: ROV crosses the proposed pipeline route in the vicinity of KP167.88 (E338667, N7781567) at approximately 10:41. ROV on bottom at 10:25, off bottom at 10:49.

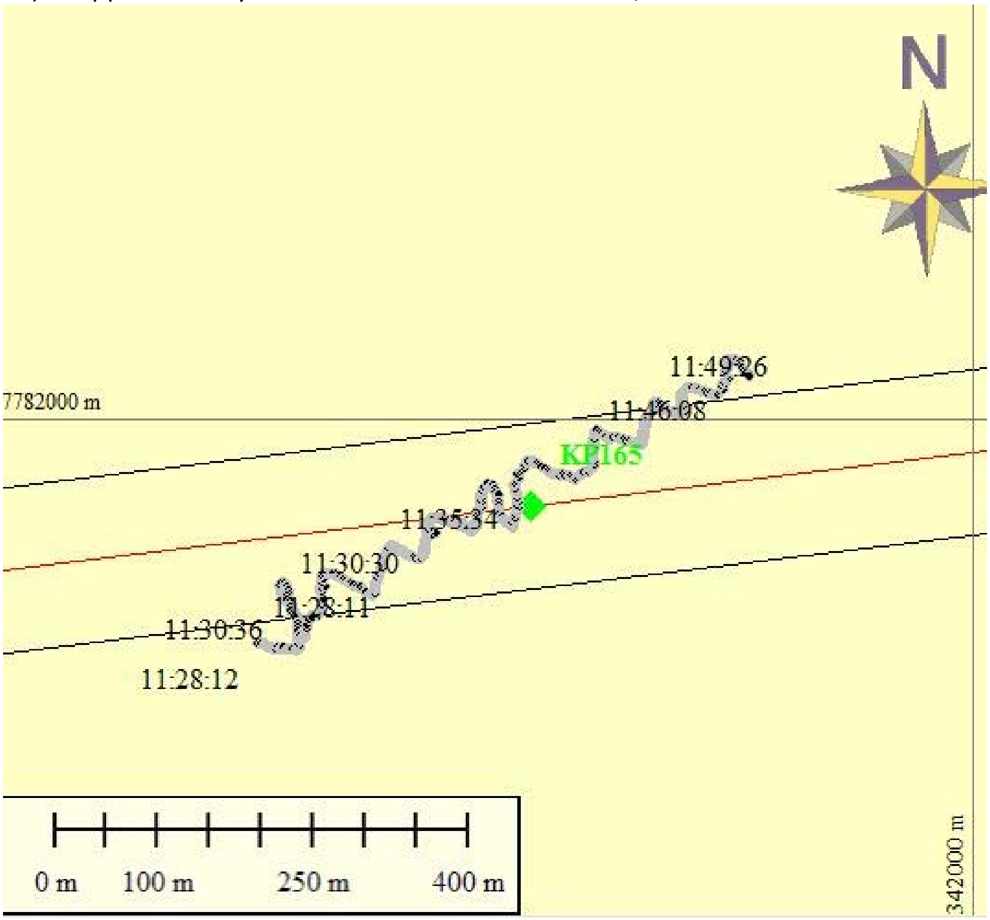


Description: The seabed is typically flat and comprises sand with subordinate bioclastic gravel. Benthic fauna includes areas of soft corals, including large gorgonians and sponges.

Conclusions and recommendations:
Seabed comprise a flat predominantly sandy seabed which has a benthic habitat in the form of areas of soft corals and sponges. No significant high relief habitat features were observed.

Author: Ian Wright	Client Approval: Mike Varsanyi

SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018				
Technical Memo: No. 09	Date: 01/02/2019	Phase: Environmental	Area of Ops: Area 3C (KP165)	Rev.0
Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 3C				
Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat. **Aim:** Report preliminary findings of ROV transect to office				
Location: ROV crosses the proposed pipeline route in the vicinity of KP164.95 (E341572, N7781919) at approximately 11:40. ROV on bottom at 11:28, off bottom at 11:54.				



Description: The seabed is typically flat to undulating and comprises sand with subordinate bioclastic gravel. Benthic fauna includes sporadic areas of soft corals, including large gorgonians and sponges as well as black 'whip' corals. Current scour moats are noted around some of the sponges.

Conclusions and recommendations:
Seabed comprise a flat predominantly sandy seabed which has a benthic habitat in the form of isolated areas of soft corals and sponges. No significant high relief habitat features were observed.

Author: Ian Wright	Client Approval: Mike Varsanyi

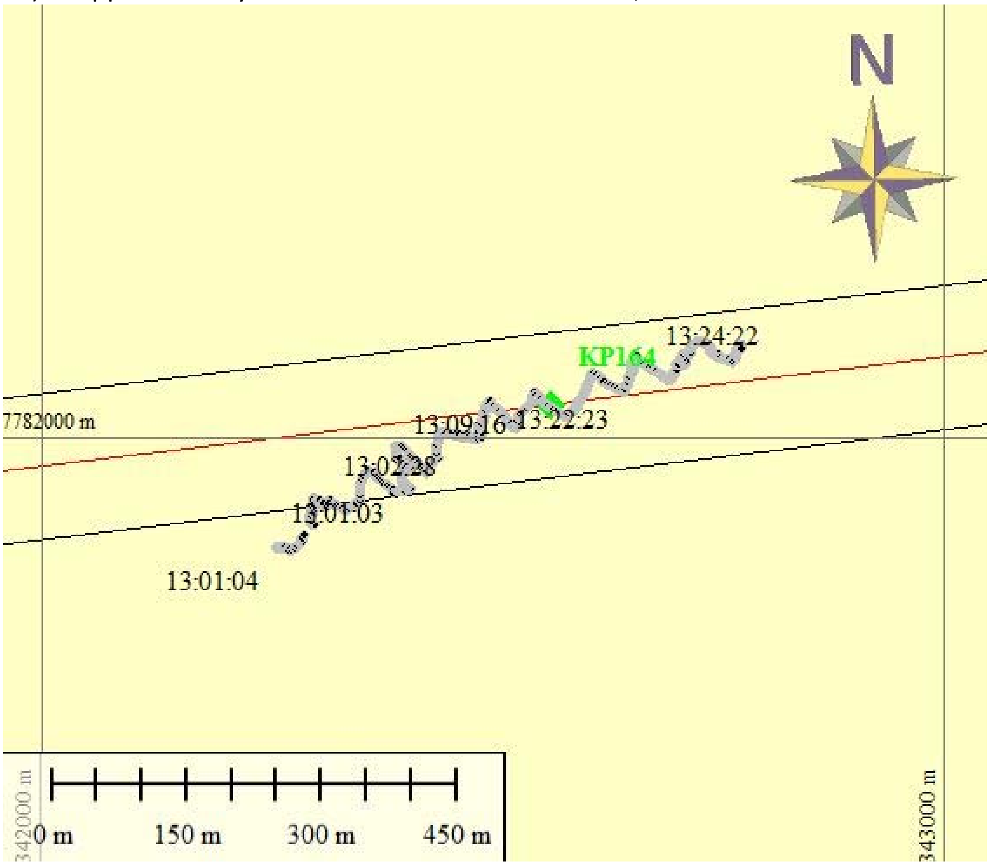
SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018				
Technical Memo: No. 10	Date: 01/02/2019	Phase: Environmental	Area of Ops: Area 4A (KP164)	Rev.0

Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 4A

Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat.

Aim: Report preliminary findings of ROV transect to office

Location: ROV crosses the proposed pipeline route in the vicinity of KP163.95 (E342566, N7782035) at approximately 13:15. ROV on bottom at 13:01, off bottom at 13:29.

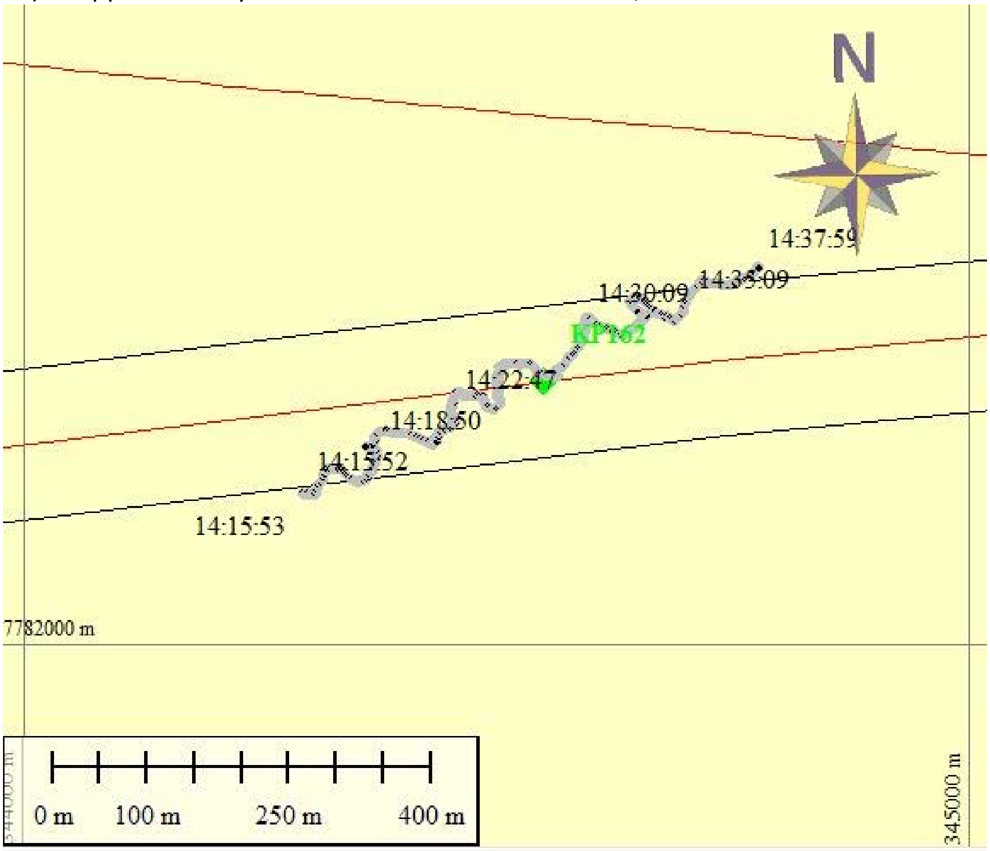


Description: The seabed is typically flat to undulating and comprises sand with subordinate bioclastic gravel. 'Starved' ripples occur and typically have coarser gravel in their troughs. Benthic fauna includes sporadic areas of soft corals, including large gorgonians and sponges as well as black 'whip' corals. Current scour moats are noted around some of the sponges.

Conclusions and recommendations:
Seabed comprise a flat predominantly sandy seabed which has a benthic habitat in the form of isolated areas of soft corals and sponges. No significant high relief habitat features were observed.

Author: Ian Wright	Client Approval: Mike Varsanyi

SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018				
Technical Memo: No. 11	Date: 01/02/2019	Phase: Environmental	Area of Ops: Area 4B (KP162)	Rev.0
Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 4B				
Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat. **Aim:** Report preliminary findings of ROV transect to office				
Location: ROV crosses the proposed pipeline route in the vicinity of KP162.00 (E344502, N7782269) at approximately 14:23. ROV on bottom at 14:15, off bottom at 14:38.				

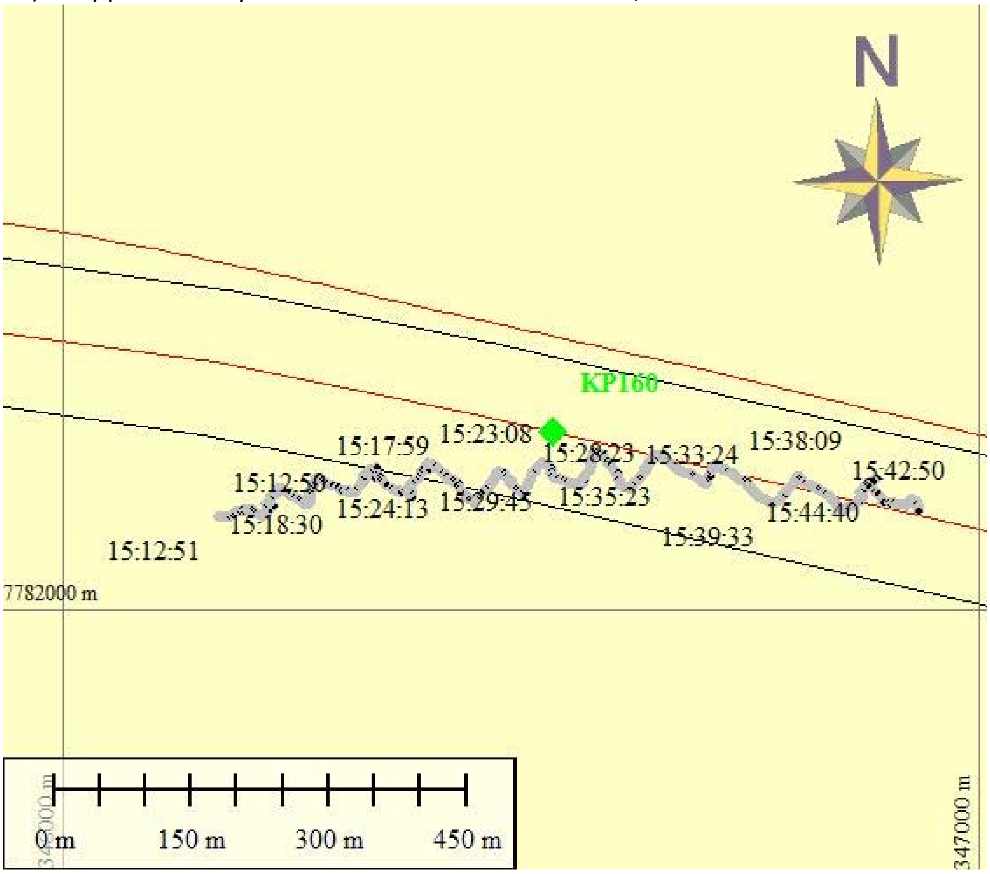


Description: The seabed is typically flat to undulating and comprises sand with subordinate bioclastic gravel. 'Starved' ripples occur and typically have coarser gravel in their troughs. Benthic fauna includes sporadic areas of soft corals, including gorgonians and sponges as well as black 'whip' corals. Current scour moats are noted around some of the sponges.	

Conclusions and recommendations:
Seabed comprise a flat predominantly sandy seabed which has a benthic habitat in the form of isolated areas of soft corals and sponges. No significant high relief habitat features were observed.

Author: Ian Wright	Client Approval: Mike Varsanyi

SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018				
Technical Memo: No. 12	Date: 01/02/2019	Phase: Environmental	Area of Ops: Area 4C (KP160)	Rev.0
Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 4C				
Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat. **Aim:** Report preliminary findings of ROV transect to office				
Location: ROV crosses the proposed pipeline route in the vicinity of KP159.83 (E346650, N7782160) at approximately 15:34. ROV on bottom at 15:13, off bottom at 15:47.				



Description: The seabed is typically flat to undulating and comprises sand with subordinate bioclastic gravel. 'Starved' ripples occur and typically have coarser gravel in their troughs. Benthic fauna includes sporadic areas of soft corals, including gorgonians and sponges. Current scour moats are noted around some of the sponges.

Conclusions and recommendations:
Seabed comprise a flat predominantly sandy seabed which has a benthic habitat in the form of isolated areas of soft corals and sponges. No significant high relief habitat features were observed.

Author: Ian Wright	Client Approval: Mike Varsanyi

SCARBOROUGH DEVELOPMENT - SHALLOW WATER GEOPHYSICAL & GEOTECHNICAL SURVEY 2018

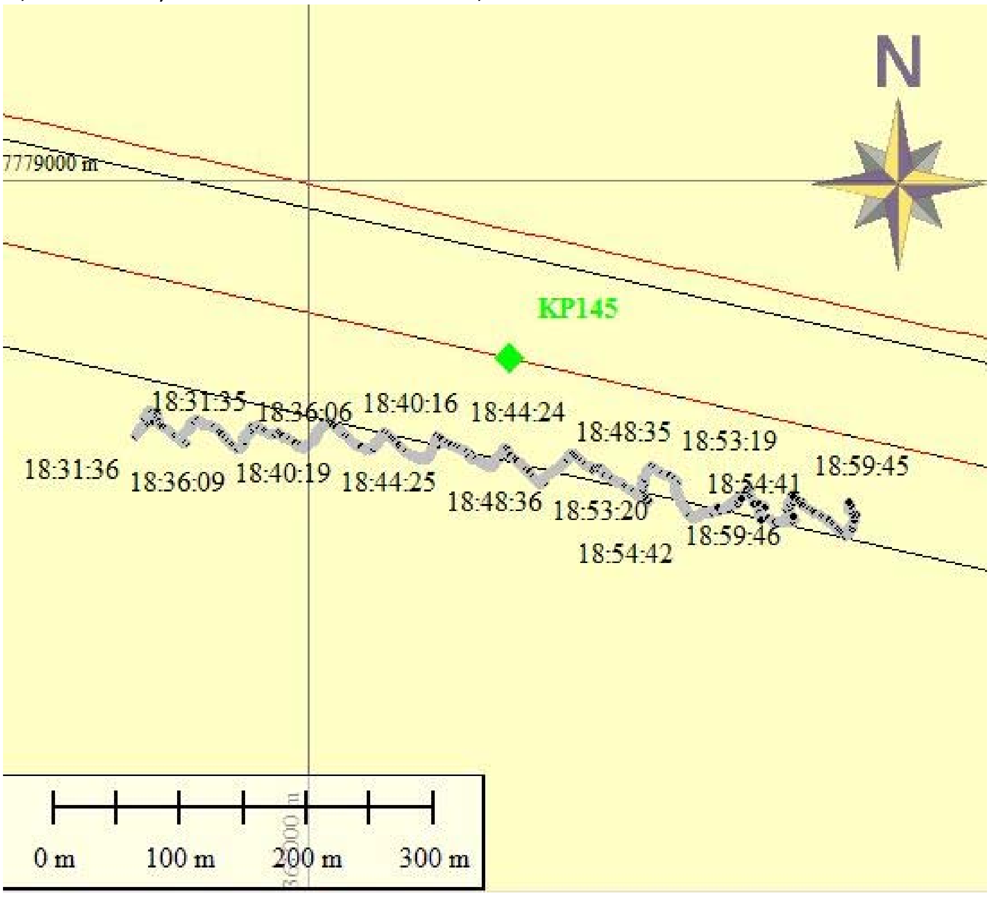
Technical Memo: No. 13	Date: 01/02/2019	Phase: Environmental	Area of Ops: Area 5A (KP145)	Rev.0

Title: ENVIRONMENTAL OBSERVATIONS FROM AREA 5A (NO 5B or C)

Scope: Undertake a ROV transect obliquely across the planned PL route to identify benthic habitat.

Aim: Report preliminary findings of ROV transect to office

Location: ROV surveyed south of the proposed pipeline route in the vicinity of KP144.93 (E361160, N7778778). ROV on bottom at 18:31, off bottom at 19:00.



Description: The seabed is typically flat to undulating and comprises sand with subordinate bioclastic gravel. Where flat, the seabed has an algae cover. Where undulating, the seabed is characterised by starved ripples and scour moats, typically around sponges. Benthic fauna includes sporadic areas of soft corals, including gorgonians and sponges.

Conclusions and recommendations:
Seabed comprise a flat predominantly sandy seabed which has a benthic habitat in the form of isolated areas of soft corals and sponges. No significant high relief habitat features were observed.

Due to strong currents and the ROV tether management it was not possible to run the transect across the proposed pipeline route.

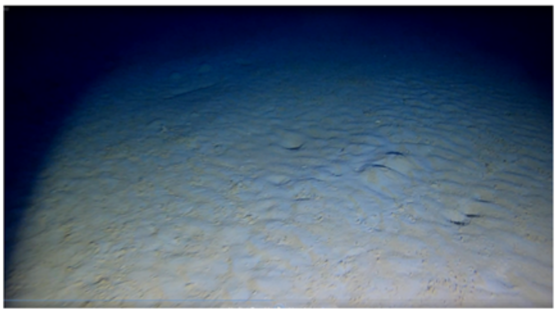
Author: Ian Wright	Client Approval: Mike Varsanyi

Appendix B: Additional Images Area 1

Transect Images – Area 1

Area 1 – Transect 1a






Benthic Organisms – Transect 1a





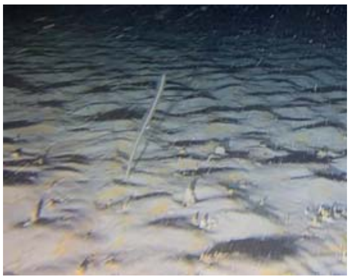



Area 1 – Transect 1b






Benthic Organisms – Transect 1b



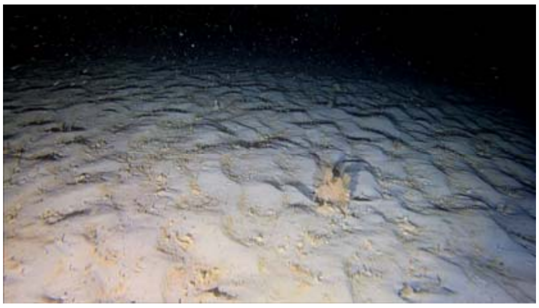
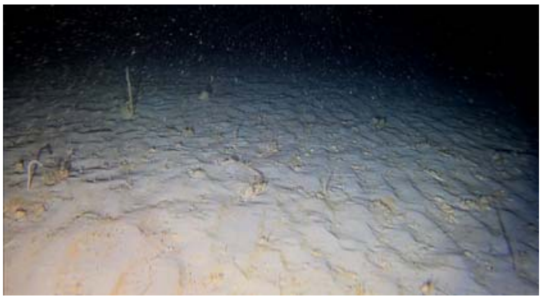
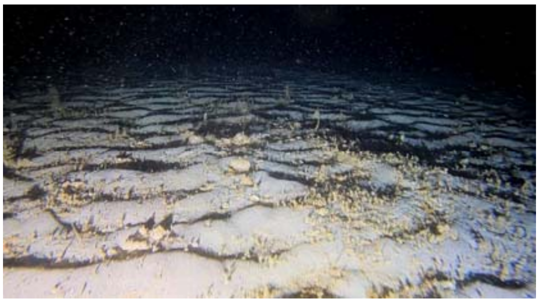
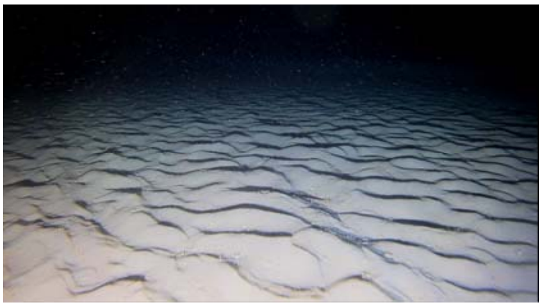





Area 1 – Transect 1c






Benthic Organisms – Transect 1c





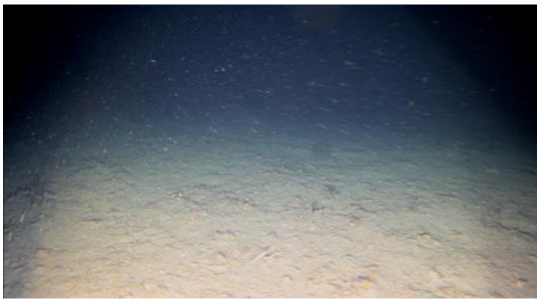
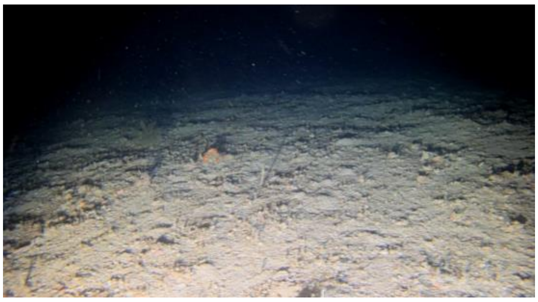
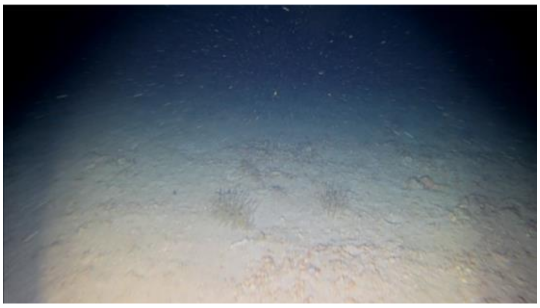
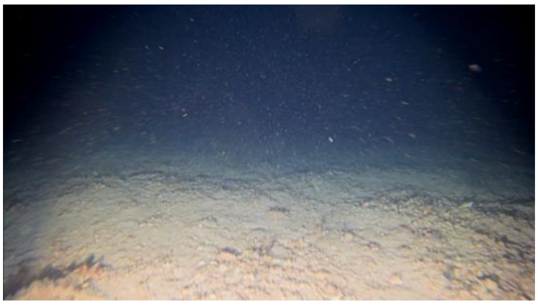


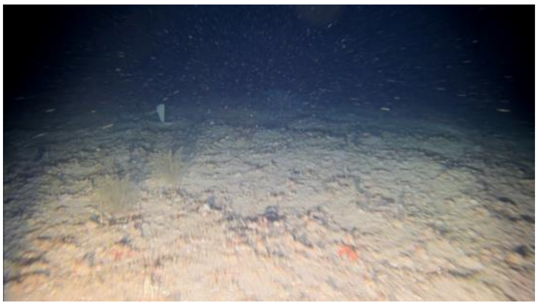
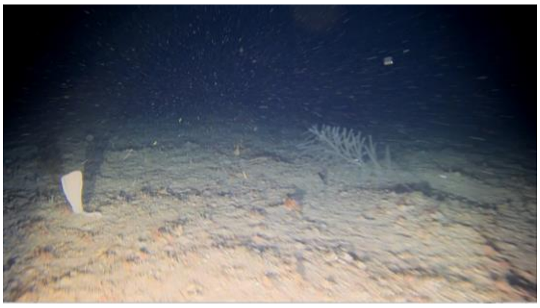
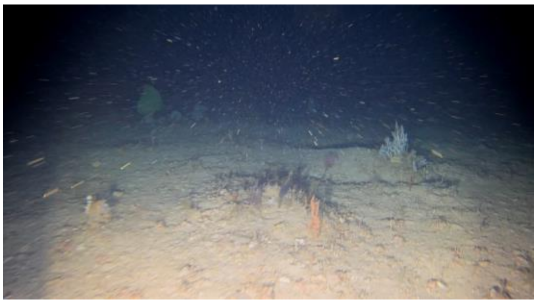
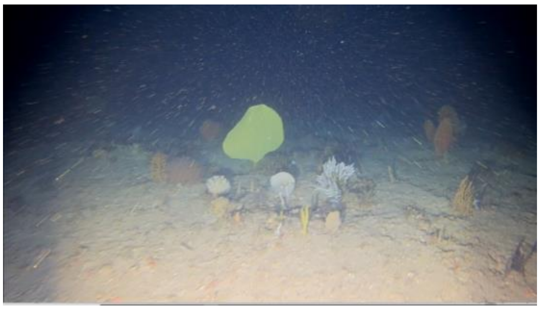


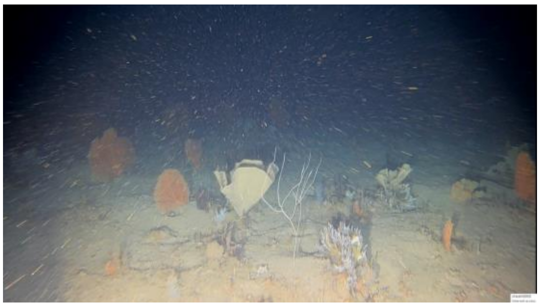
Appendix C: Additional Images Area 2

Transect Images – Area 2

Area 2 – Transect 2a

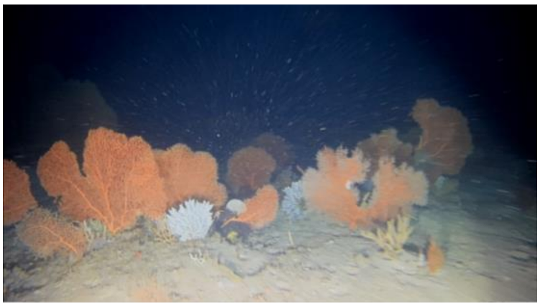





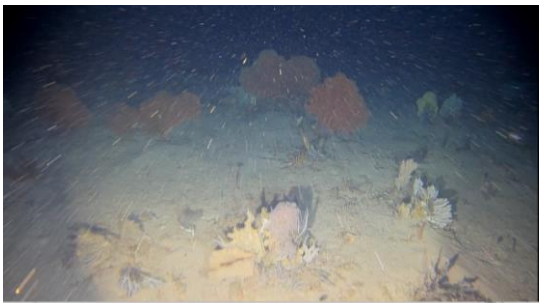





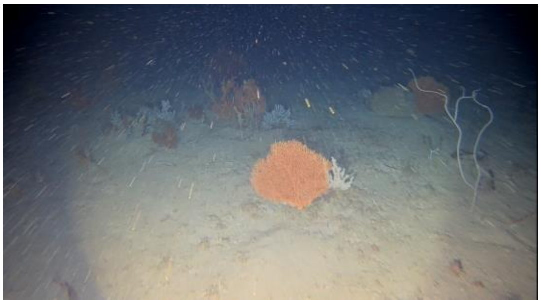



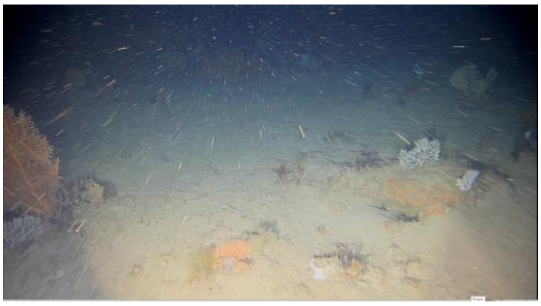


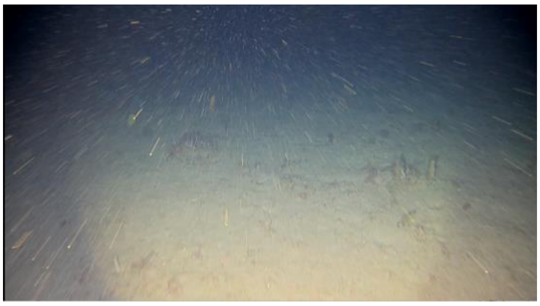
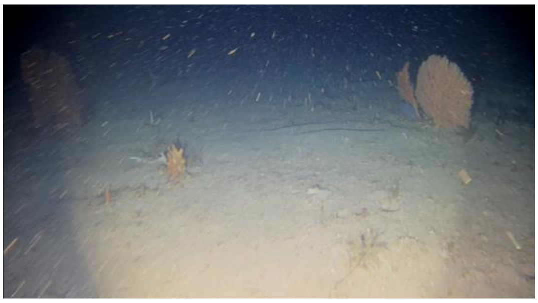
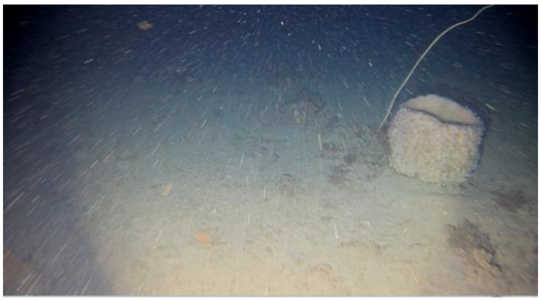


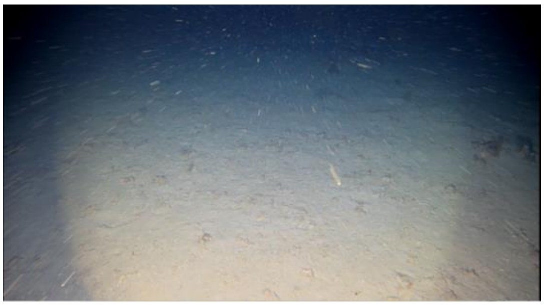


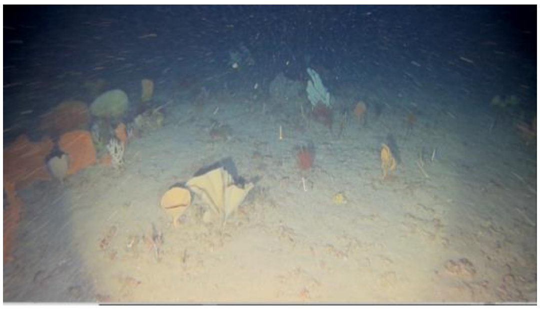







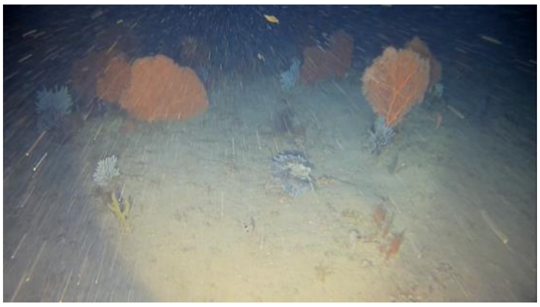




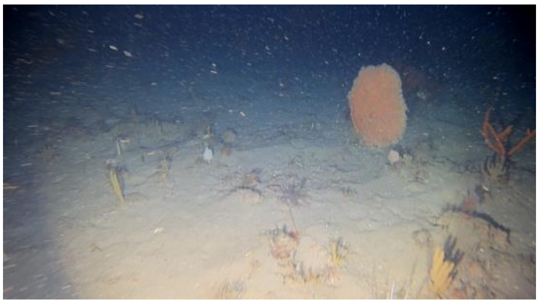
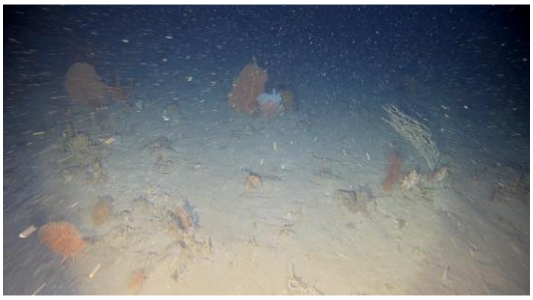




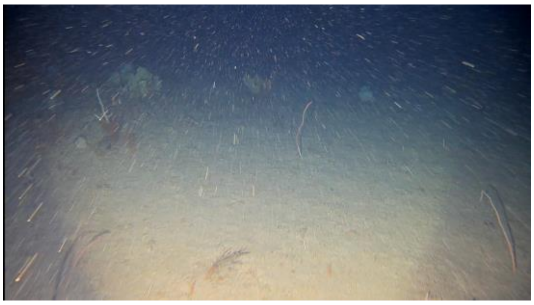


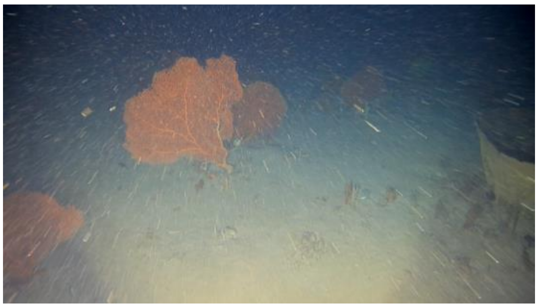



Area 2 – Transect 2b

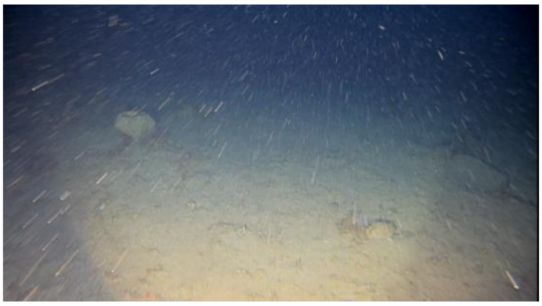


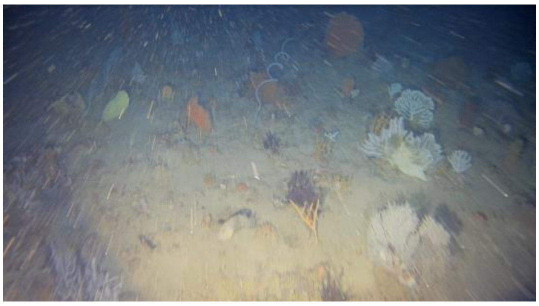
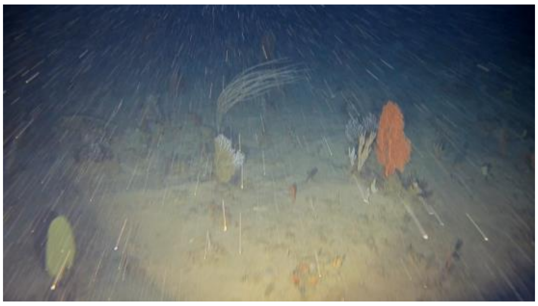


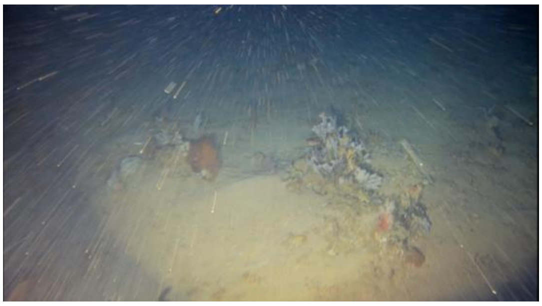


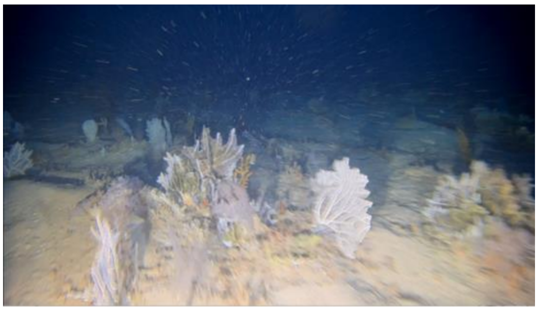


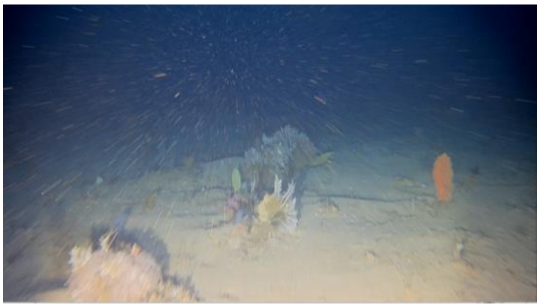
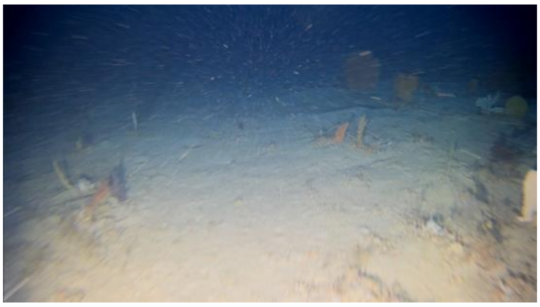
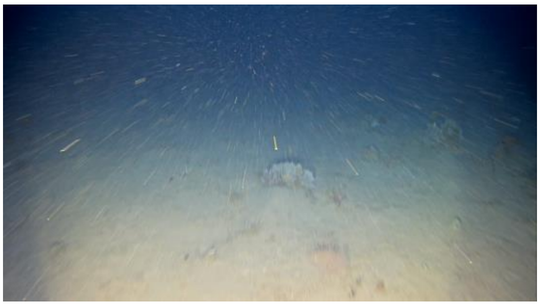
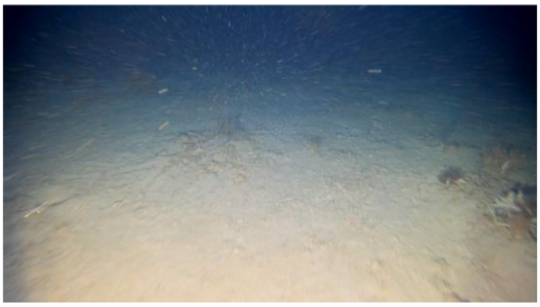







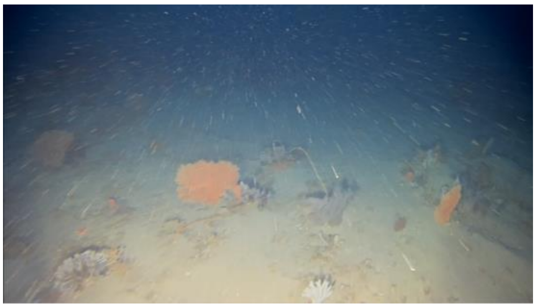



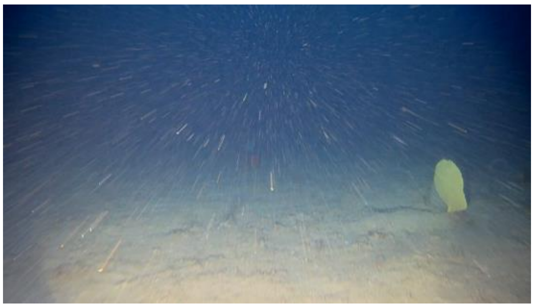
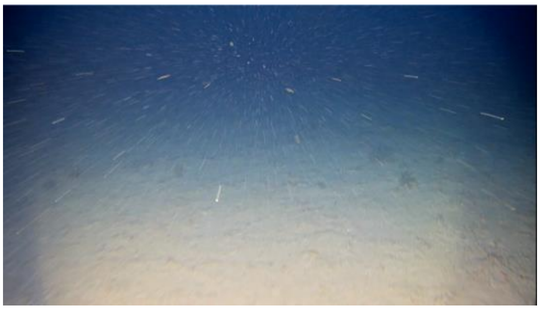
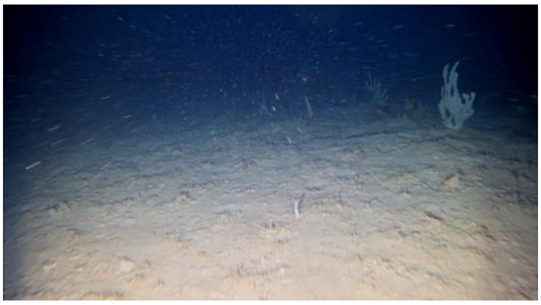


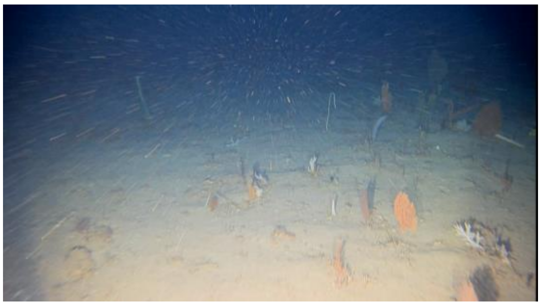
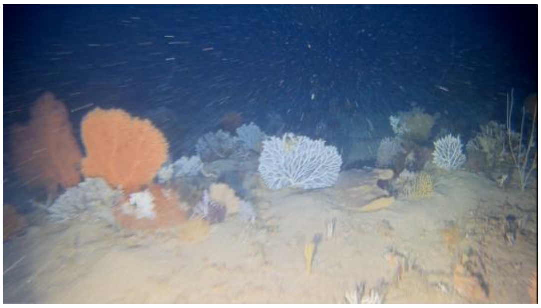
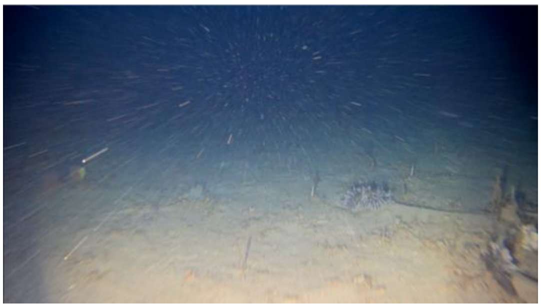





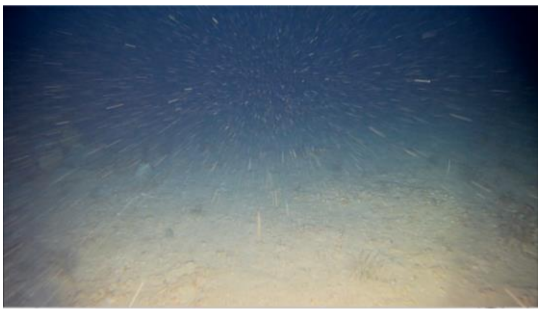

Area 2 – Transect 2c

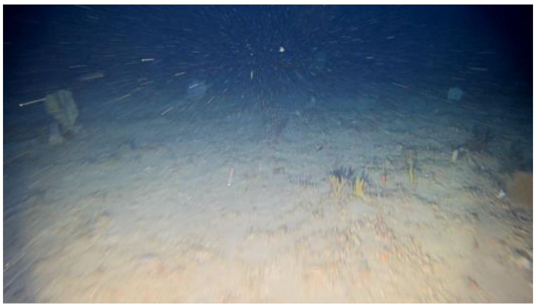


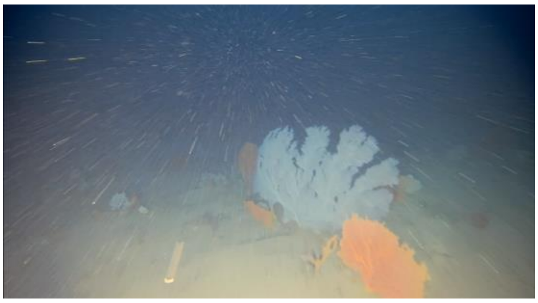
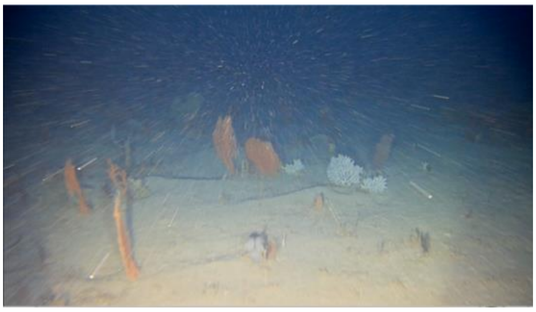



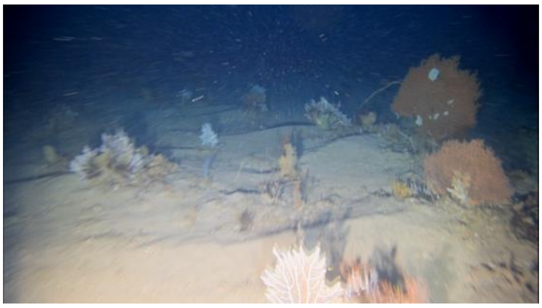





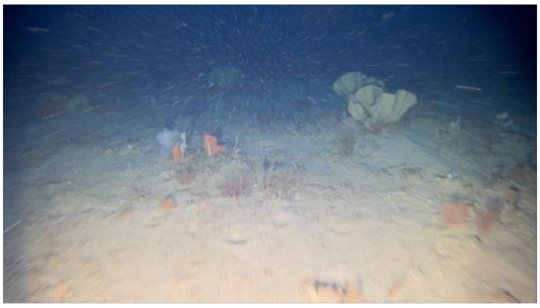
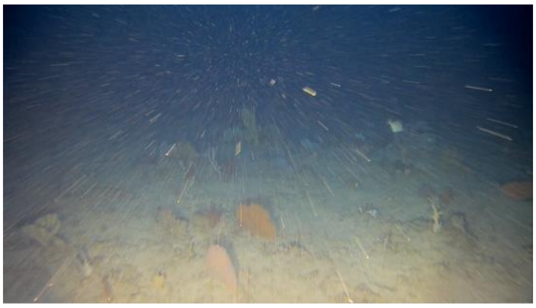






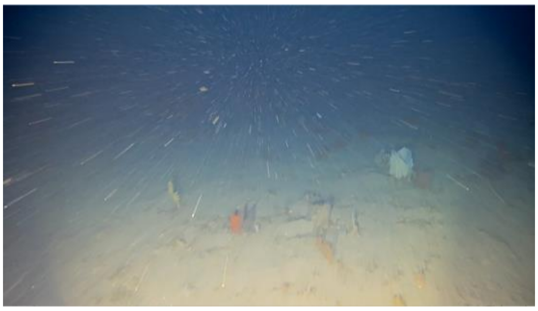


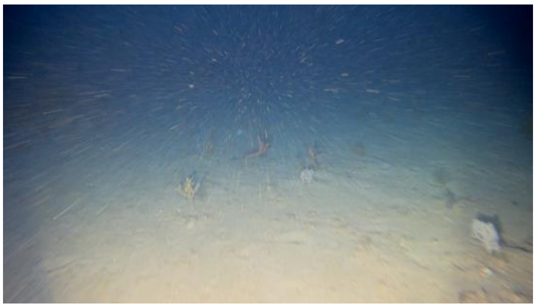




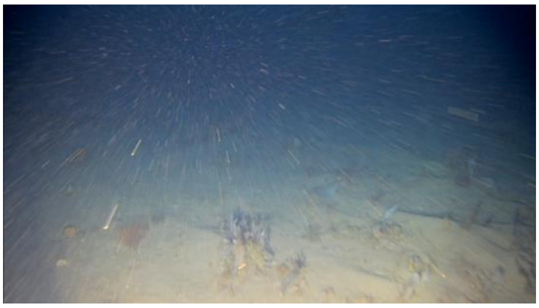
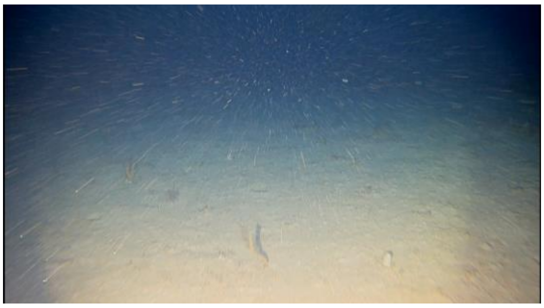
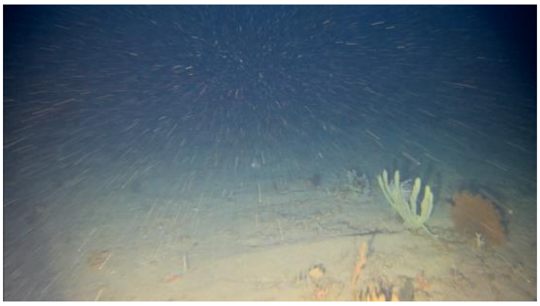


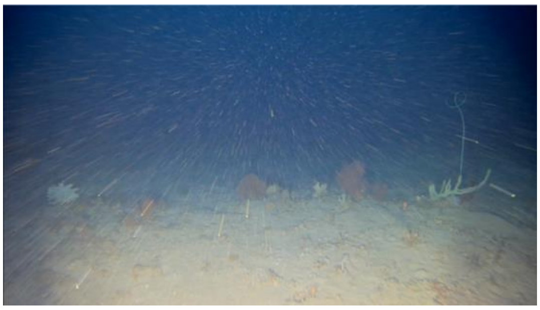




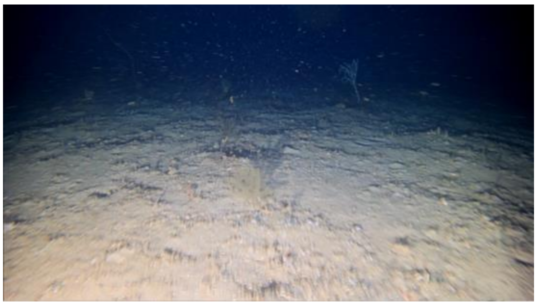
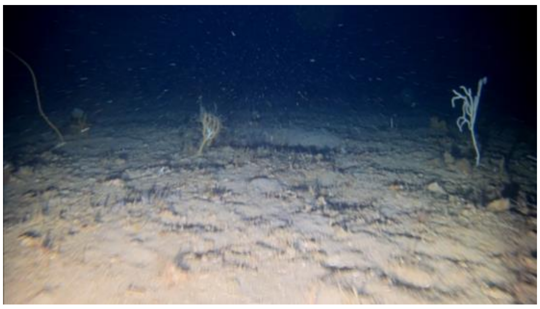


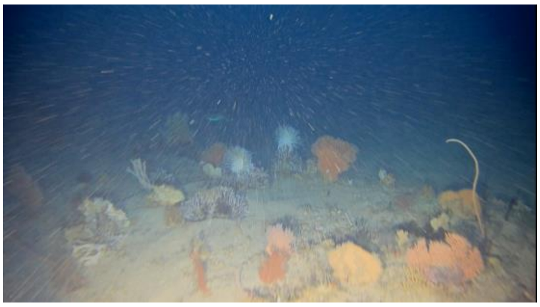








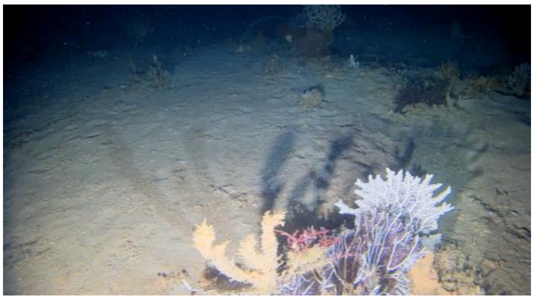


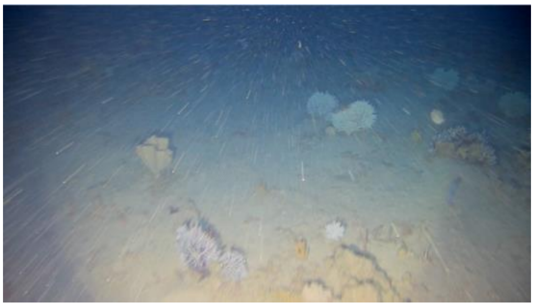


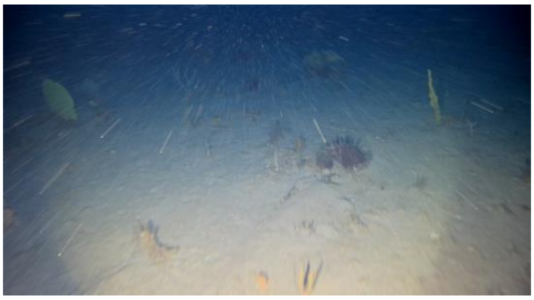
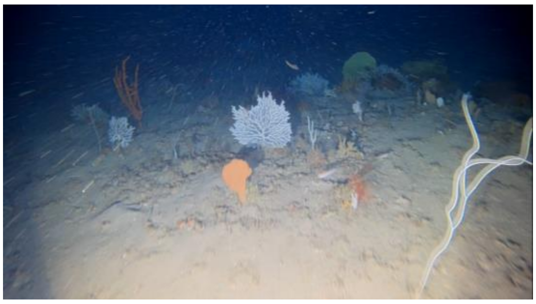

Appendix D: Additional Images Area 3

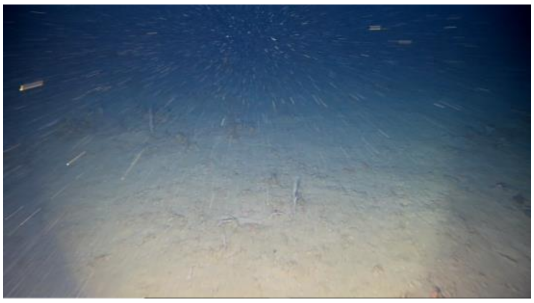
Transect Images – Area 3

Area 3 – Transect 3a



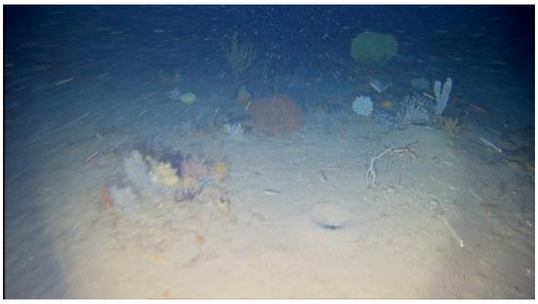
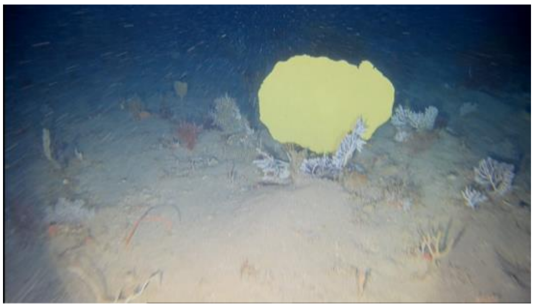


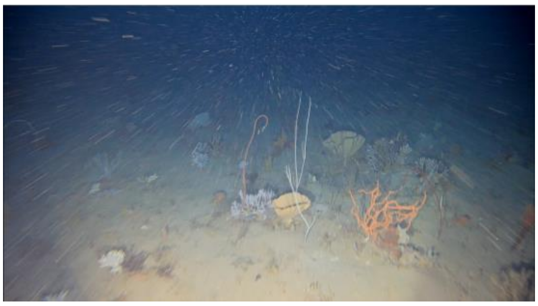





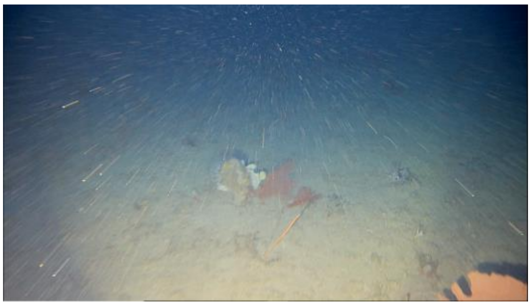




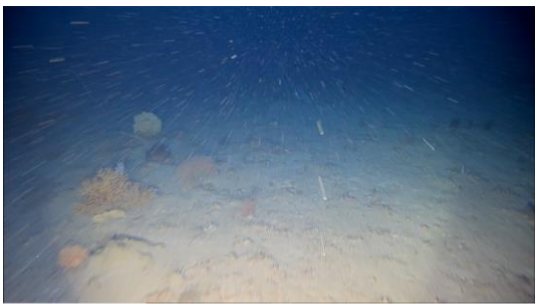




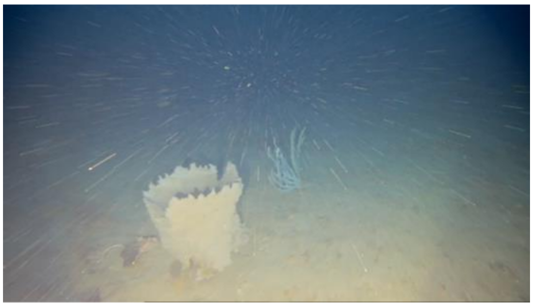




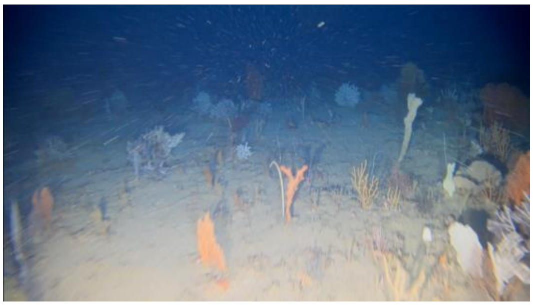


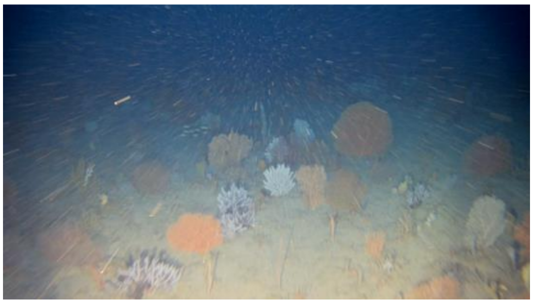
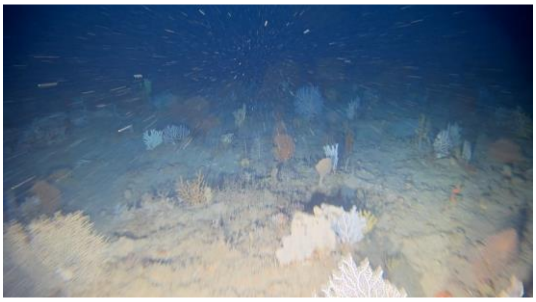
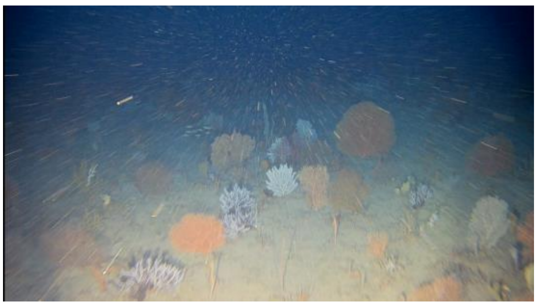
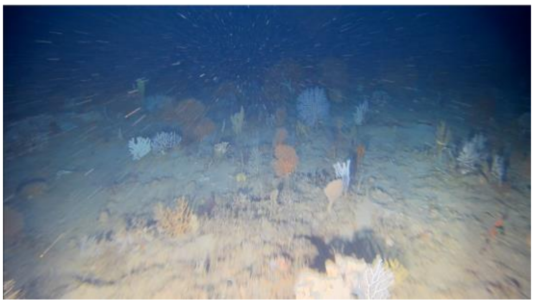



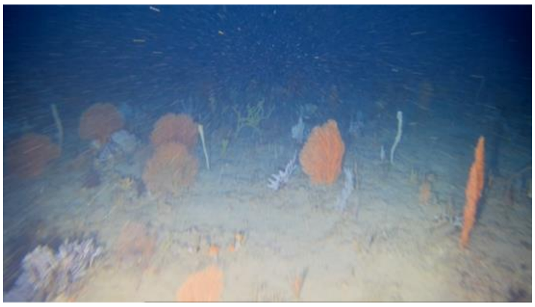




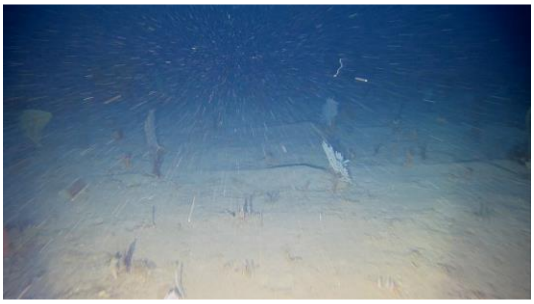




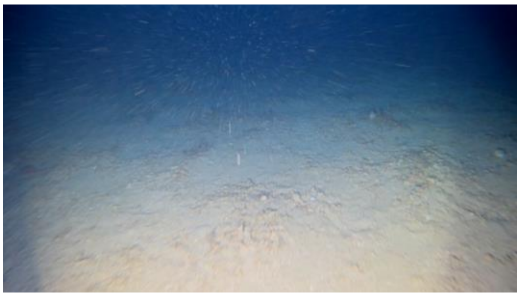


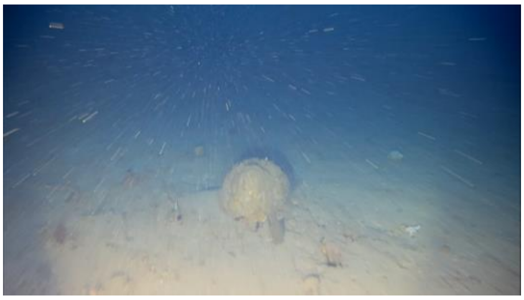
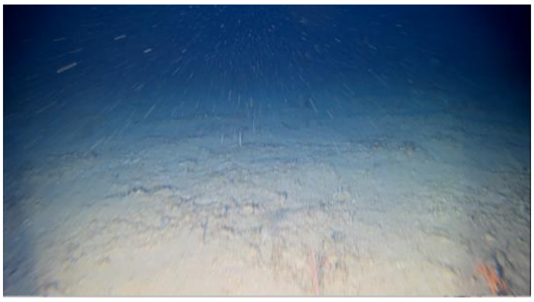
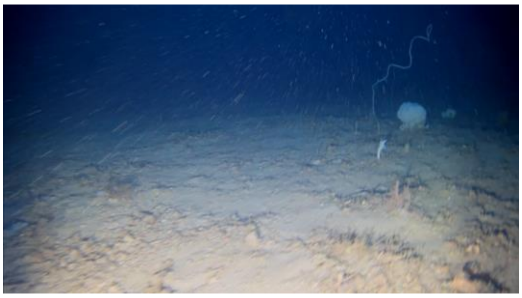
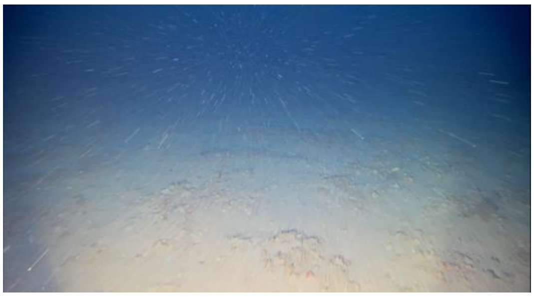
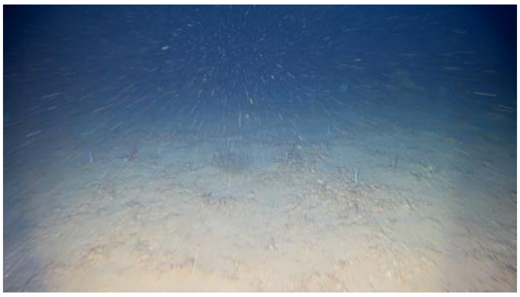
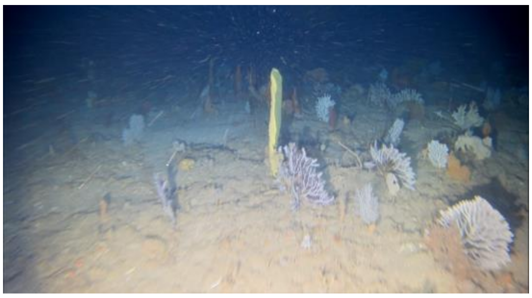








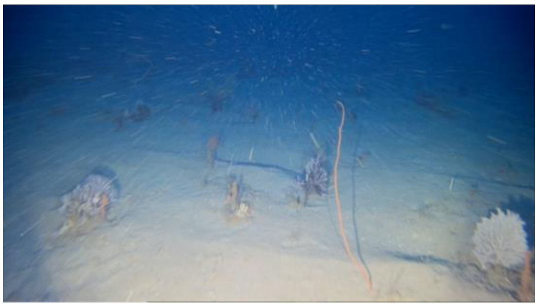







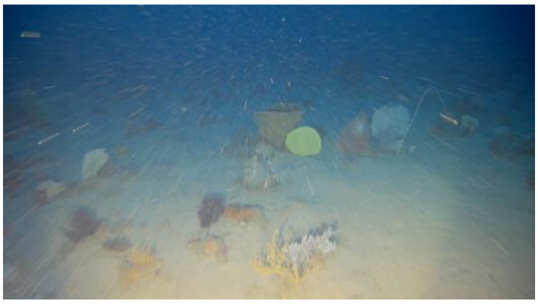

Area 3 – Transect 3b





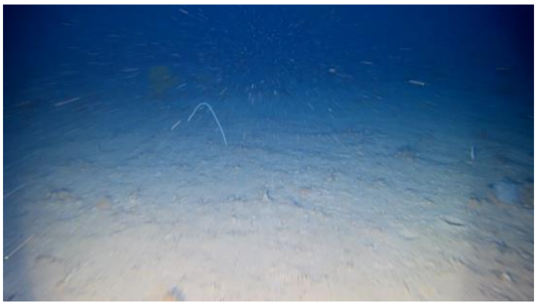


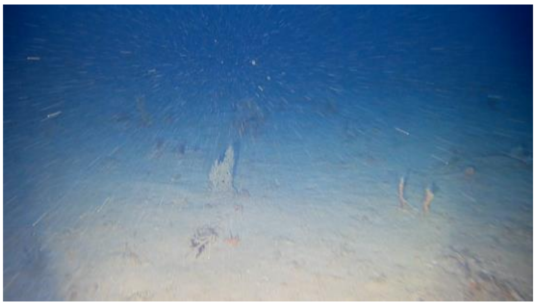
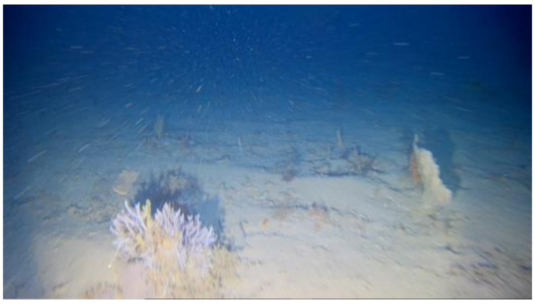



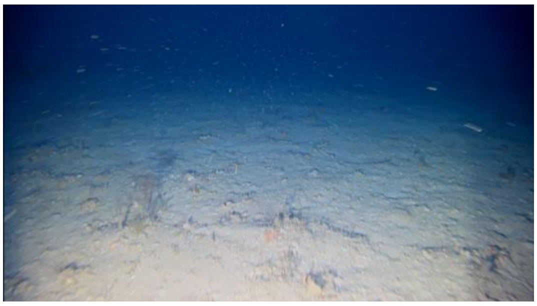






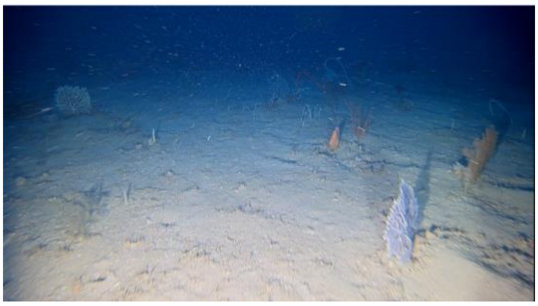


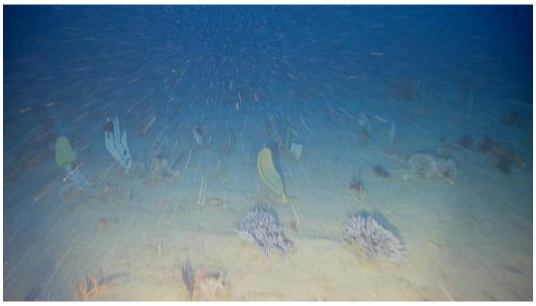






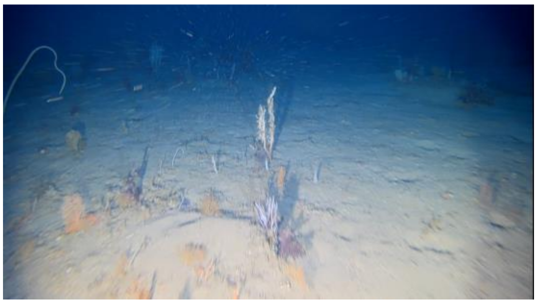
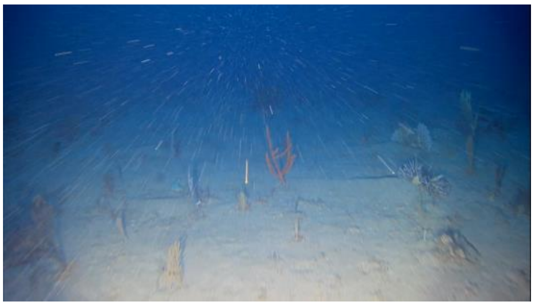








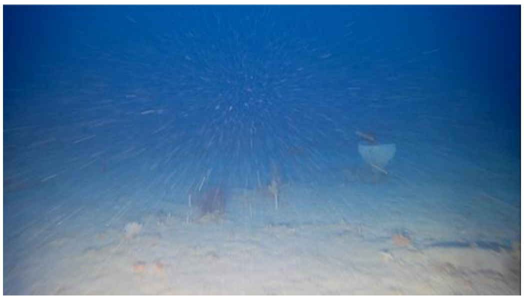


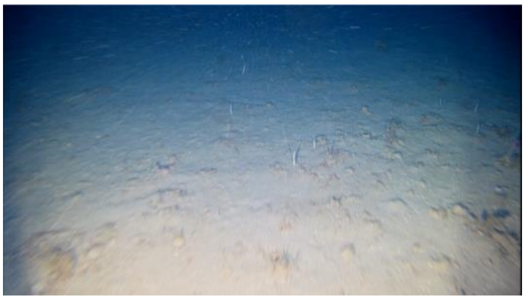
Area 3 – Transect 3c



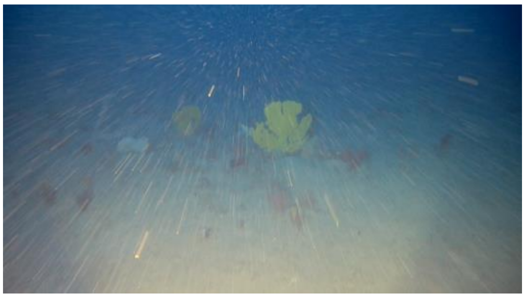
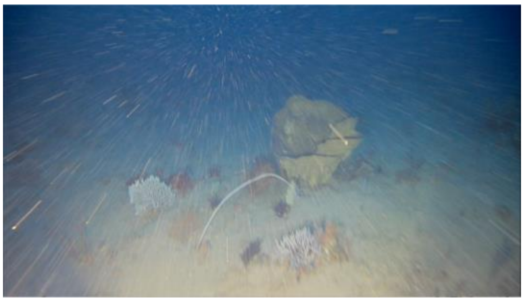


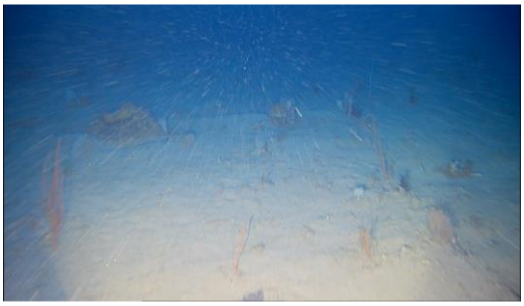







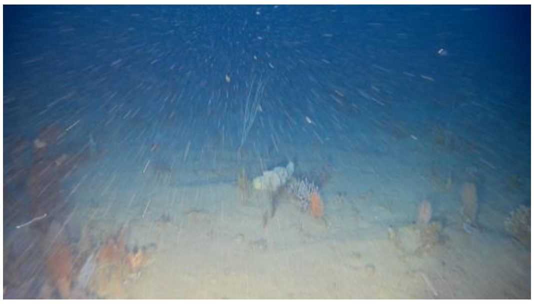
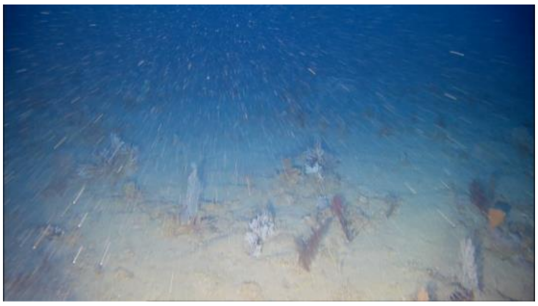
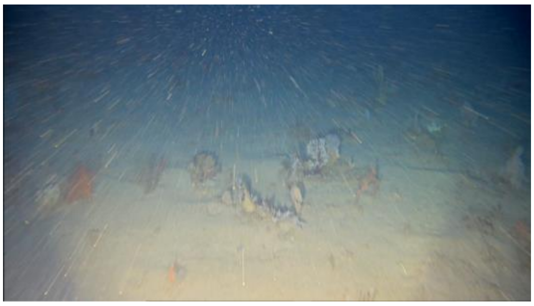






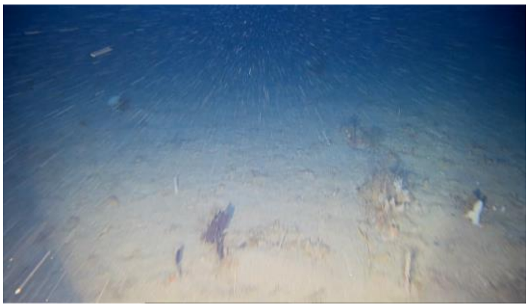


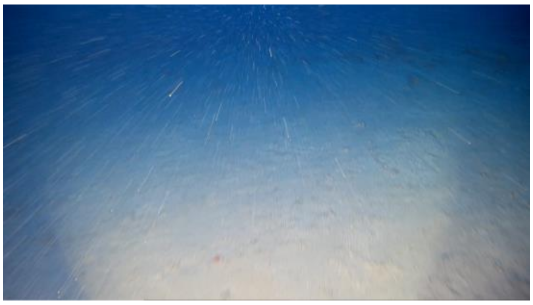






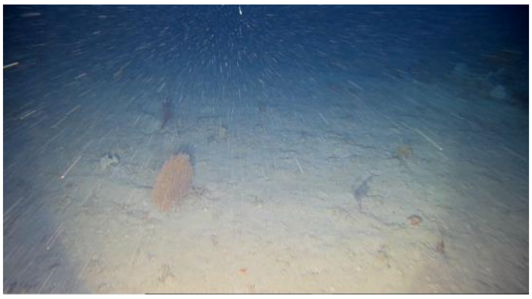
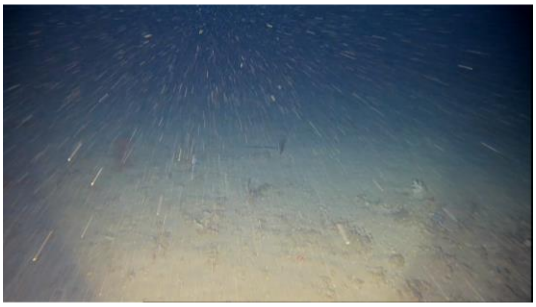


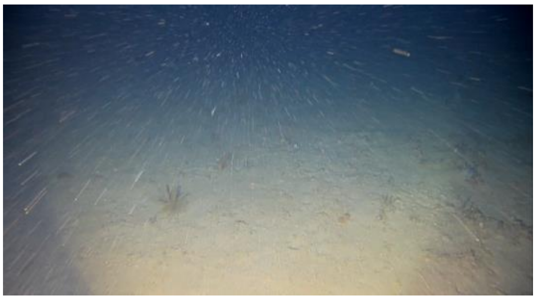
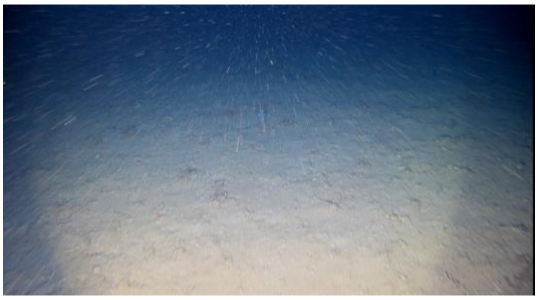
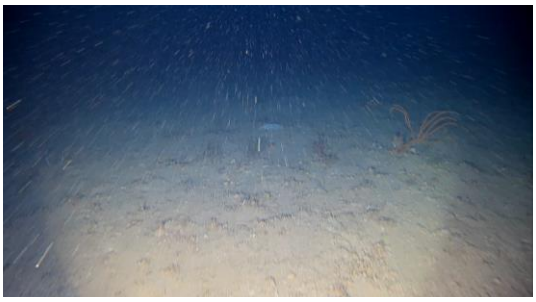
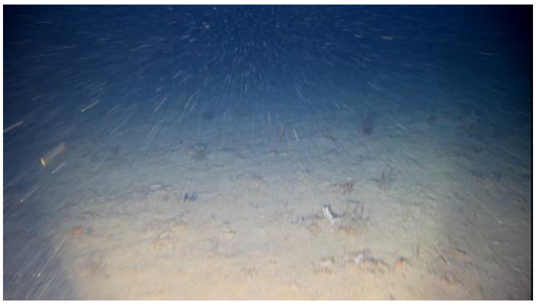


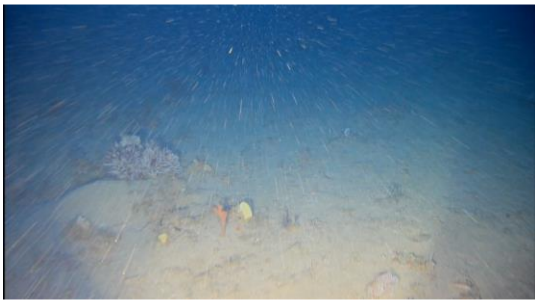






Appendix E: Additional Images Area 4

Transect Images – Area 4

Area 4 - Transect 4a

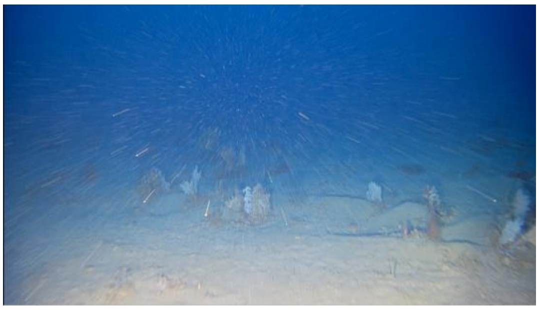


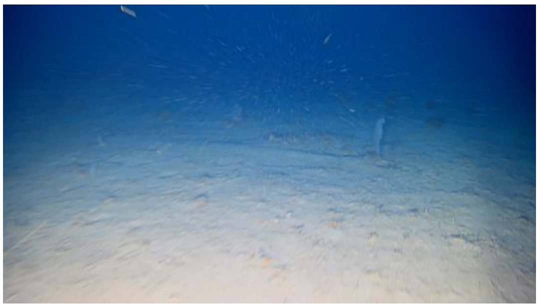
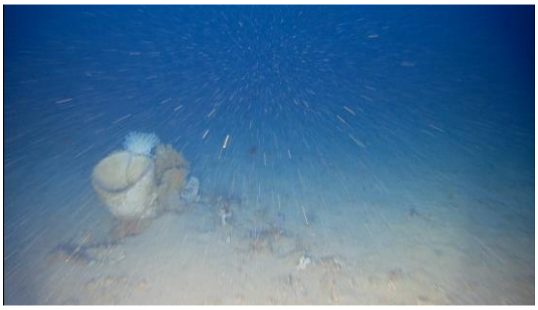


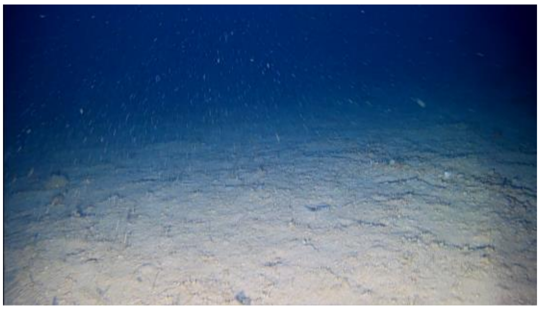
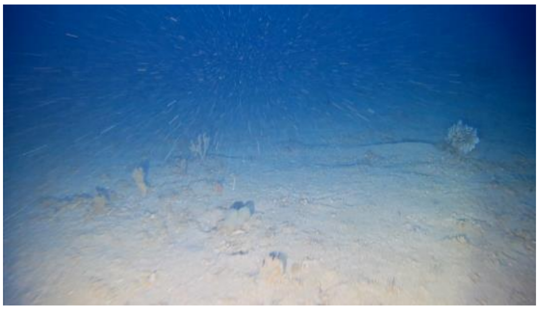
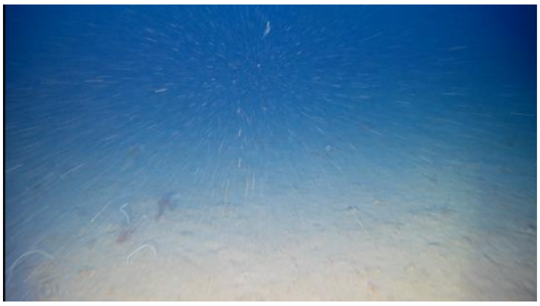






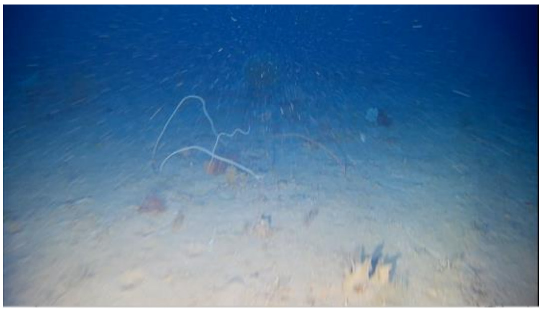



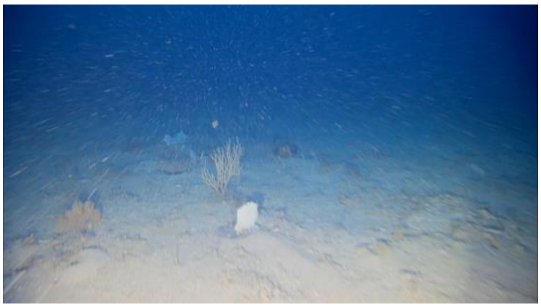
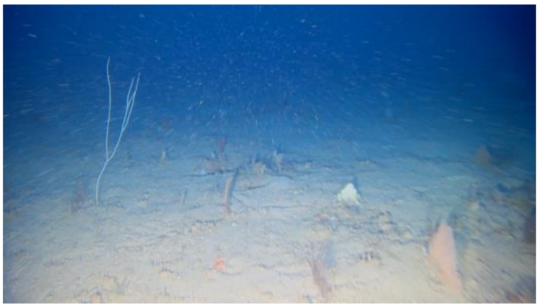



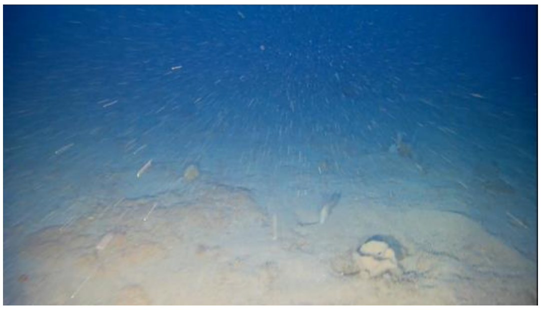






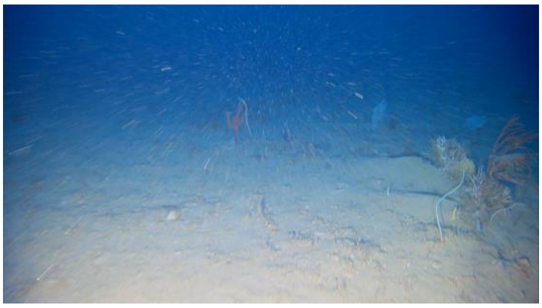
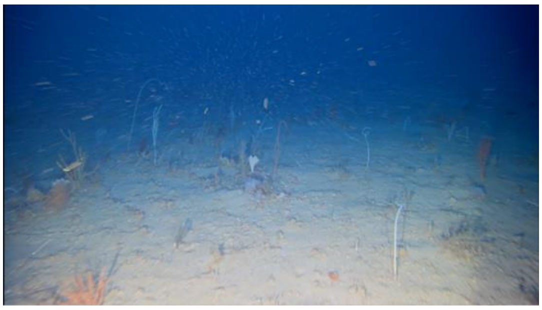


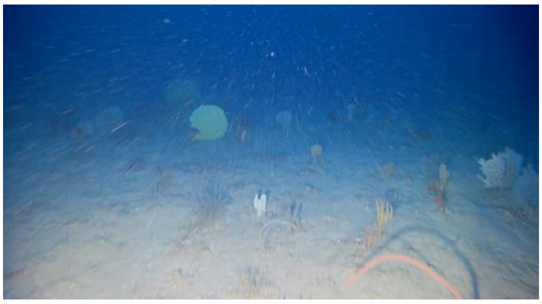
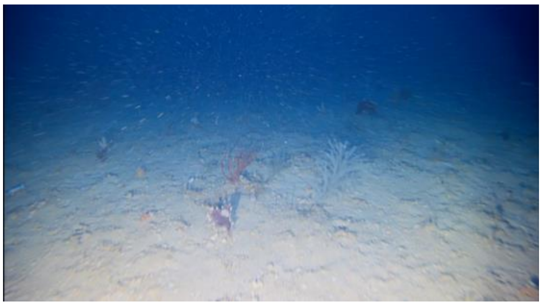




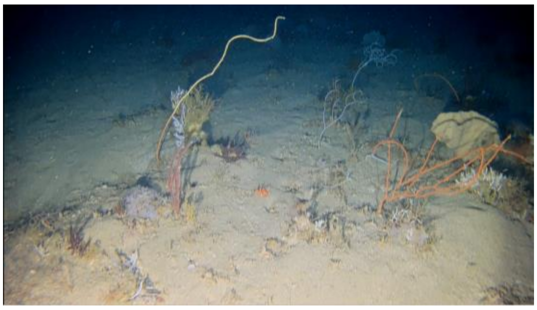






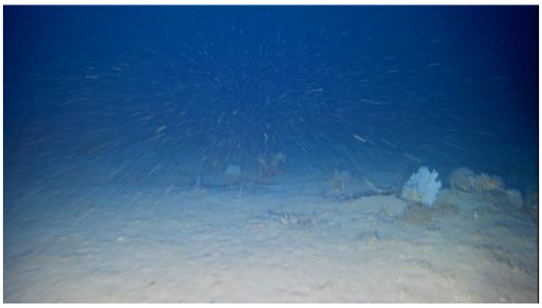


Area 4 – Transect 4b



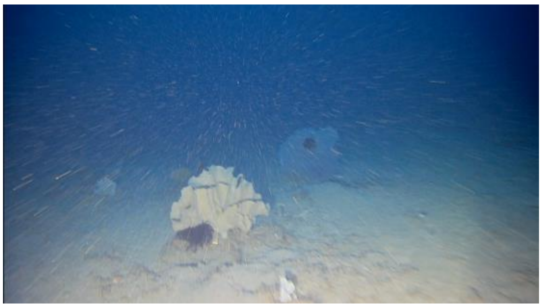


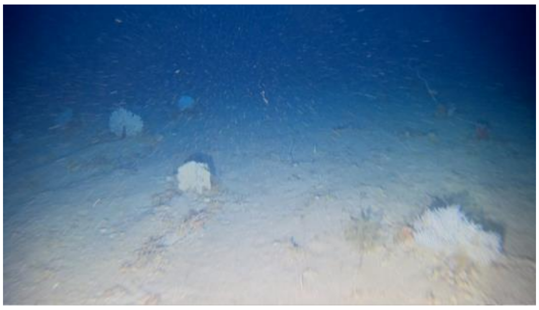








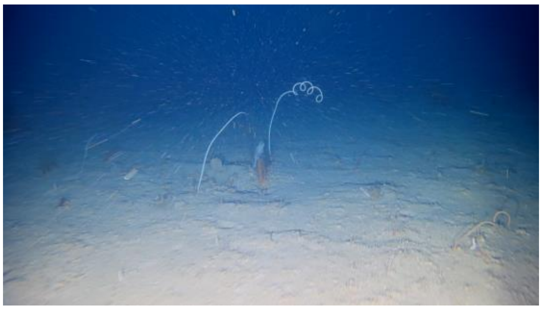


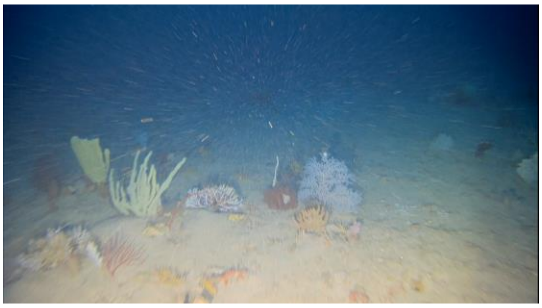






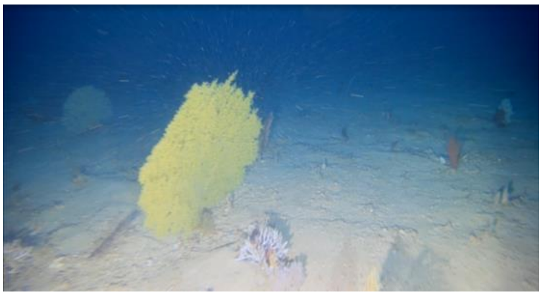


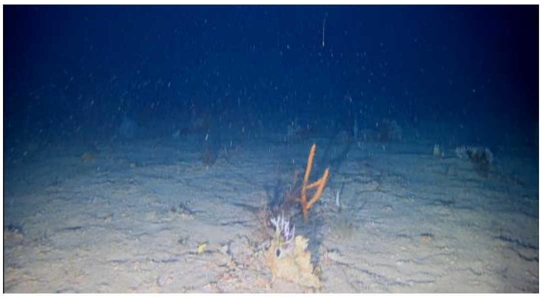



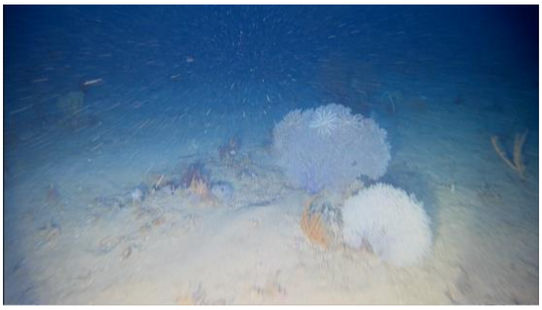


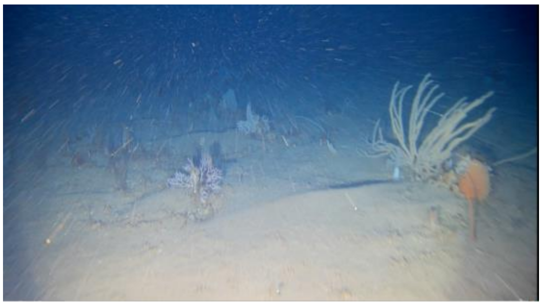




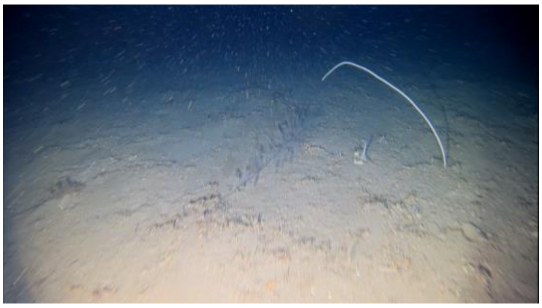





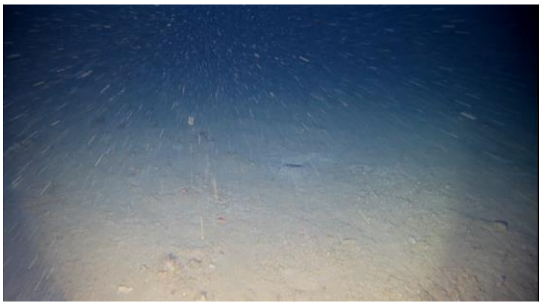


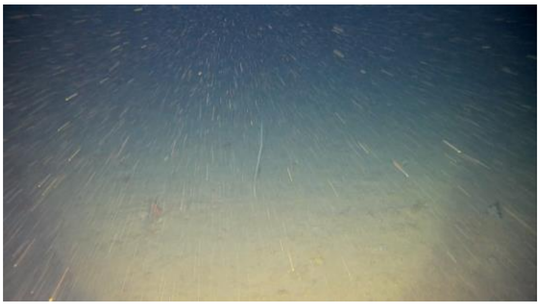


Area 4 – Transect 4c

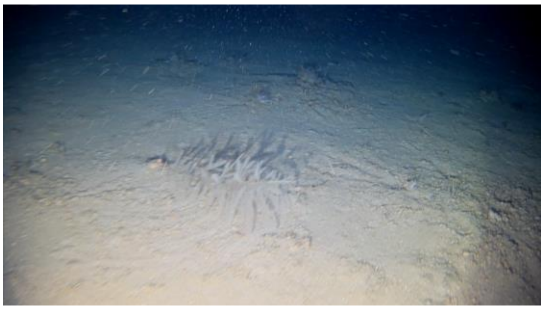
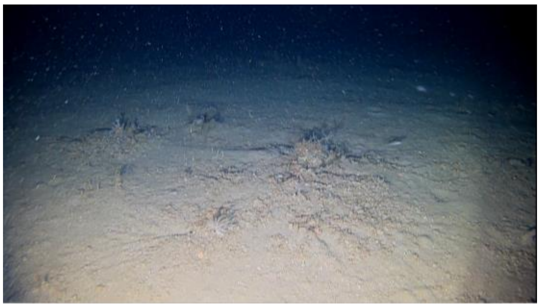


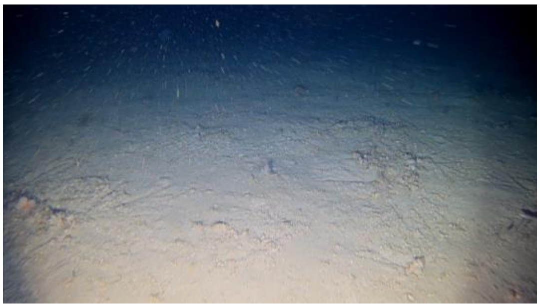
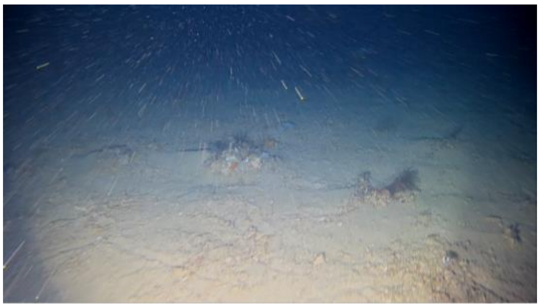


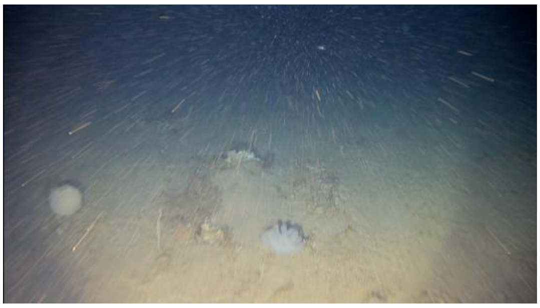







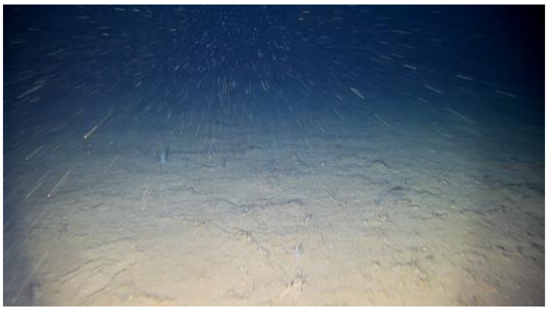




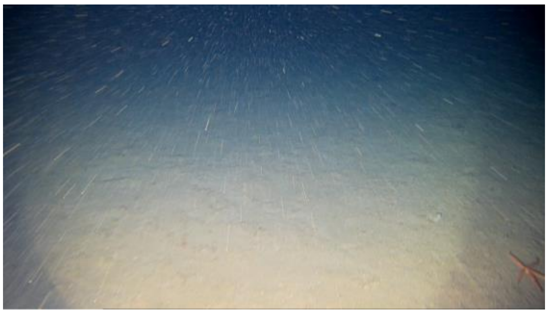
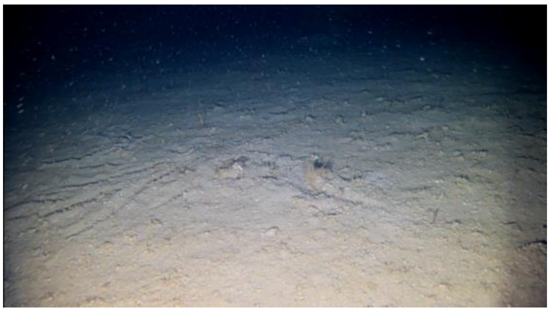




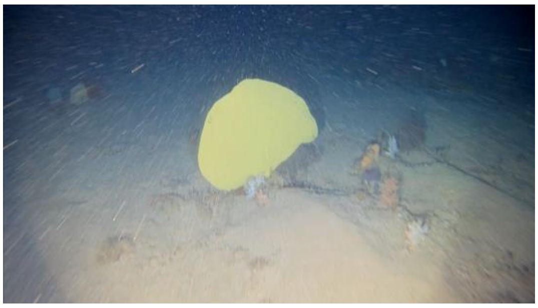


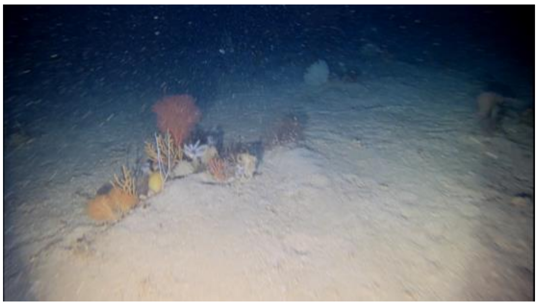





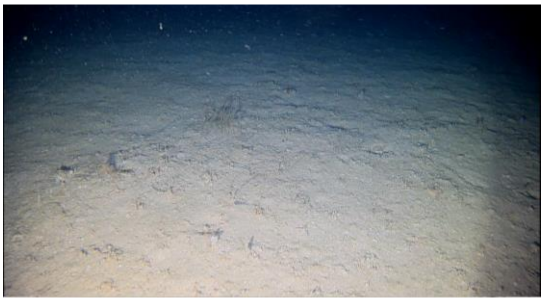
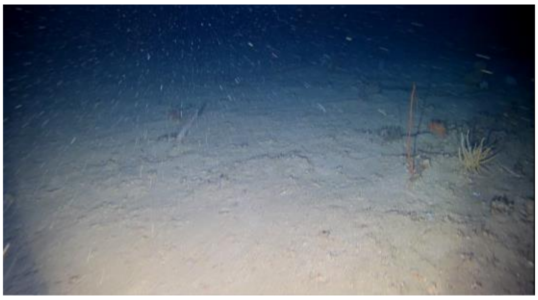






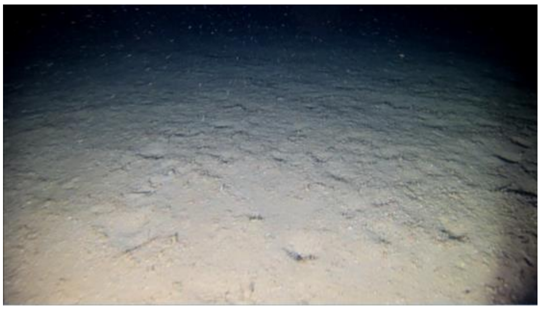
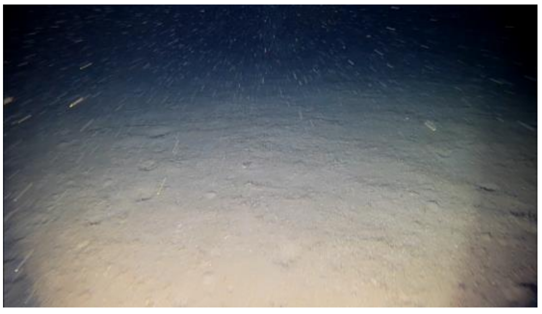


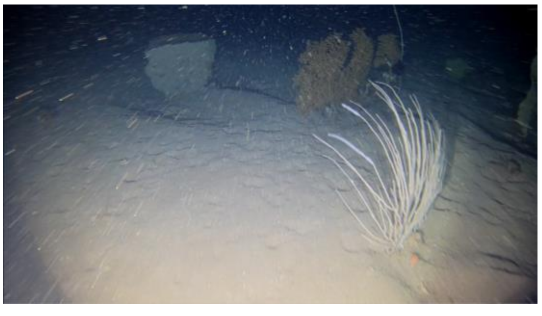
Appendix F: Additional Images Area 5

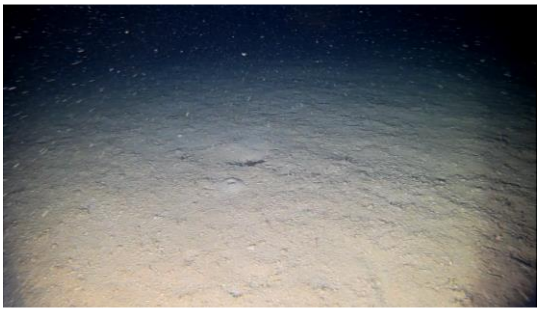
Transect Images – Area 5

Area 5 – Transect 5a



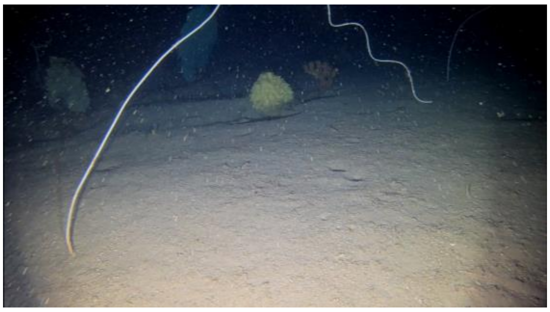


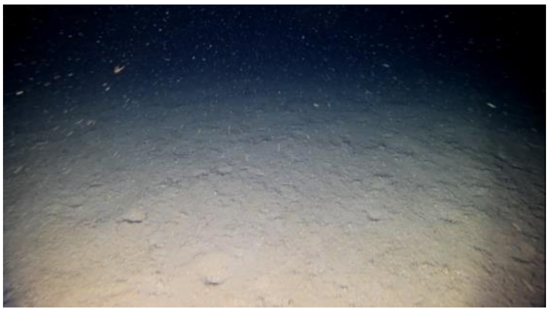



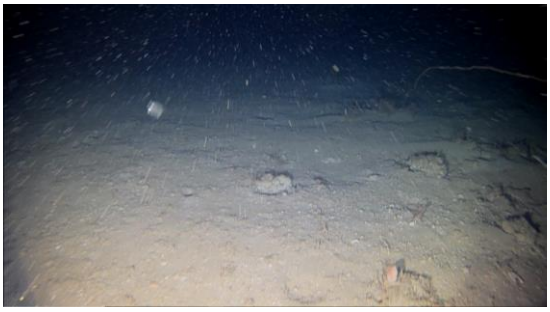
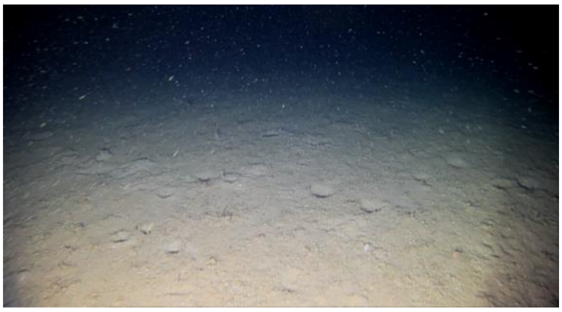
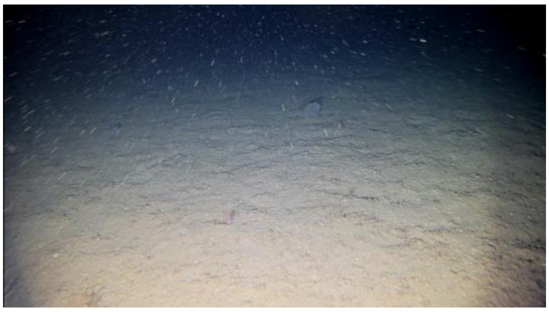


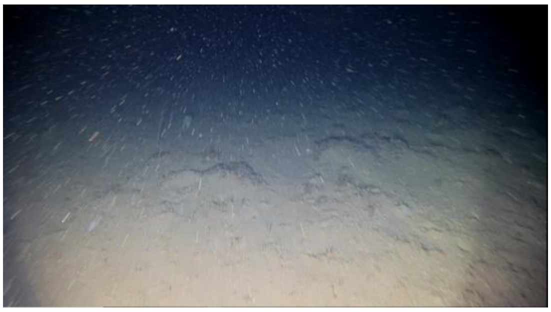
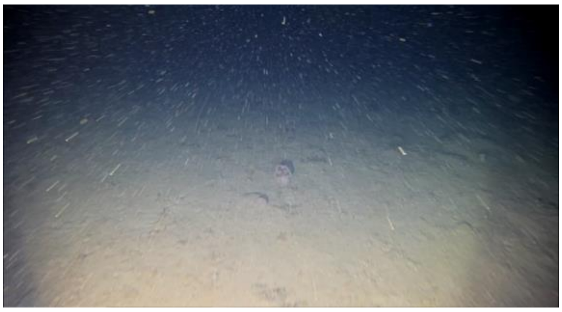
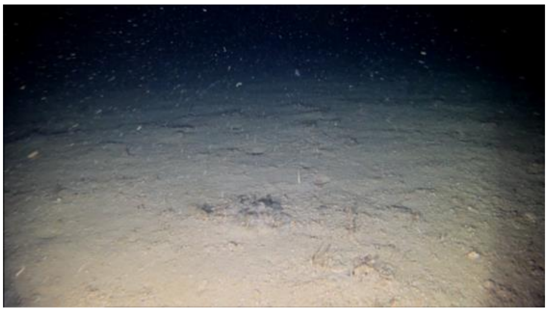
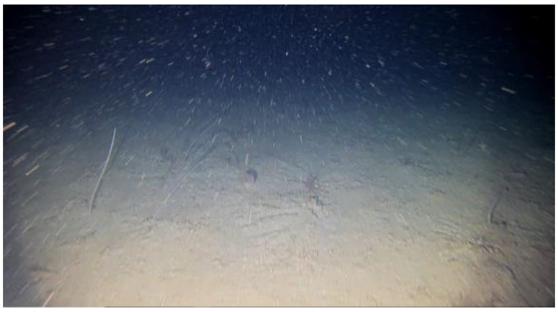


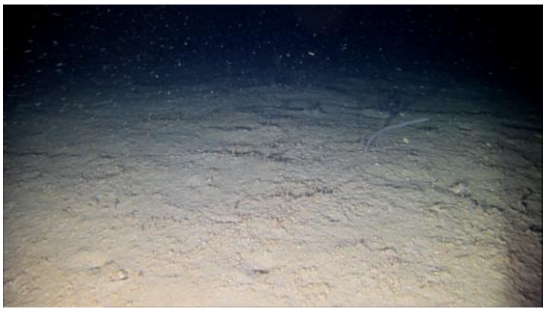


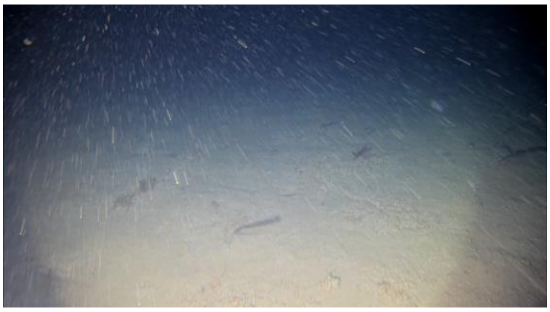






Transect 5a – Sessile Organisms



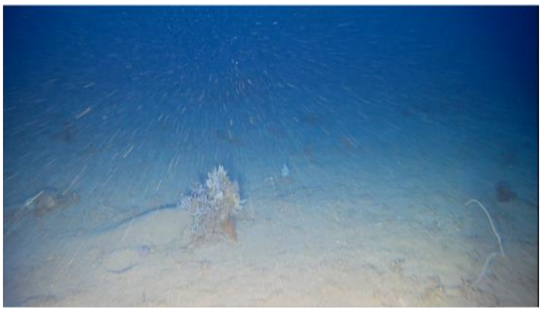



Transect Images – Area 4

Area 4 - Transect 4a

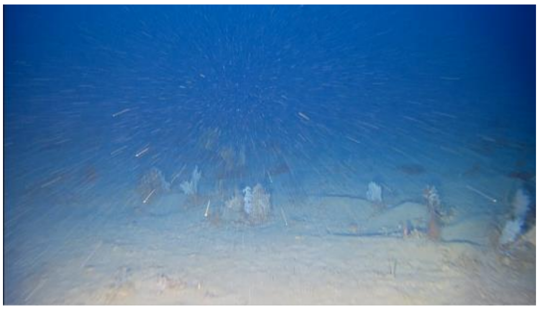


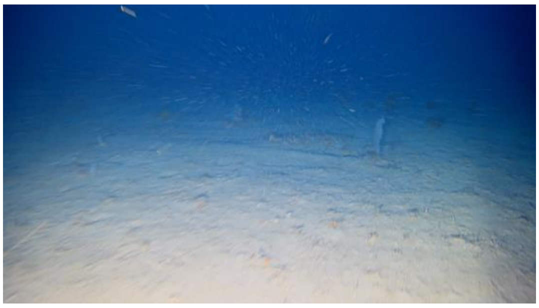
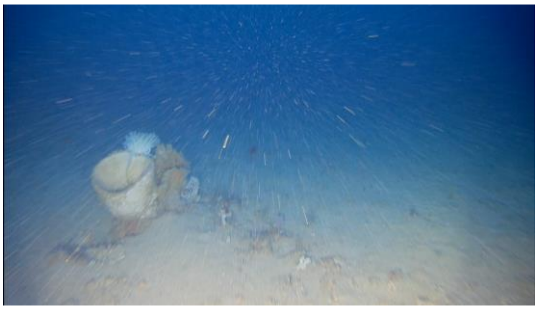


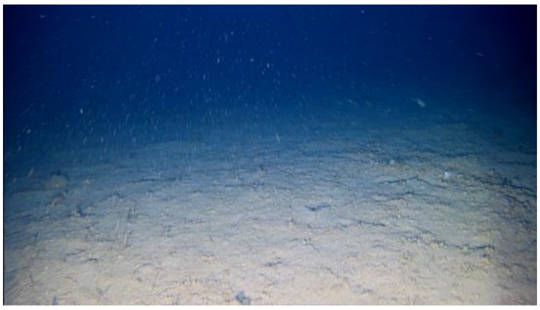
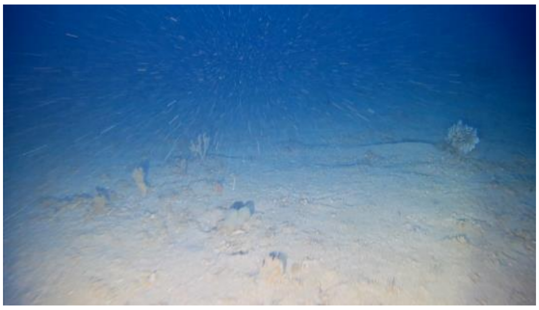



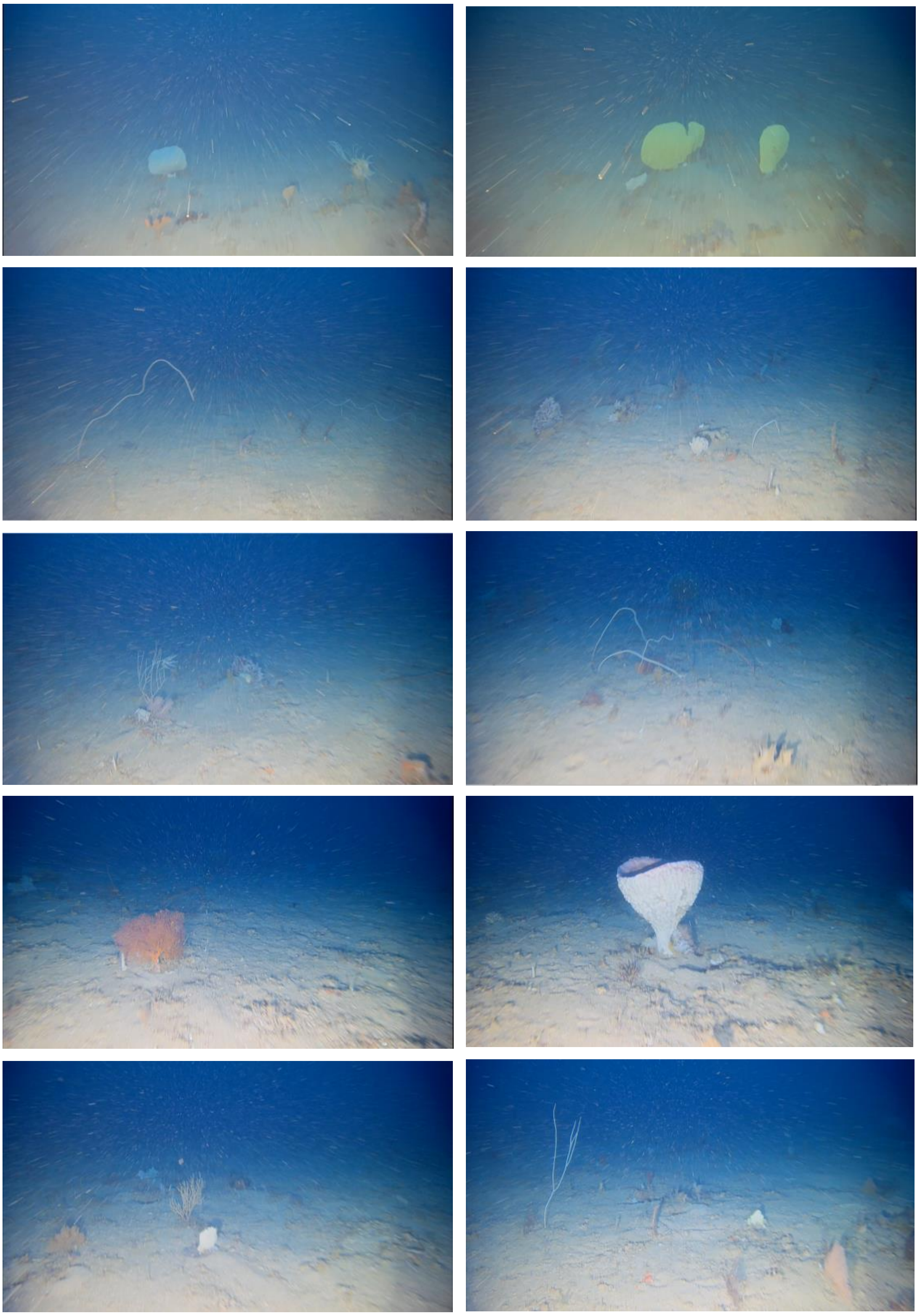


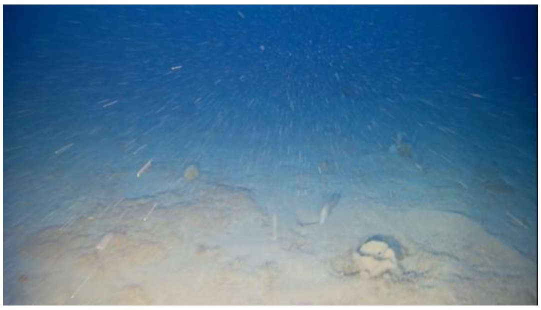




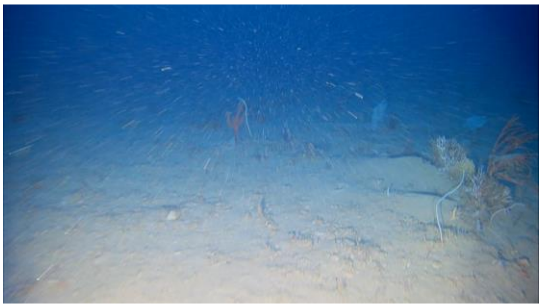
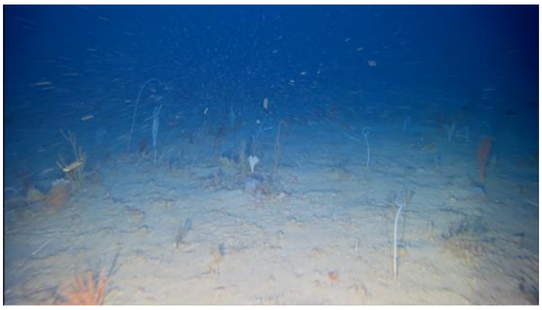



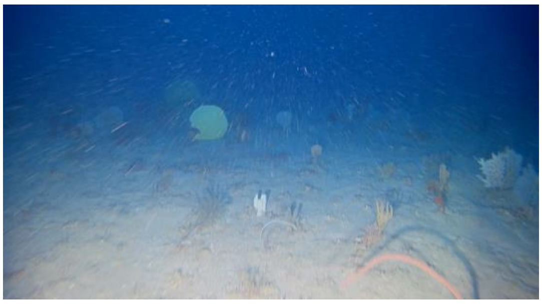
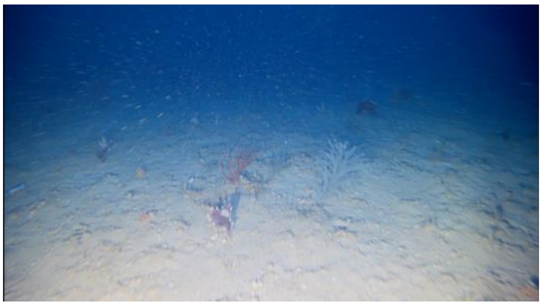




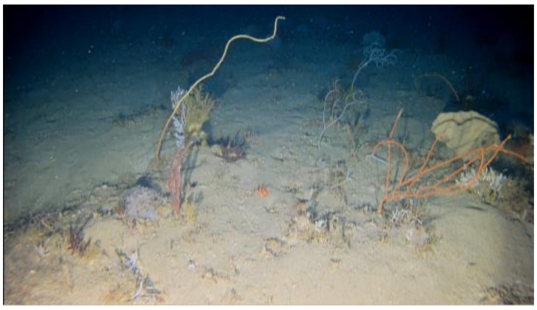






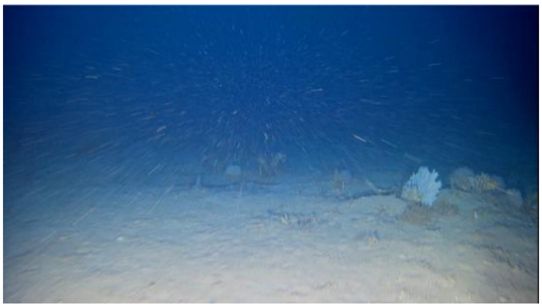


Area 4 – Transect 4b



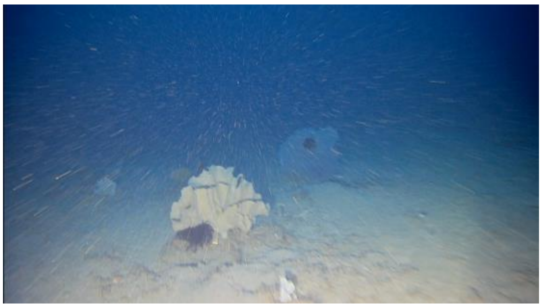


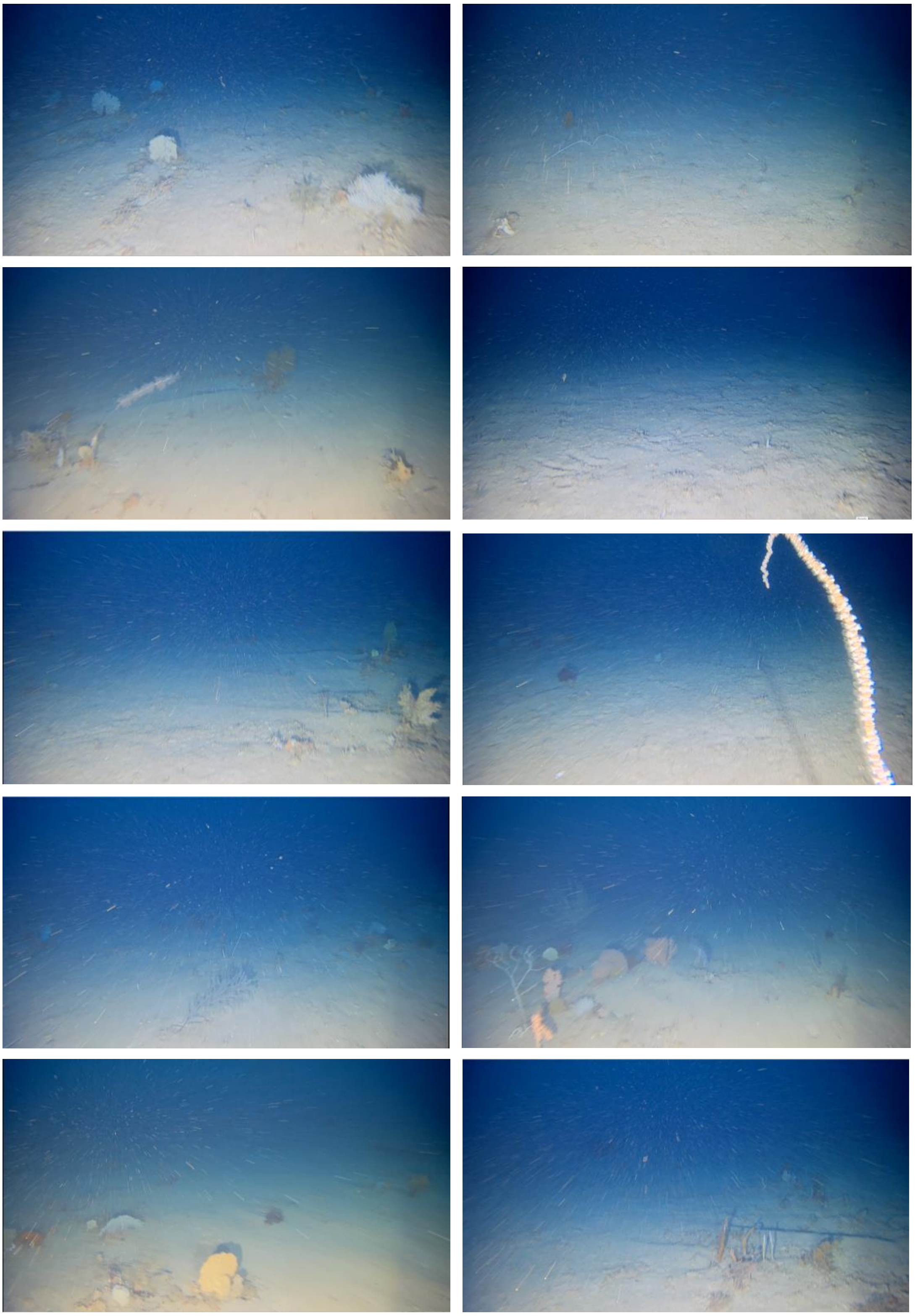


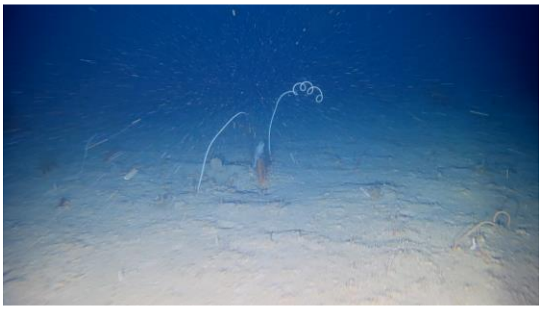


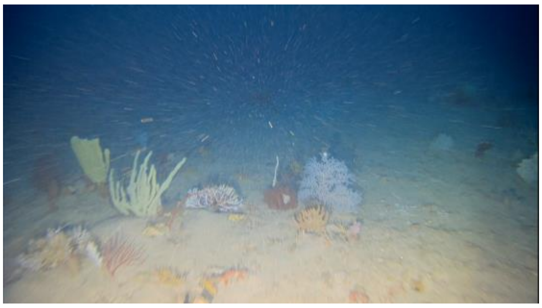








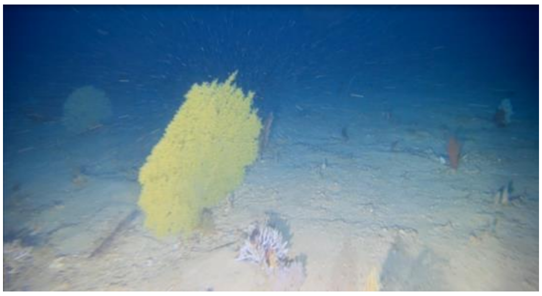
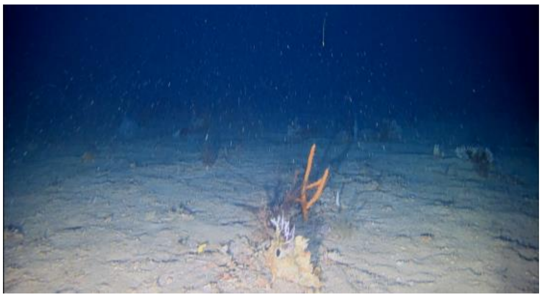
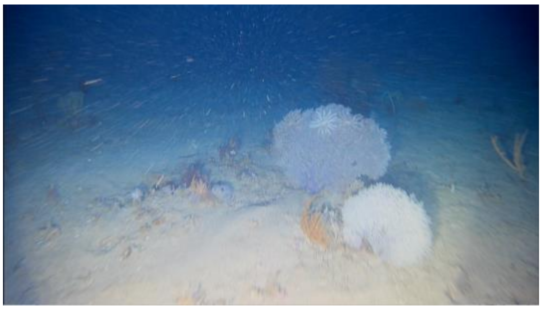


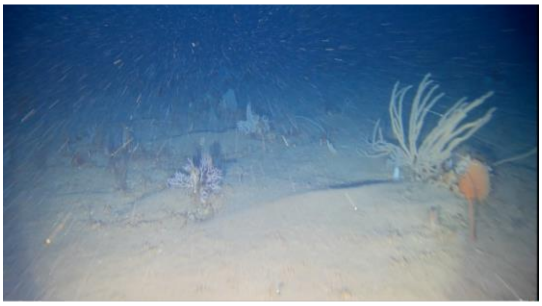




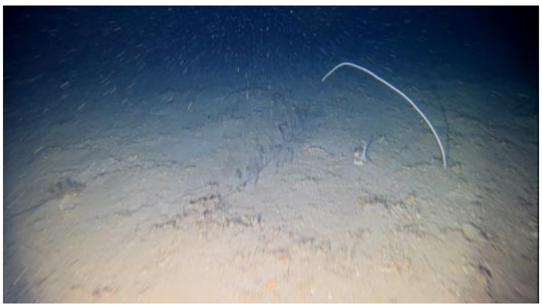




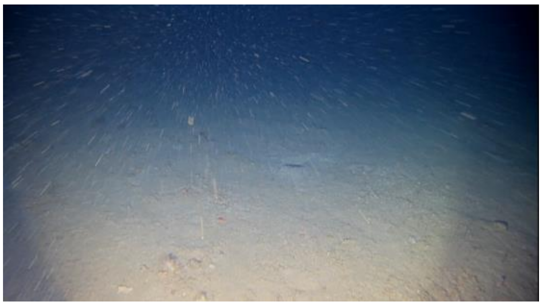


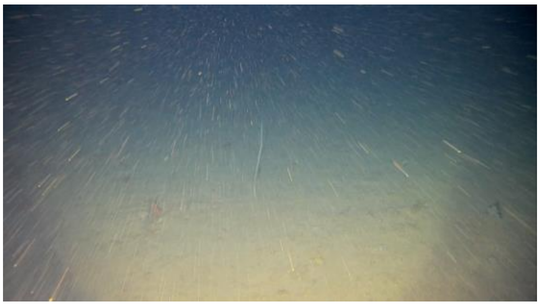

Area 4 – Transect 4c



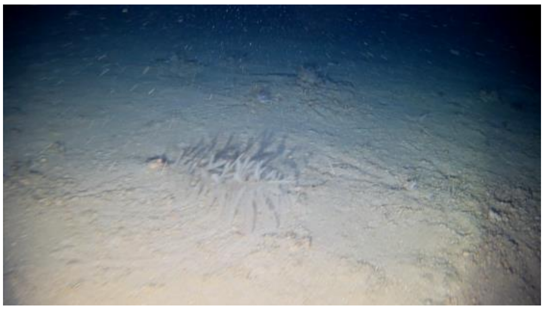
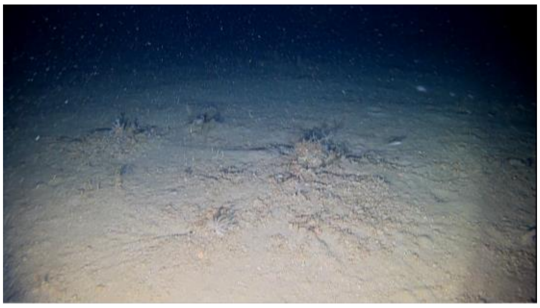


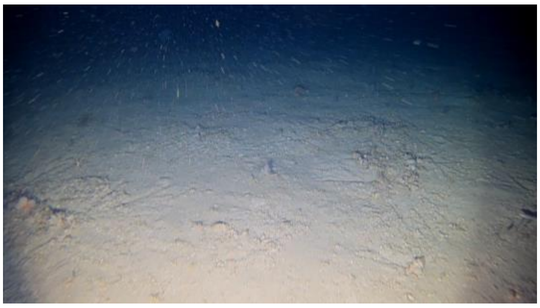
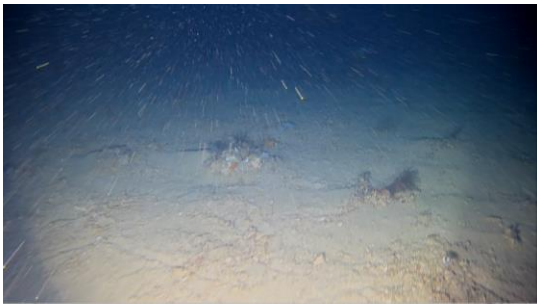


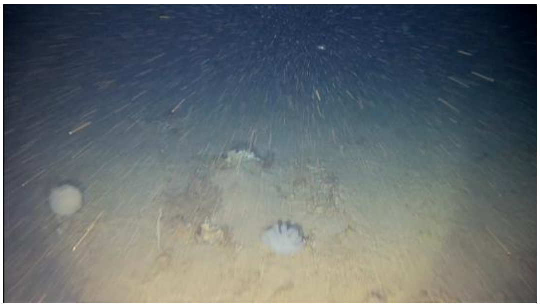






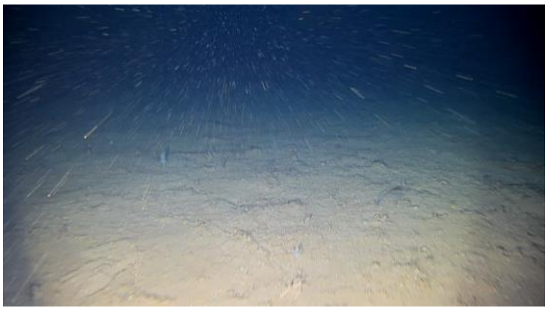




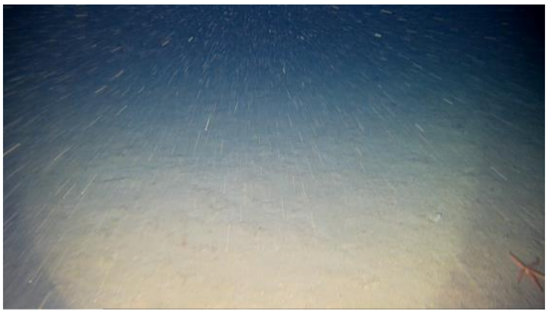
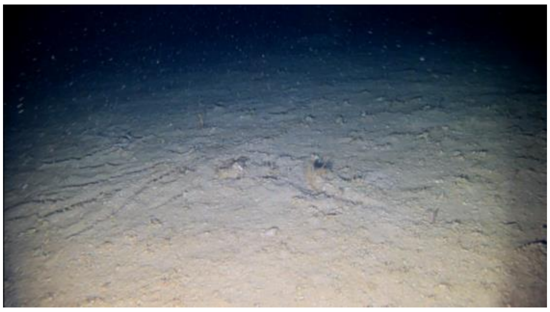




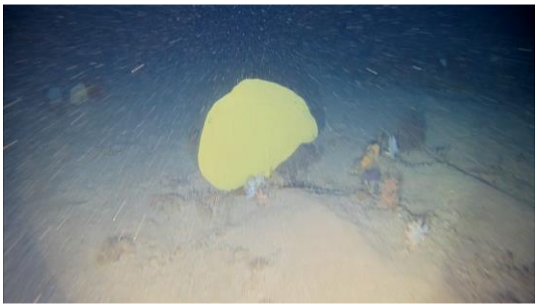


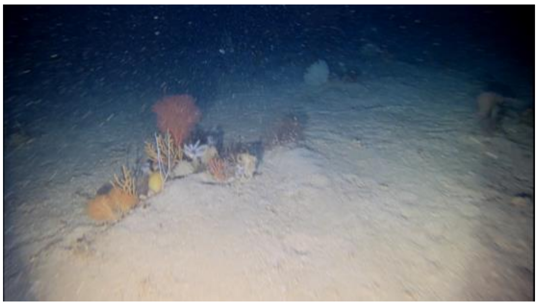





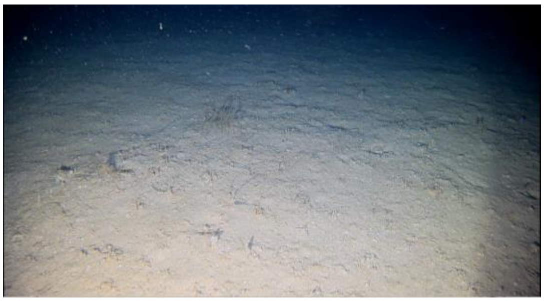
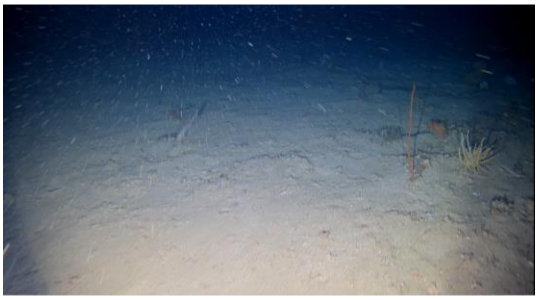








Appendix D

EPBC Act Protected Matters Reports

OFFSHORE PROJECT AREA

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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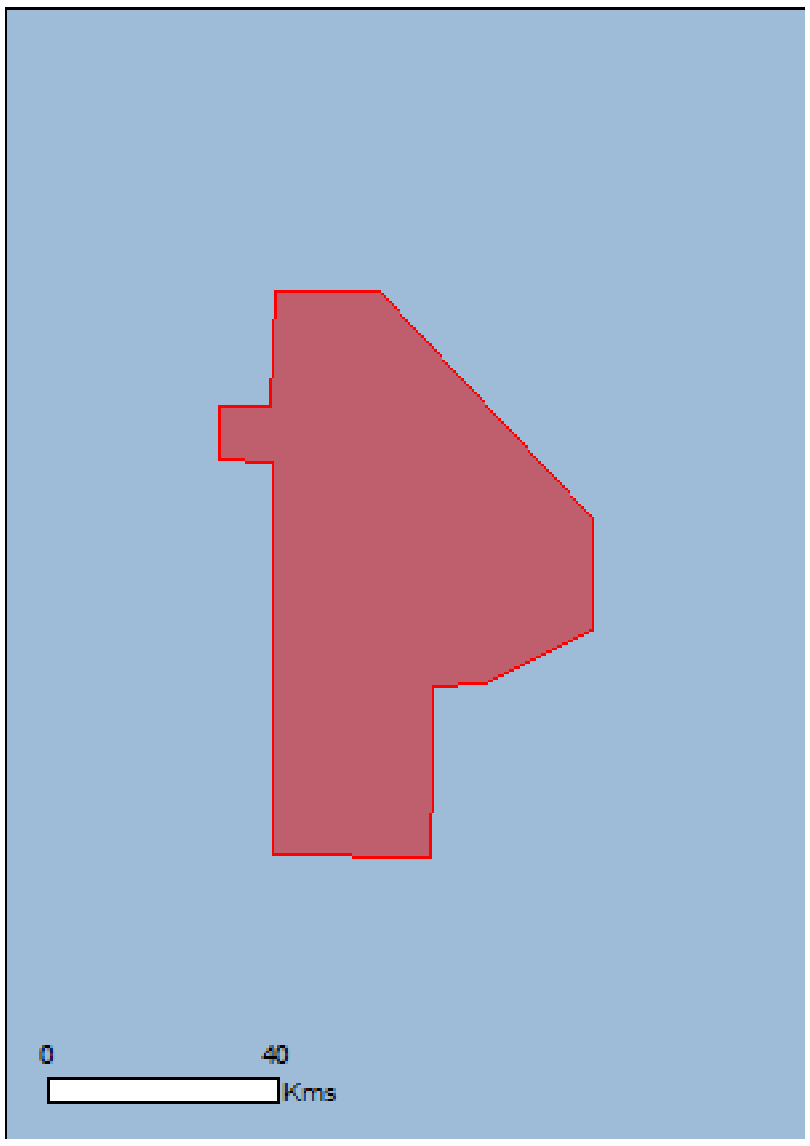

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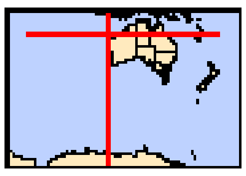

Summary

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:	12
Listed Migratory Species:	24

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:	15
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)	1

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		
Calidris canutus		
Red Knot, Knot [855]	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
Mammals		
Balaenoptera borealis		
Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera musculus		
Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Balaenoptera physalus		
Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Megaptera novaeangliae		
Humpback Whale [38]	Vulnerable	Species or species habitat may occur within area
Reptiles		
Caretta caretta		
Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas		
Green Turtle [1765]	Vulnerable	Species or species habitat likely to occur within area

Name	Status	Type of Presence
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat likely to occur within area
Sharks		
Carcharodon carcharias White Shark, Great White Shark [64470]	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 may occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		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
Migratory Marine Species		
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	Species or species habitat 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	Species or species habitat likely to occur within area
Balaenoptera physalus Fin Whale [37]	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
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area

Name	Threatened	Type of Presence
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely 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
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 may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat likely to 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
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		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 melanotos Pectoral Sandpiper [858]		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 may occur within area
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		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
Reptiles		
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat 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 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
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat 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	Species or species habitat likely to occur within area

Name	Status	Type of Presence
Balaenoptera physalus Fin Whale [37]	Vulnerable	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
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 may 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 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

Name	Status	Type of Presence
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

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
Exmouth Plateau	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

-19.165 113.087,-19.165 113.251,-19.5 113.586,-19.666 113.585,-19.746 113.419,-19.751 113.335,-20.002 113.332,-19.998 113.084,-19.418 113.084,-19.415 113.002,-19.333 113.001,-19.333 113.081,-19.165 113.087

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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TRUNKLINE PROJECT AREA

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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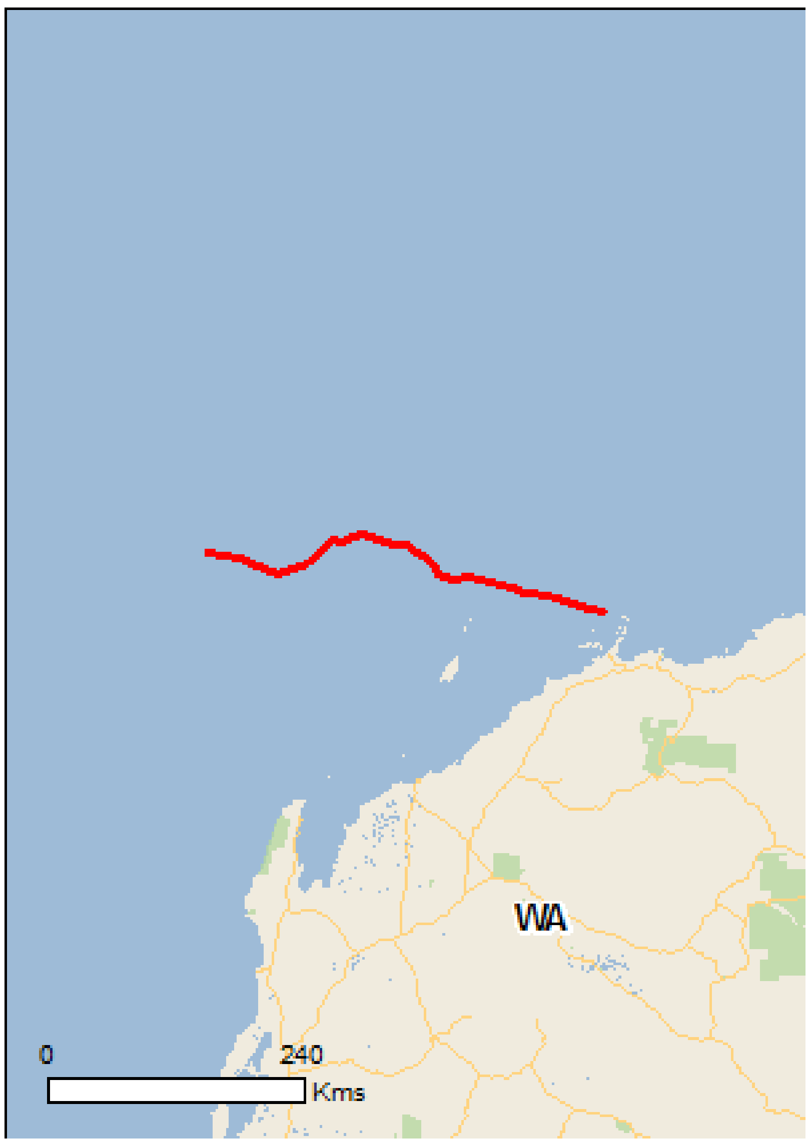

Coordinates
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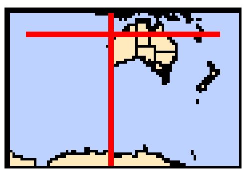

Summary

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:	71
Whales and Other Cetaceans:	28
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:	None
Regional Forest Agreements:	None
Invasive Species:	None
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	3

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		
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
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 may occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Breeding known to occur within area
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	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	Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area

Name	Status	Type of Presence
Reptiles		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Congregation or aggregation known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Congregation or aggregation known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Congregation or aggregation known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation 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	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 may 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 likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area

Name	Threatened	Type of Presence
Sterna dougallii Roseate Tern [817]		Foraging, feeding or related behaviour 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 bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat 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	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	Congregation or aggregation known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Congregation or aggregation known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Dugong dugon Dugong [28]		Species or species habitat known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Congregation or aggregation 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
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

Name	Threatened	Type of Presence
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to 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
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	Foraging, feeding or related behaviour known to occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		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 likely to occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		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
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		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 may 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
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 likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to 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 may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat may occur within area
Sterna dougallii Roseate Tern [817]		Foraging, feeding or related behaviour 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

Name	Threatened	Type of Presence
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 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 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
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
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

Name	Threatened	Type of Presence
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
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 habitat likely to occur

Name	Threatened	Type of Presence
		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	Congregation or aggregation known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Congregation or aggregation known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat 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	Congregation or aggregation 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

Name	Threatened	Type of Presence
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation 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
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat 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	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
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

Name	Status	Type of Presence
		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
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat may 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 likely 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
Montebello	Multiple Use Zone (IUCN VI)

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

Name	Region
Ancient coastline at 125 m depth contour	North-west
Continental Slope Demersal Fish Communities	North-west
Exmouth Plateau	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

-19.867 113.336,-19.911 113.628,-19.937 113.725,-20.021 113.937,-19.936 114.18,-19.755 114.403,-19.777 114.483,-19.704 114.638,-19.797 114.925,-19.789 115.025,-19.862 115.116,-19.895 115.193,-19.936 115.232,-20.038 115.284,-20.06 115.426,-20.052 115.532,-20.139 115.918,-20.172 115.997,-20.171 116.078,-20.21 116.299,-20.294 116.56,-20.318 116.672,-20.351 116.699

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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Australian Government
Department of the Environment and Energy

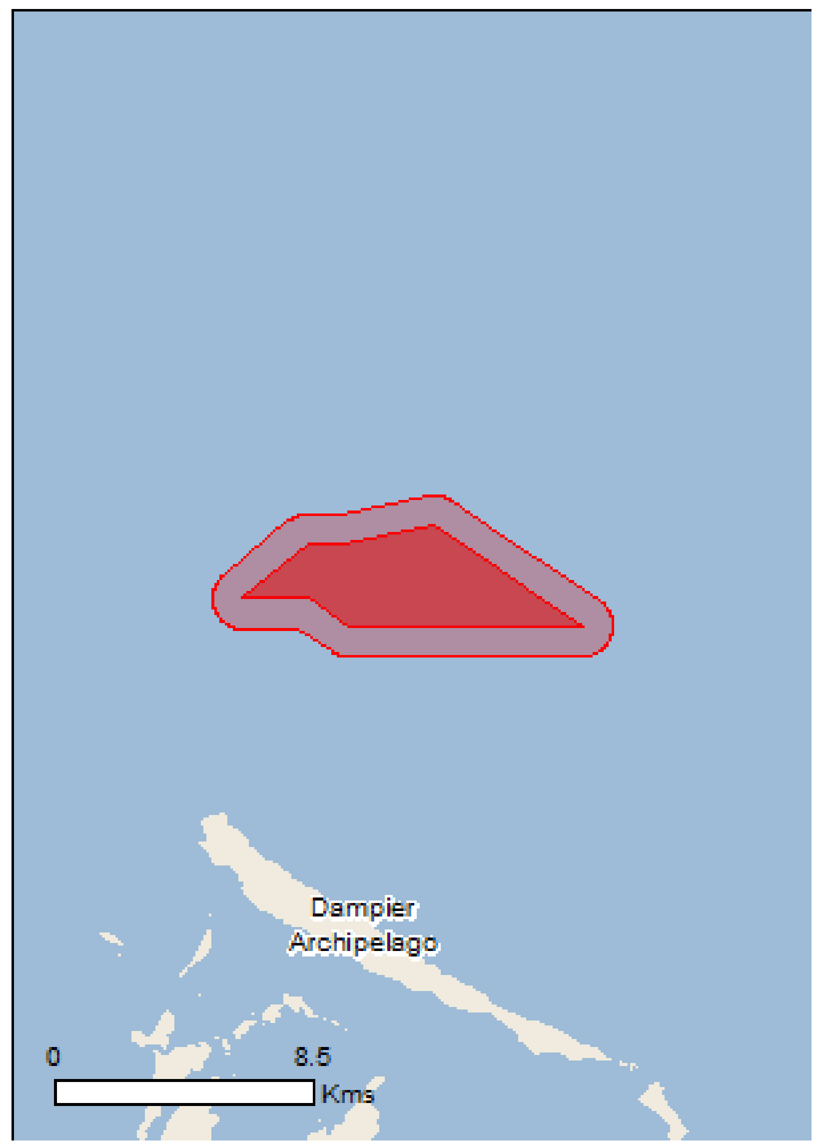
EPBC Act Protected Matters Report

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.

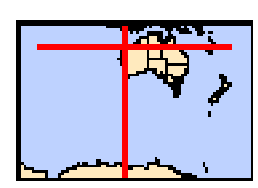
Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 29/01/19 16:47:06



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:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	1
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	18
Listed Migratory Species:	32

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:	67
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:	None
Regional Forest Agreements:	None
Invasive Species:	None
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	None

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		
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
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 may occur within area
Sternula nereis nereis		
Australian Fairy Tern [82950]	Vulnerable	Breeding known to occur within area
Mammals		
Balaenoptera musculus		
Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Megaptera novaeangliae		
Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Reptiles		
Aipysurus apraefrontalis		
Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat may occur within area
Caretta caretta		
Loggerhead Turtle [1763]	Endangered	Species or species

Name	Status	Type of Presence
		habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation 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 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
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
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may 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

Name	Threatened	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
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Dugong dugon Dugong [28]		Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	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	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation 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 may occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area

Migratory Wetlands Species

Name	Threatened	Type of Presence
Actitis hypoleucos Common Sandpiper [59309]		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
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		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 may 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
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 likely to occur within area

Name	Threatened	Type of Presence
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to 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 may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat may occur within area
Sterna dougallii Roseate Tern [817]		Breeding 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

Name	Threatened	Type of Presence
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 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		

Name	Threatened	Type of Presence
Dugong dugon Dugong [28]		Species or species habitat likely 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 may 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	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat 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	Species or species habitat 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

Name	Threatened	Type of Presence
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	Congregation or aggregation 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 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 may 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 likely 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
Dampier	Habitat Protection Zone (IUCN IV)

Extra Information

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

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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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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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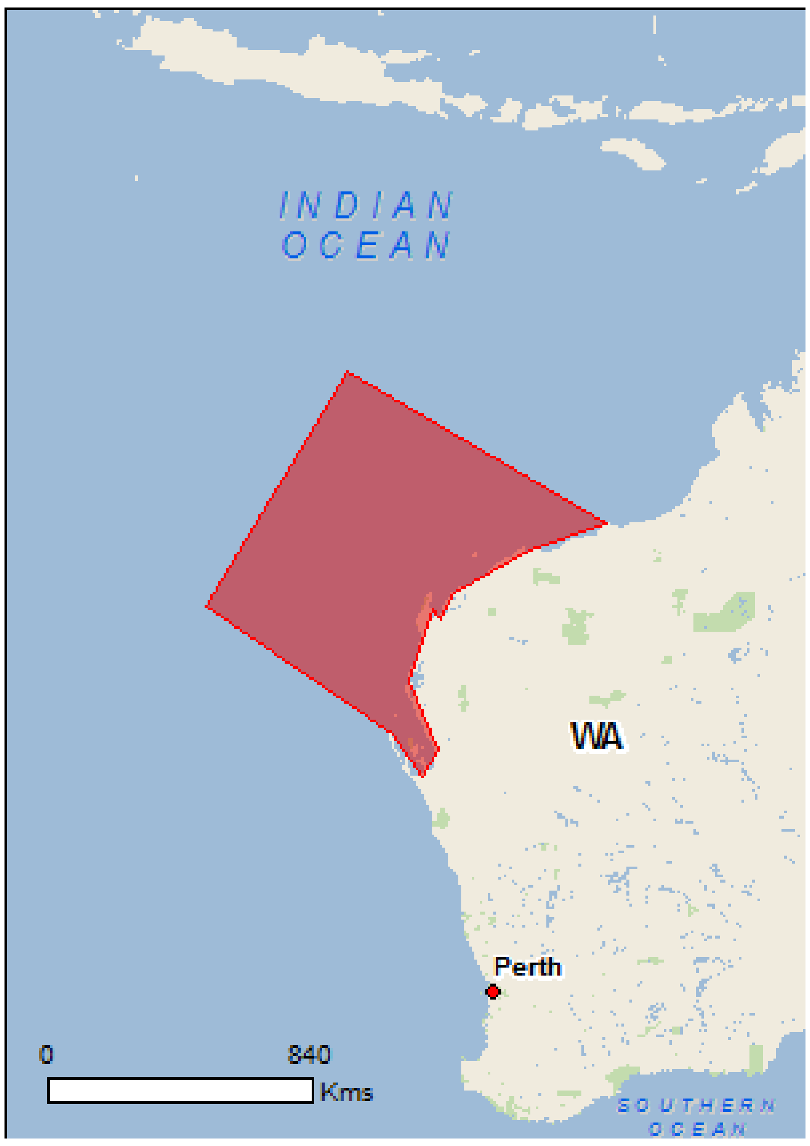

Coordinates
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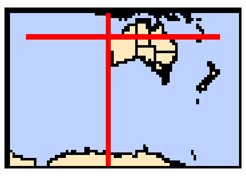

Summary

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:	2
National Heritage Places:	4
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	2
Listed Threatened Ecological Communities:	1
Listed Threatened Species:	73
Listed Migratory Species:	85

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:	10
Commonwealth Heritage Places:	2
Listed Marine Species:	138
Whales and Other Cetaceans:	31
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	11

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	53
Regional Forest Agreements:	None
Invasive Species:	25
Nationally Important Wetlands:	8
Key Ecological Features (Marine)	6

Details

Matters of National Environmental Significance

World Heritage Properties [Resource Information]

Name	State	Status
Shark Bay, Western Australia	WA	Declared property
The Ningaloo Coast	WA	Declared property

National Heritage Properties [Resource Information]

Name	State	Status
Natural		
Shark Bay, Western Australia	WA	Listed place
The Ningaloo Coast	WA	Listed place
Indigenous		
Dampier Archipelago (including Burrup Peninsula)	WA	Listed place
Historic		
Dirk Hartog Landing Site 1616 - Cape Inscription Area	WA	Listed place

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 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
Subtropical and Temperate Coastal Saltmarsh	Vulnerable	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

Name	Status	Type of Presence
Charadrius mongolus		
Lesser Sand Plover, Mongolian Plover [879]	Endangered	Species or species habitat known to occur within area
Diomedea amsterdamensis		
Amsterdam Albatross [64405]	Endangered	Species or species habitat may occur within area
Diomedea exulans		
Wandering Albatross [89223]	Vulnerable	Species or species habitat may occur within area
Leipoa ocellata		
Malleefowl [934]	Vulnerable	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 likely to occur within area
Macronectes giganteus		
Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli		
Northern Giant Petrel [1061]	Vulnerable	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 within area
Malurus leucopterus leucopterus		
White-winged Fairy-wren (Dirk Hartog Island), Dirk Hartog Black-and-White Fairy-wren [26004]	Vulnerable	Species or species habitat likely 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
Pezoporus occidentalis		
Night Parrot [59350]	Endangered	Species or species habitat may occur within area
Pterodroma mollis		
Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour likely to 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
Thalassarche carteri		
Indian Yellow-nosed Albatross [64464]	Vulnerable	Foraging, feeding or related behaviour may occur within area
Thalassarche cauta cauta		
Shy Albatross, Tasmanian Shy Albatross [82345]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta steadi		
White-capped Albatross [82344]	Vulnerable	Foraging, feeding or

Name	Status	Type of Presence
		related behaviour likely to occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	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
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
Bettongia lesueur lesueur Burrowing Bettong (Shark Bay), Boodie [66659]	Vulnerable	Species or species habitat known to occur within area
Bettongia penicillata ogilbyi Woylie [66844]	Endangered	Species or species habitat known to occur within area
Dasyurus geoffroii Chuditch, Western Quoll [330]	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 likely to 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
Lagorchestes hirsutus bernieri Rufous Hare-wallaby (Bernier Island) [66662]	Vulnerable	Species or species habitat known to occur within area
Lagorchestes hirsutus dorreae Rufous Hare-wallaby (Dorre Island) [66663]	Vulnerable	Species or species

Name	Status	Type of Presence
		habitat known to occur within area
Lagostrophus fasciatus fasciatus Banded Hare-wallaby, Merrnine, Marnine, Munning [66664]	Vulnerable	Species or species habitat known to occur within area
Leporillus conditor Wopilkara, Greater Stick-nest Rat [137]	Vulnerable	Translocated population 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 known to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Congregation or aggregation 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
Perameles bougainville bougainville Western Barred Bandicoot (Shark Bay) [66631]	Endangered	Species or species habitat 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 known to occur within area
Other		
Idiosoma nigrum Shield-backed Trapdoor Spider, Black Rugose Trapdoor Spider [66798]	Vulnerable	Species or species habitat likely to occur within area
Kumonga exleyi Cape Range Remipede [86875]	Vulnerable	Species or species habitat known to occur within area
Plants		
Caladenia hoffmanii Hoffman's Spider-orchid [56719]	Endangered	Species or species habitat may occur within area
Eucalyptus beardiana Beard's Mallee [18933]	Vulnerable	Species or species habitat likely to occur within area
Reptiles		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aprasia rostrata rostrata Monte Bello Worm-lizard, Hermite Island Worm-lizard [64481]	Vulnerable	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Breeding known to occur within area

Name	Status	Type of Presence
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 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	Foraging, feeding or related behaviour known to occur within area
Egernia stokesii badia		
Western Spiny-tailed Skink, Baudin Island Spiny-tailed Skink [64483]	Endangered	Species or species habitat known to occur within area
Eretmochelys imbricata		
Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Lerista nevinae		
Nevin's Slider [85296]	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 known to 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 likely 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]		Species or species habitat likely to occur within area
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat likely to occur within area

Name	Threatened	Type of Presence
Ardenna carneipes		
Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		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
Diomedea amsterdamensis		
Amsterdam Albatross [64405]	Endangered	Species or species habitat may occur within area
Diomedea exulans		
Wandering Albatross [89223]	Vulnerable	Species or species habitat may occur within area
Fregata ariel		
Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor		
Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may 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
Macronectes halli		
Northern Giant Petrel [1061]	Vulnerable	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 known to occur within area
Sula leucogaster		
Brown Booby [1022]		Breeding known to occur within area
Thalassarche carteri		
Indian Yellow-nosed Albatross [64464]	Vulnerable	Foraging, feeding or related behaviour may occur within area
Thalassarche cauta		
Tasmanian Shy Albatross [89224]	Vulnerable*	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
Thalassarche melanophris		
Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi		
White-capped Albatross [64462]	Vulnerable*	Foraging, feeding or related behaviour likely 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

Name	Threatened	Type of Presence
		habitat likely to 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
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 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
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
Lamna nasus Porbeagle, Mackerel Shark [83288]		Species or species habitat may 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 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

Name	Threatened	Type of Presence
Physeter macrocephalus Sperm Whale [59]		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 likely 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]		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		
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		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 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]		Species or species habitat 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

Name	Threatened	Type of Presence
Calidris ruficollis Red-necked Stint [860]		Roosting 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	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	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
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]		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]		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 likely to occur within area
Numenius phaeopus Whimbrel [849]		Roosting 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]		Roosting known to occur within area
Thalasseus bergii Crested Tern [83000]		Breeding known to occur within area
Tringa brevipes Grey-tailed Tattler [851]		Roosting known to occur within area

Name	Threatened	Type of Presence
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]		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]		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 - CARNARVON TRAINING DEPOT
Defence - EXMOUTH ADMIN & HF TRANSMITTING
Defence - EXMOUTH NAVAL HF RECEIVING STATION (H/F Receiving Station, Learmonth, WA)
Defence - EXMOUTH VLF TRANSMITTER STATION
Defence - LEARMONTH - AIR WEAPONS RANGE
Defence - LEARMONTH - RAAF BASE
Defence - LEARMONTH RADAR SITE - TWIN TANKS EXMOUTH
Defence - LEARMONTH RADAR SITE - VLAMING HEAD EXMOUTH
Defence - LEARMONTH TRANSMITTING STATION

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Natural		
Learmonth Air Weapons Range Facility	WA	Listed place
Ningaloo Marine Area - Commonwealth Waters	WA	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
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]		Breeding known to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat 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 subminuta Long-toed Stint [861]		Species or species habitat 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 likely to occur within area
Catharacta skua Great Skua [59472]		Species or species habitat may 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	Species or species habitat known to occur within area
Charadrius ruficapillus Red-capped Plover [881]		Roosting 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 known to occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered	Species or species habitat may occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Species or species habitat may occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
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]		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]		Roosting known to occur within area
Himantopus himantopus Pied Stilt, Black-winged Stilt [870]		Roosting known to 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
Larus pacificus Pacific Gull [811]		Breeding 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]		Roosting known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	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 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 likely to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area

Name	Threatened	Type of Presence
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may 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]		Roosting known to occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [1043]		Species or species habitat likely to occur within area
Puffinus pacificus Wedge-tailed Shearwater [1027]		Breeding 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 may 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
Stiltia isabella Australian Pratincole [818]		Species or species habitat known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Foraging, feeding or related behaviour may occur within area
Thalassarche cauta Tasmanian Shy Albatross [89224]	Vulnerable*	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

Name	Threatened	Type of Presence
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable*	Foraging, feeding or related behaviour likely to occur within area
Thinornis rubricollis Hooded Plover [59510]		Species or species habitat 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]		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]		Roosting known 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 galei Gale's Pipefish [66191]		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 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 dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish,		Species or species

Name	Threatened	Type of Presence
Pacific Blue-stripe Pipefish [66211]		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
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
Lissocampus fatiloquus Prophet's Pipefish [66250]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Nannocampus subosseus Bonyhead Pipefish, Bony-headed Pipefish [66264]		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
Stigmatopora argus Spotted Pipefish, Gulf Pipefish, Peacock Pipefish [66276]		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
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
Aipysurus pooleorum Shark Bay Seasnake [66061]		Species or species habitat may occur within area
Aipysurus tenuis Brown-lined Seasnake [1121]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		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
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
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

Name	Status	Type of Presence
		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
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
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	Congregation or aggregation 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
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

Name	Status	Type of Presence
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]		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
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
Carnarvon Canyon	Habitat Protection Zone (IUCN IV)
Dampier	Habitat Protection Zone (IUCN IV)
Dampier	Multiple Use Zone (IUCN VI)
Dampier	National Park Zone (IUCN II)
Gascoyne	Habitat Protection Zone (IUCN IV)
Gascoyne	Multiple Use Zone (IUCN VI)
Gascoyne	National Park Zone (IUCN II)
Montebello	Multiple Use Zone (IUCN VI)
Ningaloo	National Park Zone (IUCN II)
Ningaloo	Recreational Use Zone (IUCN IV)
Shark Bay	Multiple Use Zone (IUCN VI)

Extra Information

State and Territory Reserves [Resource Information]

Name	State
Airlie Island	WA
Barrow Island	WA
Bernier And Dorre Islands	WA
Bessieres Island	WA
Boodie, Double Middle Islands	WA
Bundegi Coastal Park	WA
Burnside And Simpson Island	WA

Name	State
Cape Range	WA
Chinamans Pool	WA
Dirk Hartog Island	WA
Faure Island	WA
Francois Peron	WA
Freycinet, Double Islands etc	WA
Giralia	WA
Gnandaroo Island	WA
Jurabi Coastal Park	WA
Koks Island	WA
Little Rocky Island	WA
Locker Island	WA
Lowendal Islands	WA
Monkey Mia Reserve	WA
Montebello Islands	WA
Muiron Islands	WA
Murujuga	WA
Nanga Station	WA
North Sandy Island	WA
North Turtle Island	WA
One Tree Point	WA
Rocky Island	WA
Round Island	WA
Serrurier Island	WA
Shell Beach	WA
Tent Island	WA
Unnamed WA36907	WA
Unnamed WA36909	WA
Unnamed WA36910	WA
Unnamed WA36913	WA
Unnamed WA36915	WA
Unnamed WA37338	WA
Unnamed WA37383	WA
Unnamed WA37500	WA
Unnamed WA40322	WA
Unnamed WA40828	WA
Unnamed WA40877	WA
Unnamed WA41080	WA
Unnamed WA44665	WA
Unnamed WA44667	WA
Unnamed WA44688	WA
Unnamed WA49144	WA
Victor Island	WA
Weld Island	WA
Y Island	WA
Yaringga	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

Name	Status	Type of Presence
		within area
Streptopelia senegalensis Laughing Turtle-dove, Laughing Dove [781]		Species or species habitat likely to occur within area
Mammals		
Camelus dromedarius Dromedary, Camel [7]		Species or species habitat likely to occur within area
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
Sus scrofa Pig [6]		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
Cylindropuntia spp. Prickly Pears [85131]		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
Lycium ferocissimum African Boxthorn, Boxthorn [19235]		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,		Species or species

Name	Status	Type of Presence
Horse Bean [12301]		habitat likely to occur within area
Prosopis spp.		
Mesquite, Algaroba [68407]		Species or species habitat likely to occur within area
Tamarix aphylla		
Athel Pine, Athel Tree, Tamarisk, Athel Tamarisk, Athel Tamarix, Desert Tamarisk, Flowering Cypress, Salt Cedar [16018]		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 likely to occur within area

Nationally Important Wetlands [Resource Information]

Name	State
Bundera Sinkhole	WA
Cape Range Subterranean Waterways	WA
Exmouth Gulf East	WA
Hamelin Pool	WA
Lake MacLeod	WA
Learmonth Air Weapons Range - Saline Coastal Flats	WA
McNeill Claypan System	WA
Shark Bay East	WA

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
Canyons linking the Cuvier Abyssal Plain and the	North-west
Commonwealth waters adjacent to Ningaloo Reef	North-west
Continental Slope Demersal Fish Communities	North-west
Exmouth Plateau	North-west
Glomar Shoals	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

-19.9557 119.0944,-15.8051 111.6964,-22.1384 107.6624,-25.4807 112.9971,-26.602 113.829,-25.914 114.282,-24.149 113.431,-22.222 114.137,-22.511 114.354,-21.801 114.744,-20.678 116.916,-19.9557 119.0944

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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Appendix E

Scarborough Gas Development Underwater Noise Modelling Study

MARSHALL DAY
Acoustics

SCARBOROUGH GAS US4A/B DEVELOPMENT

UNDERWATER NOISE MODELLING STUDY

Rp 001 20181331 | 15 February 2019

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Project:	**SCARBOROUGH GAS US4A/B DEVELOPMENT**
Prepared for:	**Advisian** **Level 4/600 Murray St** **West Perth WA 6005**
Attention:	**Paul Nichols**
Report No.:	**Rp 001 20181331**

Document Control

Status:	Rev:	Comments	Date:	Author:	Reviewer:
Final	-	For OPP issue	15/02/2019	B Wilson	A Stoker

MARSHALL DAY Acoustics

TABLE OF CONTENTS

1.0 INTRODUCTION

Advisian has engaged Marshall Day Acoustics (MDA) to carry out modelling of underwater acoustic emissions from selected activities associated with the proposed Scarborough gas field development (the Scarborough project), located in Western Australia's North West Shelf region. The Scarborough project is being developed by Woodside Energy Ltd.

Three key noise generating activities associated with the Scarborough project have been identified by Advisian for detailed modelling as follows:

1. Floating Production Unit (FPU) installation and operation
2. Vessel operations associated with pipelaying
3. Pile driving required for the trunkline connection near the Pluto LNG facility in Dampier.

This report has been prepared to inform an assessment of potential impacts from development activities in Commonwealth waters, to be included in an Offshore Project Proposal (OPP) for submission to the Australian National Offshore Petroleum Safety and Environmental Management Authority NOPSEMA. Since the activities in item 3 in the list above take place in State water, only items 1 and 2 have been considered in this report.

This report outlines details of the noise model inputs, the noise propagation prediction methodology, and a summary of the noise predication results, presented in metrics that are relevant to the various marine fauna species of interest. The predicted underwater noise levels are compared to criteria from widely used scientific studies and international guidelines, as nominated by the project ecologist, to assist with the evaluation of noise impacts.

A glossary of acoustic terms and symbols used herein is provided in Appendix A.

2.0 PROJECT DESCRIPTION

The Scarborough gas field is located within the offshore area designated as Permit Area WA-1-R by the National Offshore Petroleum Titles Administrator. The area is located approximately 380 km WNW of the Burrup Peninsula in the North West of Australia where water depths range between 900m and 1000m.

We understand that the Scarborough project proposes drilling of up to 22 subsea gas wells. It is proposed that wells will be tied back to a Floating Production Unit (FPU), with processing facilities on the FPU enabling transport of the gas through a 420-kilometre-long trunkline to the Woodside operated Pluto LNG Facility. The trunkline and associated installation works will occur in both State and Commonwealth waters.

2.1 Noise generating activities

A preliminary impact assessment has been carried out by Advisian (document reference US4A/B Noise Modelling Study Scope of work) which has identified activities associated with the proposed Scarborough project that generate noise emissions. Of these, three key noise generating activities in Commonwealth waters have been identified by Advisian for detailed modelling to assess the risk of noise impacts. These impacts include:

- Change in ambient noise;
- Disturbance to fauna behaviour;
- Injury/mortality to fauna; and
- Changes to the functions, interests or activities of other users.

A description of the three activities is presented in Table 1. Each activity has been assigned a scenario reference which will be used throughout this report.

Table 1: Activities requiring noise modelling

Scenario reference	Activity	Description of noise/sources
1a.	FPU installation	Impact piling associated with the FPU installation. Involves installation of 20 x 5 m diameter steel anchor piles. Piles located in approximately 950 m deep water at the FPU site.
1b.	FPU operation	Topside equipment noise associated with hydrocarbon processing and transportation to a shore-based refinery situation on the FPU Noise from the operation of dynamic positioning (DP) support vessel
2.	Pipelay vessel operations	Pipelay vessel with support vessels will operate in Commonwealth and State waters. Sources comprise: - Noise from the operation of dynamic positioning (DP) pipelay vessel - Noise from the operation of dynamic positioning (DP) support vessel For modelling purposes, the support vessel used for scenarios 1b and 2 is the same.

2.2 Project area

Each of the three activities will take place at separate locations as indicated in Figure 1 - Figure 2 below. The maps show the modelling calculation areas for each scenario as well as marine parks and relevant biologically important areas (BIAs) that partially overlap with the modelling areas. For some scenarios, BIAs fully overlap the modelled area and this is not easily shown using the maps in Figure 1 - Figure 2. For reference, the BIAs that either partially or fully overlap the modelled areas are listed in Appendix B. Map coordinate details of the source locations are provided in the relevant sections below.

Figure 1: Project area – Scenario 1a (FPU piling) and Scenario 1b (FPU operations)

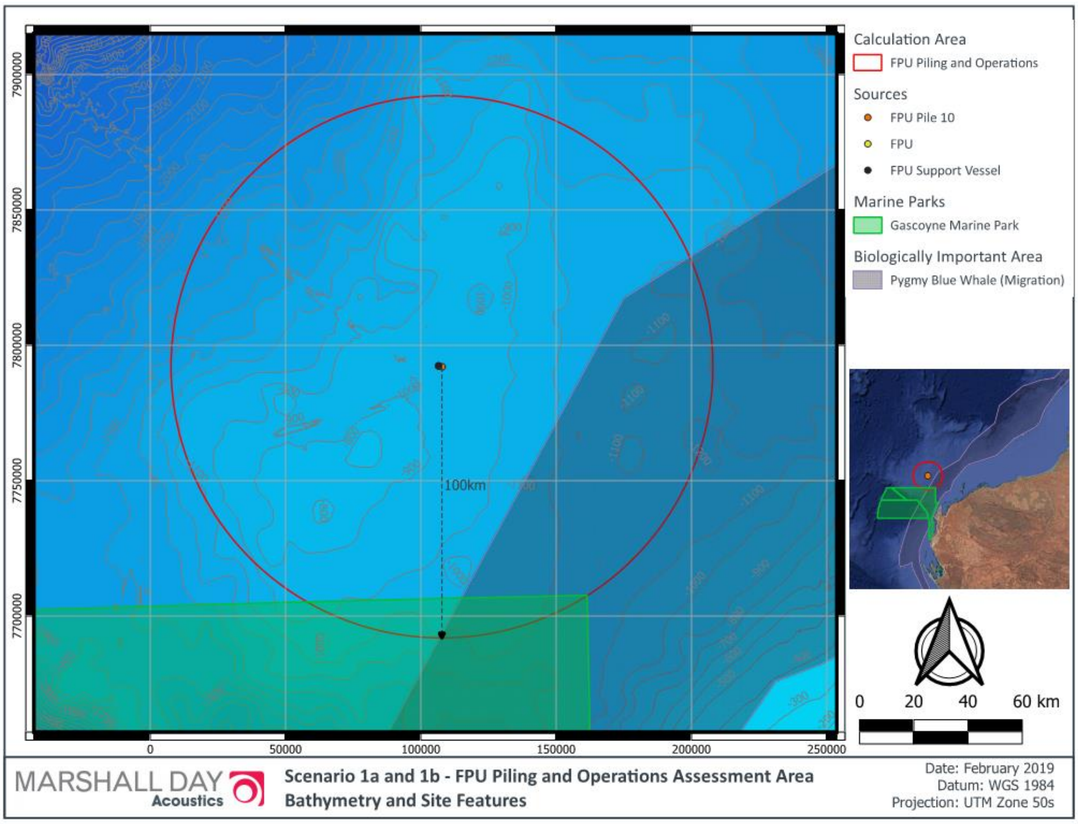
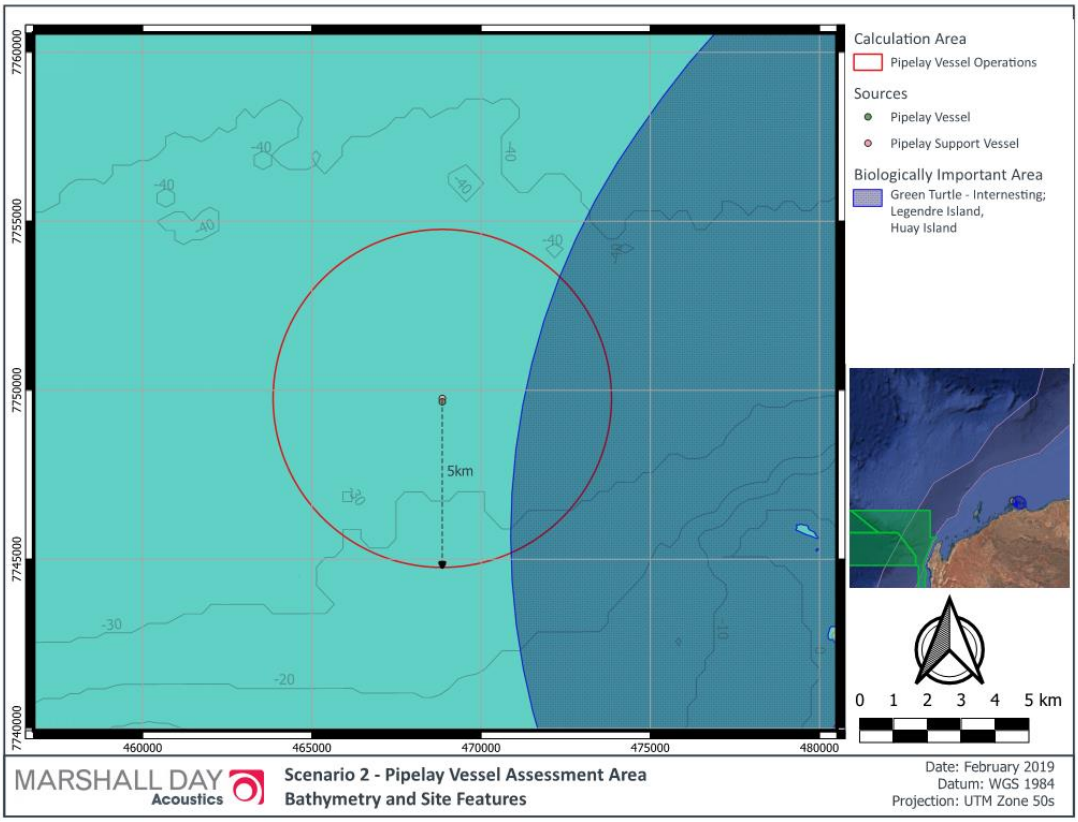


Figure 2: Project area – Scenario 2 (Vessel operations)



3.0 SPECIES OF INTEREST

The species of interest in the vicinity of the Scarborough project sites have been identified by the project environmental consultant (Advisian). Each species of interest considered in this report has been categorised based on its hearing sensitivity grouping. The guidance used to assess noise impacts set varying criteria for different hearing sensitivity groups. The corresponding hearing sensitive group for each species of interest is therefore provided in Table 2. Further details of the criteria for each species is provide in Section 4.0

Table 2: Species of interest summary

Species	Comment	Hearing Category
Pygmy blue whales	Presence of migration BIAs identified within the vicinity of the FPU and trunkline corridor.	Low-Frequency Cetaceans
Humpback whales	Presence of migration BIAs identified within the trunkline corridor	Low-Frequency Cetaceans
Flatback turtle	BIAs and (draft) critical habitat have been identified within the trunkline corridor through the Dampier Archipelago region	Sea turtles
Loggerhead turtle	BIAs and (draft) critical habitat have been identified within the trunkline corridor through the Dampier Archipelago region	Sea Turtles
Hawksbill turtle	BIAs and (draft) critical habitat have been identified within the trunkline corridor through the Dampier Archipelago region	Sea Turtles

Species	Comment	Hearing Category
Green turtle	BIAs and (draft) critical habitat have been identified within the trunkline corridor through the Dampier Archipelago region	Sea Turtles
Fish	Includes whale sharks and fish generally	Fish

The potential noise impacts on marine fauna from underwater development activity can be categorised into four discrete areas as follows, from highest to lowest in order of the degree of potential impact:

1. Physiological damage that can lead to death or injury of the organism
2. Permanent Threshold Shift (PTS), which is described as a permanent shift in hearing sensitivity and can be considered as an injury
3. Temporary Threshold Shift (TTS), which is described as a temporary effect upon hearing and is often a recoverable impact
4. Behavioural response, which may manifest as avoidance, or a change to movement pathways/migration.

For each of the species hearing categories above, relevant noise criteria have been assigned to assist with the assessment of noise impacts. Details of the noise criteria are outlined in Section 4.0.

4.0 NOISE IMPACT CRITERIA

4.1 Legislation and policy

The Environment Protection and Biodiversity Conservation Act 1999 (the EPBC Act) is the central piece of environmental legislation relevant to assessments of impacts on marine fauna. It provides the legal framework to protect and manage nationally and internationally important areas, which are defined in the EPBC Act as matters of National Environmental Significance (NES).

When a proposal has the potential to have a significant impact on a matter of national environmental significance, the proposal is assessed on the basis of a 'referral'. A referral should contain sufficient information to provide an adequate basis for a decision on the likely impacts. For noise impacts an assessment would commonly be made with reference to relevant performance criteria.

The EPBC Act Policy Statement 2.1 outlines performance criteria and provides a framework to minimise the risk of underwater acoustic impacts, however this only applies to seismic operations, and only considers impacts on whale species - there are no EPBC policy statements which address other underwater noise sources and marine species.

In the absence of any other Australian specific underwater noise performance criteria, for this assessment, reference has been made to widely used scientific studies and international guidelines in order to evaluate the underwater noise impacts. These impact criteria sources have been nominated by the project marine ecologist.

4.2 Underwater noise criteria for marine mammals

The US Department of Commerce National Oceanic and Atmospheric Administration (NOAA) has produced guidance for assessing the effects of anthropogenic (human-made) sound on marine mammals. Details are provided in the following sections.

4.2.1 Physiological impacts

NOAA Technical Memorandum[1] provides thresholds for the onset of permanent threshold shift (PTS) and temporary threshold shifts (TTS) [2] in marine mammal hearing for all underwater sound sources. The guidance of the NOAA Technical Memorandum is commonly used in Australia to help evaluate the effects of sound exposure on marine mammal hearing.

Auditory threshold shifts can be caused by both impulsive noise sources (e.g. piling or seismic airguns) and continuous noise sources (e.g. vessel noise). When the source is impulsive, threshold shifts can be caused by peak exposure (momentary, high-level impulsive events such as pile strikes) or from cumulative exposure (lower noise levels over an extended period such as from vibro-piling or multiple pile strikes).

The NOAA Technical Memorandum provide TTS and PTS onset thresholds for marine mammals using $L_{p,pk}$ and 'SEL_{cum}' assessment descriptors. The $L_{p,pk}$ level is the highest un-weighted instantaneous pressure level recorded during the measurement period, whereas SEL_{cum} is the species-weighted cumulative sound exposure level over a 24-hour period. Table 3 presents the current NOAA thresholds. Explanation of marine mammal auditory frequency weightings is provided in Appendix C.

It should be noted that the $L_{p,pk}$ assessment of noise levels is relevant for impulsive noise sources only. SEL_{cum} assessment is applicable to both impulsive and non-impulsive (continuous) noise sources.

Table 3: NOAA 2018 threshold criteria

	Impulsive				Non-Impulsive	
	$L_{p,pk}$ *		$SEL_{(cum)}$ †		$SEL_{(cum)}$	
Hearing group	**TTS**	**PTS**	**TTS**	**PTS**	**TTS**	**PTS**
Low-Frequency Cetaceans	213	219	168	183	179	199
Mid-Frequency Cetaceans	224	230	170	185	178	198
High-Frequency Cetaceans	196	202	140	155	153	173

* The $L_{p,pk}$ is the un-weighted peak instantaneous pressure level

† The $SEL_{(cum)}$ is the weighted cumulative sound exposure level over a 24-hour period

4.2.2 Behavioural impacts

Behavioural responses to underwater noise can vary significantly depending on species, the background noise levels, and the frequency content of the noise source. These effects can range from temporary avoidance of the noisy area to masking of biologically important sounds.

[1] National Oceanic and Atmospheric Administration, 2018 *Revision to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0) Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts.* Available from: https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-acoustic-technical-guidance

[2] TTS in humans can be likened to the 'muffled' effect on hearing after being exposed to high noise levels such as at a concert. The effect eventually goes away, but the longer the exposure, the longer the threshold shift lasts. Eventually, the TTS becomes permanent. Long exposure TTS causing PTS in marine mammals is typically associated with continuous noise sources but is unlikely when dealing with impulsive sources due to the understanding that there is TTS recovery in between pulses.

For underwater impulsive noise such as impact piling, NOAA guidance[3] states that behavioural impacts can occur at levels of 160 dB re. 1 μPa rms, and as low as 120 dB re. 1 μPa rms for non-impulsive noise.

Table 4: NOAA criteria for behavioural impacts

	Impulsive $L_{p,rms}$ (dB re. 1 μPa)	Non-Impulsive $L_{p,rms}$ (dB re. 1 μPa)
Behavioural	160	120

4.3 Underwater noise criteria for fish

The 2014 publication '*Effects of Sound on Fish and Turtles*'[4] (herein referred to as ASA S3/SC1.4-2014) provides comprehensive sound exposure guidelines for fishes and sea turtles. ASA S3/SC1.4-2014 was prepared by an ANSI-accredited Standards Committee Working Group of experts and was sponsored by the Acoustical Society of America.

ASA S3/SC1.4-2014 outlines hearing category groups based on the way different non-mammalian marine animals detect and respond to sound and provides sound exposure metrics for a ranges of source types for noise impact assessment purposes. ASA S3/SC1.4-2014 divides fishes and sea turtles into five groups as follows:

- Fish with no swim bladder
- Fish with swim bladder not involved with hearing
- Fish with swim bladder that is involved with hearing
- Sea turtles
- Eggs and larvae

4.3.1 Physiological impacts

ASA S3/SC1.4-2014 provides guideline noise level criteria for different types of sound sources. Sound levels from a source that are above the guideline criteria are considered likely to result in the stated effect (mortality, injury etc).

A summary of the guideline noise level criteria from ASA S3/SC1.4-2014, for piling noise sources, is provided in Table 5. A summary of the guideline noise levels criteria from ASA S3/SC1.4-2014, for shipping and other continuous noise sources, is provided in Table 6.

Where quantitative criteria have not been provided in the ASA S3/SC1.4-2014, the entry has been shown blank.

[3] https://www.westcoast.fisheries.noaa.gov/protected_species/marine_mammals/threshold_guidance.html

[4] Popper et al, 2014, Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI Accredited Standards Committee S3/SC 1 and registered with ANSI, ASA Press (ASA S3/SC1.4 TR-2014)

Table 5: Guidelines for pile driving

		Mortality and potential mortal injury		Recoverable injury		TTS
Group	**Type of Fish**	$L_{p,pk}$	$SEL_{(cum)}$	$L_{p,pk}$	$SEL_{(cum)}$	$SEL_{(cum)}$
A	Fish: no swim bladder (particle motion detection)	213	219	213	216	186
B	Fish: swim bladder is not involved in hearing (particle motion detection)	207	210	207	203	186
C	Fish: swim bladder involved in hearing (primarily pressure detection)	207	207	207	203	186
D	Sea turtles	207	210	-	-	-
E	Eggs and larvae	207	210	-	-	-

Table 6: Guidelines for shipping and continuous sounds

Group	Type of Fish	Mortality and potential mortal injury	Recoverable injury	TTS
A	Fish: no swim bladder (particle motion detection)	-	-	-
B	Fish: swim bladder is not involved in hearing (particle motion detection)	-	-	-
C	Fish: swim bladder involved in hearing (primarily pressure detection)	-	170 dB rms for 48 hrs	158 dB rms for 12 h
D	Sea turtles	-	-	-
E	Eggs and larvae	-	-	-

4.3.2 Behavioural impacts

Studies on the behavioural impacts from noise on fish are very limited and there are no widely accepted or validate guideline criteria. This is partly due to the practicalities of conducting such studies in the field, as well as the potential for large variations in responses across all fish species.

Given the lack of available evidence or validated criteria, quantitative guidelines for the behavioural impact of fish are not provided in ASA S3/SC1.4-2014, and instead a subjective risk assessment approach is used. For this reason, only physiological impacts on fish have been considered in this report. Behavioural impacts for sea turtles are addressed in the following section.

4.4 Underwater noise criteria for turtles

4.4.1 Physiological impacts

Data on hearing by sea turtles is very limited and specific TTS noise threshold criteria are not available currently[5]. Finneran et al. 2017[6] includes per-strike $L_{p,pk}$ PTS criteria for turtles of 232 dB re 1 µPa.

Physiological impacts risks relating to injury or death also have been assessed, based on ASA S3/SC1.4-2014 guidance as outlined in Table 5 above.

4.4.2 Behavioural impacts

National Science Foundation: Final Programmatic Environmental Impact Statement Overseas Environmental Impact Statement (OEIS), June 2011 (NSF 2011) provides guideline noise criteria for sea turtle behavioural responses, as presented in Table 7. Also included in the table is criteria for increased behavioural response from McCauley et al. (2000a)[7].

Table 7: Sea turtle guideline criteria

Response	$L_{p,rms}$ (dB re 1 µPa)
Behavioural	166
Turtles (increased response)	175 dB re 1µPa

5.0 METHODOLOGY

5.1 Modelling overview

There is no defined international standard for the prediction or underwater propagation. However, a number of established analytical methods are representative of current industry practice and are routinely used for impact assessment purpose. These methods have been implemented in the proprietary dBSea software to produce noise contours which show the distribution of levels around a source of noise.

It should be noted that modelling of underwater noise can be are highly sensitive to input parameters. Also, while the methods provide high accuracy for a specific environmental condition, in practice, propagation is highly variable and sensitive to temporal and spatial variations in environmental conditions (in contrast to the to the water condition simplifications which are necessary for practical modelling purposes).

5.2 Model input parameters

To predict underwater noise levels, the following factors have been considered:

- Source noise level spectra based on in-water measurement or other suitable reference data, as provided by Advisian.
- Source locations and depths as provided by Advisian
- The noise levels are calculated using a dBSea propagation solvers. The particular solvers used for each scenario are outlined in the relevant sections below. A description of solvers can be found in Appendix D.

[5] NSF 2011 provides conservative safety radius of 180 dB re 1 µPa above which TTS or PTS is considered possible, however specific threshold criteria are not defined.

[6] Reference detail are required from Advisian

[7] Reference detail are required from Advisian

- Bathymetry of the area as provided by Advisian (9 second longitude grid spacing, ~ 250mx250m)
- The yearly average sound speed profile variations with depth as provided by Advisian. Details and discussion of the sound speed profile are provided in Appendix E.
- Seafloor/seabed sediment properties as provided by Advisian (map in Appendix F). Common to all modelling scenarios.

For this report, three different modelling scenarios have been considered, each involving different sources, geographic locations and environmental inputs. Each scenario is discussed in greater detail in the following sections.

5.3 Scenario 1a – FPU installation

For this study, FPU installation refers to piling activity associated with the construction of mooring anchors for the FPU.

5.3.1 Piling details

The mooring arrangement drawing provided by Woodside[8] shows 20 anchor piles positioned around the FPU site.

Details of the piling properties, as provided by Woodside, are presented in Table 8. Installation details (strike rate, number of blows) has been provided by Woodside, as determined by a piling drivability assessment.

Table 8: Piling details

Parameter description	Value
Pile length	60 m
Pile diameter	5 m
Wall Thickness	50 mm
Material	Steel
Water depth	~950 m
Installation depth below sea floor (total driven depth)	60 m
Installation type	Impact
Installation rate	1 pile per day
Total blows per pile	2752 (case #1)

5.3.2 Source levels

Piling noise level predications in underwater environments are commonly made on the basis of measured near-field source levels of similar piling operations (operations that have used comparable pile sizes, pile types and in similar environments). A commonly used source for reference piling noise levels is the CALTRANS *Compendium of Pile Driving Sound Data*[9] (CALTRANS). However, following a

[8] Woodside drawing reference 195369-MA-GAS-015.01 (rev 00)

[9] The document California Department of Transportation's document 'Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish' (referred to as CALTRANS) Appendix I, *Compendium of Pile Driving Sound Data*, provides a summary of measured underwater sound levels for a variety of pile driving situations.

review of CALTRANS and other available literature, no suitable measured noise level data corresponding to the specific configuration proposed could be found.

For this study, reference has been made to the South Australia Pile Driving Guidelines[10] (SA piling guidelines). While this document does not provide specific details of measured piling noise data, it does provide guidance on the typical range of levels. The SA piling guidelines state that '*Typical source levels range from SEL 170–225 dB re 1 µPa²·s for a single pulse….*' For this study, the SEL maximum value of the SA piling guidelines range has been used to represent piling associated with the FPU installation on the basis that the proposed pile size is at the upper end of the typical pile diameter size range[11]. It should be noted there can be significant variation between piling noise level measurements, even when measured at the same site (as a result of poor hammer strikes for example) so the maximum values have been referenced to account for the potential upper emissions of the proposed piling operations.

Source noise levels and other piling details used in this underwater noise modelling scenario are presented in Table 9. The RMS noise levels in Table 9 have been estimated based on analysis of the measured data provided in CALTRANS.

Modelling the sound propagation of peak noise levels requires complex numerical methods that take into account multipath, multi-component (time, frequency, phase etc) interference effects from the seafloor, sea surface and other propagation variables. Such methods require significant computation power and are generally not suited for practical use due to the significant processing times required. Alternative methods that can estimate the $L_{p,pk}$ levels based on the SEL have been developed to overcome these issues. Such methods typically overestimate the $L_{p,pk}$ and are therefore considered to be conservative. For this study, a simple linear regression method outlined in Lippert et. Al. (2015) has been used to estimate the $L_{p,pk}$ level based on the received SEL level, as calculated in the dBSea model. Since the estimated $L_{p,pk}$ level varies with range, a single figure has not been shown in the source levels in Table 9.

Figure 3 shows a plot of the 1/3 octave levels for the source (SEL values shown). The source spectrum is based on in-water measurements of impact driven steel piles[12] between 31.5Hz – 20kHz, scaled to the levels provided in Table 9.

Table 9: Broadband source levels – Impact piling

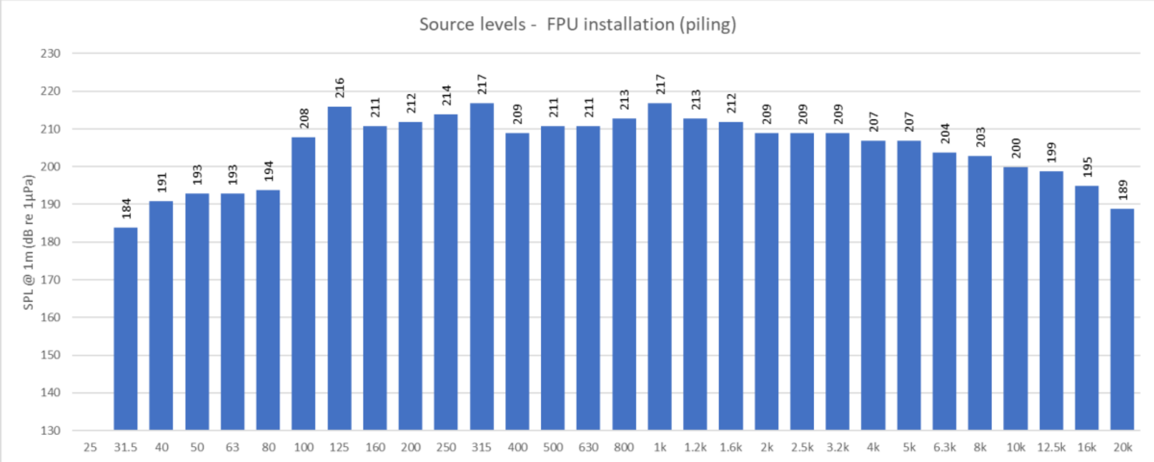
Type	Size and Method	Source Levels (@ 1m)		
		Peak	$L_{p,rms}$, (dB re 1µPa)	$SEL_{(single\ strike)}$, (dB re 1µPa²)
Anchor pile	Impact driven 5000mm steel	See discussion above	235	225

[10] South Australian Department of Planning, Transport and Infrastructure (DPTI), South Australia Pile Driving Guidelines, November 2012, Document: # 4785592

[11] Pile noise source estimates are supported by analysis of the available large pile data in CALTRANS and reference to other publicly available studies (e.g. Barossa Area Development OPP - www.nopsema.gov.au/assets/OPPs/A598152.pdf)

[12] ITAP –Institut für technische und angewandte Physik GmbH: 'Spektren der Vibrationsramme beim Umspannwerk' (2011)

Figure 3: 1/3 Octave spectral source levels – Impact piling (per strike)



5.3.3 Source locations

The location coordinates for the noise sources and the assumed source depth are provided in Table 14. The source depth is based on 0m pile penetration on the basis that this would represent a worst-case scenario in terms of noise propagation.

For impact assessment purposes, a single representative pile location only (pile #10) has been considered in the noise model. On the basis that the environmental conditions are similar at each pile location, the results (threshold distances) are considered to be representative for all pile locations i.e. derived threshold distances will be the same for each pile with the subject pile location representing the origin.

Table 10: Source locations and depths

Source description	MGA 94 coordinates (Zone 50K)		Modelling Source Depth
	Easting (X)	Northing (Y)	
Impact piling (pile #10)	107832.5	7792069.4	880 m

5.3.4 Underwater modelling parameters

The dbSea modelling software allows various input parameters to be set, based on the specific requirements and limitations of the modelling scenarios. A summary of the key parameter settings for the FPU installation scenario is presented in Table 11.

The maximum model distance was determined using a simplified cylindrical spreading model to estimate the noise levels and then calculate the maximum distance from the source to the lowest threshold level contour.

The frequency range considered is dictated by the range provided in the source data.

The cross over frequency was determined by considering guidance provided in the dBSea documentation (see Appendix D and through sensitivity analysis carried out during preliminary model runs.

Table 11: Key modelling parameters – Scenario 1a

Propagation Solver Configuration	
Maximum model distance	100 km
Frequency Range	31.5Hz – 20kHz
Azimuthal Increment	4.5^{o} (80 radials)
Crossover frequency	615Hz
Low Frequency Solver	dBSeaPE
High Frequency Solver	dBSeaRay

5.3.5 Seabed geoacoustic properties

Information provided in the benthic substrate map (see Appendix F) is limited to a single geoacoustic seabed type. This simplified data provides no information with respect to the presence of shallow layer structures or ocean floor strata. As such, the influence of any complicated sub-surface characteristics has not been evaluated in the model. Review of the benthic substrate map indicates that the sea bed in the vicinity of FPC location is described as 'mud and calcareous clay'. This has been modelled as a halfspace due to insufficient information on shallow layered structures.

This substrate description has been used in in conjunction with literature information on seafloor geoacoustics[13] to determine the properties shown in Table 16.

Table 12: Geoacoustic properties for Scenario 1

Sediment Description	**Thickness (m)**	ρ (kg/m^3)	c_p (m/s)	α_p (dB/λ)
Clay	Halfspace	1500	1500	0.2

5.4 Scenario 1b – FPU operations

5.4.1 Source levels

Noise source data has been provided by Advisian. Broadband source noise levels used in this underwater noise modelling scenario are presented in Table 13. Figure 4 shows a plot of the corresponding 1/3 octave levels for the sources. Note that source data for FPU operations is limited to a frequency range of 31.5 Hz to 2.5kHz. Modelling for the FPU operations scenario is accordingly limited to this range only.

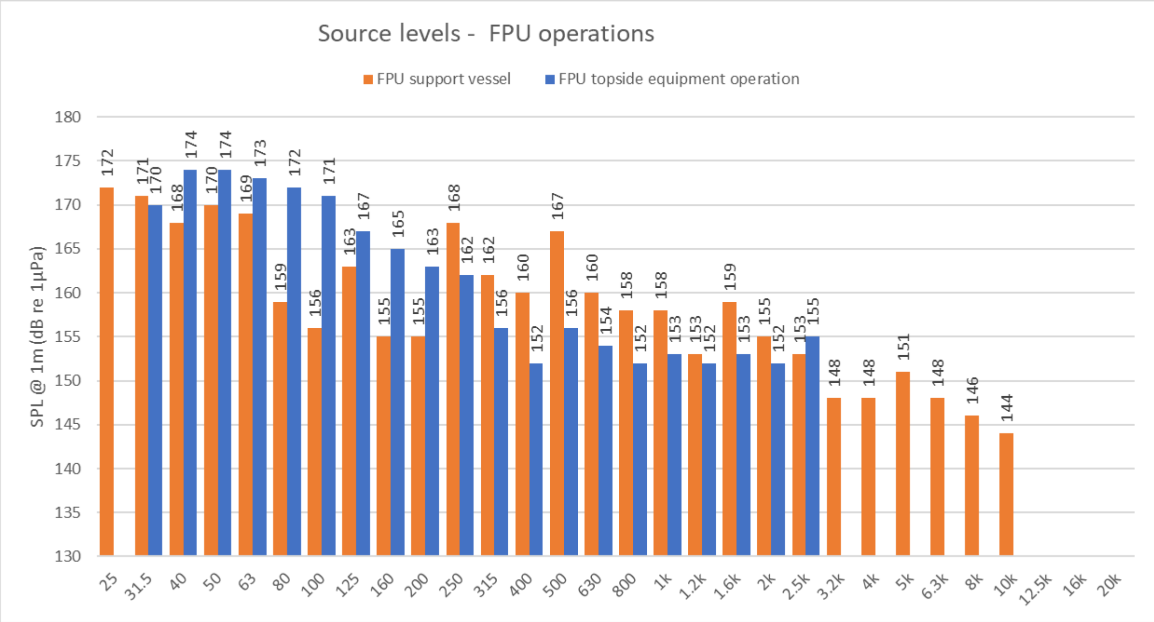
Table 13: Broadband source levels for noise prediction – Scenario 1b

Source description	**Details**	$L_{p,rms}$ **@1m (dB re 1 µPa)**
FPU	Stationary moored, typically FPU topside equipment operating. Data derived from Erbe et al [14] (50^{th} percentile data used) as directed by Advisian.	180

[13] Hamilton, E. L. (1980). Geoacoustic modelling of the sea floor. The Journal of the Acoustical Society of America, 68(5), 1313-1340.

Source description	Details	$L_{p,rms}$ @1m (dB re 1 µPa)
Support vessel	Data derived from measured levels of the *Setouchi Surveyor* (Hannay et al. 2004) as directed by Advisian	186

Figure 4: 1/3 Octave spectral source levels - FPU operations



5.4.2 Source locations

The location coordinates for the noise sources and the assumed source depth location are provided in Table 14.

Table 14: Source locations and depths

Source description	UTM coordinates (MGA94)		Modelling Source Depth
	Easting (X)	Northing (Y)	
FPU	106450	7792300	5 m
Support vessel	106450	7792500	5 m

5.4.3 Underwater modelling parameters

For the FPU operation scenario, the key parameter settings presented in Table 15 have been used for modelling in dbSea.

Maximum model distances, evaluation frequency ranges and solver cross-over frequency have been determined based on the methodologies described in Section 5.3.4.

[14] Erbe, C., McCauley, R., McPherson, C., & Gavrilov, A. (2013). Underwater noise from offshore oil production vessels. *The Journal of the Acoustical Society of America*, *133*(6), EL465-EL470.

Table 15: Key modelling parameters – Scenario 1b

Propagation Solver Configuration	
Maximum model distance	100 km
Frequency Range	31.5Hz – 2.5kHz (limited by source data)
Azimuthal Increment	3.6^{o}
Crossover frequency	615kHz
Low Frequency Solver	dBSeaPE
High Frequency Solver	dBSeaRay

5.4.4 Seabed geoacoustic properties

As the FPU installation and FPU operations activities occur in the same localised area, benthic substrate data and, consequentially, dbSea modelling parameters, are common for the two scenarios, with the same shallow surface layer limitations described in Section 5.3.5. These geoacoustic properties are repeated in Table 16 for convenience.

Table 16: Geoacoustic properties for Scenario 1

Sediment Description	**Thickness (m)**	ρ (kg/m^3)	c_p (m/s)	α_p (dB/λ)
Clay	Halfspace	1500	1500	0.2

5.5 Scenario 2 – Pipelay vessel operations

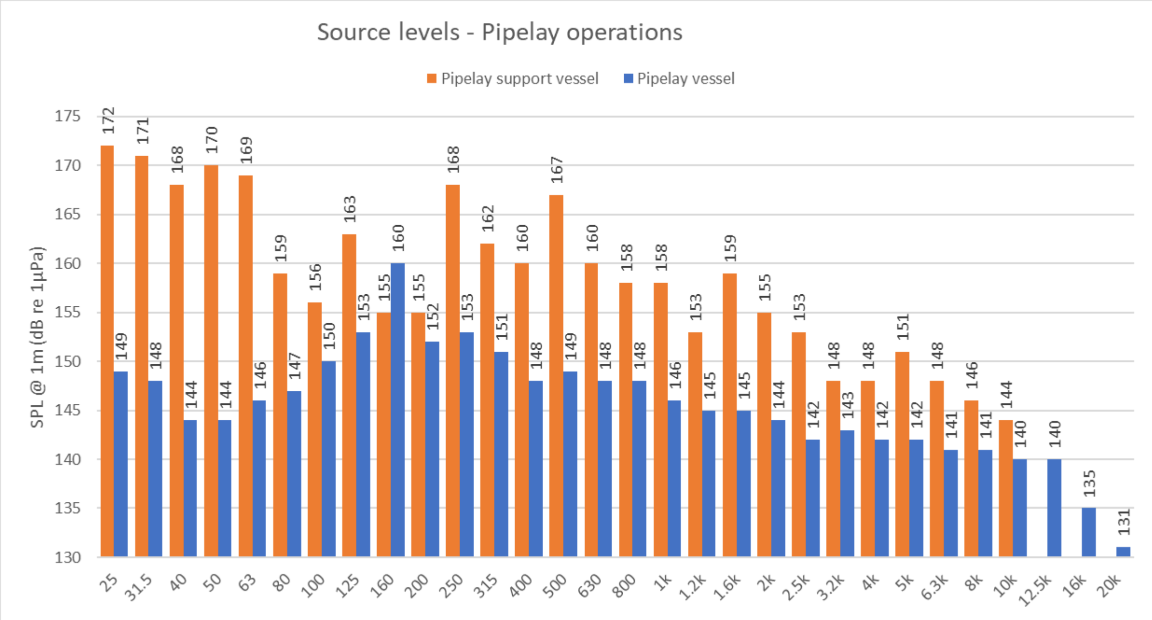
5.5.1 Source levels

Noise source data has been provided by Woodside. Broadband source noise levels used in this underwater noise modelling scenario are presented in Table 17. Figure 5 shows a plot of the 1/3 octave levels. Note that source data for support vessel operation is limited to a frequency range of 31.5 Hz to 10kHz. Modelling for the pipelay vessel operation scenario is accordingly limited to this range only.

Table 17: Broadband source levels for noise prediction – Scenario 1b

Source description	**Details**	**$L_{p,rms}$ @1m (dB re 1 µPa)**
Pipelay vessel	Data derived from measured levels of the *Deep Orient*. Length 135 m, Breadth – 27m, Draft 6.85m. Source data based on dynamic positioning in calm seas as directed by Advisian.	168
Support vessel	Data derived from measured levels of the *Setouchi Surveyor* (Hannay et al. 2004) as directed by Advisian.	186

Figure 5: 1/3 Octave spectral source levels - Pipelay operations



5.5.2 Source locations

The location coordinates for the noise sources and the assumed source depth location are provided in Table 18.

Table 18: Source locations and depths

Source description	MGA 94 coordinates (Zone 50K)		Modelling Source Depth
	Easting (X)	Northing (Y)	
Pipelay vessel	468850	7749658	5 m
Support vessel	468850	7749758	5 m

5.5.3 Underwater modelling parameters

For the pipelay vessel operation scenario, the key parameter settings presented in Table 19 have been used for modelling in dbSea.

Maximum model distances and evaluation frequency ranges have been determined based on the methodologies described in Section 5.3.4.

Evaluation of pipelay vessel operation noise has been conducted using dbSeaModes normal mode solver. Normal mode calculation techniques are a fundamental concept of underwater noise modelling and have been verified to be appropriate for use in shallow water environments with homogenous bathymetry and sediment composition[15]. Bathymetry and benthic substrate data in the 5km maximum model distance area have minor variations making dbSeaModes an appropriate solver for the subject site. Further information on dBSea solvers provided in Appendix D.

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[15] Pedersen R., Keane, M. (2016), V*alidation of dBSea, Underwater Noise Prediction Software. Pile Driving Focus*

Table 19: Key modelling parameters – Scenario 2

Propagation Solver Configuration	
Maximum model distance	5 km
Frequency Range	25Hz – 10kHz
Azimuthal Increment	1.2°
Solver	dBSeaModes

5.5.4 Seabed geoacoustic properties

Review of the benthic substrate map indicates that the sea bed in the vicinity of FPC location is described as 'gravel.' This substrate description has been used in in conjunction with literature information on seafloor geoacoustics[16] to determine the properties shown in Table 20. As per Section 5.3.5 this has been modelled as a halfspace due to insufficient information on shallow layered structures.

Table 20: Geoacoustic properties for Scenario 1

Sediment Description	**Thickness (m)**	ρ (kg/m^3)	c_p (m/s)	α_p (dB/λ)
Gravel	halfspace	1800	2000	0.6

6.0 MODELLING RESULTS

The following sections outline the results of the noise modelling for each scenario. The results are split into tables based on the species and/or threshold type. The results are presented in the form of a distance from the source to the predicted noise level contour with a value equal to the threshold of interest for each species and type of effect (referred to as the *threshold contour*).

Selected noise contour plots for each scenario are presented in Appendix G. The noise level contours represent the maximum predicted noise level across all water depths at each point (as opposed to presenting the predicted noise level for a single constant depth). This is often referred to as a 'maximum over depth' result.

The distances presented in the tables below are stated in terms of a R_{max} (the maximum radial distance in any direction from the source to the threshold contour) and the R_{95} (the radius of the circular area, equivalent to 95% of the total area encompassed by the threshold contour).

6.1 Scenario 1a – FPU installation (anchor piling)

Table 21 through Table 28 present the modelling results for the FPU installation scenario (anchor piling).

[16] Hamilton, E. L. (1980). Geoacoustic modelling of the sea floor. The Journal of the Acoustical Society of America, 68(5), 1313-1340.

Table 21: SEL_{cum} threshold distances (maximum over depth) - Impulsive noise TTS

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Low-frequency cetaceans	168 re 1µPa^2.s	99.44	90.77
Mid-Frequency Cetaceans	170 re 1µPa^2.s	7.75	7.36
High-Frequency Cetaceans	140 re 1µPa^2.s	42.91	39.24

Table 22: $SEL_{(cum)}$ threshold distances (maximum over depth) - Impulsive noise PTS

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Low-frequency cetaceans	183 re 1µPa^2.s	34.34	29.13
Mid-Frequency Cetaceans	185 re 1µPa^2.s	1.14	1.02
High-Frequency Cetaceans	155 re 1µPa^2.s	17.49	14.85

Table 23: $L_{p,pk}$ threshold distances (maximum over depth) - Impulsive noise TTS

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Low-frequency cetaceans	213 re 1µPa	0.751	0.440
Mid-Frequency Cetaceans	224 re 1µPa	0.468	0.282
High-Frequency Cetaceans	196 re 1µPa	1.512	1.195

Table 24: $L_{p,pk}$ threshold distances (maximum over depth) - Impulsive noise PTS

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Low-frequency cetaceans	219 re 1µPa	0.59	0.35
Mid-Frequency Cetaceans	230 re 1µPa	0.31	0.19
High-Frequency Cetaceans	202 re 1µPa	0.88	0.74
Turtle	232 re 1µPa	0.26	0.17

Table 25: $L_{p,rms}$ threshold distances (maximum over depth) – Impulsive noise behavioural response

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Marine mammals	160 dB re 1µPa	38.25	33.80
Turtles	166 dB re 1µPa	24.61	21.85
Turtles (increased response	175 dB re 1µPa	11.11	10.36

Table 26: Fish and sea turtle $SEL_{(cum)}$ threshold distances (maximum over depth) – Impulsive noise mortality and potential mortal injury

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Fish: no swim bladder (particle motion detection)	219 re 1µPa^2.s	0.75	0.58
Fish: swim bladder is not involved in hearing (particle motion detection)	210 re 1µPa^2.s	2.39	2.28
Fish: swim bladder involved in hearing (primarily pressure detection)	207 re 1µPa^2.s	3.50	3.28
Sea turtles	210 re 1µPa^2.s	2.39	2.28
Eggs and larvae	210 re 1µPa^2.s	2.39	2.28

Table 27: Fish and sea turtle $SEL_{(cum)}$ threshold distances (maximum over depth) - Impulsive noise recoverable injury

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Fish: no swim bladder (particle motion detection)	216 re 1µPa^2.s	0.99	0.89
Fish: swim bladder is not involved in hearing (particle motion detection)	203 re 1µPa^2.s	9.62	9.12
Fish: swim bladder involved in hearing (primarily pressure detection)	203 re 1µPa^2.s	9.62	9.12
Sea turtles	-		
Eggs and larvae	-		

Table 28 Fish $SEL_{(cum)}$ threshold distances (maximum over depth) - Impulsive noise TTS

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
All fish	186 re 1µPa^2.s	34.06	27.86

6.1.1 Results summary – Marine mammals

The TTS and PTS cumulative exposure (SEL_{cum}) thresholds distances represent a boundary, outside of which, there is predicted to be no significant risk of hearing impairment regardless of the duration a marine mammal is in the project vicinity. These thresholds distances are significantly greater than the thresholds distances for the peak pressure criteria.

If a marine mammal enters a cumulative exposure threshold zone, there is potential for the onset of TTS or PTS. How close the marine mammal gets to the piling determines how fast the cumulative exposure thresholds limits are reached. For this scenario, the low-frequency cetacean TTS threshold contour extends into the pygmy blue whale migration BIA, however this is not the case for the PTS threshold contour, as shown in Appendix G, Figure 8.

6.1.2 Results summary – Turtles

The R_{max} distance to the various threshold zone boundaries considered for turtles is as follows:

- Behavioural response -24.61 km (Table 25).
- Possible mortality and potential mortal injury - 2.395 km (Table 26)

6.1.3 Results summary – Fish

The greatest R_{max} distance to the various threshold contours, when considering all fish type, is as follows:

- Possible mortality and potential mortal injury – 3.50 km (see Table 26)
- Recoverable injury - 9.62 km (see Table 27)
- Temporary threshold shift - 34.06 km (see Table 28)

6.2 Scenario 1b – FPU operations

Table 29 through Table 31 present the modelling results for the FPU operations scenario (FPU topside equipment operating, and support vessel operating).

Threshold distances for PTS and TTS have not been presented on the basis that these effects are unlikely to occur in a real-world situation. To exceed the cumulative PTS or TTS threshold levels would necessarily require marine mammals to remain in vicinity of the vessel over a 24-hour period, which is unlikely. Furthermore, the model is based on a point source representation of the vessels so the predicted levels (and distances to the thresholds) are conservative estimates at close range, given the relatively large scale of the vessels.

Table 29: SPL threshold distances (maximum over depth) – Continuous noise behavioural response

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Marine mammals	120 dB re 1µPa	4.55	4.29
Turtles	166 dB re 1µPa	0.48	0.32
Turtles (increased response)	175 dB re 1µPa	0.23	0.18

Table 30: Fish $SEL_{(cum)}$ threshold distances (maximum over depth) – Continuous noise recoverable injury

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Fish: swim bladder involved in hearing (primarily pressure detection)	170 re 1µPa^2.s	0.36	0.26

Table 31 Fish $SEL_{(cum)}$ threshold distances (maximum over depth) -Continuous noise TTS

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Fish: swim bladder involved in hearing (primarily pressure detection)	156 re 1µPa^2.s	0.78	0.48

6.2.1 Results summary – Marine mammals

The R_{max} distance to the behavioural response threshold contour for marine mammals is 4.55 km (Table 29).

The TTS and PTS effects on marine mammals are not a consideration this scenario, as discussed above.

6.2.2 Results summary – Turtles

The R_{max} distance to the behavioural response threshold contour for turtles is 0.48 km (Table 29).

6.2.3 Results summary – Fish

The greatest R_{max} distance to the various threshold zone boundaries, when considering all fish type, is as follows:

- Recoverable injury - 0.36 km (Table 30)
- Temporary threshold shift (TTS) - 0.78 km (Table 31)

6.3 Scenario 2 – Vessel operations

Table 32 through Table 34 present the modelling results for the pipelay operations scenario (pipelay vessel and support vessel operating).

As was the case for scenario 1b, threshold distances for PTS and TTS have not been presented on the basis that these effects are unlikely to occur in a real-world situation.

Table 32: SLP threshold distances (maximum over depth) – Continuous noise behavioural response

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Marine mammals	120 dB re 1µPa	4.903	4.581
Turtles	166 dB re 1µPa	0.046	0.022
Turtles (increased response)	175 dB re 1µPa	<0.010	<0.010

Table 33: Fish $SEL_{(cum)}$ threshold distances (maximum over depth) – Continuous noise recoverable injury

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Fish: swim bladder involved in hearing (primarily pressure detection)	170 re 1µPa^2.s	<0.010	<0.010

Table 34 Fish $SEL_{(cum)}$ threshold distances (maximum over depth) -Continuous noise TTS

Hearing group	Threshold criterion	R_{max} (km)	$R_{95\%}$ (km)
Fish: swim bladder involved in hearing (primarily pressure detection)	156 re 1µPa^2.s	0.097	0.063

6.3.1 Results summary – Marine mammals

The R_{max} distance to the behavioural response threshold contour for marine mammals is 4.903 km (Table 32). .

The TTS and PTS effects on marine mammals are not a consideration this scenario, as discussed in Section 6.2 above.

6.3.2 Results summary – Turtles

The R_{max} distance to the behavioural response threshold contour for turtles is 0.046 km (Table 32).

6.3.3 Results summary – Fish

The greatest R_{max} distance to the various threshold contours, when considering all fish types, is as follows:

- Recoverable injury - less than 10 m (Table 33)
- Temporary threshold shift (TTS) - 0.097km (Table 34)

7.0 SUMMARY

A study of underwater noise levels from the proposed Scarborough gas field development has been carried out to determine the areas over which marine fauna could be impacted. The study has considered three scenarios which represent the main noise generating activities associated with the development.

Noise modelling has been carried out using dBSea software. The model has taken into account various data inputs including the noise sources and locations, bathymetry data, sound speed profile data and seafloor properties. Suitable noise propagation solvers have been configured for each scenario.

There are no prescribed underwater noise criteria that apply to the project. To assist with the assessment of underwater noise impacts, reference has been made to noise level criteria from widely used scientific studies and international guidelines. These impact criteria sources have been nominated by the project marine ecologist.

The results of the noise modelling have been presented in the form of a distance from the various noise sources to the predicted noise level contour representing the particular threshold of interest.

APPENDIX A GLOSSARY OF TERMINOLOGY

dB	Decibel The unit of sound level. Expressed as a logarithmic ratio of sound pressure P relative to a reference pressure
Frequency	The number of pressure fluctuation cycles per second of a sound wave. Measured in units of Hertz (Hz).
Hertz (Hz)	Hertz is the unit of frequency. One hertz is one cycle per second. One thousand hertz is a kilohertz (kHz).
$L_{p,pk}$	The peak instantaneous pressure level (un-weighted).
PTS	Permanent Threshold Shift (PTS) is the permanent loss of hearing caused by acoustic trauma. PTS results in irreversible damage to the sensory hair cells of the ear.
R_{95}	The distance defined by the radius of the circular area that is equivalent to 95% of the total area encompassed by the threshold boundary contour.
R_{max}	The maximum radial distance in any direction from the source to the threshold contour boundary.
$L_{p,rms}$	Root Mean Square (RMS) is the equivalent continuous (time-averaged) sound level commonly referred to as the average level (period matches the event duration).
SEL	Sound exposure level (SEL) is the total sound energy of an event, normalised to an average sound level over one second. It is the time-integrated, sound-pressure-squared level. SEL is typically used to compare transient sound events having different time durations, pressure levels and temporal characteristics.
SEL_{cum}	The SEL_{cum} is the 'cumulative' sound energy of all events in a 24-hour period, normalised to an average sound level over one second.
TTS	Temporary Threshold Shift (TTS) is the temporary loss of hearing caused by sound exposure. The duration of TTS varies depending on the nature of the stimulus, but there is generally recovery of full hearing over time. TTS in humans can be likened to the 'muffled' effect on hearing after being exposed to high noise levels such as at a concert. The effect eventually goes away, but the longer the exposure, the longer the threshold shift lasts. Eventually, the TTS becomes permanent (PTS).
Underwater noise	A sound that is unwanted by, or distracting to, the receiver underwater.

APPENDIX B BIA OVERLAP WITH MODELLED AREAS

Table 35: BIA overlap summary for modelled scenarios

Species	BIA type	Scenario 1a		Scenario 1b		Scenario 2	
		Partial	Full	Partial	Full	Partial	Full
Pygmy Blue Whale	Migration	✓	✗	✗	✗	✗	✗
	Distribution	✗	✓	✗	✓	✗	✗
Humpback Whale	Migration	✗	✗	✗	✗	✗	✓
Green Turtle	Internesting Buffer;Legendre Island Huay Island	✗	✗	✗	✗	✓	✗
	Internesting buffer; Dampier Archipelago (islands to the west of the Burrup Peninsula)	✗	✗	✗	✗	✗	✓
Flatback Turtle	Internesting buffer; Dixon Island	✗	✗	✗	✗	✗	✓
	Internesting buffer; Intercourse Is	✗	✗	✗	✗	✗	✓
	Internesting buffer; Dampier Archipelago (islands to the west of the Burrup Peninsula)	✗	✗	✗	✗	✗	✓
	Internesting buffer; Legendre Is, Huay Is	✗	✗	✗	✗	✗	✓
	Internesting buffer; Delambre Is	✗	✗	✗	✗	✗	✓
	Internesting buffer; West of Cape Lambert	✗	✗	✗	✗	✗	✓
Hawksbill Turtle	Internesting buffer; Rosemary Is	✗	✗	✗	✗	✗	✓
	Internesting buffer; Dampier Archipelago (islands to the west of the Burrup Peninsula)	✗	✗	✗	✗	✗	✓
	Internesting buffer; Delambre Is (and other Dampier Archipelago Islands)	✗	✗	✗	✗	✗	✓
Loggerhead Turtle	Internesting buffer; Rosemary Island	✗	✗	✗	✗	✗	✓
	Internesting buffer; Cohen Island	✗	✗	✗	✗	✗	✓

APPENDIX C MARINE MAMMAL AUDITORY WEIGHTING FUNCTIONS

The following extract from the NOAA Technical Memorandum provides an industry referred explanation of marine mammal auditory weighting functions.

2.2 MARINE MAMMAL AUDITORY WEIGHTING FUNCTIONS

The ability to hear sounds varies across a species' hearing range. Most mammal audiograms have a typical "U-shape," with frequencies at the bottom of the "U" being those to which the animal is more sensitive, in terms of hearing (i.e. the animal's best hearing range; for example audiogram, see Glossary, Figure F1). Auditory weighting functions best reflect an animal's ability to hear a sound (and do not necessarily reflect how an animal will perceive and behaviorally react to that sound). To reflect higher hearing sensitivity at particular frequencies, sounds are often weighted. For example, A-weighting for humans deemphasize frequencies below 1 kHz and above 6 kHz based on the inverse of the idealized (smoothed) 40-phon equal loudness hearing function across frequencies, standardized to 0 dB at 1 kHz (e.g., Harris 1998). Other types of weighting functions for humans (e.g., B, C, D) deemphasize different frequencies to different extremes (e.g., flattens equal-loudness perception across wider frequencies with increasing received level; for example, C-weighting is uniform from 50 Hz to 5 kHz; ANSI 2011).

Auditory weighting functions have been proposed for marine mammals, specifically associated with PTS onset thresholds expressed in the weighted SEL_{cum} [17] metric, which take into account what is known about marine mammal hearing (Southall et al. 2007; Erbe et al. 2016). The Finneran Technical Report (Finneran 2016) developed marine mammal auditory weighting functions that reflect new data on:

- Marine mammal hearing (e.g., Sills et al. 2014; Sills et al. 2015; Cranford and Krysl, 2015; Kastelein et al. 2015c)
- Marine mammal equal latency contours (e.g., Reichmuth 2013; Wensveen et al. 2014; Mulsow et al. 2015
- Effects of noise on marine mammal hearing (e.g., Kastelein et al. 2012a; Kastelein et al. 2012b; Finneran and Schlundt 2013; Kastelein et al. 2013a; Kastelein et al. 2013b; Popov et al. 2013; Kastelein et al. 2014a; Kastelein et al. 2014b; Popov et al. 2014; Finneran et al. 2015; Kastelein et al., 2015a; Kastelein et al. 2015b; Popov et al. 2015).

This reflects a transition from auditory weighting functions that have previously been more similar to human dB(C) functions (i.e., M-weighting from Southall et al. 2007) to that more similar to human dB(A) functions. These marine mammal auditory weighting functions also provide a more consistent approach/methodology for all hearing groups.

Upon evaluation, NMFS determined that the proposed methodology in Finneran 2016 reflects the scientific literature and incorporated it directly into this Technical Guidance (Appendix A) following an independent peer review (see Appendix C for details on peer review and link to Peer Review Report).

2.2.2 Marine Mammal Auditory Weighting Functions

Frequency-dependent marine mammal auditory weighting functions were derived using data on hearing ability (composite audiograms), effects of noise on hearing, and data on equal latency (Finneran 2016[18]). Separate functions were derived for each marine mammal hearing group (Figures 1 and 2).

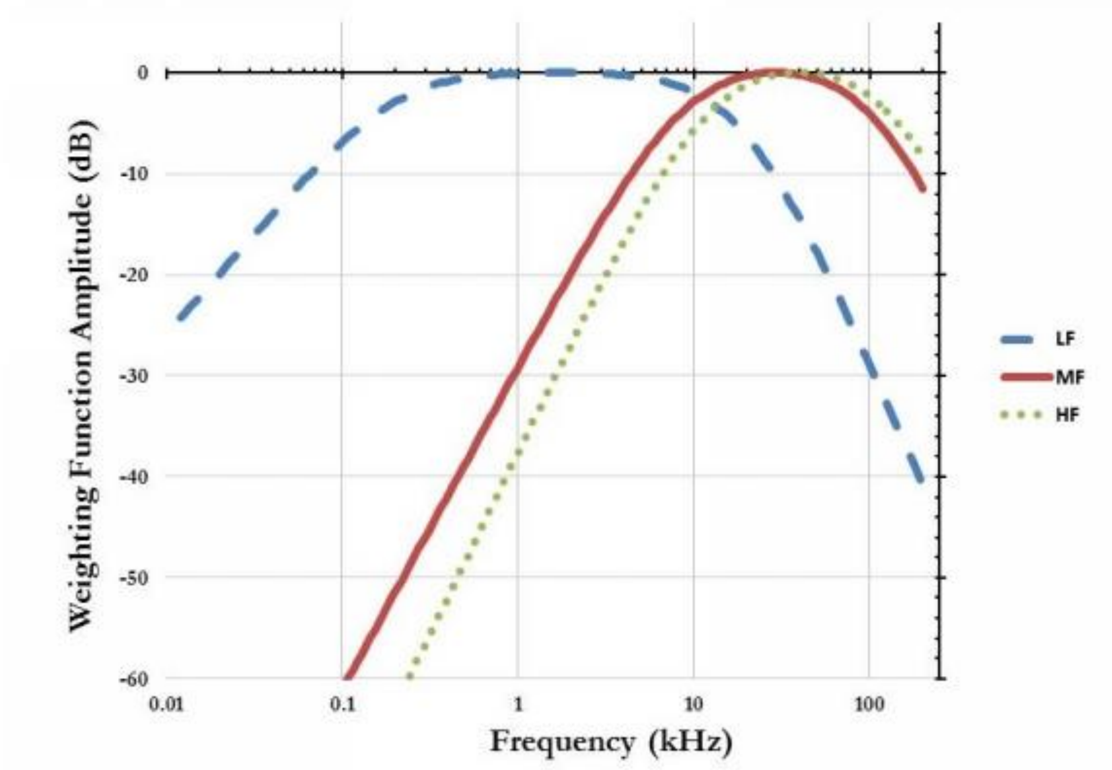


Figure 1: Auditory weighting functions for low-frequency (LF; dashed line), mid-frequency (MF; solid line), and high-frequency (HF; dotted line) cetaceans.

APPENDIX D PROPAGATION SOLVERS

Underwater acoustic propagation is commonly described mathematically by a partial differential called the "Helmholtz Wave Equation". The different solvers available in dBSea each employ various methods and approximations to yield a solution to the wave equation, i.e. the propagation loss. The propagation loss is used to make predictions of acoustic levels. As such each solver has specific scenarios of applicability.

The 3D levels predicted by dBSea are interpolated from 2D slices. All the solvers in dBSea can calculate propagation loss for range-dependent environments. A range-dependant is an environmental where parameters such as, bathymetry, sound speed and/or seabed geoacoustic properties, may vary in range away from the source. dBSea does not yet support elastic geoacoustic properties in the seabed. Approximations can be made where necessary to best derive equivalent fluid parameters to represent elastic seabed layers.

Table 36 provides a summary types of environment where dBSea's numerical solvers are applicable, in general the table follows a similar form to that presented in standard underwater acoustic textbooks[17].

Table 36: Applicability of dBSea solvers types

	Shallow water		**Deep water**	
Propagation Solver Type	**Low Frequency**	**High Frequency**	**Low Frequency**	**High Frequency**
Parabolic Equations	●	◍	◍	◍
Normal Modes	●	◍	◍	◍
Rays	○	◍	●	●

Symbol Key:

●	Applicable solver type, fit for purpose and widely used and numerically benchmarked
◍	Applicable solver type, however there may be limitation due to excessive computation time or accuracy
○	None applicable

Shallow water and deep water environments are distinguished by the extent that acoustic waves interact with the seabed. Acoustic wave interact significantly with the seabed in shallow water environments. Typical transition water depths are 50 m – 100 m. Similarly, the cross over between high and low frequencies is not a precisely defined and is also dependent on the water depth. Typical cross over frequencies would be between 100 – 500 Hz, this frequency can be estimated using the equation below,

$$f_{crossover} = 10 * \frac{c_w}{H}$$

Where c_w is the water column wave speed and H is the thickness of the duct or water column.

The dBSea solvers have been validated and benchmarked against accepted analytical solutions. Information on the benchmarking results can be found on dBSea's website[18]. A description of the three main

---

[17] Etter, P. C. (2013). *Underwater Acoustic Modelling and Simulation*. CRC Press.

[18] http://www.dbsea.co.uk/validation/

propagation solvers is presented below. Refer to textbooks like Jensen et al. (2011)[19] for further detailed information numerical implementations and description of each solver type.

D1 dBSeaModes

dBSeaModes is a propagation solver is finite difference implementation of a normal mode algorithm. The solver can be used in range-dependent scenarios where there is variation in bathymetry, sound speed and/or seabed geoacoustic properties in range away from the source. Range dependent calculations are based on the outward propagating adiabatic approximation. The adiabatic method is not applicable to scenarios where significant range-dependant variations in parameters occur. Care must be taken in applying dBSeaModes to range-dependent environments.

D2 dBSeaPE

dBSea's parabolic equation solver (dBSeaPE) is a finite difference implementation of the parabolic equation method. Parabolic equation methods are the preferred low frequency solvers for range-dependent scenarios and have been used extensively in research and commercial applications for underwater propagation modelling. The solver can incorporate range-dependent environmental parameters in bathymetry, sound speed and seabed geoacoustic properties into the propagation loss predictions.

The algorithm is implemented by calculating an initial starting sound field, which is source depth dependent, and is stepped out in range from the source using the PE method. dBSeaPE will use the dBSeaModes solver to generate the starting field. If the modal solver fails to converge to a results Greene's starter is used. If the modal starter fails, the software will prompt with a message 'PE solver used analytical starter', which indicates that the software is using an analytical starter (i.e. Greene's starter) for the specified frequencies and slice numbers.

D3 dBSeaRay

Ray tracing methods are family of numerical solvers that use a frequency approximation to reduce the Helmholtz equation to a form that can be solved numerically. The ray solver forms a solution by tracing rays from the source out into the sound field. A large number of rays leave the source covering a range of angles, and the sound level at each point in the receiving field is calculated by combining the components from each individual ray.

When multiple seafloor layers are present, rays are not split and traced into the seafloor. A complex reflection coefficient is calculated which is representative of the underlying layers, and this coefficient is applied to the ray at the point of seafloor reflection.

dBSeaRay is used for time domain calculations. Instead of returning a transmission loss at each point in the slice, a list of ray arrivals is returned (with separate entries for each frequency). These arrivals lists can be used to calculate the effective time series at each point in the slice, which is then used to calculate peak, peak to peak, and frequency band SEL levels.

[19] Jensen, F. B., Kuperman, W. A., Porter, M. B., & Schmidt, H. (2011). Computational ocean acoustics. Springer Science & Business Media.

APPENDIX E WATER COLUMN SOUND SPEED PROPERTIES

Due to the sparse environmental data in deep oceans, a single representative sound speed profile (SSP) has been applied for the entire area considered in the modelling. The average SSP was calculated from temperature and salinity data for Scarborough field, as provided by Woodside. No data was provided for depths below 1000m so a constant sound profile was been assumed below this depth, as directed by Advisian. The resultant SSP is shown in Figure 6 (full depth profile) and Figure 7 (detail of upper 100m).

The yearly average SPP profile in Figure 6 shows no significant surface duct or deep sound channel for the depths considered. It is noted that these SSP characteristics may be more pronounced at particular times of year, however seasonal SPP data for the areas was not provided for this assessment.

Figure 6: Average sound speed profile

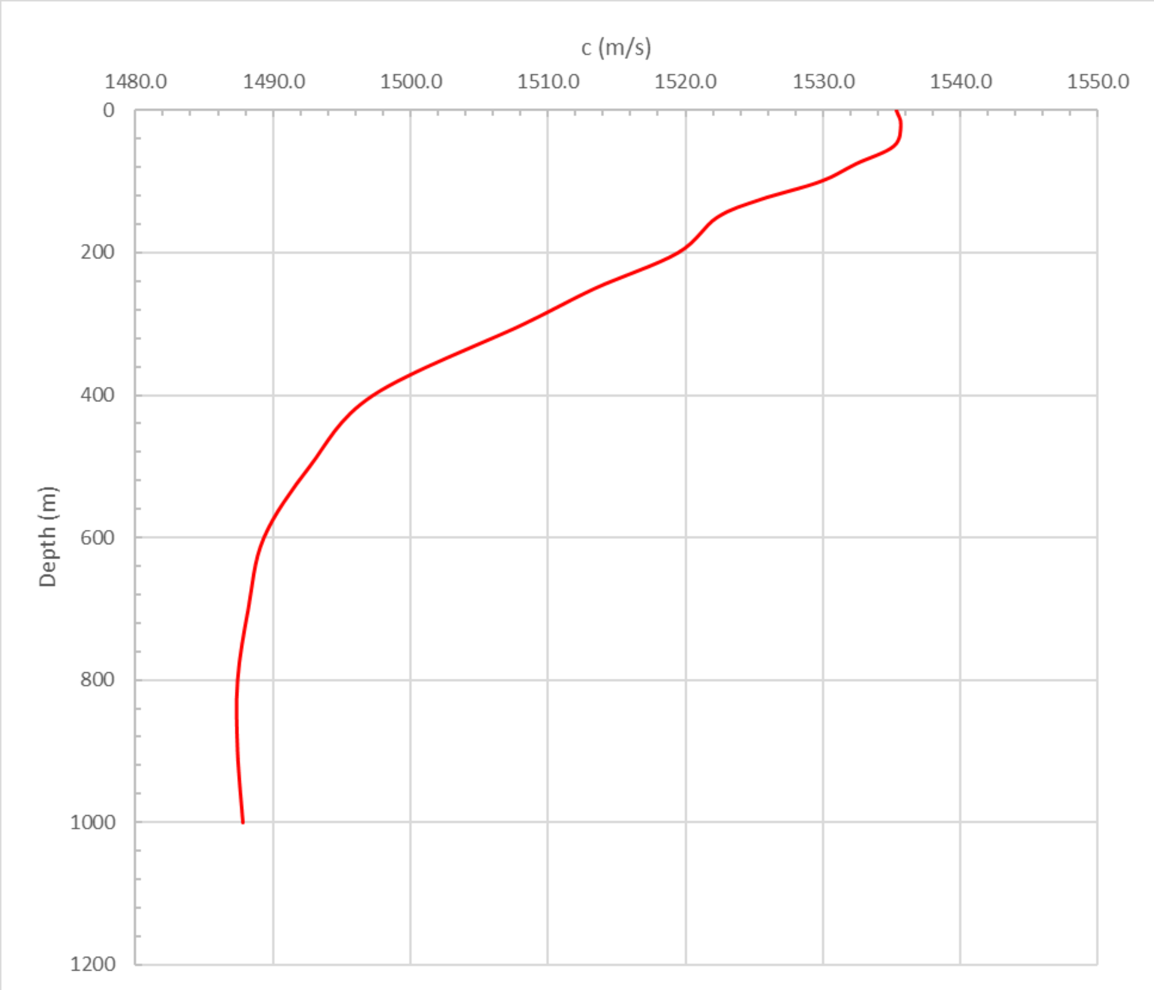
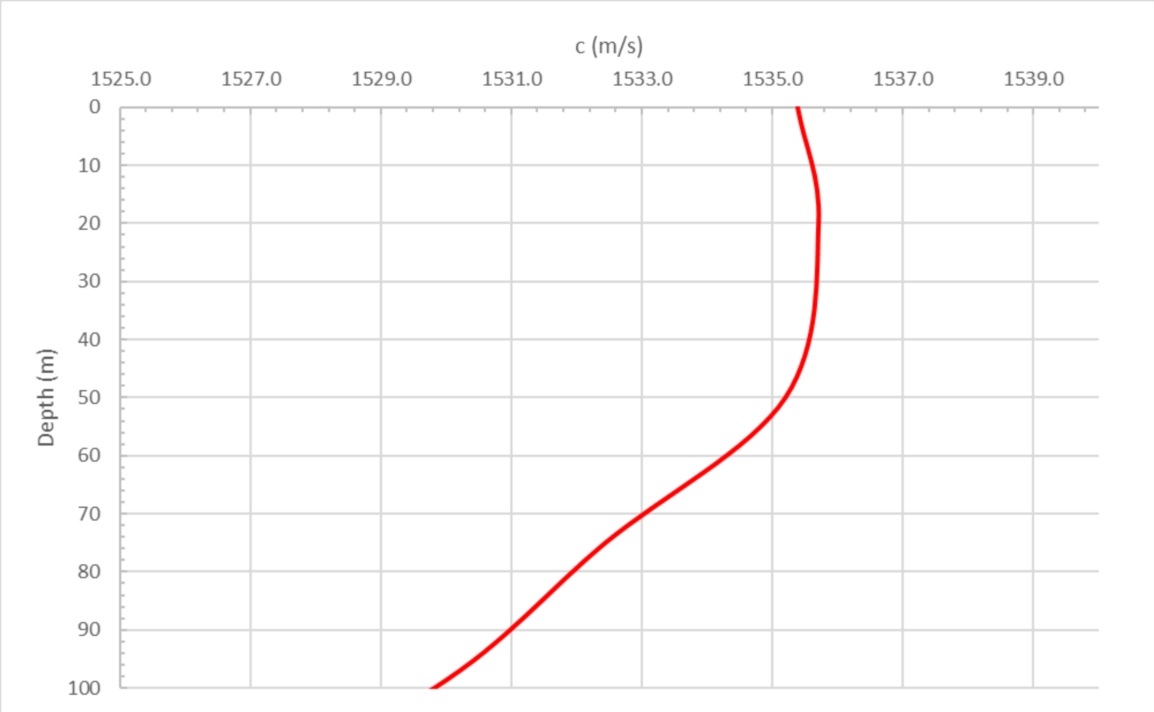
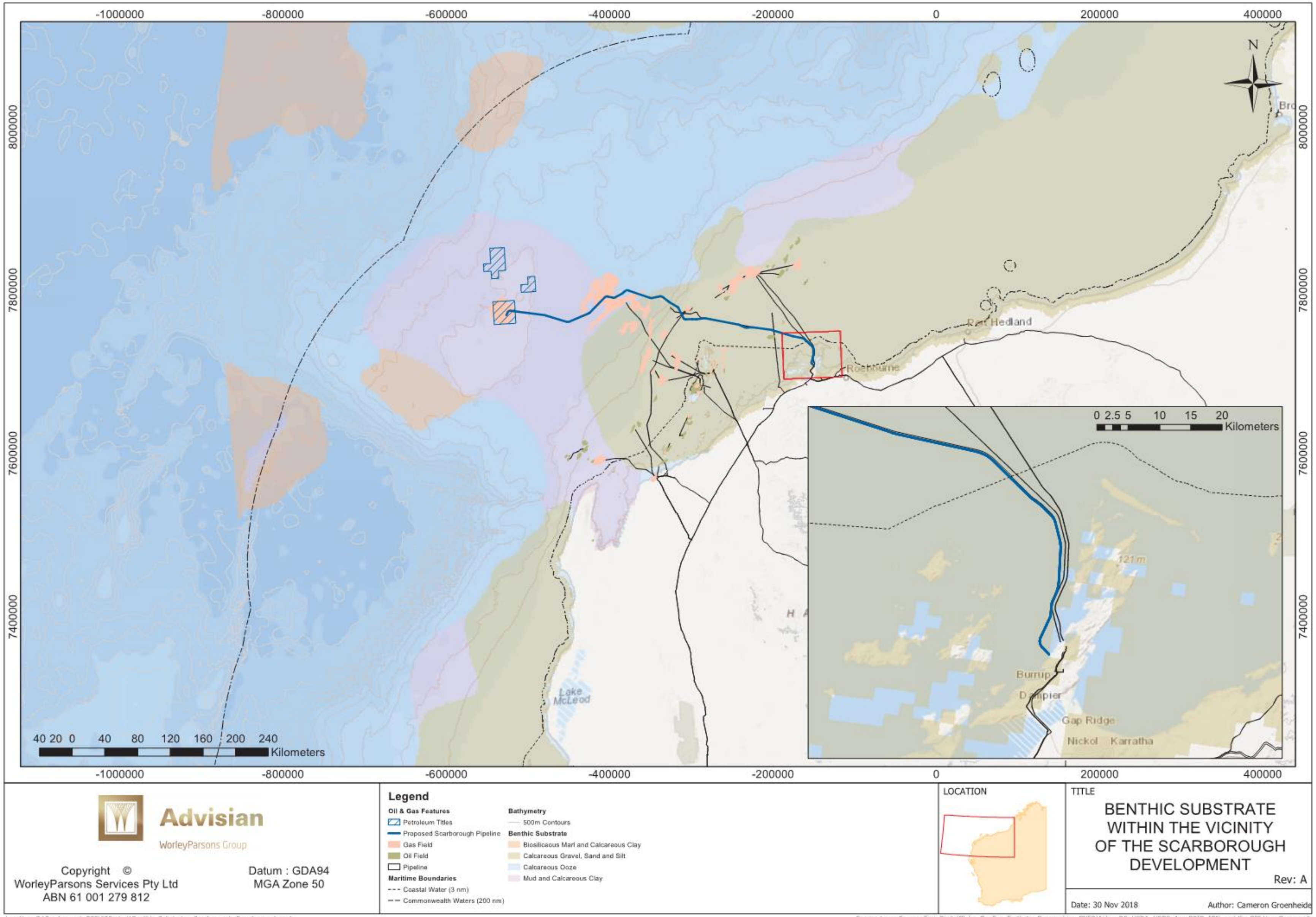


Figure 7: Average sound speed profile – upper 100m



APPENDIX F SEA BED PROPERTIES


-1000000
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0
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Roebourne
Lake McLeod
0 2.5 5 10 15 20 Kilometers
121 m
Burrup
Dampier
Gap Ridge
Nickol
Karratha
40 20 0 40 80 120 160 200 240 Kilometers
Advisian
WorleyParsons Group
Copyright © WorleyParsons Services Pty Ltd ABN 61 001 279 812
Datum : GDA94
MGA Zone 50
Legend
Oil & Gas Features
Petroleum Titles
Proposed Scarborough Pipeline
Gas Field
Oil Field
Pipeline
Maritime Boundaries
Coastal Water (3 nm)
Commonwealth Waters (200 nm)
Bathymetry
500m Contours
Benthic Substrate
Biosiliceous Marl and Calcareous Clay
Calcareous Gravel, Sand and Silt
Calcareous Ooze
Mud and Calcareous Clay
LOCATION
TITLE
BENTHIC SUBSTRATE WITHIN THE VICINITY OF THE SCARBOROUGH DEVELOPMENT
Rev: A
Date: 30 Nov 2018
Author: Cameron Groenheide

APPENDIX G PREDICTED UNDERWATER NOISE CONTOURS

G1 Scenario 1a

Figure 8: Noise contour map - Scenario 1a $SEL_{(cum)}$ unweighted (maximum over depth) – Marine mammal PTS thresholds

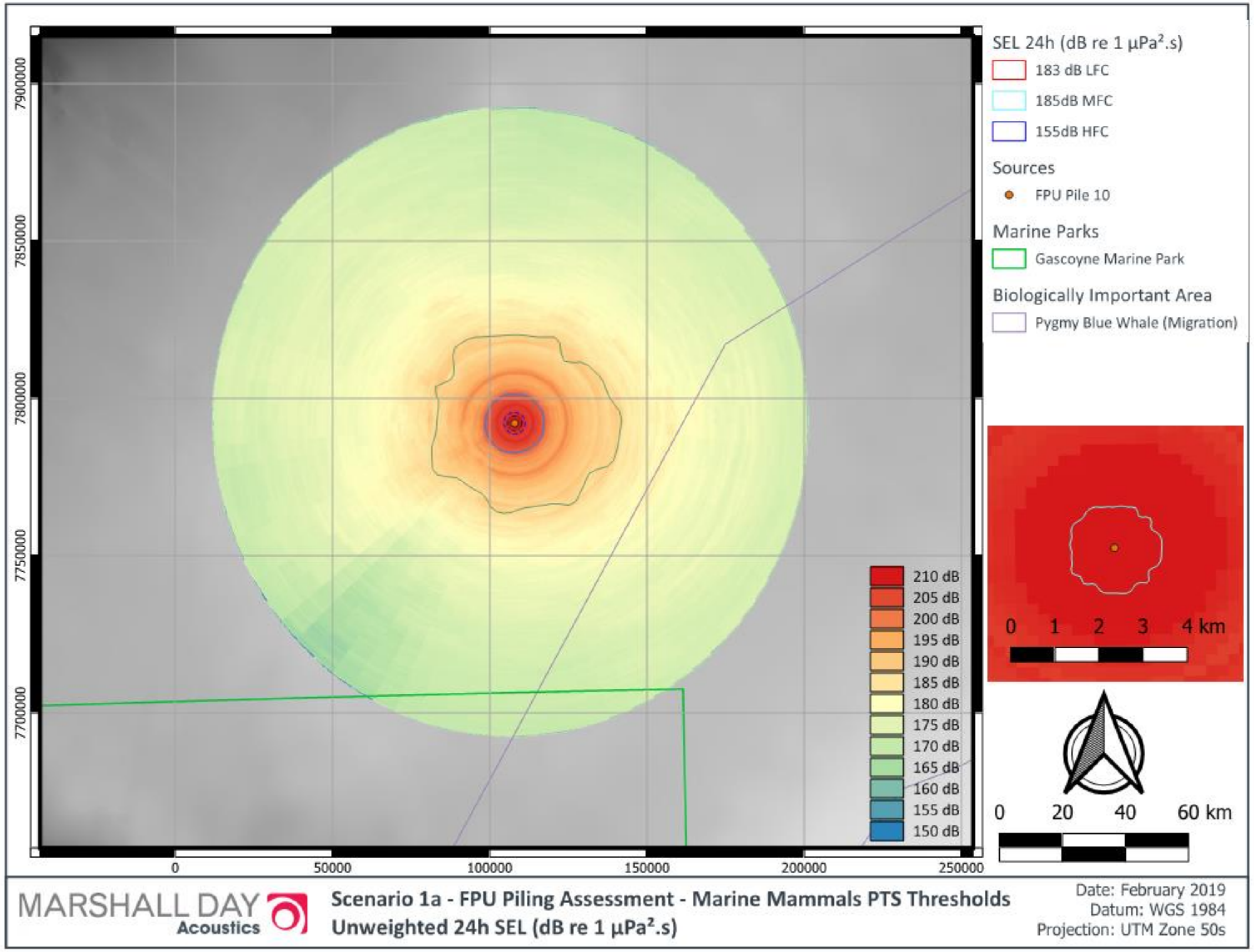


Figure 9: Noise contour map - Scenario 1a $SEL_{(cum)}$ unweighted (maximum over depth) – Fish and marine turtle thresholds

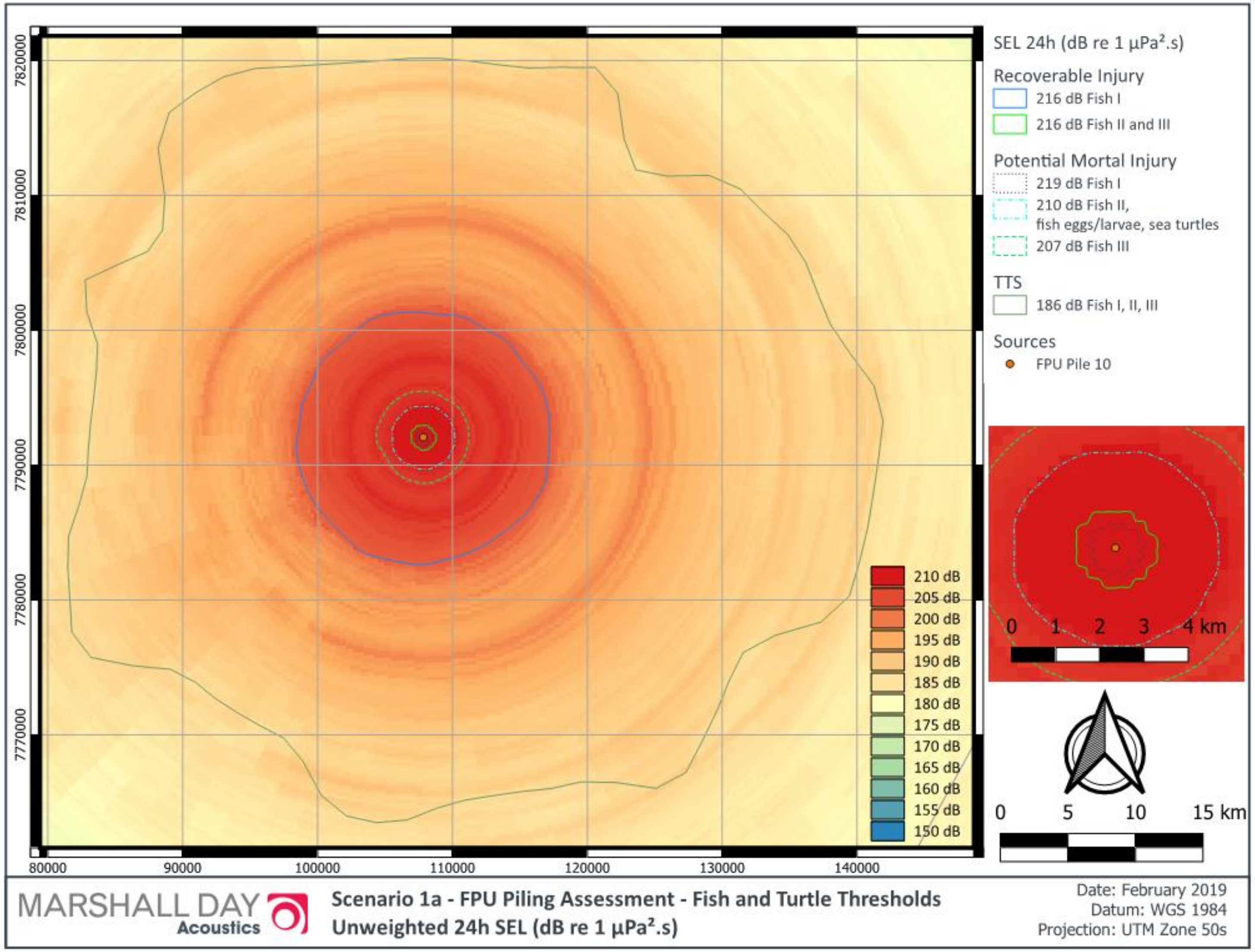
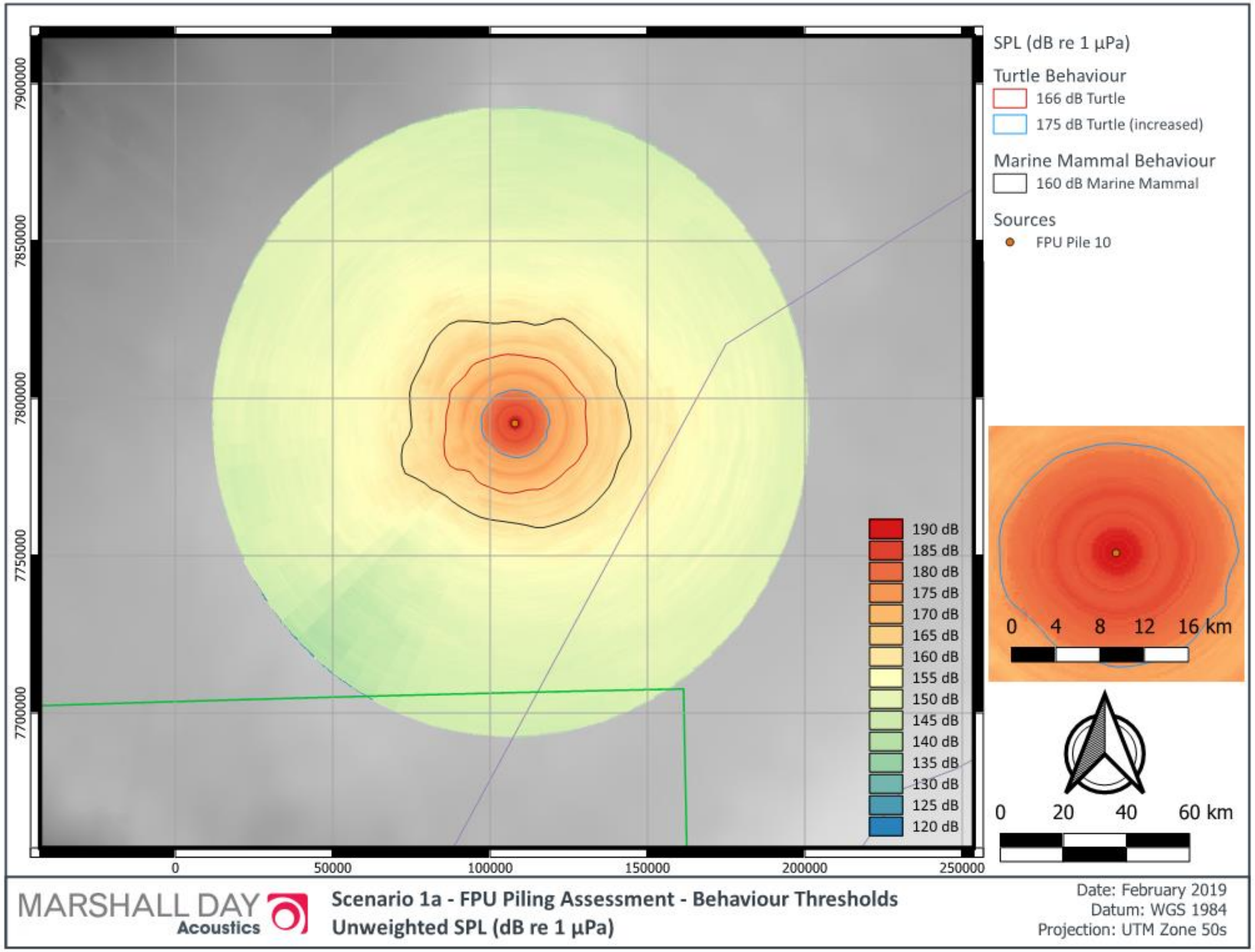


Figure 10: Noise contour map - Scenario 1a $L_{p,rms}$ (un-weighted) maximum over depth – Behavioural thresholds



G2 Scenario 1b

Figure 11: Noise contour map - Scenario 1b SEL(cum) (unweighted) maximum over depth

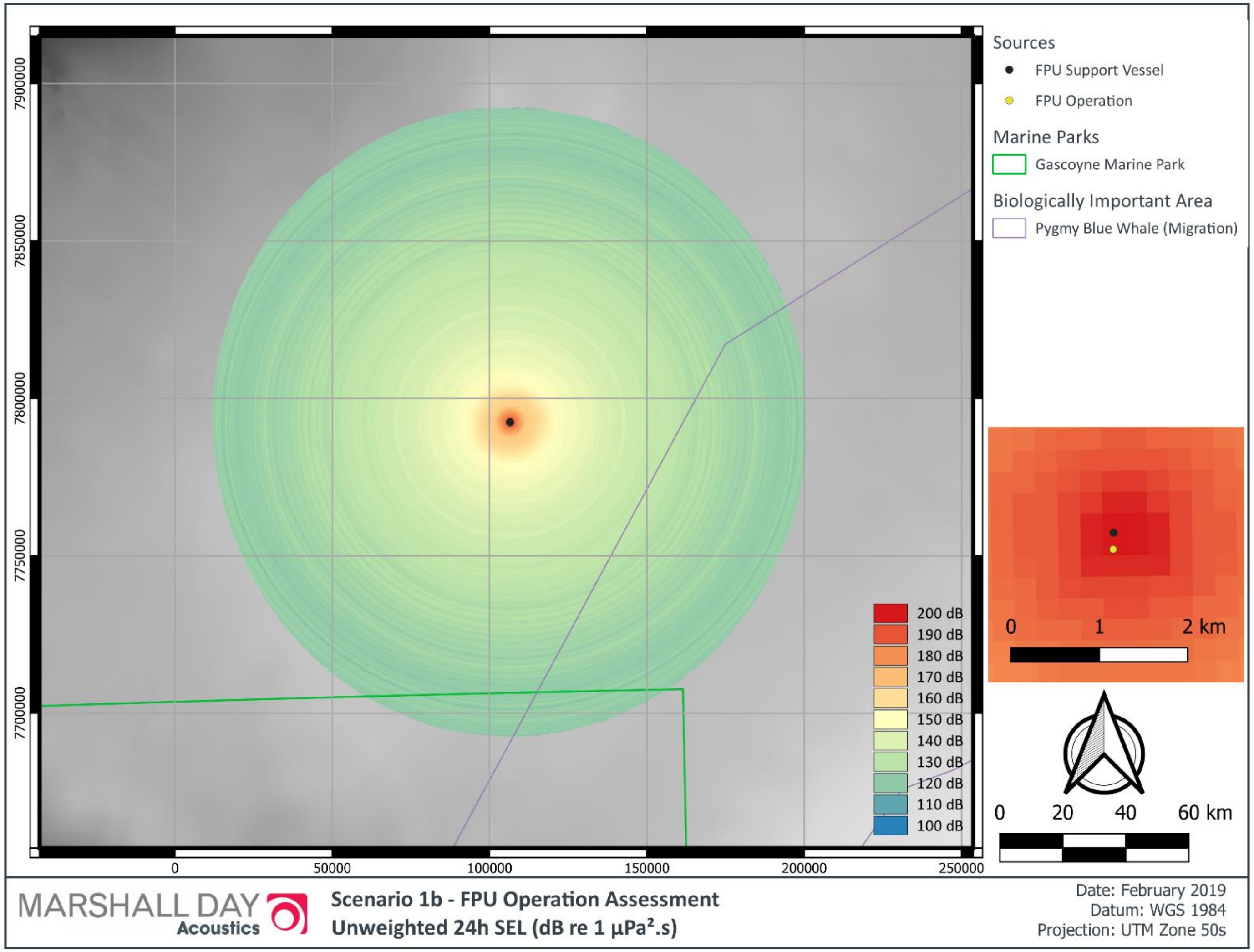
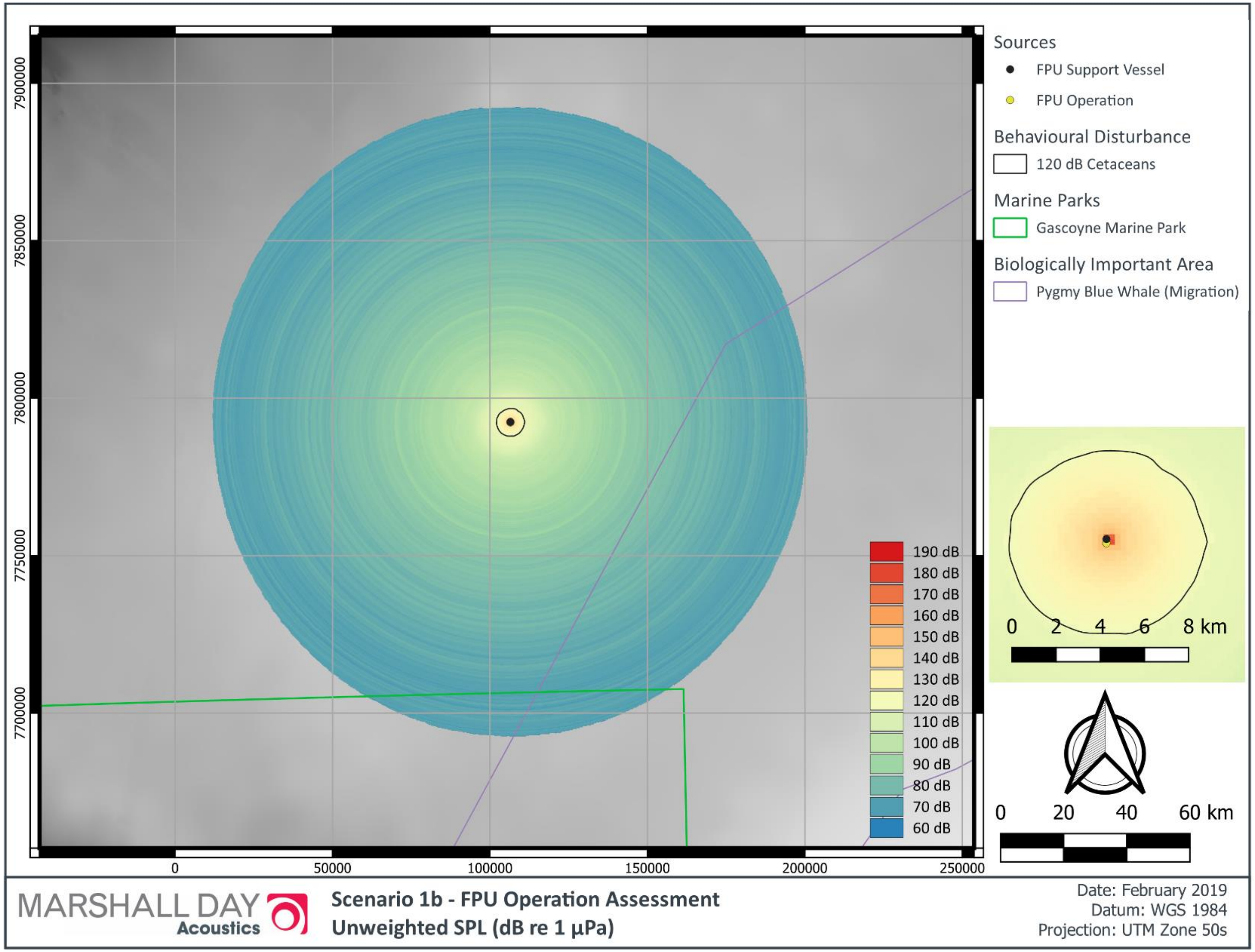


Figure 12: Noise contour map - Scenario 1b $L_{p,rms}$ (un-weighted) maximum over depth



G3 Scenario 2

Figure 13: Noise contour map - Scenario 2 $SEL_{(cum)}$ (un-weighted) maximum over depth

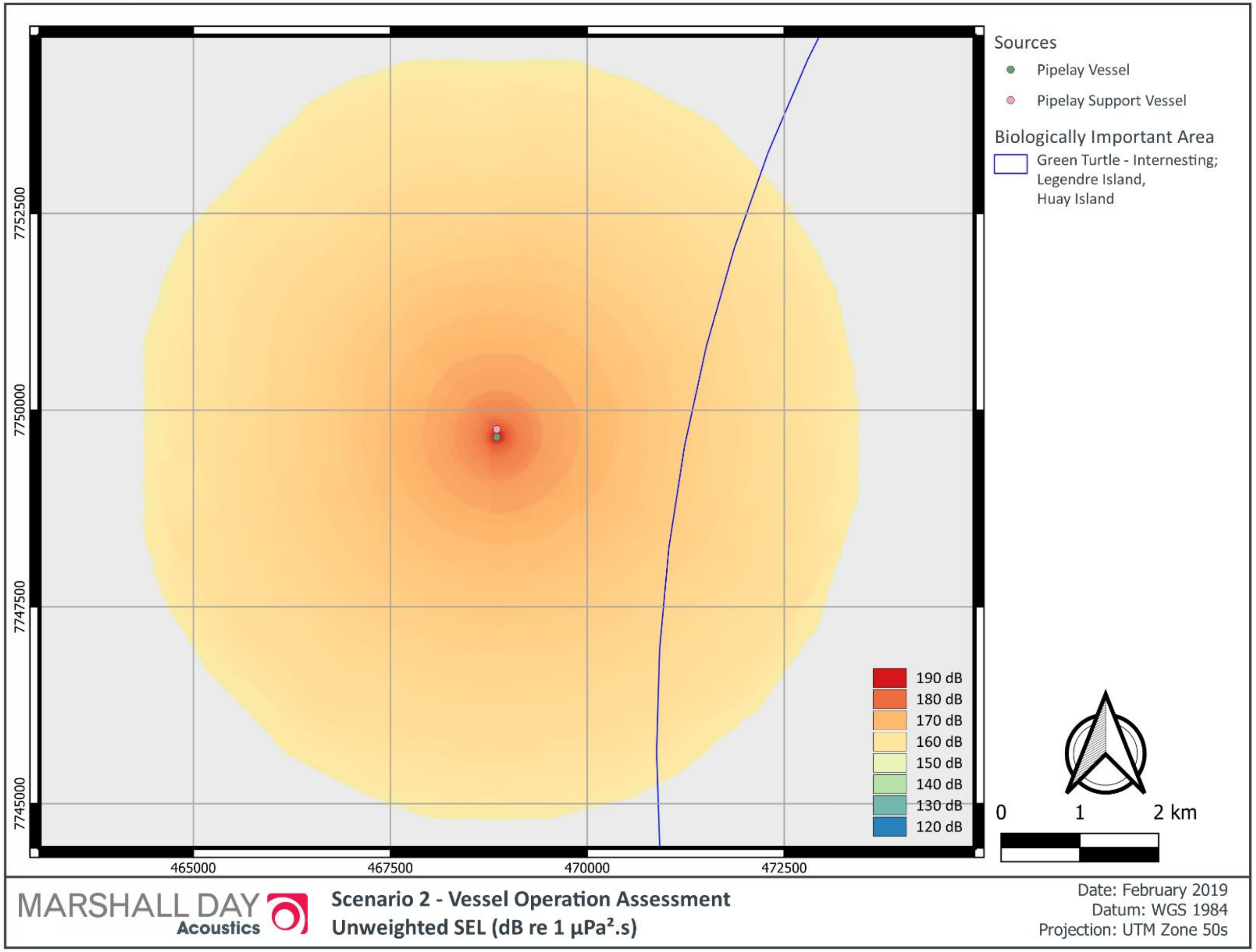
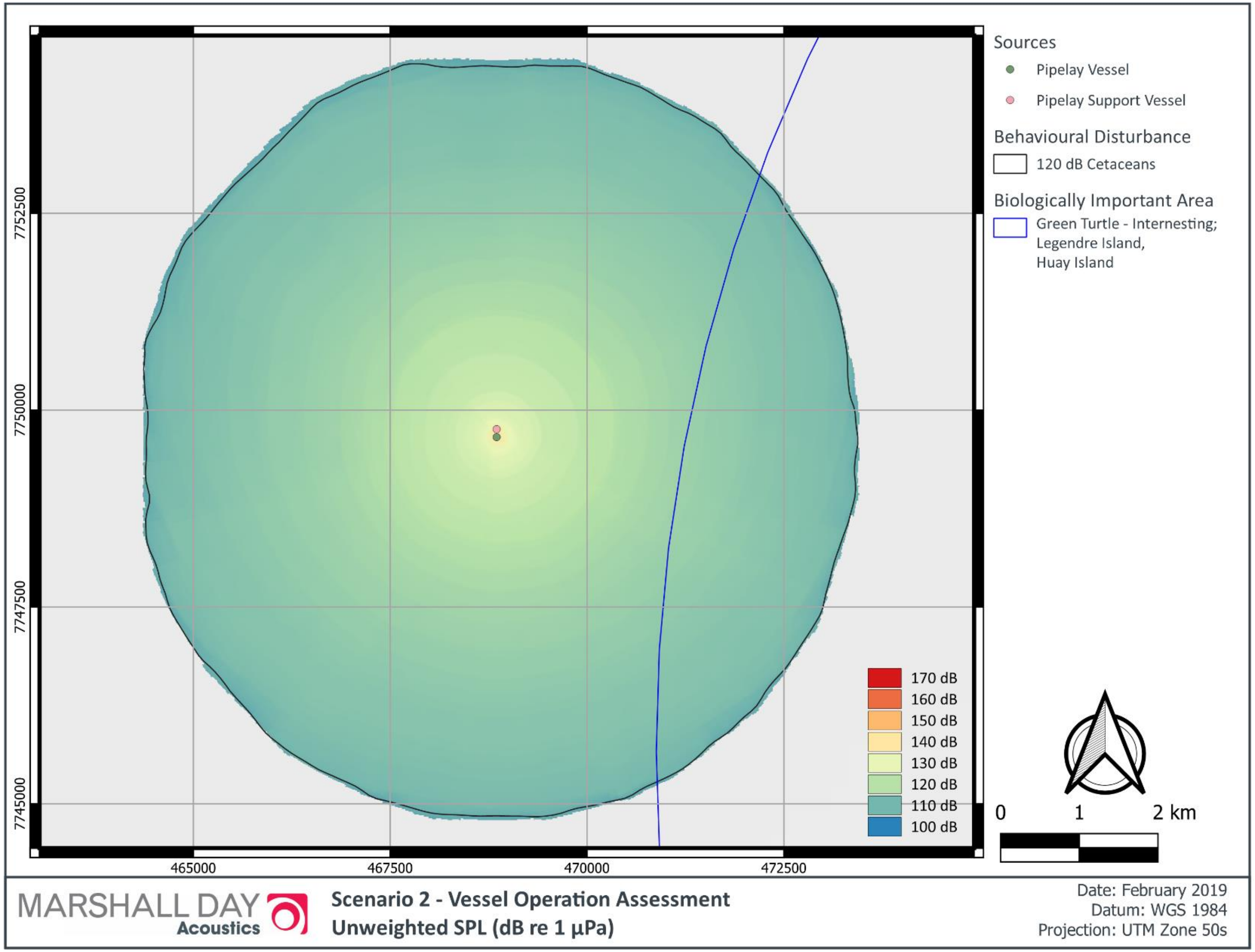


Figure 14: Noise contour map - Scenario 2 $L_{p,rms}$ (un-weighted) maximum over depth



Appendix F

Scarborough Gas Development Cooling Water Discharge Modelling Study

WOODSIDE SCARBOROUGH PROJECT – COOLING WATER DISCHARGE MODELLING

Report

MAW0764J
Woodside Scarborough Project – Cooling Water Discharge Modelling
Rev 2
17 April 2019

www.rpsgroup.com/mst

Document status

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Rev 0	Client review	B. Gómez J. Wynen-Gaugg M. Watt	D. Wright	D. Wright	08/03/2019
Rev 1	Client review	B. Gómez J. Wynen-Gaugg M. Watt	D. Wright	D. Wright	22/03/2019
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Contents

Tables

Figures

EXECUTIVE SUMMARY

RPS was commissioned by Advisian Pty Ltd (Advisian), on behalf of Woodside Energy Ltd (Woodside), to undertake a marine dispersion modelling study of proposed water discharges from the Scarborough Project's Floating Production Unit (FPU).

The Scarborough gas resource, located in Commonwealth waters approximately 375 km off the Burrup Peninsula, forms part of the Greater Scarborough gas fields, comprising the Scarborough, North Scarborough, Thebe and Jupiter gas fields.

As Operator of the Greater Scarborough gas fields, Woodside is proposing to develop the gas resource through new offshore facilities. These will be connected to the mainland through an approximately 430 km trunkline.

The Scarborough Project will involve the processing of hydrocarbons which will result in the production of cooling water (CW).

The principal aim of the study was to quantify the likely extents of the near-field and far-field mixing zones based on the required dilution levels for chlorine in the cooling water (CW) discharge and temperature differential between the discharge and the ambient receiving water. This will indicate whether concentrations of this contaminant and the temperature of the plume are still likely to be above stated threshold levels at the limits of the mixing zones (i.e. are not predicted to be diluted below the relevant threshold).

To accurately determine the dilution of the CW discharge 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 FPU, dispersion modelling was carried out for flow rates of 165,600 m^3/d (45 °C), 64,800 m^3/d (57 °C) and 82,800 m^3/d (60 °C) at discharge depths of 0 m, 10 m and 30 m below the water surface.

The potential area that may be influenced by the CW discharge stream 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

- 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 0 m (Cases C1, C4 and C7), 10 m (Cases C2, C5 and C8) and 30 m (Cases C3, C6 and C9) below the water surface. The surface discharges 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 C1, C4 and C7 (0 m depth discharge), the plume is predicted to plunge up to 14 m below the sea surface, with the highest flow rate yielding the greatest plunge depth due to the vertical orientation of the discharges. For the discharges at depths of 10 m and 30 m, the plumes are predicted

to plunge up to 25 m and 43 m below the sea surface, respectively, with the highest flow rate yielding the greatest plunge depths.

- Increased ambient current strengths are shown to increase the horizontal distance travelled by the plume from the discharge point.
- For a discharge at a 165,600 m^3/d flow rate, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a discharge at 30 m depth as 75.0 m. The dilution level for this case is predicted as 1:52.
- For a discharge at a 64,800 m^3/d flow rate, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a discharge at 30 m depth as 69.7 m. The dilution level for this case is predicted as 1:77.
- For a discharge at an 82,800 m^3/d flow rate, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a discharge at 30 m depth as 59.8 m. The dilution level for this case is predicted as 1:59.
- For a discharge at 0 m depth, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a 165,600 m^3/d flow rate discharge as 5.7 m. The dilution level for this case is predicted as 1:6.
- For a discharge at 10 m depth, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a 165,600 m^3/d flow rate discharge as 11.1 m. The dilution level for this case is predicted as 1:17.
- For a discharge at 30 m depth, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a 165,600 m^3/d flow rate discharge as 24.5 m. The dilution level for this case is predicted as 1:52.
- For each combination of discharge flow rate and depth, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to plunge further and reach the surface (or 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 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.
- The results for each combination of discharge flow rate and depth indicate that the chlorine constituent of the CW discharge is not expected to reach the required levels of dilution in the near field mixing zone.
- The temperature differential between the plume and the ambient water meets the required criterion in all conditions for Cases C2, C3, C6 and C9, and in the stronger-current simulations for Cases C1, C5 and C8. For Cases C4 and C7, however, compliance with the temperature differential criterion is not achieved.
- Some failures to reach the required threshold concentration and temperature are attributable to the plume rapidly breaking the surface.

Far-Field Modelling

- For Cases C1 and C3, dilution to reach threshold concentration is achieved for chlorine within an area of influence extending up to 1.79 km and 2.47 km, respectively, at the 99^{th} percentile. For Cases C4 and C6, the maximum spatial extents of the relevant dilution contour are up to 0.62 km and 0.63 km, respectively, at the 99^{th} percentile.
- For Cases C1 and C3, the areas of exposure defined by the relevant dilution contour are predicted to reach maximums of 4.59 km^2 and 6.56 km^2, respectively, at the 99^{th} percentile. For Cases C4 and C6, the corresponding maximum areas of exposure are up to 0.40 km^2 and 0.68 km^2, respectively, at the 99^{th} percentile.
- Maximum depths reached by. the discharges are predicted as 8 m, 38 m, 6 m and 38 m for Cases C1, C3, C4 and C6, respectively.
- Because the 3 °C plume-ambient temperature differential requirement is forecast to be met within a distance of 115 m at the 99^{th} percentile in any case, the limiting factor for the plume's area of influence will be defined by its chlorine constituent rather than its temperature.

Key Observations

- Due to the similarity in typical magnitude of the hindcast currents throughout the depth range of discharges under consideration, predicted outcomes are broadly similar.
- The greater variability in surface-layer currents may promote the highest levels of mixing and dilution.
- Because the discharge will be initially positively buoyant, it will rise in the water column and may resurface in the vicinity of the discharge point prior to acclimation with ambient receiving water conditions. This outcome is particularly likely for the surface discharge.
- Outcomes show that below-threshold chlorine concentrations are achieved closer to the discharge point for a flow rate of 64,800 m^3/d than for a higher flow rate of 165,600 m^3/d. This is attributable to the fact that initial peak chlorine concentrations in the water column are lower in the former case, which reduces the average concentrations likely to be recorded in each model grid cell during episodes of recirculation and pooling.

1 INTRODUCTION

1.1 Background

RPS was commissioned by Advisian Pty Ltd (Advisian), on behalf of Woodside Energy Ltd (Woodside), to undertake a marine dispersion modelling study of proposed water discharges from the Scarborough Project's Floating Production Unit (FPU).

The Scarborough gas resource, located in Commonwealth waters approximately 375 km off the Burrup Peninsula, forms part of the Greater Scarborough gas fields, comprising the Scarborough, North Scarborough, Thebe and Jupiter gas fields.

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The Scarborough Project will involve the processing of hydrocarbons which will result in the production of cooling water (CW).

The principal aim of the study was to quantify the likely extents of the near-field and far-field mixing zones based on the required dilution levels for chlorine in the cooling water (CW) discharge and temperature differential between the discharge and the ambient receiving water. This will indicate whether concentrations of this contaminant and the temperature of the plume are still likely to be above stated threshold levels at the limits of the mixing zones (i.e. are not predicted to be diluted below the relevant threshold).

To accurately determine the dilution of the CW discharge 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 FPU (location shown in Table 1.1), dispersion modelling was carried out for flow rates of 165,600 m^3/d (45 °C), 64,800 m^3/d (57 °C) and 82,800 m^3/d (60 °C) at discharge depths of 0 m, 10 m and 30 m below the water surface.

The potential area that may be influenced by the CW discharge stream 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 CW discharge characteristics used as input to the modelling are specified in the Model Input Form for this study (Advisian, 2018).

Table 1.1 Location of the proposed FPU used as the release site for the CW dispersion modelling assessment.

Release Site	Latitude (°S)	Longitude (°E)	Water Depth (m)
FPU	19° 53' 54.715"	113° 14' 19.561"	930

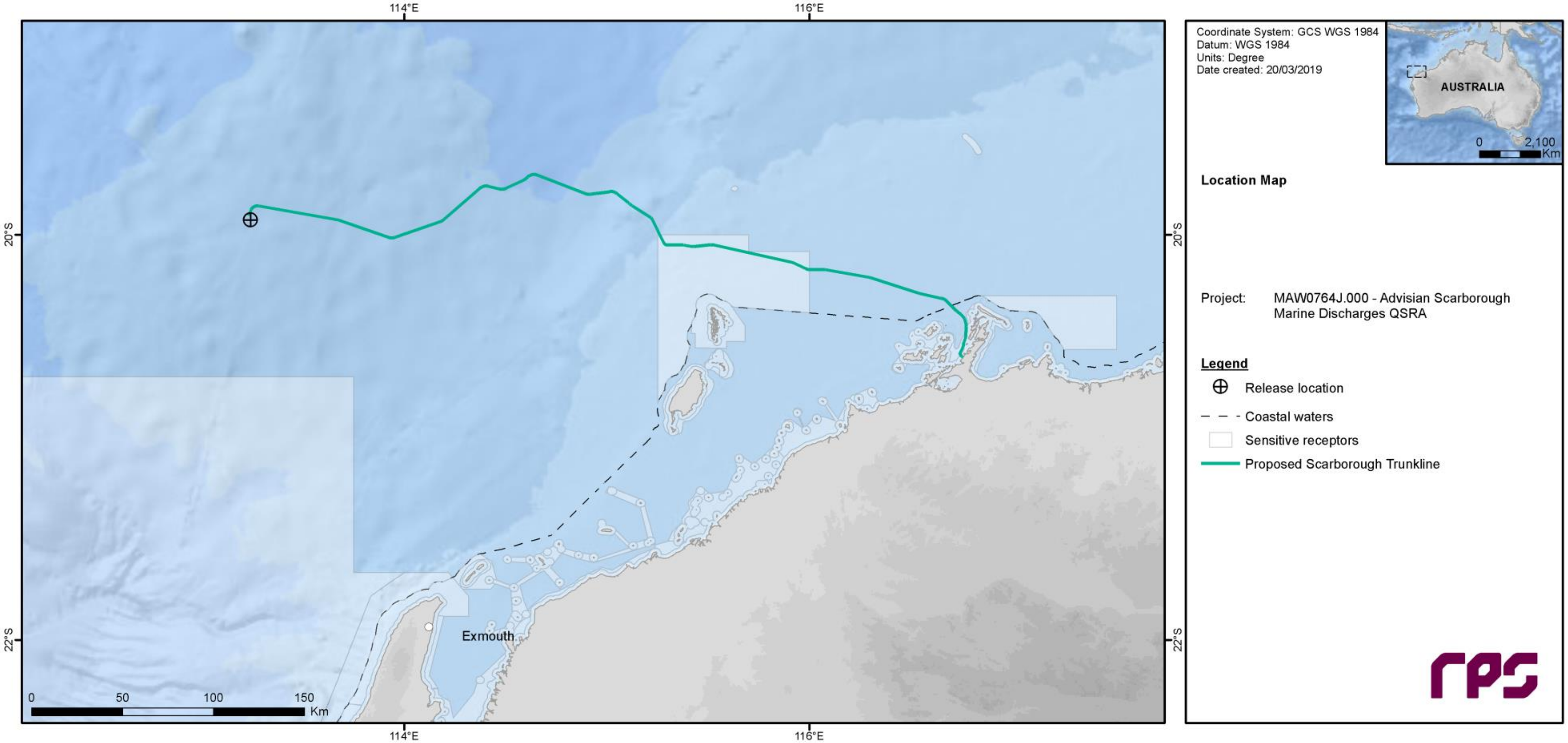


Figure 1.1 Location of the proposed Scarborough trunkline and FPU on the North West Shelf of Australia.

1.2 Modelling Scope

The physical mixing of the CW plume 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 the 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 FPU location 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 Scarborough Project 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 FPU location 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 contaminant 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 water discharges, in terms of the distribution of the maximum contaminant 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 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 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 FPU location.

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 shows a conceptual diagram of the dispersion and fates of a positively buoyant discharge and the idealised representation of the discharge phases.

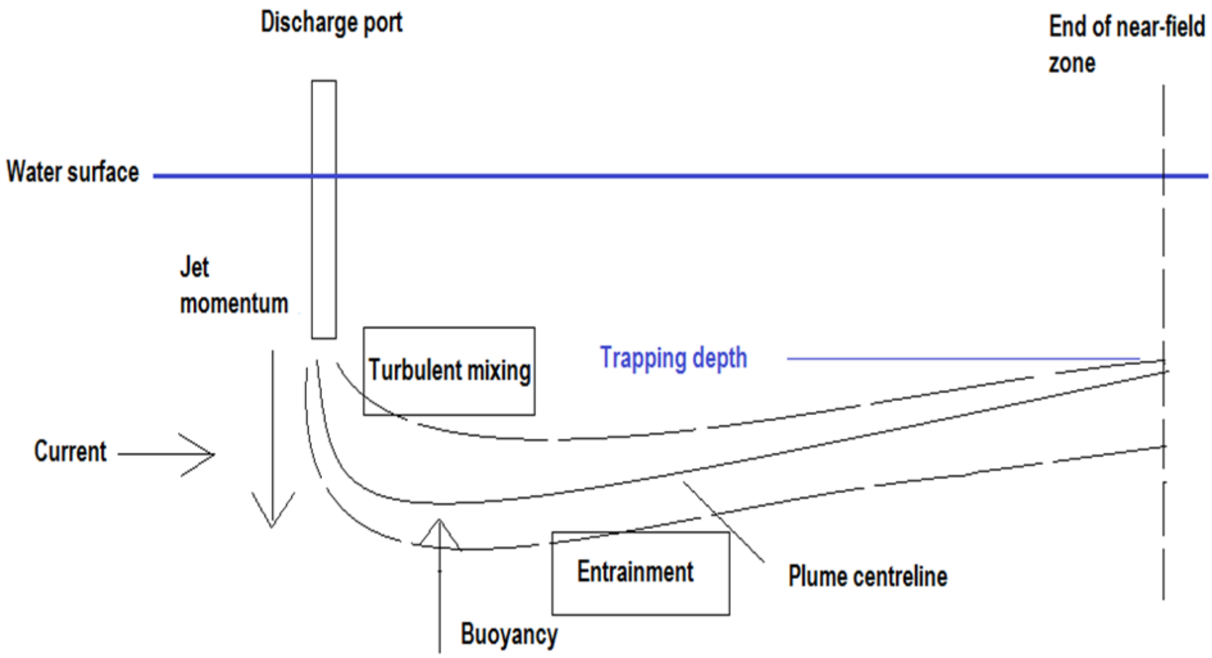


Figure 2.1 Conceptual diagram showing the general behaviour of positively buoyant discharge.

2.1.3 Setup of Near-Field Model

2.1.3.1 Discharge Characteristics

The CW discharge characteristics for Cases C1 to C9 are summarised in Table 2.1.

Cases C1 to C3 were assumed to occur at depths of 0 m below mean sea level (BMSL), 10 m BMSL and 30 m BMSL, respectively. The flow was assumed to occur through a single outlet of 1.4 m diameter at a rate of 165,600 m^3/d and have a salinity and temperature of 35 parts per thousand (ppt) and 45 °C, respectively.

Cases C4 to C6 were assumed to occur at depths of 0 m, 10 m and 30 m BMSL, respectively. The flow was assumed to occur through a single outlet of 1.4 m diameter at a rate of 64,800 m^3/d and have a salinity and temperature of 35 parts per thousand (ppt) and 57 °C, respectively.

Cases C7 to C9 were assumed to occur at depths of 0 m, 10 m and 30 m BMSL, respectively. The flow was assumed to occur through a single outlet of 1.4 m diameter at a rate of 82,800 m^3/d and have a salinity and temperature of 35 parts per thousand (ppt) and 60 °C, respectively.

Concentrations of the constituent of interest (chlorine) within the discharges are described in Table 2.2, along with the required dilution factor to reach the defined threshold concentration (Advisian, 2018).

Table 2.1 Summary of CW discharge characteristics.

Parameter	Case C1	Case C2	Case C3	Case C4	Case C5	Case C6	Case C7	Case C8	Case C9
Flow rate (m^3/d)		165,600			64,800			82,800	
Outlet pipe internal diameter (m) [in]					1.4 [55]				
Outlet pipe orientation					Vertical (downwards)				
Depth of pipe below sea surface (m)	0	10	30	0	10	30	0	10	30
Discharge salinity (ppt)					35				
Discharge temperature (°C)		45 °C			57 °C			60 °C	

Table 2.2 Constituent of interest within the CW discharges and criteria for analysis of exposure.

Constituent/Property	Source Concentration or Temperature	Threshold Concentration or Temperature	Required Dilution Factor
Chlorine	1,000 ppb	5 ppb	200
Temperature	45-60 °C	3 °C above ambient	-

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 plume. 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 2.3 shows the average seasonal water temperature and salinity levels at varying depths from 0 m to 50 m. This data can be considered representative of seasonal conditions at the FPU location.

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 (34.7-34.8 practical salinity unit, PSU), irrespective of season or depth.

Table 2.3 Average temperature and salinity levels adjacent to the proposed FPU location.

Season	Depth (m)	Temperature (°C)	Salinity (PSU)
Summer	0	27.8	34.7
	20	27.3	34.8
	50	26.2	34.8
Transitional	0	26.0	34.7
	20	25.7	34.7
	50	25.1	34.7
Winter	0	26.4	34.7
	20	26.3	34.7
	50	26.2	34.7
Annualised	0	26.6	34.7
	20	26.3	34.7
	50	25.8	34.7

2.1.3.2.2 Ambient Current

Ocean current data was sourced from a 10-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 FPU location.

Table 2.4 presents the steady-state, unidirectional current speeds at varying depths used as input to the near-field model as forcing for each discharge case:

- 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 2.4 Adopted ambient current conditions adjacent to the proposed FPU 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	0.041	0.158	0.326
	22.7	0.049	0.154	0.312
	56.7	0.044	0.138	0.267
Transitional	2.5	0.045	0.177	0.375
	22.7	0.045	0.173	0.369
	56.7	0.043	0.157	0.322
Winter	2.5	0.044	0.172	0.395
	22.7	0.043	0.166	0.375
	56.7	0.039	0.156	0.341
Annualised	2.5	0.043	0.170	0.374
	22.7	0.045	0.164	0.361
	56.7	0.042	0.151	0.320

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 pollutant concentrations in the receiving waters.

2.2.2 Description of Far-Field Model: MUDMAP

The mixing and dispersion of the 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).

2.2.3 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 (25) simulations of a given discharge scenario and season, 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.

2.2.4 Setup of Far-Field Model

2.2.4.1 Discharge Characteristics

The MUDMAP model simulated the discharge into a time-varying current field with the initial dilution set by the near-field results described in Section 2.1.

Four CW discharge scenarios were modelled as a continuous discharge using 25 simulations for each season. 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 discharge characteristics for the selected cases (C1, C3, C4 and C6) are summarised in Table 2.5. These cases were chosen to cover the full range of proposed discharge flow rates and depths.

Table 2.5 Summary of far-field CW discharge modelling assumptions.

Parameter	Case C1	Case C3	Case C4	Case C6
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)	165,600		64,800	
Discharge depth (m)	0	30	0	30
Discharge salinity (ppt)	35			
Discharge temperature (°C)	45 °C		57 °C	
Number of simulations	75 (25 per season)			
Simulated discharge type	Continuous			
Simulated discharge period (days)	5			

2.2.4.2 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 0.15 m^2/s and 0.00005 m^2/s were used to control the spreading of the CW plume 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.

2.2.4.3 Grid Configuration

MUDMAP uses 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 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), which was subdivided horizontally into 1,000 x 1,000 cells. The vertical resolution was set to 2 m.

2.2.5 Regional Ocean Currents

2.2.5.1 Background

The area of interest for this study is typified by strong tidal flows over the shallower regions, particularly along the inshore region of the North West Shelf and among the island groups stretching from the Dampier Archipelago to the North West Cape. However, the 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 slicks over time scales exceeding a few hours.

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. Hence, the current-induced transport of pollutants 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 of pollutants. As measured current data is not available for simultaneous periods over a network of locations covering the wide area of this study, the analysis relied upon hindcasts of the circulation generated by numerical modelling. Estimates of the net currents were derived by combining predictions of the drift currents, available from mesoscale ocean models, with estimates of the tidal currents generated by an RPS model set up for the study area.

2.2.5.2 Mesoscale Circulation Model

Representation of the drift currents that affect the area were available from the output of the BRAN (Bluelink ReANalysis; 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 Commonwealth Scientific and Industrial Research Organisation (CSIRO). 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).

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, time series of current speed and direction were 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.

Figure 2.2 shows the seasonal distribution of current speeds and directions for the BRAN data point closest to the FPU location. Note that the convention for defining current direction is the direction towards which the current flows.

The data shows that current speeds and directions vary between seasons. In general, during transitional months (March and September to November) currents have the strongest average speed (0.22 m/s with a maximum of 0.56 m/s) and tend to flow south-east. During winter (April to August), current flow conditions are more variable, with lower average speed (0.21 m/s with a maximum of 0.53 m/s). During summer (December to February), the current flow occurs in a predominantly south/south-westerly direction with the lowest average speed (0.20 m/s with a maximum of 0.46 m/s).

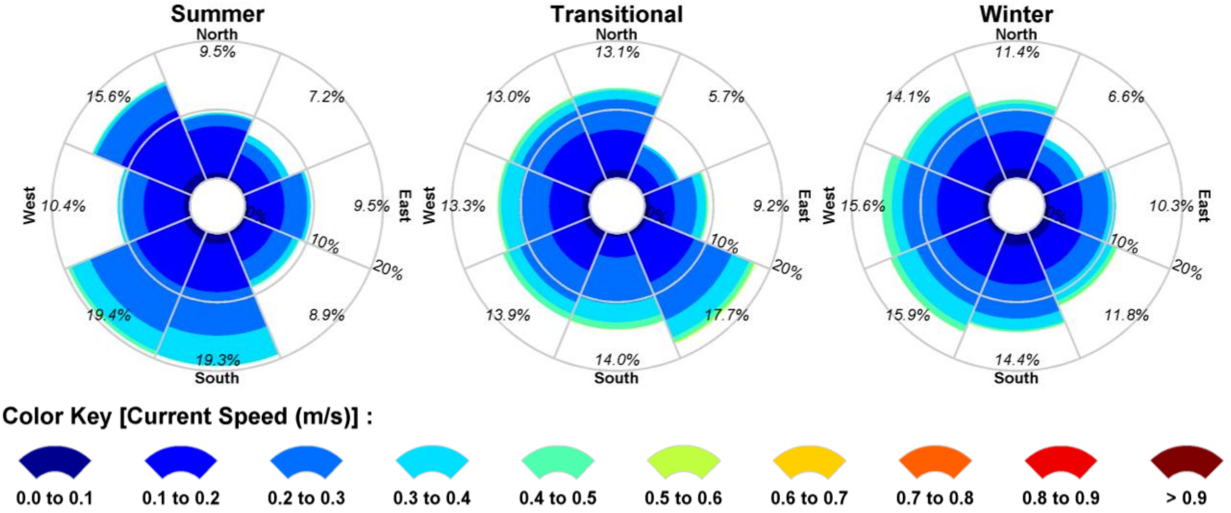


Figure 2.2 Seasonal current distribution (2006-2015, inclusive) derived from the BRAN database near to the proposed FPU location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

2.2.5.3 Tidal Circulation Model

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 25 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).

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 2.3).

Four layers of sub-gridding were 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. Approximately 98,600 cells were used to define the region.

Bathymetric data used to define the three-dimensional shape of the study domain was extracted from the CMAP electronic chart database and 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.

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.

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. Of more than 40 tidal stations within the HYDROMAP model domain, ten were used for comparison.

Water level time series for these locations are shown in Figure 2.4 for a one-month period (January 2005). 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 location. A scatter plot 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) is presented in Figure 2.5. 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 2.6 shows the seasonal distribution of current speeds and directions for the HYDROMAP data point closest to the FPU location. 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 northeast-southwest axis, with maximum speeds of around 0.09 m/s.

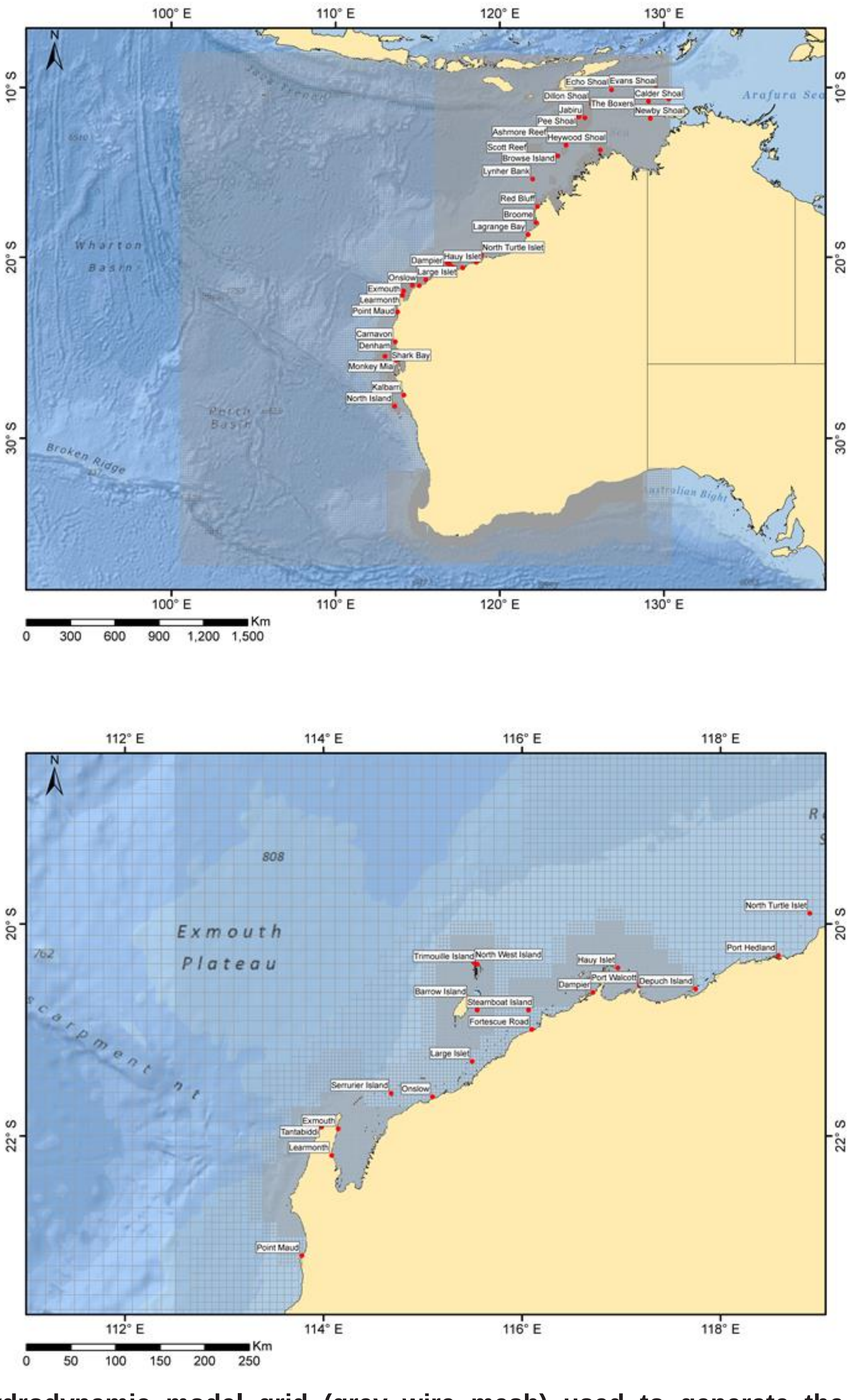


Figure 2.3 **Hydrodynamic model grid (grey wire mesh) used to generate the tidal currents, showing locations available for tidal comparisons (red labelled dots). The top panel shows the full domain in context with the continental land mass, while the bottom panel shows a zoomed subset near the discharge locations. Higher-resolution areas are indicated by the denser mesh zones.**

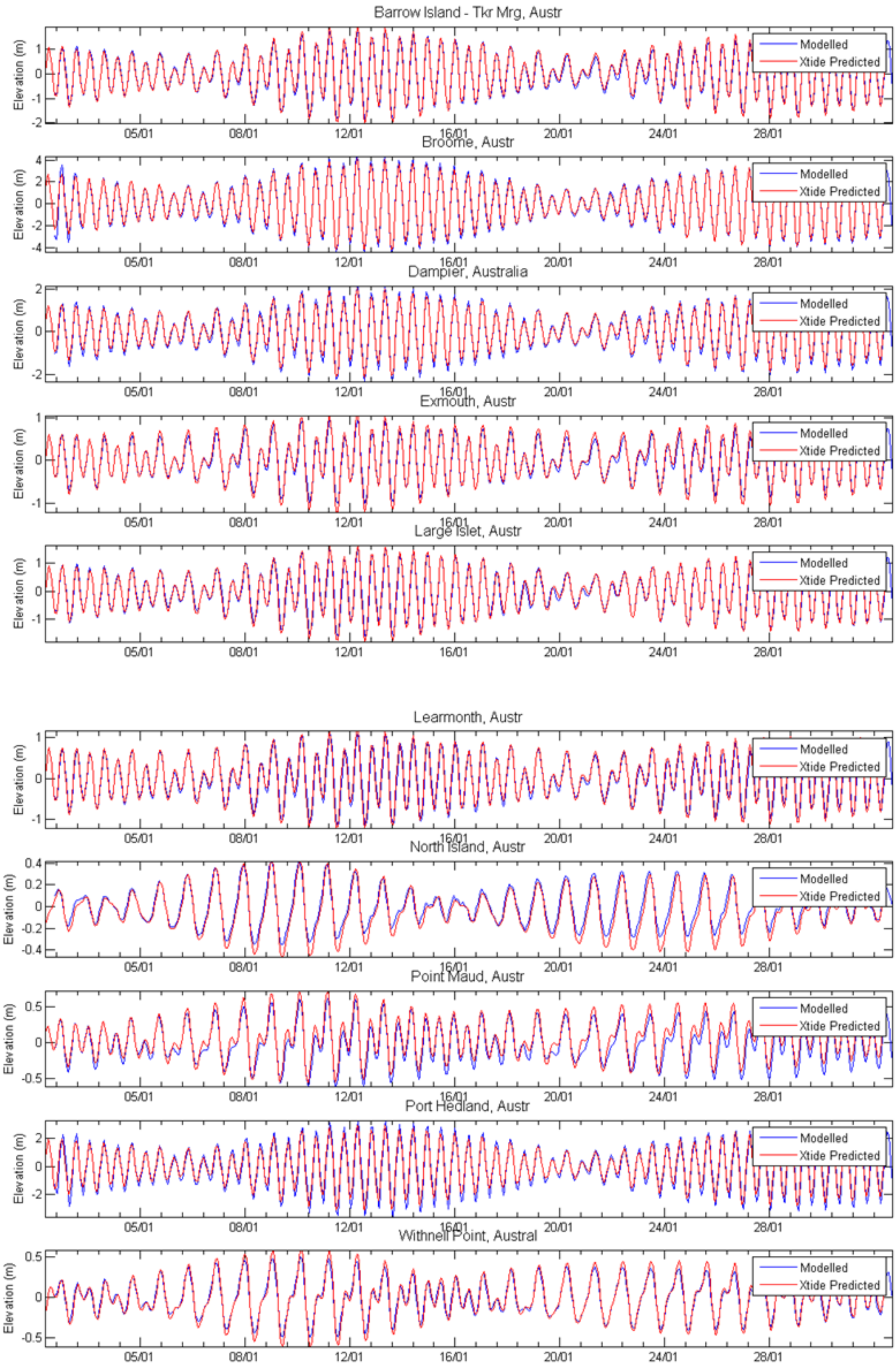
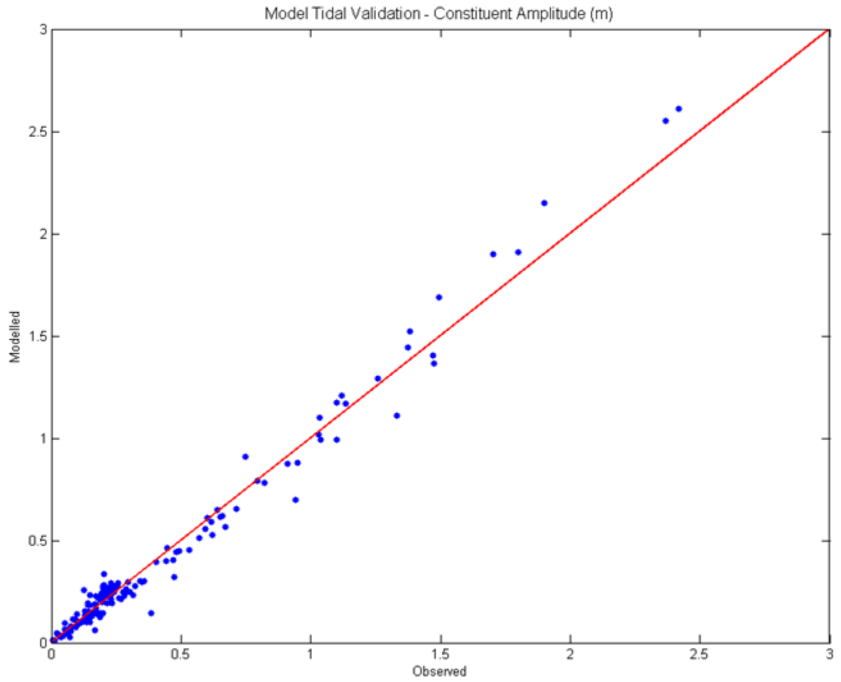


Figure 2.4 Comparisons between the predicted (blue line) and observed (red line) surface elevation variations at ten locations in the tidal model domain for January 2005.



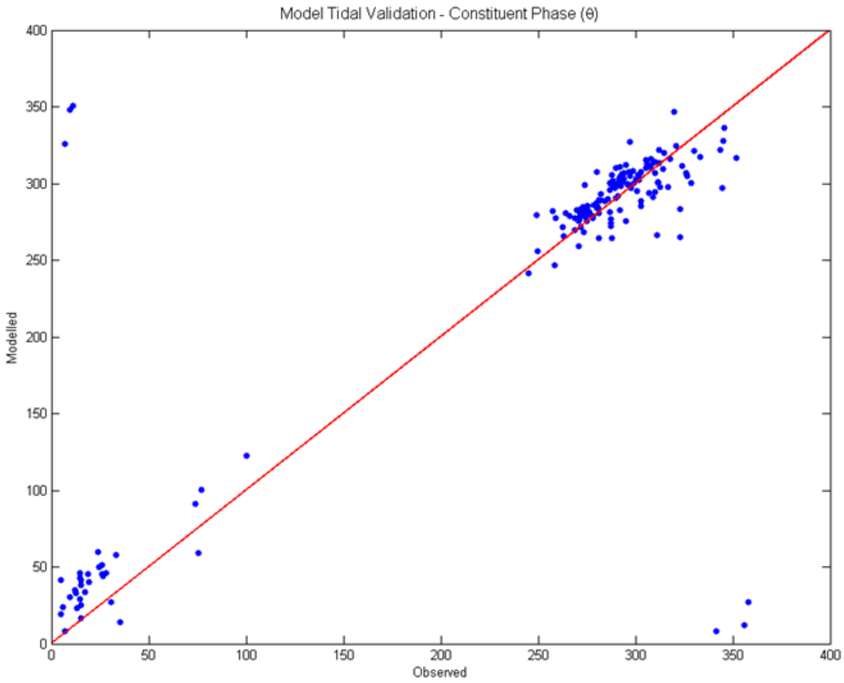


Figure 2.5 Comparisons between modelled and observed tidal constituent amplitudes (top) and phases (bottom) at all stations in the HYDROMAP model domain. The red line indicates a 1:1 correlation between the modelled and observed data.

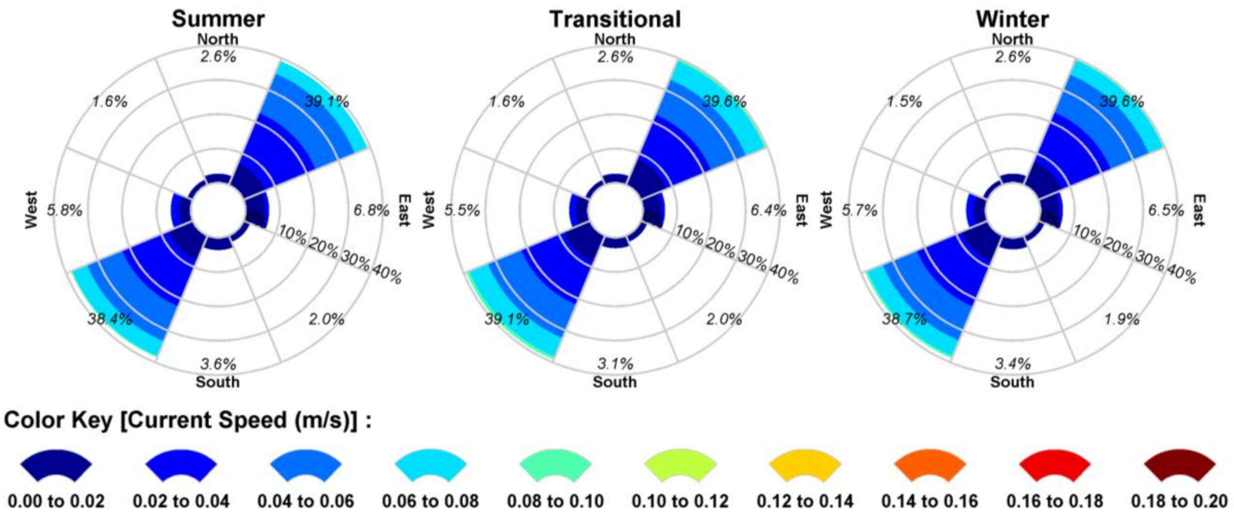


Figure 2.6 Seasonal current distribution (2006-2015, inclusive) derived from the HYDROMAP database near to the proposed FPU location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

3 MODELLING RESULTS

3.1 Near-Field Modelling

3.1.1 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 at the end of the near-field mixing zone, the concentration threshold, and the amount of dilution for each season and for the annual period. Any dilution rates indicated in red show that suitable dilution is not achieved during the near-field stage for at least one current-speed case.

Figure 3.1 to Figure 3.72 (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 (165,600 m^3/day, 64,800 m^3/day and 82,800 m^3/day), depths (0 m, 10 m and 30 m), seasonal conditions (summer, transitional, winter and annual) and current speeds (weak, medium and strong). The figures show the predicted horizontal distances travelled by the plume before the trapping depth is reached (i.e. before the plume becomes neutrally buoyant).

In each figure, the plots have been arranged to: (i) demonstrate the variation in predicted outcomes for the same discharge at different depths under identical current conditions (Sections 3.1.3.1, 3.1.3.2 and 3.1.3.3); and (ii) demonstrate the variation in predicted outcomes for different discharges at the same depth under identical current conditions (Sections 3.1.3.4, 3.1.3.5 and 3.1.3.6).

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 0 m (Cases C1, C4 and C7), 10 m (Cases C2, C5 and C8) and 30 m (Cases C3, C6 and C9) below the water surface. The surface discharges 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 the surface discharges, the plume is predicted to plunge up to 14 m below the sea surface depending on flow rate and season. For the discharges at depths of 10 m and 30 m, the plumes are predicted to plunge up to 25 m and 43 m below the sea surface, respectively, depending on flow rate and season. Increased ambient current strengths are shown to increase the horizontal distance travelled by the plume from the discharge point.

The plume characteristics data for each of the discharge flow rates, depths, seasonal conditions and current speeds show that the plume will reach a maximum horizontal distance of between <1 m and 81 m before surfacing, in the case of the surface discharges, or reaching the trapping depth, in the case of the subsea discharges.

The diameter of the plume at the end of the near-field zone ranged from <1 m to 17 m. Increases in current speed serve to restrict the diameter of the plume.

For most combinations of season, flow rate and discharge depth, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to plunge further and reach the trapping depth closer to the discharge point, which slows the rate of dilution. Note that 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.

The results for each of the discharge flow rates, depths, seasonal conditions and current speeds indicate that the chlorine constituent of the CW discharge is not expected to reach the required levels of dilution in the near field mixing zone. The temperature differential between the plume and the ambient water meets the required criterion in all conditions for Cases C2, C3, C6 and C9, and in the stronger-current simulations for Cases C1, C5 and C8. For Cases C4 and C7, however, compliance with the temperature differential criterion is not achieved. Some failures to reach the required threshold concentration and temperature are attributable to the plume rapidly breaking the surface.

3.1.2 Results – Tables

3.1.2.1 Discharge Case C1: Flow Rate of 165,600 m^3/day at 0 m Depth (Surface)

Table 3.1 Predicted plume characteristics at the end of the near-field mixing zone for the 0 m depth (surface) 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	
Summer	Weak (0.04)	15.2 [6.9]	34.02	6.33	1.4	2.7	0.5
	Medium (0.16)	7.6 [1.9]	30.44	2.64	2.8	6.4	5.6
	Strong (0.33)	8.4 [3.9]	29.72	1.95	2.3	8.8	10.3
Transitional	Weak (0.05)	14.4 [6.6]	33.07	3.16	1.3	2.7	0.5
	Medium (0.18)	7.5 [2.0]	28.97	2.96	2.7	6.3	5.7
	Strong (0.38)	8.0 [3.7]	28.09	2.12	2.2	9.0	10.7
Winter	Weak (0.04)	14.7 [6.7]	33.28	6.97	1.3	2.7	0.5
	Medium (0.17)	7.6 [1.9]	29.27	2.87	2.8	6.4	5.7
	Strong (0.40)	7.9 [3.8]	28.40	2.03	2.2	9.1	11.1
Annual	Weak (0.04)	14.8 [6.7]	33.39	6.88	1.3	2.7	0.5
	Medium (0.17)	7.6 [1.8]	29.43	2.83	2.8	6.4	5.7
	Strong (0.37)	8.0 [3.8]	28.61	2.04	2.2	9.0	10.8

Table 3.2 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the summer season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 2.7, 6.4 and 8.8, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		2.7x Dilution	6.4x Dilution	8.8x Dilution		
Chlorine in Water (ppb)	1,000	370.4	156.3	113.6	5	200
Δ Temperature (°C)	45	6.33	6.24	1.95	3° above ambient	-

Table 3.3 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the transitional season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 2.7, 6.3 and 9.0, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		2.7x Dilution	6.3x Dilution	9.0x Dilution		
Chlorine in Water (ppb)	1,000	370.4	158.7	111.1	5	200
Δ Temperature (°C)	45	3.16	2.96	2.12	3° above ambient	-

Table 3.4 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the winter season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 2.7, 6.4 and 9.1, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		2.7x Dilution	6.4x Dilution	9.1x Dilution		
Chlorine in Water (ppb)	1,000	370.4	156.3	109.9	5	200
Δ Temperature (°C)	45	6.97	2.87	2.03	3° above ambient	-

Table 3.5 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the annual period. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 2.7, 6.4 and 9.0, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		2.7x Dilution	6.4x Dilution	9.0x Dilution		
Chlorine in Water (ppb)	1,000	370.4	156.3	111.1	5	200
Δ Temperature (°C)	45	6.88	2.83	2.04	3° above ambient	-

3.1.2.2 Discharge Case C2: Flow Rate of 165,600 m³/day at 10 m Depth

Table 3.6 Predicted plume characteristics at the end of the near-field mixing zone for the 10 m depth (surface) 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	
Summer	Weak (0.04)	7.5 [0.3]	29.73	1.93	4.3	8.2	2.2
	Medium (0.16)	12.3 [3.5]	28.72	0.95	6.7	15.8	10.6
	Strong (0.33)	15.4 [7.1]	28.13	0.44	9.0	32.4	26.7
Transitional	Weak (0.05)	7.4 [0.1]	28.16	2.16	4.3	8.3	2.3
	Medium (0.18)	12.6 [3.8]	26.98	1.01	6.8	16.8	11.4
	Strong (0.38)	15.2 [7.1]	26.35	0.45	9.6	35.6	30.5
Winter	Weak (0.04)	7.4 [0.2]	28.52	2.12	4.2	8.2	2.3
	Medium (0.17)	12.4 [3.8]	27.38	1.01	6.7	16.4	11.1
	Strong (0.40)	15.1 [7.2]	26.72	0.43	9.9	37.1	32.8
Annual	Weak (0.04)	7.3 [0.3]	28.72	2.12	4.2	8.1	2.2
	Medium (0.17)	12.5 [3.7]	27.56	0.99	6.8	16.5	11.1
	Strong (0.37)	15.2 [7.2]	26.93	0.44	9.6	35.7	30.8

Table 3.7 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the summer season. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 8.2, 15.8 and 32.4, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		8.2x Dilution	15.8x Dilution	32.4x Dilution		
Chlorine in Water (ppb)	1,000	122.0	60.3	30.9	5	200
Δ Temperature (°C)	45	1.93	0.95	0.44	3° above ambient	-

Table 3.8 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the transitional season. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 8.3, 16.8 and 35.6, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		8.3x Dilution	16.8x Dilution	35.6x Dilution		
Chlorine in Water (ppb)	1,000	120.5	59.5	28.1	5	200
Δ Temperature (°C)	45	2.16	1.01	0.45	3° above ambient	-

Table 3.9 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the winter season. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 8.2, 16.4 and 37.1, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		8.2x Dilution	16.4x Dilution	37.1x Dilution		
Chlorine in Water (ppb)	1,000	121.9	60.9	26.9	5	200
Δ Temperature (°C)	45	2.12	1.01	0.43	3° above ambient	-

Table 3.10 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the annual period. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 8.1, 16.5 and 35.7, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		8.1x Dilution	16.5x Dilution	35.7x Dilution		
Chlorine in Water (ppb)	1,000	123.5	60.6	28.0	5	200
Δ Temperature (°C)	45	2.12	0.99	0.44	3° above ambient	-

3.1.2.3 Discharge Case C3: Flow Rate of 165,600 m³/day at 30 m Depth

Table 3.11 Predicted plume characteristics at the end of the near-field mixing zone for the 30 m depth (surface) 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	
Summer	Weak (0.04)	12.7 [0.3]	28.35	0.55	9.8	19.1	4.4
	Medium (0.16)	24.6 [9.2]	27.74	0.11	17.5	49.1	23.2
	Strong (0.33)	28.0 [16.9]	27.45	0.00	27.3	104.1	63.1
Transitional	Weak (0.05)	12.5 [0.6]	26.67	0.67	9.8	19.1	4.6
	Medium (0.18)	25.1 [10.1]	25.97	0.14	18.5	54.4	25.5
	Strong (0.38)	28.4 [16.6]	25.68	0.00	31.9	122.5	76.7
Winter	Weak (0.04)	12.5 [0.7]	27.05	0.65	9.8	19.0	4.5
	Medium (0.17)	25.0 [9.8]	26.36	0.13	18.3	53.1	24.9
	Strong (0.40)	27.8 [17.2]	26.06	0.00	31.9	123.2	80.7
Annual	Weak (0.04)	12.4 [0.8]	27.24	0.64	9.7	18.8	4.4
	Medium (0.17)	24.9 [9.8]	26.56	0.13	18.1	52.2	24.5
	Strong (0.37)	27.9 [17.1]	26.26	0.00	30.7	117.9	75.0

Table 3.12 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the summer season. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 19.1, 49.1 and 104.1, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		19.1x Dilution	49.1x Dilution	104.1x Dilution		
Chlorine in Water (ppb)	1,000	52.4	20.4	9.6	5	200
Δ Temperature (°C)	45	0.55	0.11	0.00	3° above ambient	-

Table 3.13 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the transitional season. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 19.1, 54.4 and 122.5, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		19.1x Dilution	54.4x Dilution	122.5x Dilution		
Chlorine in Water (ppb)	1,000	52.4	18.4	8.2	5	200
Δ Temperature (°C)	45	0.67	0.14	0.00	3° above ambient	-

Table 3.14 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the winter season. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 19.0, 53.1 and 123.2, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		19.0x Dilution	53.1x Dilution	123.2x Dilution		
Chlorine in Water (ppb)	1,000	52.6	18.8	8.1	5	200
Δ Temperature (°C)	45	0.65	0.13	0.00	3° above ambient	-

Table 3.15 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the annual period. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 18.8, 52.2 and 117.9, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		18.8x Dilution	52.2x Dilution	117.9x Dilution		
Chlorine in Water (ppb)	1,000	53.2	19.2	8.5	5	200
Δ Temperature (°C)	45	0.64	0.13	0.00	3° above ambient	-

3.1.2.4 Discharge Case C4: Flow Rate of 64,800 m^3/day at 0 m Depth (Surface)

Table 3.16 Predicted plume characteristics at the end of the near-field mixing zone for the 0 m depth (surface) 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	
Summer	Weak (0.04)	6.5 [0.9]	51.43	23.63	1.0	1.2	<0.1
	Medium (0.16)	3.7 [0.9]	48.64	20.84	1.0	1.4	0.1
	Strong (0.33)	2.7 [0.7]	47.58	19.78	1.0	1.5	0.2
Transitional	Weak (0.05)	6.3 [0.9]	51.18	25.15	1.0	1.2	<0.1
	Medium (0.18)	3.5 [0.8]	48.08	22.08	1.0	1.4	0.1
	Strong (0.38)	2.5 [0.7]	47.42	21.42	1.0	1.4	0.1
Winter	Weak (0.04)	6.4 [0.9]	51.24	24.84	1.0	1.2	<0.1
	Medium (0.17)	3.6 [0.9]	48.21	21.81	1.0	1.4	0.1
	Strong (0.40)	2.4 [0.7]	47.62	21.22	1.0	1.4	0.1
Annual	Weak (0.04)	6.4 [0.9]	51.28	24.68	1.0	1.2	<0.1
	Medium (0.17)	3.6 [0.9]	48.27	21.67	1.0	1.4	0.1
	Strong (0.37)	2.5 [0.7]	47.55	20.95	1.0	1.4	0.1

Table 3.17 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the summer season. Note from Table 3.16 that dilutions at the 5th, 50th and 95th percentile current speeds were 1.2, 1.4 and 1.5, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		1.2x Dilution	1.4x Dilution	1.5x Dilution		
Chlorine in Water (ppb)	1,000	833.3	714.3	666.7	5	200
Δ Temperature (°C)	57	23.63	20.84	19.78	3° above ambient	-

Table 3.18 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the transitional season. Note from Table 3.16 that dilutions at the 5th, 50th and 95th percentile current speeds were 1.2, 1.4 and 1.4, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		1.2x Dilution	1.4x Dilution	1.4x Dilution		
Chlorine in Water (ppb)	1,000	833.3	714.3	714.3	5	200
Δ Temperature (°C)	57	25.15	22.08	21.42	3° above ambient	-

Table 3.19 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the winter season. Note from Table 3.16 that dilutions at the 5th, 50th and 95th percentile current speeds were 1.2, 1.4 and 1.4, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		1.2x Dilution	1.4x Dilution	1.4x Dilution		
Chlorine in Water (ppb)	1,000	833.3	714.3	714.3	5	200
Δ Temperature (°C)	57	25.15	22.08	21.42	3° above ambient	-

Table 3.20 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the annual period. Note from Table 3.16 that dilutions at the 5th, 50th and 95th percentile current speeds were 1.2, 1.4 and 1.5, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		1.2x Dilution	1.4x Dilution	1.5x Dilution		
Chlorine in Water (ppb)	1,000	833.3	714.3	714.3	5	200
Δ Temperature (°C)	57	24.68	21.67	20.95	3° above ambient	-

3.1.2.5 Discharge Case C5: Flow Rate of 64,800 m^3/day at 10 m Depth

Table 3.21 Predicted plume characteristics at the end of the near-field mixing zone for the 10 m depth (surface) 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	
Summer	Weak (0.04)	3.8 [0.1]	32.22	4.42	3.3	6.4	0.7
	Medium (0.16)	6.3 [1.5]	30.11	2.31	5.5	12.1	3.9
	Strong (0.33)	8.8 [4.0]	28.75	0.99	8.0	27.7	11.0
Transitional	Weak (0.05)	3.8 [<0.1]	30.66	4.66	3.4	6.5	0.7
	Medium (0.18)	6.7 [1.8]	28.19	2.19	5.8	13.6	4.3
	Strong (0.38)	9.0 [4.2]	26.86	0.90	8.9	32.3	14.9
Winter	Weak (0.04)	3.8 [0.1]	31.01	4.61	3.4	6.5	0.7
	Medium (0.17)	6.6 [1.7]	28.61	2.21	5.8	13.3	4.3
	Strong (0.40)	9.1 [4.3]	27.18	0.82	9.4	34.6	14.9
Annual	Weak (0.04)	3.8 [0.1]	31.19	4.59	3.3	6.5	0.7
	Medium (0.17)	6.5 [1.7]	28.85	2.25	5.7	13.0	4.2
	Strong (0.37)	9.0 [4.2]	27.44	0.88	8.9	32.3	13.5

Table 3.22 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the summer season. Note from Table 3.21 that dilutions at the 5th, 50th and 95th percentile current speeds were 6.4, 12.1 and 27.7, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		6.4x Dilution	12.1x Dilution	27.7x Dilution		
Chlorine in Water (ppb)	1,000	156.3	82.6	36.1	5	200
Δ Temperature (°C)	57	4.42	2.31	0.99	3° above ambient	-

Table 3.23 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the transitional season. Note from Table 3.21 that dilutions at the 5th, 50th and 95th percentile current speeds were 6.5, 13.6 and 32.3, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		6.5x Dilution	13.6x Dilution	32.3x Dilution		
Chlorine in Water (ppb)	1,000	153.8	73.5	30.9	5	200
Δ Temperature (°C)	57	4.66	2.19	0.90	3° above ambient	-

Table 3.24 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the winter season. Note from Table 3.21 that dilutions at the 5th, 50th and 95th percentile current speeds were 6.5, 13.3 and 34.6, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		6.5x Dilution	13.3x Dilution	34.6x Dilution		
Chlorine in Water (ppb)	1,000	153.8	75.2	28.9	5	200
Δ Temperature (°C)	57	4.61	2.21	0.82	3° above ambient	-

Table 3.25 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the annual period. Note from Table 3.21 that dilutions at the 5th, 50th and 95th percentile current speeds were 6.6, 13.0 and 32.3, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		6.6x Dilution	13.0x Dilution	32.3x Dilution		
Chlorine in Water (ppb)	1,000	151.5	76.9	31.0	5	200
Δ Temperature (°C)	57	4.59	2.25	0.88	3° above ambient	-

3.1.2.6 Discharge Case C6: Flow Rate of 64,800 m^3/day at 30 m Depth

Table 3.26 Predicted plume characteristics at the end of the near-field mixing zone for the 30 m depth (surface) 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	
Summer	Weak (0.04)	8.9 [0.5]	28.72	0.92	12.7	24.6	2.8
	Medium (0.16)	18.1 [6.7]	27.92	0.22	25.0	69.2	16.2
	Strong (0.33)	24.0 [11.9]	27.57	0.00	51.5	196.6	57.1
Transitional	Weak (0.05)	9.0 [0.3]	26.98	0.98	13.0	25.4	3.1
	Medium (0.18)	19.2 [7.8]	26.10	0.22	27.1	80.6	18.9
	Strong (0.38)	24.3 [12.1]	25.78	0.00	59.6	229.7	70.9
Winter	Weak (0.04)	9.0 [0.2]	27.36	0.96	13.0	25.3	3.0
	Medium (0.17)	18.9 [7.5]	26.51	0.23	26.5	77.5	18.1
	Strong (0.40)	23.6 [12.8]	26.16	0.00	59.1	228.3	73.4
Annual	Weak (0.04)	8.9 [0.6]	27.58	0.98	12.7	24.8	2.9
	Medium (0.17)	18.9 [7.3]	26.71	0.22	26.5	76.8	18.0
	Strong (0.37)	24.0 [12.3]	26.37	0.00	58.2	224.0	69.7

Table 3.27 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the summer season. Note from Table 3.26 that dilutions at the 5th, 50th and 95th percentile current speeds were 24.6, 69.2 and 196.6, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		24.6x Dilution	69.2x Dilution	196.6x Dilution		
Chlorine in Water (ppb)	1,000	40.7	14.5	5.1	5	200
Δ Temperature (°C)	57	0.92	0.22	0.00	3° above ambient	-

Table 3.28 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the transitional season. Note from Table 3.26 that dilutions at the 5th, 50th and 95th percentile current speeds were 25.4, 80.6 and 229.7, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		25.4x Dilution	80.6x Dilution	229.7x Dilution		
Chlorine in Water (ppb)	1,000	39.4	12.4	4.4	5	200
Δ Temperature (°C)	57	0.98	0.22	0.00	3° above ambient	-

Table 3.29 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the winter season. Note from Table 3.26 that dilutions at the 5th, 50th and 95th percentile current speeds were 25.3, 77.5 and 228.3, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		25.3x Dilution	77.5x Dilution	228.3x Dilution		
Chlorine in Water (ppb)	1,000	39.5	12.9	4.4	5	200
Δ Temperature (°C)	57	0.96	0.23	0.00	3° above ambient	-

Table 3.30 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the annual period. Note from Table 3.26 that dilutions at the 5th, 50th and 95th percentile current speeds were 24.8, 76.8 and 224.0, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		24.8x Dilution	76.8x Dilution	224.0x Dilution		
Chlorine in Water (ppb)	1,000	40.3	13.0	4.5	5	200
Δ Temperature (°C)	57	0.98	0.22	0.00	3° above ambient	-

3.1.2.7 Discharge Case C7: Flow Rate of 82,800 m^3/day at 0 m Depth (Surface)

Table 3.31 Predicted plume characteristics at the end of the near-field mixing zone for the 0 m depth (surface) 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	
Summer	Weak (0.04)	7.5 [1.3]	52.22	24.42	1.0	1.3	<0.1
	Medium (0.16)	4.4 [1.2]	49.01	21.21	1.0	1.5	0.2
	Strong (0.33)	3.2 [1.0]	46.97	19.17	1.0	1.7	0.3
Transitional	Weak (0.05)	7.2 [1.3]	51.92	25.92	1.0	1.3	<0.1
	Medium (0.18)	4.1 [1.2]	48.24	22.24	1.0	1.5	0.2
	Strong (0.38)	3.0 [0.1]	46.45	20.45	1.0	1.7	0.3
Winter	Weak (0.04)	7.3 [1.3]	51.99	25.59	1.0	1.3	<0.1
	Medium (0.17)	4.2 [1.2]	48.43	22.03	1.0	1.5	0.2
	Strong (0.40)	2.9 [0.9]	46.55	20.15	1.0	1.7	0.3
Annual	Weak (0.04)	7.4 [1.3]	52.03	25.43	1.0	1.3	<0.1
	Medium (0.17)	4.2 [1.2]	48.51	21.91	1.0	1.5	0.2
	Strong (0.37)	3.0 [1.0]	46.58	19.98	1.0	1.7	0.3

Table 3.32 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the summer season. Note from Table 3.31 that dilutions at the 5th, 50th and 95th percentile current speeds were 1.3, 1.5 and 1.7, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		1.3x Dilution	1.5x Dilution	1.7x Dilution		
Chlorine in Water (ppb)	1,000	769.2	666.7	588.2	5	200
Δ Temperature (°C)	60	24.42	21.21	19.17	3° above ambient	-

Table 3.33 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the transitional season. Note from Table 3.31 that dilutions at the 5th, 50th and 95th percentile current speeds were 1.3, 1.5 and 1.7, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		1.3x Dilution	1.5x Dilution	1.7x Dilution		
Chlorine in Water (ppb)	1,000	769.2	666.7	588.2	5	200
Δ Temperature (°C)	57	25.92	22.24	20.45	3° above ambient	-

Table 3.34 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the winter season. Note from Table 3.31 that dilutions at the 5th, 50th and 95th percentile current speeds were 1.3, 1.5 and 1.7, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		1.3x Dilution	1.5x Dilution	1.7x Dilution		
Chlorine in Water (ppb)	1,000	769.2	666.7	588.2	5	200
Δ Temperature (°C)	60	25.59	22.03	20.15	3° above ambient	-

Table 3.35 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the annual period. Note from Table 3.31 that dilutions at the 5th, 50th and 95th percentile current speeds were 1.3, 1.5 and 1.7, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		1.3x Dilution	1.5x Dilution	1.7x Dilution		
Chlorine in Water (ppb)	1,000	769.2	666.7	588.2	5	200
Δ Temperature (°C)	60	25.43	21.91	19.98	3° above ambient	-

3.1.2.8 Discharge Case C8: Flow Rate of 82,800 m³/day at 10 m Depth

Table 3.36 Predicted plume characteristics at the end of the near-field mixing zone for the 10 m depth (surface) 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	
Summer	Weak (0.04)	4.1 [<0.1]	32.77	4.97	3.3	6.3	0.7
	Medium (0.16)	6.3 [1.3]	30.65	2.85	5.1	10.9	3.7
	Strong (0.33)	9.1 [3.9]	29.04	1.28	7.1	27.3	10.2
Transitional	Weak (0.05)	4.1 [0.1]	31.30	5.30	3.2	6.3	0.7
	Medium (0.18)	6.7 [1.6]	28.76	2.76	5.3	11.8	4.2
	Strong (0.38)	9.3 [4.2]	27.13	1.17	7.8	27.5	12.4
Winter	Weak (0.04)	4.1 [0.1]	31.65	5.25	3.2	6.2	0.7
	Medium (0.17)	6.6 [1.6]	29.20	2.80	5.2	11.6	4.1
	Strong (0.40)	9.3 [4.4]	27.45	1.09	8.0	28.9	13.4
Annual	Weak (0.04)	4.1 [0.1]	31.84	5.24	3.2	6.2	0.7
	Medium (0.17)	6.5 [1.5]	29.41	2.81	5.2	11.5	4.0
	Strong (0.37)	9.3 [4.3]	27.71	1.15	7.7	27.3	12.3

Table 3.37 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the summer season. Note from Table 3.36 that dilutions at the 5th, 50th and 95th percentile current speeds were 6.3, 10.9 and 27.3, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		6.3x Dilution	10.9x Dilution	27.3x Dilution		
Chlorine in Water (ppb)	1,000	158.7	91.7	36.6	5	200
Δ Temperature (°C)	60	4.97	2.85	1.28	3° above ambient	-

Table 3.38 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the transitional season. Note from Table 3.36 that dilutions at the 5th, 50th and 95th percentile current speeds were 6.3, 11.8 and 27.5, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		6.3x Dilution	11.8x Dilution	27.5x Dilution		
Chlorine in Water (ppb)	1,000	158.7	84.7	36.4	5	200
Δ Temperature (°C)	60	5.30	2.76	1.17	3° above ambient	-

Table 3.39 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the winter season. Note from Table 3.36 that dilutions at the 5th, 50th and 95th percentile current speeds were 6.2, 11.6 and 28.9, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		6.2x Dilution	11.6x Dilution	28.9x Dilution		
Chlorine in Water (ppb)	1,000	161.3	86.2	34.6	5	200
Δ Temperature (°C)	60	5.25	2.80	1.09	3° above ambient	-

Table 3.40 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the annual period. Note from Table 3.36 that dilutions at the 5th, 50th and 95th percentile current speeds were 6.2, 11.5 and 27.3, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		6.2x Dilution	11.5x Dilution	27.3x Dilution		
Chlorine in Water (ppb)	1,000	161.3	86.9	36.6	5	200
Δ Temperature (°C)	60	5.24	2.81	1.15	3° above ambient	-

3.1.2.9 Discharge Case C9: Flow Rate of 82,800 m^3/day at 30 m Depth

Table 3.41 Predicted plume characteristics at the end of the near-field mixing zone for the 30 m depth (surface) 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	
Summer	Weak (0.04)	9.1 [0.1]	28.94	1.14	11.7	22.7	2.6
	Medium (0.16)	17.0 [5.7]	28.10	0.38	21.4	53.9	14.1
	Strong (0.33)	24.0 [11.7]	27.63	0.05	41.6	155.6	47.2
Transitional	Weak (0.05)	9.1 [0.1]	27.22	1.22	11.9	23.0	2.8
	Medium (0.18)	18.4 [6.7]	26.25	0.35	23.3	63.6	16.6
	Strong (0.38)	24.7 [11.9]	25.83	0.04	49.1	187.1	60.1
Winter	Weak (0.04)	9.0 [0.5]	27.63	1.23	11.6	22.5	2.7
	Medium (0.17)	18.0 [6.4]	26.67	0.36	22.8	60.9	16.0
	Strong (0.40)	24.6 [12.1]	26.21	0.03	51.1	195.6	65.0
Annual	Weak (0.04)	9.1 [0.1]	27.80	1.20	11.8	22.9	2.7
	Medium (0.17)	17.8 [6.4]	26.88	0.37	22.4	59.2	15.5
	Strong (0.37)	24.6 [11.2]	26.41	0.03	48.7	185.7	59.8

Table 3.42 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the summer season. Note from Table 3.41 that dilutions at the 5th, 50th and 95th percentile current speeds were 22.7, 53.9 and 155.6, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		22.7x Dilution	53.9x Dilution	155.6x Dilution		
Chlorine in Water (ppb)	1,000	44.1	18.6	6.4	5	200
Δ Temperature (°C)	60	1.14	0.38	0.05	3° above ambient	-

Table 3.43 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the transitional season. Note from Table 3.41 that dilutions at the 5th, 50th and 95th percentile current speeds were 23.0, 63.6 and 187.1, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		23.0x Dilution	63.6x Dilution	187.1x Dilution		
Chlorine in Water (ppb)	1,000	43.5	15.7	5.3	5	200
Δ Temperature (°C)	60	1.22	0.35	0.04	3° above ambient	-

Table 3.44 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the winter season. Note from Table 3.41 that dilutions at the 5th, 50th and 95th percentile current speeds were 22.5, 60.9 and 195.6, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		22.5x Dilution	60.9x Dilution	195.6x Dilution		
Chlorine in Water (ppb)	1,000	44.4	16.4	5.1	5	200
Δ Temperature (°C)	60	1.23	0.36	0.03	3° above ambient	-

Table 3.45 Concentration of chlorine and plume-ambient temperature difference at the end of the near-field stage, the required concentration and temperature threshold, and the number of dilutions for the annual period. Note from Table 3.41 that dilutions at the 5th, 50th and 95th percentile current speeds were 22.9, 59.2 and 185.7, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration or Temperature	End of Near-Field Concentration or ΔT			Threshold Concentration or Temperature	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		22.9x Dilution	59.2x Dilution	185.7x Dilution		
Chlorine in Water (ppb)	1,000	43.7	16.9	5.4	5	200
Δ Temperature (°C)	60	1.20	0.37	0.03	3° above ambient	-

3.1.3 Results – Figures

3.1.3.1 Discharge Flow Rate of 165,600 m^3/day at Varying Depths

3.1.3.1.1 Annualised

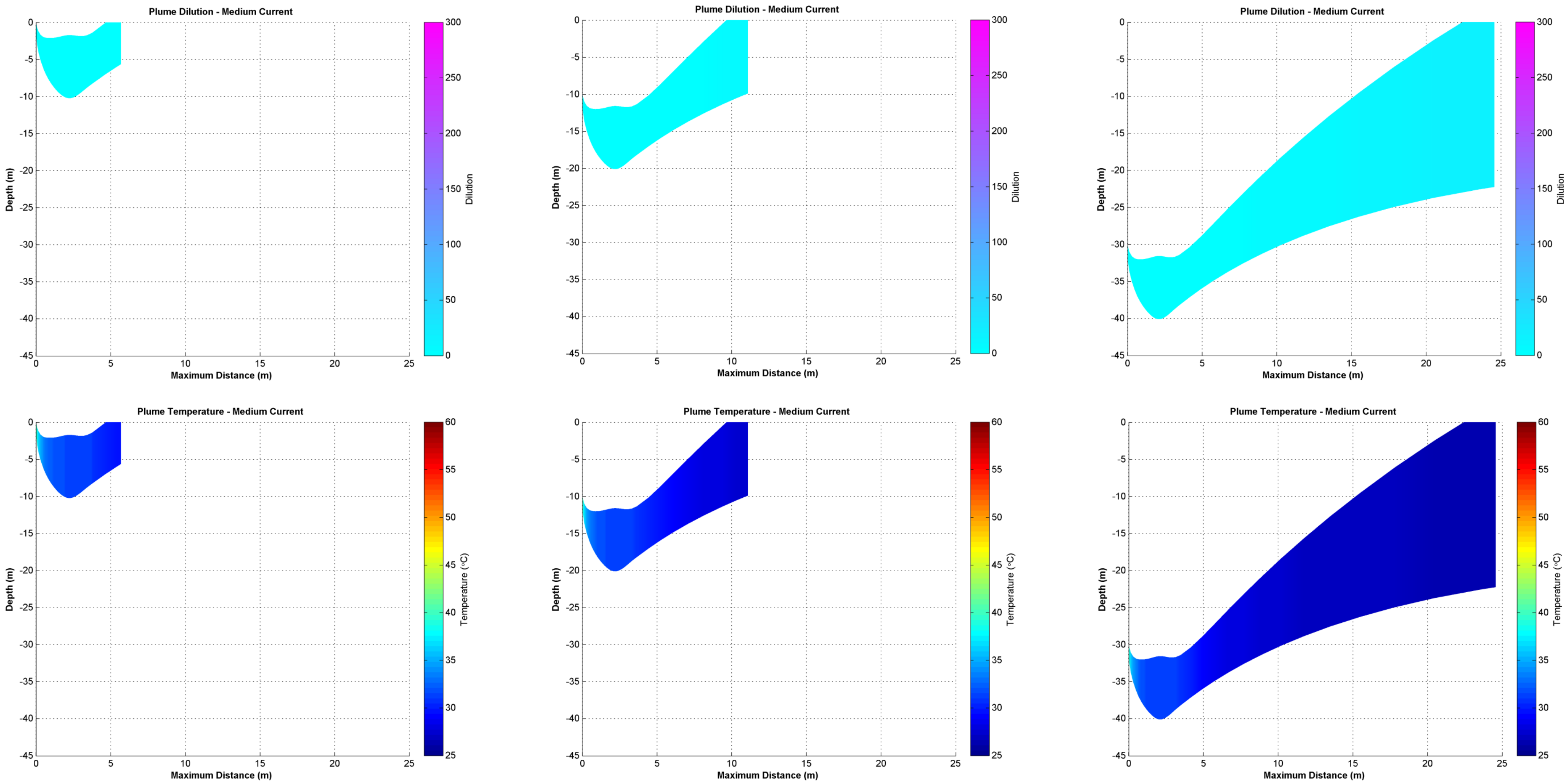


Figure 3.1 **Near-field average dilution and temperature results for constant medium annualised currents with a discharge flow rate of 165,600 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).**

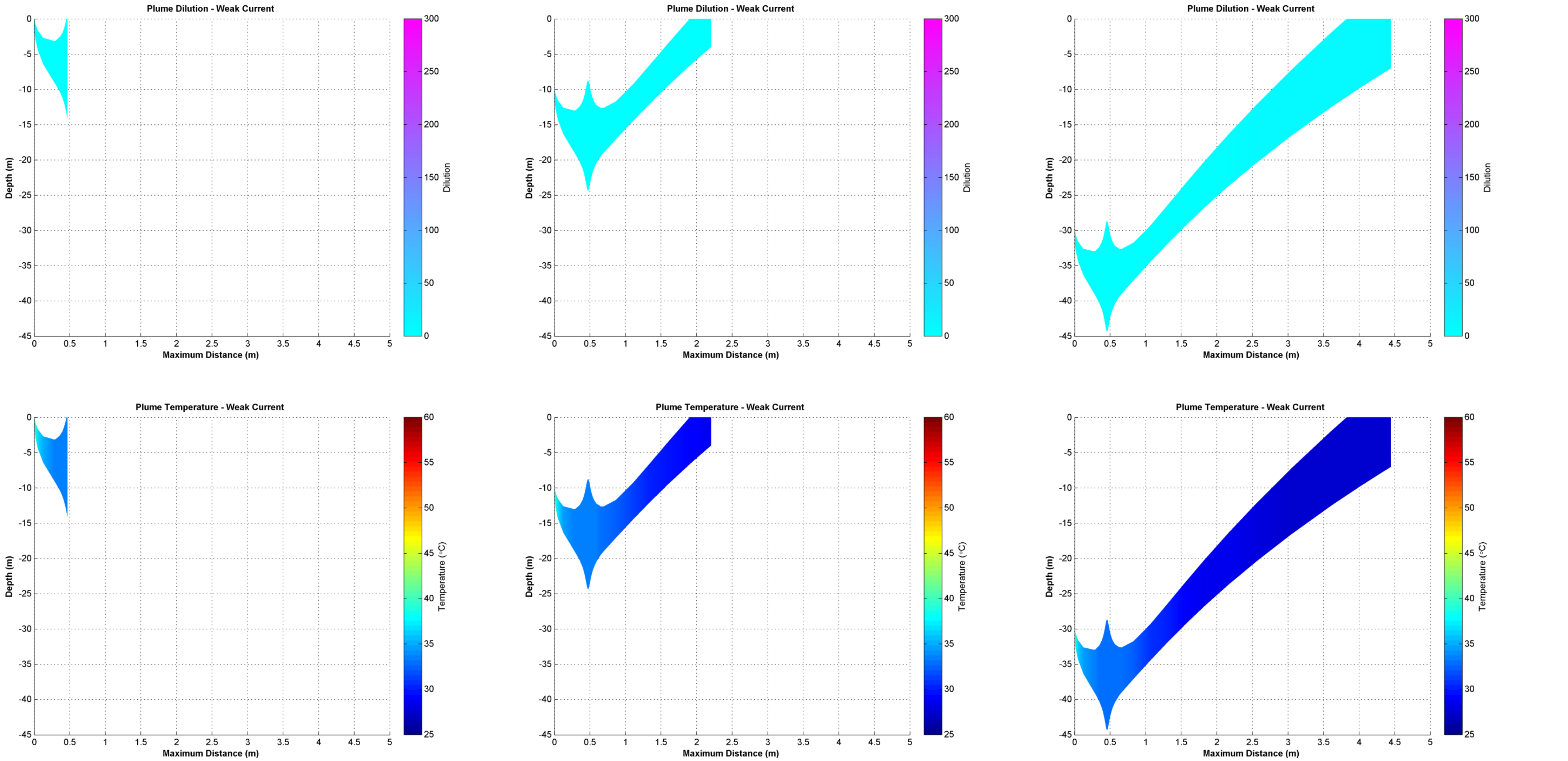


Figure 3.2 Near-field average dilution and temperature results for constant weak annualised currents with a discharge flow rate of 165,600 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

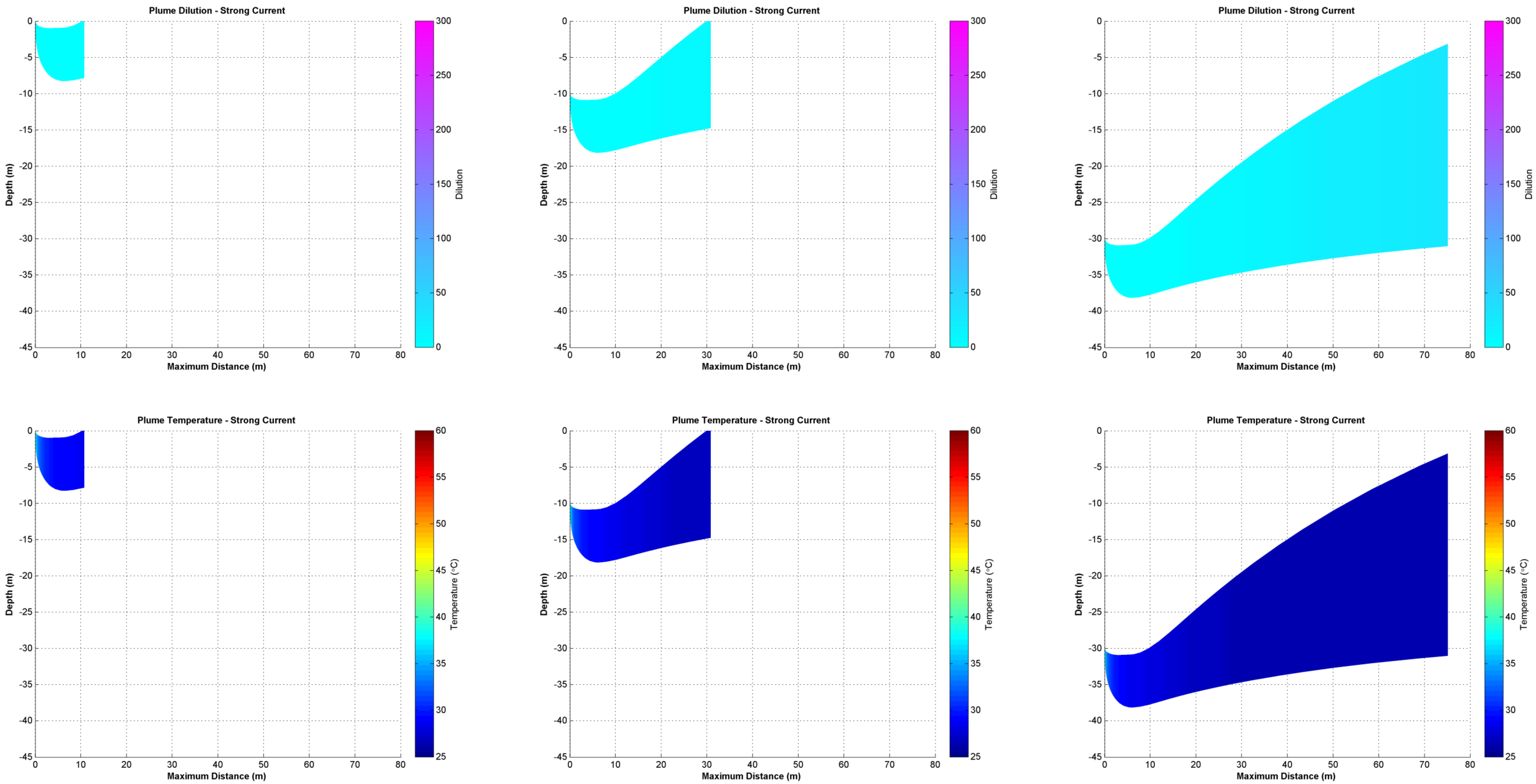


Figure 3.3 Near-field average dilution and temperature results for constant strong annualised currents with a discharge flow rate of 165,600 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

3.1.3.1.2 Summer

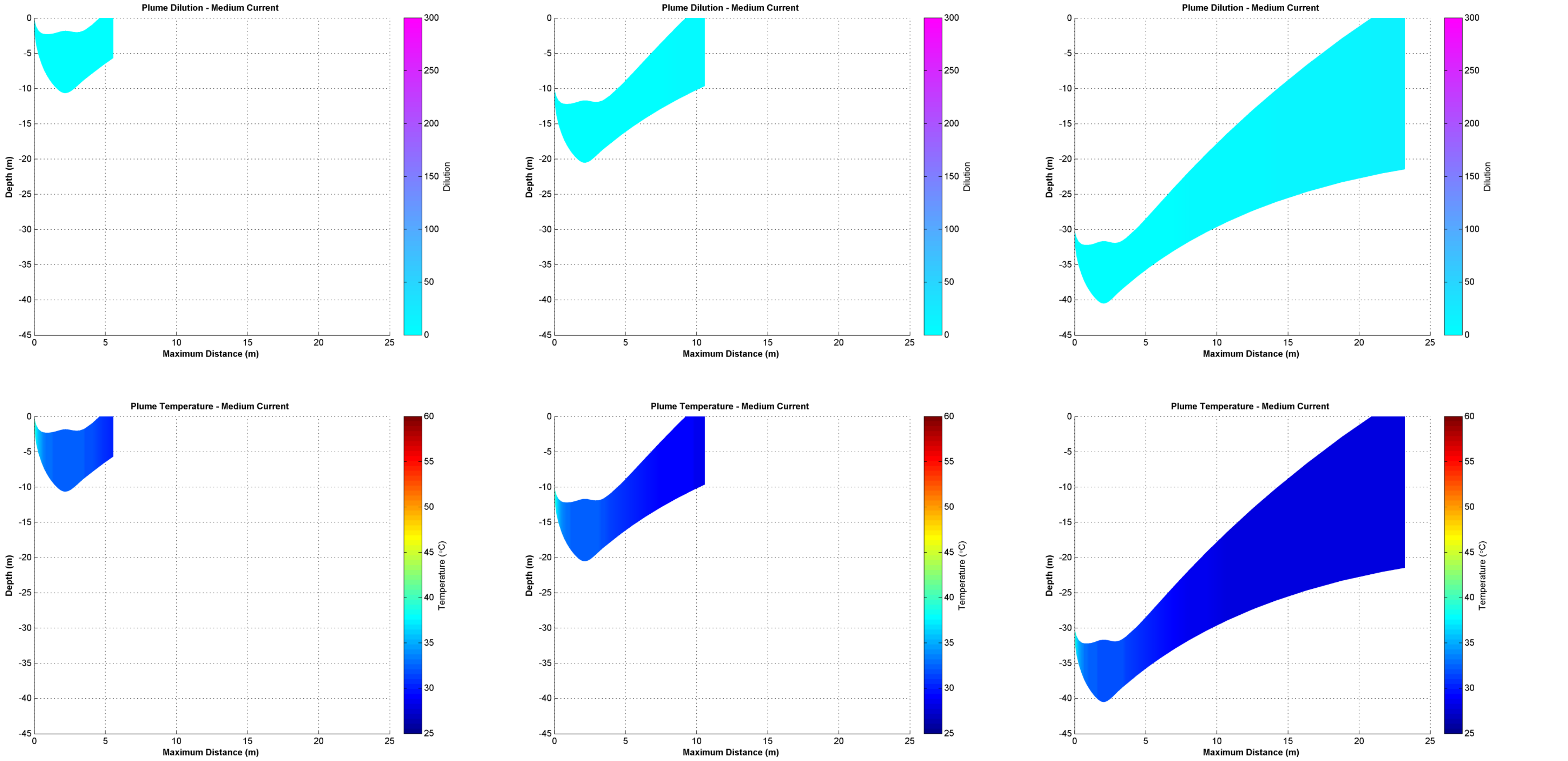


Figure 3.4 Near-field average dilution and temperature results for constant medium summer currents with a discharge flow rate of 165,600 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

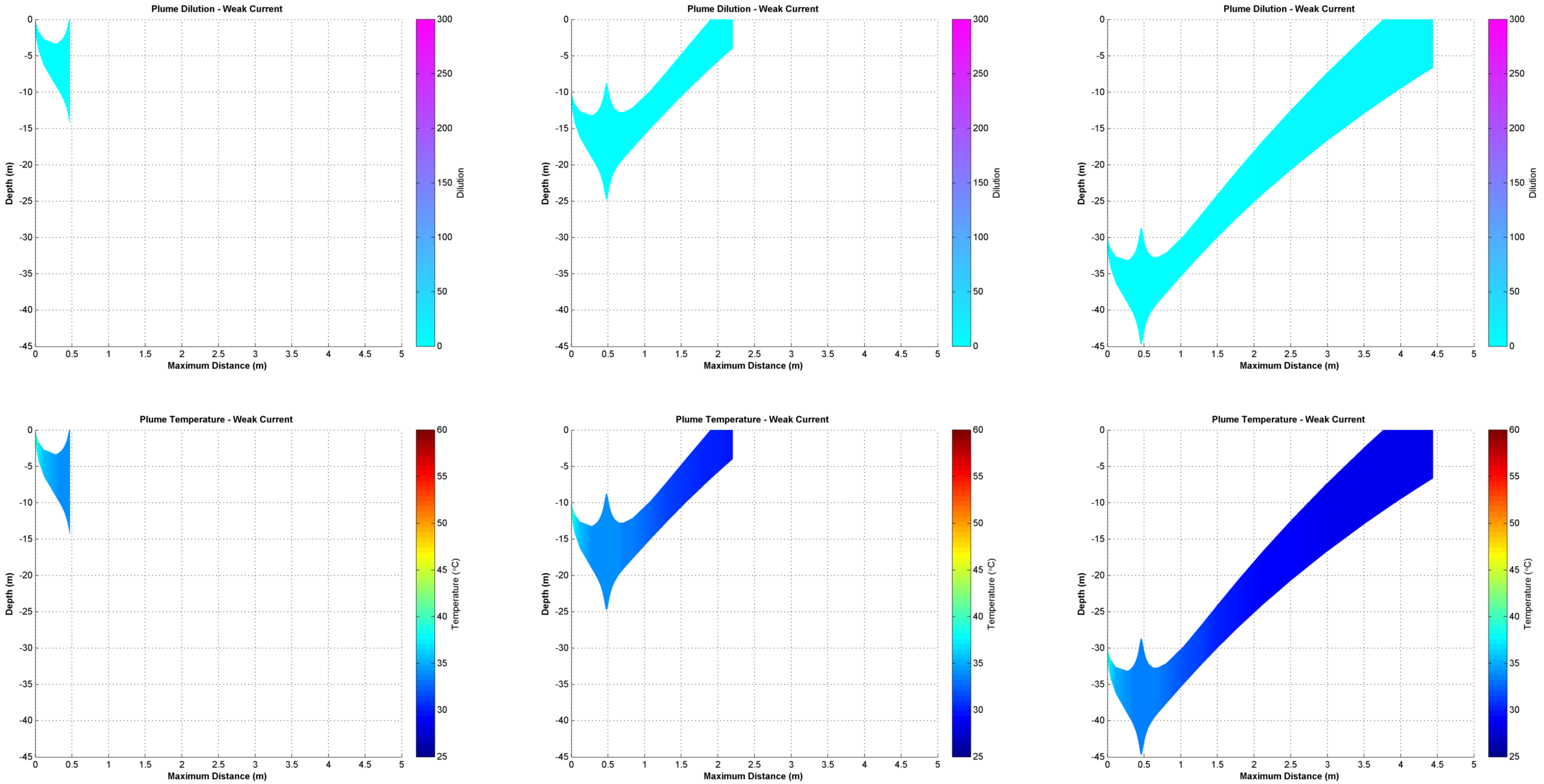


Figure 3.5 **Near-field average dilution and temperature results for constant weak summer currents with a discharge flow rate of 165,600 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).**

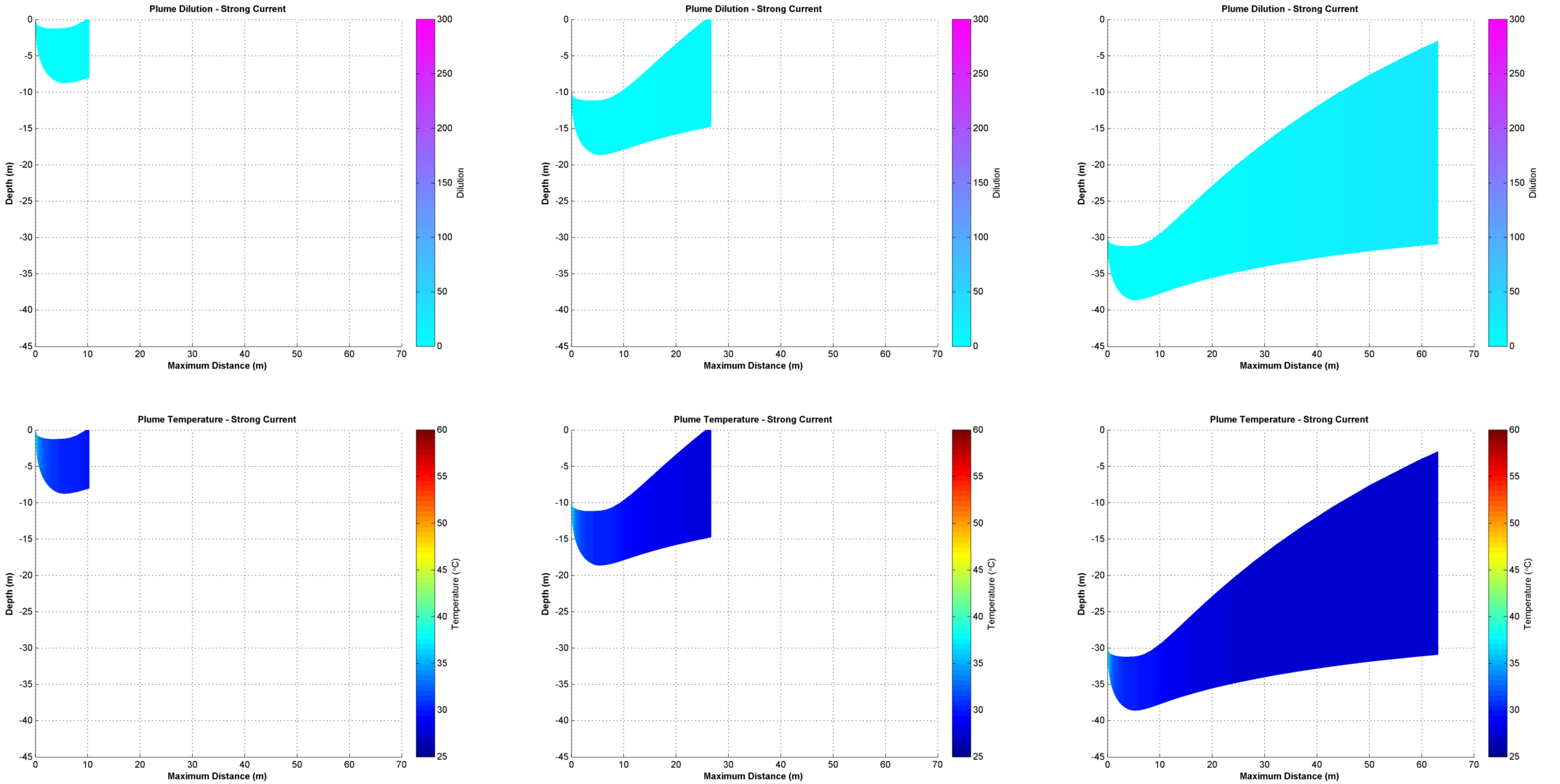


Figure 3.6 **Near-field average dilution and temperature results for constant strong summer currents with a discharge flow rate of 165,600 m³/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).**

3.1.3.1.3 Transitional

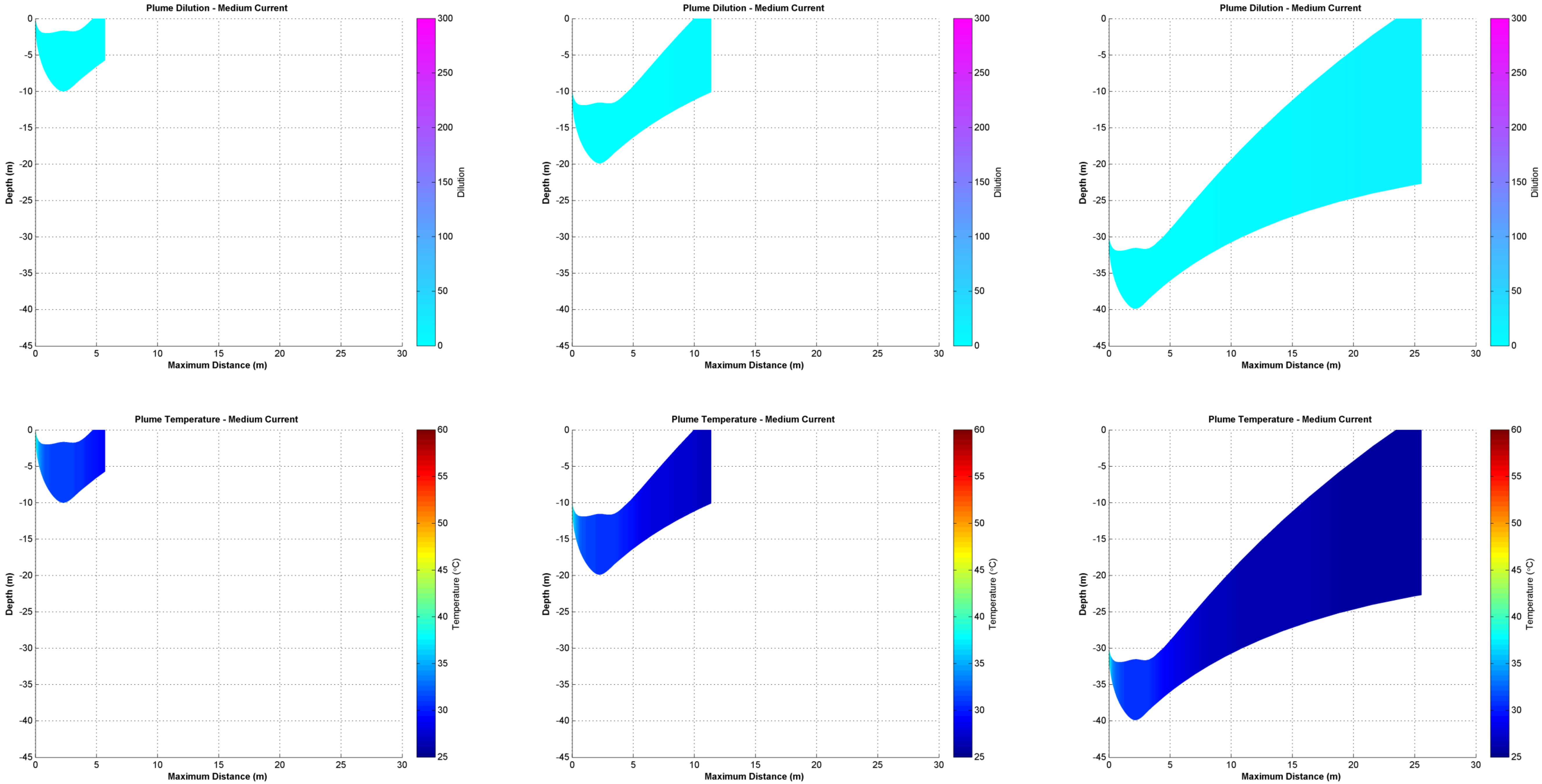


Figure 3.7 Near-field average dilution and temperature results for constant medium transitional currents with a discharge flow rate of 165,600 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

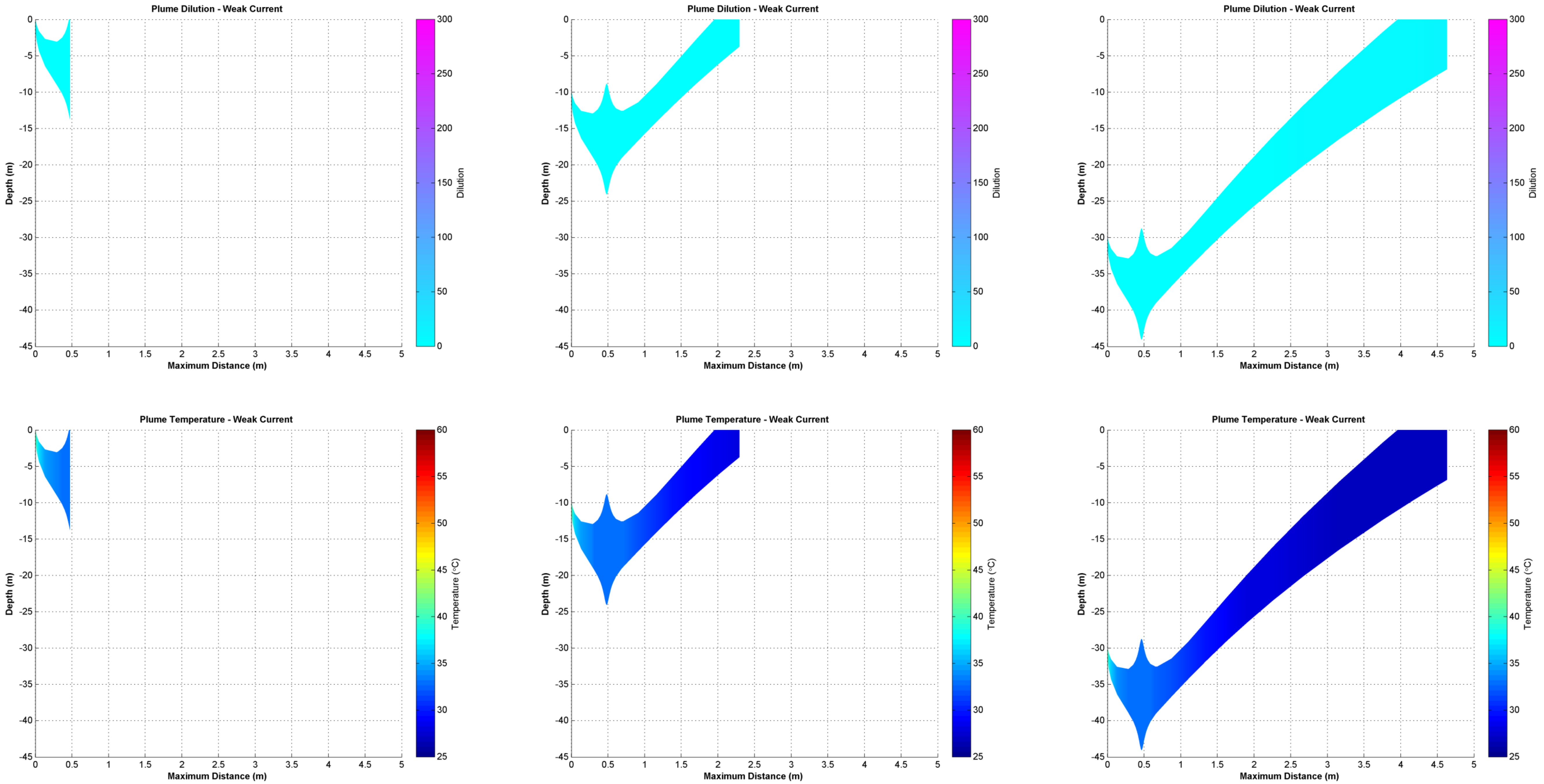


Figure 3.8 **Near-field average dilution and temperature results for constant weak transitional currents with a discharge flow rate of 165,600 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).**

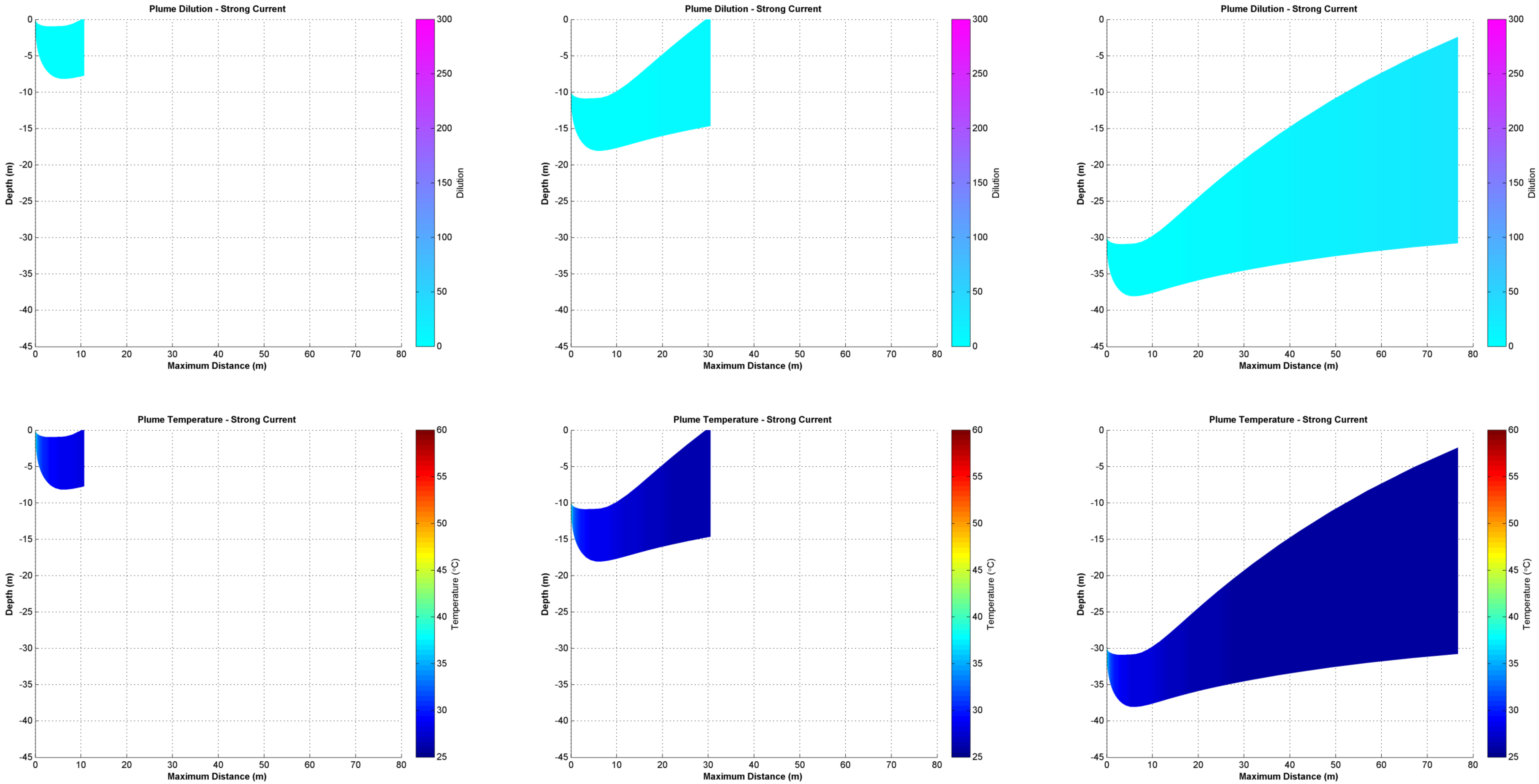


Figure 3.9 **Near-field average dilution and temperature results for constant strong transitional currents with a discharge flow rate of 165,600 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).**

3.1.3.1.4 Winter

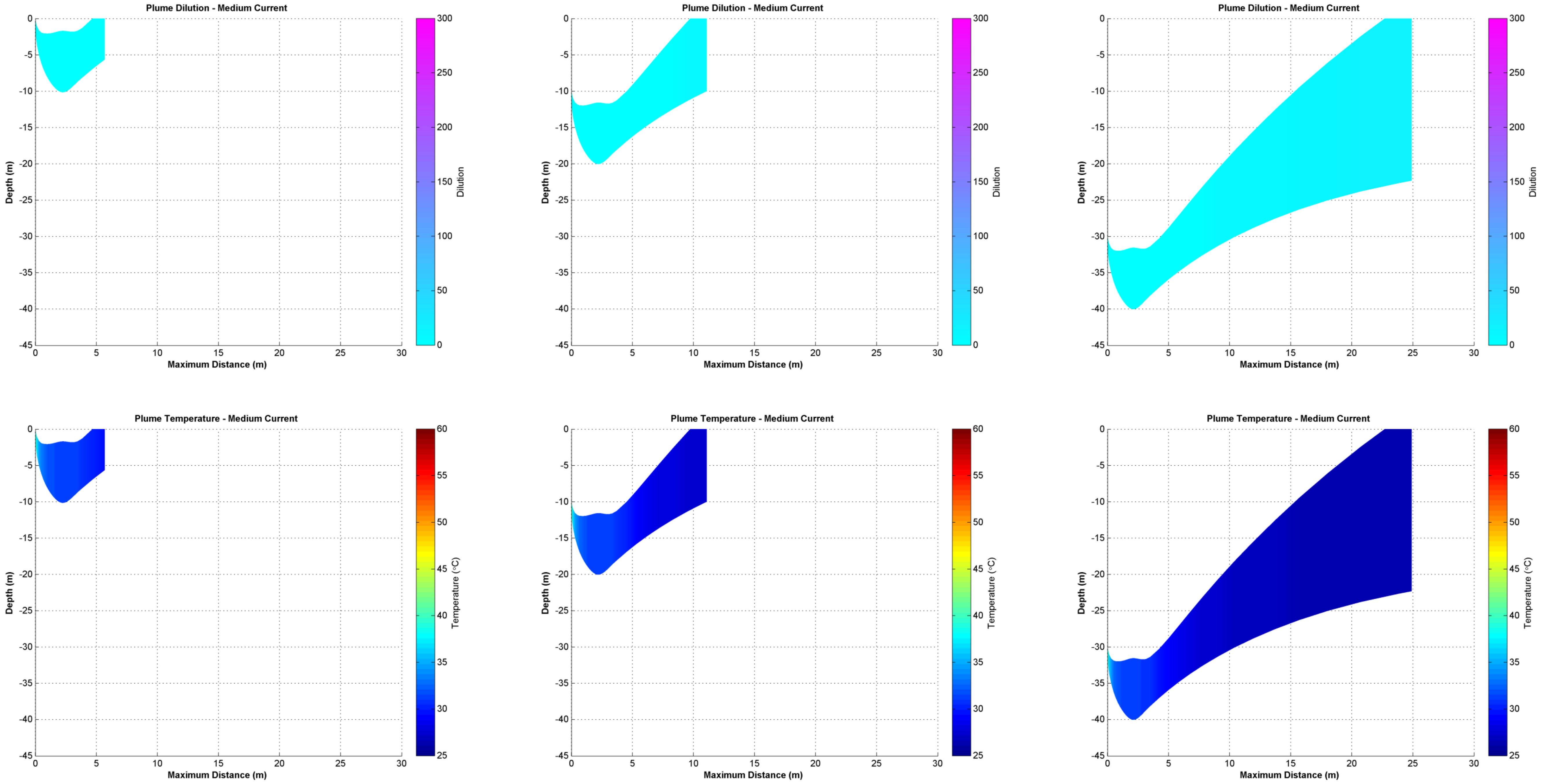


Figure 3.10 Near-field average dilution and temperature results for constant medium winter currents with a discharge flow rate of 165,600 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

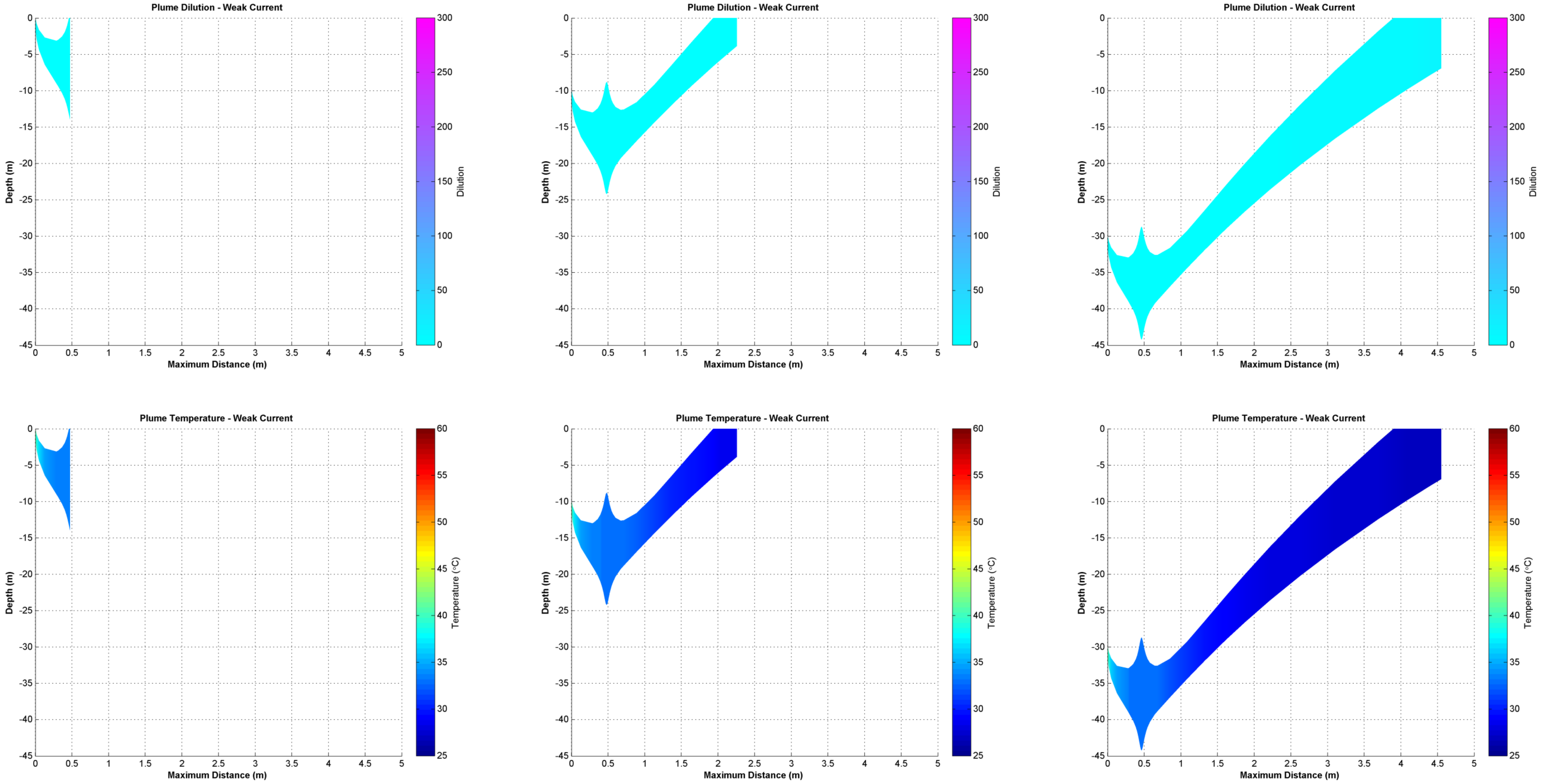


Figure 3.11 Near-field average dilution and temperature results for constant weak winter currents with a discharge flow rate of 165,600 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

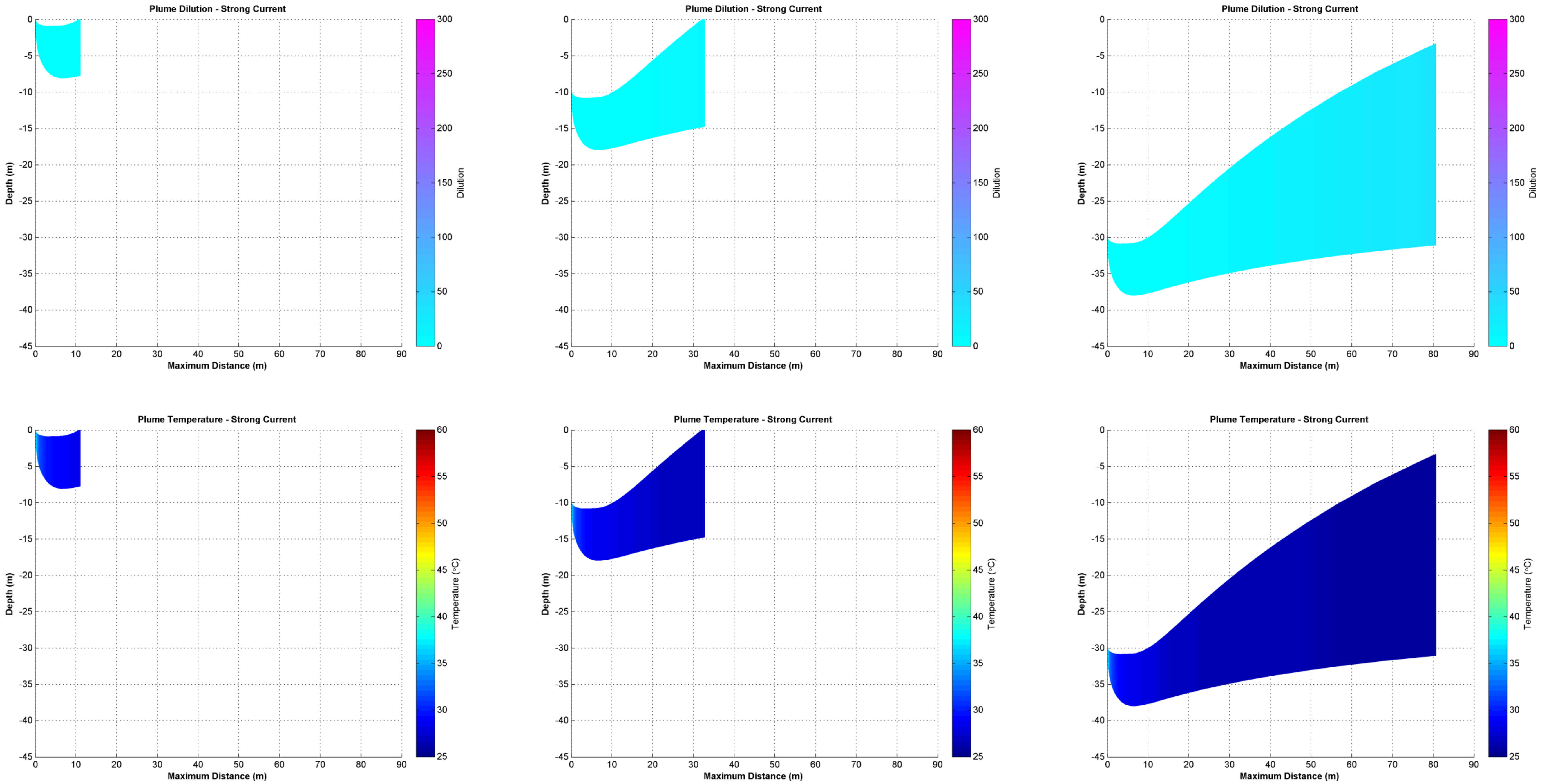


Figure 3.12 Near-field average dilution and temperature results for constant strong winter currents with a discharge flow rate of 165,600 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

3.1.3.2 Discharge Flow Rate of 64,800 m³/day at Varying Depths

3.1.3.2.1 Annualised

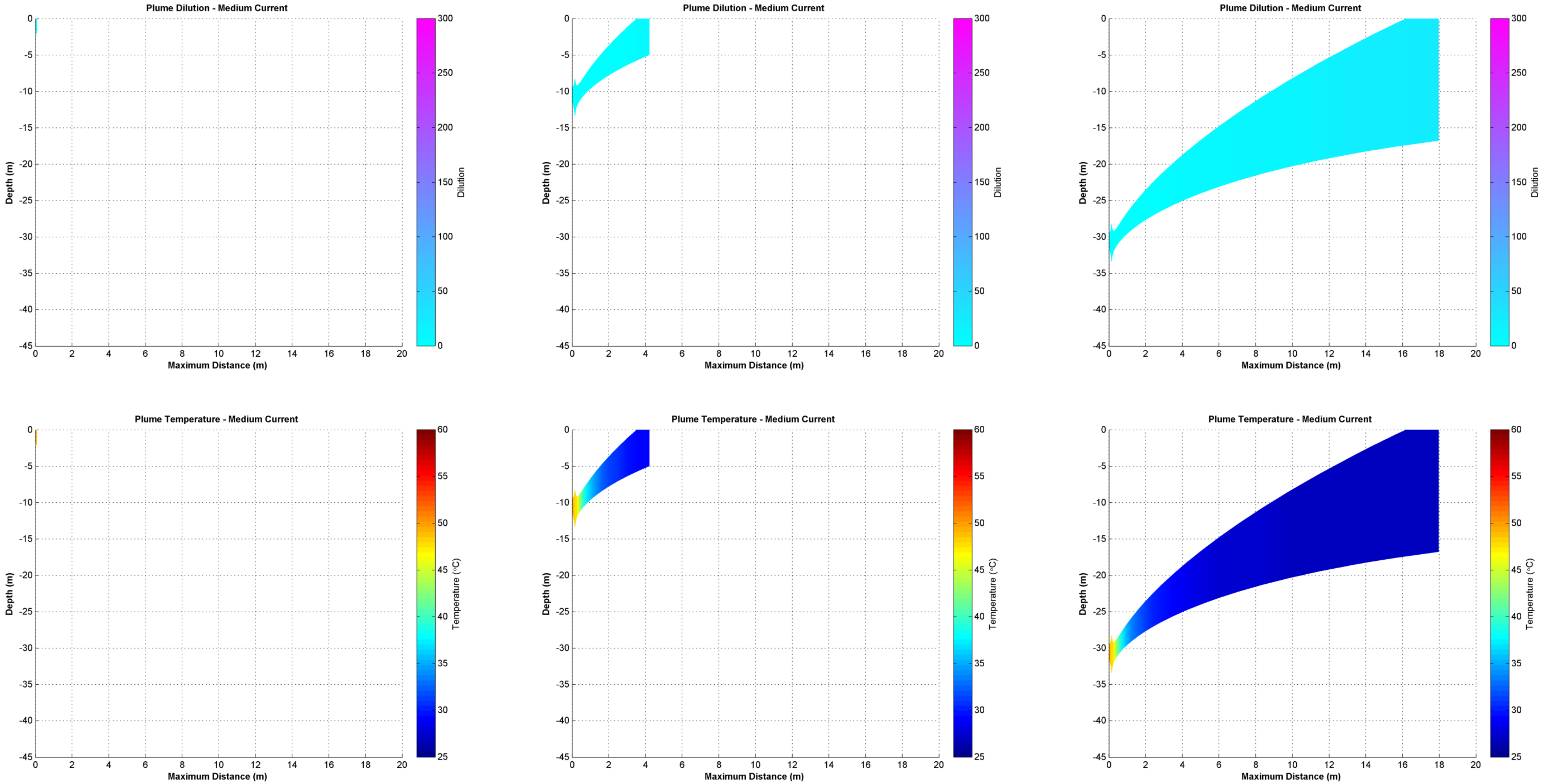


Figure 3.13 Near-field average dilution and temperature results for constant medium annualised currents with a discharge flow rate of 64,800 m³/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

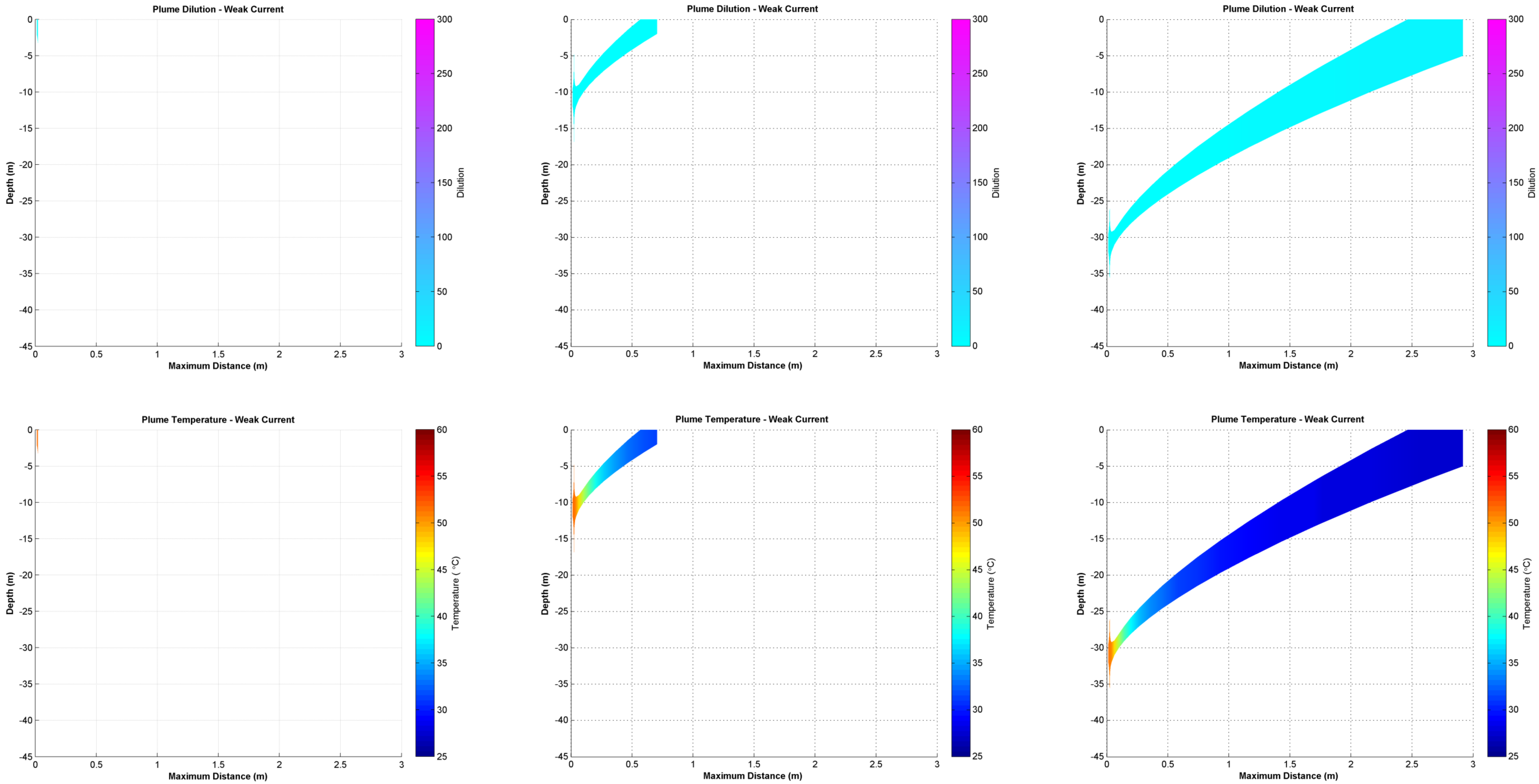


Figure 3.14 Near-field average dilution and temperature results for constant weak annualised currents with a discharge flow rate of 64,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

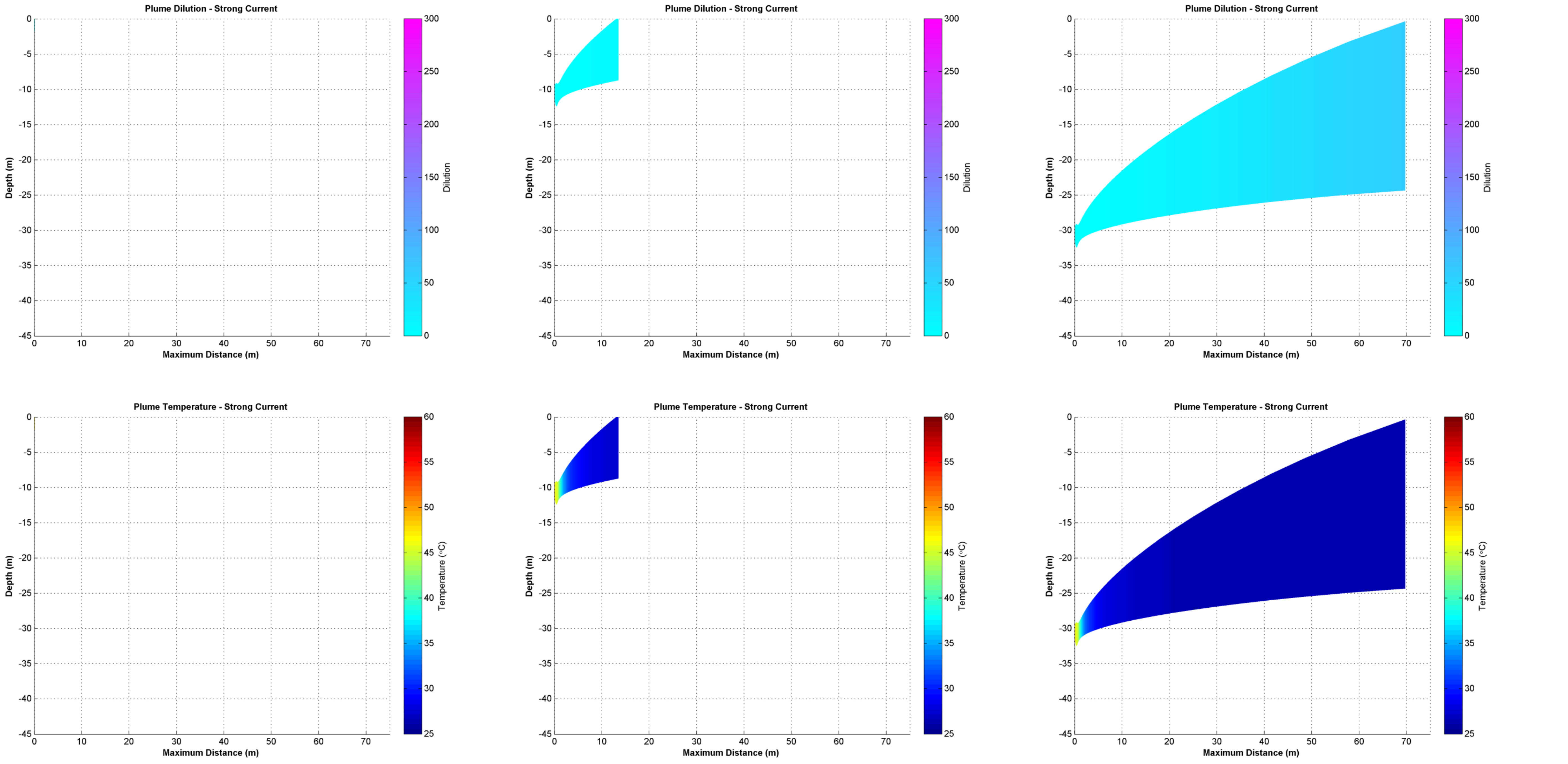


Figure 3.15 **Near-field average dilution and temperature results for constant strong annualised currents with a discharge flow rate of 64,800 m³/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).**

3.1.3.2.2 Summer

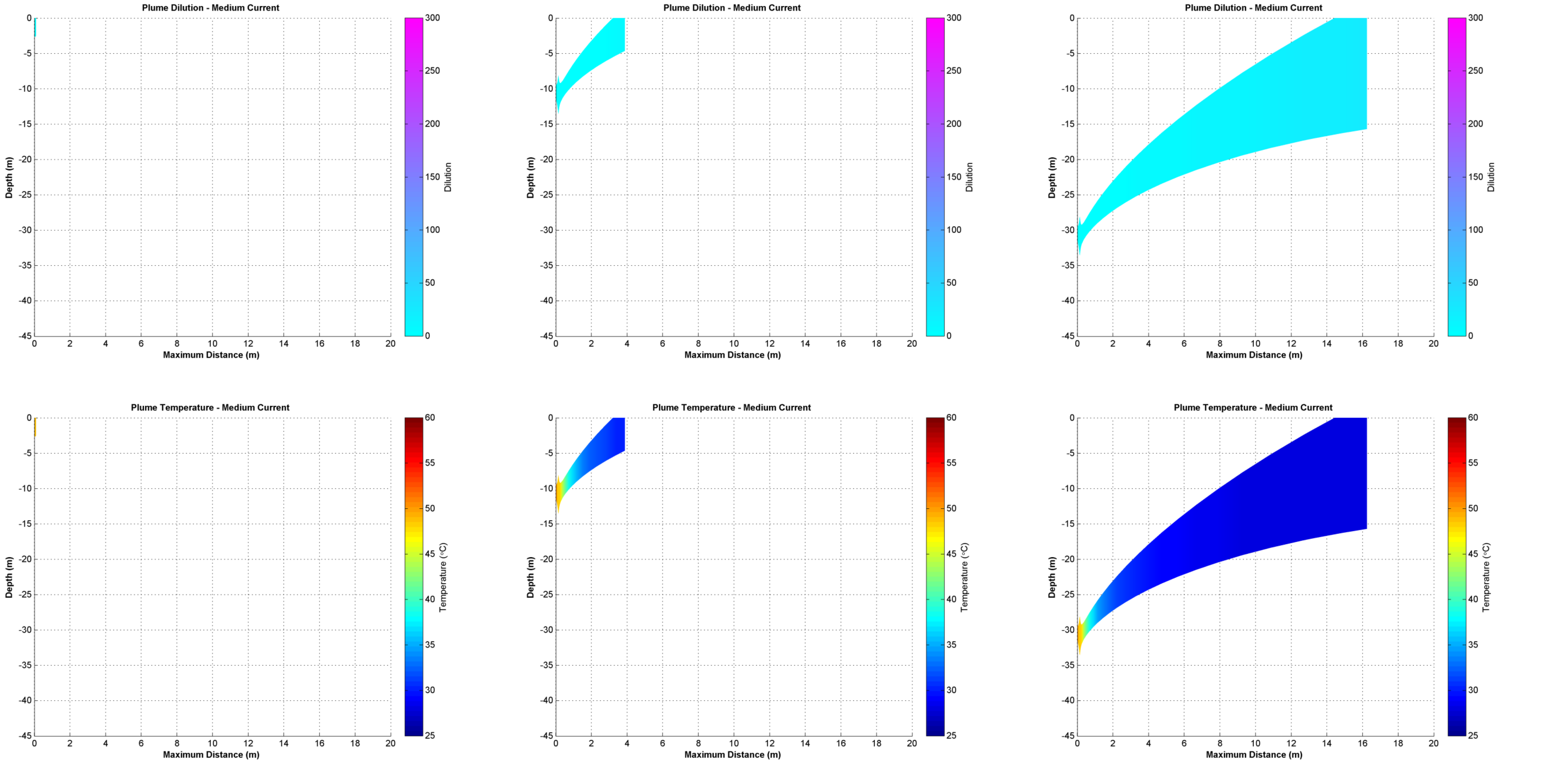


Figure 3.16 Near-field average dilution and temperature results for constant medium summer currents with a discharge flow rate of 64,800 m³/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

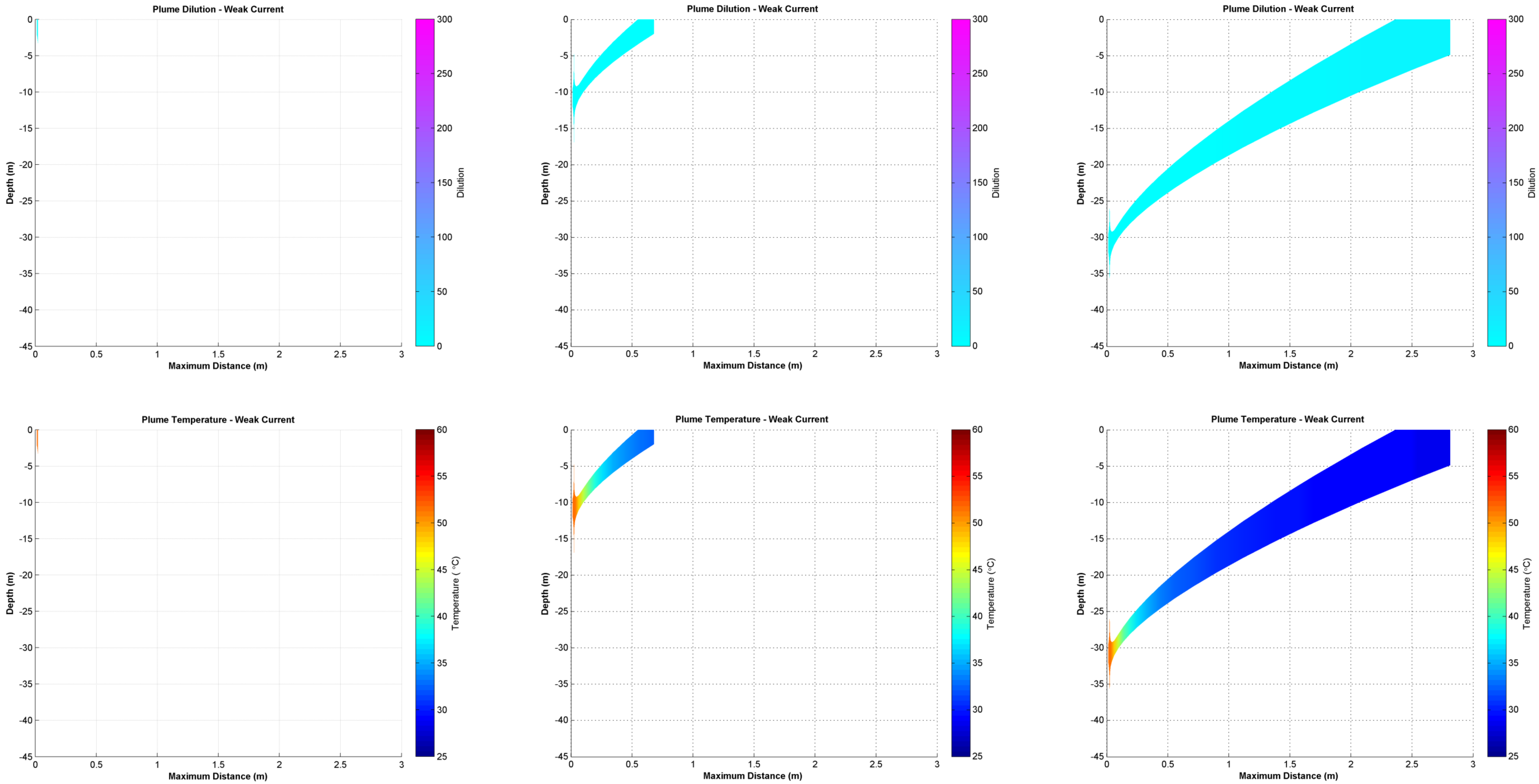


Figure 3.17 Near-field average dilution and temperature results for constant weak summer currents with a discharge flow rate of 64,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

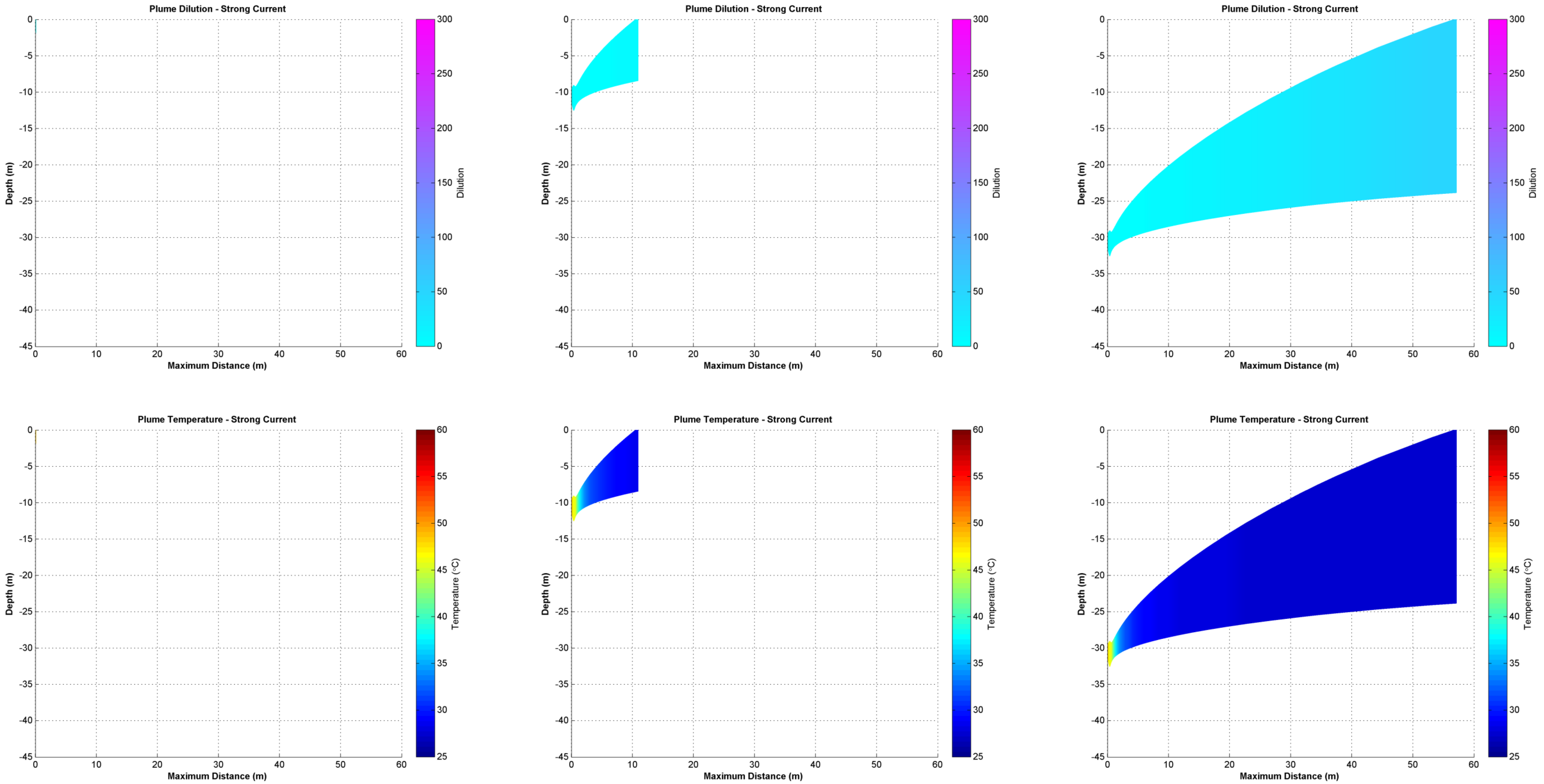


Figure 3.18 Near-field average dilution and temperature results for constant strong summer currents with a discharge flow rate of 64,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

3.1.3.2.3 Transitional

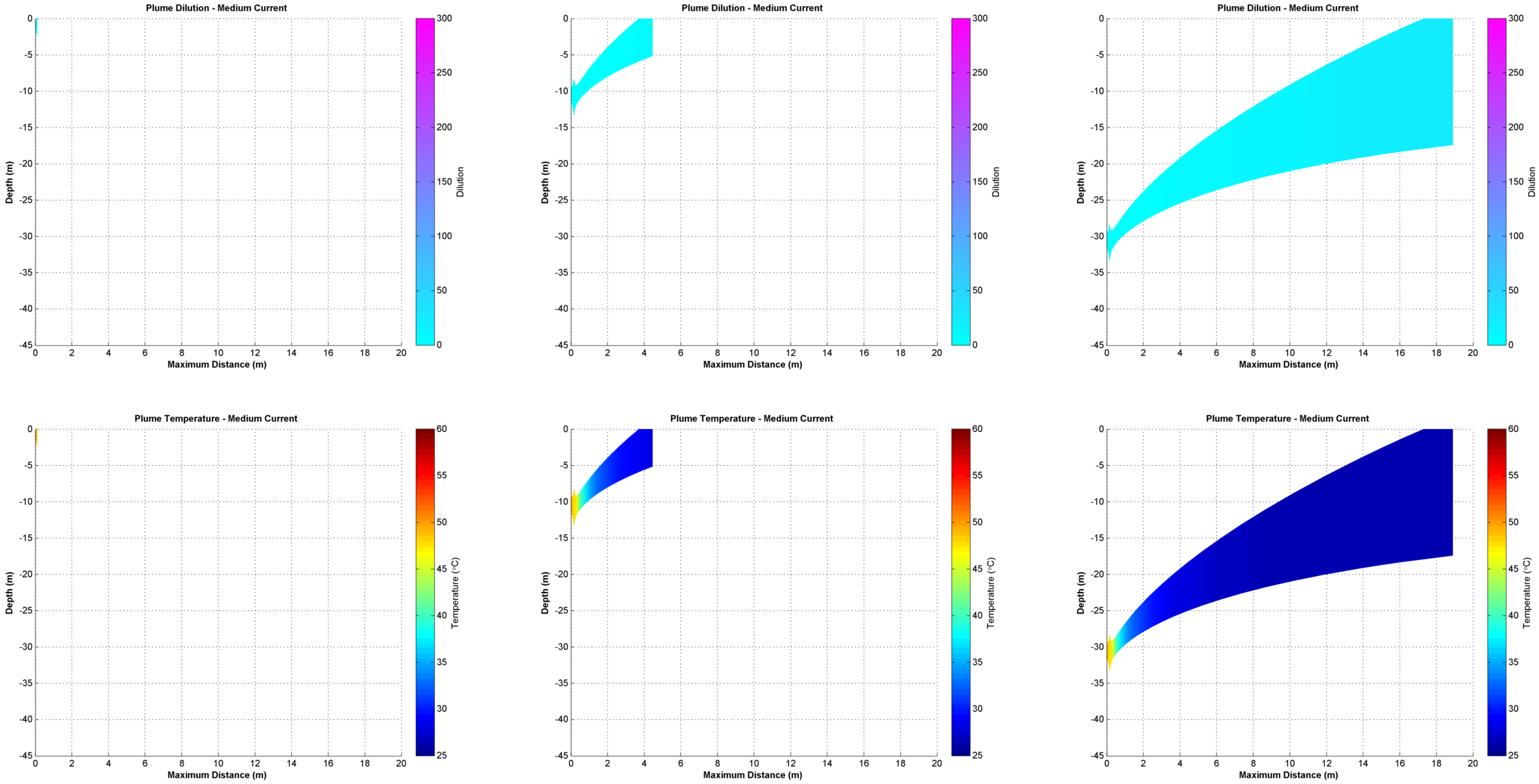


Figure 3.19 Near-field average dilution and temperature results for constant medium transitional currents with a discharge flow rate of 64,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

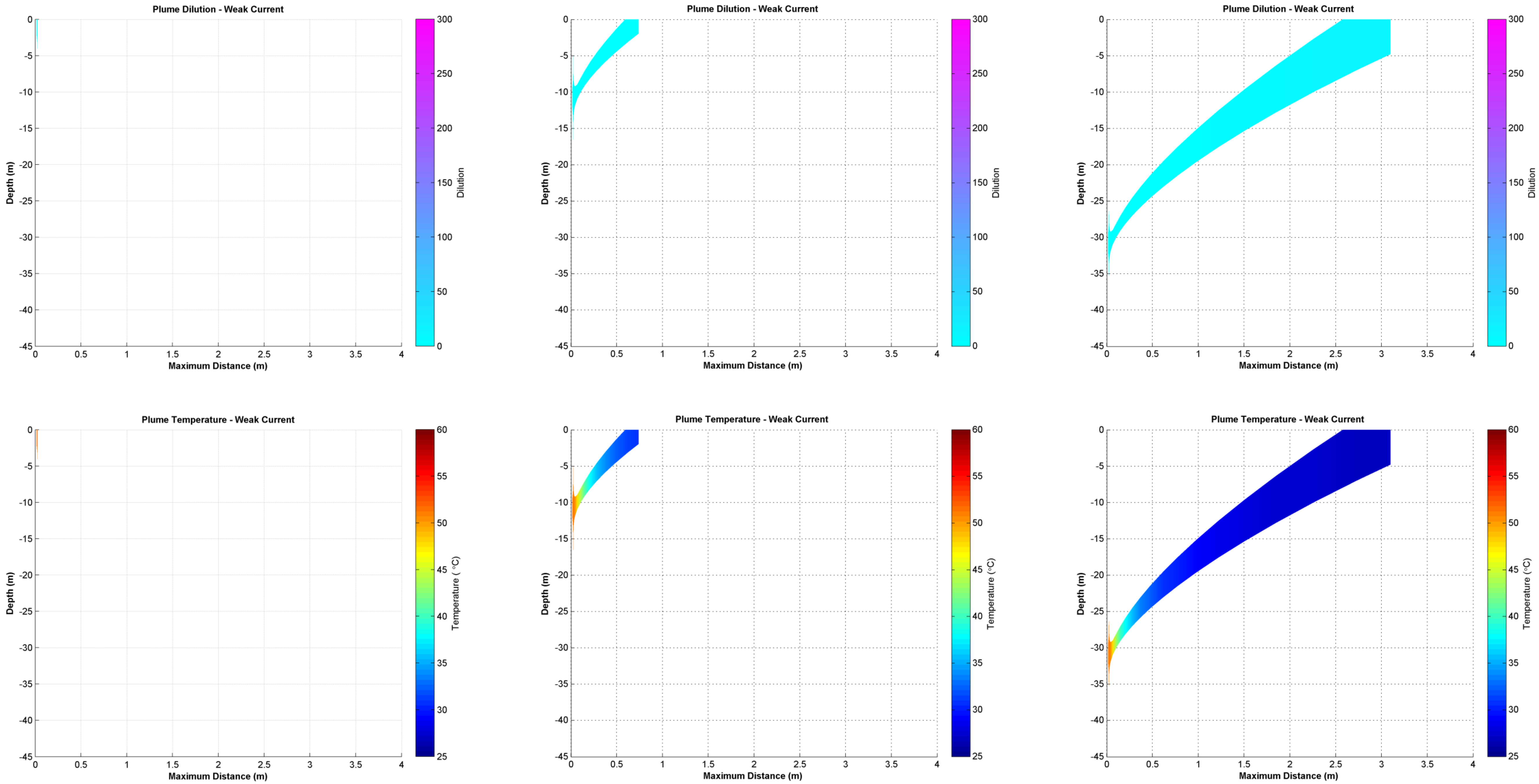


Figure 3.20 Near-field average dilution and temperature results for constant weak transitional currents with a discharge flow rate of 64,800 m³/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

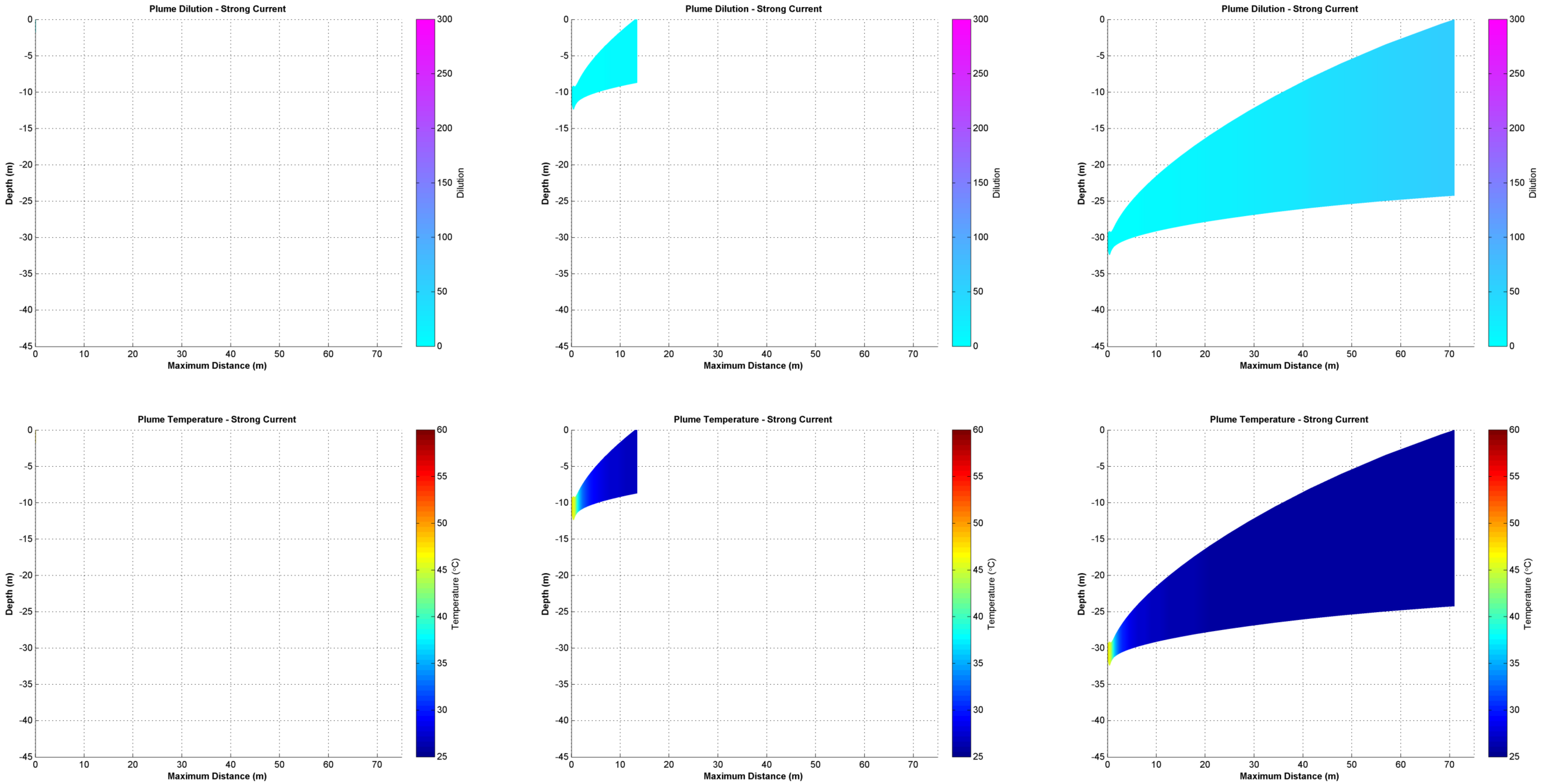


Figure 3.21 Near-field average dilution and temperature results for constant strong transitional currents with a discharge flow rate of 64,800 m³/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

3.1.3.2.4 Winter

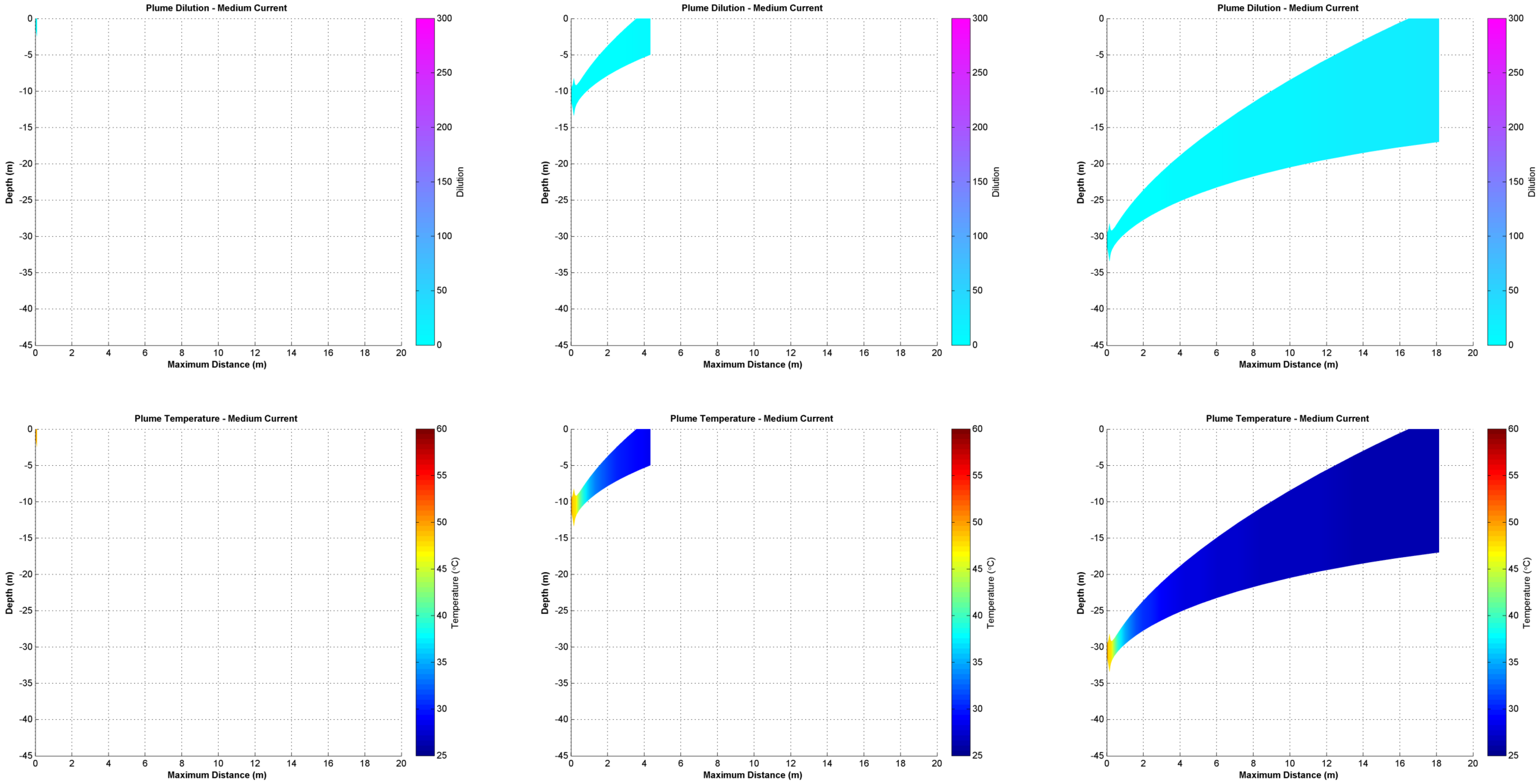


Figure 3.22 Near-field average dilution and temperature results for constant medium winter currents with a discharge flow rate of 64,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

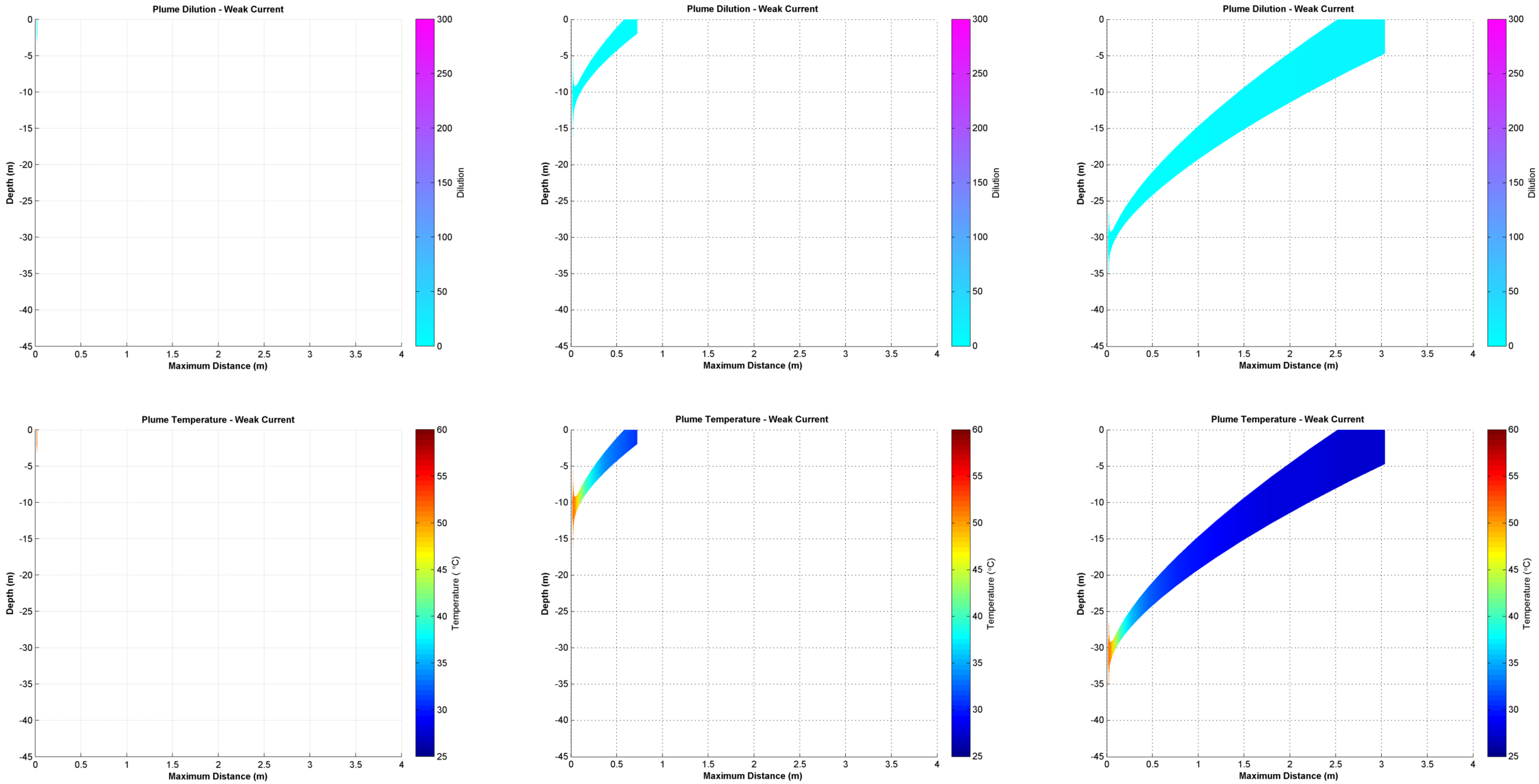


Figure 3.23 Near-field average dilution and temperature results for constant weak winter currents with a discharge flow rate of 64,800 m³/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

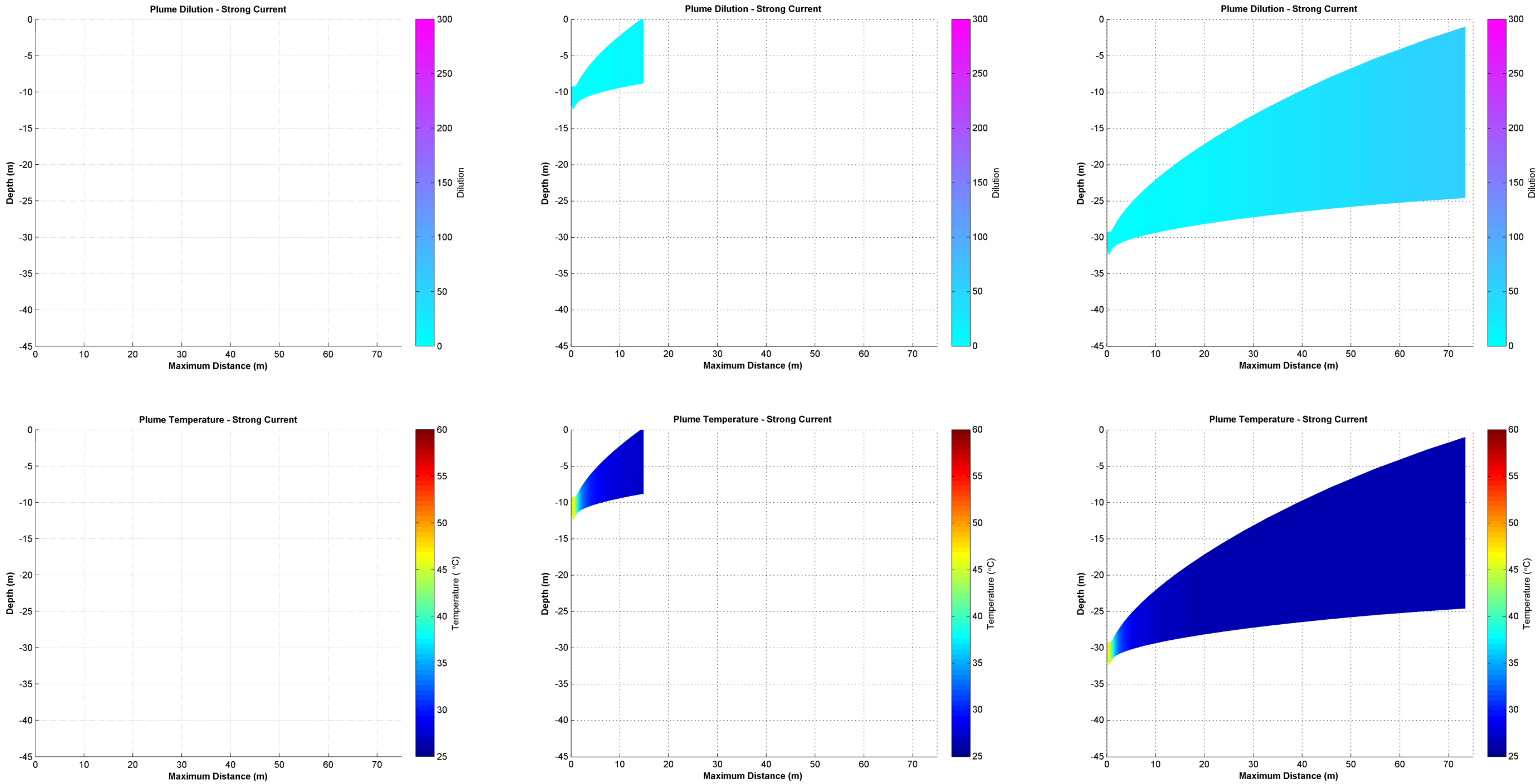


Figure 3.24 **Near-field average dilution and temperature results for constant strong winter currents with a discharge flow rate of 64,800 m³/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).**

3.1.3.3 Discharge Flow Rate of 82,800 m³/day at Varying Depths

3.1.3.3.1 Annualised

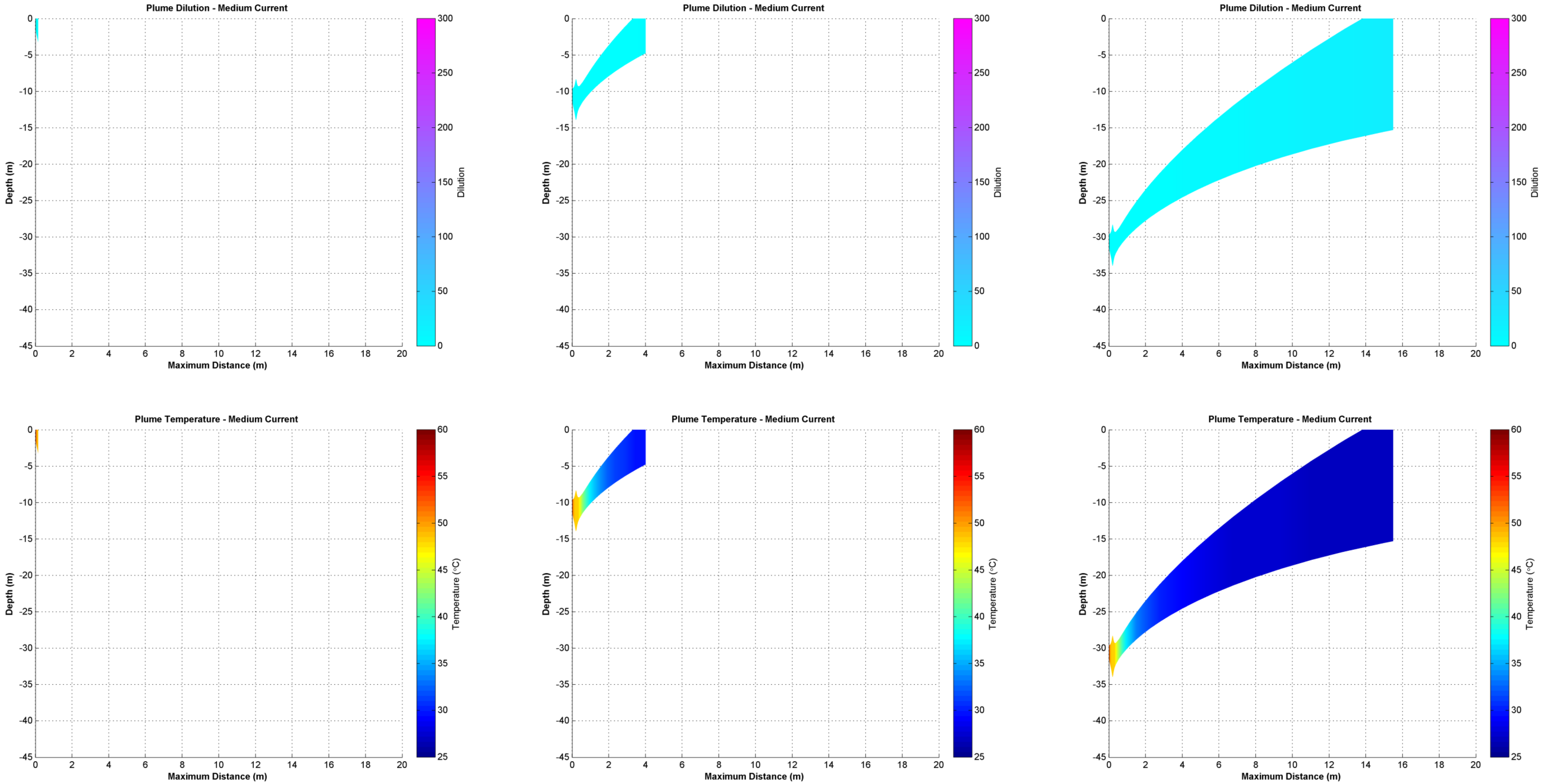


Figure 3.25 Near-field average dilution and temperature results for constant medium annualised currents with a discharge flow rate of 82,800 m³/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

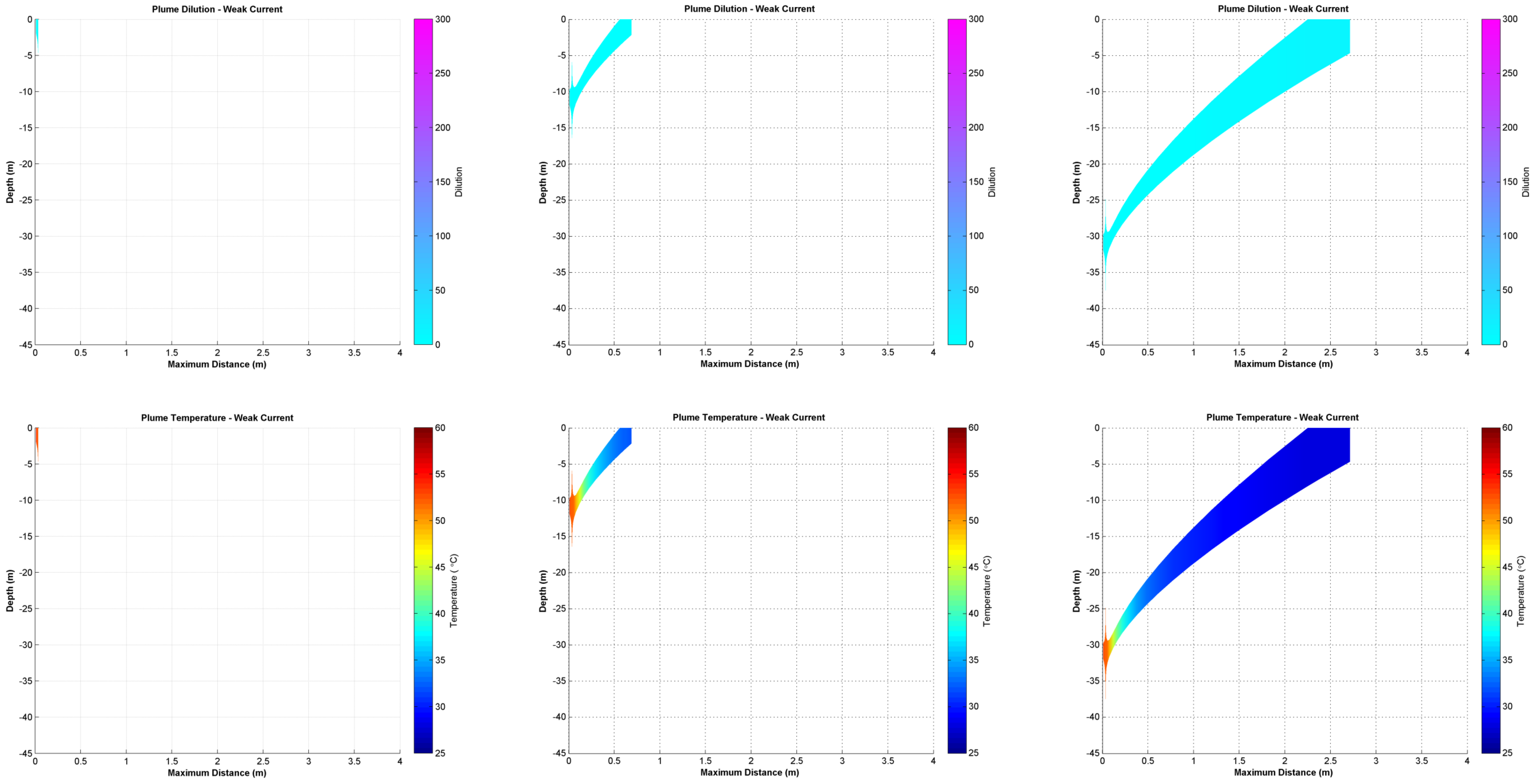


Figure 3.26 Near-field average dilution and temperature results for constant weak annualised currents with a discharge flow rate of 82,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

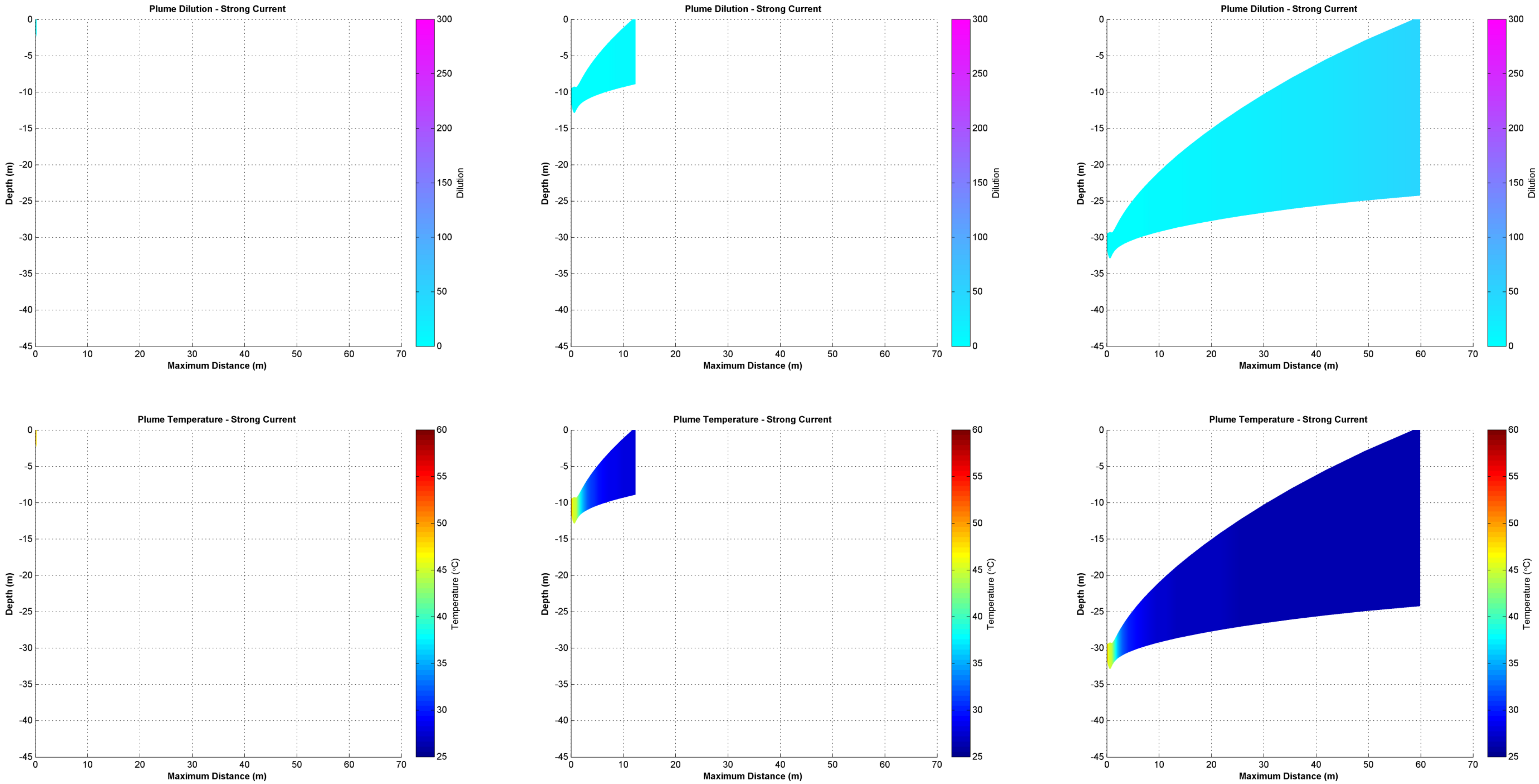


Figure 3.27 Near-field average dilution and temperature results for constant strong annualised currents with a discharge flow rate of 82,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

3.1.3.3.2 Summer

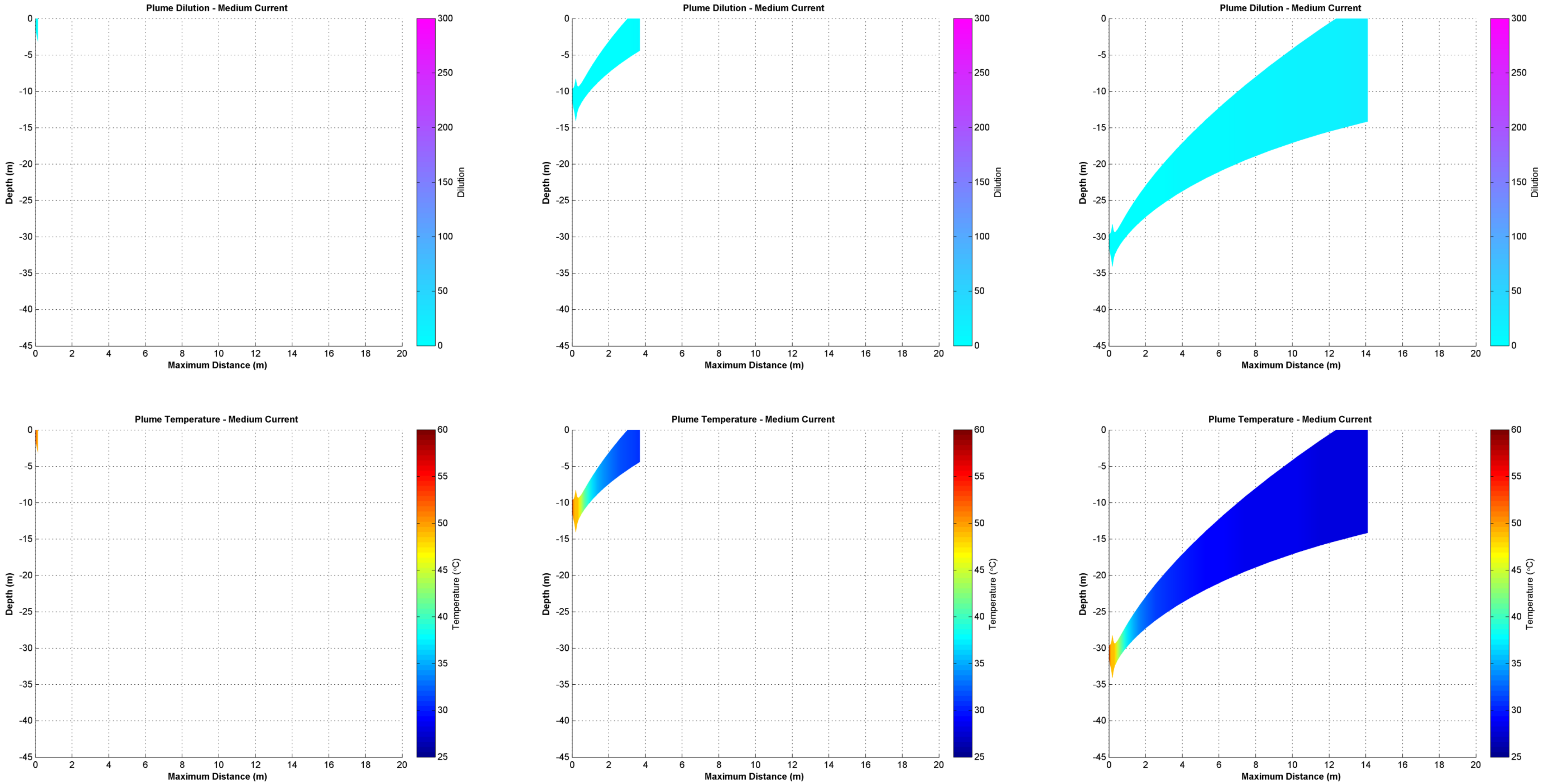


Figure 3.28 Near-field average dilution and temperature results for constant medium summer currents with a discharge flow rate of 82,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

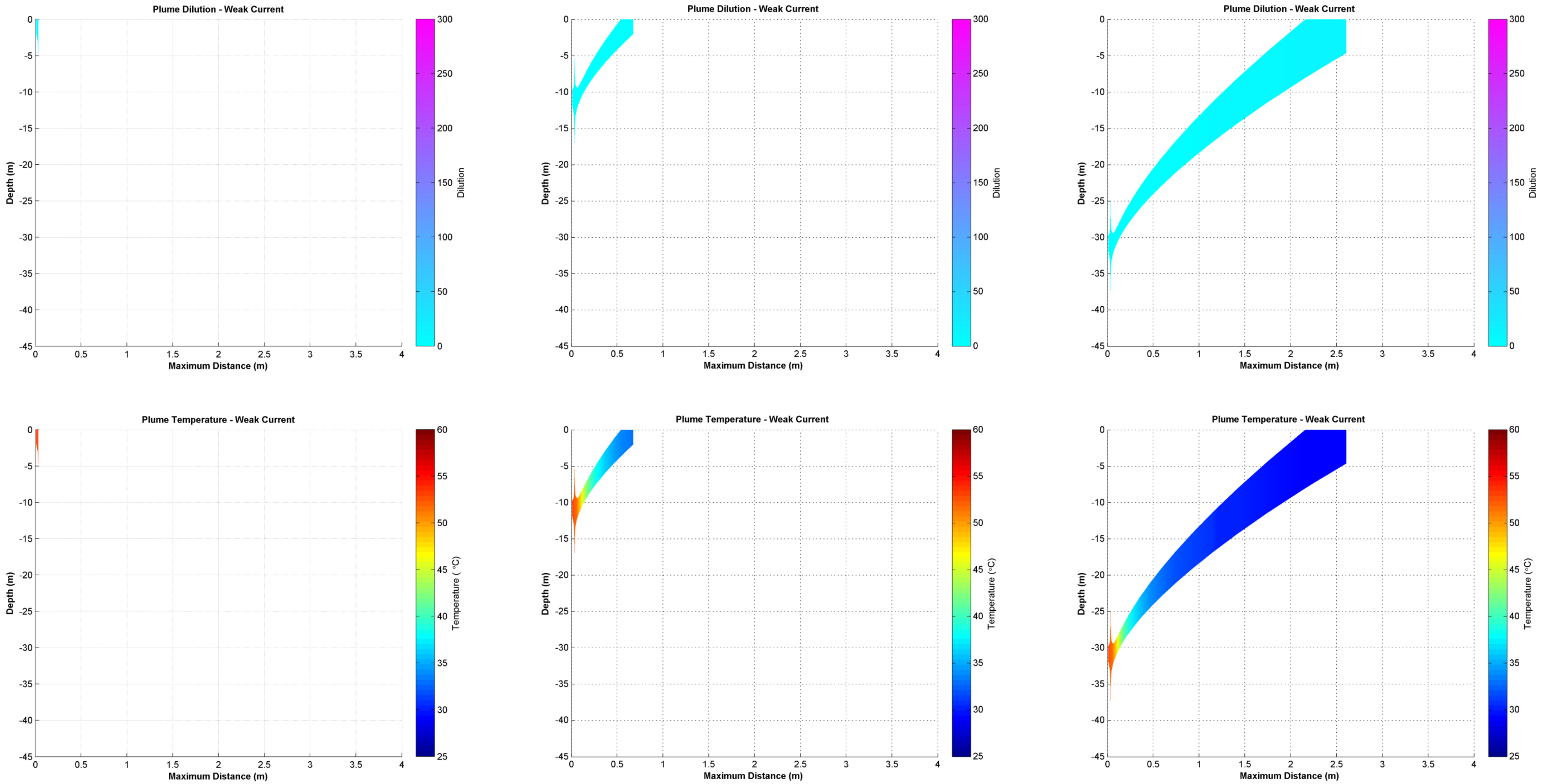


Figure 3.29 Near-field average dilution and temperature results for constant weak summer currents with a discharge flow rate of 82,800 m³/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

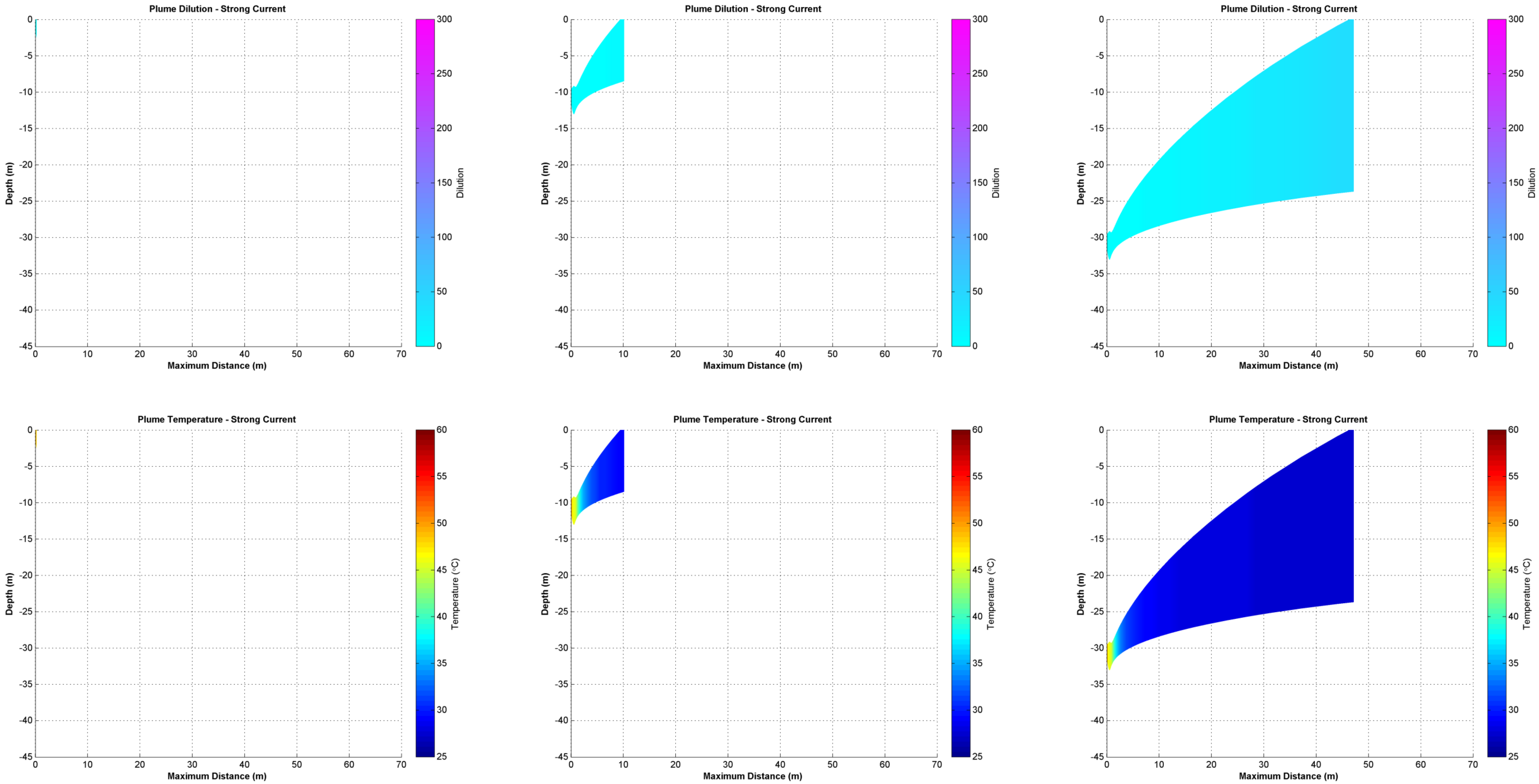


Figure 3.30 Near-field average dilution and temperature results for constant strong summer currents with a discharge flow rate of 82,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

3.1.3.3.3 Transitional

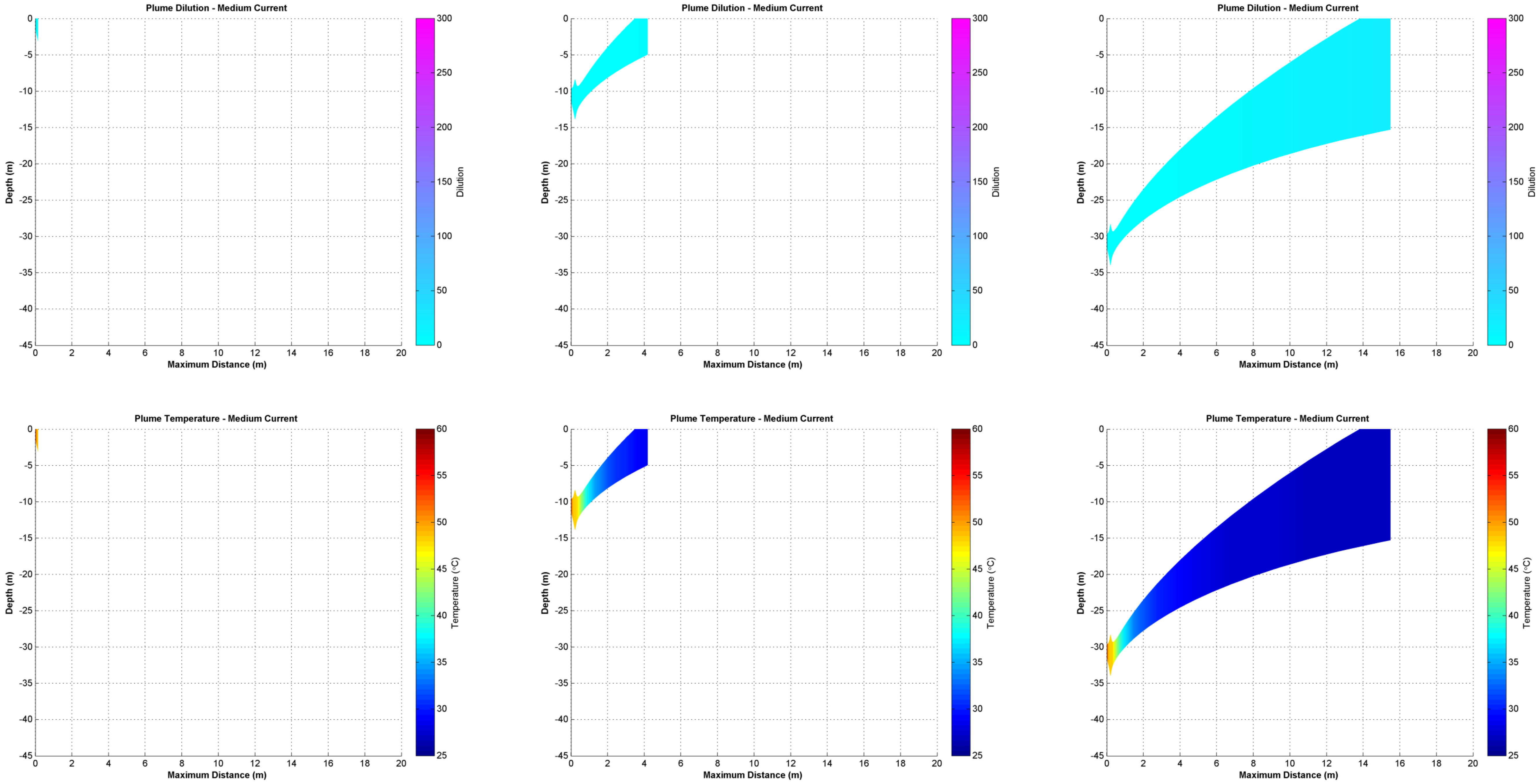


Figure 3.31 Near-field average dilution and temperature results for constant medium transitional currents with a discharge flow rate of 82,800 m³/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

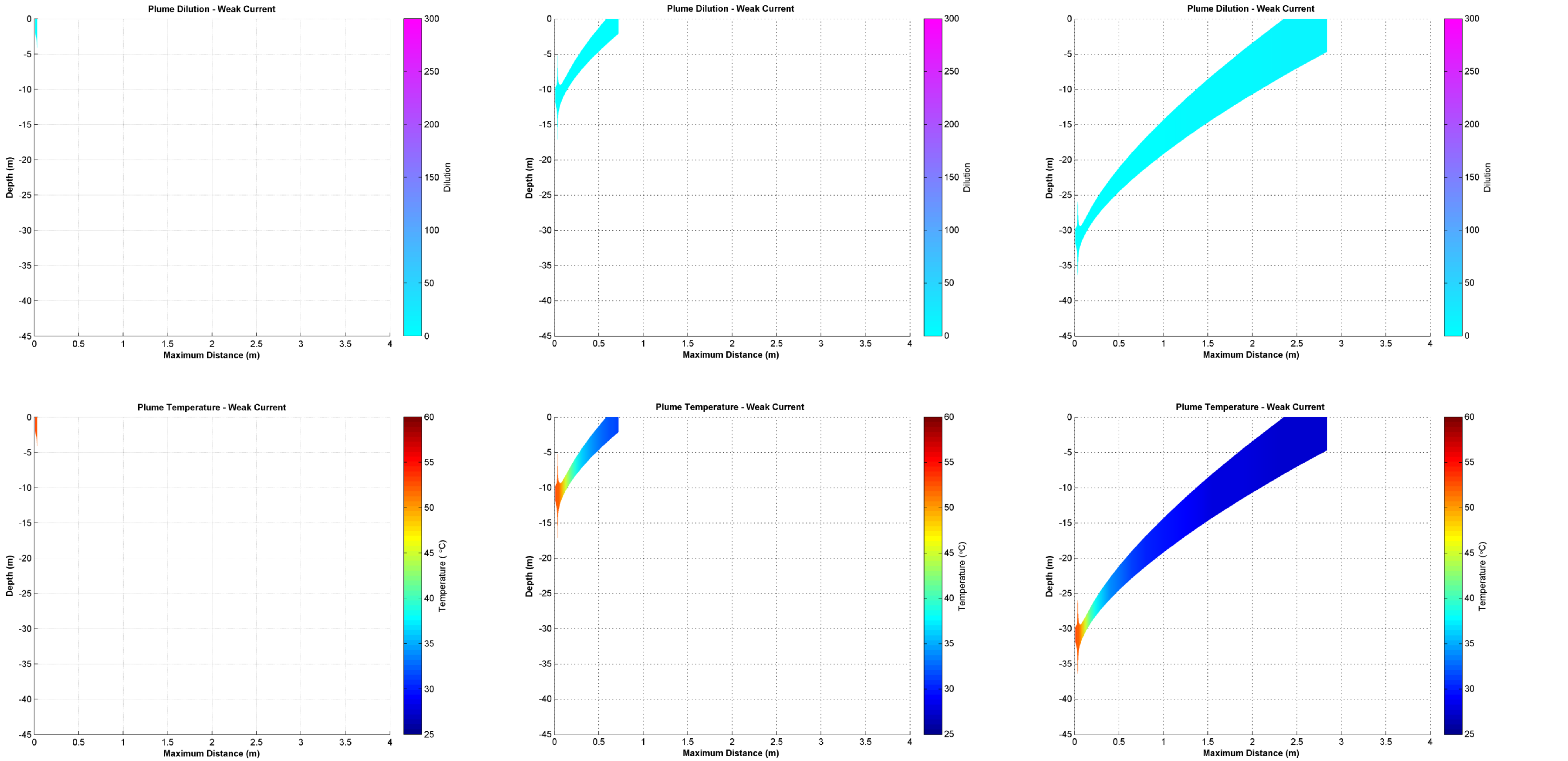


Figure 3.32 Near-field average dilution and temperature results for constant weak transitional currents with a discharge flow rate of 82,800 m³/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

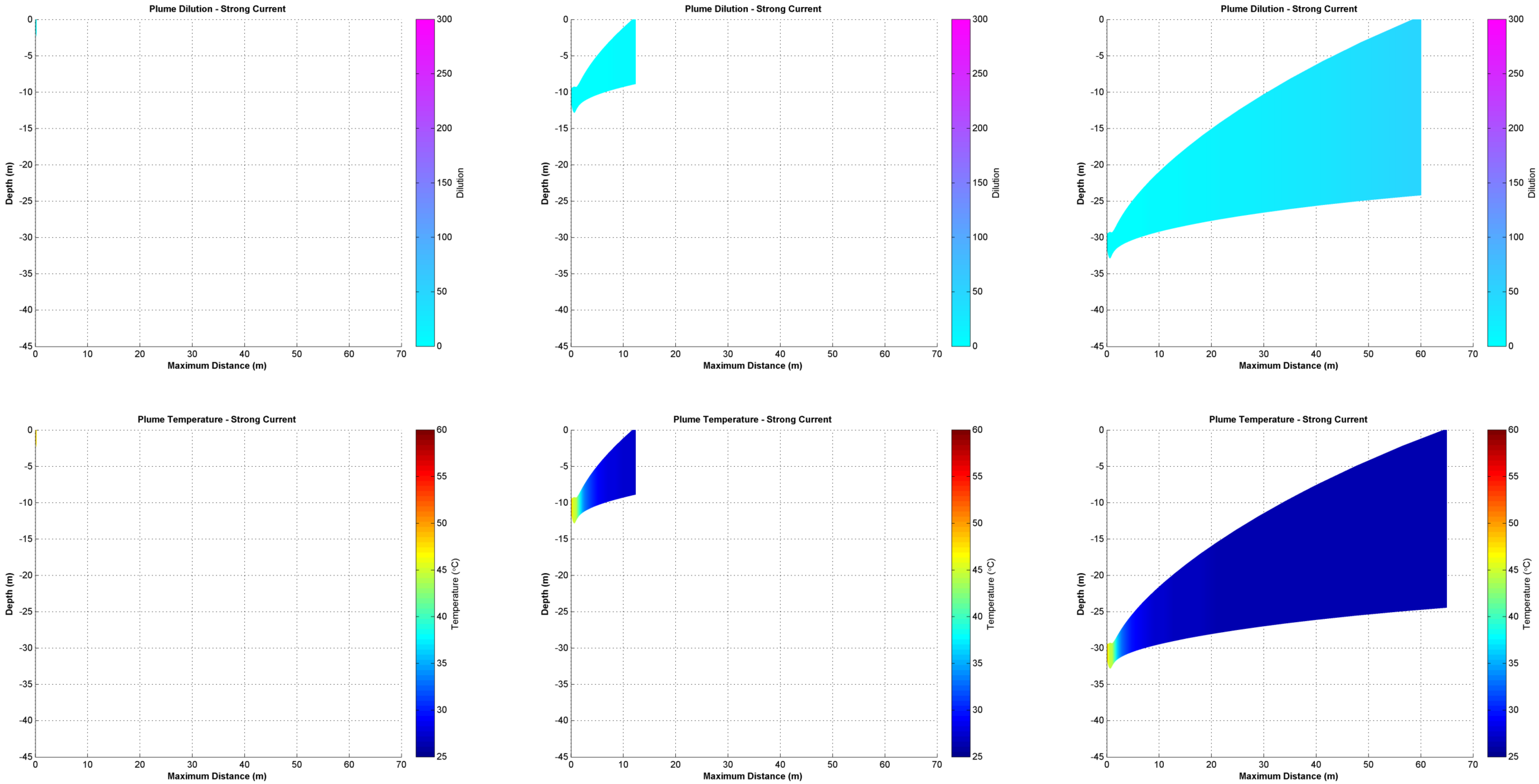


Figure 3.33 **Near-field average dilution and temperature results for constant strong transitional currents with a discharge flow rate of 82,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).**

3.1.3.3.4 Winter

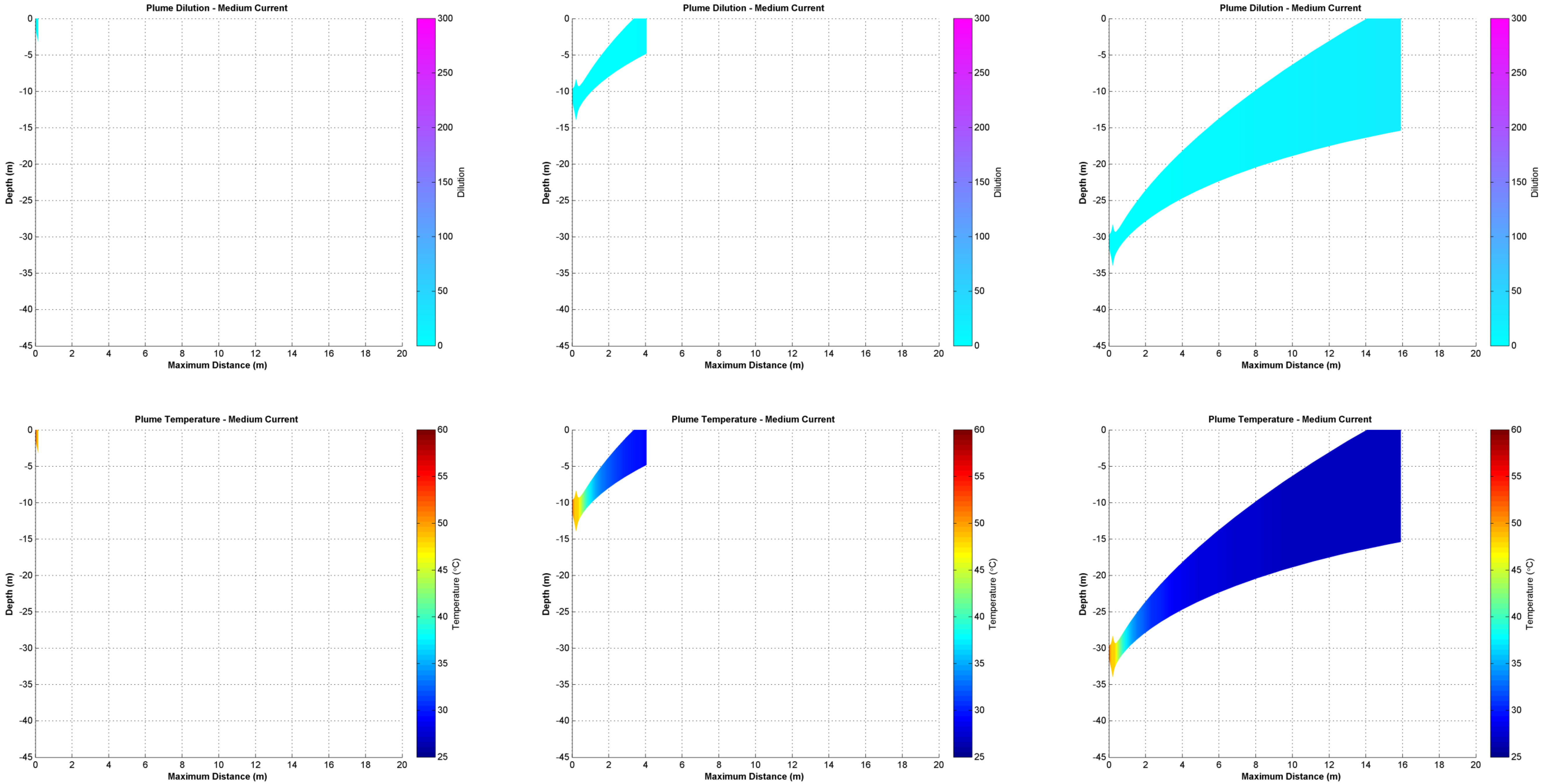


Figure 3.34 Near-field average dilution and temperature results for constant medium winter currents with a discharge flow rate of 82,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

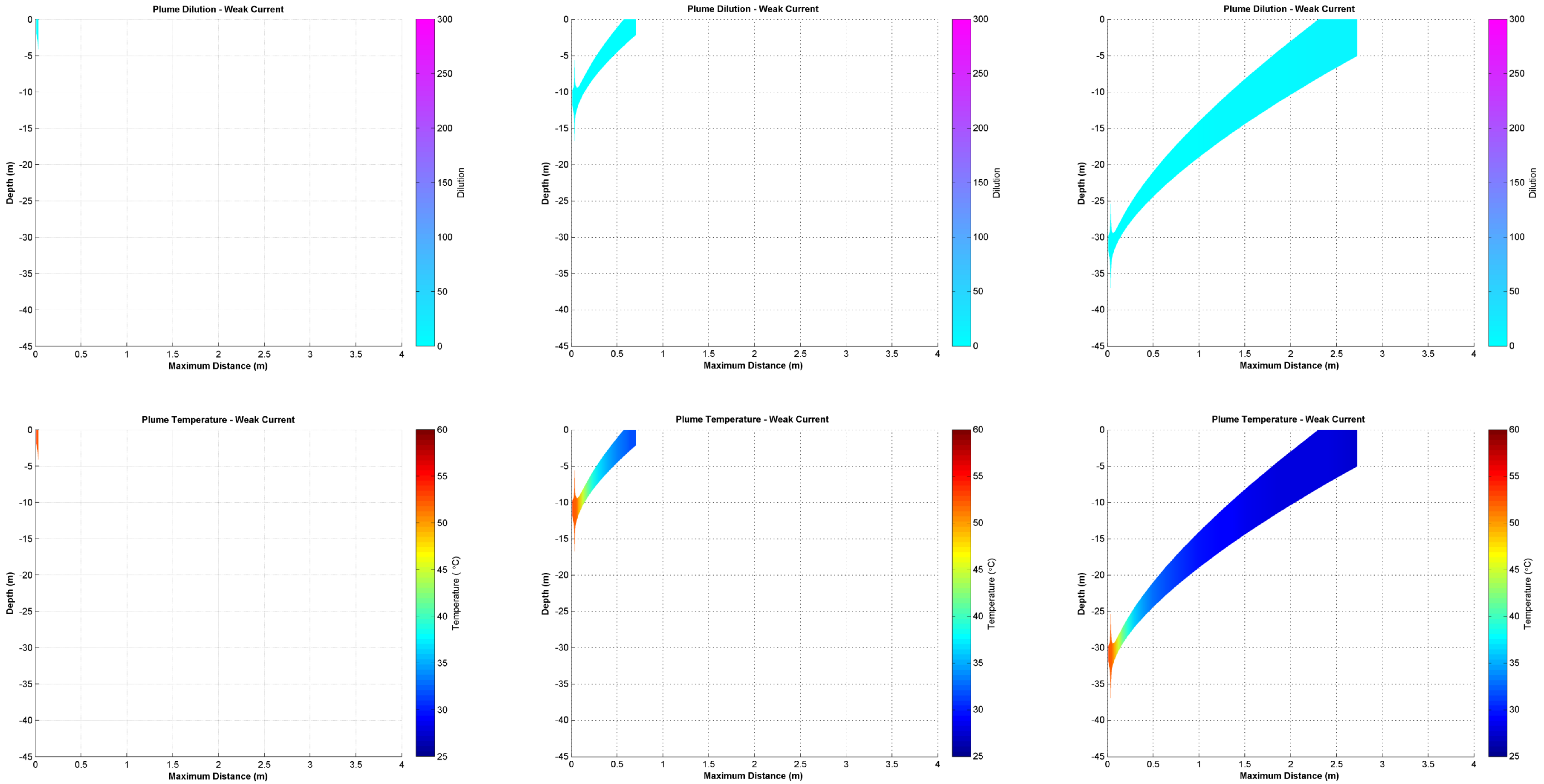


Figure 3.35 Near-field average dilution and temperature results for constant weak winter currents with a discharge flow rate of 82,800 m³/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

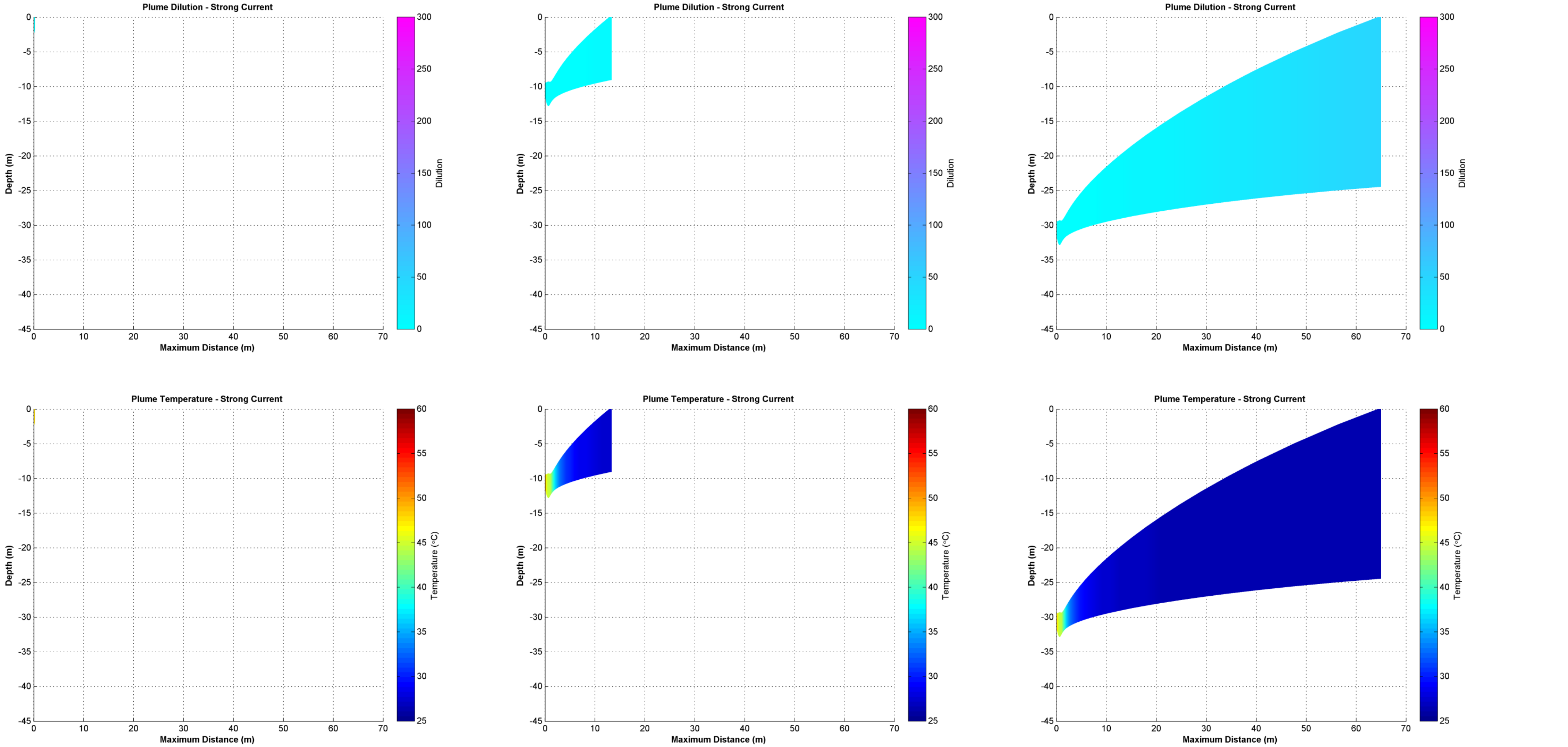


Figure 3.36 Near-field average dilution and temperature results for constant strong winter currents with a discharge flow rate of 82,800 m^3/d at discharge depths of 0 m (Case C1; left column), 10 m (Case C2; middle column) and 30 m (Case C3; right column).

3.1.3.4 Discharge Depth of 0 m (Surface) with Varying Flow Rates

3.1.3.4.1 Annualised

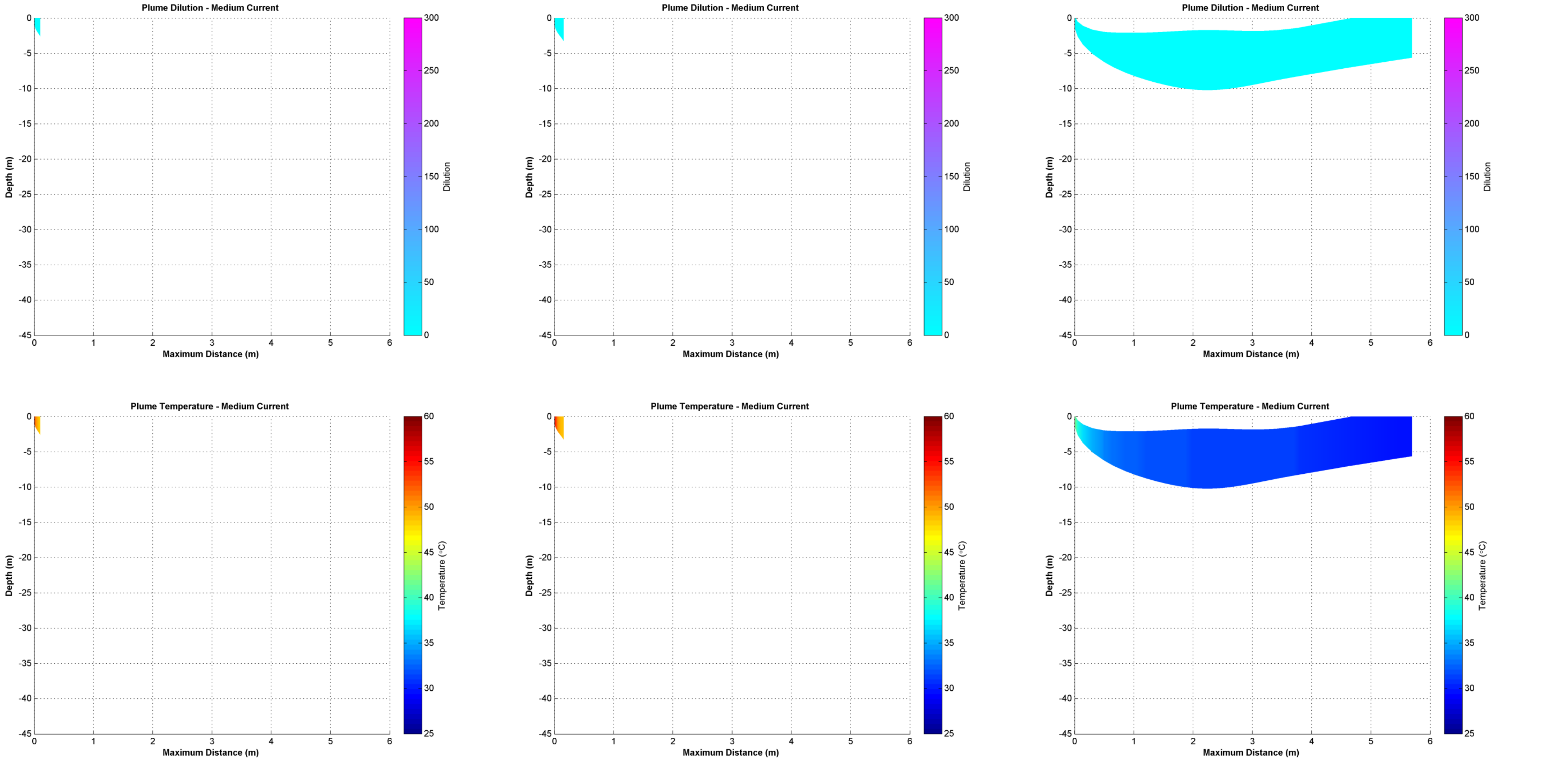


Figure 3.37 Near-field average dilution and temperature results for constant medium annualised currents with discharge flow rates of 64,800 m^3/d (Case C4; left column), 82,800 m^3/d (Case C7; middle column) and 165,600 m^3/d (Case C1; right column) at a discharge depth of 0 m.

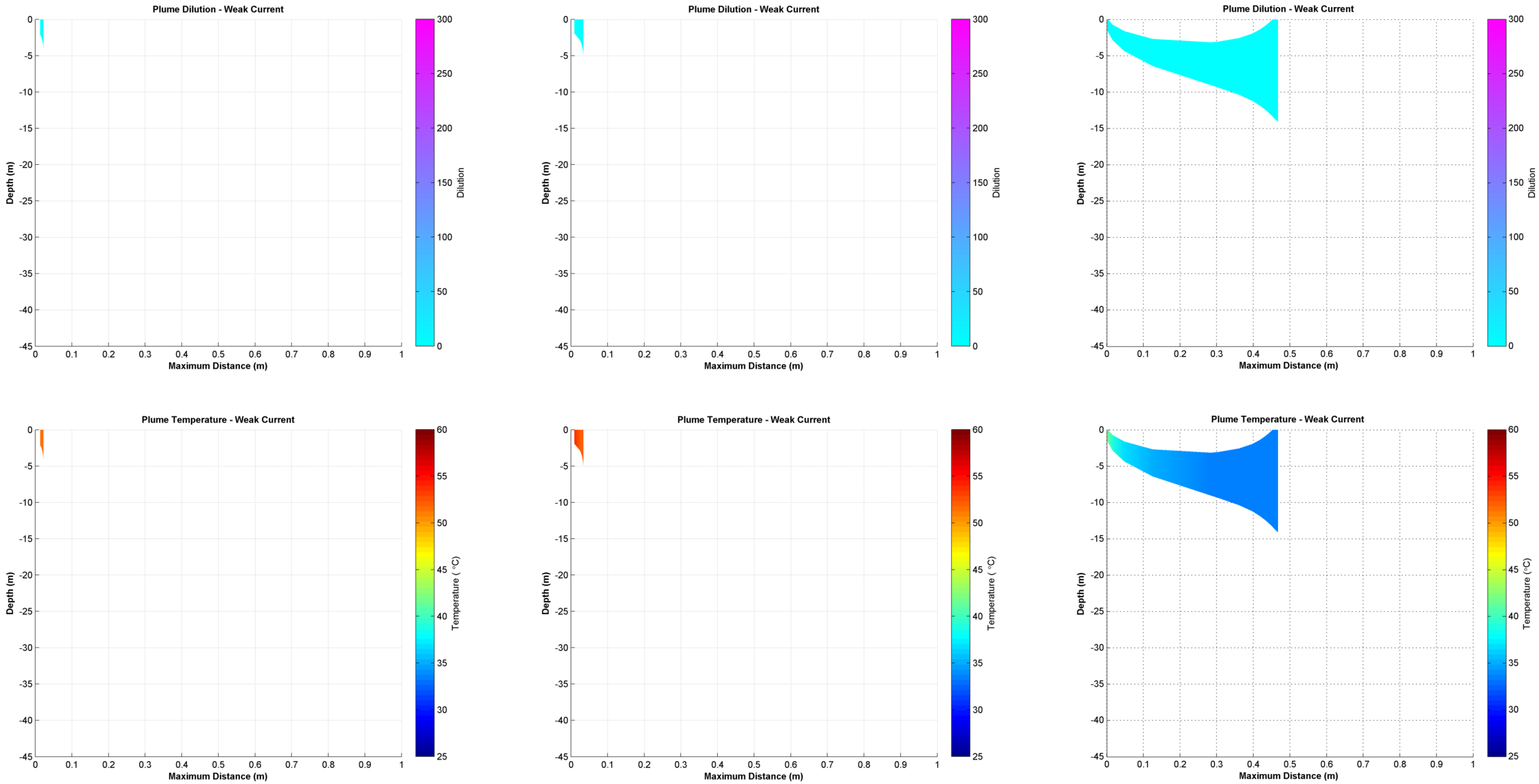


Figure 3.38 Near-field average dilution and temperature results for constant weak annualised currents with discharge flow rates of 64,800 m^3/d (Case C4; left column), 82,800 m^3/d (Case C7; middle column) and 165,600 m^3/d (Case C1; right column) at a discharge depth of 0 m.

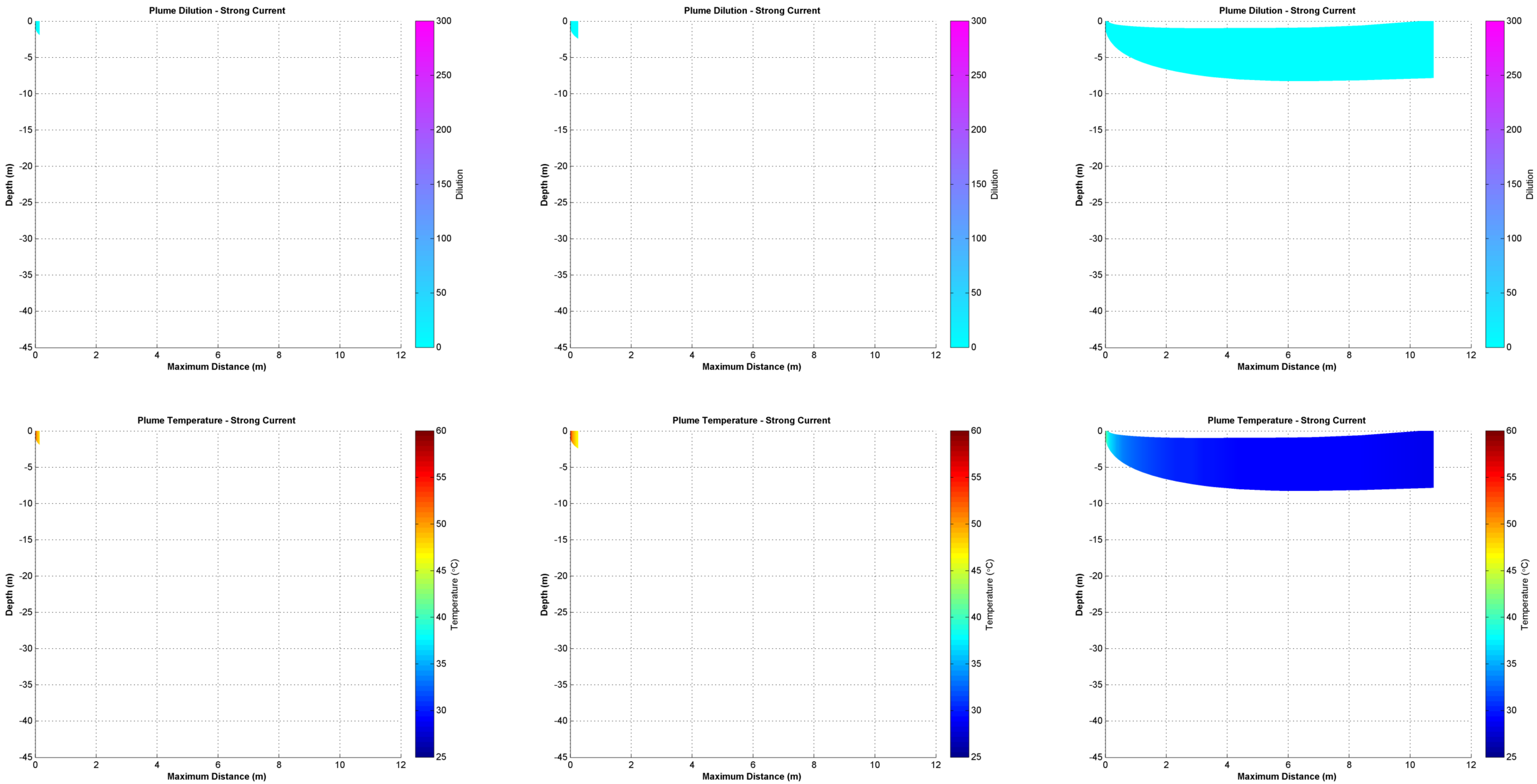


Figure 3.39 Near-field average dilution and temperature results for constant strong annualised currents with discharge flow rates of 64,800 m^3/d (Case C4; left column), 82,800 m^3/d (Case C7; middle column) and 165,600 m^3/d (Case C1; right column) at a discharge depth of 0 m.

3.1.3.4.2 Summer

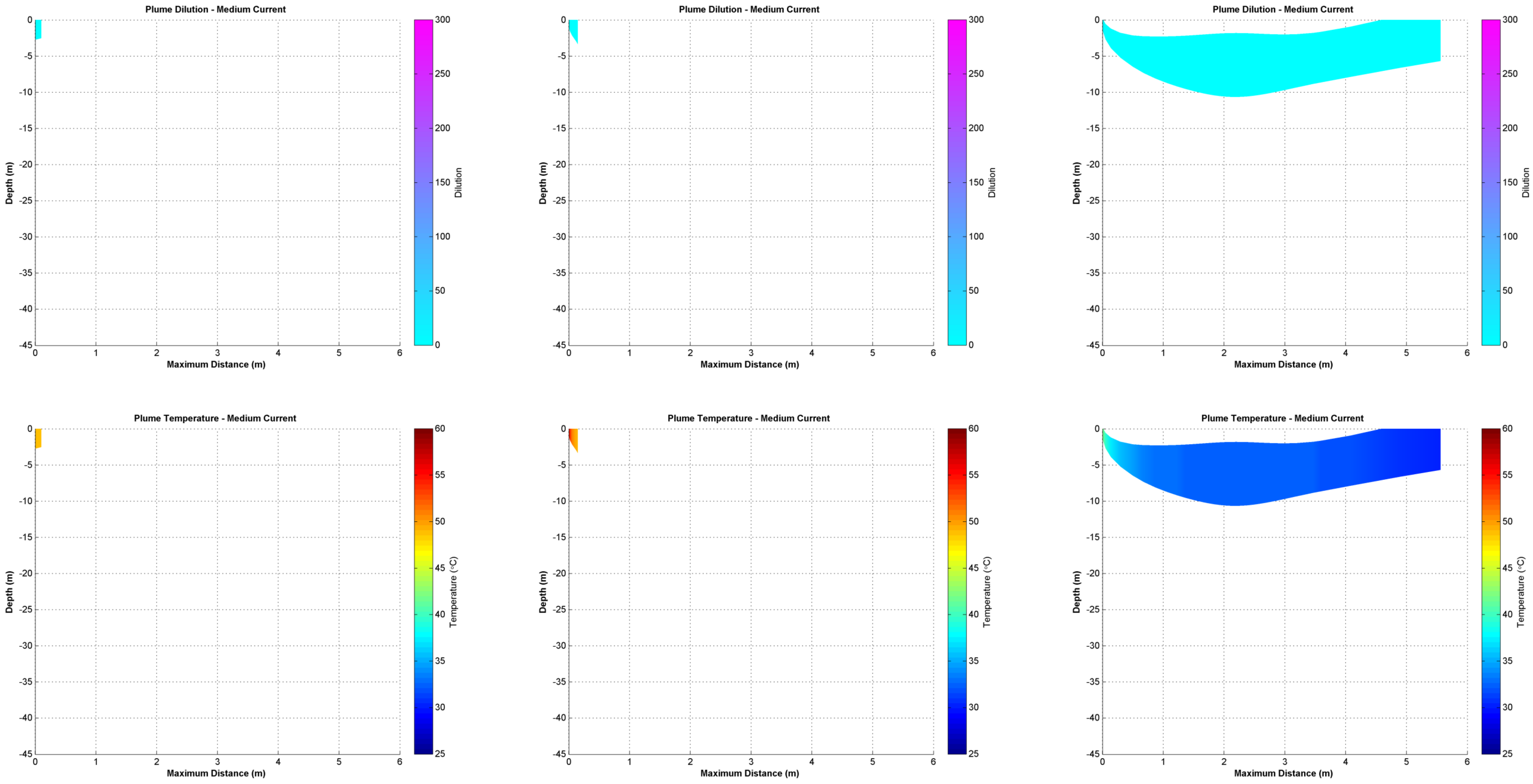


Figure 3.40 Near-field average dilution and temperature results for constant medium summer currents with discharge flow rates of 64,800 m³/d (Case C4; left column), 82,800 m³/d (Case C7; middle column) and 165,600 m³/d (Case C1; right column) at a discharge depth of 0 m.

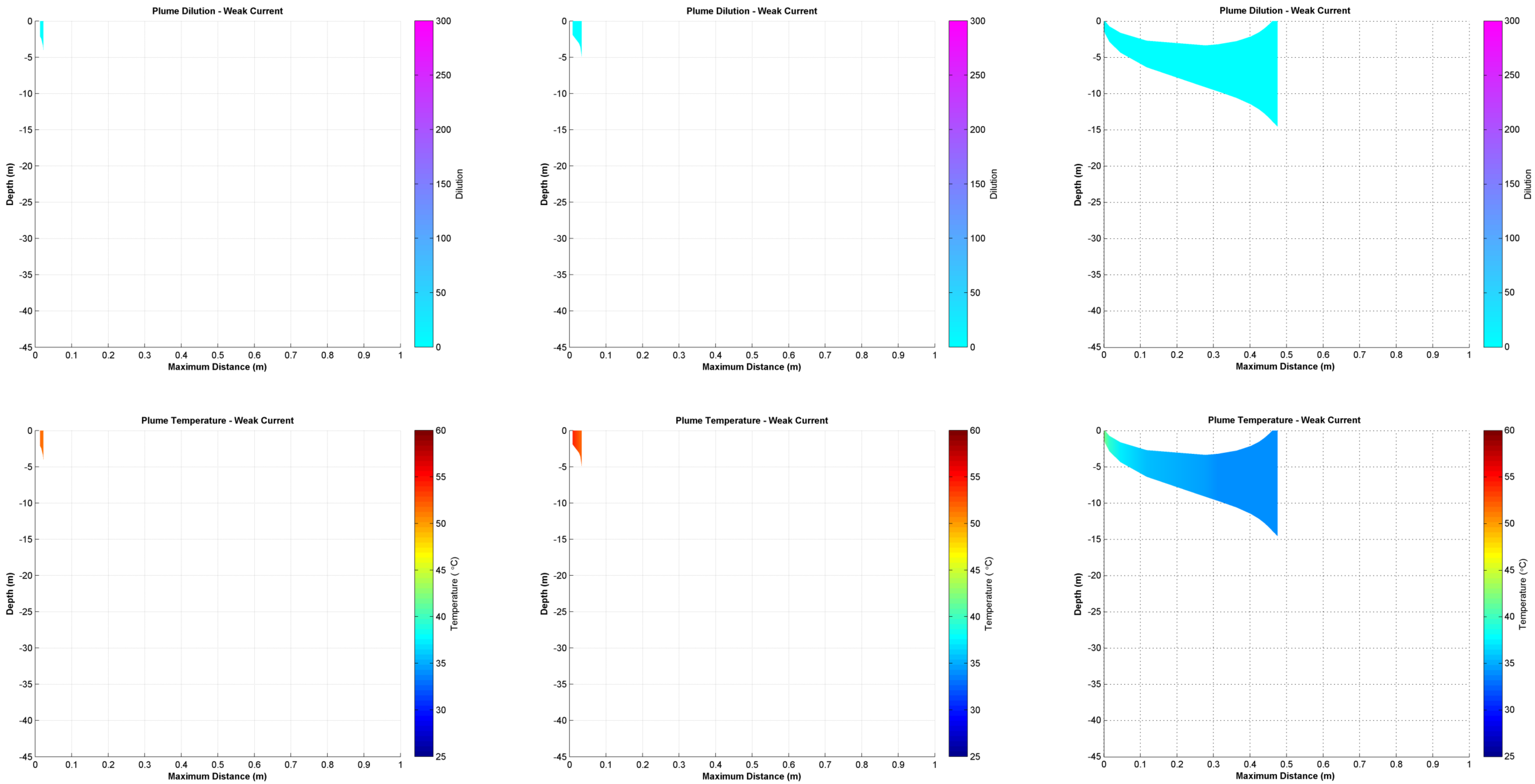


Figure 3.41 Near-field average dilution and temperature results for constant weak summer currents with discharge flow rates of 64,800 m^3/d (Case C4; left column), 82,800 m^3/d (Case C7; middle column) and 165,600 m^3/d (Case C1; right column) at a discharge depth of 0 m.

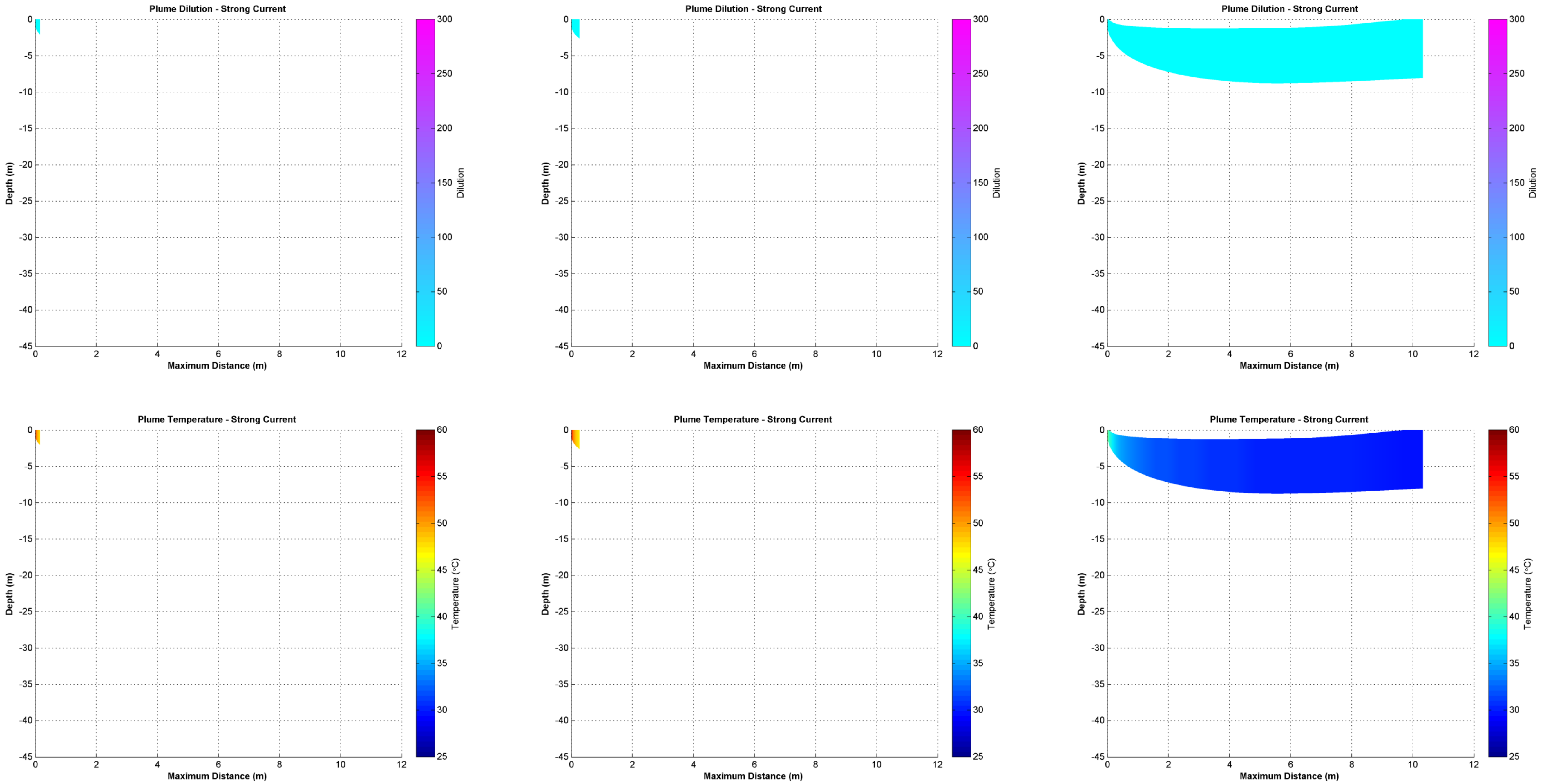


Figure 3.42 **Near-field average dilution and temperature results for constant strong summer currents with discharge flow rates of 64,800 m^3/d (Case C4; left column), 82,800 m^3/d (Case C7; middle column) and 165,600 m^3/d (Case C1; right column) at a discharge depth of 0 m.**

3.1.3.4.3 Transitional

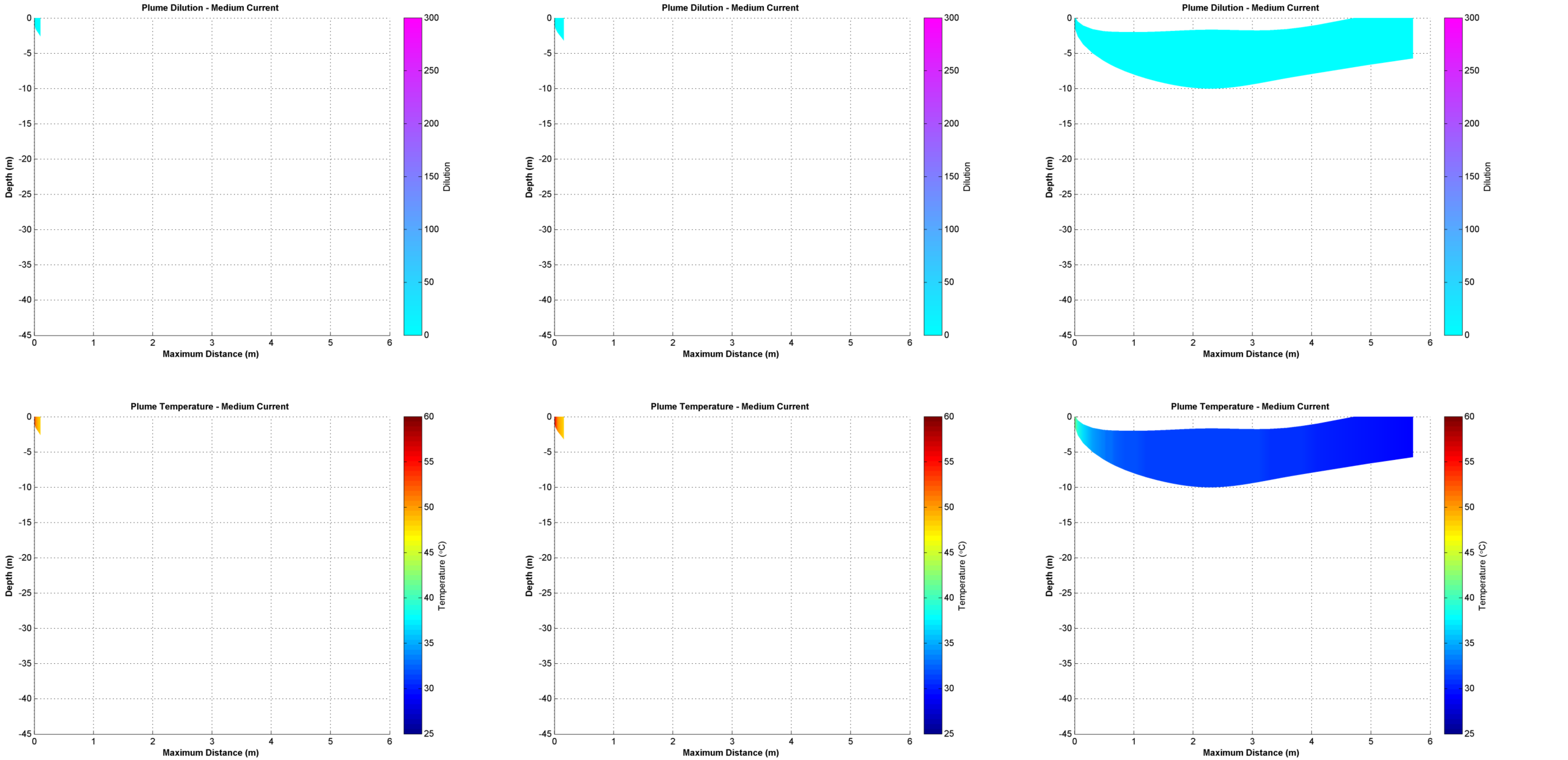


Figure 3.43 Near-field average dilution and temperature results for constant medium transitional currents with discharge flow rates of 64,800 m^3/d (Case C4; left column), 82,800 m^3/d (Case C7; middle column) and 165,600 m^3/d (Case C1; right column) at a discharge depth of 0 m.

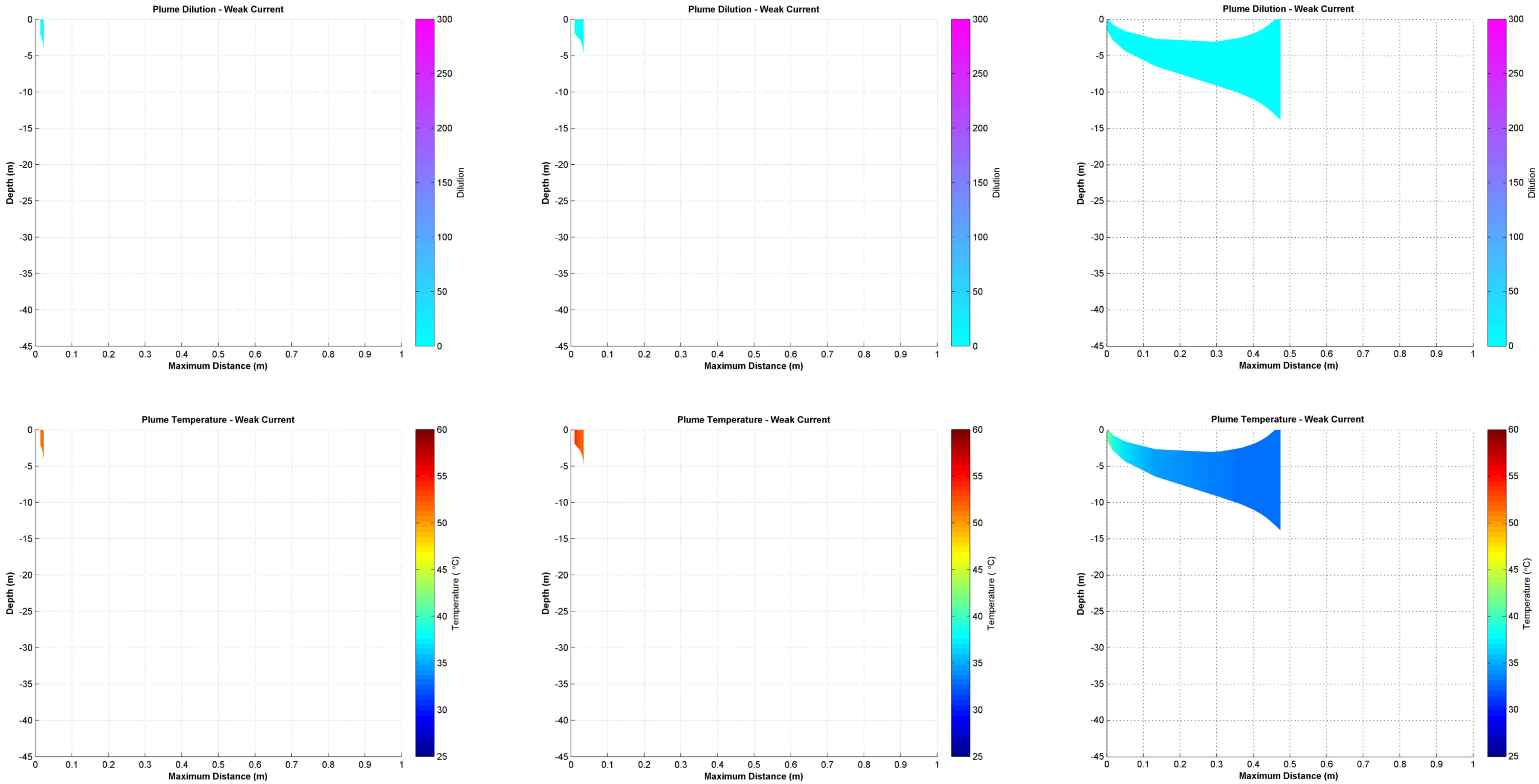


Figure 3.44 Near-field average dilution and temperature results for constant weak transitional currents with discharge flow rates of 64,800 m^3/d (Case C4; left column), 82,800 m^3/d (Case C7; middle column) and 165,600 m^3/d (Case C1; right column) at a discharge depth of 0 m.

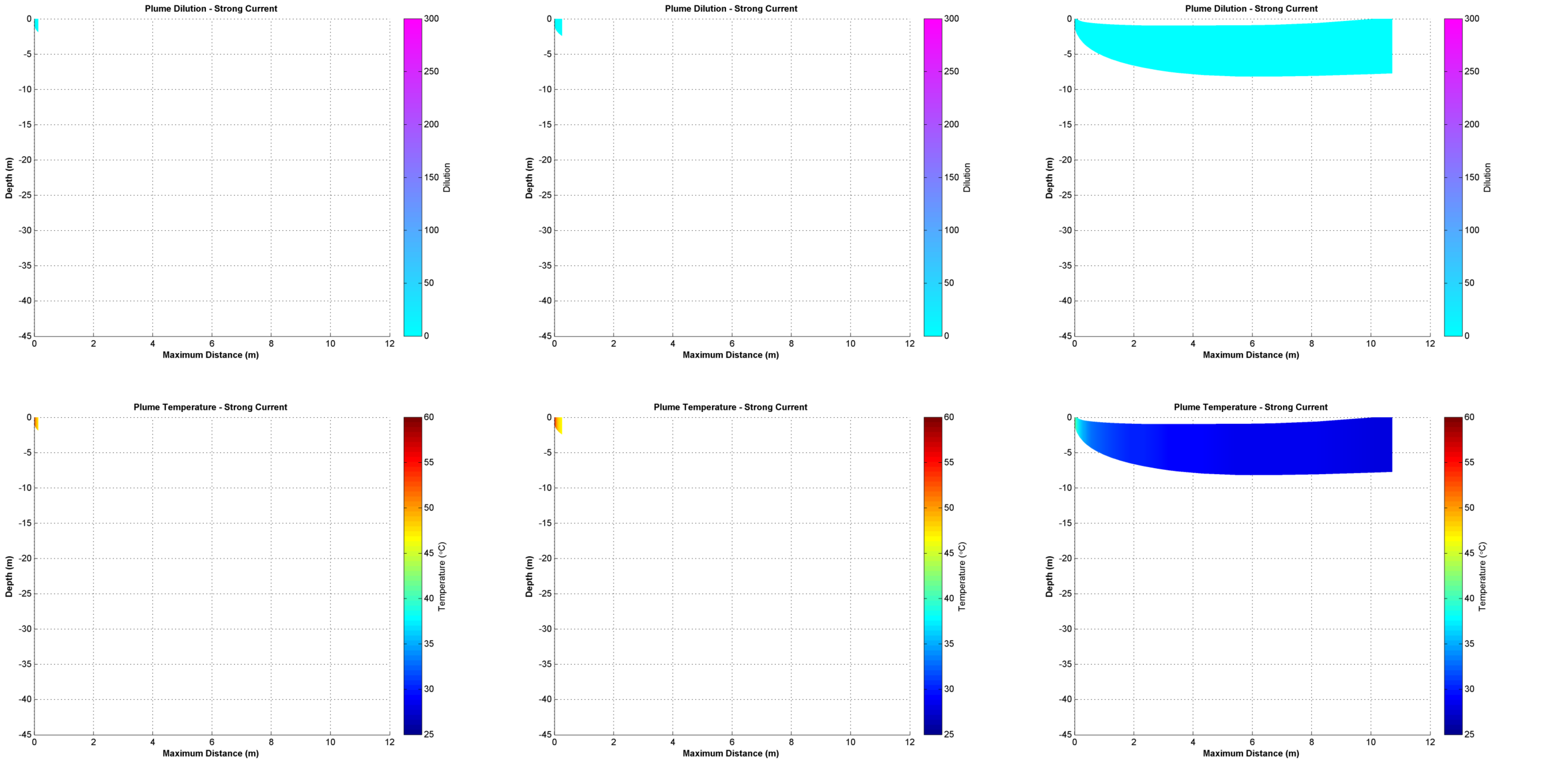


Figure 3.45 Near-field average dilution and temperature results for constant strong transitional currents with discharge flow rates of 64,800 m^3/d (Case C4; left column), 82,800 m^3/d (Case C7; middle column) and 165,600 m^3/d (Case C1; right column) at a discharge depth of 0 m.

3.1.3.4.4 Winter

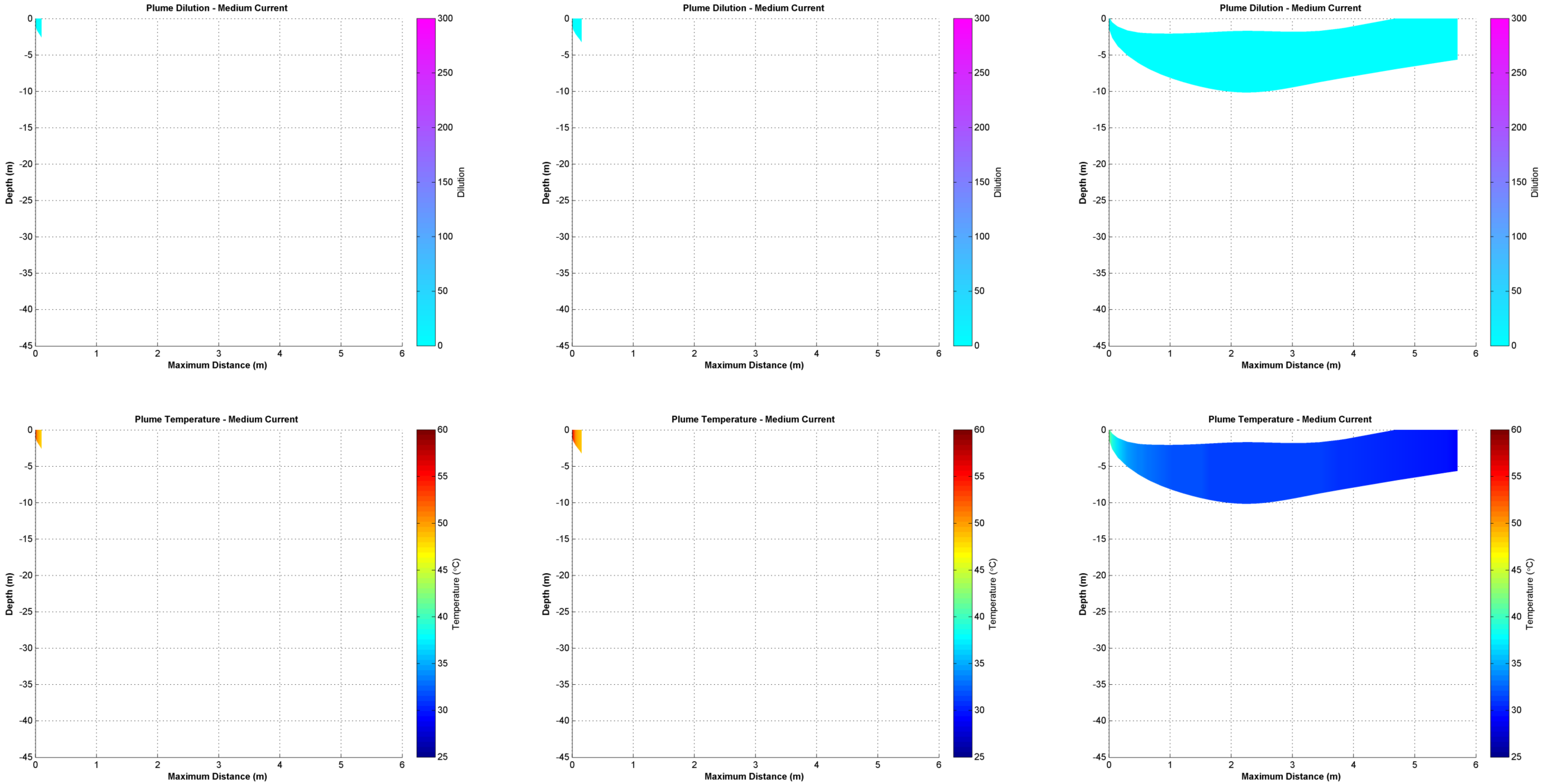


Figure 3.46 Near-field average dilution and temperature results for constant medium winter currents with discharge flow rates of 64,800 m^3/d (Case C4; left column), 82,800 m^3/d (Case C7; middle column) and 165,600 m^3/d (Case C1; right column) at a discharge depth of 0 m.

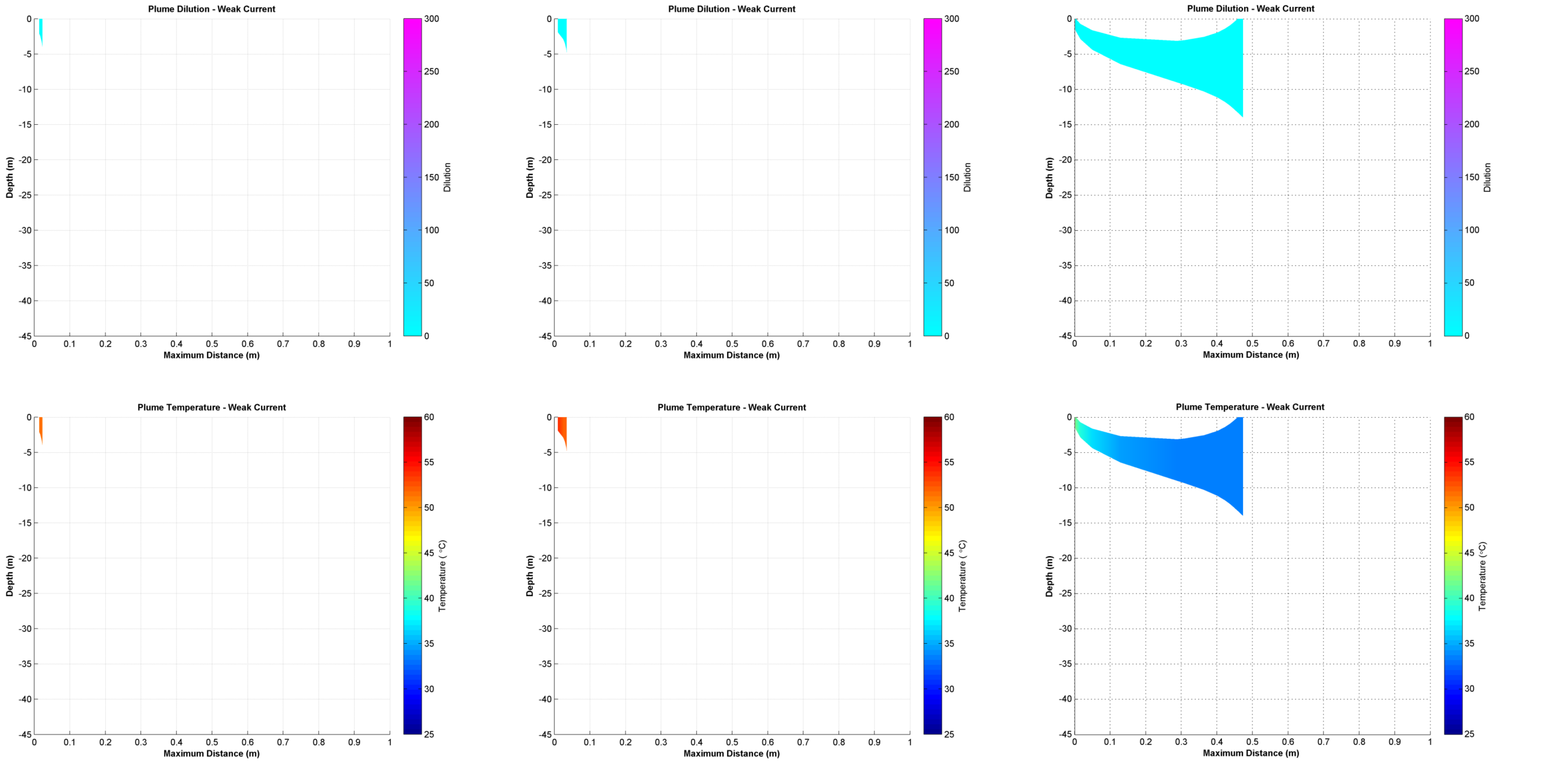


Figure 3.47 **Near-field average dilution and temperature results for constant weak winter currents with discharge flow rates of 64,800 m^3/d (Case C4; left column), 82,800 m^3/d (Case C7; middle column) and 165,600 m^3/d (Case C1; right column) at a discharge depth of 0 m.**

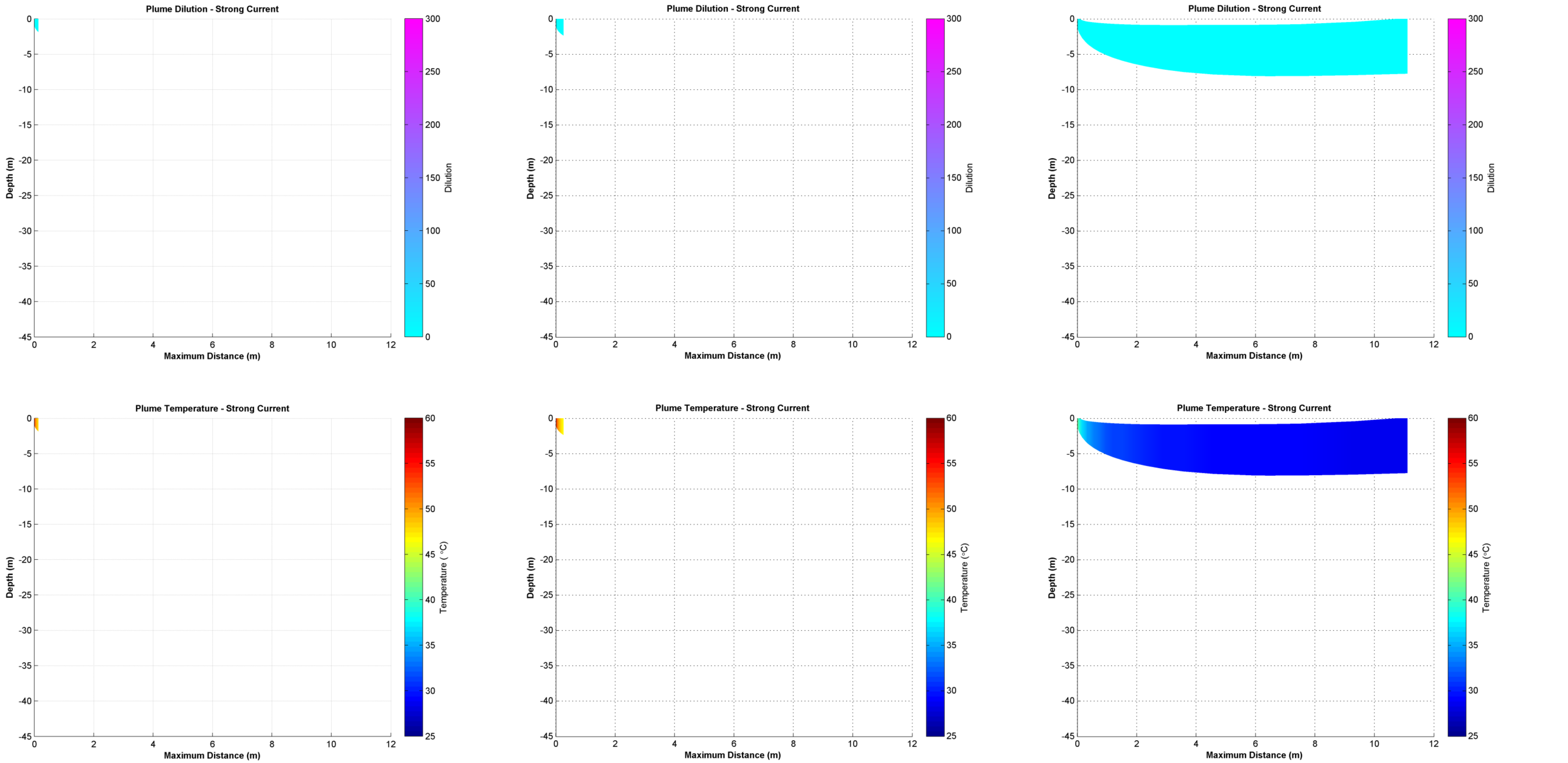


Figure 3.48 Near-field average dilution and temperature results for constant strong winter currents with discharge flow rates of 64,800 m^3/d (Case C4; left column), 82,800 m^3/d (Case C7; middle column) and 165,600 m^3/d (Case C1; right column) at a discharge depth of 0 m.

3.1.3.5 Discharge Depth of 10 m with Varying Flow Rates

3.1.3.5.1 Annualised

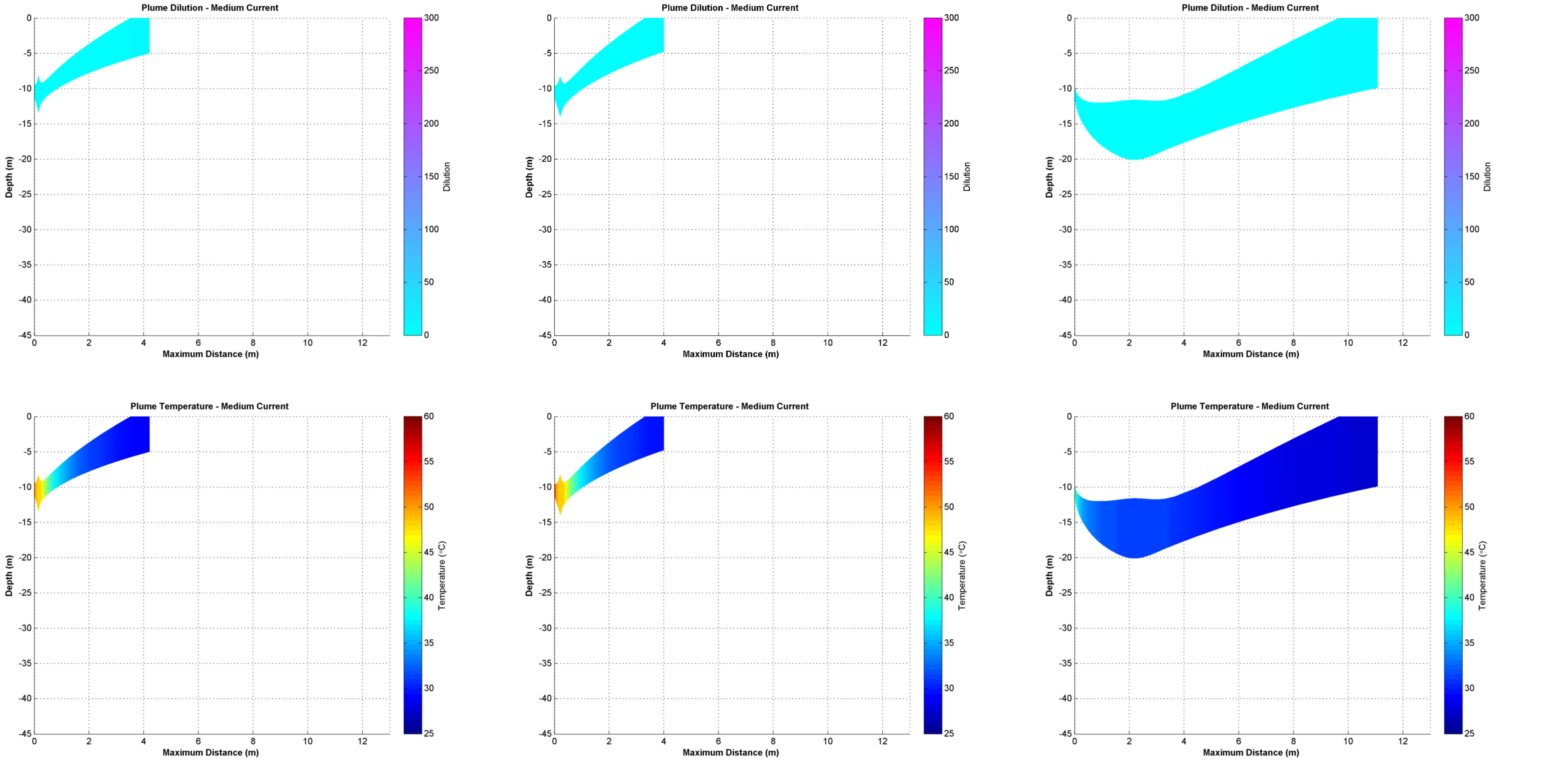


Figure 3.49 **Near-field average dilution and temperature results for constant medium annualised currents with discharge flow rates of 64,800 m^3/d (Case C5; left column), 82,800 m^3/d (Case C8; middle column) and 165,600 m^3/d (Case C2; right column) at a discharge depth of 10 m.**

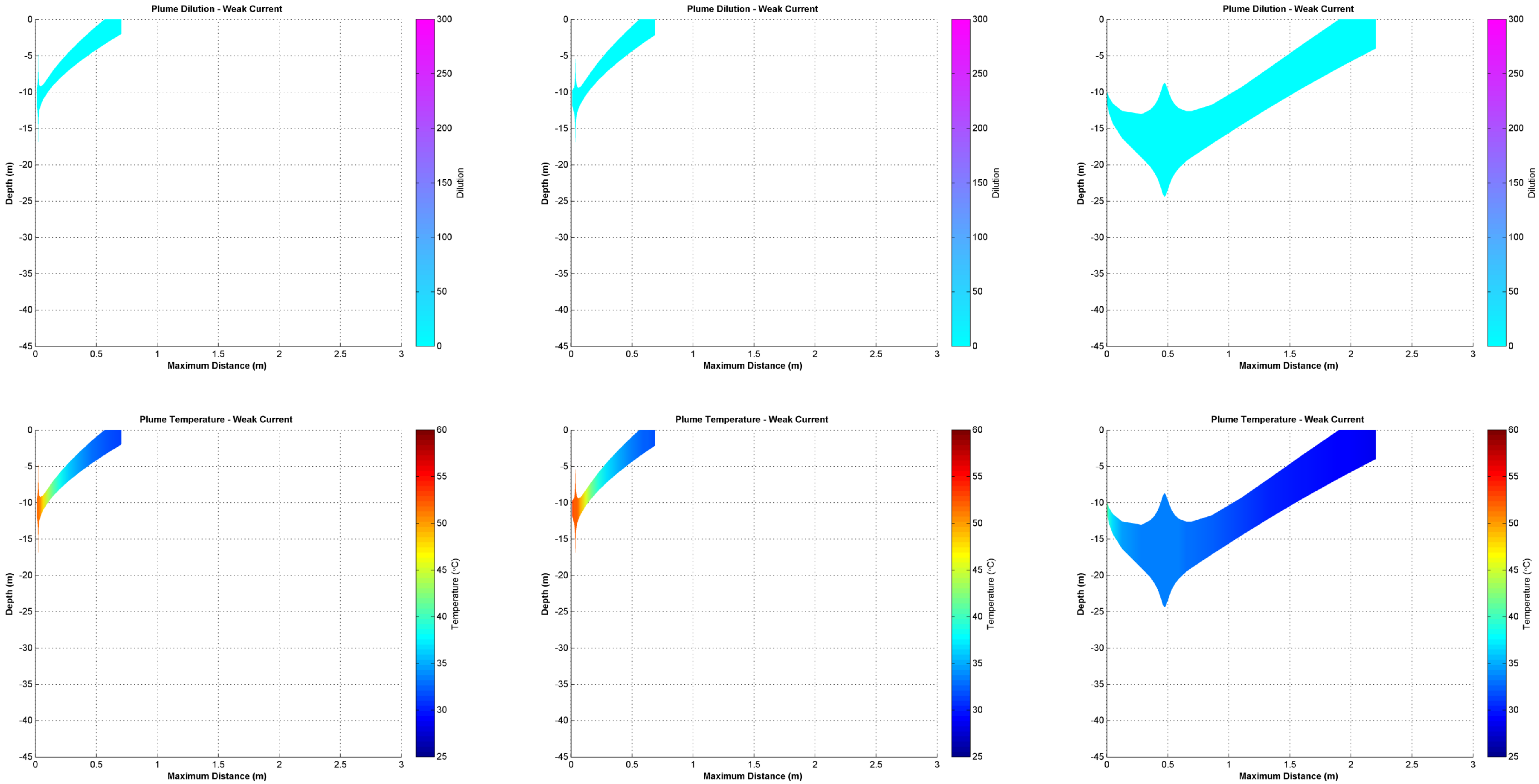


Figure 3.50 Near-field average dilution and temperature results for constant weak annualised currents with discharge flow rates of 64,800 m³/d (Case C5; left column), 82,800 m³/d (Case C8; middle column) and 165,600 m³/d (Case C2; right column) at a discharge depth of 10 m.

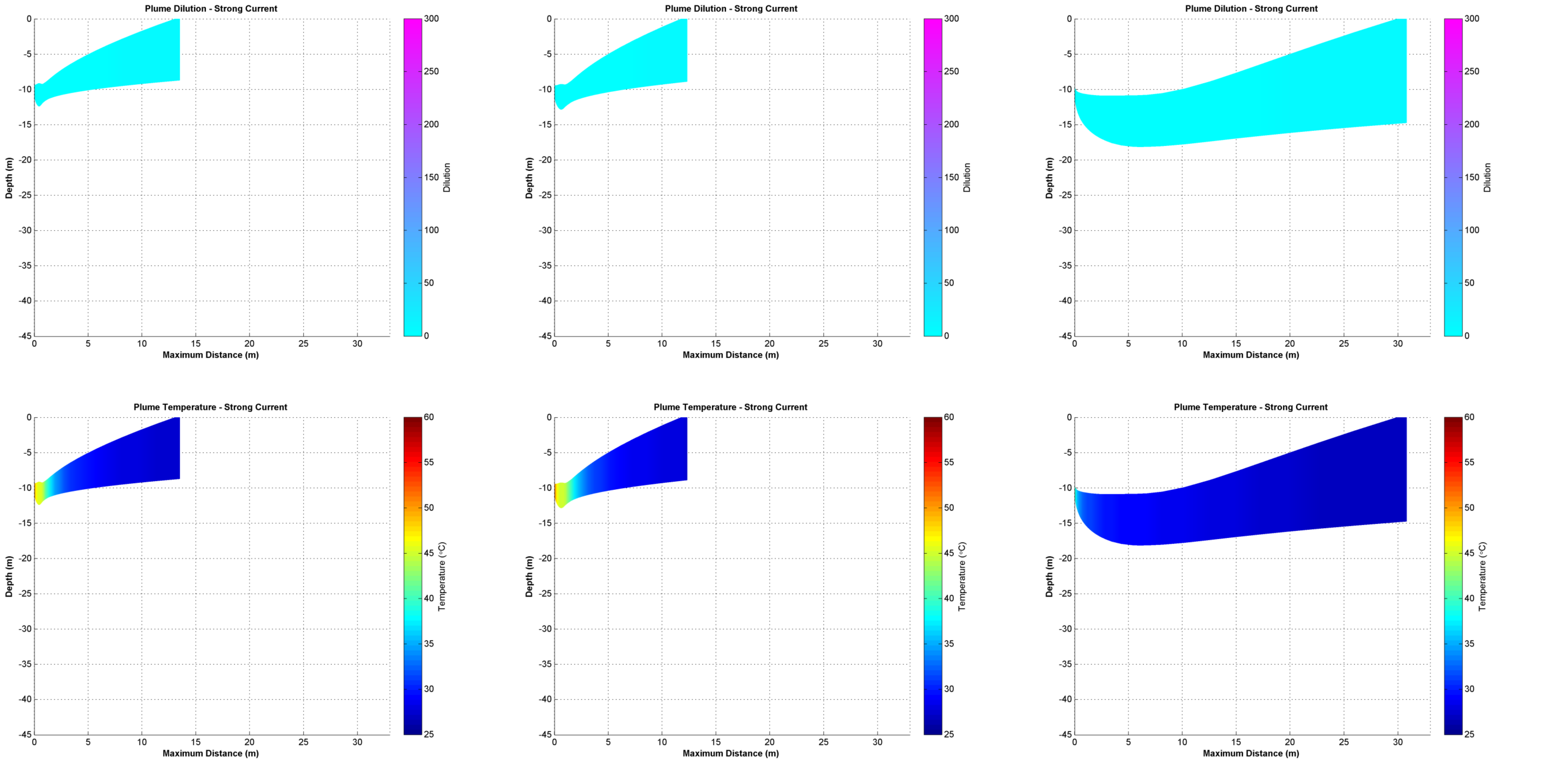


Figure 3.51 Near-field average dilution and temperature results for constant strong annualised currents with discharge flow rates of 64,800 m³/d (Case C5; left column), 82,800 m³/d (Case C8; middle column) and 165,600 m³/d (Case C2; right column) at a discharge depth of 10 m.

3.1.3.5.2 Summer

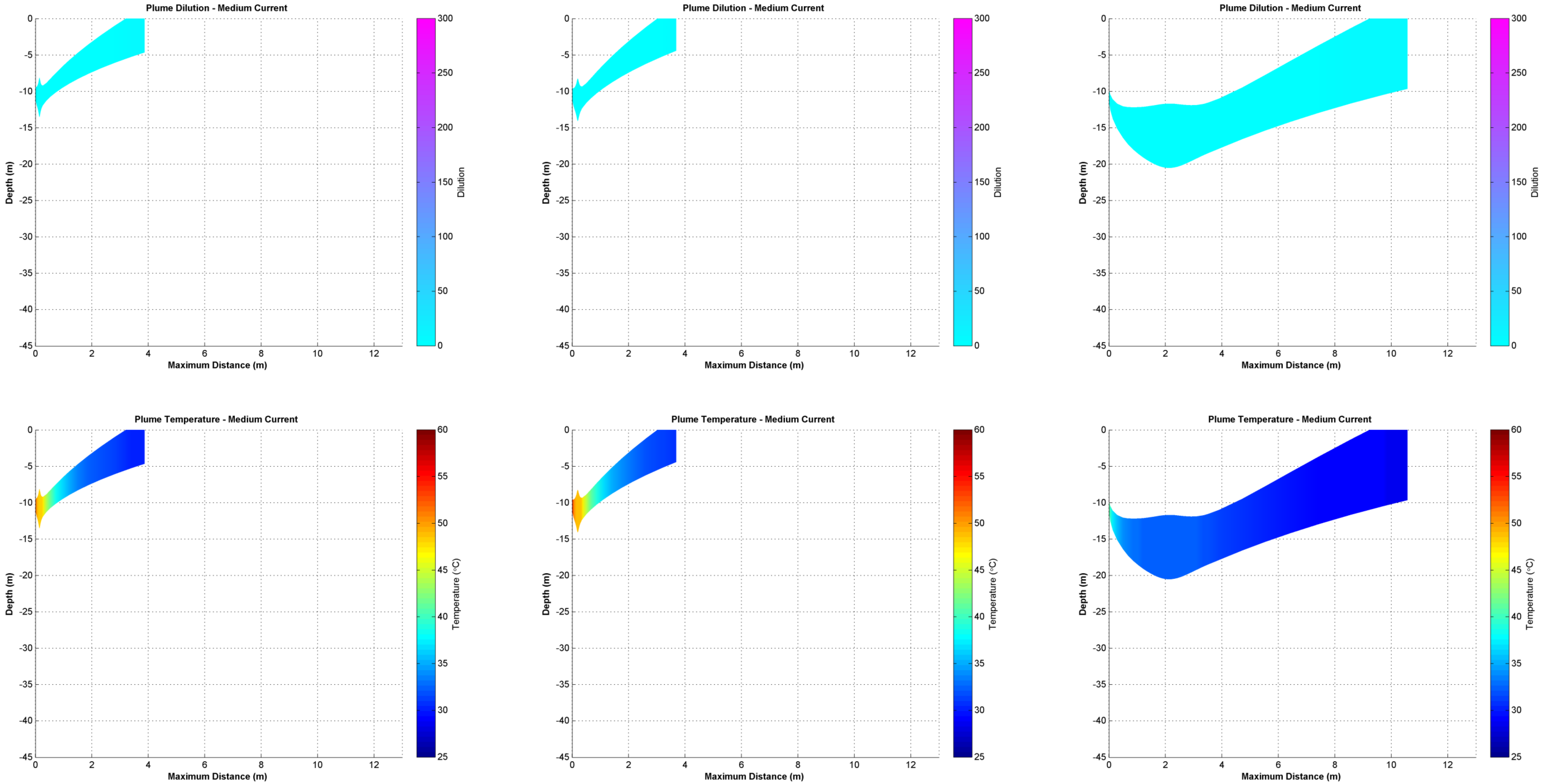


Figure 3.52 Near-field average dilution and temperature results for constant medium summer currents with discharge flow rates of 64,800 m³/d (Case C5; left column), 82,800 m³/d (Case C8; middle column) and 165,600 m³/d (Case C2; right column) at a discharge depth of 10 m.

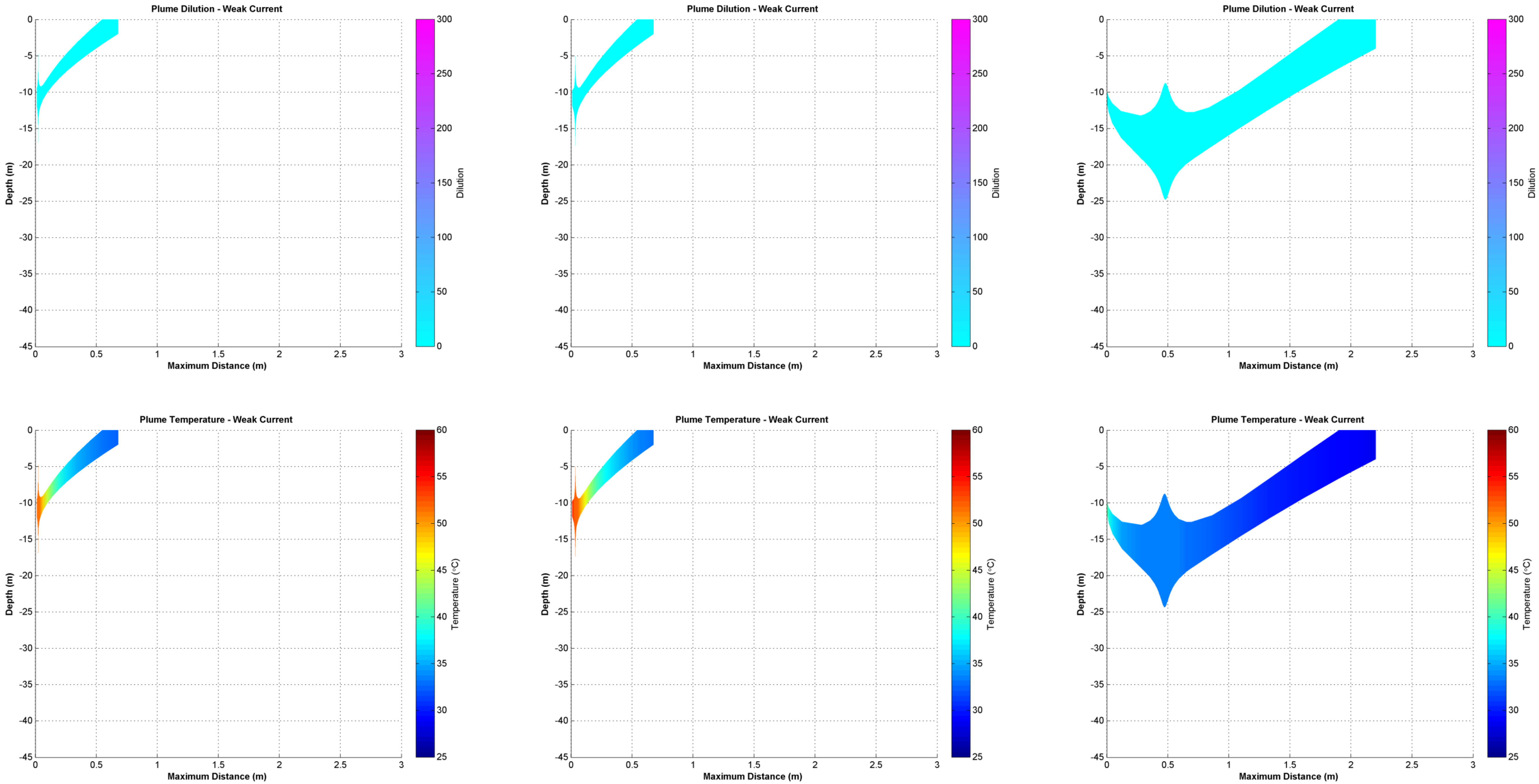


Figure 3.53 Near-field average dilution and temperature results for constant weak summer currents with discharge flow rates of 64,800 m³/d (Case C5; left column), 82,800 m³/d (Case C8; middle column) and 165,600 m³/d (Case C2; right column) at a discharge depth of 10 m.

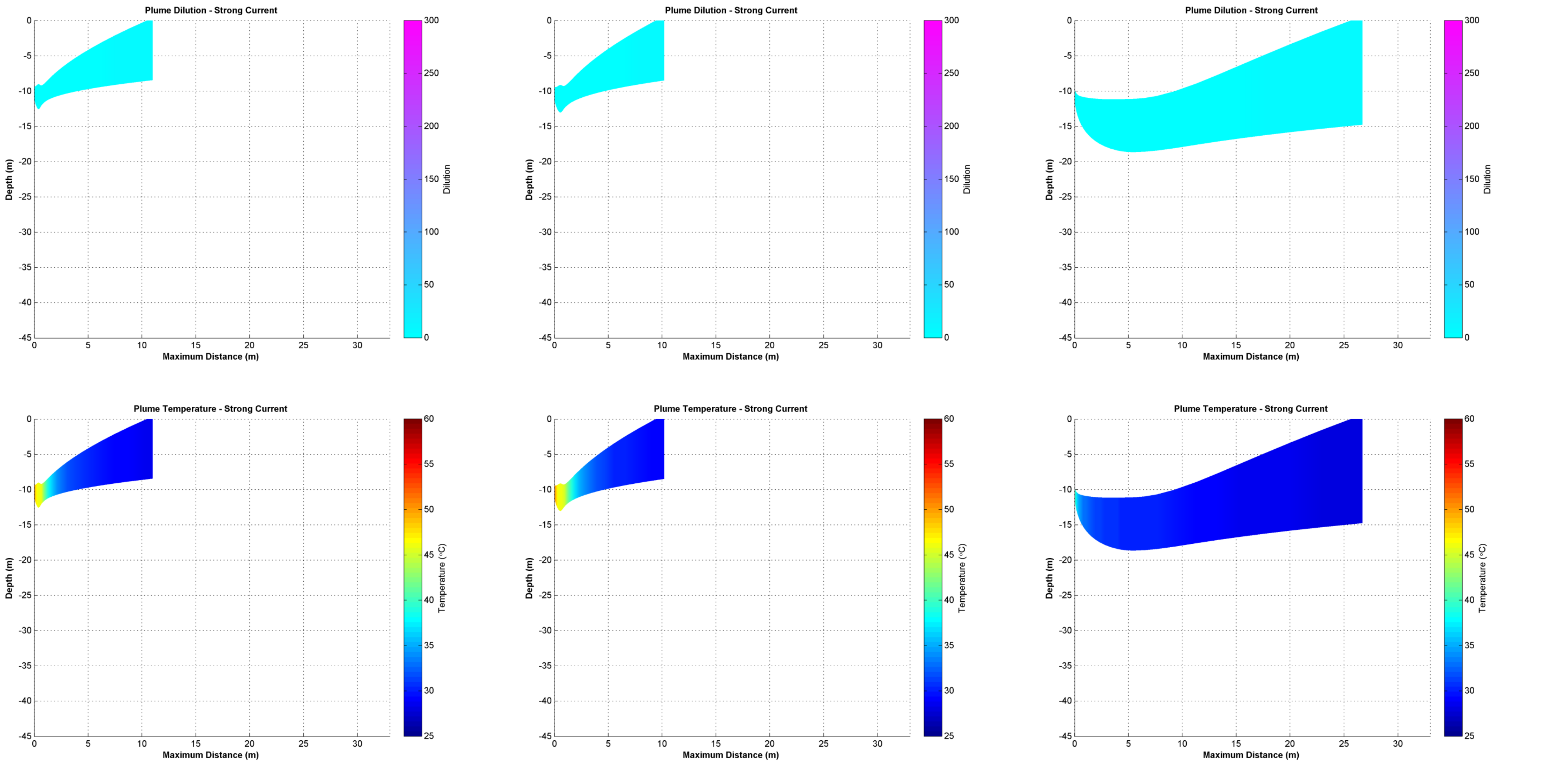


Figure 3.54 Near-field average dilution and temperature results for constant strong summer currents with discharge flow rates of 64,800 m^3/d (Case C5; left column), 82,800 m^3/d (Case C8; middle column) and 165,600 m^3/d (Case C2; right column) at a discharge depth of 10 m.

3.1.3.5.3 Transitional

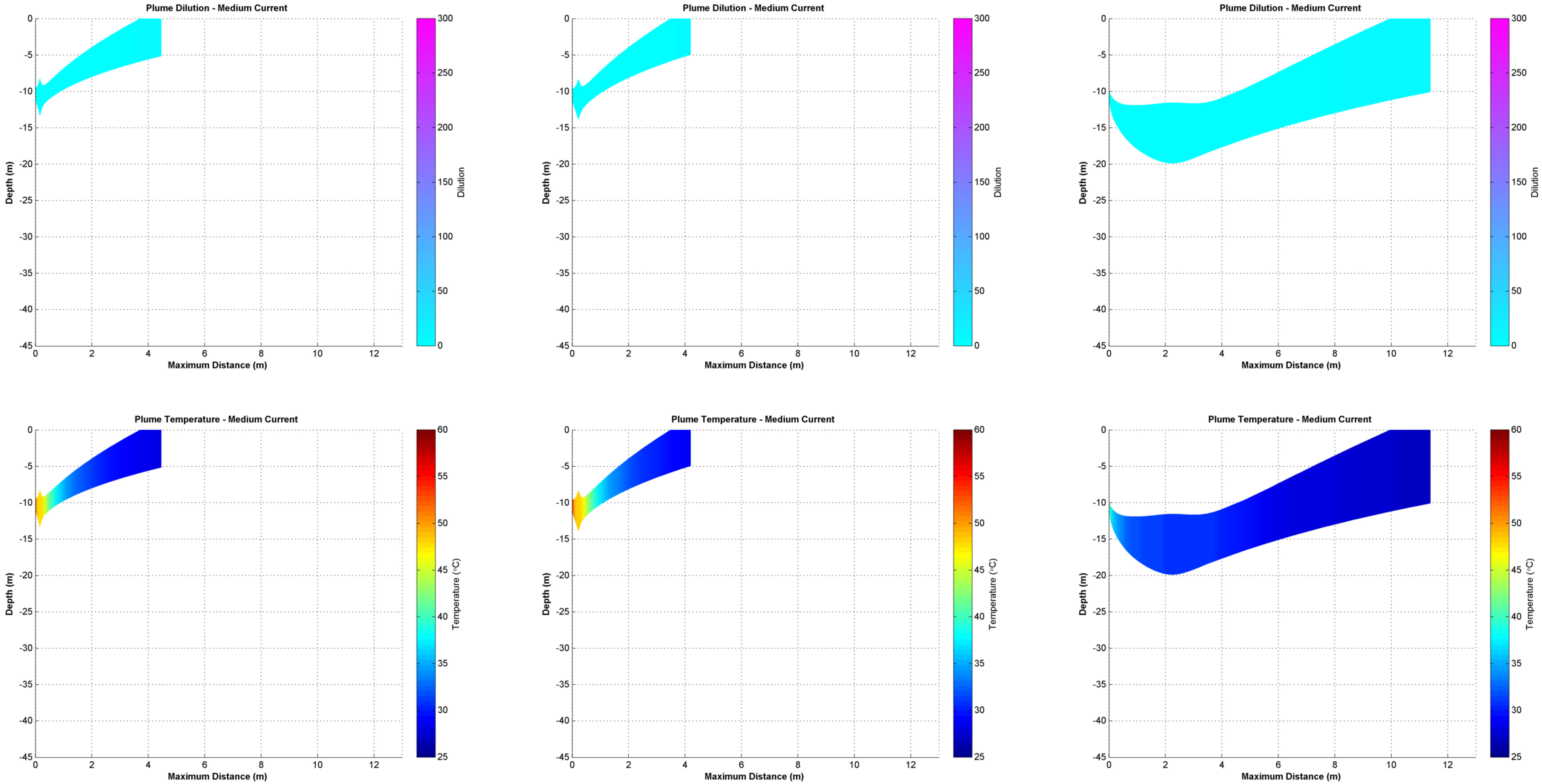


Figure 3.55 Near-field average dilution and temperature results for constant medium transitional currents with discharge flow rates of 64,800 m^3/d (Case C5; left column), 82,800 m^3/d (Case C8; middle column) and 165,600 m^3/d (Case C2; right column) at a discharge depth of 10 m.

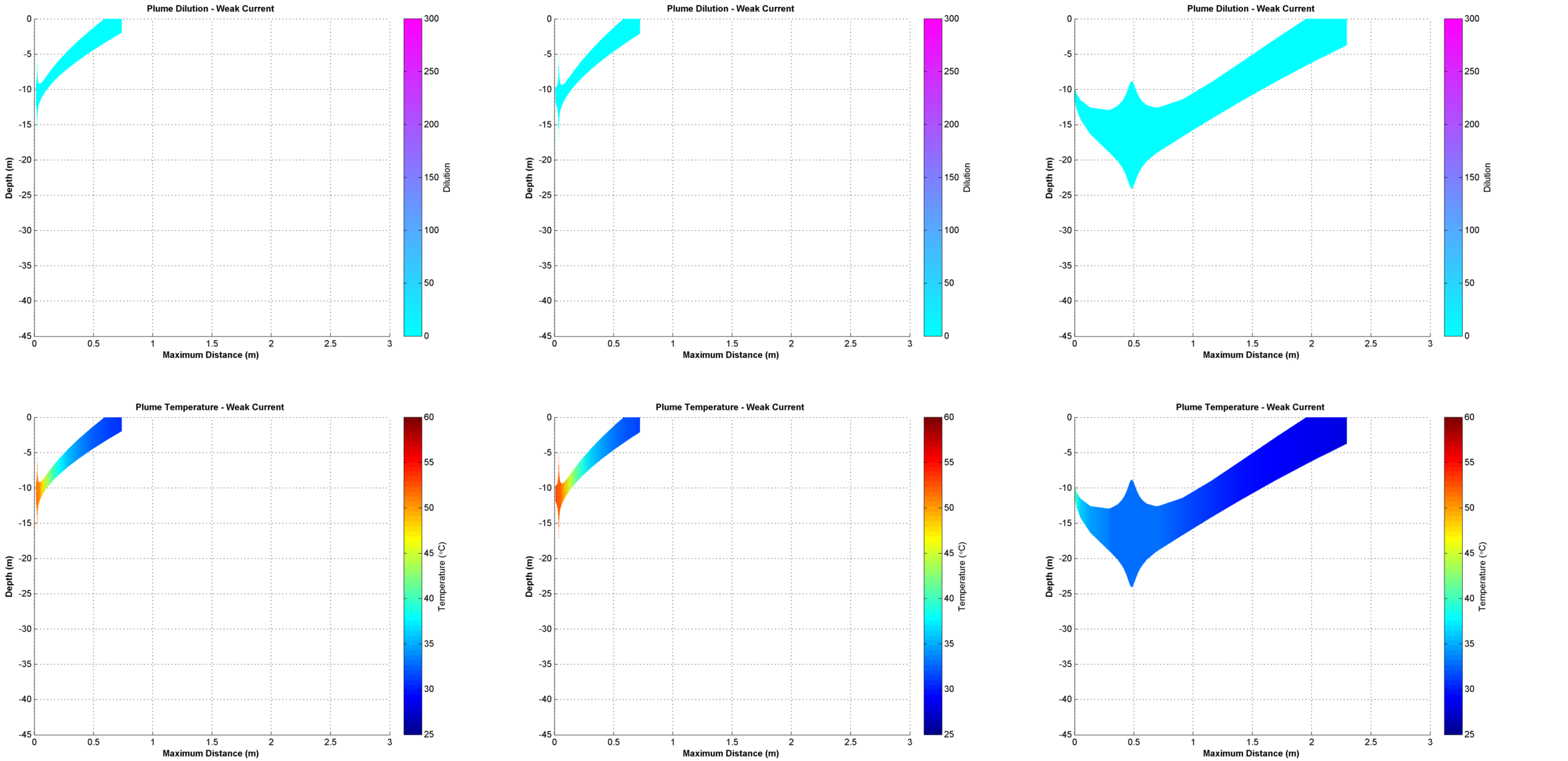


Figure 3.56 **Near-field average dilution and temperature results for constant weak transitional currents with discharge flow rates of 64,800 m³/d (Case C5; left column), 82,800 m³/d (Case C8; middle column) and 165,600 m³/d (Case C2; right column) at a discharge depth of 10 m.**

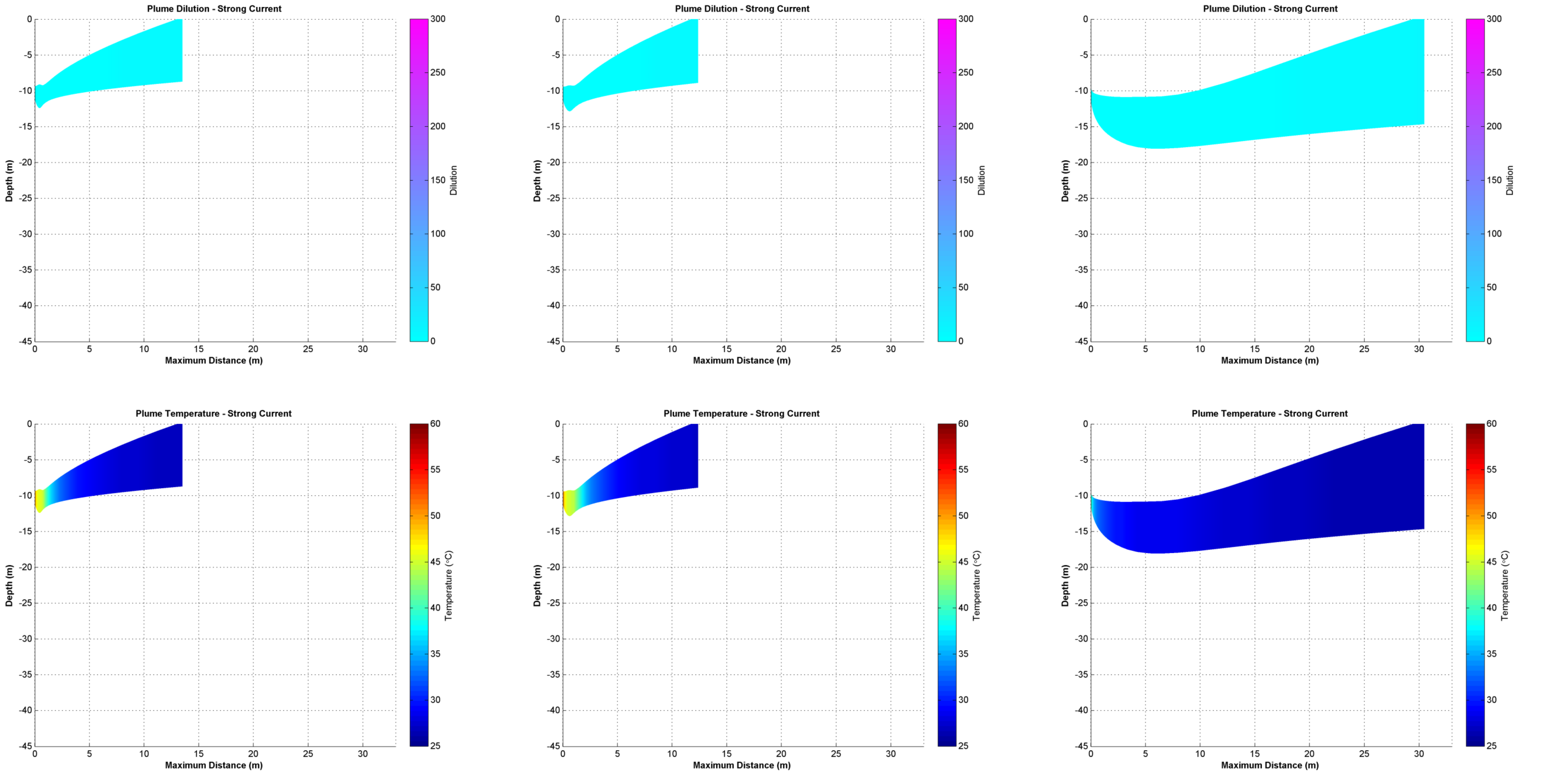


Figure 3.57 **Near-field average dilution and temperature results for constant strong transitional currents with discharge flow rates of 64,800 m^3/d (Case C5; left column), 82,800 m^3/d (Case C8; middle column) and 165,600 m^3/d (Case C2; right column) at a discharge depth of 10 m.**

3.1.3.5.4 Winter

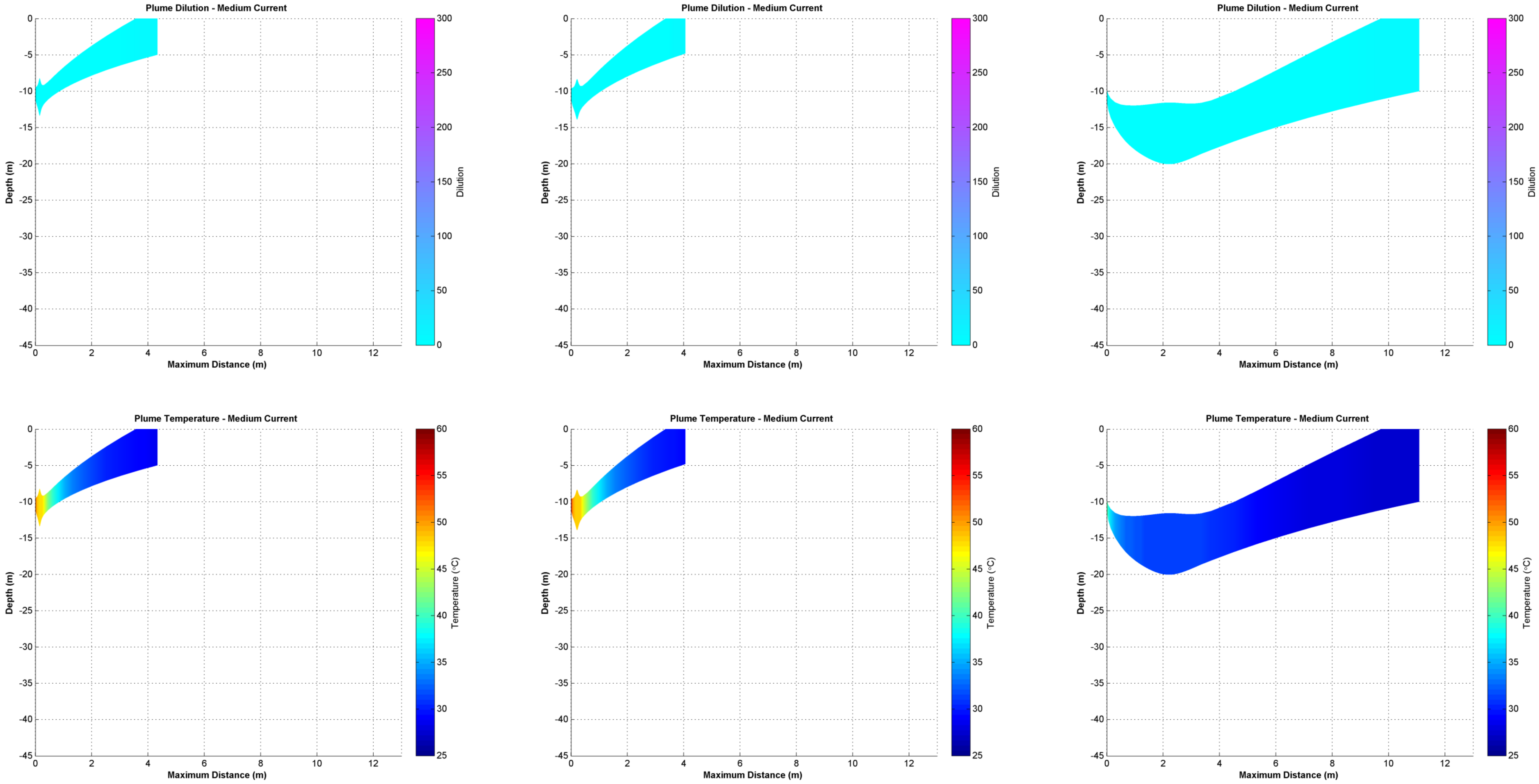


Figure 3.58 Near-field average dilution and temperature results for constant medium winter currents with discharge flow rates of 64,800 m^3/d (Case C5; left column), 82,800 m^3/d (Case C8; middle column) and 165,600 m^3/d (Case C2; right column) at a discharge depth of 10 m.

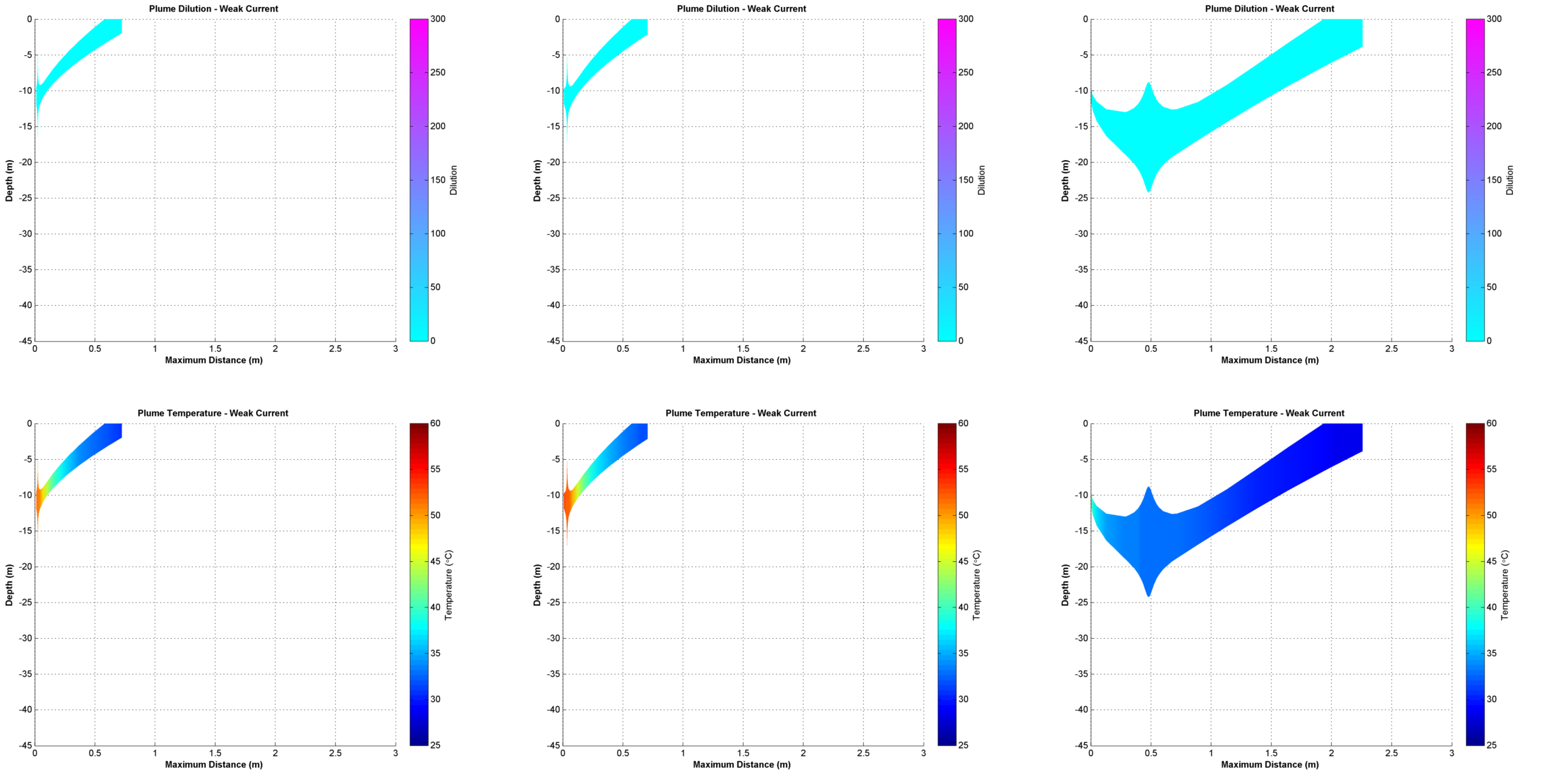


Figure 3.59 **Near-field average dilution and temperature results for constant weak winter currents with discharge flow rates of 64,800 m³/d (Case C5; left column), 82,800 m³/d (Case C8; middle column) and 165,600 m³/d (Case C2; right column) at a discharge depth of 10 m.**

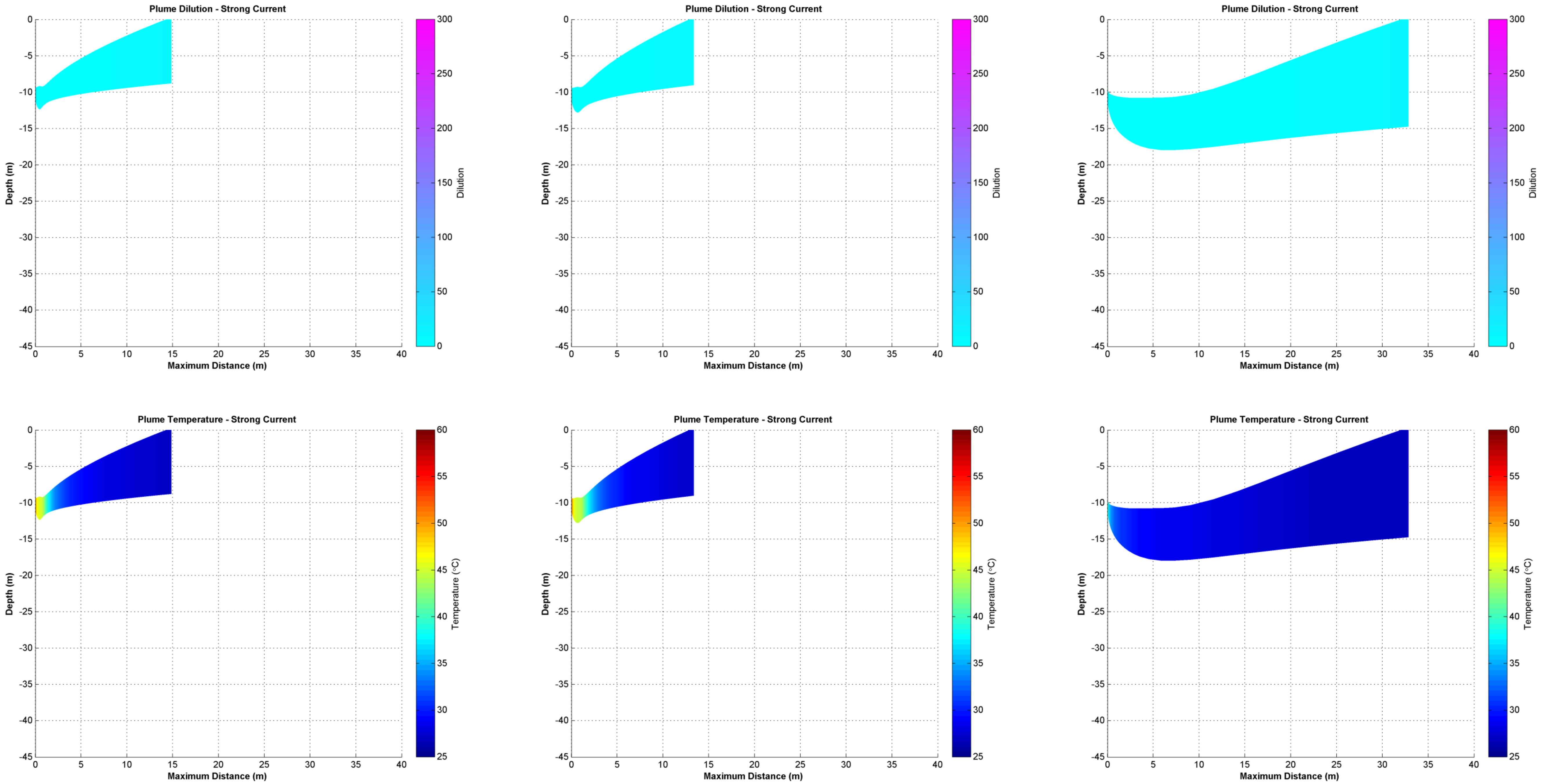


Figure 3.60 **Near-field average dilution and temperature results for constant strong winter currents with discharge flow rates of 64,800 m^3/d (Case C5; left column), 82,800 m^3/d (Case C8; middle column) and 165,600 m^3/d (Case C2; right column) at a discharge depth of 10 m.**

3.1.3.6 Discharge Depth of 30 m with Varying Flow Rates

3.1.3.6.1 Annualised

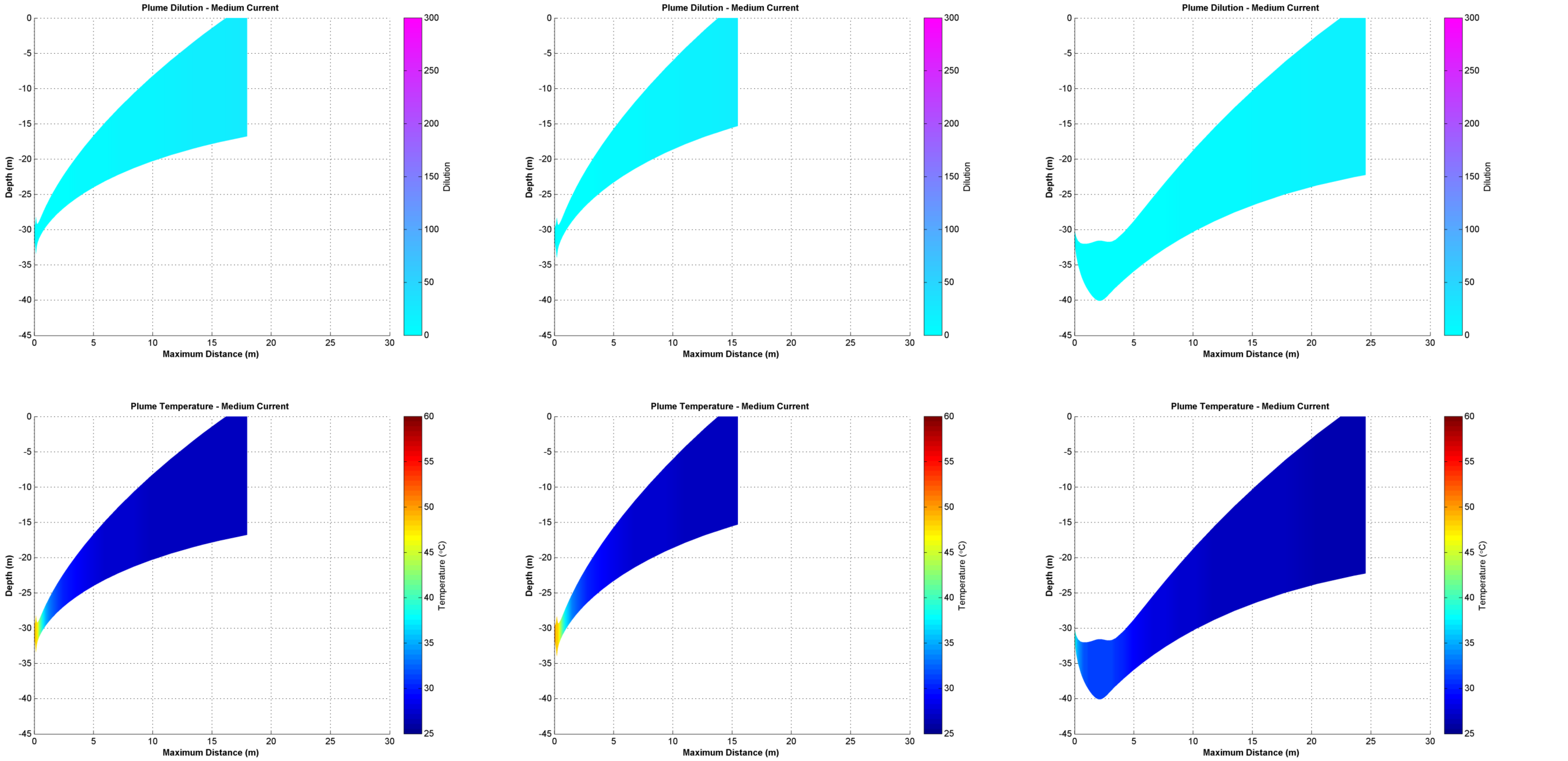


Figure 3.61 Near-field average dilution and temperature results for constant medium annualised currents with discharge flow rates of 64,800 m³/d (Case C6; left column), 82,800 m³/d (Case C9; middle column) and 165,600 m³/d (Case C3; right column) at a discharge depth of 30 m.

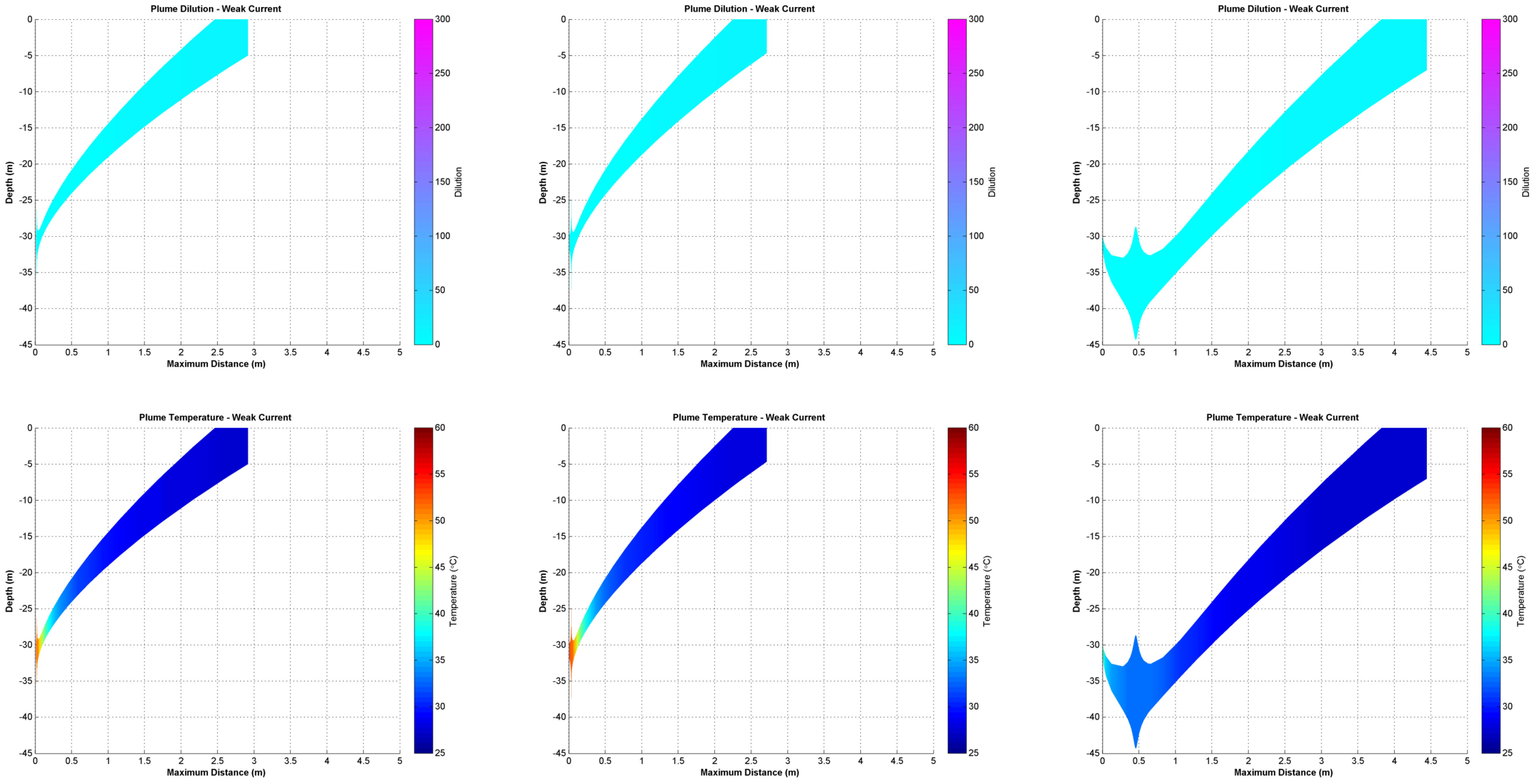


Figure 3.62 Near-field average dilution and temperature results for constant weak annualised currents with discharge flow rates of 64,800 m^3/d (Case C6; left column), 82,800 m^3/d (Case C9; middle column) and 165,600 m^3/d (Case C3; right column) at a discharge depth of 30 m.

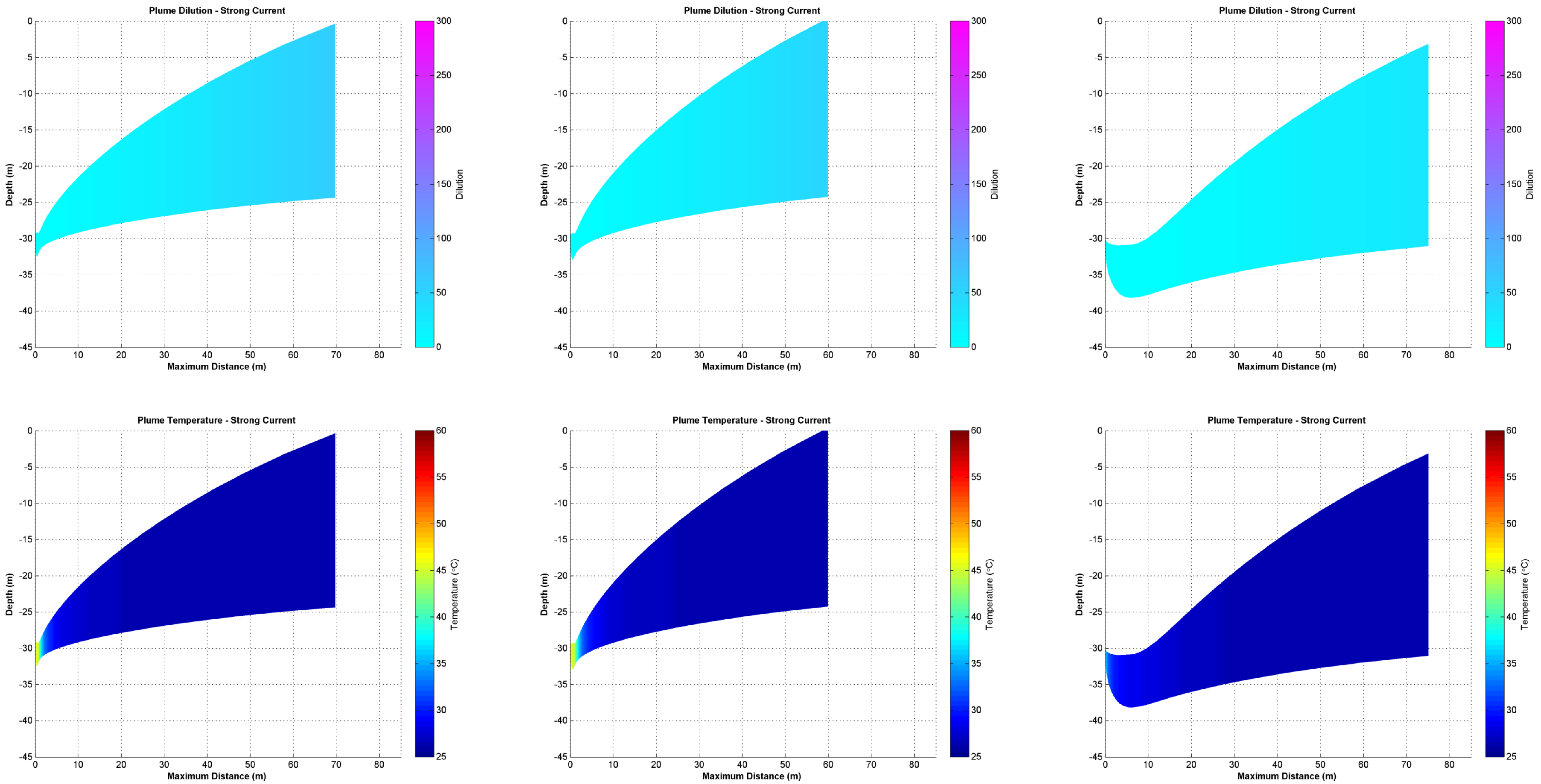


Figure 3.63 Near-field average dilution and temperature results for constant strong annualised currents with discharge flow rates of 64,800 m^3/d (Case C6; left column), 82,800 m^3/d (Case C9; middle column) and 165,600 m^3/d (Case C3; right column) at a discharge depth of 30 m.

3.1.3.6.2 Summer

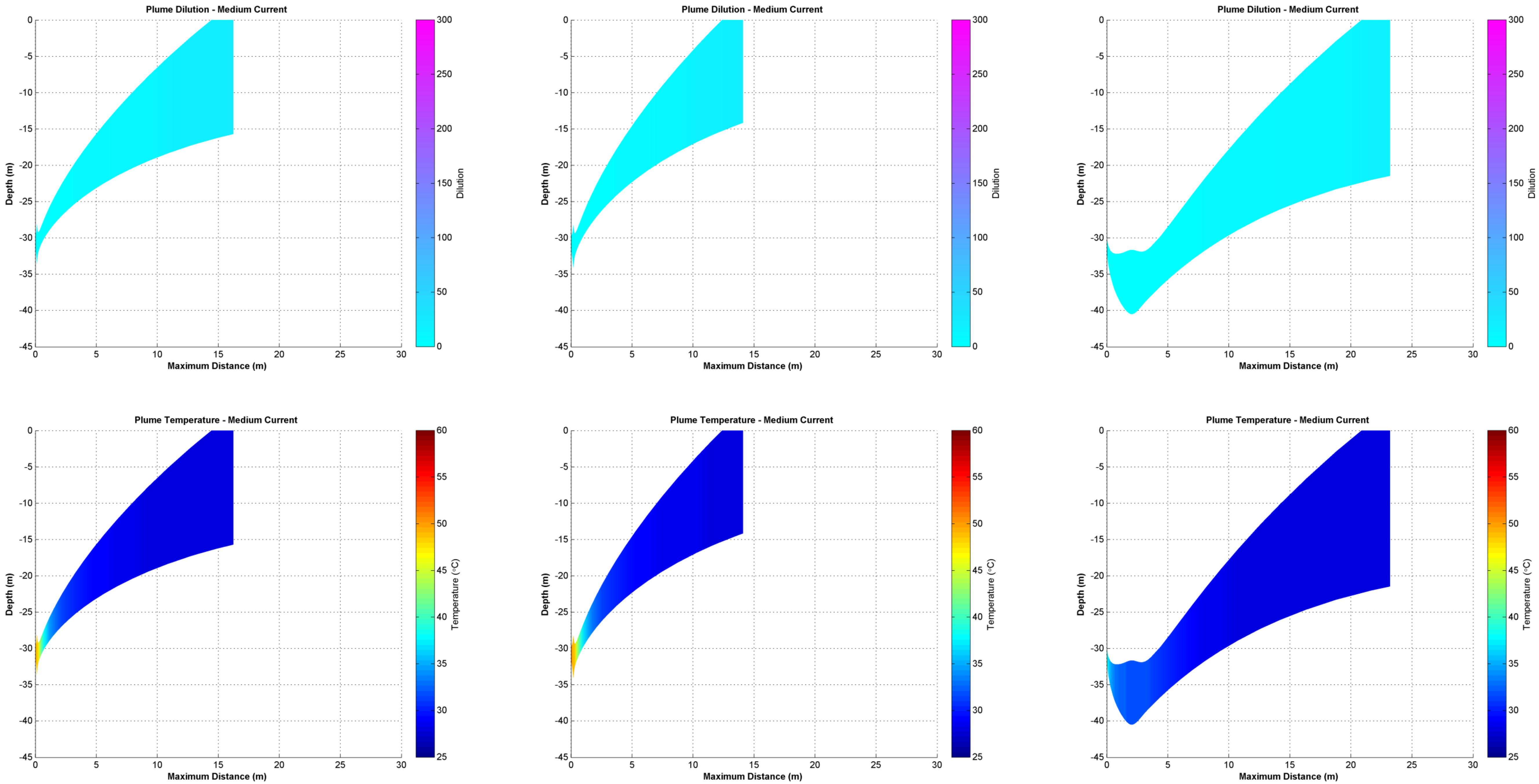


Figure 3.64 Near-field average dilution and temperature results for constant medium summer currents with discharge flow rates of 64,800 m³/d (Case C6; left column), 82,800 m³/d (Case C9; middle column) and 165,600 m³/d (Case C3; right column) at a discharge depth of 30 m.

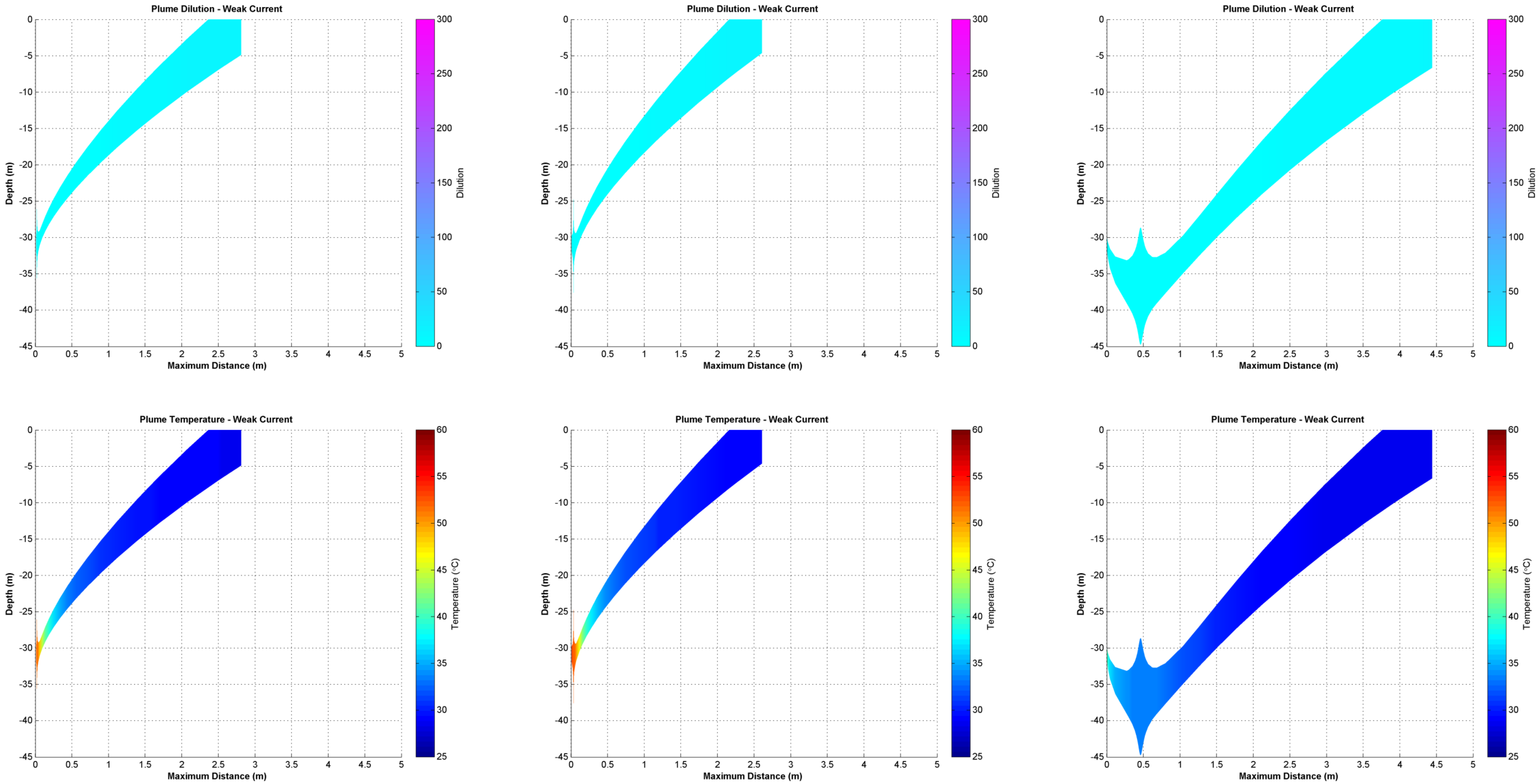


Figure 3.65 Near-field average dilution and temperature results for constant weak summer currents with discharge flow rates of 64,800 m³/d (Case C6; left column), 82,800 m³/d (Case C9; middle column) and 165,600 m³/d (Case C3; right column) at a discharge depth of 30 m.

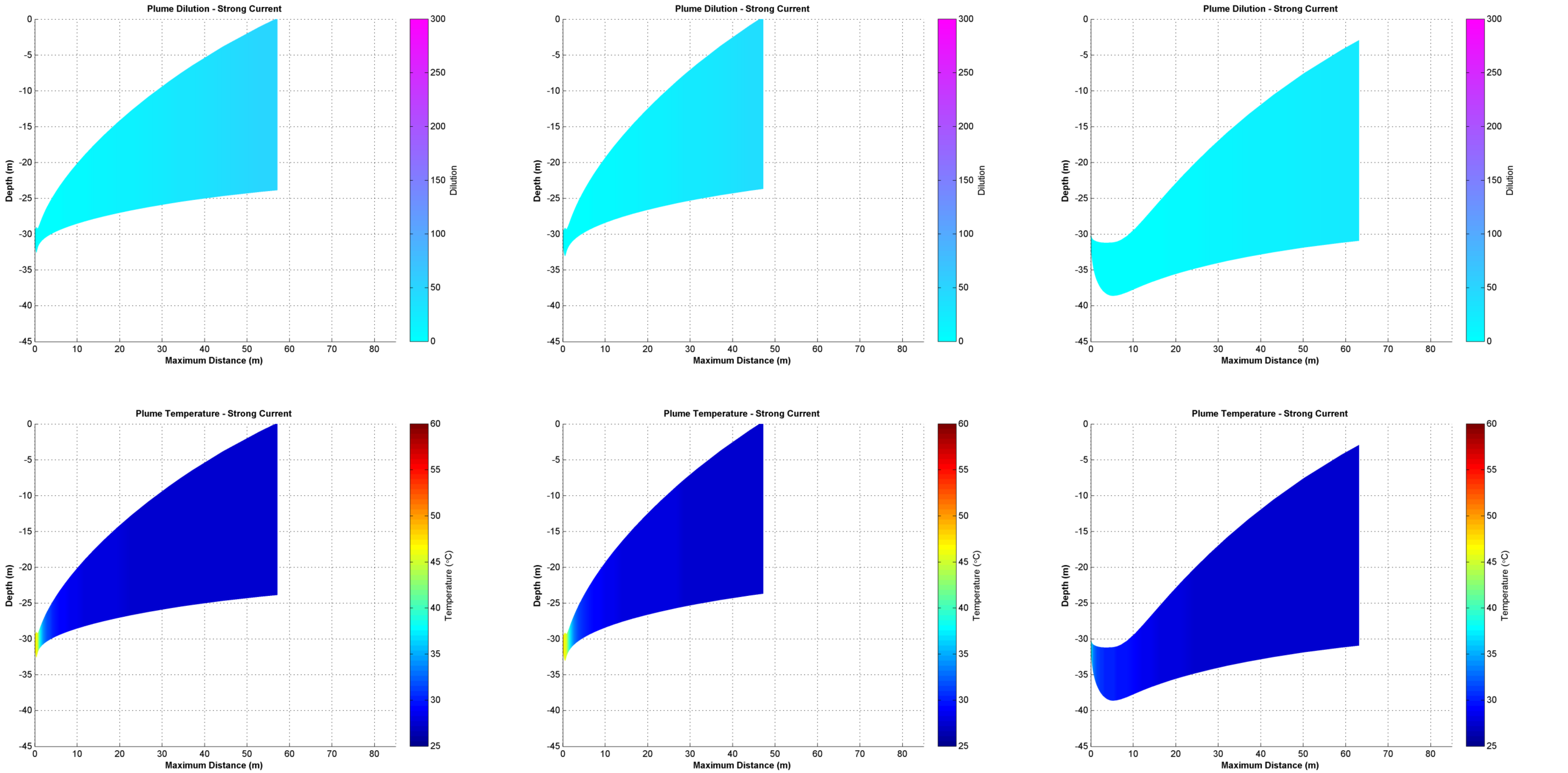


Figure 3.66 Near-field average dilution and temperature results for constant strong summer currents with discharge flow rates of 64,800 m^3/d (Case C6; left column), 82,800 m^3/d (Case C9; middle column) and 165,600 m^3/d (Case C3; right column) at a discharge depth of 30 m.

3.1.3.6.3 Transitional

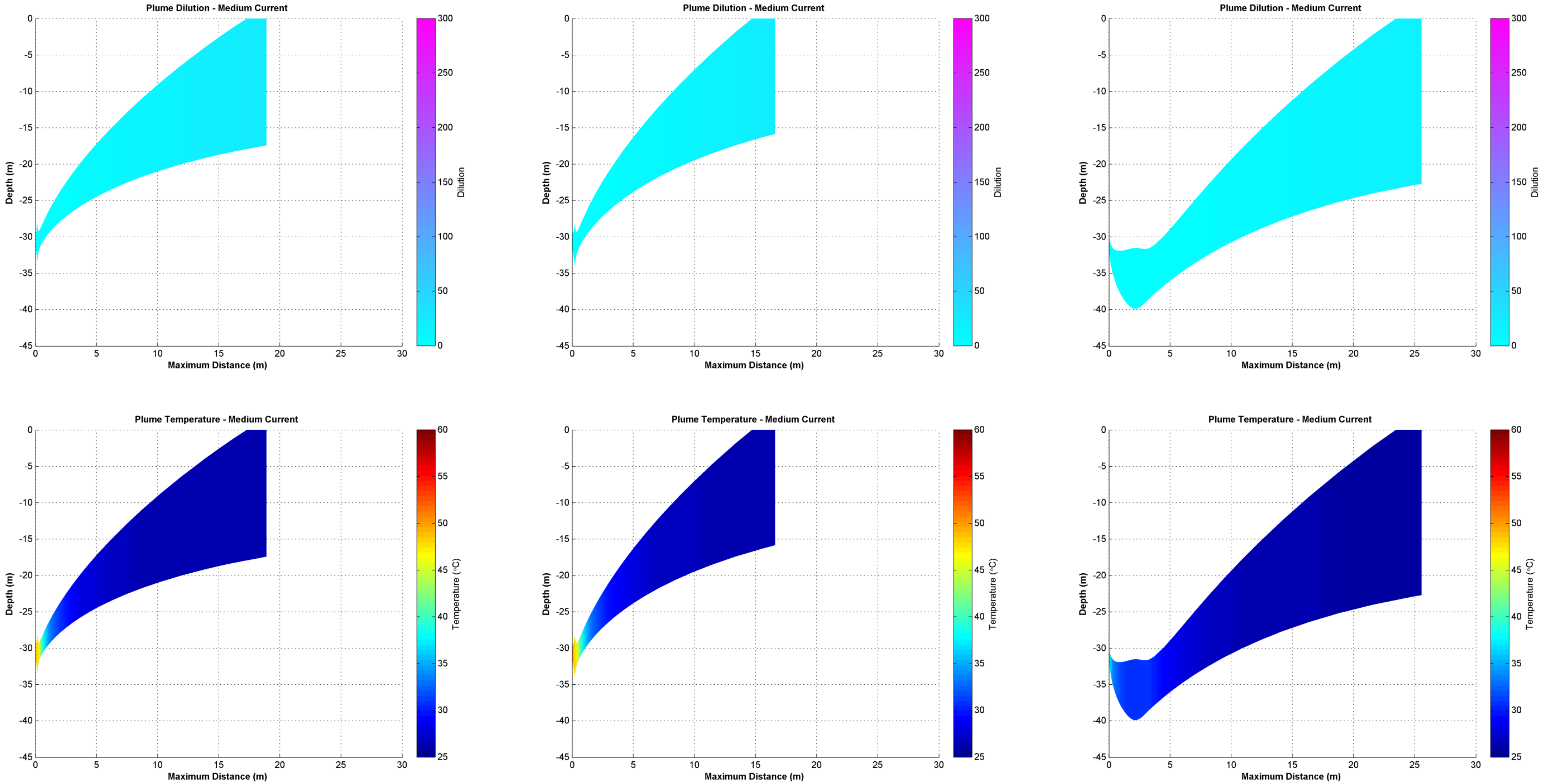


Figure 3.67 **Near-field average dilution and temperature results for constant medium transitional currents with discharge flow rates of 64,800 m^3/d (Case C6; left column), 82,800 m^3/d (Case C9; middle column) and 165,600 m^3/d (Case C3; right column) at a discharge depth of 30 m.**

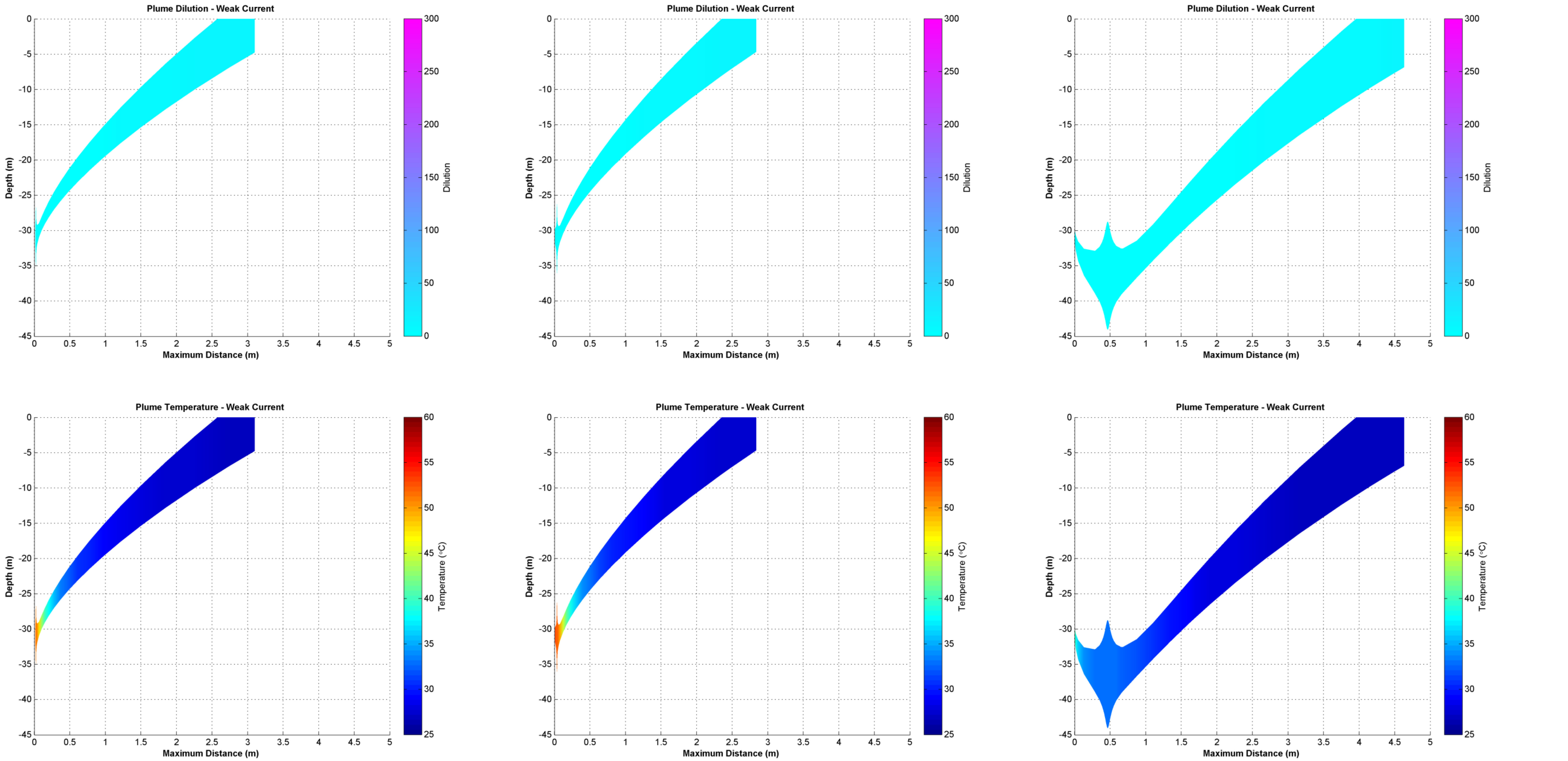


Figure 3.68 Near-field average dilution and temperature results for constant weak transitional currents with discharge flow rates of 64,800 m^3/d (Case C6; left column), 82,800 m^3/d (Case C9; middle column) and 165,600 m^3/d (Case C3; right column) at a discharge depth of 30 m.

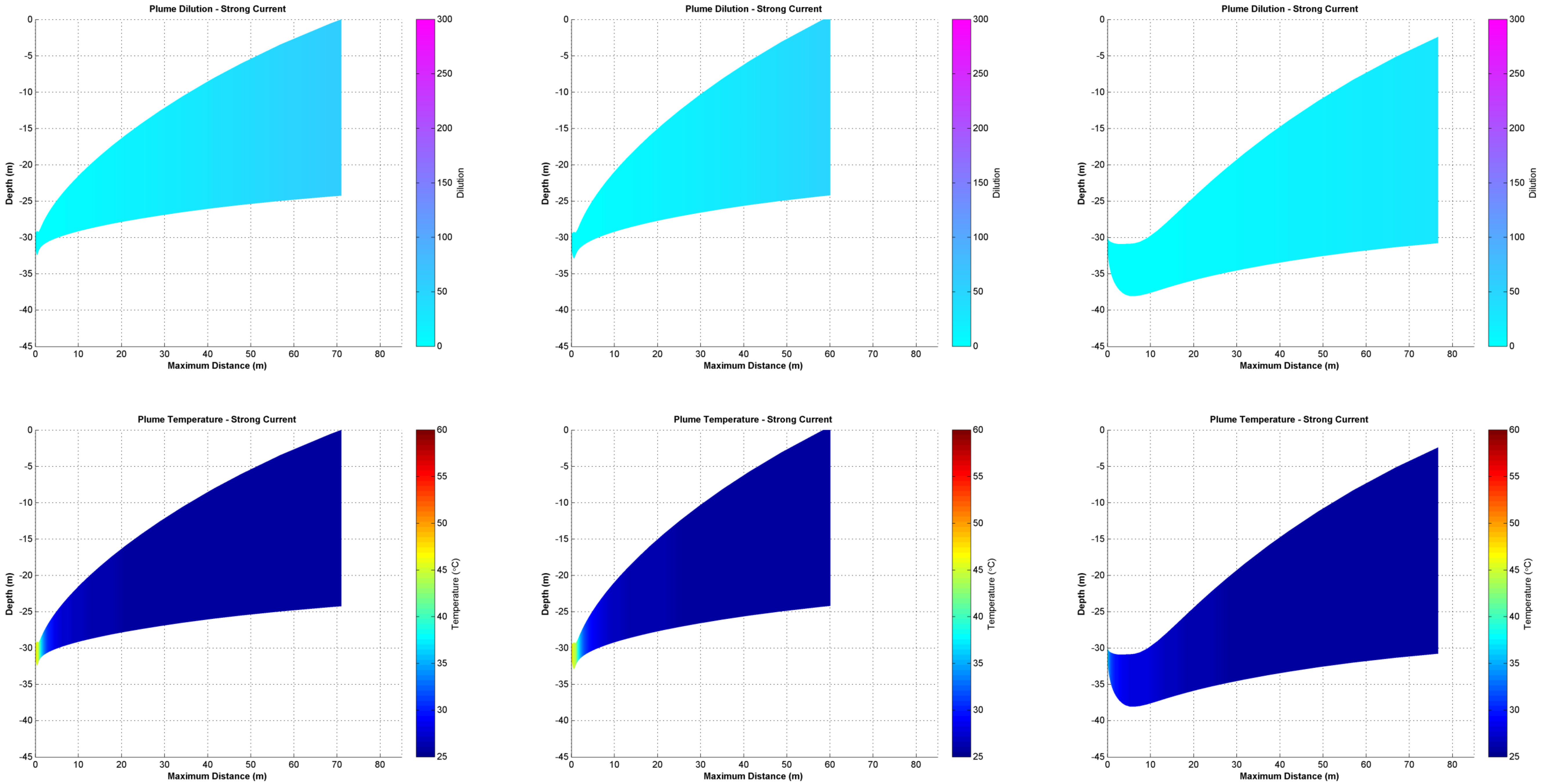


Figure 3.69 Near-field average dilution and temperature results for constant strong transitional currents with discharge flow rates of 64,800 m^3/d (Case C6; left column), 82,800 m^3/d (Case C9; middle column) and 165,600 m^3/d (Case C3; right column) at a discharge depth of 30 m.

3.1.3.6.4 Winter

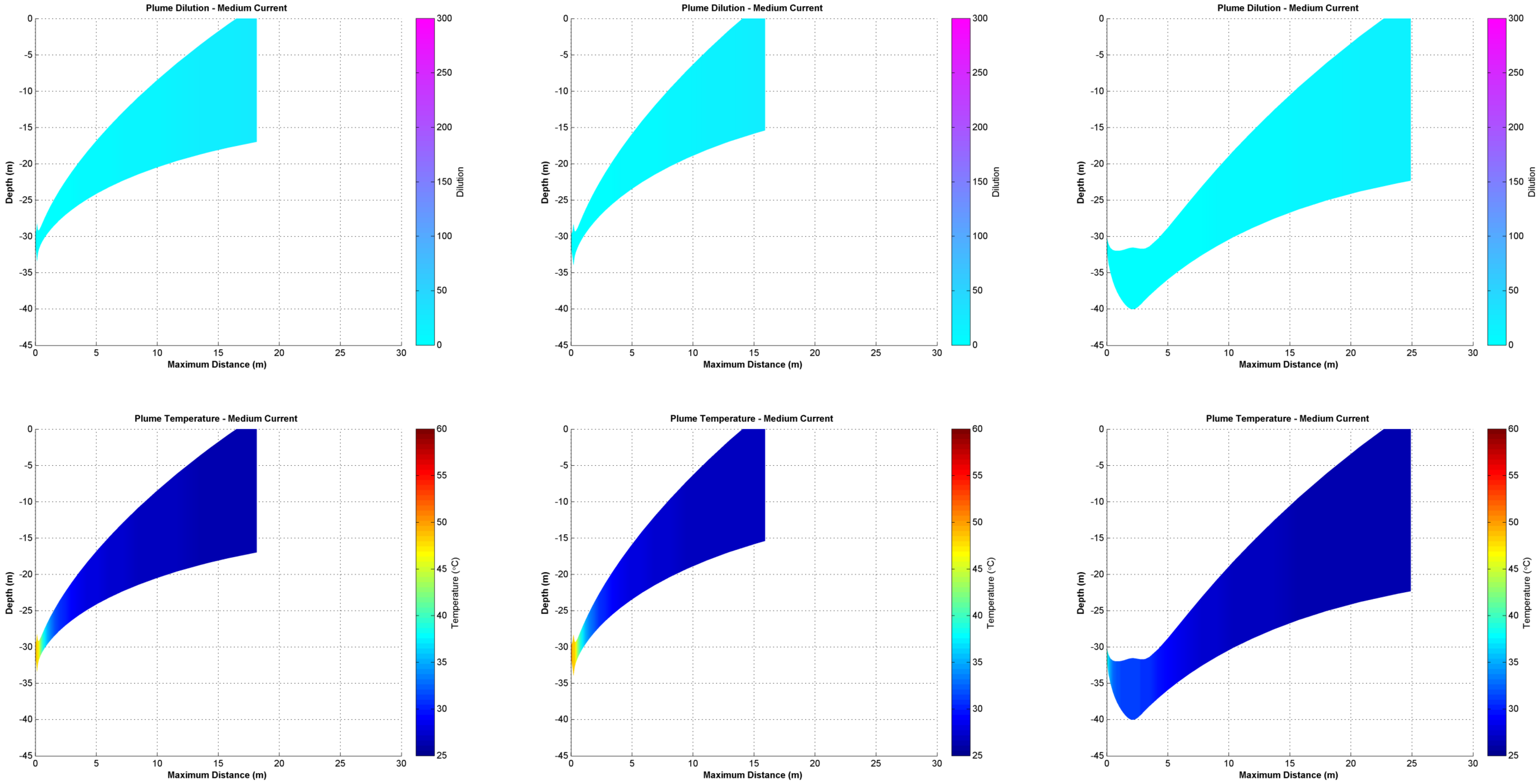


Figure 3.70 Near-field average dilution and temperature results for constant medium winter currents with discharge flow rates of 64,800 m^3/d (Case C6; left column), 82,800 m^3/d (Case C9; middle column) and 165,600 m^3/d (Case C3; right column) at a discharge depth of 30 m.

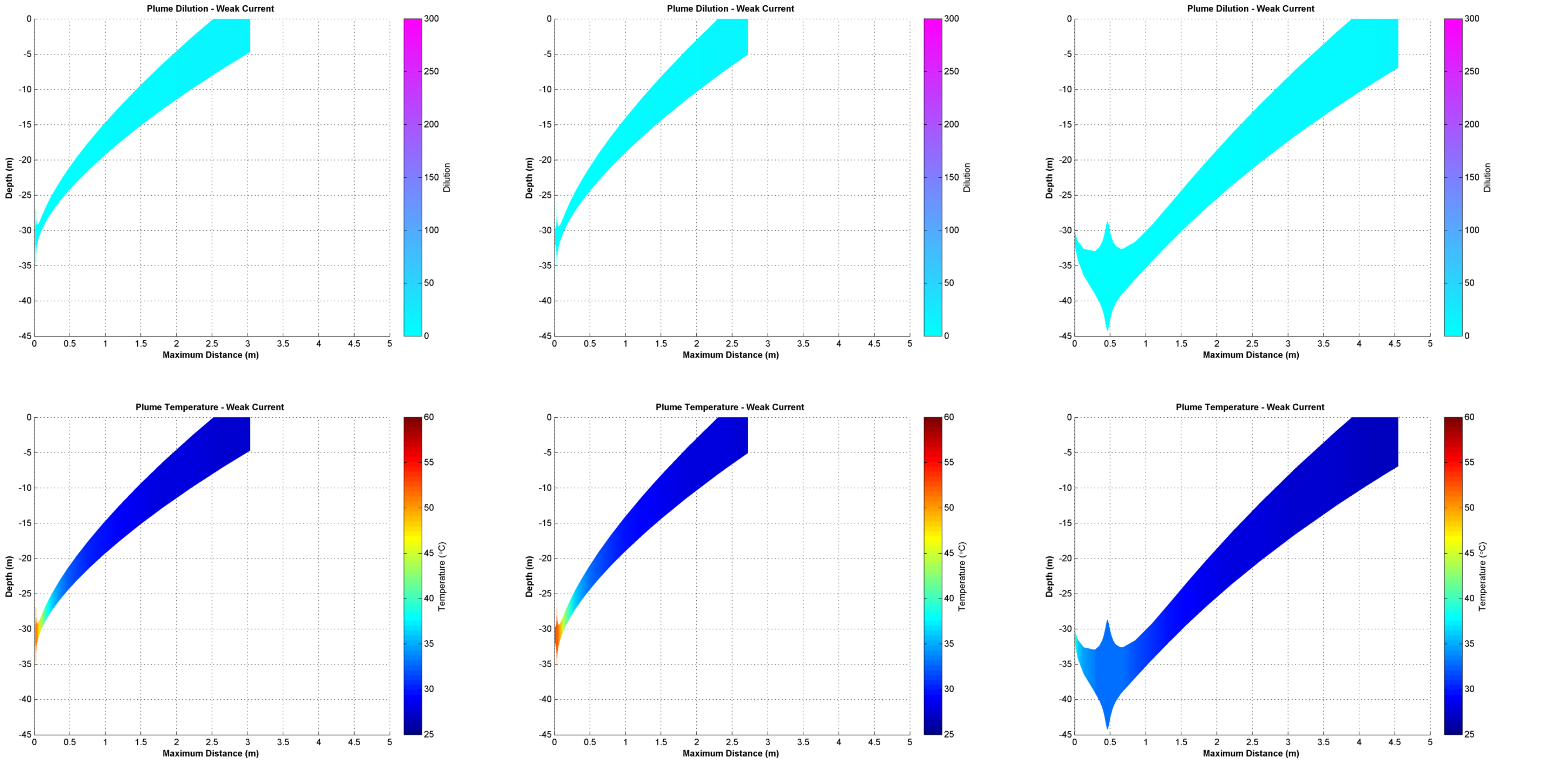


Figure 3.71 Near-field average dilution and temperature results for constant weak winter currents with discharge flow rates of 64,800 m^3/d (Case C6; left column), 82,800 m^3/d (Case C9; middle column) and 165,600 m^3/d (Case C3; right column) at a discharge depth of 30 m.

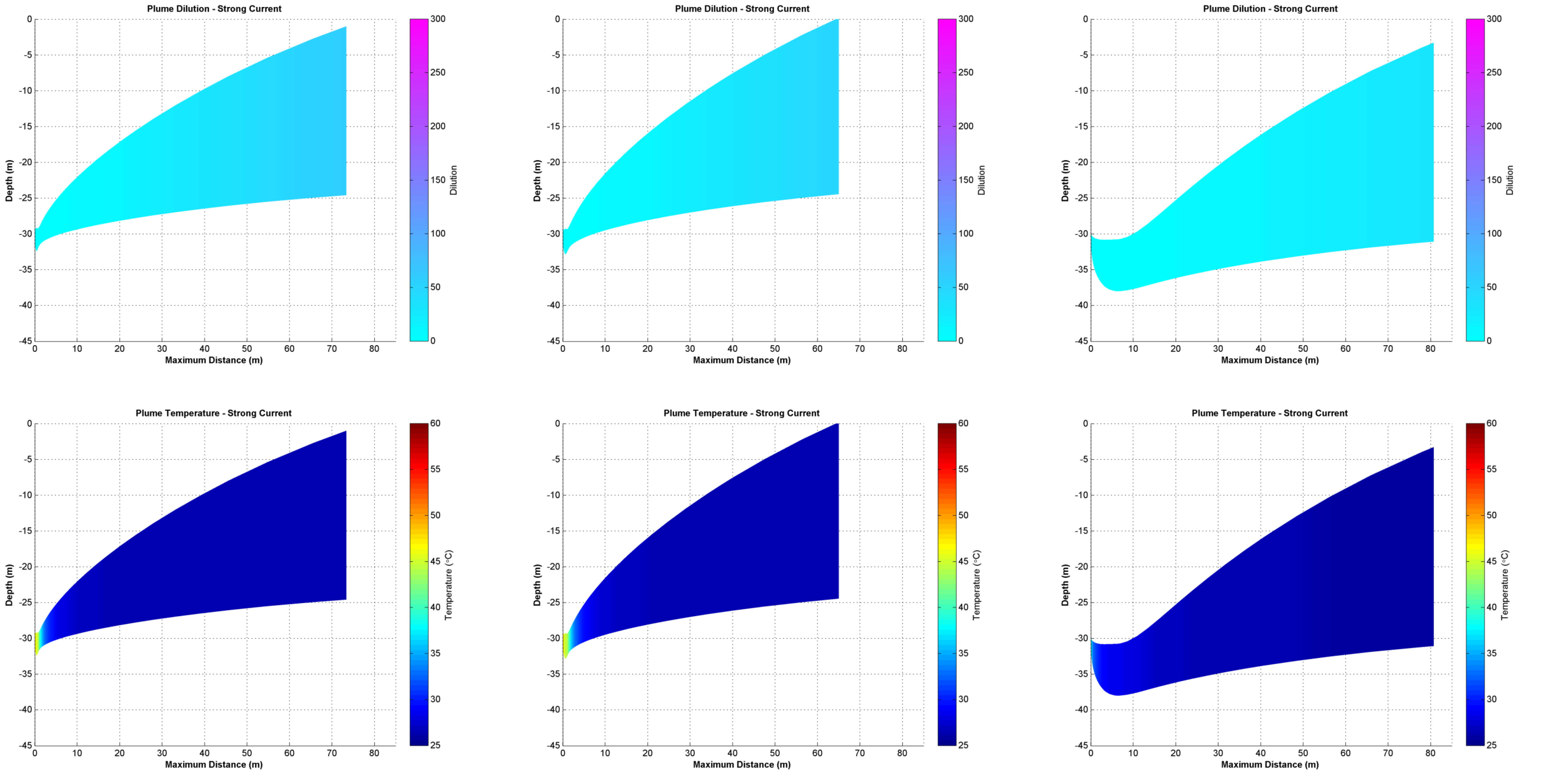


Figure 3.72 Near-field average dilution and temperature results for constant strong winter currents with discharge flow rates of 64,800 m³/d (Case C6; left column), 82,800 m³/d (Case C9; middle column) and 165,600 m³/d (Case C3; right column) at a discharge depth of 30 m.

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 and 99th percentile dilution contours are presented.

Calculation of 95th and 99th 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 of 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 the plume extents shown in Figure 3.73 with those shown in Sections 3.2.4 and 3.2.5 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 contaminant concentrations in the receiving waters to the initial concentration of the contaminant 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 3.46 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). These concentrations may be useful to consider when interpreting the contour plots of percentile dilutions.

Table 3.46 Initial concentrations of chlorine and equivalent concentrations at example dilution levels.

Chlorine Parameter	Chlorine Concentration (mg/L)
Initial concentration in discharge	1,000.0
Initial concentration in receiving waters	0.0
Concentration at 1:100 dilution	10.0
Concentration at 1:200 dilution	5.0
Concentration at 1:400 dilution	1.5

3.2.3 General Observations

Figure 3.73 shows example time series snapshots of predicted dilutions during a single simulation at 3-hour intervals from 18:00 on 25th October 2013 to 10:00 on 26th October 2013. This simulation – selected merely to be representative of typical conditions – considers the Case C1 flow rate of 165,600 m^3/d at 0 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. 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.

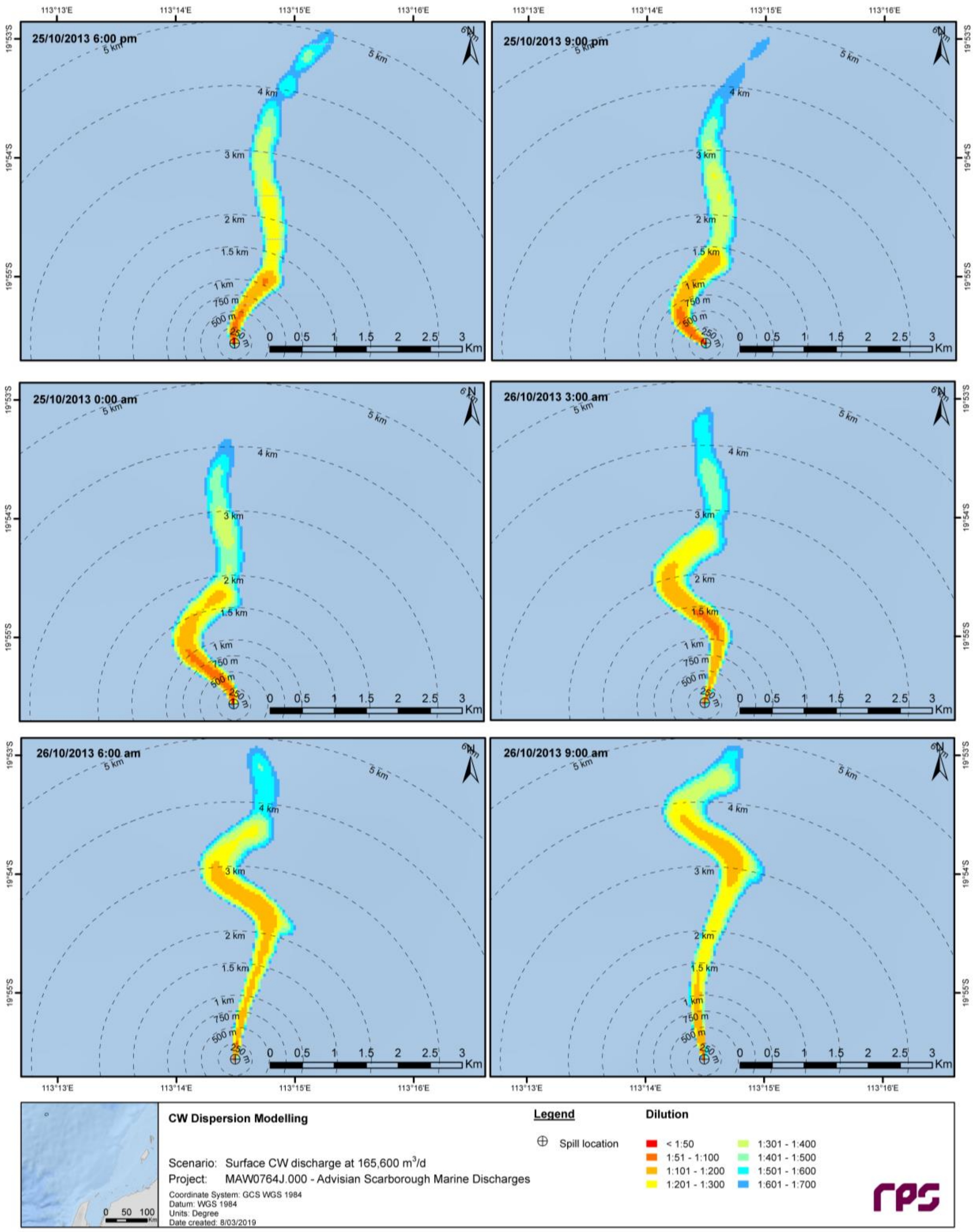


Figure 3.73 Snapshots of predicted dilution levels, at 3-hour intervals from 18:00 on 25th October 2013 to 09:00 on 26th October 2013, for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

3.2.4 Seasonal Analysis

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 3.47 to Table 3.50 summarise the minimum dilution achieved at specific radial distances from the discharge location for each season and percentile.

Table 3.51 to Table 3.54 provide summaries of the maximum distances from the discharge location to achieve 1:200 dilution 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. For Cases C1 and C3, dilution to reach threshold concentration is achieved for chlorine within an area of influence ranging from 588 m to 639 m and 623 m to 771 m, respectively, at the 95th percentile across all seasons (Table 3.51 and Table 3.52). For Cases C4 and C6, the maximum spatial extents of the relevant dilution contour vary from 140 m to 182 m and 169 m to 212 m, respectively, at the 95th percentile across all seasons (Table 3.53 and Table 3.54). The greatest spatial extents are observed in winter.

Table 3.55 to Table 3.58 provide summaries of the total area of coverage for the 1:200 dilution contour for each season and percentile. For Cases C1 and C3, the area of exposure defined by the relevant dilution contour is predicted to reach maximums of 0.34 km^2 to 0.53 km^2 and 0.39 km^2 to 0.70 km^2, respectively, at the 95th percentile (Table 3.55 and Table 3.56). For Cases C4 and C6, the corresponding maximum areas of exposure vary from 0.04 km^2 to 0.05 km^2 and 0.05 km^2 to 0.08 km^2, respectively, at the 95th percentile (Table 3.57 and Table 3.58).

Table 3.59 to Table 3.62 provide summaries of the maximum depths from the discharge location to achieve 1:200 dilution for each season and percentile. Maximum depths are predicted as 8 m (summer and winter), 38 m (winter), 6 m (all seasons) and 38 m (summer) for Cases C1, C3, C4 and C6, respectively.

Table 3.63 to Table 3.66 provide summaries of the maximum distances from the discharge location to achieve a 3 °C plume-ambient temperature differential for each season and percentile. For all cases, the requirement is forecast to be met within 115 m at the 99th percentile across all seasons. In many cases, the requirement is forecast to be met within the scale of the model grid resolution (40 m).

For Cases C1, C3, C4 and C6, Figure 3.74 to Figure 3.97 show the aggregated spatial extents of the minimum dilutions for each season and percentile. 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.

For the cases where the temperature requirement is not met within the scale of the model grid resolution, Figure 3.98 to Figure 3.104 show the aggregated spatial extents of the maximum plume-ambient temperature differential for each season and percentile.

Table 3.47 Minimum dilution achieved at specific radial distances from the CW discharge location in each season for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location																					
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km	1.10 km	1.20 km	1.30 km	1.40 km	1.50 km	1.60 km	1.70 km	1.80 km	1.90 km	2.00 km
95th	Summer	1:35.0	1:36.0	1:41.3	1:76.0	1:107.1	1:132.7	1:151.4	1:176.0	1:205.8	1:233.6	1:261.6	1:287.6	1:303.5	1:365.1	1:391.1	1:442.6	1:489.0	1:542.9	1:588.7	1:651.8	1:671.0	1:692.1
	Transitional	1:36.8	1:34.0	1:49.5	1:72.9	1:106.5	1:128.7	1:148.8	1:182.7	1:209.1	1:232.9	1:262.4	1:293.7	1:326.9	1:344.4	1:388.6	1:418.2	1:437.6	1:476.6	1:521.2	1:548.7	1:585.7	1:617.3
	Winter	1:28.7	1:26.4	1:35.0	1:68.8	1:102.2	1:123.1	1:151.8	1:181.2	1:209.1	1:237.3	1:260.7	1:304.9	1:329.9	1:363.9	1:397.4	1:418.3	1:460.4	1:469.2	1:512.8	1:560.0	1:580.9	1:609.5
99th	Summer	1:17.0	1:18.9	1:19.1	1:38.6	1:63.9	1:75.2	1:91.1	1:104.8	1:116.5	1:130.2	1:136.2	1:147.7	1:163.1	1:165.9	1:186.4	1:196.2	1:204.9	1:230.3	1:244.1	1:250.5	1:261.8	1:268.6
	Transitional	1:19.4	1:17.2	1:18.6	1:31.6	1:49.6	1:68.6	1:89.8	1:109.7	1:132.1	1:151.3	1:160.1	1:179.2	1:186.4	1:196.1	1:214.7	1:233.0	1:235.9	1:252.3	1:267.0	1:275.4	1:288.9	1:307.6
	Winter	1:14.3	1:11.6	1:17.0	1:32.7	1:49.5	1:61.0	1:71.1	1:74.3	1:81.7	1:94.8	1:98.4	1:106.3	1:126.6	1:136.2	1:147.0	1:149.1	1:161.2	1:165.4	1:170.8	1:176.6	1:212.8	1:237.8

Table 3.48 Minimum dilution achieved at specific radial distances from the CW discharge location in each season for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location																					
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km	1.10 km	1.20 km	1.30 km	1.40 km	1.50 km	1.60 km	1.70 km	1.80 km	1.90 km	2.00 km
95th	Summer	1:29.9	1:18.0	1:30.8	1:64.2	1:98.8	1:122.8	1:157.8	1:177.0	1:204.2	1:224.0	1:256.3	1:302.6	1:320.4	1:342.1	1:387.8	1:412.1	1:426.9	1:446.3	1:506.0	1:510.9	1:548.7	1:671.9
	Transitional	1:33.2	1:23.9	1:35.6	1:66.7	1:99.2	1:120.0	1:136.7	1:156.3	1:177.5	1:196.3	1:217.3	1:231.7	1:244.4	1:260.0	1:283.8	1:292.9	1:316.9	1:330.2	1:337.8	1:363.3	1:394.3	1:408.2
	Winter	1:24.5	1:18.8	1:29.7	1:58.9	1:82.6	1:125.0	1:140.7	1:166.1	1:174.6	1:202.1	1:208.5	1:235.7	1:271.3	1:363.9	1:423.2	1:458.8	1:539.1	1:669.4	1:758.1	1:875.3	1:1,055.4	1:1,144.4
99th	Summer	1:9.7	1:13.6	1:15.1	1:32.0	1:50.0	1:61.7	1:70.1	1:84.7	1:86.5	1:100.3	1:100.9	1:107.8	1:112.1	1:124.3	1:129.1	1:141.4	1:154.8	1:165.5	1:174.5	1:181.6	1:195.5	1:206.0
	Transitional	1:18.5	1:12.8	1:16.1	1:31.8	1:51.8	1:72.1	1:83.3	1:98.7	1:104.1	1:112.3	1:115.5	1:122.4	1:132.2	1:147.0	1:163.3	1:182.0	1:186.9	1:186.0	1:187.4	1:193.9	1:211.4	1:231.7
	Winter	1:13.0	1:9.6	1:16.0	1:28.8	1:41.0	1:49.8	1:56.7	1:69.3	1:79.3	1:94.1	1:93.2	1:98.8	1:118.5	1:130.8	1:140.5	1:163.3	1:171.6	1:178.2	1:191.8	1:192.7	1:214.8	1:224.2

Table 3.49 Minimum dilution achieved at specific radial distances from the CW discharge location in each season for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location																					
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km	1.10 km	1.20 km	1.30 km	1.40 km	1.50 km	1.60 km	1.70 km	1.80 km	1.90 km	2.00 km
95th	Summer	1:89.5	1:92.5	1:105.4	1:194.0	1:273.7	1:339.0	1:387.0	1:449.9	1:526.1	1:596.9	1:668.6	1:735.0	1:775.7	1:933.1	1:999.5	1:1,131.0	1:1,249.7	1:1,387.4	1:1,504.5	1:1,665.8	1:1,714.7	1:1,768.7
	Transitional	1:94.0	1:87.0	1:90.3	1:186.4	1:272.3	1:328.8	1:380.3	1:467.0	1:534.3	1:595.2	1:670.6	1:750.6	1:835.5	1:880.1	1:993.1	1:1,068.6	1:1,118.4	1:1,217.9	1:1,331.9	1:1,402.1	1:1,496.7	1:1,577.6
	Winter	1:67.4	1:73.3	1:89.5	1:175.7	1:261.2	1:314.6	1:387.9	1:463.2	1:534.3	1:606.3	1:666.1	1:779.1	1:843.1	1:929.9	1:1,015.6	1:1,069.1	1:1,176.5	1:1,199.0	1:1,310.6	1:1,431.2	1:1,484.6	1:1,557.7
99th	Summer	1:43.5	1:48.2	1:48.8	1:98.7	1:163.2	1:192.1	1:232.8	1:267.8	1:297.8	1:332.7	1:348.0	1:377.5	1:416.9	1:424.0	1:476.4	1:501.4	1:523.6	1:588.5	1:623.9	1:640.1	1:669.0	1:686.4
	Transitional	1:49.7	1:44.0	1:47.6	1:80.8	1:126.6	1:175.4	1:229.4	1:280.4	1:337.6	1:386.8	1:409.2	1:457.9	1:476.2	1:501.0	1:548.6	1:595.4	1:602.9	1:644.8	1:682.4	1:703.9	1:738.3	1:786.2
	Winter	1:29.6	1:36.5	1:43.2	1:83.5	1:126.6	1:156.0	1:181.7	1:189.8	1:208.7	1:242.3	1:251.6	1:271.7	1:313.4	1:348.0	1:375.7	1:381.1	1:411.8	1:422.6	1:436.4	1:451.4	1:543.8	1:607.8

Table 3.50 Minimum dilution achieved at specific radial distances from the CW discharge location in each season for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location																					
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km	1.10 km	1.20 km	1.30 km	1.40 km	1.50 km	1.60 km	1.70 km	1.80 km	1.90 km	2.00 km
95th	Summer	1:44.7	1:72.6	1:99.7	1:156.6	1:256.5	1:321.2	1:400.4	1:450.5	1:537.7	1:617.3	1:655.1	1:773.2	1:818.7	1:874.3	1:991.1	1:1,053.1	1:1,091.1	1:1,140.7	1:1,293.1	1:1,305.7	1:1,402.3	1:1,717.2
	Transitional	1:61.2	1:89.4	1:111.0	1:162.2	1:252.6	1:306.6	1:350.9	1:407.4	1:458.9	1:507.0	1:561.3	1:595.5	1:630.0	1:680.7	1:741.7	1:772.3	1:856.5	1:856.6	1:892.2	1:1,001.1	1:1,064.3	1:1,056.5
	Winter	1:50.7	1:62.7	1:76.5	1:151.7	1:208.6	1:281.5	1:359.8	1:424.6	1:446.2	1:516.6	1:532.9	1:602.4	1:693.4	1:930.0	1:1,081.5	1:1,172.4	1:1,377.7	1:1,710.7	1:1,835.9	1:2,197.7	1:2,411.9	1:2,611.3
99th	Summer	1:24.6	1:34.7	1:37.9	1:81.2	1:121.0	1:150.2	1:175.3	1:209.6	1:216.6	1:256.2	1:257.8	1:275.6	1:286.6	1:317.6	1:329.9	1:361.4	1:395.6	1:423.0	1:445.9	1:464.2	1:499.6	1:526.4
	Transitional	1:29.5	1:40.6	1:60.3	1:92.6	1:132.9	1:179.8	1:207.3	1:230.8	1:251.6	1:270.1	1:285.6	1:312.6	1:315.5	1:319.8	1:376.2	1:423.1	1:465.4	1:453.9	1:455.8	1:445.5	1:503.0	1:548.3
	Winter	1:24.4	1:33.2	1:40.8	1:73.6	1:104.9	1:130.7	1:141.9	1:181.2	1:195.2	1:240.5	1:238.2	1:252.7	1:302.7	1:331.3	1:395.0	1:417.4	1:438.6	1:455.4	1:504.9	1:492.5	1:548.8	1:572.9

Table 3.51 Maximum distance from the CW discharge location to achieve 1:200 dilution in each season for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Summer	639
	Transitional	588
	Winter	636
99th	Summer	1,354
	Transitional	1,175
	Winter	1,789
100th	Summer	3,572
	Transitional	3,741
	Winter	4,705

Table 3.52 Maximum distance from the CW discharge location to achieve 1:200 dilution in each season for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Summer	623
	Transitional	757
	Winter	771
99th	Summer	1,896
	Transitional	1,758
	Winter	2,470
100th	Summer	5,857
	Transitional	6,391
	Winter	5,549

Table 3.53 Maximum distance from the CW discharge location to achieve 1:200 dilution in each season for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Summer	140
	Transitional	152
	Winter	182
99th	Summer	351
	Transitional	393
	Winter	621
100th	Summer	1,723
	Transitional	1,579
	Winter	2,272

Table 3.54 Maximum distance from the CW discharge location to achieve 1:200 dilution in each season for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Summer	188
	Transitional	169
	Winter	212
99th	Summer	519
	Transitional	413
	Winter	631
100th	Summer	3,258
	Transitional	3,258
	Winter	3,566

Table 3.55 Total area of coverage for 1:200 dilution in each season for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Summer	0.353
	Transitional	0.343
	Winter	0.528
99th	Summer	2.016
	Transitional	2.086
	Winter	4.409
100th	Summer	10.966
	Transitional	9.992
	Winter	20.163

Table 3.56 Total area of coverage for 1:200 dilution in each season for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Summer	0.441
	Transitional	0.385
	Winter	0.701
99th	Summer	4.625
	Transitional	3.768
	Winter	5.482
100th	Summer	33.376
	Transitional	29.964
	Winter	30.908

Table 3.57 Total area of coverage for 1:200 dilution in each season for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Summer	0.039
	Transitional	0.035
	Winter	0.053
99th	Summer	0.189
	Transitional	0.215
	Winter	0.374
100th	Summer	1.425
	Transitional	1.164
	Winter	3.334

Table 3.58 Total area of coverage for 1:200 dilution in each season for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Summer	0.061
	Transitional	0.045
	Winter	0.075
99th	Summer	0.465
	Transitional	0.242
	Winter	0.550
100th	Summer	5.286
	Transitional	2.948
	Winter	5.635

Table 3.59 Maximum depth from the CW discharge location to achieve 1:200 dilution in each season for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

Season	Maximum depth (m) from discharge location to achieve given dilution
Summer	8
Transitional	6
Winter	8

Table 3.60 Maximum depth from the CW discharge location to achieve 1:200 dilution in each season for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

Season	Maximum depth (m) from discharge location to achieve given dilution
Summer	36
Transitional	36
Winter	38

Table 3.61 Maximum depth from the CW discharge location to achieve 1:200 dilution in each season for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

Season	Maximum depth (m) from discharge location to achieve given dilution
Summer	6
Transitional	6
Winter	6

Table 3.62 Maximum depth from the CW discharge location to achieve 1:200 dilution in each season for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

Season	Maximum depth (m) from discharge location to achieve given dilution
Summer	38
Transitional	36
Winter	36

Table 3.63 Maximum distance from the CW discharge location to achieve 3 °C plume-ambient ΔT in each season for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given ΔT
95th	Summer	<40
	Transitional	<40
	Winter	<40
99th	Summer	<40
	Transitional	<40
	Winter	90
100th	Summer	115
	Transitional	145
	Winter	285

Table 3.64 Maximum distance from the CW discharge location to achieve 3 °C plume-ambient ΔT in each season for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given ΔT
95th	Summer	<40
	Transitional	<40
	Winter	<40
99th	Summer	115
	Transitional	115
	Winter	115
100th	Summer	350
	Transitional	380
	Winter	345

Table 3.65 Maximum distance from the CW discharge location to achieve 3 °C plume-ambient ΔT in each season for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given ΔT
95th	Summer	<40
	Transitional	<40
	Winter	<40
99th	Summer	<40
	Transitional	<40
	Winter	<40
100th	Summer	90
	Transitional	90
	Winter	145

Table 3.66 Maximum distance from the CW discharge location to achieve 3 °C plume-ambient ΔT in each season for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given ΔT
95th	Summer	<40
	Transitional	<40
	Winter	<40
99th	Summer	90
	Transitional	90
	Winter	90
100th	Summer	145
	Transitional	175
	Winter	145

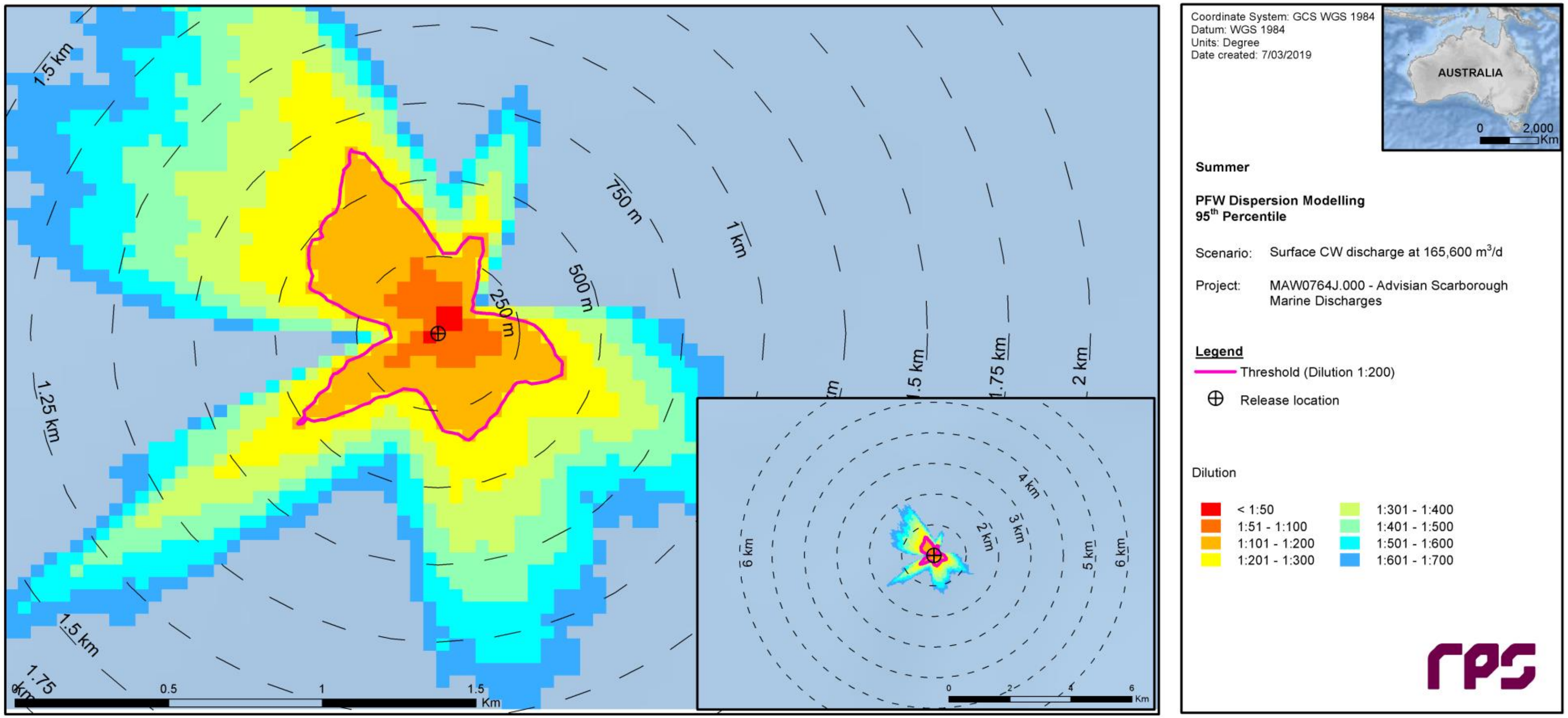


Figure 3.74 Predicted minimum dilutions at the 95th percentile under summer conditions for Case C1 (0 m depth discharge at 165,600 m³/d flow rate).

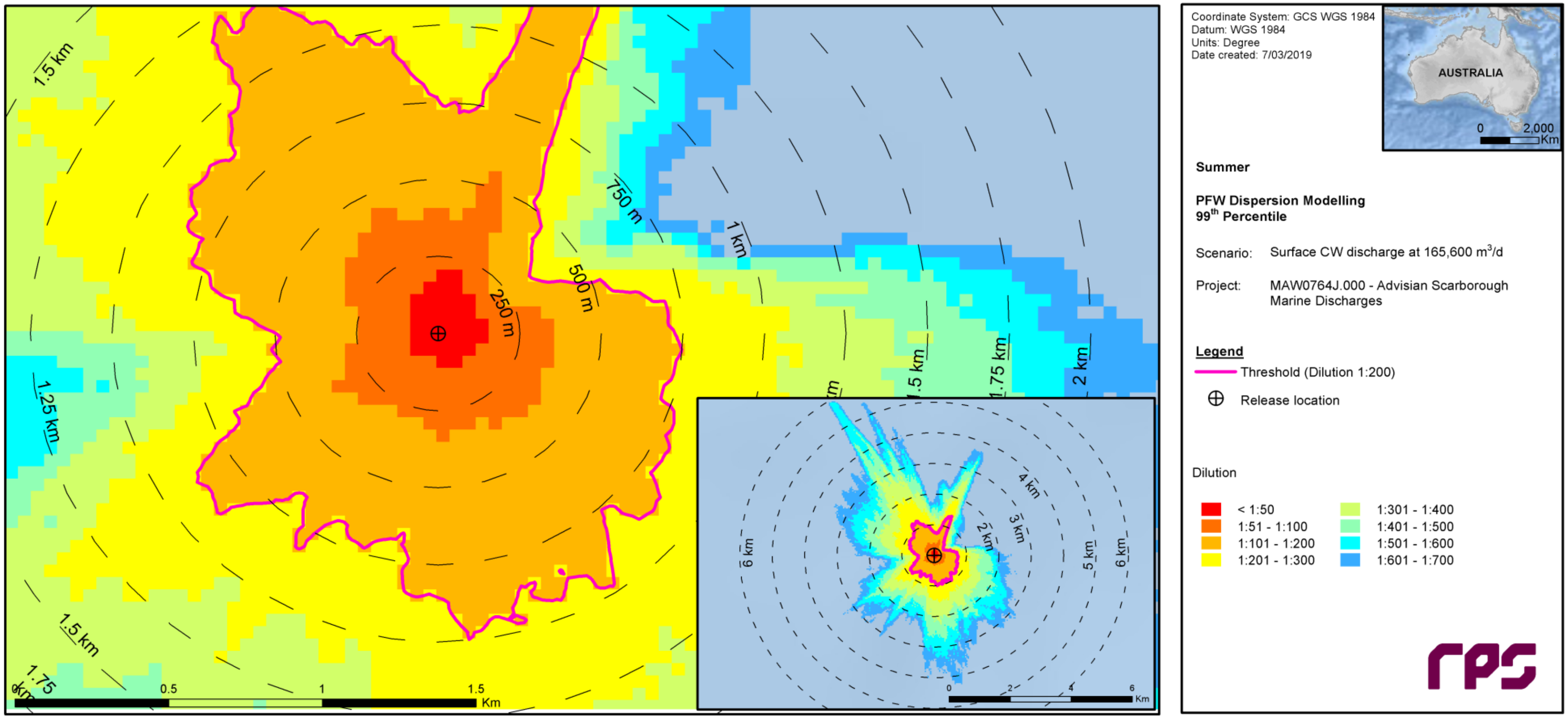


Figure 3.75 Predicted minimum dilutions at the 99th percentile under summer conditions for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

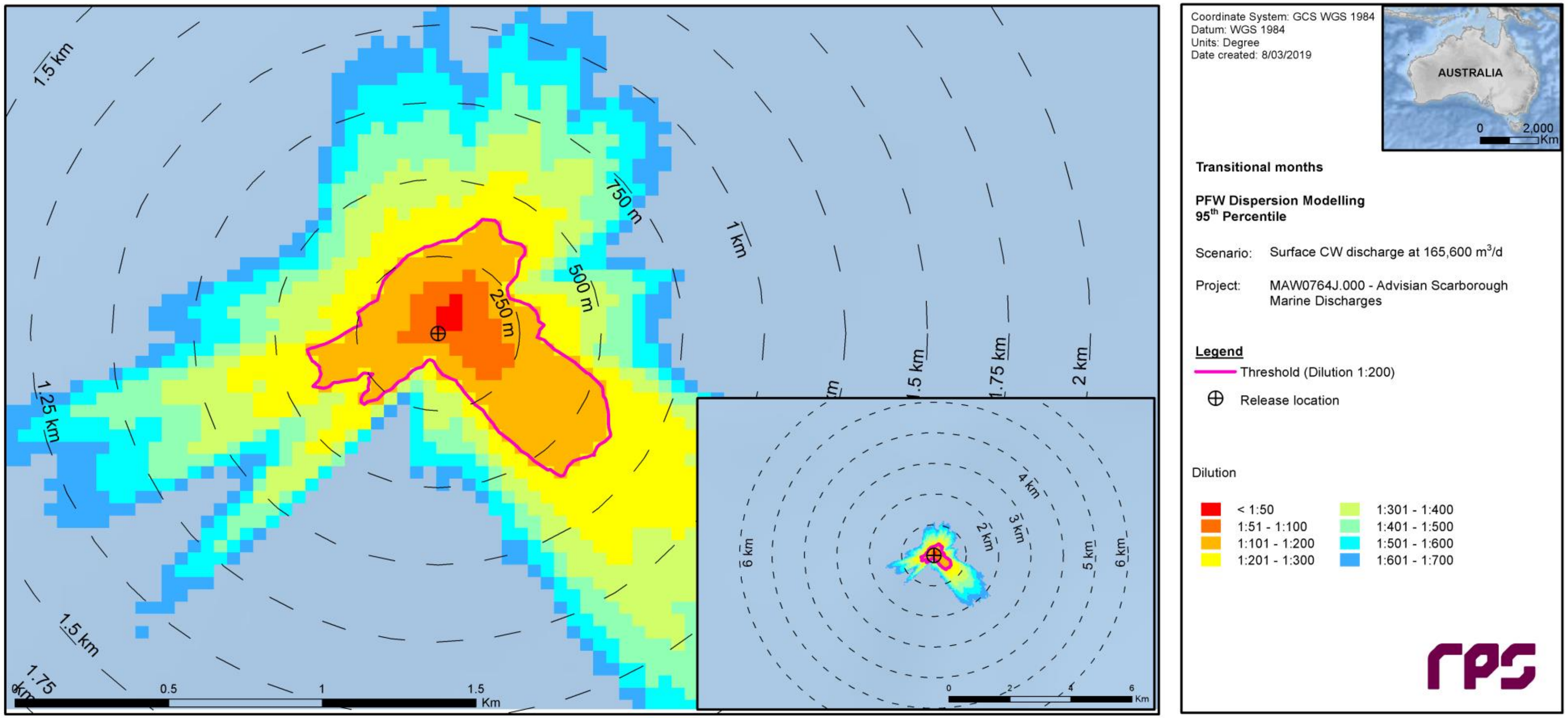


Figure 3.76 Predicted minimum dilutions at the 95th percentile under transitional conditions for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

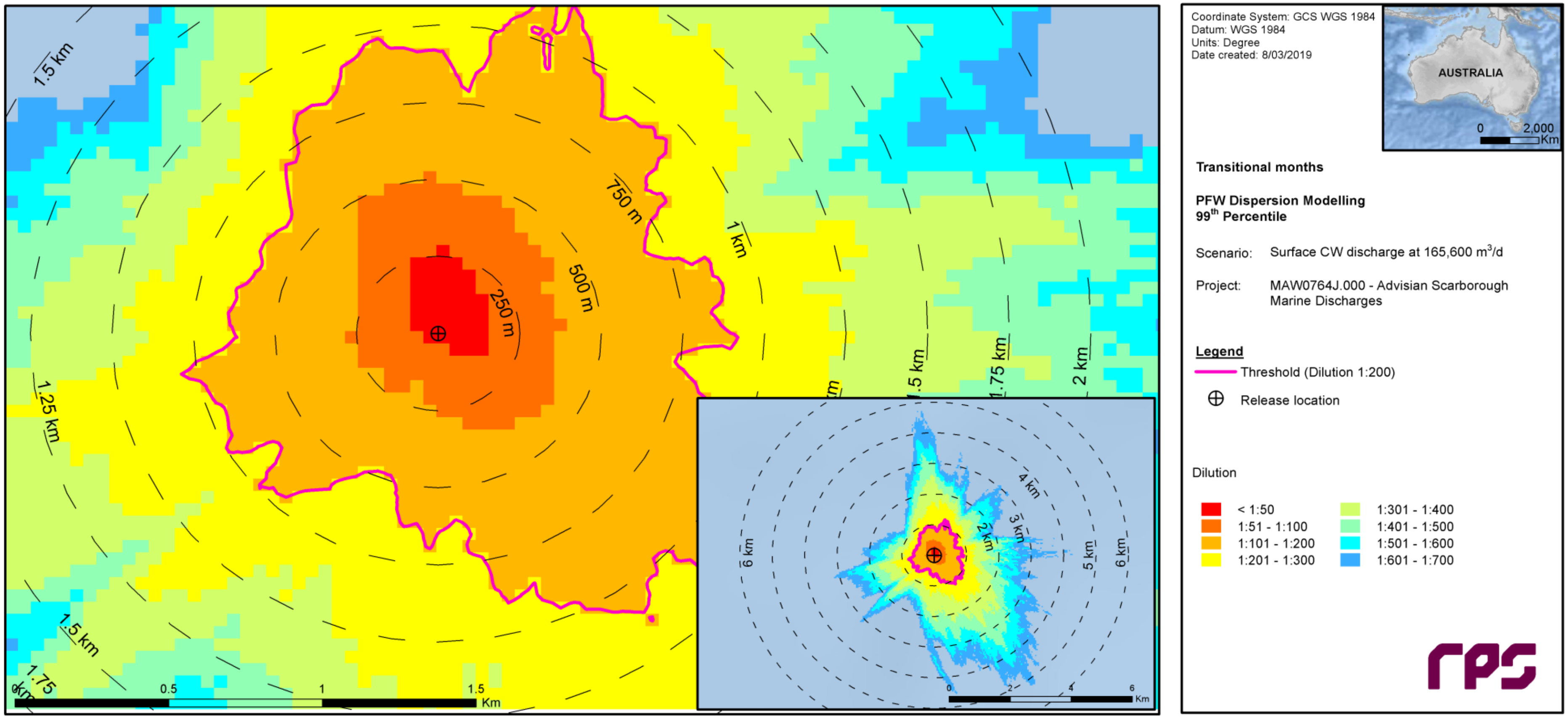


Figure 3.77 Predicted minimum dilutions at the 99th percentile under transitional conditions for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

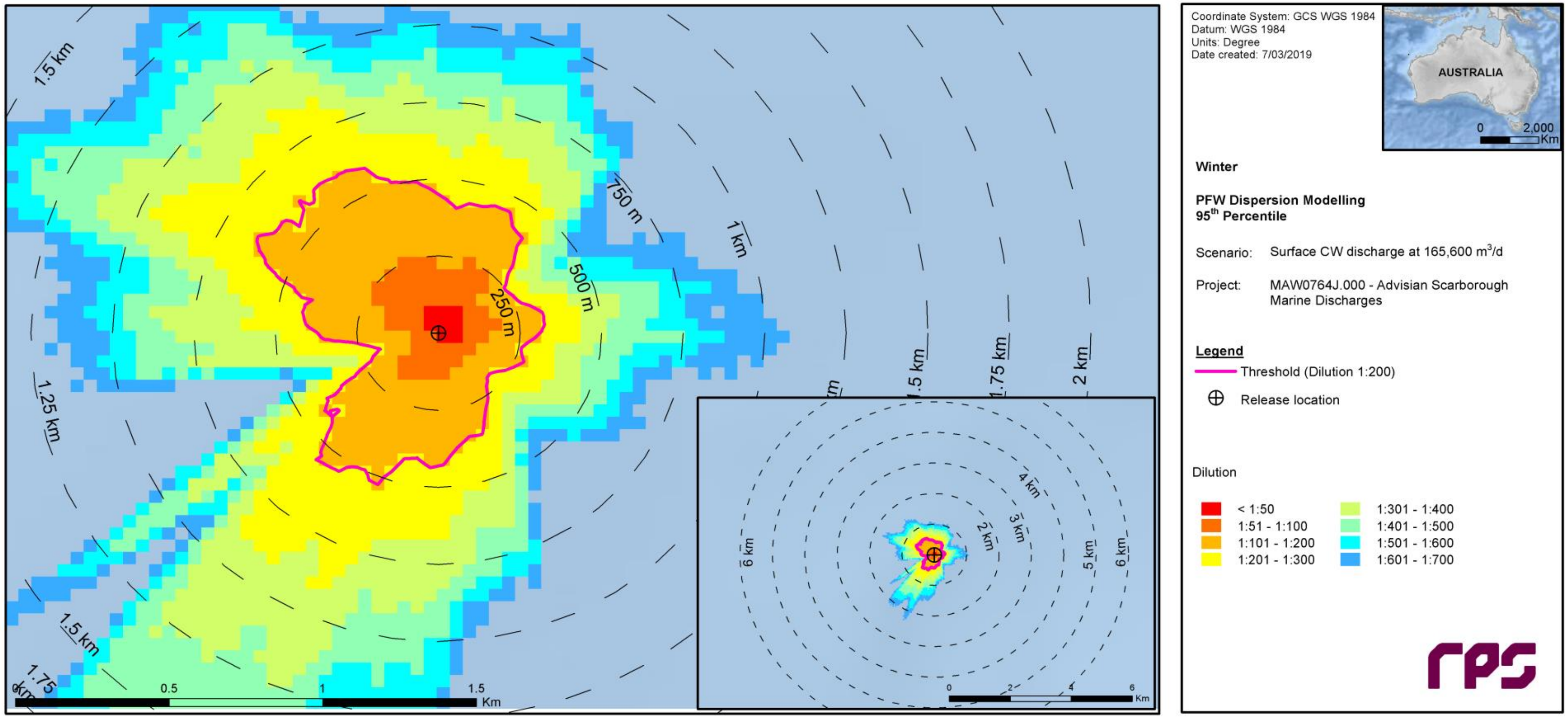


Figure 3.78 Predicted minimum dilutions at the 95th percentile under winter conditions for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

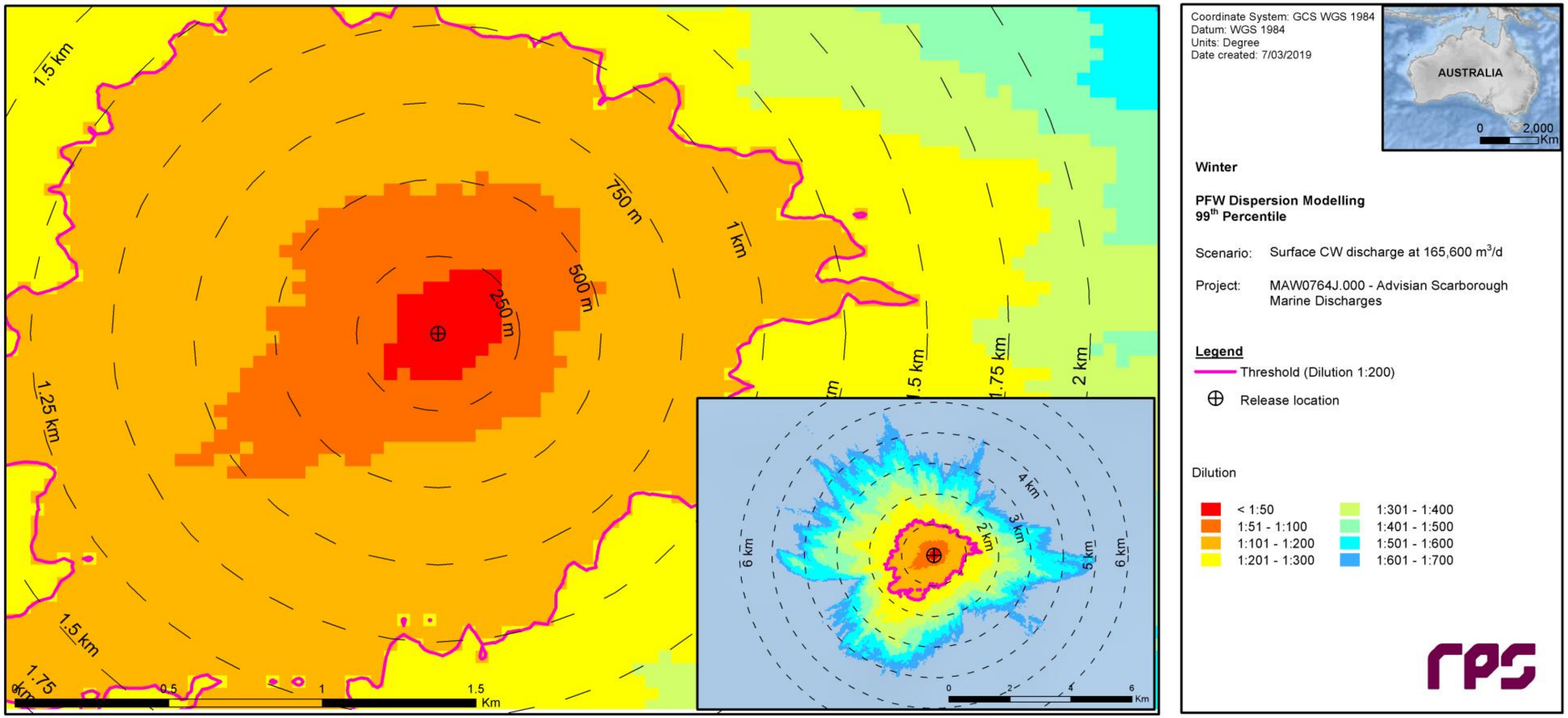


Figure 3.79 Predicted minimum dilutions at the 99th percentile under winter conditions for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

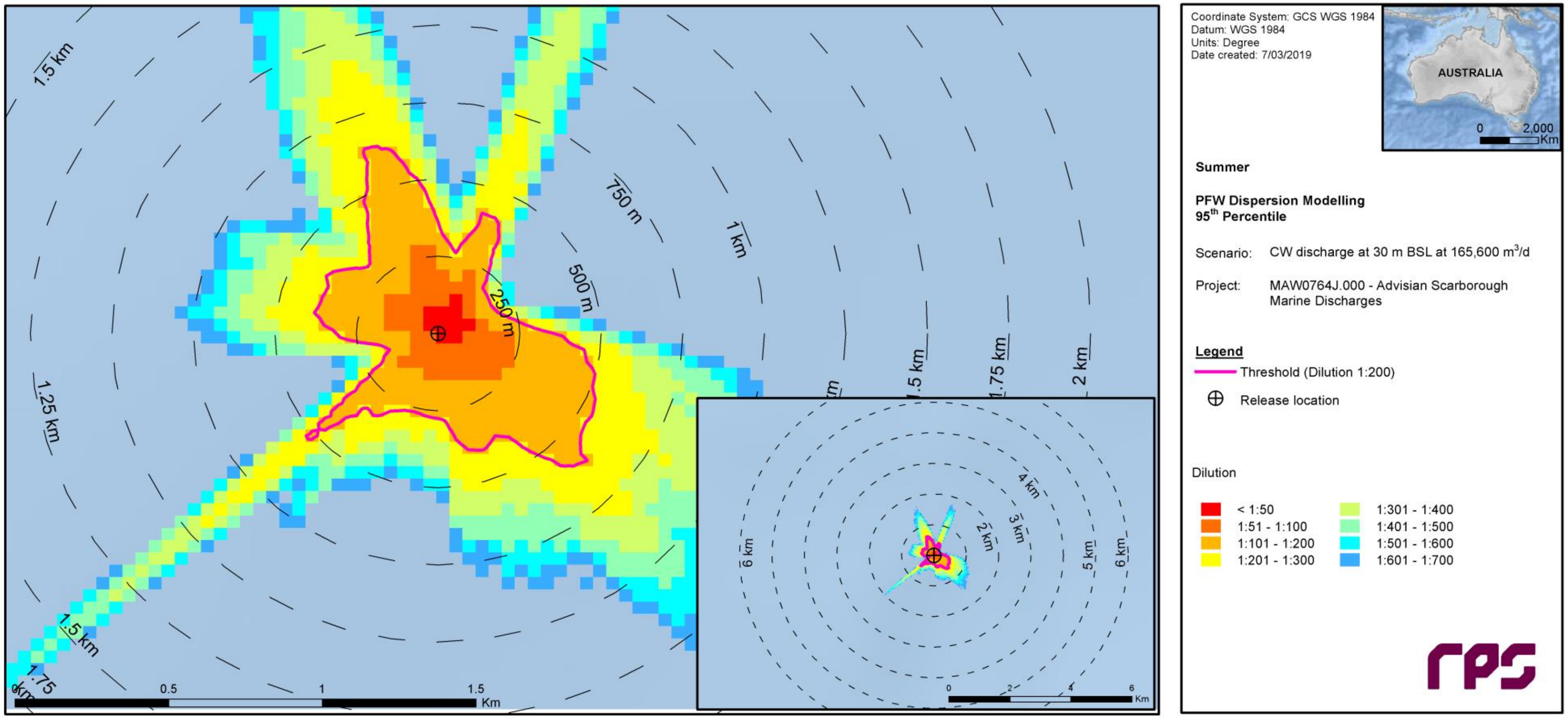


Figure 3.80 Predicted minimum dilutions at the 95th percentile under summer conditions for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

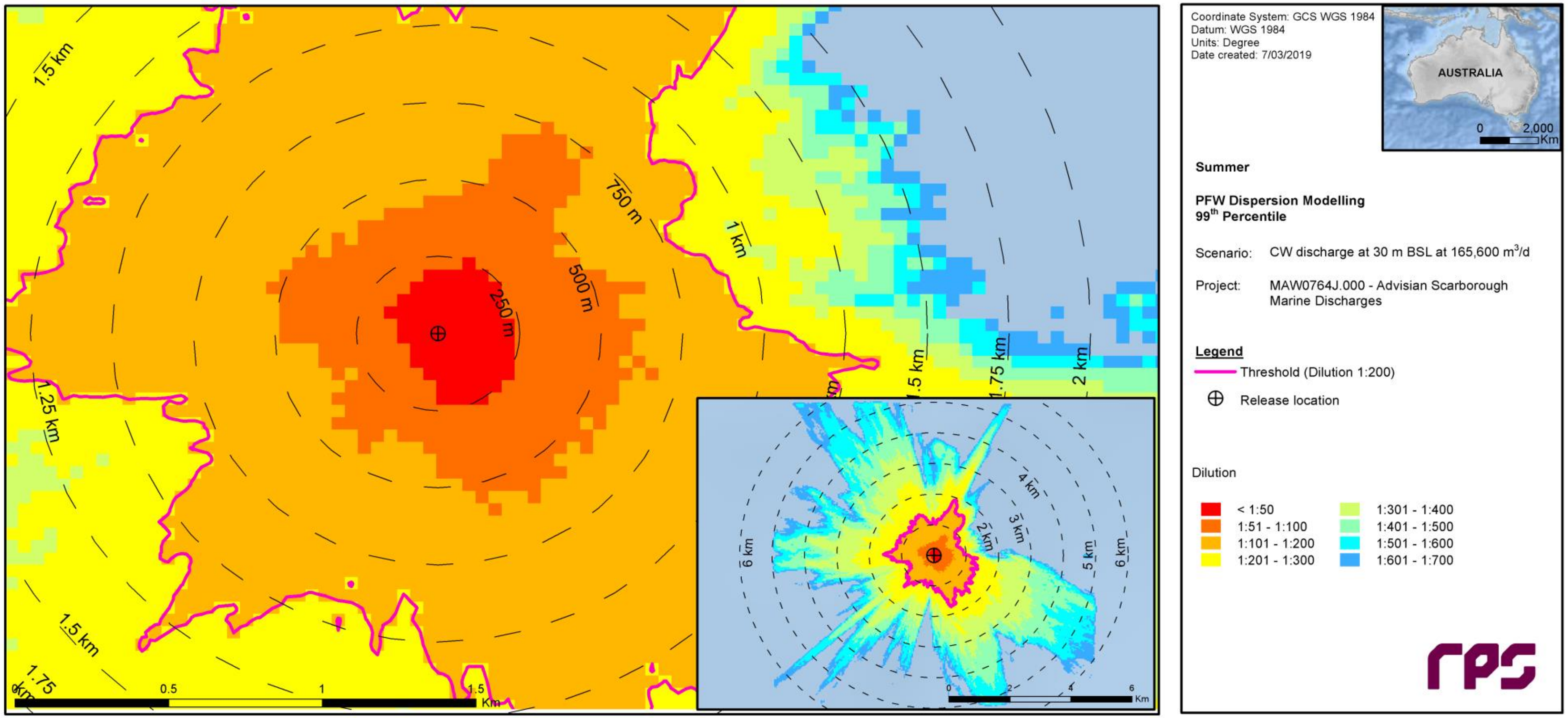


Figure 3.81 Predicted minimum dilutions at the 99th percentile under summer conditions for Case C3 (30 m depth discharge at 165,600 m³/d flow rate).

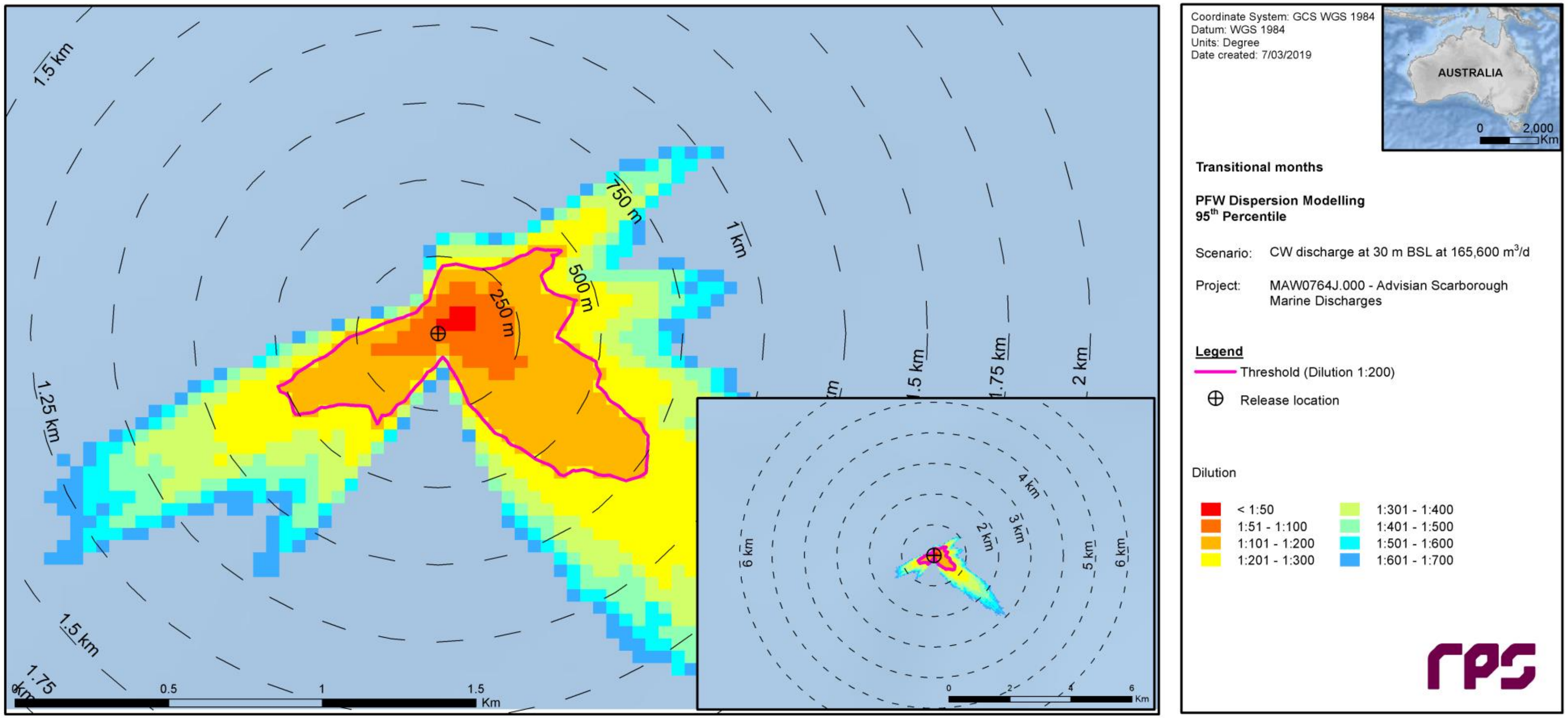


Figure 3.82 Predicted minimum dilutions at the 95th percentile under transitional conditions for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

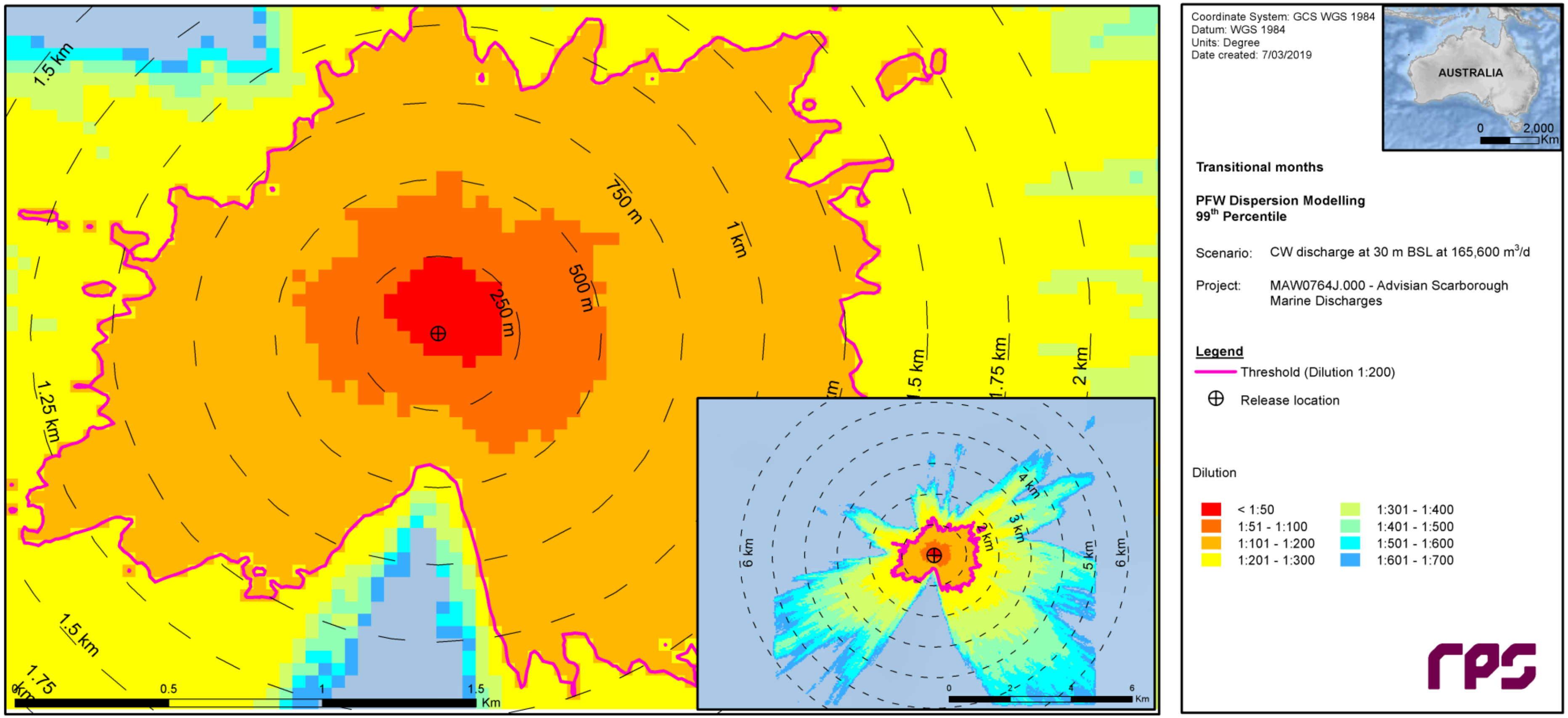


Figure 3.83 Predicted minimum dilutions at the 99th percentile under transitional conditions for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

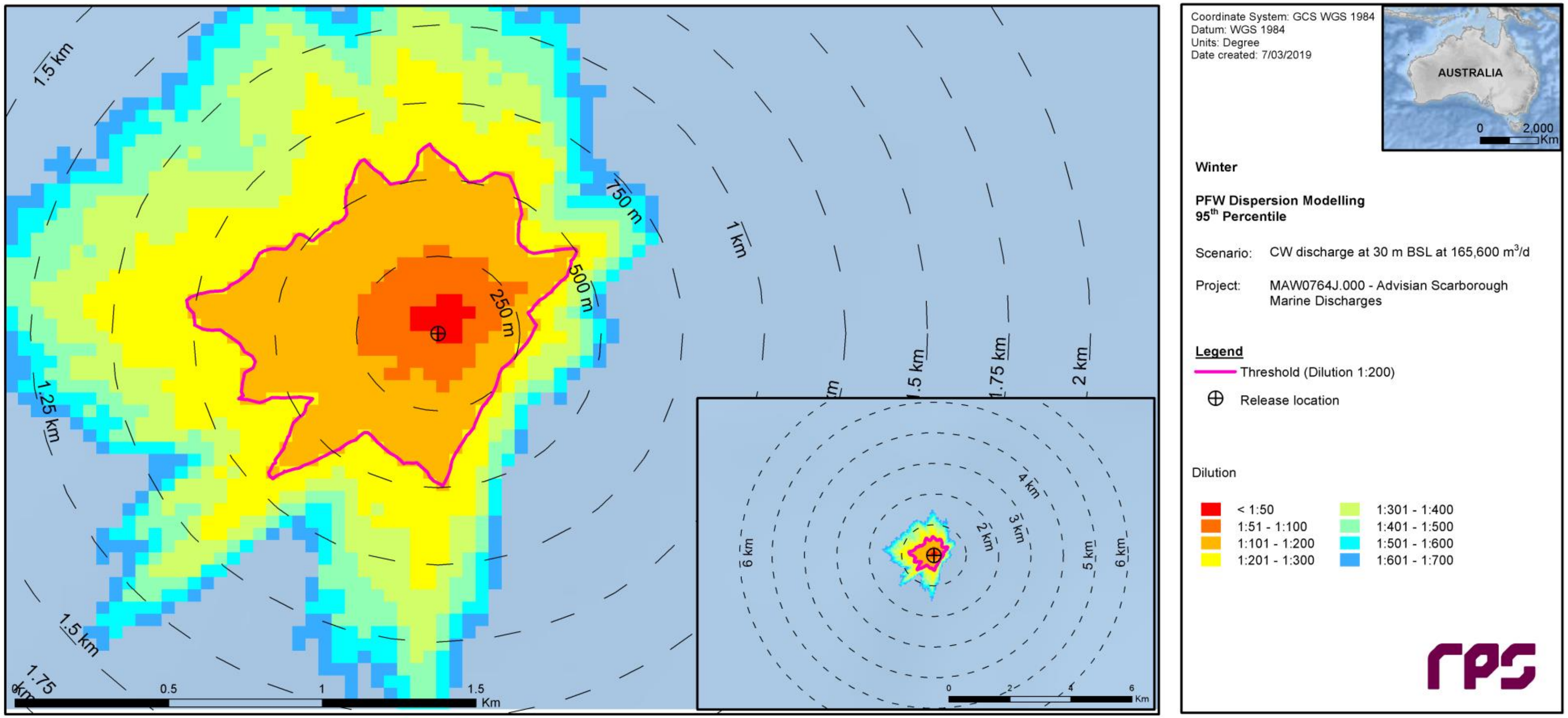


Figure 3.84 Predicted minimum dilutions at the 95th percentile under winter conditions for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

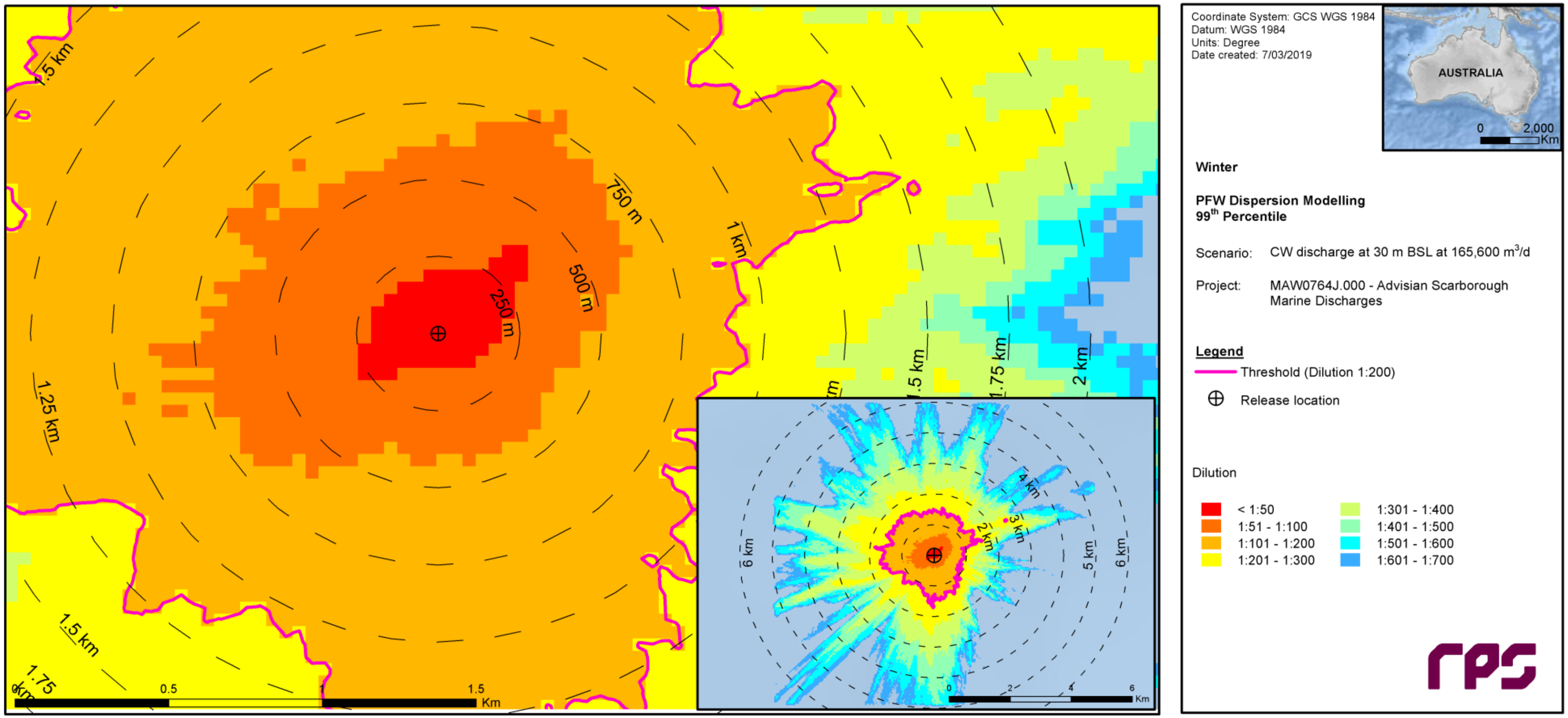


Figure 3.85 Predicted minimum dilutions at the 99th percentile under winter conditions for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

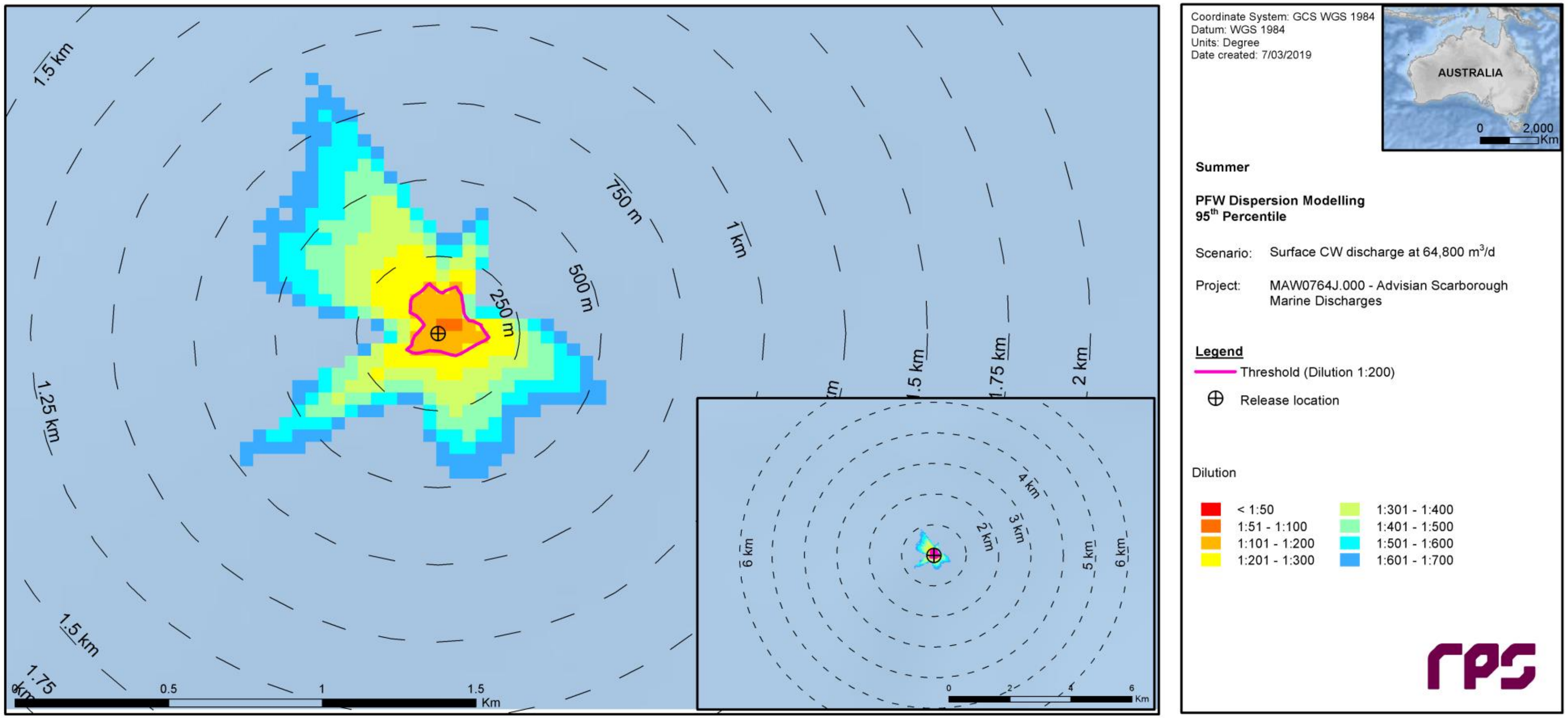


Figure 3.86 Predicted minimum dilutions at the 95th percentile under summer conditions for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

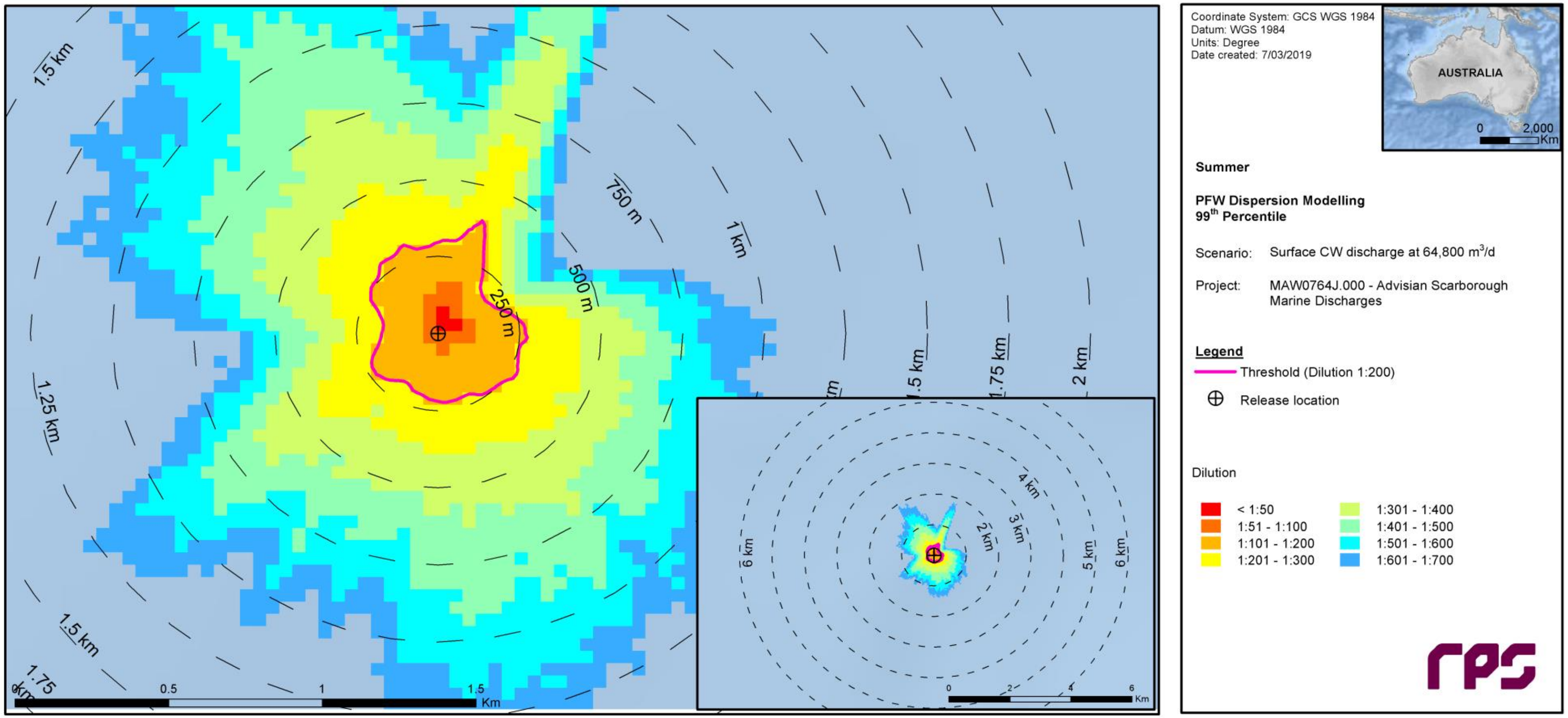


Figure 3.87 Predicted minimum dilutions at the 99th percentile under summer conditions for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

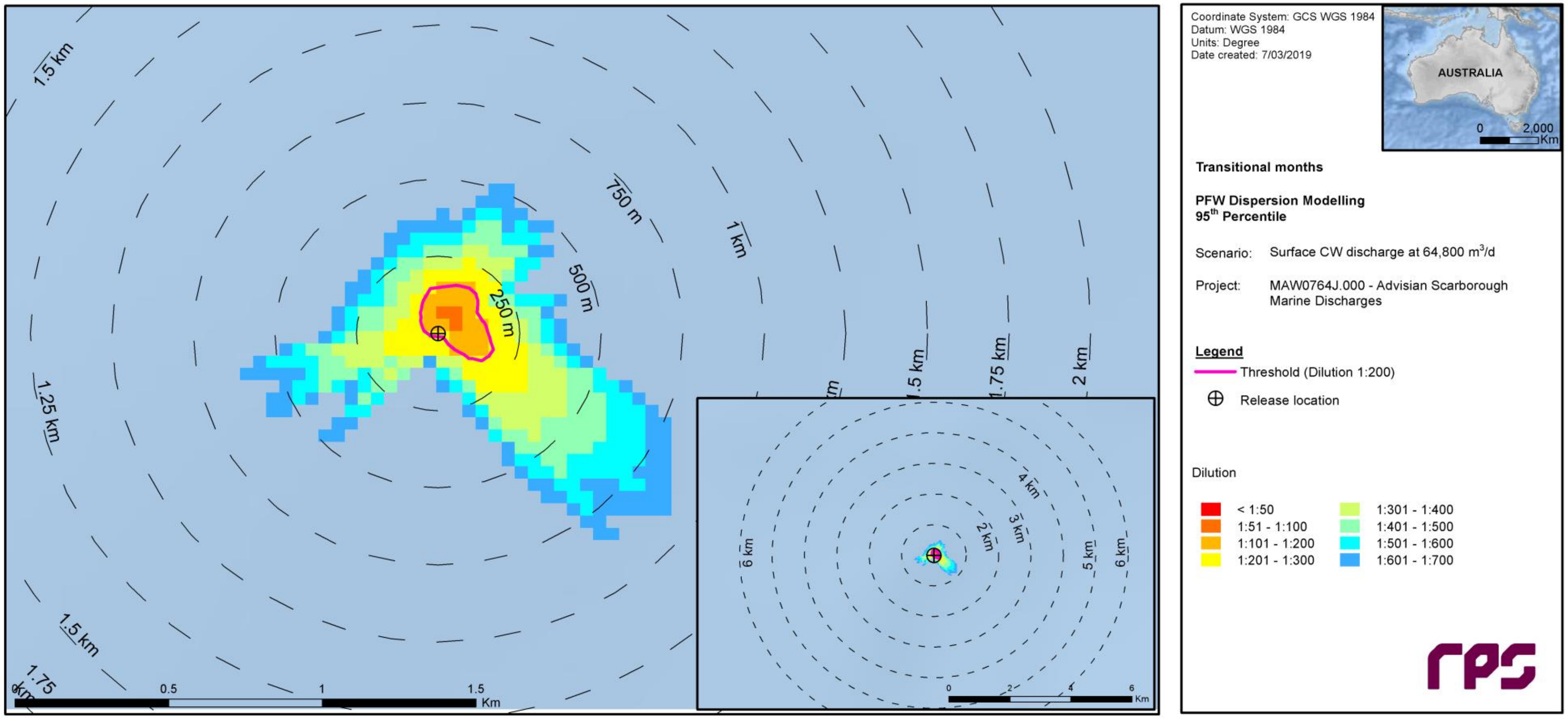


Figure 3.88 Predicted minimum dilutions at the 95th percentile under transitional conditions for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

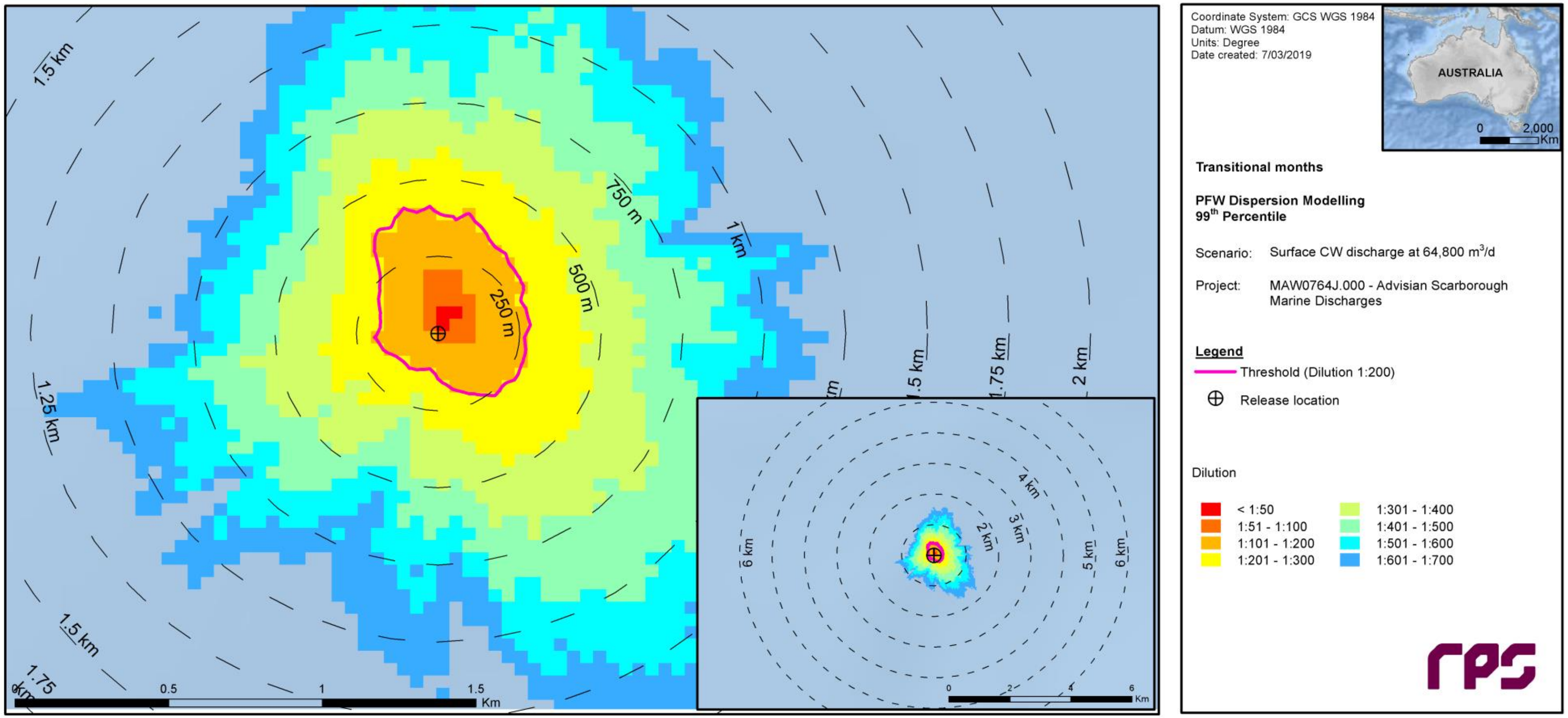


Figure 3.89 Predicted minimum dilutions at the 99th percentile under transitional conditions for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

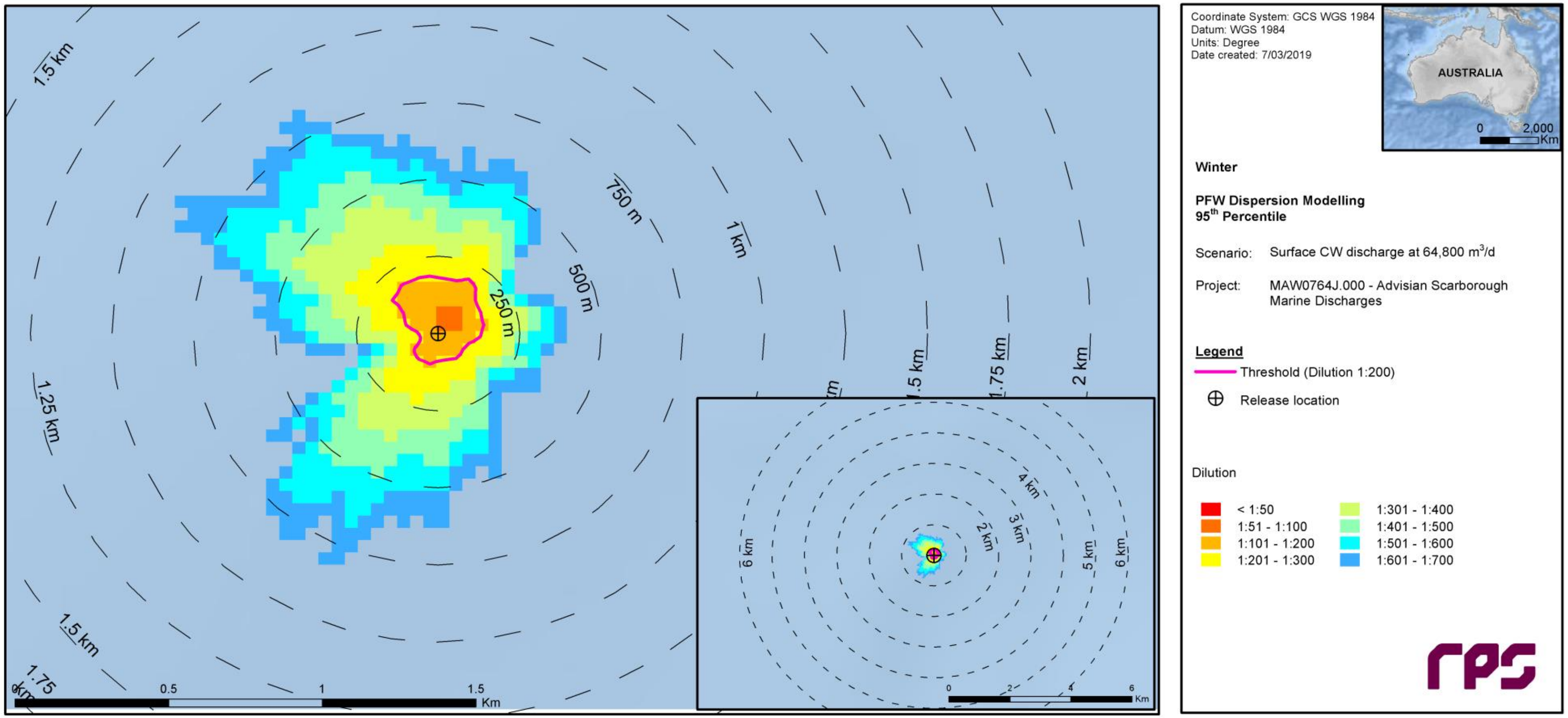


Figure 3.90 Predicted minimum dilutions at the 95th percentile under winter conditions for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

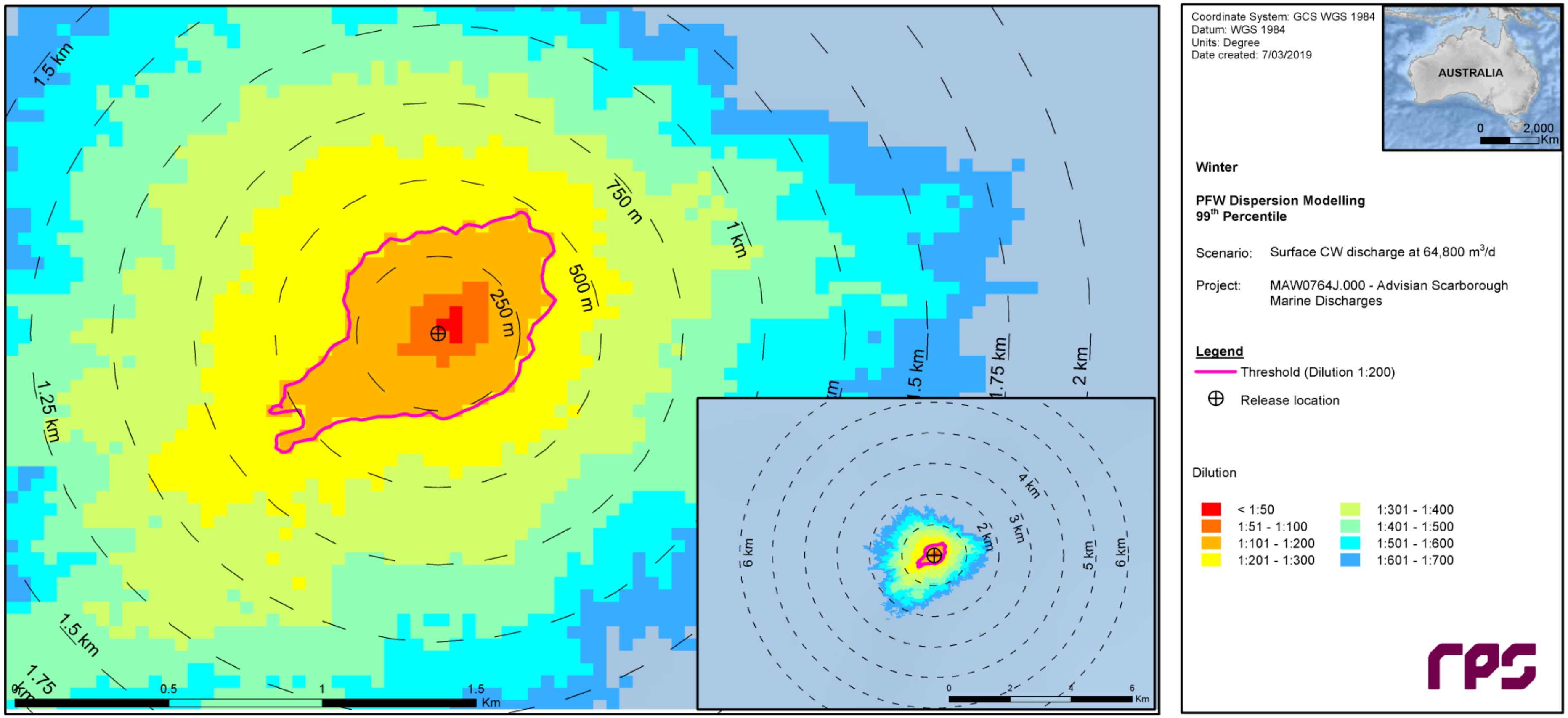


Figure 3.91 Predicted minimum dilutions at the 99th percentile under winter conditions for Case C4 (0 m depth discharge at 64,800 m³/d flow rate).

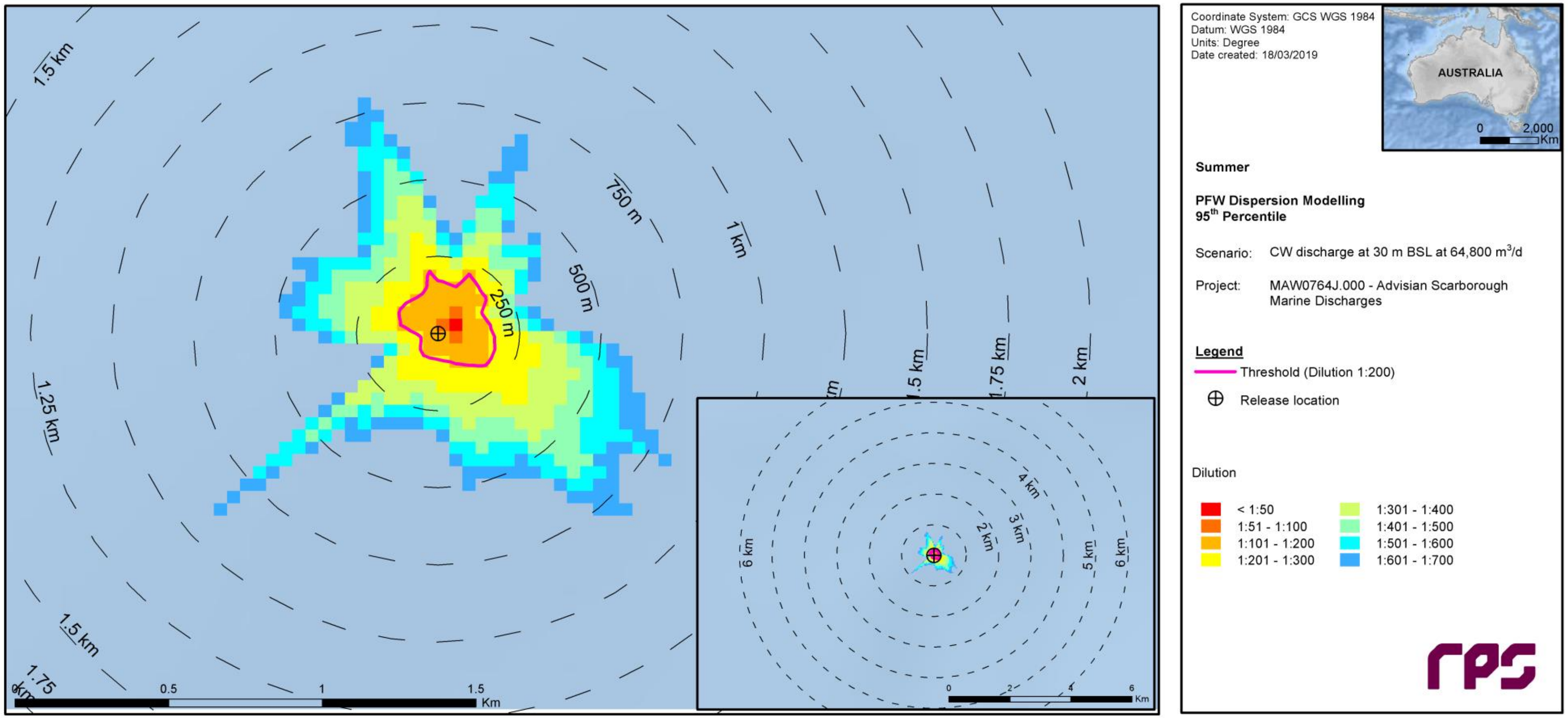


Figure 3.92 Predicted minimum dilutions at the 95th percentile under summer conditions for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

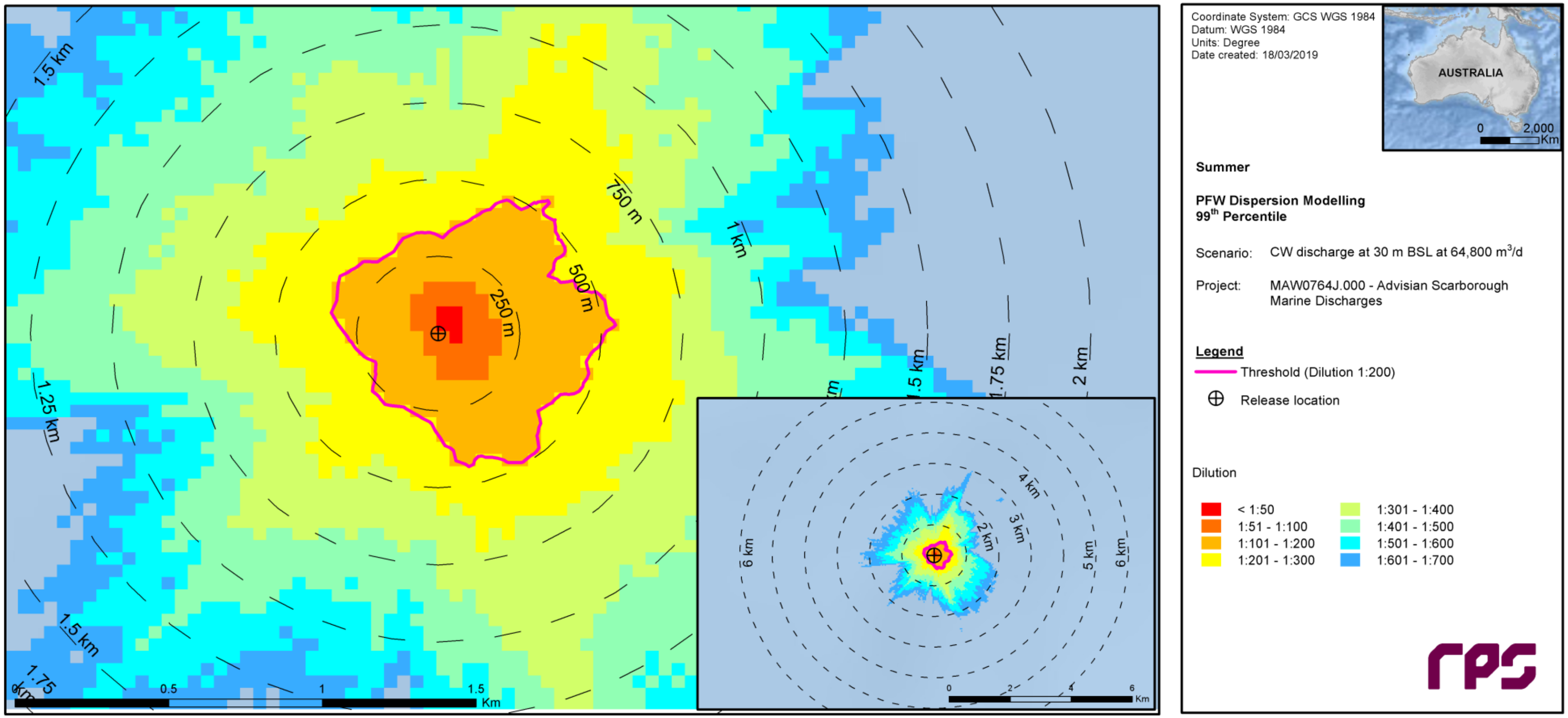


Figure 3.93 Predicted minimum dilutions at the 99th percentile under summer conditions for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

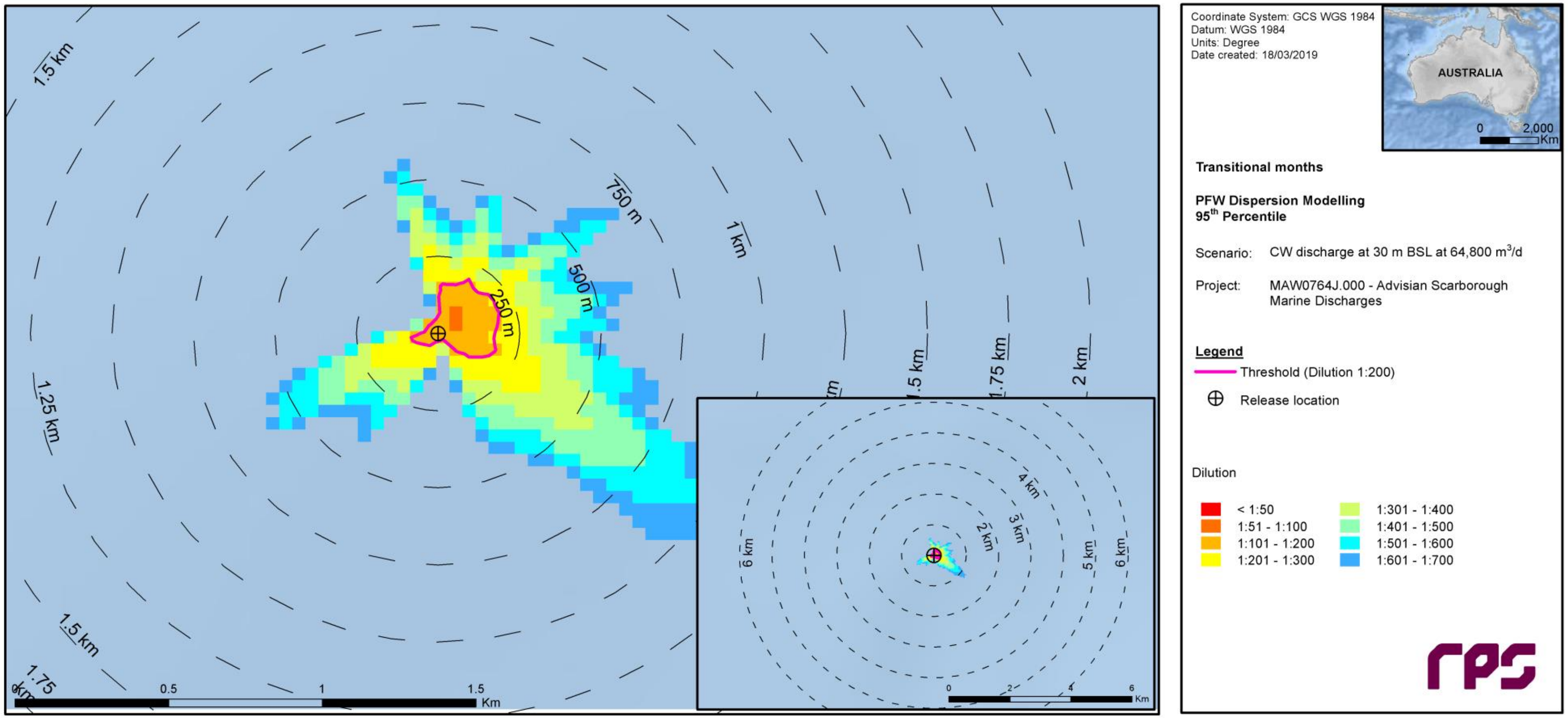


Figure 3.94 Predicted minimum dilutions at the 95th percentile under transitional conditions for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

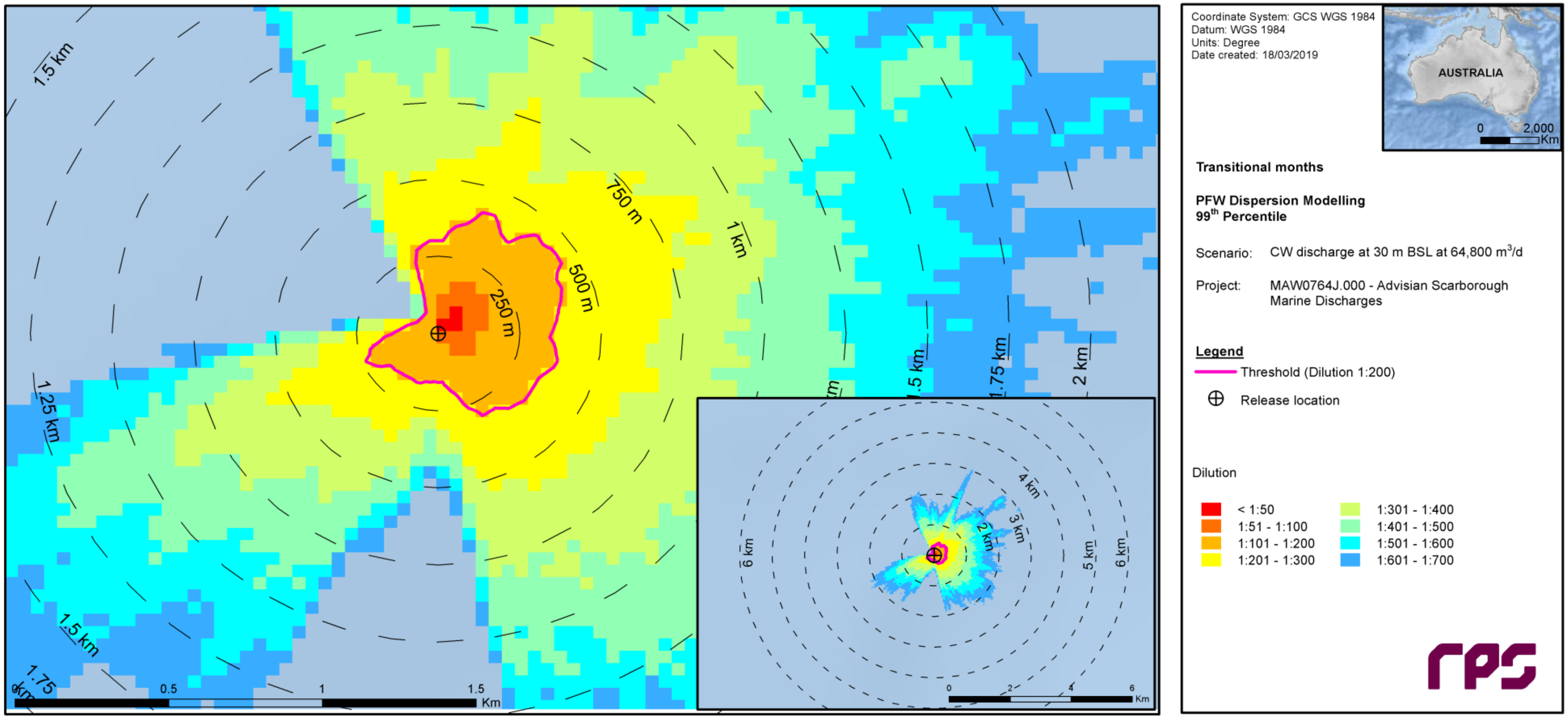


Figure 3.95 Predicted minimum dilutions at the 99th percentile under transitional conditions for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

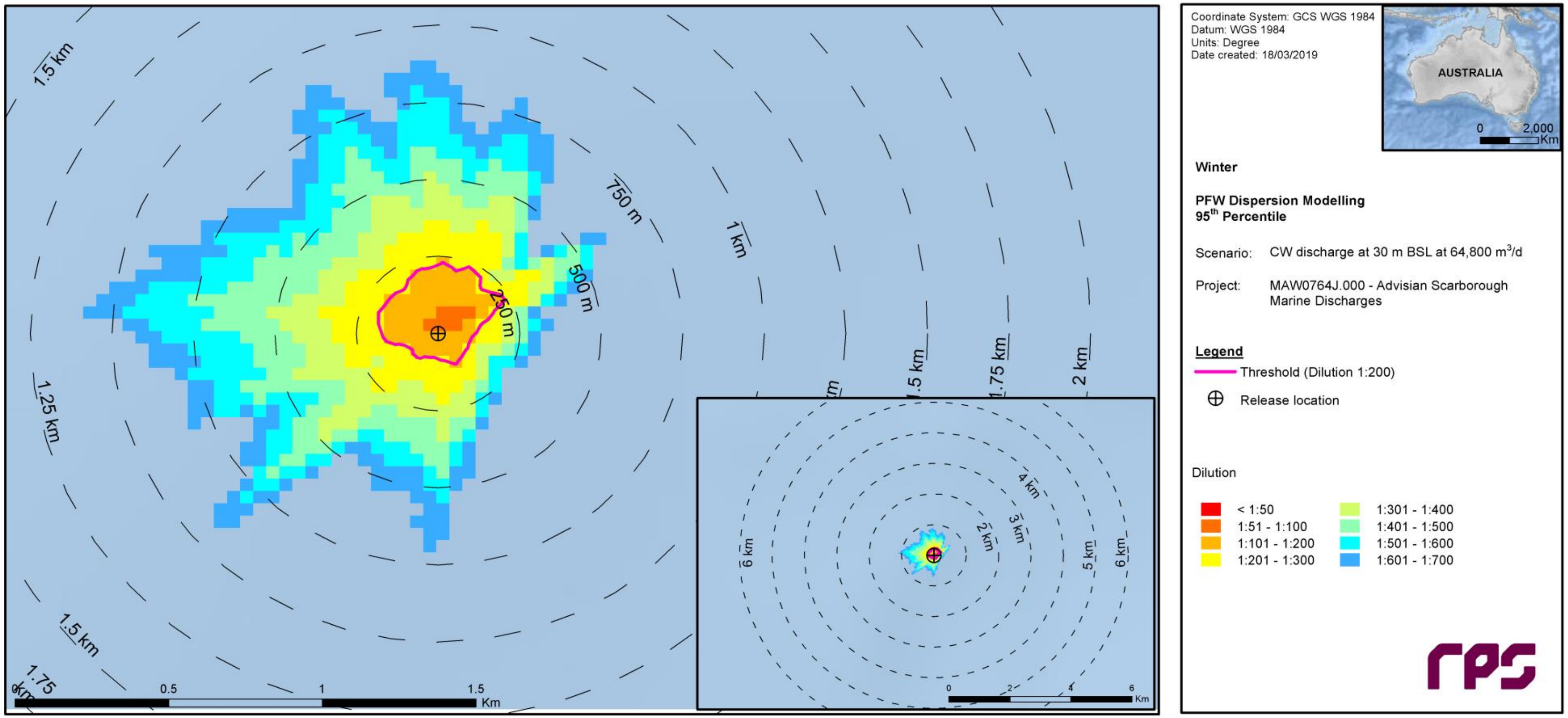


Figure 3.96 Predicted minimum dilutions at the 95th percentile under winter conditions for Case C6 (30 m depth discharge at 64,800 m³/d flow rate).

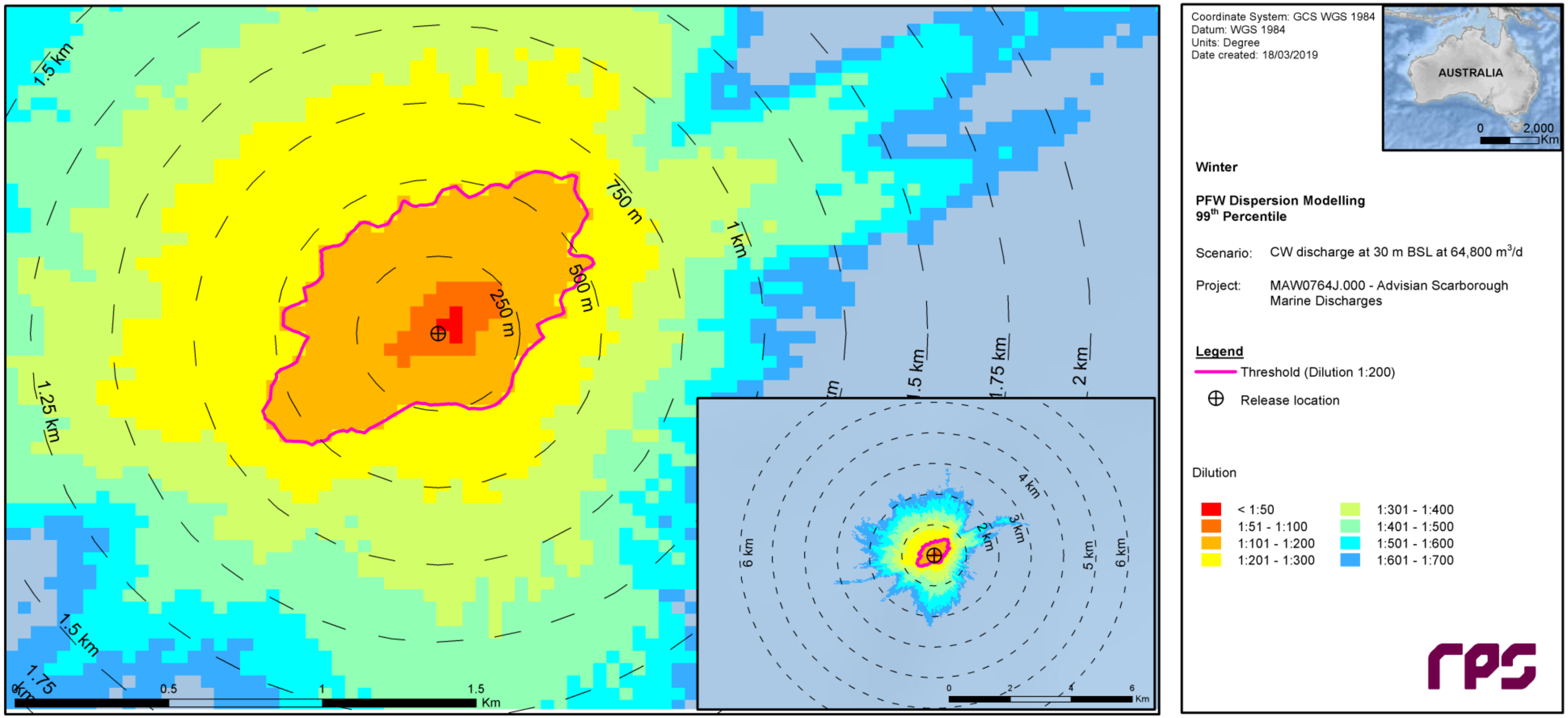


Figure 3.97 Predicted minimum dilutions at the 99th percentile under winter conditions for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

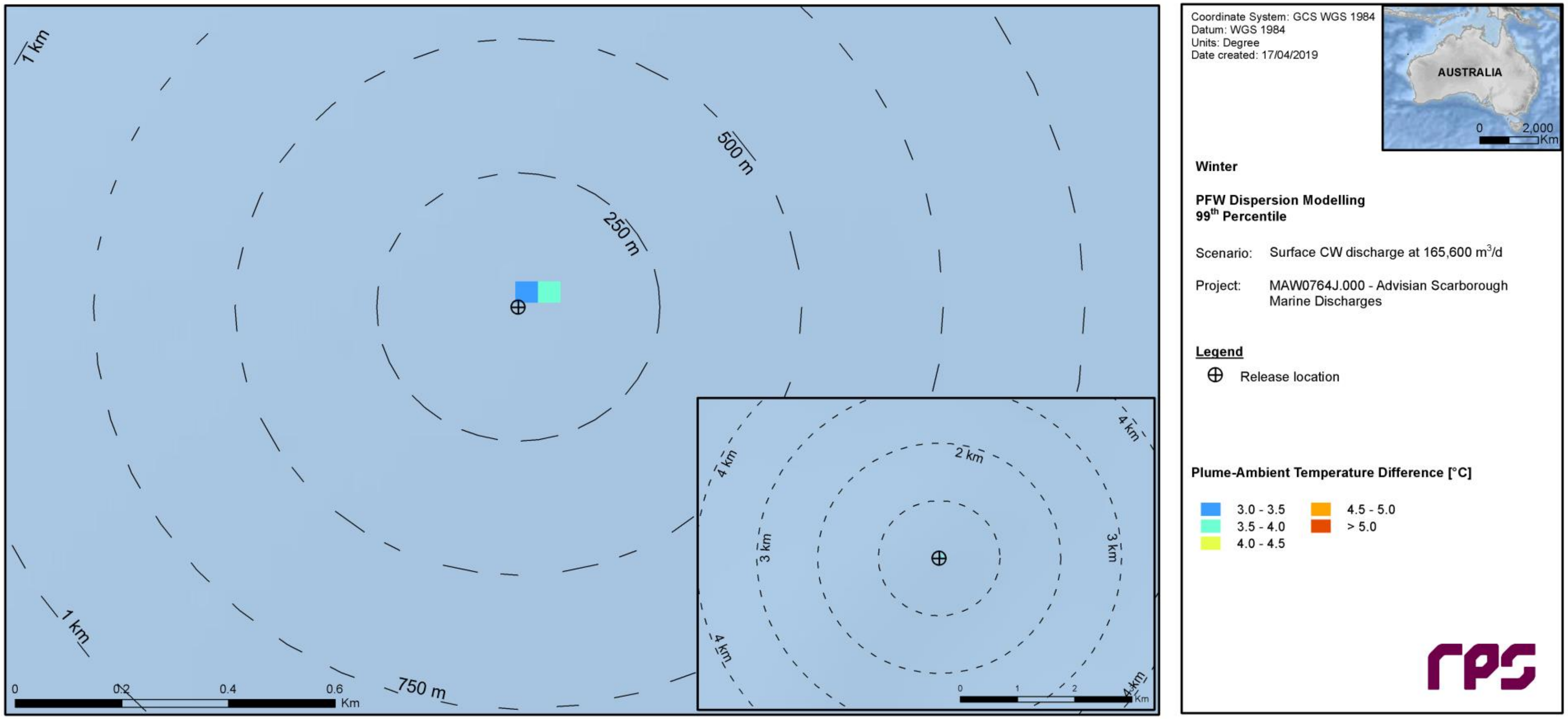


Figure 3.98 Predicted maximum plume-ambient ΔT at the 99th percentile under winter conditions for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

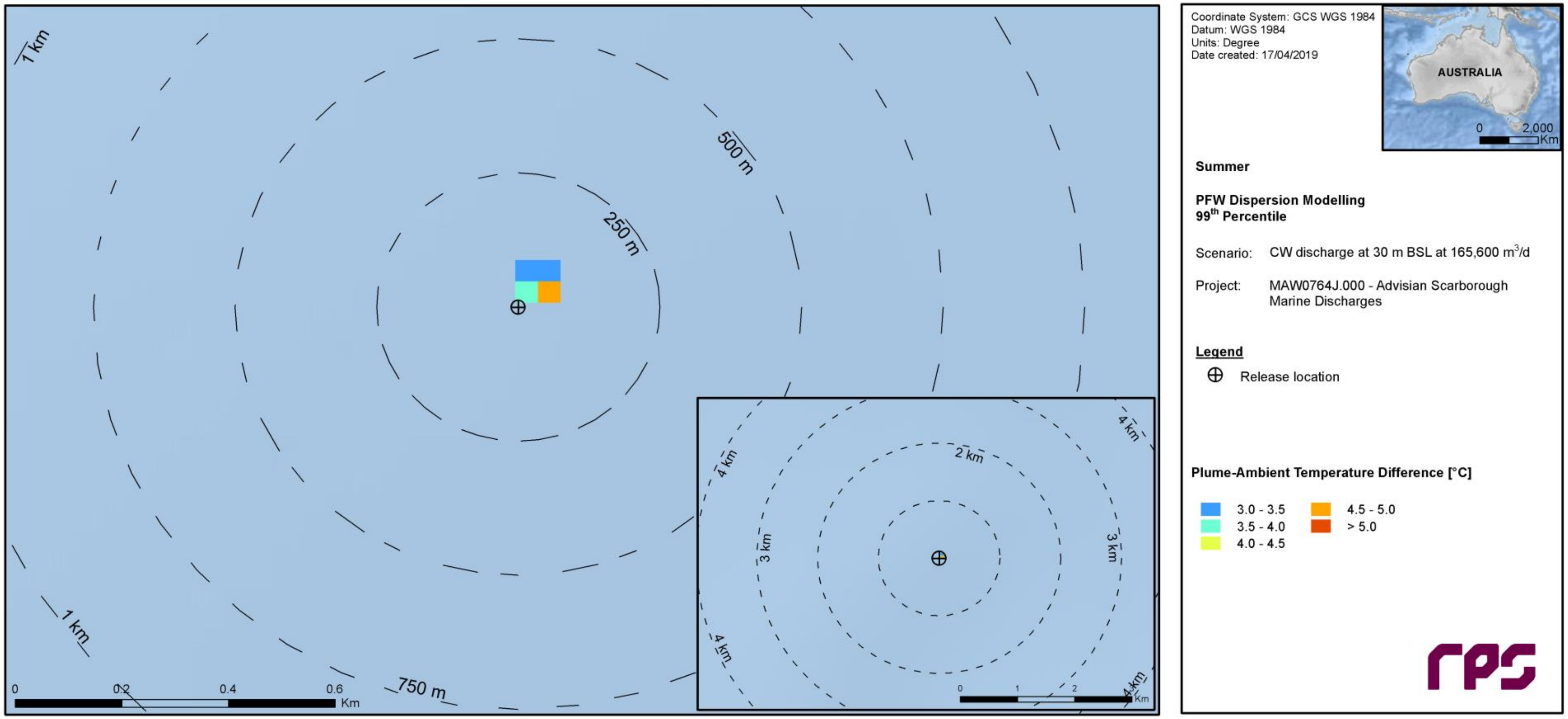


Figure 3.99 Predicted maximum plume-ambient ΔT at the 99th percentile under summer conditions for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

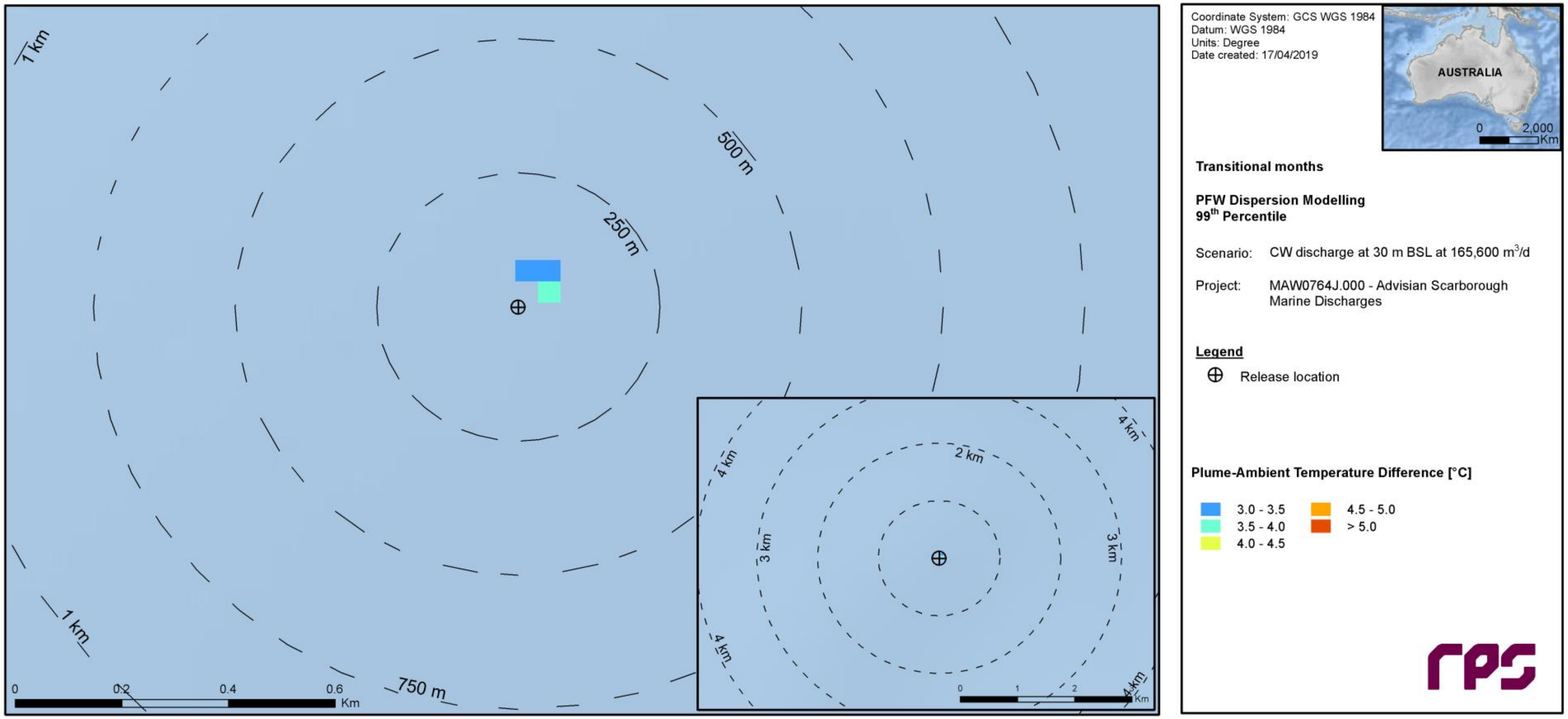


Figure 3.100 Predicted maximum plume-ambient ΔT at the 99th percentile under transitional conditions for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

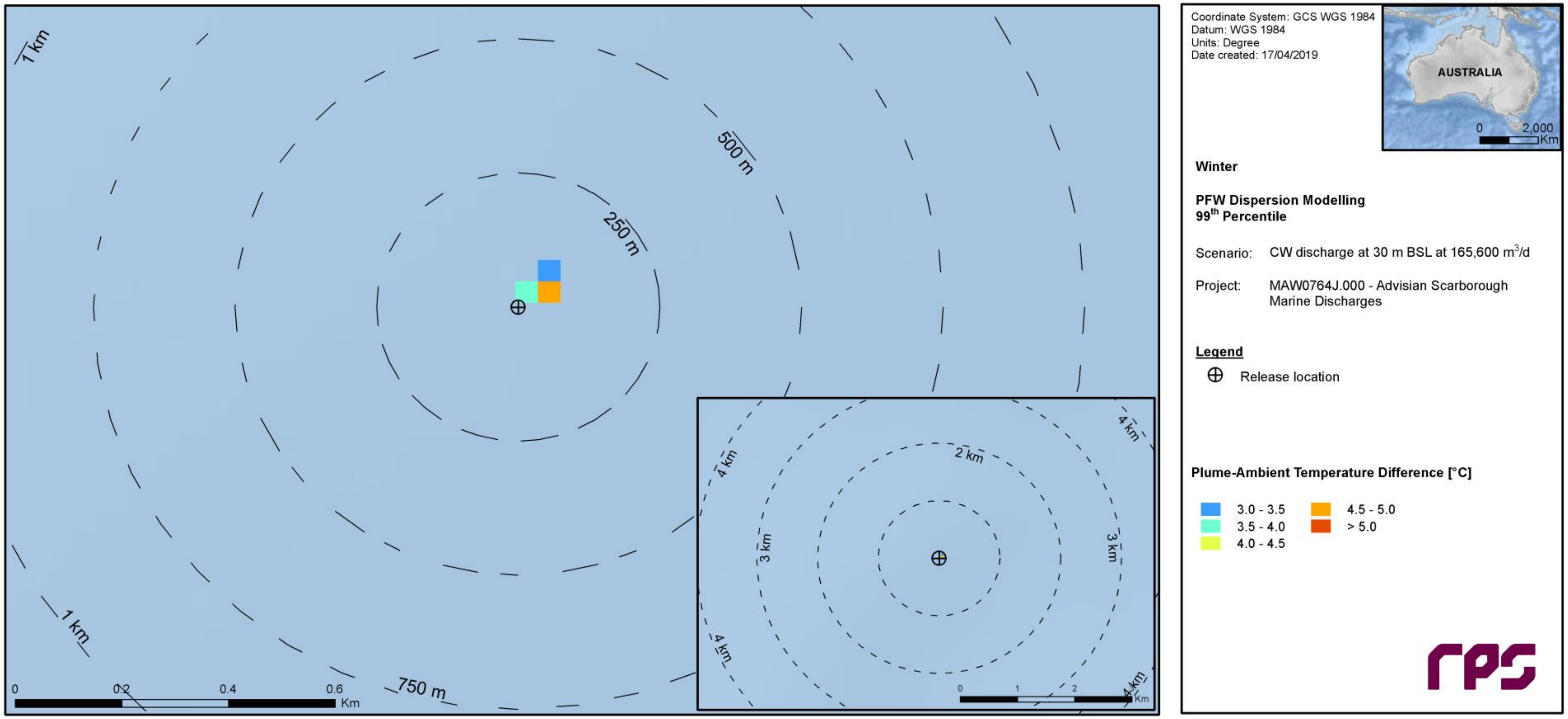


Figure 3.101 Predicted maximum plume-ambient ΔT at the 99th percentile under winter conditions for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

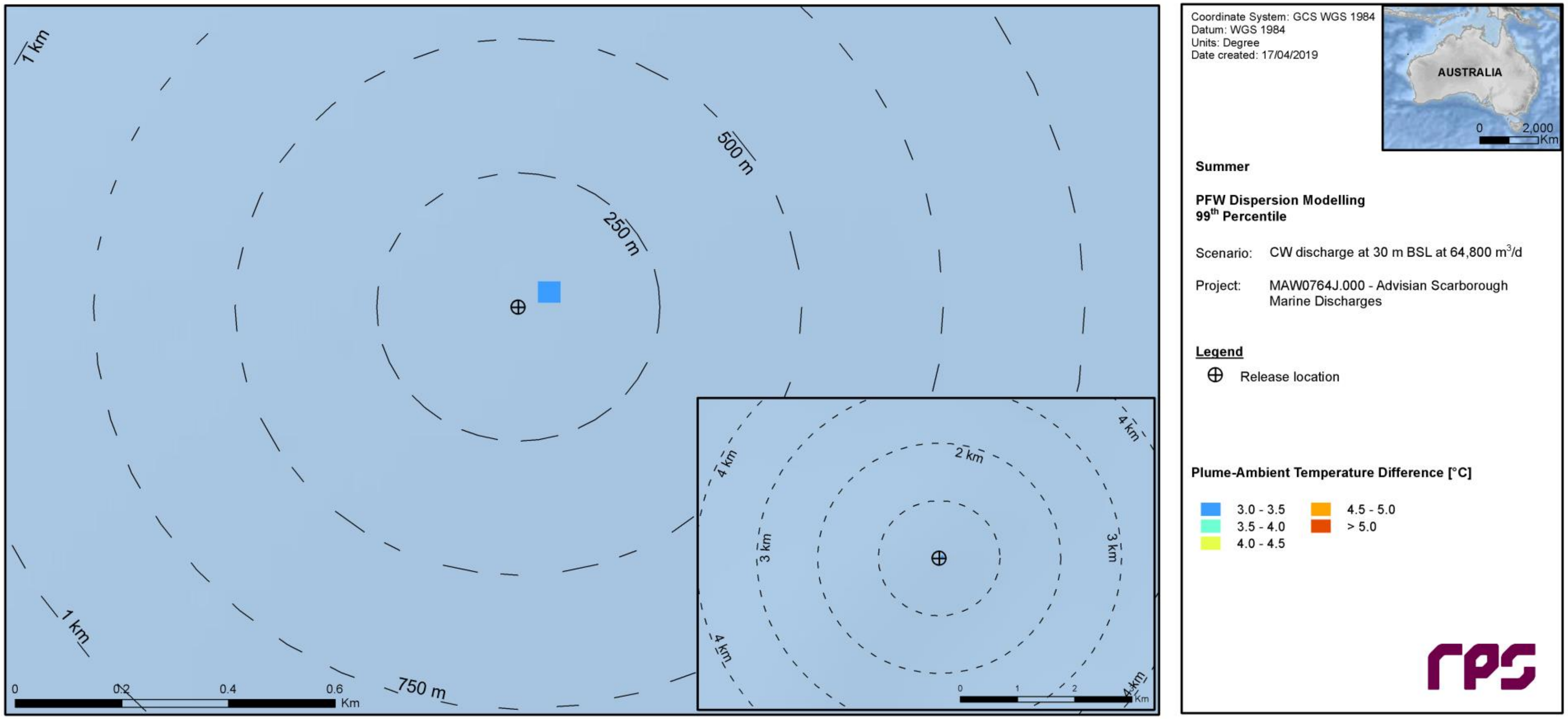


Figure 3.102 Predicted maximum plume-ambient ΔT at the 99th percentile under summer conditions for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

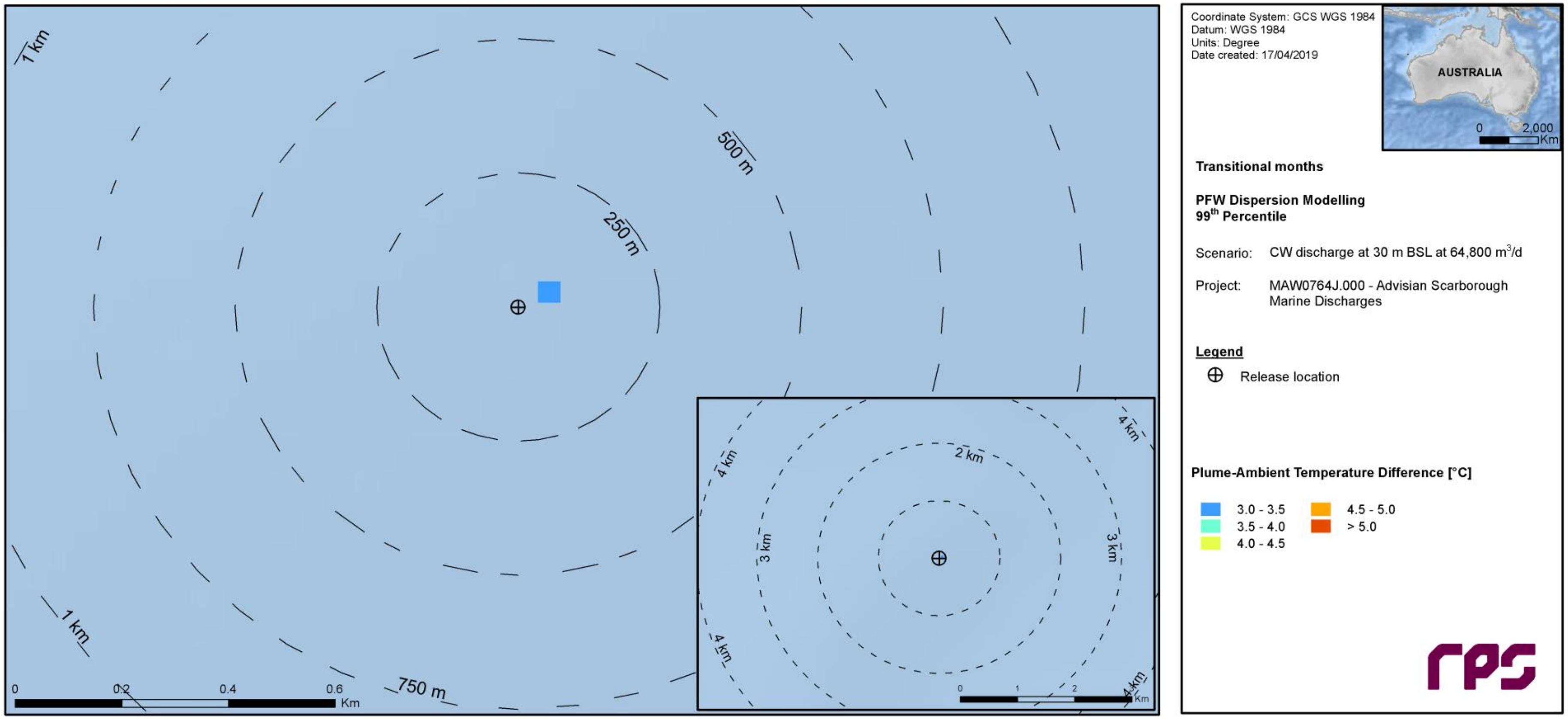


Figure 3.103 Predicted maximum plume-ambient ΔT at the 99th percentile under transitional conditions for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

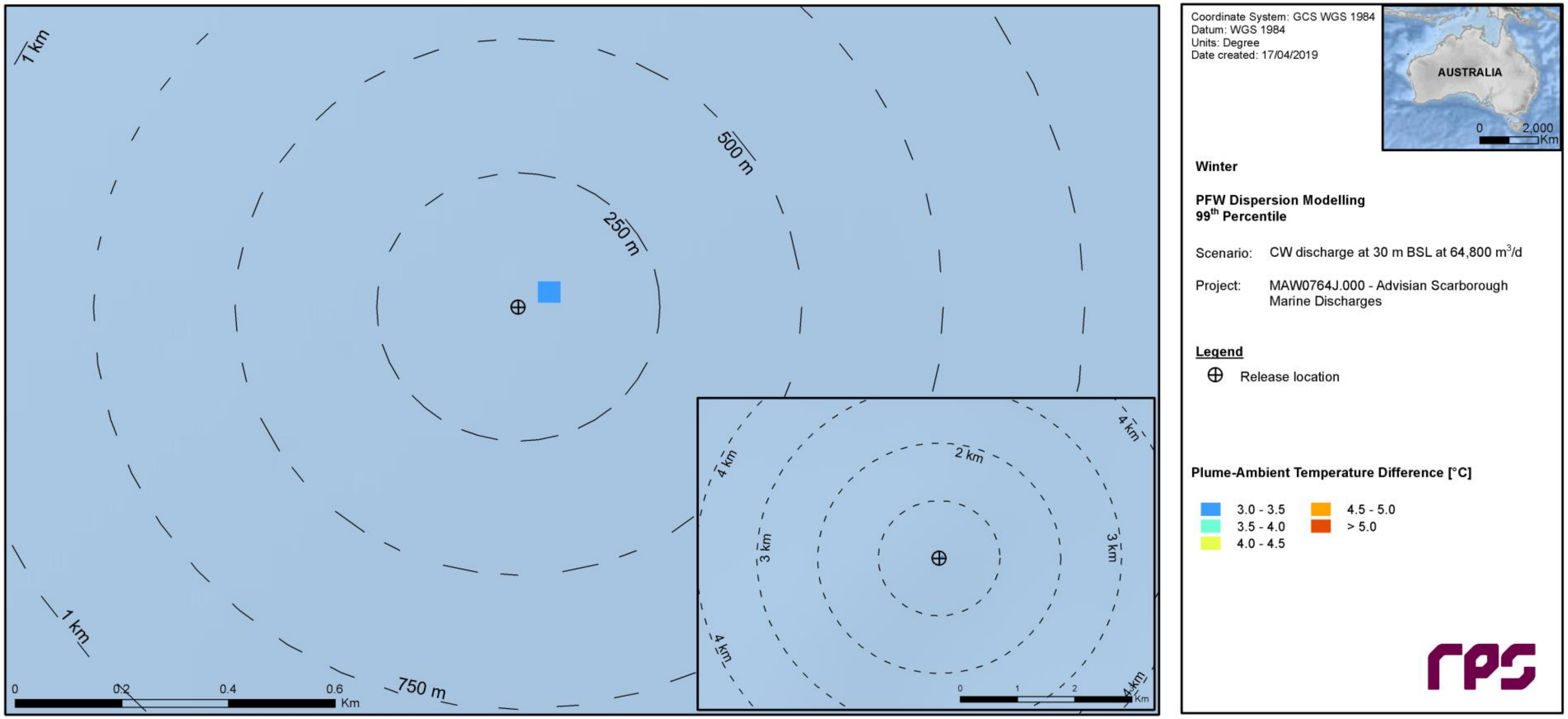


Figure 3.104 Predicted maximum plume-ambient ΔT at the 99th percentile under winter conditions for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

3.2.5 Annualised Analysis

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 3.67 to Table 3.70 summarise the minimum dilution achieved at specific radial distances from the discharge location for each percentile over the annual period.

Table 3.71 to Table 3.74 provide summaries of the annualised maximum distances from the discharge location to achieve 1:200 dilution 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 threshold concentration is achieved for chlorine within a maximum area of influence of 1.79 km (Case C1), 2.47 km (Case C3), 0.62 km (Case C4) and 0.63 km (Case C6) at the 99th percentile, this being the maximum spatial extent of the relevant dilution contour from the discharge location in any season.

Table 3.75 to Table 3.78 provide summaries of the total area of coverage for the 1:200 dilution contour for each percentile. The area of exposure defined by the relevant dilution contour is predicted to reach maximum values of 4.59 km^2 (Case C1), 6.56 km^2 (Case C3), 0.40 km^2 (Case C4) and 0.68 km^2 (Case C6) at the 99th percentile in any season.

Table 3.79 to Table 3.82 provide summaries of the annualised maximum distances from the discharge location to achieve a 3 °C plume-ambient temperature differential for each percentile. For all cases, the requirement is forecast to be met within 115 m at the 99th percentile. In many cases, the requirement is forecast to be met within the scale of the model grid resolution (40 m).

For Cases C1, C3, C4 and C6, Figure 3.105 to Figure 3.112 show the aggregated spatial extents of the minimum dilutions for each percentile. 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.

For the cases where the temperature requirement is not met within the scale of the model grid resolution, Figure 3.113 to Figure 3.115 show the aggregated spatial extents of the maximum plume-ambient temperature differential for each percentile.

Table 3.67 Annualised minimum dilution achieved at specific radial distances from the CW discharge location for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location																					
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km	1.10 km	1.20 km	1.30 km	1.40 km	1.50 km	1.60 km	1.70 km	1.80 km	1.90 km	2.00 km
95th	Annual	1:28.7	1:26.4	1:35.0	1:68.8	1:102.2	1:123.1	1:148.8	1:176.0	1:205.8	1:232.9	1:260.7	1:287.6	1:326.9	1:344.4	1:388.6	1:418.2	1:437.6	1:469.2	1:512.8	1:548.7	1:580.9	1:609.5
99th		1:14.3	1:11.6	1:17.0	1:31.6	1:49.5	1:61.0	1:71.1	1:74.3	1:81.7	1:94.8	1:98.4	1:106.3	1:126.6	1:136.2	1:147.0	1:149.1	1:161.2	1:165.4	1:244.1	1:176.6	1:212.8	1:237.8

Table 3.68 Annualised minimum dilution achieved at specific radial distances from the CW discharge location for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location																					
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km	1.10 km	1.20 km	1.30 km	1.40 km	1.50 km	1.60 km	1.70 km	1.80 km	1.90 km	2.00 km
95th	Annual	1:24.5	1:18.0	1:29.7	1:58.9	1:82.6	1:120.0	1:136.7	1:156.3	1:174.6	1:196.3	1:208.5	1:231.7	1:244.4	1:260.0	1:283.8	1:292.9	1:316.9	1:330.2	1:337.8	1:363.3	1:394.3	1:408.2
99th		1:9.7	1:9.6	1:15.1	1:28.8	1:41.0	1:49.8	1:56.7	1:69.3	1:69.3	1:94.1	1:93.2	1:98.8	1:112.1	1:124.3	1:124.3	1:141.4	1:154.8	1:165.5	1:174.5	1:181.6	1:195.5	1:206.0

Table 3.69 Annualised minimum dilution achieved at specific radial distances from the CW discharge location for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location																					
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km	1.10 km	1.20 km	1.30 km	1.40 km	1.50 km	1.60 km	1.70 km	1.80 km	1.90 km	2.00 km
95th	Annual	1:67.4	1:73.3	1:89.5	1:175.7	1:261.2	1:314.6	1:380.3	1:449.9	1:526.1	1:595.2	1:666.1	1:735.0	1:775.7	1:880.1	1:993.1	1:1,068.6	1:1,118.4	1:1,199.0	1:1,310.6	1:1,402.1	1:1,484.6	1:1,577.6
99th		1:29.6	1:36.5	1:43.2	1:80.8	1:126.6	1:156.0	1:181.7	1:189.8	1:208.7	1:242.3	1:251.6	1:271.7	1:313.4	1:348.0	1:375.7	1:381.1	1:411.8	1:422.6	1:436.4	1:451.4	1:543.8	1:607.8

Table 3.70 Annualised minimum dilution achieved at specific radial distances from the CW discharge location for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location																					
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km	1.10 km	1.20 km	1.30 km	1.40 km	1.50 km	1.60 km	1.70 km	1.80 km	1.90 km	2.00 km
95th	Annual	1:44.7	1:62.7	1:76.5	1:151.7	1:208.6	1:281.5	1:350.9	1:407.4	1:446.2	1:507.0	1:532.9	1:595.5	1:630.0	1:680.7	1:741.7	1:772.3	1:856.5	1:856.6	1:8,92.2	1:1,001.1	1:1,064.3	1:1,056.5
99th		1:24.4	1:33.2	1:37.9	1:73.6	1:104.9	1:130.7	1:141.9	1:181.2	1:195.2	1:240.5	1:238.2	1:252.7	1:302.7	1:317.6	1:329.9	1:361.4	1:395.6	1:423.0	1:445.9	1:445.5	1:499.6	1:526.4

Table 3.71 Annualised maximum distance from the CW discharge location to achieve 1:200 dilution for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Annual	639
99th		1,789
100th		4,705

Table 3.72 Annualised maximum distance from the CW discharge location to achieve 1:200 dilution for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Annual	771
99th		2,470
100th		6,391

Table 3.73 Annualised maximum distance from the CW discharge location to achieve 1:200 dilution for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Annual	182
99th		621
100th		2,272

Table 3.74 Annualised maximum distance from the CW discharge location to achieve 1:200 dilution for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Annual	212
99th		631
100th		3,566

Table 3.75 Annualised total area of coverage for 1:200 dilution for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Annual	0.680
99th		4.591
100th		22.347

Table 3.76 Annualised total area of coverage for 1:200 dilution for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Annual	0.897
99th		6.557
100th		45.284

Table 3.77 Annualised total area of coverage for 1:200 dilution for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Annual	0.059
99th		0.397
100th		3.556

Table 3.78 Annualised total area of coverage for 1:200 dilution for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Annual	0.090
99th		0.680
100th		7.597

Table 3.79 Annualised maximum distance from the CW discharge location to achieve 3 °C plume-ambient ΔT for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given ΔT
95th	Annual	<40
99th		90
100th		285

Table 3.80 Annualised maximum distance from the CW discharge location to achieve 3 °C plume-ambient ΔT for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given ΔT
95th	Annual	<40
99th		115
100th		380

Table 3.81 Annualised maximum distance from the CW discharge location to achieve 3 °C plume-ambient ΔT for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given ΔT
95th	Annual	<40
99th		<40
100th		145

Table 3.82 Annualised maximum distance from the CW discharge location to achieve 3 °C plume-ambient ΔT for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given ΔT
95th	Annual	<40
99th		90
100th		175

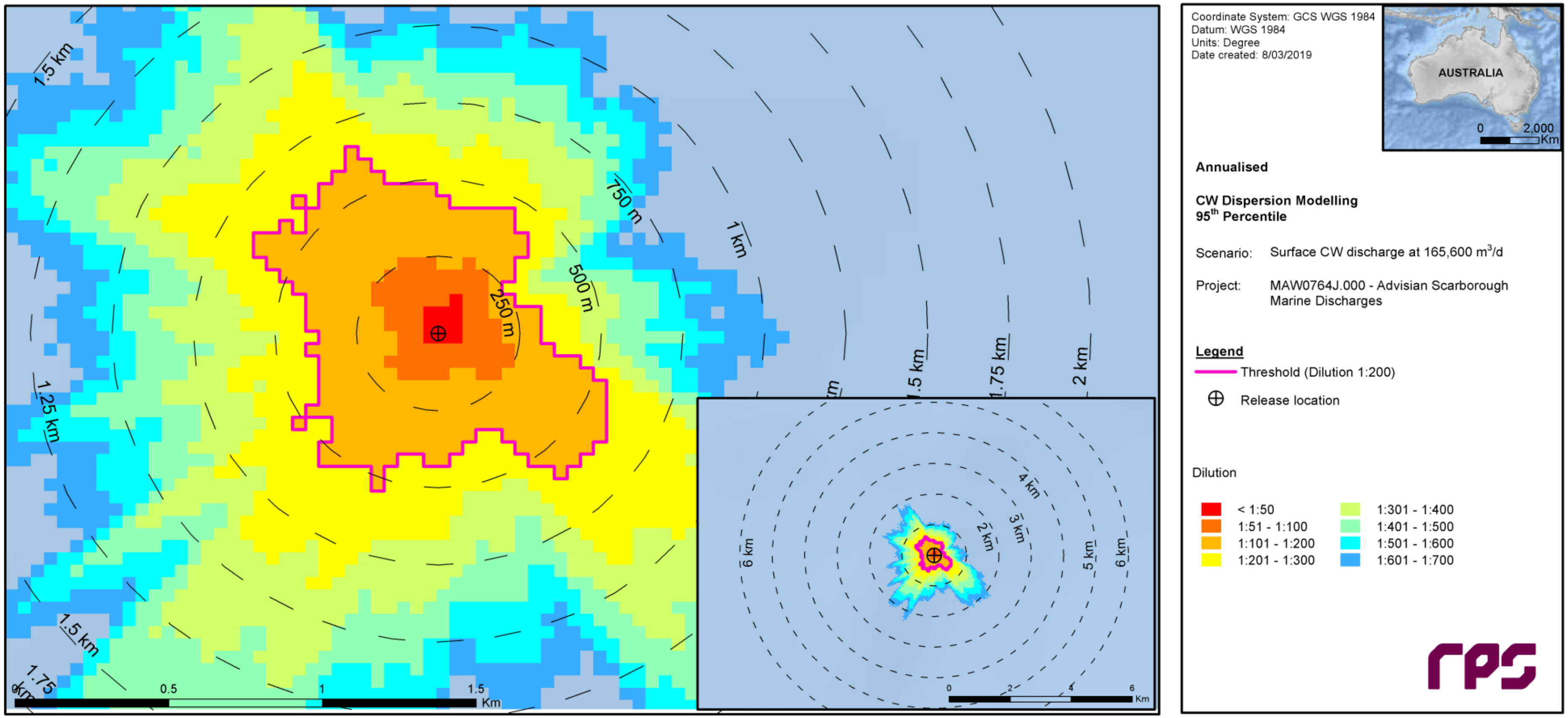


Figure 3.105 Predicted annualised minimum dilutions at the 95th percentile for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

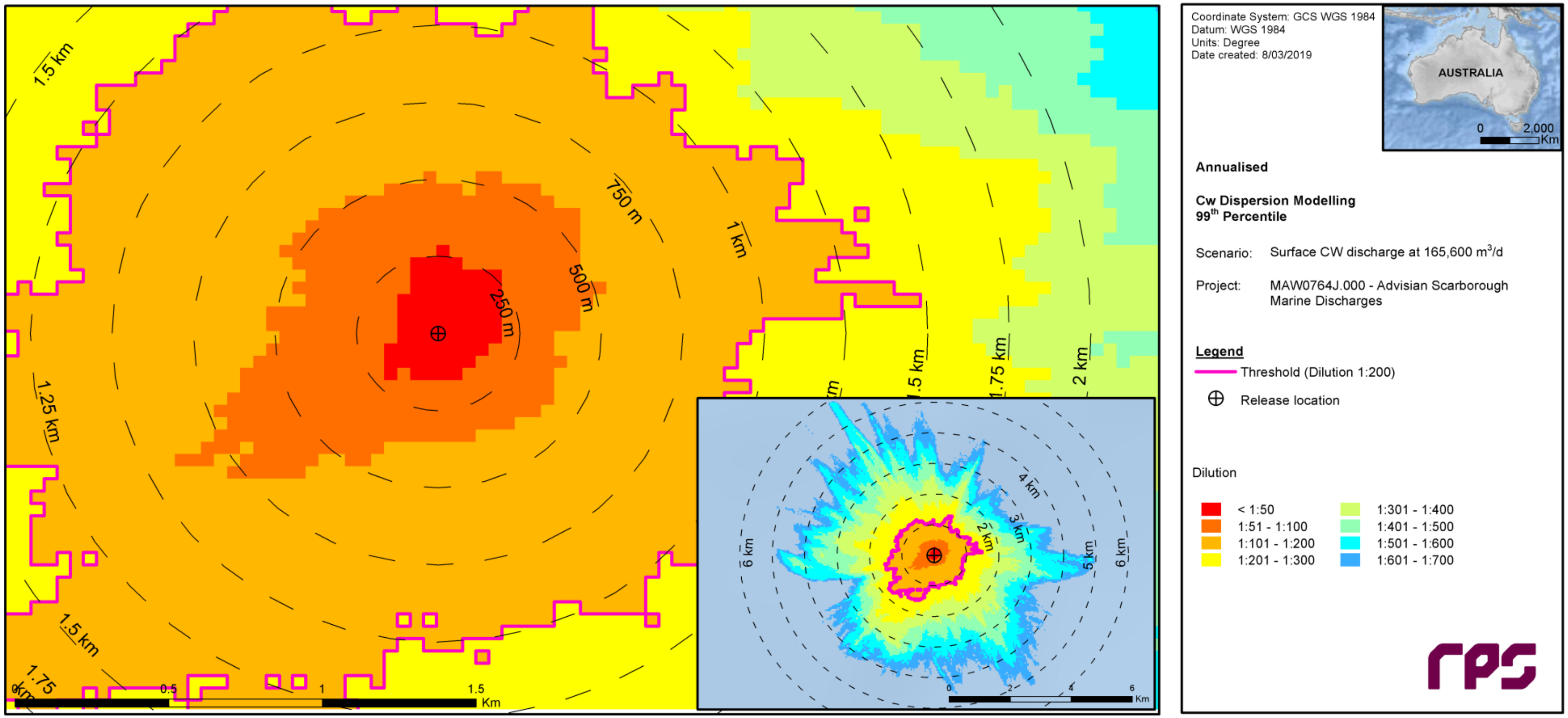


Figure 3.106 Predicted annualised minimum dilutions at the 99th percentile for Case C1 (0 m depth discharge at 165,600 m³/d flow rate).

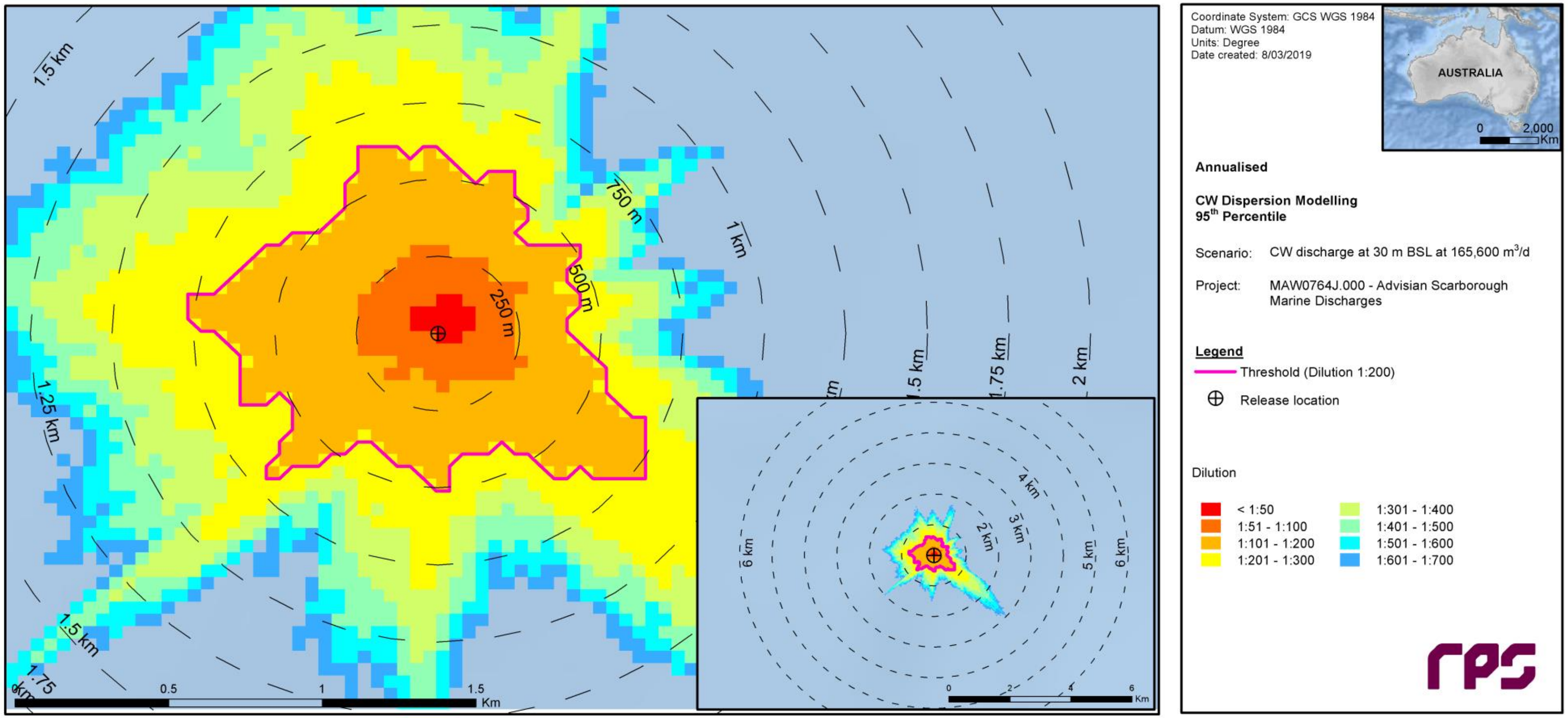


Figure 3.107 Predicted annualised minimum dilutions at the 95th percentile for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

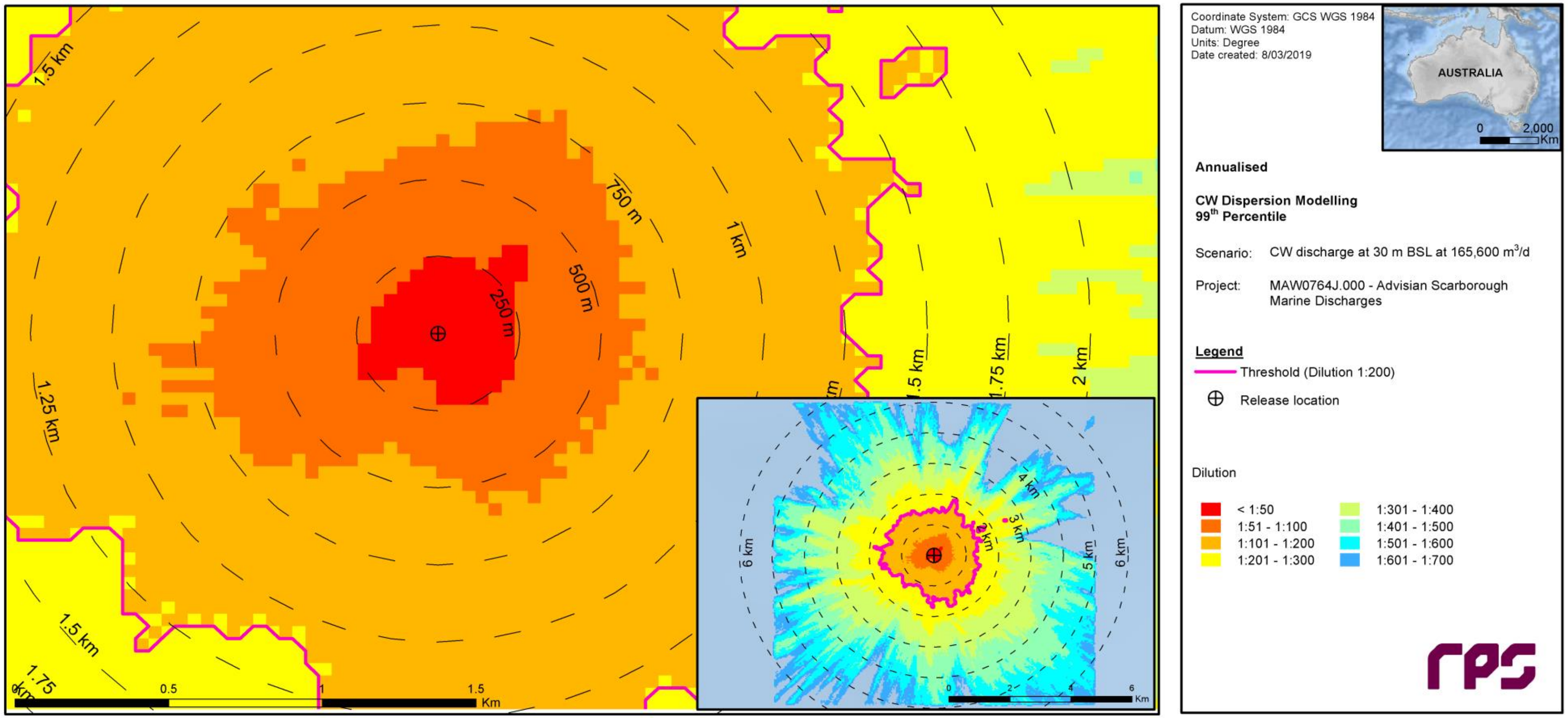


Figure 3.108 Predicted annualised minimum dilutions at the 99th percentile for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

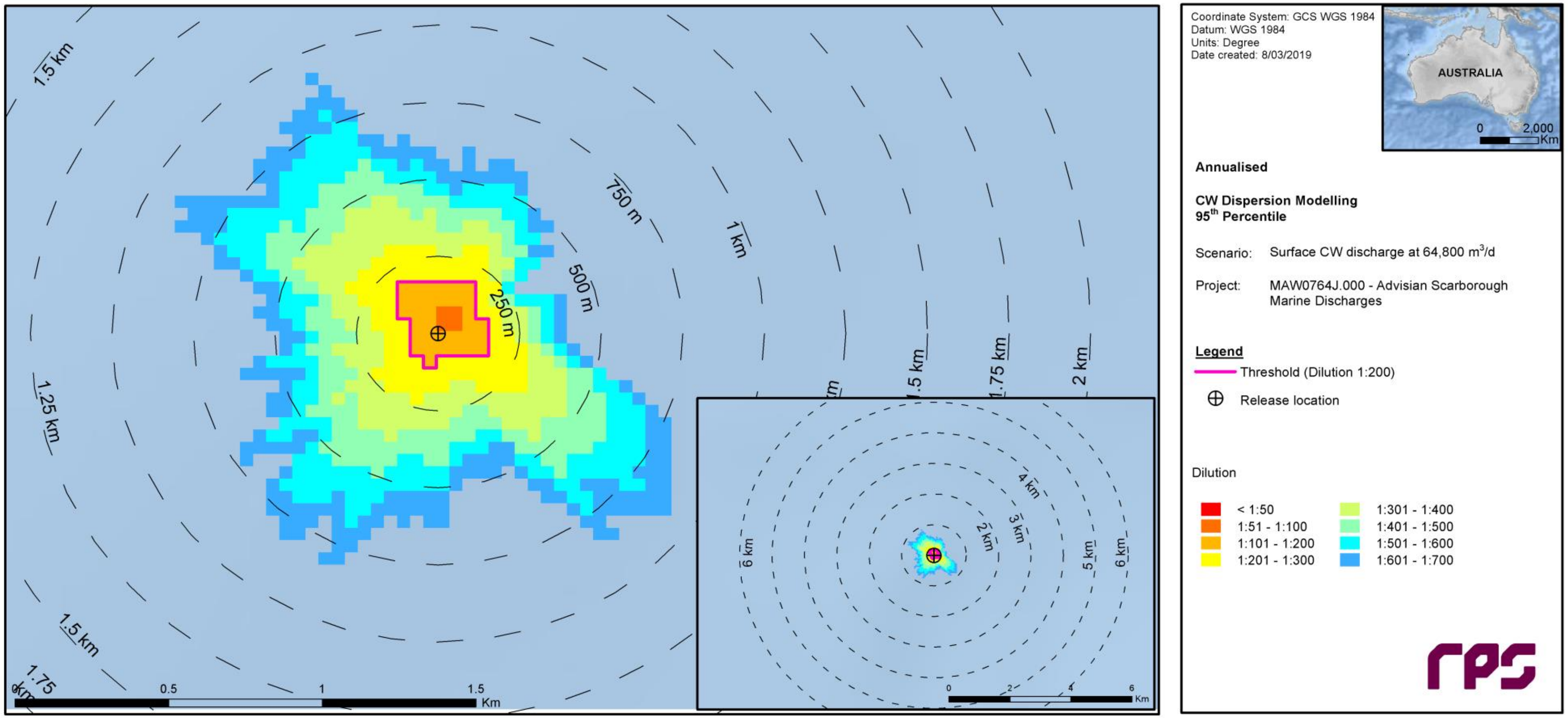


Figure 3.109 Predicted annualised minimum dilutions at the 95th percentile for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

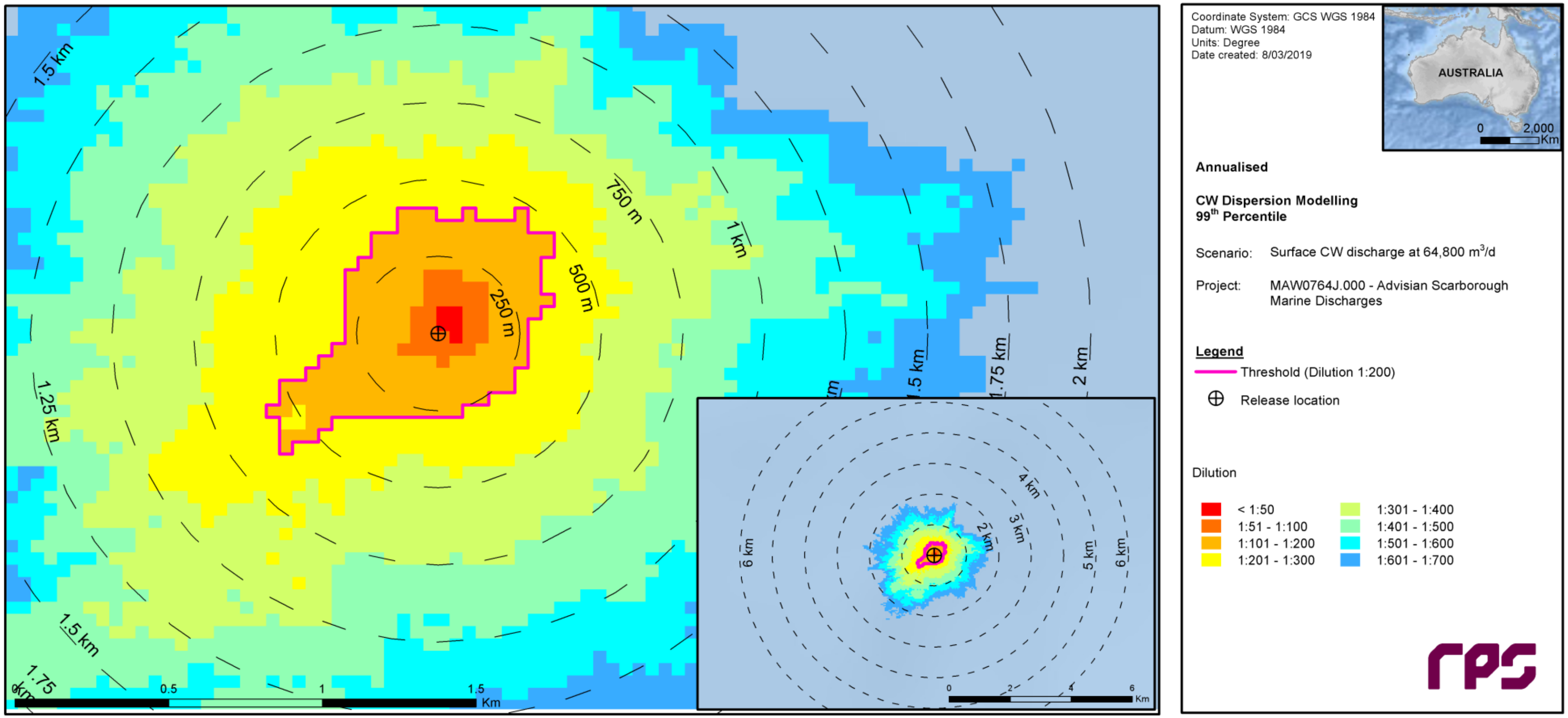


Figure 3.110 Predicted annualised minimum dilutions at the 99th percentile for Case C4 (0 m depth discharge at 64,800 m^3/d flow rate).

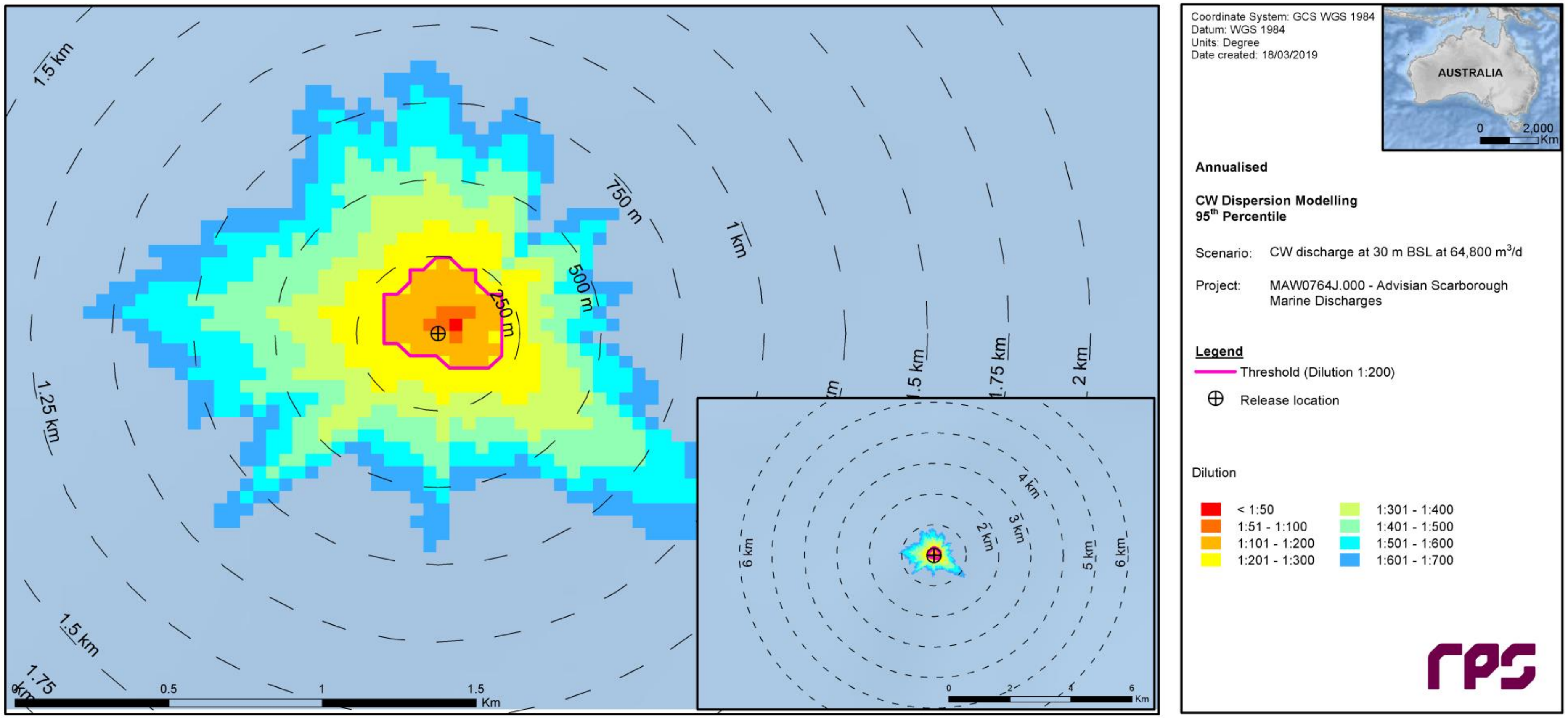


Figure 3.111 Predicted annualised minimum dilutions at the 95th percentile for Case C6 (30 m depth discharge at 64,800 m³/d flow rate).

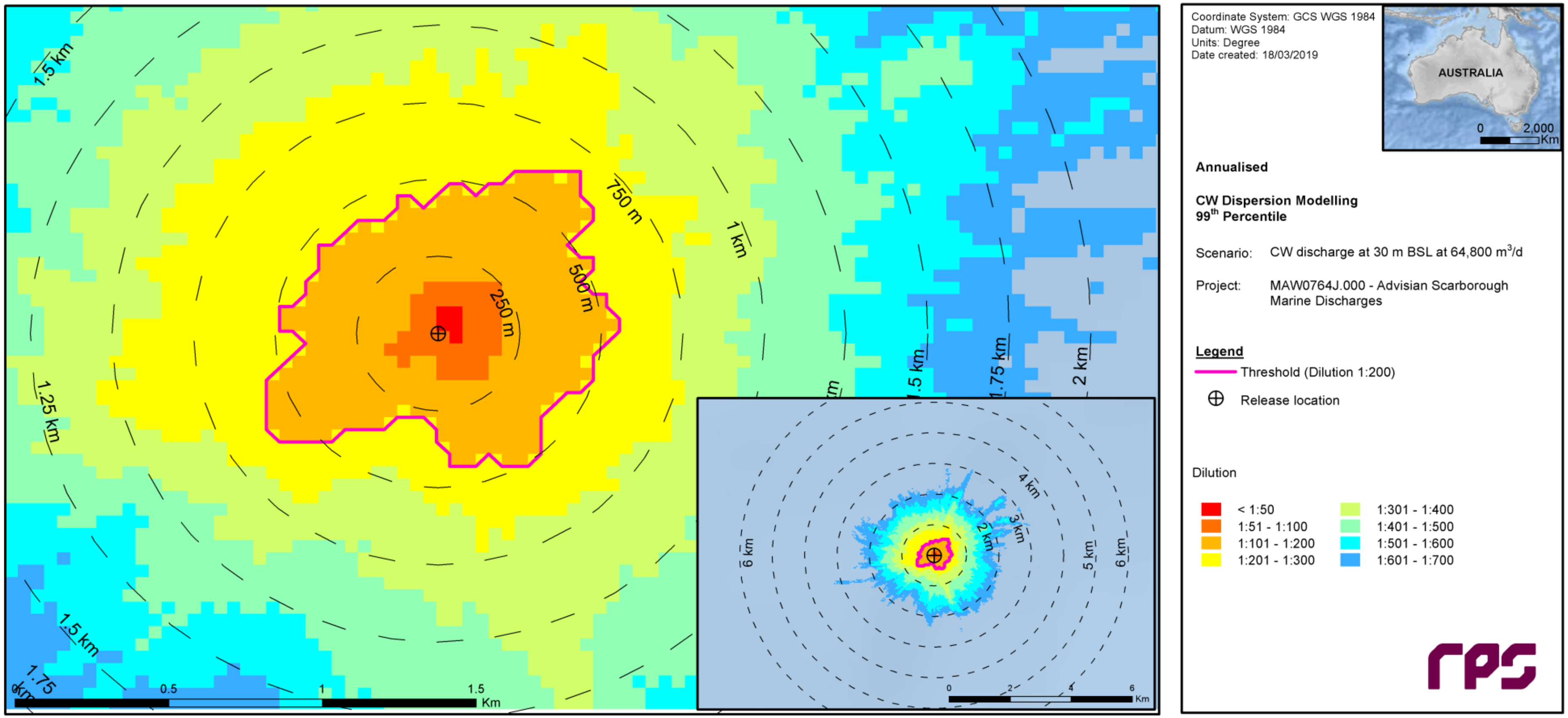


Figure 3.112 Predicted annualised minimum dilutions at the 99th percentile for Case C6 (30 m depth discharge at 64,800 m³/d flow rate).

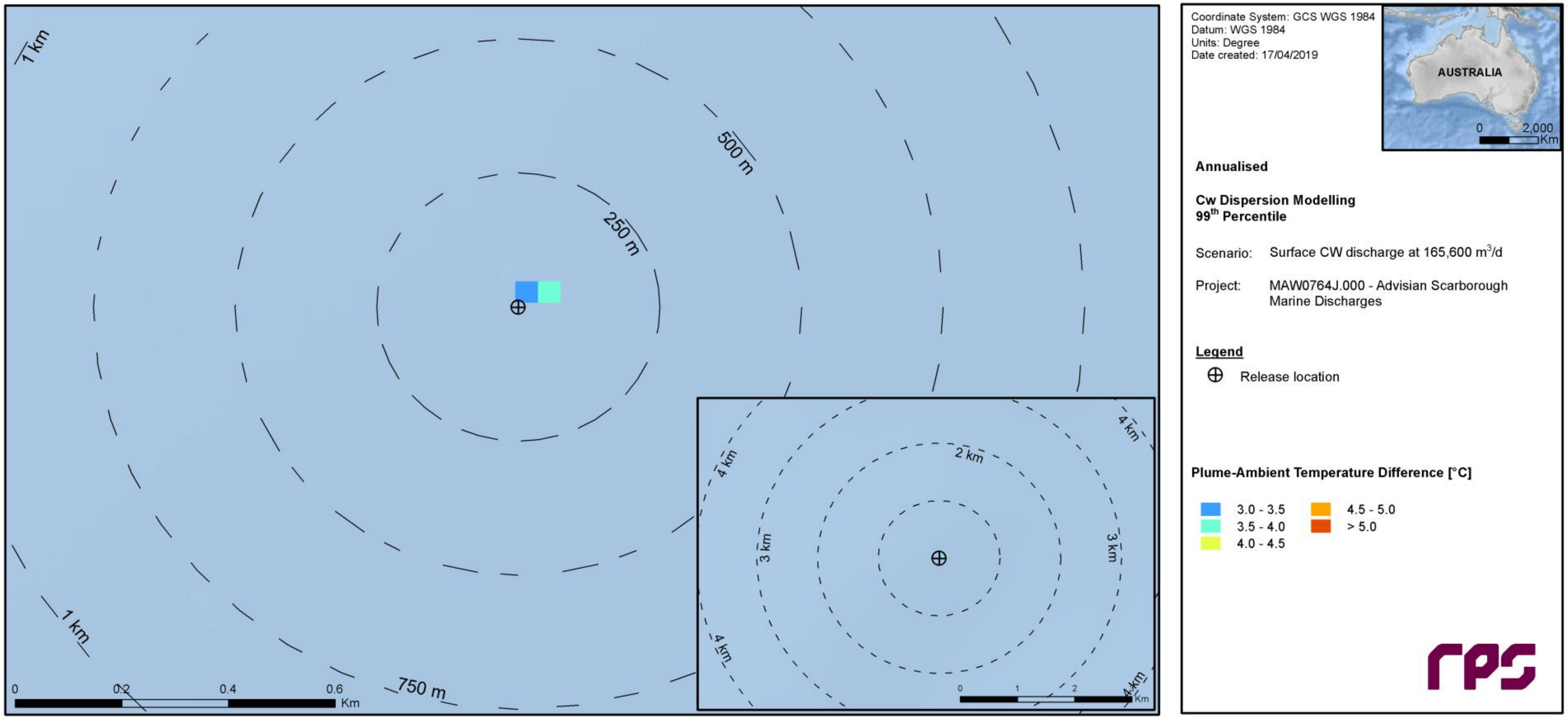


Figure 3.113 Predicted annualised maximum plume-ambient ΔT at the 99th percentile for Case C1 (0 m depth discharge at 165,600 m^3/d flow rate).

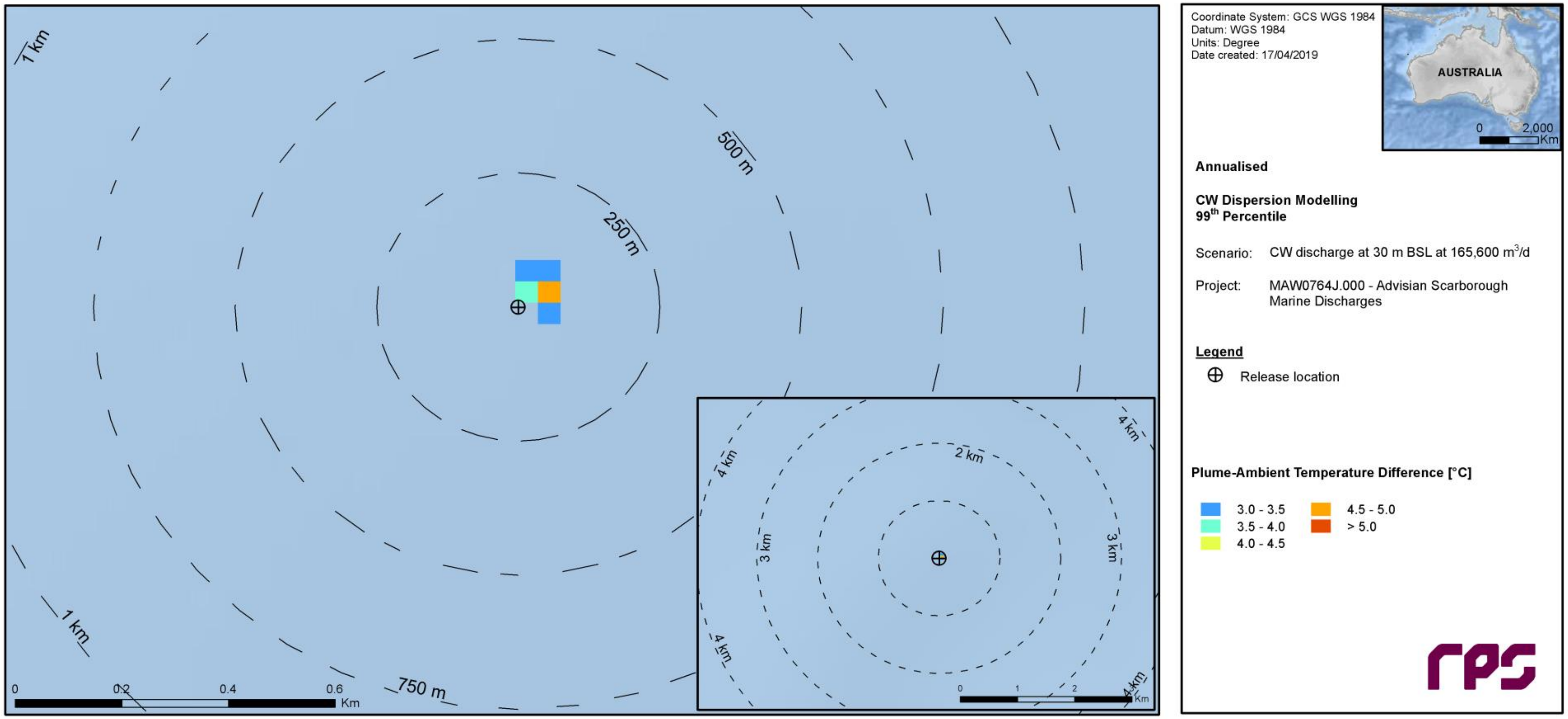


Figure 3.114 Predicted annualised maximum plume-ambient ΔT at the 99th percentile for Case C3 (30 m depth discharge at 165,600 m^3/d flow rate).

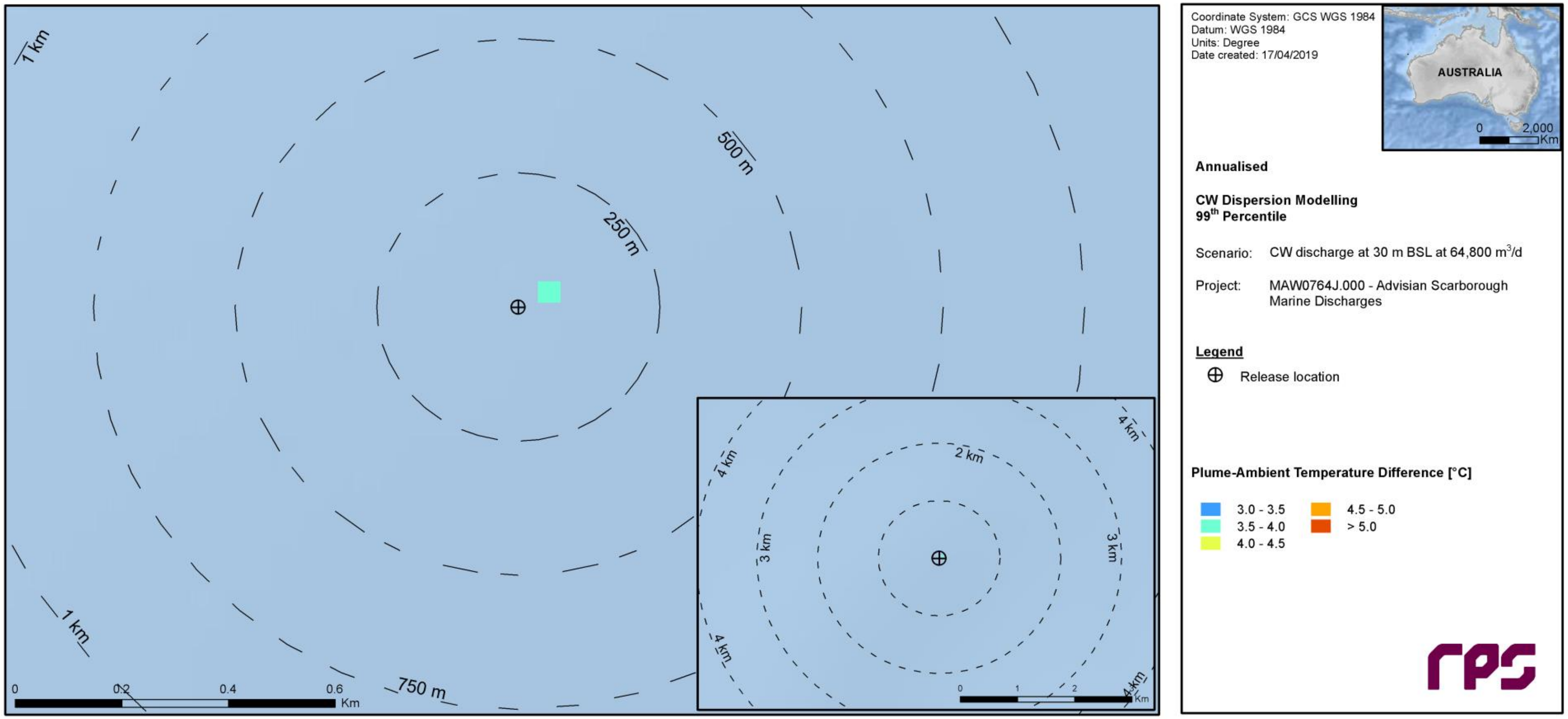


Figure 3.115 Predicted annualised maximum plume-ambient ΔT at the 99th percentile for Case C6 (30 m depth discharge at 64,800 m^3/d flow rate).

4 CONCLUSIONS

The main findings of the study are as follows:

Near-Field Modelling

- 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 0 m (Cases C1, C4 and C7), 10 m (Cases C2, C5 and C8) and 30 m (Cases C3, C6 and C9) below the water surface. The surface discharges 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 C1, C4 and C7 (0 m depth discharge), the plume is predicted to plunge up to 14 m below the sea surface, with the highest flow rate yielding the greatest plunge depth due to the vertical orientation of the discharges. For the discharges at depths of 10 m and 30 m, the plumes are predicted to plunge up to 25 m and 43 m below the sea surface, respectively, with the highest flow rate yielding the greatest plunge depths.
- Increased ambient current strengths are shown to increase the horizontal distance travelled by the plume from the discharge point.
- For a discharge at a 165,600 m^3/d flow rate, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a discharge at 30 m depth as 75.0 m. The dilution level for this case is predicted as 1:52.
- For a discharge at a 64,800 m^3/d flow rate, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a discharge at 30 m depth as 69.7 m. The dilution level for this case is predicted as 1:77.
- For a discharge at an 82,800 m^3/d flow rate, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a discharge at 30 m depth as 59.8 m. The dilution level for this case is predicted as 1:59.
- For a discharge at 0 m depth, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a 165,600 m^3/d flow rate discharge as 5.7 m. The dilution level for this case is predicted as 1:6.
- For a discharge at 10 m depth, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a 165,600 m^3/d flow rate discharge as 11.1 m. The dilution level for this case is predicted as 1:17.
- For a discharge at 30 m depth, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a 165,600 m^3/d flow rate discharge as 24.5 m. The dilution level for this case is predicted as 1:52.
- For each combination of discharge flow rate and depth, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to plunge further and reach the surface (or 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 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.
- The results for each combination of discharge flow rate and depth indicate that the chlorine constituent of the CW discharge is not expected to reach the required levels of dilution in the near field mixing zone.
- The temperature differential between the plume and the ambient water meets the required criterion in all conditions for Cases C2, C3, C6 and C9, and in the stronger-current simulations for Cases C1, C5 and C8. For Cases C4 and C7, however, compliance with the temperature differential criterion is not achieved.
- Some failures to reach the required threshold concentration and temperature are attributable to the plume rapidly breaking the surface.

Far-Field Modelling

- For Cases C1 and C3, dilution to reach threshold concentration is achieved for chlorine within an area of influence extending up to 1.79 km and 2.47 km, respectively, at the 99th percentile. For Cases C4 and C6, the maximum spatial extents of the relevant dilution contour are up to 0.62 km and 0.63 km, respectively, at the 99th percentile.
- For Cases C1 and C3, the areas of exposure defined by the relevant dilution contour are predicted to reach maximums of 4.59 km^2 and 6.56 km^2, respectively, at the 99th percentile. For Cases C4 and C6, the corresponding maximum areas of exposure are up to 0.40 km^2 and 0.68 km^2, respectively, at the 99th percentile.
- Maximum depths reached by. the discharges are predicted as 8 m, 38 m, 6 m and 38 m for Cases C1, C3, C4 and C6, respectively.
- Because the 3 °C plume-ambient temperature differential requirement is forecast to be met within a distance of 115 m at the 99th percentile in any case, the limiting factor for the plume's area of influence will be defined by its chlorine constituent rather than its temperature.

Key Observations

- Due to the similarity in typical magnitude of the hindcast currents throughout the depth range of discharges under consideration, predicted outcomes are broadly similar.
- The greater variability in surface-layer currents may promote the highest levels of mixing and dilution.
- Because the discharge will be initially positively buoyant, it will rise in the water column and may resurface in the vicinity of the discharge point prior to acclimation with ambient receiving water conditions. This outcome is particularly likely for the surface discharge.
- Outcomes show that below-threshold chlorine concentrations are achieved closer to the discharge point for a flow rate of 64,800 m^3/d than for a higher flow rate of 165,600 m^3/d. This is attributable to the fact that initial peak chlorine concentrations in the water column are lower in the former case, which reduces the average concentrations likely to be recorded in each model grid cell during episodes of recirculation and pooling.

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Appendix G

Scarborough Gas Development Produced Water Discharge Modelling Study

WOODSIDE SCARBOROUGH PROJECT – PRODUCED WATER DISCHARGE MODELLING

Report

MAW0764J
Woodside Scarborough Project – Produced Water Discharge Modelling
Rev 2
17 April 2019

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EXECUTIVE SUMMARY

RPS was commissioned by Advisian Pty Ltd (Advisian), on behalf of Woodside Energy Ltd (Woodside), to undertake a marine dispersion modelling study of proposed water discharges from the Scarborough Project's Floating Production Unit (FPU).

The Scarborough gas resource, located in Commonwealth waters approximately 375 km off the Burrup Peninsula, forms part of the Greater Scarborough gas fields, comprising the Scarborough, North Scarborough, Thebe and Jupiter gas fields.

As Operator of the Greater Scarborough gas fields, Woodside is proposing to develop the gas resource through new offshore facilities. These will be connected to the mainland through an approximately 430 km trunkline.

The Scarborough Project will involve the processing of hydrocarbons which will result in the production of produced water (PW).

The principal aim of the study was to quantify the likely extents of the near-field and far-field mixing zones based on the required dilution levels for the Total Petroleum Hydrocarbons (TPH) in the produced water (PW) discharge. This will indicate whether concentrations of this contaminant are still likely to be above stated threshold levels at the limits of the mixing zones (i.e. are not predicted to be diluted below the relevant threshold).

To accurately determine the dilution of the PW discharge 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 TPH in the PW stream from the FPU, dispersion modelling was carried out for a flow rate of 95 m^3/d at three discharge depths: 0 m, 10 m and 30 m below the water surface.

The potential area that may be influenced by the PW discharge stream 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

- 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 0 m, 10 m and 30 m below the water surface (Cases P1, P2 and P3, respectively). The surface discharges are shown to increase the extent of the turbulent mixing zone. Following this initial mixing, the near neutrally-buoyant plumes are predicted to travel laterally in the water column.
- For Case P1, the plume is predicted to plunge up to 4.4 m below the sea surface. For Cases P2 and P3, the plumes are predicted to remain at approximately the discharge depth: up to 11 m below the surface for Case P2 and up to 31 m below the surface for Case P3.
- Increased ambient current strengths are shown to increase the horizontal distance travelled by the plume from the discharge point.

- For a discharge at a 95 m^3/d flow rate, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a discharge at 0 m depth as 255 m. The dilution level for this case is predicted as 1:1,519.
- The maximum diameter of the plume at the end of the near-field zone was predicted as 3.7 m for Case P1, 1.8 m for Case P2 and 1.7 m for Case P3. Increases in current speed serve to restrict the diameter of the plume.
- For each discharge depth, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to plunge further and 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 average current speeds are predicted to be 1:1,519 for Case P1, 1:88 for Case P2 and 1:43 for Case P3. Additionally, the minimum dilution levels of the plume (i.e. dilution of the plume centreline) upon encountering the trapping depth under average current speeds are predicted to be 1:390 for Case P1, 1:22 for Case P2 and 1:11 for Case P3.
- 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.
- The results for the Case P1, P2 and P3 discharges indicate that the TPH constituent of the PW discharge is not expected to reach the required levels of dilution in the near field mixing zone.

Far-Field Modelling

- For Case P1, dilution to reach threshold concentration is achieved for TPH within an area of influence extending up to 543 m at the 99th percentile. For Case P3, the maximum spatial extents of the relevant dilution contour are up to 810 m at the 99th percentile.
- For Case P1, the area of exposure defined by the relevant dilution contour is predicted to reach a maximum of 0.48 km^2 at the 99th percentile. For Case P3, the corresponding maximum area of exposure is up to 0.70 km^2 at the 99th percentile.
- Maximum depths reached by the discharges are predicted as 5 m and 33 m for Cases P1 and P3, respectively.

Key Observations

- Due to the similarity in typical magnitude of the hindcast currents throughout the depth range of discharges under consideration, predicted outcomes are broadly similar.
- The greater variability in surface-layer currents will promote the highest levels of mixing and dilution.
- Because the discharge will be initially negatively buoyant, it will sink in the water column and even a surface discharge is unlikely to resurface in the vicinity of the discharge point prior to acclimation with ambient receiving water conditions.

1 INTRODUCTION

1.1 Background

RPS was commissioned by Advisian Pty Ltd (Advisian), on behalf of Woodside Energy Ltd (Woodside), to undertake a marine dispersion modelling study of proposed water discharges from the Scarborough Project's Floating Production Unit (FPU).

The Scarborough gas resource, located in Commonwealth waters approximately 375 km off the Burrup Peninsula, forms part of the Greater Scarborough gas fields, comprising the Scarborough, North Scarborough, Thebe and Jupiter gas fields.

As Operator of the Greater Scarborough gas fields, Woodside is proposing to develop the gas resource through new offshore facilities. These will be connected to the mainland through an approximately 430 km trunkline.

The Scarborough Project will involve the processing of hydrocarbons which will result in the production of produced water (PW).

The principal aim of the study was to quantify the likely extents of the near-field and far-field mixing zones based on the required dilution levels for the Total Petroleum Hydrocarbons (TPH) in the produced water (PW) discharge. This will indicate whether concentrations of this contaminant are still likely to be above stated threshold levels at the limits of the mixing zones (i.e. are not predicted to be diluted below the relevant threshold).

To accurately determine the dilution of the PW discharge 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 TPH in the PW stream from the FPU (location shown in Table 1.1), dispersion modelling was carried out for a flow rate of 95 m^3/d at three discharge depths: 0 m, 10 m and 30 m below the water surface.

The potential area that may be influenced by the PW discharge stream 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 PW discharge characteristics used as input to the modelling are specified in the Model Input Form for this study (Advisian, 2018).

Table 1.1 Location of the proposed FPU used as the release site for the PW dispersion modelling assessment.

Release Site	Latitude (°S)	Longitude (°E)	Water Depth (m)
FPU	19° 53' 54.715"	113° 14' 19.561"	930

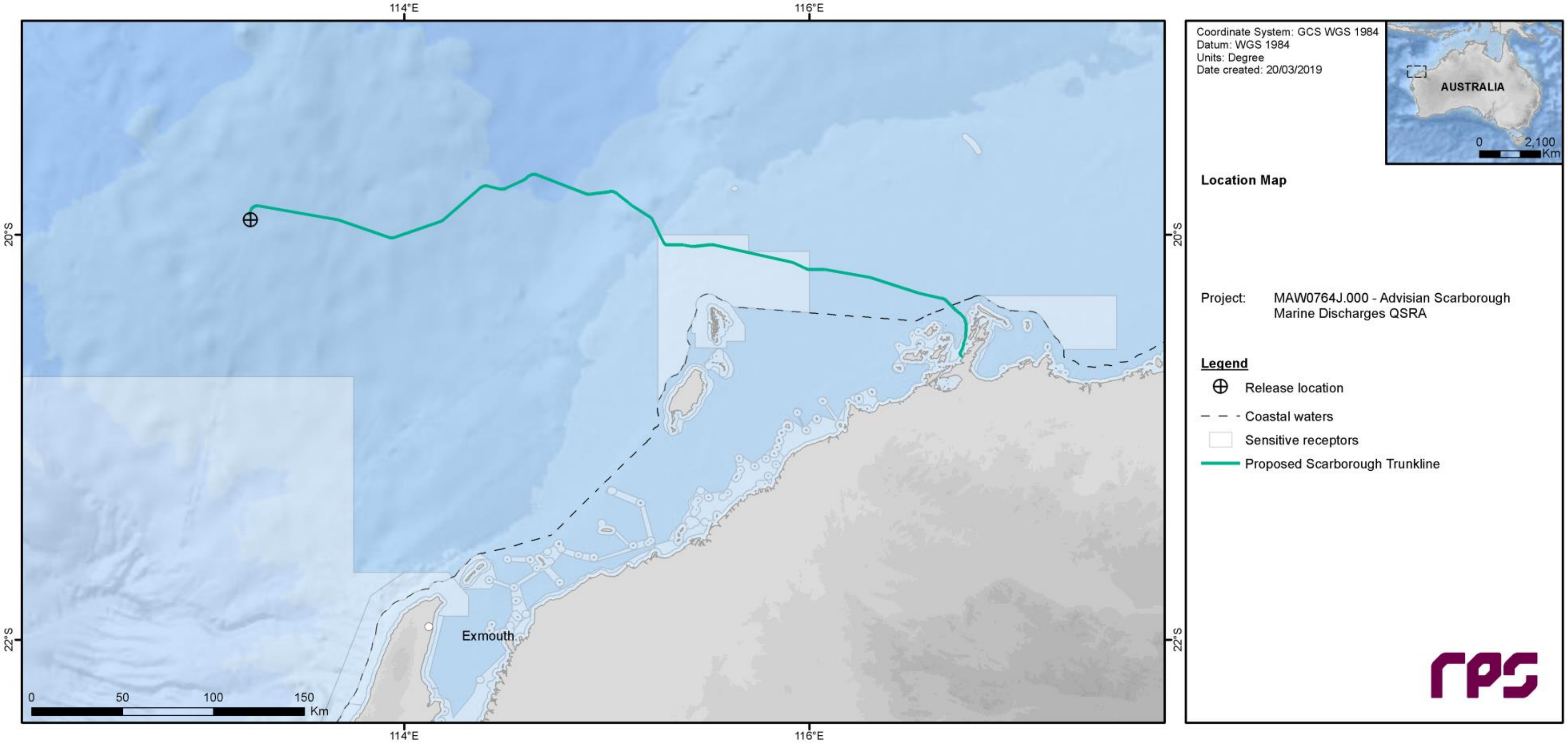

Figure 1.1 Location of the proposed Scarborough pipeline and FPU on the North West Shelf of Australia.

1.2 Modelling Scope

The physical mixing of the PW plume 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 the 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 FPU location 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 Scarborough Project 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 FPU location 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 contaminant 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 PW water discharges, in terms of the distribution of the maximum contaminant 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 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 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 FPU location.

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 shows a conceptual diagram of the dispersion and fates of a negatively buoyant discharge and the idealised representation of the discharge phases.

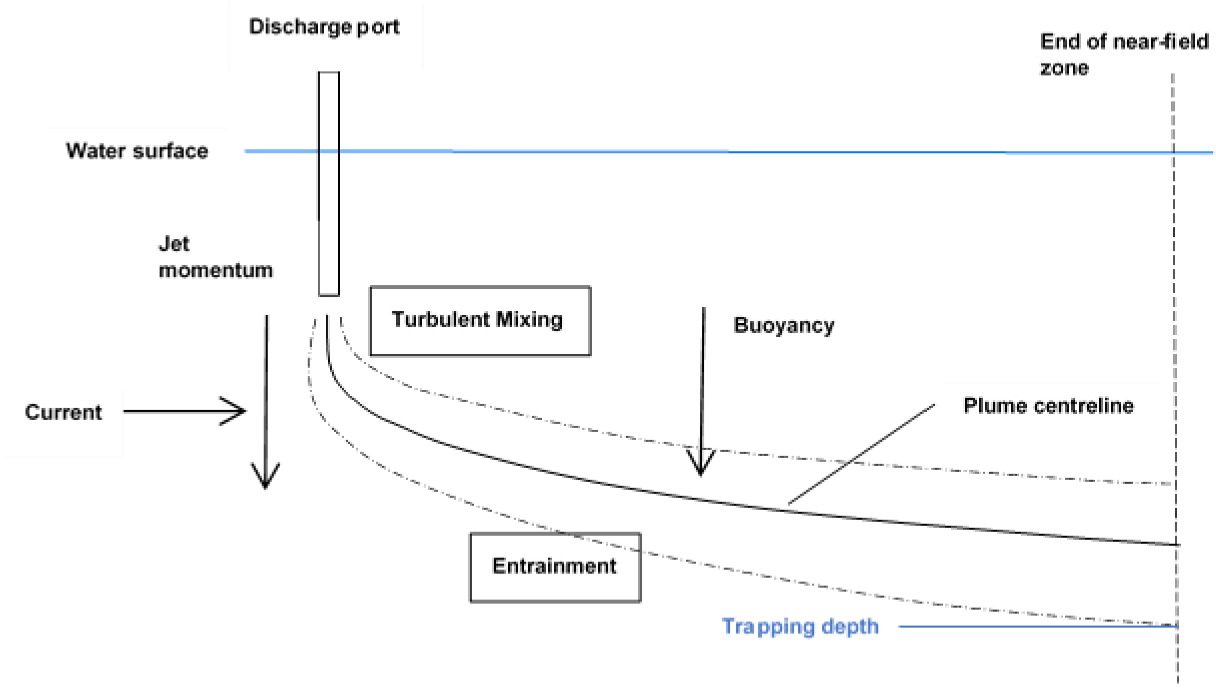

Figure 2.1 Conceptual diagram showing the general behaviour of negatively buoyant discharge.

2.1.3 Setup of Near-Field Model

2.1.3.1 Discharge Characteristics

The PW discharge characteristics for Cases P1 to P3 are summarised in Table 2.1. Cases P1, P2 and P3 were assumed to occur at depths of 0 m below mean sea level (BMSL), 10 m BMSL and 30 m BMSL, respectively. The flow was assumed to occur through a single outlet of 0.2 m diameter at a rate of 95 m^3/d and have a salinity and temperature of 40.5 parts per thousand (ppt) and 40 °C, respectively.

Concentrations of the constituent of interest (TPH) within the discharges are described in Table 2.2, along with the required dilution factor to reach the defined threshold concentration (Advisian, 2018).

Table 2.1 Summary of PW discharge characteristics.

Parameter	Case P1	Case P2	Case P3
Flow rate (m^3/d)	95		
Outlet pipe internal diameter (m) [in]	0.2 [7.9]		
Outlet pipe orientation	Vertical (downwards)		
Depth of pipe below sea surface (m)	0	10	30
Discharge salinity (ppt)	40.5		
Discharge temperature (°C)	40		

Table 2.2 Constituent of interest within the PW discharges and criteria for analysis of exposure.

Constituent	Source Concentration (mg/L)	Threshold Concentration (mg/L)	Required Dilution Factor
Total Petroleum Hydrocarbons (TPH)	29	0.07	414.3

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 PW plume. 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 2.3 shows the average seasonal water temperature and salinity levels at varying depths from 0 m to 50 m. This data can be considered representative of seasonal conditions at the FPU location.

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 (34.7-34.8 practical salinity unit, PSU), irrespective of season or depth.

Table 2.3 Average temperature and salinity levels adjacent to the proposed FPU location.

Season	Depth (m)	Temperature (°C)	Salinity (PSU)
Summer	0	27.8	34.7
	20	27.3	34.8
	50	26.2	34.8
Transitional	0	26.0	34.7
	20	25.7	34.7
	50	25.1	34.7
Winter	0	26.4	34.7
	20	26.3	34.7
	50	26.2	34.7
Annualised	0	26.6	34.7
	20	26.3	34.7
	50	25.8	34.7

2.1.3.2.2 Ambient Current

Ocean current data was sourced from a 10-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 FPU location.

Table 2.4 presents the steady-state, unidirectional current speeds at varying depths used as input to the near-field model as forcing for each discharge case:

- 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 2.4 Adopted ambient current conditions adjacent to the proposed FPU 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	0.041	0.158	0.326
	22.7	0.049	0.154	0.312
	56.7	0.044	0.138	0.267
Transitional	2.5	0.045	0.177	0.375
	22.7	0.045	0.173	0.369
	56.7	0.043	0.157	0.322
Winter	2.5	0.044	0.172	0.395
	22.7	0.043	0.166	0.375
	56.7	0.039	0.156	0.341
Annualised	2.5	0.043	0.170	0.374
	22.7	0.045	0.164	0.361
	56.7	0.042	0.151	0.320

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 pollutant concentrations in the receiving waters.

2.2.2 Description of Far-Field Model: MUDMAP

The mixing and dispersion of the 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).

2.2.3 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 (25) simulations of a given discharge scenario and season, 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.

2.2.4 Setup of Far-Field Model

2.2.4.1 Discharge Characteristics

The MUDMAP model simulated the discharge into a time-varying current field with the initial dilution set by the near-field results described in Section 2.1.

Two PW discharge scenarios were modelled as a continuous discharge using 25 simulations for each season. 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 PW discharge characteristics for the selected cases (P1 and P3) are summarised in Table 2.5. These cases were chosen to cover the full range of proposed discharge depths.

Table 2.5 Summary of far-field PW discharge modelling assumptions.

Parameter	Case P1	Case P3
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)	95	
Discharge depth (m)	0	30
Discharge salinity (ppt)	40.5	
Discharge temperature (°C)	40	
Number of simulations	75 (25 per season)	
Simulated discharge type	Continuous	
Simulated discharge period (days)	5	

2.2.4.2 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 0.15 m^2/s and 0.00005 m^2/s were used to control the spreading of the PW plume 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.

2.2.4.3 Grid Configuration

MUDMAP uses 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 5 m x 5 m to track the movement and fate of the discharge plume. The extent of the grid region measured approximately 5 km (longitude or x-axis) by 5 km (latitude or y-axis), which was subdivided horizontally into 1,000 x 1,000 cells. The vertical resolution was set to 1 m.

2.2.5 Regional Ocean Currents

2.2.5.1 Background

The area of interest for this study is typified by strong tidal flows over the shallower regions, particularly along the inshore region of the North West Shelf and among the island groups stretching from the Dampier Archipelago to the North West Cape. However, the 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 slicks over time scales exceeding a few hours.

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. Hence, the current-induced transport of pollutants 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 of pollutants. As measured current data is not available for simultaneous periods over a network of locations covering the wide area of this study, the analysis relied upon hindcasts of the circulation generated by numerical modelling. Estimates of the net currents were derived by combining predictions of the drift currents, available from mesoscale ocean models, with estimates of the tidal currents generated by an RPS model set up for the study area.

2.2.5.2 Mesoscale Circulation Model

Representation of the drift currents that affect the area were available from the output of the BRAN (Bluelink ReANalysis; 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 Commonwealth Scientific and Industrial Research Organisation (CSIRO). 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).

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, time series of current speed and direction were 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.

Figure 2.2 shows the seasonal distribution of current speeds and directions for the BRAN data point closest to the FPU location. Note that the convention for defining current direction is the direction towards which the current flows.

The data shows that current speeds and directions vary between seasons. In general, during transitional months (March and September to November) currents have the strongest average speed (0.22 m/s with a maximum of 0.56 m/s) and tend to flow south-east. During winter (April to August), current flow conditions are more variable, with lower average speed (0.21 m/s with a maximum of 0.53 m/s). During summer (December to February), the current flow occurs in a predominantly south/south-westerly direction with the lowest average speed (0.20 m/s with a maximum of 0.46 m/s).

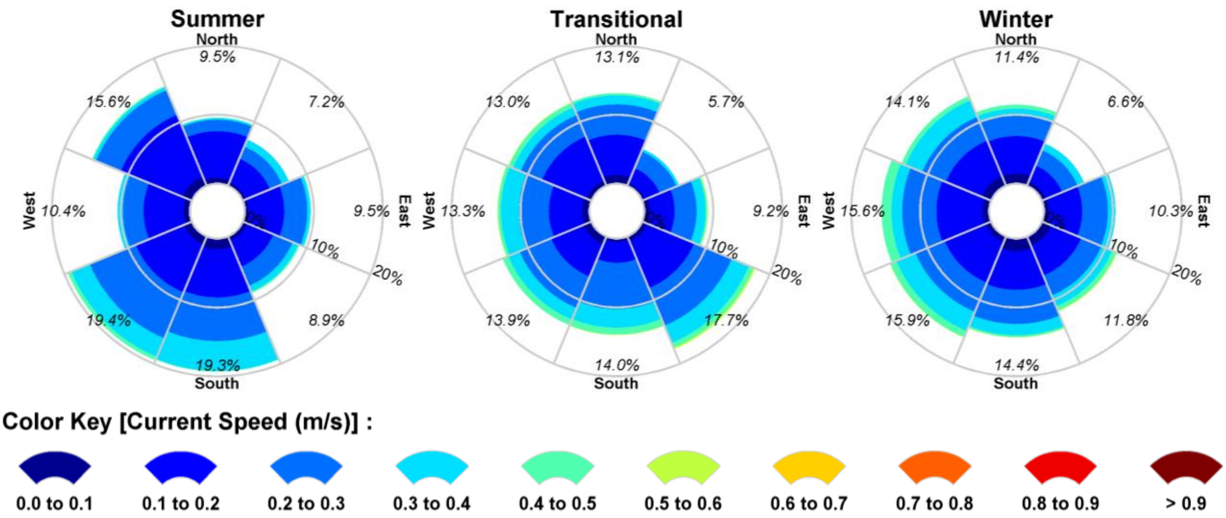

Figure 2.2 Seasonal current distribution (2006-2015, inclusive) derived from the BRAN database near to the proposed FPU location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

2.2.5.3 Tidal Circulation Model

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 25 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).

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 2.3).

Four layers of sub-gridding were 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. Approximately 98,600 cells were used to define the region.

Bathymetric data used to define the three-dimensional shape of the study domain was extracted from the CMAP electronic chart database and 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.

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.

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. Of more than 40 tidal stations within the HYDROMAP model domain, ten were used for comparison.

Water level time series for these locations are shown in Figure 2.4 for a one-month period (January 2005). 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 location. A scatter plot 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) is presented in Figure 2.5. 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 2.6 shows the seasonal distribution of current speeds and directions for the HYDROMAP data point closest to the FPU location. 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 northeast-southwest axis, with maximum speeds of around 0.09 m/s.

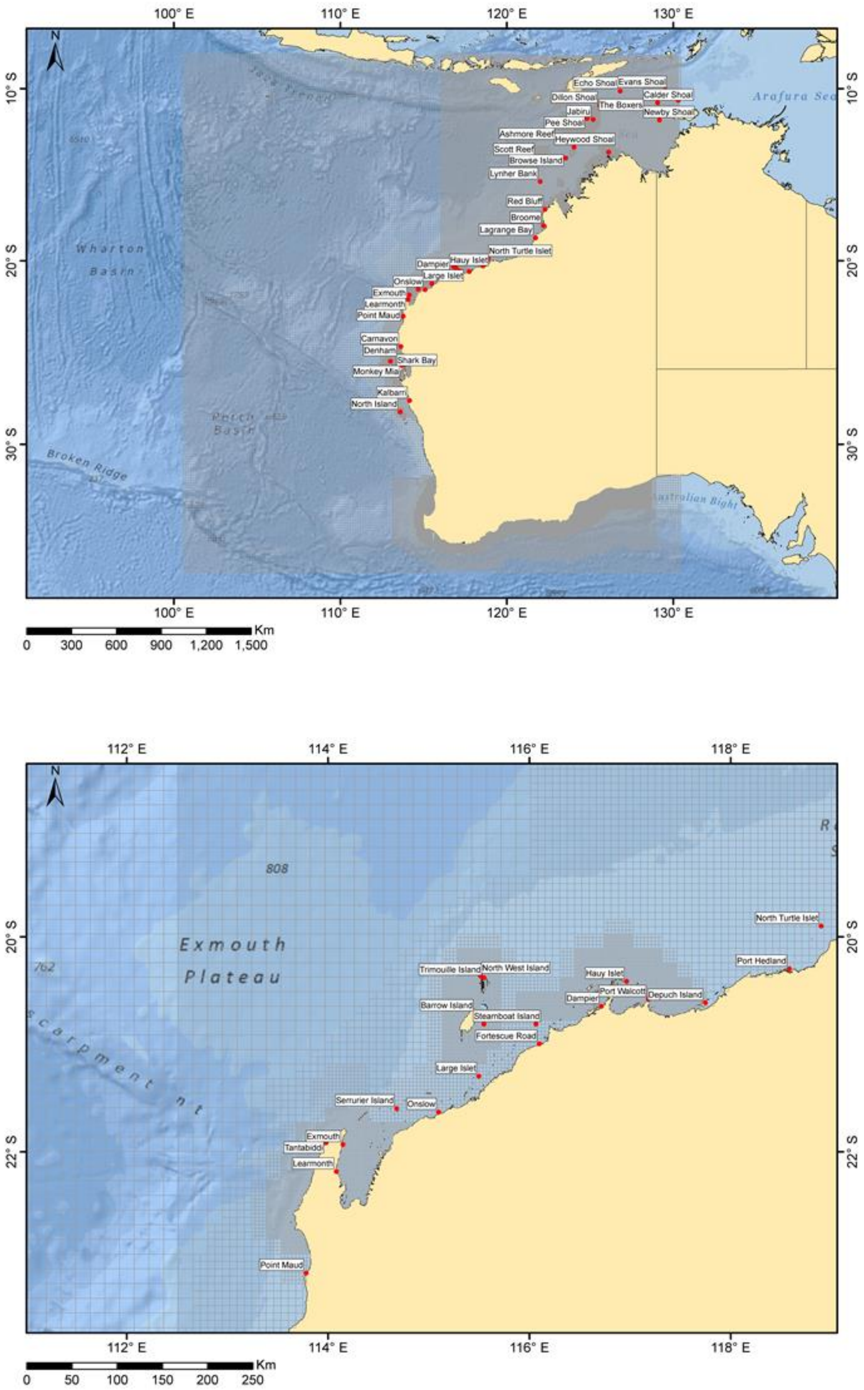

Figure 2.3 **Hydrodynamic model grid (grey wire mesh) used to generate the tidal currents, showing locations available for tidal comparisons (red labelled dots). The top panel shows the full domain in context with the continental land mass, while the bottom panel shows a zoomed subset near the discharge locations. Higher-resolution areas are indicated by the denser mesh zones.**

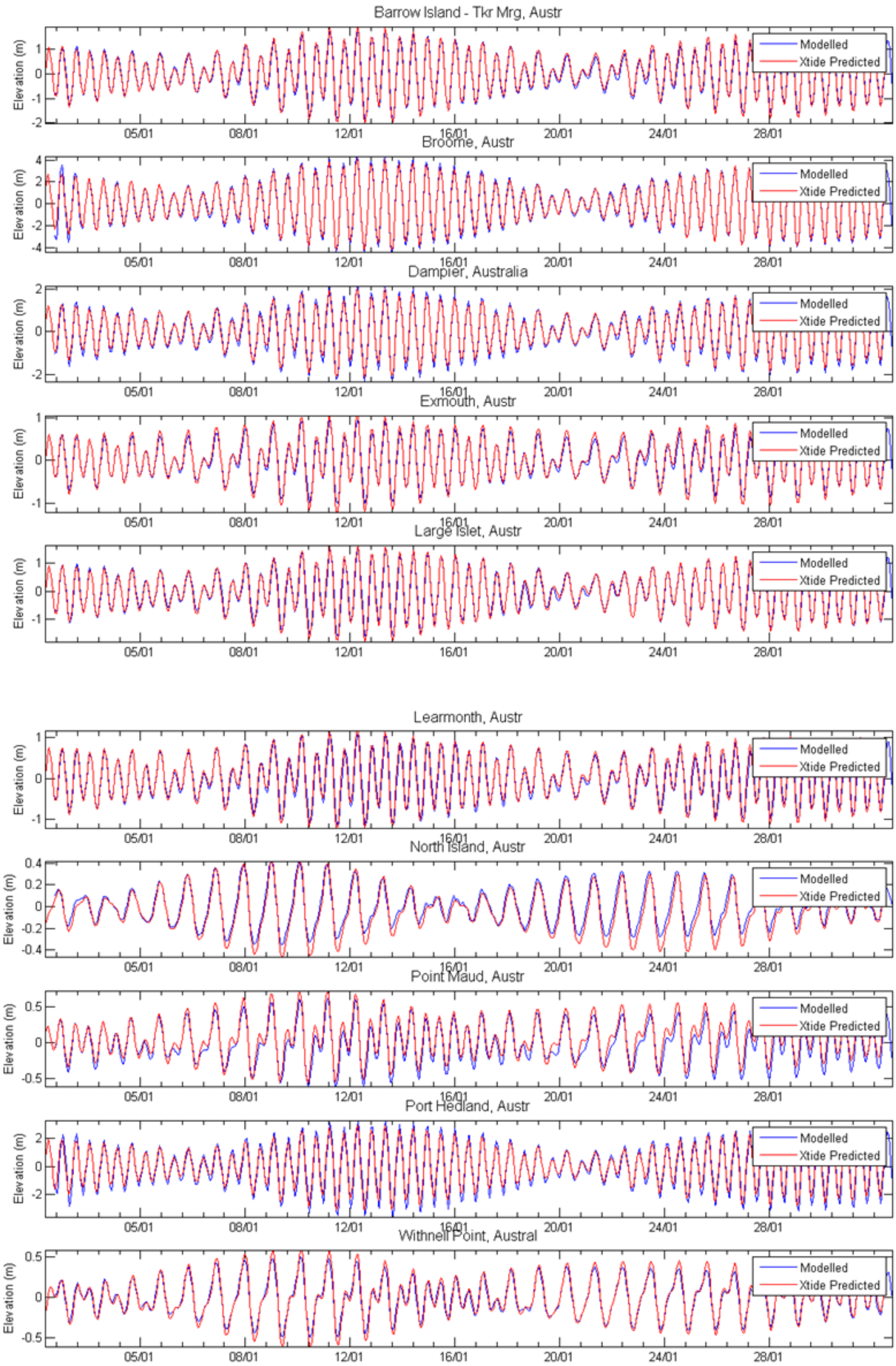

Figure 2.4 **Comparisons between the predicted (blue line) and observed (red line) surface elevation variations at ten locations in the tidal model domain for January 2005.**

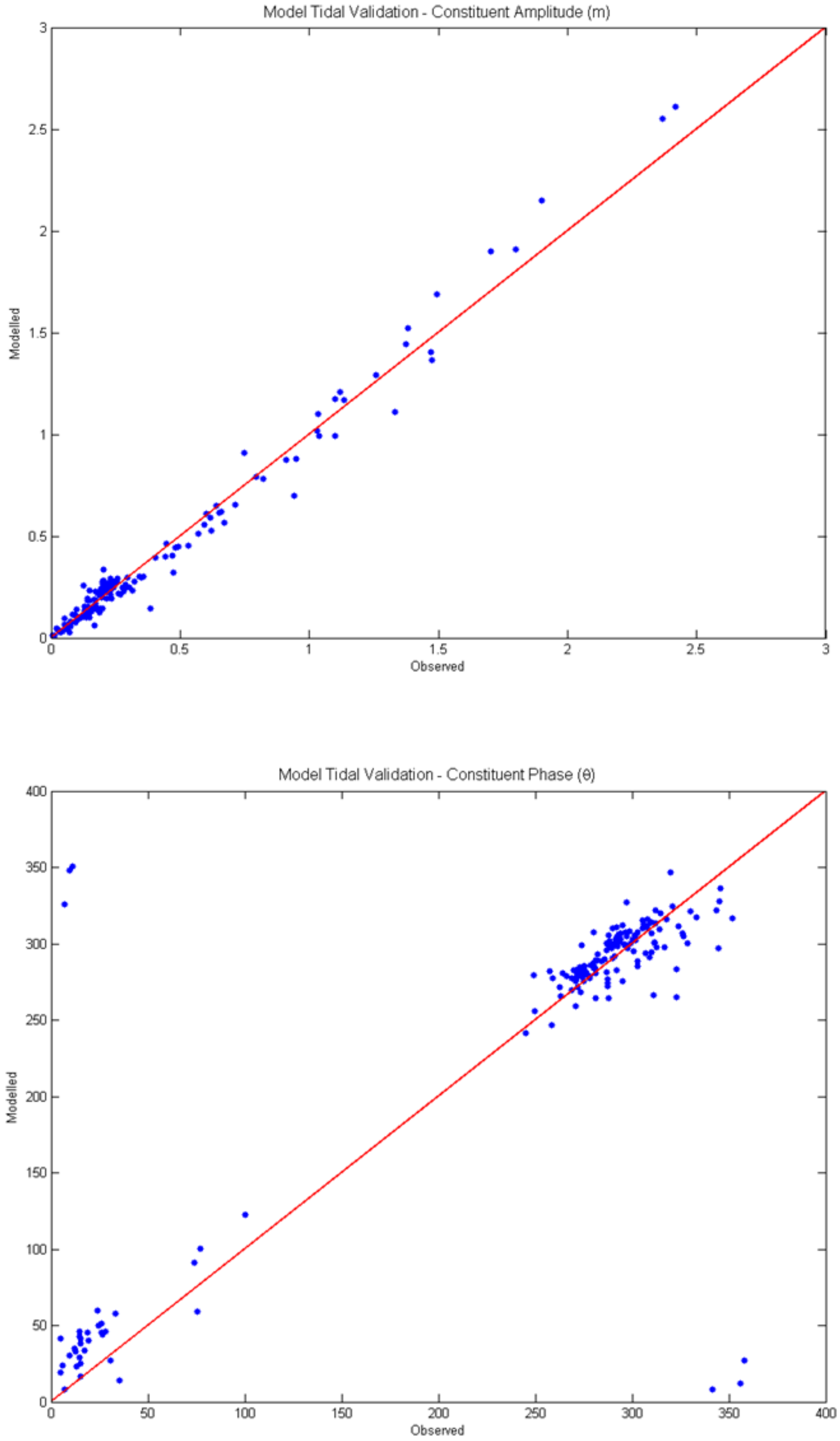

Figure 2.5 Comparisons between modelled and observed tidal constituent amplitudes (top) and phases (bottom) at all stations in the HYDROMAP model domain. The red line indicates a 1:1 correlation between the modelled and observed data.

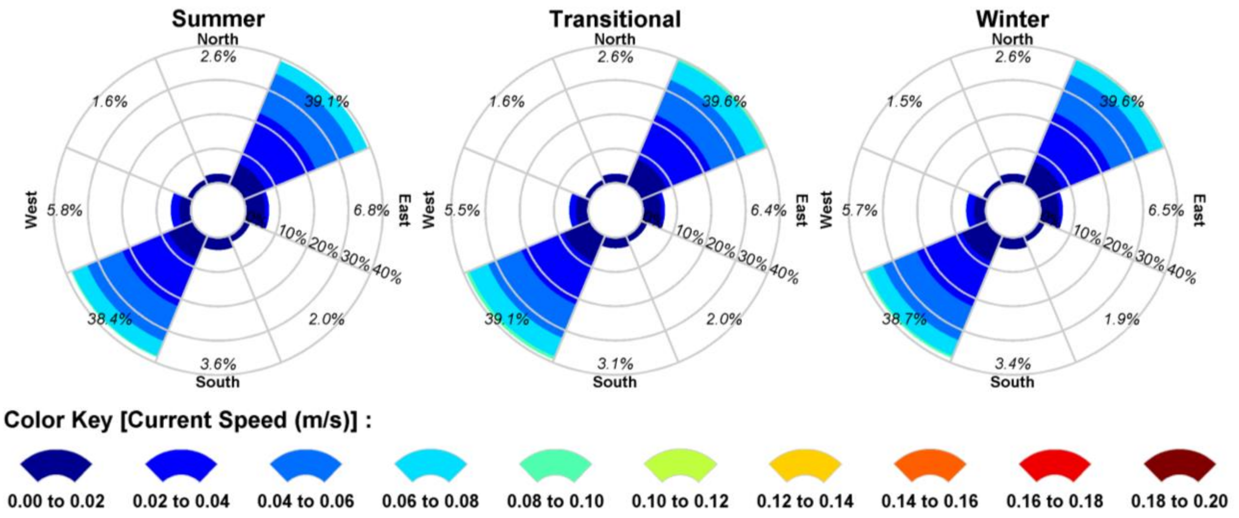

Figure 2.6 Seasonal current distribution (2006-2015, inclusive) derived from the HYDROMAP database near to the proposed FPU location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

3 MODELLING RESULTS

3.1 Near-Field Modelling

3.1.1 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 TPH at the end of the near-field mixing zone, the concentration threshold, and the amount of dilution for each season and for the annual period. Any dilution rates indicated in red show that suitable dilution is not achieved during the near-field stage for at least one current-speed case.

Figure 3.1 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 depths (0 m, 10 m and 30 m), seasonal conditions (summer, transitional, winter and annual) and current speeds (weak, medium and strong). The figures show the predicted horizontal distances travelled by the plume before the trapping depth is reached (i.e. before the plume becomes neutrally buoyant).

In each figure, the plots have been arranged to demonstrate the variation in predicted outcomes for the same discharge at different depths under identical current conditions.

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 0 m, 10 m and 30 m below the water surface (Cases P1, P2 and P3, respectively). The surface discharges are shown to increase the extent of the turbulent mixing zone. Following this initial mixing, the near neutrally-buoyant plumes are predicted to travel laterally in the water column. For Case P1, the plume is predicted to plunge between 0.1 m and 4.4 m below the sea surface depending on season. For Cases P2 and P3, the plumes are predicted to remain at approximately the discharge depth: 9-11 m below the surface for Case P2 and 29-31 m below the surface for Case P3, depending on season. Increased ambient current strengths are shown to increase the horizontal distance travelled by the plume from the discharge point.

Table 3.1, Table 3.6 and Table 3.11 show the predicted plume characteristics for the varying discharge depths, seasonal conditions and current speeds. High annualised currents push the plume to maximum horizontal distances of 866 m and 123 m for the Case P1 and Case P3 discharges, respectively.

The diameter of the plume at the end of the near-field zone ranged from 0.4 m to 3.7 m for Case P1, 0.5 m to 1.8 m for Case P2 and 0.6 m to 1.7 m for Case P3. Increases in current speed serve to restrict the diameter of the plume.

For most combinations of season and discharge depth, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to plunge further and reach the trapping depth closer to the discharge point, which slows the rate of dilution (Table 3.1, Table 3.6 and Table 3.11). The average dilution levels of the plume upon reaching the trapping depth under medium and strong currents are predicted to be 1:1,519 and 1:3,616 for Case P1, 1:88 and 1:140 for Case P2, and 1:43 and 1:181 for Case P3, respectively. Additionally, the minimum dilution levels of the plume (i.e. dilution of the plume centreline) upon encountering the trapping depth under medium and strong currents are predicted to be 1:390 and 1:929 for Case P1, 1:22 and 1:36 for Case P2, and 1:11 and 1:46 for Case P3. Note that these predictions 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.

The results for the Case P1 (Section 3.1.2; Table 3.2 to Table 3.5), Case P2 (Section 3.1.2.2; Table 3.7 to Table 3.10) and Case P3 (Section 3.1.2.3; Table 3.12 to Table 3.15) discharges indicate that the TPH constituent of the PW discharge is not expected to reach the required levels of dilution in the near field mixing zone.

3.1.2 Results – Tables

3.1.2.1 Discharge Case P1: Flow Rate of 95 m^3/day at 0 m Depth (Surface)

Table 3.1 Predicted plume characteristics at the end of the near-field mixing zone for the 0 m depth (surface) 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	
Summer	Weak (0.04)	3.5 [2.7]	27.83	0.03	91	351	16.8
	Medium (0.16)	3.4 [2.6]	27.81	0.01	339	1,321	124.1
	Strong (0.33)	3.5 [2.6]	27.80	0.00	725	2,821	376.9
Transitional	Weak (0.05)	0.3 [0.2]	32.84	6.84	1	2	0.9
	Medium (0.18)	0.4 [0.2]	26.91	0.91	4	15	4.2
	Strong (0.38)	0.3 [0.2]	26.47	0.47	7	30	7.9
Winter	Weak (0.04)	0.4 [0.2]	31.03	4.63	1	3	0.4
	Medium (0.17)	3.6 [2.6]	26.41	0.01	412	1,601	325.7
	Strong (0.40)	0.4 [0.2]	26.74	0.34	10	40	11.8
Annual	Weak (0.04)	0.4 [0.2]	29.83	3.23	1	4	0.8
	Medium (0.17)	3.5 [2.6]	26.61	0.01	390	1,519	255.0
	Strong (0.37)	3.7 [2.6]	26.60	0.00	929	3,613	866.3

Table 3.2 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the summer season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 351, 1,321 and 2,821, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		351x Dilution	1,321x Dilution	2,821x Dilution		
TPH	29	$8.3*10^{-2}$	$2.2*10^{-2}$	$1.0*10^{-2}$	0.07	414.3

Table 3.3 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the transitional season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 2, 15 and 30, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		2x Dilution	15x Dilution	30x Dilution		
TPH	29	14.5	1.9	$9.7*10^{-1}$	0.07	414.3

Table 3.4 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the winter season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 3, 1,601 and 40, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		3x Dilution	1,601x Dilution	40x Dilution		
TPH	29	9.7	$1.8*10^{-2}$	$7.2*10^{-1}$	0.07	414.3

Table 3.5 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the annual period. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 4, 1,519 and 3,613, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		4x Dilution	1,519x Dilution	3,613x Dilution		
TPH	29	7.3	$1.9*10^{-2}$	$8.0*10^{-3}$	0.07	414.3

3.1.2.2 Discharge Case P2: Flow Rate of 95 m³/day at 10 m Depth

Table 3.6 Predicted plume characteristics at the end of the near-field mixing zone for the 10 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	
Summer	Weak (0.04)	1.8 [11.3]	27.73	0.14	25	99	7.5
	Medium (0.16)	1.2 [10.8]	27.69	0.09	42	163	28.4
	Strong (0.33)	1.0 [10.5]	27.67	0.06	56	220	58.1
Transitional	Weak (0.05)	1.0 [9.5]	26.28	0.43	8	32	4.2
	Medium (0.18)	0.7 [9.9]	26.07	0.23	16	61	27.2
	Strong (0.38)	0.7 [10.0]	25.93	0.10	36	141	83.2
Winter	Weak (0.04)	0.7 [9.8]	27.36	0.12	3	12	1.8
	Medium (0.17)	0.8 [10.3]	26.41	0.18	19	76	41.3
	Strong (0.40)	0.7 [10.2]	26.34	0.11	32	127	67.1
Annual	Weak (0.04)	0.5 [10.0]	28.17	1.74	2	8	1.3
	Medium (0.17)	0.9 [10.4]	26.58	0.16	22	88	35.5
	Strong (0.37)	0.7 [10.2]	26.52	0.09	36	140	67.3

Table 3.7 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the summer season. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 99, 163 and 220, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		99x Dilution	163x Dilution	220x Dilution		
TPH	29	$2.9*10^{-1}$	$1.8*10^{-1}$	$1.3*10^{-1}$	0.07	414.3

Table 3.8 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the transitional season. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 32, 61 and 141, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		32x Dilution	61x Dilution	141x Dilution		
TPH	29	$9.1*10^{-1}$	$4.8*10^{-1}$	$2.1*10^{-1}$	0.07	414.3

Table 3.9 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the winter season. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 12, 76 and 127, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		12x Dilution	76x Dilution	127x Dilution		
TPH	29	2.4	$3.8*10^{-1}$	$2.3*10^{-1}$	0.07	414.3

Table 3.10 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the annual period. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 8, 88 and 140, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		8x Dilution	88x Dilution	140x Dilution		
TPH	29	3.6	$3.3*10^{-1}$	$2.1*10^{-1}$	0.07	414.3

3.1.2.3 Discharge Case P3: Flow Rate of 95 m^3/day at 30 m Depth

Table 3.11 Predicted plume characteristics at the end of the near-field mixing zone for the 30 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	
Summer	Weak (0.04)	1.7 [31.1]	27.29	0.17	20	79	7.9
	Medium (0.16)	1.1 [30.7]	27.23	0.10	34	134	28.9
	Strong (0.33)	0.9 [30.5]	27.21	0.08	48	186	58.5
Transitional	Weak (0.05)	1.4 [29.2]	25.66	0.25	14	57	6.01
	Medium (0.18)	0.9 [29.7]	25.55	0.15	25	99	30.3
	Strong (0.38)	0.8 [29.9]	25.49	0.09	41	160	75.2
Winter	Weak (0.04)	1.1 [29.5]	26.21	0.41	8	34	4.2
	Medium (0.17)	0.7 [29.9]	26.01	0.22	16	62	25.5
	Strong (0.40)	0.7 [30.0]	25.88	0.10	38	147	86.3
Annual	Weak (0.04)	0.9 [29.6]	26.61	0.62	6	23	2.9
	Medium (0.17)	0.6 [30.0]	26.31	0.33	11	43	19.8
	Strong (0.37)	0.8 [30.0]	26.05	0.07	46	181	122.7

Table 3.12 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the summer season. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 79, 134 and 186, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		79x Dilution	134x Dilution	186x Dilution		
TPH	29	$3.7*10^{-1}$	$2.2*10^{-1}$	$1.6*10^{-1}$	0.07	414.3

Table 3.13 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the transitional season. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 57, 99 and 160, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		57x Dilution	99x Dilution	160x Dilution		
TPH	29	$5.1*10^{-1}$	$2.9*10^{-1}$	$1.8*10^{-1}$	0.07	414.3

Table 3.14 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the winter season. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 34, 62 and 147, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		34x Dilution	62x Dilution	147x Dilution		
TPH	29	$8.5*10^{-1}$	$4.7*10^{-1}$	$2.0*10^{-1}$	0.07	414.3

Table 3.15 Concentration of TPH at the end of the near-field stage, and the required concentration threshold and number of dilutions for the annual period. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 23, 43 and 181, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (mg/L)	End of Near-Field Concentration (mg/L)			Threshold Concentration (mg/L)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		23x Dilution	43x Dilution	181x Dilution		
TPH	29	1.3	$6.7*10^{-1}$	$1.6*10^{-1}$	0.07	414.3

3.1.3 Results – Figures

3.1.3.1 Flow Rate of 95 m^3/day at Varying Depths

3.1.3.1.1 Annualised

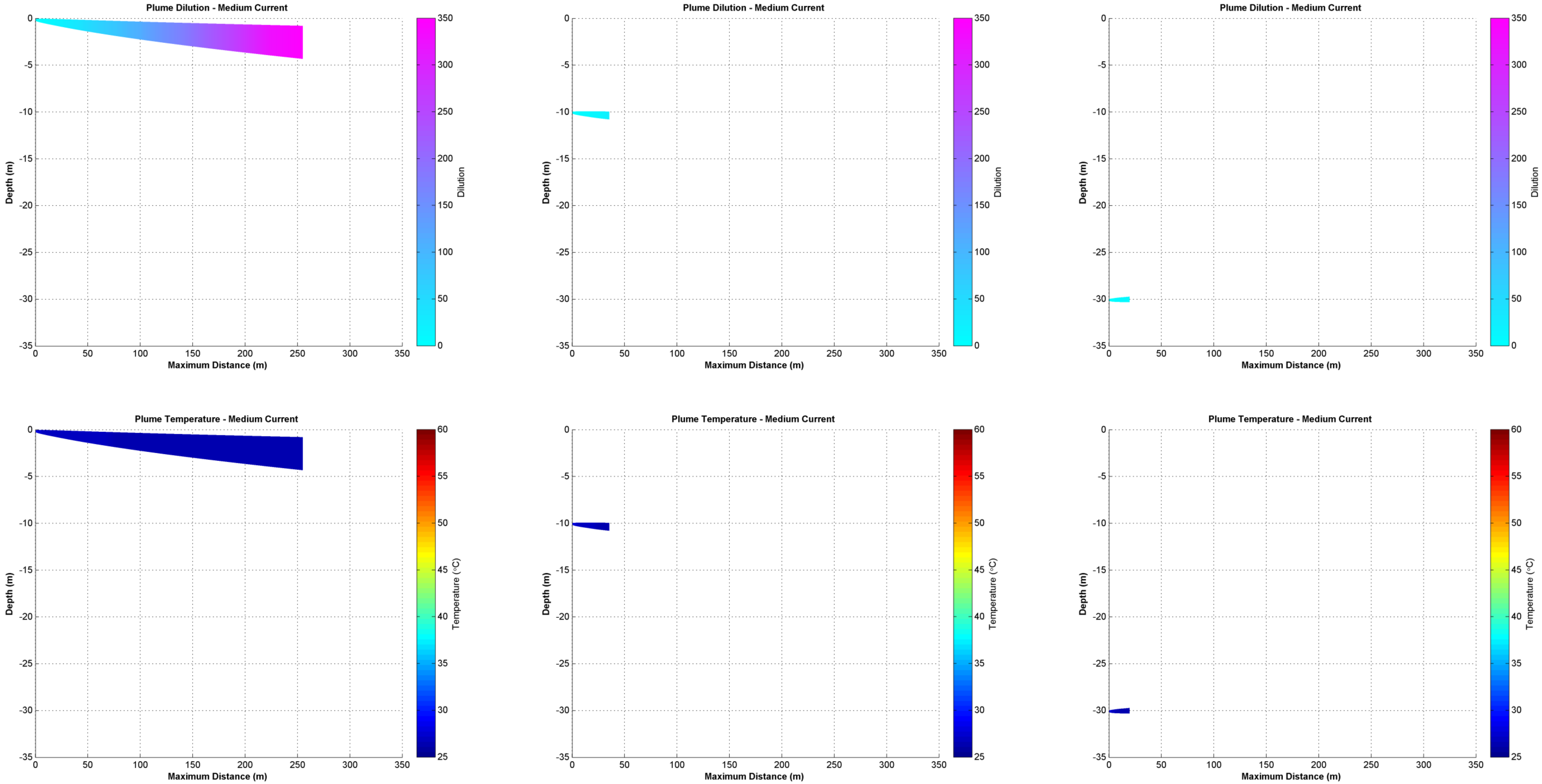

Figure 3.1 Near-field average dilution and temperature results for constant medium annualised currents with a discharge flow rate of 95 m^3/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).

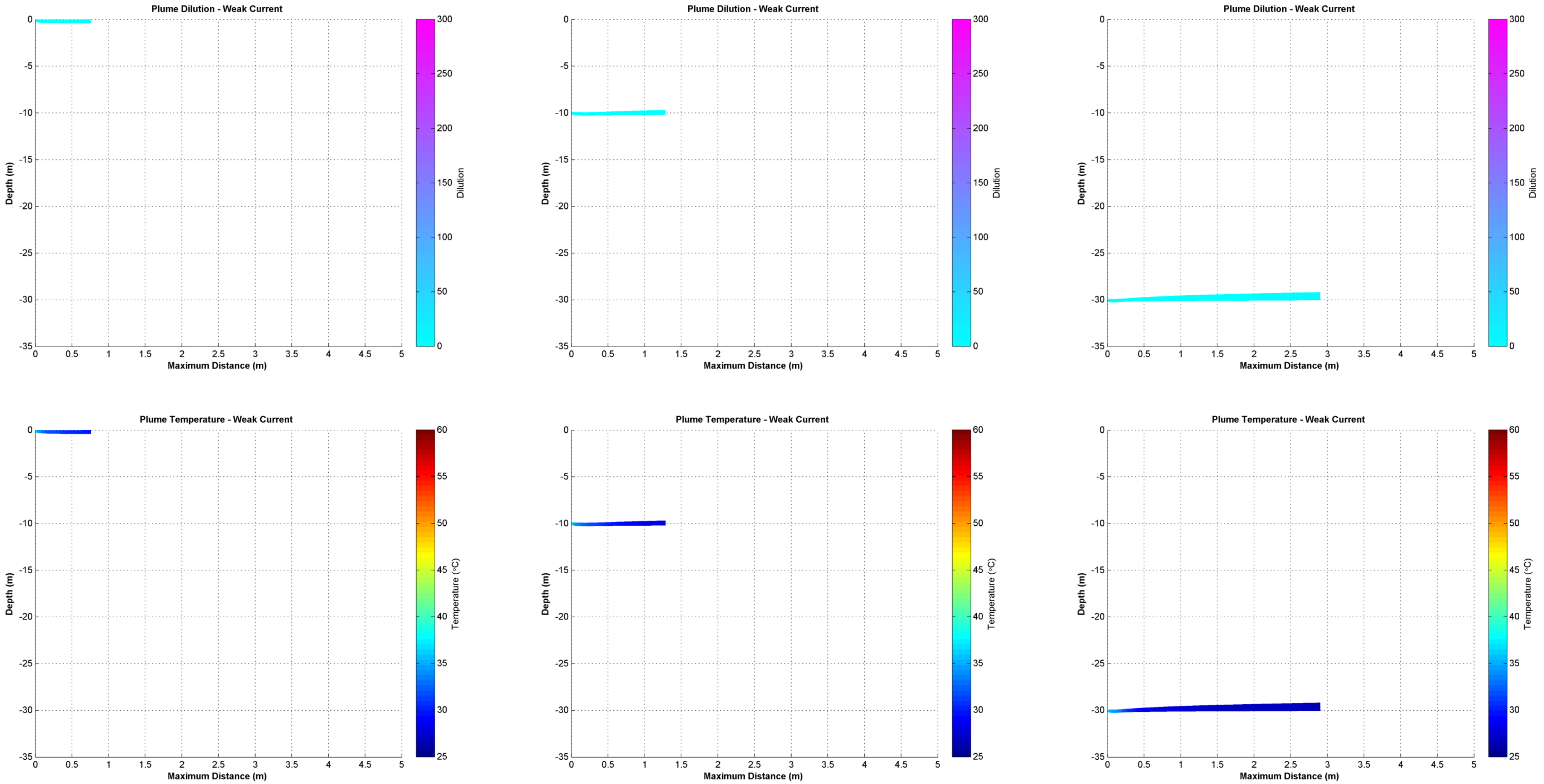

Figure 3.2 **Near-field average dilution and temperature results for constant weak annualised currents with a discharge flow rate of 95 m^3/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).**

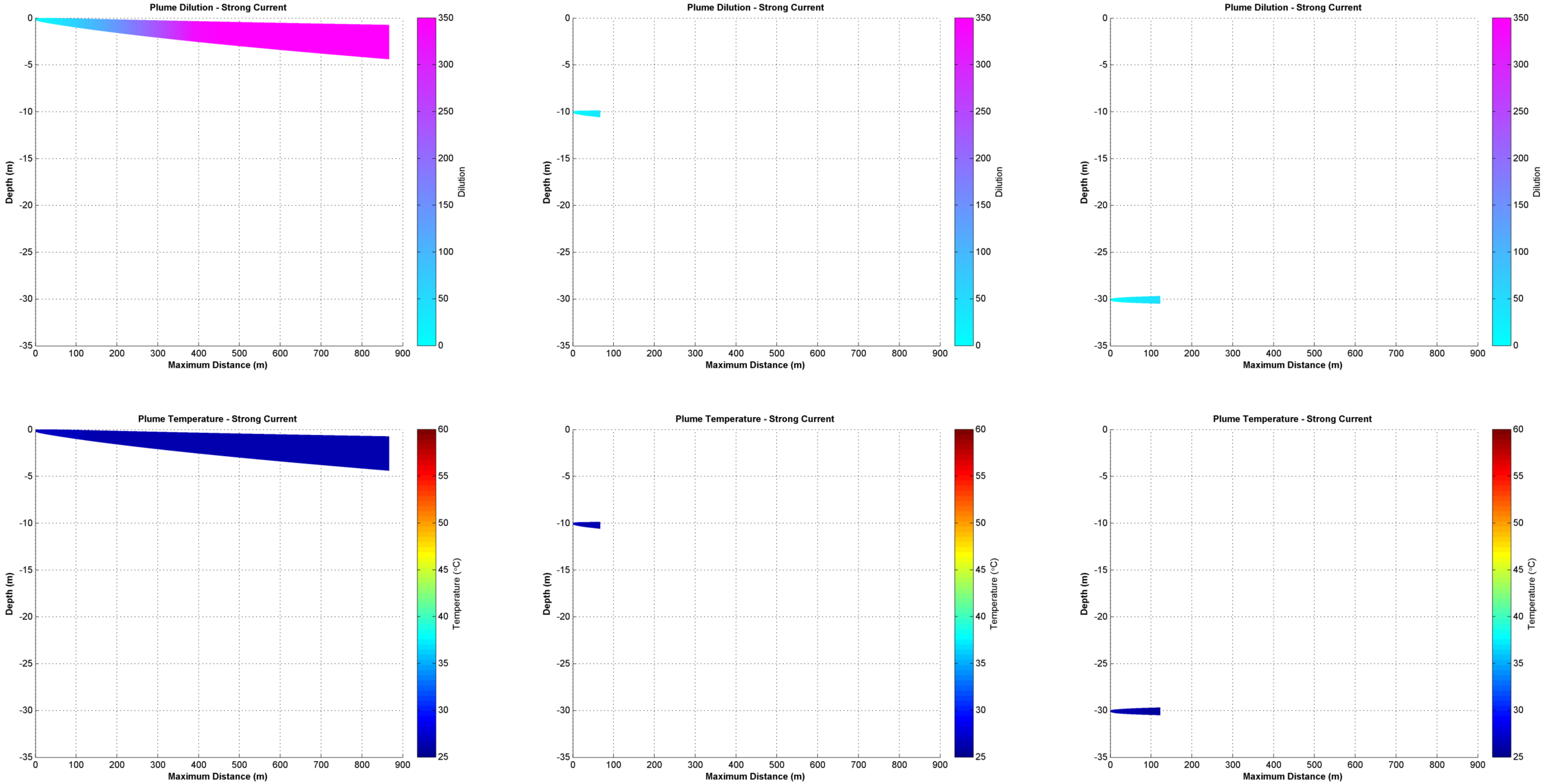

Figure 3.3 Near-field average dilution and temperature results for constant strong annualised currents with a discharge flow rate of 95 m^3/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).

3.1.3.1.2 Summer

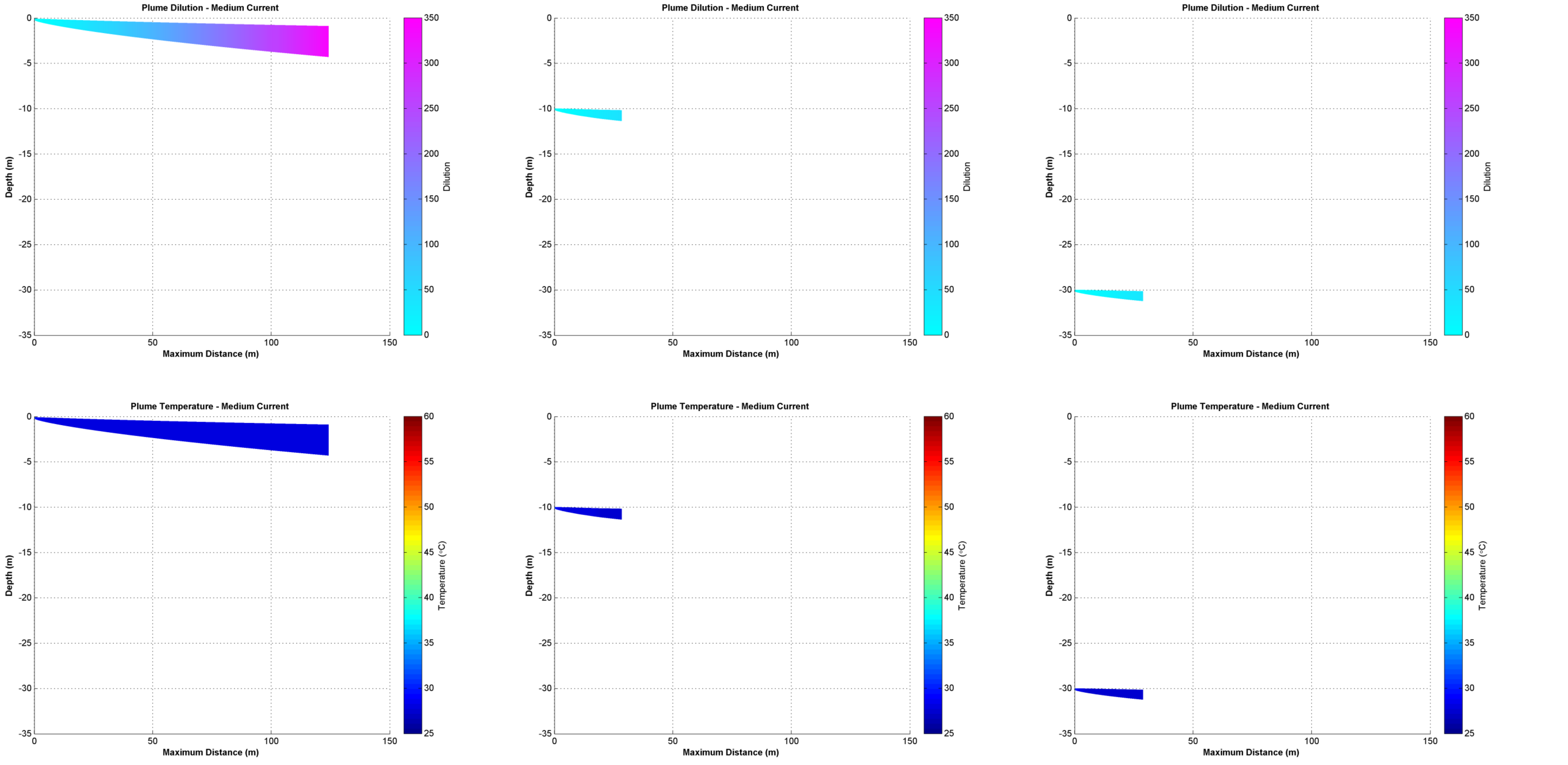

Figure 3.4 Near-field average dilution and temperature results for constant medium summer currents with a discharge flow rate of 95 m^3/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).

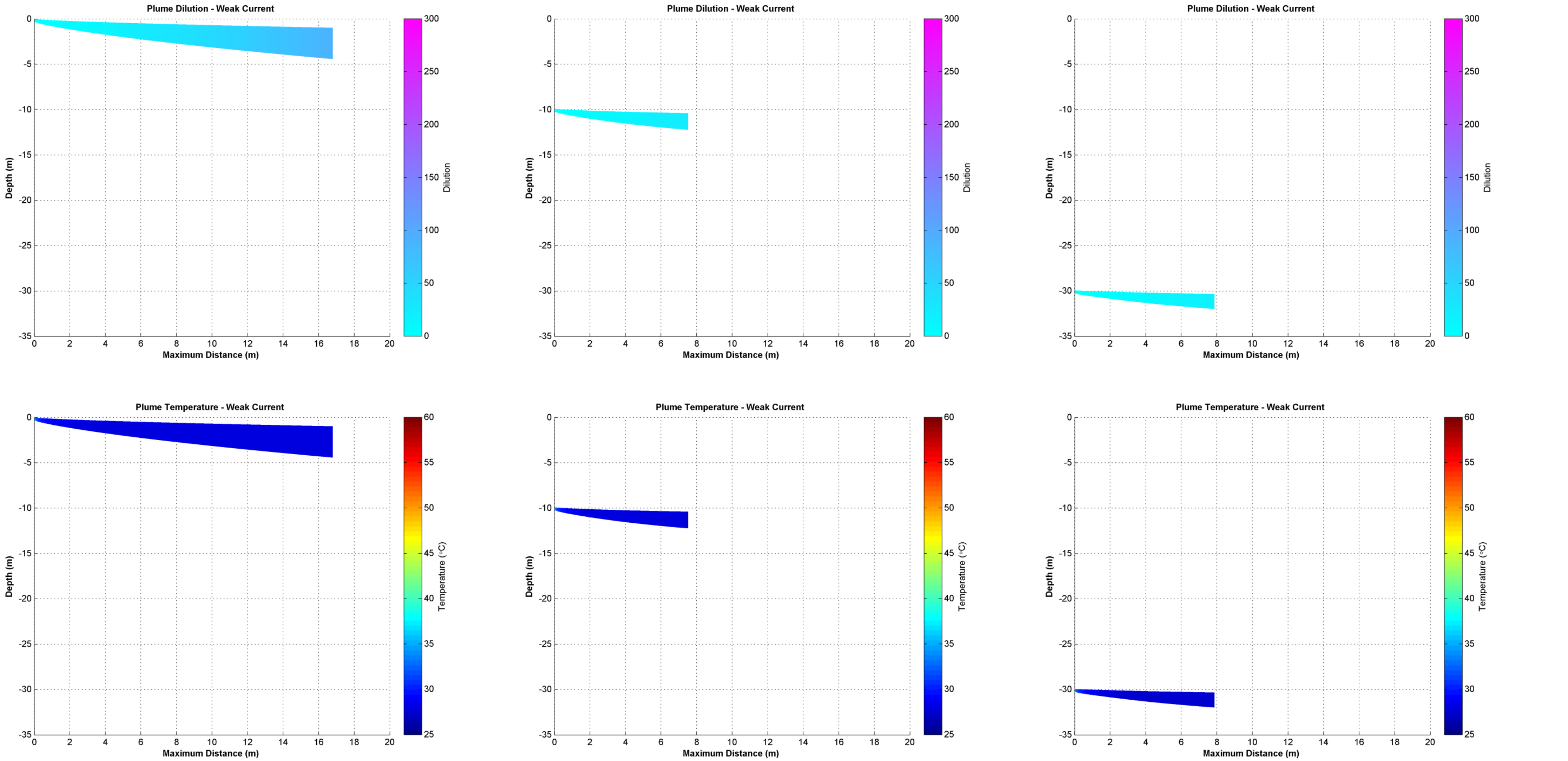

Figure 3.5 **Near-field average dilution and temperature results for constant weak summer currents with a discharge flow rate of 95 m^3/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).**

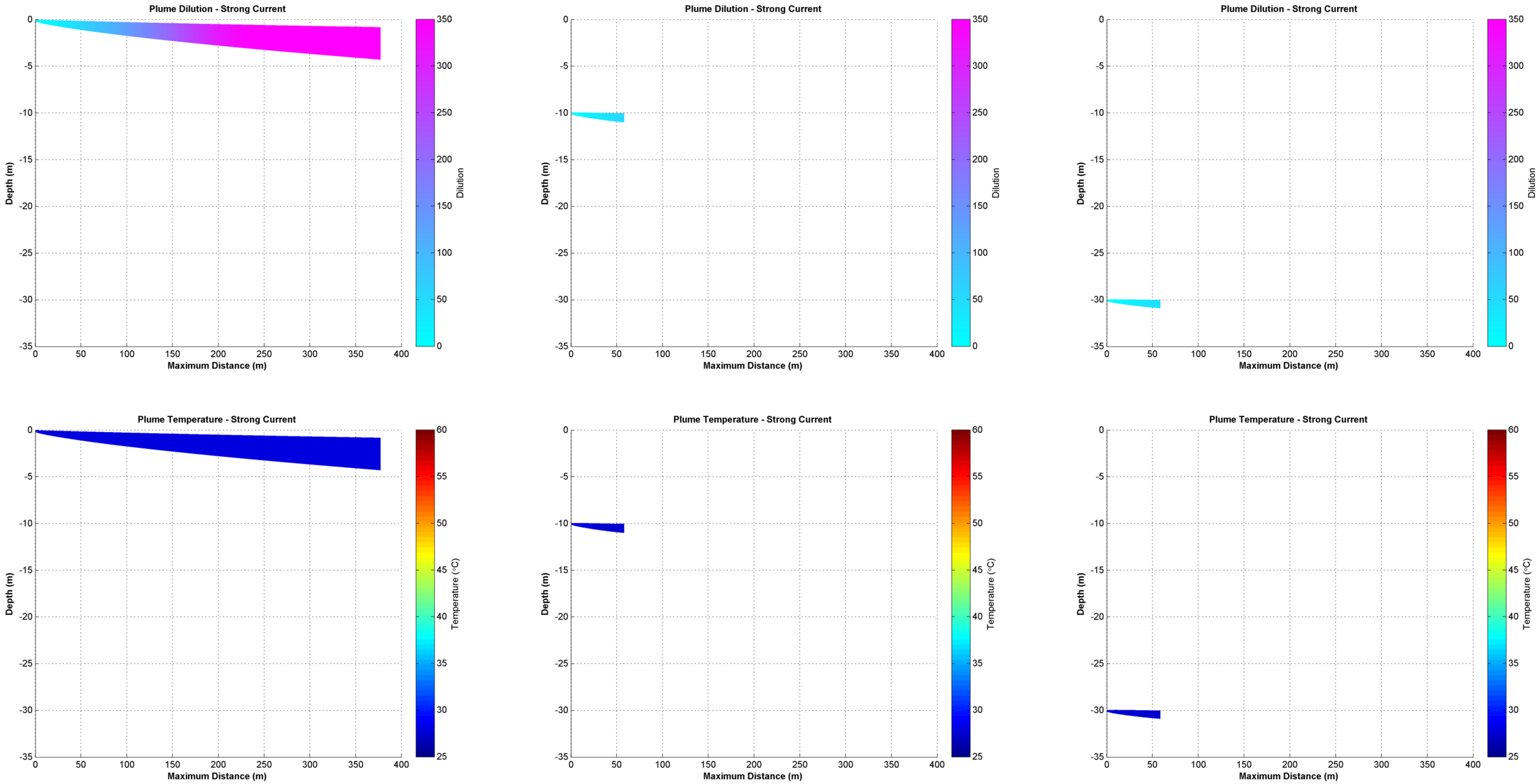

Figure 3.6 **Near-field average dilution and temperature results for constant strong summer currents with a discharge flow rate of 95 m^3/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).**

3.1.3.1.3 Transitional

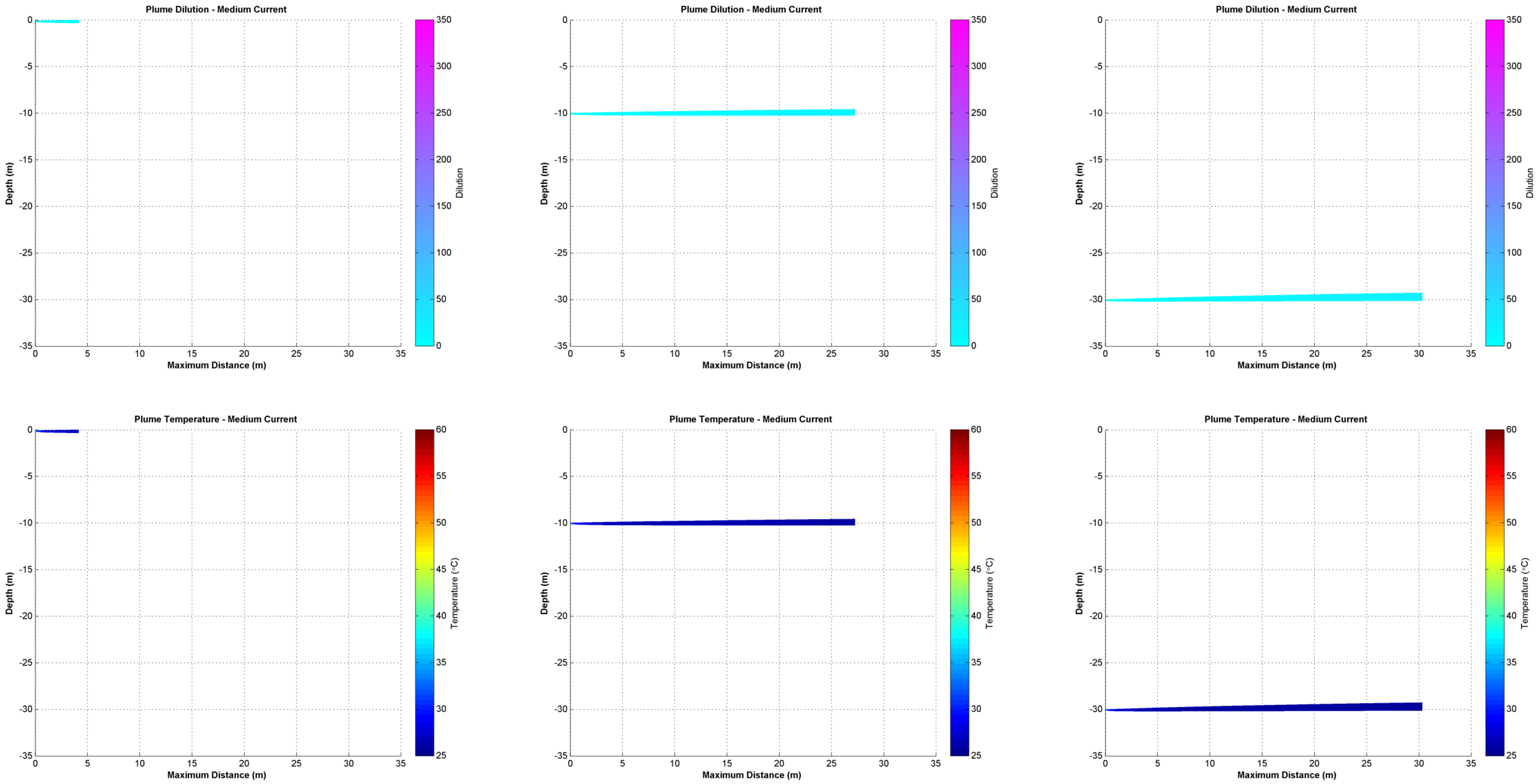

Figure 3.7 **Near-field average dilution and temperature results for constant medium transitional currents with a discharge flow rate of 95 m³/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).**

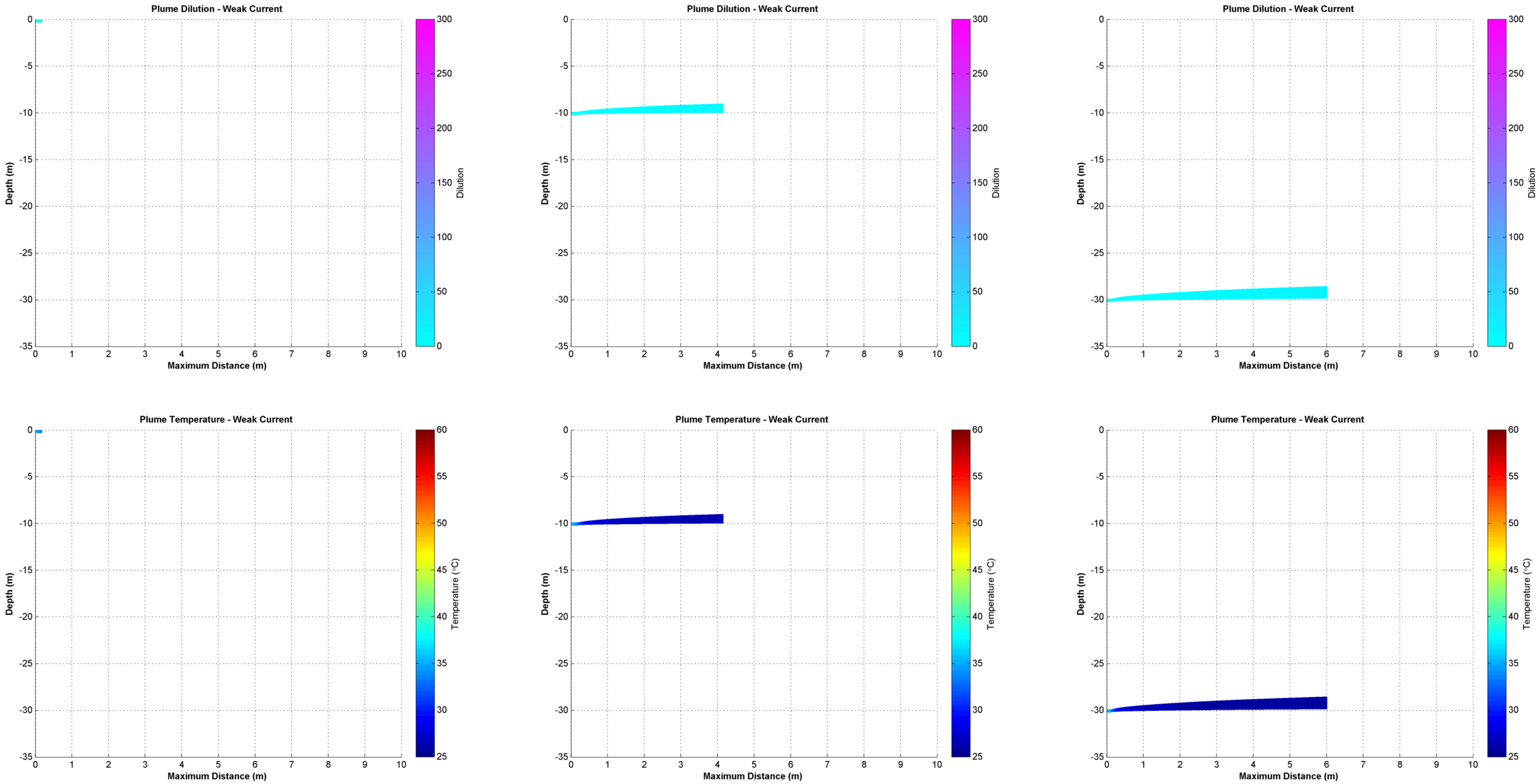

Figure 3.8 **Near-field average dilution and temperature results for constant weak transitional currents with a discharge flow rate of 95 m^3/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).**

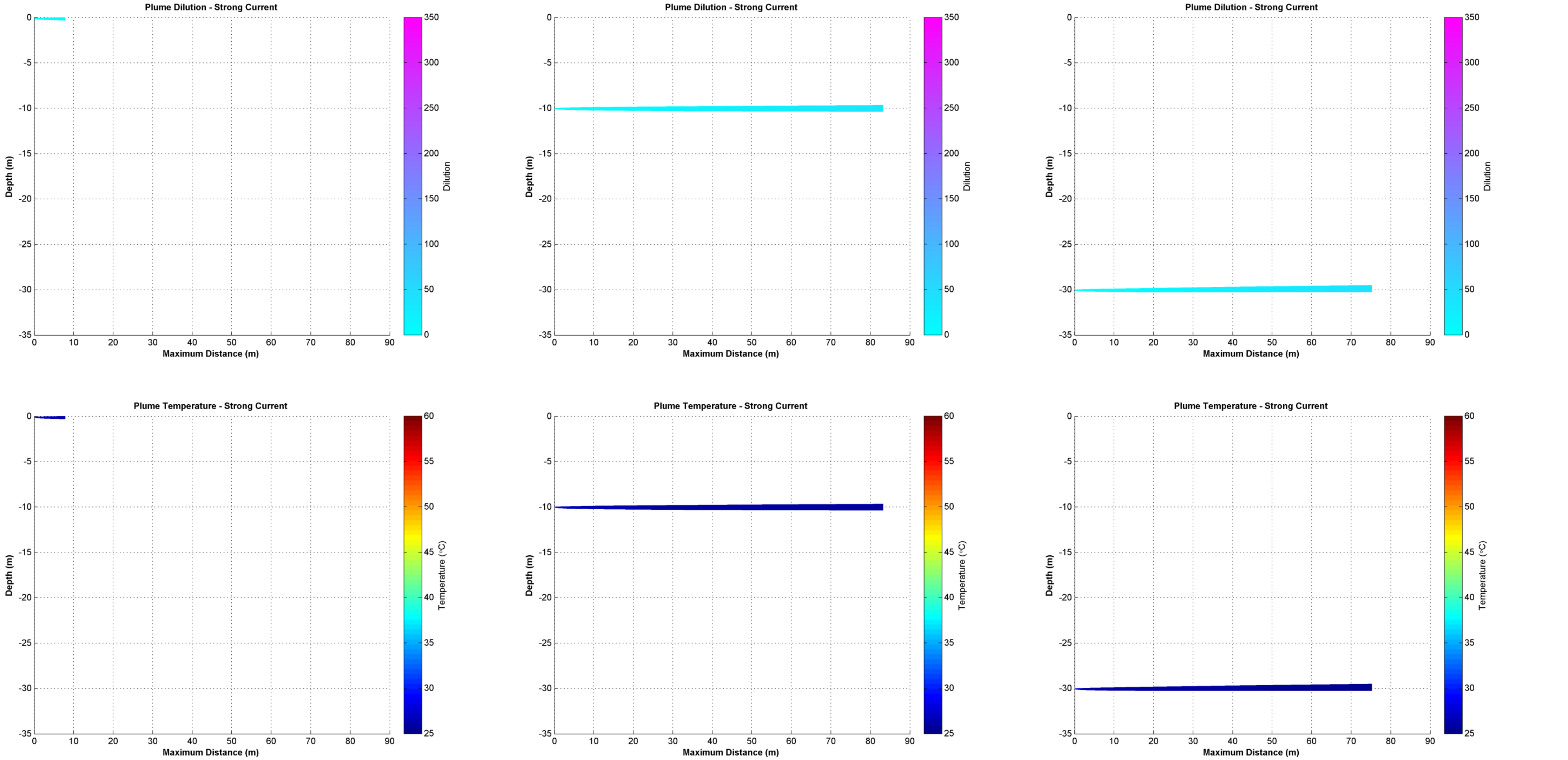

Figure 3.9 **Near-field average dilution and temperature results for constant strong transitional currents with a discharge flow rate of 95 m^3/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).**

3.1.3.1.4 Winter

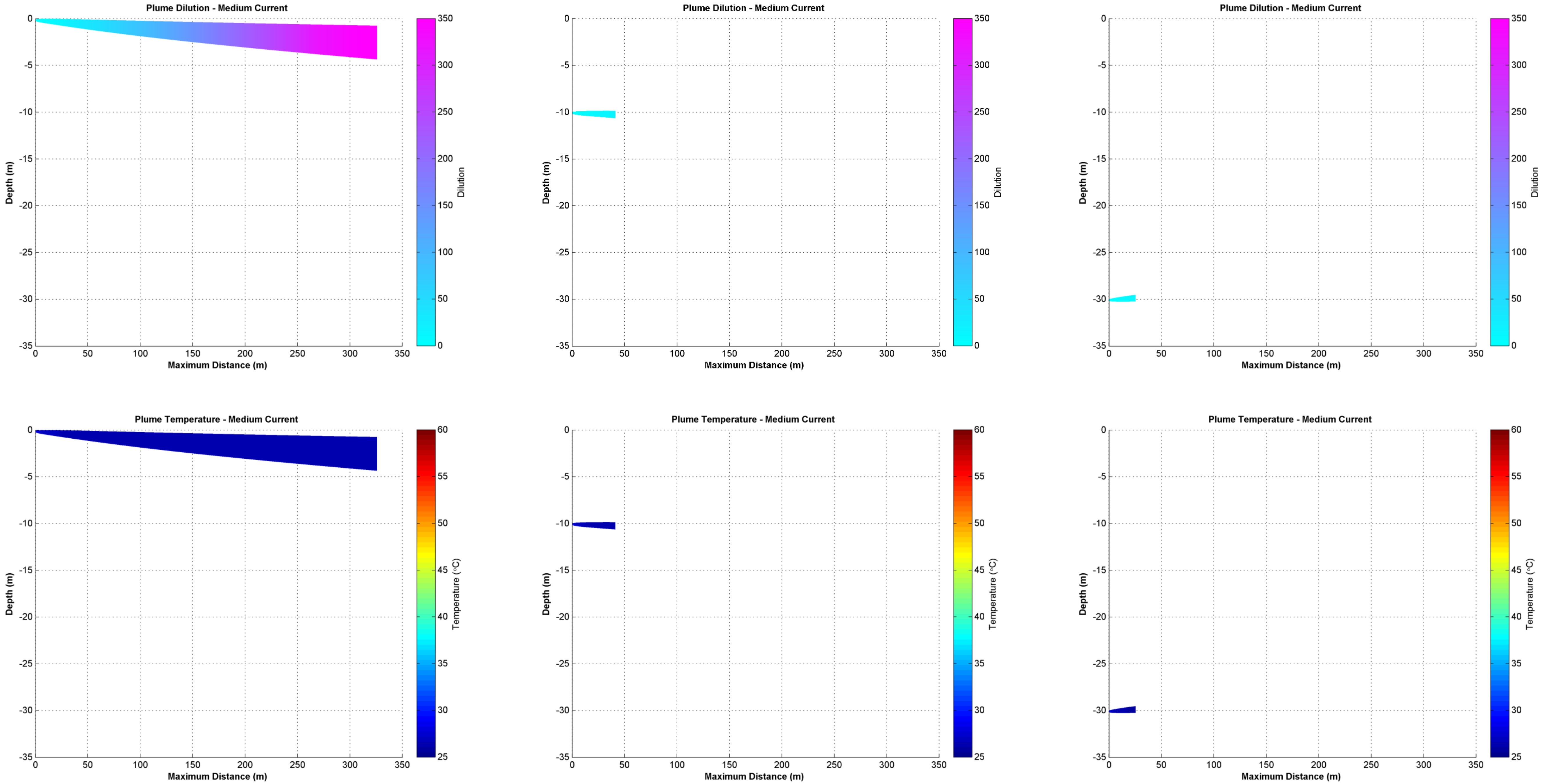

Figure 3.10 Near-field average dilution and temperature results for constant medium winter currents with a discharge flow rate of 95 m^3/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).

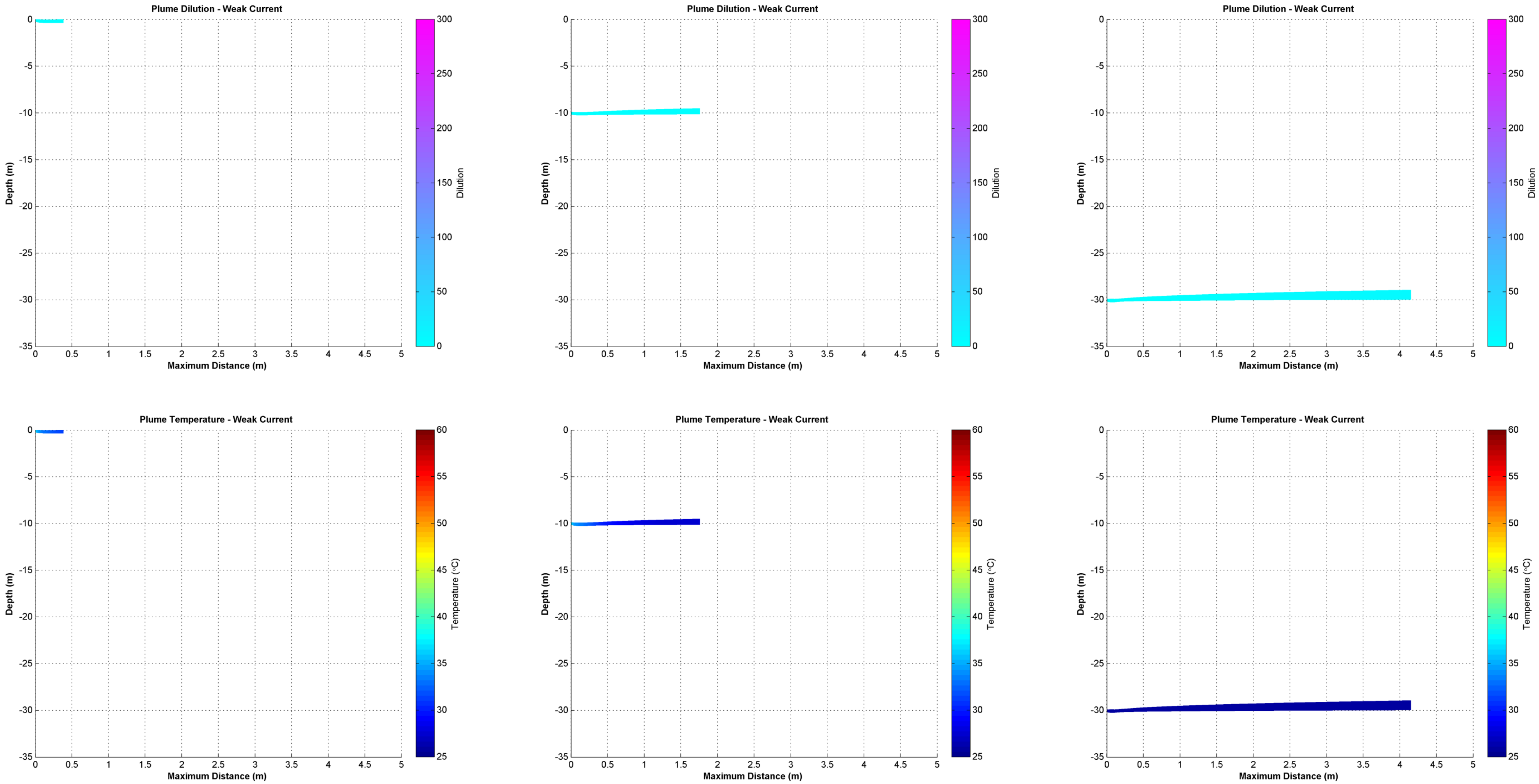

Figure 3.11 Near-field average dilution and temperature results for constant weak winter currents with a discharge flow rate of 95 m³/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).

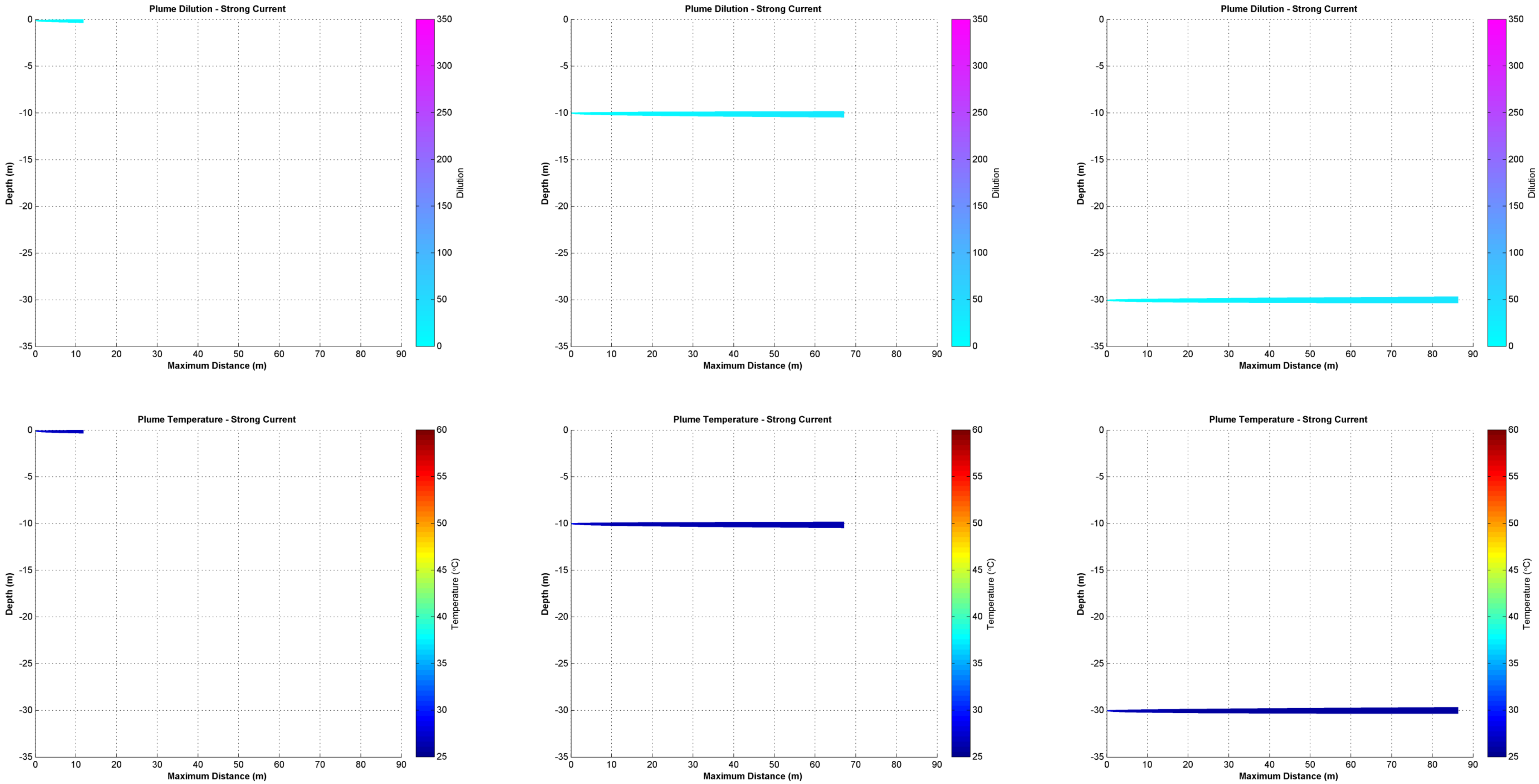

Figure 3.12 Near-field average dilution and temperature results for constant strong winter currents with a discharge flow rate of 95 m^3/d at discharge depths of 0 m (Case P1; left column), 10 m (Case P2; middle column) and 30 m (Case P3; right column).

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 and 99th percentile dilution contours are presented.

Calculation of 95th and 99th 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 the plume extents shown in Figure 3.13 with those shown in Sections 3.2.4 and 3.2.5 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 contaminant concentrations in the receiving waters to the initial concentration of the contaminant 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 3.16 summarises the initial concentrations of TPH, as specified, and the equivalent dispersed concentrations required to yield particular dilution levels (1:100, 1:200 and 1:400). These concentrations may be useful to consider when interpreting the contour plots of percentile dilutions.

Table 3.16 Initial concentrations of TPH and equivalent concentrations at example dilution levels.

TPH Parameter	TPH Concentration (mg/L)
Initial concentration in discharge	29.0
Initial concentration in receiving waters	0.0
Concentration at 1:100 dilution	0.29
Concentration at 1:200 dilution	0.145
Concentration at 1:400 dilution	0.0725

3.2.3 General Observations

Figure 3.13 shows example time series snapshots of predicted dilutions during a single simulation at 3-hour intervals from 10:00 on 29th December 2008 to 01:00 on 30th December 2008. This simulation – selected merely to be representative of typical conditions – considers the Case P1 discharge at 0 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. 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.

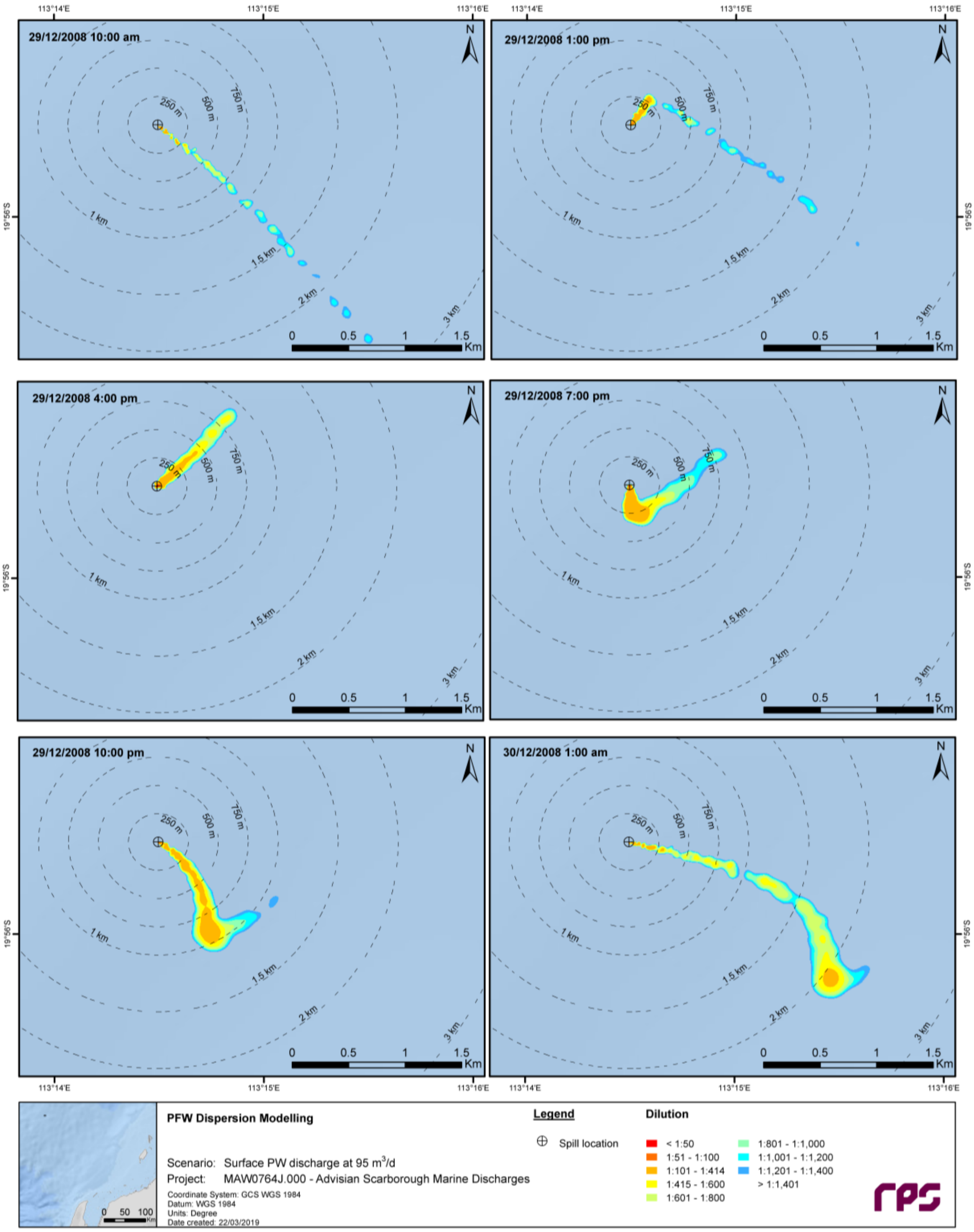

Figure 3.13 Snapshots of predicted dilution levels, at 3-hour intervals from 10:00 on 29th December 2008 to 01:00 on 30th December 2008, for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

3.2.4 Seasonal Analysis

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 3.17 and Table 3.18 summarise, for Cases P1 and P3 respectively, the minimum dilution achieved at specific radial distances from the discharge location for each season and percentile.

Table 3.19 and Table 3.20 provide, for Cases P1 and P3 respectively, summaries of the maximum distances from the discharge location to achieve 1:414 dilution 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. For Case P1, dilution to reach threshold concentration is achieved for TPH within an area of influence ranging from 181 m to 221 m at the 95th percentile across all seasons (Table 3.19). For Case P3, the maximum spatial extents of the relevant dilution contour vary from 184 m to 229 m at the 95th percentile across all seasons (Table 3.20). The greatest spatial extents are observed in winter.

Table 3.21 and Table 3.22 provide, for Cases P1 and P3 respectively, summaries of the total area of coverage for the 1:414 dilution contour for each season and percentile. For Case P1, the area of exposure defined by the relevant dilution contour is predicted to reach maximums of 0.03 km^2 to 0.04 km^2 at the 95th percentile (Table 3.21). For Case P3, the corresponding maximum areas of exposure vary from 0.03 km^2 to 0.07 km^2 at the 95th percentile (Table 3.22).

Table 3.23 and Table 3.24 provide, for Cases P1 and P3 respectively, summaries of the maximum depths from the discharge location to achieve 1:414 dilution for each season and percentile. Maximum depths are observed in winter, with predictions of 5 m and 33 m for Case P1 and Case P3, respectively.

For Cases P1 and P3, Figure 3.14 to Figure 3.25 show the aggregated spatial extents of the minimum dilutions for each season and percentile. 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.

Table 3.17 Minimum dilution achieved at specific radial distances from the PW discharge location in each season for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location											
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km
95th	Summer	1:79.2	1:148.3	1:256.9	1:459.5	1:607.7	1:793.0	1:884.7	1:1,050.1	1:1,309.4	1:1,386.7	1:1,789.6	1:1,904.4
	Transitional	1:79.3	1:145.4	1:242.6	1:414.6	1:600.5	1:790.5	1:1,004.8	1:1,221.4	1:1,429.3	1:1,606.9	1:1,931.5	1:2,150.9
	Winter	1:73.4	1:149.4	1:232.7	1:394.5	1:512.1	1:646.6	1:767.1	1:973.7	1:1,094.8	1:1,287.1	1:1,442.2	1:1,606.2
99th	Summer	1:46.6	1:87.6	1:146.5	1:239.4	1:310.1	1:389.3	1:452.1	1:532.2	1:604.6	1:662.5	1:752.2	1:829.3
	Transitional	1:47.6	1:86.4	1:144.5	1:226.1	1:286.1	1:366.0	1:436.0	1:509.9	1:587.9	1:646.4	1:716.0	1:760.1
	Winter	1:64.9	1:107.2	1:187.5	1:317.0	1:381.7	1:522.9	1:550.6	1:643.5	1:785.5	1:837.8	1:912.2	1:1,033.8

Table 3.18 Minimum dilution achieved at specific radial distances from the PW discharge location in each season for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location											
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km
95th	Summer	1:67.8	1:142.2	1:246.1	1:426.6	1:592.1	1:778.0	1:930.0	1:1,123.1	1:1,219.0	1:1,411.4	1:1,537.3	1:1,665.0
	Transitional	1:69.1	1:135.2	1:252.9	1:447.6	1:611.5	1:808.7	1:949.0	1:1,099.4	1:1,281.0	1:1,443.8	1:1,622.0	1:1,729.4
	Winter	1:57.3	1:133.4	1:226.5	1:385.0	1:513.3	1:681.2	1:825.9	1:1,002.6	1:1,227.7	1:1,445.2	1:1,534.8	1:1,860.0
99th	Summer	1:42.9	1:87.7	1:142.0	1:225.8	1:297.3	1:361.4	1:431.9	1:479.0	1:521.9	1:578.4	1:598.9	1:666.9
	Transitional	1:43.7	1:83.5	1:143.1	1:236.6	1:302.9	1:375.4	1:434.6	1:517.9	1:552.4	1:605.8	1:665.7	1:687.6
	Winter	1:37.6	1:76.2	1:123.5	1:187.5	1:232.9	1:272.0	1:277.7	1:307.6	1:381.1	1:408.7	1:474.9	1:496.6

Table 3.19 Maximum distance from the PW discharge location to achieve 1:414.3 dilution in each season for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Summer	181
	Transitional	194
	Winter	221
99th	Summer	426
	Transitional	452
	Winter	543
100th	Summer	2,190
	Transitional	3,231
	Winter	3,005

Table 3.20 Maximum distance from the PW discharge location to achieve 1:414.3 dilution in each season for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Summer	191
	Transitional	184
	Winter	229
99th	Summer	482
	Transitional	432
	Winter	810
100th	Summer	3,244
	Transitional	3,244
	Winter	3,406

Table 3.21 Total area of coverage for 1:414.3 dilution in each season for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Summer	0.033
	Transitional	0.034
	Winter	0.042
99th	Summer	0.301
	Transitional	0.340
	Winter	0.419
100th	Summer	1.973
	Transitional	2.266
	Winter	3.313

Table 3.22 Total area of coverage for 1:414.3 dilution in each season for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Summer	0.046
	Transitional	0.034
	Winter	0.065
99th	Summer	0.370
	Transitional	0.348
	Winter	0.623
100th	Summer	4.673
	Transitional	5.204
	Winter	3.406

Table 3.23 Maximum depth from the PW discharge location to achieve 1:414.3 dilution in each season for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

Season	Maximum depth (m) from discharge location to achieve given dilution
Summer	4
Transitional	4
Winter	5

Table 3.24 Maximum depth from the PW discharge location to achieve 1:414.3 dilution in each season for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

Season	Maximum depth (m) from discharge location to achieve given dilution
Summer	33
Transitional	33
Winter	34

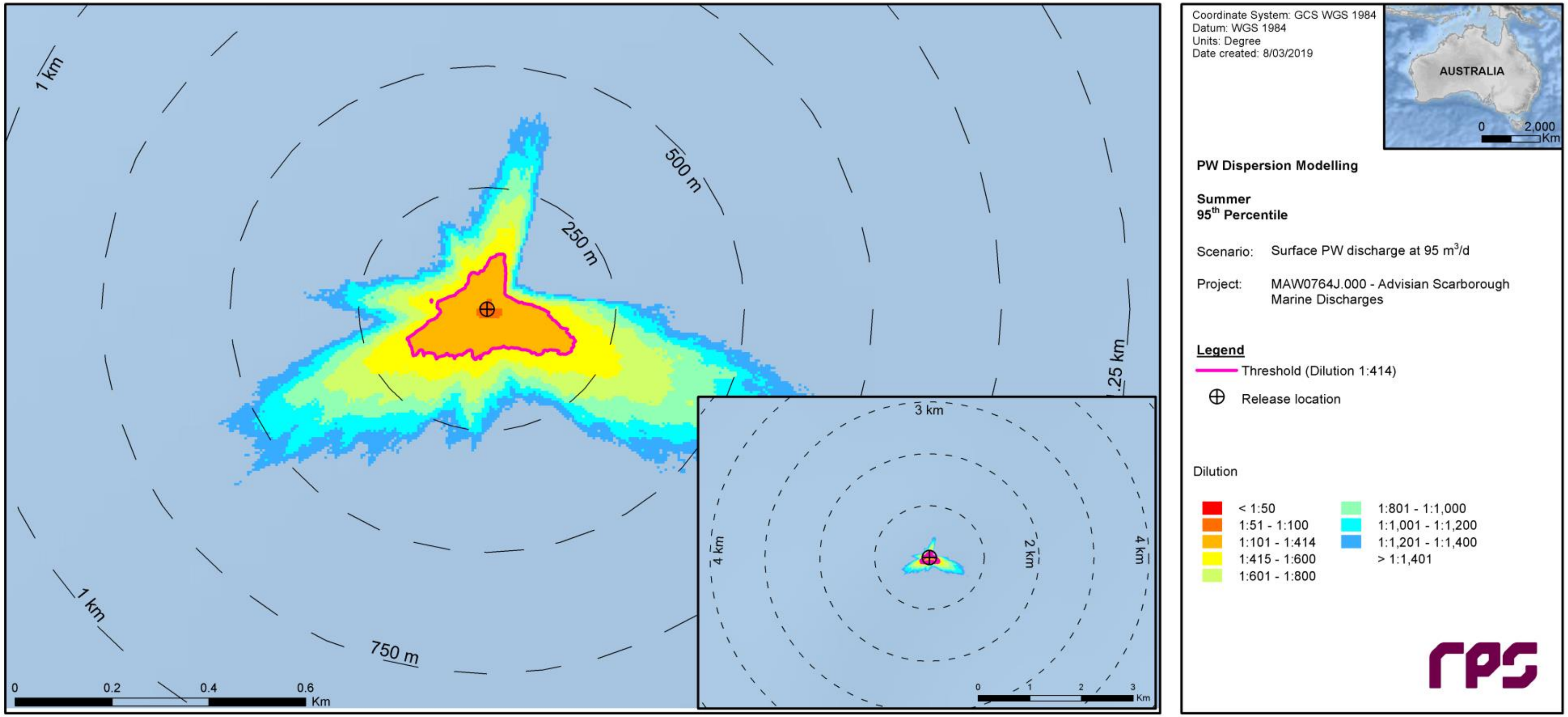

Figure 3.14 Predicted minimum dilutions at the 95th percentile under summer conditions for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

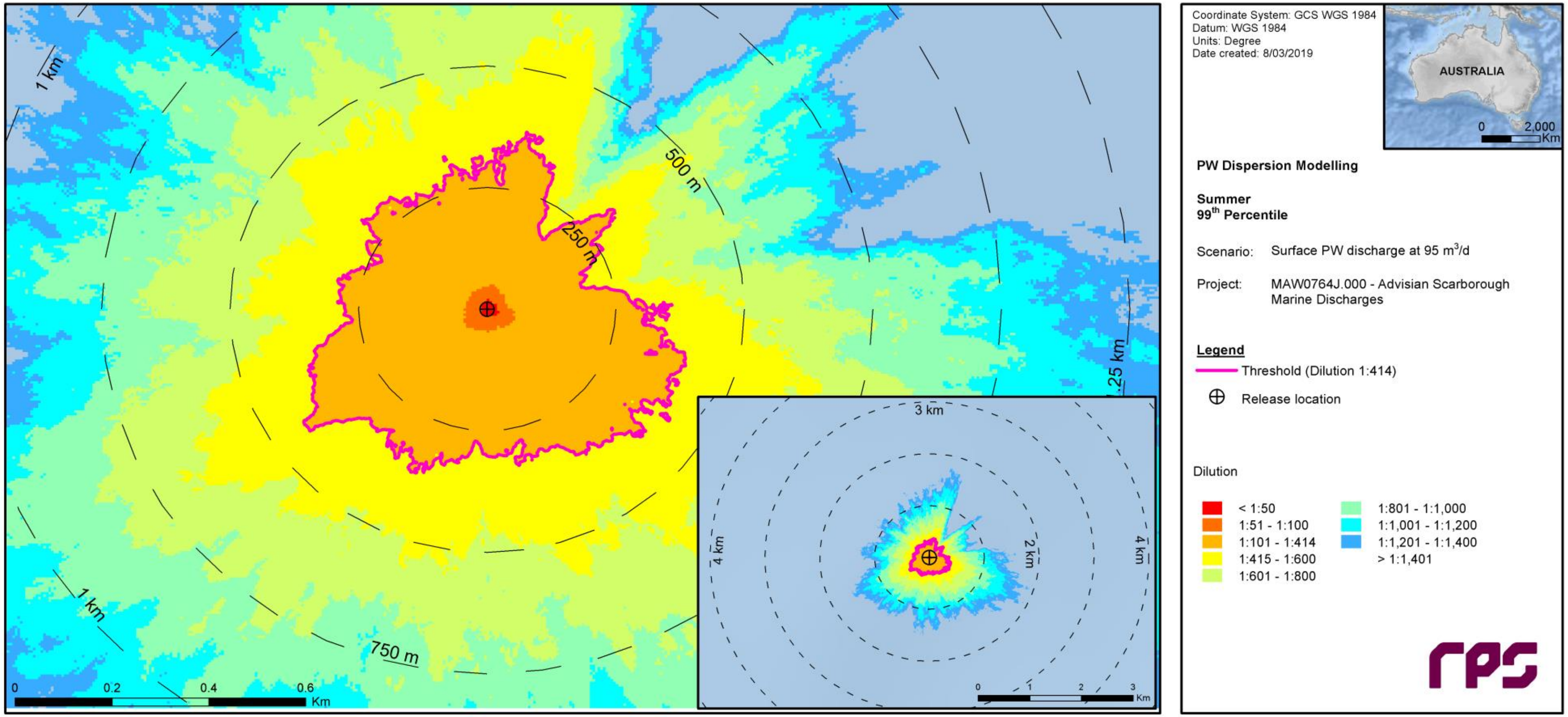

Figure 3.15 Predicted minimum dilutions at the 99th percentile under summer conditions for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

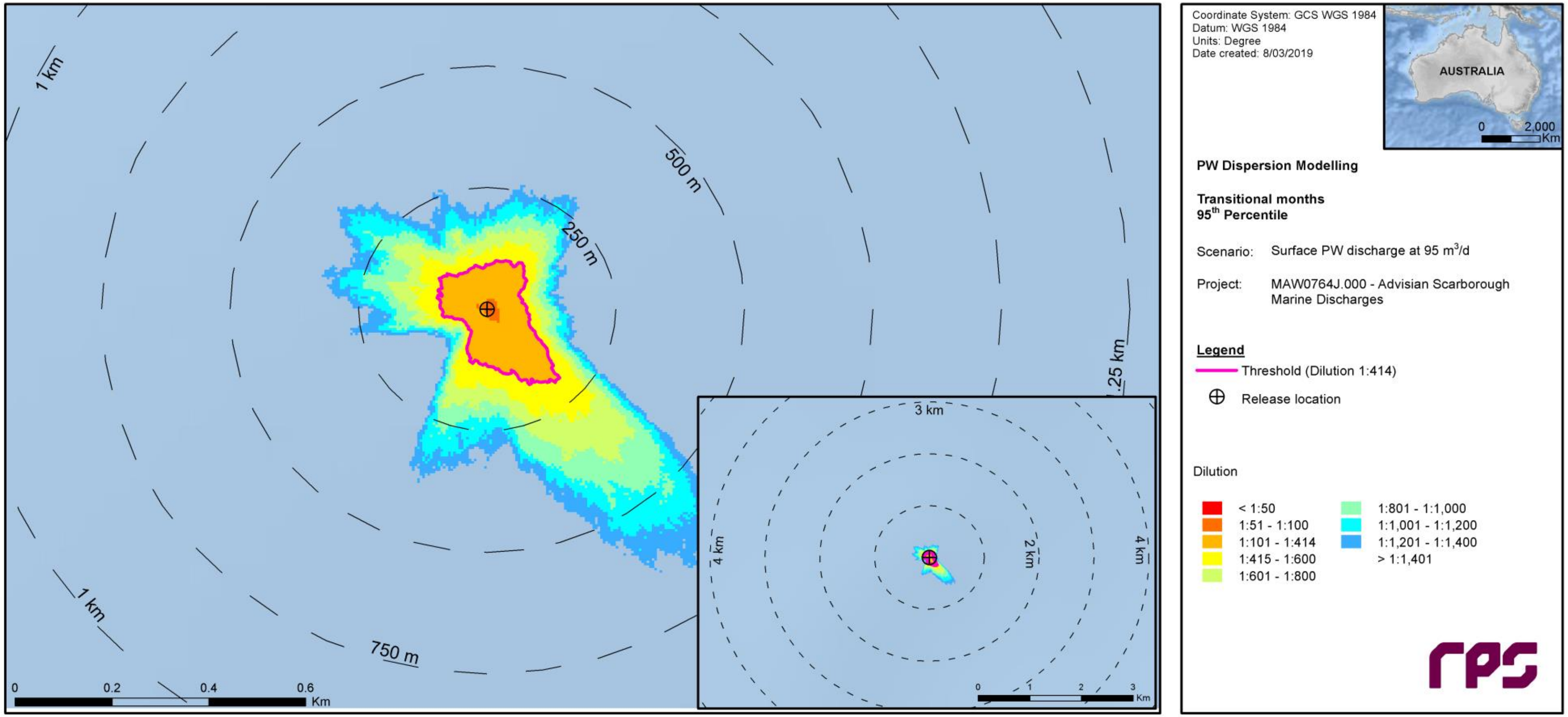

Figure 3.16 Predicted minimum dilutions at the 95th percentile under transitional conditions for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

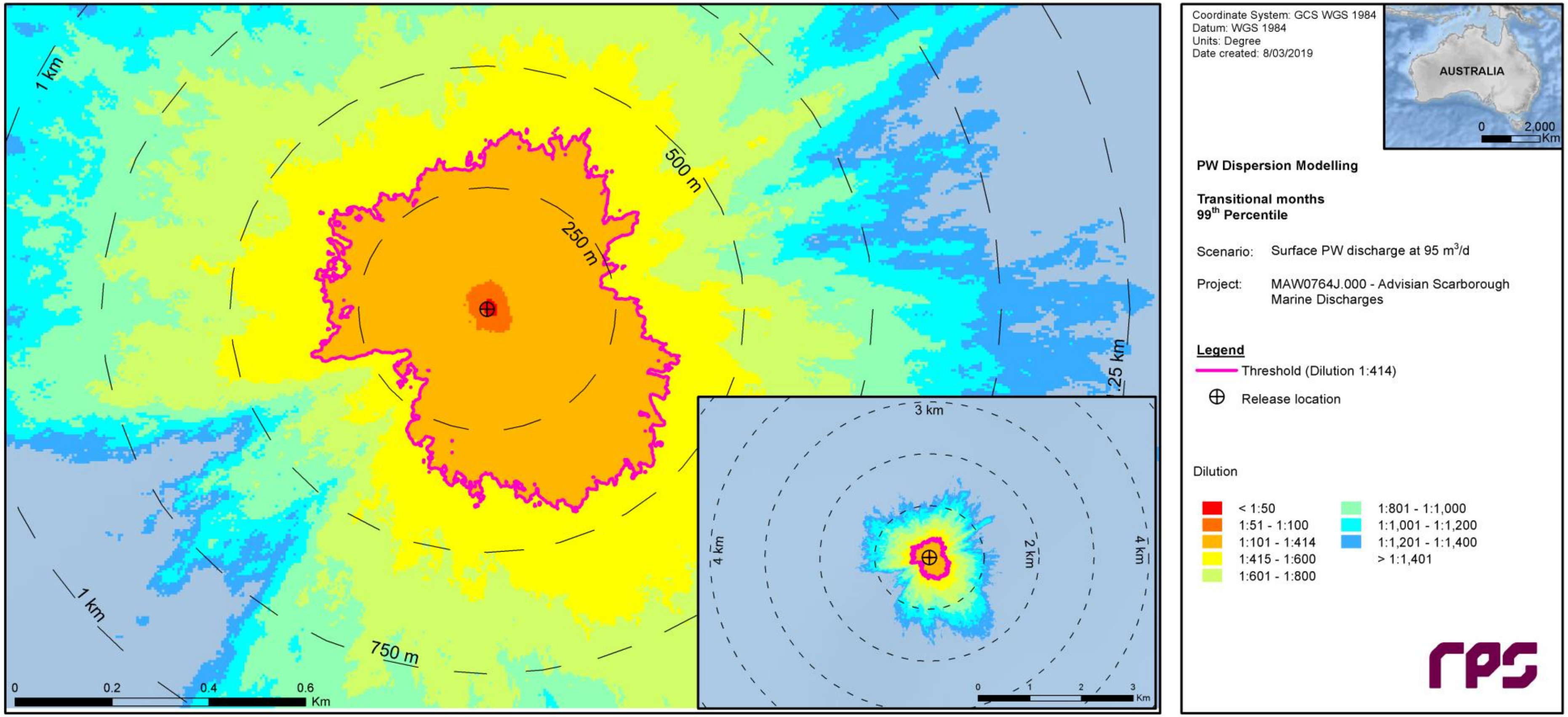

Figure 3.17 Predicted minimum dilutions at the 99th percentile under transitional conditions for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

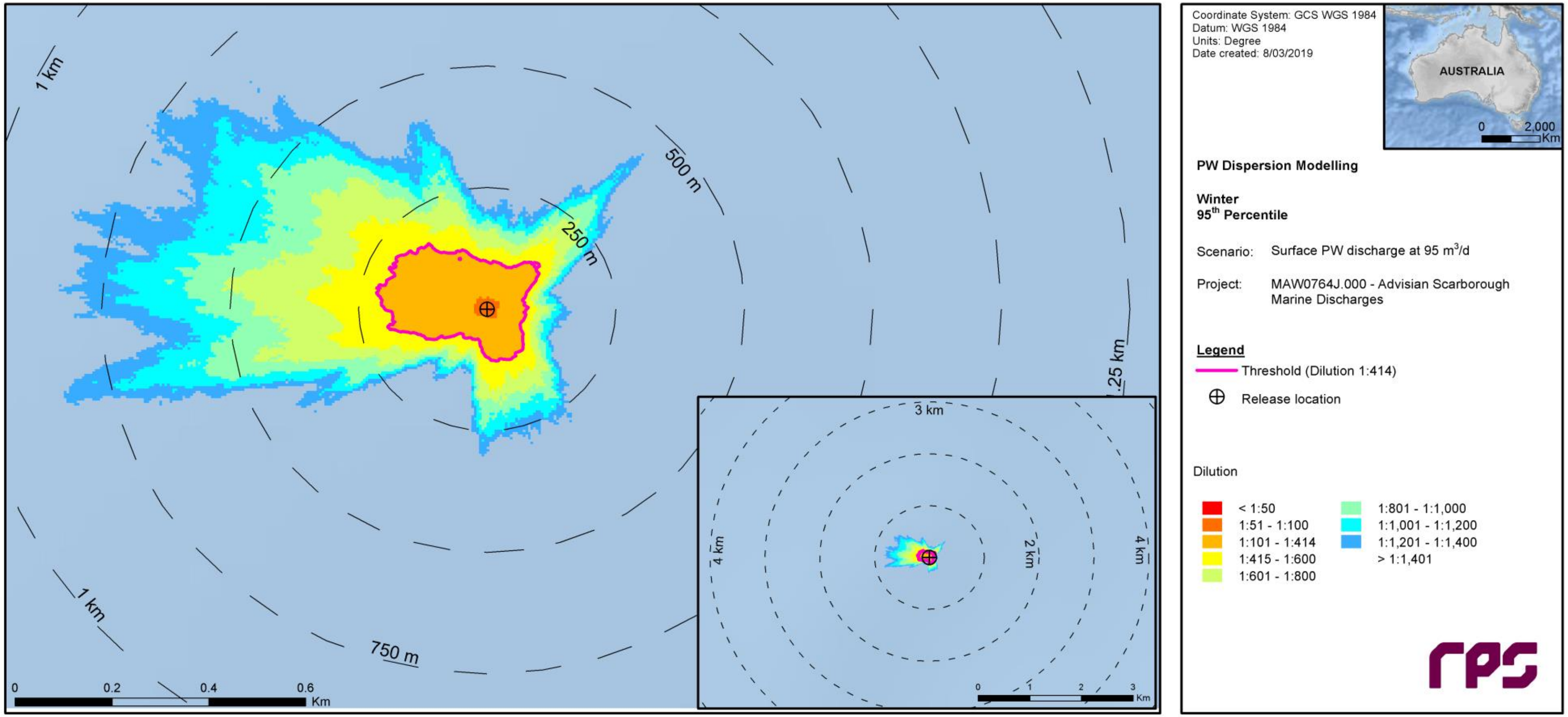

Figure 3.18 Predicted minimum dilutions at the 95th percentile under winter conditions for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

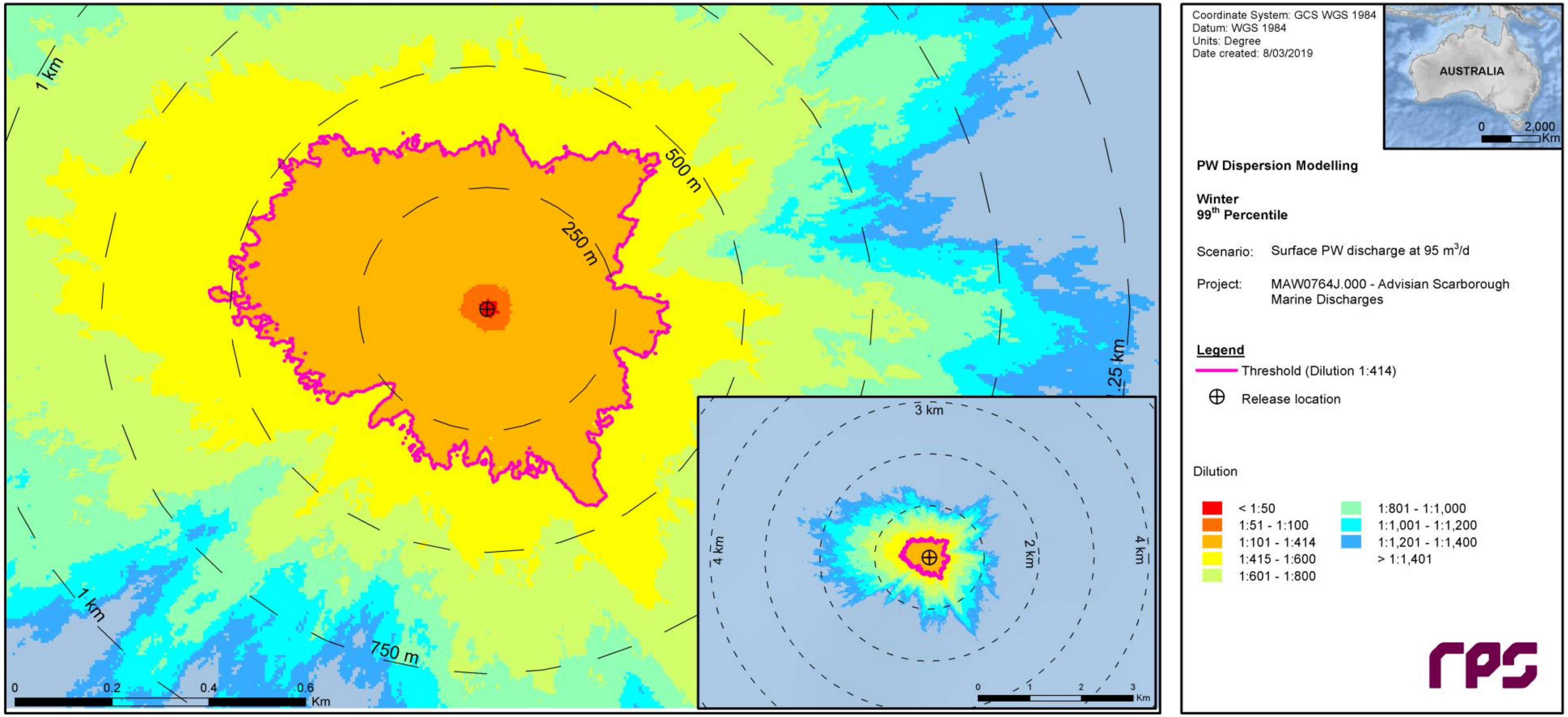

Figure 3.19 Predicted minimum dilutions at the 99th percentile under winter conditions for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

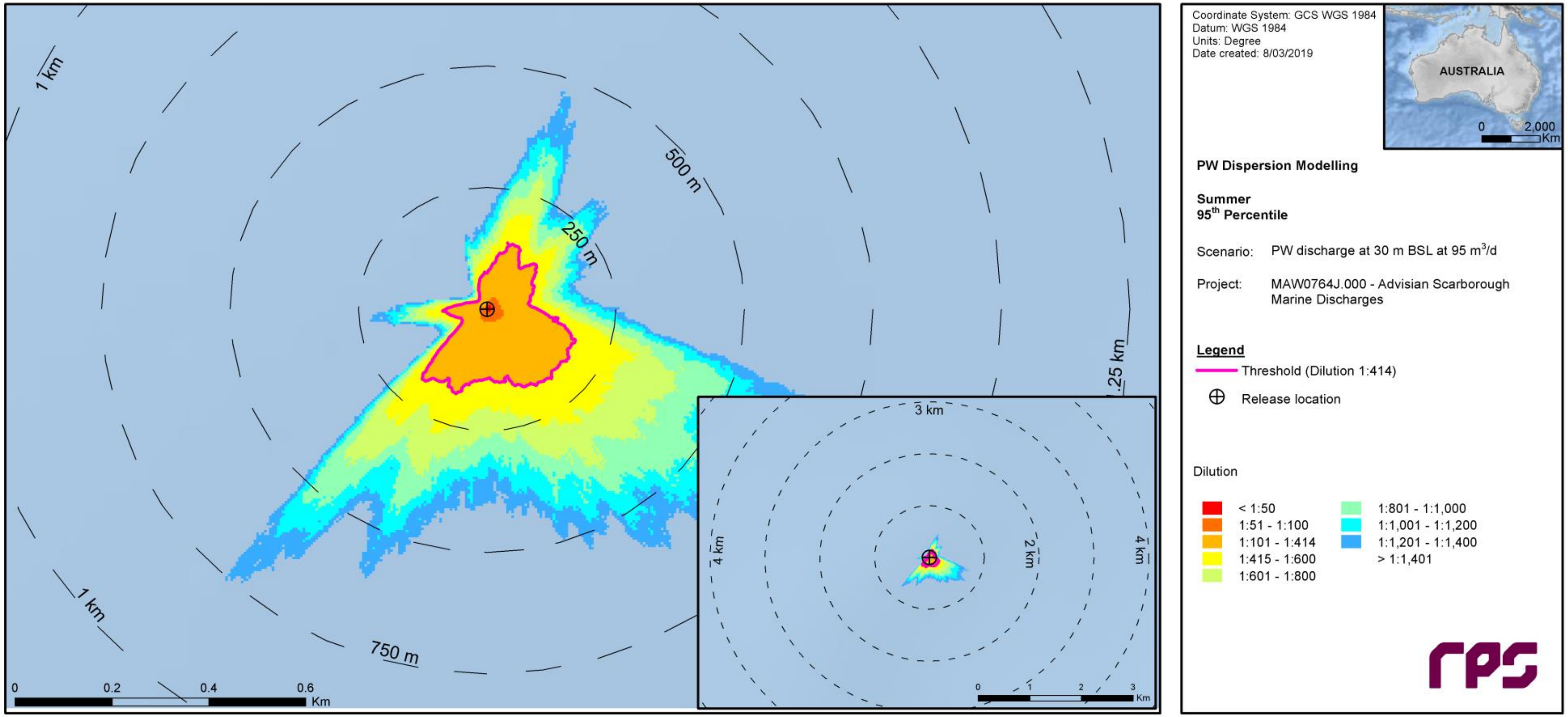

Figure 3.20 Predicted minimum dilutions at the 95th percentile under summer conditions for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

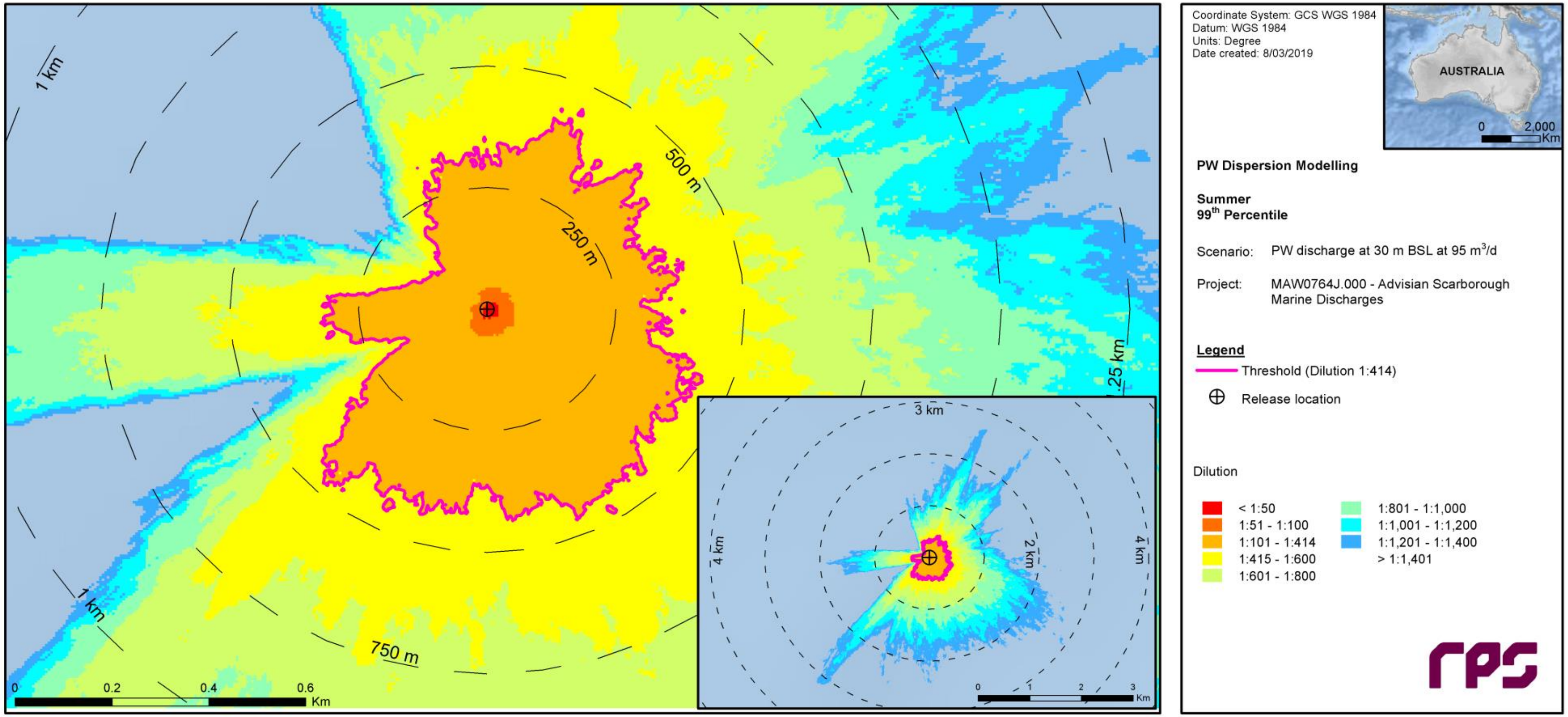

Figure 3.21 Predicted minimum dilutions at the 99th percentile under summer conditions for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

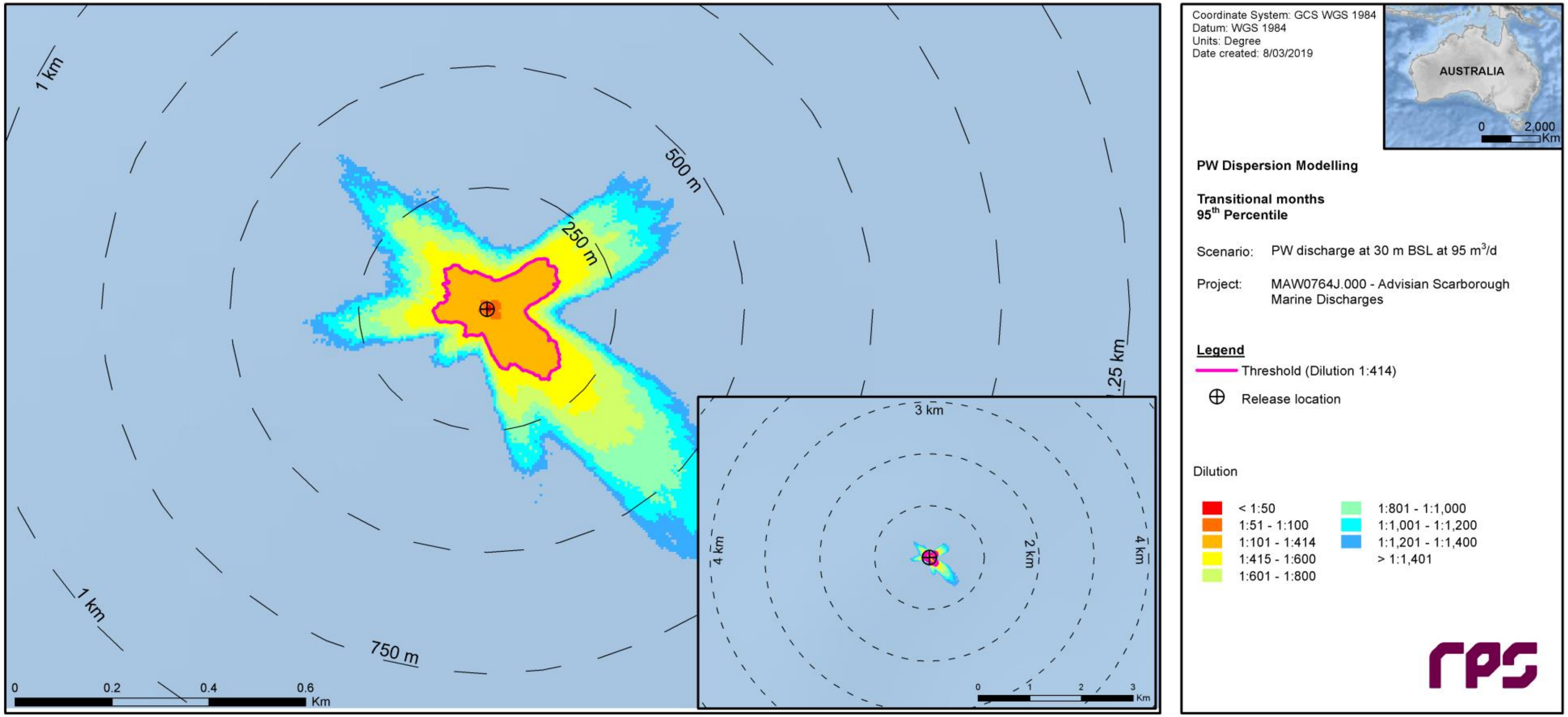

Figure 3.22 Predicted minimum dilutions at the 95th percentile under transitional conditions for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

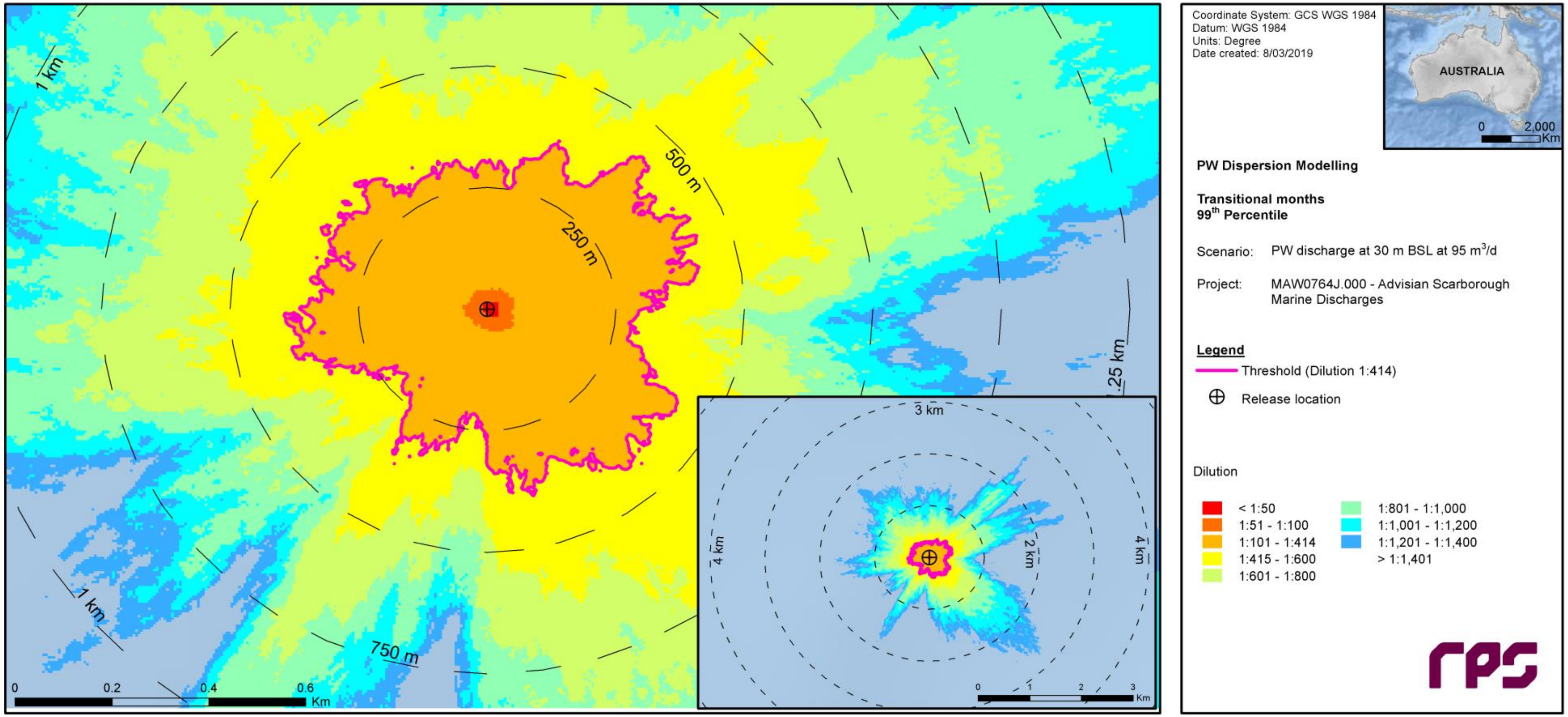

Figure 3.23 Predicted minimum dilutions at the 99th percentile under transitional conditions for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

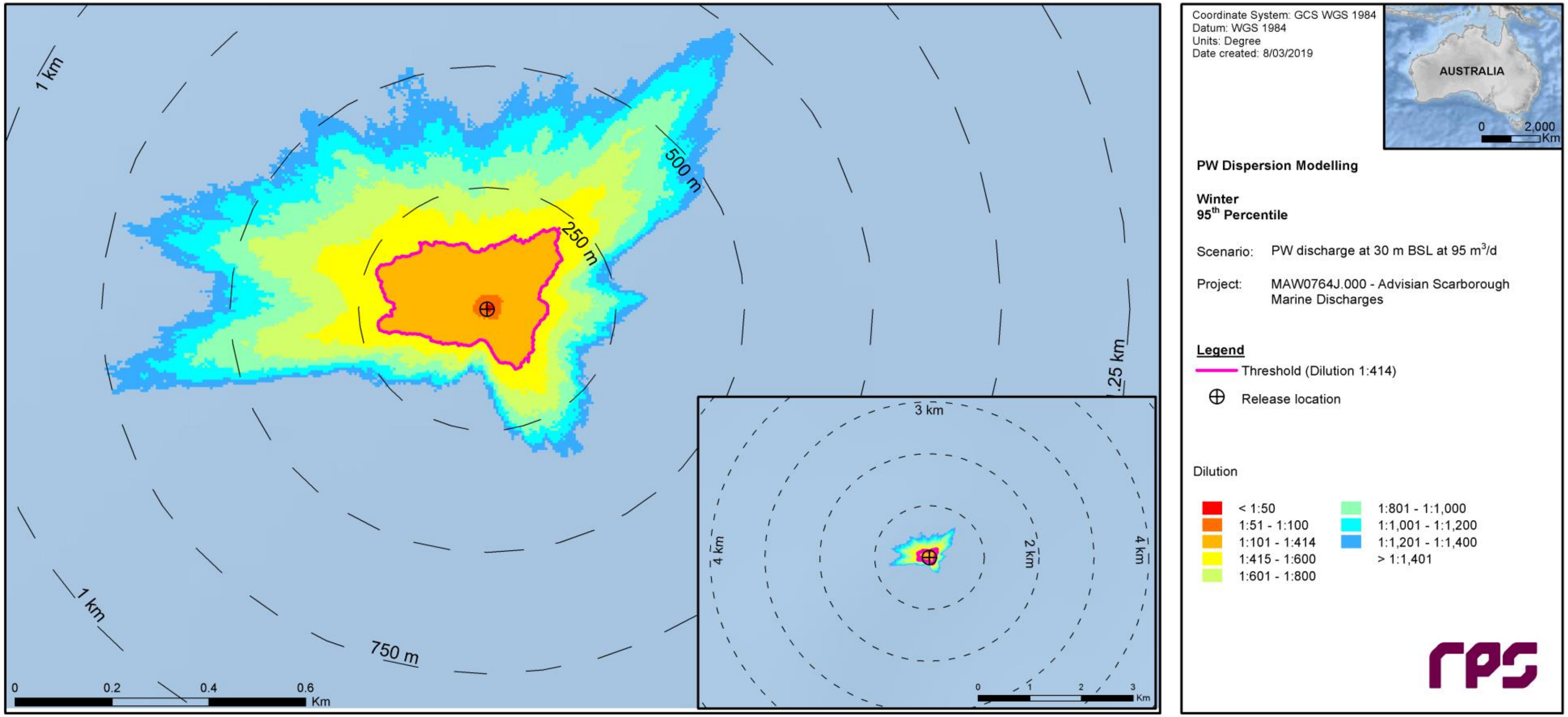

Figure 3.24 Predicted minimum dilutions at the 95th percentile under winter conditions for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

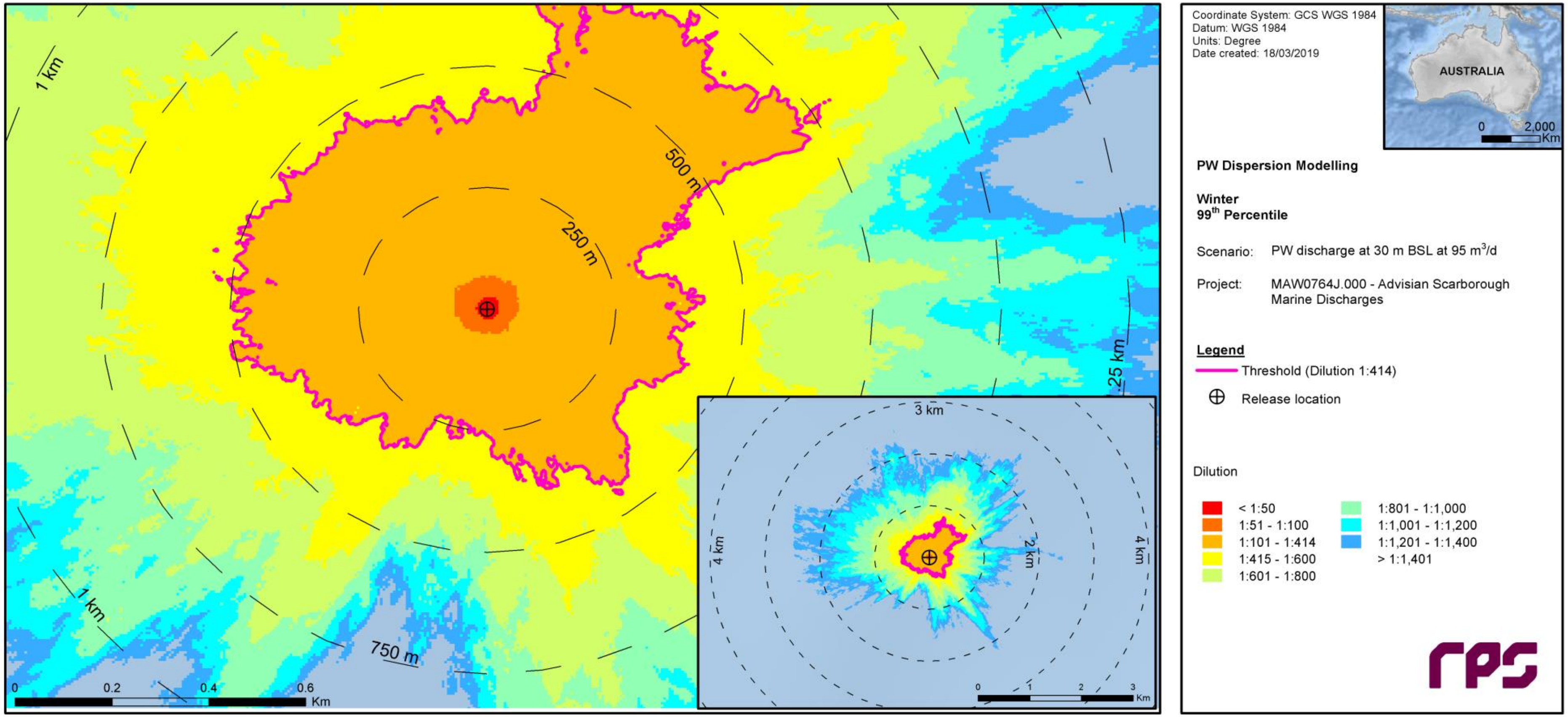

Figure 3.25 Predicted minimum dilutions at the 99th percentile under winter conditions for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

3.2.5 Annualised Analysis

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 3.25 and Table 3.26 summarise, for Cases P1 and P3 respectively, the minimum dilution achieved at specific radial distances from the discharge location for each percentile over the annual period.

Table 3.27 and Table 3.28 provide, for Cases P1 and P3 respectively, summaries of the annualised maximum distances from the discharge location to achieve 1:414 dilution 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 threshold concentration is achieved for TPH within a maximum area of influence of 543 m (Case P1) and 810 m (Case P3) at the 99th percentile, this being the maximum spatial extent of the relevant dilution contour from the discharge location in any season.

Table 3.29 and Table 3.30 provide, for Cases P1 and P3 respectively, summaries of the total area of coverage for the 1:414 dilution contour for each percentile. The area of exposure defined by the relevant dilution contour is predicted to reach maximum values of 0.48 km^2 (Case P1) and 0.70 km^2 (Case P3) at the 99th percentile in any season.

For Cases P1 and P3, Figure 3.26 to Figure 3.29 show the aggregated spatial extents of the minimum dilutions for each percentile. 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.

Table 3.25 Annualised minimum dilution achieved at specific radial distances from the PW discharge location for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location											
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km
95th	Annual	1:79.2	1:145.4	1:232.7	1:394.5	512.1	1:646.6	1:767.1	1:973.7	1:1,094.8	1:1,287.1	1:1,442.2	1:1,606.2
99th		1:46.6	1:86.4	1:144.5	1:144.5	1:286.1	1:366.0	1:436.0	1:509.9	1:587.9	1:646.4	1:716	1:760.1

Table 3.26 Annualised minimum dilution achieved at specific radial distances from the PW discharge location for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location											
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km
95th	Annual	1:57.3	1:133.4	1:226.5	1:385.0	1:513.3	1:681.2	1:825.9	1:1,002.6	1:1,219.0	1:1,411.4	1:1,534.8	1:1,860.0
99th		1:37.6	1:76.2	1:123.5	1:187.5	1:232.9	1:272.0	1:277.7	1:381.1	1:381.1	1:408.7	1:474.9	1:496.6

Table 3.27 Annualised maximum distance from the PW discharge location to achieve 1:414.3 dilution for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Annual	221
99th		543
100th		3,231

Table 3.28 Annualised maximum distance from the PW discharge location to achieve 1:414.3 dilution for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Annual	229
99th		810
100th		3,406

Table 3.29 Annualised total area of coverage for 1:414.3 dilution for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Annual	0.067
99th		0.479
100th		4.014

Table 3.30 Annualised total area of coverage for 1:414.3 dilution for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Annual	0.087
99th		0.702
100th		9.910

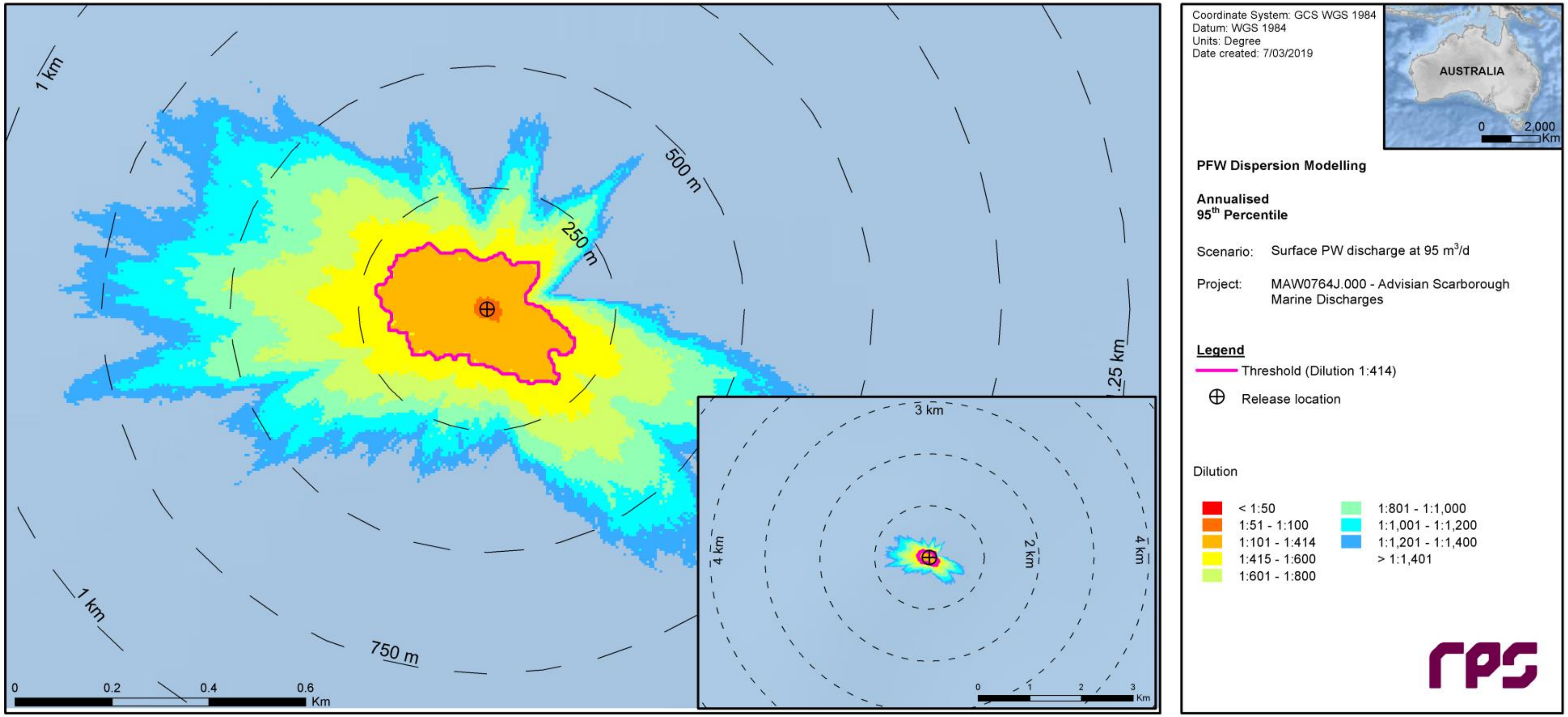

Figure 3.26 Predicted annualised minimum dilutions at the 95th percentile for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

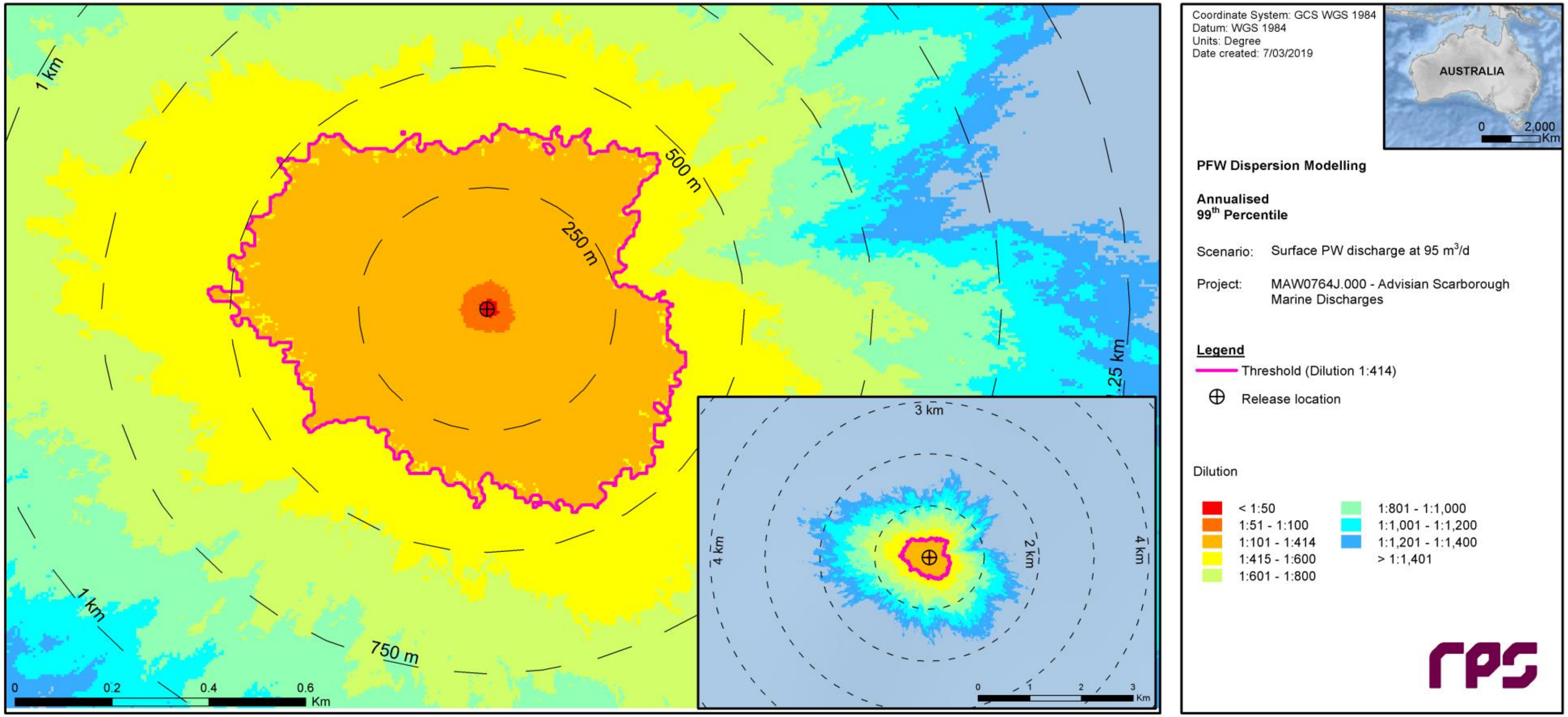

Figure 3.27 Predicted annualised minimum dilutions at the 99th percentile for Case P1 (0 m depth discharge at 95 m^3/d flow rate).

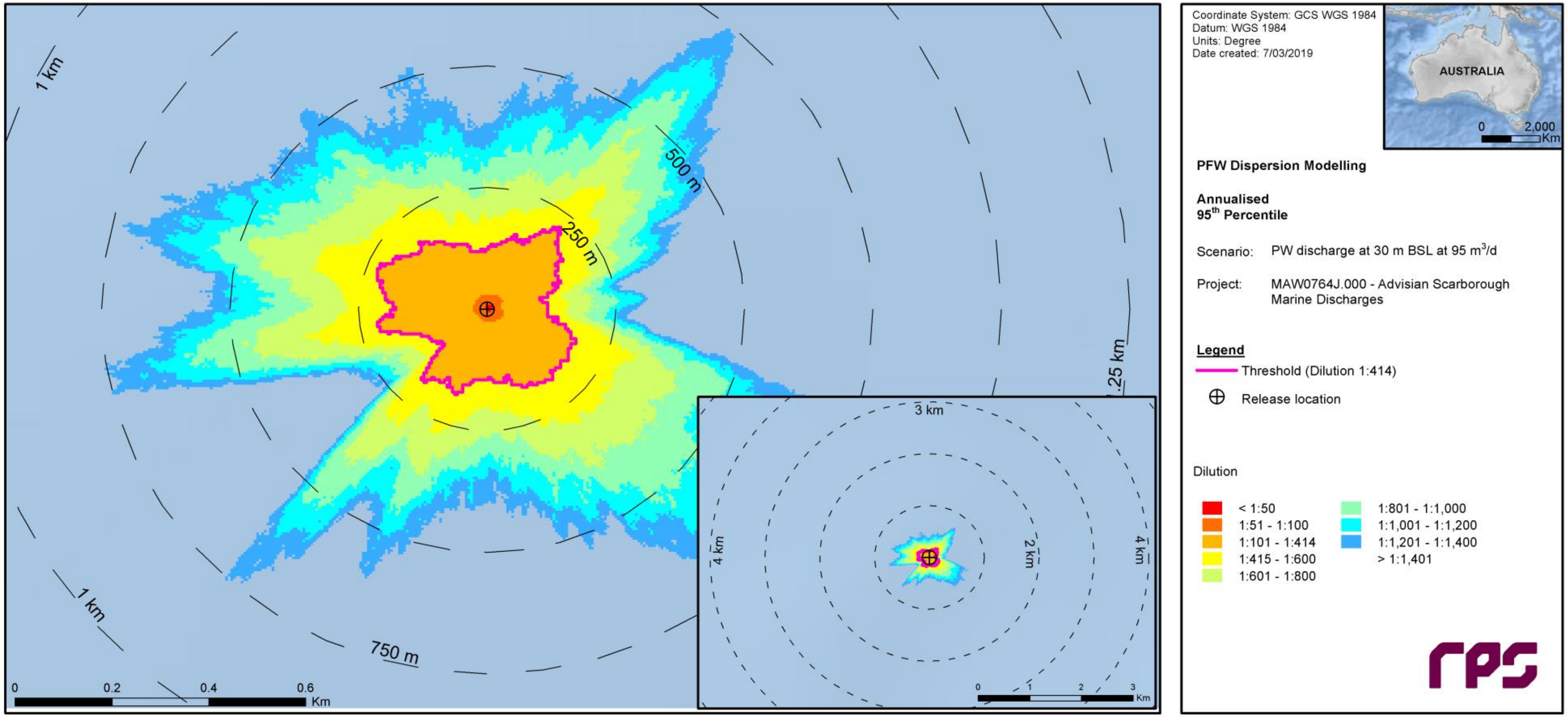

Figure 3.28 Predicted annualised minimum dilutions at the 95th percentile for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

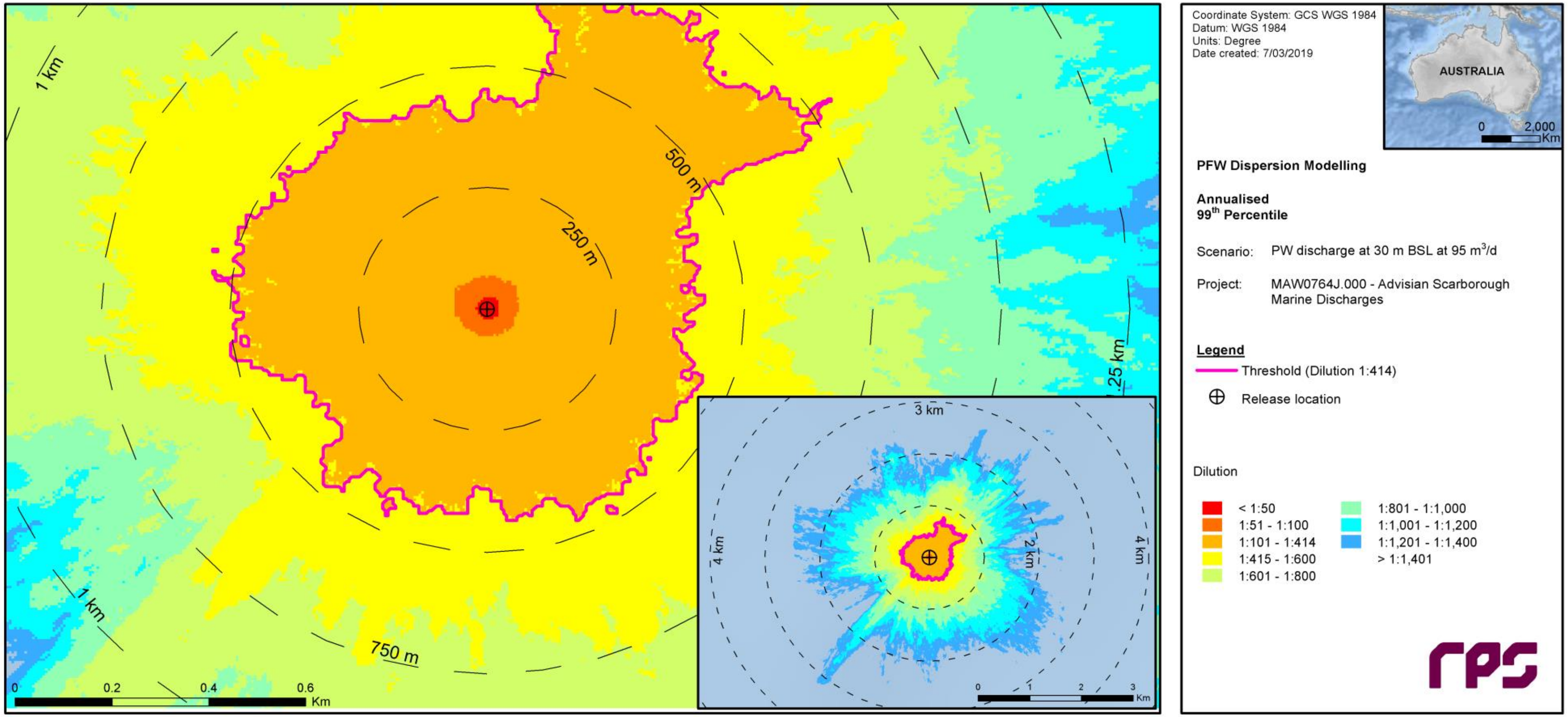

Figure 3.29 Predicted annualised minimum dilutions at the 99th percentile for Case P3 (30 m depth discharge at 95 m^3/d flow rate).

4 CONCLUSIONS

The main findings of the study are as follows:

Near-Field Modelling

- 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 0 m, 10 m and 30 m below the water surface (Cases P1, P2 and P3, respectively). The surface discharges are shown to increase the extent of the turbulent mixing zone. Following this initial mixing, the near neutrally-buoyant plumes are predicted to travel laterally in the water column.
- For Case P1, the plume is predicted to plunge up to 4.4 m below the sea surface. For Cases P2 and P3, the plumes are predicted to remain at approximately the discharge depth: up to 11 m below the surface for Case P2 and up to 31 m below the surface for Case P3.
- Increased ambient current strengths are shown to increase the horizontal distance travelled by the plume from the discharge point.
- For a discharge at a 95 m^3/d flow rate, the maximum horizontal distance travelled by the plume under annualised average current speeds is predicted for a discharge at 0 m depth as 255 m. The dilution level for this case is predicted as 1:1,519.
- The maximum diameter of the plume at the end of the near-field zone was predicted as 3.7 m for Case P1, 1.8 m for Case P2 and 1.7 m for Case P3. Increases in current speed serve to restrict the diameter of the plume.
- For each discharge depth, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to plunge further and 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 average current speeds are predicted to be 1:1,519 for Case P1, 1:88 for Case P2 and 1:43 for Case P3. Additionally, the minimum dilution levels of the plume (i.e. dilution of the plume centreline) upon encountering the trapping depth under average current speeds are predicted to be 1:390 for Case P1, 1:22 for Case P2 and 1:11 for Case P3.
- 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.
- The results for the Case P1, P2 and P3 discharges indicate that the TPH constituent of the PW discharge is not expected to reach the required levels of dilution in the near field mixing zone.

Far-Field Modelling

- For Case P1, dilution to reach threshold concentration is achieved for TPH within an area of influence extending up to 543 m at the 99th percentile. For Case P3, the maximum spatial extents of the relevant dilution contour are up to 810 m at the 99th percentile.

- For Case P1, the area of exposure defined by the relevant dilution contour is predicted to reach a maximum of 0.48 km^2 at the 99th percentile. For Case P3, the corresponding maximum area of exposure is up to 0.70 km^2 at the 99th percentile.
- Maximum depths reached by the discharges are predicted as 5 m and 33 m for Cases P1 and P3, respectively.

Key Observations

- Due to the similarity in typical magnitude of the hindcast currents throughout the depth range of discharges under consideration, predicted outcomes are broadly similar.
- The greater variability in surface-layer currents will promote the highest levels of mixing and dilution.
- Because the discharge will be initially negatively buoyant, it will sink in the water column and even a surface discharge is unlikely to resurface in the vicinity of the discharge point prior to acclimation with ambient receiving water conditions.

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Appendix H

Scarborough Gas Development Hydrotest Discharge Modelling Study

MAKING COMPLEX EASY

WOODSIDE SCARBOROUGH PROJECT – HYDROTEST DISCHARGE MODELLING

Report

MAW0764J
Woodside Scarborough Project – Hydrotest Discharge Modelling
Rev 2
17 April 2019

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EXECUTIVE SUMMARY

RPS was commissioned by Advisian Pty Ltd (Advisian), on behalf of Woodside Energy Ltd (Woodside), to undertake a marine dispersion modelling study of proposed hydrotest discharges from subsea infrastructure associated with the Scarborough Project's Floating Production Unit (FPU).

The Scarborough gas resource, located in Commonwealth waters approximately 375 km off the Burrup Peninsula, forms part of the Greater Scarborough gas fields, comprising the Scarborough, North Scarborough, Thebe and Jupiter gas fields.

As Operator of the Greater Scarborough gas fields, Woodside is proposing to develop the gas resource through new offshore facilities. These will be connected to the mainland through an approximately 430 km trunkline.

Once installation and hook-up of subsea infrastructure is complete, the infrastructure, including the SURF (subsea, umbilical, riser, flowline) and the trunkline, will be subject to pre-commissioning integrity tests. These may be conducted using hydrotest fluids, whereby the pipeline 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, at which time they will be discharged at the offshore location (subject to regulatory requirements).

The principal aim of the study was to quantify the likely extents of the near-field and far-field mixing zones based on the required dilution levels for biocide in the hydrotest discharge. This will indicate whether concentrations of this contaminant are still likely to be above stated threshold levels at the limits of the mixing zones (i.e. are not predicted to be diluted below the relevant threshold).

To accurately determine the dilution of the hydrotest discharge 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 biocide in the hydrotest stream from the trunkline and SURF, dispersion modelling was carried out for flow rates of 795 m^3/hr and 220 m^3/hr at discharge depths of 930 m and 10 m below the water surface.

The potential area that may be influenced by the hydrotest discharge stream 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

- 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 930 m (Cases 1 and 2) and 10 m (Case 3) below the water surface. The surface discharges are shown to increase the extent of the turbulent mixing zone. Following this initial mixing, the near neutrally-buoyant plumes are predicted to travel laterally in the water column.
- For Cases 1 and 2, the plumes are predicted to remain close to the seabed. For Case 3, the plume is predicted to plunge up to 19 m below the sea surface. For Cases 2 and 3, increased ambient current strengths are shown to increase the horizontal distance travelled by the plumes from the discharge point.

- The plume will reach a maximum horizontal distance of up to 152 m before reaching the trapping depth (at which the predictions of dispersion are halted due to the plume reaching equilibrium with the ambient receiving water).
- The maximum diameter of the plume at the end of the near-field zone was predicted as 23 m. Increases in current speed serve to restrict the diameter of the plume.
- For each discharge depth, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to plunge further and reach the trapping depth closer to the discharge point, which slows the rate of dilution.
- For each combination of discharge flow rate and depth, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to plunge further and reach the trapping depth closer to the discharge point, which slows the rate of dilution.
- The average dilution levels of the plume upon reaching the trapping depth under average current speeds are predicted to be 1:90 for Case 1, 1:465 for Case 2 and 1:482 for Case 3.
- 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
- The results for the Case 1, 2 and 3 discharges indicate that the biocide constituent of the hydrotest discharge is not expected to reach the required levels of dilution in the near field mixing zone.

Far-Field Modelling

- For Case 1, dilution to reach threshold concentration is achieved for biocide within an area of influence extending up to 1,388 m at the 99th percentile. For Case 3, the maximum spatial extents of the relevant dilution contour are up to 124 m at the 99th percentile.
- For Case 1, the area of exposure defined by the relevant dilution contour is predicted to reach a maximum of 2.95 km^2 at the 99th percentile. For Case 3, the corresponding maximum area of exposure is up to 0.04 km^2 at the 99th percentile.
- Maximum depths reached by the discharges are predicted as 930 m (seabed) and 12 m for Cases 1 and 3, respectively.

Key Observations

- Due to the significant variations in magnitude of the hindcast currents between the surface and seabed, where potential discharges will occur, predicted outcomes are markedly different.
- The greater strength and variability in surface-layer currents will promote the highest levels of mixing and dilution, while transport patterns at the seabed will be dictated almost solely by tidal movements.
- Because the discharge will be initially neutrally-buoyant, it will travel laterally in the water column and even a surface discharge is unlikely to resurface in the vicinity of the discharge point prior to acclimation with ambient receiving water conditions.
- Outcomes show that below-threshold biocide concentrations are achieved closer to the discharge point for the surface discharge (220 m^3/hr over 20 hours) than for the seabed discharge (795 m^3/hr over 44 hours). This is partly attributable to the stronger currents at the surface, but primarily to the lower flow rate and much lower discharge duration in the surface-discharge case.

1 INTRODUCTION

1.1 Background

RPS was commissioned by Advisian Pty Ltd (Advisian), on behalf of Woodside Energy Ltd (Woodside), to undertake a marine dispersion modelling study of proposed hydrotest discharges from subsea infrastructure associated with the Scarborough Project's Floating Production Unit (FPU).

The Scarborough gas resource, located in Commonwealth waters approximately 375 km off the Burrup Peninsula, forms part of the Greater Scarborough gas fields, comprising the Scarborough, North Scarborough, Thebe and Jupiter gas fields.

As Operator of the Greater Scarborough gas fields, Woodside is proposing to develop the gas resource through new offshore facilities. These will be connected to the mainland through an approximately 430 km trunkline.

Once installation and hook-up of subsea infrastructure is complete, the infrastructure, including the SURF (subsea, umbilical, riser, flowline) and the trunkline, will be subject to pre-commissioning integrity tests. These may be conducted using hydrotest fluids, whereby the pipeline 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, at which time they will be discharged at the offshore location (subject to regulatory requirements).

The principal aim of the study was to quantify the likely extents of the near-field and far-field mixing zones based on the required dilution levels for biocide in the hydrotest discharge. This will indicate whether concentrations of this contaminant are still likely to be above stated threshold levels at the limits of the mixing zones (i.e. are not predicted to be diluted below the relevant threshold).

To accurately determine the dilution of the hydrotest discharge 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 biocide in the hydrotest stream from the trunkline and SURF (location shown in Table 1.1), dispersion modelling was carried out for flow rates of 795 m^3/hr and 220 m^3/hr at discharge depths of 930 m and 10 m below the water surface.

The potential area that may be influenced by the hydrotest discharge stream 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 hydrotest discharge characteristics used as input to the modelling are specified in the Model Input Form for this study (Advisian, 2018).

Table 1.1 Location of the proposed FPU used as the release site for the hydrotest dispersion modelling assessment.

Release Site	Latitude (°S)	Longitude (°E)	Water Depth (m)
FPU	19° 53' 54.715"	113° 14' 19.561"	930

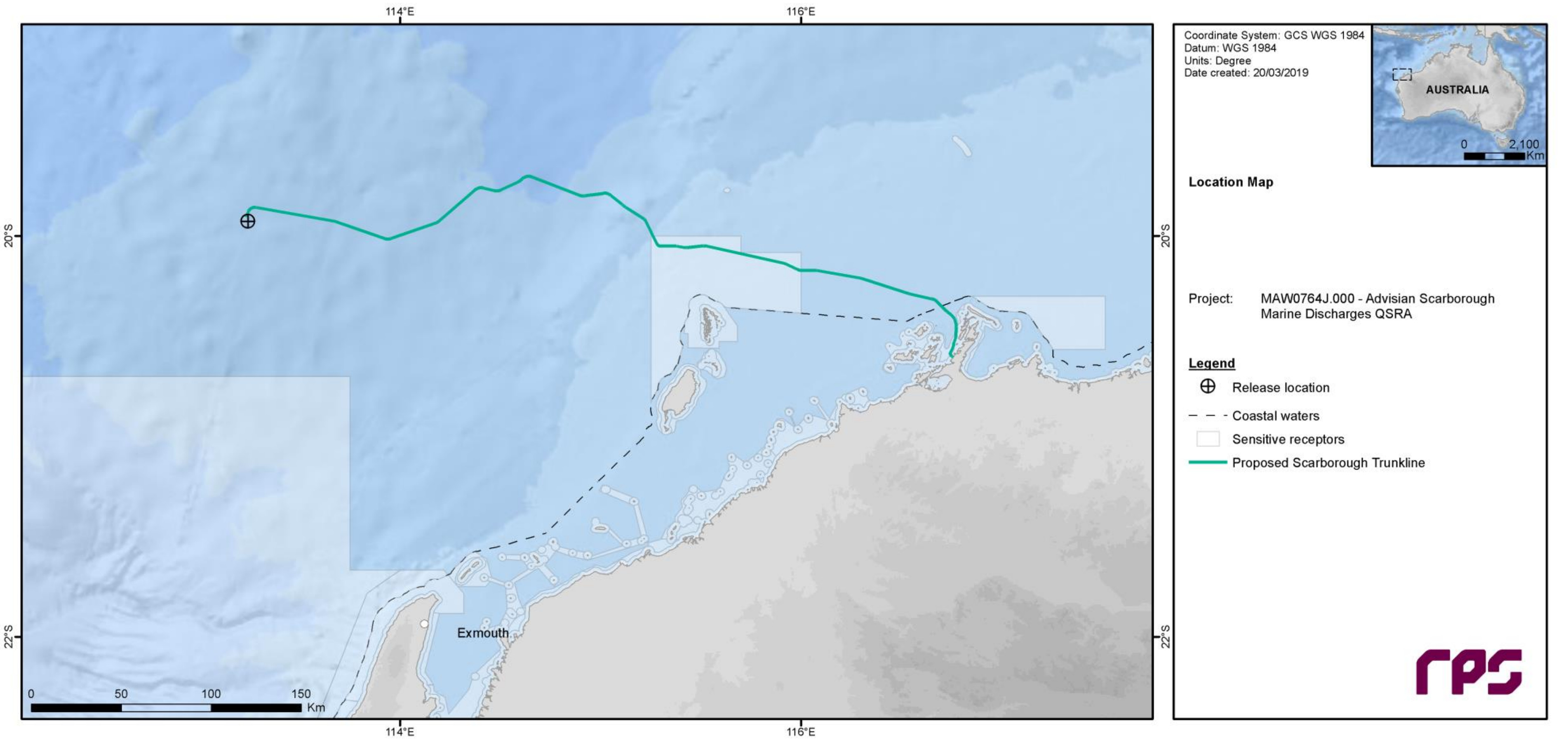


Figure 1.1 Location of the proposed Scarborough pipeline and FPU on the North West Shelf of Australia.

1.2 Modelling Scope

The physical mixing of the hydrotest plume 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 the 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 FPU location 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 Scarborough Project 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 FPU location 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 contaminant 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 hydrotest water discharges, in terms of the distribution of the maximum contaminant 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 hydrotest 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 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 FPU location.

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 shows a conceptual diagram of the dispersion and fates of a negatively buoyant discharge and the idealised representation of the discharge phases.

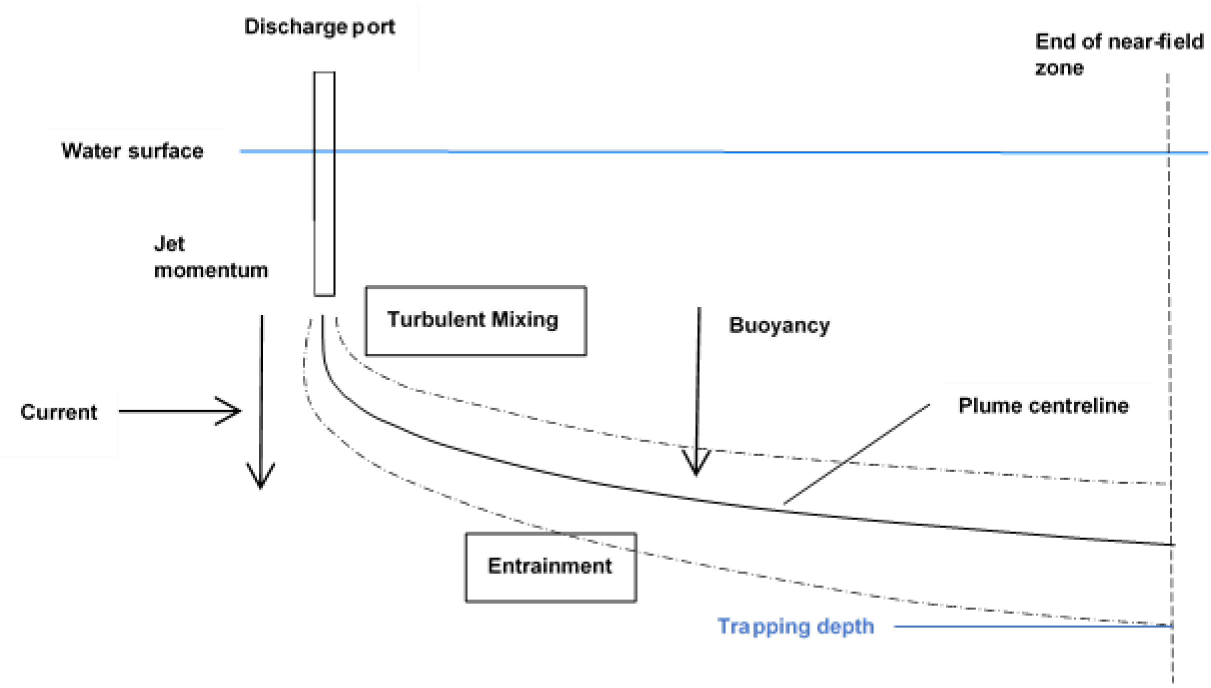


Figure 2.1 Conceptual diagram showing the general behaviour of negatively buoyant discharge.

2.1.3 Setup of Near-Field Model

2.1.3.1 Discharge Characteristics

The hydrotest discharge characteristics for cases 1 to 3 are summarised in Table 2.1.

Cases 1 and 2 were assumed to occur at a depth of 930 m below mean sea level (BMSL). The flow was assumed to occur through a single outlet of 0.1 m diameter at rates of 795 m^3/d and 220 m^3/d, respectively, and have a salinity of 35 parts per thousand (ppt) and temperature equivalent to ambient seabed conditions.

Case 3 was assumed to occur at a depth of 10 m below mean sea level (BMSL). The flow was assumed to occur through a single outlet of 0.1 m diameter at a rate of 220 m^3/d, and have a salinity of 35 parts per thousand (ppt) and temperature equivalent to ambient near-surface conditions.

The volume of hydrotest water for Case 1 was assumed as 232,800 m^3 while the volume for Cases 2 and 3 was assumed as 6,360 m^3, representing the full volumes of the trunkline and SURF equipment, respectively. Based on the engineering definitions available at the time of commissioning the dispersion modelling study, it is anticipated that the dewatering of the pipeline will take approximately 244 hours (Case 1) and 20 hours (Cases 2 and 3), based on average flow rates of 795 m^3/hr and 220 m^3/hr.

Concentrations of the constituent of interest (biocide) within the discharges are described in Table 2.2, along with the required dilution factor to reach the defined threshold concentration (Advisian, 2018).

Table 2.1 Summary of hydrotest discharge characteristics.

Parameter	Trunkline Hydrotest Discharge	SURF Hydrotest Discharge 1	SURF Hydrotest Discharge 2
Flow rate (m^3/d)	795	220	
Discharge volume (m^3)	232,800	6,360	
Discharge duration (hours)	244	20	
Outlet pipe internal diameter (m) [in]	0.1 [4]		
Outlet pipe orientation	Horizontal	Vertical (upwards)	Vertical (downwards)
Depth of pipe below sea surface (m)	930		10
Discharge salinity (ppt)	35		
Discharge temperature (°C)	Ambient (seabed)		Ambient (near-surface)

Table 2.2 Constituent of interest within the hydrotest discharges and criteria for analysis of exposure.

Constituent	Source Concentration (ppm)	Threshold Concentration (ppm)	Required Dilution Factor
Biocide	550	1	550

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 hydrotest plume. 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 2.3 shows the average seasonal water temperature and salinity levels at varying depths from 0 m to 930 m. This data can be considered representative of seasonal conditions at the FPU location.

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 (34.6-35.5 practical salinity unit, PSU), irrespective of season or depth.

Table 2.3 Average temperature and salinity levels adjacent to the proposed FPU location.

Season	Depth (m)	Temperature (°C)	Salinity (PSU)
Summer	0	27.8	34.7
	20	27.3	34.8
	50	26.2	34.8
	200	18.4	35.4
	500	8.7	34.7
	1,000	5.1	34.6
Transitional	0	26.0	34.7
	20	25.7	34.7
	50	25.1	34.7
	200	18.6	35.5
	500	8.6	34.6
	1,000	5.1	34.6
Winter	0	26.4	34.7
	20	26.3	34.7
	50	26.2	34.7
	200	19.0	35.4
	500	8.9	34.6
	1,000	5.1	34.6
Annualised	0	26.6	34.7
	20	26.3	34.7
	50	25.8	34.7
	200	18.7	35.4
	500	8.7	34.6
	1,000	5.1	34.6

2.1.3.2.2 Ambient Current

Ocean current data was sourced from a 10-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 FPU location.

Table 2.4 presents the steady-state, unidirectional current speeds at varying depths used as input to the near-field model as forcing for each discharge case:

- 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 2.4 Adopted ambient current conditions adjacent to the proposed FPU 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	0.041	0.158	0.326
	22.7	0.049	0.154	0.312
	56.7	0.044	0.138	0.267
	205.2	0.035	0.120	0.237
	545.5	0.032	0.105	0.221
	995.5	0.013	0.050	0.106
Transitional	2.5	0.045	0.177	0.375
	22.7	0.045	0.173	0.369
	56.7	0.043	0.157	0.322
	205.2	0.043	0.140	0.287
	545.5	0.032	0.118	0.282
	995.5	0.016	0.056	0.116
Winter	2.5	0.044	0.172	0.395
	22.7	0.043	0.166	0.375
	56.7	0.039	0.156	0.341
	205.2	0.036	0.142	0.307
	545.5	0.035	0.116	0.278
	995.5	0.013	0.052	0.105
Annualised	2.5	0.043	0.170	0.374
	22.7	0.045	0.164	0.361
	56.7	0.042	0.151	0.320
	205.2	0.038	0.135	0.285
	545.5	0.033	0.114	0.267
	995.5	0.014	0.053	0.109

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 pollutant concentrations in the receiving waters.

2.2.2 Description of Far-Field Model: MUDMAP

The mixing and dispersion of the 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).

2.2.3 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 (25) simulations of a given discharge scenario and season, 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.

2.2.4 Setup of Far-Field Model

2.2.4.1 Discharge Characteristics

The MUDMAP model simulated the discharge into a time-varying current field with the initial dilution set by the near-field results described in Section 2.1.

Two hydrotest discharge scenarios were modelled as a continuous discharge using 25 simulations for each season. 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 hydrotest discharge characteristics for the selected cases (Trunkline and SURF 2) are summarised in Table 2.5. These cases were chosen to cover the full range of proposed discharge flow rates and depths.

Table 2.5 Summary of far-field hydrotest discharge modelling assumptions.

Parameter	Trunkline Hydrotest Discharge	SURF Hydrotest Discharge 2
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)	795	220
Discharge volume (m^3)	232,800	6,360
Discharge duration (hours)	244	20
Discharge depth (m)	930	10
Discharge salinity (ppt)	35	
Discharge temperature (°C)	Ambient (seabed)	Ambient (near-surface)
Number of simulations	75 (25 per season)	
Simulated discharge type	One-off	
Simulated discharge period (days)	Discharge duration	

2.2.4.2 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 0.15 m^2/s and 0.00005 m^2/s were used to control the spreading of the hydrotest plume 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.

MUDMAP uses 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 5 m x 5 m to track the movement and fate of the discharge plume. The extent of the grid region measured approximately 5 km (longitude or x-axis) by 5 km (latitude or y-axis), which was subdivided horizontally into 1,000 x 1,000 cells. The vertical resolution was set to 1 m.

2.2.5 Regional Ocean Currents

2.2.5.1 Background

The area of interest for this study is typified by strong tidal flows over the shallower regions, particularly along the inshore region of the North West Shelf and among the island groups stretching from the Dampier Archipelago to the North West Cape. However, the 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 slicks over time scales exceeding a few hours.

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. Hence, the current-induced transport of pollutants 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 of pollutants. As measured current data is not available for simultaneous periods over a network of locations covering the wide area of this study, the analysis relied upon hindcasts of the circulation generated by numerical modelling. Estimates of the net currents were derived by combining predictions of the drift currents, available from mesoscale ocean models, with estimates of the tidal currents generated by an RPS model set up for the study area.

2.2.5.2 Mesoscale Circulation Model

Representation of the drift currents that affect the area were available from the output of the BRAN (Bluelink ReANalysis; 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 Commonwealth Scientific and Industrial Research Organisation (CSIRO). 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).

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, time series of current speed and direction were 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.

Figure 2.2 shows the seasonal distribution of current speeds and directions for the BRAN data point closest to the FPU location. Note that the convention for defining current direction is the direction towards which the current flows.

The data shows that current speeds and directions vary between seasons. In general, during transitional months (March and September to November) currents have the strongest average speed (0.22 m/s with a maximum of 0.56 m/s) and tend to flow south-east. During winter (April to August), current flow conditions are more variable, with lower average speed (0.21 m/s with a maximum of 0.53 m/s). During summer (December to February), the current flow occurs in a predominantly south/south-westerly direction with the lowest average speed (0.20 m/s with a maximum of 0.46 m/s).

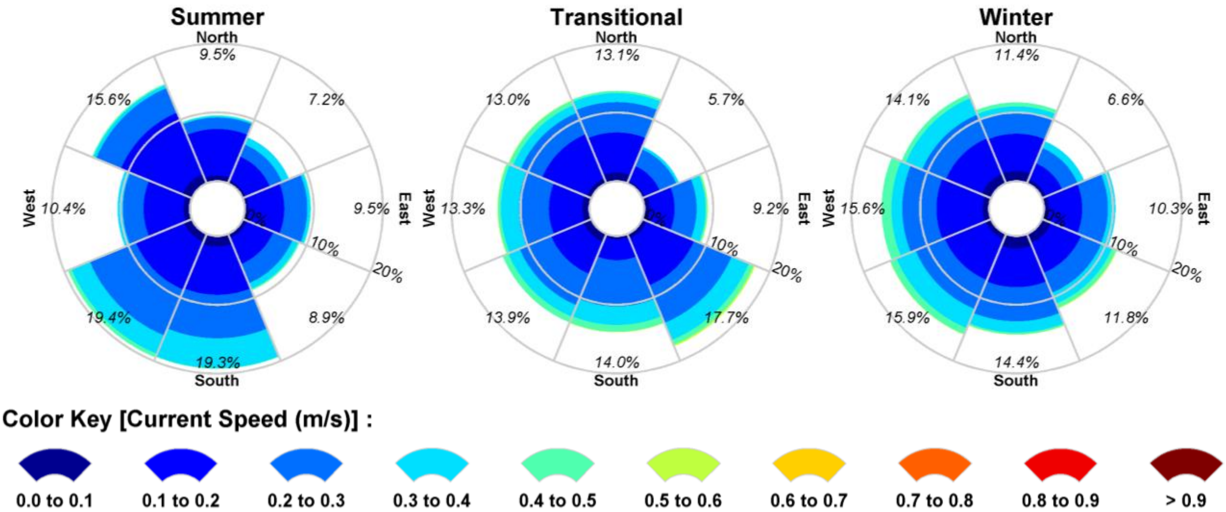


Figure 2.2 Seasonal current distribution (2006-2015, inclusive) derived from the BRAN database near to the proposed FPU location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

2.2.5.3 Tidal Circulation Model

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 25 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).

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 2.3).

Four layers of sub-gridding were 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. Approximately 98,600 cells were used to define the region.

Bathymetric data used to define the three-dimensional shape of the study domain was extracted from the CMAP electronic chart database and 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.

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.

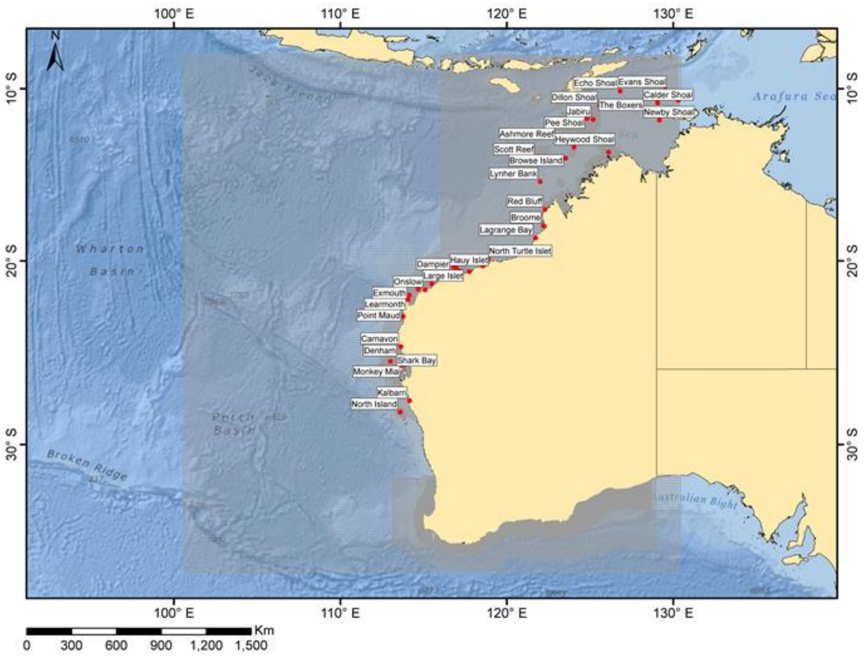
For the purpose of verification of the tidal predictions, the model output was compared against independent predictions of tides using the XTide database (Flater, 1998). The XTide database contains harmonic tidal constituents derived from measured water level data at locations around the world. Of more than 40 tidal stations within the HYDROMAP model domain, ten were used for comparison.

Water level time series for these locations are shown in Figure 2.4 for a one-month period (January 2005). 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 location. A scatter plot 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) is presented in Figure 2.5. 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 2.6 shows the seasonal distribution of current speeds and directions for the HYDROMAP data point closest to the FPU location. 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 northeast-southwest axis, with maximum speeds of around 0.09 m/s.



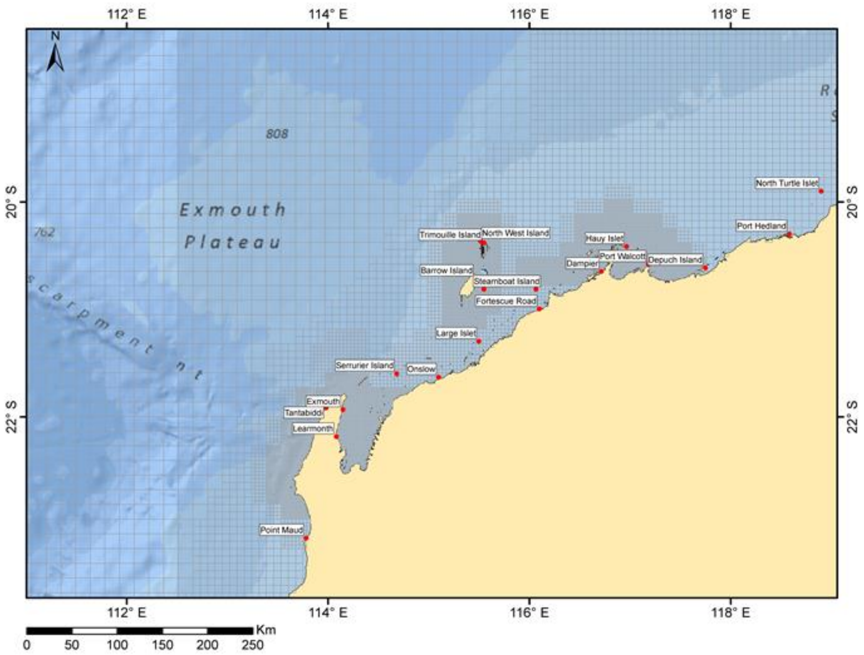


Figure 2.3 **Hydrodynamic model grid (grey wire mesh) used to generate the tidal currents, showing locations available for tidal comparisons (red labelled dots). The top panel shows the full domain in context with the continental land mass, while the bottom panel shows a zoomed subset near the discharge locations. Higher-resolution areas are indicated by the denser mesh zones.**

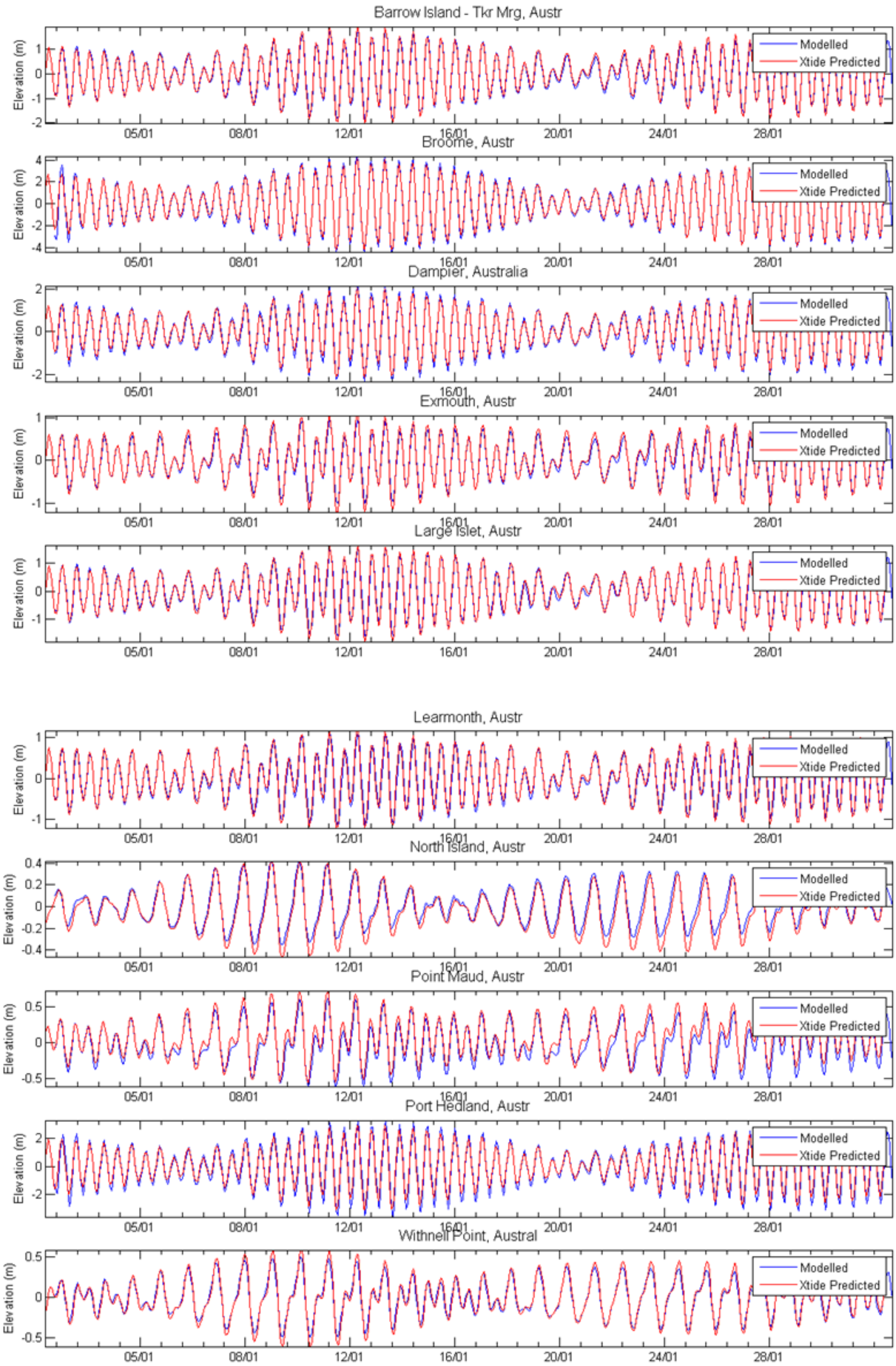
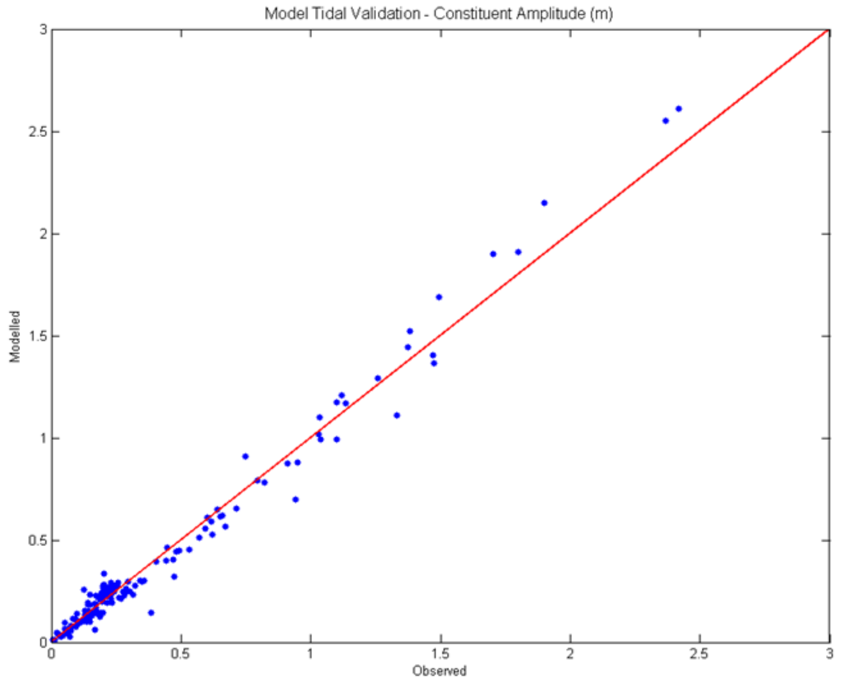


Figure 2.4 Comparisons between the predicted (blue line) and observed (red line) surface elevation variations at ten locations in the tidal model domain for January 2005.



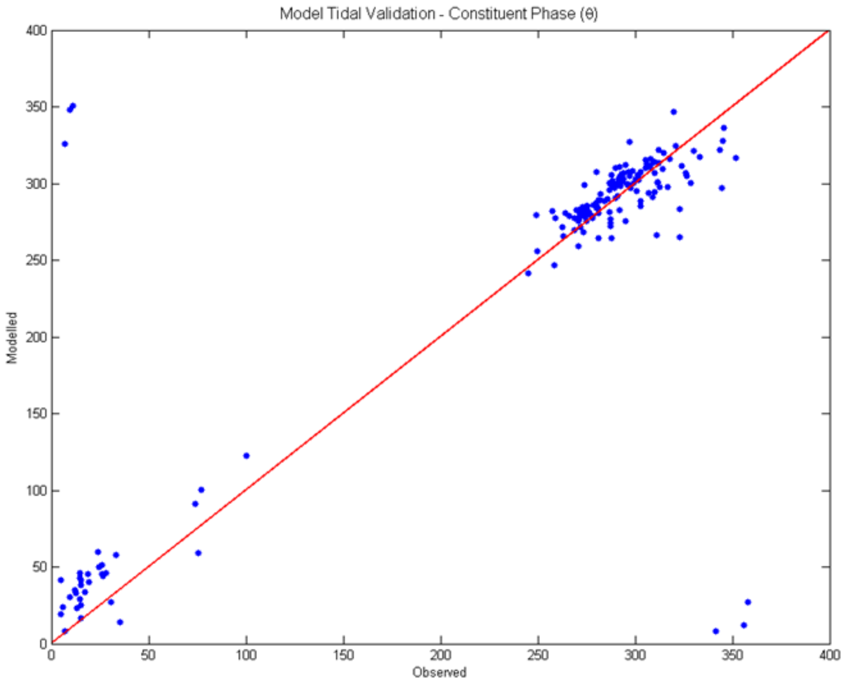


Figure 2.5 Comparisons between modelled and observed tidal constituent amplitudes (top) and phases (bottom) at all stations in the HYDROMAP model domain. The red line indicates a 1:1 correlation between the modelled and observed data.

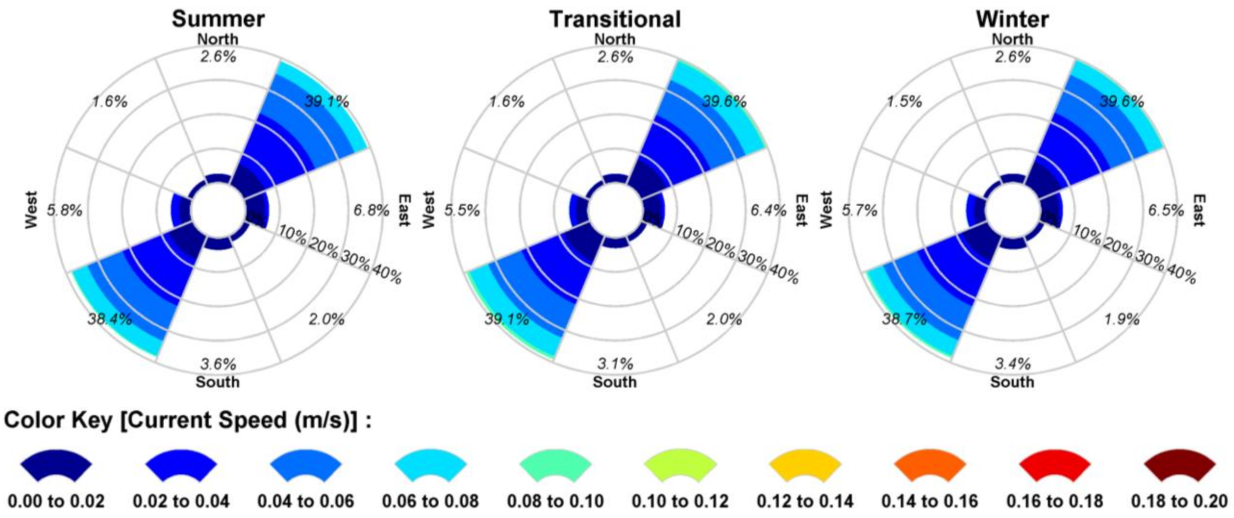


Figure 2.6 Seasonal current distribution (2006-2015, inclusive) derived from the HYDROMAP database near to the proposed FPU location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

3 MODELLING RESULTS

3.1 Near-Field Modelling

3.1.1 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 at the end of the near-field mixing zone, the concentration threshold, and the amount of dilution for each season and for the annual period. Any dilution rates indicated in red show that suitable dilution is not achieved during the near-field stage for at least one current-speed case.

Figure 3.1 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 (795 m^3/hr and 220 m^3/hr), depths (930 m and 10 m), seasonal conditions (summer, transitional, winter and annual) and current speeds (weak, medium and strong). The figures show the predicted horizontal distances 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 930 m (Cases 1 and 2) and 10 m (Case 3) below the water surface. The surface discharges are shown to increase the extent of the turbulent mixing zone. Following this initial mixing, the near neutrally-buoyant plumes are predicted to travel laterally in the water column. For Cases 1 and 2, the plumes are predicted to remain close to the seabed. For Case 3, the plume is predicted to plunge up to 19 m below the sea surface depending on season. For Cases 2 and 3, increased ambient current strengths are shown to increase the horizontal distance travelled by the plumes from the discharge point.

Table 3.1, Table 3.6 and Table 3.11 show the predicted plume characteristics for the varying discharge flow rates, depths, seasonal conditions and current speeds. The plume will reach a maximum horizontal distance of between 7 m and 152 m before reaching the trapping depth.

The diameter of the plume at the end of the near-field zone ranged from 10 m to 23 m. Increases in current speed serve to restrict the diameter of the plume.

For most combinations of season, flow rate and discharge depth, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to plunge further and reach the trapping depth closer to the discharge point, which slows the rate of dilution (Table 3.1, Table 3.6 and Table 3.11). The average dilution levels of the plume upon reaching the trapping depth under medium and strong currents are predicted to be 1:90 and 1:81 for Case 1, 1:465 and 1:629 for Case 2, and 1:482 and 1:641 for Case 3, respectively. Note that 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.

The results for the Case 1 (Section 3.1.2.1; Table 3.2 to Table 3.5), Case 2 (Section 3.1.2.2; Table 3.7 to Table 3.10) and Case 3 (Section 3.1.2.3; Table 3.12 to Table 3.15) discharges indicate that the biocide constituent of the hydrotest discharge is not expected to reach the required levels of dilution in the near-field mixing zone.

3.1.2 Results – Tables and Figures

3.1.2.1 Discharge Case 1: Trunkline Hydrotest Discharge at 930 m Depth

Table 3.1 Predicted plume characteristics at the end of the near-field mixing zone for the trunkline 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	
Summer	Weak (0.04)	10.0 [925.0]	5.74	0.00	52	97	23.8
	Medium (0.16)	10.0 [925.0]	5.74	0.00	52	90	21.1
	Strong (0.33)	10.0 [925.0]	5.74	0.00	55	81	18.1
Transitional	Weak (0.05)	10.0 [925.0]	5.71	0.00	52	97	23.7
	Medium (0.18)	10.0 [925.0]	5.71	0.00	53	90	21.0
	Strong (0.38)	10.0 [925.0]	5.71	0.00	54	78	17.2
Winter	Weak (0.04)	10.0 [925.0]	5.76	0.00	52	97	23.8
	Medium (0.17)	10.0 [925.0]	5.76	0.00	53	90	21.1
	Strong (0.40)	10.0 [925.0]	5.76	0.00	54	80	17.6
Annual	Weak (0.04)	10.0 [925.0]	5.73	0.00	52	97	23.8
	Medium (0.17)	10.0 [925.0]	5.73	0.00	53	90	21.0
	Strong (0.37)	10.0 [925.0]	5.73	0.00	55	80	17.6

Table 3.2 Concentration of biocide at the end of the near-field stage, and the required concentration threshold and number of dilutions for the summer season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 97, 90 and 81, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (ppm)	End of Near-Field Concentration (ppm)			Threshold Concentration (ppm)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		97x Dilution	90x Dilution	81x Dilution		
Biocide	550	5.7	6.1	6.8	1	550

Table 3.3 Concentration of biocide at the end of the near-field stage, and the required concentration threshold and number of dilutions for the transitional season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 97, 90 and 78, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (ppm)	End of Near-Field Concentration (ppm)			Threshold Concentration (ppm)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		97x Dilution	90x Dilution	78x Dilution		
Biocide	550	5.7	6.1	7.1	1	550

Table 3.4 Concentration of biocide at the end of the near-field stage, and the required concentration threshold and number of dilutions for the winter season. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 97, 90 and 80, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (ppm)	End of Near-Field Concentration (ppm)			Threshold Concentration (ppm)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		97x Dilution	90x Dilution	80x Dilution		
Biocide	550	5.7	6.1	6.9	1	550

Table 3.5 Concentration of biocide at the end of the near-field stage, and the required concentration threshold and number of dilutions for the annual period. Note from Table 3.1 that dilutions at the 5th, 50th and 95th percentile current speeds were 97, 90 and 80, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (ppm)	End of Near-Field Concentration (ppm)			Threshold Concentration (ppm)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		97x Dilution	90x Dilution	80x Dilution		
Biocide	550	5.7	6.1	6.9	1	550

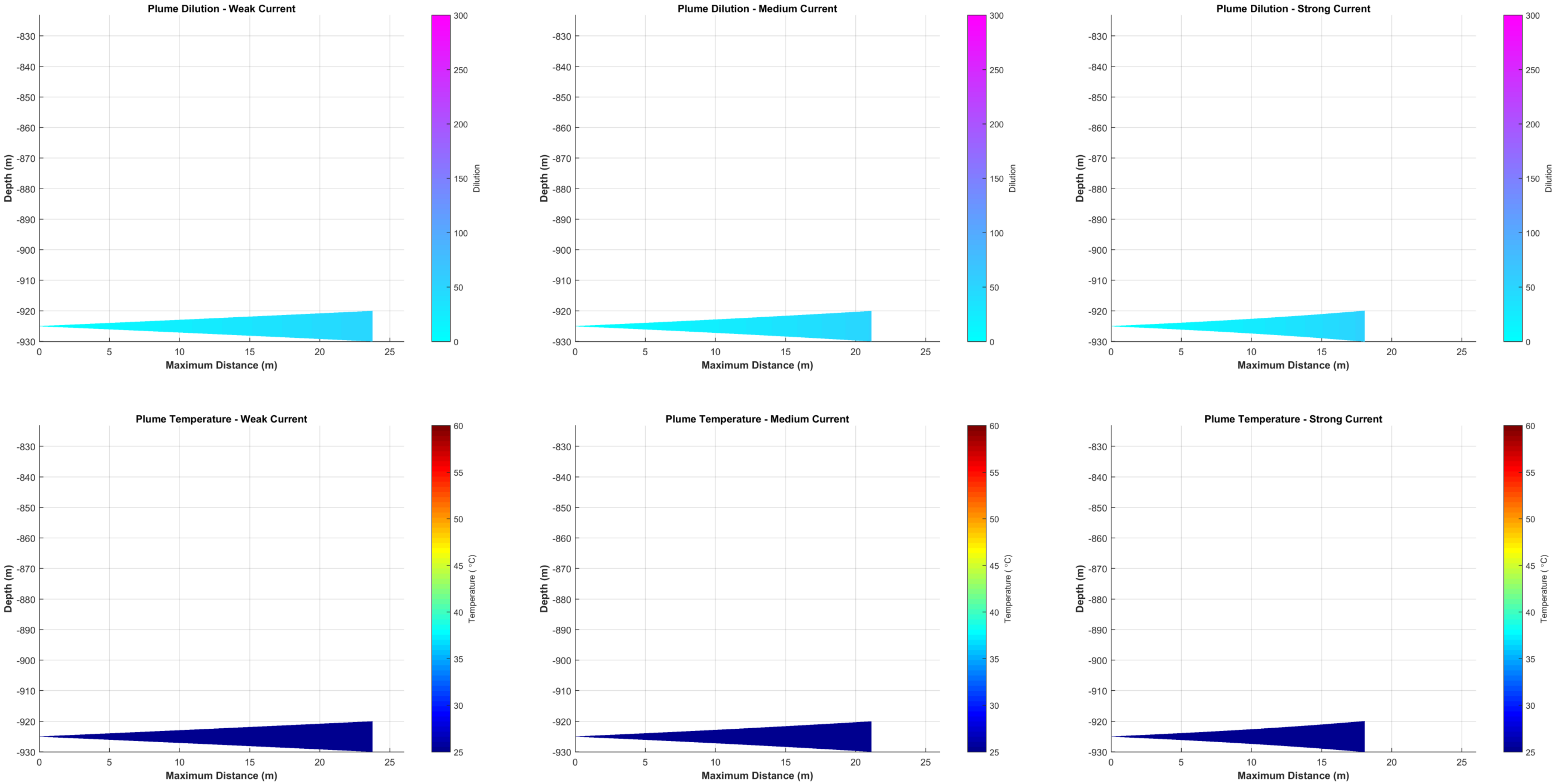


Figure 3.1 Near-field average dilution and temperature results for constant weak, medium and strong summer currents (930 m depth discharge at 795 m^3/hr flow rate).

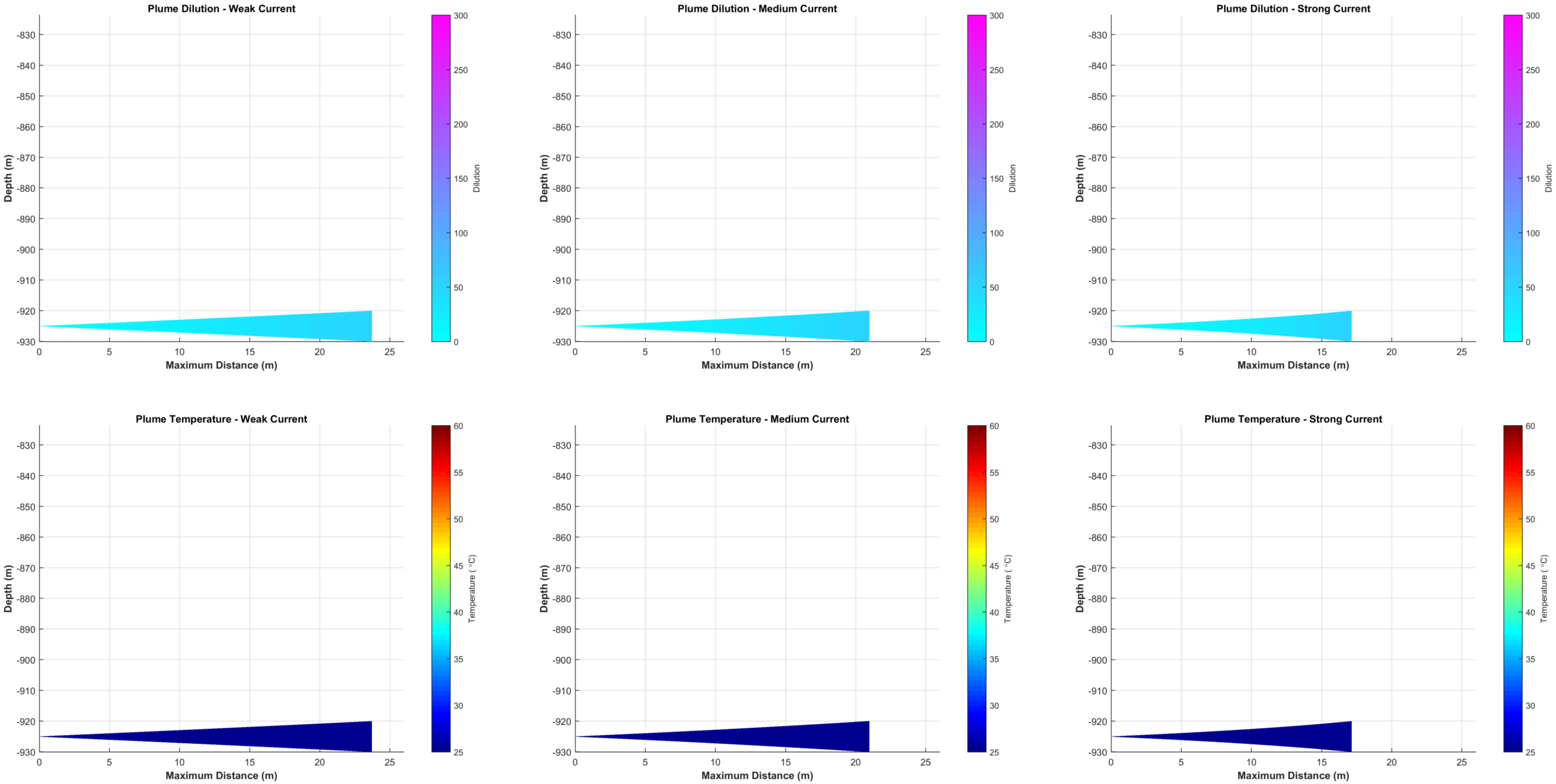


Figure 3.2 Near-field average dilution and temperature results for constant weak, medium and strong transitional currents (930 m depth discharge at 795 m^3/hr flow rate).

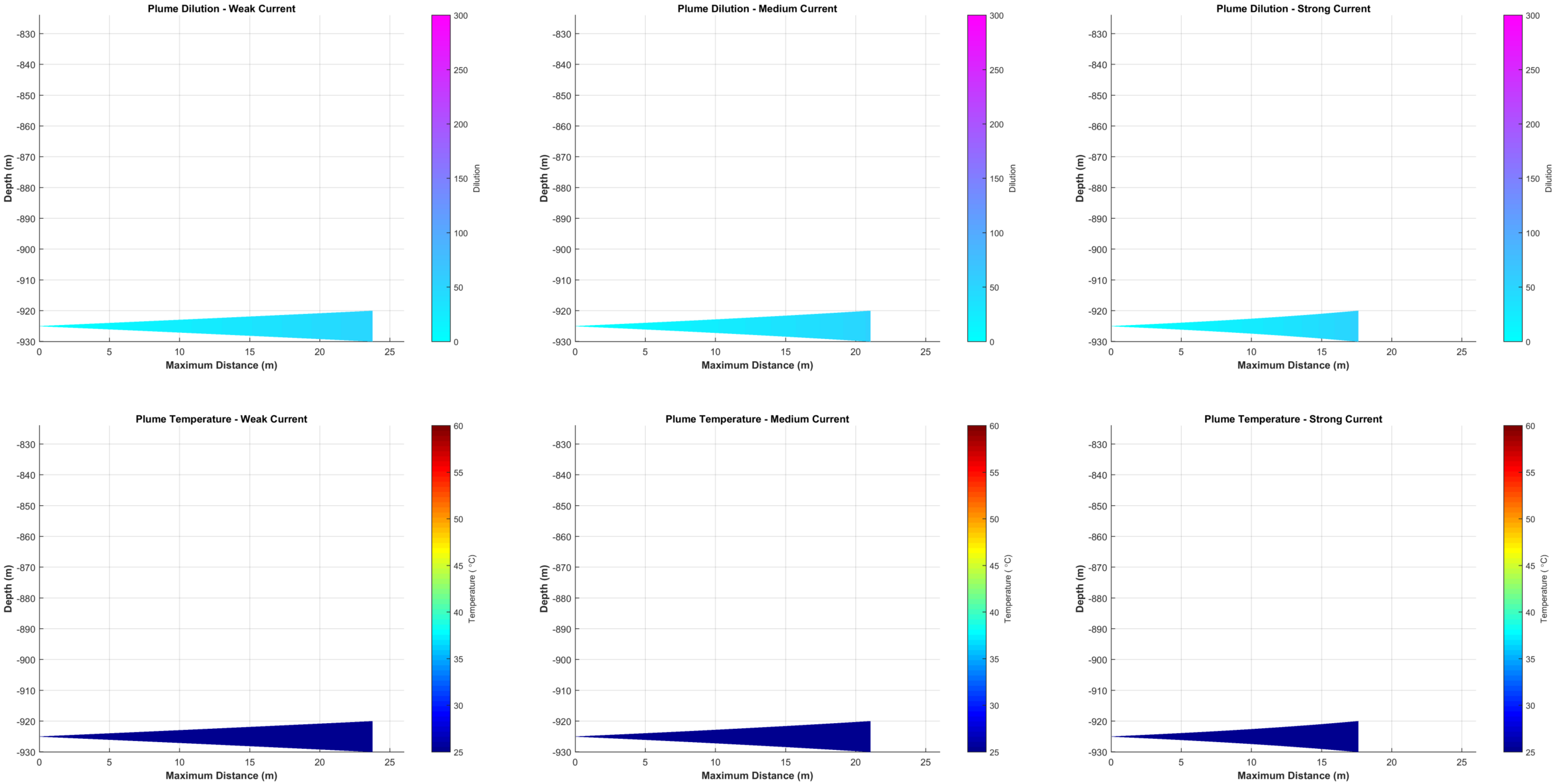


Figure 3.3 Near-field average dilution and temperature results for constant weak, medium and strong winter currents (930 m depth discharge at 795 m^3/hr flow rate).

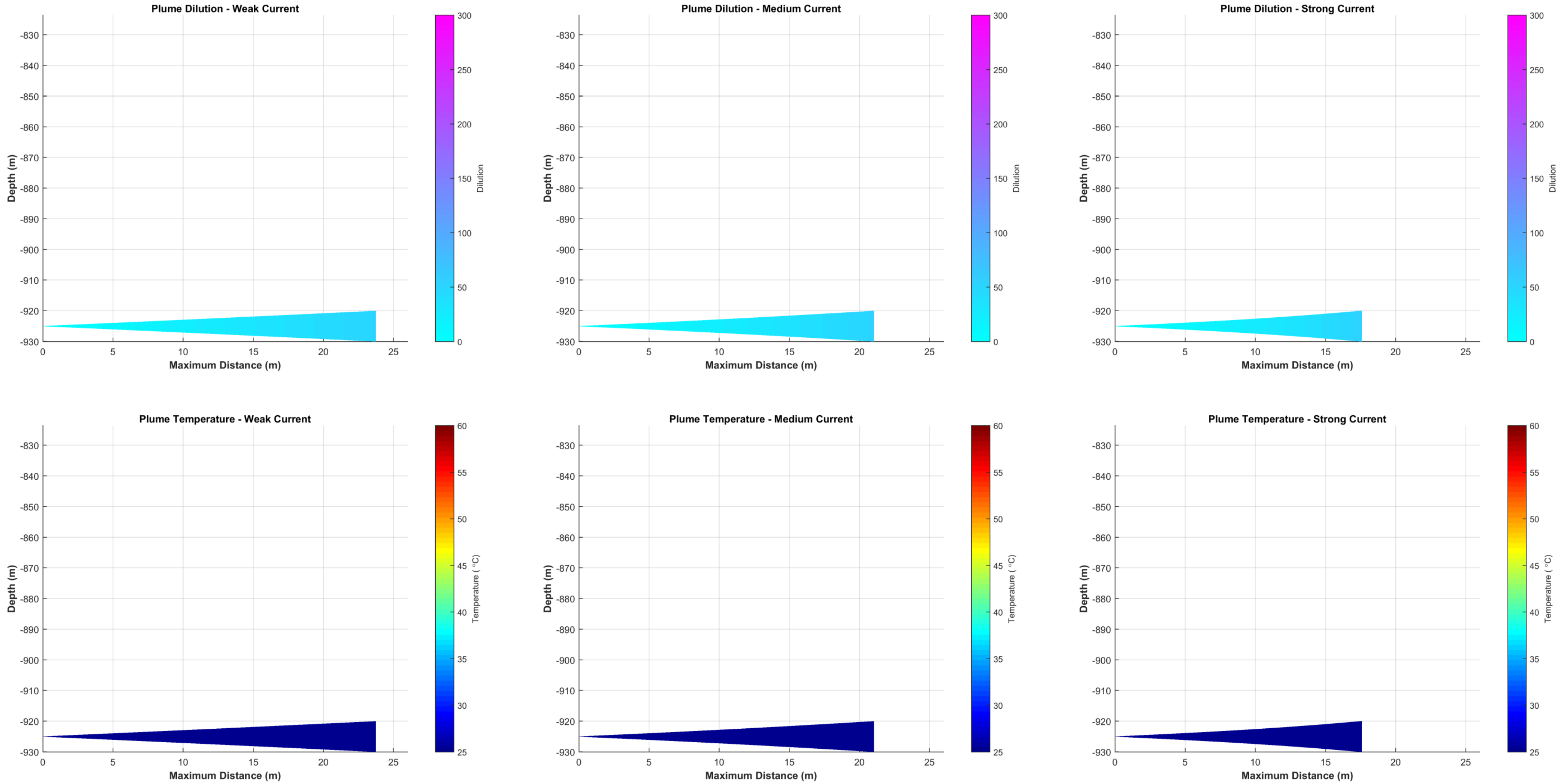


Figure 3.4 Near-field average dilution and temperature results for constant weak, medium and strong annualised currents (930 m depth discharge at 795 m^3/hr flow rate).

3.1.2.2 Discharge Case 2: SURF Hydrotest Discharge at 930 m Depth

Table 3.6 Predicted plume characteristics at the end of the near-field mixing zone for the SURF 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	
Summer	Weak (0.04)	16.4 [910.9]	6.11	0.00	85	173	9.6
	Medium (0.16)	22.9 [914.2]	6.10	0.00	119	426	35.8
	Strong (0.33)	18.9 [914.2]	6.01	0.00	151	581	74.7
Transitional	Weak (0.05)	17.6 [910.3]	6.07	0.00	89	188	11.6
	Medium (0.18)	22.8 [910.8]	6.04	0.00	127	465	41.9
	Strong (0.38)	18.4 [914.7]	5.95	0.00	163	629	89.4
Winter	Weak (0.04)	16.8 [910.5]	6.11	0.00	87	178	10.2
	Medium (0.17)	22.8 [910.4]	6.10	0.00	122	443	38.7
	Strong (0.40)	18.8 [914.5]	6.01	0.00	159	613	83.0
Annual	Weak (0.04)	17.1 [910.9]	6.09	0.00	88	182	10.6
	Medium (0.17)	22.9 [910.6]	6.07	0.00	123	448	39.2
	Strong (0.37)	18.7 [914.6]	5.98	0.00	159	615	83.7

Table 3.7 Concentration of biocide at the end of the near-field stage, and the required concentration threshold and number of dilutions for the summer season. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 173, 426 and 581, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (ppm)	End of Near-Field Concentration (ppm)			Threshold Concentration (ppm)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		173x Dilution	426x Dilution	581x Dilution		
Biocide	550	3.2	1.3	0.9	1	550

Table 3.8 Concentration of biocide at the end of the near-field stage, and the required concentration threshold and number of dilutions for the transitional season. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 188, 465 and 629, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (ppm)	End of Near-Field Concentration (ppm)			Threshold Concentration (ppm)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		188x Dilution	465x Dilution	629x Dilution		
Biocide	550	2.9	1.2	0.9	1	550

Table 3.9 Concentration of biocide at the end of the near-field stage, and the required concentration threshold and number of dilutions for the winter season. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 178, 443 and 613, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (ppm)	End of Near-Field Concentration (ppm)			Threshold Concentration (ppm)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		178x Dilution	443x Dilution	613x Dilution		
Biocide	550	3.1	1.2	0.9	1	550

Table 3.10 Concentration of biocide at the end of the near-field stage, and the required concentration threshold and number of dilutions for the annual period. Note from Table 3.6 that dilutions at the 5th, 50th and 95th percentile current speeds were 182, 448 and 615, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (ppm)	End of Near-Field Concentration (ppm)			Threshold Concentration (ppm)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		182x Dilution	448x Dilution	615x Dilution		
Biocide	550	3.0	1.2	0.9	1	550

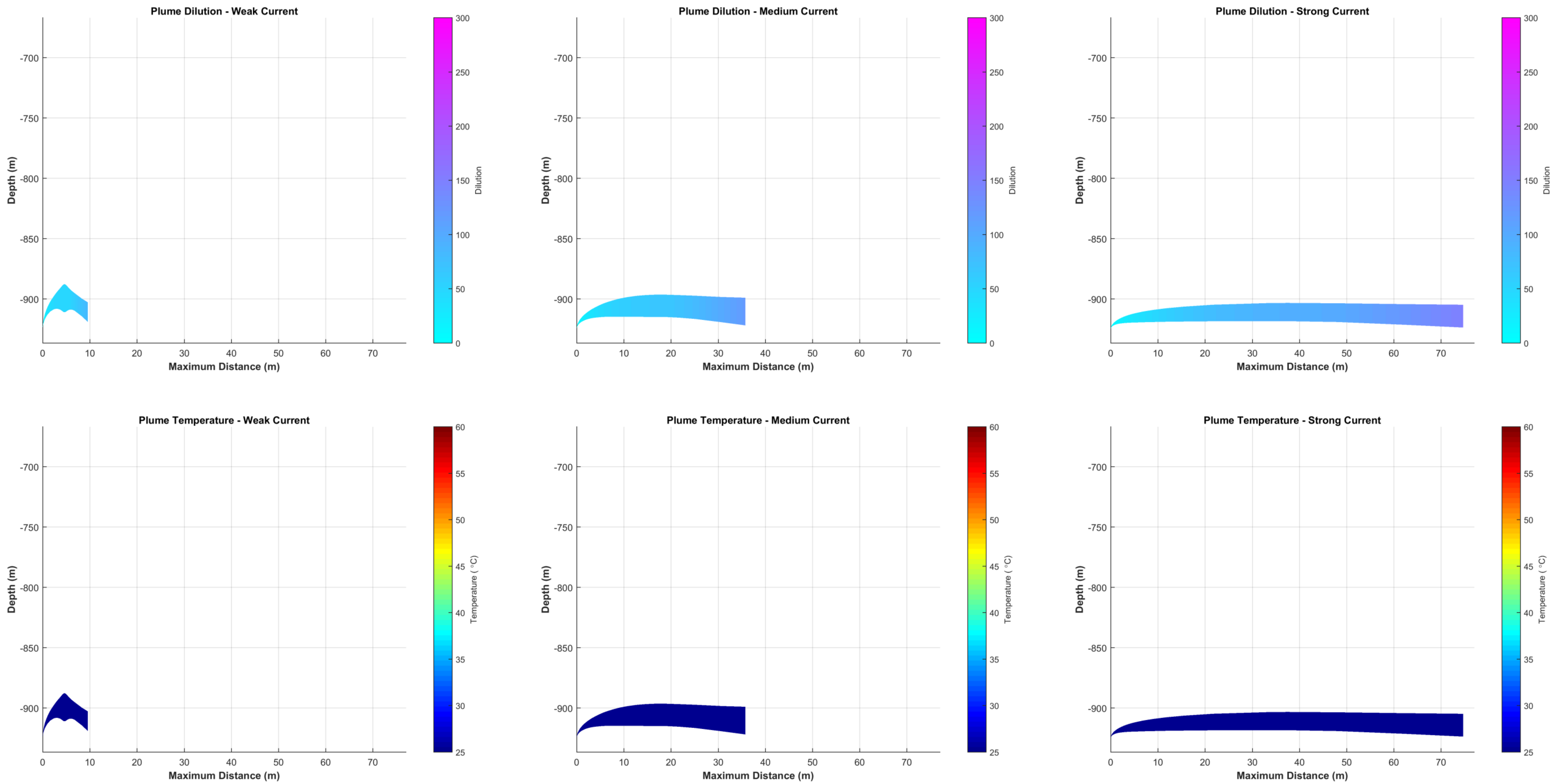


Figure 3.5 Near-field average dilution and temperature results for constant weak, medium and strong summer currents (930 m depth discharge at 220 m^3/hr flow rate).

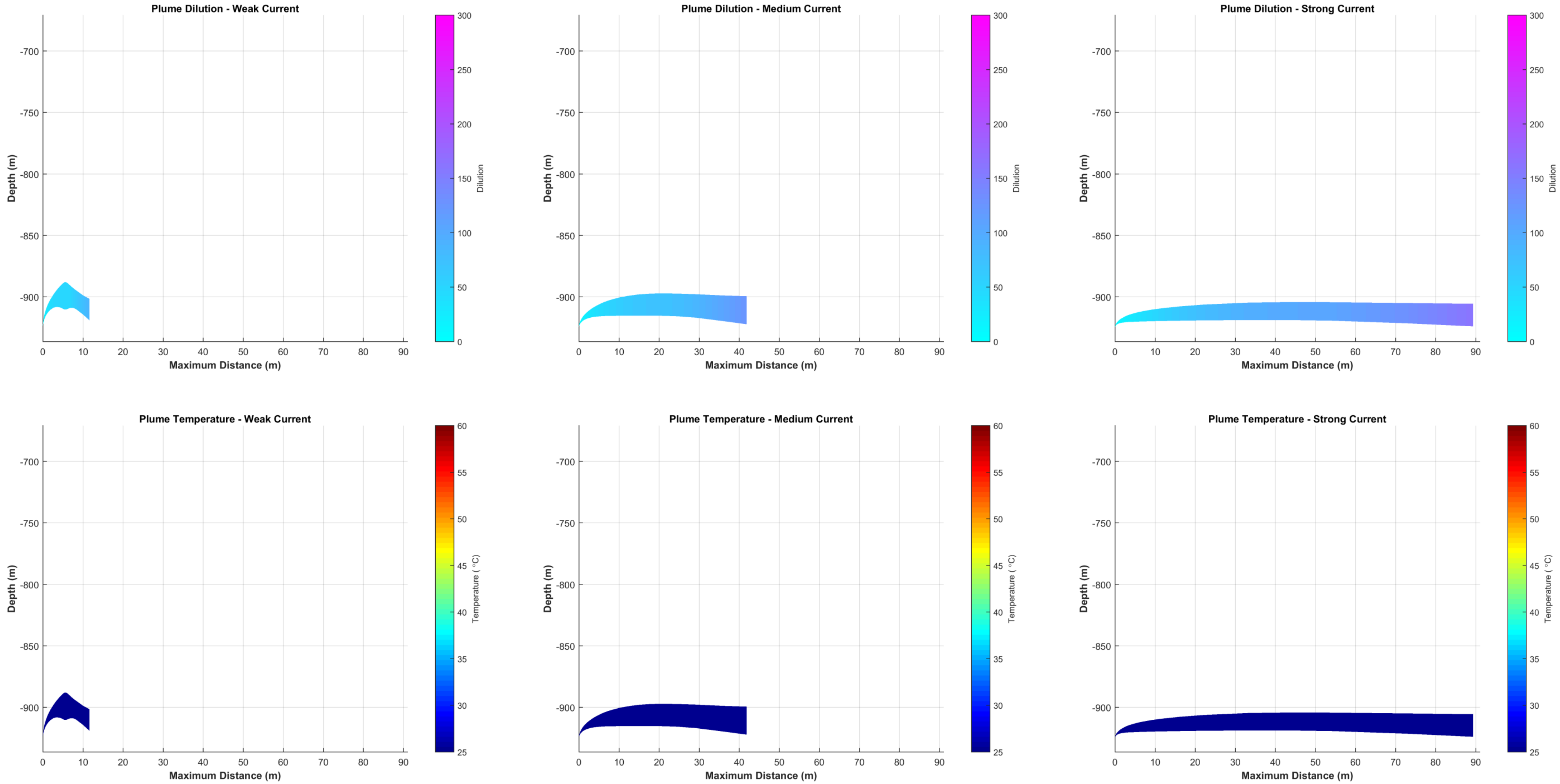


Figure 3.6 Near-field average dilution and temperature results for constant weak, medium and strong transitional currents (930 m depth discharge at 220 m³/hr flow rate).

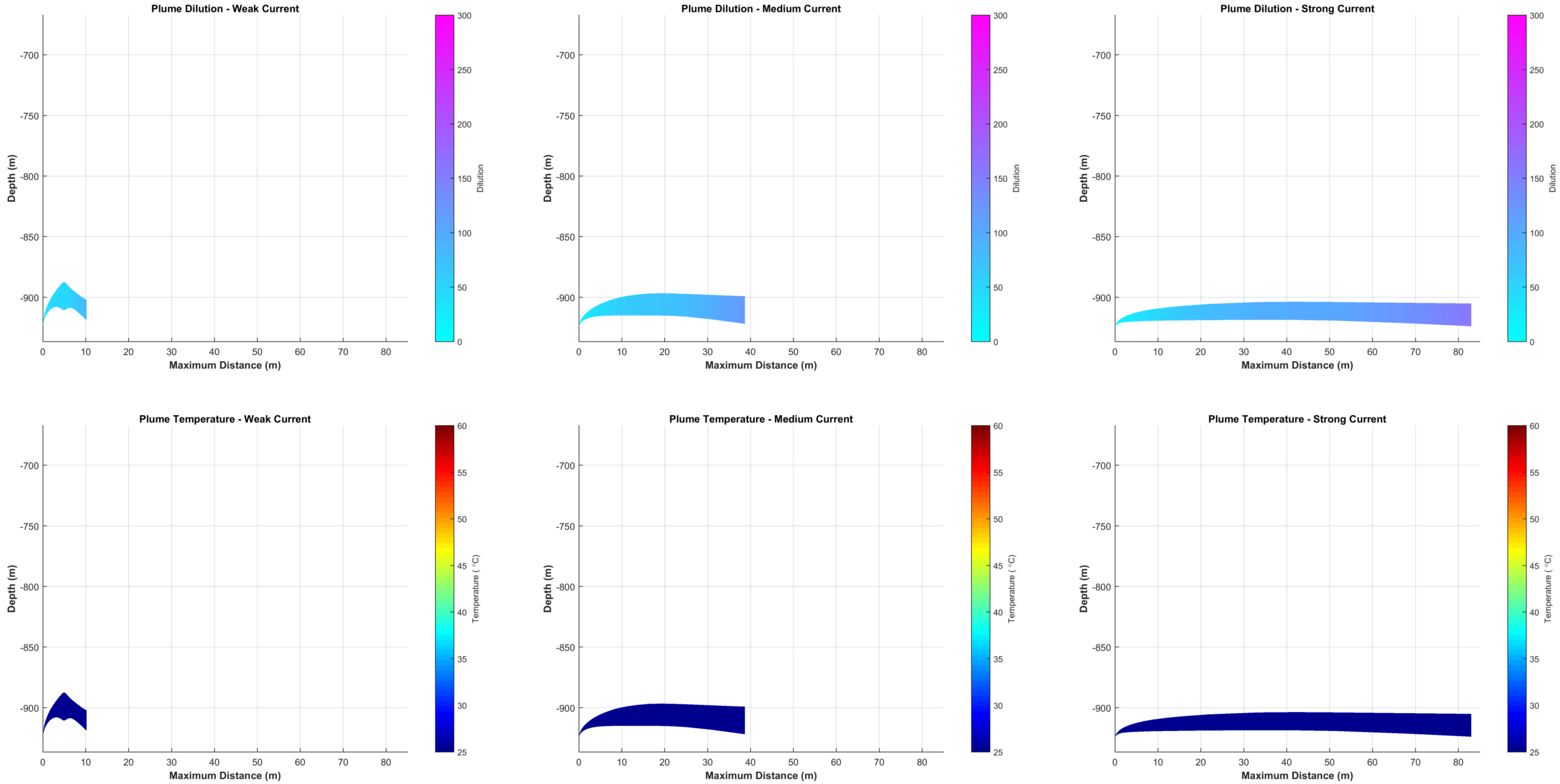


Figure 3.7 Near-field average dilution and temperature results for constant weak, medium and strong winter currents (930 m depth discharge at 220 m^3/hr flow rate).

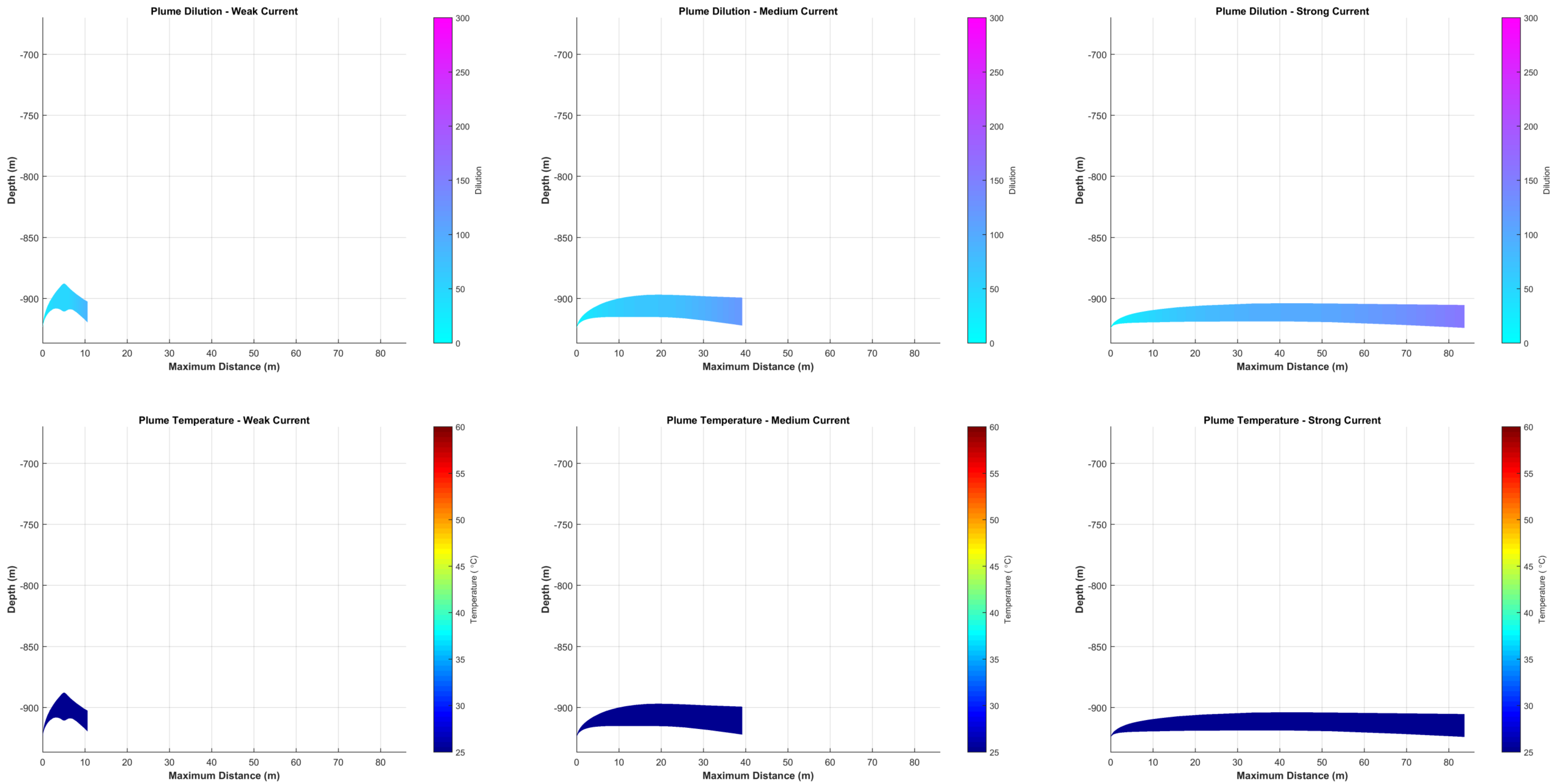


Figure 3.8 **Near-field average dilution and temperature results for constant weak, medium and strong annualised currents (930 m depth discharge at 220 m^3/hr flow rate).**

3.1.2.3 Discharge Case 3: SURF Hydrotest Discharge at 10 m Depth

Table 3.11 Predicted plume characteristics at the end of the near-field mixing zone for the SURF 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	
Summer	Weak (0.04)	15.1 [28.9]	27.40	0.00	42	118	7.5
	Medium (0.16)	12.2 [21.4]	27.40	0.00	77	229	29.7
	Strong (0.33)	9.8 [18.2]	27.50	0.00	101	395	63.0
Transitional	Weak (0.05)	16.8 [21.8]	25.60	0.00	77	211	17.3
	Medium (0.18)	14.8 [17.9]	25.70	0.00	128	496	69.3
	Strong (0.38)	11.5 [15.6]	25.70	0.00	162	629	144.4
Winter	Weak (0.04)	16.7 [21.9]	26.00	0.00	77	207	16.8
	Medium (0.17)	14.8 [18.2]	26.00	0.00	125	482	65.8
	Strong (0.40)	11.3 [15.5]	26.10	0.00	165	641	151.7
Annual	Weak (0.04)	16.4 [22.1]	26.20	0.00	76	201	16.2
	Medium (0.17)	14.9 [18.3]	26.20	0.00	124	480	64.9
	Strong (0.37)	11.5 [15.6]	26.30	0.00	162	629	143.2

Table 3.12 Concentration of biocide at the end of the near-field stage, and the required concentration threshold and number of dilutions for the summer season. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 118, 229 and 395, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (ppm)	End of Near-Field Concentration (ppm)			Threshold Concentration (ppm)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		118x Dilution	229x Dilution	395x Dilution		
Biocide	550	4.7	2.4	1.4	1	550

Table 3.13 Concentration of biocide at the end of the near-field stage, and the required concentration threshold and number of dilutions for the transitional season. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 211, 496 and 629, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (ppm)	End of Near-Field Concentration (ppm)			Threshold Concentration (ppm)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		211x Dilution	496x Dilution	629x Dilution		
Biocide	550	2.6	1.1	0.9	1	550

Table 3.14 Concentration of biocide at the end of the near-field stage, and the required concentration threshold and number of dilutions for the winter season. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 207, 482 and 641, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (ppm)	End of Near-Field Concentration (ppm)			Threshold Concentration (ppm)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		207x Dilution	482x Dilution	641x Dilution		
Biocide	550	2.7	1.1	0.9	1	550

Table 3.15 Concentration of biocide at the end of the near-field stage, and the required concentration threshold and number of dilutions for the annual period. Note from Table 3.11 that dilutions at the 5th, 50th and 95th percentile current speeds were 201, 480 and 629, respectively. Dilution rates highlighted in red indicate that suitable dilution is not achieved during the near-field stage.

Contaminant	Source Concentration (ppm)	End of Near-Field Concentration (ppm)			Threshold Concentration (ppm)	Required Dilution Factor
		5th %ile	50th %ile	95th %ile		
		201x Dilution	480x Dilution	629x Dilution		
Biocide	550	2.7	1.1	0.9	1	550

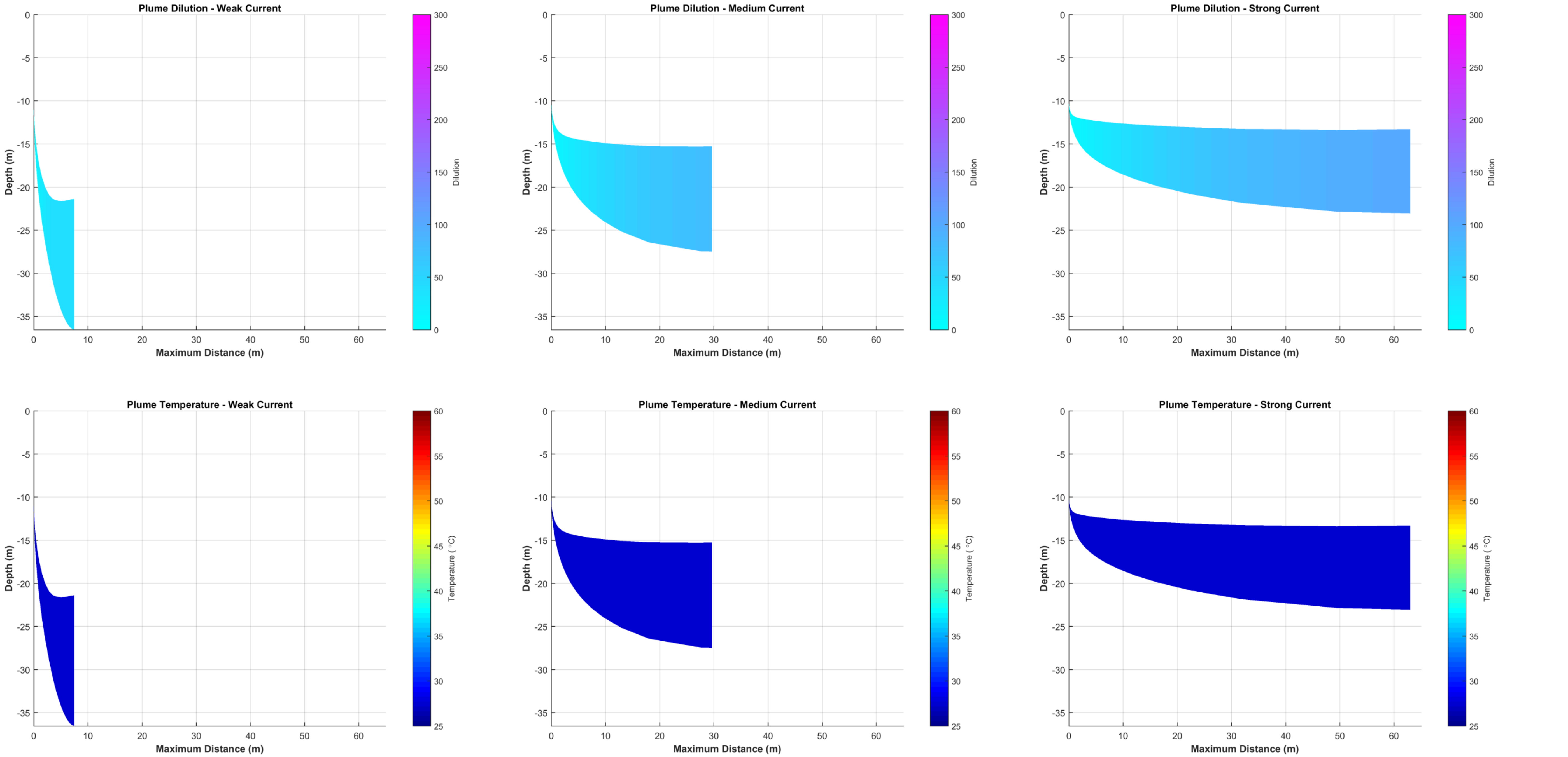


Figure 3.9 **Near-field average dilution and temperature results for constant weak, medium and strong summer currents (10 m depth discharge at 220 m^3/hr flow rate).**

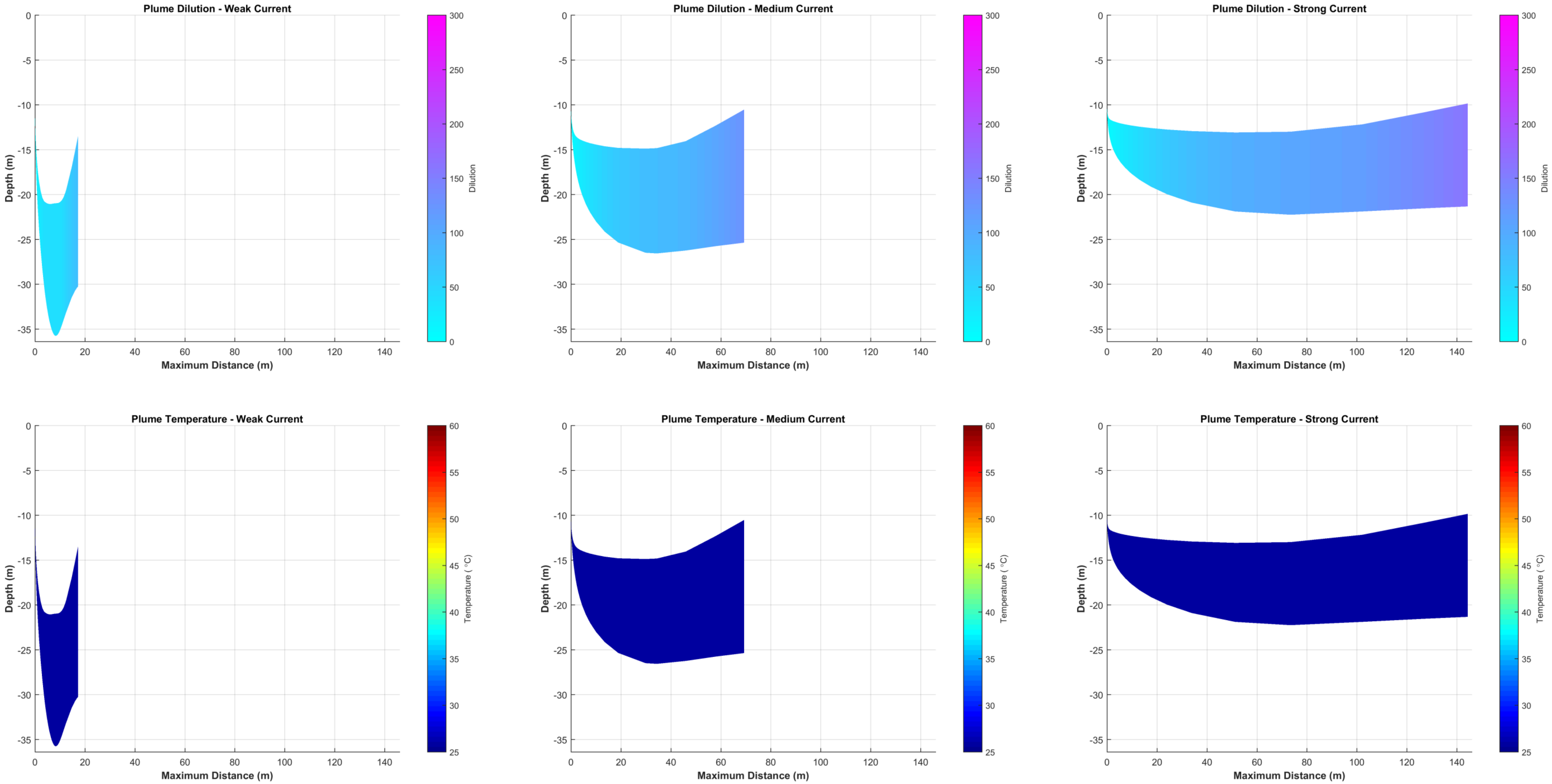


Figure 3.10 Near-field average dilution and temperature results for constant weak, medium and strong transitional currents (10 m depth discharge at 220 m^3/hr flow rate).

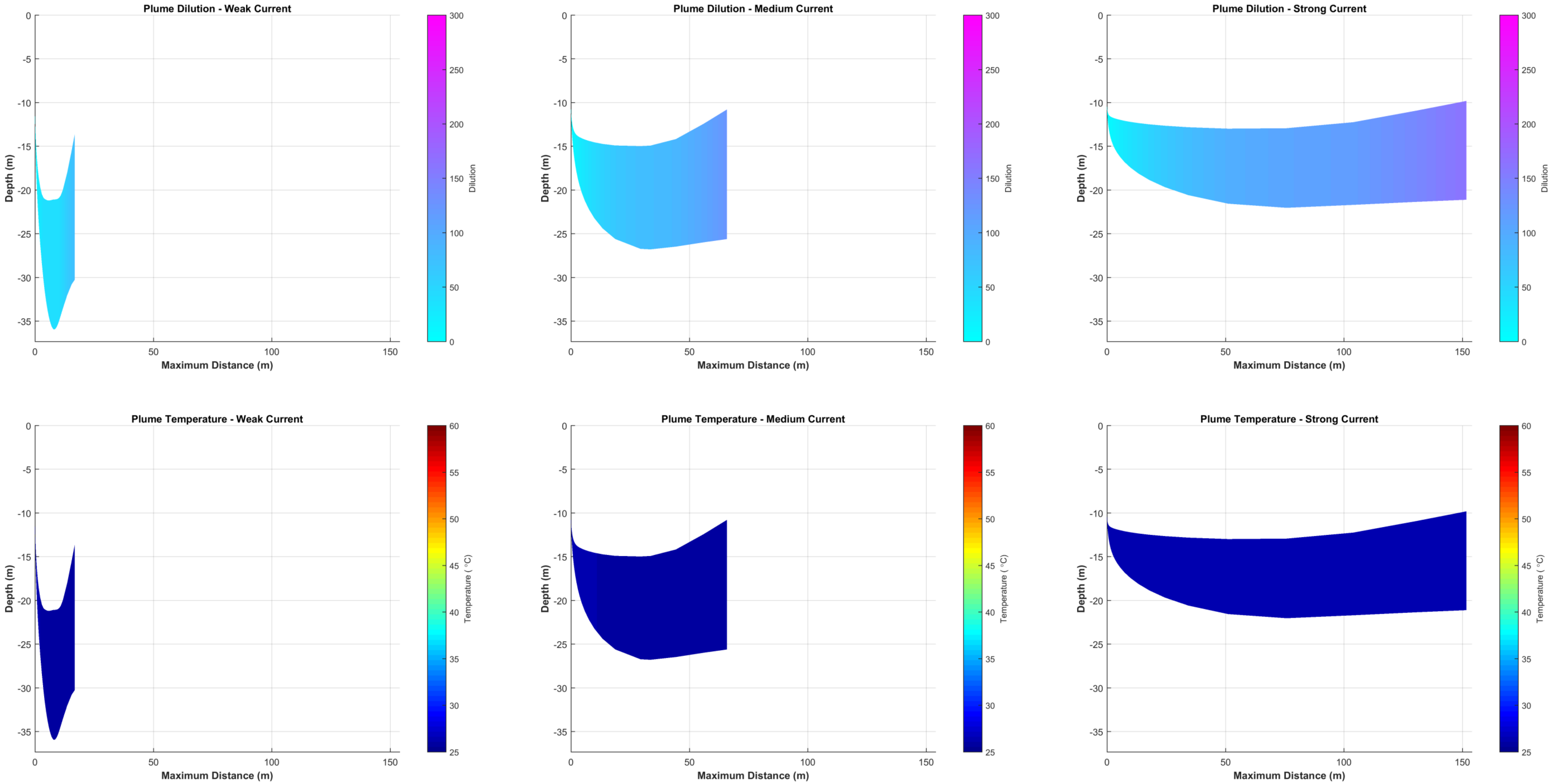


Figure 3.11 Near-field average dilution and temperature results for constant weak, medium and strong winter currents (10 m depth discharge at 220 m^3/hr flow rate).

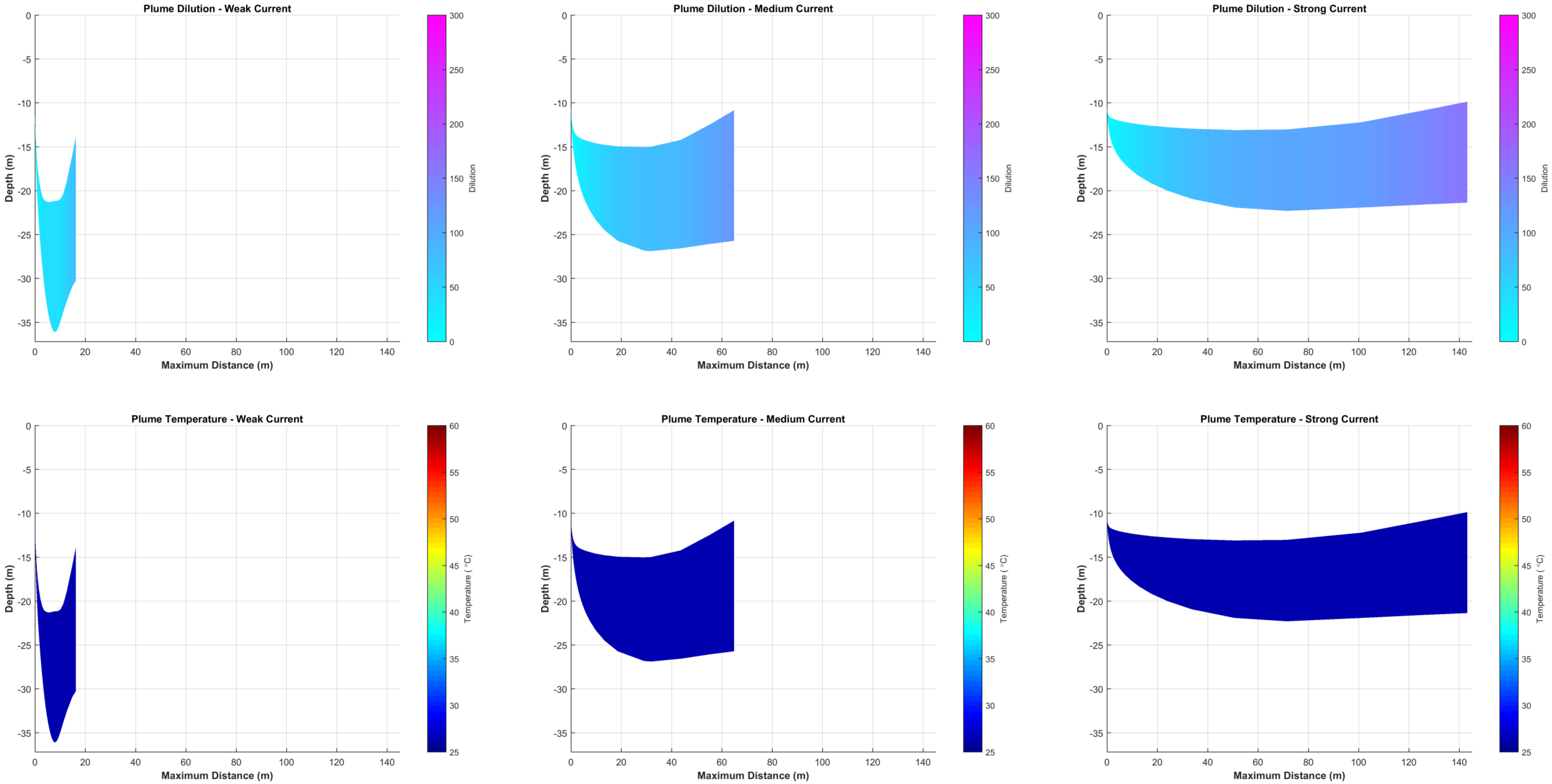


Figure 3.12 Near-field average dilution and temperature results for constant weak, medium and strong annualised currents (10 m depth discharge at 220 m³/hr flow rate).

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 and 99th percentile dilution contours are presented.

Calculation of 95th and 99th 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 of 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 the plume extents shown in Figure 3.13 with those shown in Sections 3.2.4 and 3.2.5 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 contaminant concentrations in the receiving waters to the initial concentration of the contaminant 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 3.16 summarises the initial concentrations of biocide, as specified, and the equivalent dispersed concentrations required to yield particular dilution levels (1:100, 1:200 and 1:400). These concentrations may be useful to consider when interpreting the contour plots of percentile dilutions.

Table 3.16 Initial concentrations of biocide and equivalent concentrations at example dilution levels.

Biocide Parameter	Biocide Concentration (mg/L)
Initial concentration in discharge	550.0
Initial concentration in receiving waters	0.0
Concentration at 1:100 dilution	5.5
Concentration at 1:200 dilution	2.75
Concentration at 1:400 dilution	1.375

3.2.3 General Observations

Figure 3.13 shows example time series snapshots of predicted dilutions during a single simulation at 3-hour intervals from 04:00 to 19:00 on 4th February 2010. This simulation – selected merely to be representative of typical conditions – considers the Case 1 flow rate of 795 m^3/d at 930 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. 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.

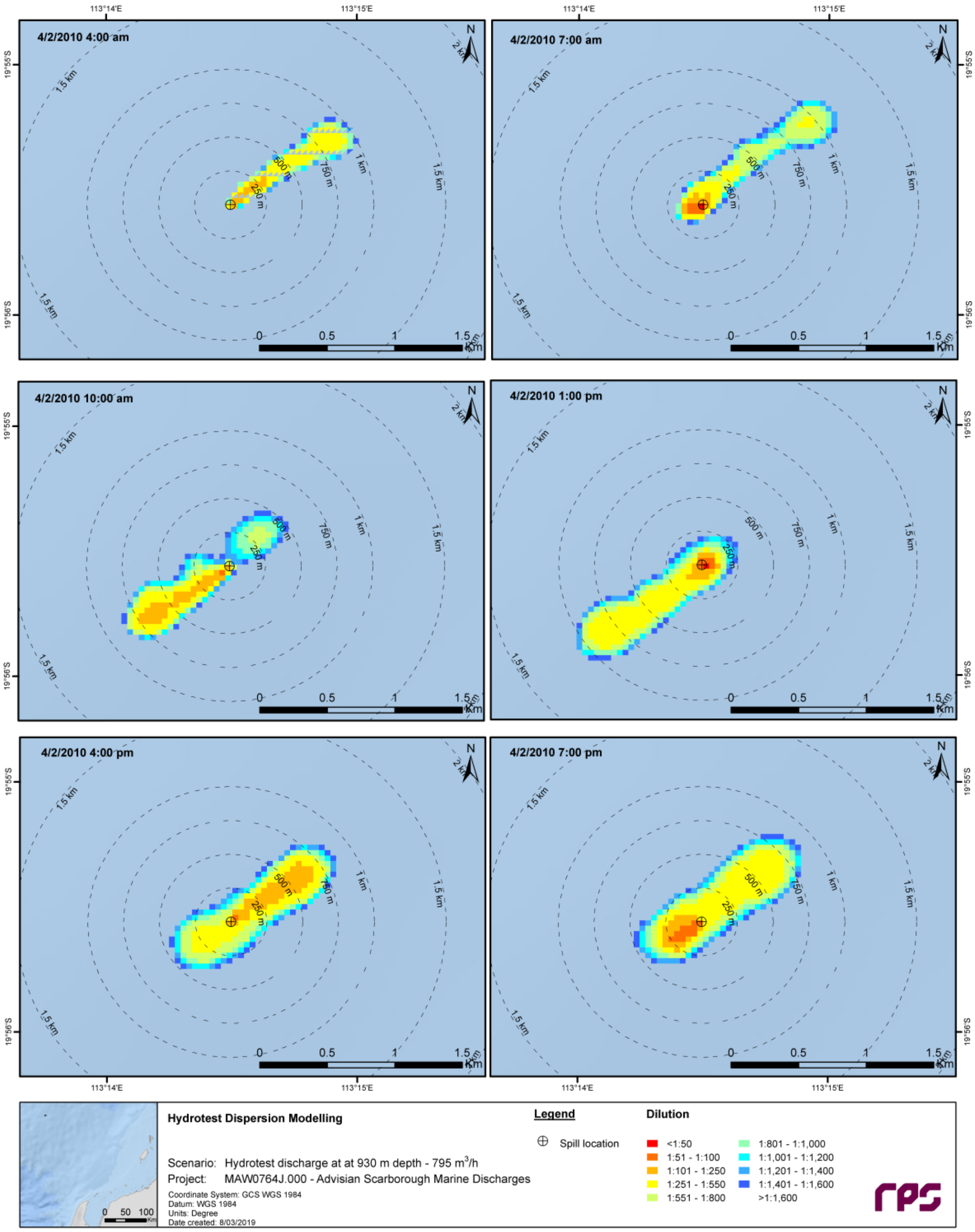


Figure 3.13 Snapshots of predicted dilution levels, at 3-hour intervals from 04:00 to 19:00 on 4th February 2010, for Case 1 (930 m depth discharge at 795 m³/hr flow rate).

3.2.4 Seasonal Analysis

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 3.17 and Table 3.18 summarise, for Cases 1 and 3 respectively, the minimum dilution achieved at specific radial distances from the discharge location for each season and percentile.

Table 3.19 and Table 3.20 provide, for Cases 1 and 3 respectively, summaries of the maximum distances from the discharge location to achieve 1:550 dilution 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. For Case 1, dilution to reach threshold concentration is achieved for biocide within an area of influence ranging from 1,173 m to 1,196 m at the 95th percentile across all seasons (Table 3.19). For Case 3, the maximum spatial extent of the relevant dilution contour is 18 m at the 95th percentile across all seasons (Table 3.20). The greatest spatial extents are observed in the transitional months.

Table 3.21 and Table 3.22 provide, for Cases 1 and 3 respectively, summaries of the total area of coverage for the 1:550 dilution contour for each season and percentile. For Case 1, the area of exposure defined by the relevant dilution contour is predicted to reach maximums of 2.21 km^2 to 2.30 km^2 at the 95th percentile (Table 3.21). For Case 3, the corresponding maximum area of exposure is <0.01 km^2 at the 95th percentile (Table 3.22).

Table 3.23 and Table 3.24 provide, for Cases 1 and 3 respectively, summaries of the maximum depths from the discharge location to achieve 1:550 dilution for each season and percentile. Maximum depths are predicted as 930 m (seabed; all seasons) and 12 m (all seasons) for Case 1 and Case 3, respectively.

For Cases 1 and 3, Figure 3.14 to Figure 3.25 show the aggregated spatial extents of the minimum dilutions for each season and percentile. 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.

Table 3.17 Minimum dilution achieved at specific radial distances from the hydrotest discharge location in each season for Case 1 (930 m depth discharge at 795 m^3/hr flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location																
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km	1.10 km	1.20 km	1.30 km	1.40 km	1.50 km
95^{th}	Summer	1:21.7	1:31.0	1:36.8	1:52.0	1:63.9	1:74.5	1:81.9	1:90.5	1:104.3	1:117.2	1:153.8	1:208.9	1:314.0	1:453.5	1:666.7	1:952.8	1:1,444.3
	Transitional	1:20.7	1:30.1	1:35.1	1:49.6	1:62.9	1:73.9	1:84.0	1:93.4	1:105.0	1:114.0	1:138.9	1:181.4	1:273.4	1:400.2	1:603.2	1:869.8	1:1,386.1
	Winter	1:21.8	1:31.8	1:37.3	1:53.3	1:65.3	1:76.5	1:84.8	1:93.1	1:104.3	1:112.3	1:133.6	1:173.2	1:261.2	1:394.9	1:595.8	1:875.4	1:1,324.8
99^{th}	Summer	1:18.5	1:24.6	1:30.5	1:41.4	1:51.0	1:59.1	1:65.9	1:73.4	1:83.1	1:90.6	1:103.9	1:120.1	1:168.1	1:243.5	1:382.9	1:557.4	1:825.5
	Transitional	1:17.6	1:24.2	1:28.1	1:39.9	1:50.6	1:59.7	1:68.4	1:75.6	1:83.3	1:90.0	1:99.4	1:106.8	1:126.3	1:174.2	1:275.8	1:428.9	1:632.9
	Winter	1:18.6	1:25.4	1:30.3	1:42.4	1:52.7	1:60.8	1:68.0	1:75.4	1:82.8	1:89.0	1:98.1	1:106.8	1:130.2	1:180.9	1:281.6	1:438.6	1:682.9

Table 3.18 Minimum dilution achieved at specific radial distances from the hydrotest discharge location in each season for Case 3 (10 m depth discharge at 220 m^3/hr flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location																
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km	1.10 km	1.20 km	1.30 km	1.40 km	1.50 km
95^{th}	Summer	1:501.3	1:930.5	1:1,243.6	>1:10,000	>1:10,000	>1:10,000	>1:10,000	>1:10,000	-	-	-	-	-	-	-	-	-
	Transitional	1:489.5	1:1,450.3	1:1,594.5	>1:10,000	>1:10,000	>1:10,000	>1:10,000	>1:10,000	-	-	-	-	-	-	-	-	-
	Winter	1:387.1	1:1,002.1	1:1,149.9	>1:10,000	>1:10,000	>1:10,000	-	-	-	-	-	-	-	-	-	-	-
99^{th}	Summer	1:309.1	1:367.1	1:435.1	1:775.8	1:1,050.9	1:1,370.6	1:1,758.5	1:2,007.1	1:2,315.7	1:2,609.9	1:2,699.5	1:3,124.9	1:3,346.2	1:3,724.6	1:4,147.3	1:4,531.2	1:4,793.6
	Transitional	1:335.7	1:330.3	1:431.6	1:697.9	1:966.3	1:1,316.0	1:1,569.5	1:1,828.7	1:2,124.7	1:2,297.0	1:2,604.5	1:2,838.4	1:3,174.4	1:3,525.3	1:3,450.6	1:3,980.1	1:4,042.6
	Winter	1:160.9	1:279.8	1:320.5	1:600.5	1:779.8	1:1,129.1	1:1,364.3	1:1,609.3	1:1,881.9	1:2,202.9	1:2,595.3	1:2,937.8	1:3,472.2	1:3,580.6	1:3,938.0	1:4,743.0	1:5,882.2

Table 3.19 Maximum distance from the hydrotest discharge location to achieve 1:550 dilution in each season for Case 1 (930 m depth discharge at 795 m^3/hr flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Summer	1,173
	Transitional	1,196
	Winter	1,196
99th	Summer	1,317
	Transitional	1,388
	Winter	1,373
100th	Summer	1,532
	Transitional	1,564
	Winter	1,551

Table 3.20 Maximum distance from the hydrotest discharge location to achieve 1:550 dilution in each season for Case 3 (10 m depth discharge at 220 m^3/hr flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Summer	18
	Transitional	18
	Winter	18
99th	Summer	82
	Transitional	91
	Winter	124
100th	Summer	630
	Transitional	292
	Winter	1,147

Table 3.21 Total area of coverage for 1:550 dilution in each season for Case 1 (930 m depth discharge at 795 m^3/hr flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Summer	2.213
	Transitional	2.266
	Winter	2.298
99th	Summer	2.751
	Transitional	2.902
	Winter	2.900
100th	Summer	3.531
	Transitional	3.699
	Winter	3.596

Table 3.22 Total area of coverage for 1:550 dilution in each season for Case 3 (10 m depth discharge at 220 m^3/hr flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Summer	0.002
	Transitional	0.002
	Winter	0.002
99th	Summer	0.011
	Transitional	0.010
	Winter	0.029
100th	Summer	0.144
	Transitional	0.108
	Winter	0.495

Table 3.23 Maximum depth from the hydrotest discharge location to achieve 1:550 dilution in each season for Case 1 (930 m depth discharge at 795 m^3/hr flow rate).

Season	Maximum depth (m) from discharge location to achieve given dilution
Summer	930 (seabed)
Transitional	930 (seabed)
Winter	930 (seabed)

Table 3.24 Maximum depth from the hydrotest discharge location to achieve 1:550 dilution in each season for Case 3 (10 m depth discharge at 220 m^3/hr flow rate).

Season	Maximum depth (m) from discharge location to achieve given dilution
Summer	12
Transitional	12
Winter	12

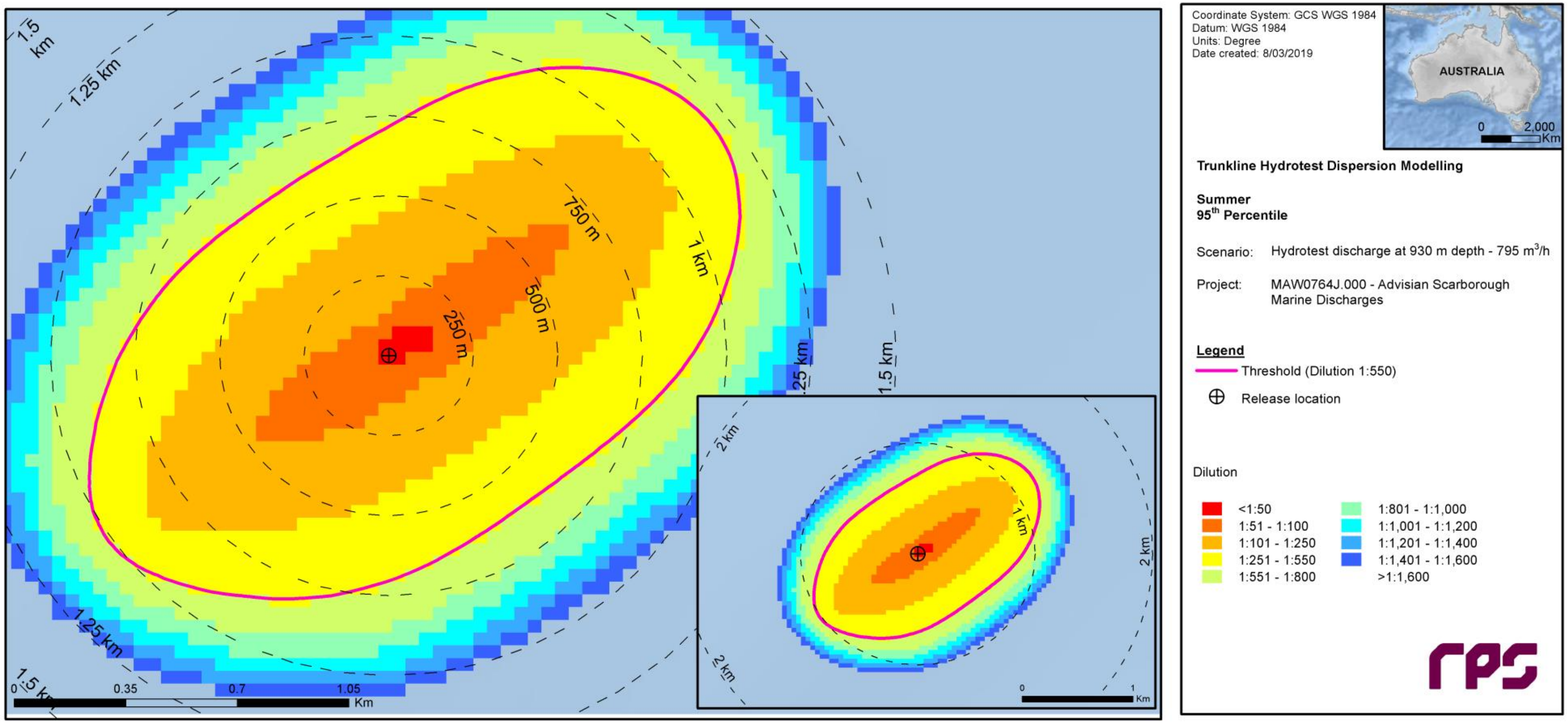


Figure 3.14 Predicted minimum dilutions at the 95th percentile under summer conditions for Case 1 (930 m depth discharge at 795 m^3/hr flow rate).

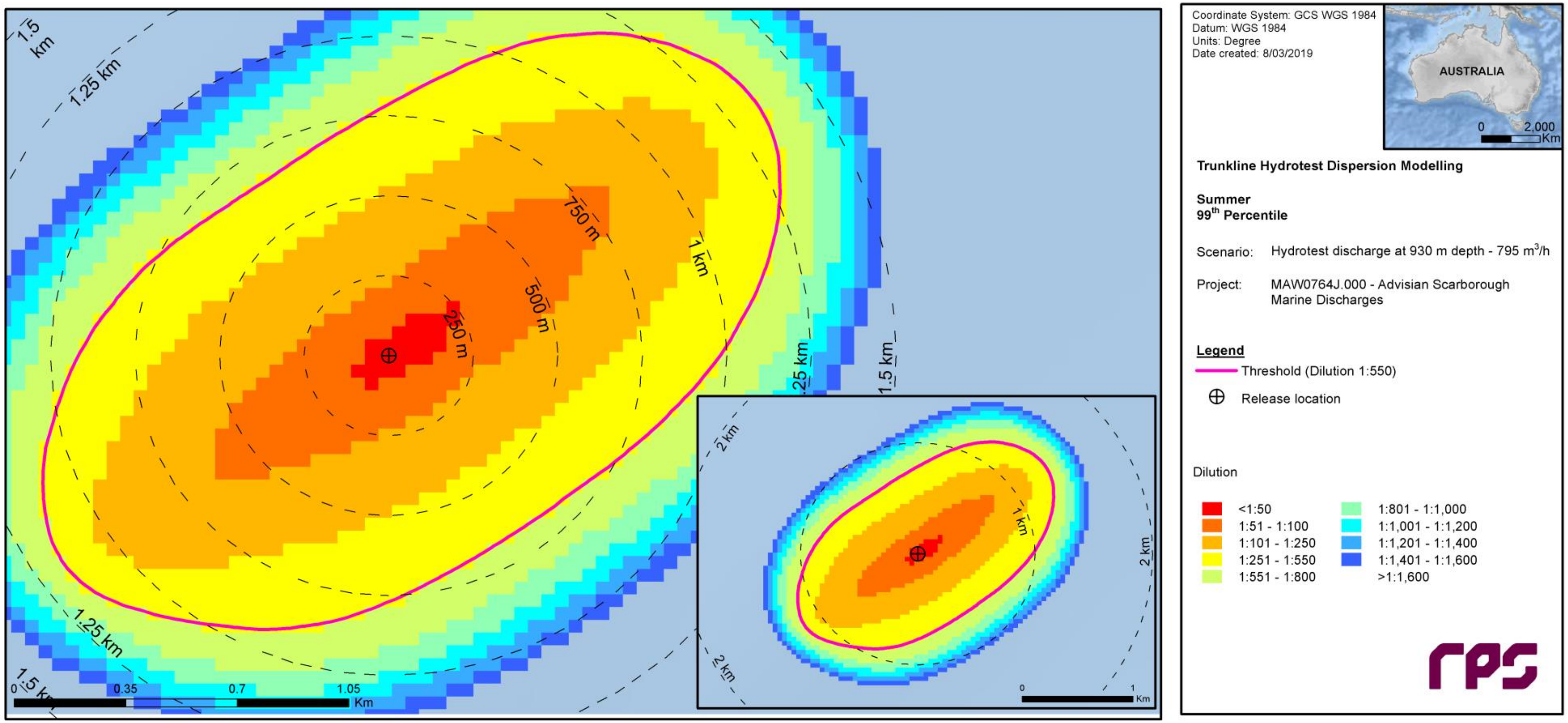


Figure 3.15 Predicted minimum dilutions at the 99th percentile under summer conditions for Case 1 (930 m depth discharge at 795 m^3/hr flow rate).

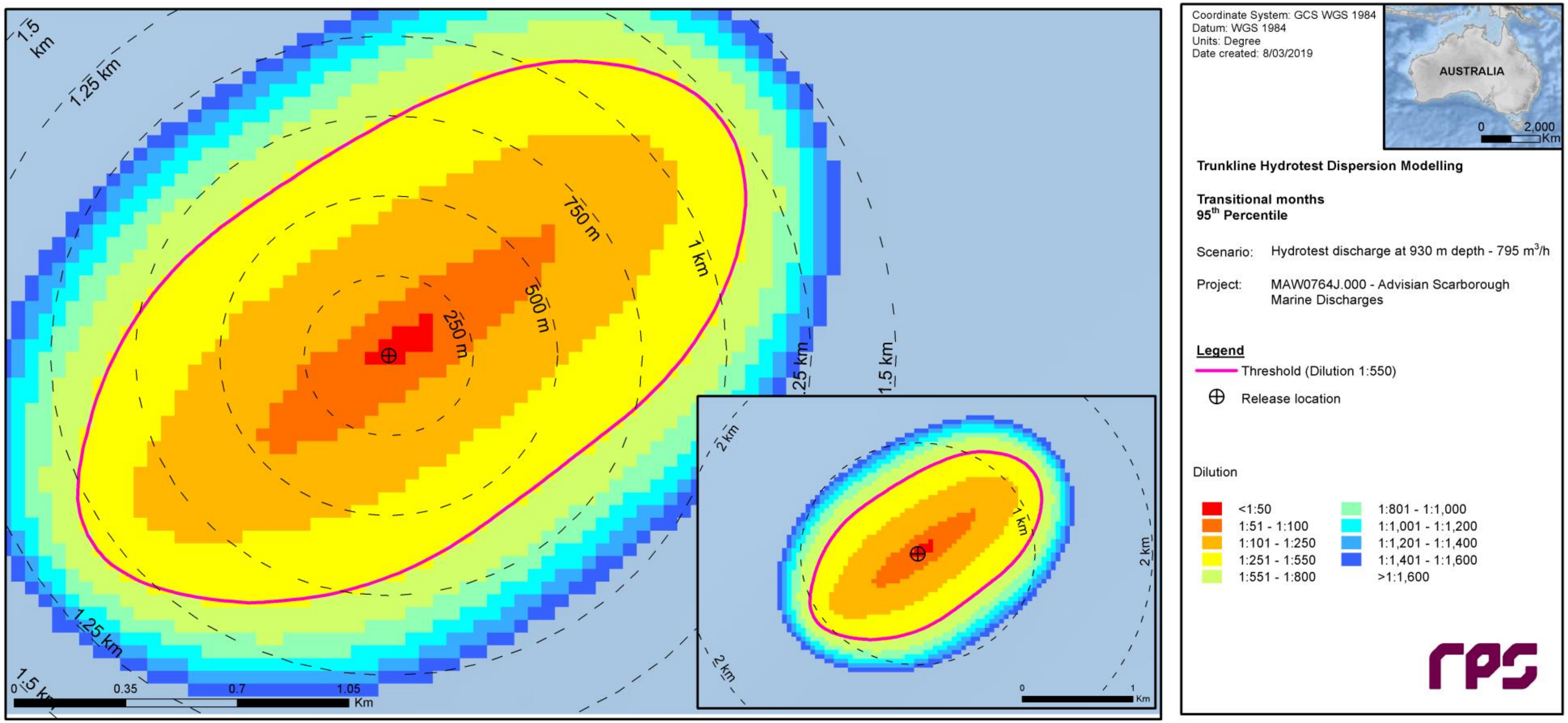


Figure 3.16 Predicted minimum dilutions at the 95th percentile under transitional conditions for Case 1 (930 m depth discharge at 795 m^3/hr flow rate).

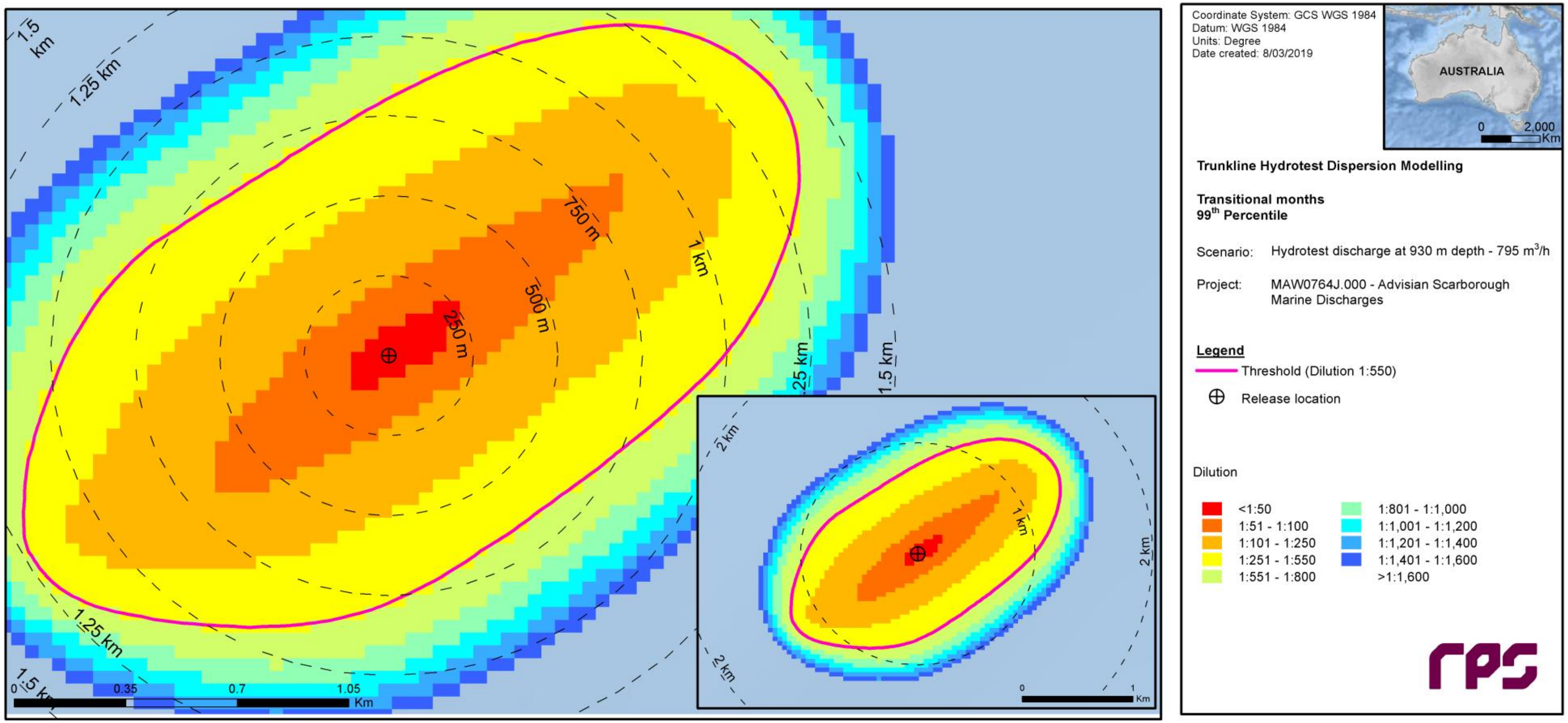


Figure 3.17 Predicted minimum dilutions at the 99th percentile under transitional conditions for Case 1 (930 m depth discharge at 795 m^3/hr flow rate).

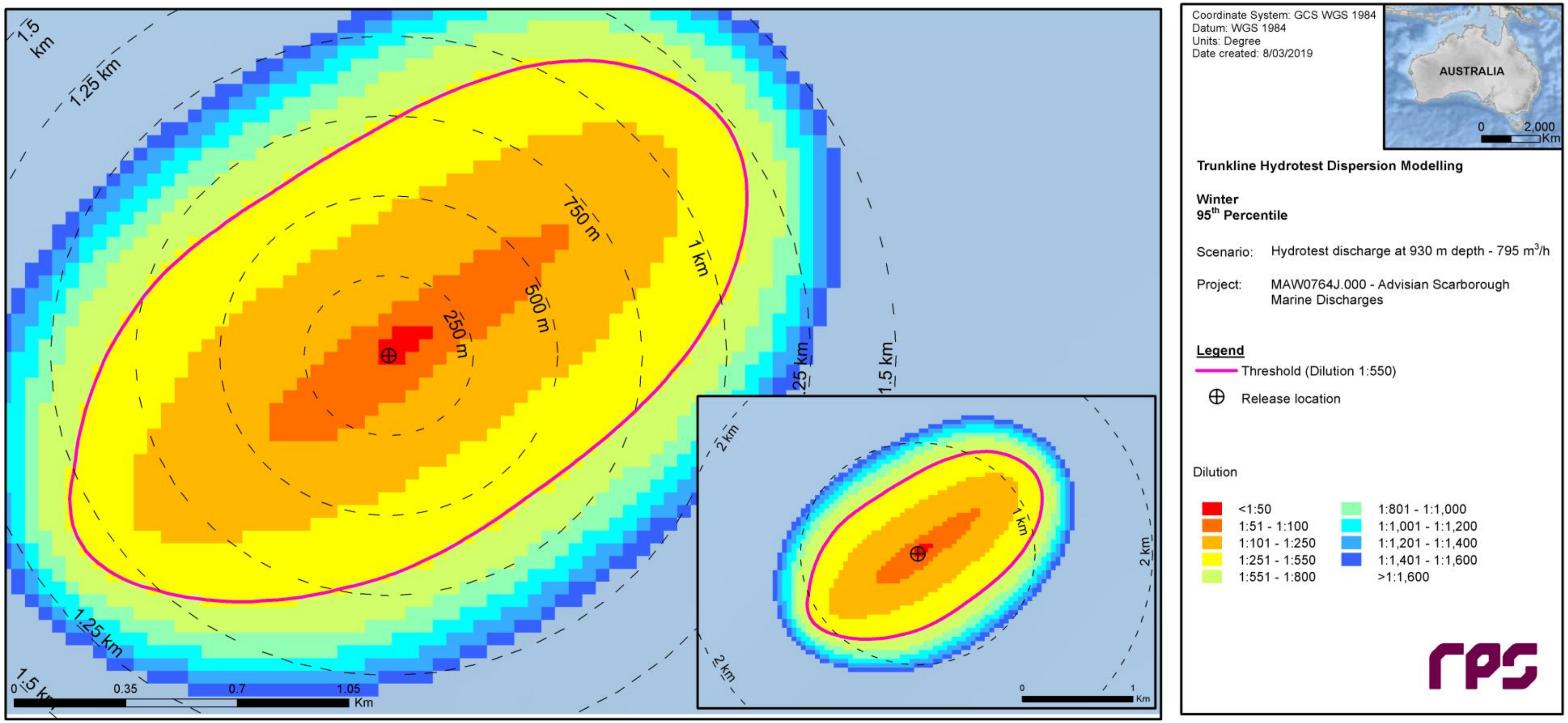


Figure 3.18 Predicted minimum dilutions at the 95th percentile under winter conditions for Case 1 (930 m depth discharge at 795 m^3/hr flow rate).

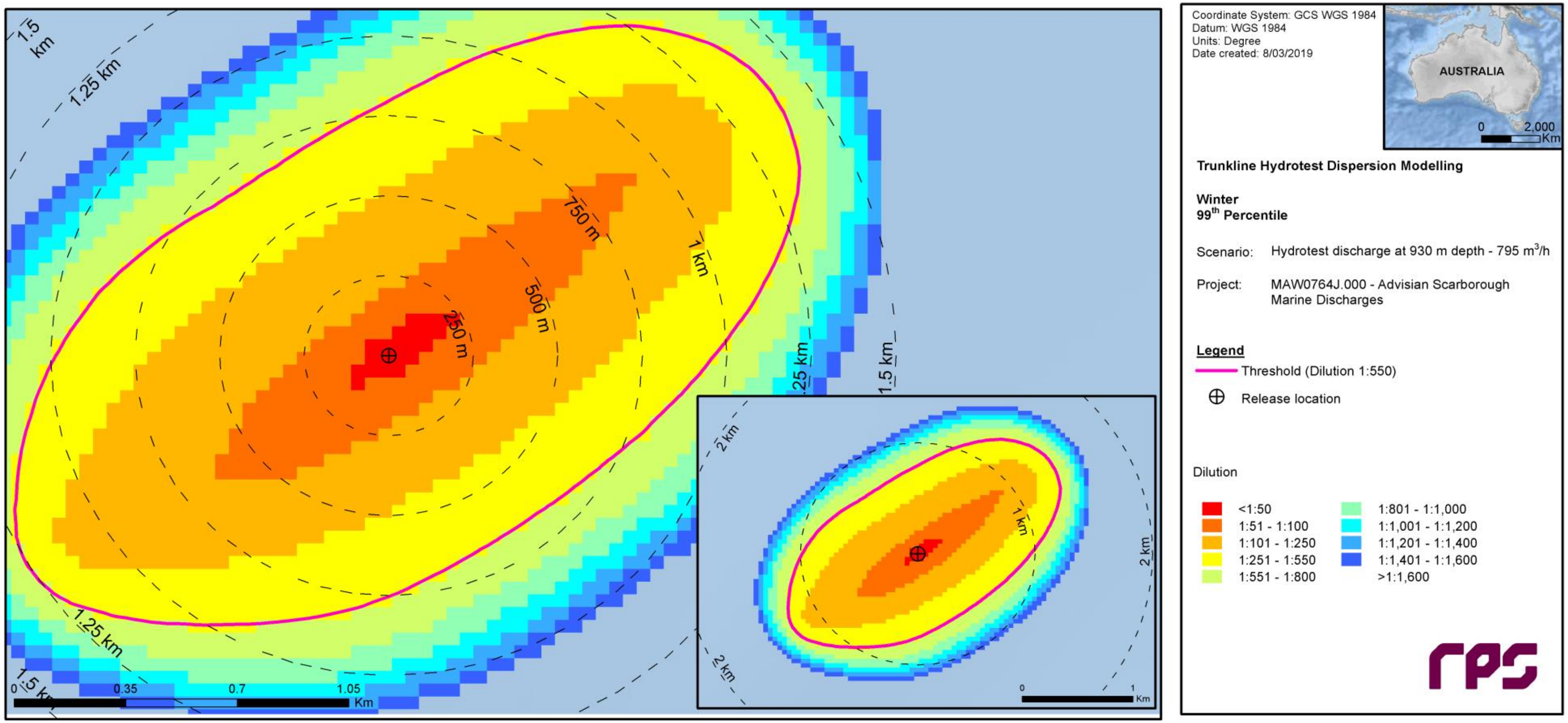


Figure 3.19 Predicted minimum dilutions at the 99th percentile under winter conditions for Case 1 (930 m depth discharge at 795 m³/hr flow rate).

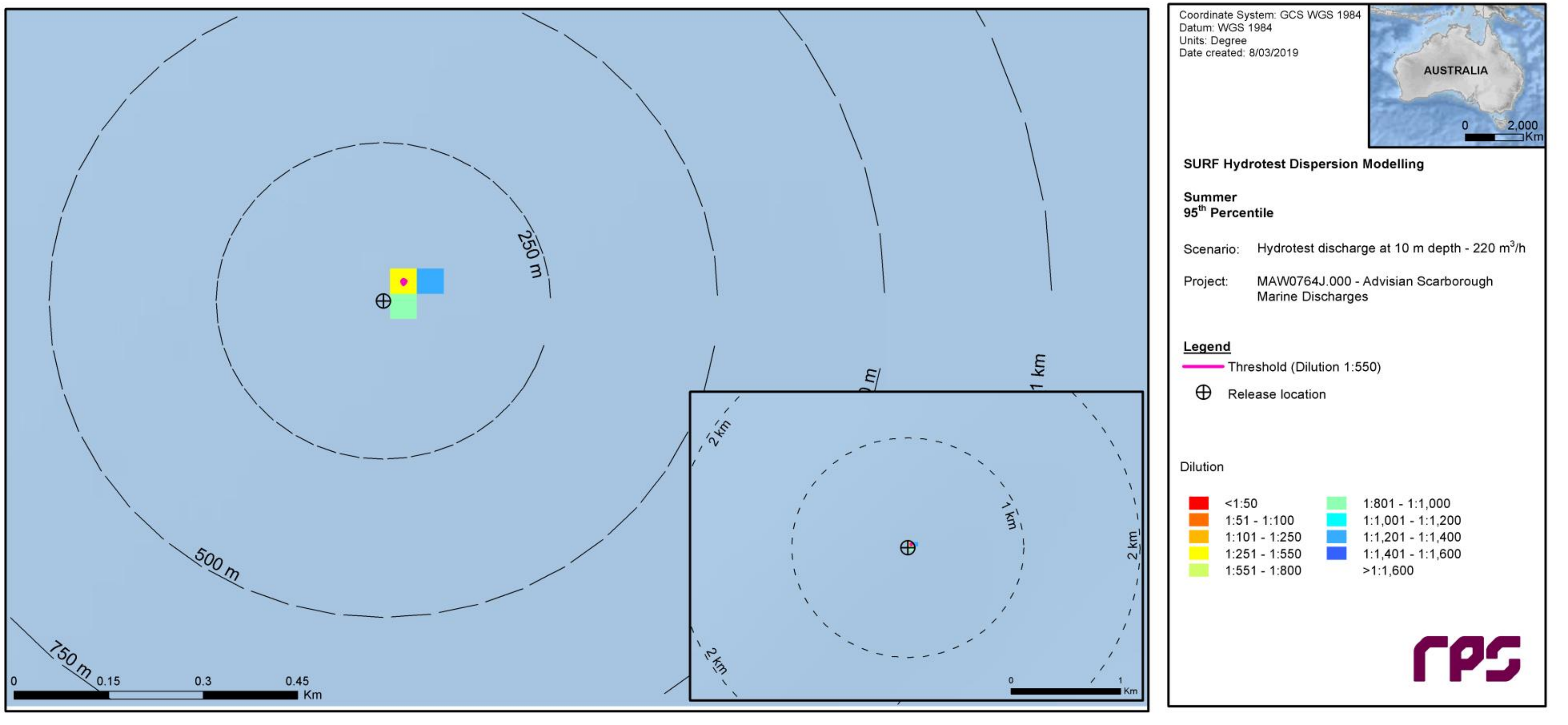


Figure 3.20 Predicted minimum dilutions at the 95th percentile under summer conditions for Case 3 (10 m depth discharge at 220 m^3/hr flow rate).

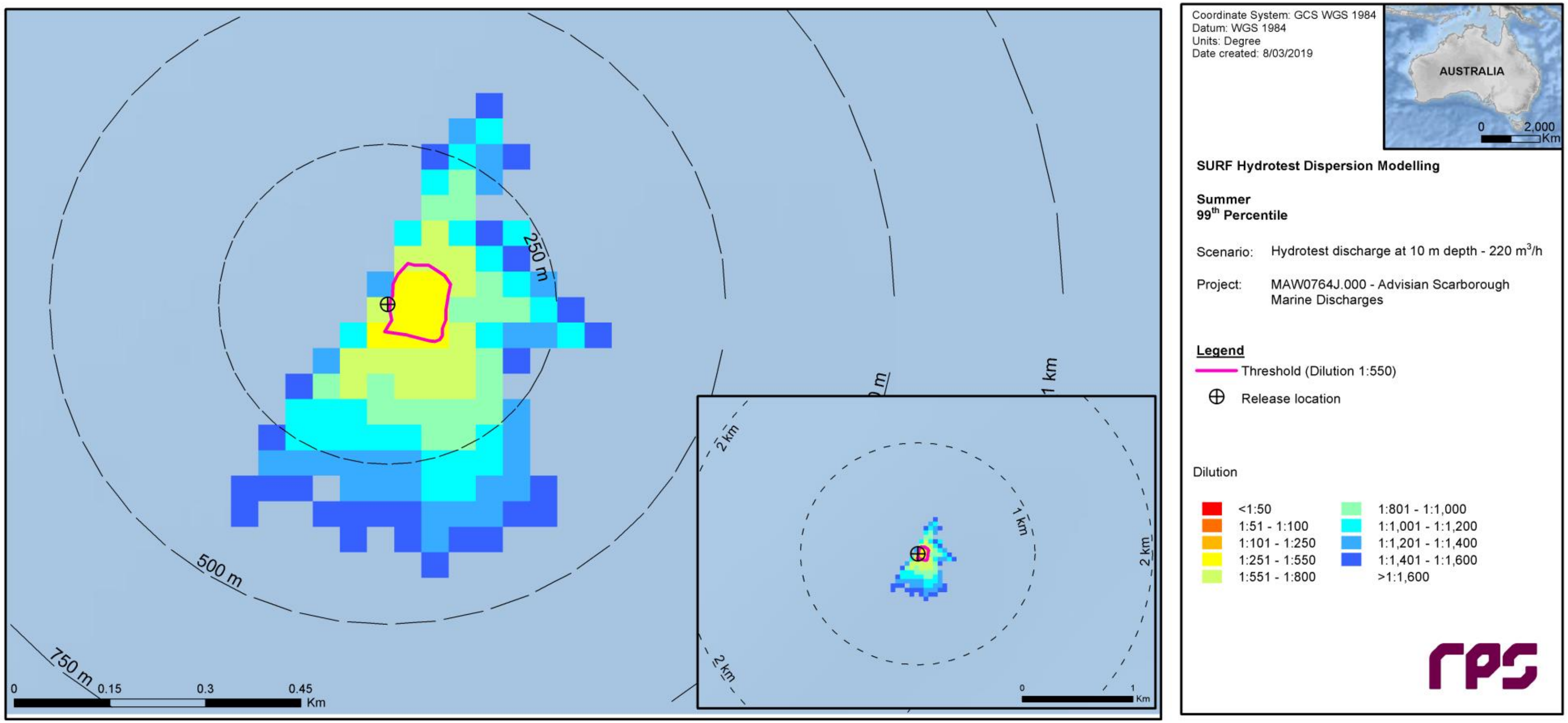


Figure 3.21 Predicted minimum dilutions at the 99th percentile under summer conditions for Case 3 (10 m depth discharge at 220 m^3/hr flow rate).

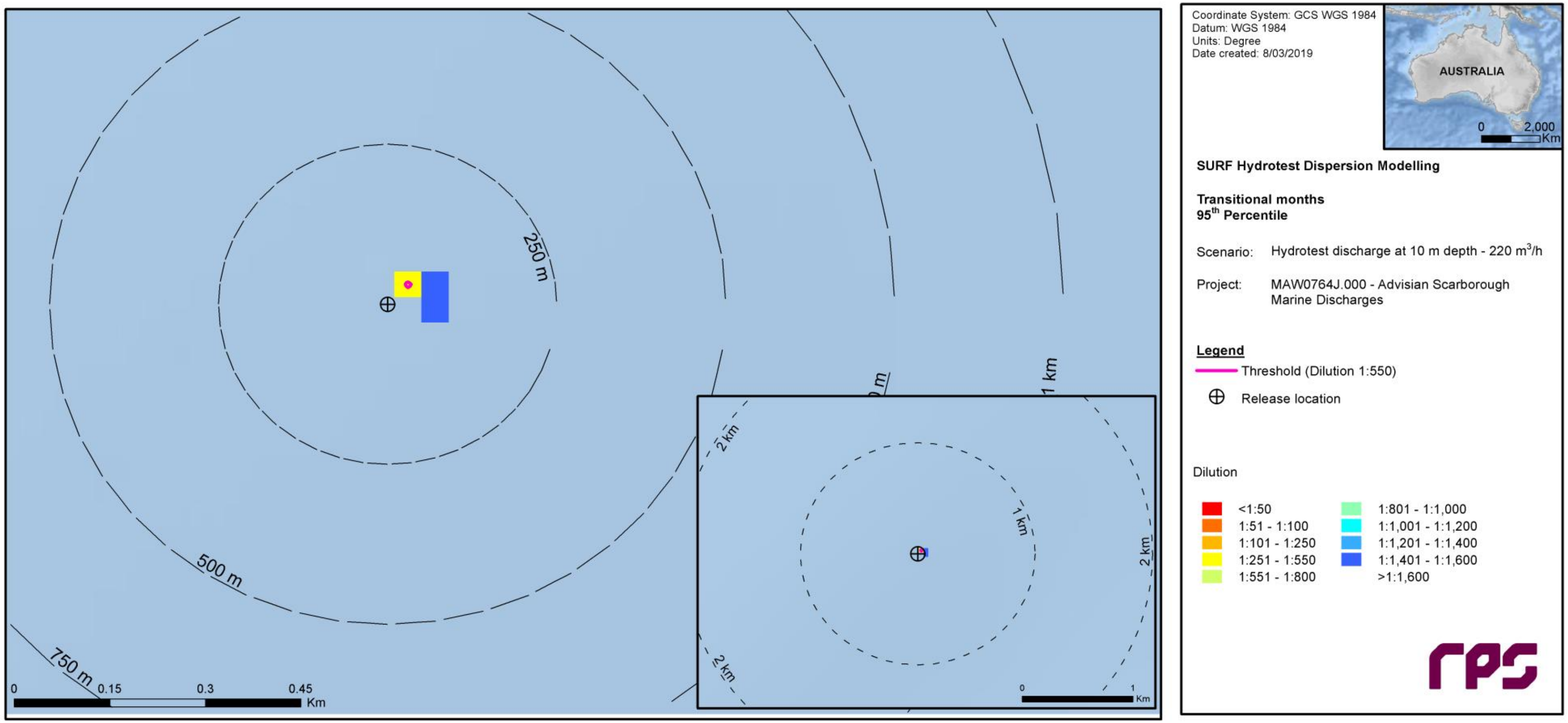


Figure 3.22 Predicted minimum dilutions at the 95th percentile under transitional conditions for Case 3 (10 m depth discharge at 220 m^3/hr flow rate).

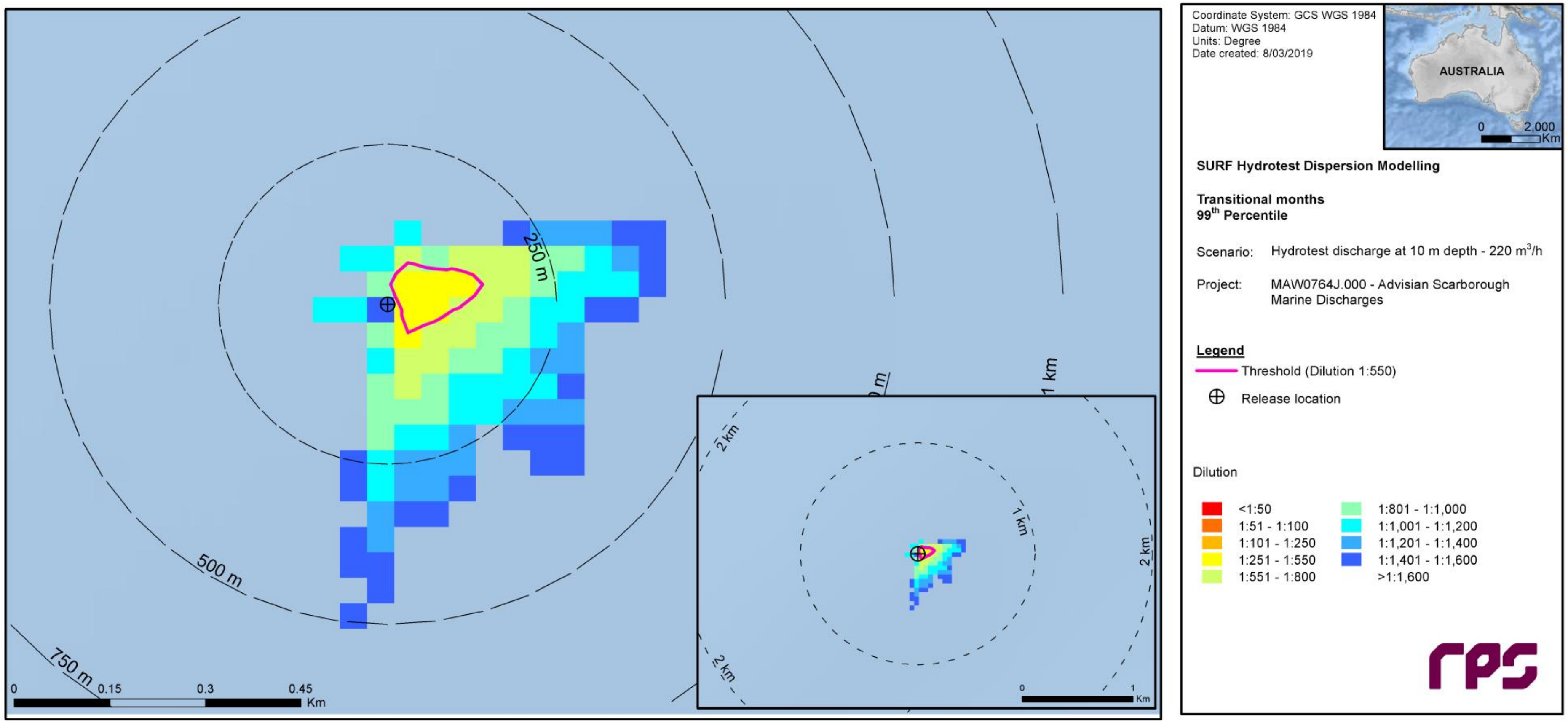


Figure 3.23 Predicted minimum dilutions at the 99th percentile under transitional conditions for Case 3 (10 m depth discharge at 220 m^3/hr flow rate).

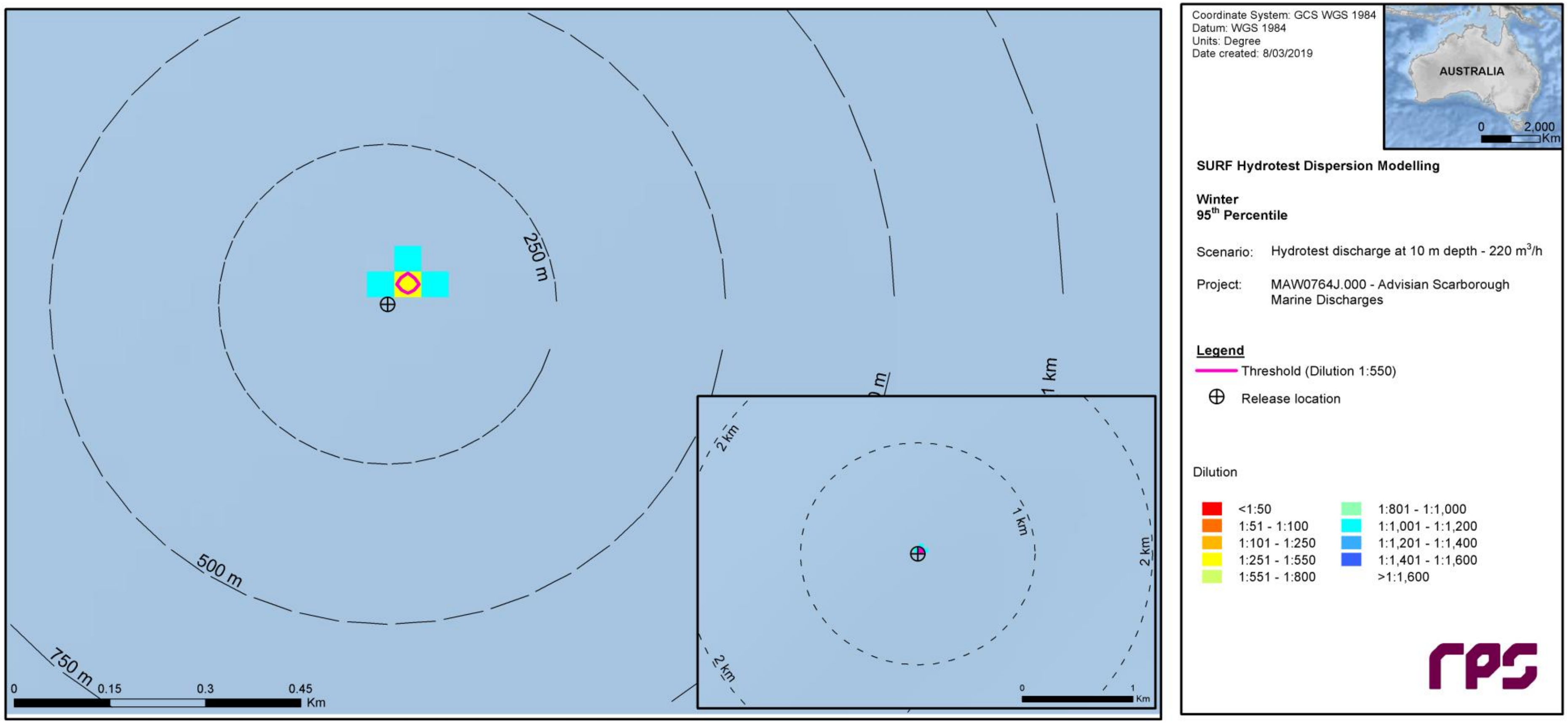


Figure 3.24 Predicted minimum dilutions at the 95th percentile under winter conditions for Case 3 (10 m depth discharge at 220 m^3/hr flow rate).

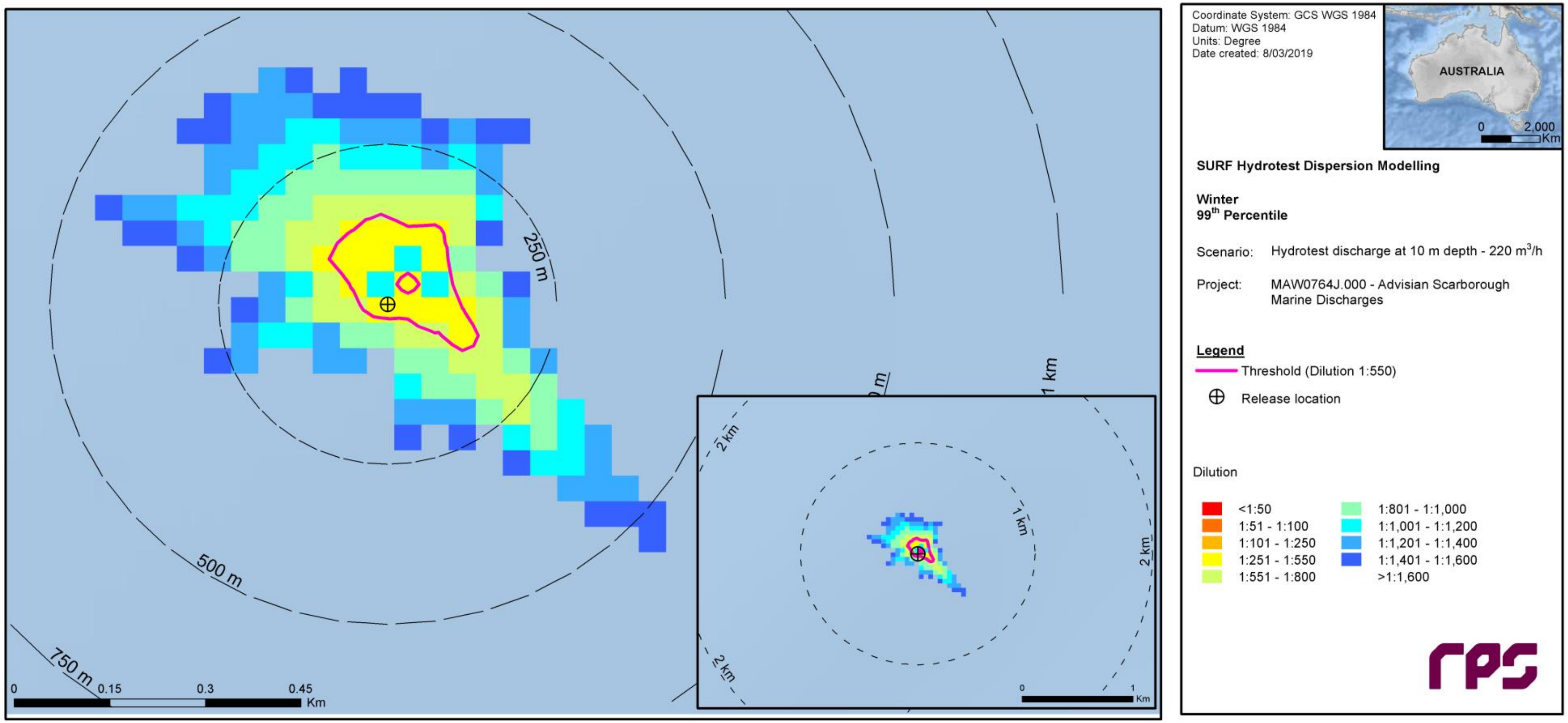


Figure 3.25 Predicted minimum dilutions at the 99th percentile under winter conditions for Case 3 (10 m depth discharge at 220 m^3/hr flow rate).

3.2.5 Annualised Analysis

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 3.25 and Table 3.26 summarise, for Cases 1 and 3 respectively, the minimum dilution achieved at specific radial distances from the discharge location for each percentile over the annual period.

Table 3.27 and Table 3.28 provide, for Cases 1 and 3 respectively, summaries of the annualised maximum distances from the discharge location to achieve 1:550 dilution 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 threshold concentration is achieved for biocide within a maximum area of influence of 1,388 m (Case 1) and 124 m (Case 3) at the 99th percentile, this being the maximum spatial extent of the relevant dilution contour from the discharge location in any season.

Table 3.29 and Table 3.30 provide, for Cases 1 and 3 respectively, summaries of the total area of coverage for the 1:550 dilution contour for each percentile. The area of exposure defined by the relevant dilution contour is predicted to reach maximum values of 2.95 km^2 (Case 1) and 0.04 km^2 (Case 3) at the 99th percentile in any season.

For Cases 1 and 3, Figure 3.26 to Figure 3.29 show the aggregated spatial extents of the minimum dilutions for each percentile. 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.

Table 3.25 Annualised minimum dilution achieved at specific radial distances from the hydrotest discharge location for Case 1 (930 m depth discharge at 795 m^3/hr flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location																
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km	1.10 km	1.20 km	1.30 km	1.40 km	1.50 km
95th	Annual	1:20.7	1:30.1	1:35.1	1:49.6	1:62.9	1:73.9	1:81.9	1:90.5	1:104.3	1:112.3	1:133.6	1:173.2	1:261.2	1:394.9	1:595.8	1:869.8	1:1,324.8
99th		1:17.6	1:24.2	1:28.1	1:39.9	1:50.6	1:59.1	1:68.0	1:73.4	1:82.8	1:89.0	1:98.1	1:106.8	1:126.3	1:174.2	1:275.8	1:428.9	1:632.9

Table 3.26 Annualised minimum dilution achieved at specific radial distances from the hydrotest discharge location for Case 3 (10 m depth discharge at 220 m^3/hr flow rate).

Percentile	Season	Minimum dilution (1:x) achieved at specific radial distances from discharge location																
		0.02 km	0.05 km	0.10 km	0.20 km	0.30 km	0.40 km	0.50 km	0.60 km	0.70 km	0.80 km	0.90 km	1.00 km	1.10 km	1.20 km	1.30 km	1.40 km	1.50 km
95th	Annual	1:387.1	1:930.5	1:1,149.9	>1:10,000	>1:10,000	>1:10,000	>1:10,000	>1:10,000	-	-	-	-	-	-	-	-	-
99th		1:160.9	1:279.8	1:320.5	1:600.5	1:779.8	1:1,129.1	1:1,364.3	1:1,609.3	1:1,881.9	1:2,202.9	1:2,595.3	1:2,838.4	1:3,174.4	1:3,525.3	1:3,450.6	1:3,980.1	1:4,042.6

Table 3.27 Annualised maximum distance from the hydrotest discharge location to achieve 1:550 dilution for Case 1 (930 m depth discharge at 795 m^3/hr flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Annual	1,196
99th		1,388
100th		1,564

Table 3.28 Annualised maximum distance from the hydrotest discharge location to achieve 1:550 dilution for Case 3 (10 m depth discharge at 220 m^3/hr flow rate).

Percentile	Season	Maximum distance (m) from discharge location to achieve given dilution
95th	Annual	18
99th		124
100th		1,147

Table 3.29 Annualised total area of coverage for 1:550 dilution for Case 1 (930 m depth discharge at 795 m^3/hr flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Annual	2.325
99th		2.945
100th		3.730

Table 3.30 Annualised total area of coverage for 1:550 dilution for Case 3 (10 m depth discharge at 220 m^3/hr flow rate).

Percentile	Season	Total area (km^2) of coverage for given dilution
95th	Annual	0.002
99th		0.035
100th		0.522

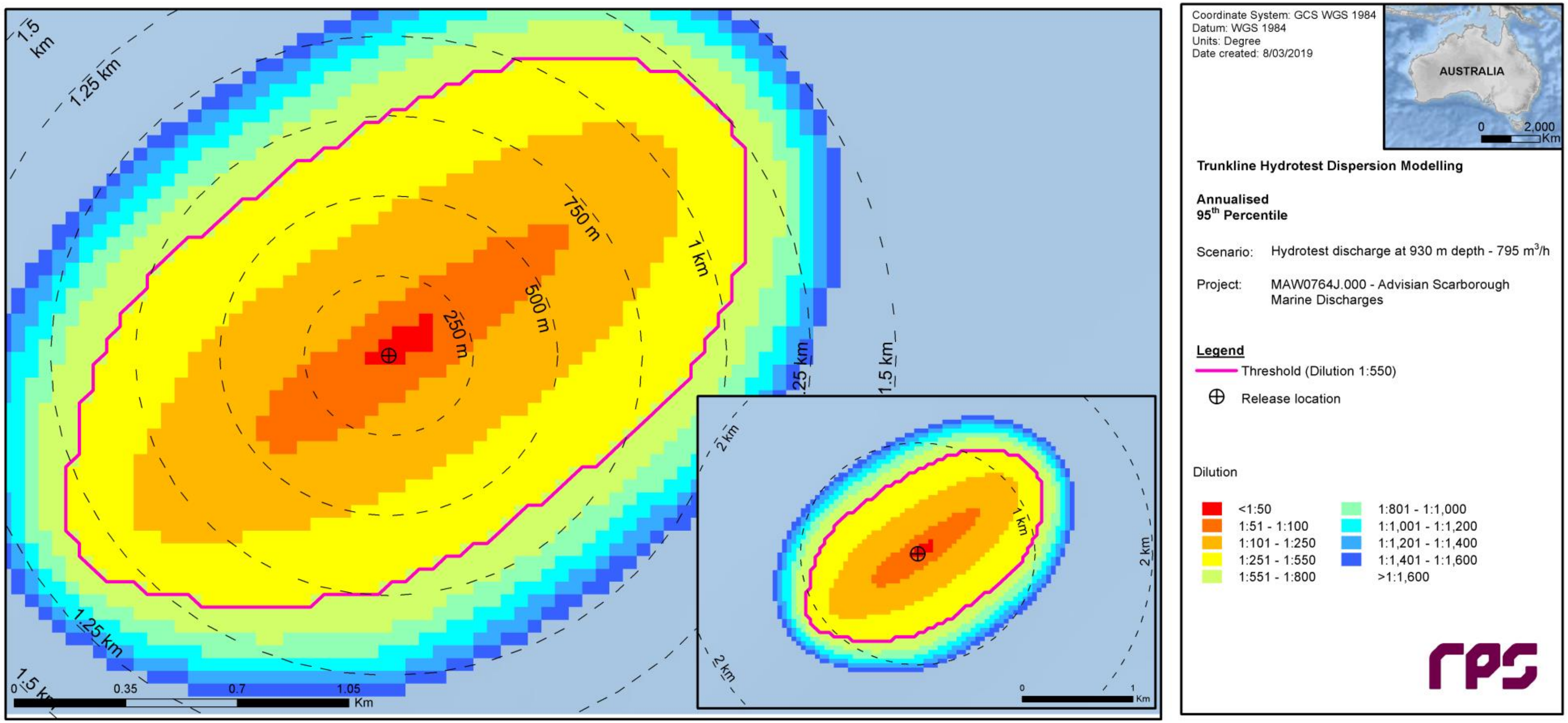


Figure 3.26 Predicted annualised minimum dilutions at the 95th percentile for Case 1 (930 m depth discharge at 795 m³/hr flow rate).

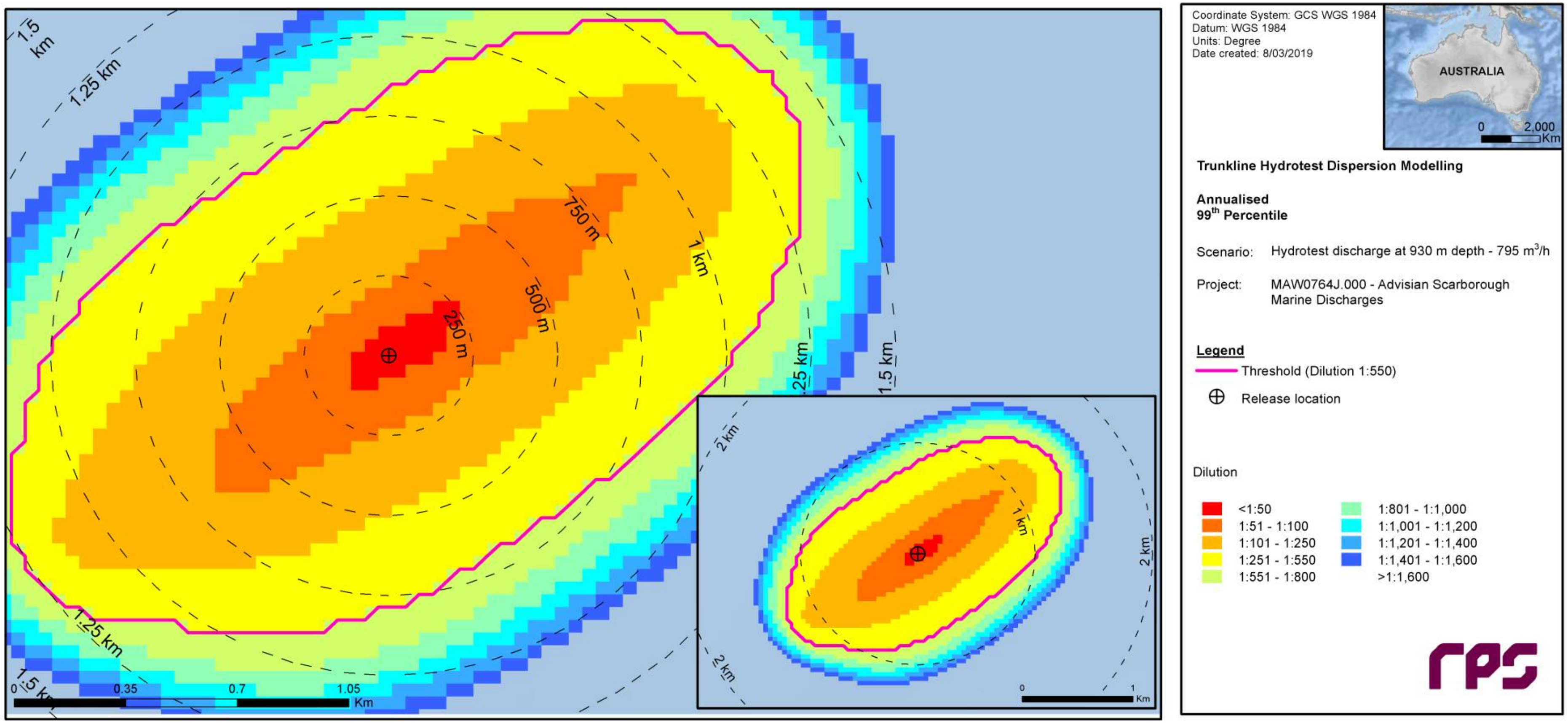


Figure 3.27 Predicted annualised minimum dilutions at the 99th percentile for Case 1 (930 m depth discharge at 795 m^3/hr flow rate).

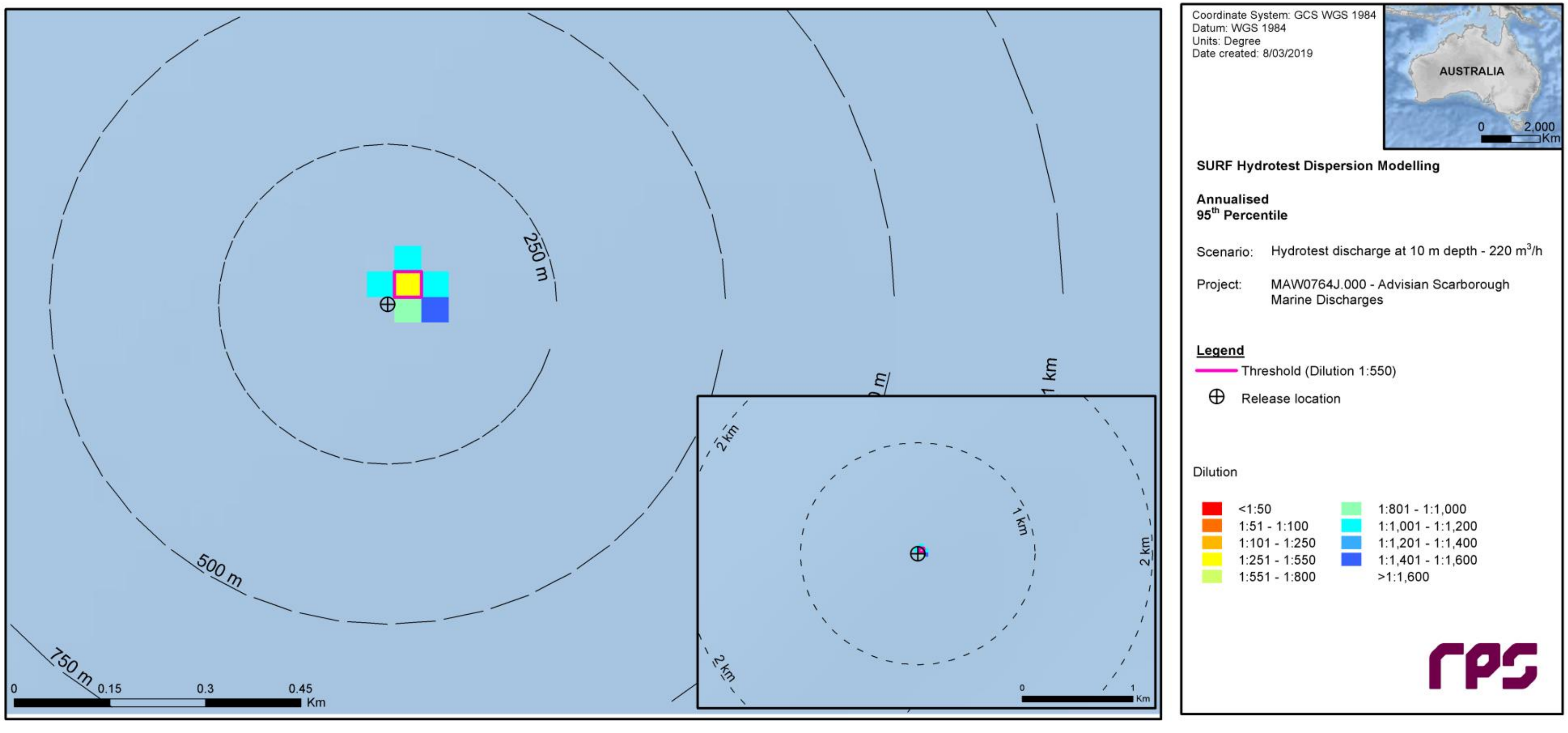


Figure 3.28 Predicted annualised minimum dilutions at the 95th percentile for Case 3 (10 m depth discharge at 220 m³/hr flow rate).

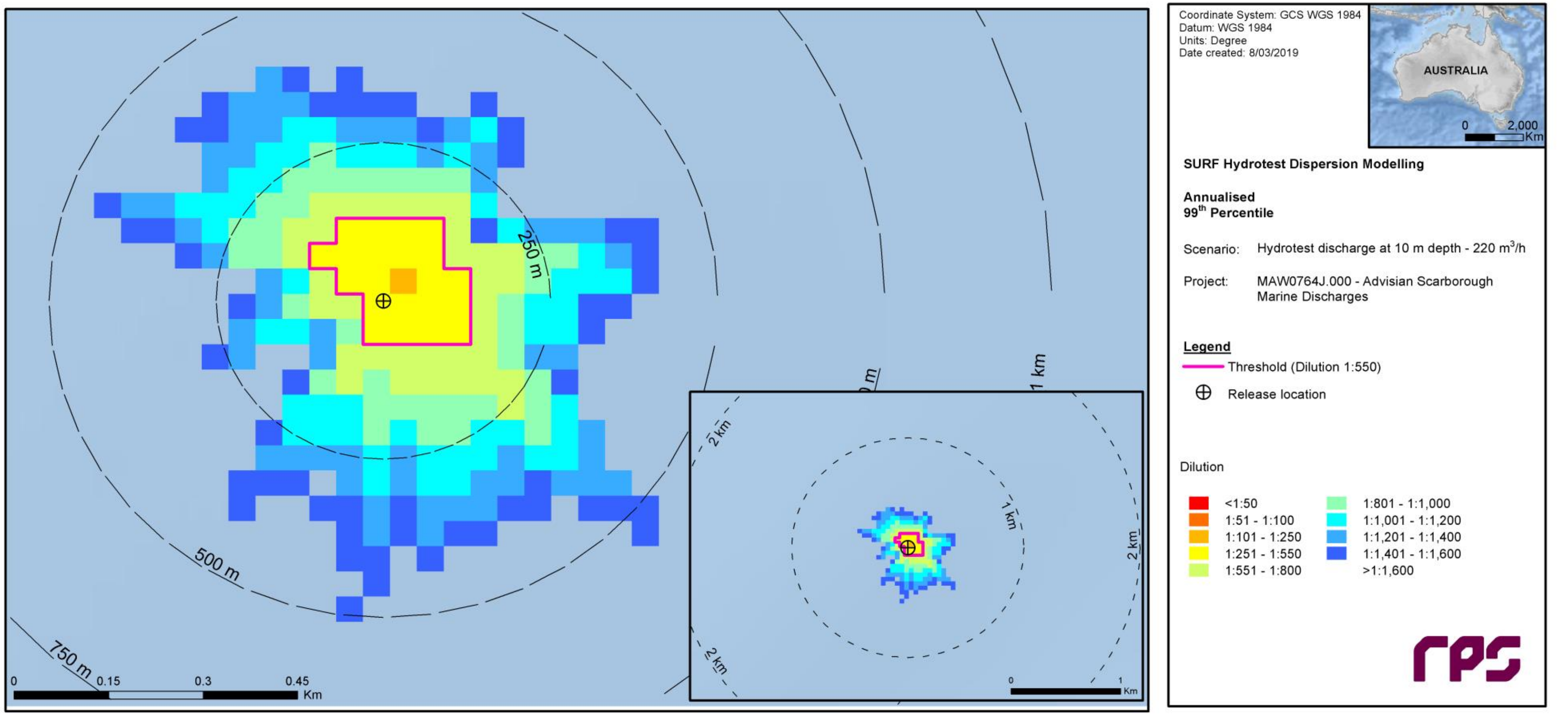


Figure 3.29 Predicted annualised minimum dilutions at the 99th percentile for Case 3 (10 m depth discharge at 220 m^3/hr flow rate).

4 CONCLUSIONS

The main findings of the study are as follows:

Near-Field Modelling

- 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 930 m (Cases 1 and 2) and 10 m (Case 3) below the water surface. The surface discharges are shown to increase the extent of the turbulent mixing zone. Following this initial mixing, the near neutrally-buoyant plumes are predicted to travel laterally in the water column.
- For Cases 1 and 2, the plumes are predicted to remain close to the seabed. For Case 3, the plume is predicted to plunge up to 19 m below the sea surface. For Cases 2 and 3, increased ambient current strengths are shown to increase the horizontal distance travelled by the plumes from the discharge point.
- The plume will reach a maximum horizontal distance of up to 152 m before reaching the trapping depth (at which the predictions of dispersion are halted due to the plume reaching equilibrium with the ambient receiving water).
- The maximum diameter of the plume at the end of the near-field zone was predicted as 23 m. Increases in current speed serve to restrict the diameter of the plume.
- For each discharge depth, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to plunge further and reach the trapping depth closer to the discharge point, which slows the rate of dilution.
- For each combination of discharge flow rate and depth, the primary factor influencing dilution of the plume is the strength of the ambient current. Weak currents allow the plume to plunge further and reach the trapping depth closer to the discharge point, which slows the rate of dilution.
- The average dilution levels of the plume upon reaching the trapping depth under average current speeds are predicted to be 1:90 for Case 1, 1:465 for Case 2 and 1:482 for Case 3.
- 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
- The results for the Case 1, 2 and 3 discharges indicate that the biocide constituent of the hydrotest discharge is not expected to reach the required levels of dilution in the near field mixing zone.

Far-Field Modelling

- For Case 1, dilution to reach threshold concentration is achieved for biocide within an area of influence extending up to 1,388 m at the 99th percentile. For Case 3, the maximum spatial extents of the relevant dilution contour are up to 124 m at the 99th percentile.
- For Case 1, the area of exposure defined by the relevant dilution contour is predicted to reach a maximum of 2.95 km^2 at the 99th percentile. For Case 3, the corresponding maximum area of exposure is up to 0.04 km^2 at the 99th percentile.
- Maximum depths reached by the discharges are predicted as 930 m (seabed) and 12 m for Cases 1 and 3, respectively.

Key Observations

- Due to the significant variations in magnitude of the hindcast currents between the surface and seabed, where potential discharges will occur, predicted outcomes are markedly different.
- The greater strength and variability in surface-layer currents will promote the highest levels of mixing and dilution, while transport patterns at the seabed will be dictated almost solely by tidal movements.
- Because the discharge will be initially neutrally-buoyant, it will travel laterally in the water column and even a surface discharge is unlikely to resurface in the vicinity of the discharge point prior to acclimation with ambient receiving water conditions.
- Outcomes show that below-threshold biocide concentrations are achieved closer to the discharge point for the surface discharge (220 m^3/hr over 20 hours) than for the seabed discharge (795 m^3/hr over 44 hours). This is partly attributable to the stronger currents at the surface, but primarily to the lower flow rate and much lower discharge duration in the surface-discharge case.

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Appendix I

Scarborough Gas Development Quantatative Spill Risk Assessment Modelling Study

WOODSIDE SCARBOROUGH PROJECT – QUANTITATIVE SPILL RISK ASSESSMENT

Report

MAW0764J
Woodside Scarborough Project – Quantitative Spill Risk Assessment
Rev 1
17 April 2019

www.rpsgroup.com/mst

Document status

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EXECUTIVE SUMMARY

RPS was commissioned by Advisian Pty Ltd (Advisian), on behalf of Woodside Energy Ltd (Woodside), to undertake a quantitative spill risk assessment of three hydrocarbon spill scenarios related to the Scarborough Project.

The Scarborough gas resource, located in Commonwealth waters approximately 375 km off the Burrup Peninsula, forms part of the Greater Scarborough gas fields, comprising the Scarborough, North Scarborough, Thebe and Jupiter gas fields.

As Operator of the Greater Scarborough gas fields, Woodside is proposing to develop the gas resource through new offshore facilities. These will be connected to the mainland through an approximately 430 km trunkline.

The Scarborough gas field consists of gas which is classified as 'dry' with only trace levels of condensate, and as such a loss of well control event will not have a significant liquid component. As such, the exposure from an unplanned hydrocarbon release is based on a release of marine diesel oil (MDO) from a vessel.

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 three hydrocarbon spill scenarios for investigation. Each scenario was modelled in a stochastic manner and assessed over an annual period in this study.

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.

The main findings of this study are as follows:

Metocean Influences

- Tidal flows will have a significant influence on the 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.
- Due to the location of the hypothetical spill site and the dominance of tidal flows, the coastal areas predicted to be most likely to be impacted by spilled oil are those bordering Mermaid Sound and its numerous passages.

Oil Characteristics and Weathering Behaviour

- Marine diesel is a mixture of volatile and persistent hydrocarbons with low percentages of highly volatile and residual components. 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. The influence of entrainment will regulate the degree of mass retention in the environment.

- During the surface release, floating oil will be susceptible to entrainment into the wave-mixed layer under typical wind conditions. Evaporation rates will be significant, given the moderate proportion of volatile compounds in the oil (41%). The low-volatility fraction of the oil (54%) will take longer durations of the order of days to evaporate, and the residual fraction of 5% is expected to persist in the environment until degradation processes occur. Considering the spill volume, there is a low potential for dissolution of soluble aromatic compounds.

Summary of Stochastic Assessment Results

Scenario 1: Short-Term (Instantaneous) Surface Release of Marine Diesel after a Vessel Collision outside Mermaid Sound

- Floating oil at concentrations equal to or greater than the 10 g/m^2, 50 g/m^2 and 100 g/m^2 thresholds could potentially be found up to 29 km, 21 km and 18 km from the spill site, respectively.
- The Dampier Archipelago shoreline receptor is predicted to be contacted by floating oil concentrations at the 10 g/m^2 threshold with a probability of 2% and a minimum time to contact of 27 hours.
- Potential for accumulation of oil on shorelines is predicted to be low, with a maximum accumulated volume and concentration of 3 m^3 and 156 g/m^2, respectively, forecast at the Dampier Archipelago.
- Entrained oil at concentrations equal to or greater than the 500 ppb threshold is predicted to be found up to around 163 km from the spill site.
- The Dampier MP and Dampier Archipelago receptors are predicted to receive entrained oil concentrations at the 500 ppb threshold with probabilities of 44% and 23%, respectively.
- The maximum entrained oil concentration forecast for any receptor is predicted as 10.9 ppm within the Dampier Archipelago.
- Dissolved aromatic hydrocarbons at concentrations equal to or greater than the 500 ppb threshold are predicted to be found up to around 34 km from the spill site.
- The Dampier MP is predicted to receive dissolved aromatic hydrocarbon concentrations at the 500 ppb threshold with a probability of 2%.
- The maximum dissolved aromatic hydrocarbon concentration forecast for any receptor is predicted as 635 ppb within the Dampier MP.

Scenario 2: Short-Term (Instantaneous) Surface Release of Marine Diesel after a Vessel Collision within Montebello Marine Park

- Floating oil at concentrations equal to or greater than the 10 g/m^2, 50 g/m^2 and 100 g/m^2 thresholds could potentially be found up to 39 km, 36 km and 33 km from the spill site, respectively.
- Given that the spill location lies within the Montebello MP receptor area, floating oil at concentrations equal to or greater than 100 g/m^2 are forecast with a probability of 100% and a minimum time to contact of less than 1 hour.
- Potential for accumulation of oil on shorelines is predicted to be low, with a maximum accumulated volume and concentration of <1 m^3 and 1 g/m^2, respectively, forecast at Barrow Island.

- Entrained oil at concentrations equal to or greater than the 500 ppb threshold is predicted to be found up to around 308 km from the spill site.
- The Montebello MP and Muiron Islands MMA-WHA receptors are predicted to receive entrained oil concentrations at the 500 ppb threshold with probabilities of 70% and 7%, respectively.
- The maximum entrained oil concentration forecast for any receptor is predicted as 157.0 ppm within the Montebello MP.
- Dissolved aromatic hydrocarbons at concentrations equal to or greater than the 500 ppb threshold are predicted to be found up to around 85 km from the spill site.
- The Montebello MP is predicted to receive dissolved aromatic hydrocarbon concentrations at the 500 ppb threshold with a probability of 2%.
- The maximum dissolved aromatic hydrocarbon concentration forecast for any receptor is predicted as 2.0 ppm within the Montebello MP.

Scenario 3: Short-Term (Instantaneous) Surface Release of Marine Diesel after a Vessel Collision at the FPU Location

- Floating oil at concentrations equal to or greater than the 10 g/m^2, 50 g/m^2 and 100 g/m^2 thresholds could potentially be found up to 113 km, 60 km and 58 km from the spill site, respectively.
- No shoreline receptors are predicted to be contacted by floating oil concentrations at any of the assessed thresholds.
- No accumulation of oil on shorelines is predicted.
- Entrained oil at concentrations equal to or greater than the 500 ppb threshold is predicted to be found up to around 476 km from the spill site.
- The Gascoyne MP receptor is predicted to receive entrained oil concentrations at the 500 ppb threshold with a probability of 8%.
- The maximum entrained oil concentration forecast for any receptor is predicted as 7.2 ppm within the Gascoyne MP.
- Dissolved aromatic hydrocarbons at concentrations equal to or greater than the 500 ppb threshold are predicted to be found up to around 74 km from the spill site.
- No receptors are predicted to receive dissolved aromatic hydrocarbon concentrations at the 500 ppb threshold.
- The maximum dissolved aromatic hydrocarbon concentration forecast for any receptor is predicted as 462 ppb within the Gascoyne MP.

1 INTRODUCTION

1.1 Background

RPS was commissioned by Advisian Pty Ltd (Advisian), on behalf of Woodside Energy Ltd (Woodside), to undertake a quantitative spill risk assessment of three hydrocarbon spill scenarios related to the Scarborough Project.

The Scarborough gas resource, located in Commonwealth waters approximately 375 km off the Burrup Peninsula, forms part of the Greater Scarborough gas fields, comprising the Scarborough, North Scarborough, Thebe and Jupiter gas fields.

As Operator of the Greater Scarborough gas fields, Woodside is proposing to develop the gas resource through new offshore facilities. These will be connected to the mainland through an approximately 430 km trunkline.

The Scarborough gas field consists of gas which is classified as 'dry' with only trace levels of condensate, and as such a loss of well control event will not have a significant liquid component. As such, the exposure from an unplanned hydrocarbon release is based on a release of marine diesel oil (MDO) from a vessel.

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 three hydrocarbon spill scenarios for investigation (Advisian, 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 short-term (instantaneous) surface release of 2,000 m^3 of marine diesel, representing loss of vessel fuel tank integrity after a collision outside Mermaid Sound (20° 21' 3.28" S, 116° 42' 5.58" E).
- Scenario 2: A short-term (instantaneous) surface release of 2,000 m^3 of marine diesel, representing loss of vessel fuel tank integrity after a collision within Montebello Marine Park (MP) (20° 03' 1.44" S, 115° 31' 35.04" E).
- Scenario 3: A short-term (instantaneous) surface release of 2,000 m^3 of marine diesel, representing loss of vessel fuel tank integrity after a collision at the FPU location (19° 53' 54.72" S, 113° 14' 19.56" E).

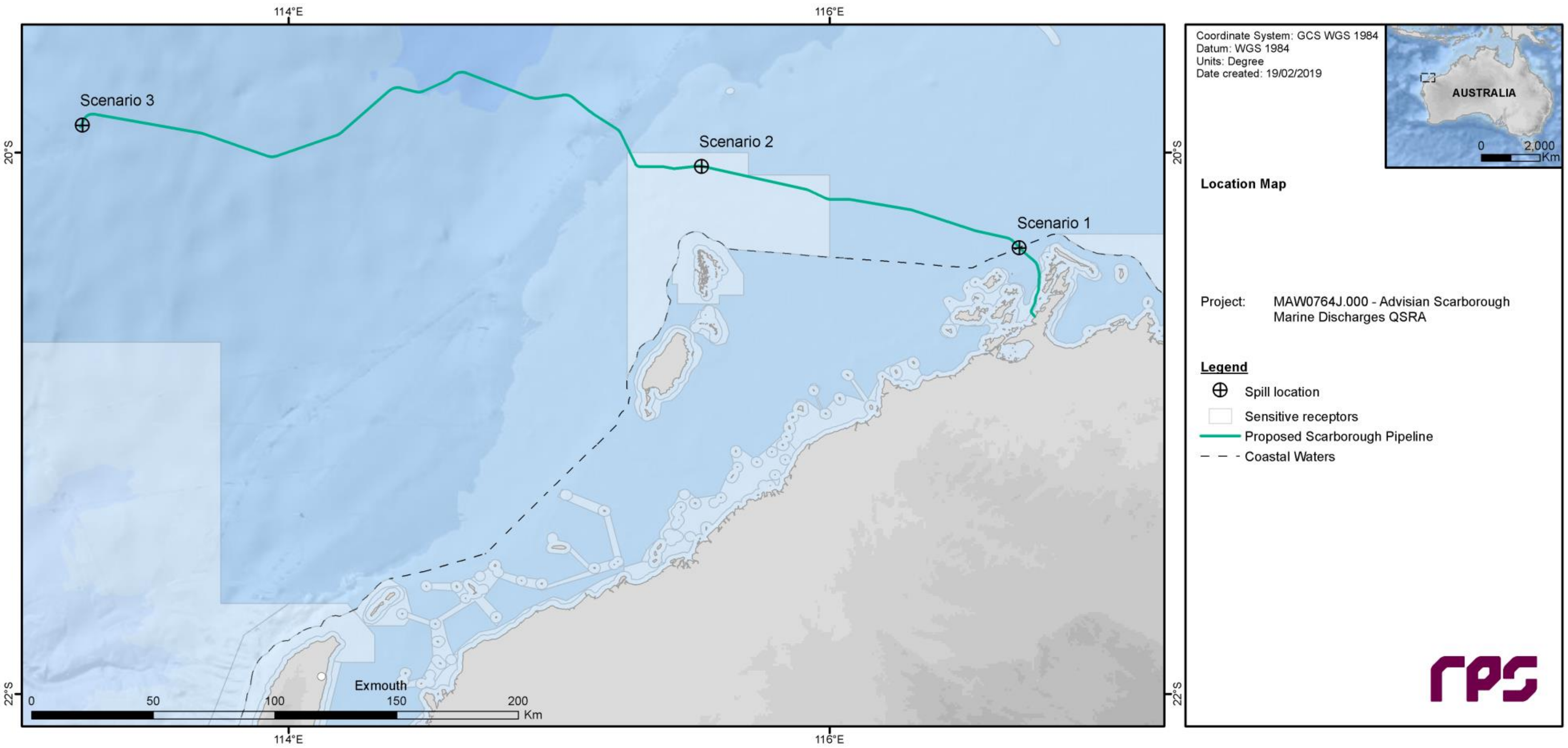


Figure 1.1 Locations of the modelled hydrocarbon spill scenario release sites.

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.

The SIMAP model simulates both surface and subsurface 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 North West Shelf of Australia and 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 vessel fuel tank integrity after a collision outside Mermaid Sound	Marine Diesel	2,000	20° 21' 03.28" S 116° 42' 05.58 " E	0	Instantaneous	42 days	Annual
2	Loss of vessel fuel tank integrity after a collision within Montebello Marine Park (MP)	Marine Diesel	2,000	20° 03' 01.44" S 115° 31' 35.04 " E	0	Instantaneous	42 days	Annual
3	Loss of vessel fuel tank integrity after a collision at the FPU location	Marine Diesel	2,000	19° 53' 54.72" S 113° 14' 19.56 " E	0	Instantaneous	42 days	Annual

1.3 Deterministic Analysis of Spill Scenarios

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 far-field computational models, risk assessment methodology, environmental data used as input to the models, environmental threshold trigger levels defined for the assessment and characteristics of the oil type used in the modelling of the defined scenarios 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.

Spatial figures for floating oil, entrained oil, dissolved aromatic hydrocarbons and shoreline oil are presented in Section 4 to summarise the outcomes of the deterministic analysis and modelling.

The overall findings of the study are summarised in Section 5.

2 MODELLING METHODOLOGY

2.1 Description of the SIMAP Model

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.

2.2 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. Note that this statistic has been previously referred to as the “mean expected maximum” in earlier reports.

- 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 typified by strong tidal flows over the shallower regions, particularly along the inshore region of the North West Shelf and among the island groups stretching from the Dampier Archipelago to the North West Cape. However, the 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 slicks over time scales exceeding a few hours.

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. Hence, the current-induced transport of oil 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 spill location.

To appropriately allow for temporal and spatial variation in the current field, spill modelling requires the current speed and direction over a spatial grid covering the potential migration of oil. As measured current data is not available for simultaneous periods over a network of locations covering the wide area of this study, the analysis relied upon hindcasts of the circulation generated by numerical modelling. Estimates of the net currents were derived by combining predictions of the drift currents, available from mesoscale ocean models, with estimates of the tidal currents generated by an RPS model set up for the study area.

2.3.1.2 Mesoscale Circulation Model

Representation of the drift currents that affect the area were available from the output of the BRAN (Bluelink ReANalysis; 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

Commonwealth Scientific and Industrial Research Organisation (CSIRO). 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).

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, time series of current speed and direction were 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.

Figure 2.1 to Figure 2.3 show the monthly distribution of current speeds and directions for the BRAN data points closest to the spill locations for Scenarios 1 to 3. Note that the convention for defining current direction is the direction towards which the current flows.

The current data indicates higher average current speeds are characteristic of the May to September period, with the highest average speeds (0.26 m/s) occurring at the Scenario 3 spill site in September. Lower average current speeds at the release locations are more common during the February to April period, with lowest average speeds (0.04 m/s) occurring at the Scenario 1 spill site in April. Peak current speeds across all months and sites are approximately 0.7 m/s.

Throughout the year, westerly currents are dominant at the Scenario 2 spill site and westerly/south-westerly currents are dominant at the Scenario 3 spill site. Current directions at the Scenario 1 spill site are seasonal, with north-easterly currents dominant between September and March, and south-westerly currents dominant between April and August.

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.

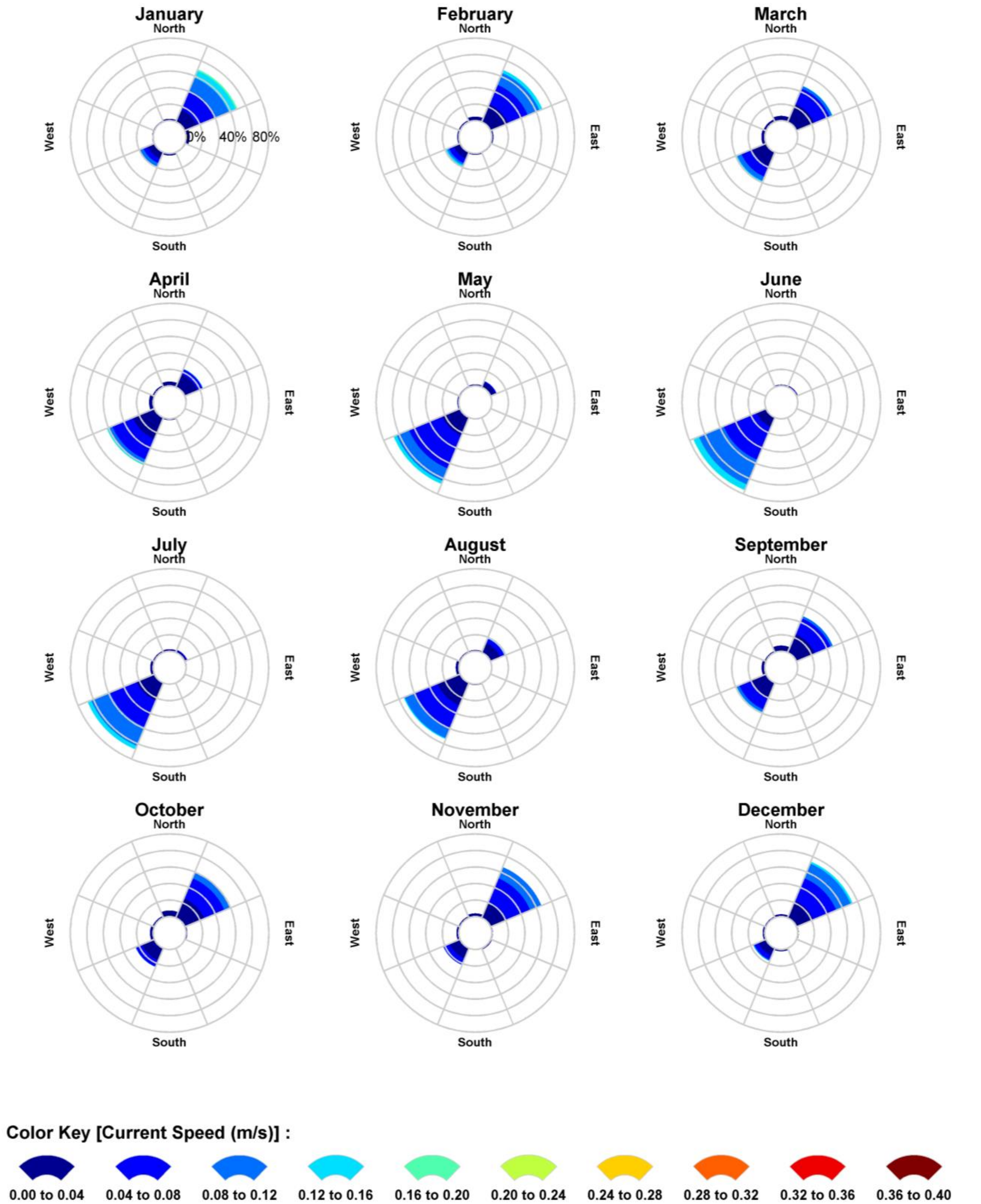


Figure 2.1 Monthly current distribution (2006-2015, inclusive) derived from the BRAN database near to the Scenario 1 spill location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

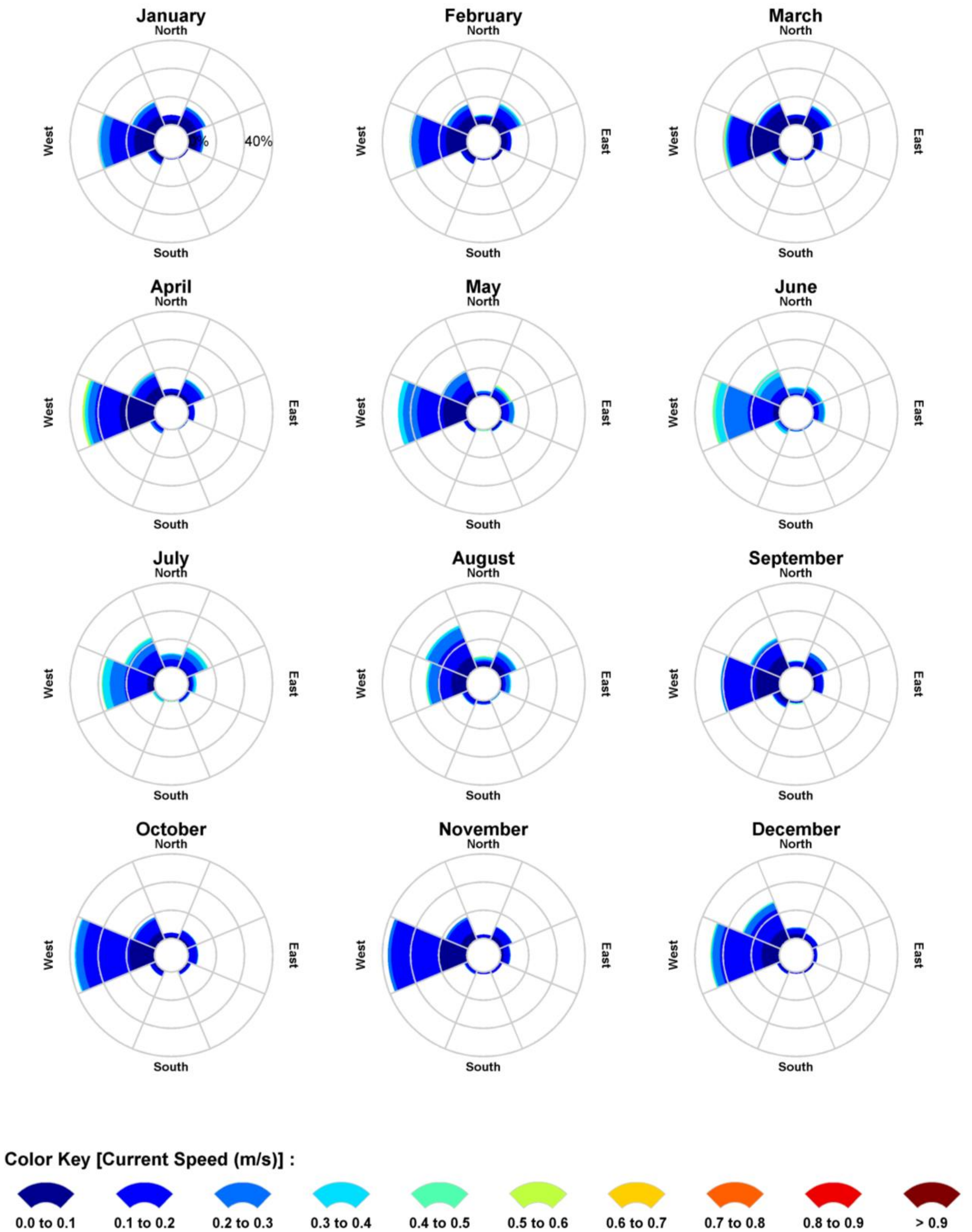


Figure 2.2 Monthly current distribution (2006-2015, inclusive) derived from the BRAN database near to the Scenario 2 spill location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

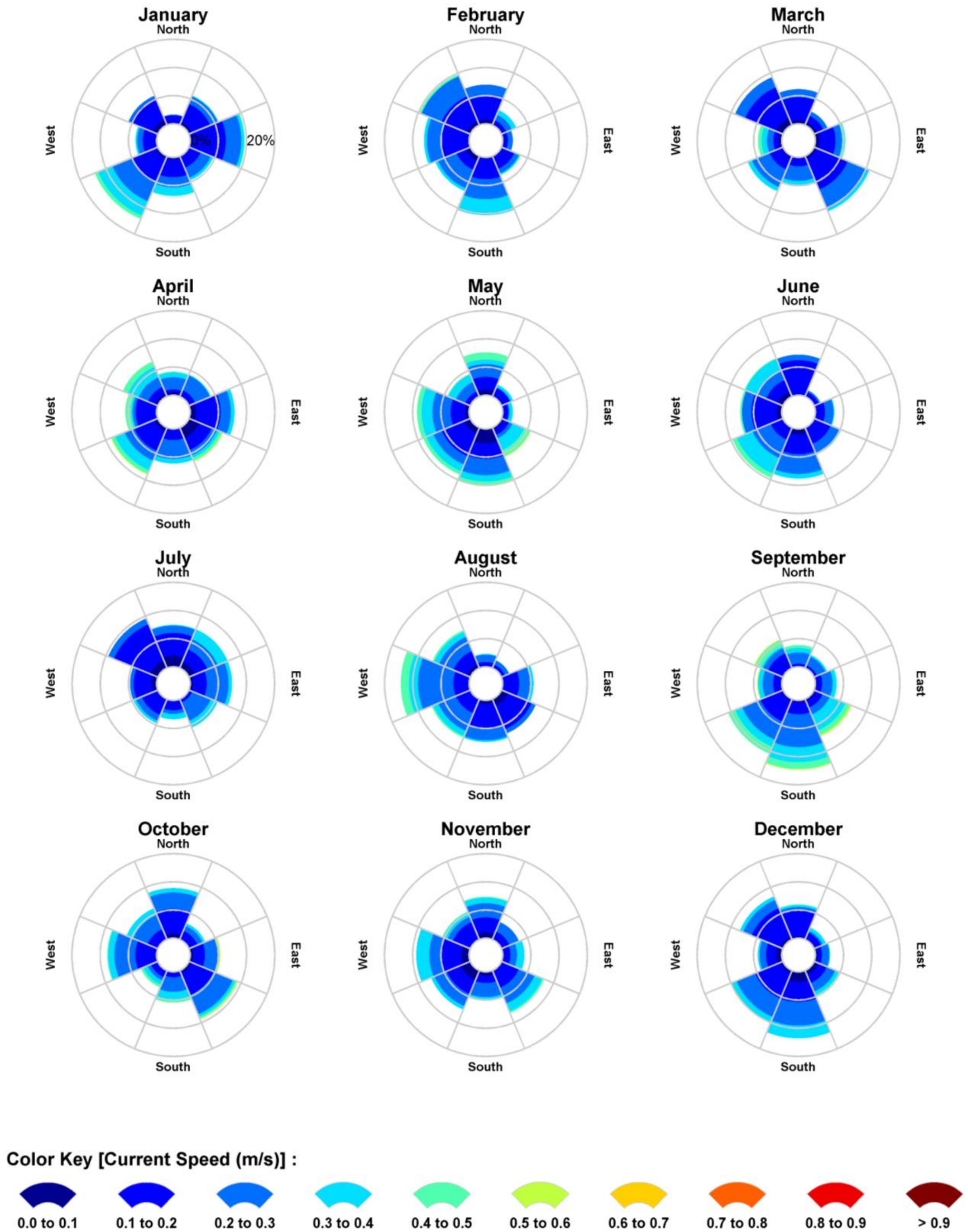


Figure 2.3 Monthly current distribution (2006-2015, inclusive) derived from the BRAN database near to the Scenario 3 spill location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

2.3.1.3 Tidal Circulation Model

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 25 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).

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 2.4).

Four layers of sub-gridding were 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. Approximately 98,600 cells were used to define the region.

Bathymetric data used to define the three-dimensional shape of the study domain was extracted from the CMAP electronic chart database and 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.

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.

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. Of more than 40 tidal stations within the HYDROMAP model domain, ten were used for comparison.

Water level time series for these locations are shown in Figure 2.5 for a one-month period (January 2005). 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 location. A scatter plot 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) is presented in Figure 2.6. 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 2.7 to Figure 2.9 show the monthly distribution of current speeds and directions for the HYDROMAP data points closest to the spill locations for Scenarios 1 to 3. 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 an east-west axis at the Scenario 1 site, an east-southeast/west-northwest axis at the Scenario 2 site, and a northeast-southwest axis at the Scenario 3 site. Maximum speeds at the Scenario 1 and 2 sites are in the range 0.5-0.6 m/s, with peak speeds at the Scenario 3 site being around 0.09 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.

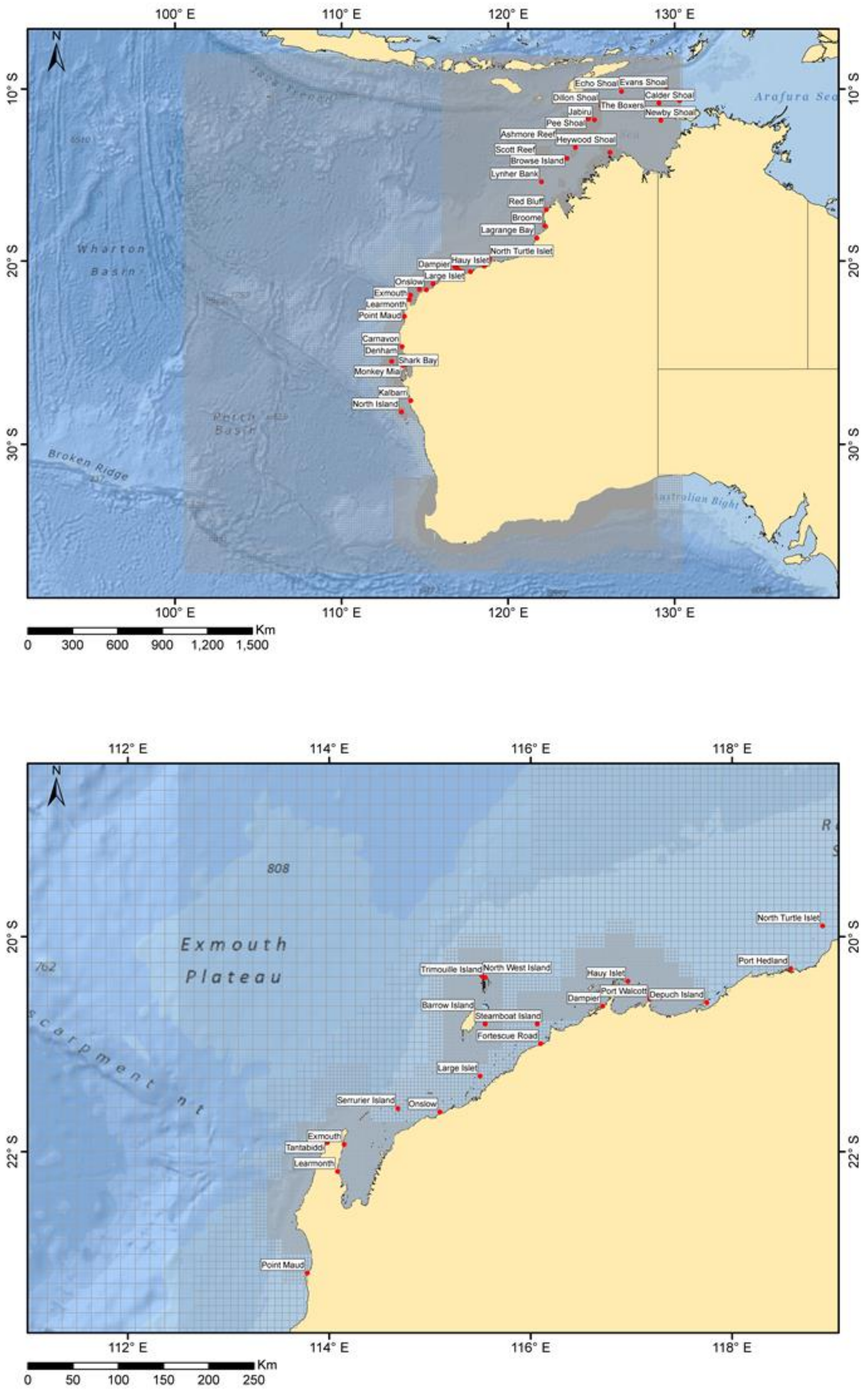


Figure 2.4 Hydrodynamic model grid (grey wire mesh) used to generate the tidal currents, showing locations available for tidal comparisons (red labelled dots). The top panel shows the full domain in context with the continental land mass, while the bottom panel shows a zoomed subset near the spill locations. Higher-resolution areas are indicated by the denser mesh zones.

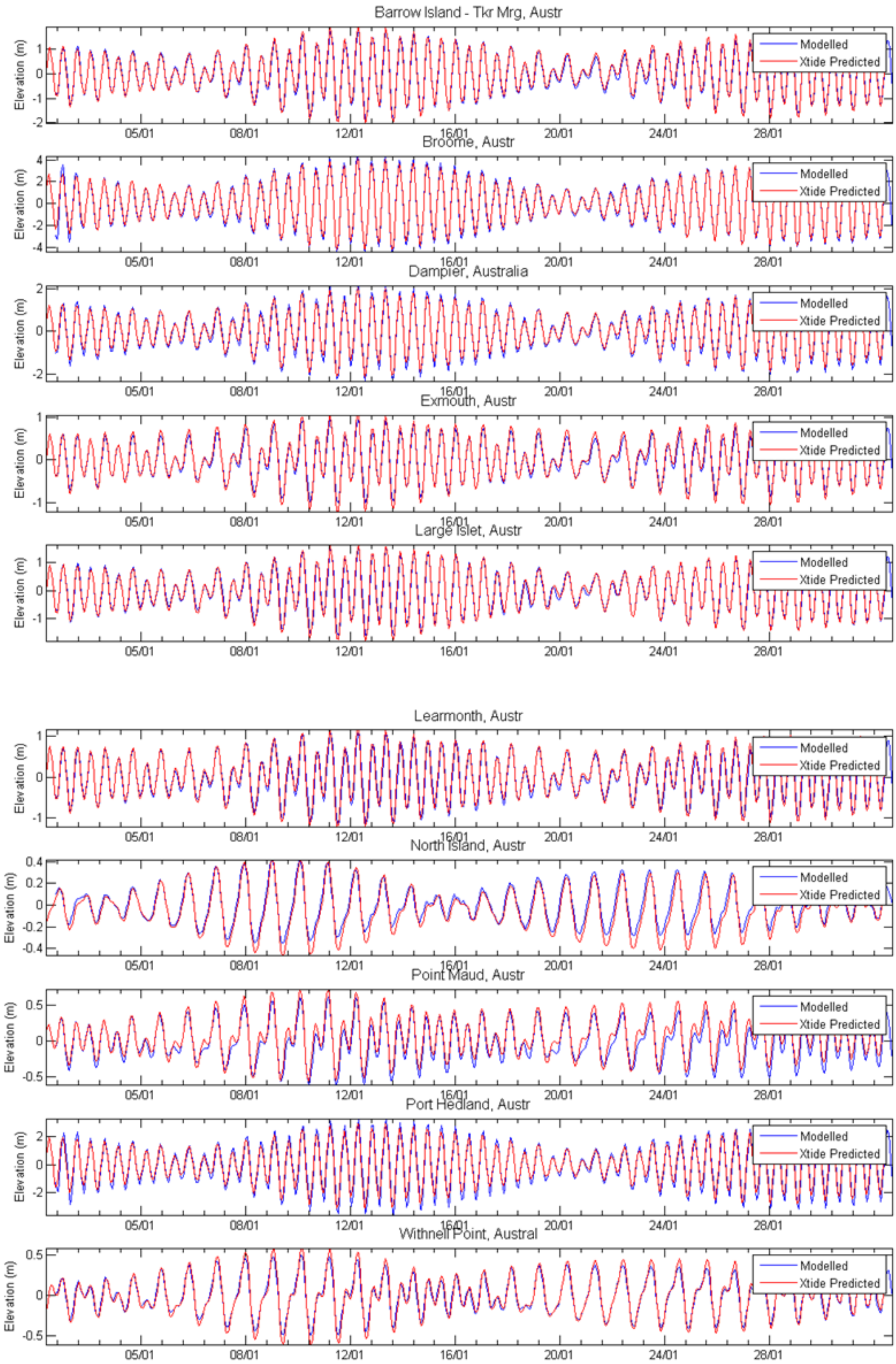
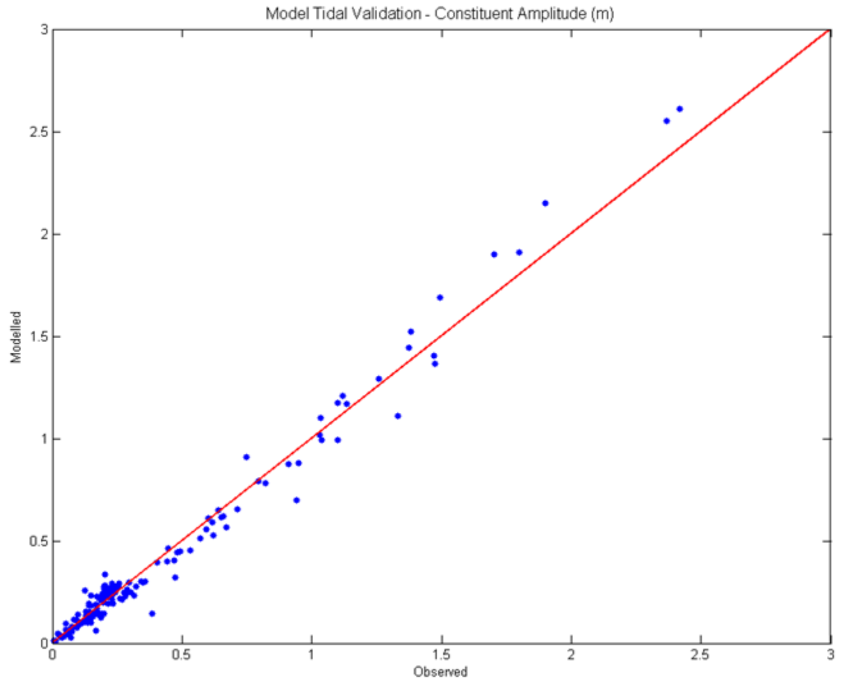


Figure 2.5 Comparisons between the predicted (blue line) and observed (red line) surface elevation variations at ten locations in the tidal model domain for January 2005.



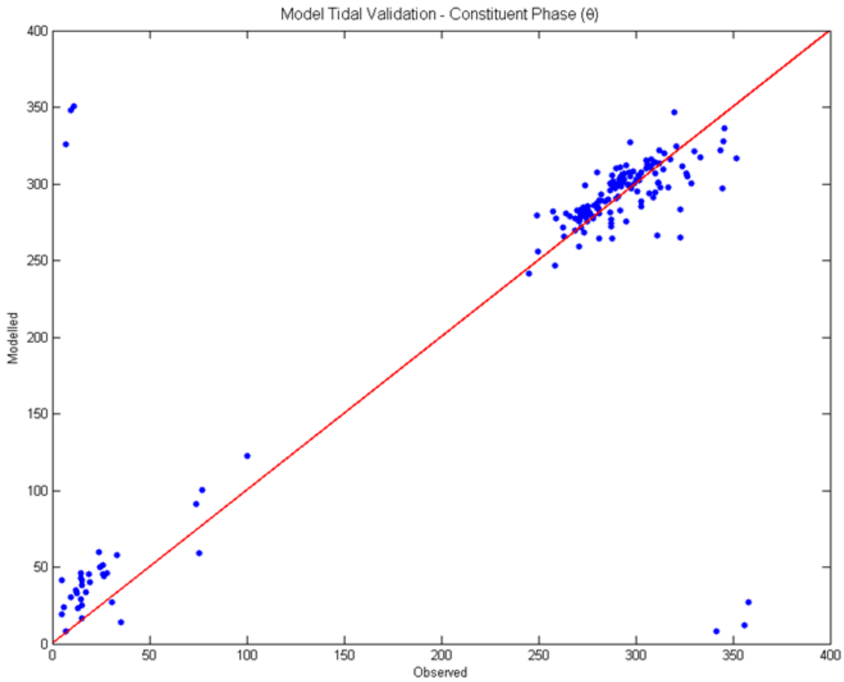


Figure 2.6 Comparisons between modelled and observed tidal constituent amplitudes (top) and phases (bottom) at all stations in the HYDROMAP model domain. The red line indicates a 1:1 correlation between the modelled and observed data.

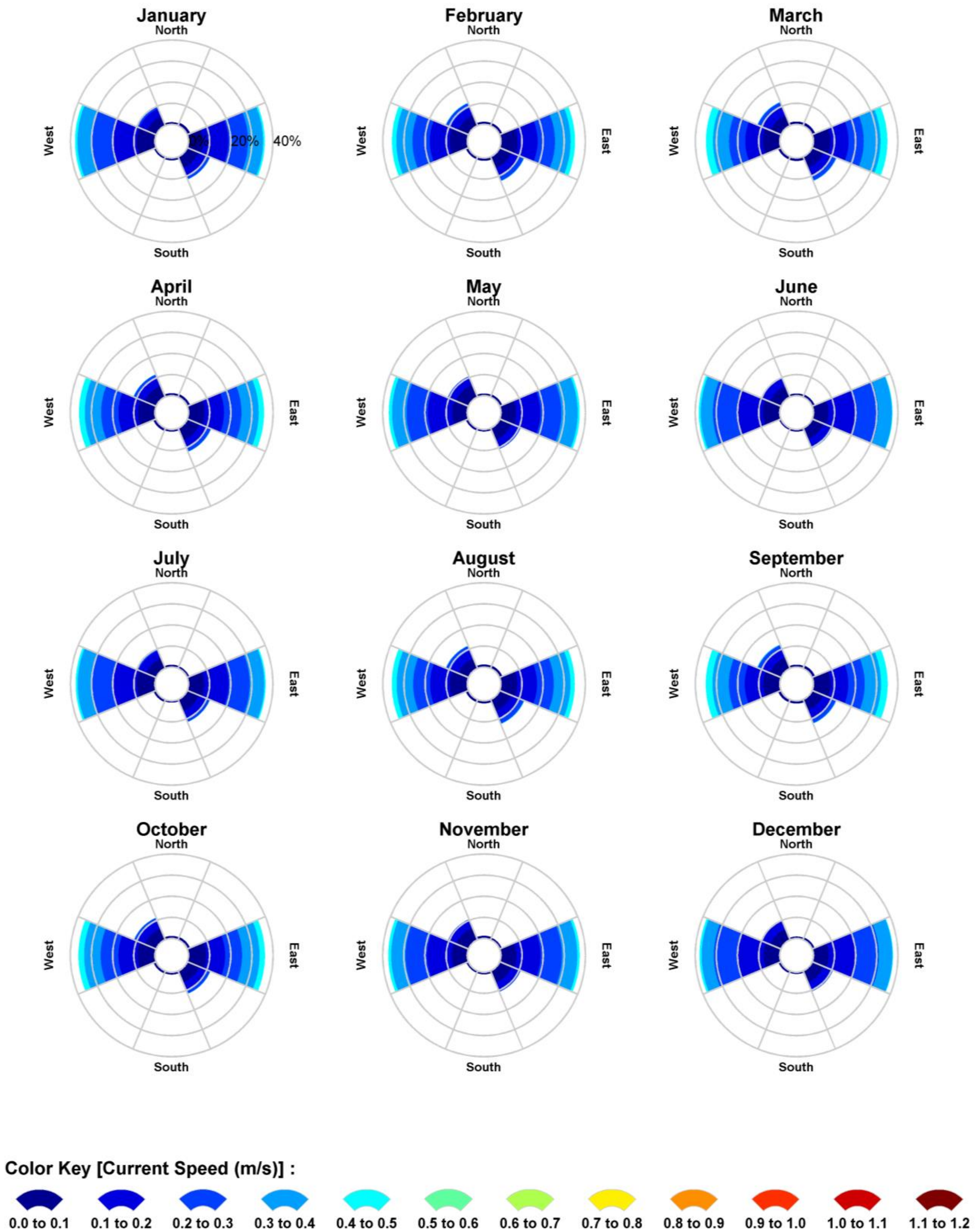


Figure 2.7 Monthly current distribution (2006-2015, inclusive) derived from the HYDROMAP database near to the Scenario 1 spill location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

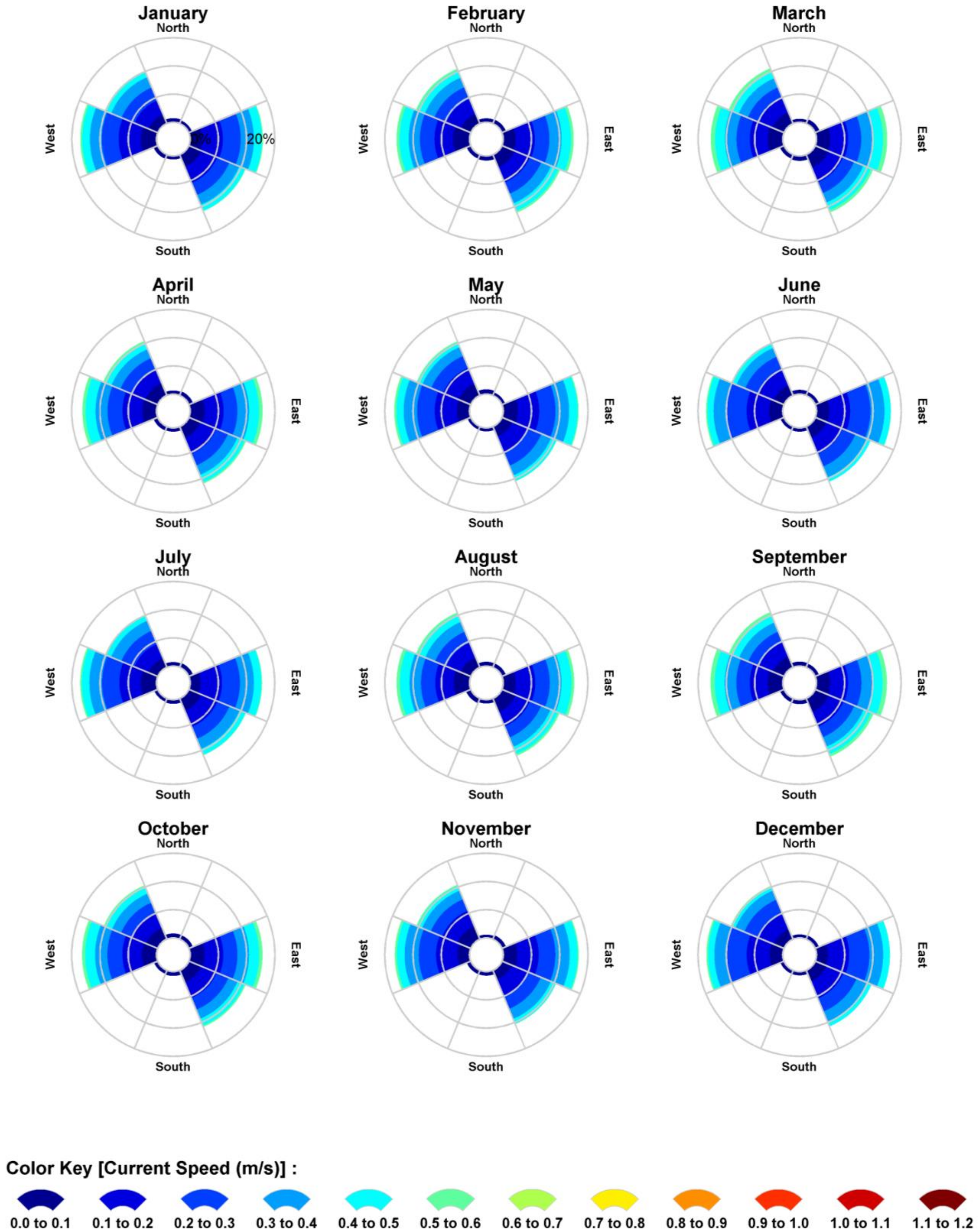


Figure 2.8 Monthly current distribution (2006-2015, inclusive) derived from the HYDROMAP database near to the Scenario 2 spill location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage of the record.

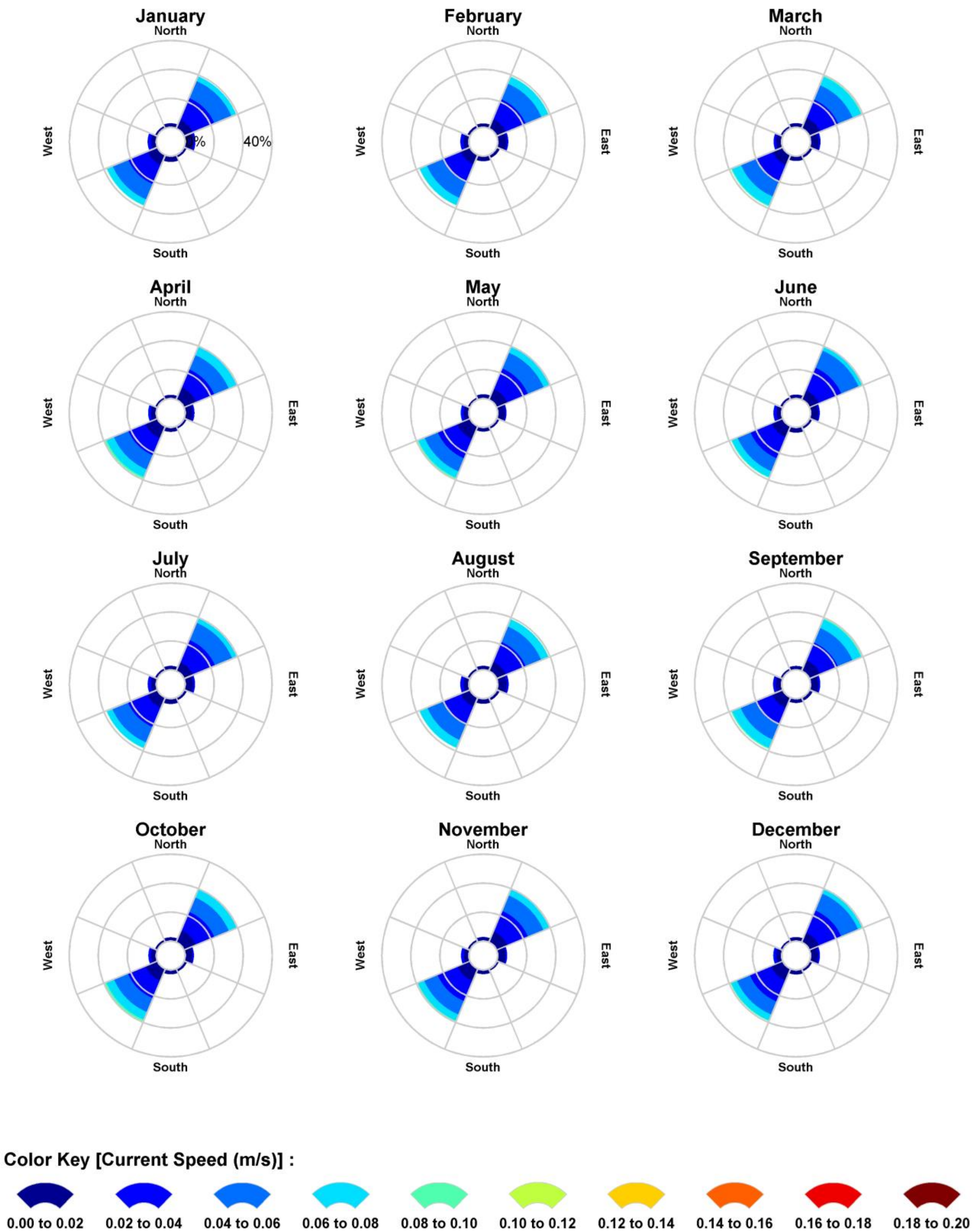


Figure 2.9 Monthly current distribution (2006-2015, inclusive) derived from the HYDROMAP database near to the Scenario 3 spill location. The colour key shows the current magnitude, the compass direction provides the direction towards which the current is flowing, and the size of the wedge gives the percentage 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 2.10 to Figure 2.12 show the monthly distribution of wind speed and direction for the CFSR data points closest to the spill locations for Scenarios 1 to 3. Note that the convention for defining wind direction is the direction from which the wind blows.

The wind data indicates similar trends in wind direction at the Scenario 1 and 2 spill locations, with predominantly easterly directions between May and July, and westerly/south-westerly directions dominating in the October to February period. At the Scenario 3 spill location, easterly/south-easterly directions are most common between April and August, with southerly directions most prominent between September and March. Average wind speeds across the year at the three spill locations 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.

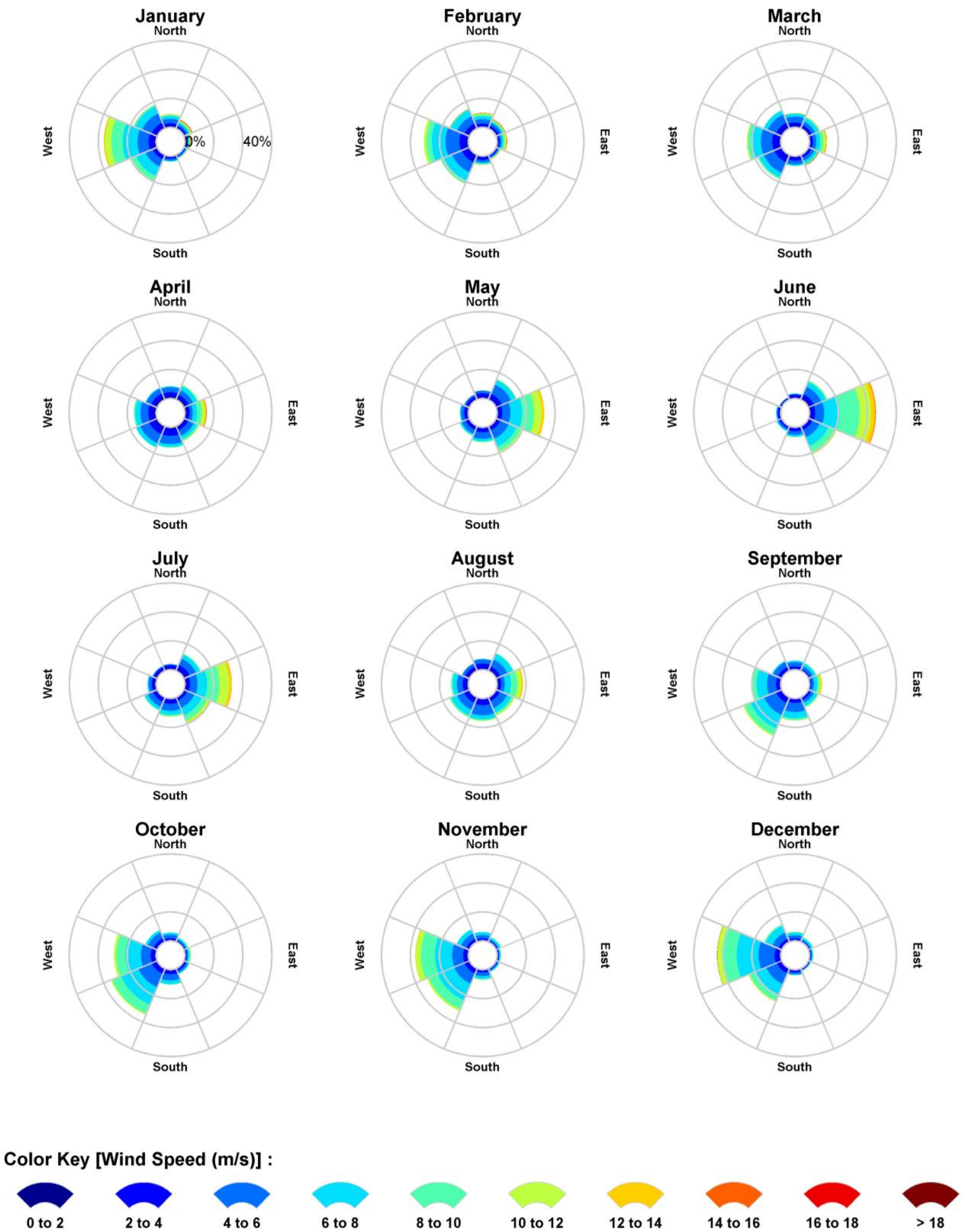


Figure 2.10 Monthly wind distribution (2006-2015, inclusive) derived from the CFSR database near to the Scenario 1 spill location. The colour key shows the wind magnitude, the compass direction provides the direction from which the wind is blowing, and the size of the wedge gives the percentage of the record.

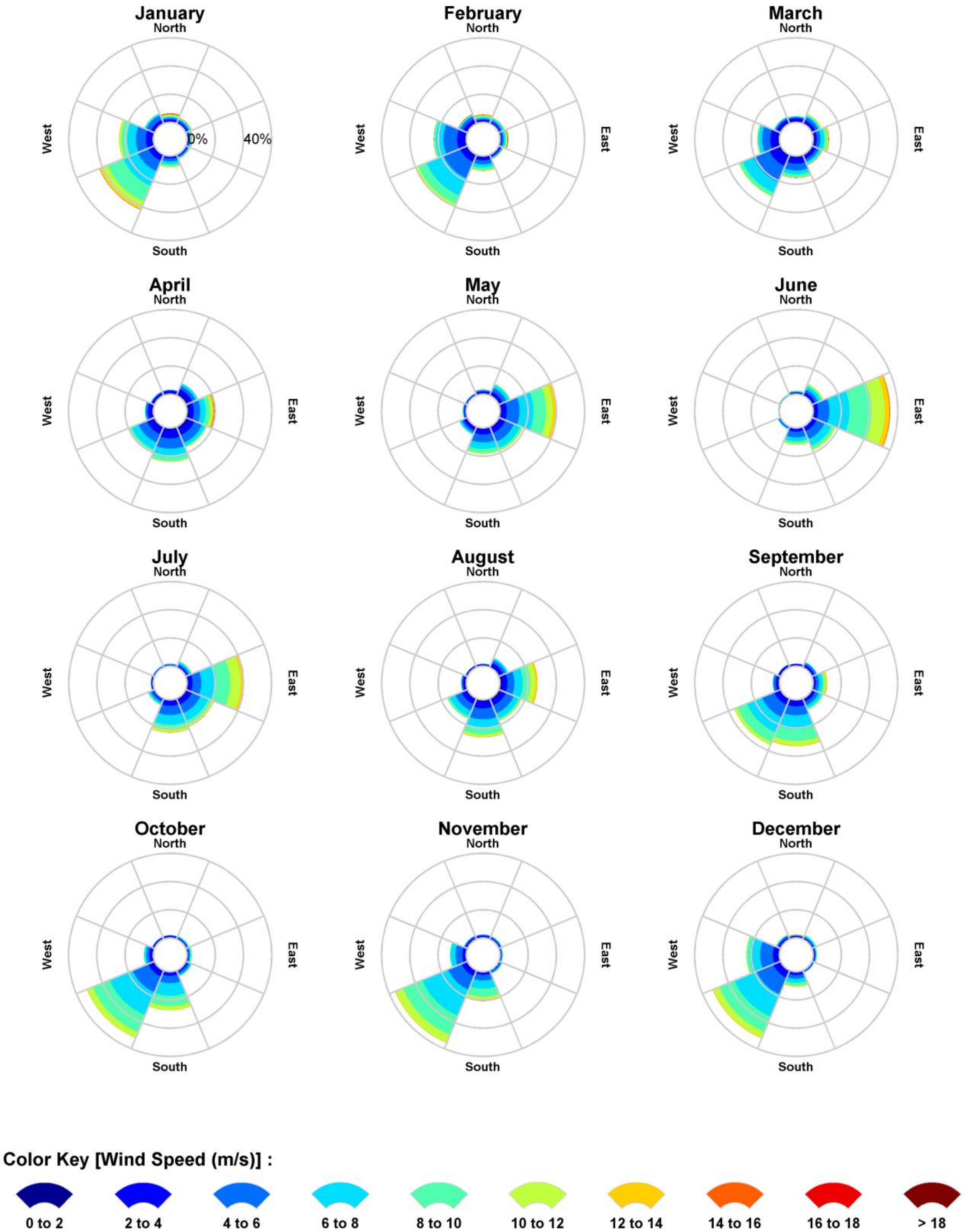


Figure 2.11 Monthly wind distribution (2006-2015, inclusive) derived from the CFSR database near to the Scenario 2 spill location. The colour key shows the wind magnitude, the compass direction provides the direction from which the wind is blowing, and the size of the wedge gives the percentage of the record.

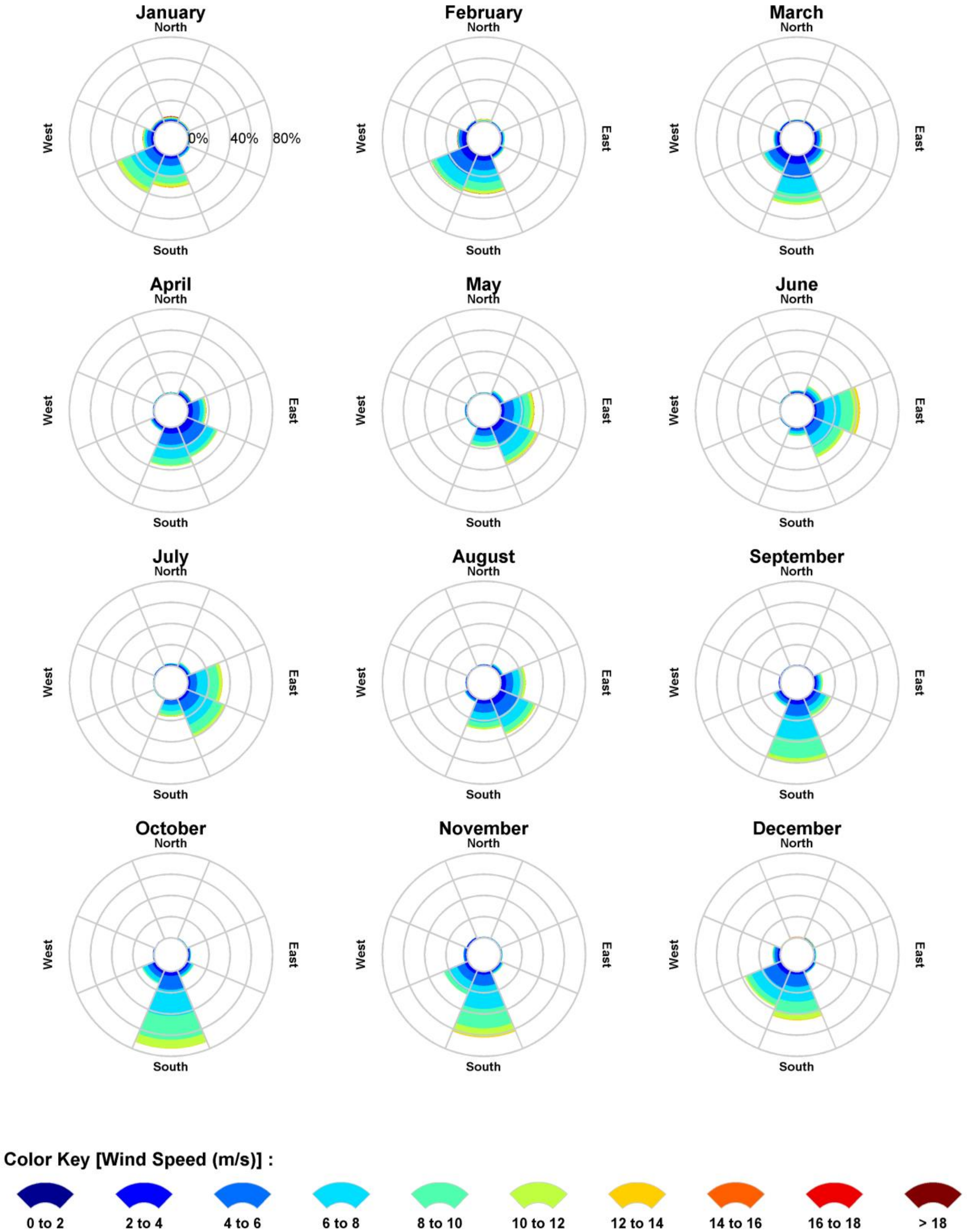


Figure 2.12 Monthly wind distribution (2006-2015, inclusive) derived from the CFSR database near to the Scenario 3 spill location. The colour key shows the wind magnitude, the compass direction provides the direction from which the wind is blowing, and the size of the wedge gives the percentage of the 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 Scarborough Project (19° 53' 54.60" S, 116° 14' 19.68" E), with monthly averages used as input to SIMAP.

Figure 2.13 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 50-150 m of the water column (where the depth is approximately 1,000 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 200 m of the water column varies between approximately 15-29 °C across the year, while the average salinity over this depth range varies between approximately 34.6-35.8 PSU year-round.

2.3.4 Dispersion

A horizontal dispersion coefficient of 5 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 Scenarios 1-3, a total of 100 replicate simulations were run over an annual period.

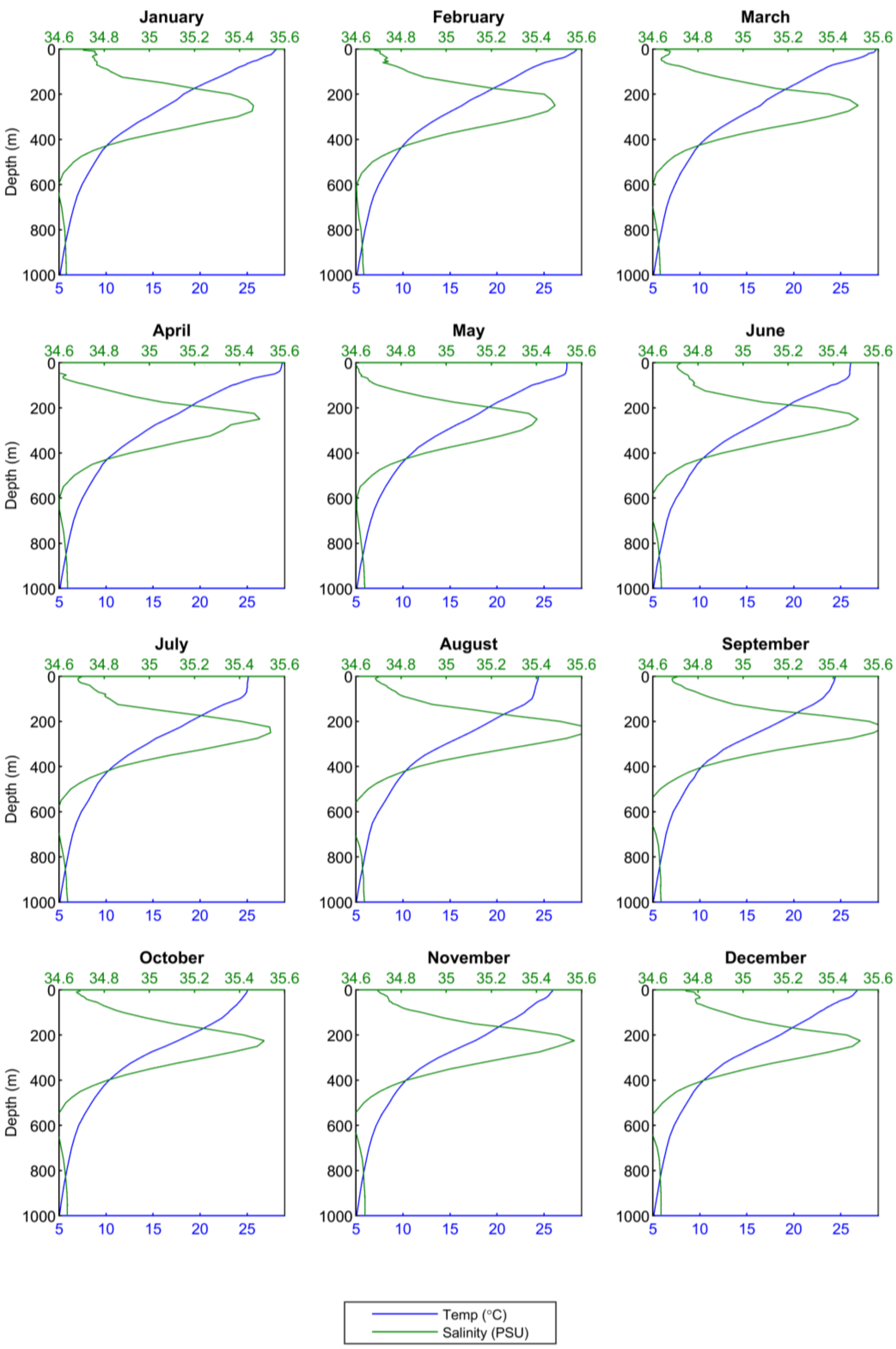


Figure 2.13 Temperature (blue line) and salinity (green line) profiles derived from the WOA13 database near the Scarborough Project (19° 53' 54.60" S, 113° 14' 19.68" E). Depth of 0 m is the water surface.

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 2.1 and discussed afterwards.

Table 2.1 Summary of the thresholds applied in this study.

<table>
<tr><th>Floating Oil Concentration (g/m^2)</th><th>Shoreline Oil Concentration (g/m^2)</th><th>Entrained Oil Concentration (ppb)</th><th>Dissolved Aromatic Hydrocarbon Concentration (ppb)</th></tr>
<tr><td>10</td><td rowspan="2">100</td><td rowspan="4">500</td><td rowspan="4">500</td></tr>
<tr><td rowspan="2">50</td></tr>
<tr><td rowspan="2">250</td></tr>
<tr><td>100</td></tr>
</table>

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. Floating oil is also visible at relatively low concentrations (> ~0.05 g/m^2). Hence, the area affected by visible oil, which might trigger social or economic impacts, will be larger than the area where biological impacts might be expected.

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 (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). The 250 g/m^2 threshold is above the minimum thresholds observed to cause ecological impact and would therefore be considered high exposure.

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 an indication of potential exposure, a threshold for concentrations of entrained oil was defined at 500 ppb. This threshold is particularly relevant for short duration (acute) exposure to organisms or fixed habitats affected by the dynamically-varying oil plume. A lower threshold, such as 10 ppb – which would be considered a conservative estimate of the lowest concentration that may be harmful to sensitive marine organisms over relatively long exposure times (tens of hours; French, 2000) – would be more meaningful for larvae and organisms that might be entrained (and therefore moving) within the oil plumes.

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 an indication of potential exposure, a threshold for concentrations of dissolved aromatic hydrocarbons was defined at 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), the 500 ppb threshold is 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 marine diesel are summarised in Table 2.2.

Table 2.2 Characteristics of the oil type used in the modelling of Scenarios 1-3.

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**
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 Marine Diesel

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 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 Marine Diesel

The mass balance forecast for the constant-wind case (Figure 2.14) 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 2.15), 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.

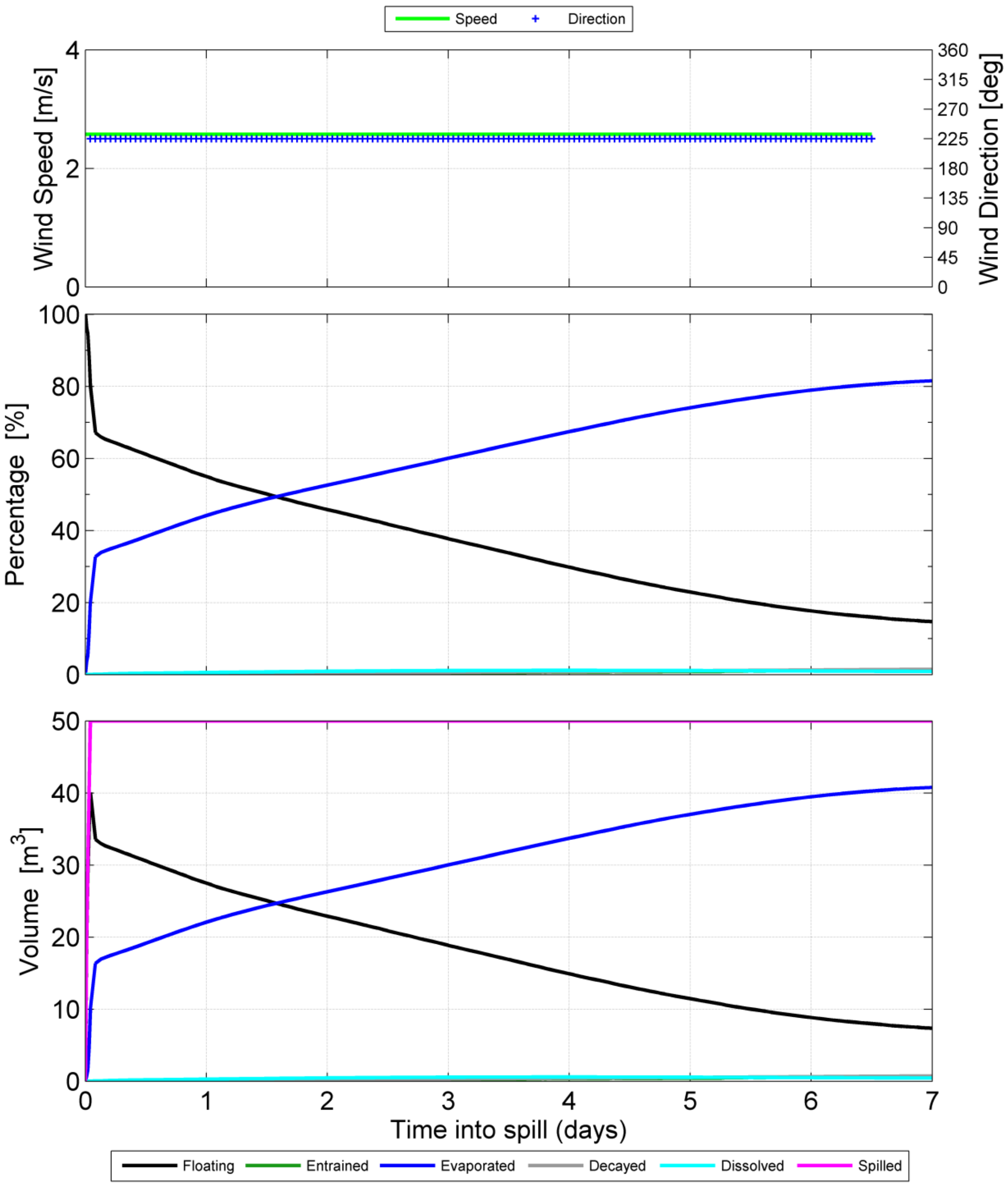


Figure 2.14 Mass balance plot representing, as proportion (middle panel) and volume (bottom panel), the weathering of marine diesel spilled onto the water surface as a one-off release (50 m^3 over 1 hour) and subject to a constant 5 kn (2.6 m/s) wind at 27 °C water temperature and 25 °C air temperature.

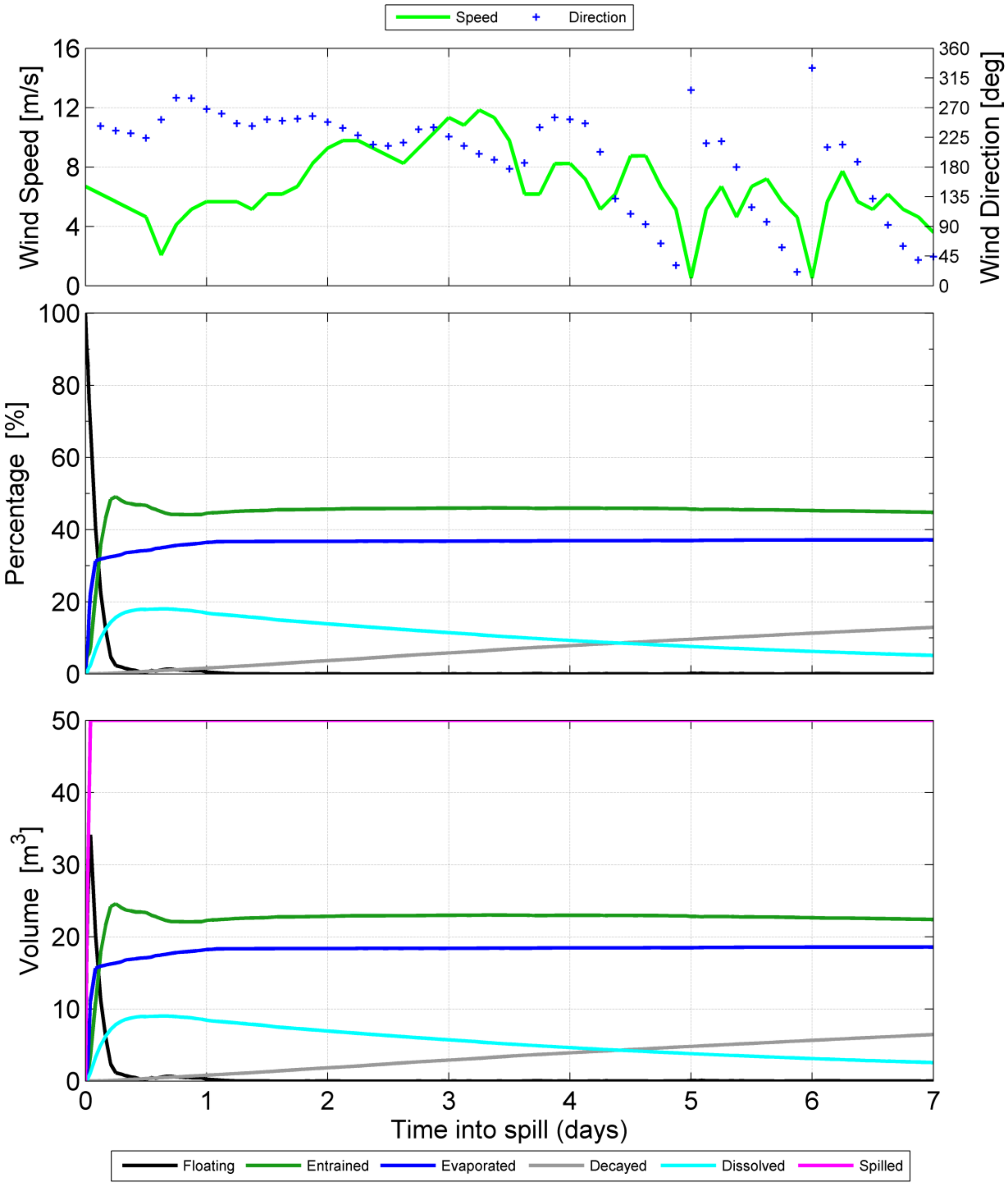


Figure 2.15 Mass balance plot representing, as proportion (middle panel) and volume (bottom panel), the weathering of marine diesel spilled onto the water surface as a one-off release (50 m^3 over 1 hour) and subject to variable wind at 27 °C water temperature and 25 °C air temperature.

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 (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 200 replicate simulations for each assessed scenario.

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 Zones of Consequence (ZoCs) 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.

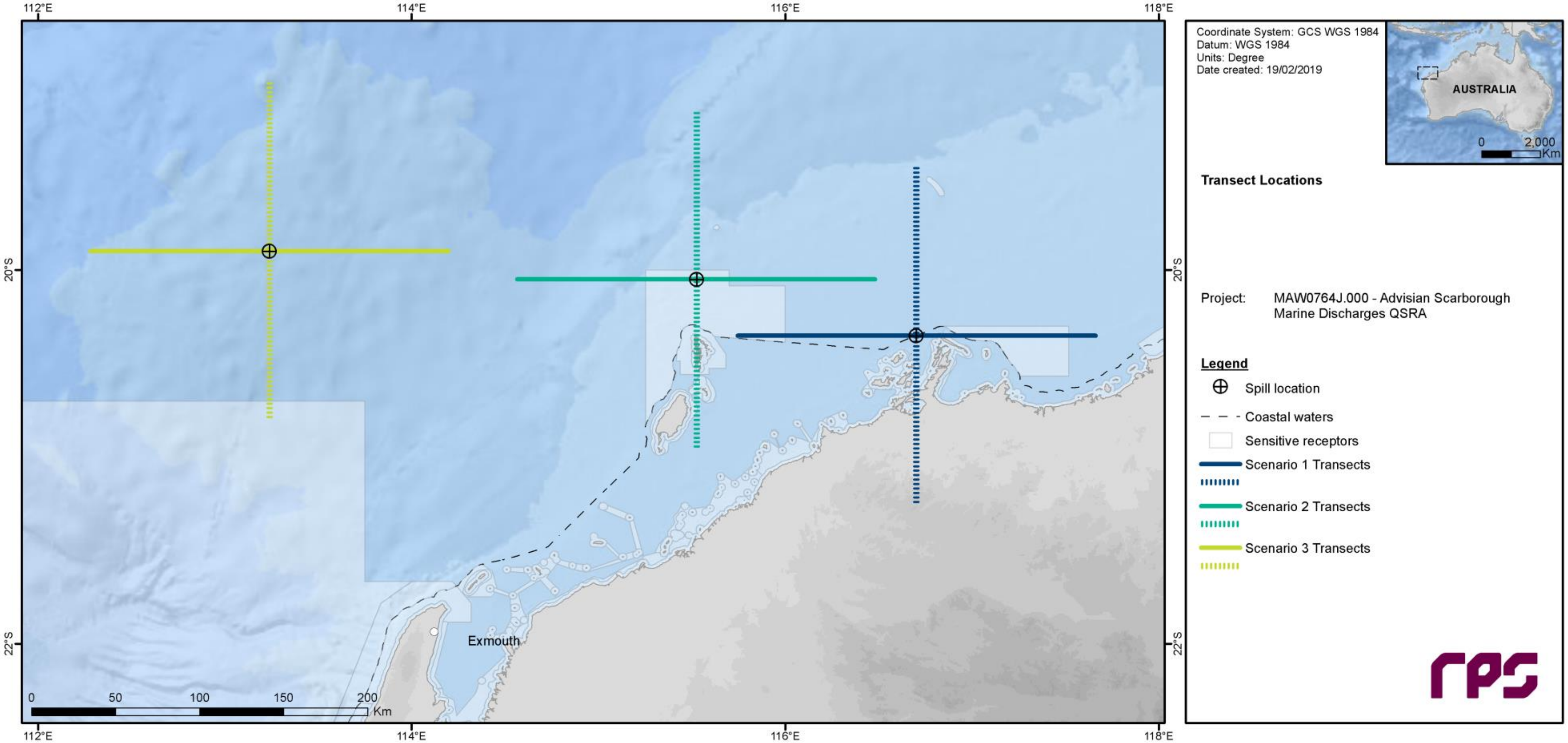


Figure 3.1 Locations of cross-sections, over a varying latitude (dashed line) and longitude (solid line), along which the distributions of maximum entrained oil and dissolved aromatic hydrocarbon concentrations were extracted for each spill scenario in this study.

3.2 Scenario 1: Short-Term (Instantaneous) Surface Release of Marine Diesel after a Vessel Collision outside Mermaid Sound

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 short-term (instantaneous) surface release of 2,000 m^3 of marine diesel outside Mermaid Sound during operations at any time of year, with no mitigation measures applied.

Considering the discharge characteristics, the properties of the oil and its expected weathering behaviour, floating oil will be susceptible to entrainment into the wave-mixed layer under typical wind conditions. Evaporation rates will be significant, given the moderate proportion of volatile compounds in the oil (41%). The low-volatility fraction of the oil (54%) will take longer durations of the order of days to evaporate, and the residual fraction of 5% is expected to persist in the environment until degradation processes occur. Considering the spill volume, there is a low 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, 50 g/m^2 and 100 g/m^2 thresholds could potentially be found, in the form of slicks, up to 29 km, 21 km and 18 km from the spill site, respectively (Figure 3.2, Figure 3.3 and Figure 3.4).

The Dampier Archipelago shoreline receptor is predicted to be contacted by floating oil concentrations at the 10 g/m^2 threshold with a probability of 2% and a minimum time to contact of 27 hours (Table 3.1). Probabilities of floating oil contact at the 50 g/m^2 and 100 g/m^2 thresholds are forecast to be equal to or less than 1% for other shoreline receptors.

Potential for accumulation of oil on shorelines is predicted to be low, with a maximum accumulated volume of 3 m^3 and a maximum local accumulated concentration on shorelines of 156 g/m^2 forecast at the Dampier Archipelago (Table 3.1).

The forecast annualised minimum times to contact, ZoC and smoothed ZoC for floating oil at or above the 10 g/m^2, 50 g/m^2 and 100 g/m^2 threshold concentrations are depicted in Figure 3.5 to Figure 3.7, Figure 3.8 to Figure 3.10 and Figure 3.11 to Figure 3.13, respectively.

3.2.1.3 Entrained Oil

Entrained oil at concentrations equal to or greater than the 500 ppb threshold is predicted to be found up to around 163 km from the spill site (Figure 3.15).

The Dampier MP and Dampier Archipelago receptors are predicted to receive entrained oil concentrations at the 500 ppb threshold with probabilities of 44% and 23%, respectively (Table 3.2). The maximum entrained oil concentration is forecast as 10.9 ppm within the Dampier Archipelago.

The forecast annualised minimum times to contact, ZoC and smoothed ZoC for entrained oil at or above the 500 ppb threshold concentration are depicted in Figure 3.16, Figure 3.17 and Figure 3.18, 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 3.19).

3.2.1.4 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 34 km from the spill site (Figure 3.20).

The Dampier MP receptor is predicted to receive dissolved aromatic hydrocarbon concentrations at the 500 ppb threshold with a probability of 2% (Table 3.3). The maximum dissolved aromatic hydrocarbon concentration is forecast as 635 ppb within the Dampier MP.

The forecast annualised minimum times to contact, ZoC and smoothed ZoC for dissolved aromatic hydrocarbons at or above the 500 ppb threshold concentration are depicted in Figure 3.21, Figure 3.22 and Figure 3.23, 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 20 m (Figure 3.24).

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 an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.

Receptor	Probability (%) of floating oil concentration ≥10 g/m^2	Probability (%) of floating oil concentration ≥50 g/m^2	Probability (%) of floating oil concentration ≥100 g/m^2	Minimum time to receptor (hours) for floating oil at ≥10 g/m^2	Minimum time to receptor (hours) for floating oil at ≥50 g/m^2	Minimum time to receptor (hours) for floating oil at ≥100 g/m^2	Probability (%) of shoreline oil concentration ≥100 g/m^2	Probability (%) of shoreline oil concentration ≥250 g/m^2	Minimum time to receptor (hours) for shoreline oil at ≥100 g/m^2	Minimum time to receptor (hours) for shoreline oil at ≥250 g/m^2	Maximum local accumulated concentration (g/m^2) averaged over all replicate simulations	Maximum local accumulated concentration (g/m^2) in the worst replicate simulation	Maximum accumulated volume (m^3) along this shoreline, averaged over all replicate simulations	Maximum accumulated volume (m^3) along this shoreline, in the worst replicate simulation
Barrow Island	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	<0.1	4.6	<1	<1
Dampier Archipelago	2	1	<1	27	42	NC	1	<1	53	NC	2.8	156	<1	3
Glomar Shoals*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA
Montebello Islands	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	<0.1	4.2	<1	<1
Muiron Islands MMA-WHA	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	<0.1	3.4	<1	<1
Ningaloo Coast North WHA	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	<0.1	1.5	<1	<1
Ningaloo RUZ*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA
Pilbara - Middle Pilbara - Islands & Shoreline	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	<0.1	4.3	<1	<1
Pilbara - Northern Pilbara - Islands & Shoreline	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	NC	NC	<1	<1
Pilbara Islands - Southern Island Group	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	0.3	7	<1	<1
Rankin Bank*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA
Lowendal Islands	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	<0.1	2	<1	<1
Montebello MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA
Montebello State Marine Park	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	<0.1	4.2	<1	<1
Muiron Islands	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	<0.1	3.4	<1	<1
Dampier MP*	2	<1	<1	37	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA
Eighty Mile Beach MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA
Gascoyne MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA
WA Coastline	3	1	<1	26	43	NC	1	<1	53	NC	2.8	156	<1	3

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.

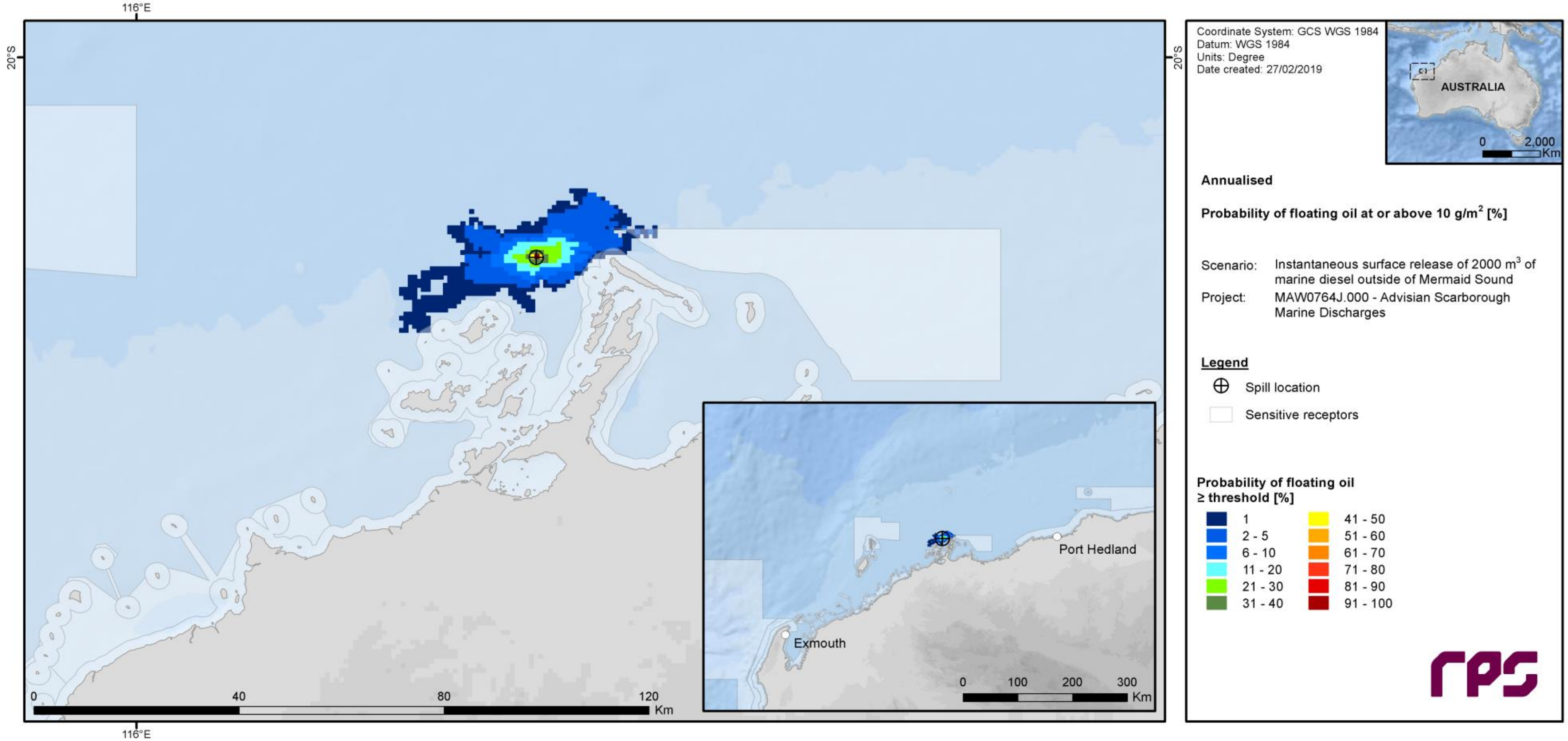


Figure 3.2 Predicted annualised probability of floating oil concentrations at or above 10 g/m² resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.

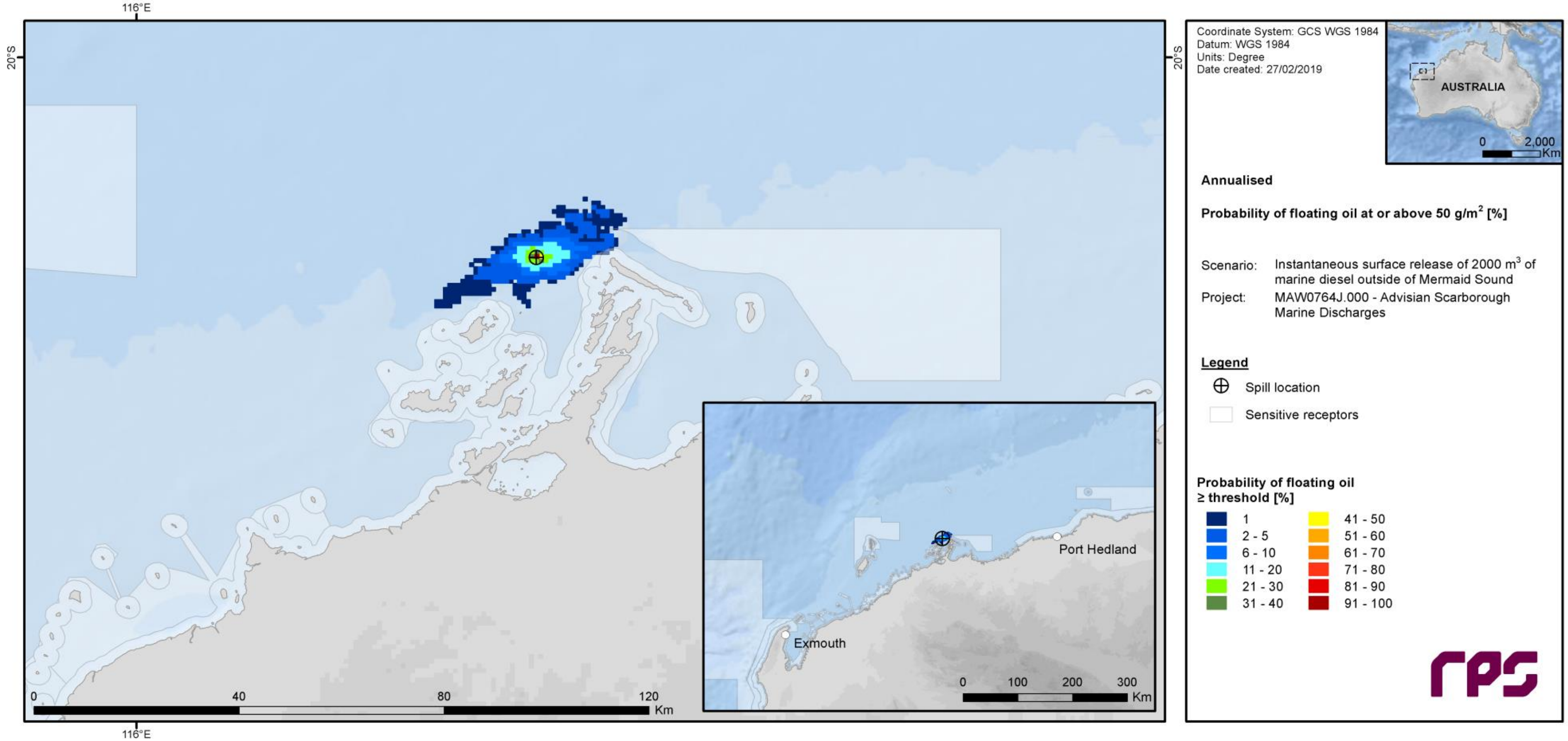


Figure 3.3 **Predicted annualised probability of floating oil concentrations at or above 50 g/m² resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.**

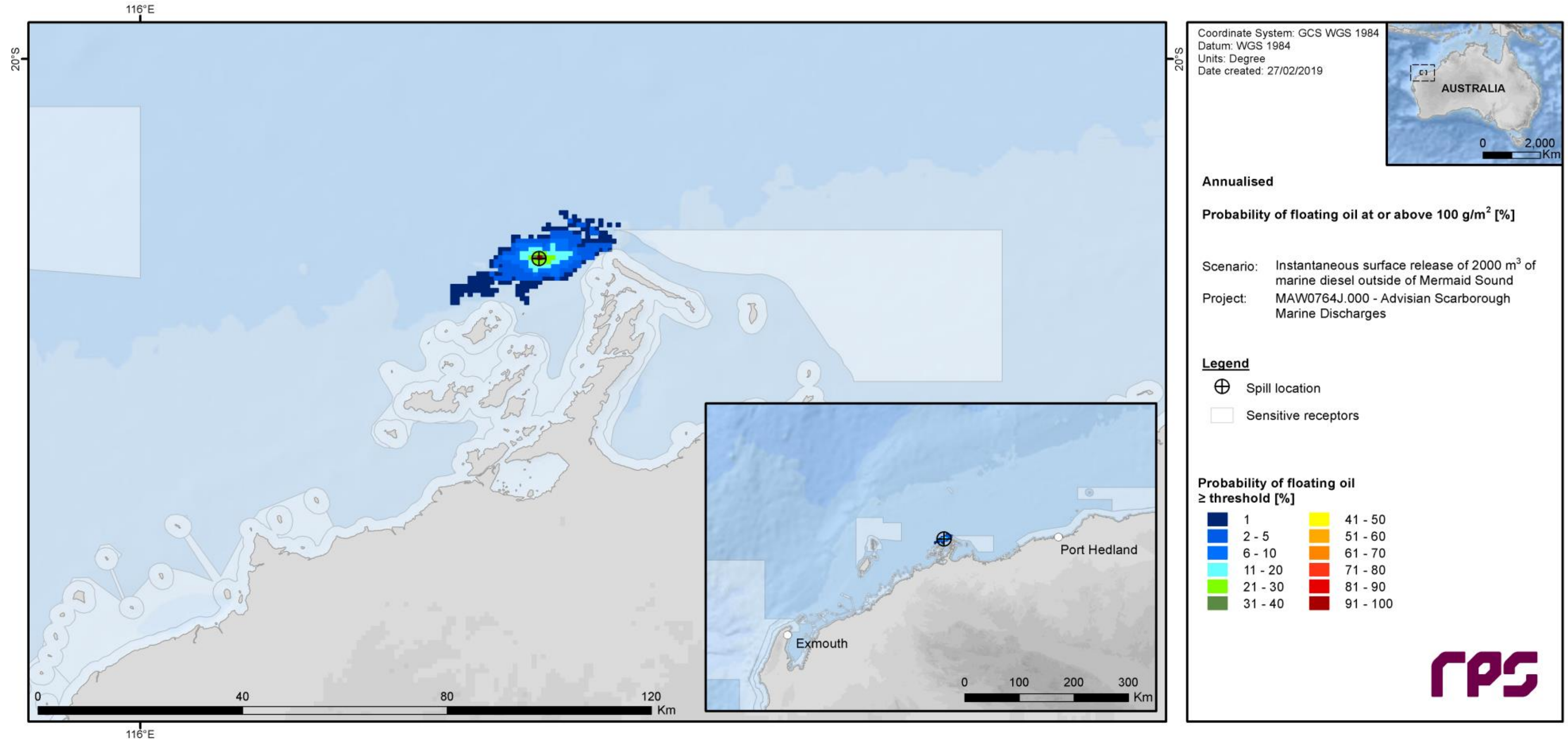


Figure 3.4 **Predicted annualised probability of floating oil concentrations at or above 100 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.**

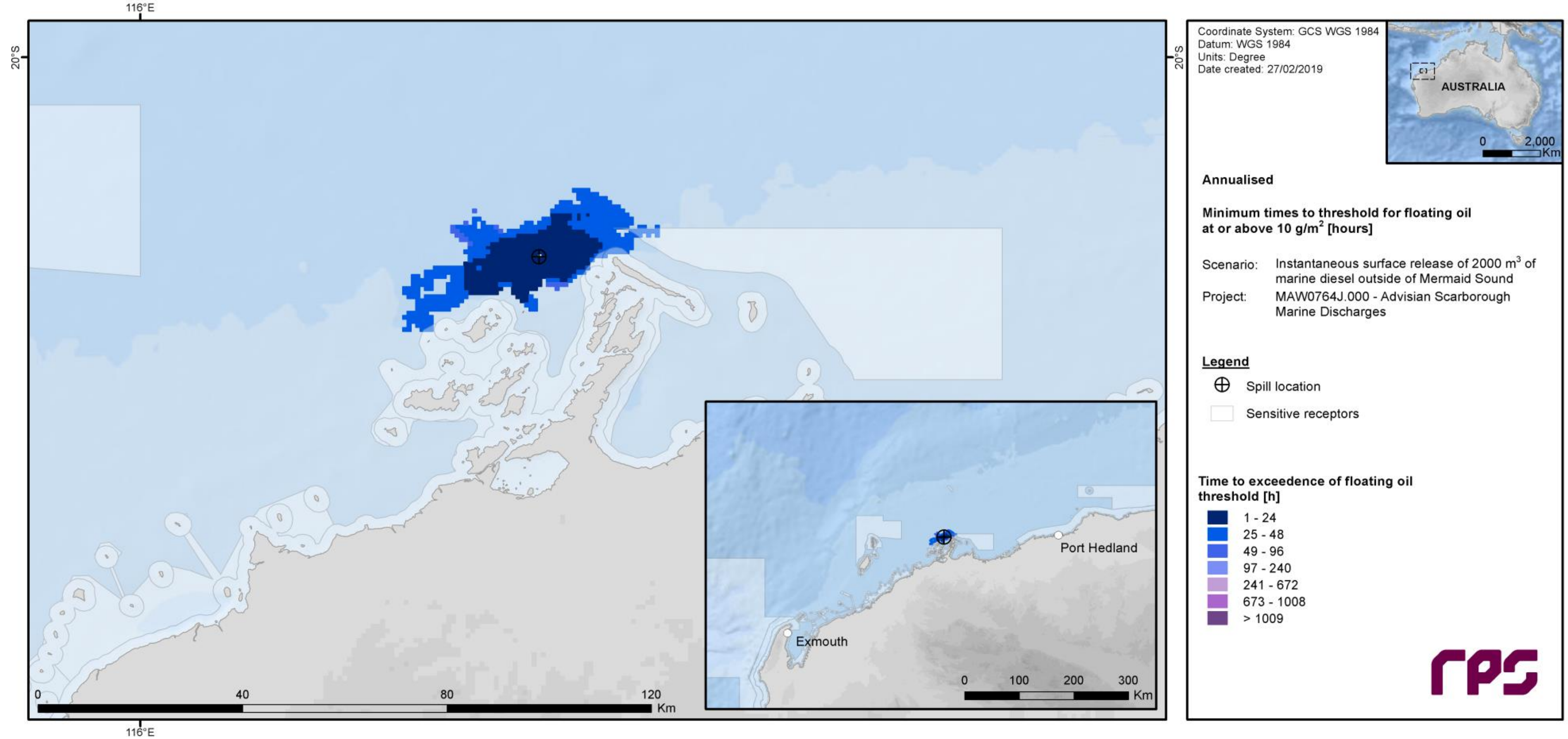


Figure 3.5 **Predicted annualised minimum times to contact by floating oil concentrations at or above 10 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.**

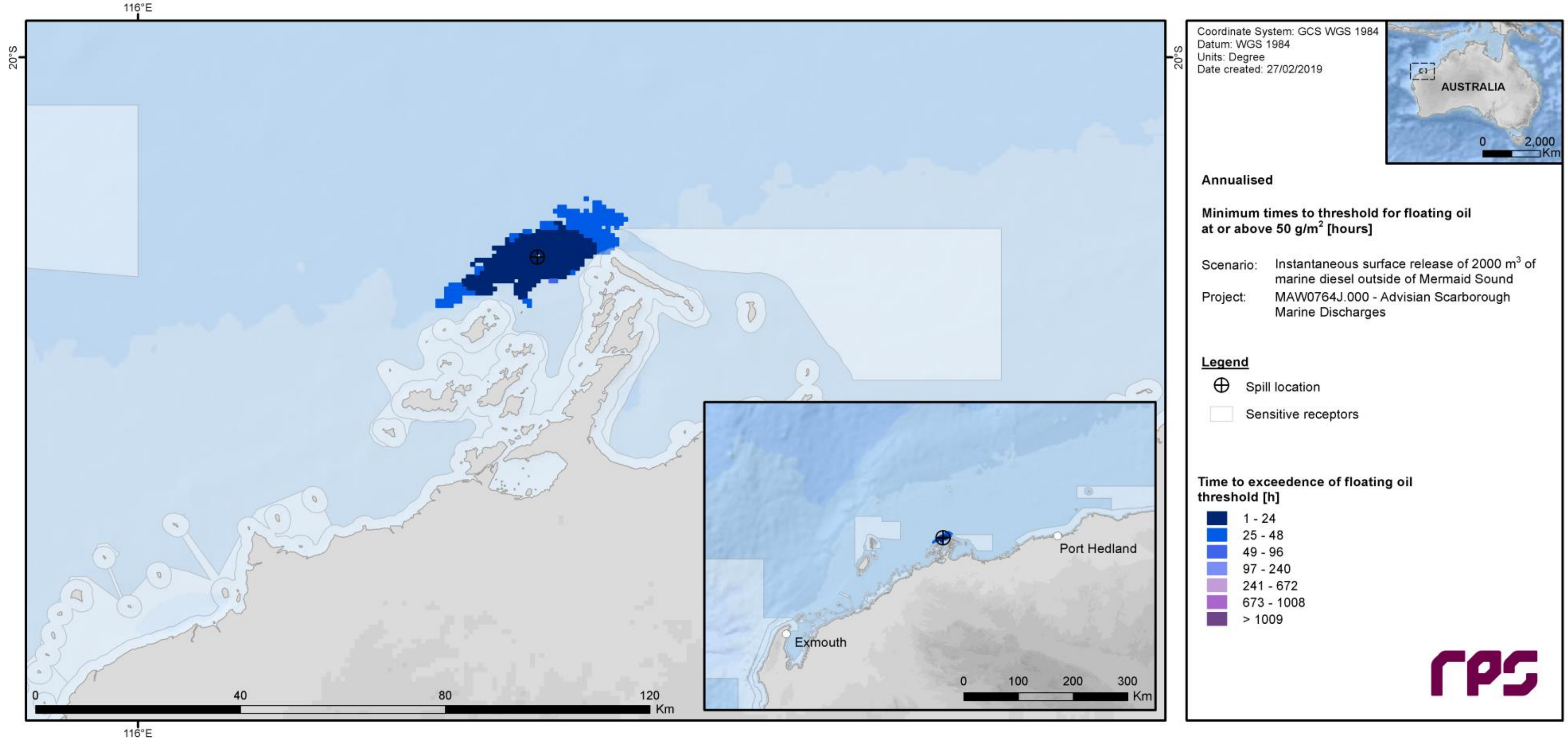


Figure 3.6 Predicted annualised minimum times to contact by floating oil concentrations at or above 50 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.

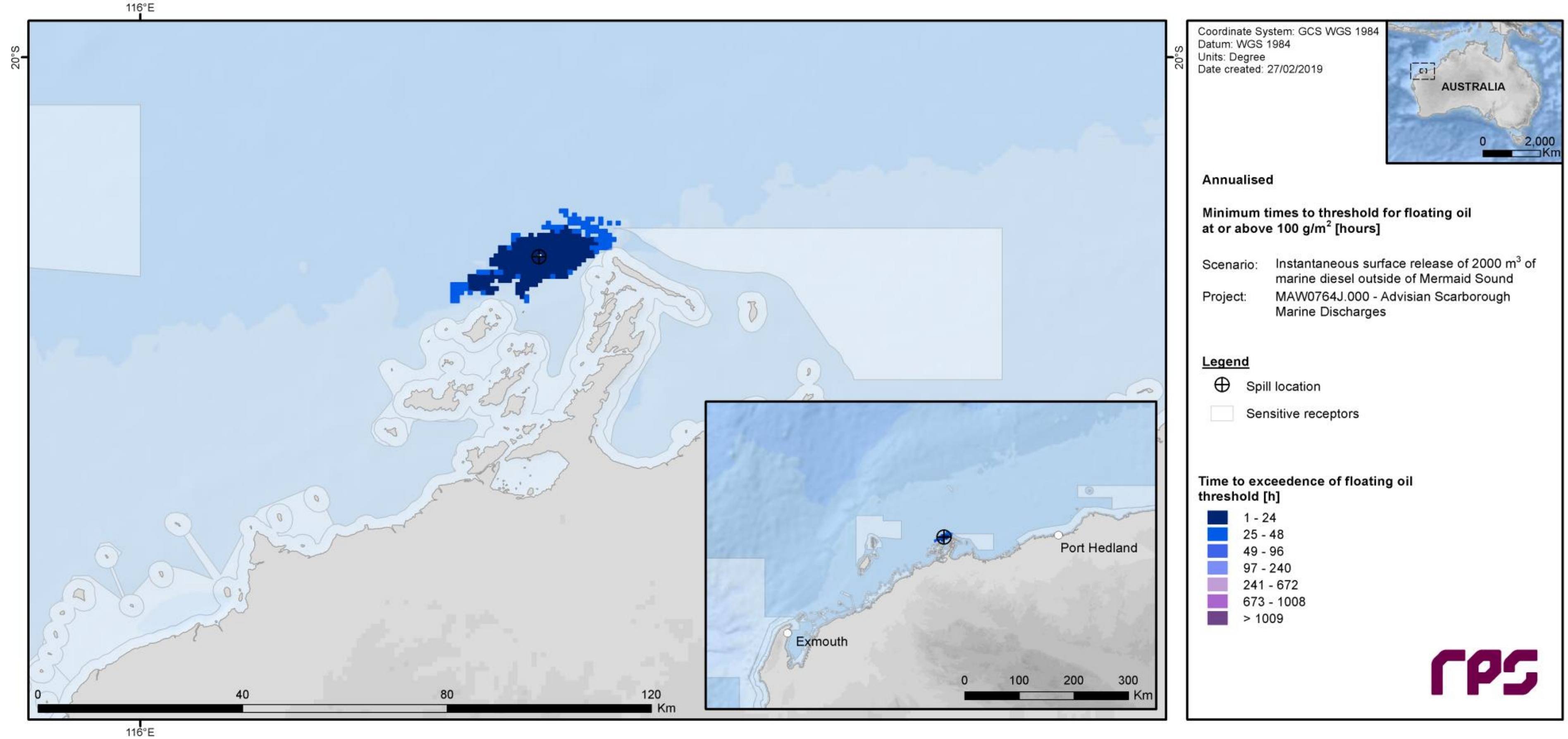


Figure 3.7 Predicted annualised minimum times to contact by floating oil concentrations at or above 100 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.

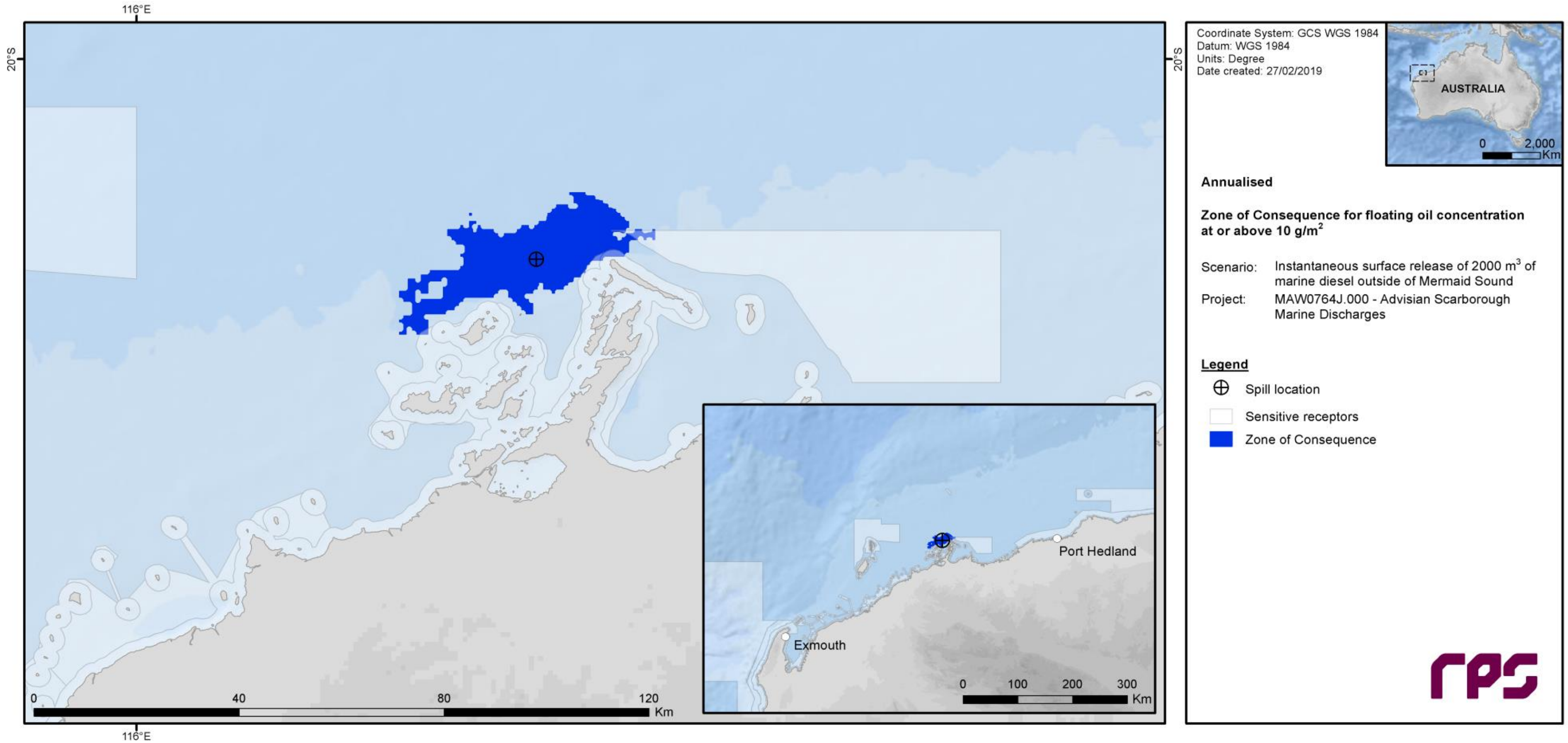


Figure 3.8 Predicted annualised Zone of Consequence of floating oil concentrations at or above 10 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.

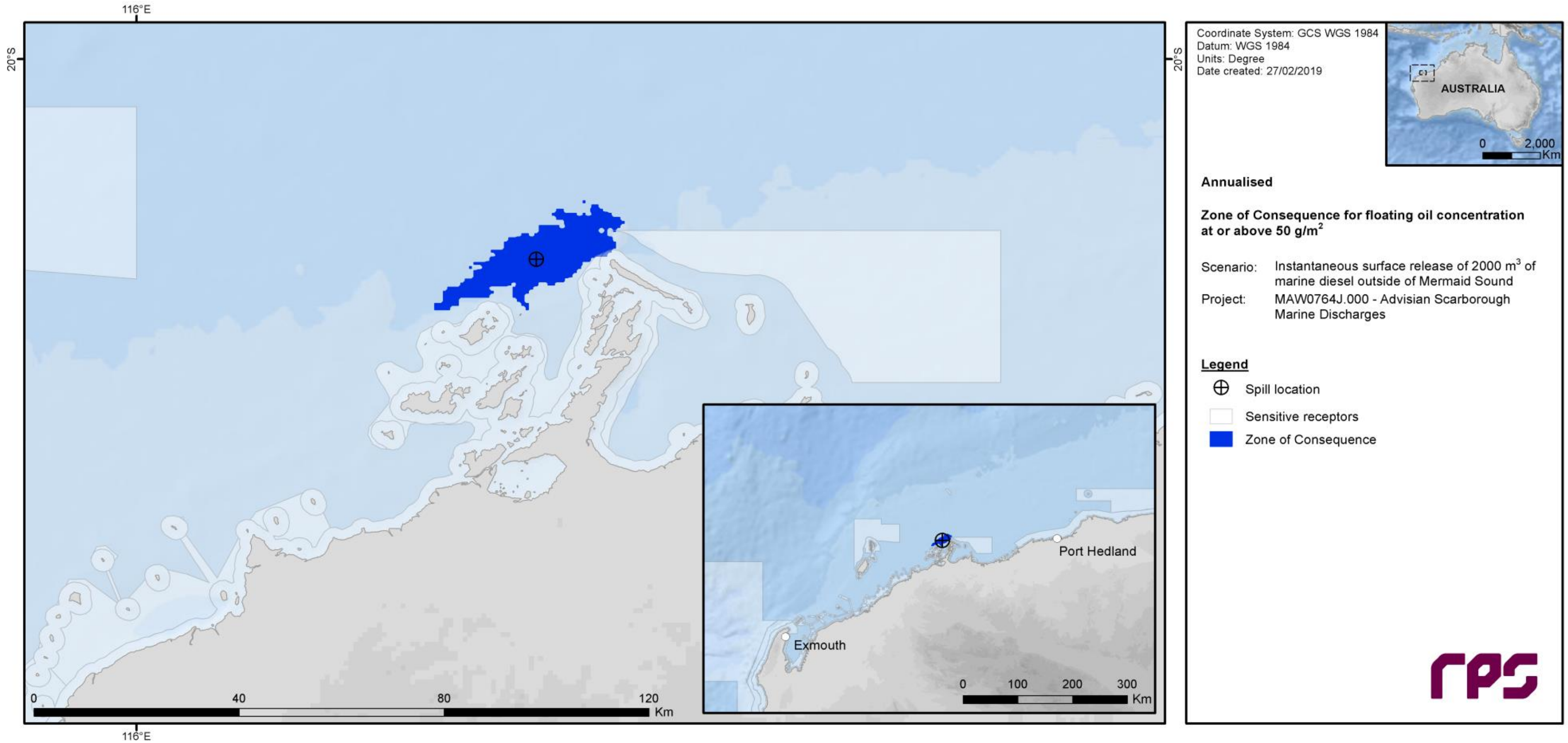


Figure 3.9 Predicted annualised Zone of Consequence of floating oil concentrations at or above 50 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.

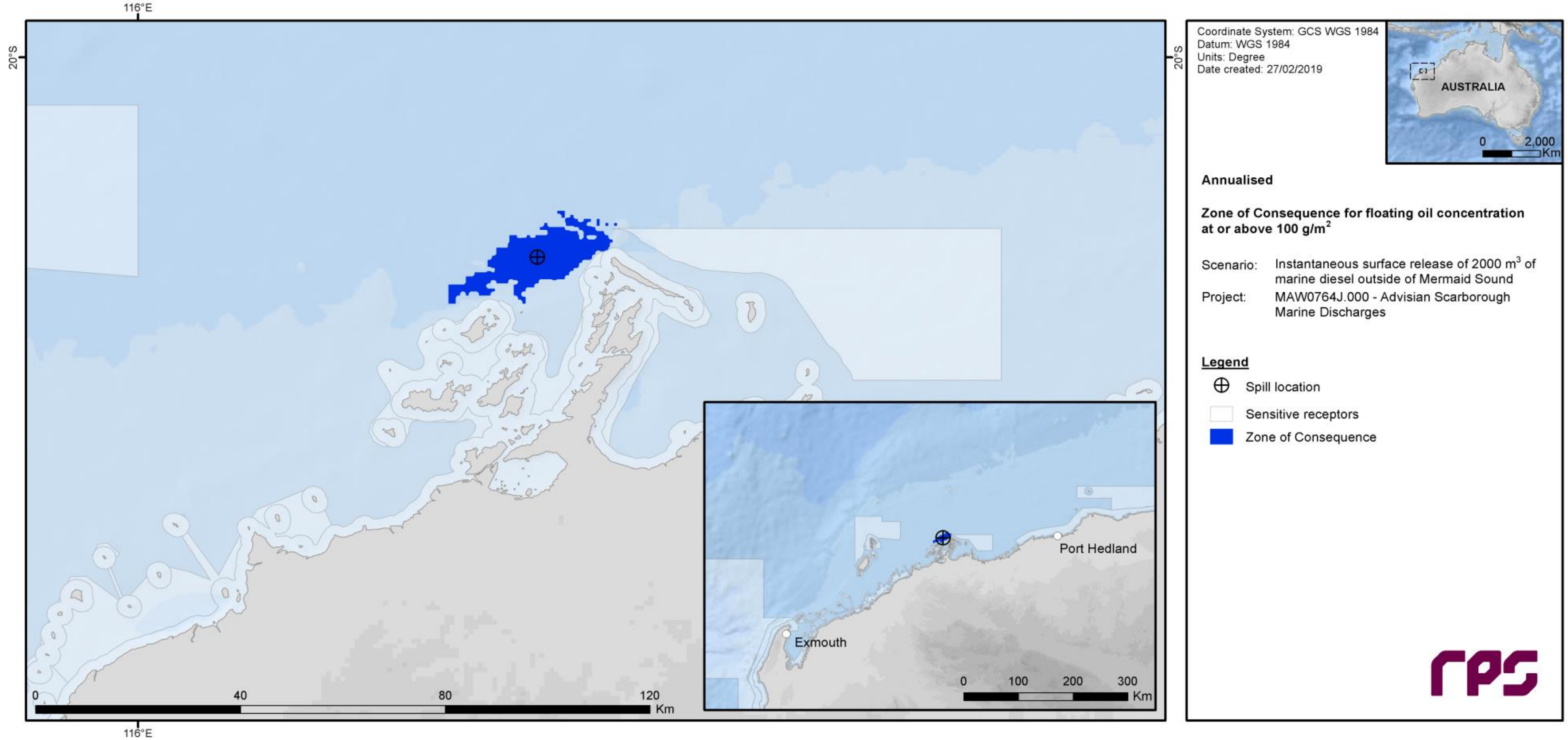


Figure 3.10 Predicted annualised Zone of Consequence of floating oil concentrations at or above 100 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.

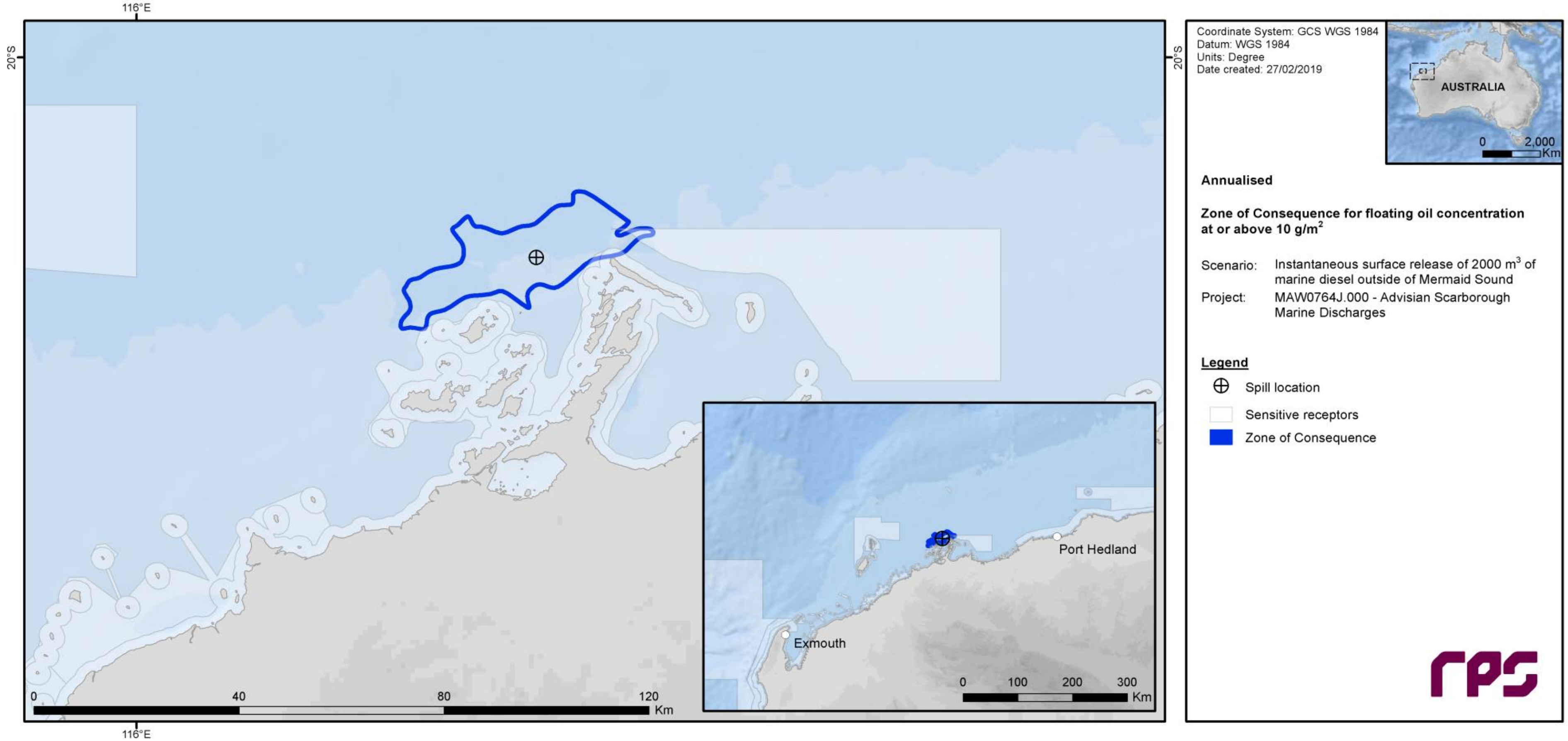


Figure 3.11 Predicted annualised smoothed Zone of Consequence of floating oil concentrations at or above 10 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.

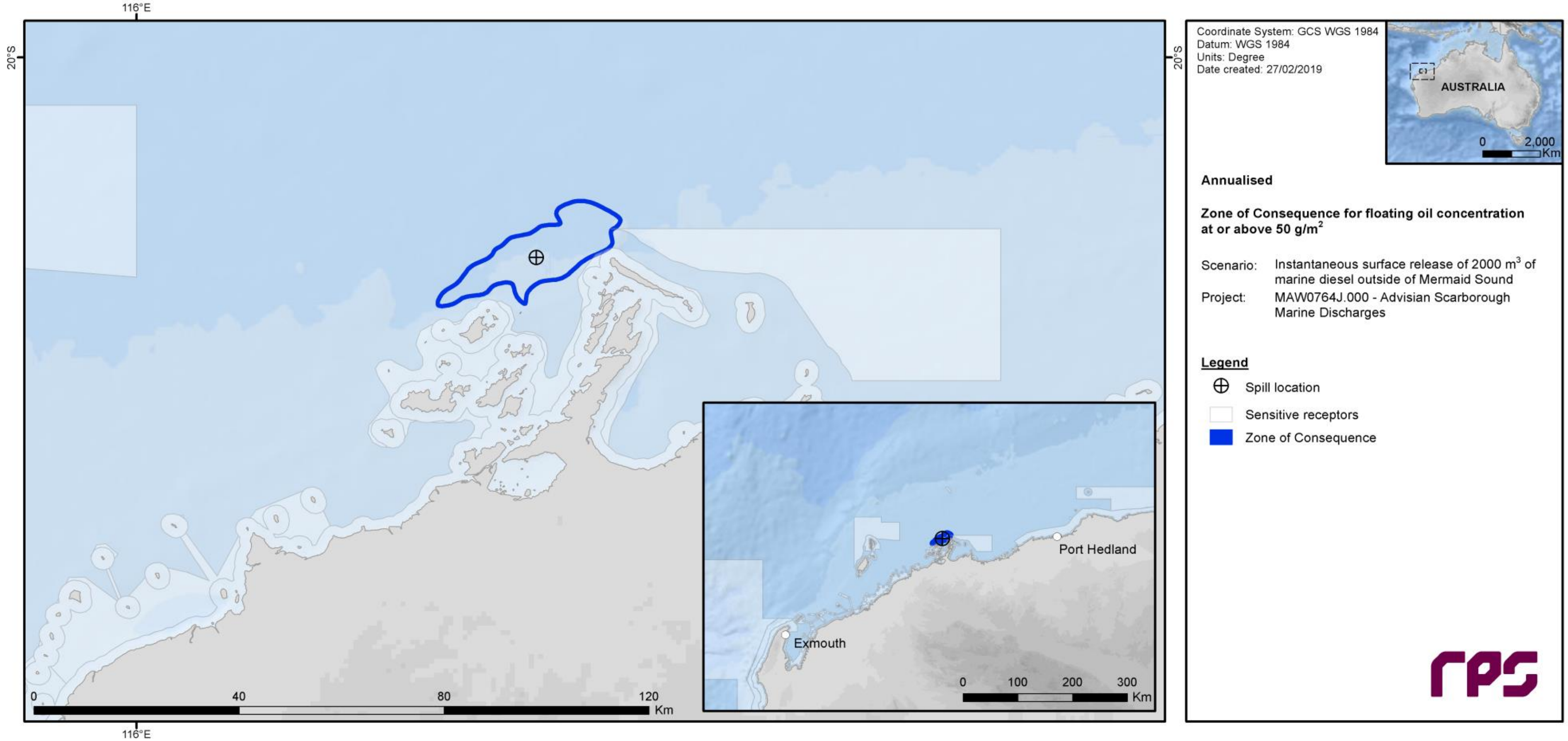


Figure 3.12 Predicted annualised smoothed Zone of Consequence of floating oil concentrations at or above 50 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.

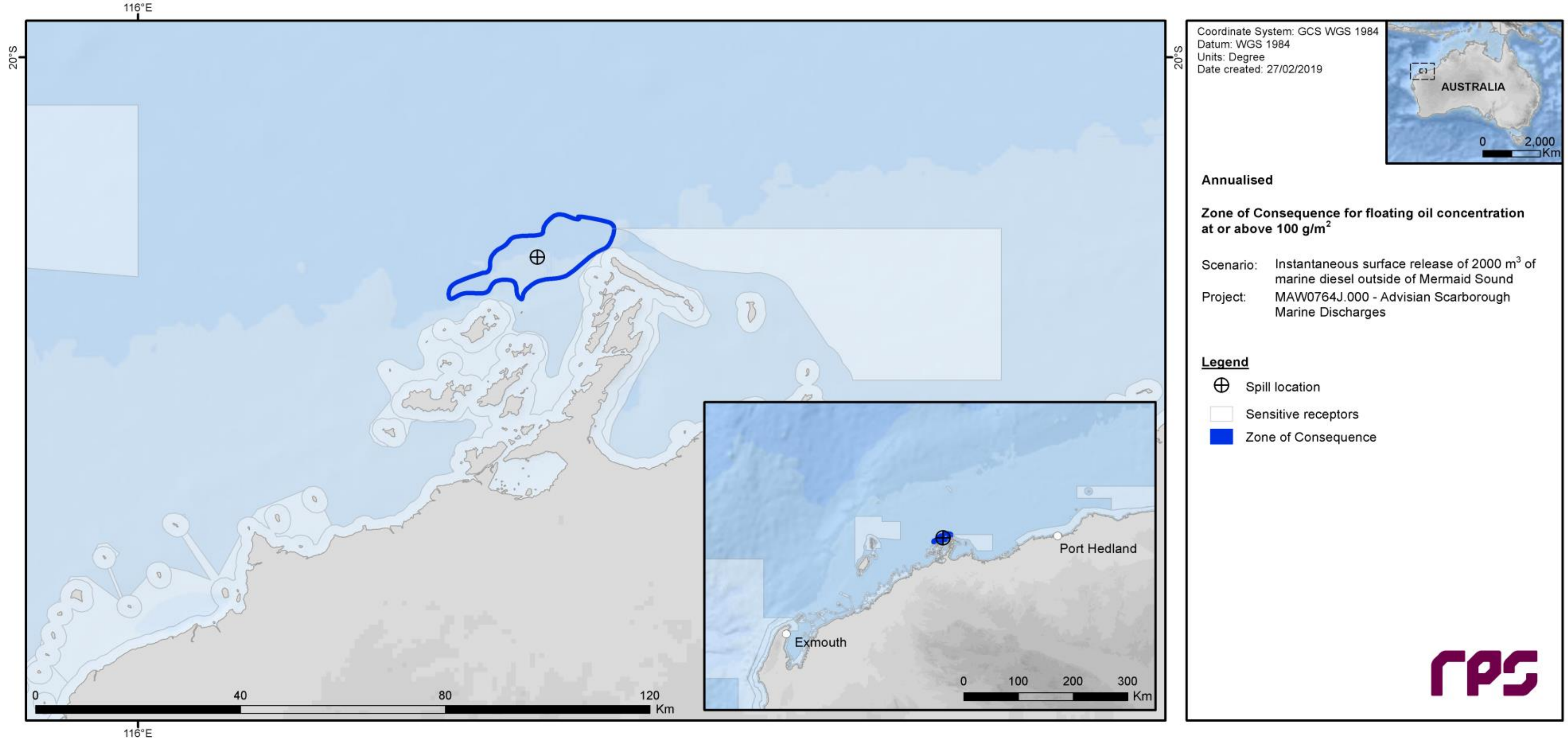


Figure 3.13 Predicted annualised smoothed Zone of Consequence of floating oil concentrations at or above 100 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.

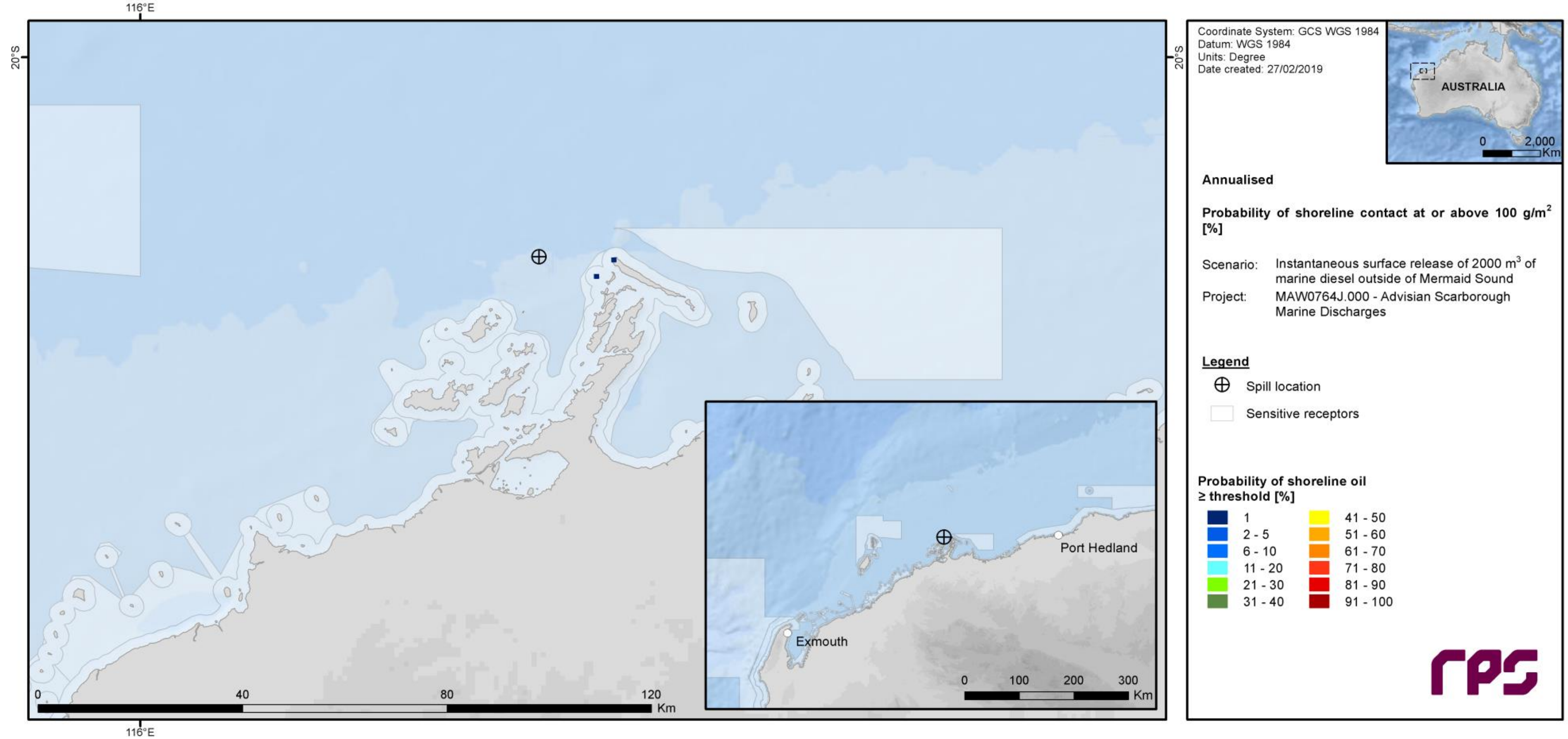


Figure 3.14 Predicted annualised probability of shoreline oil concentrations at or above 100 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.

3.2.2.2 Entrained Oil

Table 3.2 Expected annualised entrained oil outcomes at sensitive receptors resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.

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
Barrow Island	<1	NC	6	72
Dampier Archipelago	23	15	583	10,911
Glomar Shoals*	<1	NC	3	3
Montebello Islands	<1	NC	15	235
Muiron Islands MMA-WHA	<1	NC	9	185
Ningaloo Coast North WHA	<1	NC	4	70
Ningaloo RUZ	<1	NC	4	70
Pilbara - Middle Pilbara - Islands & Shoreline	<1	NC	14	150
Pilbara - Northern Pilbara - Islands & Shoreline	<1	NC	3	79
Pilbara Islands - Southern Island Group	<1	NC	15	192
Rankin Bank*	<1	NC	<1	13
Lowendal Islands	<1	NC	4	66
Montebello MP	1	433	30	822
Montebello State Marine Park	<1	NC	16	263
Muiron Islands	<1	NC	9	172
Dampier MP	44	20	1,215	10,407
Eighty Mile Beach MP	<1	NC	6	161
Gascoyne MP	<1	NC	4	222
WA Coastline	23	15	583	6,832

NC: No contact to receptor predicted for specified threshold.

* Probabilities and maximum concentrations calculated at depth of submerged feature.

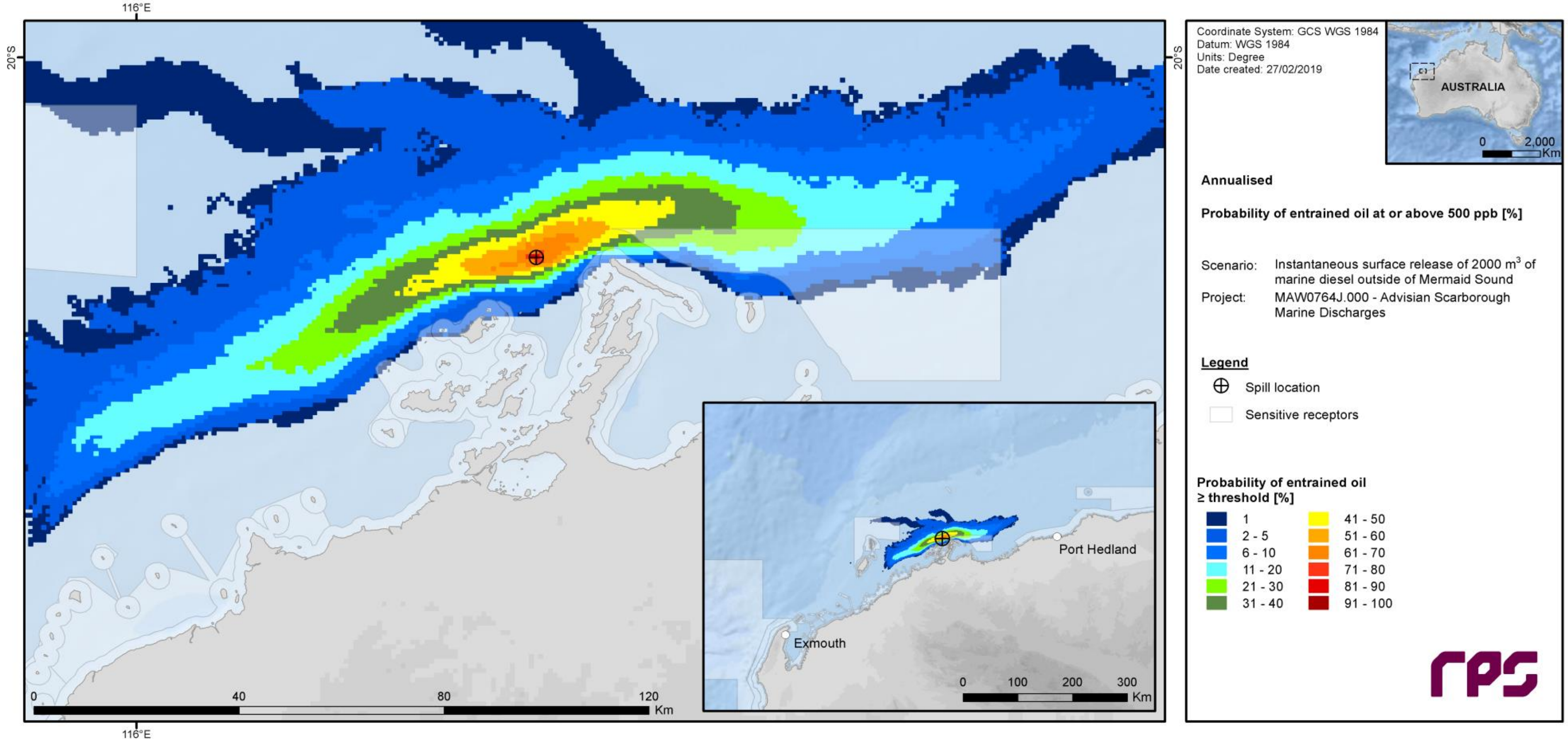


Figure 3.15 Predicted annualised probability of entrained oil concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.

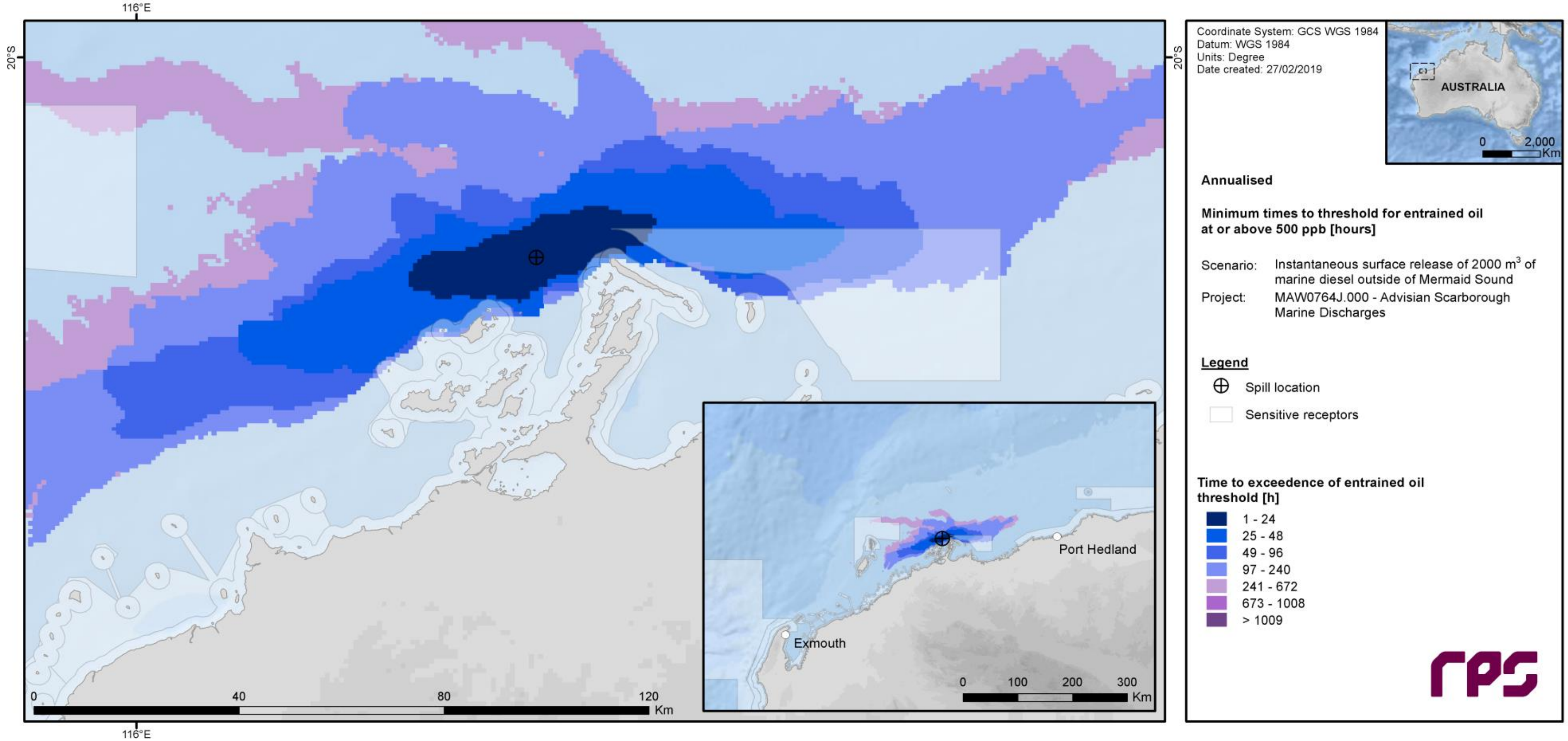


Figure 3.16 Predicted annualised minimum times to contact by entrained oil concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.

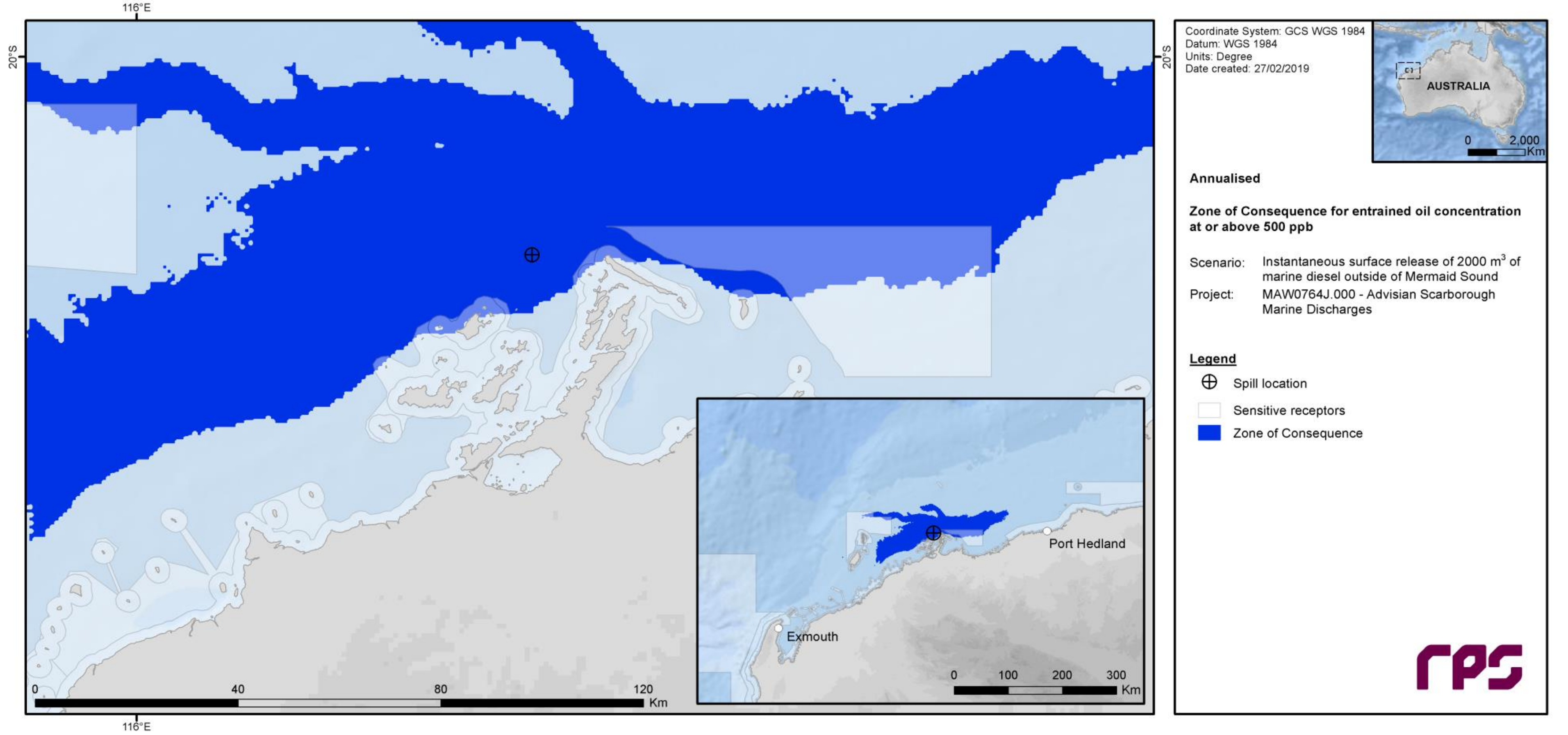


Figure 3.17 Predicted annualised Zone of Consequence of entrained oil concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.

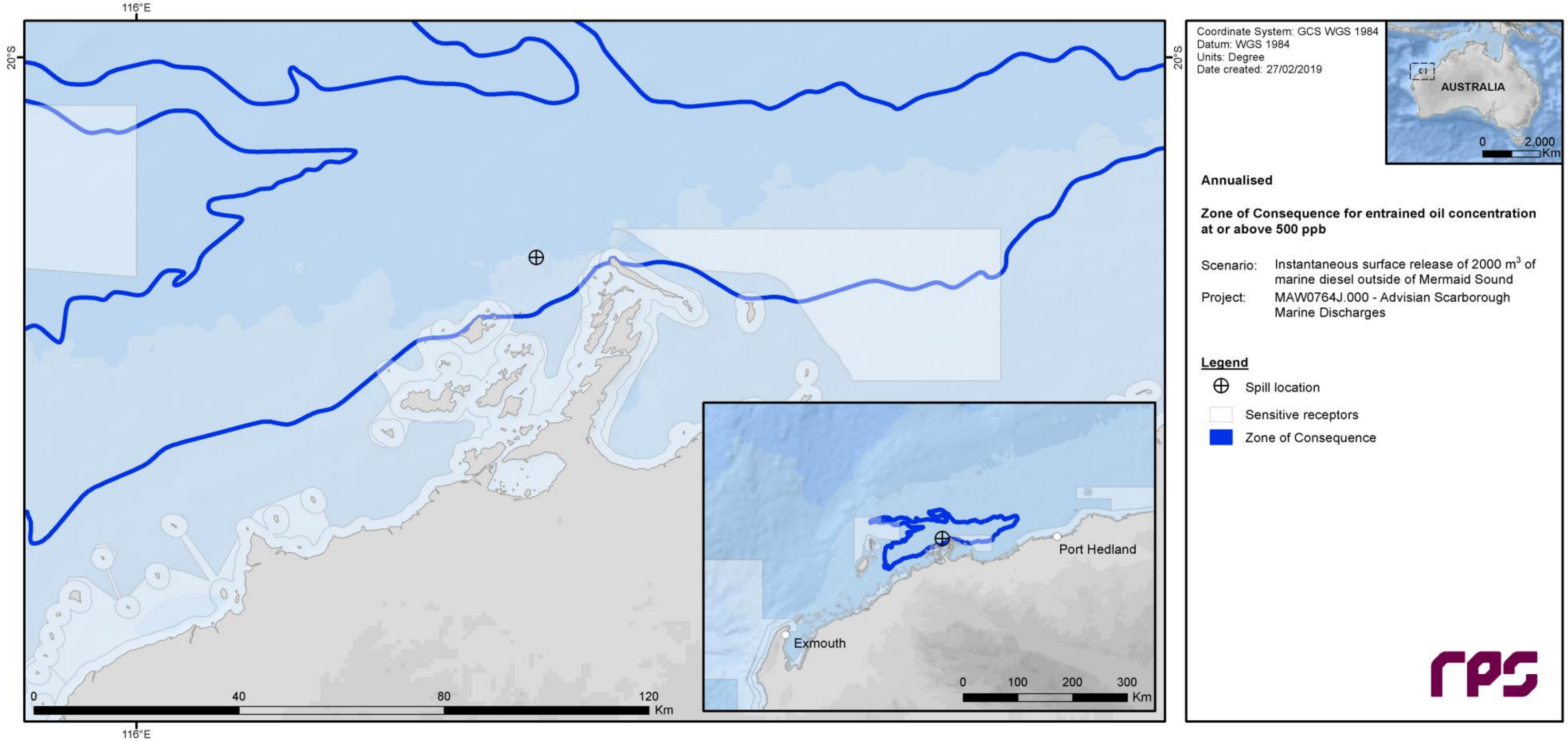


Figure 3.18 Predicted annualised smoothed Zone of Consequence of entrained oil concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.

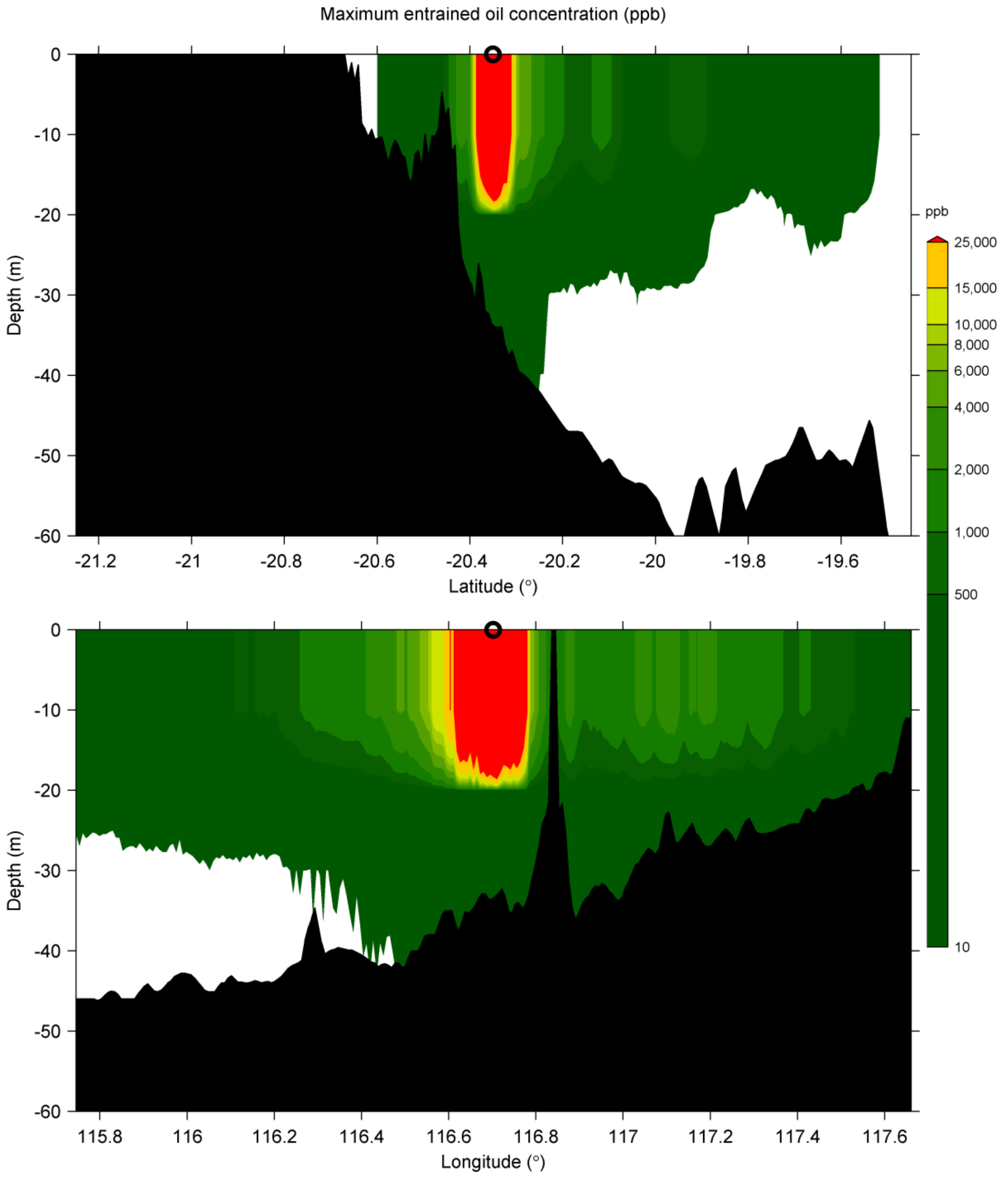


Figure 3.19 Cross-section transects of predicted annualised maximum entrained oil concentrations for an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound. Transect locations are shown in Figure 3.1.

3.2.2.3 Dissolved Aromatic Hydrocarbons

Table 3.3 Expected annualised dissolved aromatic hydrocarbon outcomes at sensitive receptors resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.

Receptor	Probability (%) of dissolved aromatic hydrocarbon concentration ≥500 ppb	Maximum dissolved aromatic hydrocarbon concentration (ppb) averaged over all replicate simulations	Maximum dissolved aromatic hydrocarbon concentration (ppb), at any depth, in the worst replicate simulation
Barrow Island	<1	<1	<1
Dampier Archipelago	<1	27	366
Glomar Shoals*	<1	NC	NC
Montebello Islands	<1	<1	<1
Muiron Islands MMA-WHA	<1	NC	NC
Ningaloo Coast North WHA	<1	NC	NC
Ningaloo RUZ	<1	NC	NC
Pilbara - Middle Pilbara - Islands & Shoreline	<1	<1	<1
Pilbara - Northern Pilbara - Islands & Shoreline	<1	<1	<1
Pilbara Islands - Southern Island Group	<1	NC	NC
Rankin Bank*	<1	<1	NC
Lowendal Islands	<1	<1	<1
Montebello MP	<1	<1	7
Montebello State Marine Park	<1	<1	<1
Muiron Islands	<1	NC	NC
Dampier MP	2	41	635
Eighty Mile Beach MP	<1	NC	NC
Gascoyne MP	<1	NC	NC
WA Coastline	<1	27	366

NC: No contact to receptor predicted for specified threshold.

* Probabilities and maximum concentrations calculated at depth of submerged feature.

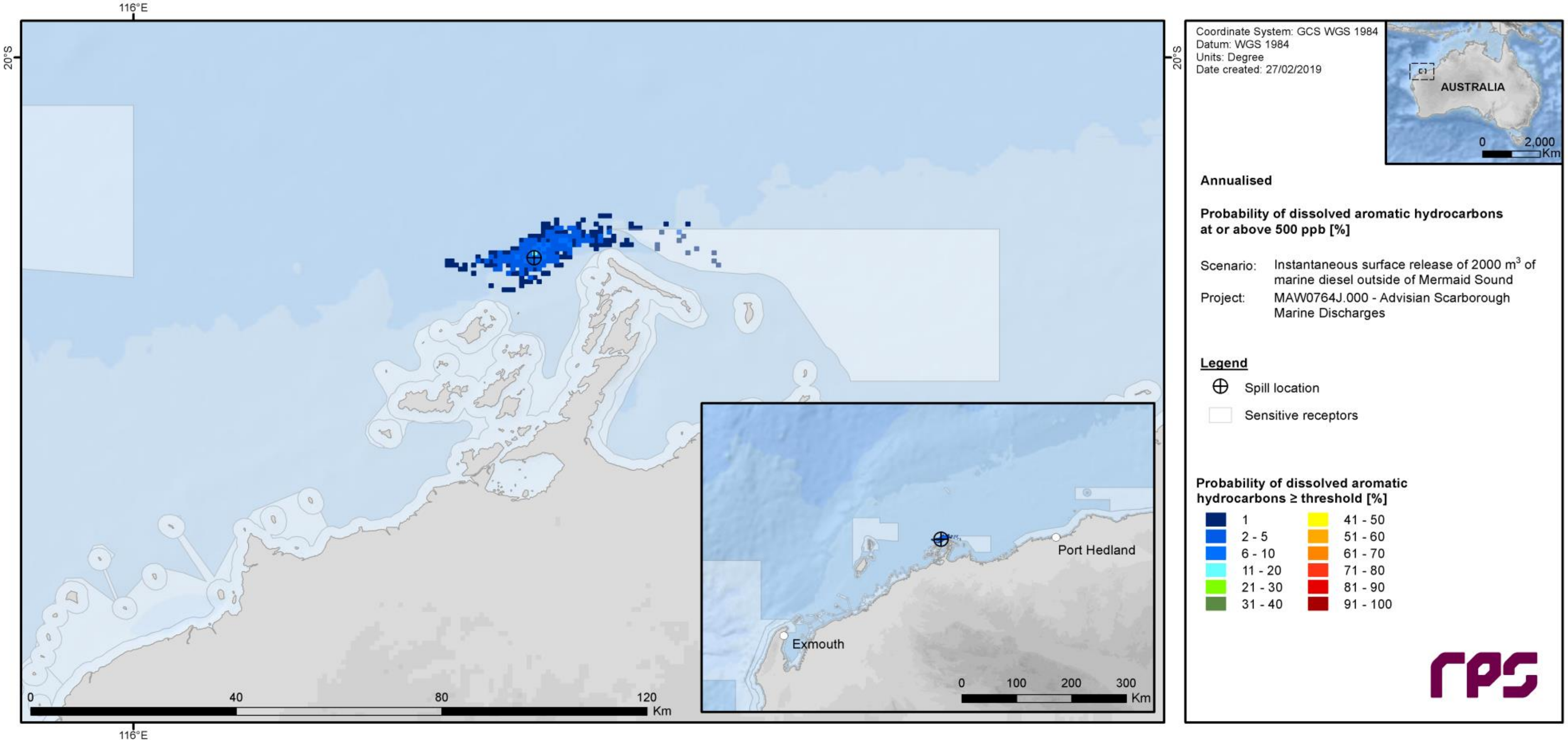


Figure 3.20 Predicted annualised probability of dissolved aromatic hydrocarbon concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.

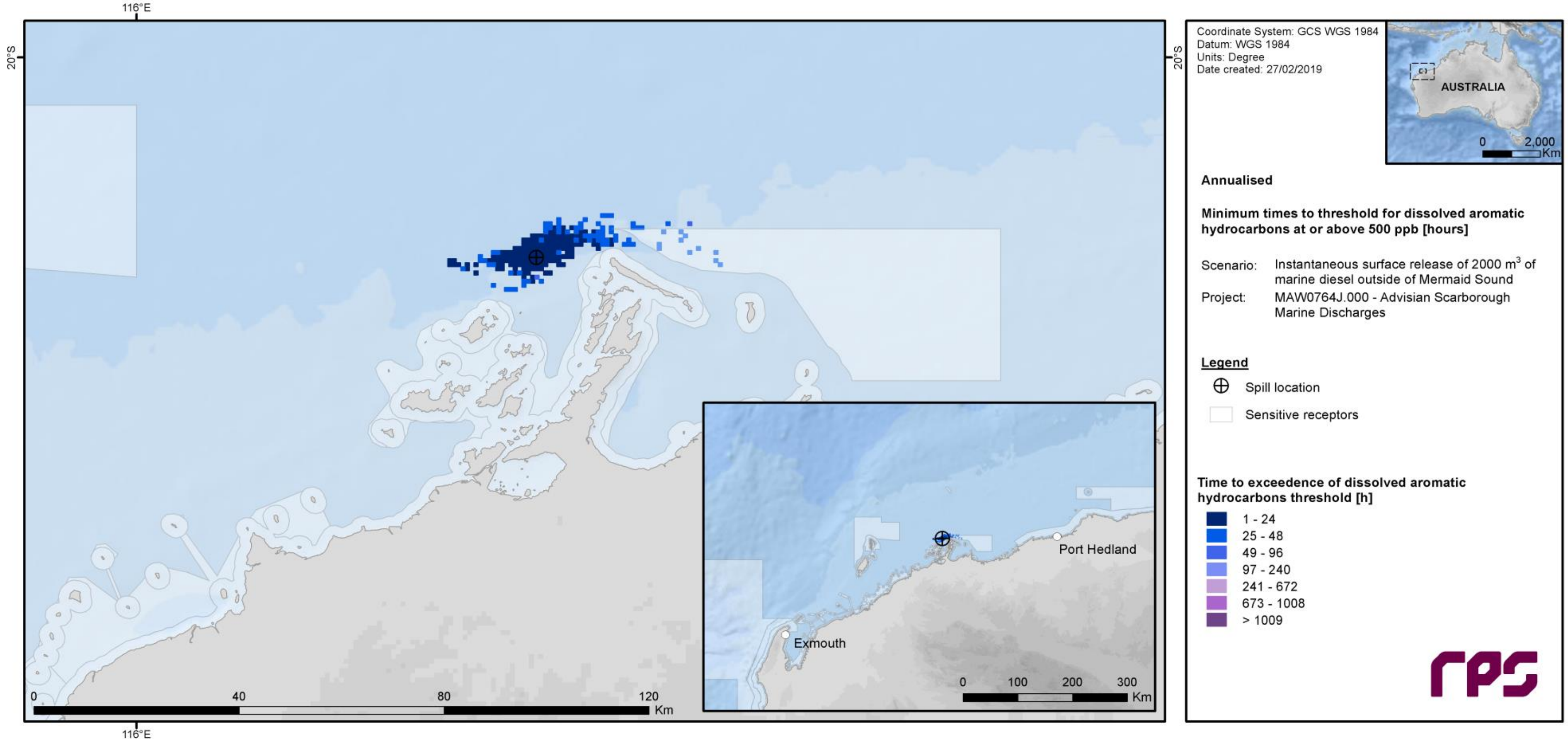


Figure 3.21 Predicted annualised minimum times to contact by dissolved aromatic hydrocarbon concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.

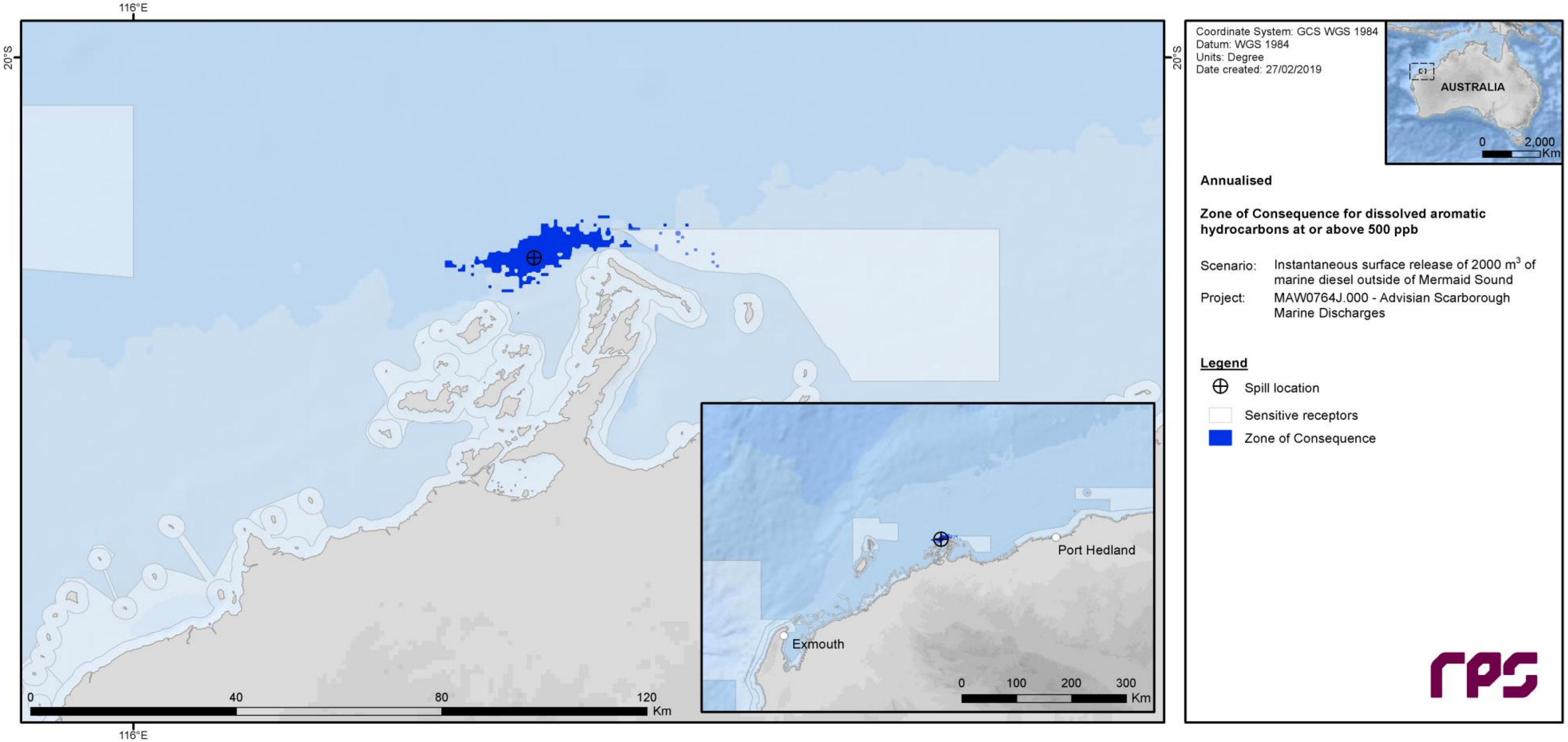


Figure 3.22 Predicted annualised Zone of Consequence of dissolved aromatic hydrocarbon concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.

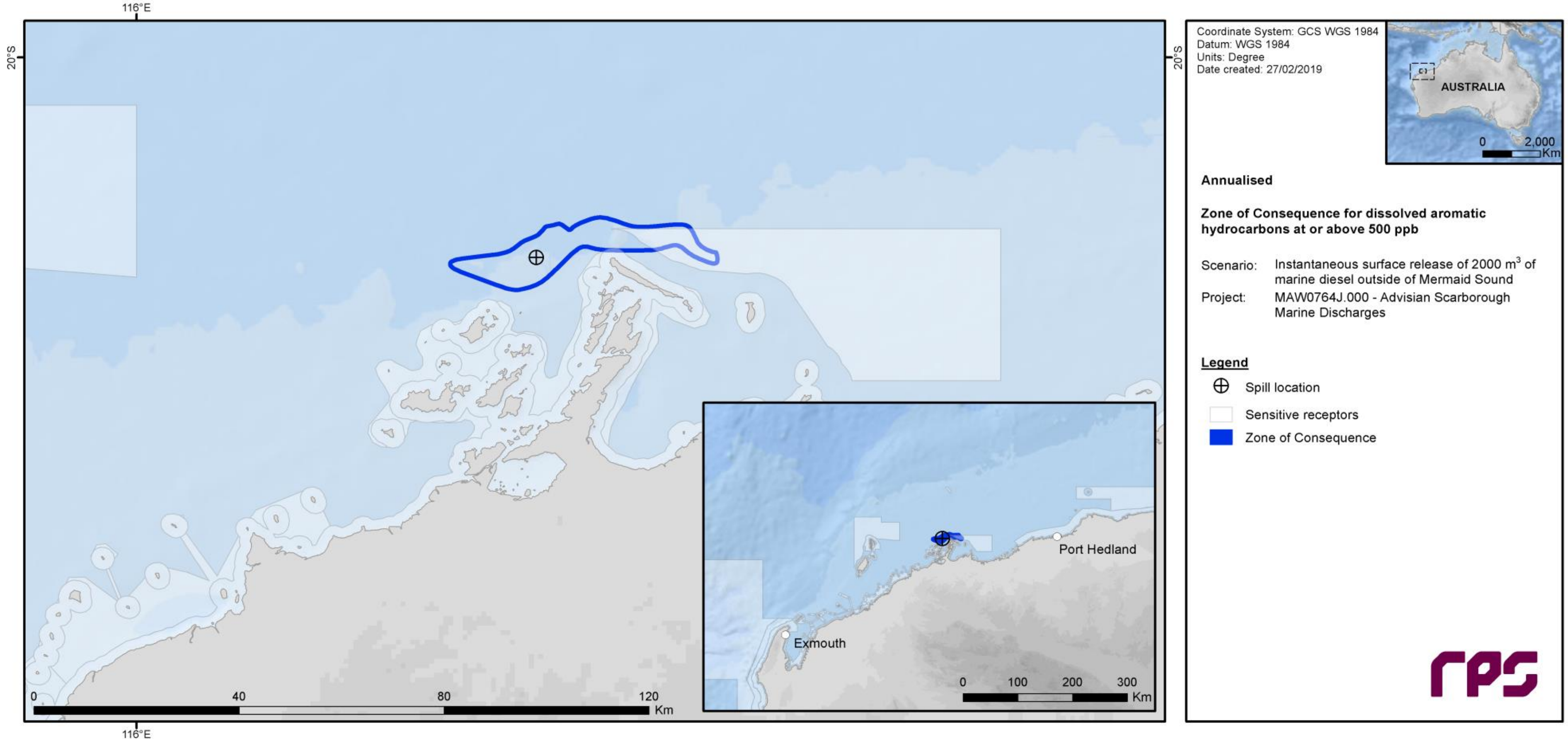


Figure 3.23 Predicted annualised smoothed Zone of Consequence of dissolved aromatic hydrocarbon concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound.

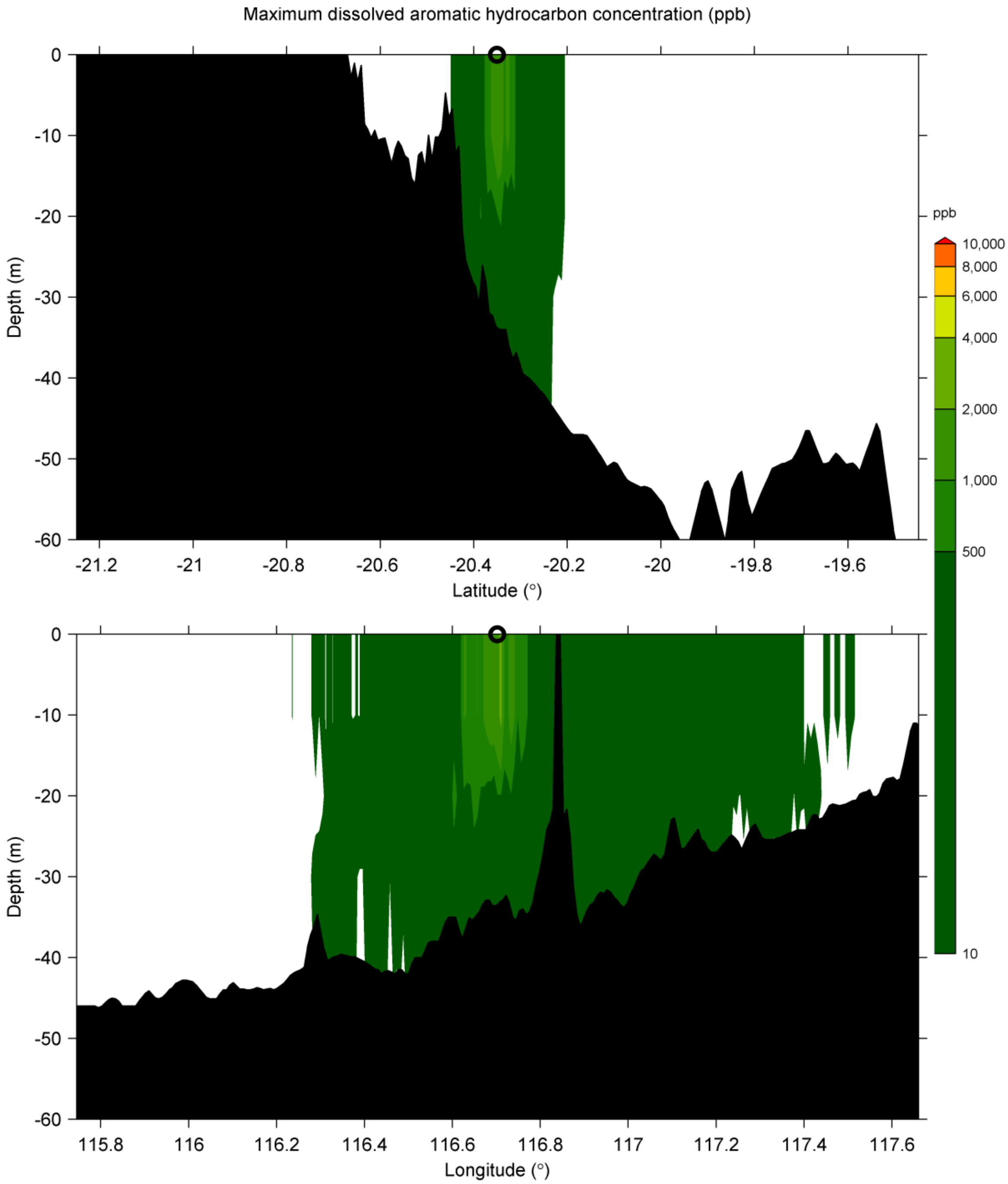


Figure 3.24 Cross-section transects of predicted annualised maximum dissolved aromatic hydrocarbon concentrations for an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound. Transect locations are shown in Figure 3.1.

3.3 Scenario 2: Short-Term (Instantaneous) Surface Release of Marine Diesel after a Vessel Collision within Montebello Marine Park

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 (instantaneous) surface release of 2,000 m^3 of marine diesel within the Montebello Marine Park during operations at any time of year, with no mitigation measures applied.

Considering the discharge characteristics, the properties of the oil and its expected weathering behaviour, floating oil will be susceptible to entrainment into the wave-mixed layer under typical wind conditions. Evaporation rates will be significant, given the moderate proportion of volatile compounds in the oil (41%). The low-volatility fraction of the oil (54%) will take longer durations of the order of days to evaporate, and the residual fraction of 5% is expected to persist in the environment until degradation processes occur. Considering the spill volume, there is a low potential for dissolution of soluble aromatic compounds.

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, 50 g/m^2 and 100 g/m^2 thresholds could potentially be found, in the form of slicks, up to 39 km, 36 km and 33 km from the spill site, respectively (Figure 3.25, Figure 3.26 and Figure 3.27).

Given that the spill location lies within the Montebello MP receptor area, floating oil at concentrations equal to or greater than 100 g/m^2 are forecast with a probability of 100% and a minimum time to contact of less than 1 hour (Table 3.4). Probabilities of floating oil contact at the 10 g/m^2 threshold are forecast to be less than 1% for all other shoreline receptors.

Potential for accumulation of oil on shorelines is predicted to be low, with a maximum accumulated volume of <1 m^3 and a maximum local accumulated concentration on shorelines of 11 g/m^2 forecast at Barrow Island (Table 3.4).

The forecast annualised minimum times to contact, ZoC and smoothed ZoC for floating oil at or above the 10 g/m^2, 50 g/m^2 and 100 g/m^2 threshold concentrations are depicted in Figure 3.28 to Figure 3.30, Figure 3.31 to Figure 3.33 and Figure 3.34 to Figure 3.36, respectively.

3.3.1.3 Entrained Oil

Entrained oil at concentrations equal to or greater than the 500 ppb threshold is predicted to be found up to around 308 km from the spill site (Figure 3.37).

The Montebello MP and Muiron Islands MMA-WHA receptors are predicted to receive entrained oil concentrations at the 500 ppb threshold with probabilities of 70% and 7%, respectively (Table 3.5). The maximum entrained oil concentration is forecast as 157.0 ppm within the Montebello MP.

The forecast annualised minimum times to contact, ZoC and smoothed ZoC for entrained oil at or above the 500 ppb threshold concentration are depicted in Figure 3.38, Figure 3.39 and Figure 3.40, 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 15 m (Figure 3.41).

3.3.1.4 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 85 km from the spill site (Figure 3.42).

The Montebello MP receptor is predicted to receive dissolved aromatic hydrocarbon concentrations at the 500 ppb threshold with a probability of 9% (Table 3.6). The maximum dissolved aromatic hydrocarbon concentration is forecast as 2.0 ppm within the Montebello MP.

The forecast annualised minimum times to contact, ZoC and smoothed ZoC for dissolved aromatic hydrocarbons at or above the 500 ppb threshold concentration are depicted in Figure 3.43, 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 15 m (Figure 3.46).

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 an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

Receptor	Probability (%) of floating oil concentration ≥10 g/m^2	Probability (%) of floating oil concentration ≥50 g/m^2	Probability (%) of floating oil concentration ≥100 g/m^2	Minimum time to receptor (hours) for floating oil at ≥10 g/m^2	Minimum time to receptor (hours) for floating oil at ≥50 g/m^2	Minimum time to receptor (hours) for floating oil at ≥100 g/m^2	Probability (%) of shoreline oil concentration ≥100 g/m^2	Probability (%) of shoreline oil concentration ≥250 g/m^2	Minimum time to receptor (hours) for shoreline oil at ≥100 g/m^2	Minimum time to receptor (hours) for shoreline oil at ≥250 g/m^2	Maximum local accumulated concentration (g/m^2) averaged over all replicate simulations	Maximum local accumulated concentration (g/m^2) in the worst replicate simulation	Maximum accumulated volume (m^3) along this shoreline, averaged over all replicate simulations	Maximum accumulated volume (m^3) along this shoreline, in the worst replicate simulation
Argo-Rowley Terrace MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA
Barrow Island	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	0.1	11	<1	<1
Glomar Shoals*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA
Montebello Islands	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	<0.1	4.1	<1	<1
Muiron Islands MMA-WHA	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	<0.1	7.1	<1	<1
Ningaloo Coast Middle	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	NC	NC	NC	NC
Ningaloo Coast Middle WHA	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	NC	NC	NC	NC
Ningaloo Coast North	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	<0.1	7	<1	<1
Ningaloo Coast North WHA	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	<0.1	7	<1	<1
Ningaloo Coast South WHA	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	NC	NC	NC	NC
Ningaloo RUZ*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA
Pilbara Islands - Southern Island Group	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	<0.1	1.7	<1	<1
Rankin Bank*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA
Shark Bay Open Ocean Coast	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	NC	NC	NC	NC
Shark Bay WHA	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	NC	NC	NC	NC
Bernier & Dorre Islands	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	NC	NC	NC	NC
Lowendal Islands	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	NC	NC	NC	NC
Montebello MP*	100	100	100	1	1	1	NA	NA	NA	NA	NA	NA	NA	NA
Montebello State Marine Park	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	<0.1	4.1	<1	<1
Muiron Islands	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	<0.1	7.1	<1	<1
Gascoyne MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA
WA Coastline	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	0.1	11	<1	<1

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.

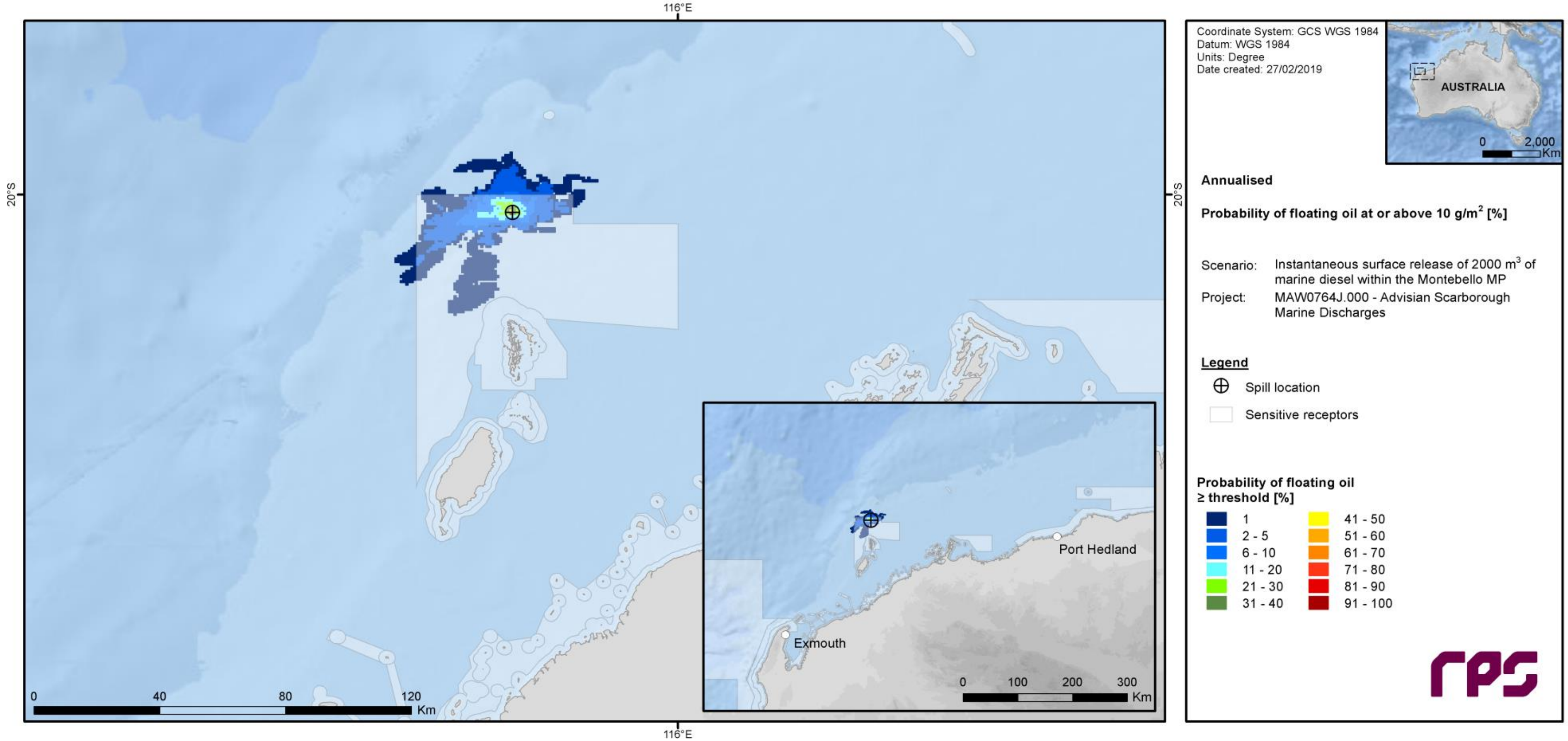


Figure 3.25 Predicted annualised probability of floating oil concentrations at or above 10 g/m² resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

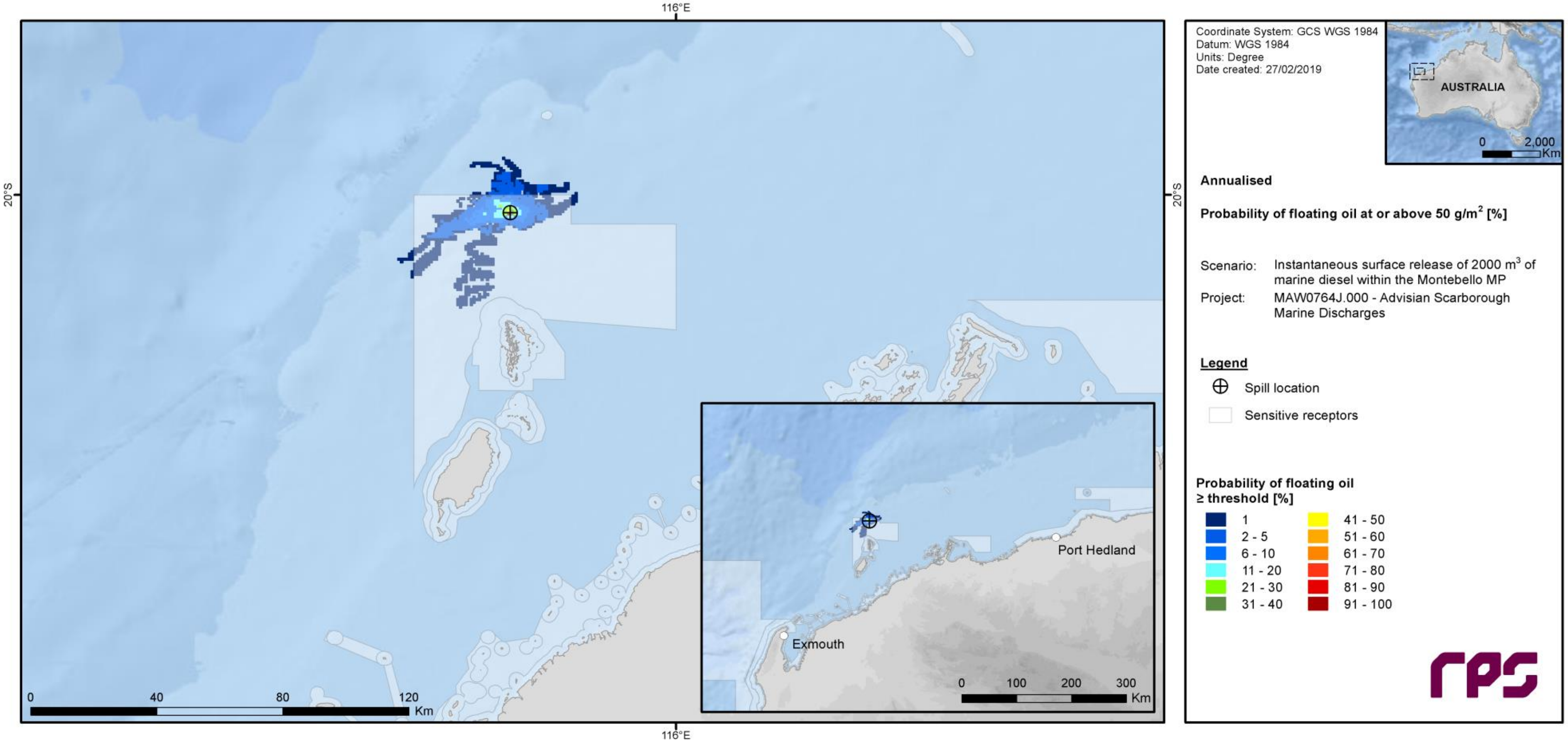


Figure 3.26 Predicted annualised probability of floating oil concentrations at or above 50 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

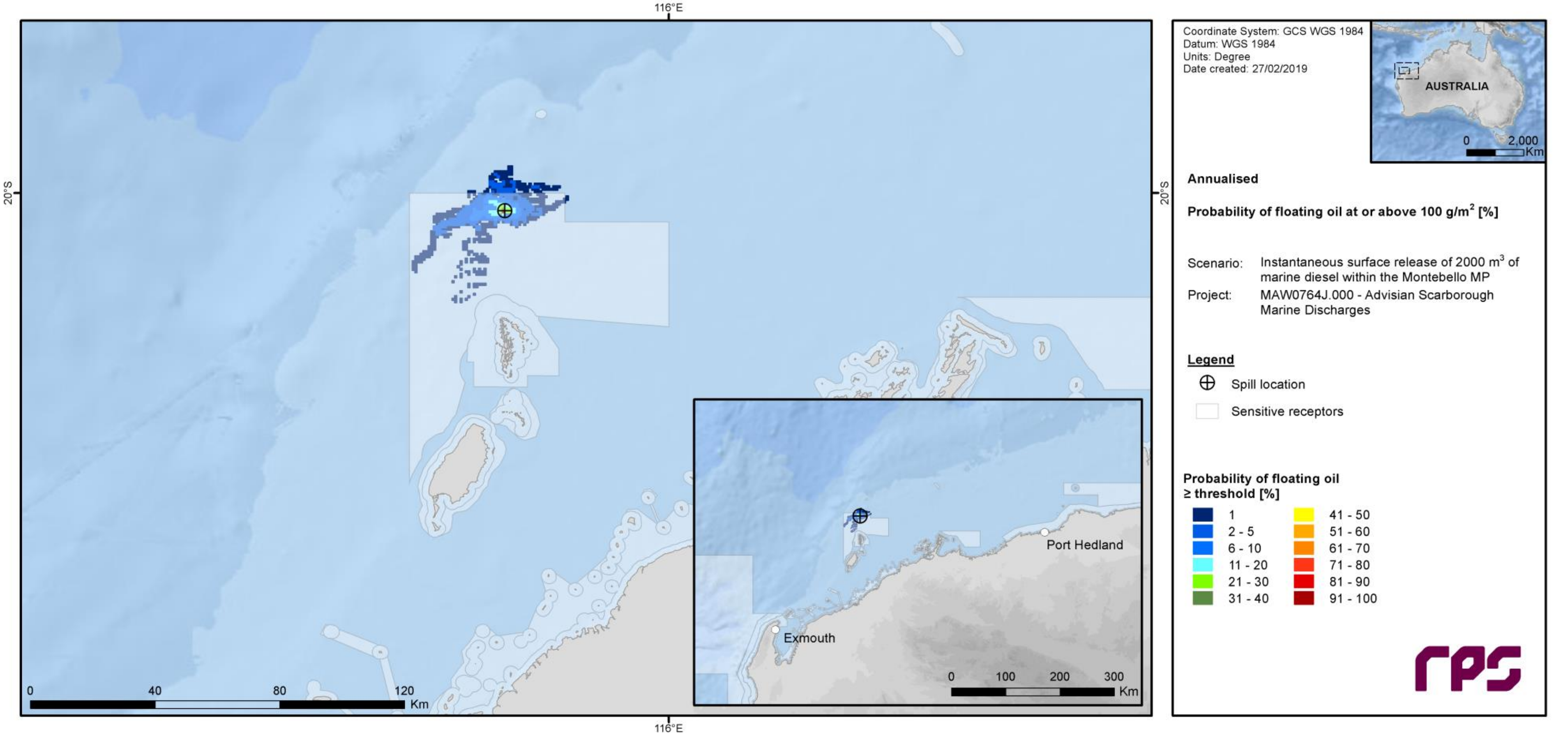


Figure 3.27 Predicted annualised probability of floating oil concentrations at or above 100 g/m² resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

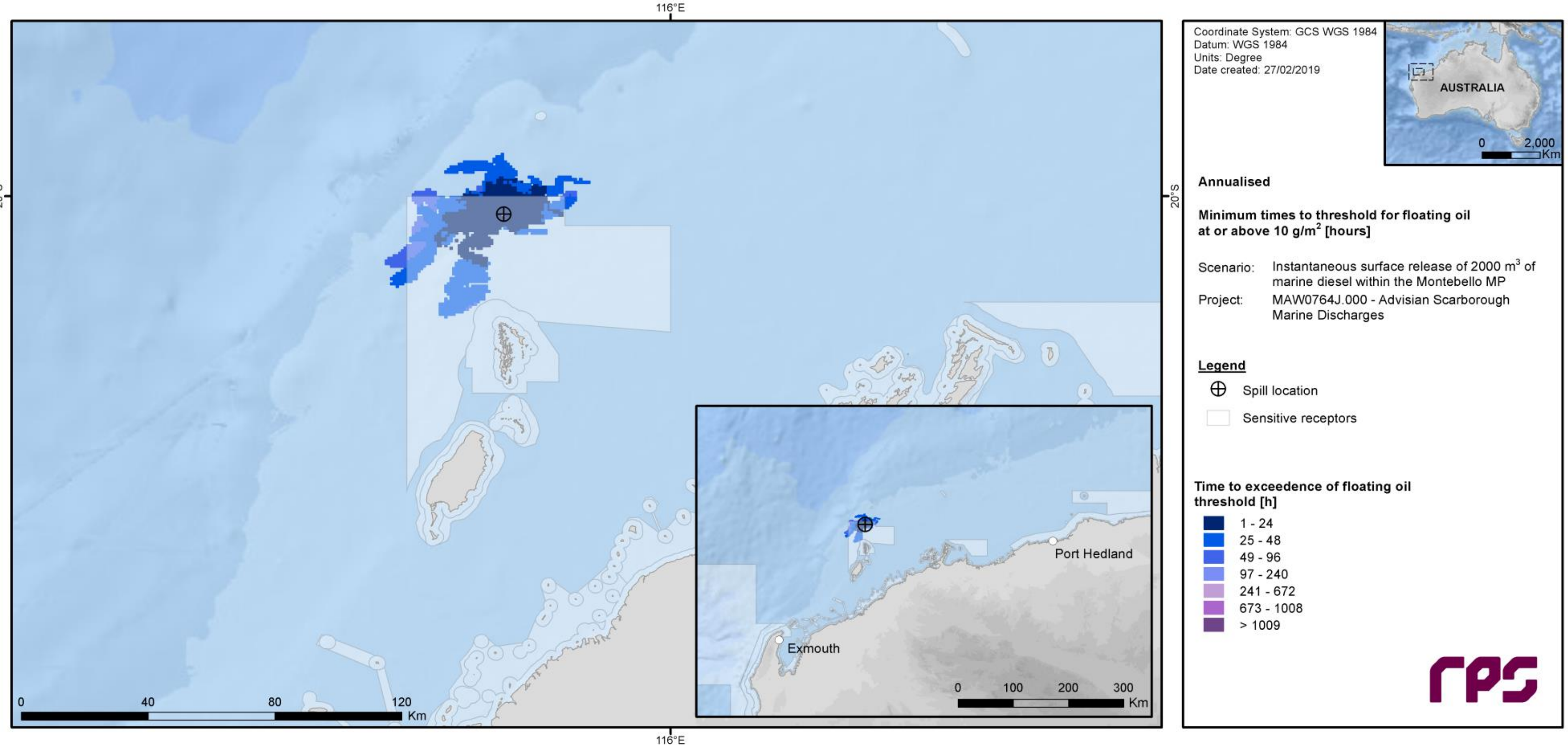


Figure 3.28 Predicted annualised minimum times to contact by floating oil concentrations at or above 10 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

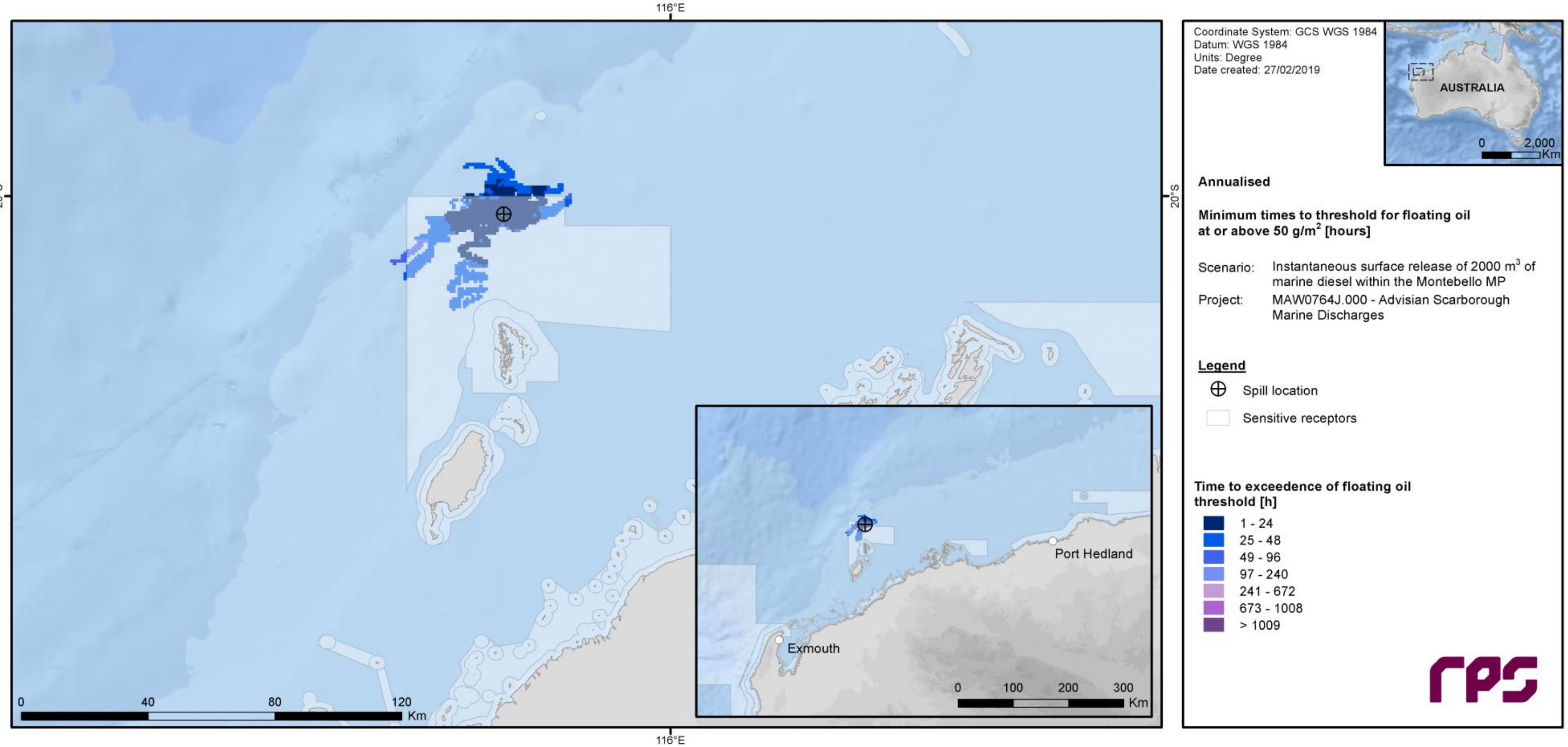


Figure 3.29 Predicted annualised minimum times to contact by floating oil concentrations at or above 50 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

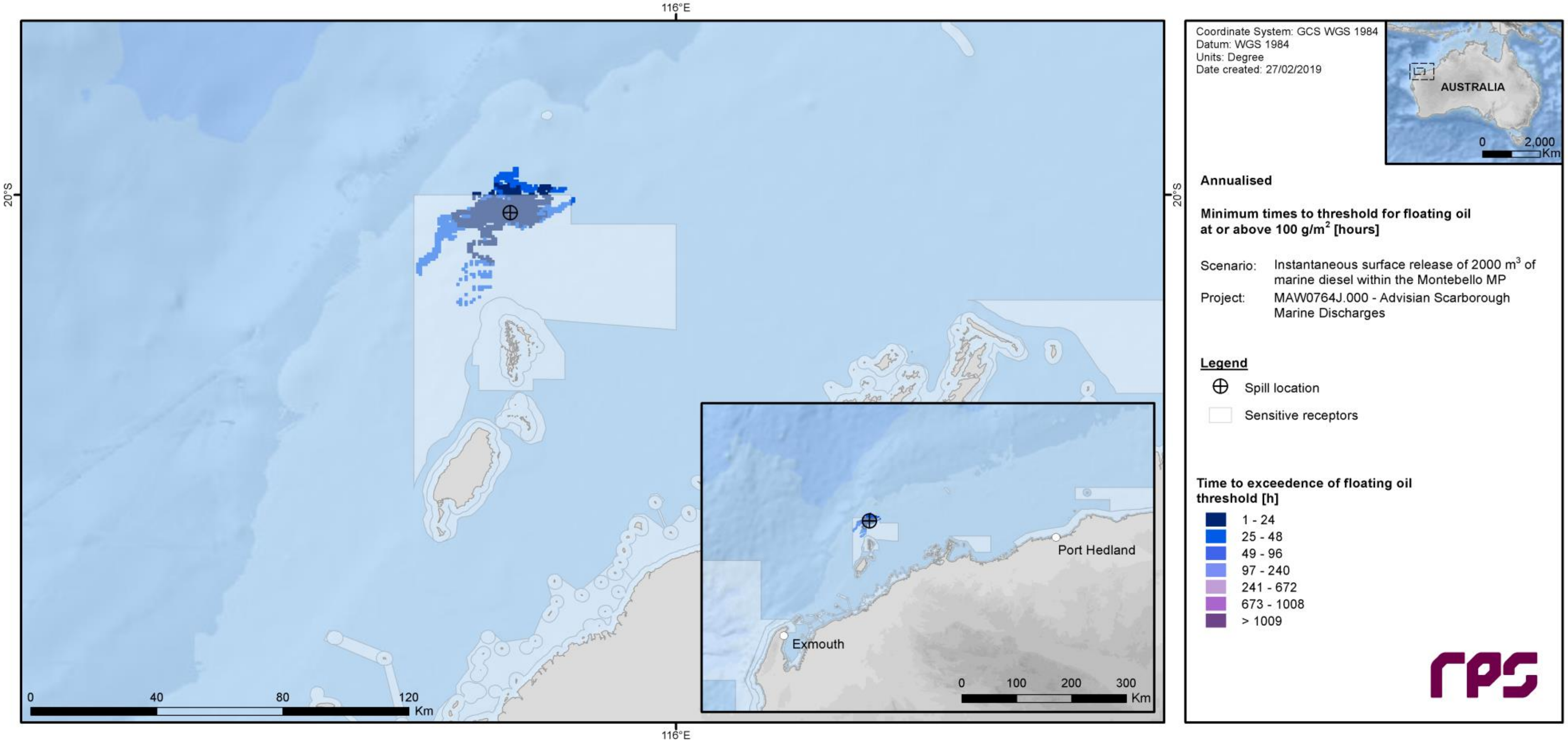


Figure 3.30 Predicted annualised minimum times to contact by floating oil concentrations at or above 100 g/m² resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

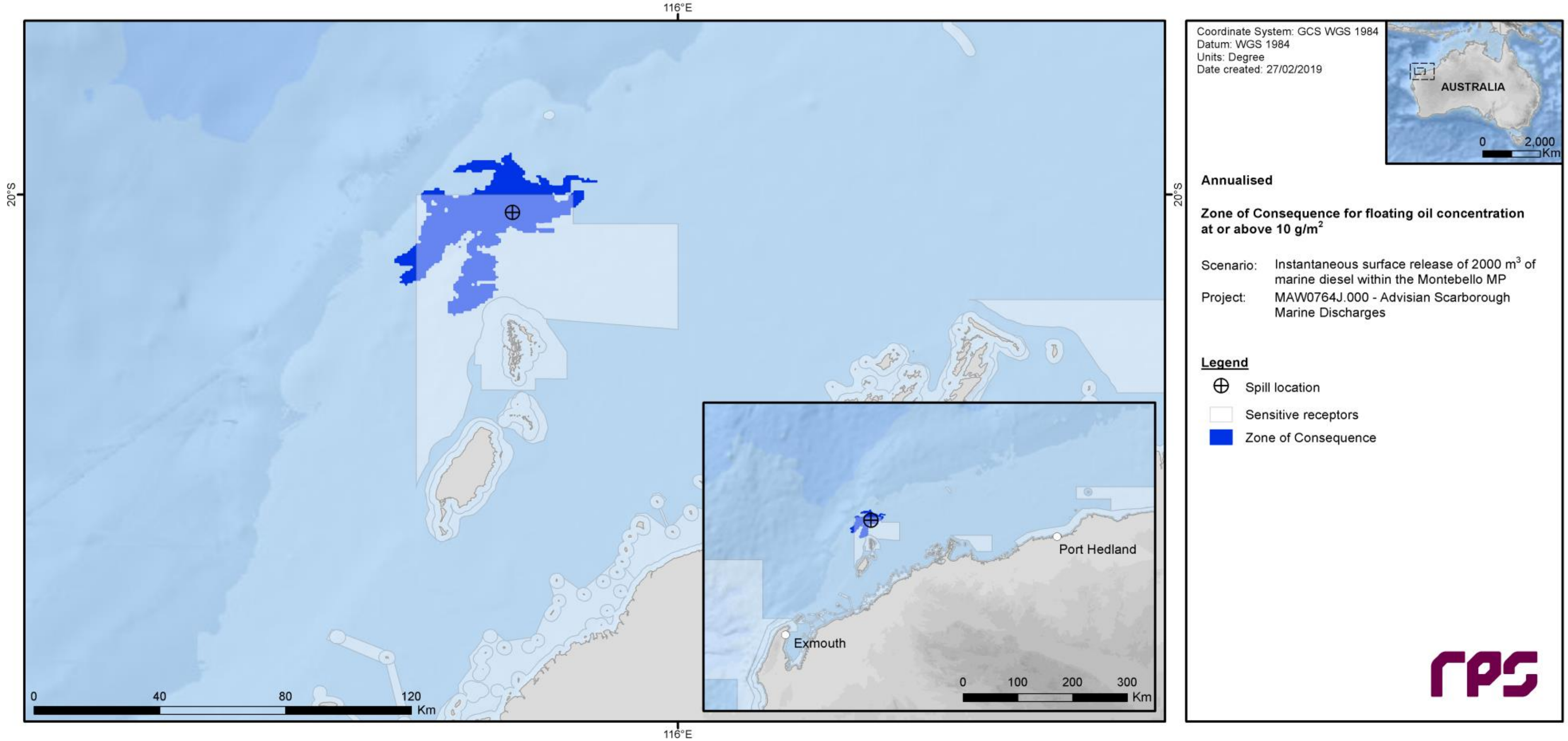


Figure 3.31 Predicted annualised Zone of Consequence of floating oil concentrations at or above 10 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

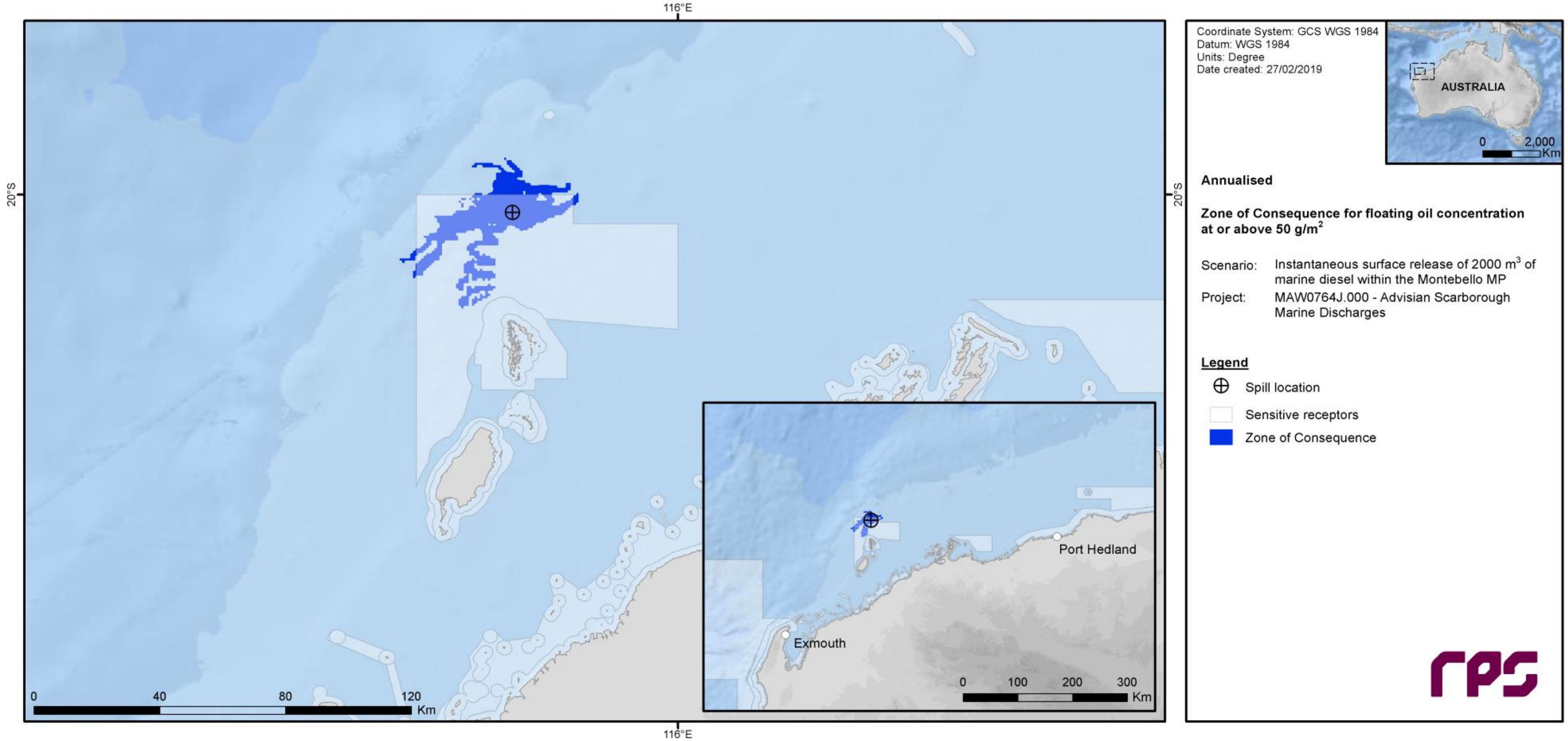


Figure 3.32 Predicted annualised Zone of Consequence of floating oil concentrations at or above 50 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

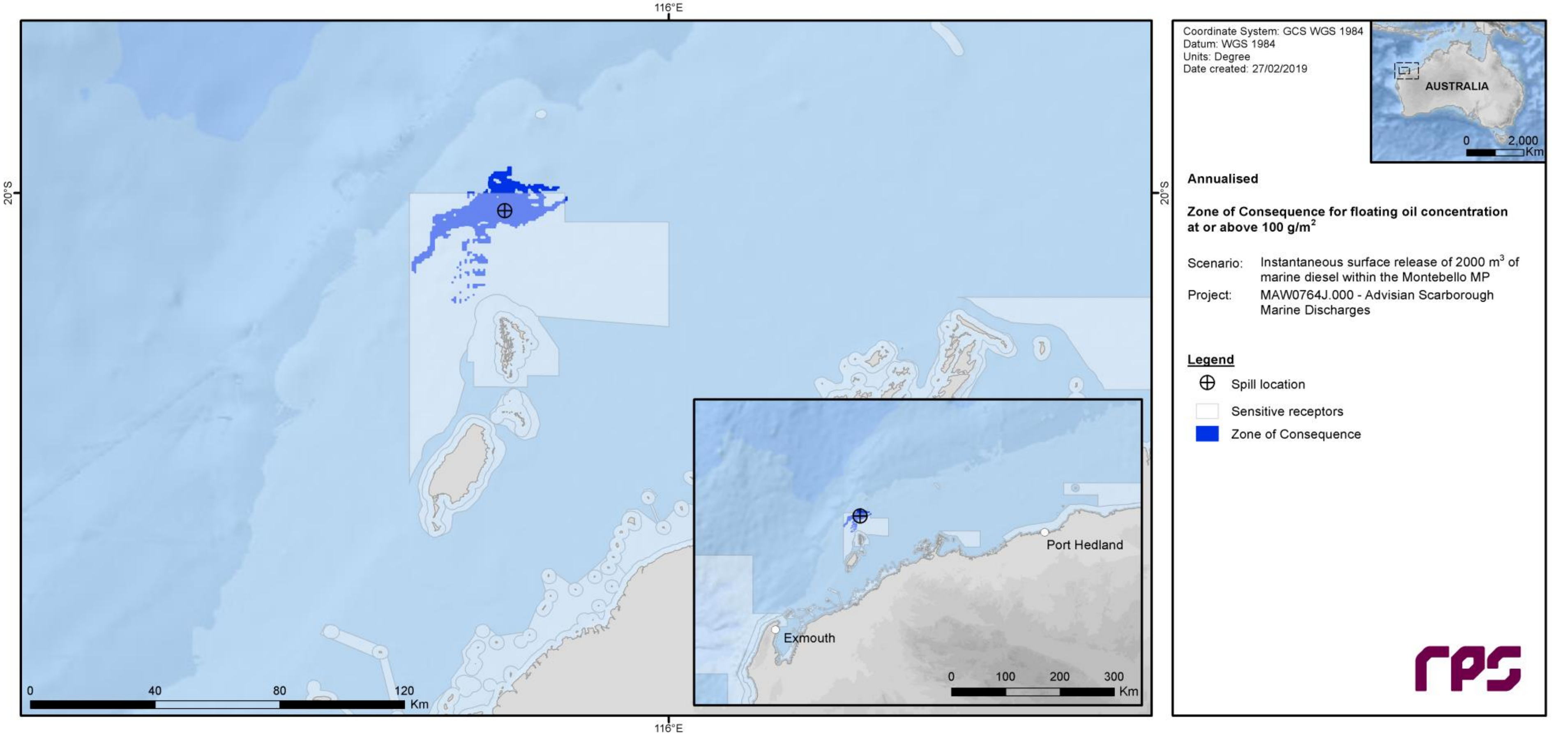


Figure 3.33 Predicted annualised Zone of Consequence of floating oil concentrations at or above 100 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

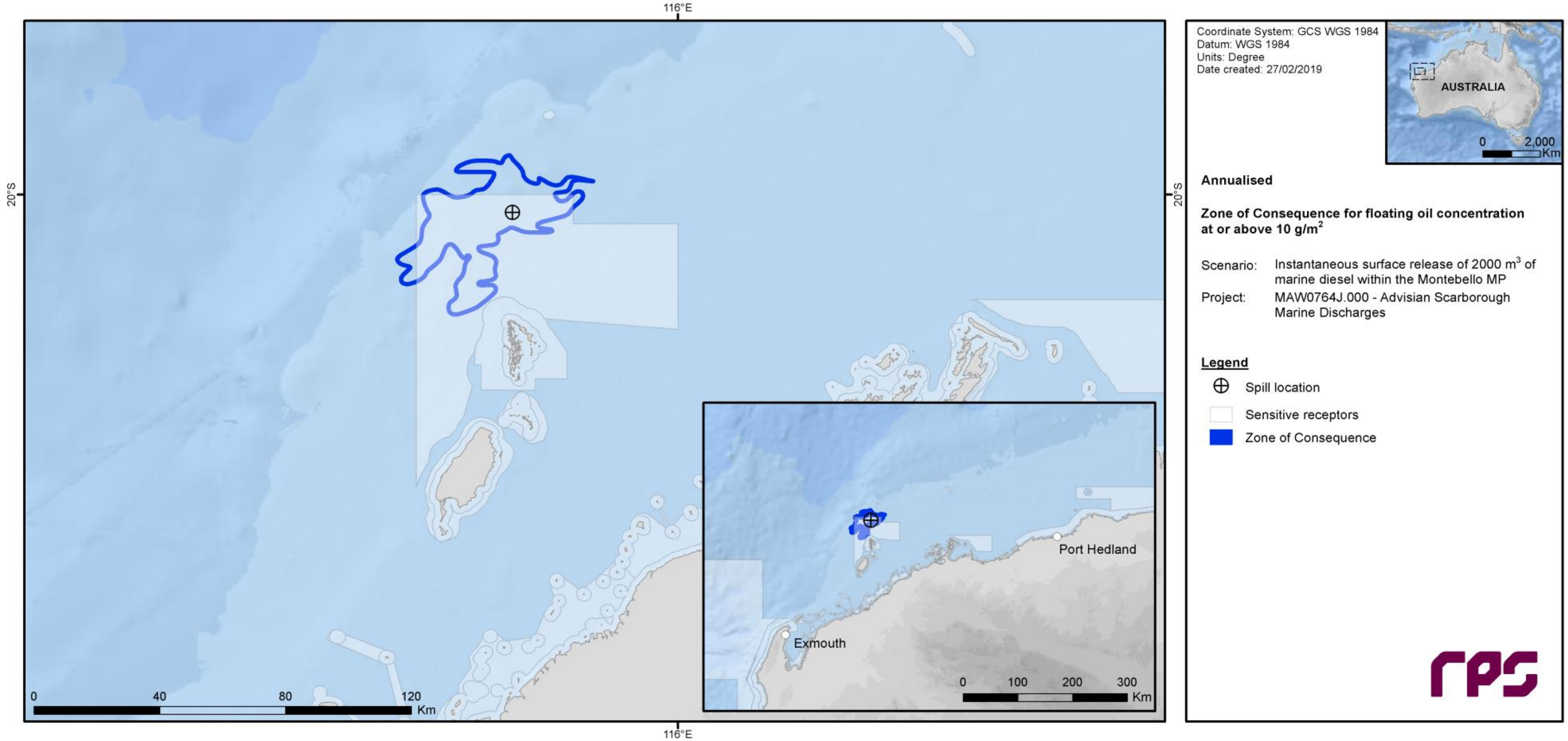


Figure 3.34 Predicted annualised smoothed Zone of Consequence of floating oil concentrations at or above 10 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

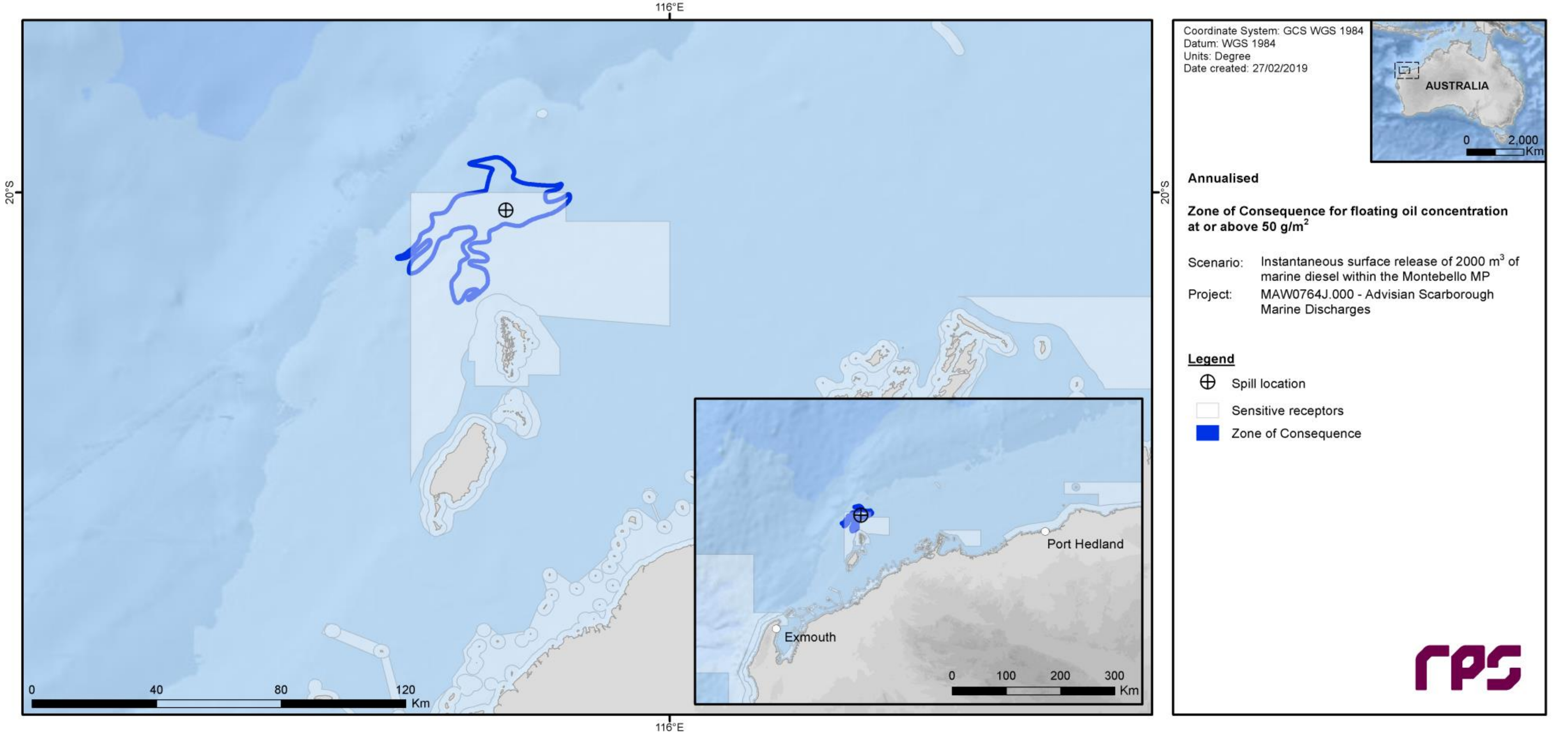


Figure 3.35 Predicted annualised smoothed Zone of Consequence of floating oil concentrations at or above 50 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

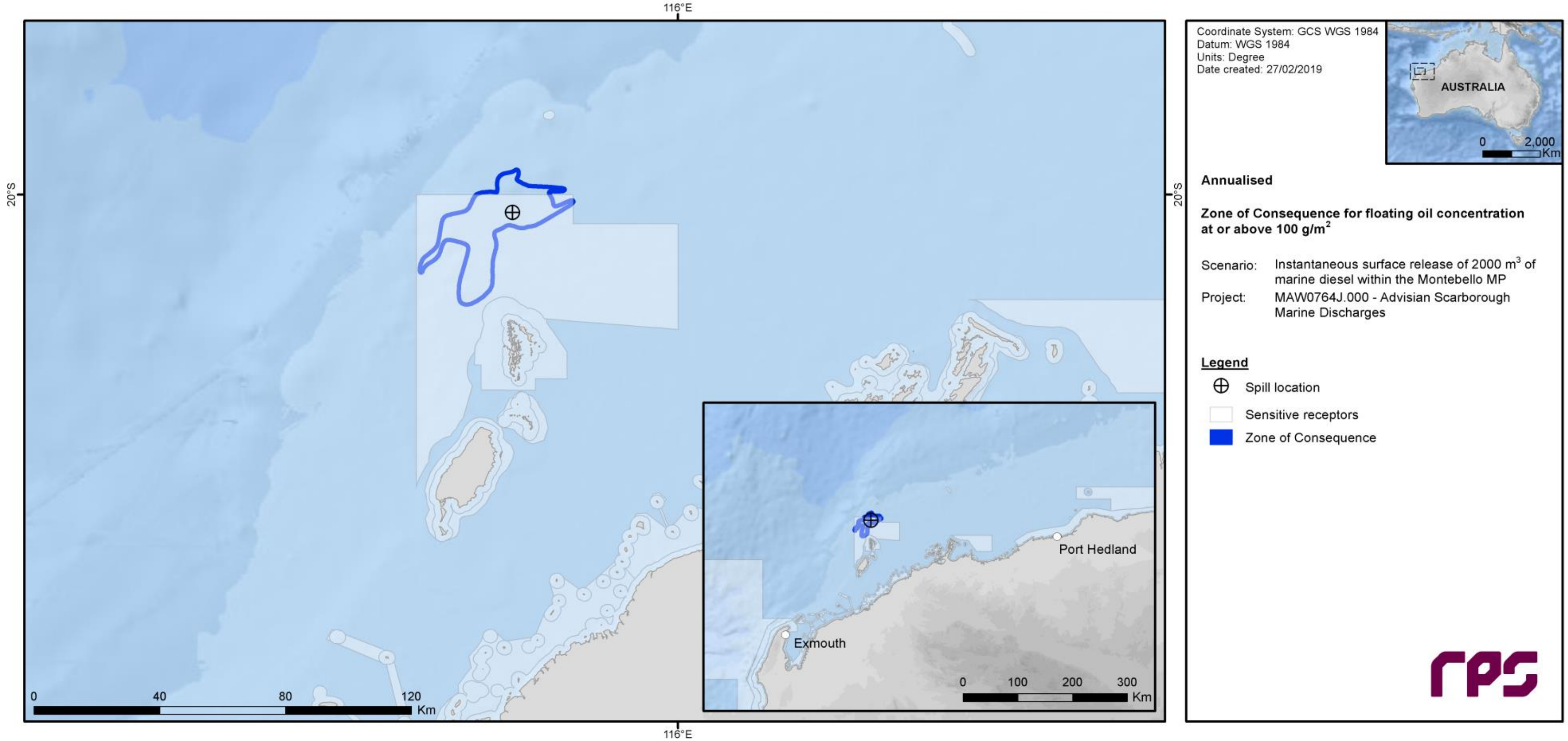


Figure 3.36 Predicted annualised smoothed Zone of Consequence of floating oil concentrations at or above 100 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

3.3.2.2 Entrained Oil

Table 3.5 Expected annualised entrained oil outcomes at sensitive receptors resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

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 MP	<1	NC	2	109
Barrow Island	1	88	55	4,225
Glomar Shoals*	<1	389	9	8
Montebello Islands	2	212	28	963
Muiron Islands MMA-WHA	7	183	100	2,392
Ningaloo Coast Middle	<1	NC	3	228
Ningaloo Coast Middle WHA	<1	NC	7	472
Ningaloo Coast North	1	314	24	690
Ningaloo Coast North WHA	4	223	66	2,438
Ningaloo Coast South WHA	<1	NC	<1	51
Ningaloo RUZ	4	223	66	2,438
Pilbara Islands - Southern Island Group	2	171	45	2,536
Rankin Bank*	<1	101	78	193
Shark Bay Open Ocean Coast	<1	NC	2	153
Shark Bay WHA	<1	NC	2	153
Bernier & Dorre Islands	<1	NC	2	156
Lowendal Islands	1	164	8	639
Montebello MP	70	1	14,381	156,954
Montebello State Marine Park	4	85	95	4,577
Muiron Islands	5	185	78	1,676
Gascoyne MP	2	339	36	836
WA Coastline	5	93	71	3,381

NC: No contact to receptor predicted for specified threshold.

* Probabilities and maximum concentrations calculated at depth of submerged feature.

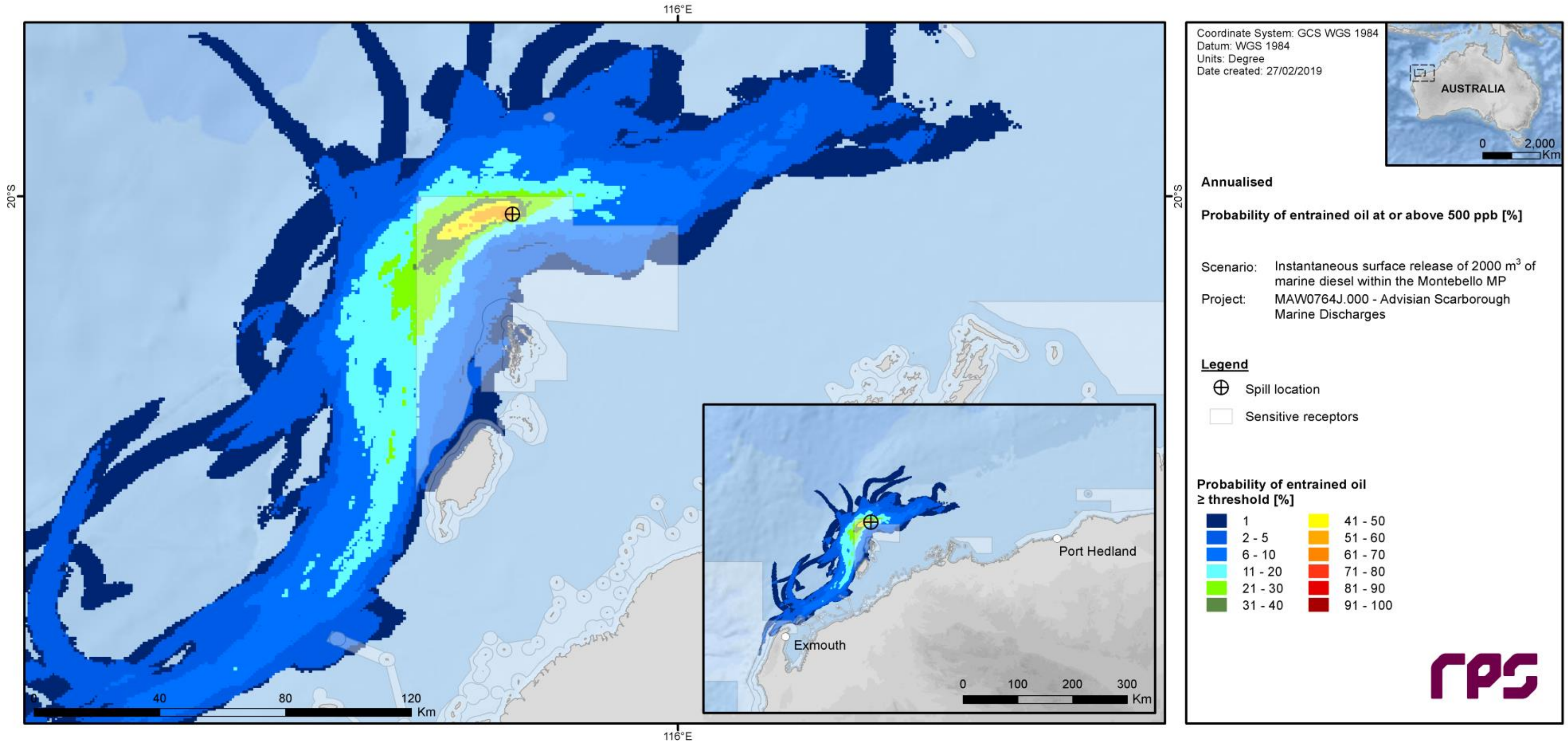


Figure 3.37 Predicted annualised probability of entrained oil concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

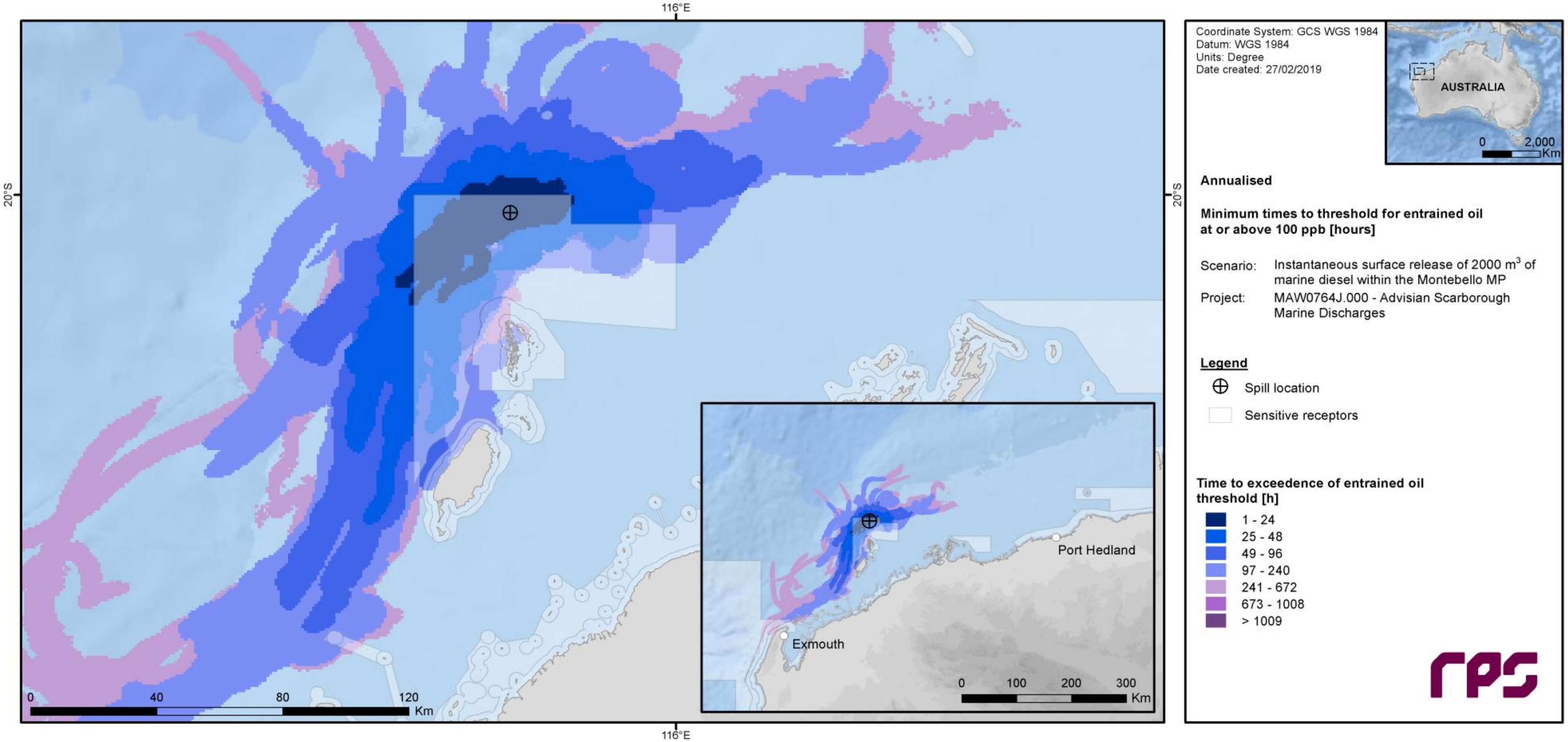


Figure 3.38 Predicted annualised minimum times to contact by entrained oil concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

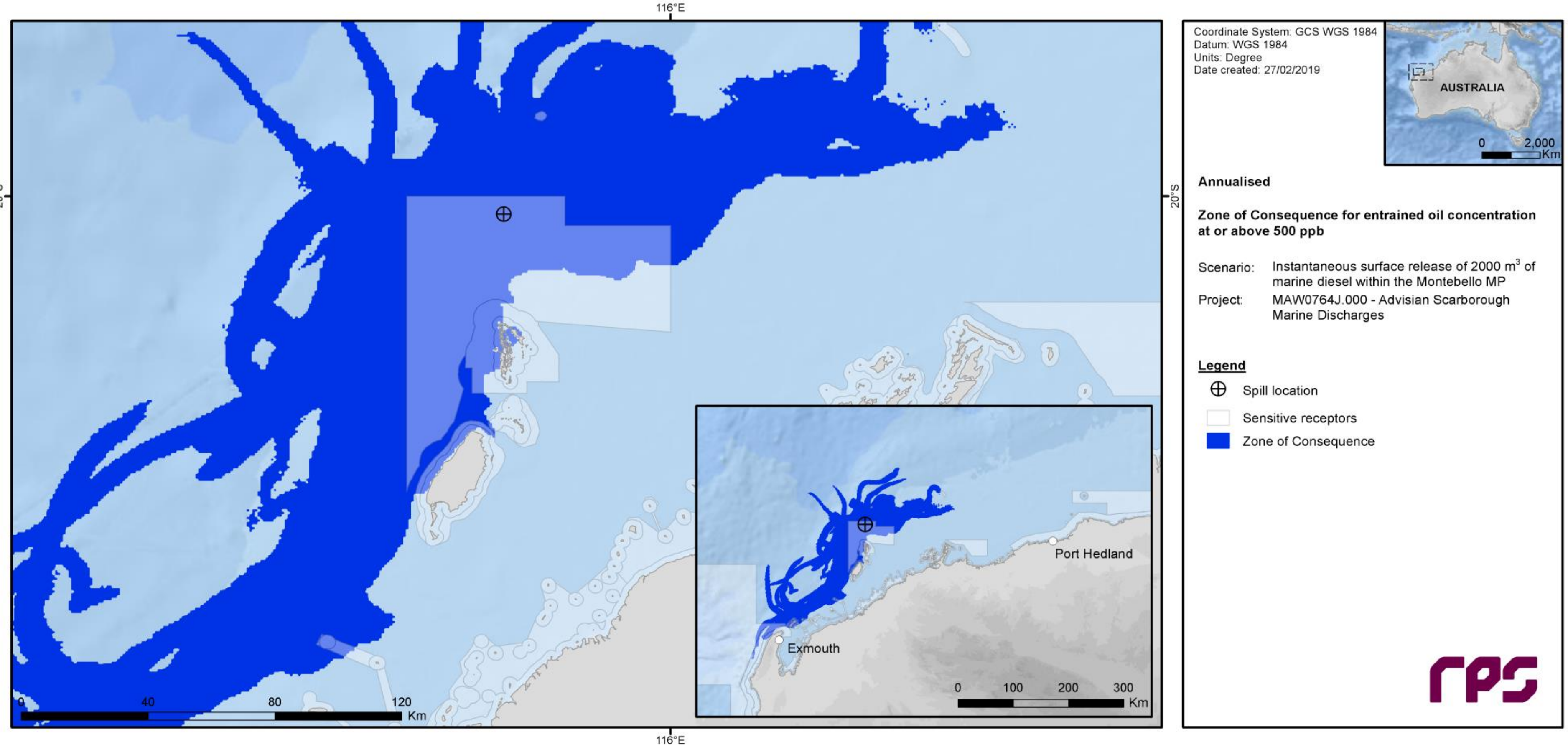


Figure 3.39 Predicted annualised Zone of Consequence of entrained oil concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

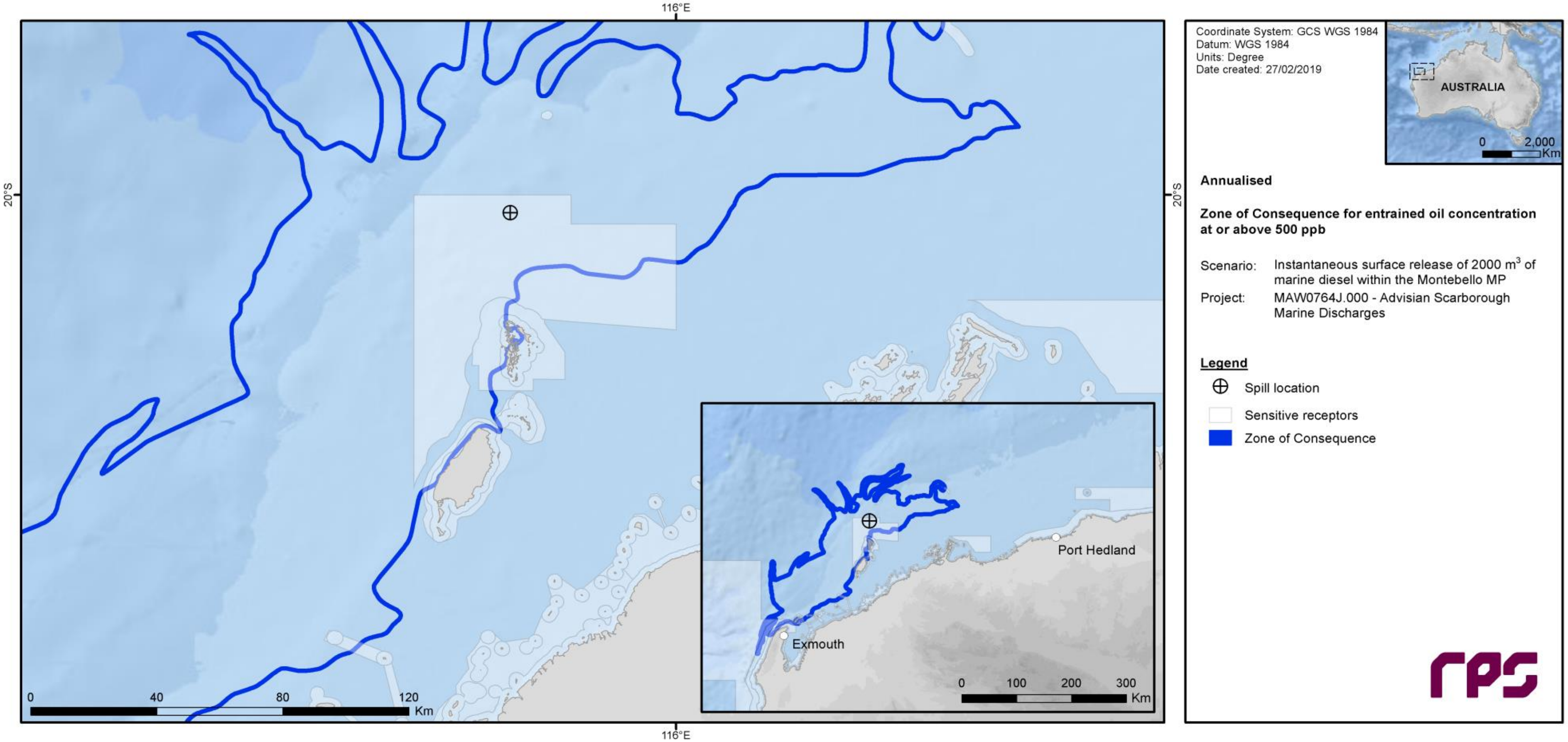


Figure 3.40 Predicted annualised smoothed Zone of Consequence of entrained oil concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

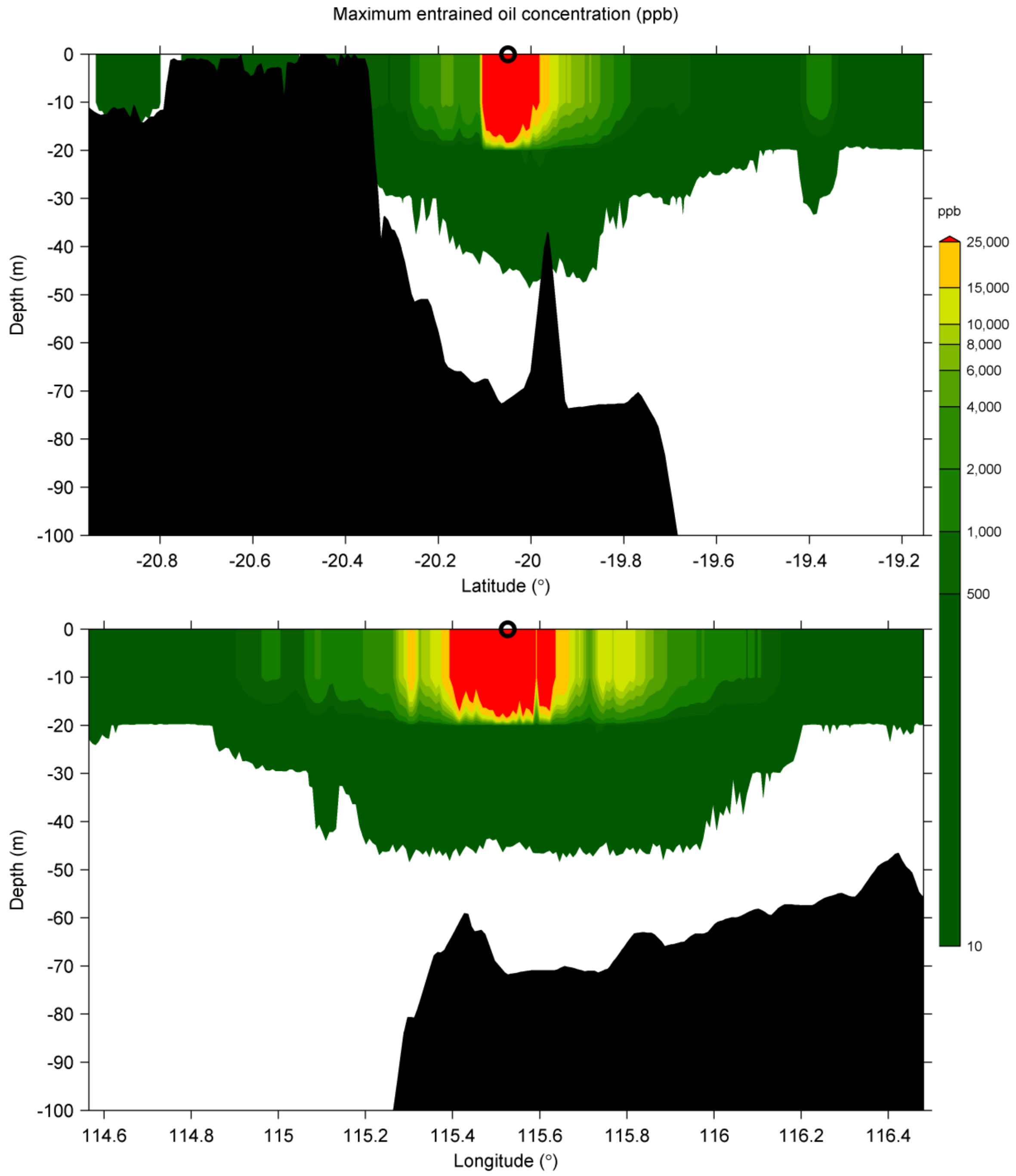


Figure 3.41 Cross-section transects of predicted annualised maximum entrained oil concentrations for an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park. Transect locations are shown in Figure 3.1.

3.3.2.3 Dissolved Aromatic Hydrocarbons

Table 3.6 Expected annualised dissolved aromatic hydrocarbon outcomes at sensitive receptors resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

Receptor	Probability (%) of dissolved aromatic hydrocarbon concentration ≥500 ppb	Maximum dissolved aromatic hydrocarbon concentration (ppb) averaged over all replicate simulations	Maximum dissolved aromatic hydrocarbon concentration (ppb), at any depth, in the worst replicate simulation
Argo-Rowley Terrace MP	<1	NC	NC
Barrow Island	<1	3	200
Glomar Shoals*	<1	<1	<1
Montebello Islands	<1	<1	56
Muiron Islands MMA-WHA	<1	<1	29
Ningaloo Coast Middle	<1	<1	2
Ningaloo Coast Middle WHA	<1	<1	2
Ningaloo Coast North	<1	<1	10
Ningaloo Coast North WHA	<1	<1	47
Ningaloo Coast South WHA	<1	<1	<1
Ningaloo RUZ	<1	<1	47
Pilbara Islands - Southern Island Group	<1	<1	25
Rankin Bank*	<1	2	69
Shark Bay Open Ocean Coast	<1	NC	NC
Shark Bay WHA	<1	NC	NC
Bernier & Dorre Islands	<1	NC	NC
Lowendal Islands	<1	<1	3
Montebello MP	9	154	1,990
Montebello State Marine Park	<1	2	108
Muiron Islands	<1	<1	26
Gascoyne MP	<1	<1	23
WA Coastline	<1	<1	97

NC: No contact to receptor predicted for specified threshold.

* Probabilities and maximum concentrations calculated at depth of submerged feature.

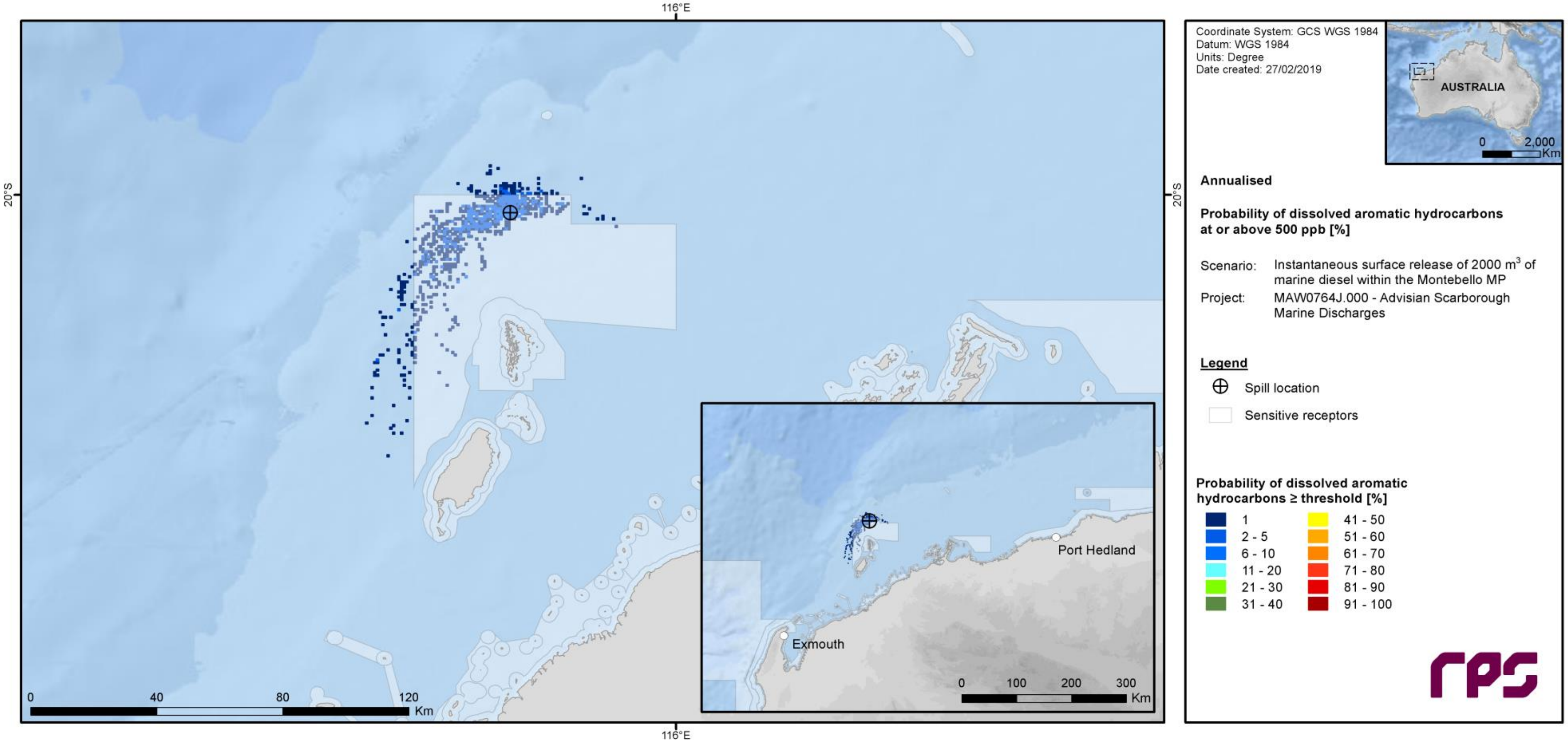


Figure 3.42 Predicted annualised probability of dissolved aromatic hydrocarbon concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

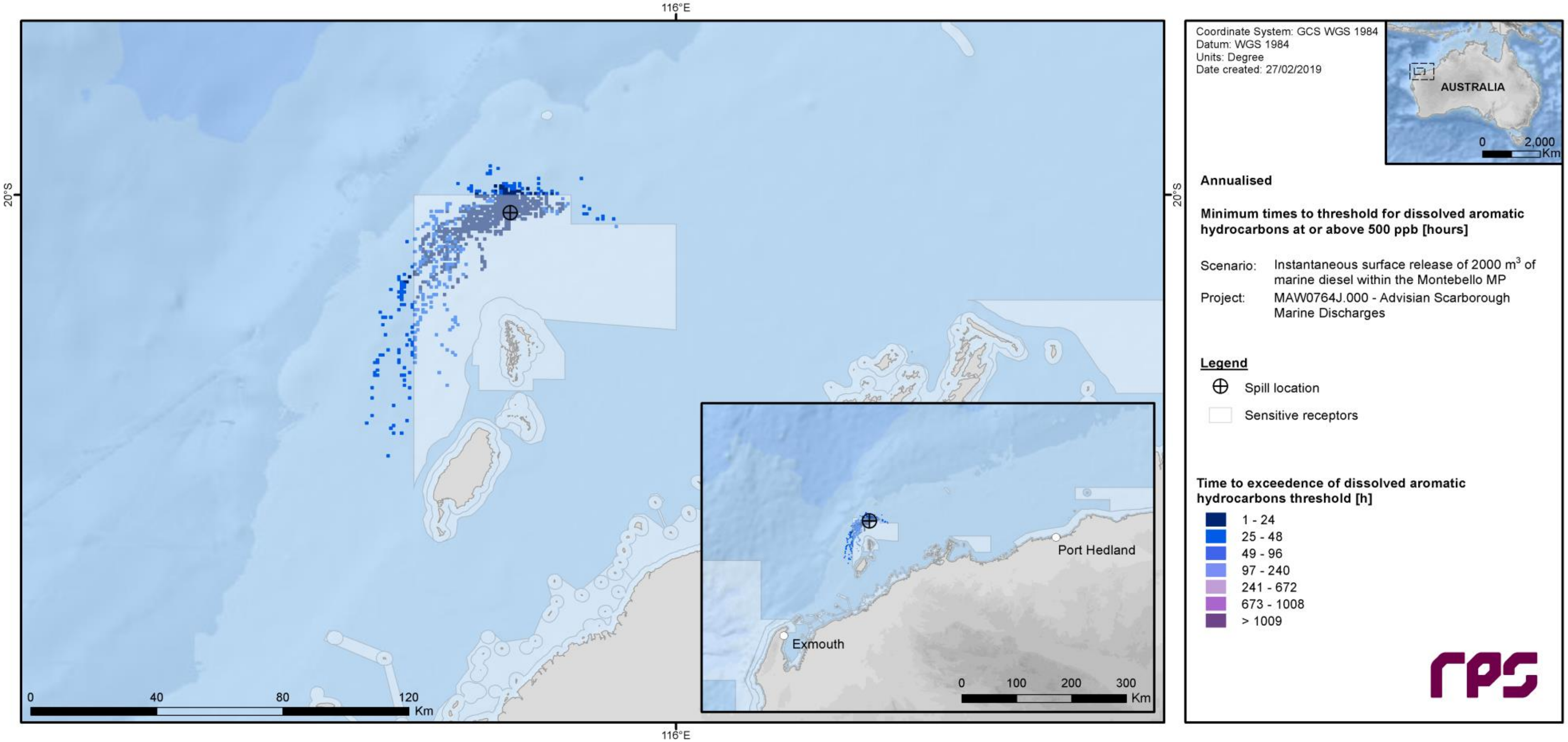


Figure 3.43 Predicted annualised minimum times to contact by dissolved aromatic hydrocarbon concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

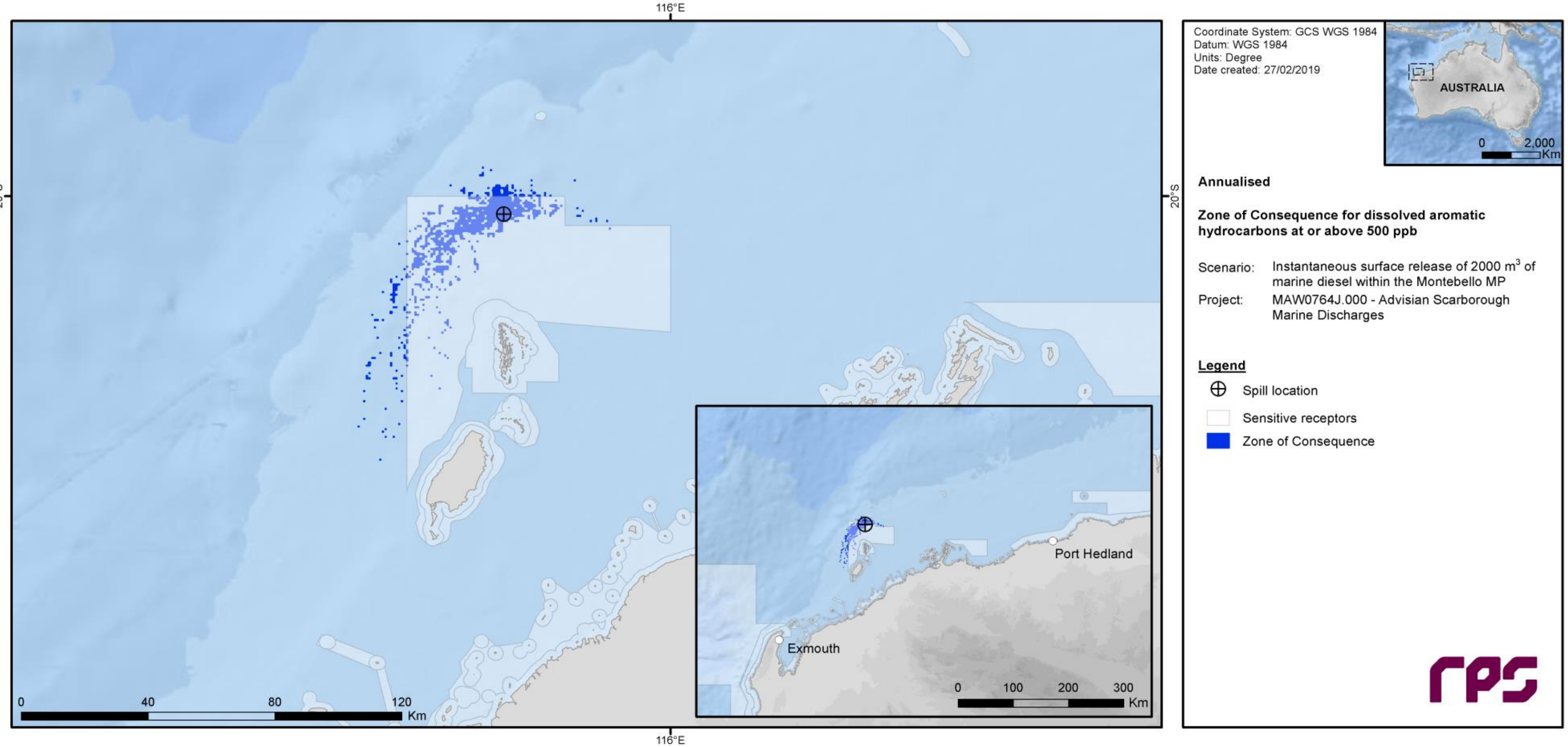


Figure 3.44 Predicted annualised Zone of Consequence of dissolved aromatic hydrocarbon concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

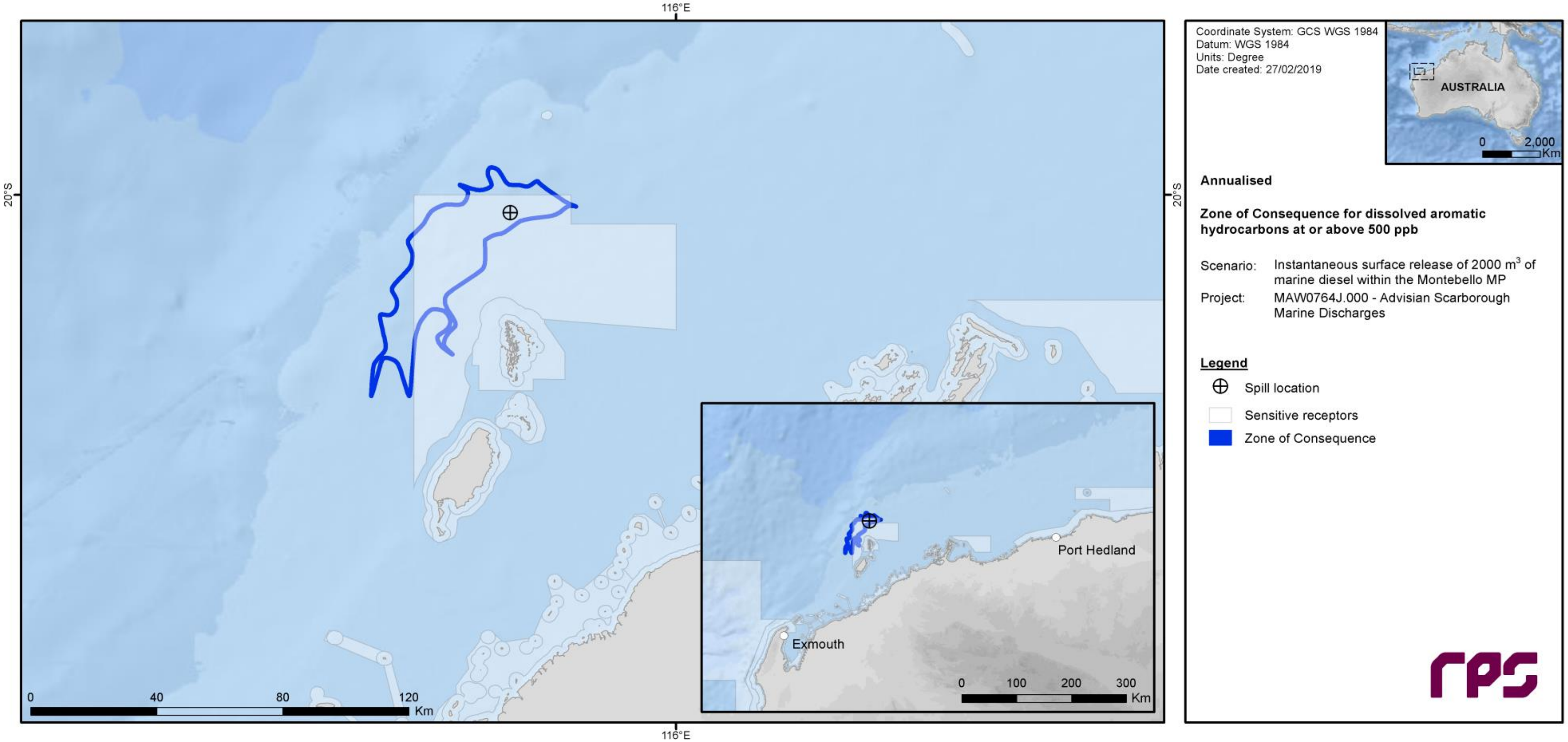


Figure 3.45 Predicted annualised smoothed Zone of Consequence of dissolved aromatic hydrocarbon concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park.

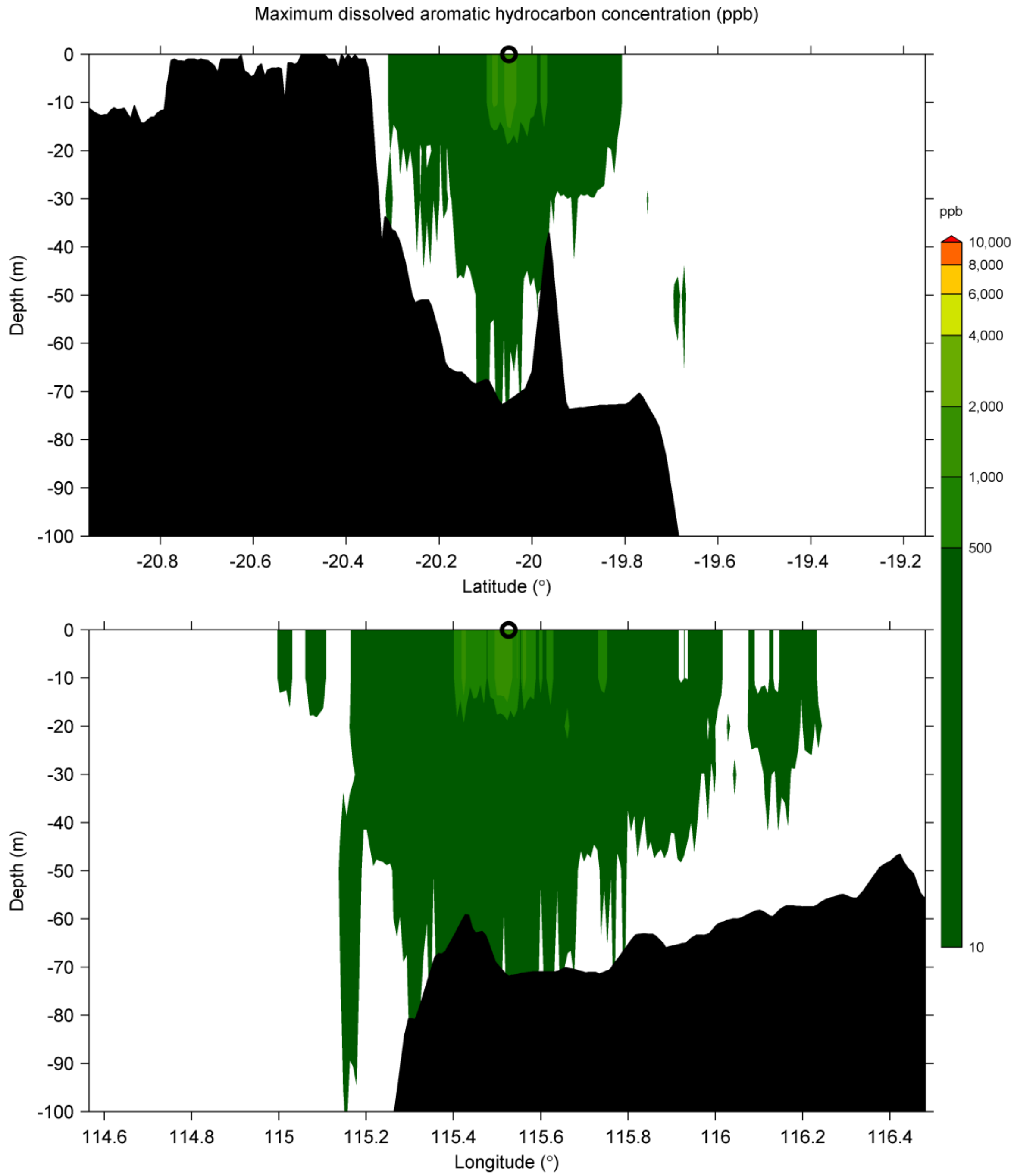


Figure 3.46 Cross-section transects of predicted annualised maximum dissolved aromatic hydrocarbon concentrations for an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park. Transect locations are shown in Figure 3.1.

3.4 Scenario 3: Short-Term (Instantaneous) Surface Release of Marine Diesel after a Vessel Collision at the FPU 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 2,000 m^3 of marine diesel at the FPU location during operations at any time of year, with no mitigation measures applied.

Considering the discharge characteristics, the properties of the oil and its expected weathering behaviour, floating oil will be susceptible to entrainment into the wave-mixed layer under typical wind conditions. Evaporation rates will be significant, given the moderate proportion of volatile compounds in the oil (41%). The low-volatility fraction of the oil (54%) will take longer durations of the order of days to evaporate, and the residual fraction of 5% is expected to persist in the environment until degradation processes occur. Considering the spill volume, there is a low potential for dissolution of soluble aromatic compounds.

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, 50 g/m^2 and 100 g/m^2 thresholds could potentially be found, in the form of slicks, up to 113 km, 60 km and 58 km from the spill site, respectively (Figure 3.47, Figure 3.48 and Figure 3.49).

No shoreline receptors are predicted to be contacted by floating oil concentrations at any of the assessed thresholds (Table 3.7). Floating oil at the 10 g/m^2 threshold is predicted to arrive at the surface waters of the Gascoyne MP receptor with a probability of 1% after 64 hours.

No accumulation of oil on shorelines is predicted (Table 3.7).

The forecast annualised minimum times to contact, ZoC and smoothed ZoC for floating oil at or above the 10 g/m^2, 50 g/m^2 and 100 g/m^2 threshold concentrations are depicted in Figure 3.50 to Figure 3.52, Figure 3.53 to Figure 3.55 and Figure 3.56 to Figure 3.58, respectively.

3.4.1.3 Entrained Oil

Entrained oil at concentrations equal to or greater than the 500 ppb threshold is predicted to be found up to around 476 km from the spill site (Figure 3.59).

The Gascoyne MP is predicted to receive entrained oil concentrations at the 500 ppb threshold with a probability of 8% (Table 3.8). The maximum entrained oil concentration is forecast as 7.2 ppm within the Gascoyne MP.

The forecast annualised minimum times to contact, ZoC and smoothed ZoC for entrained oil at or above the 500 ppb threshold concentration are depicted in Figure 3.60, Figure 3.61 and Figure 3.62, 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 15 m (Figure 3.63).

3.4.1.4 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 74 km from the spill site (Figure 3.64).

No receptors are predicted to receive dissolved aromatic hydrocarbon concentrations at the 500 ppb threshold (Table 3.9). The maximum dissolved aromatic hydrocarbon concentration is forecast as 462 ppb within the Gascoyne MP.

The forecast annualised minimum times to contact, ZoC and smoothed ZoC for dissolved aromatic hydrocarbons at or above the 500 ppb threshold concentration are depicted in Figure 3.65, Figure 3.66 and Figure 3.67, 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 15 m (Figure 3.68).

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 marine diesel after a vessel collision at the FPU location.

Receptor	Probability (%) of floating oil concentration ≥10 g/m^2	Probability (%) of floating oil concentration ≥50 g/m^2	Probability (%) of floating oil concentration ≥100 g/m^2	Minimum time to receptor (hours) for floating oil at ≥10 g/m^2	Minimum time to receptor (hours) for floating oil at ≥50 g/m^2	Minimum time to receptor (hours) for floating oil at ≥100 g/m^2	Probability (%) of shoreline oil concentration ≥100 g/m^2	Probability (%) of shoreline oil concentration ≥250 g/m^2	Minimum time to receptor (hours) for shoreline oil at ≥100 g/m^2	Minimum time to receptor (hours) for shoreline oil at ≥250 g/m^2	Maximum local accumulated concentration (g/m^2) averaged over all replicate simulations	Maximum local accumulated concentration (g/m^2) in the worst replicate simulation	Maximum accumulated volume (m^3) along this shoreline, averaged over all replicate simulations	Maximum accumulated volume (m^3) along this shoreline, in the worst replicate simulation
Ningaloo Coast North WHA	<1	<1	<1	NC	NC	NC	<1	<1	NC	NC	NC	NC	NC	NC
Ningaloo RUZ*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA
Abrolhos Islands MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA
Carnarvon Canyon MP*	<1	<1	<1	NC	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA
Gascoyne MP*	1	<1	<1	64	NC	NC	NA	NA	NA	NA	NA	NA	NA	NA

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.

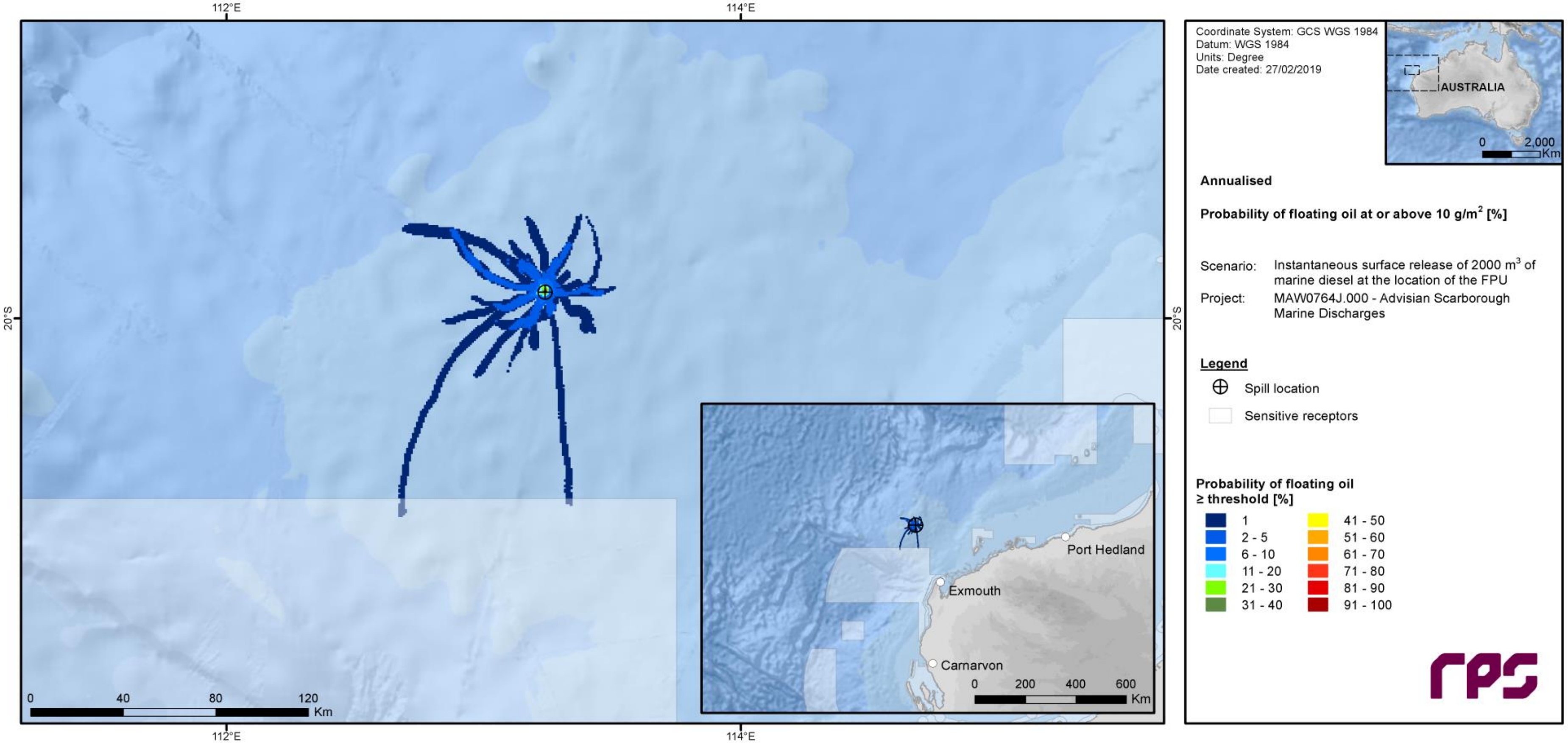


Figure 3.47 Predicted annualised probability of floating oil concentrations at or above 10 g/m² resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location.

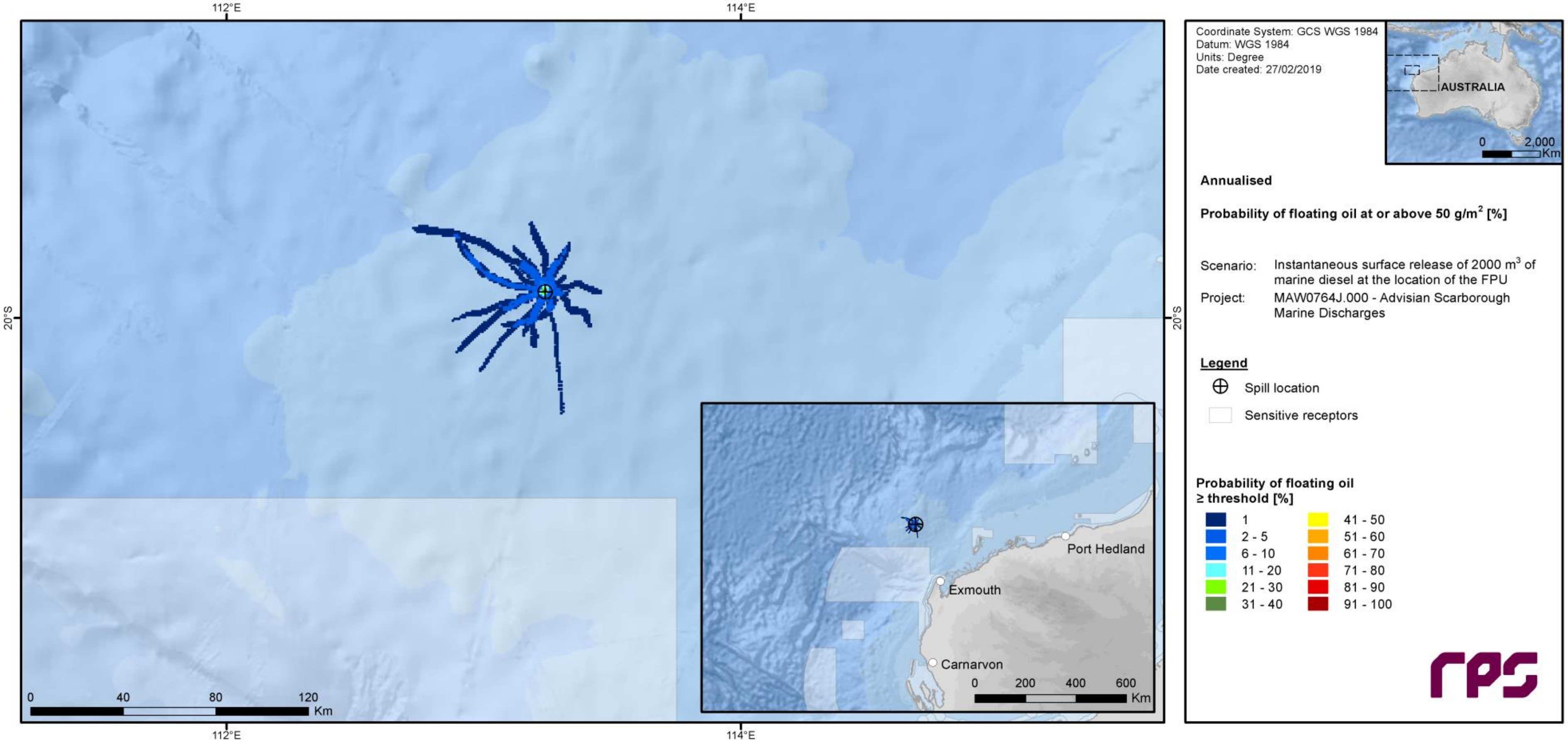


Figure 3.48 **Predicted annualised probability of floating oil concentrations at or above 50 g/m² resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location.**

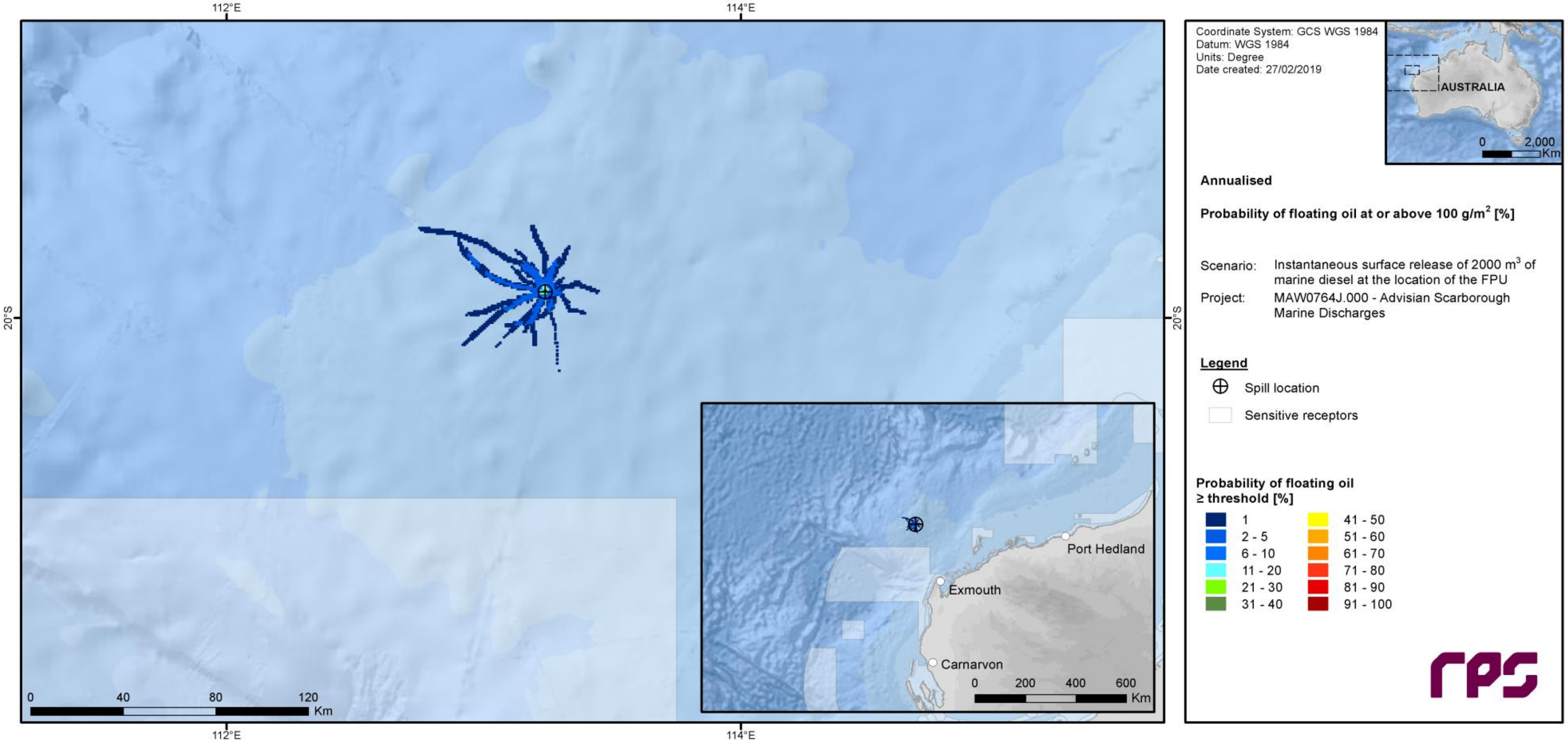


Figure 3.49 Predicted annualised probability of floating oil concentrations at or above 100 g/m² resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location.

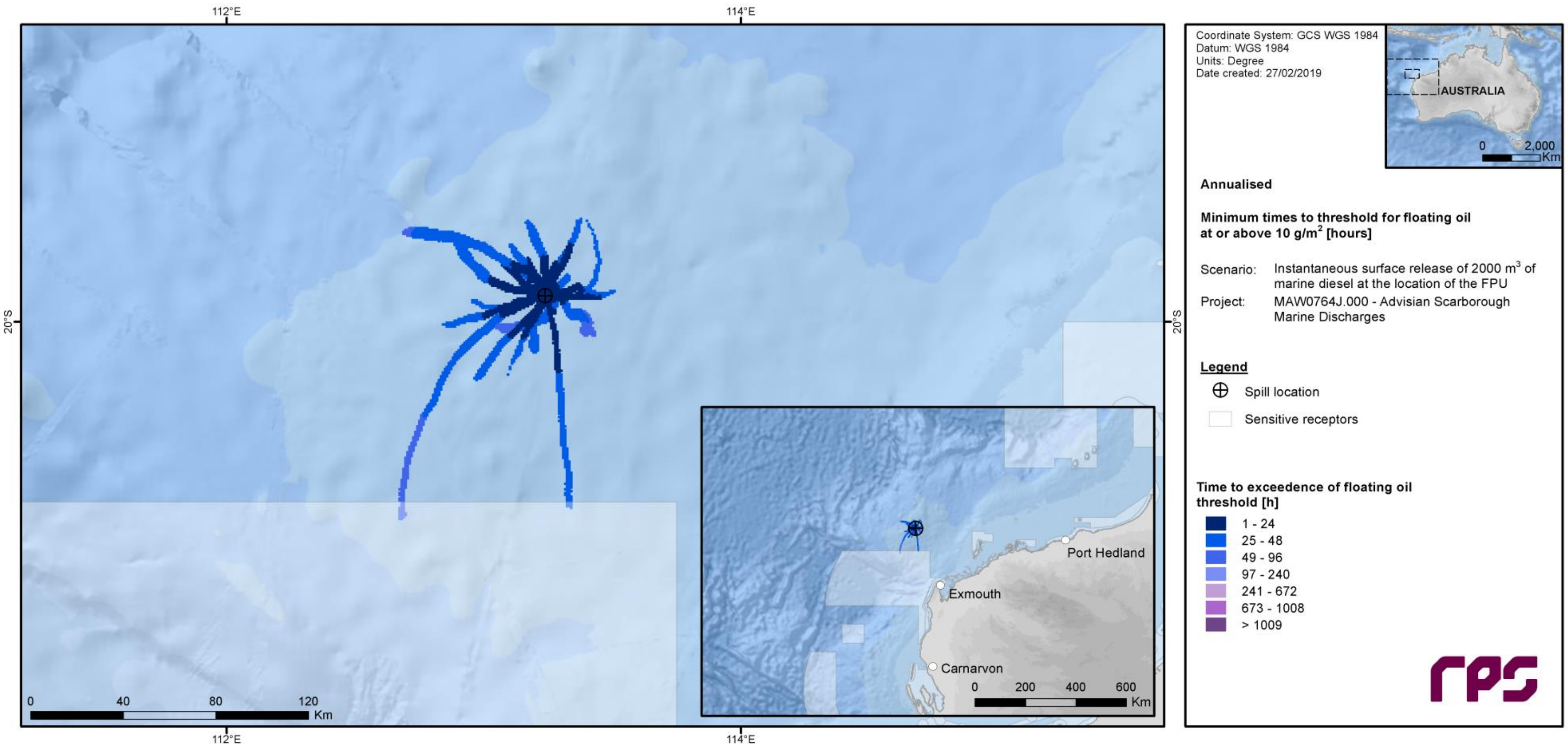


Figure 3.50 Predicted annualised minimum times to contact by floating oil concentrations at or above 10 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location.

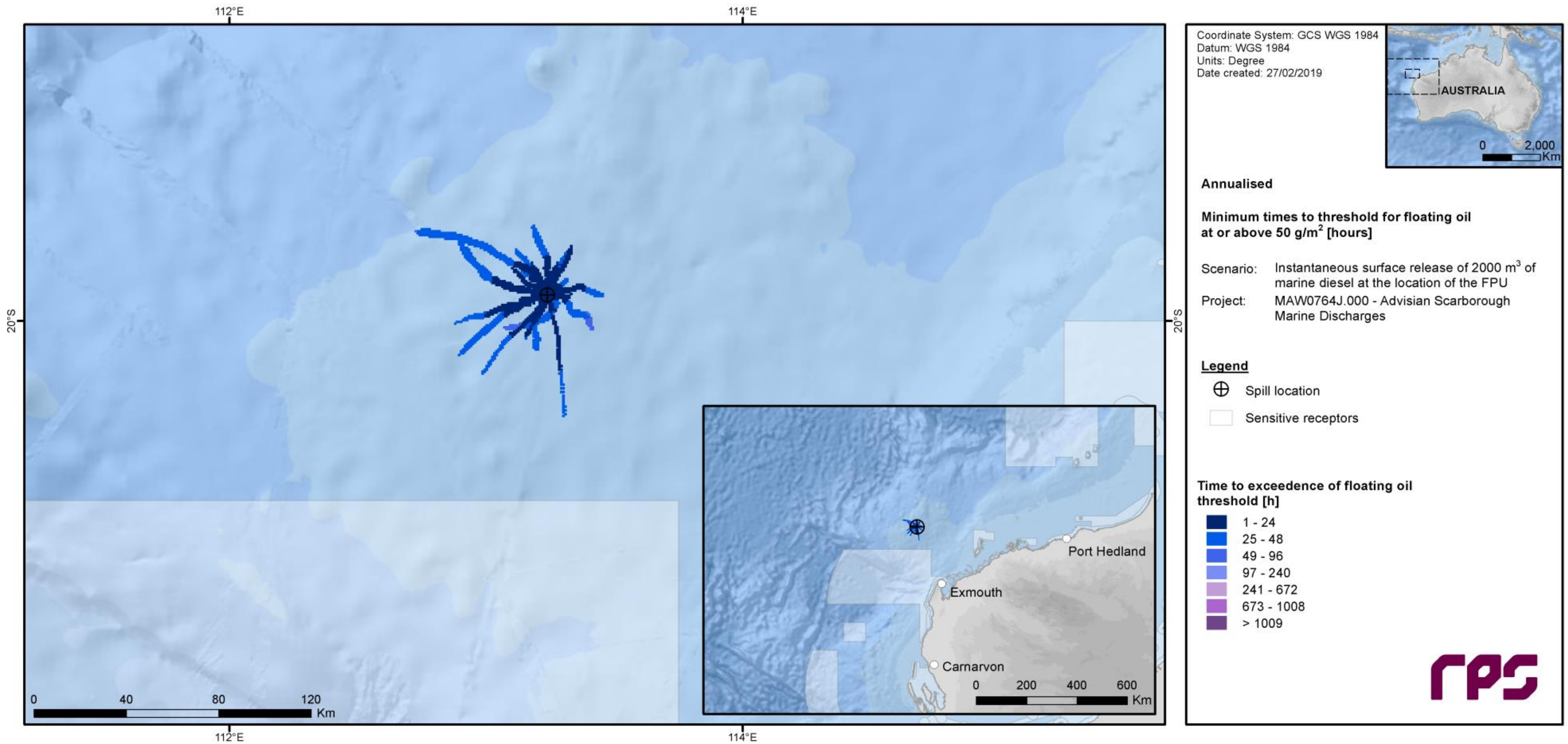


Figure 3.51 Predicted annualised minimum times to contact by floating oil concentrations at or above 50 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location.

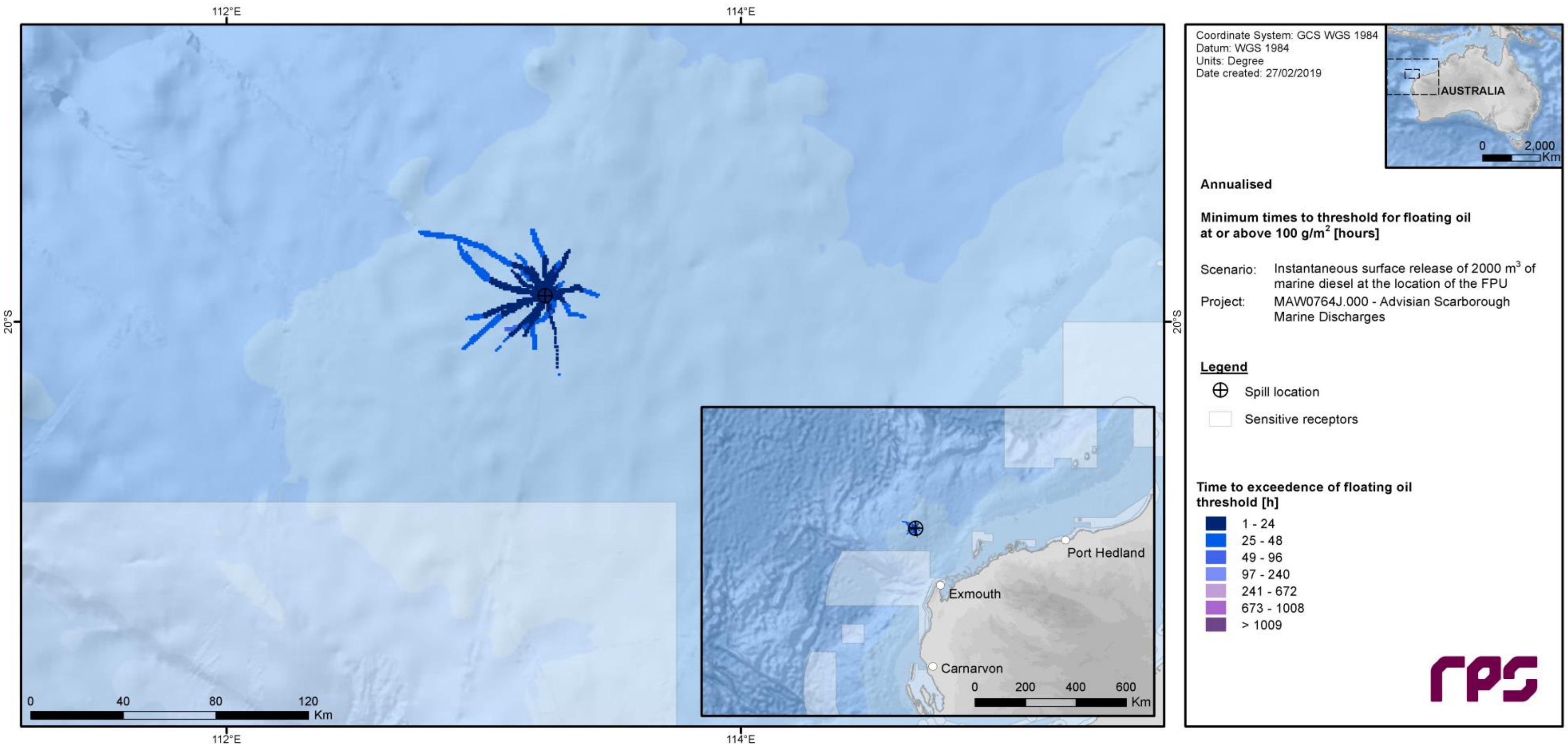


Figure 3.52 Predicted annualised minimum times to contact by floating oil concentrations at or above 100 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location.

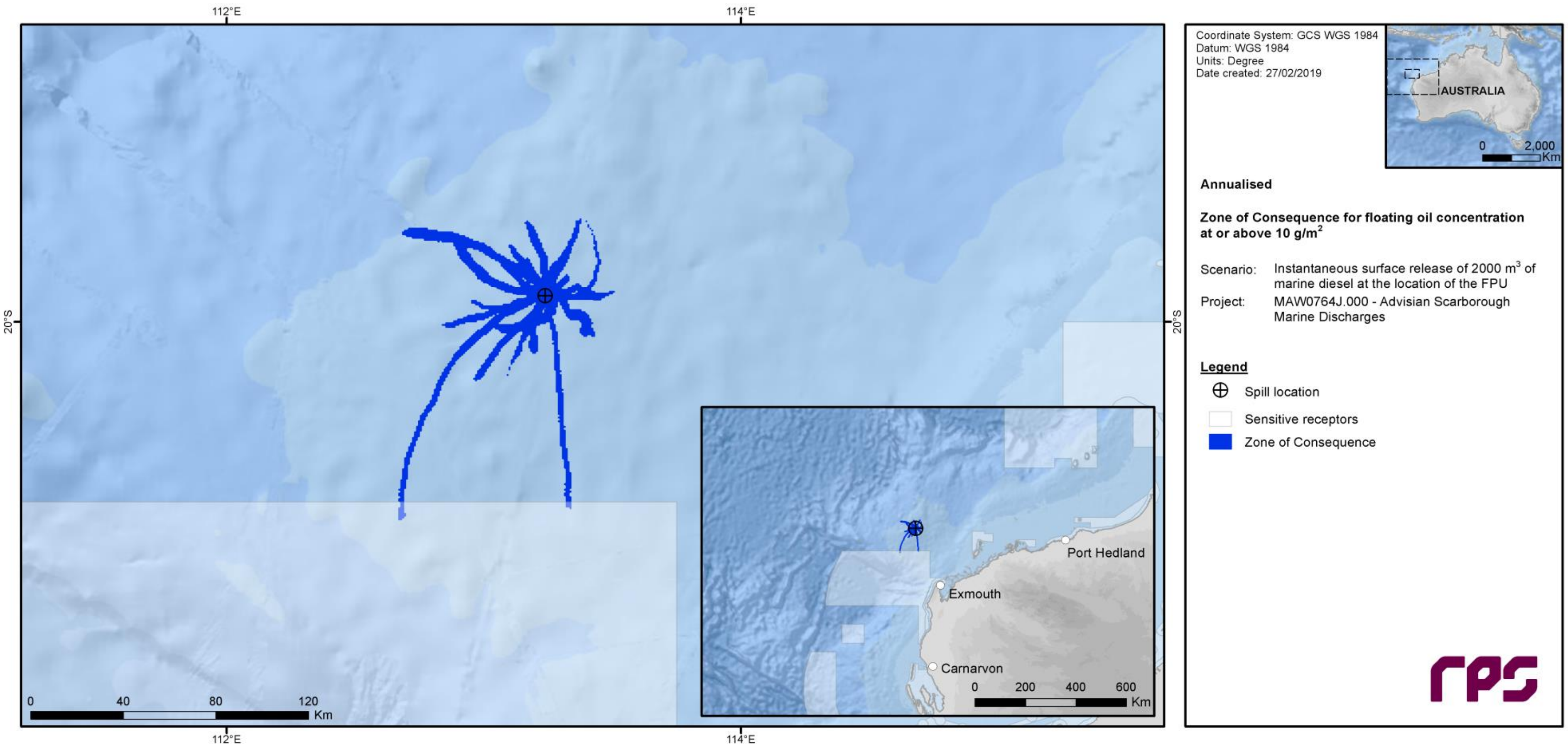


Figure 3.53 Predicted annualised Zone of Consequence of floating oil concentrations at or above 10 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location.

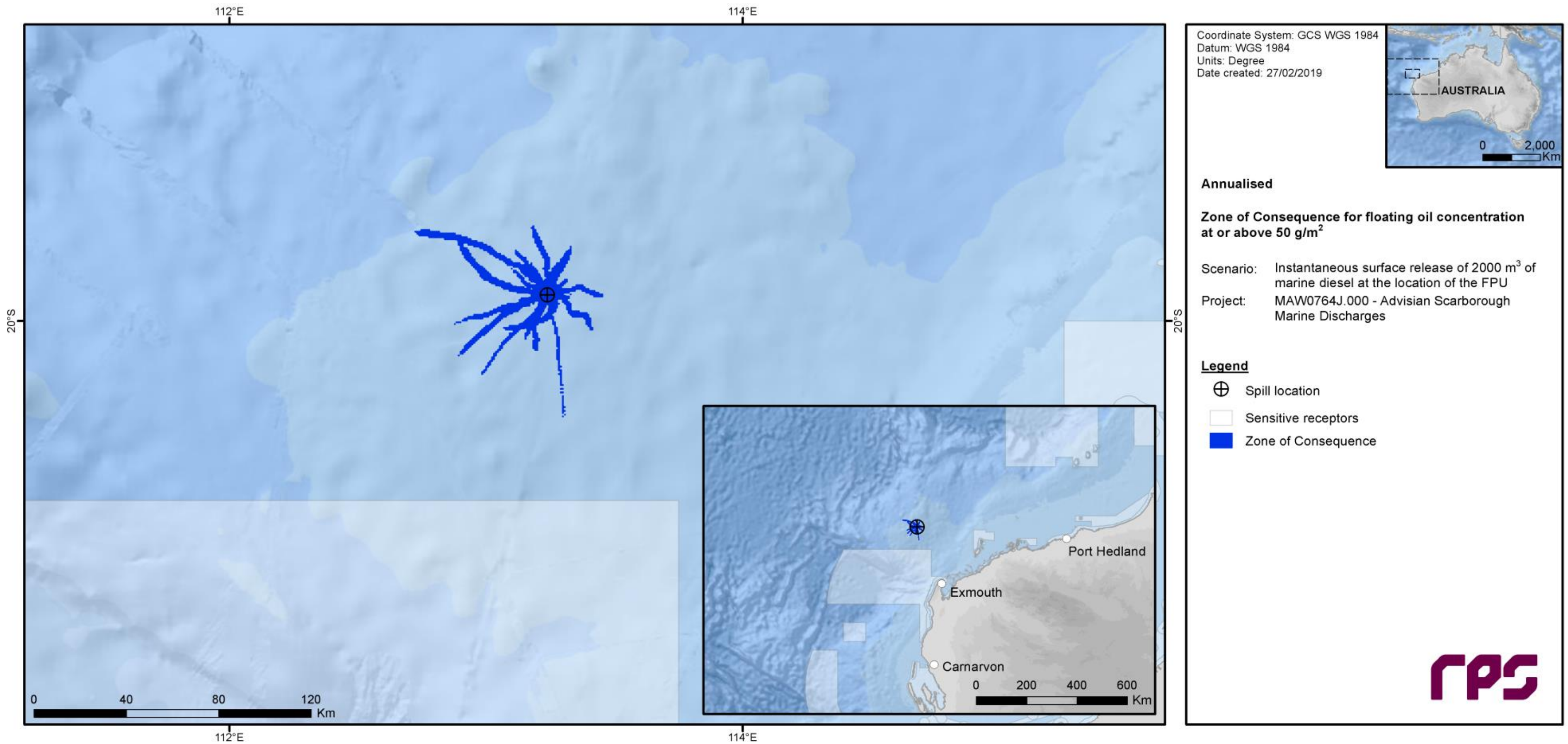


Figure 3.54 Predicted annualised Zone of Consequence of floating oil concentrations at or above 50 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location.

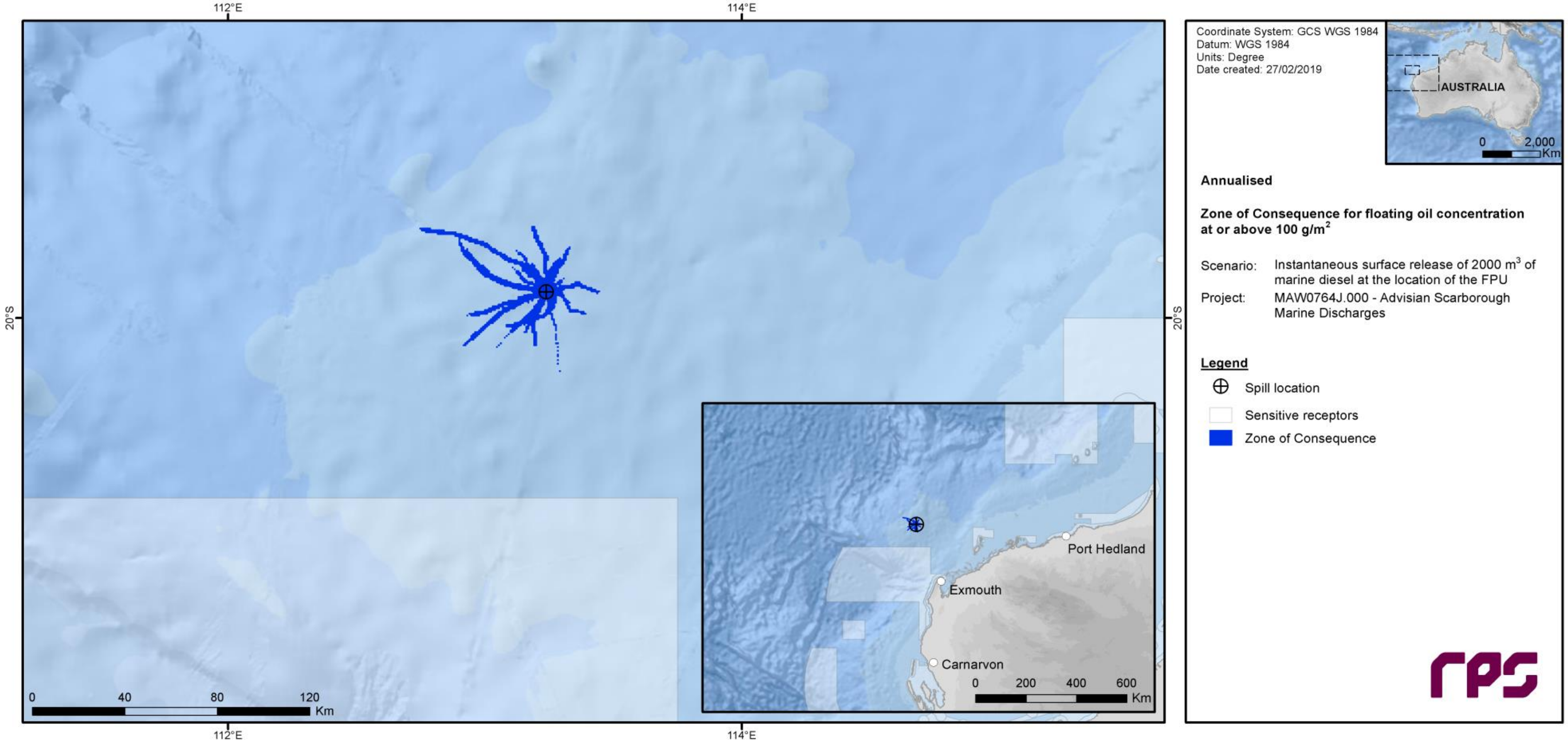


Figure 3.55 Predicted annualised Zone of Consequence of floating oil concentrations at or above 100 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location.

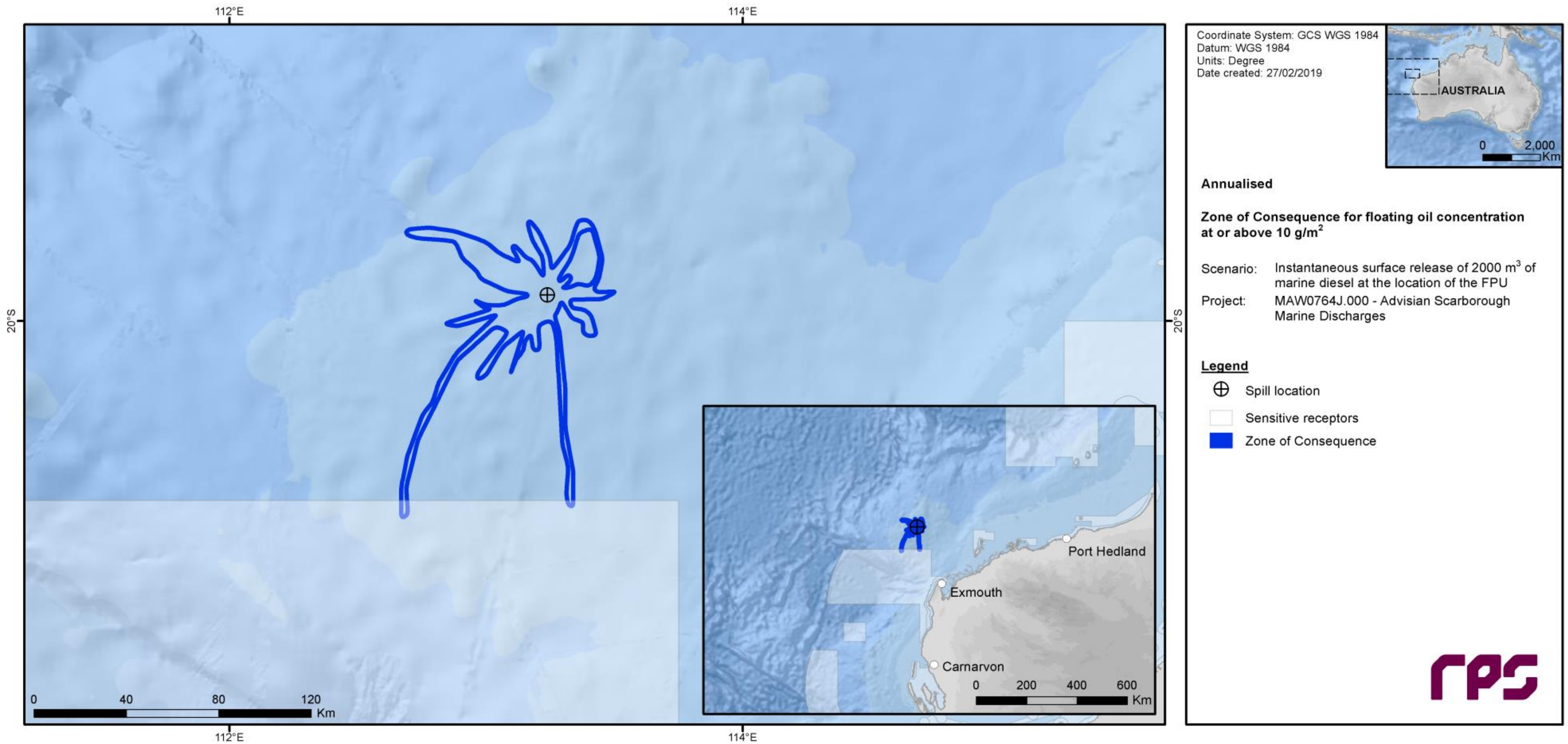


Figure 3.56 Predicted annualised smoothed Zone of Consequence of floating oil concentrations at or above 10 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location.

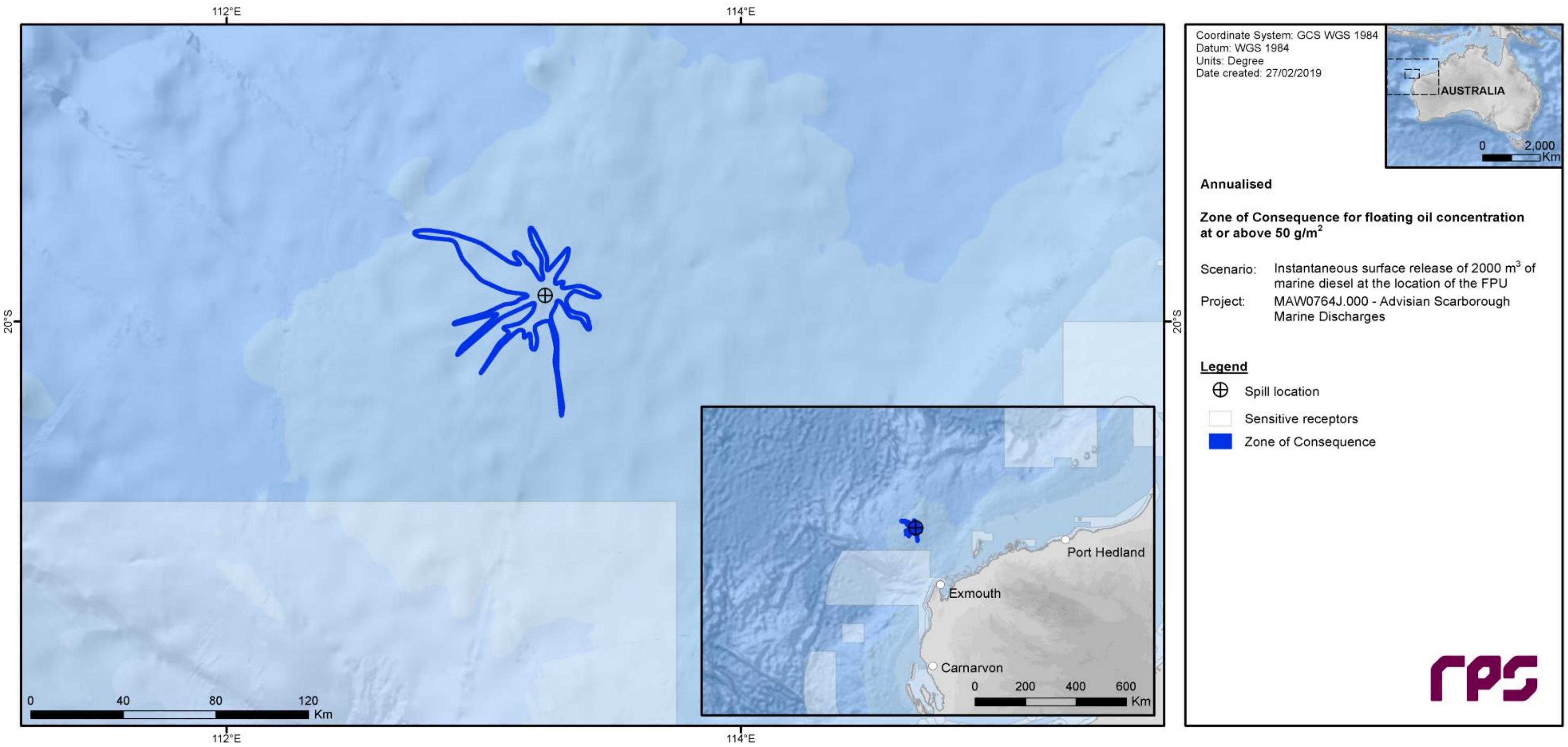


Figure 3.57 Predicted annualised smoothed Zone of Consequence of floating oil concentrations at or above 50 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location.

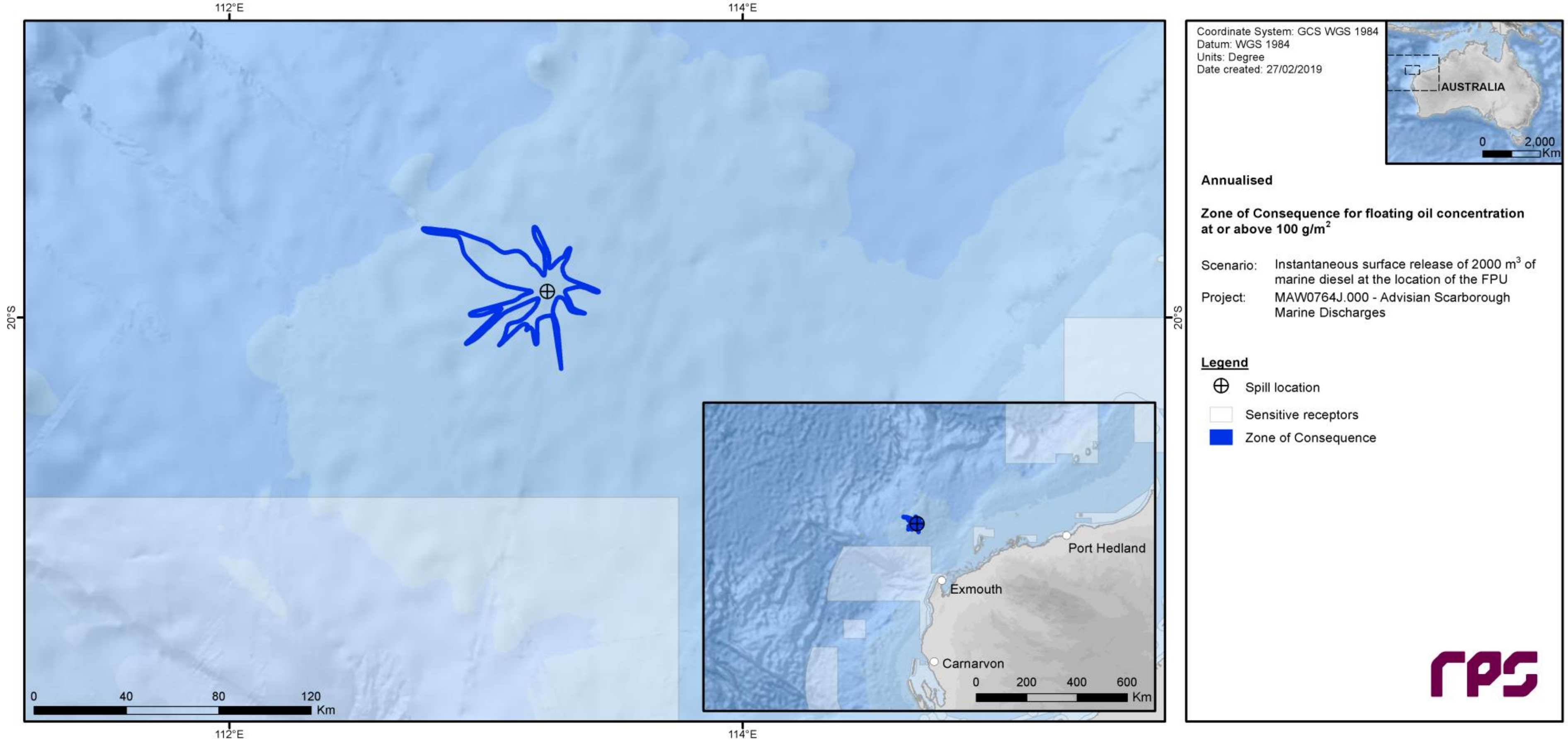


Figure 3.58 Predicted annualised smoothed Zone of Consequence of floating oil concentrations at or above 100 g/m^2 resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location.

3.4.2.2 Entrained Oil

Table 3.8 Expected annualised entrained oil outcomes at sensitive receptors resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location.

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
Ningaloo Coast North WHA	<1	NC	<1	52
Ningaloo RUZ	<1	NC	<1	52
Abrolhos Islands MP	<1	NC	2	167
Carnarvon Canyon MP	<1	NC	3	196
Gascoyne MP	8	62	185	7,236

NC: No contact to receptor predicted for specified threshold.

* Probabilities and maximum concentrations calculated at depth of submerged feature.

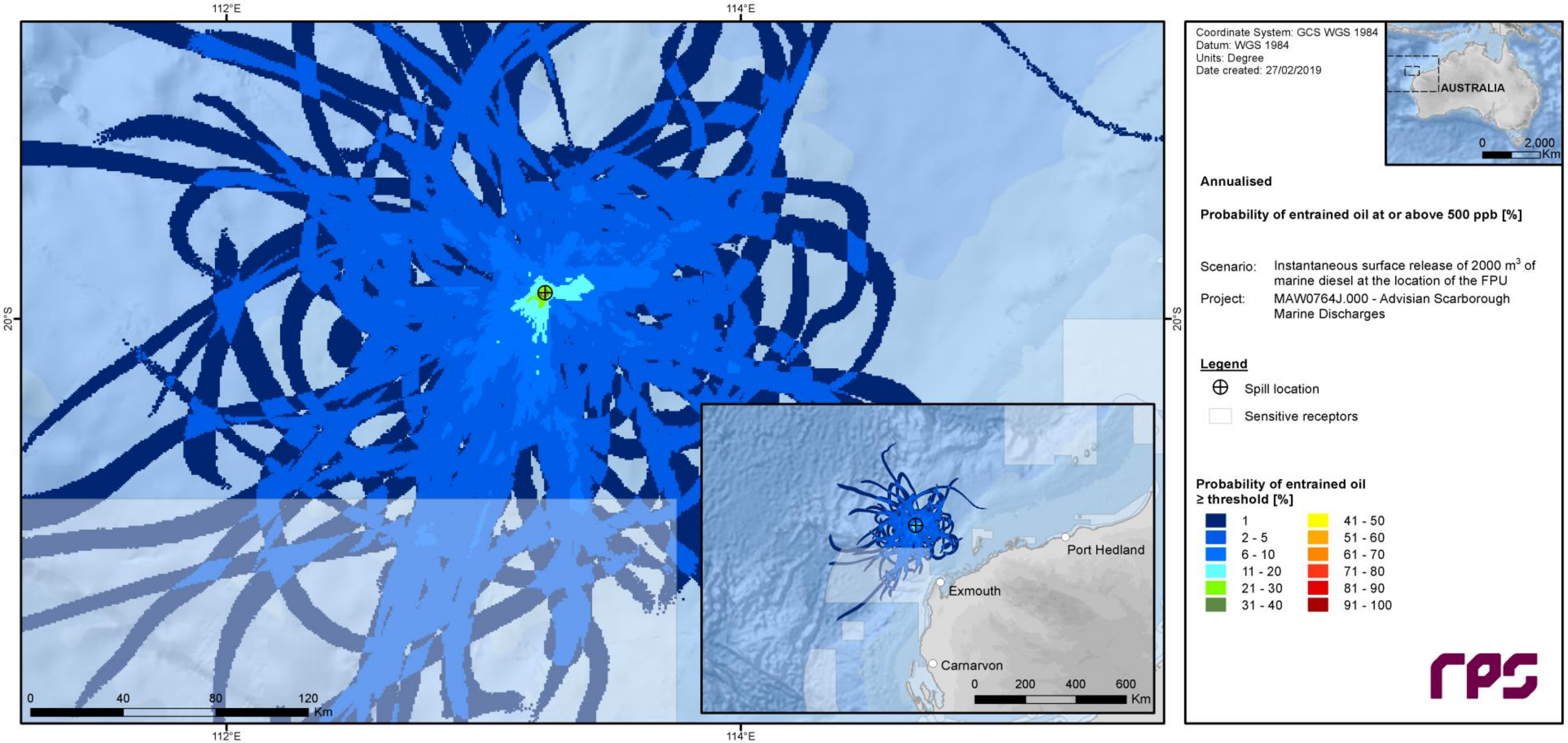


Figure 3.59 Predicted annualised probability of entrained oil concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location.

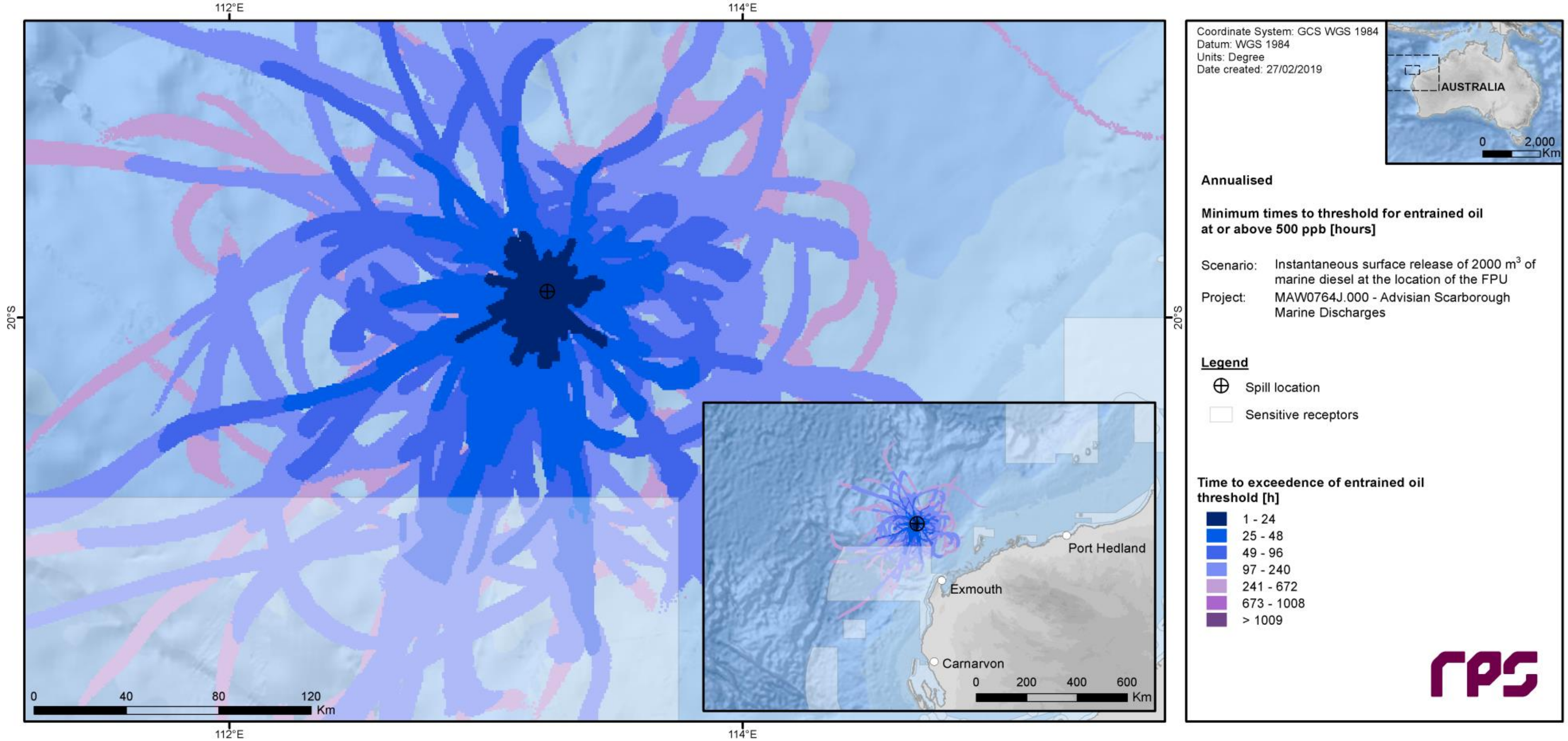


Figure 3.60 Predicted annualised minimum times to contact by entrained oil concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location.

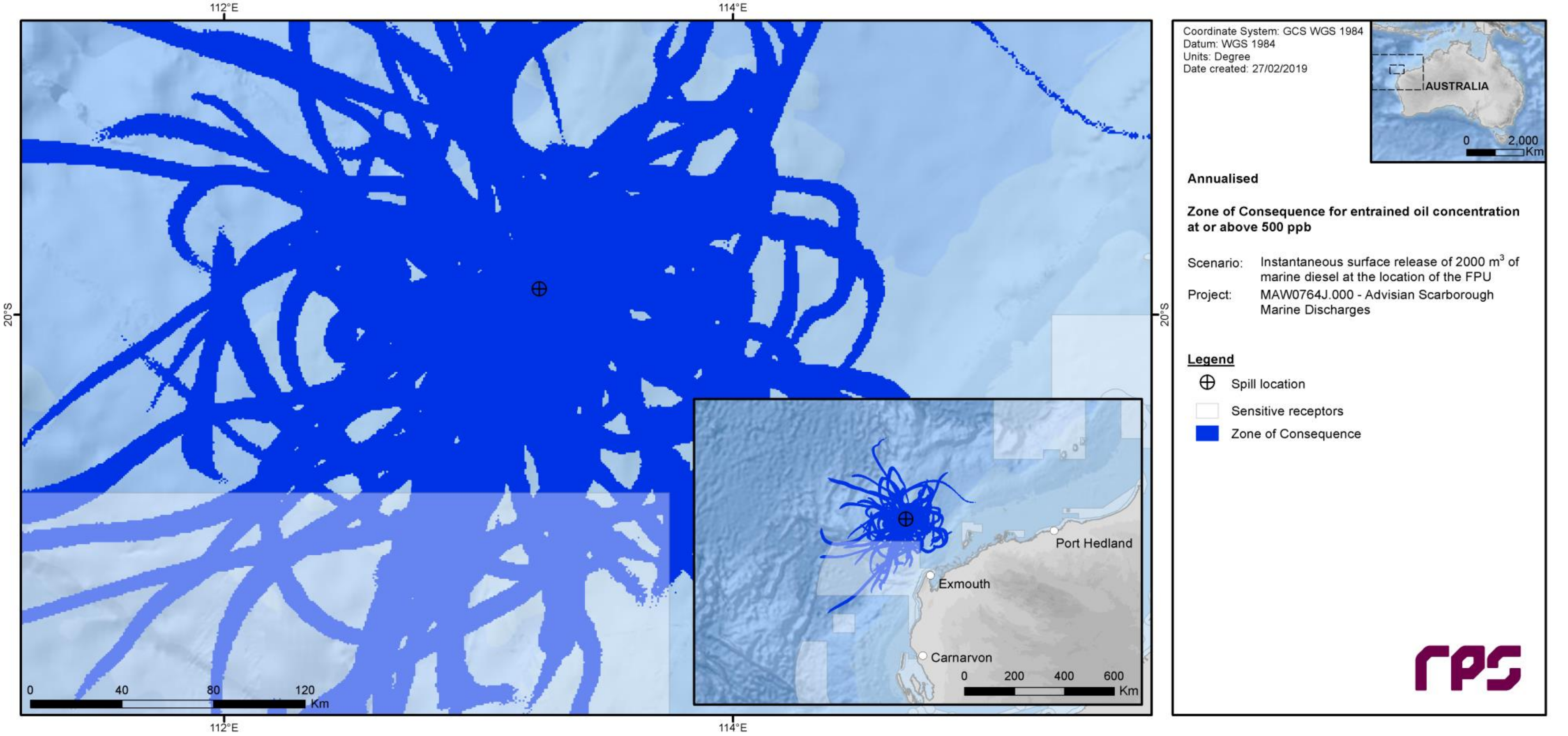


Figure 3.61 Predicted annualised Zone of Consequence of entrained oil concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location.

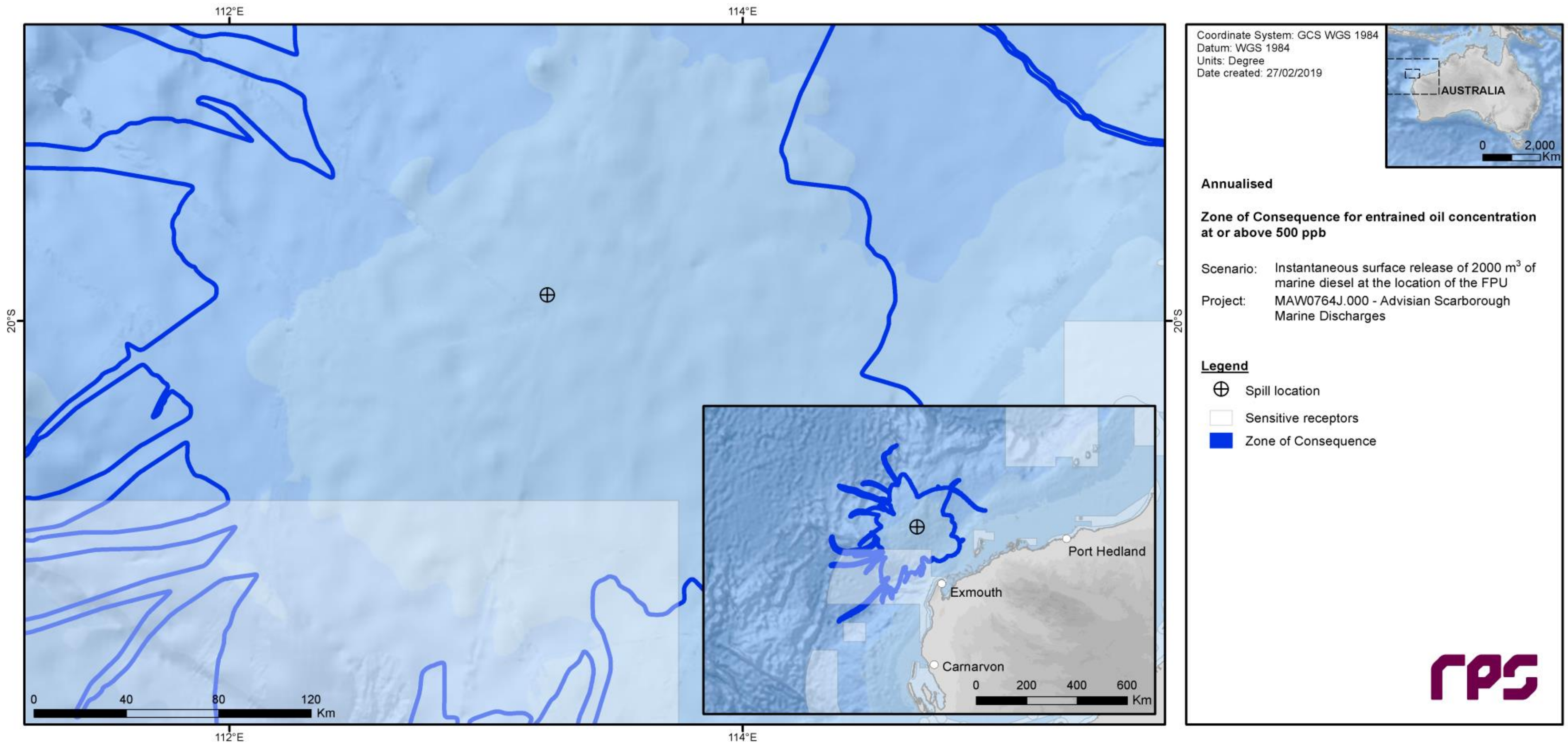


Figure 3.62 Predicted annualised smoothed Zone of Consequence of entrained oil concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location.

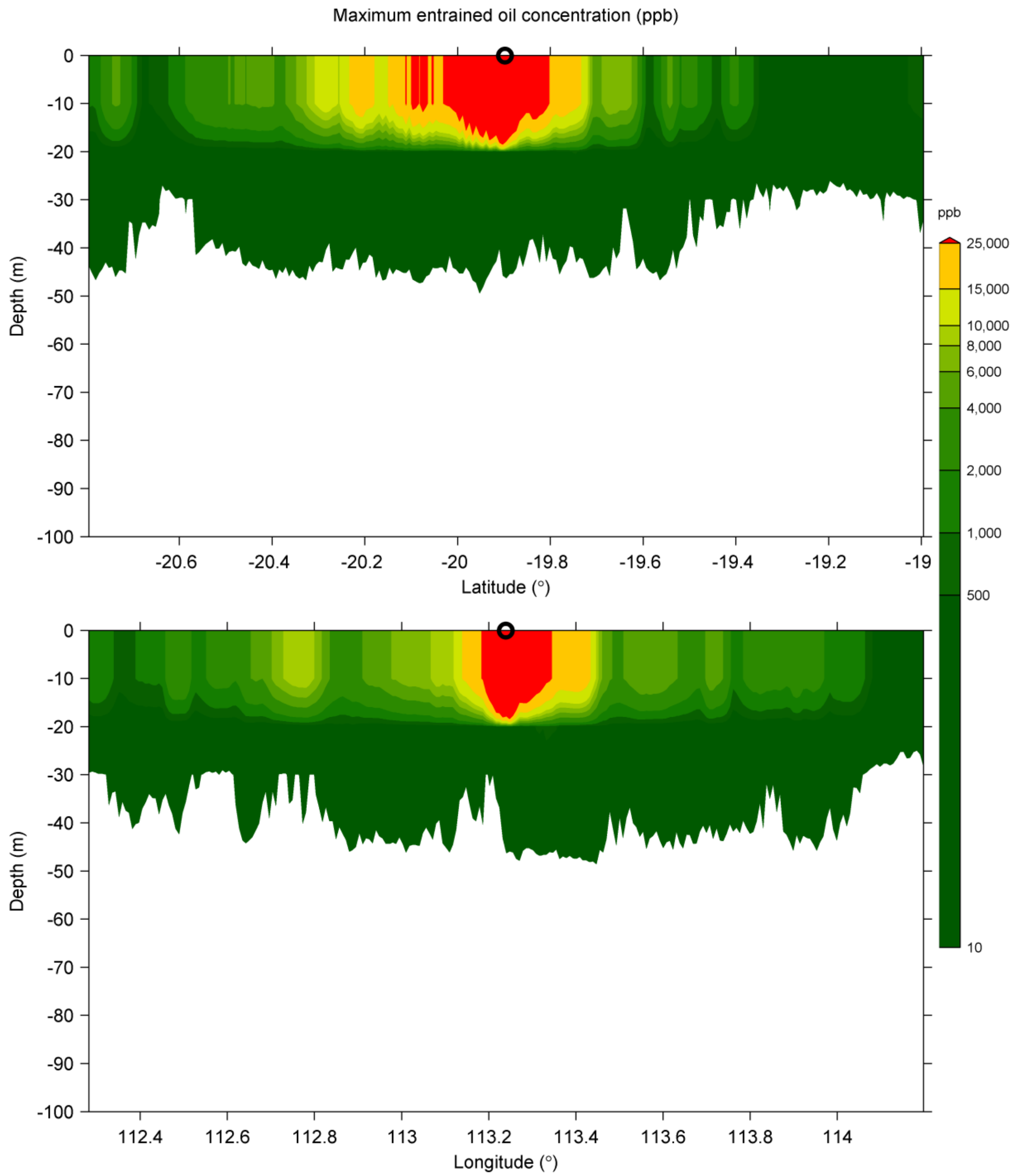


Figure 3.63 Cross-section transects of predicted annualised maximum entrained oil concentrations for an instantaneous surface release of marine diesel after a vessel collision at the FPU location. Transect locations are shown in Figure 3.1.

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 marine diesel after a vessel collision at the FPU location.

Receptor	Probability (%) of dissolved aromatic hydrocarbon concentration ≥500 ppb	Maximum dissolved aromatic hydrocarbon concentration (ppb) averaged over all replicate simulations	Maximum dissolved aromatic hydrocarbon concentration (ppb), at any depth, in the worst replicate simulation
Ningaloo Coast North WHA	<1	<1	2
Ningaloo RUZ	<1	<1	3
Abrolhos Islands MP	<1	<1	<1
Carnarvon Canyon MP	<1	<1	6
Gascoyne MP	<1	6	462

NC: No contact to receptor predicted for specified threshold.

* Probabilities and maximum concentrations calculated at depth of submerged feature.

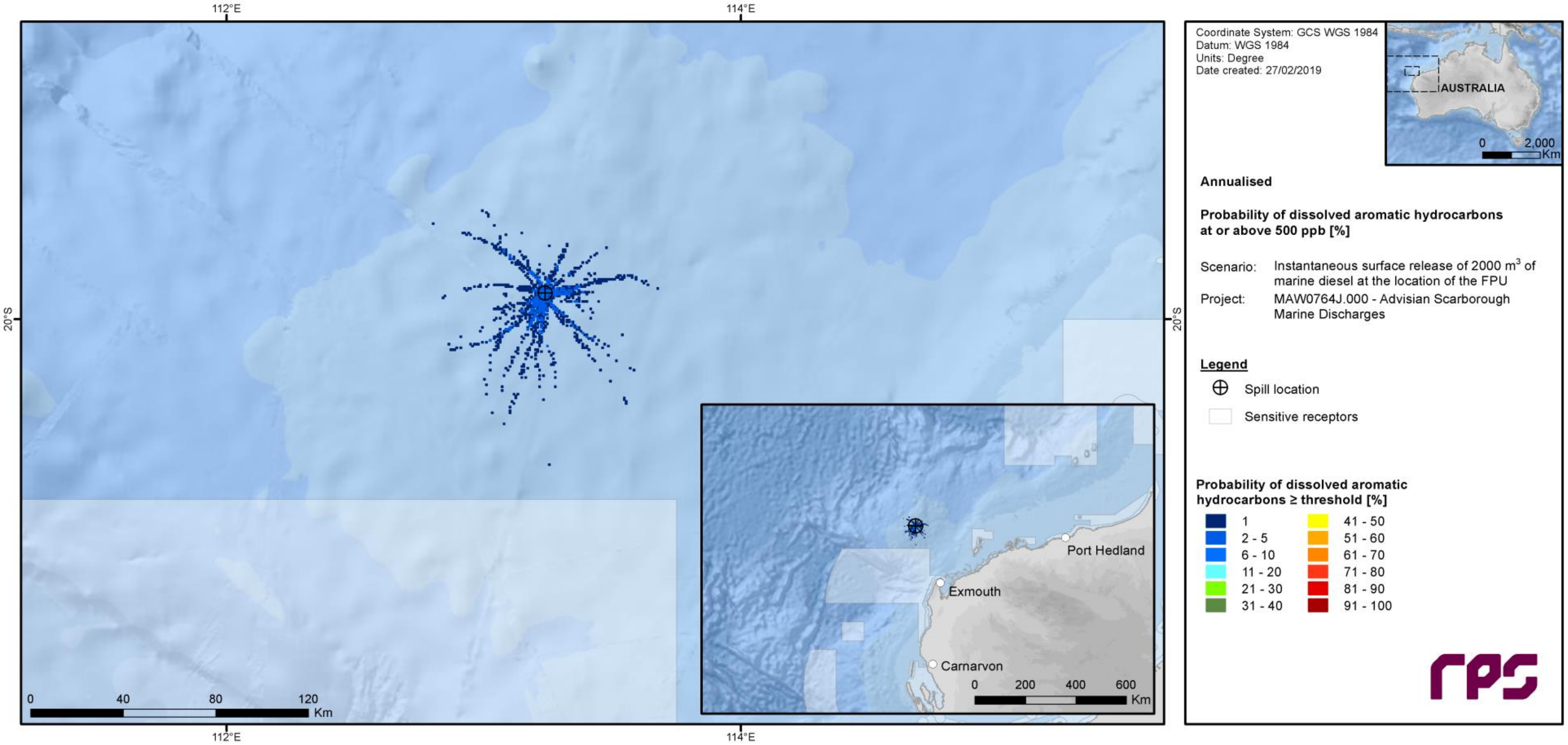


Figure 3.64 Predicted annualised probability of dissolved aromatic hydrocarbon concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location.

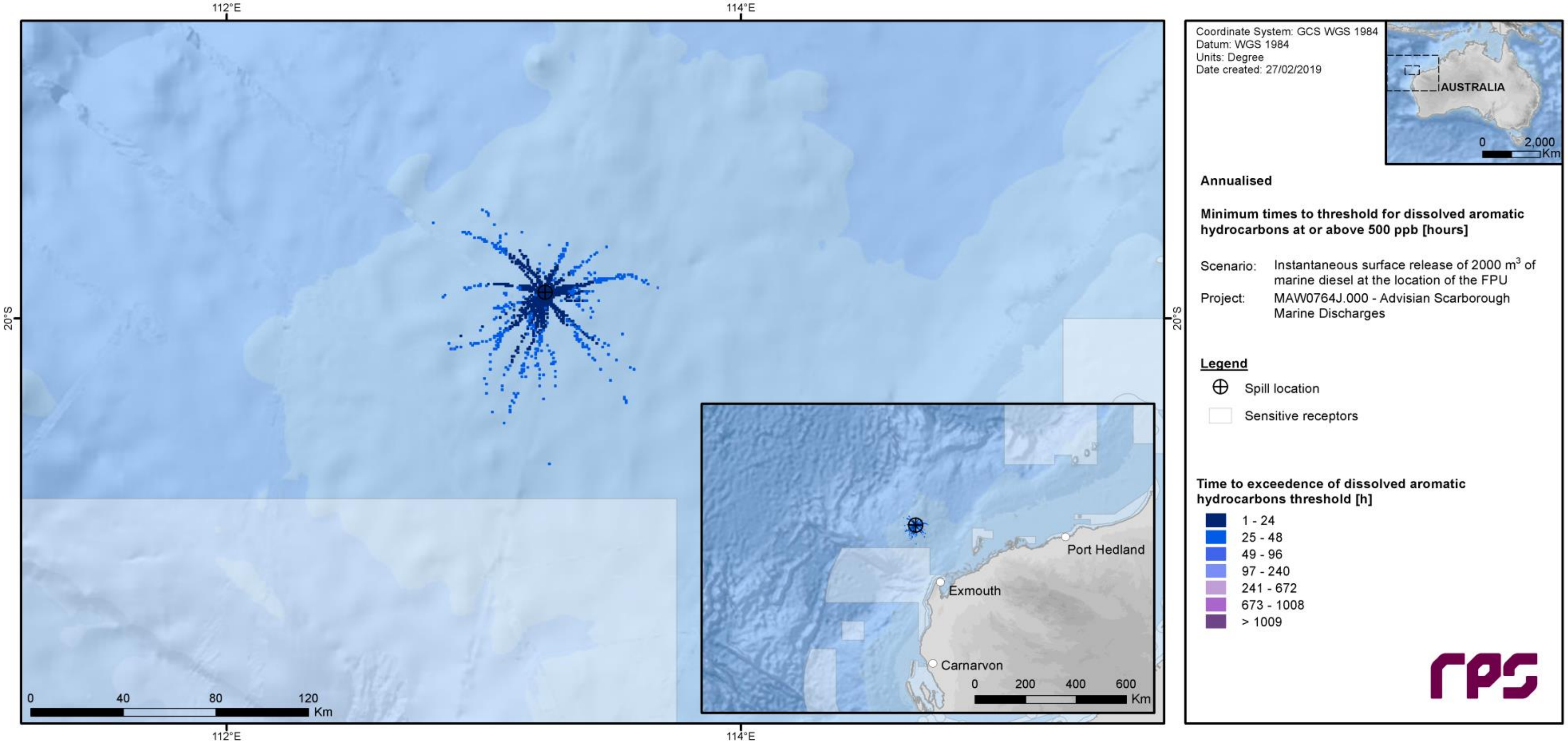


Figure 3.65 Predicted annualised minimum times to contact by dissolved aromatic hydrocarbon concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location.

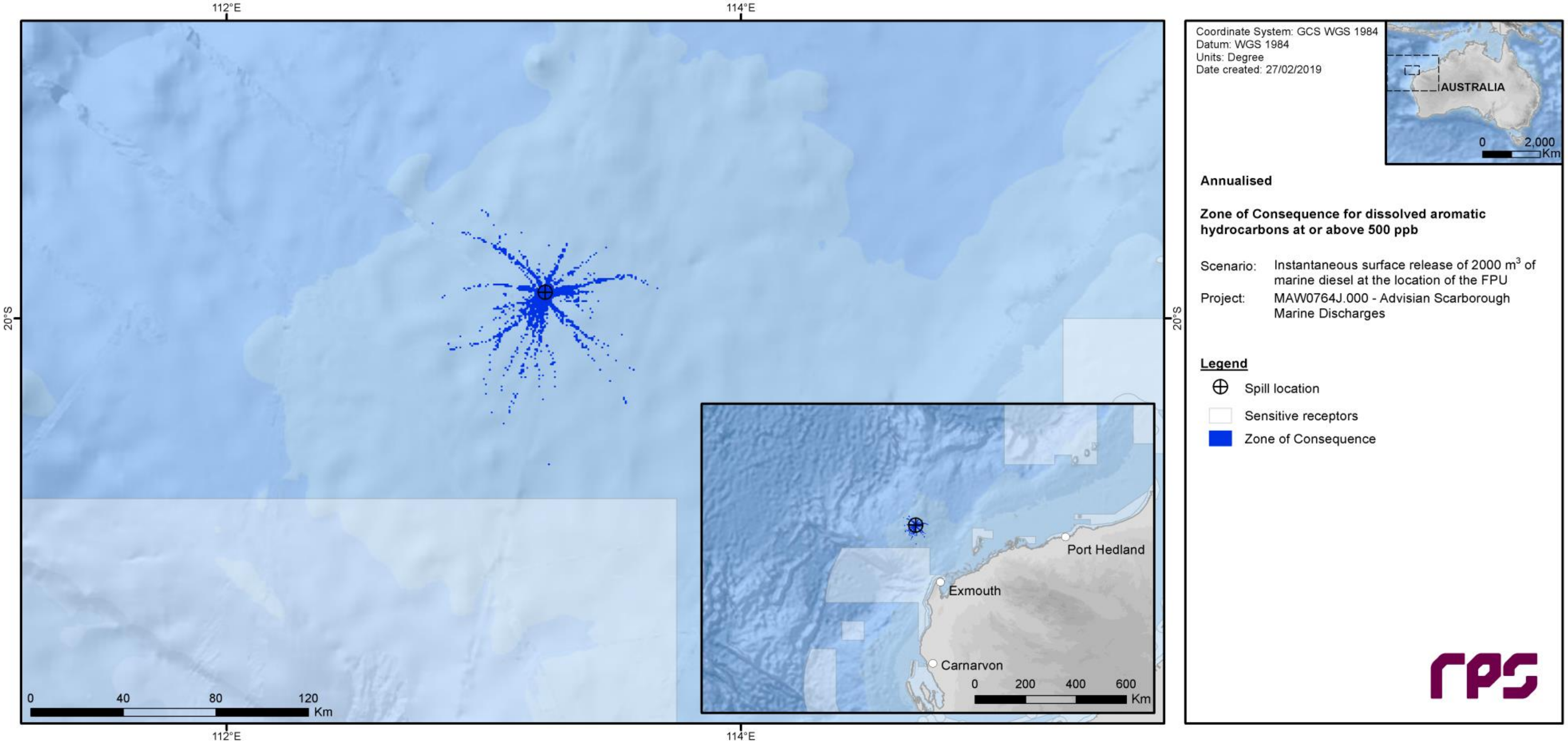


Figure 3.66 Predicted annualised Zone of Consequence of dissolved aromatic hydrocarbon concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location.

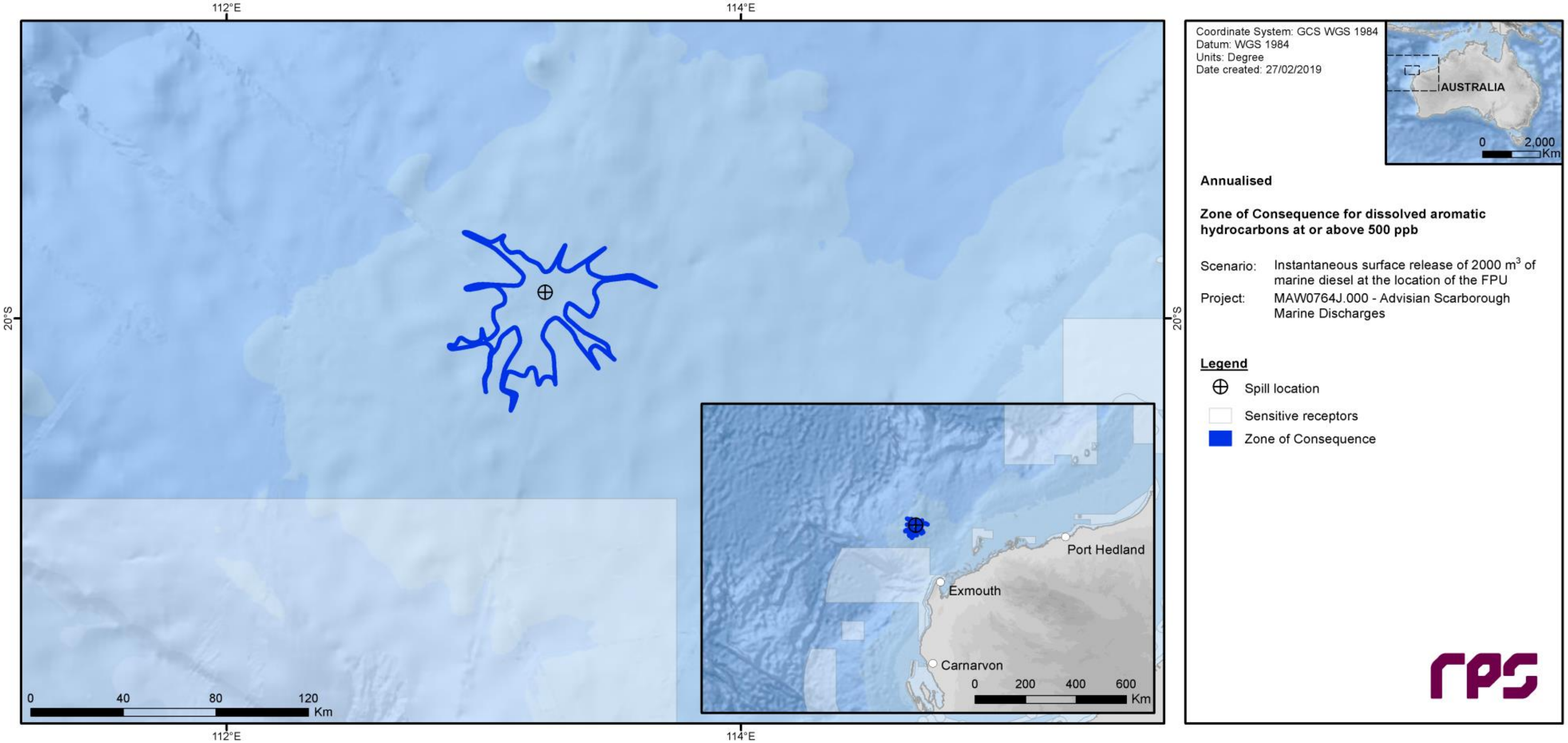


Figure 3.67 Predicted annualised smoothed Zone of Consequence of dissolved aromatic hydrocarbon concentrations at or above 500 ppb resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location.

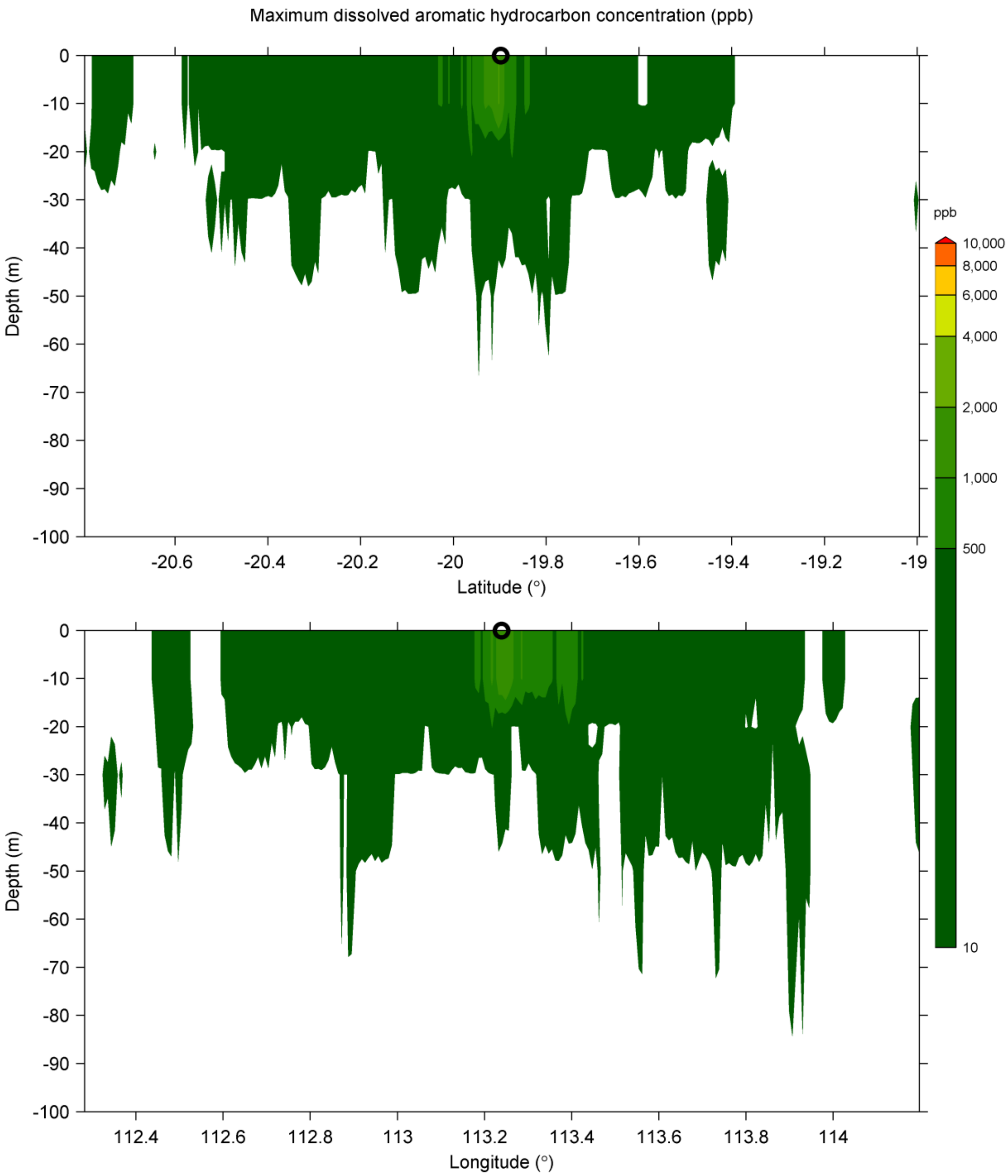


Figure 3.68 Cross-section transects of predicted annualised maximum dissolved aromatic hydrocarbon concentrations for an instantaneous surface release of marine diesel after a vessel collision at the FPU location. Transect locations are shown in Figure 3.1.

4 DETERMINISTIC ASSESSMENT RESULTS

4.1 Overview

For each scenario, deterministic model runs of interest were selected from the stochastic set of replicate simulations according to the following criteria:

- Maximum distance in a south-westerly direction from the release site reached by entrained oil (at a threshold of 500 ppb);
- Maximum total area covered by entrained oil (at a threshold of 500 ppb) over the course of a simulation.

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: Short-Term (Instantaneous) Surface Release of Marine Diesel after a Vessel Collision outside Mermaid Sound

4.2.1 Simulation with Maximal South-Westerly Extent of Entrained Oil at the 500 ppb Threshold

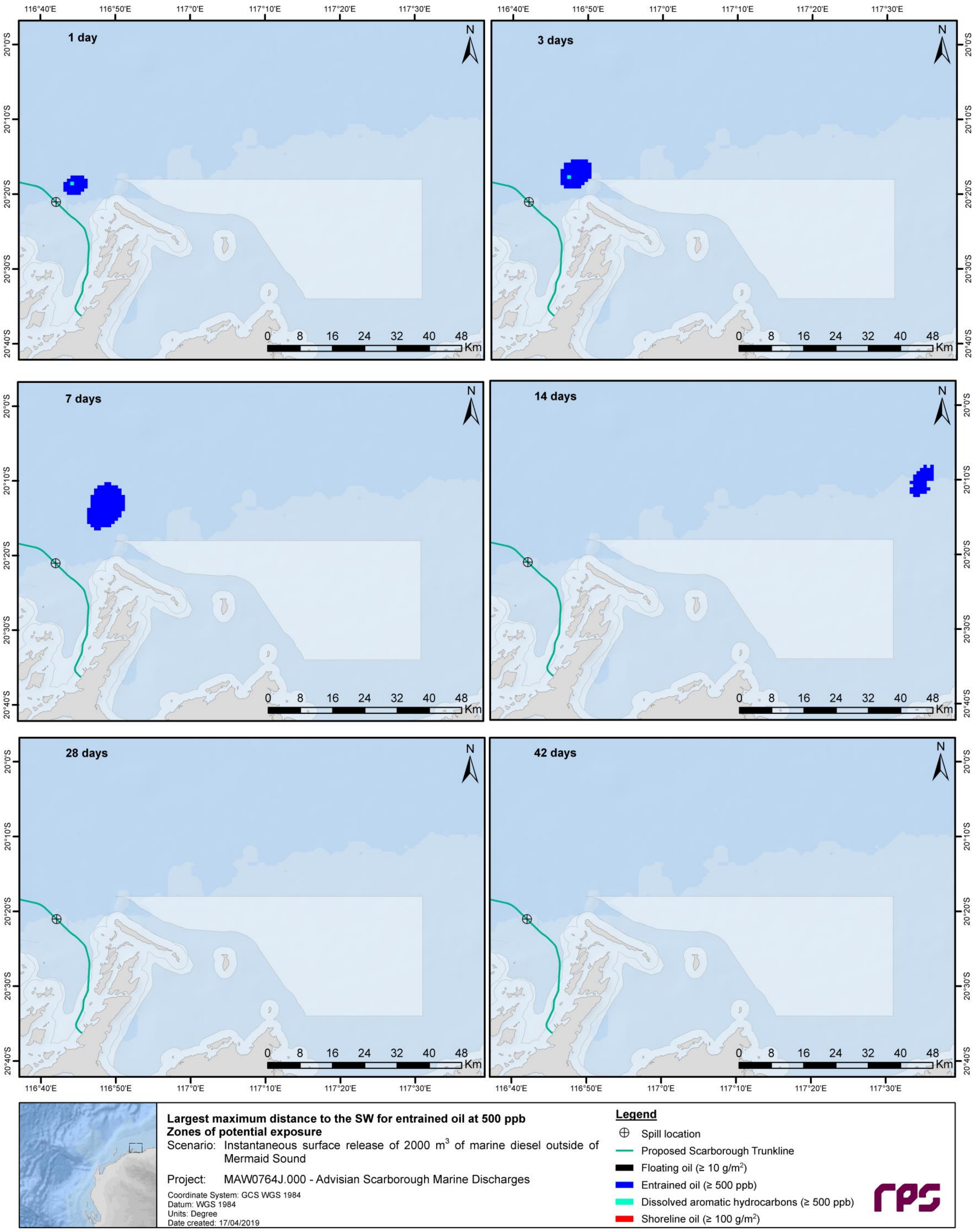


Figure 4.1 Time-varying areal extent of potential exposure at defined floating oil, entrained oil, dissolved aromatic hydrocarbon and shoreline oil threshold concentrations, resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound, for the replicate simulation where entrained oil at the 500 ppb threshold is forecast to reach the greatest distance in a south-westerly direction from the release site.

4.2.2 Simulation with Maximal Overall Swept Area of Entrained Oil at the 500 ppb Threshold

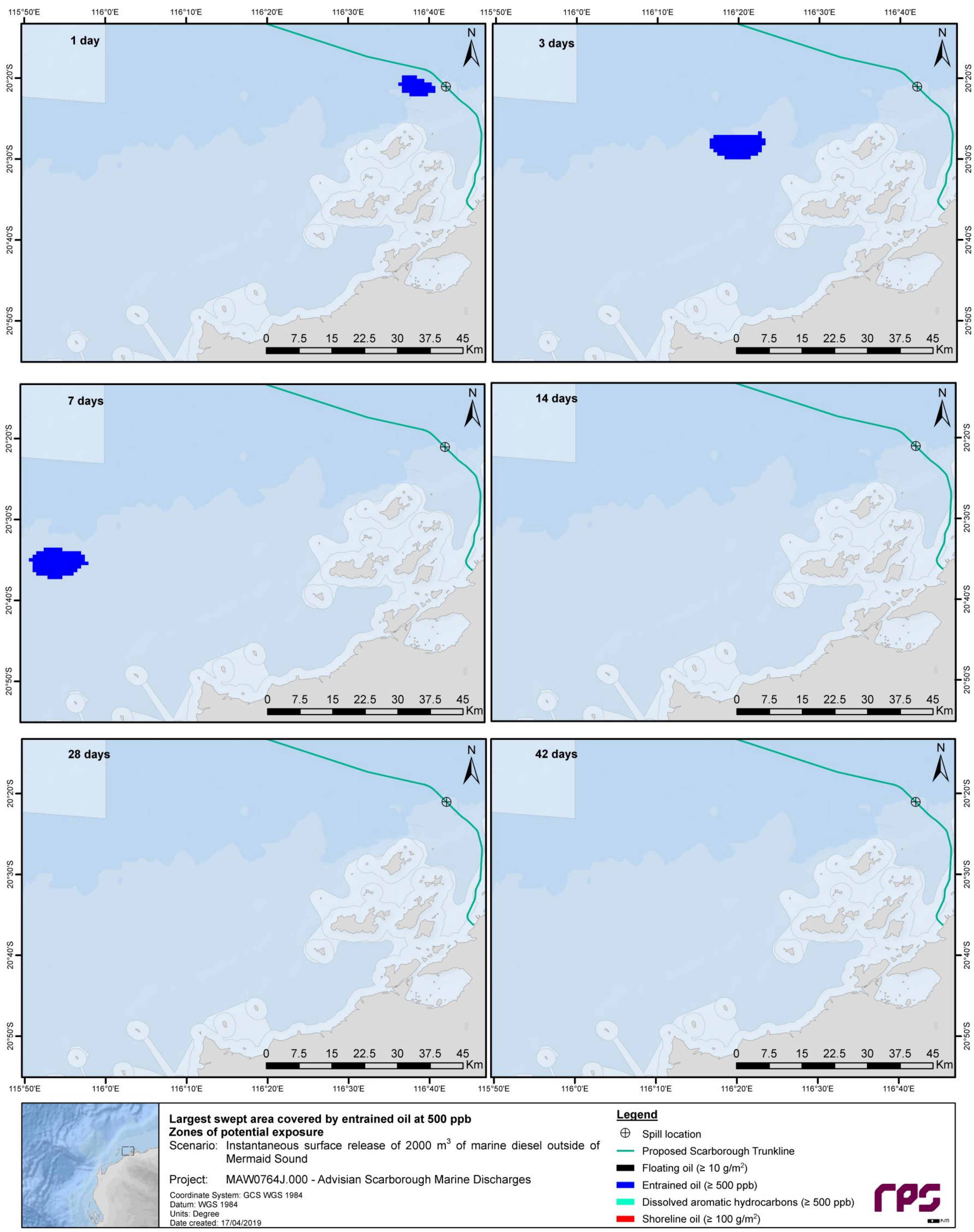


Figure 4.2 Time-varying areal extent of potential exposure at defined floating oil, entrained oil, dissolved aromatic hydrocarbon and shoreline oil threshold concentrations, resulting from an instantaneous surface release of marine diesel after a vessel collision outside Mermaid Sound, for the replicate simulation where entrained oil at the 500 ppb threshold is forecast to cover the greatest total area over the course of a simulation.

4.3 Scenario 2: Short-Term (Instantaneous) Surface Release of Marine Diesel after a Vessel Collision within Montebello Marine Park

4.3.1 Simulation with Maximal South-Westerly Extent of Entrained Oil at the 500 ppb Threshold

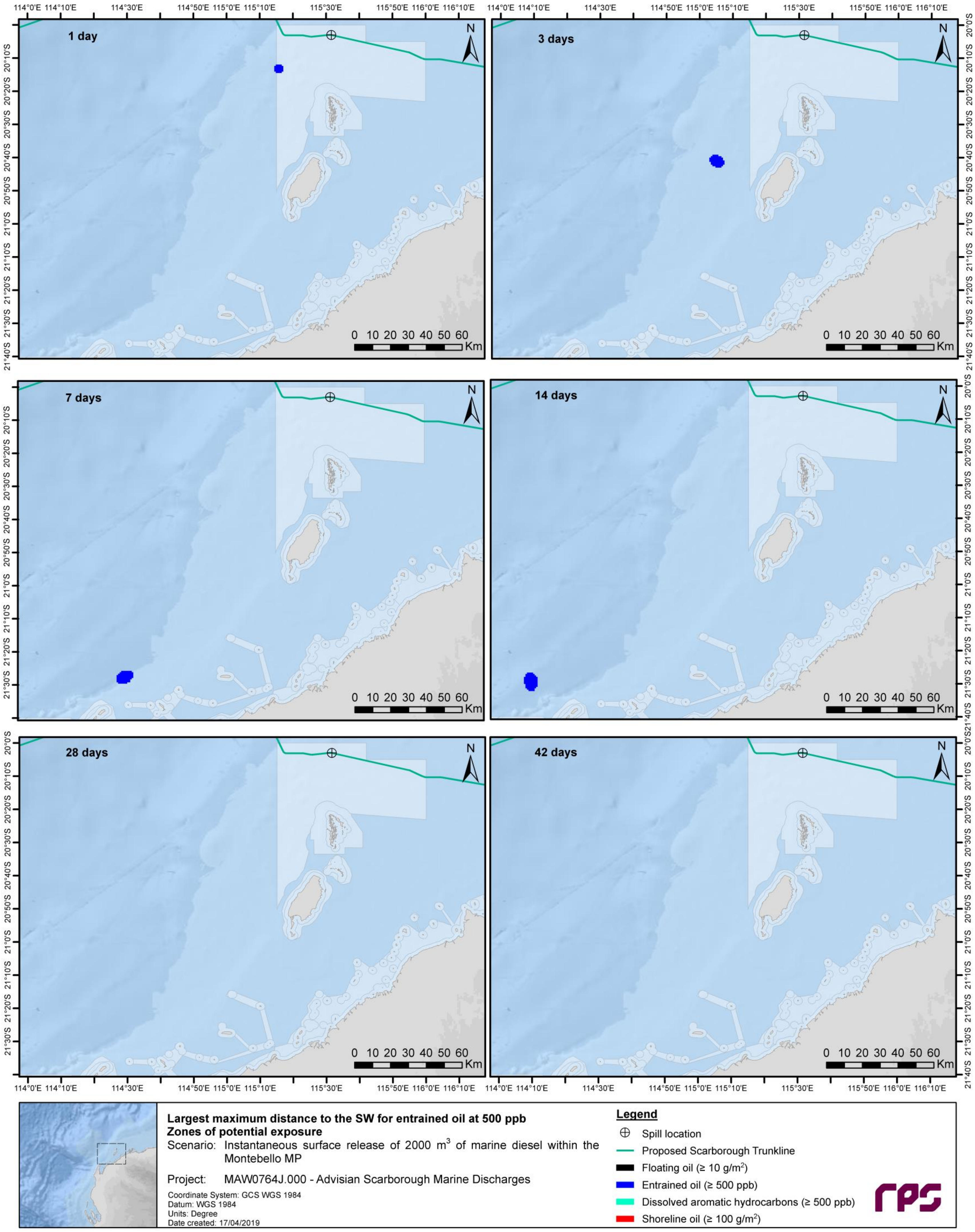


Figure 4.3 Time-varying areal extent of potential exposure at defined floating oil, entrained oil, dissolved aromatic hydrocarbon and shoreline oil threshold concentrations, resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park, for the replicate simulation where entrained oil at the 500 ppb threshold is forecast to reach the greatest distance in a south-westerly direction from the release site.

4.3.2 Simulation with Maximal Overall Swept Area of Entrained Oil at the 500 ppb Threshold

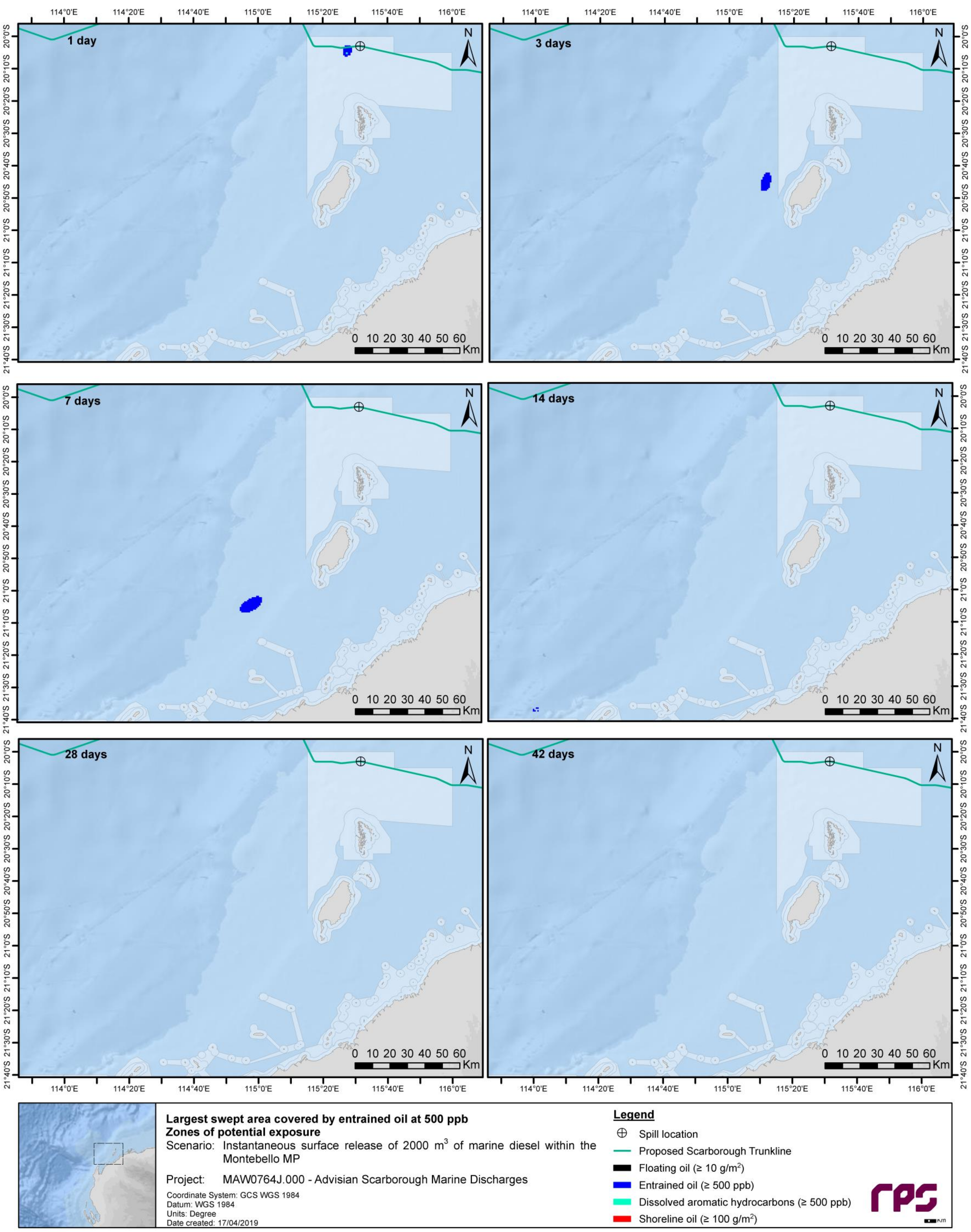


Figure 4.4 Time-varying areal extent of potential exposure at defined floating oil, entrained oil, dissolved aromatic hydrocarbon and shoreline oil threshold concentrations, resulting from an instantaneous surface release of marine diesel after a vessel collision within Montebello Marine Park, for the replicate simulation where entrained oil at the 500 ppb threshold is forecast to cover the greatest total area over the course of a simulation.

4.4 Scenario 3: Short-Term (Instantaneous) Surface Release of Marine Diesel after a Vessel Collision at the FPU Location

4.4.1 Simulation with Maximal South-Westerly Extent of Entrained Oil at the 500 ppb Threshold

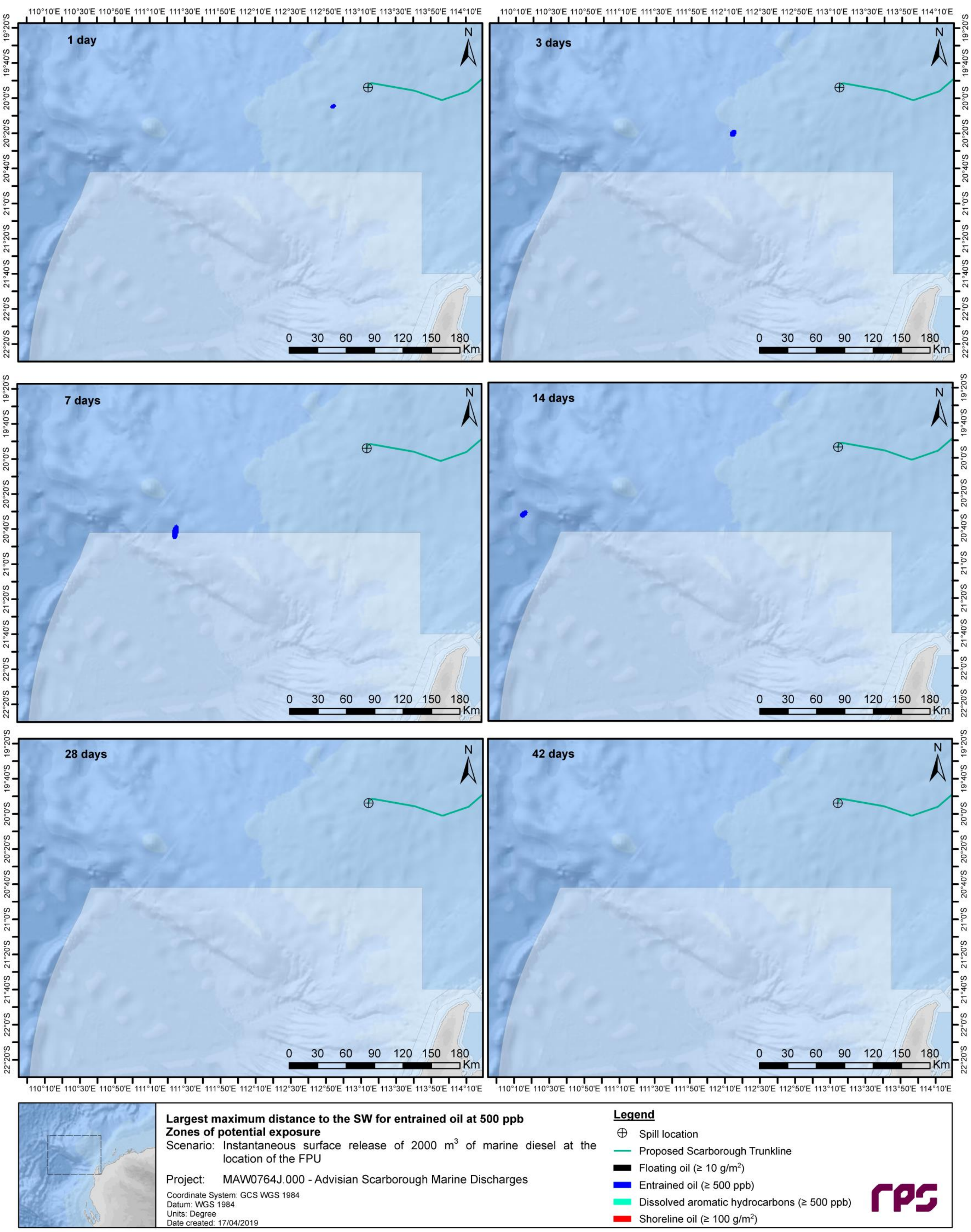


Figure 4.5 Time-varying areal extent of potential exposure at defined floating oil, entrained oil, dissolved aromatic hydrocarbon and shoreline oil threshold concentrations, resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location, for the replicate simulation where entrained oil at the 500 ppb threshold is forecast to reach the greatest distance in a south-westerly direction from the release site.

4.4.2 Simulation with Maximal Overall Swept Area of Entrained Oil at the 500 ppb Threshold

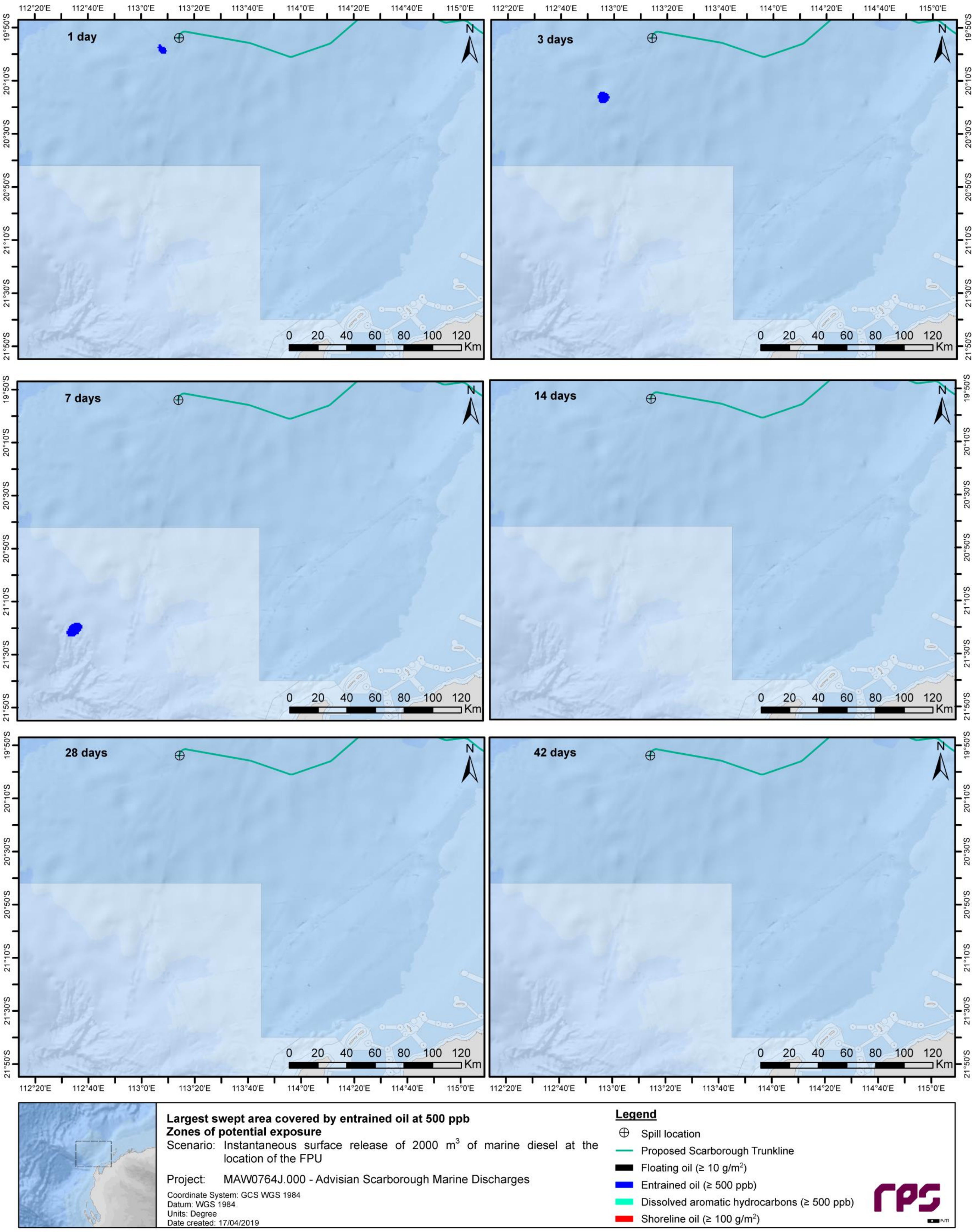


Figure 4.6 Time-varying areal extent of potential exposure at defined floating oil, entrained oil, dissolved aromatic hydrocarbon and shoreline oil threshold concentrations, resulting from an instantaneous surface release of marine diesel after a vessel collision at the FPU location, for the replicate simulation where entrained oil at the 500 ppb threshold is forecast to cover the greatest total area over the course of a simulation.

5 CONCLUSIONS

The main findings of this study are as follows:

Metocean Influences

- Tidal flows will have a significant influence on the 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.
- Due to the location of the hypothetical spill site and the dominance of tidal flows, the coastal areas predicted to be most likely to be impacted by spilled oil are those bordering Mermaid Sound and its numerous passages.

Oil Characteristics and Weathering Behaviour

- Marine diesel is a mixture of volatile and persistent hydrocarbons with low percentages of highly volatile and residual components. 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. The influence of entrainment will regulate the degree of mass retention in the environment.
- During the surface release, floating oil will be susceptible to entrainment into the wave-mixed layer under typical wind conditions. Evaporation rates will be significant, given the moderate proportion of volatile compounds in the oil (41%). The low-volatility fraction of the oil (54%) will take longer durations of the order of days to evaporate, and the residual fraction of 5% is expected to persist in the environment until degradation processes occur. Considering the spill volume, there is a low potential for dissolution of soluble aromatic compounds.

Summary of Stochastic Assessment Results

Scenario 1: Short-Term (Instantaneous) Surface Release of Marine Diesel after a Vessel Collision outside Mermaid Sound

- Floating oil at concentrations equal to or greater than the 10 g/m^2, 50 g/m^2 and 100 g/m^2 thresholds could potentially be found up to 29 km, 21 km and 18 km from the spill site, respectively.
- The Dampier Archipelago shoreline receptor is predicted to be contacted by floating oil concentrations at the 10 g/m^2 threshold with a probability of 2% and a minimum time to contact of 27 hours.
- Potential for accumulation of oil on shorelines is predicted to be low, with a maximum accumulated volume and concentration of 3 m^3 and 156 g/m^2, respectively, forecast at the Dampier Archipelago.
- Entrained oil at concentrations equal to or greater than the 500 ppb threshold is predicted to be found up to around 163 km from the spill site.
- The Dampier MP and Dampier Archipelago receptors are predicted to receive entrained oil concentrations at the 500 ppb threshold with probabilities of 44% and 23%, respectively.

- The maximum entrained oil concentration forecast for any receptor is predicted as 10.9 ppm within the Dampier Archipelago.
- Dissolved aromatic hydrocarbons at concentrations equal to or greater than the 500 ppb threshold are predicted to be found up to around 34 km from the spill site.
- The Dampier MP is predicted to receive dissolved aromatic hydrocarbon concentrations at the 500 ppb threshold with a probability of 2%.
- The maximum dissolved aromatic hydrocarbon concentration forecast for any receptor is predicted as 635 ppb within the Dampier MP.

Scenario 2: Short-Term (Instantaneous) Surface Release of Marine Diesel after a Vessel Collision within Montebello Marine Park

- Floating oil at concentrations equal to or greater than the 10 g/m^2, 50 g/m^2 and 100 g/m^2 thresholds could potentially be found up to 39 km, 36 km and 33 km from the spill site, respectively.
- Given that the spill location lies within the Montebello MP receptor area, floating oil at concentrations equal to or greater than 100 g/m^2 are forecast with a probability of 100% and a minimum time to contact of less than 1 hour.
- Potential for accumulation of oil on shorelines is predicted to be low, with a maximum accumulated volume and concentration of <1 m^3 and 1 g/m^2, respectively, forecast at Barrow Island.
- Entrained oil at concentrations equal to or greater than the 500 ppb threshold is predicted to be found up to around 308 km from the spill site.
- The Montebello MP and Muiron Islands MMA-WHA receptors are predicted to receive entrained oil concentrations at the 500 ppb threshold with probabilities of 70% and 7%, respectively.
- The maximum entrained oil concentration forecast for any receptor is predicted as 157.0 ppm within the Montebello MP.
- Dissolved aromatic hydrocarbons at concentrations equal to or greater than the 500 ppb threshold are predicted to be found up to around 85 km from the spill site.
- The Montebello MP is predicted to receive dissolved aromatic hydrocarbon concentrations at the 500 ppb threshold with a probability of 2%.
- The maximum dissolved aromatic hydrocarbon concentration forecast for any receptor is predicted as 2.0 ppm within the Montebello MP.

Scenario 3: Short-Term (Instantaneous) Surface Release of Marine Diesel after a Vessel Collision at the FPU Location

- Floating oil at concentrations equal to or greater than the 10 g/m^2, 50 g/m^2 and 100 g/m^2 thresholds could potentially be found up to 113 km, 60 km and 58 km from the spill site, respectively.
- No shoreline receptors are predicted to be contacted by floating oil concentrations at any of the assessed thresholds.
- No accumulation of oil on shorelines is predicted.
- Entrained oil at concentrations equal to or greater than the 500 ppb threshold is predicted to be found up to around 476 km from the spill site.

- The Gascoyne MP receptor is predicted to receive entrained oil concentrations at the 500 ppb threshold with a probability of 8%.
- The maximum entrained oil concentration forecast for any receptor is predicted as 7.2 ppm within the Gascoyne MP.
- Dissolved aromatic hydrocarbons at concentrations equal to or greater than the 500 ppb threshold are predicted to be found up to around 74 km from the spill site.
- No receptors are predicted to receive dissolved aromatic hydrocarbon concentrations at the 500 ppb threshold.
- The maximum dissolved aromatic hydrocarbon concentration forecast for any receptor is predicted as 462 ppb within the Gascoyne MP.

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Appendix J

Scarborough Dredge Dispersion Modelling - Offshore Borrow Ground

WOODSIDE SCARBOROUGH PROJECT DREDGED SEDIMENT DISPERSION MODELLING - OFFSHORE BORROW GROUND

Report

MAW0753J
Woodside Scarborough Project Dredged Sediment Dispersion Modelling - Offshore Borrow Ground
Rev 1
18 April 2019

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1 INTRODUCTION

1.1 Background

RPS was commissioned by Advisian Pty Ltd (Advisian), on behalf of Woodside Energy Ltd (WEL), to undertake sediment dispersion modelling of dredging, disposal and backfill operations associated with the Scarborough Project, in support of the State and Commonwealth referrals and an Offshore Project Proposal to NOPSEMA. The Scarborough gas field is located 380 km west-northwest of the Burrup Peninsula in the northwest of Australia within offshore permit WA-1-R.

The Scarborough Project includes drilling of subsea gas wells (which includes wells in the Scarborough, Thebe and Jupiter reservoirs). Wells will be tied back to a Floating Production Unit (FPU) moored in approximately 900 m of water, over the Scarborough field. The FPU topsides has processing facilities for gas dehydration and compression to transport the gas through a 420 km pipeline to the mainland.

Dredging, disposal and backfill operations along the pipeline route, from the mainland outwards to a chainage of KP50, are proposed as part of the project.

RPS has conducted sediment dispersion modelling to quantify the potential magnitude, intensity and spatial distribution of suspended sediment concentrations (SSC) and sedimentation that would be expected for the dredging, disposal and backfill operations proposed for the Scarborough Project. The predicted outcomes are to be used to inform the assessment of the potential for influence or impact upon water quality and benthic habitats in the region.

This technical report focuses only on dredging of backfill material from the offshore borrow ground (Figure 1.1) and contains a summary of the sediment fate model inputs, methodologies and assumptions, and the model outcomes following analysis of specified threshold criteria.

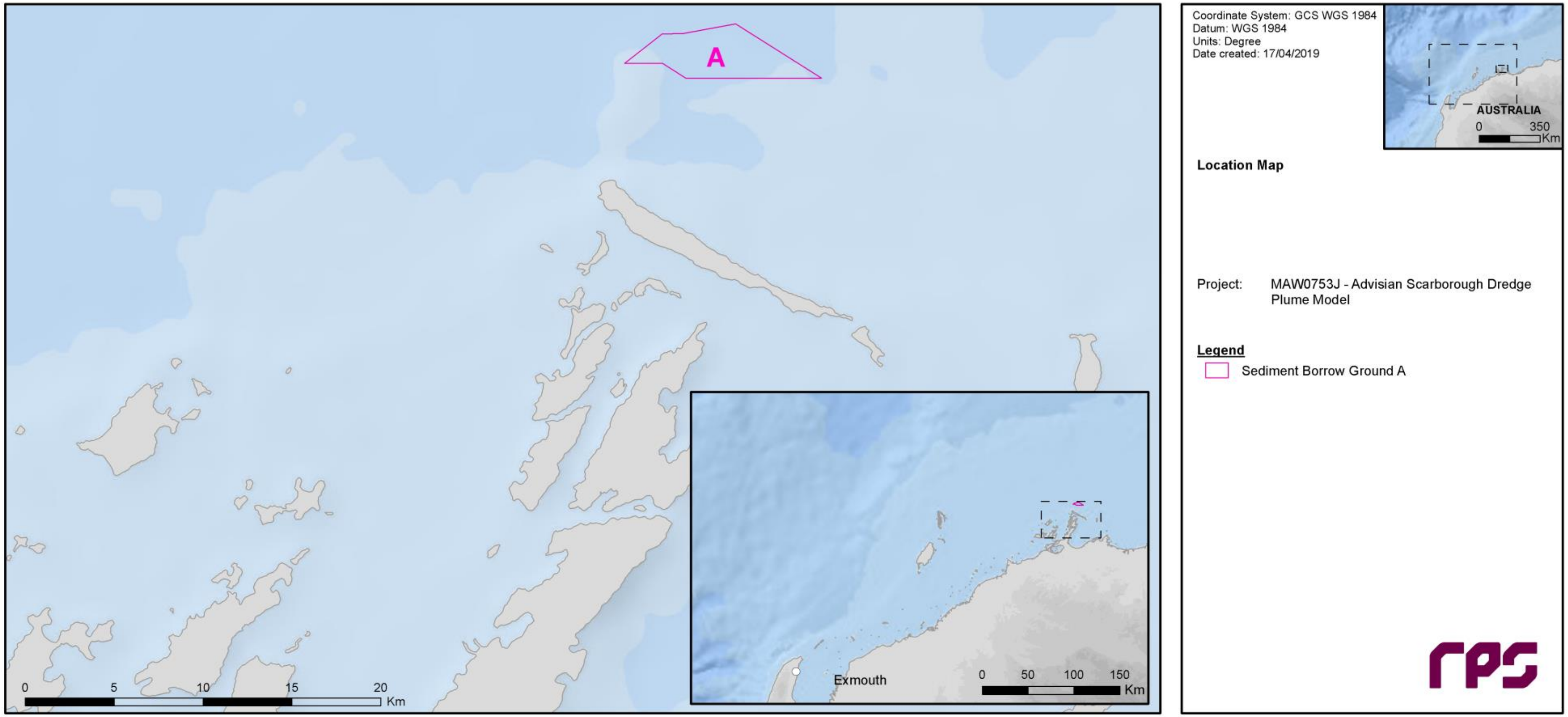

Figure 1.1 Location of the offshore sediment borrow ground (A) that may be utilised during backfill activities associated with the proposed Scarborough pipeline.

1.2 Modelling Scope

RPS was commissioned to conduct sediment dispersion modelling for the following activity:

- Dredging of the offshore borrow ground.

The scope of work required to complete the sediment dispersion modelling included:

1. Hydrodynamic Modelling.
    a. An initial assessment of the existing D-FLOW hydrodynamic model framework in the Mermaid Sound region determined that refinements were necessary to suit the requirements of this scope of work. Reconfiguration of the model was conducted, followed by re-validation of the model predictions against available measurements of water levels and currents for the same validation period as utilised previously.
    b. Two years (2016-2017) of hydrodynamic simulation data was produced for use as input to the sediment dispersion model.
2. Wave Modelling.
    a. An initial assessment of the existing D-WAVE wave model framework in the Mermaid Sound region determined that refinements were necessary to suit the requirements of this scope of work. Reconfiguration of the model was conducted, followed by re-validation of the model predictions against available predictions from an operational RPS model for the same validation period as utilised previously.
    b. Two years (2016-2017) of wave simulation data was produced for use as input to the sediment dispersion model.
3. Sediment Dispersion Modelling.
    a. Inputs for the dredging programme were prepared for the DREDGEMAP model, accounting for all potential concurrent sources of sediment characterised by location, intensity, particle size distribution, vertical distribution in the water column, and levels of cohesivity.
    b. Two dredging scenarios were simulated: (i) dredging of the offshore borrow ground during summer; (ii) dredging of the offshore borrow ground during winter.
    c. Simulation outputs from each separate dredging activity were post-processed, combined and analysed to determine outcomes including zones of impact and influence for each scenario based on specified threshold criteria.
    d. Key model outcomes were provided as spatial datasets in GIS shapefile format.
4. Reporting. A technical report detailing the sediment fate model inputs, methodologies, assumptions and model outcomes following analysis of specified threshold criteria was provided.

2 HYDRODYNAMIC AND WAVE MODELLING

2.1 Overview

Modelling of the potential sediment dispersion from the dredging and disposal activities associated with the Scarborough Project required temporal and spatial representation of the hydrodynamic and wave conditions within the project area. A hydrodynamic and wave model framework for the Mermaid Sound area was constructed, calibrated and validated for a past marine modelling study of dredge spoil stability and navigation for WEL (RPS, 2016). This model framework has been refined for the Scarborough scope of work and is described in the following sections.

The hydrodynamic and wave modelling for the project was conducted using the Delft3D suite of software. The Delft3D suite is a fully integrated computer software package composed of several modules (e.g. flow, waves, sediment, water quality, and ecology) grouped around a common interface. This software suite has been developed to carry out studies with a multi-disciplinary approach and multi-dimensional calculations (e.g. 2-D and 3-D) for a range of systems, such as oceanic, coastal, estuarine and river environments. It can simulate the interaction of flows, waves, sediment transport, morphological developments, water quality and aquatic ecology. Specific modules of the Delft3D suite are referenced in this report, following the convention of the software developers, with the suffix D- (e.g. D-FLOW for the Delft3D Hydrodynamics module and D-WAVE for the Delft3D Spectral Wave module).

The Delft3D suite has been developed by Deltares, an independent institute for applied research on water with over 30 years of experience in modelling aquatic systems (http://www.deltares.nl/en). The Delft3D suite of models adheres to the International Association for Hydro-Environment Engineering and Research guidelines for documenting the validity of computational modelling software, closely replicating an array of analytical, laboratory, schematic and real-world data.

The configuration of the current and wave models is in line with recommendations of best practice for sediment dispersion modelling in Western Australia as outlined by WAMSI Dredging Science Node guidance (Sun *et al.*, 2016). Inclusion of mesoscale ocean currents is recommended, as these currents have a significant influence on the net drift of suspended material over the time scales of dredging operations (days to weeks) and are therefore important to predictions of sediment transport. The use of three-dimensional current modelling with a series of interconnected grids of progressively finer resolution is also recommended, as are coupling of the current and wave models and validation of current predictions against measured data.

2.2 Hydrodynamic Model (D-FLOW)

2.2.1 Model Description

To simulate the hydrodynamics within Mermaid Sound and the surrounding area, a three-dimensional model with accurate representations of the bathymetry, bottom roughness and spatially-varying wind stress was utilised for the region. The model framework was developed through the combination of a large-scale regional model with smaller refined regions, or sub-domains.

The D-FLOW model is ideally suited to represent the hydrodynamics of complex coastal waters, including regions where the tidal range creates large intertidal zones and where buoyancy processes are important. RPS has applied the model for numerous studies in the region.

D-FLOW is a multi-dimensional (2-D or 3-D) hydrodynamic (and transport) simulation program which calculates non-steady flow and transport phenomena that result from tidal, meteorological and baroclinic forcing on a rectilinear or a curvilinear, boundary-fitted grid. In three-dimensional simulations, the vertical grid can be defined following the sigma-coordinate approach, where the local water depth is divided into a series of layers with thickness at a set proportion of the depth.

D-FLOW allows for the establishment of a series of interconnected (two-way, dynamically-nested) curvilinear grids of varying resolution; a technique referred to as “domain decomposition”. This allows for the generation of a series of grids with progressively increasing spatial resolution, down to an appropriate scale for accurate resolution of the hydrodynamics associated with features such as dredged channels. The main advantage of domain decomposition over traditional one-way, or static, nesting systems is that the model domains interact seamlessly, allowing transport and feedback between the regions of different scales. The ability to dynamically couple multiple model domains offers a flexible framework for hydrodynamic model development. This modelling method was applied in this study.

Inputs to the model, as discussed in the following sections, included:

- Bathymetry of the study area, including shipping channels, islands, and adjacent features. The wetting and drying of the intertidal zones was simulated in applicable areas.
- Boundary elevation forcing data.
- Spatially-varying surface wind and pressure data.

2.2.2 Bathymetry and Domain Definition

The hydrodynamic model was established over the domain shown in Figure 2.1. Accurate bathymetry is a significant factor in development of a model framework required to resolve highly variable wave and current conditions. The bathymetry was developed using data provided by WEL and supplemented with data from Geoscience Australia and the C-MAP electronic chart database where relevant and required.

The composite bathymetric data was interpolated onto the D-FLOW Cartesian grid. The resultant bathymetry is shown in Figure 2.2. The extent and shape of the model coastline will change as water levels rise and fall with tidal movements due to the inclusion of wetting and drying within the model system.

The vertical grid of the model comprised five layers of varying thickness, depending on location, throughout the domain. Five layers was found to be enough to resolve the circulation and provide suitable bed level currents, without overly compromising model performance. As the model was set up as a proportional sigma-grid in the vertical dimension, these layers therefore represented a terrain-following arrangement with a layer thickness of 20% of the total local water depth.

To offset the computational effort required for a large, multi-layered model domain, and to achieve adequate horizontal and temporal resolution, a multiple-grid (domain-decomposition) strategy was applied using three sub-domains of varying horizontal grid cell size (Figure 2.1 and Figure 2.2). Horizontal resolutions within each sub-domain were 250 m for the Mermaid Sound region from Enderby Island to Legendre Island (sub-grid 2), 500 m for the intermediate region (sub-grid 1) and 2 km for the outer domain (sub-grid 0).

Each sub-domain is an individual hydrodynamic model simulated in parallel with the others, with dynamic coupling at the shared boundaries between sub-domains. The outermost sub-domain captured large-scale oceanographic phenomena which progressively fed into the finer-resolution domains representing the area of interest. The resolution of the innermost sub-domain was specified after assessment of the requirement to adequately resolve the variation in current fields, and in turn the sediment dynamics.

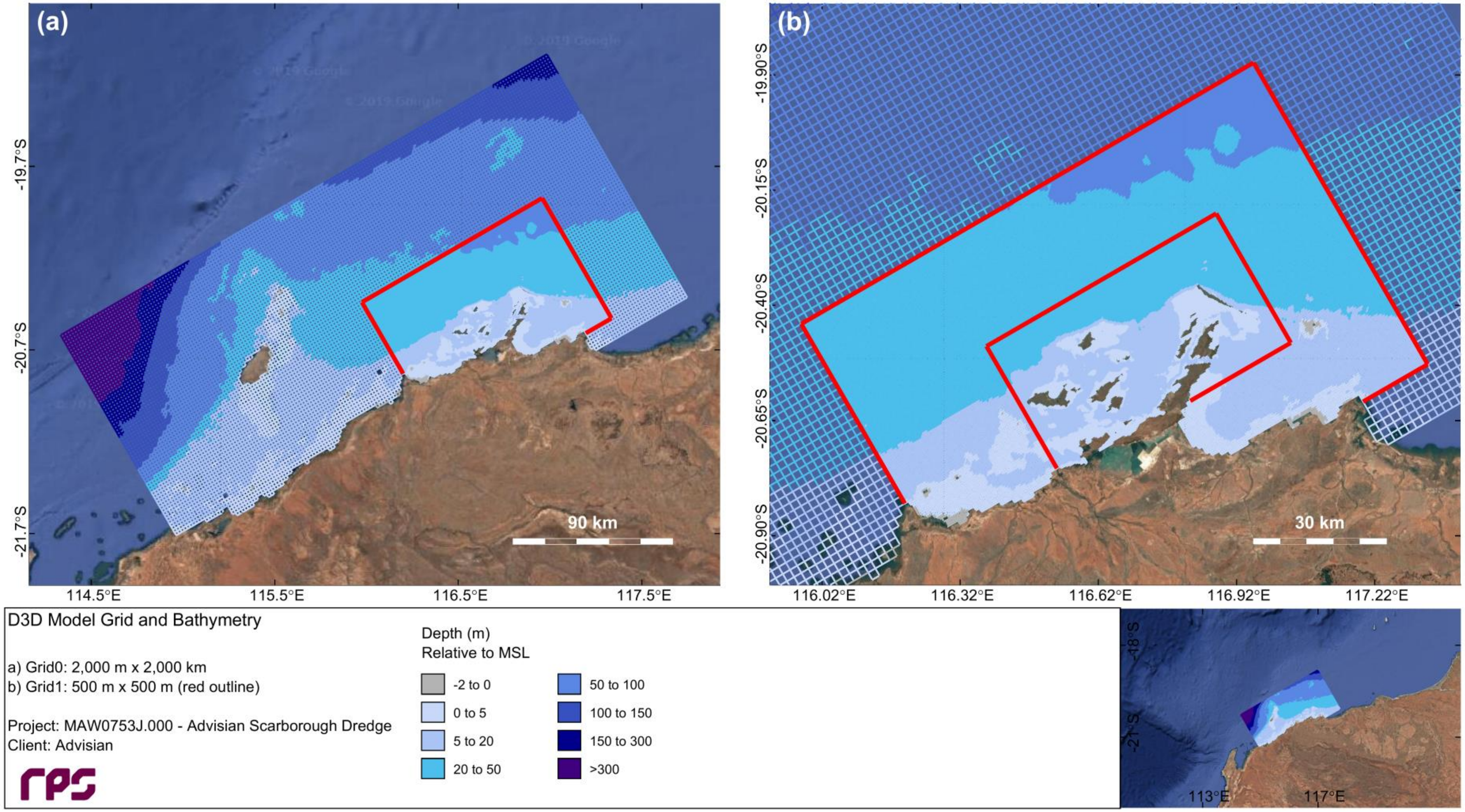

Figure 2.1 Model grid setup showing the domain-decomposition scheme applied, highlighting the two outermost grids.

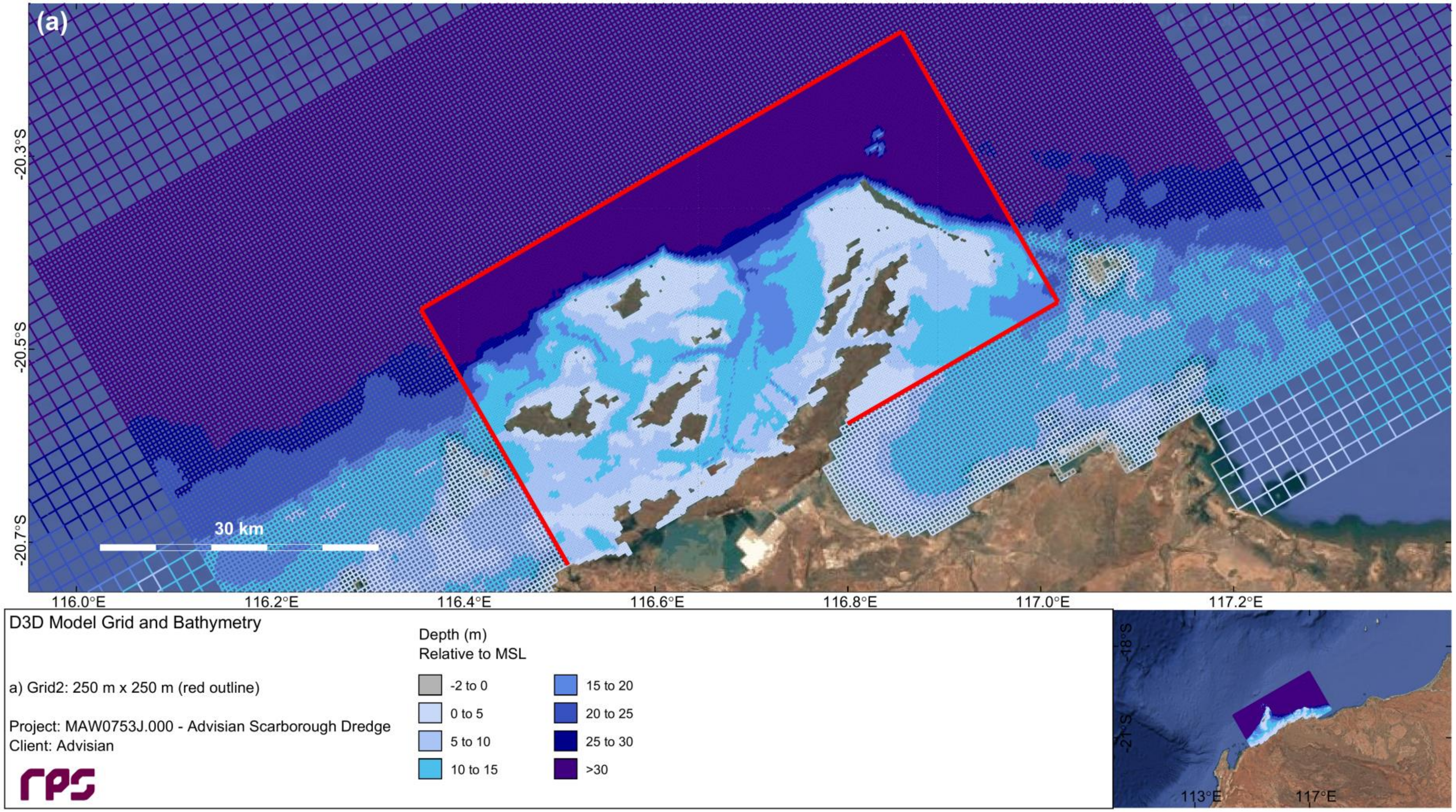

Figure 2.2 Model grid setup showing the domain-decomposition scheme applied, highlighting the innermost grid.

2.2.3 Boundary and Initial Conditions

2.2.3.1 Overview

As the hydrodynamics in the study area are controlled primarily by tidal flows and wind forcing, these processes were explicitly included in the developed model.

The model was forced on the open boundaries of the outer sub-domain with time series of water elevation obtained for the chosen simulation period. Spatially-varying wind speed and wind direction data was used to force the model across the entire domain.

2.2.3.2 Water Elevation

Water elevations at hourly intervals were obtained from the TPXO8.0 database, which is the most recent iteration of a global model of ocean tides derived from measurements of sea-surface topography by the TOPEX/Poseidon satellite-borne radar altimeters. Tides are provided as complex amplitudes of earth-relative sea-surface elevation for eight primary (M_2, S_2, N_2, K_2, K_1, O_1, P_1, Q_1), two long-period (M_f, M_m) and three non-linear (M_4, MS_4, MN_4) harmonic constituents at a spatial resolution of 0.25°.

The tidal sea level data was augmented with non-tidal sea level elevation data from the global Hybrid Coordinate Ocean Model (HYCOM; Bleck, 2002; Chassignet *et al.*, 2003; Halliwell, 2004), created by the USA's National Ocean Partnership Program (NOPP) as part of the Global Ocean Data Assimilation Experiment (GODAE). The HYCOM model is a three-dimensional model that assimilates observations of sea surface temperature, sea surface salinity and surface height, obtained by satellite instrumentation, along with atmospheric forcing conditions from atmospheric models to predict drift currents generated by such forces as wind shear, density, sea height variations and the rotation of the Earth.

The HYCOM model is configured to combine the three vertical coordinate types currently in use in ocean models: depth (z-levels), density (isopycnal layers), and terrain-following (σ-levels). HYCOM uses isopycnal layers in the open, stratified ocean, but uses the layered continuity equation to make a dynamically smooth transition to a terrain-following coordinate in shallow coastal regions, and to z-level coordinates in the mixed layer and/or unstratified seas. Thus, this hybrid coordinate system allows for the extension of the geographic range of applicability to shallow coastal seas and unstratified parts of the world ocean. It maintains the significant advantages of an isopycnal model in stratified regions while allowing more vertical resolution near the surface and in shallow coastal areas, hence providing a better representation of the upper ocean physics than non-hybrid models. The model has global coverage with a horizontal resolution of $1/12^{th}$ of a degree (~7 km at mid-latitudes) and a temporal resolution of 24 hours.

2.2.3.3 Wind Forcing

Spatially-variable wind data was sourced from the Global Data Assimilation System (GDAS), which is used by the National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS) model to place observations into a gridded model space for the purpose of starting, or initializing, weather forecasts with observed data. The GFS Forecasts model variant used has a horizontal resolution of $1/12^{th}$ of a degree and a temporal resolution of 6 hours (NCEP, 2016).

2.2.4 Model Validation

2.2.4.1 Comparison of Modelled and Measured Water Elevation

Validation of the water level changes predicted by the D-FLOW hydrodynamic model configuration was provided through comparisons to independent predictions from the XTide tidal constituent database (Flater, 1998). Comparison of model tidal amplitudes with the XTide database showed strong agreement (Figure 2.3), with slight overprediction of tidal amplitudes at some stations. Time series comparisons for two tide stations situated at locations that are relevant to this study also showed good agreement (Figure 2.4).

In general, a consistent match is observed between water elevations calculated by the D-FLOW model and those predicted by XTide (Figure 2.4). Both the amplitude and phase of the semidiurnal tidal signal are clearly reproduced at each station, as is the timing of the spring-neap cycle. The D-FLOW model slightly overpredicts high tides and underpredicts low tides, which indicates there was a small difference between the datums used to compare these different data sets rather than actual amplitude differences.

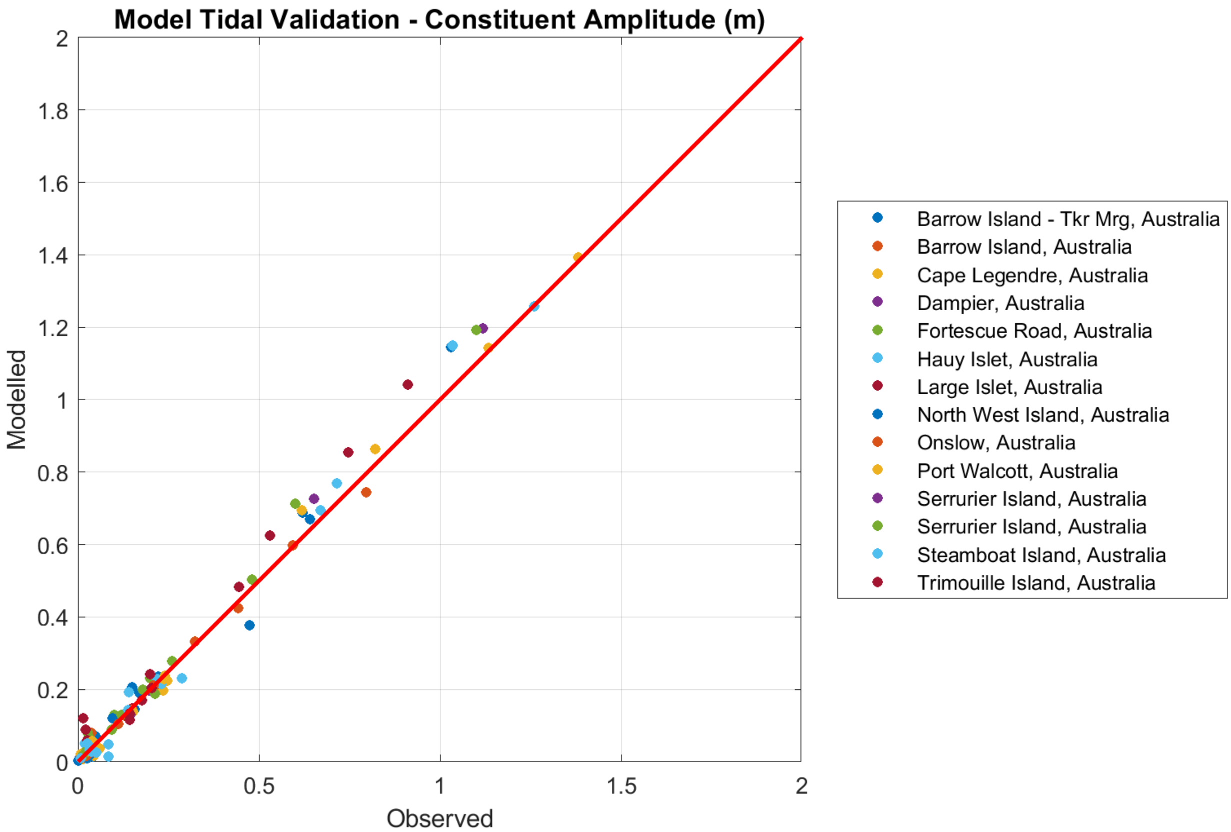

Figure 2.3 Comparison of tidal amplitudes from the D-FLOW hydrodynamic model (y-axis) with those from the XTide database (x-axis) at 14 stations located within the model domain.

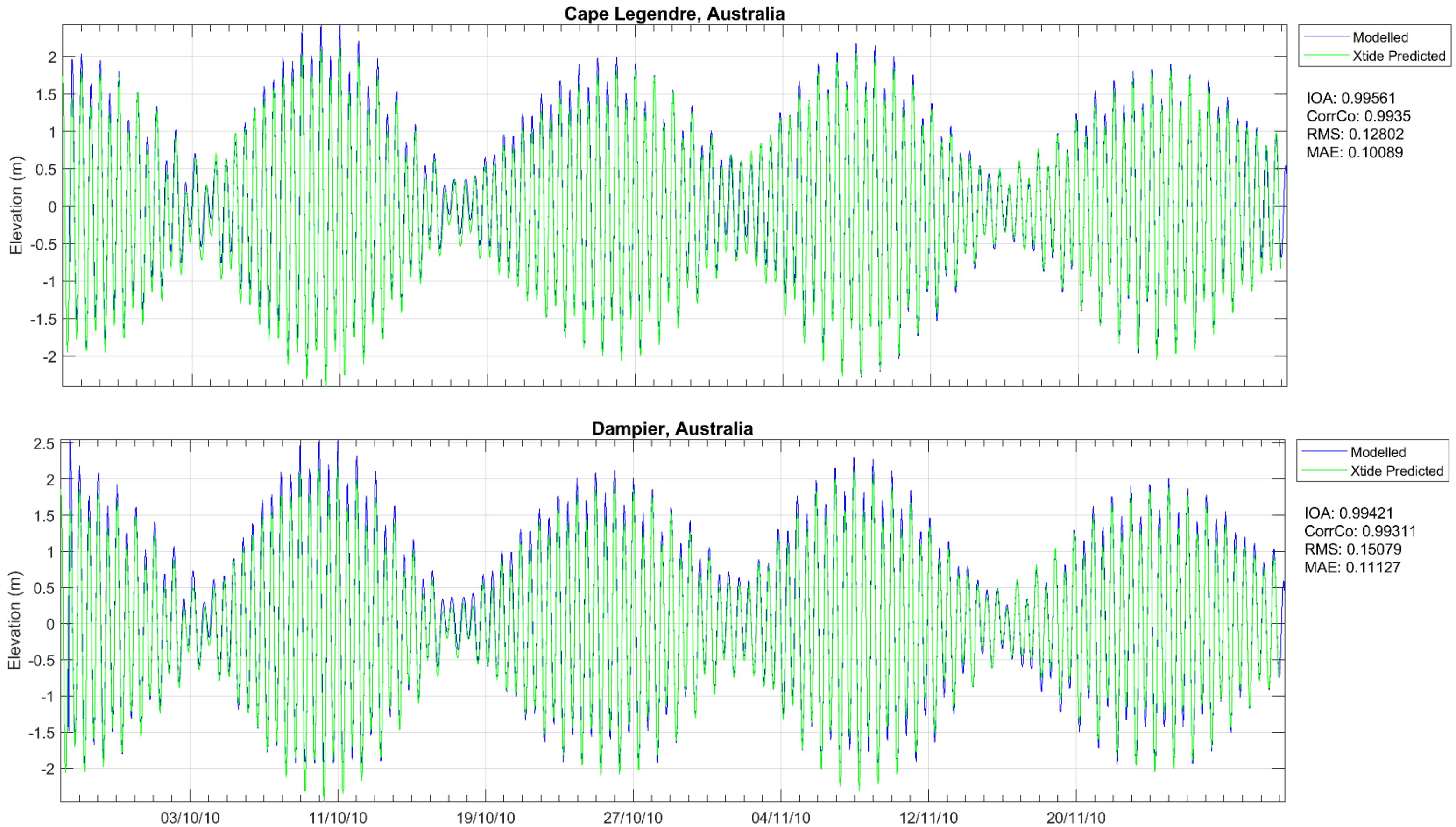

Figure 2.4 Comparisons of water elevations predicted by the D-FLOW hydrodynamic model (blue line) with those predicted by the XTide database (green line) over the validation period of October-November 2010 at two selected station locations.

2.2.4.2 Comparison of Modelled and Measured Currents

Validation of the model-predicted currents was conducted for a spring/neap tide period during October and November 2010 by comparing the model results to measured data from the WEL LNG Channel AWAC that was located within Mermaid Sound (116.738° E, 20.561° S) in water depth of approximately 12 m. Comparisons of current speed and direction at a depth interval representative of the mid-water column are provided in Figure 2.5.

Overall, the comparison indicates that the model provides a good prediction of tidal currents at the comparison site. There was a minor mismatch in the phase of the tidal oscillations, with a slight lag apparent in the modelled data. However, this lag was not evident in the XTide water level comparisons (Figure 2.4).

The amplitudes of the modelled and measured current fluctuations were generally well-matched, but there were some spikes in the measured data that were not reproduced. These spikes in the measured data, assuming they were not instrument errors, may have been caused by local-scale events related to wind-driven currents. These events are difficult to reproduce in the model because the horizontal grid scale of the model in this region is 250 m. The GFS wind driving the model can be less accurate close to the coast when sea breeze effects are dominant. The inability of the model to reproduce some spikes observed in the measured data might be explained by inaccuracies in the NCEP wind data near to the WEL LNG Channel AWAC location.

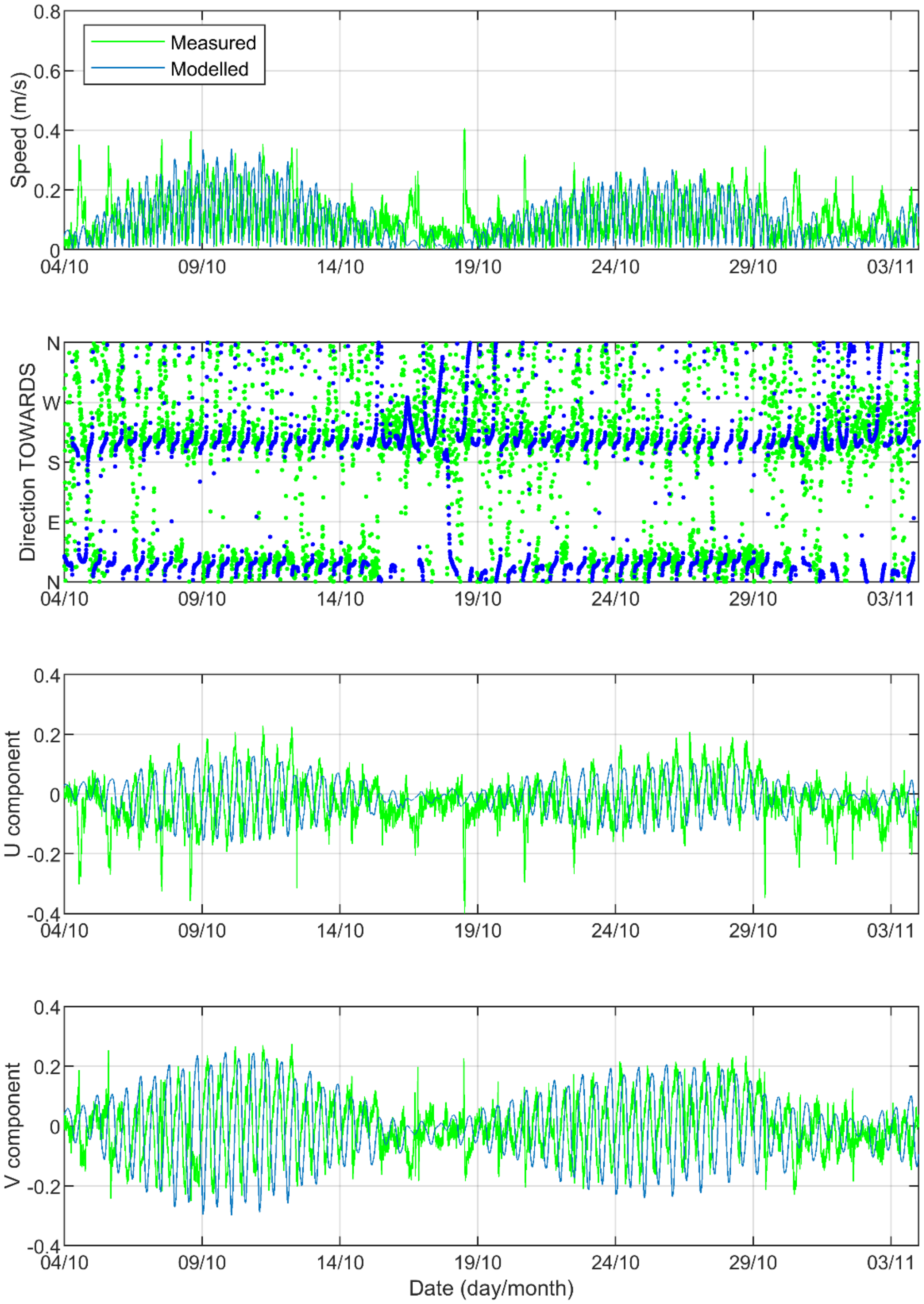

Figure 2.5 **Comparisons of modelled (blue line) and measured (green line) currents for a mid-water column depth interval at the WEL LNG Channel AWAC location during the 2010 validation period.**

2.3 Wave Model (D-WAVE)

2.3.1 Model Description

Reliable forecasting for the fate of fine sediments in the study location, which is a wave-exposed coastal region, required the input of wave spectra information to calculate the shear-stress and orbital velocities imposed by waves which will affect the settlement and re-suspension of fine material that is initially suspended by dredging and related operations. D-WAVE is a variant of the well-known SWAN wave model that has been customised for compatibility with the Delft3D software suite.

The D-WAVE model is a spectral phase-averaging wave model originally developed by the Delft University of Technology. D-WAVE, a third-generation model based on the energy balance equation, is a numerical model for simulating realistic estimates of wave parameters in coastal areas for given wind, bottom and current conditions.

D-WAVE includes algorithms for the following wave propagation processes: propagation through geographic space; refraction and shoaling due to bottom and current variations; blocking and reflections by opposing currents; and transmission through or blockage by obstacles. The model also accounts for dissipation effects due to white-capping, bottom friction and wave breaking as well as non-linear wave-wave interactions. D-WAVE is fully spectral (in all directions and frequencies) and computes the evolution of wind waves in coastal regions with shallow water depths and ambient currents.

RPS has successfully applied D-WAVE in many studies in the region, including ambient condition modelling in Mermaid Sound and dredging fate projects in the wider Pilbara region.

2.3.2 Model Implementation

The D-WAVE model was developed to cover the same grid regions defined by the hydrodynamic model (Figure 2.1 and Figure 2.2). The bathymetry and wind data input to the wave model was the same as used for the hydrodynamic model. Time-varying water level information for each grid node in the wave model was provided by the output of the hydrodynamic model. The boundary data to represent swells imposed from a distance was sourced from the WAVEWATCH III 0.5° model, operated by the National Oceanic and Atmospheric Administration (NOAA) (NOAA, 2018).

The wave model was run in a coupled mode with the hydrodynamic model for the years of 2016 and 2017. The model results were independently validated by comparison to other modelled wave data for the Mermaid Sound region that is held internally by RPS.

3 SEDIMENT FATE MODELLING

3.1 General Approach

Estimates for the three-dimensional distribution of sediments suspended by dredging operations have been derived for the full duration of the dredging programme using numerical modelling. The approach of modelling dredging operations in full and in three dimensions is in line with best practice for sediment dispersion modelling in Western Australia as outlined by WAMSI Dredging Science Node guidance (Sun *et al.*, 2016).

This modelling relied upon specification of sediment discharges over time for each of the expected sources of sediment suspension, and predicted the evolution of the combined sediment plumes via current transport, dispersion, sinking and sedimentation. The model allowed for the subsequent resuspension of settling sediments due to the erosive effects of currents and waves. Thus, the fate of sediments was assessed beyond their initial settling.

Forcing was provided using predictions of three-dimensional current fields and two-dimensional wave fields for the study area, which are described in Section 2.

3.2 Model Description

Modelling of the dispersion of suspended sediment resulting from the various dredging operations was undertaken using an advanced sediment fate model, Suspended Sediment FATE (SSFATE), operating within the RPS DREDGEMAP model framework. This model computes the advection, dispersion, differential sinking, settlement and resuspension of sediment particles. The model can be used to represent inputs from a wide range of suspension sources, producing predictions of sediment fate both over the short-term (minutes to days following a discharge source) and longer term (days to years following a discharge source).

SSFATE allows the three-dimensional predictions of SSC and seabed sedimentation to be assessed against allowable exposure thresholds. Sedimentation thresholds often relate to burial depths or rates, while SSC thresholds are usually more complicated, involving tiered exposure duration and intensities. As a result, assessing the project-generated sediment distributions against these thresholds in both three-dimensional space and time is a computationally intensive task. A variety of SSC threshold formulations have recently been applied in Western Australian coastal waters and at present there are no general guidelines.

SSFATE is a computer model originally developed jointly by the US Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC) and RPS to estimate SSC generated in the water column and deposition patterns generated due to dredging operations in a current-dominated environment, such as a river (Johnson *et al.*, 2000; Swanson *et al*., 2000, 2004). RPS has significantly enhanced the capability of SSFATE to allow the prediction of sediment fate in marine and coastal environments where wave forcing becomes important for reworking the distribution of sediments (Swanson *et al.*, 2007).

SSFATE is formulated to simulate far-field effects (~25 m or larger scale) in which the mean transport and turbulence associated with ambient currents are dominant over the initial turbulence generated at the discharge point. A five-class particle-based model predicts the transport and dispersion of the suspended material. The classes include the 0-130 µm range of sediment grain sizes that typically result in plumes. Heavier sediments tend to settle very rapidly, remain more stable over time and are not relevant over the longer durations (>1 hour) and larger spatial scales (>25 m) of interest here. Table 3.1 shows the standard material classes used in SSFATE for suspended sediment.

Table 3.1 Material size classes used in SSFATE.

Material Class Description	Particle Size Range (µm)
Clay	<7
Fine Silt	8-34
Coarse Silt	35-74
Fine Sand	75-130
Coarse Sand	>130

Particle advection is calculated using three-dimensional current fields, obtained from hydrodynamic modelling, thus the model can account for vertical changes in the currents within the water column. For example, as particles sink towards the seabed they will tend to be moved at slower speeds due to the slowing of currents by friction at the seabed. Particle diffusion is assumed to follow a random walk process using a Lagrangian approach of calculating transport, which uses a grid-less space to remove limitations of grid resolution, artefacts due to grid boundaries, and also maintain a high degree of mass conservation.

Following release into the model space, the sediment cloud evolves according to the following processes:

- Advection due to the three-dimensional current field.
- Diffusion by a random walk model with the mass diffusion rate specified, ideally, from measurements at the site. As particles represent an ensemble of real particles, each particle in the model has an associated Gaussian distribution governed by particle age and the mass diffusion properties of the surrounding water.
- Settlement or sinking of the sediment due to buoyancy forces. Settlement rates are determined from the particle class sizes and include allowance for flocculation and other concentration-dependent behaviour, following the model of Teeter (2000).
- Potential deposition to the seabed determined using a model that couples the deposition across particle classes (Teeter, 2000). The likelihood and rate of deposition depends on the shear stress at the seabed. High shear inhibits deposition, and in some cases excludes it altogether with sediment remaining in suspension. The model allows for partial deposition of individual particles according to a practical deposition rate, thereby allowing the bulk sediment mass to be represented by fewer particles.
- Potential resuspension from the seabed, if previously deposited, at a rate governed by exceedance of a shear stress threshold at the seabed due to the combined action of waves and currents. Different thresholds are applied for resuspension depending upon the size of the particle and the duration of sedimentation, based on empirical studies that have demonstrated that newly-settled sediments will have higher water content and are more easily resuspended by lower shear stresses (Swanson *et al.*, 2007). The resuspension flux calculation also accounts for armouring of fine particles within the interstitial spaces of larger particles. Thus, the model can indicate whether deposits will stabilise or continue to erode over time given the shear forces that occur at the site. Resuspended material is released back into the water column to be affected by the processes defined above.

SSFATE formulations and proof of performance have been documented in a series of USACE Dredging Operations and Environmental Research (DOER) Program technical notes (Johnson *et al.*, 2000; Swanson *et al.*, 2000), and published in the peer-reviewed literature (Andersen *et al.*, 2001; Swanson *et al.*, 2004; Swanson *et al.*, 2007). SSFATE has been applied and validated by RPS against observations of sedimentation and suspended sediments at multiple locations in Australia, notably Cockburn Sound for Fremantle Ports and Mermaid Sound for the Pluto dredging project.

3.3 Model Limitations

There are inherent limitations to the accuracy of numerical models. The possible sources of uncertainty within the modelling conducted for the sediment fate assessment of the Scarborough Project include:

- *The equations and algorithms applied in the model*. The formulations included in the model, as discussed in Section 3.2, were selected to achieve the best possible representation of the relevant processes and have been proven to be valid over a range of projects.
- *The accuracy of the physical (current and wave) inputs to the model*. Current and wave forcing inputs were provided from validated three-dimensional hydrodynamic and wave models created and customised for the study area. The accuracy of these models is suitable, as good correlations with field measurements and independent model predictions have been achieved, with the uncertainties minimised and quantifiable. The hydrodynamic and wave models are described in Section 2. It should be noted that the model inputs are a hindcast of past metocean conditions; the overall trends reflected in this data will be broadly reflected in future conditions, but conditions on any given day during the actual dredging operations may be quite different.
- *The accuracy of dredge methodology inputs to the model*. Specification of the proposed dredge methodologies was provided by WEL after consultation with the dredging contractors that may be engaged to perform the work. Any assumptions made to achieve a realistic representation of the dredging activities are outlined in Section 3.5 and were based on extensive past project experience.
- *The accuracy of the material properties input to the model*. Geotechnical information obtained during previous site investigations for the Pluto Foundation Project was provided by WEL (WEL, 2018b) and is discussed in Section 3.6. From this data, the properties of the in situ material to be dredged are reasonably well known. However, it is not possible to determine how the material properties will be changed by the action of the dredge and the mixing of the material with seawater in the process of pumping it to the hopper. Therefore, assumptions were made in the model with regard to the material that is released into the water column from dredging.
- *The accuracy of the dredging sediment source terms input to the model*. The source definition in the model is flexible and can be applied to any sediment source by specifying the time-varying flux rate, particle size distribution (PSD) and vertical profile in the water column. This information will be specific to the equipment used and the material encountered at the site, and therefore can only be determined with confidence from a pilot study at the site or field measurements during dredging. In the absence of such data, assumptions were made with regard to these parameters. The assumptions are outlined in Section 3.7 and were based on literature review, including the recent WAMSI Dredging Science Node reports, and extensive past project experience.

The major sources of uncertainty for the sediment fate modelling are the modelled dredging methodology and sediment source inputs to the model. The assumptions made were based on literature review and experience, and aimed to give a good representation of the sources of suspended sediment that will result from the proposed dredging activities. However, as there were uncertainties in the inputs to the model, the results should be considered as indicative of the expected ranges in magnitude and distribution of suspended sediments and sedimentation, rather than an exact prediction.

3.4 Model Domain and Bathymetry

The DREDGEMAP model domain established for the Scarborough dredging works extended approximately 95 km north-south by 115 km east-west (Figure 3.1). The model grid covers the section of the Western Australian coastline from Regnard Bay, south of West Intercourse Island, to Point Samson in the east. The offshore boundaries of the domain were imposed at a reasonable distance from the proposed dredging area, to allow potential sediment drift patterns in offshore directions to be adequately captured.

This region lies within the model domain of the Delft3D hydrodynamic and wave models that provide the current and wave inputs to DREDGEMAP (see Section 2). A grid resolution of 100 m by 100 m was selected to ensure that existing features in the domain, including the many bays, islands and passages of the Dampier Archipelago, were adequately defined.

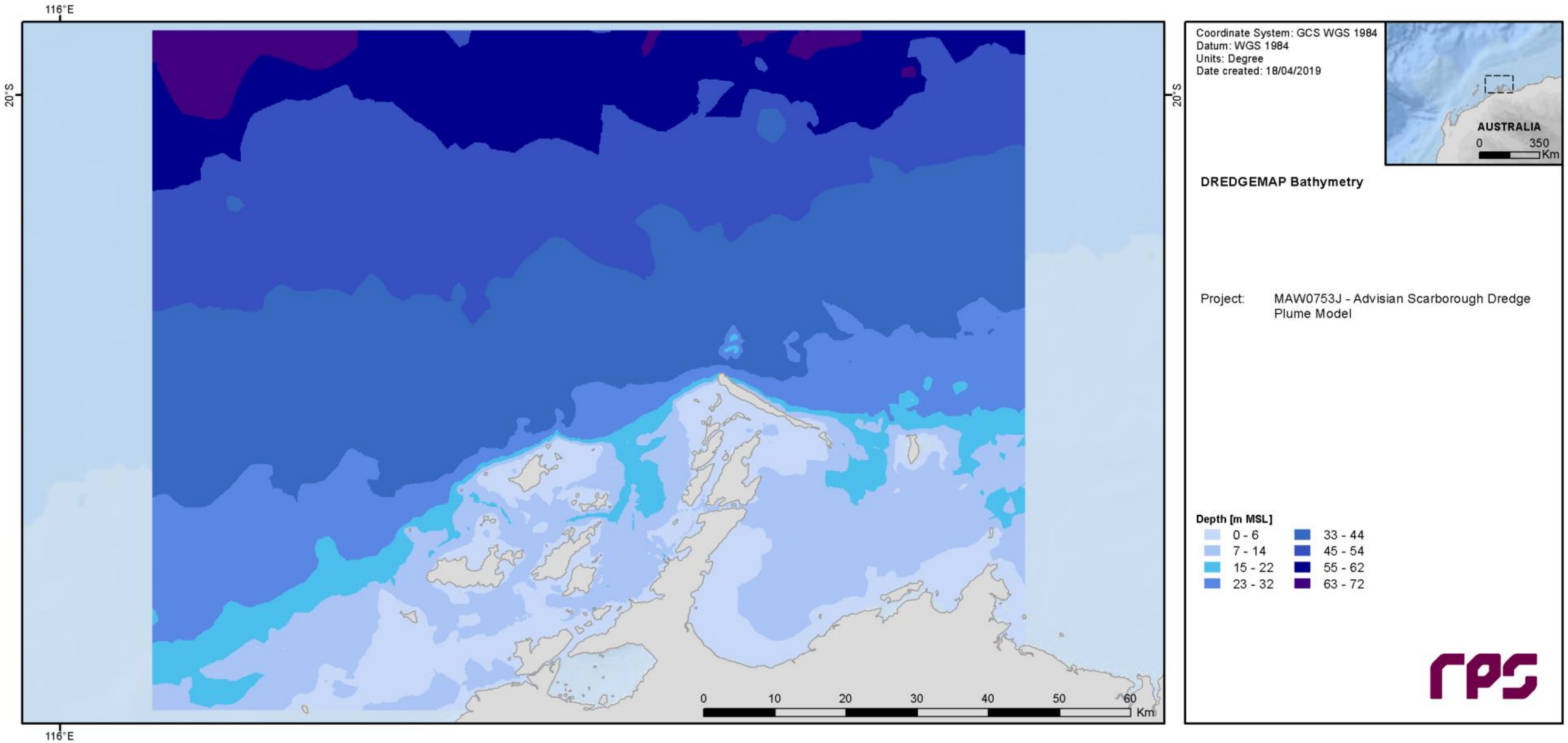

Figure 3.1 DREDGEMAP model domain and bathymetry (m MSL).

3.5 Dredging Project Description and Model Operational Assumptions

3.5.1 Overview

Information outlining the proposed dredging operations for the Scarborough Project has been drawn from the Scope of Work document (Advisian, 2018), subsequent email discussions, and input data provided by WEL and its potential dredging contractors. At the time of commencement of modelling, the collated information represented the best available data with regard to geotechnical properties of the project area, the dredging methodologies expected to be used within this area, and the typical characteristics of vessels that may be engaged for the work.

The operations modelled comprise the following activity:

- Dredging of the offshore borrow ground.

The offshore borrow ground lies in Commonwealth Waters (Figure 1.1).

The following sections outline the details of the operations for this activity and highlight any assumptions that were made.

3.5.2 Methods and Equipment

3.5.2.1 Borrow Ground Dredging

Dredging of the offshore borrow ground will consist of the removal of approximately 2 Mm^3 of sandy sediments with a low proportion of fines.

It was assumed that dredging of the offshore borrow ground (Figure 1.1) will be conducted using a TSHD. The TSHD hopper size was assumed to be 9,700 m^3 (filled at a rate of approximately 90 m^3/min). It has been specified that overflow of fines from the TSHD hopper will be permitted.

The estimated cycle times for TSHD dredging within the offshore borrow ground and placement of material within each pipeline section are presented in Table 3.2 (WEL, 2018a). The latter activity is not considered in this report and is only mentioned to contextualise the borrow-ground dredging activity.

The potential for sediment mobilisation by TSHD propeller-wash effects has been considered in the offshore borrow ground. This has been done using supplied data on vessel characteristics, and local depth and seabed composition. For the purposes of the modelling assessment, the relevant specifications were as follows:

- Vessel draft: 10.0 m loaded and 6.0 m empty.
- Number of propellers: 2 (ducted).
- Diameter of propellers: 4.0 m.
- Thrust power: 5,800 kW per propeller.

Table 3.2 Estimated cycle times for each pipeline section where the TSHD will be placing material dredged from the offshore borrow ground.

Pipeline Zone	Non-Overflow Time (min)	Overflow Time (min)	Placement Time (min)	Sailing Time (min)	Total Cycle Time (min)
POST2	30	74	107	46	257
POST4	30	74	107	46	257
POST6	30	74	107	53	264
POST8	30	74	107	53	264
POST10	30	74	107	58	269

3.5.3 Quantities and Production Rates

For dredging of the offshore borrow ground, the proposed quantities and production rates for each material type were specified for input to the modelling (Table 3.3). The sole material category within the borrow grounds was assumed to be unconsolidated sediments ("soft" material).

It is understood that:

- The estimated material quantities were based on the latest surveyed bathymetry and a geotechnical model incorporating existing geotechnical data;
- The estimated production rates were based on the material type and equipment that may be used for dredging;
- The estimated production rates were average values inclusive of expected downtime estimates.

Table 3.3 Modelled quantities of material type and production rates by material type for dredging of sand backfill material for each pipeline section from the offshore borrow ground.

Pipeline Zone	Dredged/Backfill Quantities (m^3)	Production Rates (m^3/week)
	Soft Material	Soft Material
POST2	159,992	325,000
POST4	80,394	325,000
POST6	349,334	325,000
POST8	75,343	325,000
POST10	943,032	325,000
Totals	**1,608,095**	**-**

3.5.4 Schedules

For dredging of the offshore borrow ground, the proposed duration and sequencing of operations has been specified for input to the modelling (Table 3.4).

Table 3.4 Modelled durations of dredging and backfill operations by material type for each pipeline section.

Pipeline Zone	Duration of Operations (weeks)		
	Soft Material	Moderate Material	Total
POST2	1.0	0.0	1.0
POST4	0.5	0.0	0.5
POST6	2.0	0.0	2.0
POST8	0.5	0.0	0.5
POST10	6.0	0.0	6.0
Totals	**10.0**	**0.0**	**10.0**

3.5.5 Scenario Summary

The provisional schedule for the dredging works indicates a December 2021 start for dredging of the offshore borrow ground. Analysis of wind data in the region from 1993-2017 has shown that the period of 2016-2017 is likely to be representative of typical conditions. The dredge modelling simulations were conducted using hydrodynamic and wave data drawn from this period, with nominal start dates for model simulation purposes being chosen as 1st December 2016 (summer) and 1st June 2017 (winter).

A summary of the scenarios that were modelled is as follows:

- Scenario 1: Dredging of the offshore borrow ground commencing on 1st December 2016 (summer start).
  - TSHD dredging operations were programmed to occur between 1st December 2016 and 9th February 2017.
  - A simulation run-on period was assumed to occur between 9th February 2017 and 10th April 2017. Sediments suspended in the water column during previous operations were subject to settlement and progressively-reducing levels of resuspension during this time.
- Scenario 2: Dredging of the offshore borrow ground commencing on 1st June 2017 (winter start).
  - TSHD dredging operations were programmed to occur between 1st June 2017 and 10th August 2017.
  - A simulation run-on period was assumed to occur between 31st August 2017 and 31st October 2017. Sediments suspended in the water column during previous operations were subject to settlement and progressively-reducing levels of resuspension during this time.

The outcomes of the summer-start and winter-start scenarios have been analysed and presented separately, for comparison, in Section 5.

3.6 Geotechnical Information

The material to be dredged from the offshore borrow ground will consist of the removal of 2 Mm^3 of sandy sediments with a low proportion of fines.

The critical geotechnical information required as input to the modelling is PSD data for the sediments to be dredged from the borrow ground.

This data has been specified (WEL, 2018b) for each pipeline section. The resultant PSDs have been redistributed to match the material size classes used in the DREDGEMAP model, as shown in Table 3.5.

For the offshore borrow ground, it has been assumed that the measured PSDs between KP30 and KP50 were applicable. The PSD data for these sections is characterised mainly as coarse sand, with 15% of the total mass existing as fines <75 µm.

In addition to PSD information, data and assumptions relating to the dry bulk density of the material to be dredged from the borrow ground was used as input to the modelling. A typical average dry bulk density value of 2,150 kg/m^3 was assumed.

Table 3.5 In situ PSDs broken down into DREDGEMAP material classes for the material dredged from the offshore borrow ground, derived from available geotechnical information.

Sediment Grain Size Class	Size Range (µm)	Offshore Borrow Ground (%)
Clay	<7	2.5
Fine Silt	8-34	2.5
Coarse Silt	35-74	10.0
Fine Sand	75-130	15.0
Coarse Sand	>130	70.0

3.7 Model Sediment Sources

3.7.1 Overview

To accurately represent the borrow-ground dredging operations in DREDGEMAP, a range of information was defined for the proposed operations, including dredge methodology, production rates, sediment types and quantities (see Section 3.5). It is evident that there will be two different sources of suspended sediment plumes during dredging operations, which can be broadly defined as:

- Direct suspension of material by the TSHD during dredging of unconsolidated sediments, accounting for no-overflow and overflow periods;
- Indirect suspension of material due to the propeller wash of the TSHD while dredging.

Each of these sources of suspended sediment plumes will vary in strength and persistence depending on the nature of the operations. In the DREDGEMAP model, each source is defined by specifying the time-varying flux rate, PSD and vertical profile in the water column. The following sections outline how the information provided has been used to represent the dredging operations in the model and explain any assumptions that have been made to supplement the available information.

3.7.2 Representation of TSHD Dredging

For the purposes of modelling, a TSHD of 9,700 m^3 capacity has been used to dredge material from the offshore borrow ground.

TSHD vessels remove sediments by dragging a large drag-head over the seabed and drawing up the disturbed sediment by hydraulic suction. Sources of sediment suspension from this type of operation include:

- Hydraulic disturbance of the seabed sediments by the trailing arm;
- Propeller-wash generated as the vessel manoeuvres;
- Overflow of the on-board hoppers, resulting in the discharge of water and entrained sediments.

The characteristics of each of these sources vary greatly due to a wide range of factors (USACE, 2008) making the generalisation of source terms difficult. It appears however, that the overflow source term is dominant, being typically an order of magnitude greater than the drag-head and propeller-wash terms.

For the dredging of the unconsolidated sediments during periods with no overflow, the PSDs used in the model are based on PSDs from nearby boreholes (see Section 3.6). The PSDs applied to dredging within the offshore borrow ground are shown in Table 3.6. During overflow periods, an increase in the rate of release of fine sediments, and hence initial turbidity, is observed (Anchor Environmental, 2003). The overflow water contains a high proportion of fines because the coarse material settles rapidly in the hopper while the fine material remains in suspension. After the hopper begins overflowing, PSDs heavily weighted towards finer particles has been assumed based on previous field measurements of hopper barge overflow at Geraldton Port (OPR, 2010), with the proportion >75 µm removed and the remaining distribution normalised to 100% by scaling up the proportions in the three remaining size classes. The PSDs applied to dredging within the offshore borrow ground are shown in Table 3.7.

Table 3.8 shows the assumed vertical distribution of the suspended material during the TSHD operations while the hopper is not overflowing. The distribution is concentrated near the seabed and decreases in intensity towards the surface, to represent the disturbance of seabed material by the drag-head and propeller-wash effects (HR Wallingford, 2003). After the hopper begins overflowing, a uniform distribution of sediments throughout the water column, between the hull depth and the seabed, has been assumed to represent a continuous stream of material being discharged from the hopper (Table 3.9). This is consistent with measured ADCP profiles presented by Hitchcock & Bell (2004), which show a reasonably even distribution of sediment through the water column during hopper overflow.

Table 3.6 Assumed PSDs of sediments initially suspended into the water column during TSHD dredging operations at the offshore borrow ground while the hopper is not overflowing.

Sediment Grain Size Class	Size Range (µm)	PSD (%) for Sediment Removal – Offshore Borrow Ground
Clay	<7	2.5
Fine Silt	7-34	2.5
Coarse Silt	35-74	10.0
Fine Sand	75-130	15.0
Coarse Sand	>130	70.0

Table 3.7 Assumed PSDs of sediments initially suspended into the water column during TSHD dredging operations at the offshore borrow ground while the hopper is overflowing.

Sediment Grain Size Class	Size Range (µm)	PSD (%) for Sediment Removal – Offshore Borrow Ground
Clay	<7	49.2
Fine Silt	7-34	25.5
Coarse Silt	35-74	25.3
Fine Sand	75-130	0.0
Coarse Sand	>130	0.0

Table 3.8 Assumed vertical distribution of sediments initially suspended into the water column during TSHD dredging operations at the offshore borrow ground while the hopper is not overflowing.

Elevation	Example Elevation (m ASB) – 30 m Water Depth	Vertical Distribution (%) of Sediments
10.0 m (ASB)	10.0	5.0
7.0 m (ASB)	7.0	15.0
3.0 m (ASB)	3.0	20.0
2.0 m (ASB)	2.0	40.0
1.0 m (ASB)	1.0	20.0

Table 3.9 Assumed vertical distribution of sediments initially suspended into the water column during TSHD dredging operations at the offshore borrow ground while the hopper is overflowing.

Elevation	Example Elevation (m ASB) – 30 m Water Depth and 10 m Hull Depth	Vertical Distribution (%) of Sediments
Hopper hull elevation	20.0	20.0
0.75 x hull elevation	15.0	20.0
0.50 x hull elevation	10.0	20.0
0.25 x hull elevation	5.0	20.0
0.50 m (ASB)	0.5	20.0

The resuspension of sediment when the TSHD hopper is not overflowing was estimated by combining the drag-head and propeller-wash terms. The propeller-wash component typically dominates the drag-head component, but both sources were assessed. Propeller wash generation was estimated by applying a model of the bed-induced shear stress from the TSHD vessel over the range of under-keel clearances expected during the dredging operations.

Field measurements of drag-head-induced sediment suspension was reported by Coastline Surveys Ltd (CSL, 1999). The inferred production rate was less than 1 kg/s and it was concluded that, generally, drag-head production is small in comparison to the quantity of sediment released via overflow. Given the above, a source rate of 0.6% of the gross production rate, representing a combined sediment flux due to losses from the drag-head and propeller-wash, was assumed when the TSHD is not overflowing. This rate is within the range of values (less than 1%) summarised in a review of contemporary practice conducted as part of the WAMSI Dredging Science Node by Kemps & Masini (2017).

The resuspension of sediment when the TSHD hopper is overflowing was estimated based on measurements taken of the concentrations within overflowing waters, which are generally less than 10,000 mg/L adjacent to the hopper (Hitchcock & Bell, 2004). Typical values appear to be in the 5,000-6,000 mg/L range, which correlate well with data drawn from other Western Australian projects that cannot be cited here for reasons of confidentiality. A conservative hopper overflow concentration of 10,000 mg/L was assumed for this study, which – when balanced with the expected pumping and loading rates of the dredge – resulted in a source estimate of 2.4% of the gross production rate. This flux rate is a conservative rate compared to the range of published measurements from TSHD operations (0.1-5.0%; Hayes & Wu, 2001) and is within the range of values used in modelling studies (0.3-9.8%) outlined in a review of contemporary practice by Kemps & Masini (2017).

3.7.3 Representation of TSHD Propeller Wash

Modelling of sediment suspended by propeller-induced motion at the seabed was conducted to estimate likely sediment concentrations generated by the TSHD propellers while manoeuvring during dredging operations. A specialised numerical model developed by RPS, named PROPMAP, was used to estimate a time- and space-varying rate of sediment flux from the seabed due to the thrust imposed by the vessel's propellers at the seabed level behind the moving vessel. The model uses characteristics of the vessel of interest to estimate the three-dimensional thrust-field generated by the propellers. This thrust-field is then combined with the grain size and degree of cohesion of the seabed sediments, and the varying under-keel clearance along the typical vessel paths, to calculate variations in the suspended sediment flux from the seabed in time and space.

The following details were used as input to PROPMAP to calculate variable rates of sediment flux from the seabed due to propeller-wash effects:

- Vessel tracks and speeds;
- Vessel draft, engine power and propeller size;
- Bathymetry along the vessel tracks;
- Grain size distributions of the sediment, defining the proportions of clay and silt along the vessel tracks.

The calculation steps applied by PROPMAP at discrete intervals along each vessel path were as follows:

- Based on the vessel's engine power and propeller size, determine the propeller-induced velocity profile;
- Based on the vessel's draft and the local bathymetry, determine the intersection of the thrust-field with the seabed and find the thrust imposed on it;
- Based on the velocity of water flow at the seabed, calculate the shear stress acting on it;
- Based on the calculated shear stress, and the sediment grain size and cohesiveness, calculate a theoretical erosion flux (mass per unit time) for seabed sediment.

Propeller-induced velocity profiles were calculated using empirical expressions from Blaauw & van de Kaa (1978). Thrust at the seabed will depend upon the level of the bed, which will intersect as a plane (Figure 3.2). For an under-keel clearance of 1 m, a velocity field exceeding 5 m/s would intersect the bed in this example, while at a clearance of 4 m the bed velocity would be reduced to <2 m/s. The influence of this thrust will vary with the sediment grain size. Consequently, outcomes will be sensitive to the magnitude of the thrust, the under-keel clearance and the PSD of the bed.

Sediment erosion flux was estimated from the derived velocity field using the empirical formulations of van Rijn (1989). The sediment flux component attributable to propeller wash was found to be insignificant within the offshore borrow ground due to the large under-keel clearances even with a fully-loaded vessel (maximum draft).

These findings were used to inform the definition of the sediment flux rates during TSHD dredging operations (see Section 3.7.2).

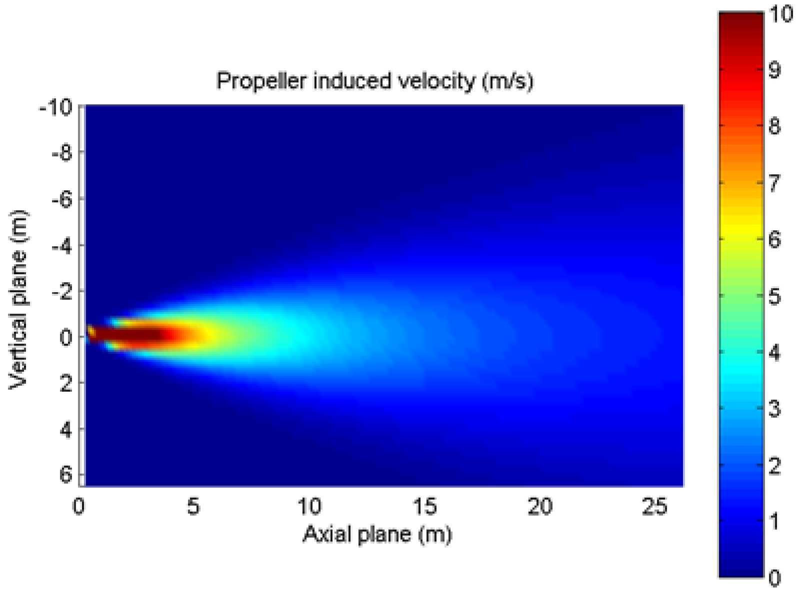

Figure 3.2 Two-dimensional view of a propeller-induced velocity profile.

4 ENVIRONMENTAL THRESHOLD ANALYSIS

4.1 Overview

Predictions of SSC for each scenario were assessed against a series of water quality thresholds to categorise the modelled outcomes into management zones of influence and impact, defined with regard to environmental sensitivities in the study region. These thresholds, and the technical justification which followed guidance from the WAMSI Dredging Science Node, were supplied to RPS by Advisian (MScience, 2019). Thresholds were selected for benthic habitats on the basis of past and present mapping of communities in the project area.

Thresholds for three management zones – a Zone of Influence (ZoI), a Zone of Moderate Impact (ZoMI) and a Zone of High Impact (ZoHI) – were defined. The criteria associated with each management zone also varied across three ecological zones, which were broadly defined based on past studies of these areas. The ecological zones are named as follows, with reference to the pipeline chainages shown in Figure 1.1, and with the spatial extents agreed for this study shown in Figure 4.1:

- Offshore: the trunkline area beyond KP25, and generally all areas north of a boundary line containing Rosemary Island, Legendre Island and Delambre Island.
- Zone B: the trunkline area between KP8 and KP25, adjacent coral and macroalgae habitats within Mermaid Sound, and generally all coral, macroalgae and mixed community habitats between Dolphin Island and Bezout Island.
- Zone A: the trunkline area between the shoreline and KP8, adjacent macroalgae and mangrove habitats within Mermaid Sound, and generally all mangrove, marsh and seagrass habitats between Nickol Bay and Point Samson.

Thresholds for coral habitats within Zone B were developed with the aid of data collected during a previous dredging campaign at Barrow Island, which is considered a similar habitat. Water quality within Zone A is more turbid, and coral communities are comprised of more sediment-tolerant or resilient species. Offshore habitats are not likely to contain corals.

In developing the thresholds, it was assumed that benthic communities around Borrow Ground A (see Figure 1.1) will be sparse and made up largely of sponges and filter feeders without corals.

4.2 Baseline Water Quality

Water quality data collected during the Pluto Foundation Project over the period of 2007 to 2010 (MScience, 2010) demonstrated that turbidity at sites within the Zone A and Zone B management areas was raised by 0.7 NTU and 0.3 NTU, respectively, as a result of dredging activities. Subtraction of these dredge-induced values across the 2007-2010 data set yielded a set of baseline turbidity measurements.

Table 4.1 presents the mean and 80th-percentile SSC values calculated from the background turbidity measurements in each zone. For the purposes of threshold assessment, it has been assumed that the summer season comprises the period of November to March and the winter season contains the months of April to October.

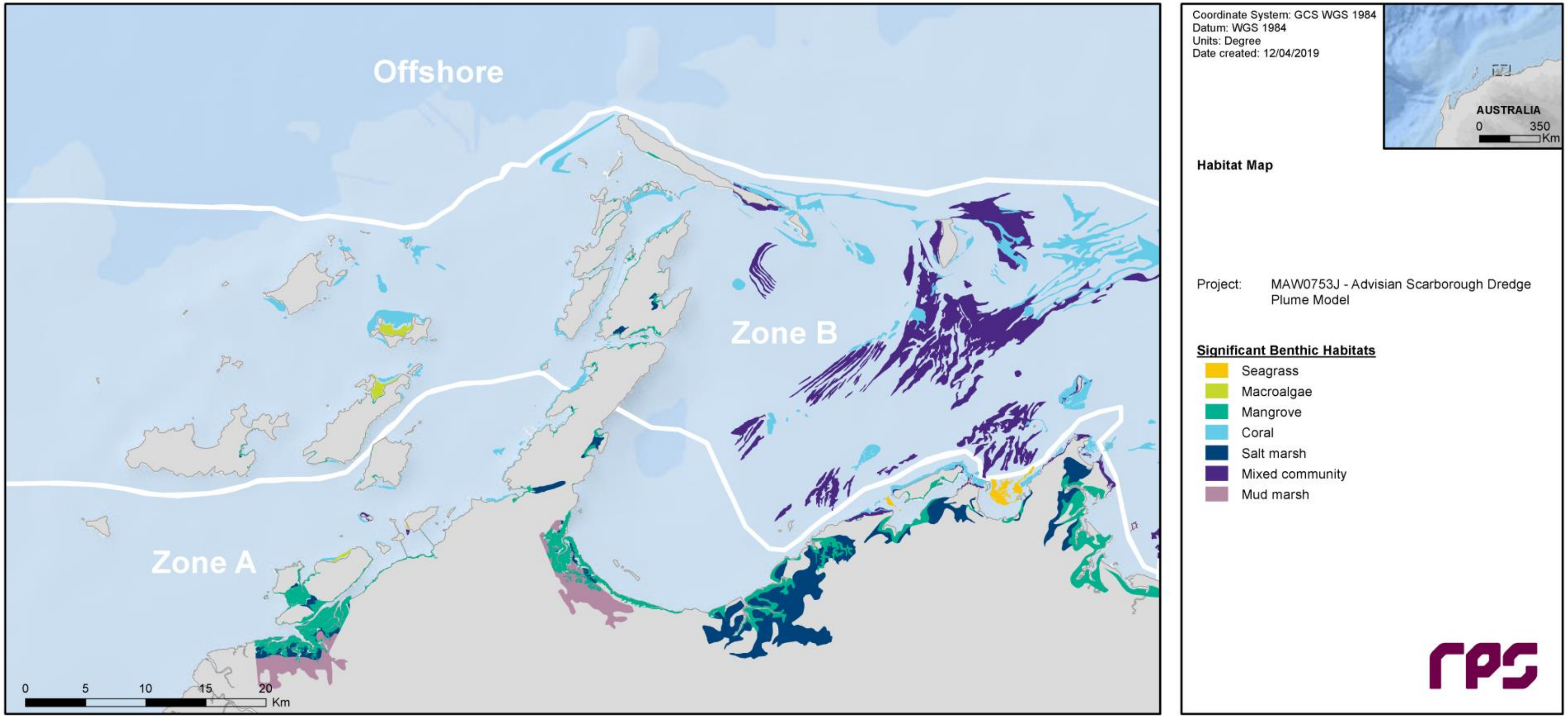

Figure 4.1 Delineation of the proposed ecological zones (Zone A, Zone B and Offshore) in the context of known habitat areas and types. Thresholds used to define the management zones will vary in magnitude between the ecological zones.

Table 4.1 **Baseline mean and 80th percentile SSC values calculated from measurements undertaken during the Pluto Foundation Project (2007-2010), categorised into summer and winter seasons for each of the three ecological zones.**

Ecological Zone	Season	Mean SSC (mg/L)	80th Percentile SSC (mg/L)
A	Summer	4.1	5.0
	Winter	1.8	2.3
B	Summer	2.5	2.7
	Winter	1.2	1.6
Offshore	Summer	1.8	1.8
	Winter	0.6	0.9

4.3 Zone of Influence (ZoI)

The ZoI is defined as "*a zone where impacts to water quality will be detectable but below a level causing detectable impacts to biota*" (MScience, 2019). This is generally considered equivalent to the area around dredging activities where a plume may be visible to the naked eye.

The ZoI threshold will be exceeded at any point within the model domain where dredging is forecast to increase the depth-averaged concentration of SSC (specifically the contribution attributable to dredging activities) by a level greater than the seasonal 80th percentile baseline SSC over a 24-hour average period.

Table 4.2 presents the threshold SSC values used to define the extents of the ZoI. A background SSC value appropriate for each ecological zone and month of the year was added to the dredge-induced SSC predictions from the sediment fate model prior to evaluation of the thresholds.

Potential exceedances of the threshold were evaluated over the duration of each dredge scenario by calculating a rolling 24-hour average of SSC concentrations in each model grid cell and checking for breaches as this time-window progressed through the data set at hourly increments (the temporal resolution of the data set). If the 24-hour average SSC concentration exceeds the threshold value at any time, even if only on one occasion, the model grid cell is included in the ZoI area. With each scenario spanning a period of approximately four months, ZoI threshold checks were undertaken for more than 2,800 time steps. This approach allowed an increased opportunity to detect threshold exceedance events, compared with that afforded by the alternative method of simply analysing each unique 24-hour sequence in turn (i.e. with no temporal overlap) from the start to the end of the data set.

Typically, averaging discrete data points over an arbitrary time period will serve to reduce the influence of transient spikes in concentration, thereby reducing the possibility of spurious exceedances. More rarely, a transient concentration spike of sufficient magnitude to skew the rolling average to an above-threshold state may result in exceedances being recorded for a longer period than will be the case in reality. Generally, applying a time-average to a data set for the purposes of threshold analysis will result in a smaller zone of effect than if instantaneous data is evaluated. This methodology also has a strong connection to critical exposure times for benthic habitats or species of concern in the project area.

Table 4.2 Background, dredge-excess and threshold SSC values used as the criteria to define the ZoI outer boundary within each ecological zone.

Ecological Zone	Season	Time-Averaged Period (hours)	Background SSC (mg/L) [a]	Dredge-Excess SSC (mg/L) [b]	Threshold SSC (mg/L) [c]
A	Summer	24	4.1	5.0	9.1
	Winter	24	1.8	2.3	4.1
B	Summer	24	2.5	2.7	5.2
	Winter	24	1.2	1.6	2.8
Offshore	Summer	24	1.8	1.8	3.6
	Winter	24	0.6	0.9	1.5

[a] Background values are equivalent to 'Mean SSC' values in Table 4.1.

[b] Dredge-excess values are equivalent to '80th Percentile SSC' values in Table 4.1.

[c] Threshold values are the sum of background and dredge-excess values.

4.4 Zone of Moderate Impact (ZoMI)

The ZoMI is defined as "*a zone where impacts are sub-lethal or lethal but recoverable (in terms of the community) within a five-year period*" (MScience, 2019).

The ZoMI threshold will be exceeded at any point within the model domain where dredging is forecast to increase the depth-averaged concentration of SSC to a level sufficient to trigger impacts to EC_{10} (10% Effect Concentration or 10% Inhibition) or to cause bleaching through loss of light or sedimentation.

Thresholds chosen to indicate a transition between the ZoI and ZoMI areas are largely based on the 'possible mortality' thresholds of Fisher *et al.* (2019). These thresholds are based on analysis of water quality and coral monitoring data collected during a previous dredging project at Barrow Island, where coral communities exist in clear, near-oceanic conditions. Distinctions must be made between the thresholds most appropriate for each ecological zone.

Within the offshore zone, only thresholds of relevance to sponges and filter feeders are appropriate because corals, seagrasses and macroalgae are not known to form significant communities. A threshold relating to an LC_{10} (10% Lethal Concentration) effect on filter feeder-sponge habitats over a 28-day exposure period was selected (Pineda *et al.*, 2017).

For Zone B, coral communities experience similar conditions to those monitored at Barrow Island and the moderate-impact thresholds of Fisher *et al.* (2019) for coral/mixed benthos communities were deemed to be appropriate (MScience, 2019).

For Zone A, coral communities experience more turbid conditions and are more tolerant of elevated SSC levels and lowered light levels than their neighbours in Zone B due to adaptation and a different mix of species. To account for this greater tolerance, the moderate-impact thresholds in Zone A were defined as those of Zone B multiplied by a factor of 1.5, which is believed to be a conservative multiplier (MScience, 2019). Within both Zones A and B, spongers and filter feeders will occur among the corals, and the mixed community is best evaluated using coral-focused thresholds.

The taxa-specific thresholds and appropriate time-averaging periods (related to exposure times from experimental data) used to define the extents of the ZoMI are detailed in Table 4.3. A background SSC value appropriate for each ecological zone and month of the year was added to the dredge-induced SSC predictions from the sediment fate model prior to evaluation of the thresholds.

Potential exceedances of the thresholds were evaluated over the duration of each dredge scenario by calculating rolling 3-day, 7-day, 10-day, 14-day and 28-day averages (as appropriate in each ecological zone) of SSC concentrations in each model grid cell and checking for breaches as this time-window progressed through the data set at hourly increments (the temporal resolution of the data set). If any time-average SSC concentration exceeds the corresponding threshold value at any time, even if only on one occasion, the model grid cell is included in the appropriate ZoMI area.

Table 4.3 Threshold SSC values used as the criteria to define the ZoMI outer boundary within each ecological zone.

Ecological Zone	Time-Averaged Period (days)	Threshold SSC (mg/L)
A	3	29.1
	7	22.5
	10	19.6
	14	17.6
B	3	19.4
	7	14.7
	10	13.1
	14	11.7
Offshore	28	22.5

4.5 Zone of High Impact (ZoHI)

Thresholds chosen to indicate a transition between the ZoMI and ZoHI areas are largely based on the 'probable mortality' thresholds of Fisher *et al.* (2019).

Within the offshore zone, a threshold relating to an LC_{50} (50% Lethal Concentration) effect on filter feeder-sponge habitats over a 28-day exposure period was selected (Pineda *et al.*, 2017).

For Zone B, the high-impact thresholds of Fisher *et al.* (2019) for coral/mixed benthos communities were deemed to be appropriate (MScience, 2019).

For Zone A, the high-impact thresholds were defined as those of Zone B multiplied by a factor of 1.5, which is believed to be a conservative multiplier (MScience, 2019).

The taxa-specific thresholds and appropriate time-averaging periods (related to exposure times from experimental data) used to define the extents of the ZoHI are detailed in Table 4.4. A background SSC value appropriate for each ecological zone and month of the year was added to the dredge-induced SSC predictions from the sediment fate model prior to evaluation of the thresholds.

Potential exceedances of the thresholds were evaluated over the duration of each dredge scenario by calculating rolling 3-day, 7-day, 10-day, 14-day and 28-day averages (as appropriate in each ecological zone) of SSC concentrations in each model grid cell and checking for breaches as this time-window progressed through the data set at hourly increments (the temporal resolution of the data set). If any time-average SSC concentration exceeds the corresponding threshold value at any time, even if only on one occasion, the model grid cell is included in the appropriate ZoHI area.

Table 4.4 Threshold SSC values used as the criteria to define the ZoHI outer boundary within each ecological zone.

Ecological Zone	Time-Averaged Period (days)	Threshold SSC (mg/L)
A	3	53.6
	7	36.8
	10	31.4
	14	27.0
B	3	35.7
	7	24.5
	10	20.9
	14	18.0
Offshore	28	47.0

5 RESULTS OF SEDIMENT FATE MODELLING

5.1 Spatial Distributions of SSC

Simulations indicated that there may be significant spatial patchiness in the distribution of SSC at any point in time during the dredging operations because of variability in the flux from each suspension source and the varying dynamics of the transport, settlement and resuspension processes affecting the sediments.

The most pronounced differences in the predicted concentrations at any point in time are found in the vertical distributions, with a distinct increase in concentration towards the seabed. Thus, the spatial area affected above a given concentration is typically greater in the near-seabed layer than in the near-surface layer. It should be noted, however, that there are instances throughout the simulations where elevated concentrations will occur in the near-surface layers – during TSHD overflow operations, or during strong resuspension events affecting sediments that have migrated to shallow areas – but they are typically not sustained for extended periods of time.

Variations in large-scale circulation mean that reasonably distinct seasonal trends are evident in the modelling outcomes. The bulk of the overall dredged sediment volume is forecast to be dispersed in the offshore area between the borrow ground and Legendre Island in both seasons. Strong tidal flows between Hauy Island and Delambre Island will aid movement of sediment towards the shallow waters of Nickol Bay, with this effect being greater in summer due to predominant net drift towards the east imposed by prevailing south-westerly winds. In contrast, the net drift direction forecast during winter conditions is towards the south-west, mostly following the bathymetric contours to the north of Rosemary Island.

The results observed on any given day will not always be representative of the given season's prevailing transport patterns, and plume concentrations and distributions are forecast to vary markedly. To explore this variability, statistical distributions for each scenario are examined. Percentile distributions will summarise the outcomes over the entire scenario and do not represent an instantaneous plume footprint at any point in time.

Forecasts of median depth-averaged SSC concentrations (values exceeded 50% of the time) do not exceed 0.1 mg/L for works commencing in either season. At the 95th percentile (values exceeded only 5% of the time), forecasts of depth-averaged SSC concentrations 1 mg/L or greater are found along a ~10 km south-easterly trajectory from the borrow ground in summer, and along a ~25 km south-easterly trajectory in winter.

Recurrent elevations of near-seabed SSC north of Legendre Island is expected as a consequence of intensive dredging operations in the vicinity. Within Nickol Bay, there are many shallow locales where strong tidal flows both inhibit settlement of fine suspended sediments and stimulate significant levels of resuspension of sediments deposited after initial release in the water column.

Concentrations of suspended sediment in the key activity area will represent the combined influence of new discharges and resuspension of fine sediments from earlier discharges. Temporal variations in intensity of the dredging operations will also influence turbidity peaks and troughs. At progressively more distant areas, the importance of resuspension as a contributor to the distribution of SSC concentrations in general, and near-seabed concentrations in particular, becomes a greater factor. The areas forecast to receive elevated concentrations are substantially larger than would be affected by plumes only from the initial sources. The plume extents tend to expand over periods of several weeks in the direction of net drift, indicating the progressive transport of fine sediments through continuous patterns of settlement and resuspension.

Periodic high wave-energy events will be a major contributor to estimates of high SSC in the near-seabed layer, particularly in shallow exposed areas. While these processes are forecast to extend the influence of dredging activities over a wider area, the longshore dispersal of finer sediments is indicated to be an important mechanism for limiting the trapping and build-up of fine sediments in the local region around the key activity area. The build-up of resuspendable fine sediments in areas remote from dredging activities indicates that the supply of fines to these areas will be greater than their removal due to ongoing resuspension and longshore transport, for as long as sediment input from dredging activities continues.

5.2 Predictions of Management Zone Extents

Figures showing the calculated extents of the defined ZoI management zone over the entire programme of offshore borrow-ground dredging operations are listed in Table 5.1 for each scenario. No exceedances of any ZoMI or ZoHI threshold are predicted, so no figures are presented in relation to these thresholds.

Presentation of the ZoI areas is done on the basis of 95th percentile threshold exceedances for the 24-hour rolling average data.

It should be noted that the indicated management zone extents in each case represent a cumulative measure of exceedances of the relevant thresholds over a five-month period, following the threshold criteria described in Section 4. They do not represent an instantaneous plume footprint at any point in time.

The indicated areas of threshold exceedances are largely a reflection of the areas of sediment confluence due to the proximity to the key activity area, where there is a sustained input of suspended sediments over periods of several months, and the influence of local metocean conditions acting to inhibit rates of settling and increase rates of resuspension.

The significantly larger ZoI observed for dredging works commencing in winter is largely a consequence of the lower thresholds applicable during this period, and consequently the lower levels of dredge-excess SSC required to cause exceedances.

Table 5.1 Index of the ZoI, ZoMI and ZoHI figures for each scenario.

Management Zone	Scenario 1	Scenario 2
Zone of Influence (95th percentile): 24-hour rolling average of total SSC	Figure 5.1	Figure 5.2
Zone of Moderate Impact: 3-day (Zones A and B) and 28-day (Offshore) rolling average of total SSC	N/A	N/A
Zone of Moderate Impact: 7-day (Zones A and B) and 28-day (Offshore) rolling average of total SSC	N/A	N/A
Zone of Moderate Impact: 10-day (Zones A and B) and 28-day (Offshore) rolling average of total SSC	N/A	N/A
Zone of Moderate Impact: 14-day (Zones A and B) and 28-day (Offshore) rolling average of total SSC	N/A	N/A
Zone of High Impact: 3-day (Zones A and B) and 28-day (Offshore) rolling average of total SSC	N/A	N/A
Zone of High Impact: 7-day (Zones A and B) and 28-day (Offshore) rolling average of total SSC	N/A	N/A
Zone of High Impact: 10-day (Zones A and B) and 28-day (Offshore) rolling average of total SSC	N/A	N/A
Zone of High Impact: 14-day (Zones A and B) and 28-day (Offshore) rolling average of total SSC	N/A	N/A

5.2.1 Scenario 1: Dredging Operations at the Offshore Borrow Ground Commencing during Summer

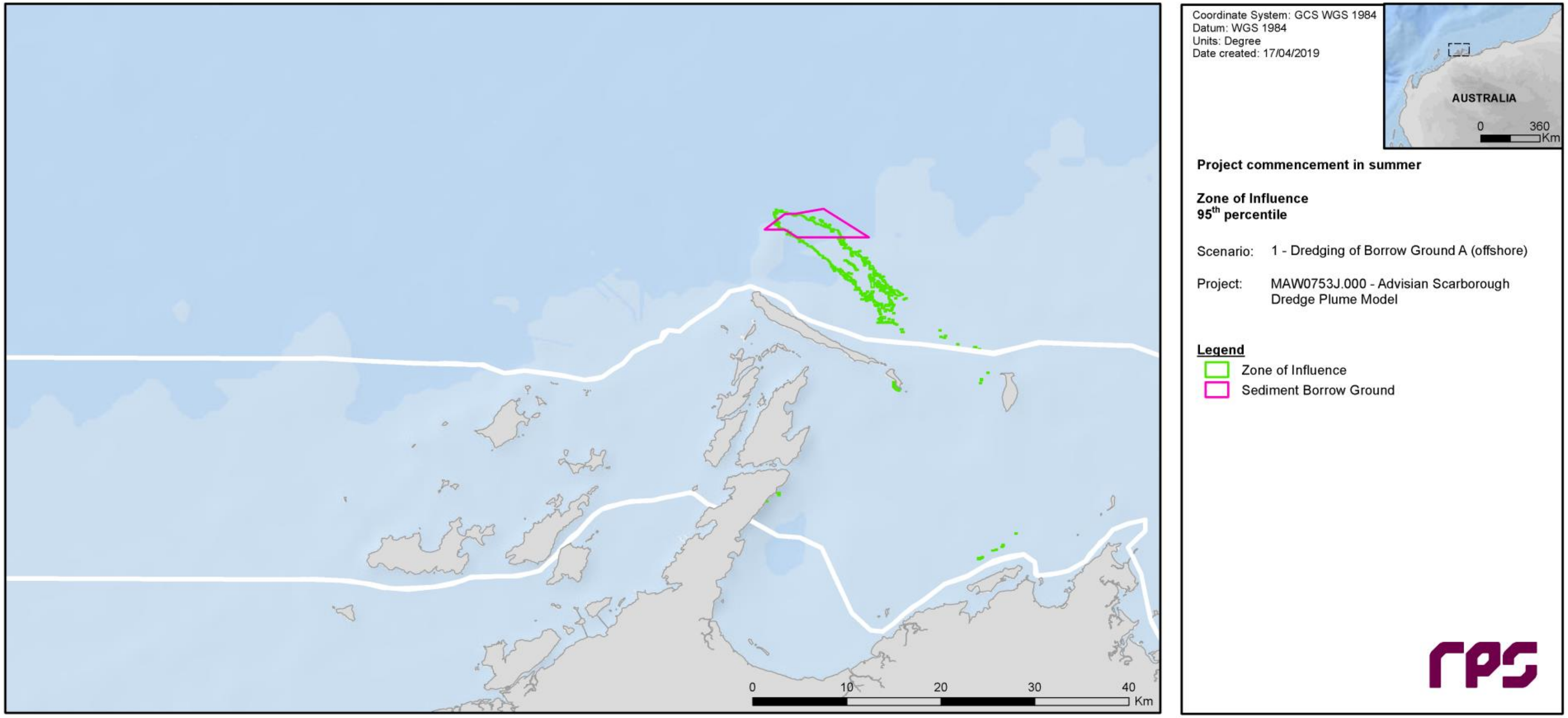

Figure 5.1 **Predicted 95th percentile Zone of Influence following application of the appropriate spatial thresholds in Table 4.2 to a 24-hour rolling average of total (dredge and background) SSC throughout the entire scenario duration (1st December 2016 to 10th April 2017).**

5.2.2 Scenario 2: Dredging Operations at the Offshore Borrow Ground Commencing during Winter

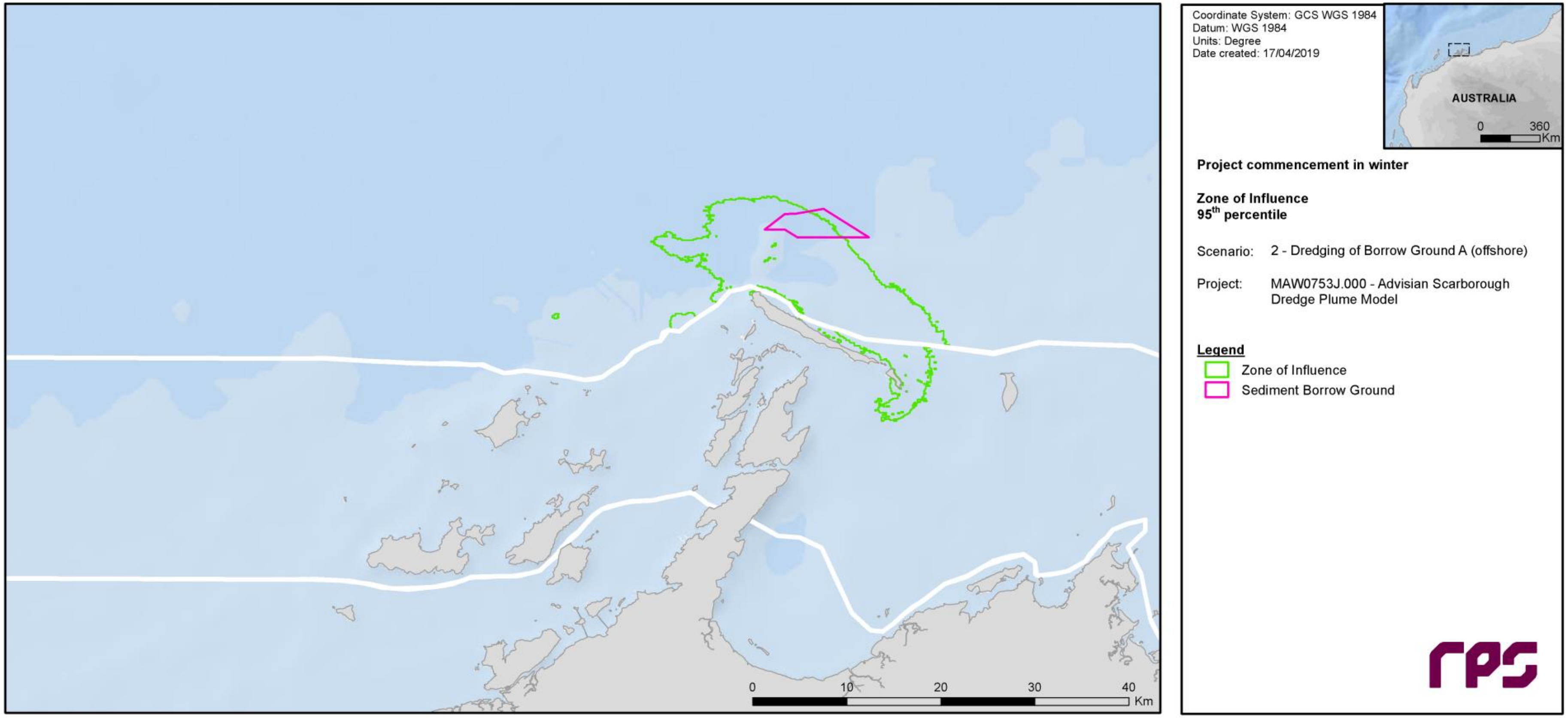

Figure 5.2 Predicted 95th percentile Zone of Influence following application of the appropriate spatial thresholds in Table 4.2 to a 24-hour rolling average of total (dredge and background) SSC throughout the entire scenario duration (1st June 2017 to 9th October 2017).

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