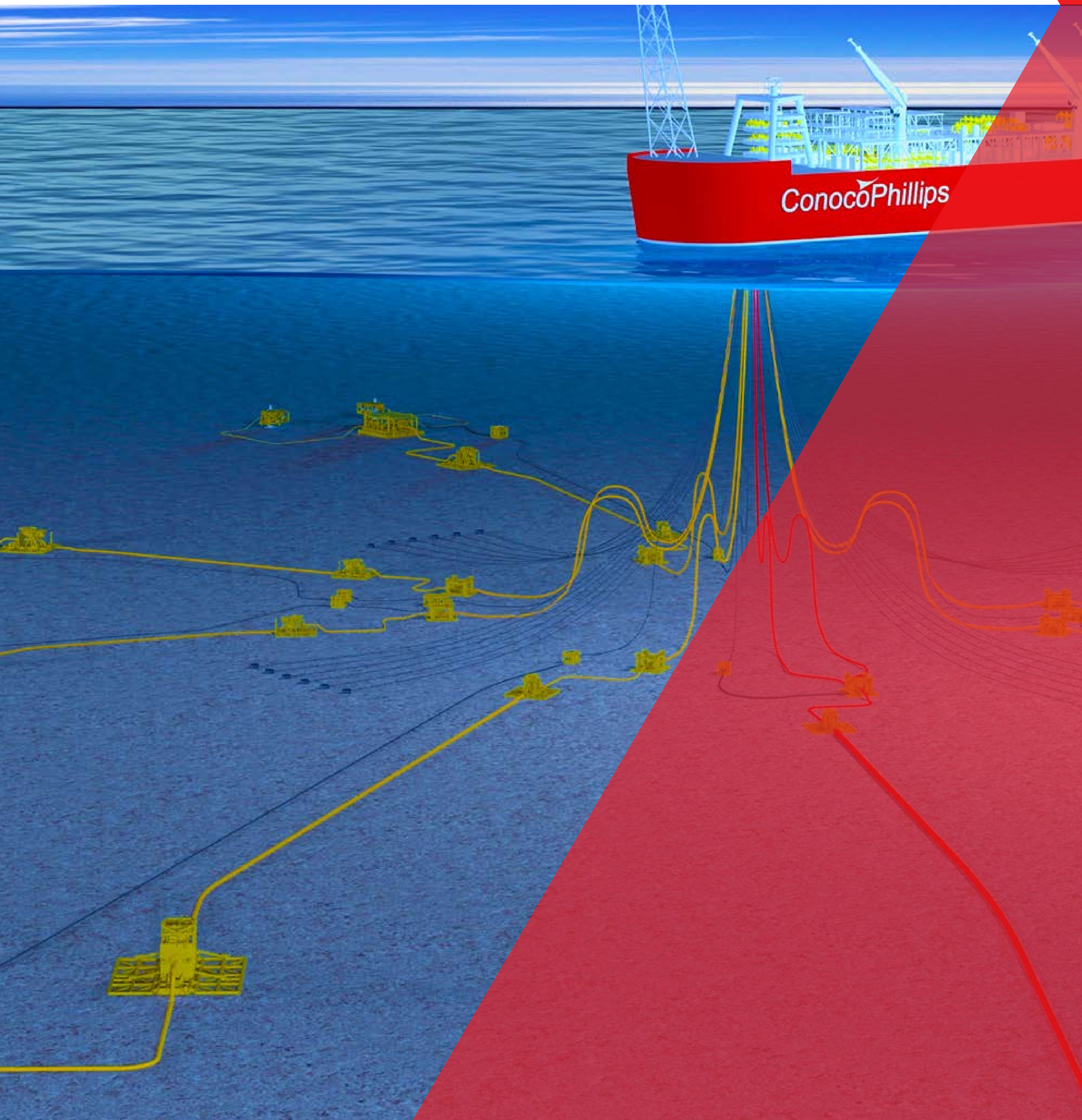
BAROSSA AREA DEVELOPMENT

OFFSHORE PROJECT PROPOSAL

APPENDICES



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Environmental legislation, regulations, standards, systems, practices and procedures

Table A-1: NT legislation and regulations

Legislation	Governing department	Summary	Relevance to project
Environmental Assessment Act	NT Environment Protection Authority (NT EPA) Department of Environment and Natural Resources (DENR)	This Act provides for the assessment of the environmental effects of development proposals and for the protection of the environment within the NT.	The project will adhere to the requirements of this Act, as relevant to potential project development activities in NT jurisdiction.
Waste Management and Pollution Control Act	NT EPA DENR	This Act provides for the protection of the NT environment through encouragement of effective waste management and pollution prevention and control practices.	The project will involve activities which will result in the generation and management of waste. ConocoPhillips will adhere to the Act and Regulations with regard to appropriate waste management and pollution prevention practices. In the unlikely event of a large-scale release impacting NT waters, any spill response operations will be undertaken in accordance with plans produced under this Act (e.g. NT Oil Spill Contingency Plan), in consultation with the relevant NT response agencies.
Northern Territory Environment Protection Authority Act	NTEPA	This Act establishes the NT EPA whose key objectives are to promote ecologically sustainable development, protect the environment, and promote effective waste management and minimisation strategies.	The project will adhere to the requirements of the NT EPA where required.
National Environment Protection Council (Northern Territory) Act	DENR	This Act provides for the establishment and operation of the NT National Environment Protection Council whose purpose is to make national environment protection measures.	The project will adhere to the requests of the NT National Environment Protection Council as required.

Legislation	Governing department	Summary	Relevance to project
Heritage Act	Department of Tourism and Culture	This Act establishes the NT Heritage Council and governs the protection of both natural and cultural heritages places within NT jurisdiction by setting out the process for obtaining permission to do work within these places.	The project will take into consideration any NT natural and cultural heritage values.
Dangerous Goods Act and Dangerous Goods Regulations	Department of the Attorney-General and Justice	This Act relates to the handling of certain dangerous goods within the NT. Regulations stipulate requirements for the safe handling, storage and transportation of dangerous goods, including provision of adequate training for personnel, and suitable hazard labelling, storage facilities and on-site management.	Dangerous marine goods shipped during the project will be stored, handled and transported in line with these regulations.
Darwin Port Corporation Act and Port By-Laws	Darwin Port Corporation	The Darwin Port Corporation is responsible for the movement and control of all vessels within the Port, including traffic, mooring and anchoring of vessels within the Port limits. Port officers are responsible for the prevention, management and control of pollution by oil in this jurisdiction.	Vessels associated with the project that may be entering and exiting the Darwin Port will comply with the vessel movement and Emergency Response Plan requirements.
Marine Pollution Act 1999 and Marine Pollution Regulations	NT Department of Transport	This Act protects the NT marine and coastal environment from ship sourced pollution, including litter/ rubbish, hydrocarbons and substances that may be hazardous to the marine environment (including substances that may be in ballast and greywater). This Act also gives effect to MARPOL in NT waters. Operation of support vessels and Emergency Response Plans, to be compliant with requirements of this Act.	Operation of vessels in NT waters associated with the project will adhere to the requirements of this Act and Regulations.

Legislation	Governing department	Summary	Relevance to project
Environment Protection (National Pollutant Inventory) Objective (established under the *Waste Management and Pollution Control Act)* Also: *National Environment Protection Council (Northern Territory) Act*	NT EPA DENR	The Environment Protection Objective provides for implementation of Commonwealth NEPMs in conjunction with the *National Environment Protection Council (NT) Act*, which provides for the establishment of a National Environment Protection Council. The Environment Protection (National Pollutant Inventory) Objective outlines the requirements to annually calculate and report emissions to the NPI.	Emissions released during the project will adhere to the Act and Environment Protection Objective.
Marine Act	Department of Infrastructure, Planning and Logistics	The Act regulates shipping in the NT and provides for the application to the Territory of the Commonwealth's Uniform Shipping Laws Code.	Operation of vessels associated with the project in NT waters will adhere to the requirements of this Act and Regulations.

Table A-2: International agreements and conventions

International agreements and conventions	Summary	Relevance to project
United Nations Convention on the Law of the Sea 1982	This convention establishes a legal order for the seas and oceans which will facilitate international communication, and will promote the peaceful uses of the seas and oceans, the equitable and efficient utilisation of their resources, the conservation of their living resources, and the study, protection and preservation of the marine environment.	All vessels and offshore facilities will adhere to the laws of the sea during the project to avoid any unplanned vessel interactions.
The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, 1992	This convention deals with the transboundary movement of hazardous wastes, particularly by sea. This convention is implemented through the Commonwealth *Hazardous Waste (Regulation of Exports and Imports) Act 1989*.	All hazardous wastes generated and disposed throughout the project will adhere to the requirements of this convention. Specifically, all hazardous waste materials will be contained, handled and disposed of onshore by a licensed waste contractor at a licensed facility. The project will have a strict 'no disposal at sea' policy.
Convention on Oil Pollution Preparedness, Response and Co-operation 1990	This convention comprises national arrangements for responding to oil pollution incidents from ships, offshore oil facilities, sea ports and oil handling. The convention recognises that in the event of pollution incident, prompt and effective action is essential.	Oil spill response planning for the project will provide prompt and effective emergency responses that can be implemented in the event of an oil spill.
International Convention for the Establishment of an International Fund for Compensation for Oil Pollution Damage	This convention ensures compensation is provided for damage caused by oil pollution.	This convention becomes relevant in the unlikely event of a large-scale spill scenario associated with the project (i.e. long-term well blowout during development drilling).
Convention on the Conservation of Migratory Species of Wild Animals 1979 (Bonn Convention)	The Bonn Convention aims to improve the status of all threatened migratory species through national action and international agreements between range states of particular groups of species.	ConocoPhillips recognises the importance of international conventions. Project operations are not expected to significantly influence any areas significant to migratory species.
International Convention on Wetlands of International Importance (Ramsar)	This convention is an international treaty for the conservation and sustainable use of wetlands. Ramsar wetlands are listed as a matter of national environmental significance under the EPBC Act 1999) (Commonwealth).	The nearest Ramsar wetland in relation to the project is Ashmore Reef (situated approximately 185 km north-east). Routine operations associated with the project are not expected to influence these areas.

International agreements and conventions	Summary	Relevance to project
Agreement Between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and Their Environment 1974 (commonly referred to as JAMBA)	This agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between Australia and Japan. Implemented in EPBC Act 1999.	ConocoPhillips recognises the importance of international conventions. The project is not expected to significantly influence any areas significant to migratory bird species.
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 1986 (commonly referred to as CAMBA)	This agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between Australia and China. Implemented in EPBC Act 1999.	ConocoPhillips recognises the importance of international conventions. The project is not expected to significantly influence any areas significant to migratory bird species.
Agreement Between the Government of Australia and the Government of the Republic of Korea for the Protection of Migratory Birds and Their Environment 2002 (commonly referred to as ROKAMBA)	ROKAMBA formalises Australia's relationship with the Republic of Korea in respect to migratory bird conservation and provides a basis for collaboration on the protection of migratory shorebirds and their habitat. All migratory bird species listed in the annexes to these bilateral agreements are protected in Australia as Matters of National Environmental Significance under the EPBC Act 1999.	ConocoPhillips recognises the importance of international conventions. The project is not expected to significantly influence any areas significant to migratory bird species.
International Convention for the Prevention of Pollution from Ships 1973/1978 (MARPOL 73/78)	This convention aims to preserve the marine environment through the complete elimination of pollution by oil and other harmful substances and the minimisation of accidental discharge of such substances. MARPOL is given effect in Australia by the Commonwealth *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* and the *Navigation Act 2012*. This convention is implemented through the WA *Pollution of Waters by Oil and Noxious Substances Act 1987* and NT *Marine Pollution Act 1999*.	All discharges associated with the project will align with MARPOL requirements, as appropriate.
International Convention for the Safety of Life at Sea (SOLAS) 1974	This convention is generally regarded as the most important of all international treaties concerning the safety of merchant ships. This convention is implemented through the *Navigation Act 2012* (Commonwealth).	Vessels utilised during the project will meet the requirements of the SOLAS Convention which specifies minimum standards for the construction, equipment and operation of ships, compatible with their safety.

International agreements and conventions	Summary	Relevance to project
International Convention on Civil Liability for Oil Pollution Damage 1969	This convention provides a mechanism for ensuring the payment of compensation for oil pollution damage.	This convention becomes relevant in the unlikely event of a large-scale spill scenario associated with the project (i.e. long-term well blowout during development drilling).
International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties 1969	Under this convention a coastal state may take action to prevent, mitigate or eliminate danger to its coastline or related interests from pollution by oil or the threat thereof, following upon a maritime casualty. This convention is implemented through the *Protection of the Sea (Powers of Intervention) Act 1981* (Commonwealth).	This convention becomes relevant in the unlikely event of a large-scale spill scenario associated with the project and that spill was likely to affect the shoreline of a coastal state.
International Marine Dangerous Goods (IMDG) Code 1994	The IMDG Code was developed as a uniform international code for the transport of DG by sea covering such matters as packing, marking, labelling and stowage of DG with particular reference to the segregation of incompatible substances.	Dangerous marine goods shipped during the project will be stored, handled and transported in line with this code.
International Convention for the Control and Management of Ships' Ballast Water and Sediment 2004	The convention aims to prevent the spread of harmful aquatic organisms from one region to another, by establishing standards and procedures for the management and control of ships' ballast water and sediments.	All ballast water exchanges undertaken during the project will be managed in accordance with the convention.
Convention on the Control of Harmful Anti-fouling Systems on Ships (IMO 2001)	The convention prohibits the use of harmful organotins in anti-fouling paints used on ships and establishes a mechanism to prevent the potential future use of other harmful substances in anti-fouling systems.	The project will comply with the anti-fouling requirements of this convention.
The Paris Agreement	The Paris Agreement aims to strengthen the global response to climate change by keeping a global temperature rise this century well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change. The Paris Agreement entered into force on 4 November 2016.	ConocoPhillips will undertake the sustainable development of its activities with regard to the contemporary international policy position on climate change.

Table A-3: Guidelines and codes of practice

Guidelines, standards and codes	Summary	Relevance to project
Australian Ballast Water Management Requirements (DoAWR)	These guidelines state the mandatory ballast water requirements and provide information on ballast pump tests, ballast water reporting and ballast water exchange calculations.	All ballast water exchanges undertaken during the project will be managed in accordance with Australian ballast water requirements. Specifically, all ballast water exchanges will be conducted > 12 nm from land and in > 200 m water depth and ballast water exchange records will be maintained.
Offshore Petroleum Installations – Biosecurity Guide (DoAWR 2016)	This document provides the offshore petroleum industry with guidance on Australian biosecurity requirements.	All offshore facilities, in-water equipment and vessels associated with the drilling campaign will comply with the requirements of this guidance document.
Environmental Management in Oil and Gas Exploration and Production 1997 – United Nations Environment Program Industry and Environment and the Oil Industry International Exploration and Production Forum	Provides an overview of the environmental issues and the technical and management approaches to achieving high environmental performance in oil and gas exploration and production.	ConocoPhillips recognises the environmental issues posed by oil and gas production and broadly follows the proposed management approaches for achieving high environmental performance.
EPBC Act Policy Statement 2.1 - Interactions between offshore seismic activities and whales (September 2008)	This Policy Statement provides practical standards to minimise the risk of acoustic disturbance and injury from seismic sources to whales. The Policy Statement also provides advice to operators conducting seismic surveys on their legal responsibilities under the EPBC Act.	This Policy Statement becomes relevant should seismic surveying be undertaken as part of the project. All management measures will be adhered during seismic activities, including pre-start observations, pre-caution zones, standard management procedures and, where necessary, additional management procedures.
APPEA Code of Environmental Practice 2008	The APPEA Code of Environmental Practice provides an outline of environmental objectives which represent guidance on key aspects of good environmental practice in the petroleum industry.	ConocoPhillips recognises the need to avoid, minimise and manage impacts to the environment and broadly follows the recommendations presented in the code of practice.

Guidelines, standards and codes	Summary	Relevance to project
NOPSEMA Offshore Project Proposal Content Requirements Guidance Note (N-04750-GN1663, Revision 1, August 2016)	The guidance note seeks to assist proponents in preparing an OPP in accordance with the OPGGS (E) Regulations by providing an overview of the content requirements of an OPP.	ConocoPhillips has developed the Barossa OPP in accordance with the guidance provided.
NOPSEMA Offshore Project Proposal Assessment Policy (N-04790-PL-1650, Revision 0, August 2016)	The purpose of the policy is to provide a documented, systematic and consistent approach for conducting the assessment of OPPs. The policy also clarifies the requirements and NOPSEMA advice that proponents must take into consideration during the preparation of OPP submissions.	ConocoPhillips has developed the Barossa OPP in accordance with the policy.
NOPSEMA Consultation requirements under the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 Information Paper (N-04750-IP1411, Rev 2, December 2014)	The information paper seeks to provide guidance to titleholders with regard to consultation requirements of the OPGGS (E) Regulations.	While the information paper focusses on consultation requirements applicable to EPs and does not discuss the processes for public comment in an OPP context, the consultation principles outlined provide guidance on how the consultation process may be undertaken in a meaningful and transparent manner with regard to the offshore projects.
NOPSEMA Assessment of Environment Plans: Deciding on Consultation Requirements Guidance Note (N-04750-GL1629, Rev 0, April 2016)	This guideline describes NOPSEMA's consideration of consultation requirements when assessing EPs with the aim of assisting the public, titleholders and consulted parties gain a broader understanding of NOPSEMA's interpretation of consultation requirements of the OPGGS (E) Regulations.	

Appendix B.

Water quality field survey report (Jacobs 2016a)

Barossa Environmental Studies

ConocoPhillips

Water Quality Field Survey Report

WV04831-NMS-PR-0013 | Rev 2

18 August 2016

Barossa Environmental Studies

Project no:	WV04831 (IW021200)
Document title:	Water Quality Field Survey Report – Autumn
Document No.:	WV04831-NMS-PR-0013
Revision:	Rev 2
Date:	18 August 2016
Client name:	ConocoPhillips
Project manager:	Arne de Vos
Author:	Celeste Wilson
File name:	T:\Transfer\Aug2016\WVES\TMiley\Barossa OPP Tech Appendices\Water Quality Baseline Report_050716_CCW.docx

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Document history and status

Revision	Date	Description	Review	Approved
Rev A	04/06/2015	Technical Review	P Erftemeijer	C Teasdale
Rev A	05/06/2015	Editorial Review	J Phillips	C Teasdale
Rev 0	08/06/2015	Issue to client	T Mitchell	C Teasdale
Rev 1	08/07/2015	Final Report	T Mitchell	C Teasdale
Rev 2	18/08/2016	Revised Final	A de Vos	A de Vos

JACOBS

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Important note about this report

The sole purpose of this report and the associated services performed by Jacobs is to undertake the studies in accordance with the scope of services set out in the contract between Jacobs and the Client. That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

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Abbreviations

ALS	Australian Laboratory Services Pty Ltd
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agricultural and Resource Management Council of Australia and New Zealand
AS/NZS	Australian and New Zealand Standards
BETXN	benzene, toluene, ethylbenzene, xylenes (meta-, para- and ortho-xylene) and naphthalene
Bq/L	becquerels per litre
ConocoPhillips	ConocoPhillips Australia Exploration Pty Ltd
GPS	global positioning system
LOR	limit of reporting
MAFRL	Marine and Freshwater Research Laboratory (Murdoch University)
MRL	minimum reporting limit
NATA	National Association of Testing Authorities
NEPM	National Environment Protection Measure(s)
NORM	naturally occurring radioactive material
NT	Northern Territory
NTU	nephelometric turbidity unit
ppb	parts per billion
PSU	practical salinity unit
QC	quality control
SP1-S	sampling point 1 – near-surface water
SP1-M	sampling point 1 – mid-water
SP1-B	sampling point 1 – near-bottom water
spp	species (plural)
TPH	total petroleum hydrocarbon
TRH	total recoverable hydrocarbon
TSS	total suspended solids
˚C	degrees Celsius
µg/L	micrograms per litre

Executive Summary

ConocoPhillips Australia Exploration Pty Ltd (ConocoPhillips) are proposing to develop natural gas resources as part of the Barossa area development, located in waters up to 300 m deep in the Bonaparte Basin, in Commonwealth waters offshore of northern Australia. To develop a robust understanding of the existing marine environmental values of the area to inform any future approvals, a targeted baseline marine studies program is being progressed within and surrounding the Barossa field.

A key component of the baseline marine studies program is a series of water quality surveys during different seasons over a 12-month period. This report summarises the results of the final water quality survey and discusses the results of the three seasonal surveys overall. The seasonal water quality surveys took place during 26–29 June 2014 (winter, or tropical dry season), 18–20 January 2015 (summer or tropical wet season) and 12–15 April 2015 (autumn or tropical transitional).

Seventeen water quality sampling sites were positioned to provide representative coverage of the permit area and areas of regional interest such as shoals and banks. Sites were located in the permit area (five sites, labelled SP1 to SP5), around Evans Shoal (four sites, SP7 to SP10), around Tassie Shoal (four sites, SP11 to SP14), around Lynedoch Bank (three sites, SP15 to SP17) and between the permit area and Evans Shoal (one site, SP6). Sampling sites ranged in depth from around 10 m–30 m on top of shoals and banks through to approximately 280 m in the permit area.

At each site, physico-chemical profiles of the water column were obtained for dissolved oxygen, salinity, temperature, turbidity, pH, chlorophyll *a* and hydrocarbons. Water samples were collected at each site from three depths — near-surface (0–5 m), mid-water and near-bottom (within 5 m of the seabed) — for analysis of nutrients, metals/metalloids, hydrocarbons and naturally occurring radioactive materials (NORMs). Phytoplankton and zooplankton samples were obtained using 20 µm mesh (300 mm diameter) and 100 µm mesh (500 mm diameter) plankton nets, respectively. All water samples were collected, handled, preserved and had holding times in accordance with the recommendations of the Australian and New Zealand Standards (AS/NZS 5667.1:1998).

Autumn survey results were comparable to those recorded during previous (summer and winter) surveys, confirming general patterns, trends and conclusions from those surveys.

Key conclusions from the three seasonal water quality surveys include:

- The depth of the autumn thermocline was similar to winter but deeper than summer. During winter (and autumn), atmospheric cooling at the sea surface produces convective overturning of water and strong, continual winds, which cause the depth of the thermocline to be greater.
- Summer, autumn and winter conditions were similar for concentrations of nutrients (nitrate+nitrite and orthophosphate) and certain metals (arsenic, barium, chromium and nickel) increasing with depth, associated with decomposition of organic matter at depth.
- Generally, nutrients were below ANZECC & ARMCANZ (2000b) trigger values for marine tropical waters in the surface water of all sites but above trigger values in the mid-water and bottom water of the deepest sites. Nutrients are released when organic compounds decay and oxygen is consumed, which was evident in the bottom water of the deepest sites in the permit area where phosphorus and nitrate concentrations were high and oxygen levels were low.
- No dissolved metal samples exceeded the ANZECC & ARMCANZ (2000a) trigger value for 99% species protection, except for copper in four samples in winter and five samples in summer being slightly higher than the ANZECC & ARMCANZ (2000a) trigger value of 0.3 µg/L.
- Total recoverable hydrocarbons and benzene, toluene, xylenes (meta-, para- and ortho-xylene) and naphthalene were below the laboratory reporting limits at all sites and depths for each season. There was little difference in the hydrocarbon profiles between sites, which indicates a lack of hydrocarbons in the areas sampled.

- Radium^{226} and radium^{228} were above the minimum reporting limit (MRL) at a number of sites during the three surveys, while thorium^{228} was below the MRL. There are no ANZECC & ARMCANZ (2000a) trigger values associated with NORMs but the concentrations detected in these surveys were below the NHMRC & ARMCANZ (2011) drinking water guidelines.

- *Trichodesmium erythraeum* (blue-green alga) was the phytoplankton species captured in highest abundance at most sites during each season. Dinoflagellates were the most diverse group during the autumn survey, whereas diatoms were the most diverse group during summer and winter surveys. The phytoplankton assemblage composition in autumn was similar to summer and winter, although silicoflagellates were only present during winter and cryptomonads were only present during summer and autumn.

- Copepods were the most abundant zooplankton collected during each season. Copepods also displayed the highest species diversity whereas the majority of other Classes contained only one species.

Generally the data collected during the three seasonal surveys were typical of water quality in offshore environments distant from emergent reefs (Gilmour et al. 2013, Heyward et al. 1997) and consistent with our previous observations in deep, offshore waters in the Browse Basin (SKM 2014).

1. Introduction

1.1 Background

ConocoPhillips Australia Exploration Pty Ltd (ConocoPhillips), as proponent on behalf of the current and future joint ventures, are proposing to develop natural gas resources as part of the Barossa area development, located approximately 300 kilometres (km) north of Darwin, Northern Territory (NT).

To facilitate the environmental approvals process for any future development of the Barossa field and surrounds, a robust understanding of the existing state of the key environmental values and sensitivities will be necessary. This understanding will be gained from a series of studies and surveys to assess and monitor the baseline state of environmental factors such as water quality, sediment quality, noise, metocean conditions and benthic habitats within petroleum retention lease permit NT/RL5 (referred to as the 'permit area' in this report) and across a broader geographical area. The field studies assessing these factors commenced in June 2014.

1.2 Overview of existing regional environment

The Barossa area is located in the North Marine Region (Department of Sustainability, Environment, Water, Population and Communities 2012), which comprises the Commonwealth waters of the Gulf of Carpentaria, Timor Sea and Arafura Sea as far west as the NT and Western Australian border. The Northern Marine Region contains internationally significant breeding and/or feeding grounds for a number of listed threatened and migratory marine species, including nearshore dolphins, turtles, dugongs, seabirds and migratory shorebirds afforded protection under national legislation and international conventions.

The Timor and Arafura Seas support a variety of shark, pelagic finfish and crustacean species of commercial and recreational game-fishing importance, e.g. trawl and various finfish fisheries. The shelf break and slope of the Arafura Shelf is characterised by patch reefs and hard substrate pinnacles that support a diverse array of invertebrate groups, with polychaetes and crustaceans being the most prolific (Heyward et al. 1997, CEE 2002). Surveys indicate that between 50 m and 200 m depth, the seabed consists of predominantly soft, easily resuspended sediments (Heyward et al. 1997, URS 2005, 2007). The diversity and coverage of epibenthos is low and organisms present are predominantly sponges, gorgonians and soft corals (Heyward et al. 1997, URS 2005, 2007).

Numerous shoals (submerged calcareous banks or 'seamounts') exist in the broader region around the permit area; the closest being Evans Shoal, 60 km to the west and Tassie Shoal, 70 km south-west, and Lynedoch Bank, 40 km to the south-east. In addition, the new Oceanic Shoals Commonwealth marine reserve (multiple use zone) lies to the south and south-east of the permit area.

1.3 Objectives

Water quality surveys are a key component of the Barossa marine baseline studies program.

Baseline studies were undertaken with reference to the permit area, as shown in **Figure 1-1**. While this represents the area of primary interest as part of ConocoPhillips' staged field development, the broader surrounds were also characterised, including the nearest seabed features of regional interest to the Barossa area (i.e. Evans Shoal, Tassie Shoal and Lynedoch Bank).

The survey was completed during different seasonal conditions over a 12-month period. The specific objectives of the marine water quality surveys were to:

- determine the water quality of the marine waters within the permit area and in the vicinity of Evans Shoal, Tassie Shoal and Lynedoch Bank
- determine any seasonal variation in water quality.

This report summarises the results of the water quality surveys undertaken in:

- mid to late January 2015 in the northern Australian summer (tropical wet)
- mid-April 2015 during the northern Australian autumn (tropical transitional).
- end June 2014 during the northern Australian winter (tropical dry season).

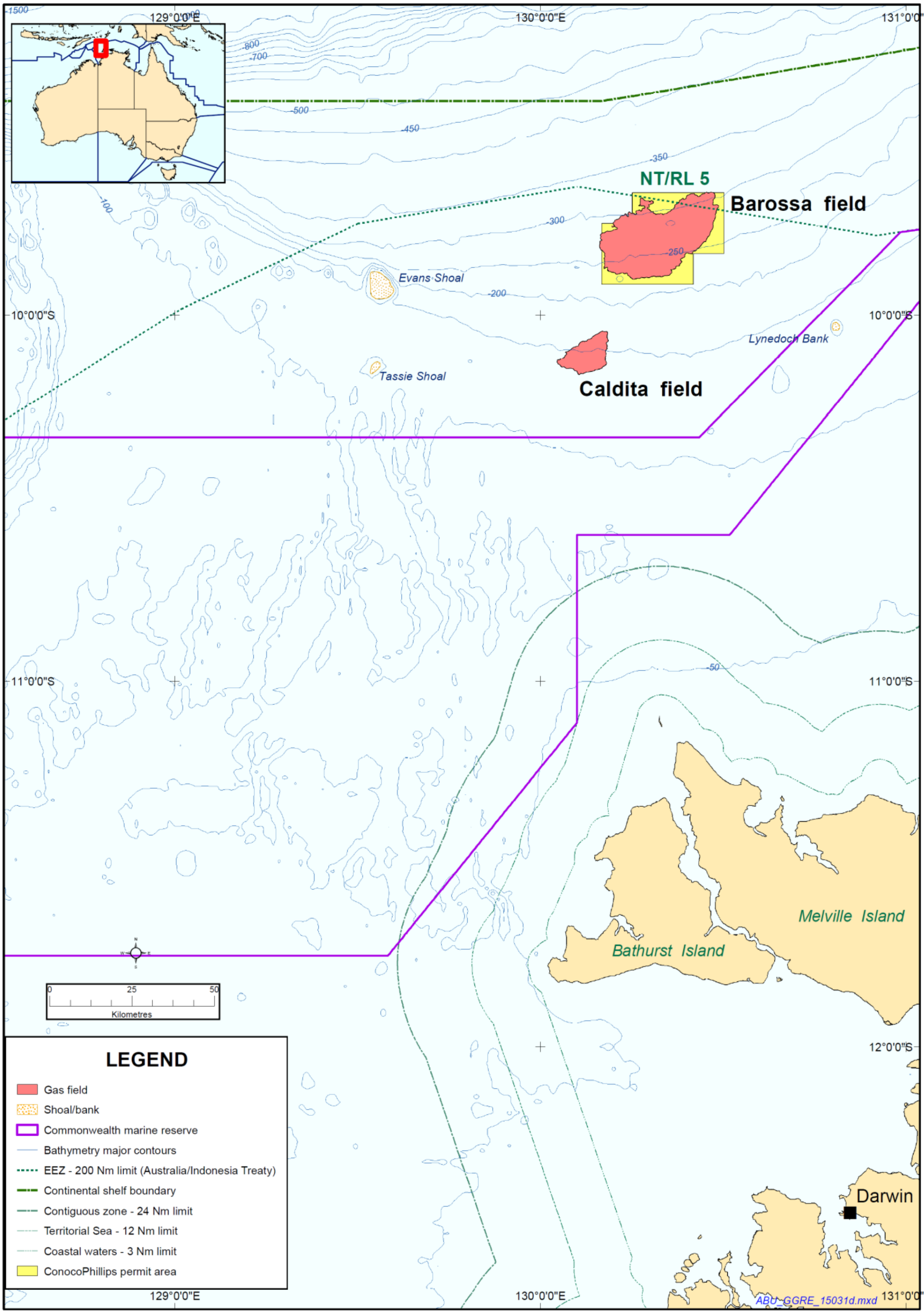


Figure 1-1: Barossa field location

2. Methods

The methods employed during the autumn water quality survey follow those detailed in the *Barossa Environmental Studies: Water Quality Field Sampling Plan Method Statement* (Jacobs 2014). A brief overview of the methods is provided in the sections below.

2.1 Water quality sampling sites

Seventeen sampling sites (**Table 2-1**, **Figure 2-1**) were positioned to provide coverage of the permit area and of areas of regional interest such as shoals and banks. Sites were located at:

- the permit area (five sites, labelled SP1 to SP5)
- Evans Shoal, approximately 60 km west of the permit area (four sites, SP7 to SP10)
- Tassie Shoal, approximately 70 km south-west of the permit area (four sites, SP11 to SP14)
- Lynedoch Bank, approximately 40 km south-east of the permit area (three sites, SP15 to SP17)
- between the permit area and Evans Shoal, approximately 20 km west of the permit area (one site, SP6).

The number of sites sampled is considered appropriate to characterise the water quality in the permit area and broader surrounds. Some sites were not able to be sampled during each survey (**Table 2-1**). Due to inclement weather during the winter water quality survey, not all of the sites listed above were able to be visited, and therefore sites SP8, SP9, and SP15 to SP17 were not sampled. Due to a malfunction in the zooplankton and phytoplankton equipment during the autumn survey, sites SP2, SP4, SP9, SP12 and SP15 were not able to be sampled.

2.2 Timing

Three water quality surveys were undertaken:

- 26 to 29 June 2014, during the northern Australian (tropical dry) winter
- 18 to 20 January 2015, during the northern Australian (tropical wet) summer
- 12 to 15 April 2015, during the northern Australian (tropical transitional) autumn.

2.3 Water column profiles

At each of the sites sampled during the surveys, physico-chemical profiles of the water column were obtained for:

- dissolved oxygen
- salinity
- temperature
- turbidity
- total suspended solids (TSS) (summer and winter surveys only)
- pH
- chlorophyll *a* (winter and autumn surveys only)
- hydrocarbons.

Parameters were measured using an SBE 19plus V2 SeaCAT profiler (Sea-Bird Electronics) with auxiliary sensors, lowered through the water column at approximately half a metre per second. All sensors were calibrated at the Marine and Freshwater Research Laboratory prior to the field survey commencing. A calibration certificate for each of the sensors can be found in **Appendix A**. Depth was recorded at all sites.

2.4 Water quality sampling

2.4.1 Sample collection

Water samples were collected from three depths at each site, from near-surface (2–5 m), mid-water (half the bottom depth) and near-bottom (within 5 m of the seabed). Samples were collected using 10 L Niskin bottles, arranged in a daisy chain to facilitate the collection of replicate mid-water and near-bottom samples. For surface water samples, a single 10 L Niskin bottle was lowered to 2–5 m below the surface. For sites <30 m deep, only surface and near-bottom water samples were collected.

Table 2-1: Water quality site coordinates and sampling overview

Site name	Sample type[1]						Coordinates (DDD° MM' SS.SSS")[2]	
	Water column profiles[3]	Nutrients	Metals	Hydrocarbons[4]	Radioactive materials[5]	Phytoplankton and zooplankton	Latitude	Longitude
Permit area								
SP1	✓	✓	✓	✓	✓	✓	9° 43' 30.129" S	130° 28' 54.041" E
SP2	✓	✓	✓	✓	✓	✓#	9° 44' 55.592" S	130° 20' 31.955" E
SP3	✓	✓	✓	✓	✓	✓	9° 45' 43.841" S	130° 10' 48.070" E
SP4	✓	✓	✓	✓	✓	✓#	9° 54' 17.419" S	130° 10' 43.252" E
SP5	✓	✓	✓	✓	✓	✓	9° 53' 17.222" S	130° 24' 19.322" E
SP6[6]	✓	✓	✓	✓	✓	✓	9° 48' 44.030" S	129° 58' 5.259" E
Evans Shoal								
SP7	✓	✓	✓	✓	✓	✓	9° 55' 2.690" S	129° 33' 38.636" E
SP8*	✓	✓	✓	✓	✓	✓	9° 57' 7.960" S	129° 32' 5.857" E
SP9*	✓	✓	✓	✓	✓	✓#	9° 56' 21.446" S	129° 36' 11.536" E
SP10	✓	✓	✓	✓	✓	✓	9° 51' 25.533" S	129° 32' 5.302" E
Tassie Shoal								
SP11	✓	✓	✓	✓	✓	✓	10° 7' 59.795" S	129° 33' 0.096" E
SP12	✓	✓	✓	✓	✓	✓#	10° 3' 49.966" S	129° 28' 40.532" E
SP13	✓	✓	✓	✓	✓	✓	10° 11' 44.040" S	129° 39' 46.178" E
SP14	✓	✓	✓	✓	✓	✓	10° 14' 57.851" S	129° 46' 5.394" E
Lynedoch Bank								
SP15*	✓	✓	✓	✓	✓	✓#	10° 0' 30.772" S	130° 46' 39.566" E
SP16*	✓	✓	✓	✓	✓	✓	10° 1' 38.218" S	130° 48' 34.785" E
SP17*	✓	✓	✓	✓	✓	✓	10° 2' 25.991" S	130° 50' 15.953" E

[1] Refer to **Section 2.4.2** for full details.

[2] Datum = GDA94.

[3] TSS was only sampled during the summer survey

[4] Total recoverable hydrocarbons, total petroleum hydrocarbons and BTEXN**.**

[5] Naturally occurring radioactive materials (NORMs).

[6] Located between the permit area and Evans Shoal.

* Sites were not sampled during the winter survey due to inclement weather.

Sites were not sampled during the autumn survey due to equipment malfunction.

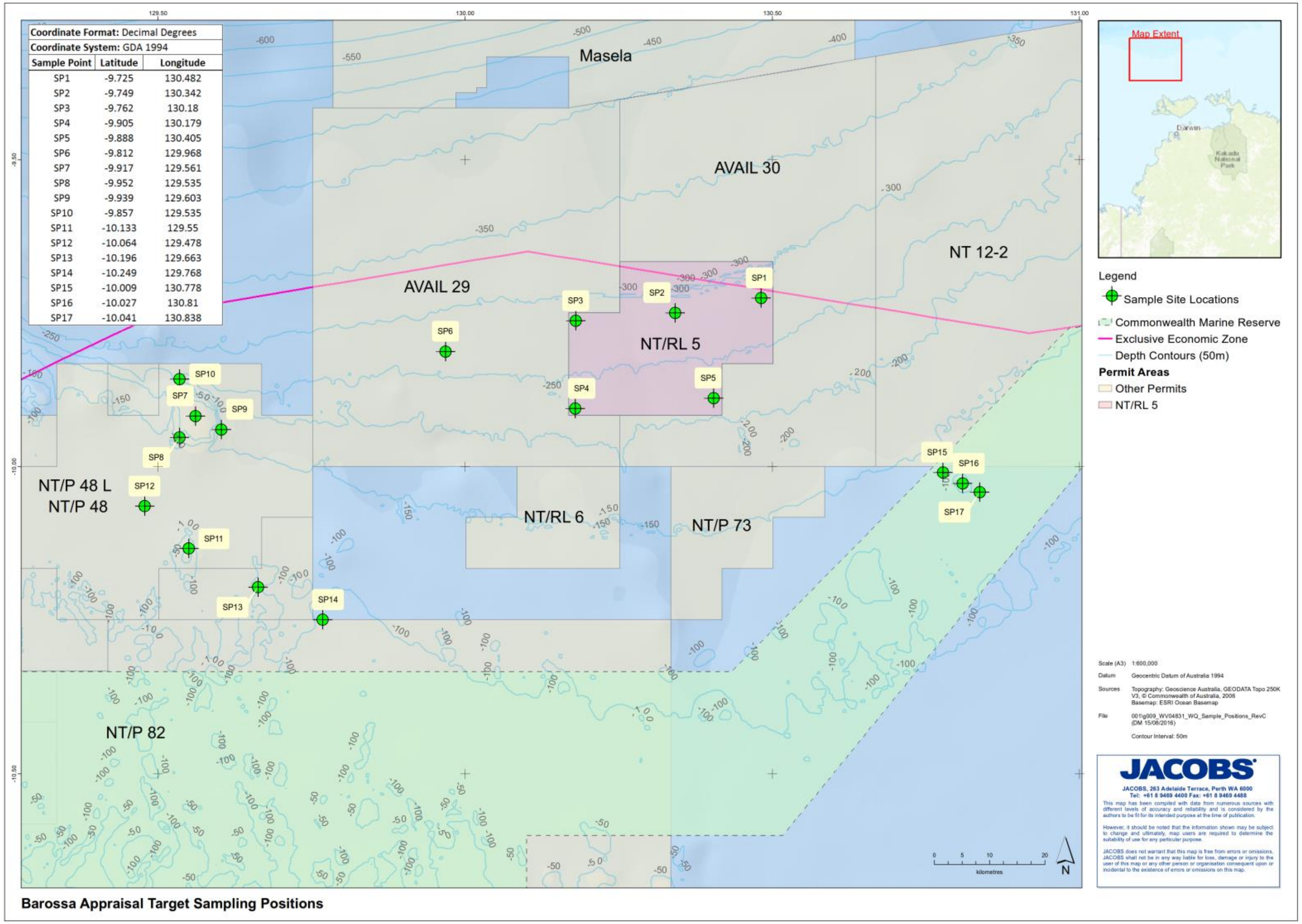


Figure 2-1: Water quality sampling site locations

2.4.2 Sample processing, preservation and storage

All samples were preserved and handled in accordance with Australian and New Zealand Standard (AS/NZS) 5667.1:1998 and with the requirements of the analytical laboratories. The location of the sampling sites was considered remote and therefore the preservation techniques were selected to achieve the maximum allowable holding times for each parameter. For example, the holding time for hydrocarbons is seven days; therefore, these samples were collected late in the survey to allow Jacobs' personnel to transport the samples back to Perth to be hand delivered to the appropriate laboratory in time to meet the holding time requirements.

Samples were stored in laboratory-supplied bottles/containers, with preservatives added where appropriate, and labelled with the site name and depth, the date and the analysis required. All samples collected were recorded on a field sheet and then stored under the required conditions and holding times until delivery to the laboratories (**Table 2-2**). Samples were delivered to the appropriate National Association of Testing Authorities (NATA) accredited laboratories (**Table 2-3**) along with a chain of custody form requesting the analysis required.

Water samples for pigments (chlorophyll *a* and phaeophytin), nutrients and dissolved metals/metalloids were filtered on board the vessel. For pigment samples, 0.2 µm GF/F filter papers were retained and frozen after a known volume of water sample had been filtered. Dissolved nutrient and dissolved metals samples were filtered directly into pre-rinsed sample containers. Nutrient samples were frozen until delivery to the laboratory whereas metals sample bottles had the appropriate acid added prior to sample collection and were then kept cool (approximately 4°C) during transportation.

Hydrocarbon samples were processed on board the vessel by filling sample bottles to the top, leaving minimal air space, and refrigerating until delivery to the laboratory. For the more volatile hydrocarbons (benzene, toluene, ethylbenzene, xylenes (meta-, para- and ortho-xylene) and naphthalene (BTEXN) and total petroleum hydrocarbon (TPH) (C_6–C_9)), sample bottles contained sulfuric acid preservative.

Samples for naturally occurring radioactive materials (NORMs) were processed on board the vessel by adding unfiltered water to sample bottles containing nitric acid as a preservative. Samples were kept cool until delivery to the laboratory.

2.4.3 Sample analysis

Analytes and their respective laboratory limits of reporting (LOR), 99% species protection guideline trigger value (ANZECC & ARMCANZ 2000a) and low reliability values for contaminants having insufficient data to derive reliable national guidelines (ANZECC & ARMCANZ 2000b) are presented in **Table 2-2**. All analyses were undertaken using standard methods at NATA-accredited laboratories.

2.4.4 Data analysis

Nutrient and pigment values were compared to ANZECC & ARMCANZ (2000b) trigger values for Western Australian tropical offshore waters, as Northern Territory values were not supplied. All other values were compared to ANZECC & ARMCANZ (2000a) trigger values for marine water with a 99% level of species protection where available. In some cases where no high reliability trigger value was available, low reliability trigger vales were used as indicative working levels.

2.4.5 Quality control procedures

To test for potential sample contamination during collection, storage or transport, low analyte concentration water samples were provided by the laboratories to be split in two ways:

- transport blank: to estimate any contamination introduced to the sample during the transportation and storage stage, low analyte water was poured directly into the sample containers at the laboratory with no filtering or handling.
- field blank: to estimate any contamination introduced to the sample during the collection procedure. This involved following the same sampling procedure using the low analyte water instead of the sample seawater.

Quality control procedures that related to the water sampling were:

- sun cream/zinc and any other potential anthropogenic contaminants were avoided by the personnel in contact with the water sampling equipment
- smoking was prohibited in the sampling area
- care was taken to not open the bottles containing nitric acid while bottling or filtering nutrient samples
- as far as possible, the insides of the sample container lids did not come in contact with any potentially contaminated surfaces or substances (such as hands, workbenches or vessel emissions)
- hands did not come into contact with the insides or lip of the bucket or sample bottles, the tip of the syringe or of the syringe filters.

Procedural and record-keeping quality control measures implemented were:

- global positioning system (GPS) waypoints were recorded for all sites sampled from the vessel
- site locations and samples collected were logged onto field sheets
- appropriate chain of custody forms to accompany samples were completed for each laboratory
- any changes to the field procedures were documented.

2.5 Phytoplankton and zooplankton

Phytoplankton and zooplankton samples were collected at selected sites within each location (**Figure 2-1**):

- permit area and surrounds – sites SP1, SP3, SP5 and SP6
- Evans Shoal – sites SP7, SP8 and SP10
- Tassie Shoal – sites SP11, SP13 and SP14
- Lynedoch Banks – sites SP16 and SP17.

At each site, a zooplankton net (100 µm mesh, 500 mm diameter) was towed at a speed of less than one knot behind the vessel along designated transects of approximately 300 m long. GPS coordinates were recorded at the start and end of every tow (**Appendix B**). A phytoplankton net (20 µm mesh, 300 mm diameter) was suspended on the vessel, as 40 L of surface seawater collected at the transect start was poured through the net. A 125 mL 'raw' (not concentrated) sample of seawater was also collected at each of these sites to aid in the identification of phytoplankton species. This phytoplankton method eliminates the potential for species to be excluded from the net due to the speed of the tow coupled with the very fine mesh size.

Once sampling was completed, the phytoplankton sample was rinsed into the cod end of the net with seawater and transferred to a labelled sample container, adding Lugol's solution to a final concentration of 1%. Lugol's was also added to the raw phytoplankton sample to achieve the same final concentration. The zooplankton sample was rinsed into the cod end of the net with seawater and concentrated by pouring the sample into a 100 µm sieve. The contents of the sieve were then washed into a labelled sample container with 75% ethanol. Phytoplankton and zooplankton samples were kept refrigerated in the dark until delivery to the laboratory for taxonomic identification. All samples were accompanied by a chain of custody form requesting the appropriate analysis. The parameters and laboratory used to undertake the analyses are summarised in **Table 2-3**.

Table 2-2: Analytical limits of reporting (LOR), trigger values and sample storage, preservation and holding times

Test parameter	Guideline (µg/L)[1]	LOR (µg/L)	Storage container	Preservation	Holding time
Total nitrogen	140[5]	50	Polypropylene	Freeze	1 month
Total phosphorus	10[6]	5	Polypropylene	Freeze	1 month
Ammonium	4[6]	3	Polypropylene	Filter on site (0.45 µm filter) and freeze	1 month
Nitrate+nitrite	4[6]	2	Polypropylene	Filter on site (0.45 µm filter) and freeze	1 month
Orthophosphate	5[6]	2	Polypropylene	Filter on site (0.45 µm filter) and freeze	1 month
Chlorophyll *a* and phaeophytin	0.5–0.9	0.1	Seed envelope	Filter on site (GFF filter) and freeze residue	1 month
TSS	—	0.5	Seed envelope	Filter on site (GFC filter) and freeze residue	1 month
Arsenic	4.5[2]	0.5	Polypropylene	Acidify with nitric acid to pH 1 to 2	1 month
Barium	—	0.5	Polypropylene	Acidify with nitric acid to pH 1 to 2	1 month
Cadmium	0.7	0.1	Polypropylene	Acidify with nitric acid to pH 1 to 2	1 month
Chromium	7.7[4]	0.2	Polypropylene	Acidify with nitric acid to pH 1 to 2	1 month
Cobalt	1.0[3]	0.05	Polypropylene	Acidify with nitric acid to pH 1 to 2	1 month
Copper	0.3	0.2	Polypropylene	Acidify with nitric acid to pH 1 to 2	1 month
Mercury	0.1	0.1	Amber glass with Teflon cap liner	Acidify with nitric acid to pH 1 to 2 and add potassium dichromate	1 month
Nickel	7	0.3	Polypropylene	Acidify with nitric acid to pH 1 to 2	1 month
Lead	2.2	0.1	Polypropylene	Acidify with nitric acid to pH 1 to 2	1 month
Zinc	7	1	Polypropylene	Acidify with nitric acid to pH 1 to 2	1 month
BTEXN	5-500[2]	1-2	Amber glass with Teflon cap liner	Acidify with sulphuric acid and chill to 4°C	1 week
TPH (C_{10}–C_{36})	7[2]	20–100	Amber glass with Teflon cap liner	Chill to 4°C	1 week
PAHs	0.01-50[2]	0.5–1.0	Amber glass with Teflon cap liner	Chill to 4°C	1 week
$Radium^{226}$	—	0.1 Bq/L	Polypropylene	Acidify with nitric acid to pH 1 to 2	2 months
$Radium^{228}$	—	0.1 Bq/L	Polypropylene	Acidify with nitric acid to pH 1 to 2	2 months
$Thorium^{228}$	—	0.1 Bq/L	Polypropylene	Acidify with nitric acid to pH 1 to 2	2 months

[1] ANZECC & ARMCANZ (2000a) 99% species protection value unless otherwise specified.
[2] ANZECC & ARMCANZ (2000b) Low reliability trigger value.
[3] ANZECC & ARMCANZ (2000a) 95% species protection value.
[4] ANZECC & ARMCANZ (2000a) Chromium III trigger value.
[5] ANZECC & ARMCANZ (2000b) winter values (tropical Australian offshore waters)
[6] ANZECC & ARMCANZ (2000b) summer values (tropical Australian offshore waters)

Table 2-3: Analytes and the corresponding analytical laboratory

Parameter	Laboratory[1]
Total nitrogen (TN), total phosphorus (TP)	MAFRL
Orthophosphate (FRP), nitrate+nitrite (NO_x), ammonium (NH_4)	MAFRL
Pigments (chlorophyll *a* and phaeophytin)	MAFRL
Total suspended solids (TSS)	MAFRL
Total petroleum hydrocarbons (TPHs)/total recoverable hydrocarbons (TRHs)	ALS
Benzene, toluene, ethylbenzene, xylenes (meta-, para- and ortho-xylene) and naphthalene (BTEXN)	ALS
Polycyclic aromatic hydrocarbons (PAHs; only where TPHs detected)	ALS
NORMs (radium^{226}, radium^{228} and thorium^{228})	Western Radiation
Trace metals/metalloids (As, Ba, Cd, Cr, Co, Cu, Hg, Ni, Pb, Zn) (filtered and unfiltered)	MAFRL
Phytoplankton – full count Utermohl	Dalcon Environmental
Zooplankton – lowest level Sedgwick-Rafter counting cell	Dalcon Environmental

[1] MAFRL – Marine and Freshwater Research Laboratory, ALS – Australian Laboratory Services.

3. Results

3.1 Water column profiles

3.1.1 Depth

The deepest sites were within the permit area and ranged from 204 m at SP5 in winter to 282 m at SP3 in winter (**Table 3-1**). Water depths at Evans Shoal ranged from shallow (25 m) on top of the shoal at SP7 in autumn to 207 m at SP10 in summer. Depths were generally shallower at Tassie Shoal ranging from 11 m on top of the shoal at SP11 in summer to 108 m at SP12 in winter, and at Lynedoch Bank, where sites ranged from 14 m at SP16 in autumnr to 125 m at SP15 in summer.

Table 3-1: Water depths of the various sites sampled during the water quality surveys

Site	Permit area Depth (m)			Site	Evans Shoal Depth (m)			Site	Tassie Shoal Depth (m)			Site	Lynedoch Bank Depth (m)		
	W	S	A		W	S	A		W	S	A		W	S	A
SP1	277	271	274	SP7	27	26	25	SP11	16	11	14	SP15	NS	125	122
SP2	279	281	279	SP8	NS	78	69	SP12	108	101	102	SP16	NS	16	14
SP3	282	281	278	SP9	NS	160	113	SP13	100	99	98	SP17	NS	114	115
SP4	226	224	221	SP10	206	207	200	SP14	100	100	99				
SP5	204	211	210												
SP6	271	270	276												

W = winter, S = summer, A = autumn.

NS = no sample due to inclement weather conditions.

3.1.2 Dissolved oxygen

Winter

The percentages of dissolved oxygen in the surface water at the various sites in and near the permit area (SP1 to SP6) were approximately 96% (**Figure 3-1**). In general, the dissolved oxygen remained fairly constant at 96% to approximately 70 m depth, at which the dissolved oxygen rapidly declined to 50% at approximately 100 m. There was a gradual decline of dissolved oxygen after this point to the lowest level, which was approximately 35% in the bottom water.

The percentages of dissolved oxygen at sites around Evans Shoal and Tassie Shoal, although on the whole shallower than sites in the permit area, still exhibited a similar vertical distribution pattern according to the depth of the site (**Figure 3-1**). For example the dissolved oxygen of the very shallow sites, SP7 and SP11 in less than 30 m depth did not change from top to bottom. At other sites SP12, SP13 and SP14, at approximately 100 m depth, had similar percentages of dissolved oxygen from the surface to 80 m which then declined rapidly to the seabed.

Summer

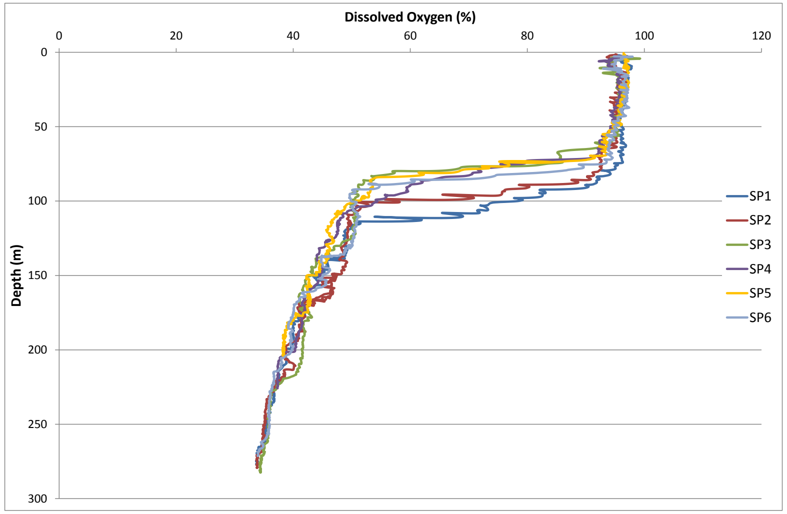
Dissolved oxygen was approximately 90% in the surface water at the various sites in and near the permit area (SP1 to SP6) (**Figure 3-2**). In general, the dissolved oxygen remained relatively constant from the surface to around 45 m deep at most sites and to 60 m deep at SP1 and SP2. There was a rapid decrease in dissolved oxygen at sites SP3, SP4 and SP6 from 90% to 70% at approximately 60 m depth, and then more gradual decline of dissolved oxygen with increasing depth to the lowest level of approximately 32% in the bottom water. Dissolved oxygen at SP5 decreased rapidly from 90% at 45 m to 42% at 80 m, remained constant until 144 m and then rapidly increased to 55% at 150 m, and then gradually declined to 35% in the bottom water. Similar dissolved oxygen profiles were recorded at sites SP5 and SP6 with the pertinent changes generally occurring in slightly deeper waters.

Although generally shallower than the permit area sites, dissolved oxygen at sites around Evans Shoal, Tassie Shoal and Lynedoch Bank exhibited a similar vertical pattern according to the depth of the site (**Figure 3-2**). For example, dissolved oxygen at the shallowest (<30 m deep) sites, SP7, SP11 and SP16, did not change from surface water to bottom water. At the remaining sites, trends in dissolved oxygen profiles were similar, with a layer of relatively constant dissolved oxygen in surface waters followed by a rapid decline from 90% to 50% over approximately 40 m, and then a further gradual decline to the seafloor.

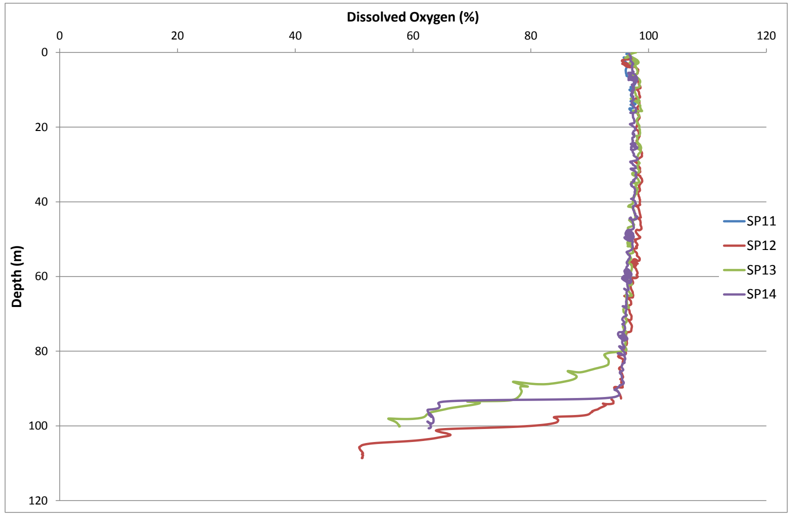
Autumn

Dissolved oxygen saturation was approximately 99% in the surface water at the various sites in and near the permit area (SP1 to SP6) (**Figure 3-3**). In general, the dissolved oxygen remained relatively constant from the surface to approximately 60 m depth at all sites. There was a rapid decrease in dissolved oxygen from 100% to 50% at approximately 100 m and then a more gradual decline of dissolved oxygen with increasing depth to the lowest saturation level of approximately 40% in the bottom water.

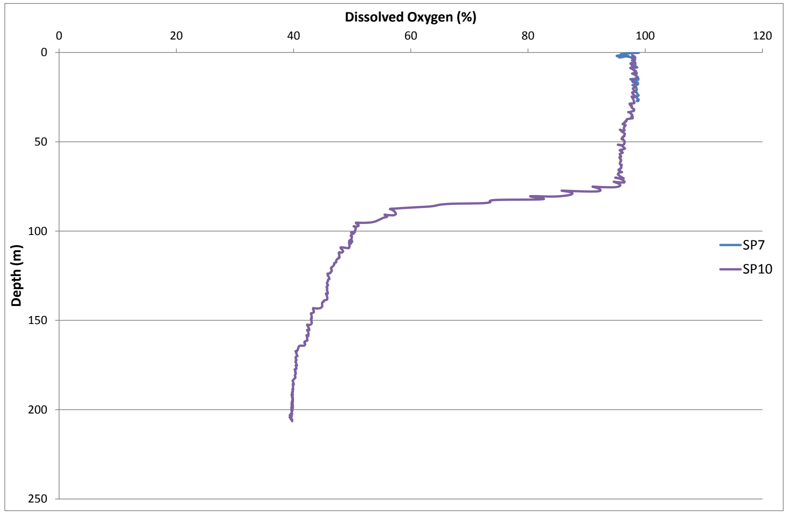
Although generally shallower than the permit area sites, dissolved oxygen at sites around Evans Shoal, Tassie Shoal and Lynedoch Bank exhibited a similar vertical distribution pattern according to the depth of the site (**Figure 3-3**). For example, dissolved oxygen at the shallowest (<30 m deep) sites, SP7, SP11 and SP16, did not change from surface water to bottom water. At the remaining sites, trends in dissolved oxygen profiles were similar to those at the permit area, with a layer of relatively constant dissolved oxygen in surface waters (approximately 60 m) followed by a rapid decline from 100% to 50% over approximately 40 m, and then a further gradual decline to the seafloor.



a) Permit area

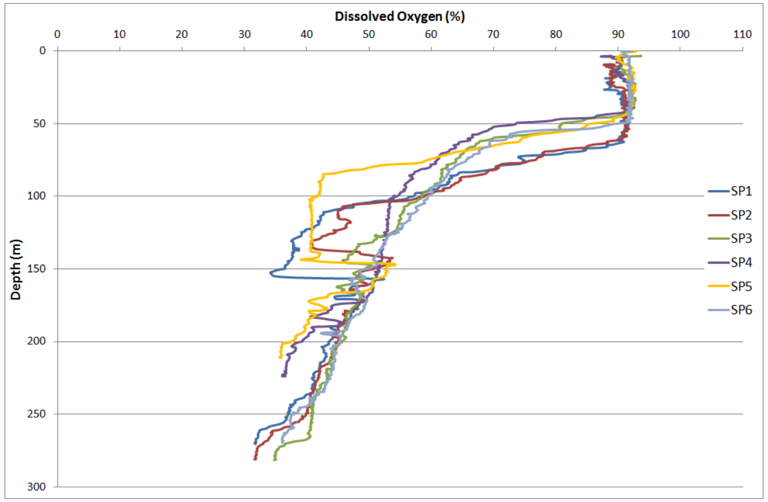


c) Tassie Shoal

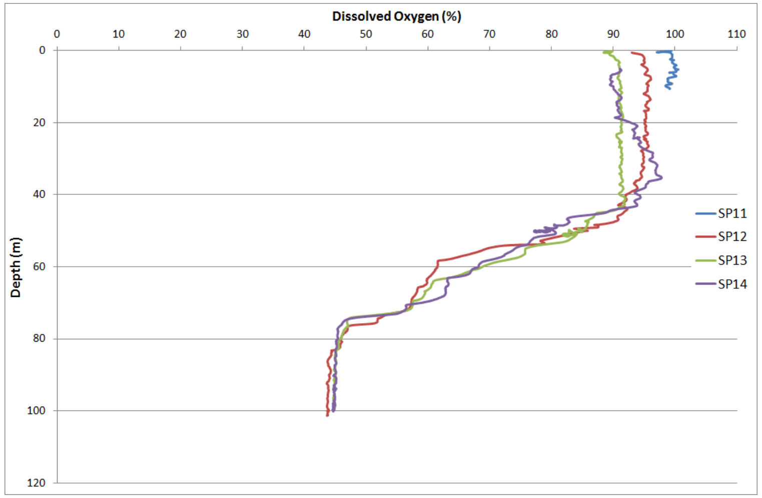


b) Evans Shoal

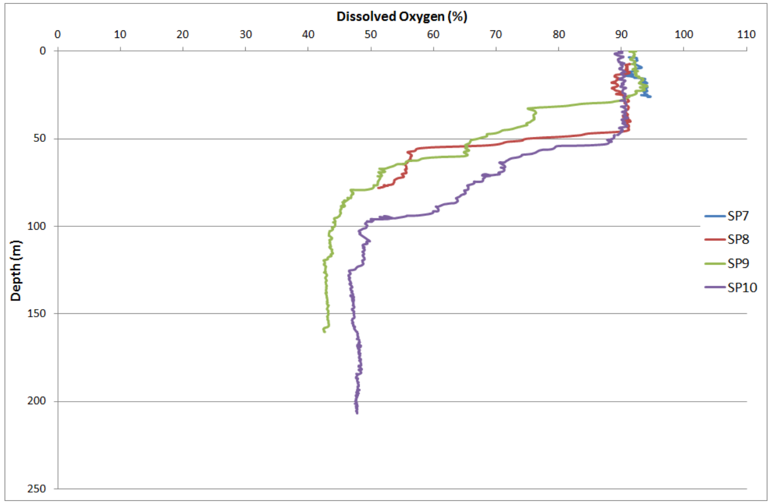
Figure 3-1: Dissolved oxygen profiles – winter



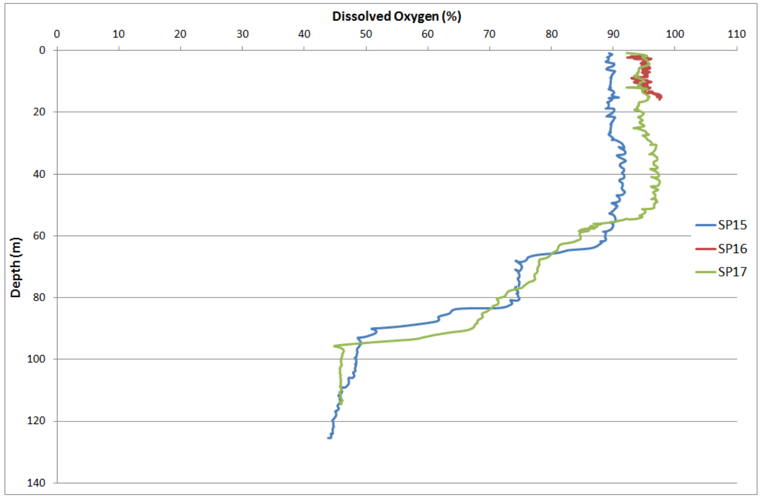
a) Permit area



c) Tassie Shoal

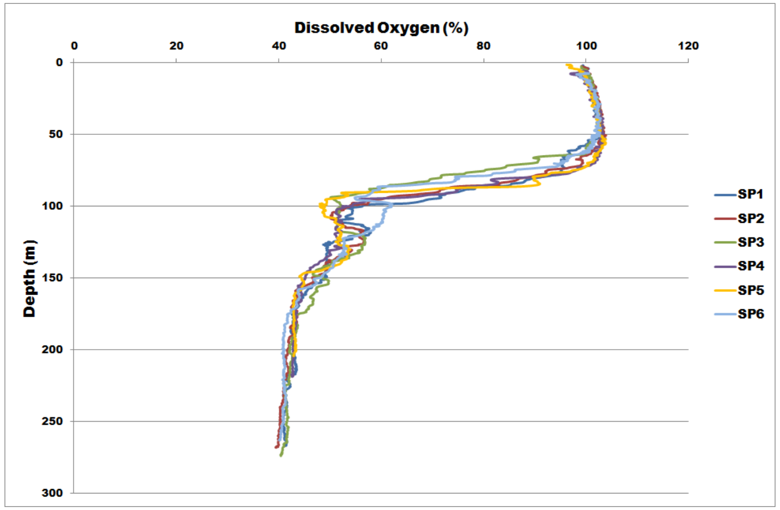


b) Evans Shoal

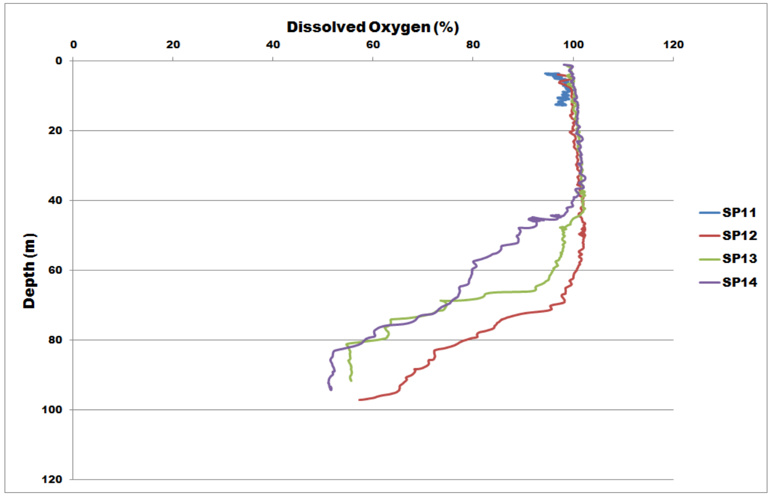


d) Lynedoch Bank

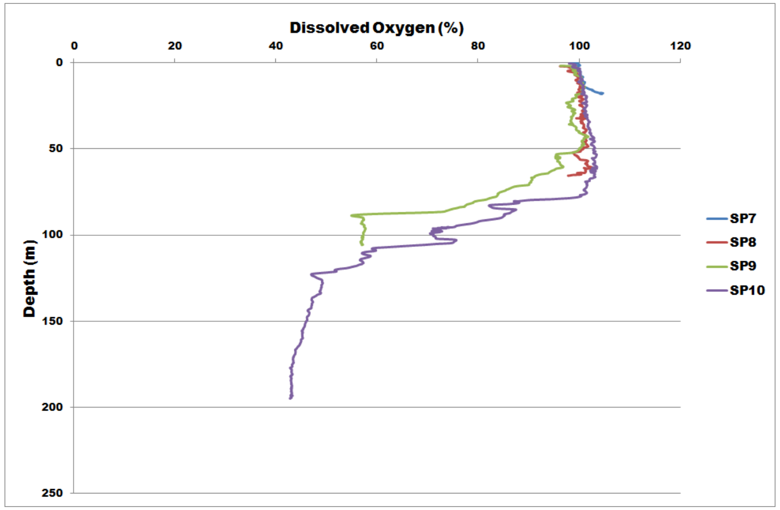
Figure 3-2: Dissolved oxygen profiles – summer



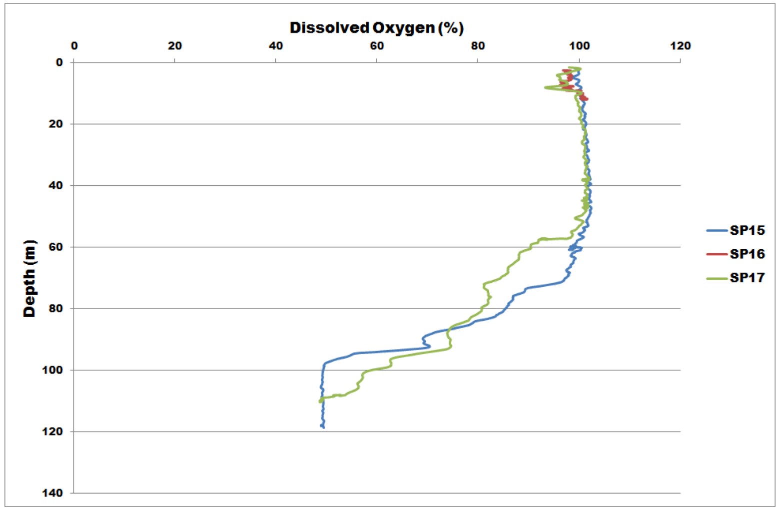
a) Permit area



c) Tassie Shoal



b) Evans Shoal



d) Lynedoch Bank

Figure 3-3: Dissolved oxygen profiles – autumn

3.1.3 Salinity

Winter

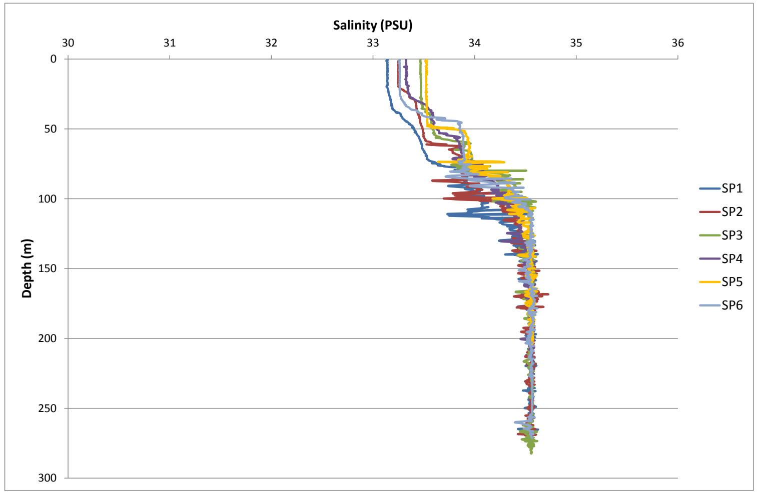
The vertical distributions of the salinity profiles of the various sites from within and around the permit area, Evans Shoal and Tassie Shoal (**Figure 3-4**) were similar depending on the depth of the individual site. Generally, the salinity was stable from the surface to the first 20 to 50 m, with a stepwise increase in salinity to approximately 75 m. After 75 m the salinity was quite erratic until 100 to 120 m then was stable to the seabed. The salinity at the surface ranged from 33.1 to 33.8 PSU depending on the site, which increased to approximately 34.5 PSU at the deepest sites.

Summer

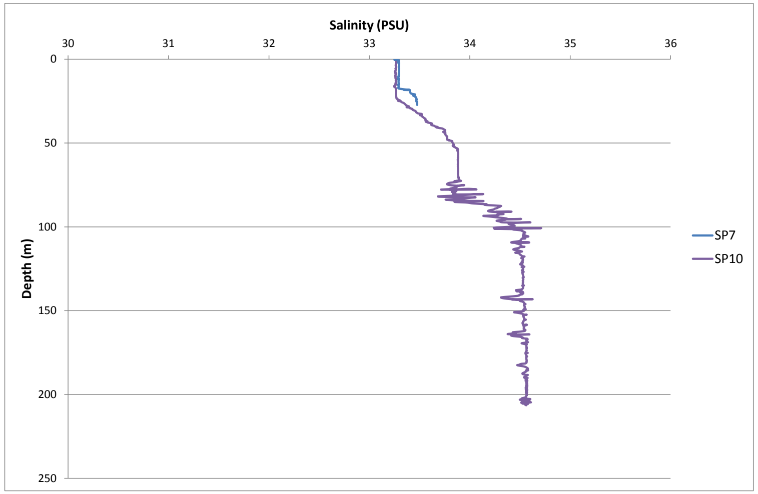
The vertical salinity profiles of the various sites within and around the permit area, Evans Shoal, Tassie Shoal and Lynedoch Bank (**Figure 3-5**) were similar and did not change markedly with depth. Generally, salinity was stable at approximately 34.0 PSU from the surface to 50 m depth and then increased slightly to the seabed. The change in salinity from surface to bottom was minor and depended on the depth of the site. At the shallowest sites (<30 m deep), there was no change in salinity from surface water to bottom water. At the mid-depth sites (approximately 100 m deep) salinity increased by approximately 0.2 PSU from surface to bottom. At the deepest sites (>200 m deep), there was an increase of 0.4 PSU from surface to bottom.

Autumn

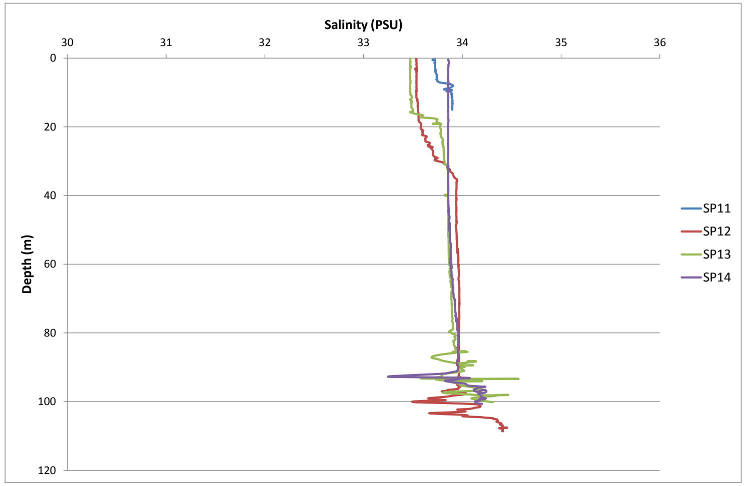
The vertical salinity profiles of the various sites within and around the permit area, Evans Shoal, Tassie Shoal and Lynedoch Bank (**Figure 3-6**) were similar and did not change markedly from surface to bottom. Generally, salinity was stable at approximately 34.0 PSU from the surface to approximately 60 m depth and then increased slightly to the seabed. The change in salinity from surface to bottom was minor and depended on the depth of the site. At the shallowest sites (<30 m depth), there was no change in salinity from surface water to bottom water. At the mid-depth sites (approximately 100 m depth), salinity increased by approximately 0.3 PSU. At the deepest sites (>200 m), there was an increase of 0.6 PSU from surface to bottom.



a) Permit area

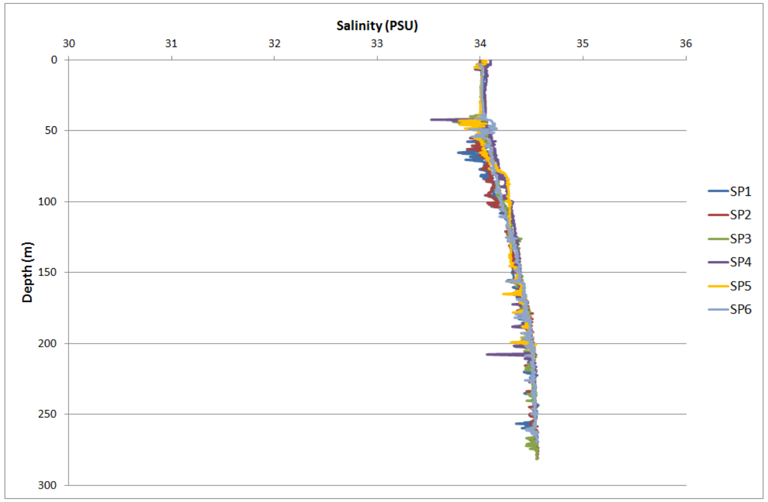


b) Evans Shoal

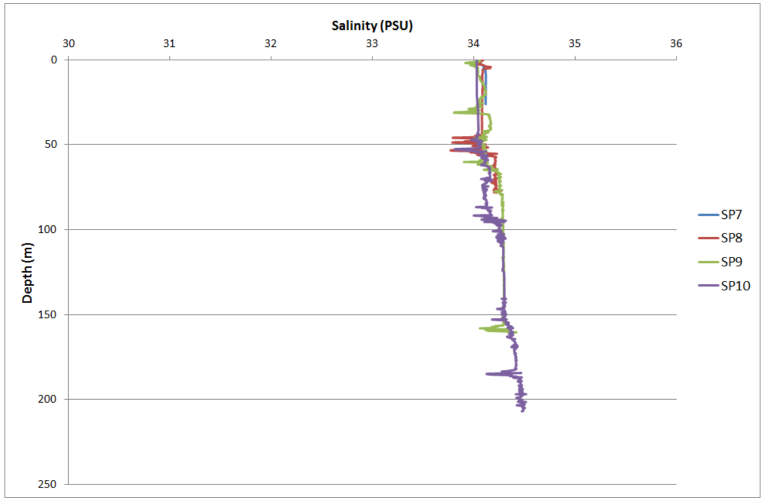


c) Tassie Shoal

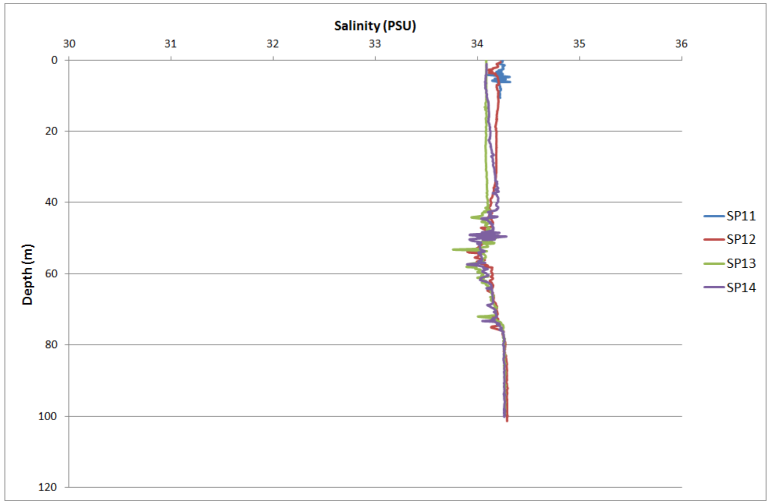
Figure 3-4: Salinity profiles – winter



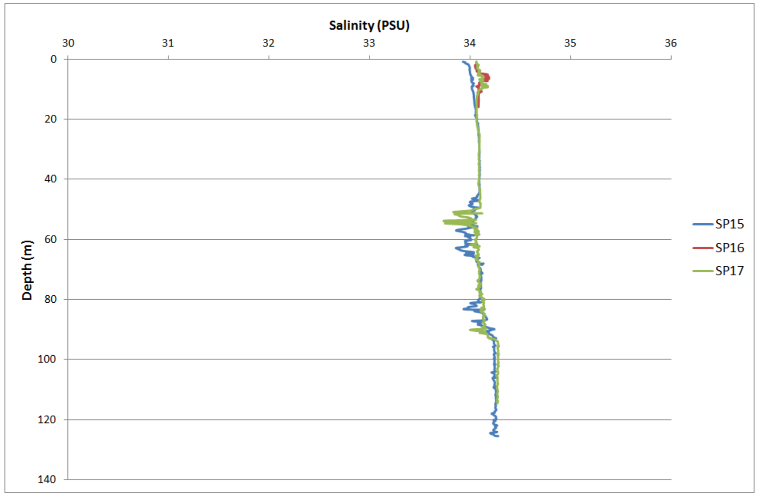
a) Permit area



b) Evans Shoal

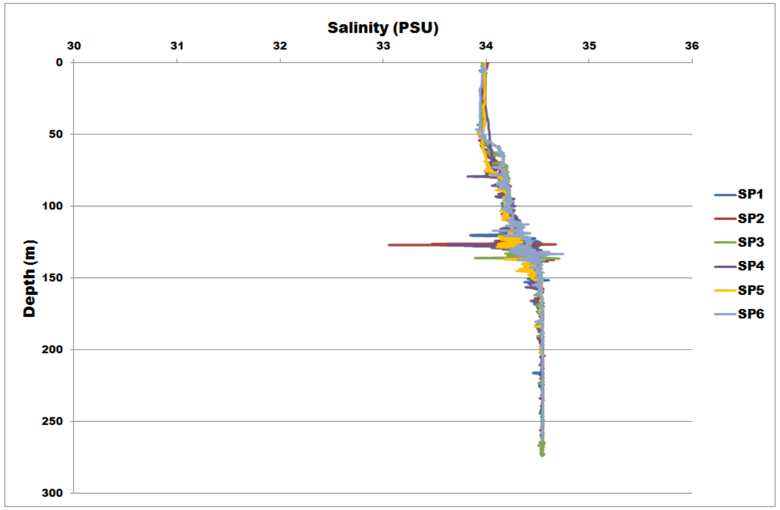


c) Tassie Shoal

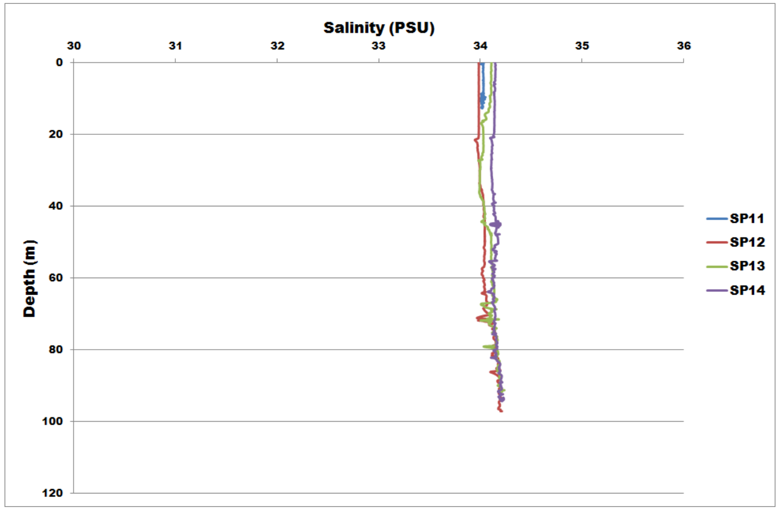


d) Lynedoch Bank

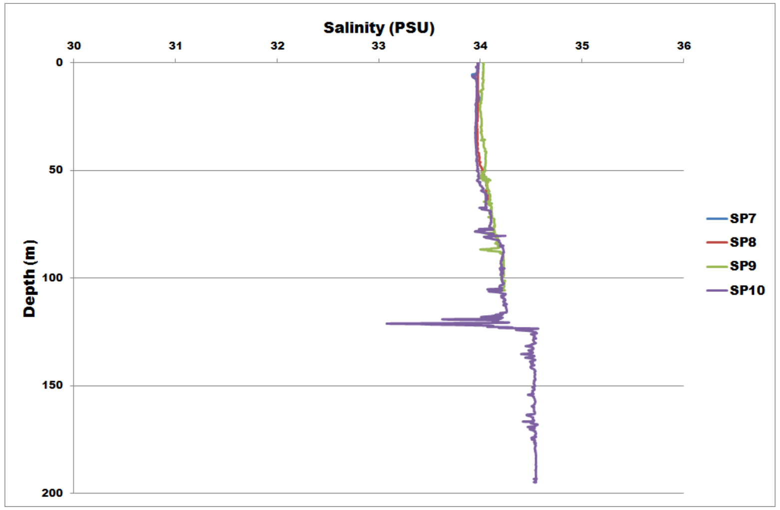
Figure 3-5: Salinity profiles – summer



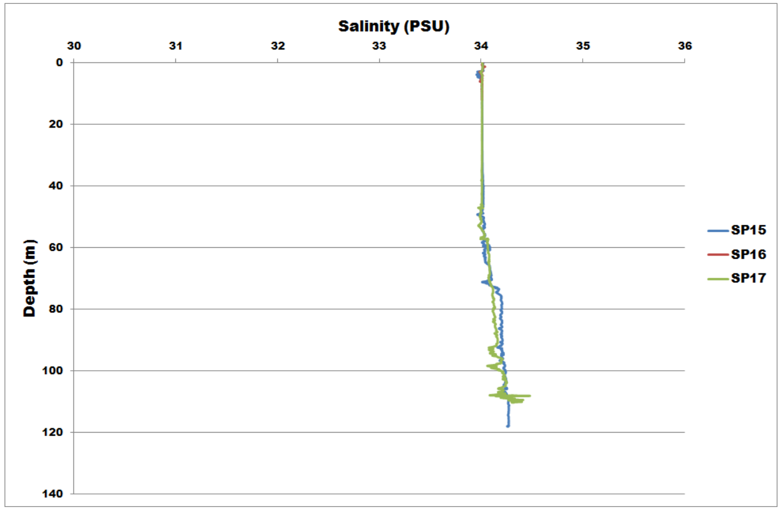
a) Permit area



c) Tassie Shoal



b) Evans Shoal



d) Lynedoch Bank

Figure 3-6: Salinity profiles – autumn

3.1.4 Water temperature

Winter

Temperature in the surface water at each of the sites in and near the permit area (**Figure 3-7**) were generally at 27ºC which stayed constant through the water column until approximately 50 m, at that point there was a slight increase in temperature to approximately 27.8ºC for approximately 20 m, then there was a rapid decline in temperature to approximately 17ºC at 150 m. The temperature continued to decline steadily to approximately 11ºC at the bottom of deepest sites.

The vertical profiles of the Evans Shoal and Tassie Shoal sites (**Figure 3-7**) were similar to the permit area sites, depending on the depth of the sample site. For example, the shallow sites SP7 and SP11 changed very little from surface to bottom, the temperature of the sites at 100 m depth (SP12, SP13 and SP14) increased slightly in the first 30 m then remained constant to 80 m from which there was a rapid decline in temperature to the bottom water. The thermocline is considered to lie in the zone in which the greatest temperature decrease occurs; in this case it occurred between approximately 70 m and 150 m. The zone above the thermocline is called 'the mixed zone' and the zone below it 'the deep zone'.

Summer

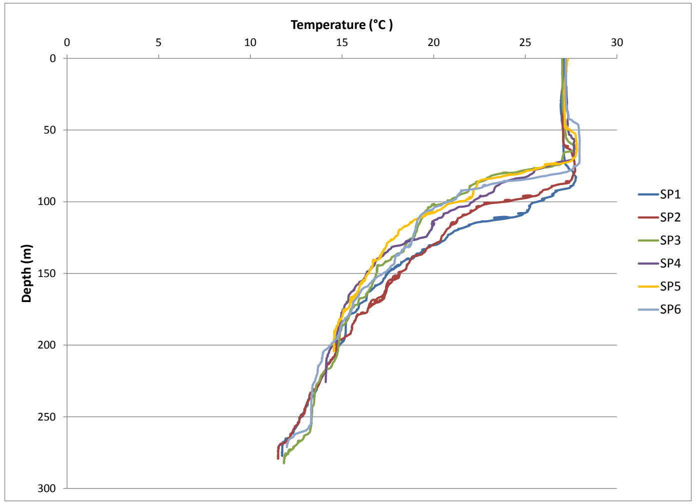
Water temperature in the surface layer at sites in and near the permit area (**Figure 3-8**) was generally around 29°C and stayed constant through the water column until approximately 40 m depth at most sites and until 50 m depth at SP1 and SP2. There was a rapid decline in temperature to approximately 25°C at 50 m at most sites and at 70 m depth at SP1 and SP2. Water temperature gradually declined to approximately 13ºC at the bottom of deepest sites.

The vertical profiles of the Evans Shoal sites, Tassie Shoal sites and Lynedoch Bank sites (**Figure 3-8**) were similar to those observed at the permit area sites, depending on the depth of the site. For example, the shallow sites SP7, SP11 and SP16 changed very little from surface to bottom. The sites that were around 100 m deep (namely SP8, SP9, SP12, SP13, SP14, SP15 and SP17) had constant water temperatures of 29°C in the upper 50 m of water, which then decreased rapidly to 25°C in the next 20 m of water and then gradually declined to the bottom water. The thermocline is considered to lie in the zone in which the greatest temperature decrease occurs; in this case it occurred between approximately 40 m and 70 m.

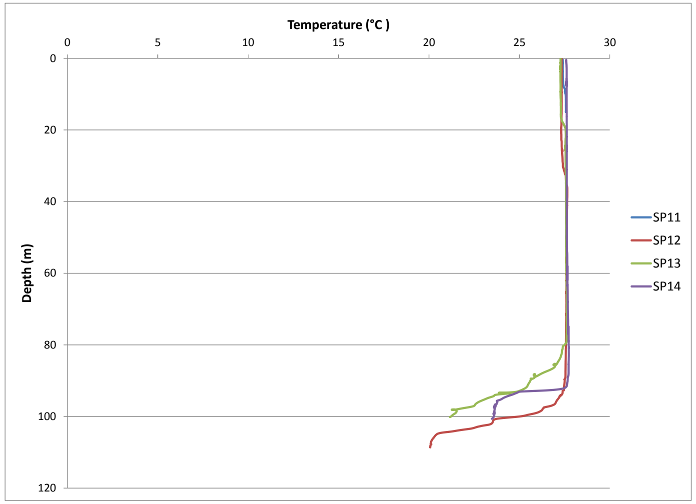
Autumn

Water temperature in the surface layer at sites in and near the permit area (**Figure 3-9)** was generally around 30ºC and stayed constant through the water column until a depth of approximately 50 m. Temperature declined to approximately 25ºC at approximately 110 m, rapidly declined to approximately 16ºC at 140 m and gradually declined to approximately 12ºC at the bottom of deepest sites.

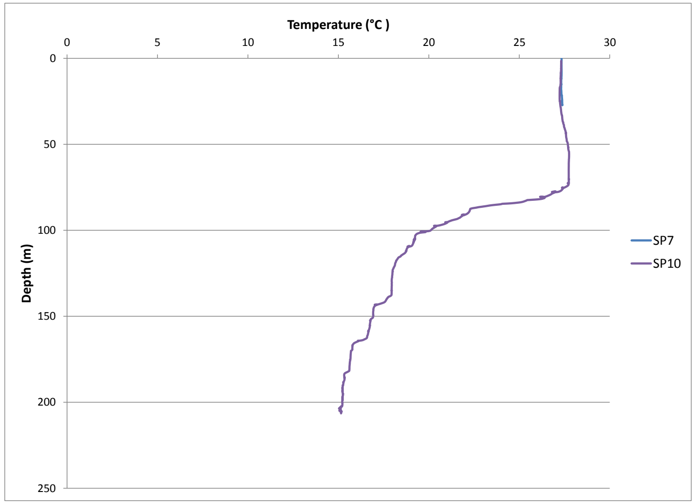
The vertical profiles of Evans Shoal, Tassie Shoal and Lynedoch Bank sites (**Figure 3-9**) were similar to those observed at the permit area sites, depending on the depth of the site. For example, the temperature of the shallow sites SP7, SP11 and SP16 changed very little from surface to bottom. The sites that were around 100 m deep (namely SP8, SP9, SP12, SP13, SP14, SP15 and SP17) had constant water temperatures of 30ºC in the upper 50 m of water, declining to approximately 25ºC in the bottom water. The thermocline is considered to lie in the zone in which the greatest temperature decrease occurs; in this case it occurred between 100 m and 150 m.



a) Permit area

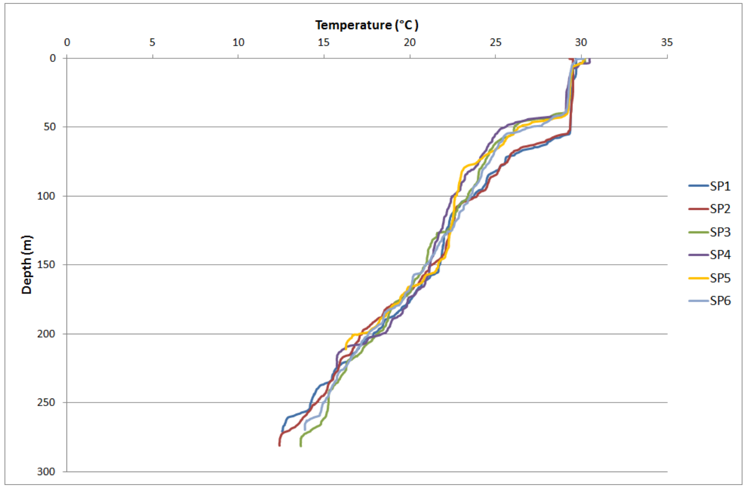


c) Tassie Shoal

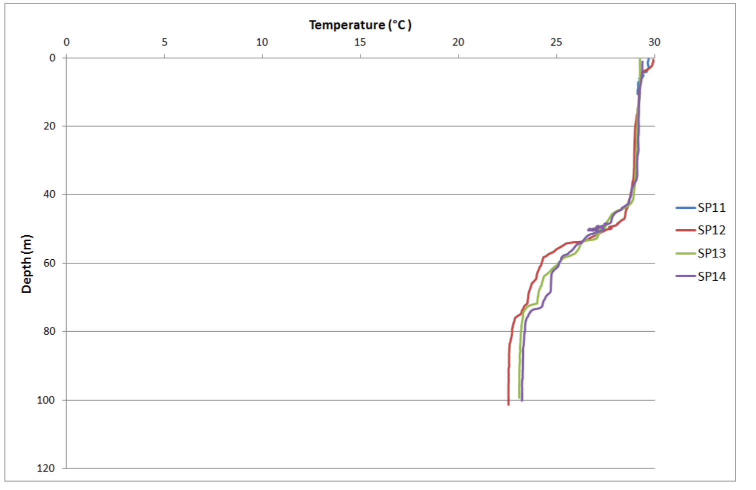


b) Evans Shoal

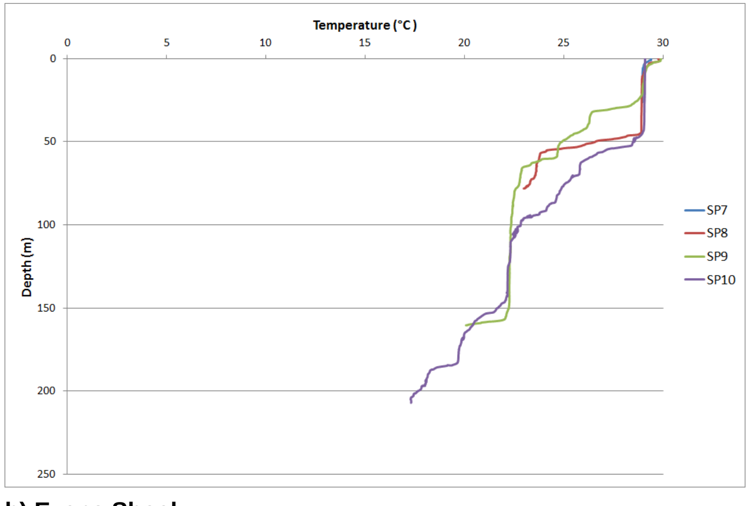
Figure 3-7: Temperature profiles – winter



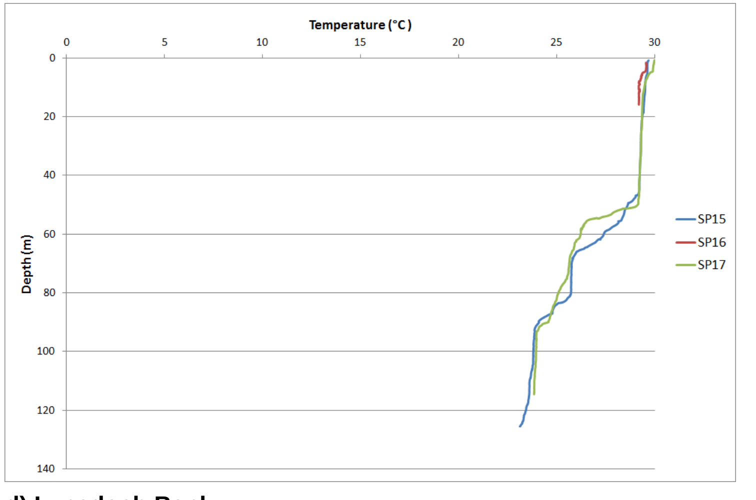
a) Permit area



c) Tassie Shoal

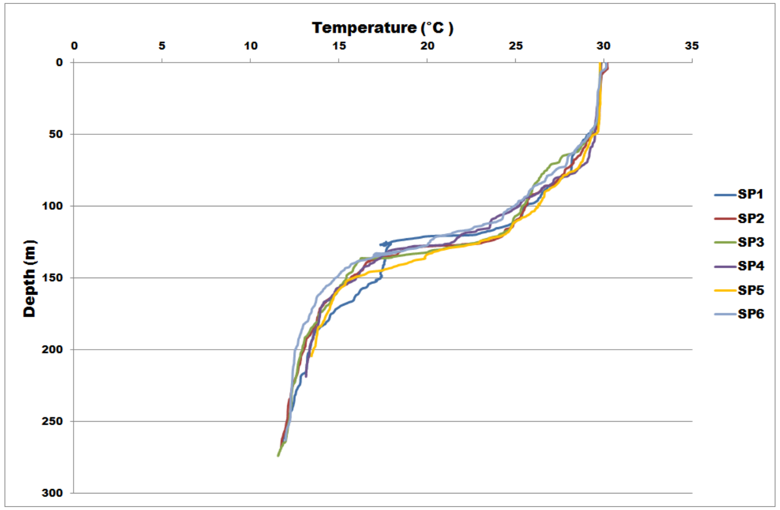


b) Evans Shoal

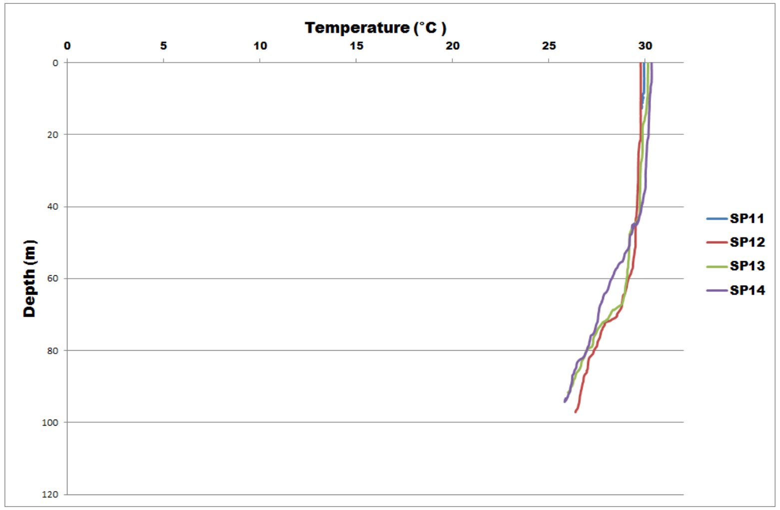


d) Lynedoch Bank

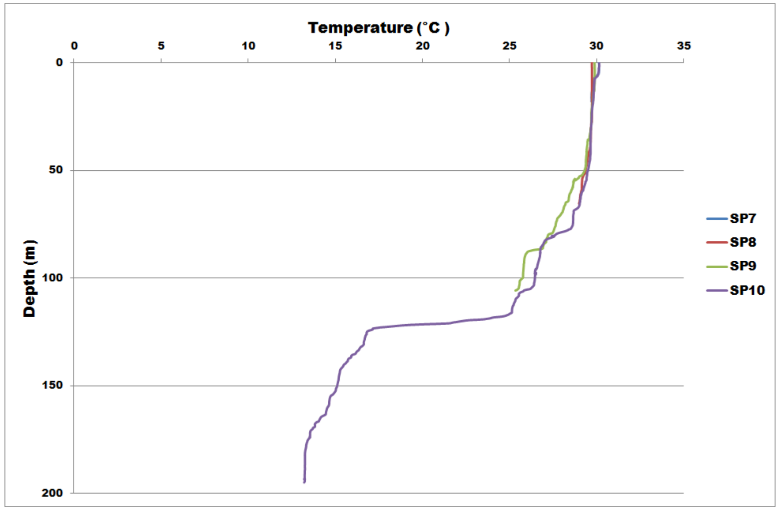
Figure 3-8: Temperature profiles – summer



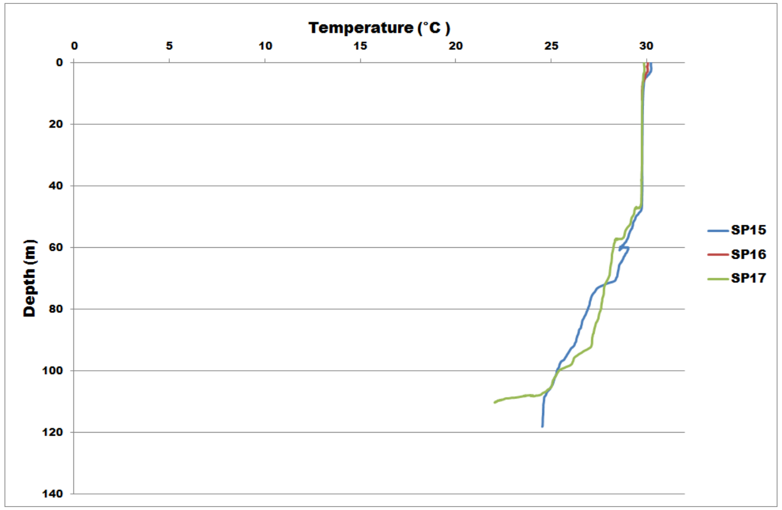
a) Permit area



c) Tassie Shoal



b) Evans Shoal



d) Lynedoch Bank

Figure 3-9: Temperature profiles – autumn

3.1.5 Turbidity

Winter

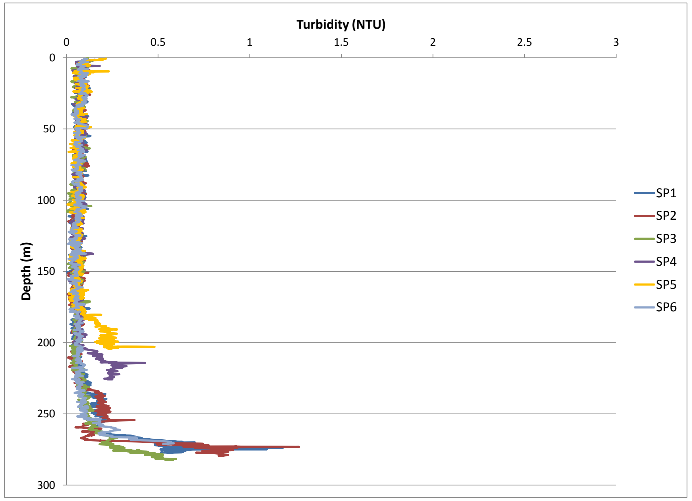
The turbidity of the water at sites in and around the permit area, Evans Shoal and Tassie Shoal were very low (<1.3 NTU) at all sites from the surface to near the seabed (**Figure 3-10**). It was constant at < 0.1 NTU from the surface to approximately 20–50 m from the bottom, at that point the turbidity increased towards the seabed; however, the increase was only minor. The exception was the shallow sites which remained similar from surface to bottom. Site SP10 had very slight increase in turbidity at 80 m.

Summer

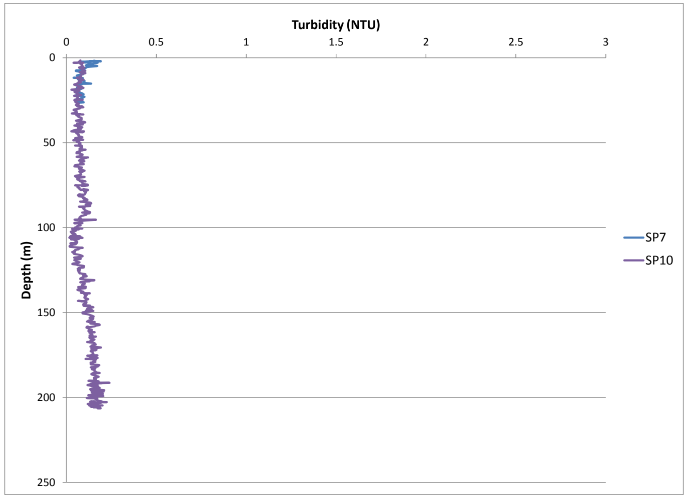
Turbidity at all sites in and around the permit area, Evans Shoal, Tassie Shoal and Lynedoch Bank was very low (<2 NTU) from the surface to near the seabed (**Figure 3-11**). At most sites, turbidity was constant at <0.1 NTU from the surface to approximately 20–50 m above the seabed, at which point the turbidity increased slightly to the bottom. The exception was at shallow sites whereby turbidity remained similar throughout the water column. Sites SP1, SP2 and SP5 had very slight increases in turbidity between 80 m and 156 m.

Autumn

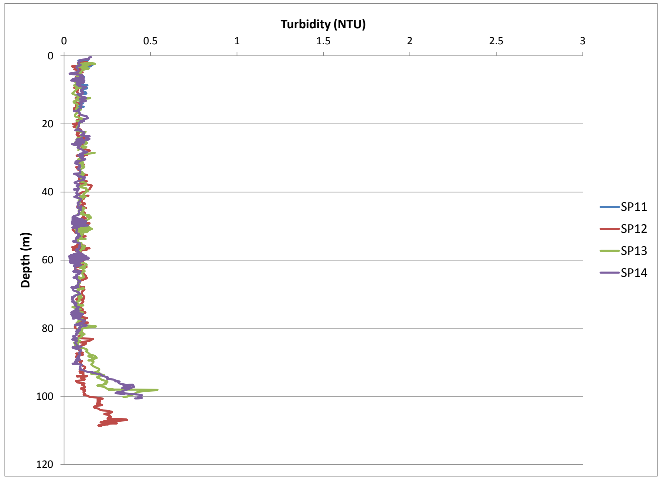
Turbidity at all sites in and around the permit area, Evans Shoal, Tassie Shoal and Lynedoch Bank were very low (<0.5 NTU) from the surface to near the seabed (**Figure 3-12**). At most sites, turbidity was constant at <0.1 NTU from the surface to approximately 20–50 m above the seabed, below which turbidity increased towards the seabed; however, this increase was slight. The exception was the shallow sites (≤25 m), where turbidity remained similar throughout the water column.



a) Permit area

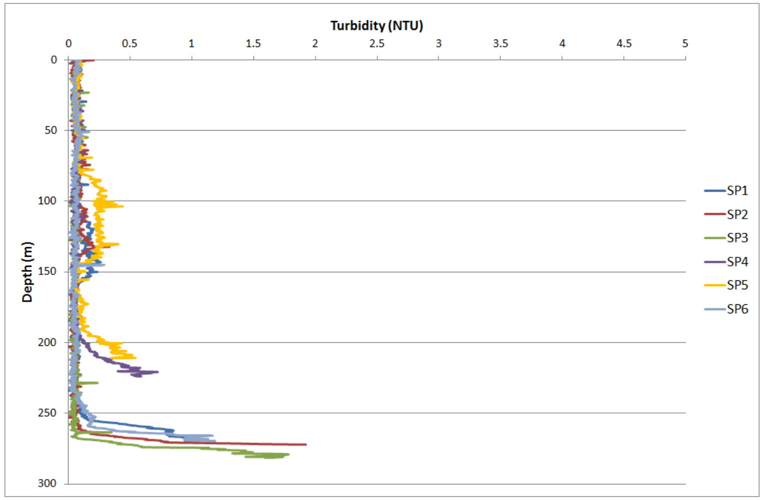


b) Evans Shoal

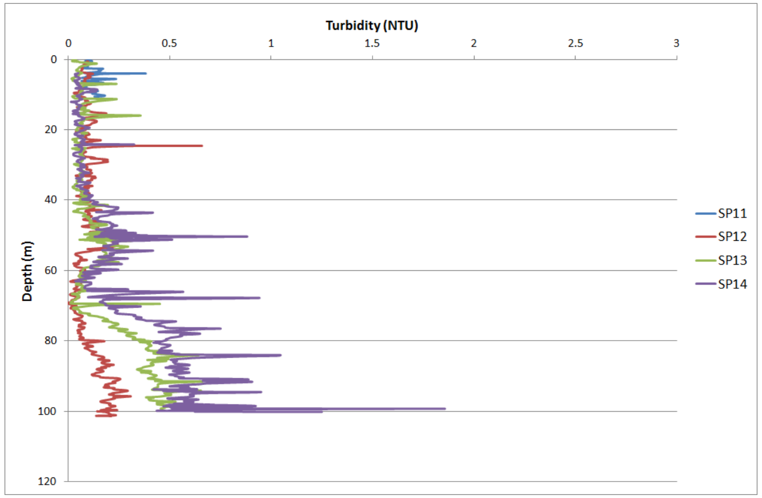


c) Tassie Shoal

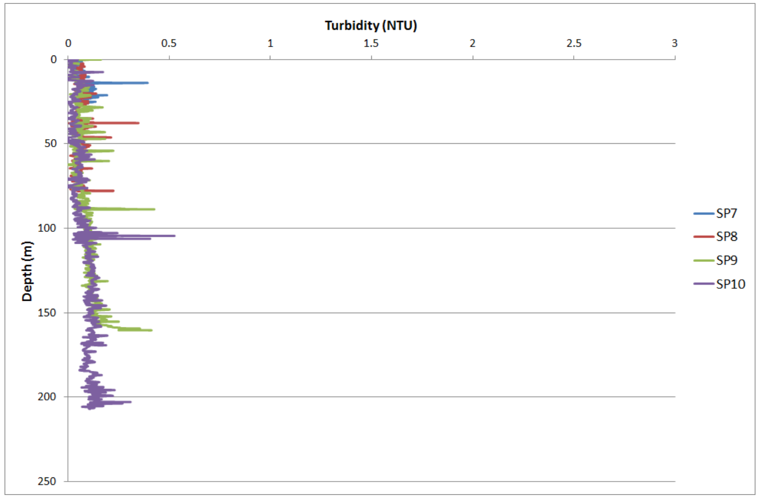
Figure 3-10: Turbidity profiles – winter



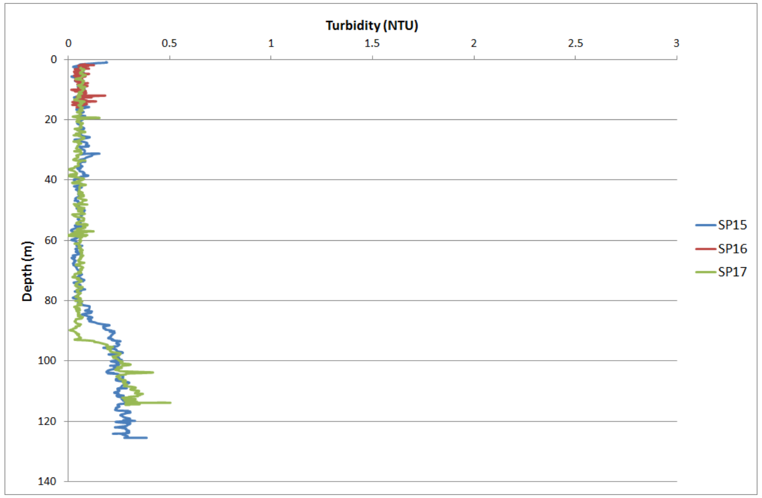
a) Permit area



c) Tassie Shoal

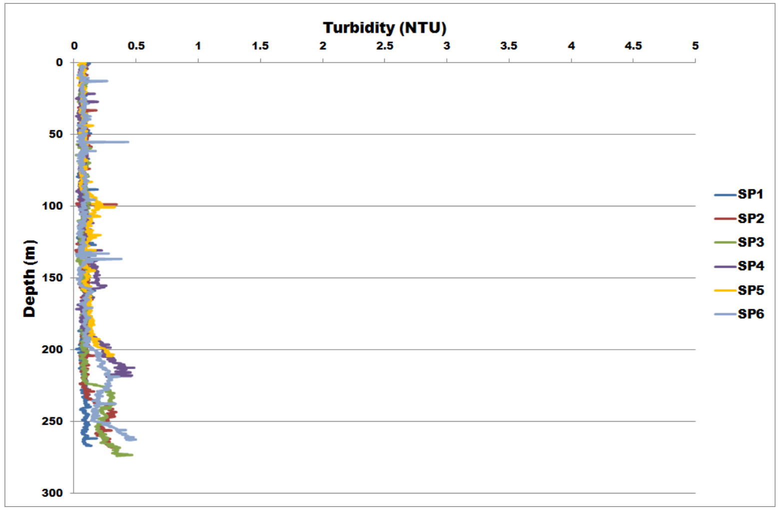


b) Evans Shoal

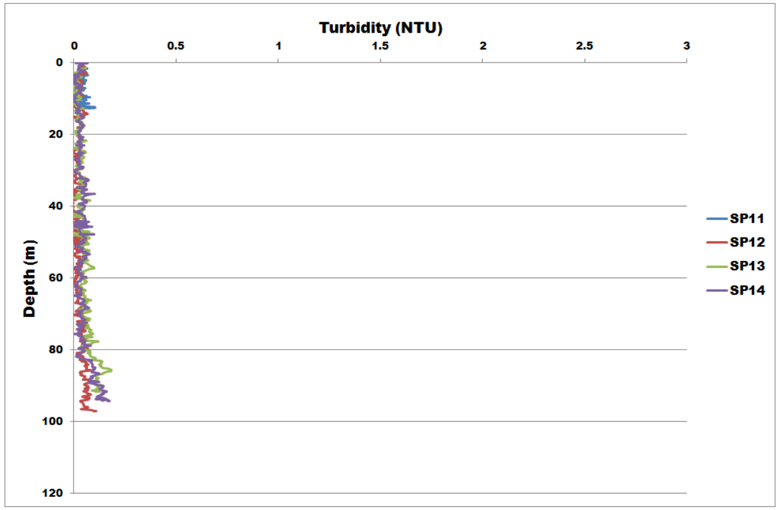


d) Lynedoch Bank

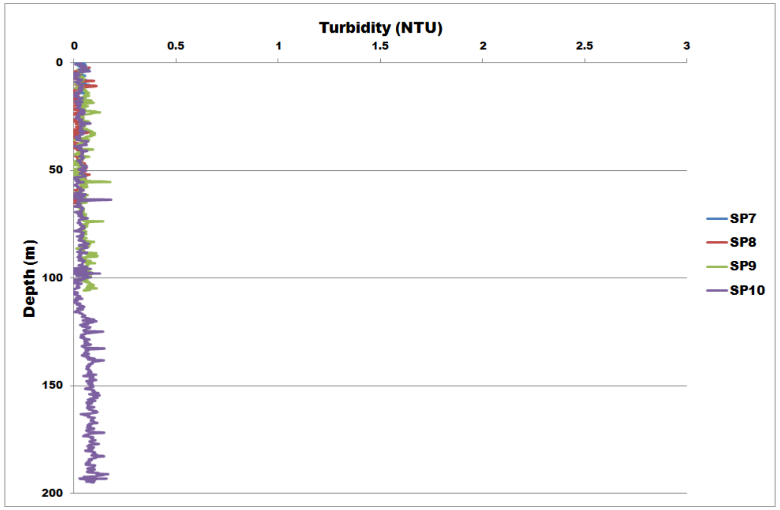
Figure 3-11: Turbidity profiles – summer



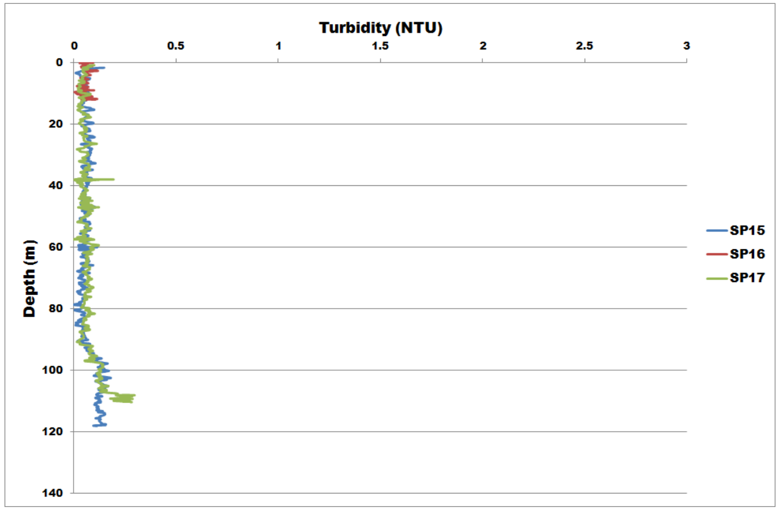
a) Permit area



c) Tassie Shoal



b) Evans Shoal



d) Lynedoch Bank

Figure 3-12: Turbidity profiles – autumn

3.1.6 TSS

Winter

TSS concentrations were below detection limit at the surface of the selected sites sampled during this survey (**Table 3-2**).

Summer

TSS concentrations were low (≤1 mg/L) at the water surface of all sites sampled during this survey, and below the laboratory detection limit at sites SP2 and SP6 (**Table 3-2**).

Autumn

No sampling of TSS was undertaken at any of the sites during the autumn survey.

Table 3-2: TSS in surface water at selected sites

Location	Sites	Turbidity (mg/L)	
		Winter	Summer
Permit area	SP2	<0.5	<0.5
	SP3	<0.5	0.8
	SP6	<0.5	<0.5
Evans Shoal	SP7	NS	0.7
Tassie Shoal	SP12	<0.5	0.8
Lynedoch Bank	SP16	NS	1.0

NS – no sample

3.1.7 pH

Winter

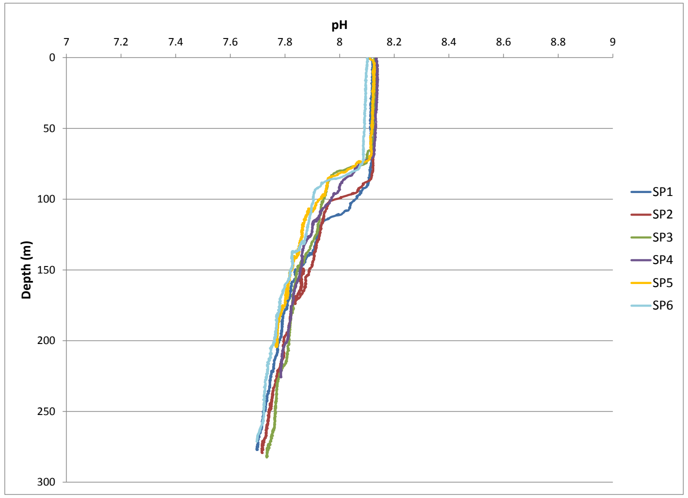
The pH of the surface water for each of the sites from in and around the permit area, Evans Shoal and Tassie Shoal (Figure 3-13) was approximately 8.1. The pH remained stable from the surface waters to approximately 80 m and then decreased rapidly to 7.9 at about 100 m of water depth. The pH decreased further to approximately 7.7 at the deepest sites.

Summer

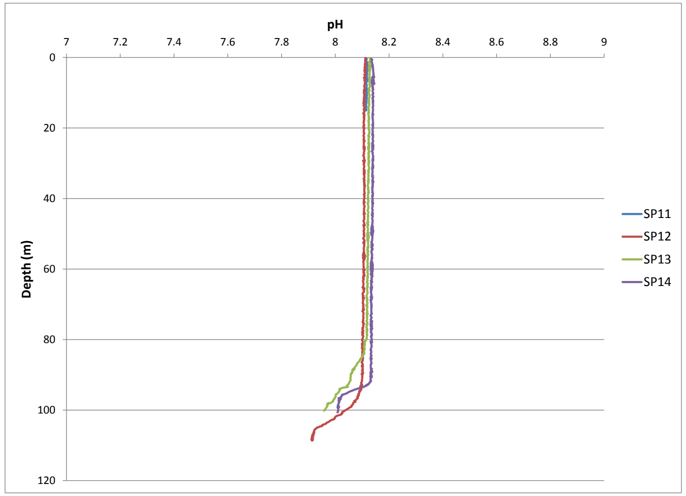
The pH of the surface water for sites within and around the permit area, Evans Shoal, Tassie Shoal and Lynedoch Bank (**Figure 3-14**) ranged from 8.15 to 8.25. The pH remained stable from the surface waters to ~50 m depth; there was a rapid decrease after this and then a more gradual decrease to the bottom water. The pH decreased to approximately 7.9 at the deepest sites. The shape of the individual pH profiles was similar to the dissolved oxygen profiles.

Autumn

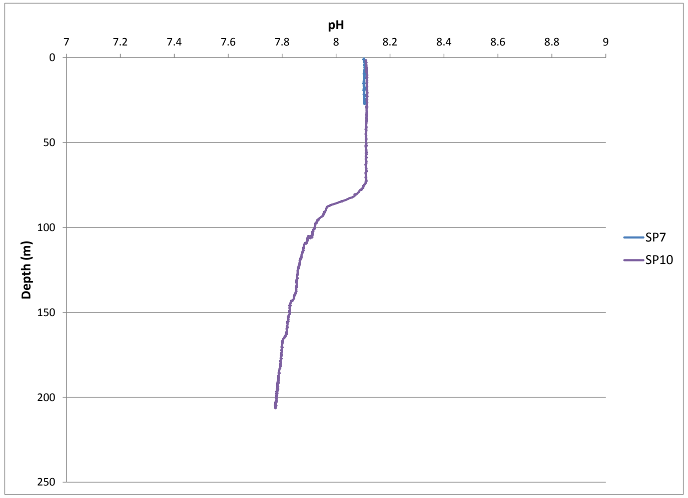
The pH of the surface water for sites within and around the permit area, Evans Shoal, Tassie Shoal and Lynedoch Bank (**Figure 3-15**) ranged from 8.19 to 8.31. The pH remained stable from the surface waters to approximately 60 m depth and then decreased rapidly to 8.0 at approximately 110 m deep, there was more gradual decrease to the seabed. The pH decreased to approximately 7.7 at the deepest sites (>200 m). The shape of the individual pH profiles was similar to that of the dissolved oxygen profiles.



a) Permit area

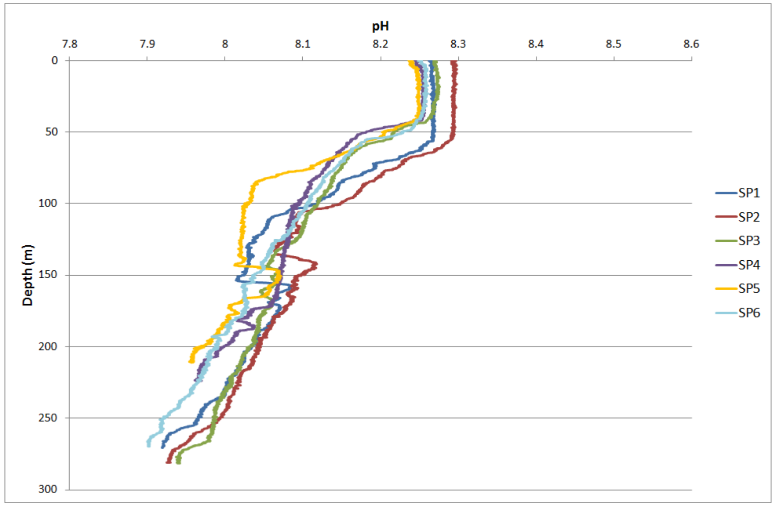


c) Tassie Shoal

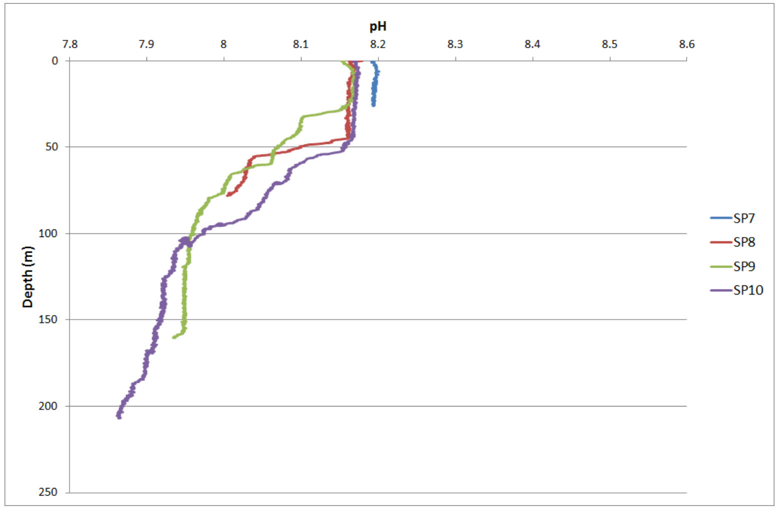


b) Evans Shoal

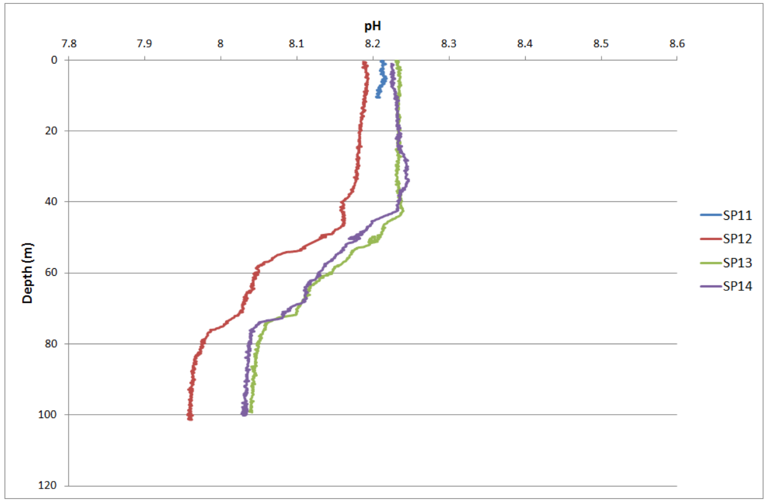
Figure 3-13: pH profiles – winter



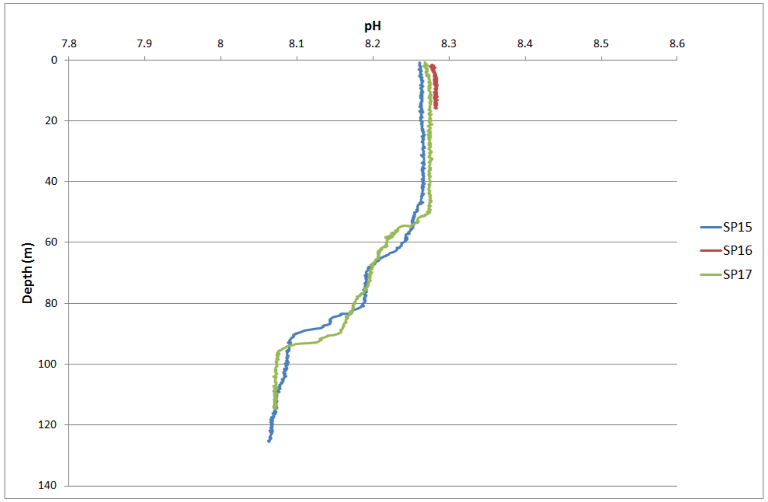
a) Permit area



b) Evans Shoal

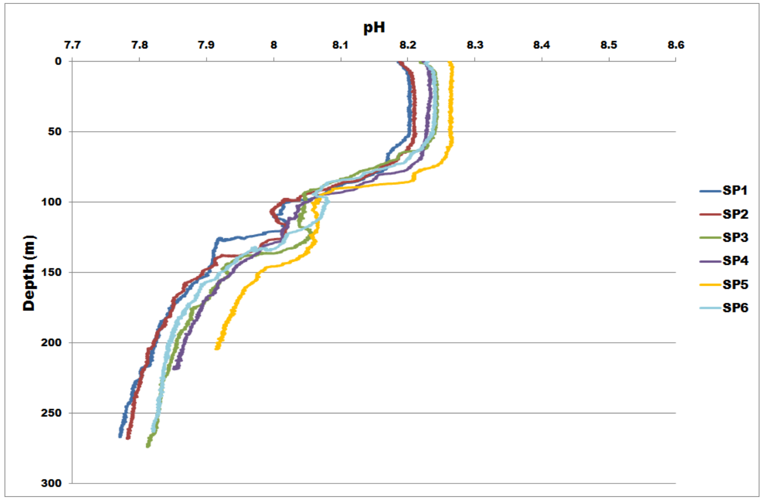


c) Tassie Shoal

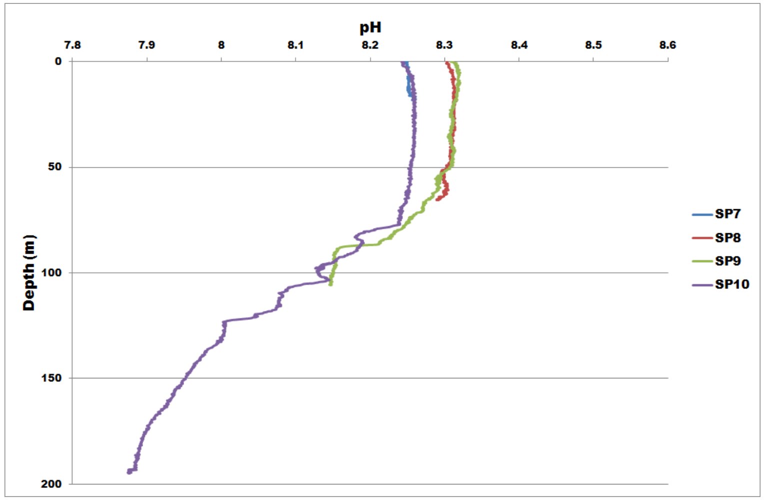


d) Lynedoch Bank

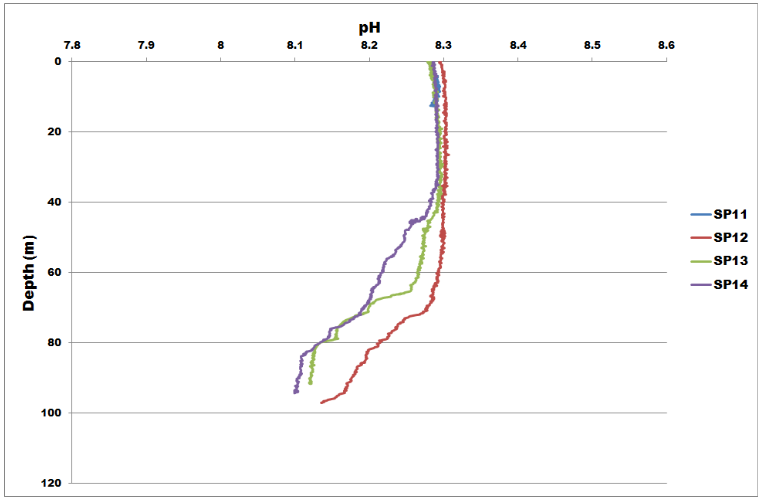
Figure 3-14: pH profiles – summer



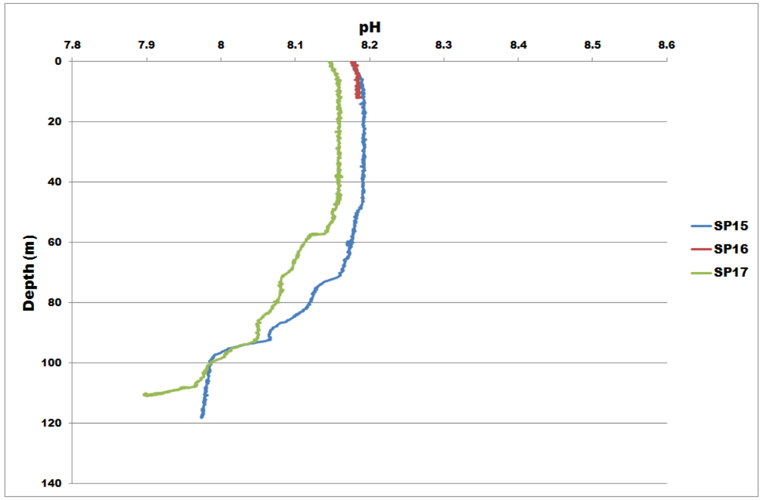
a) Permit area



b) Evans Shoal



c) Tassie Shoal



d) Lynedoch Bank

Figure 3-15: pH profiles – autumn

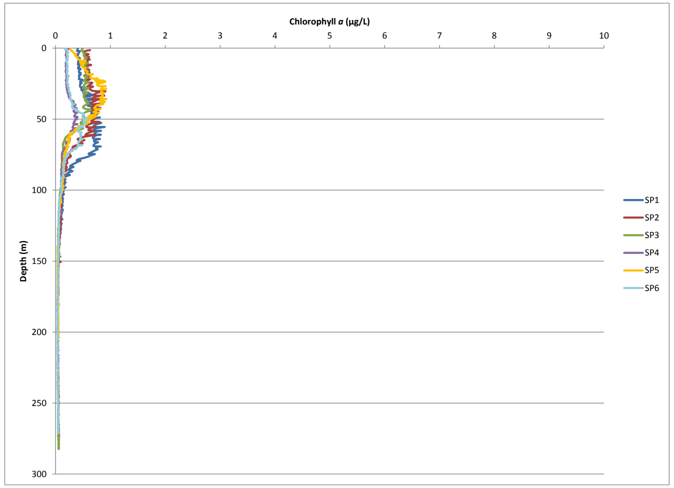
3.1.8 Chlorophyll *a*

Winter

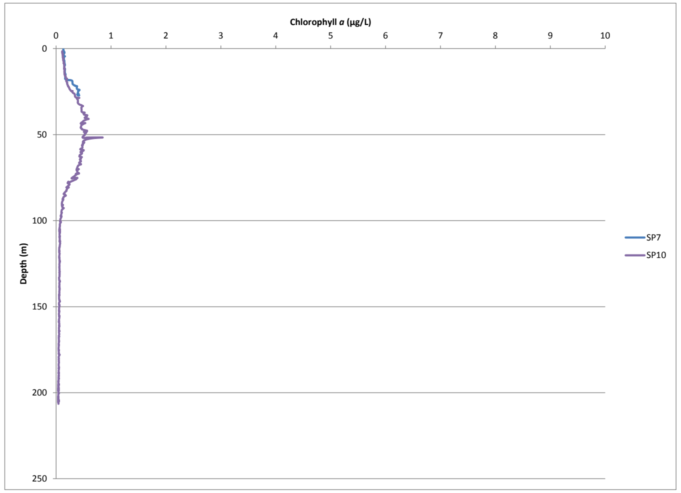
As expected, chlorophyll *a* was highest in the surface water compared with deeper water over 100 m, where the penetration of light would be minimal. The chlorophyll *a* concentrations were very low throughout the water column (<1 µg/L) and appeared to peak at different depths for the various sites in each area (**Figure 3-16**). The chlorophyll *a* concentration at SP5 increased from the surface water to approximately 30 m. For most of the other sites the highest concentration occurred at 50–60 m.

Autumn

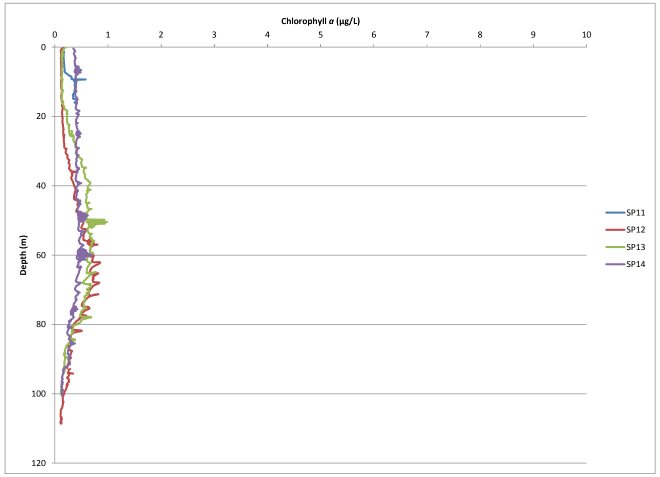
Chlorophyll *a* concentrations of the surface water for sites in and around the permit area, Evans Shoal, Tassie Shoal and Lynedoch Bank were <0.1 µg/L (**Figure 3-17**). Chlorophyll *a* concentrations generally peaked at approximately 70 m depth and decreased to <0.1 µg/L after 100 m depth, suggesting the euphotic zone reached a depth of approximately 70 m during this survey.



a) Permit area

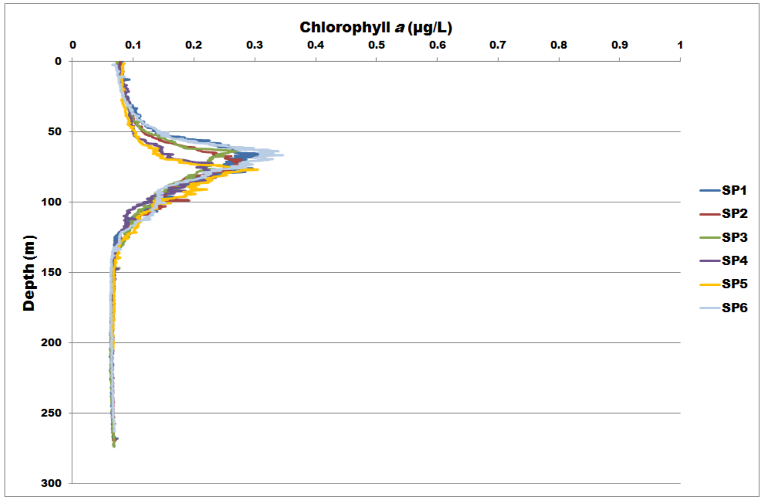


b) Evans Shoal

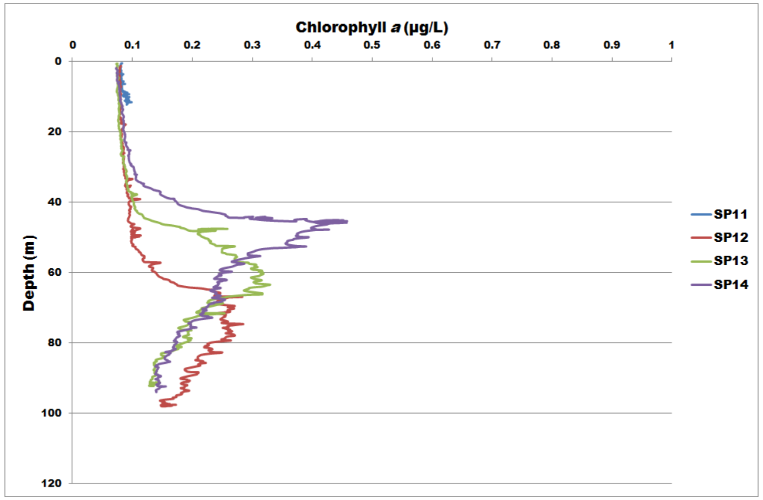


c) Tassie Shoal

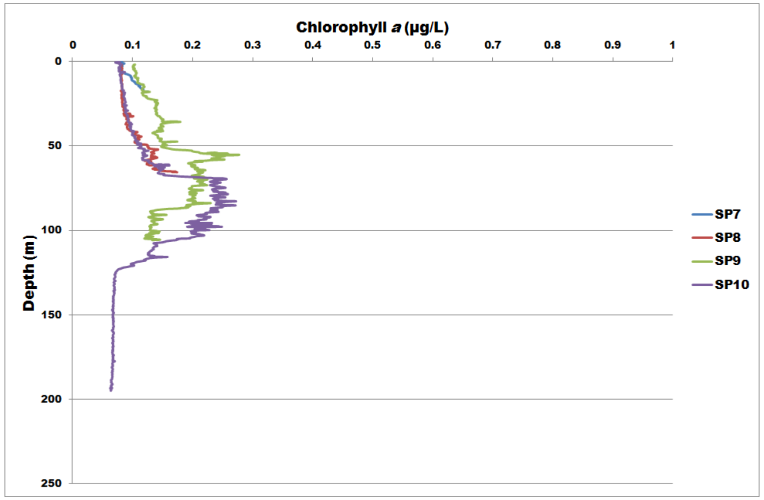
Figure 3-16: Chlorophyll *a* profile – winter



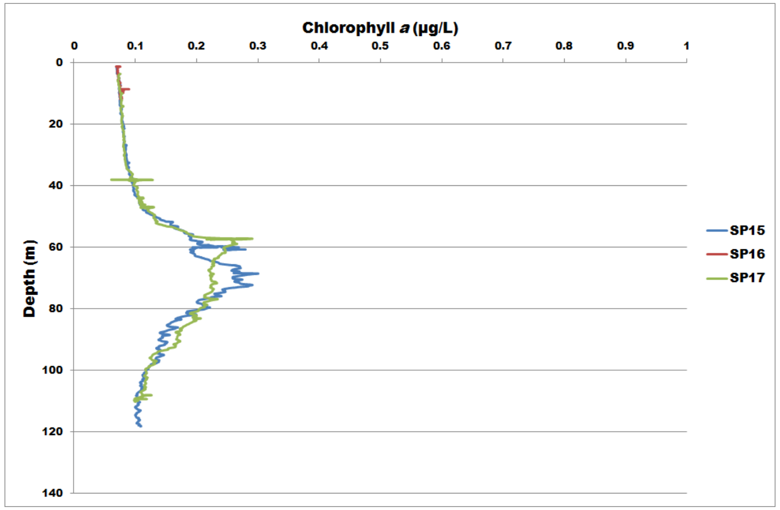
a) Permit area



c) Tassie Shoal



b) Evans Shoal



d) Lynedoch Bank

Figure 3-17: Chlorophyll *a* profile – autumn

3.1.9 Hydrocarbons

The hydrocarbon profiles at all sites and for all seasons in and around the permit area, Evans Shoal, Tassie Shoal and Lynedoch Bank were similar for sites with similar depths therefore only the autumn graphs are shown (**Figure 3-18**). Generally, there was little difference in hydrocarbon readings between the top (4 µg/L) and bottom (11 µg/L) of the water column for any season. These slight differences are considered interferences on the hydrocarbon fluorescence sensor and it is unlikely that they represent changes in hydrocarbon concentrations with depth. At the surface, the sensor readings were very erratic due to high incident light levels interfering with the fluorescence readings. Hydrocarbon profiles also tend to show a reverse of dissolved oxygen profiles, albeit with a much smaller response. If oxygen molecules are present then the amount of fluorescing is reduced, referred to as fluorescence quenching. Therefore, while the oxygen is highest in the mixing zone, the fluorescence sensor had a slightly lower reading compared with deep water where dissolved oxygen is much lower.

All sites for all seasons produced very similar profiles, without any spikes associated with hydrocarbon presence. It can therefore be concluded that there were no naturally occurring hydrocarbons present at any of the sites sampled during the surveys.

Verification of specific hydrocarbons in seawater can only be completed once laboratory results are available for hydrocarbons samples from the surface, middle and bottom water from each site. If results showed high and low hydrocarbon readings, a correlation coefficient could be calculated to convert the equivalent quinine sulfate concentrations (used to calibrate the sensor) into specific hydrocarbon concentrations. However, all the hydrocarbon readings from the laboratory were below the laboratory detection limit of 20 µg/L (**Section 3.2.3**) so a correlation coefficient could not be calculated.

For comparative purposes, a test was conducted in the Darwin Harbour (winter) to provide an example of the readings that would be expected to occur if hydrocarbons were present. The results are presented in **Figure 3-19**.

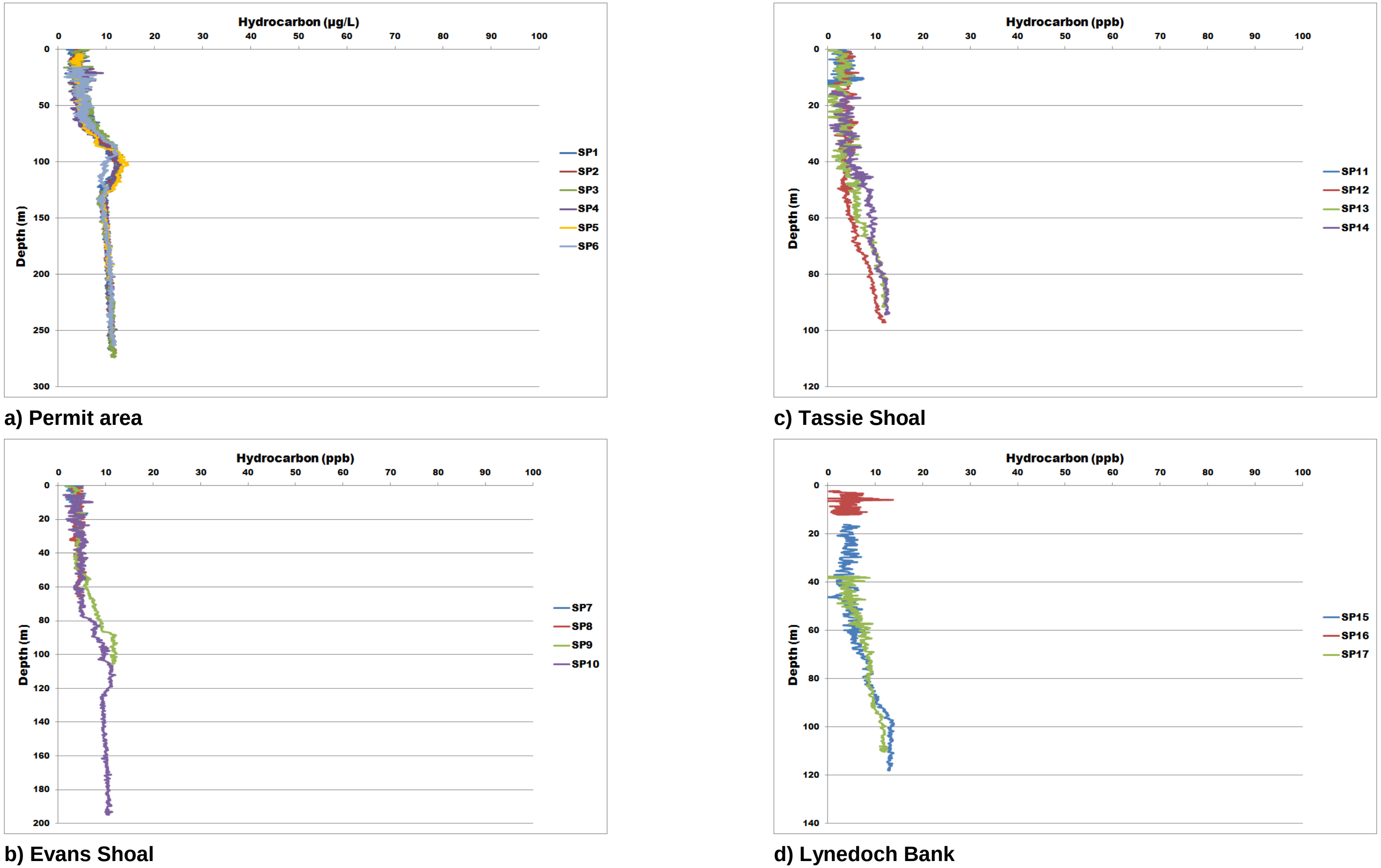


Figure 3-18: Hydrocarbon profiles – autumn

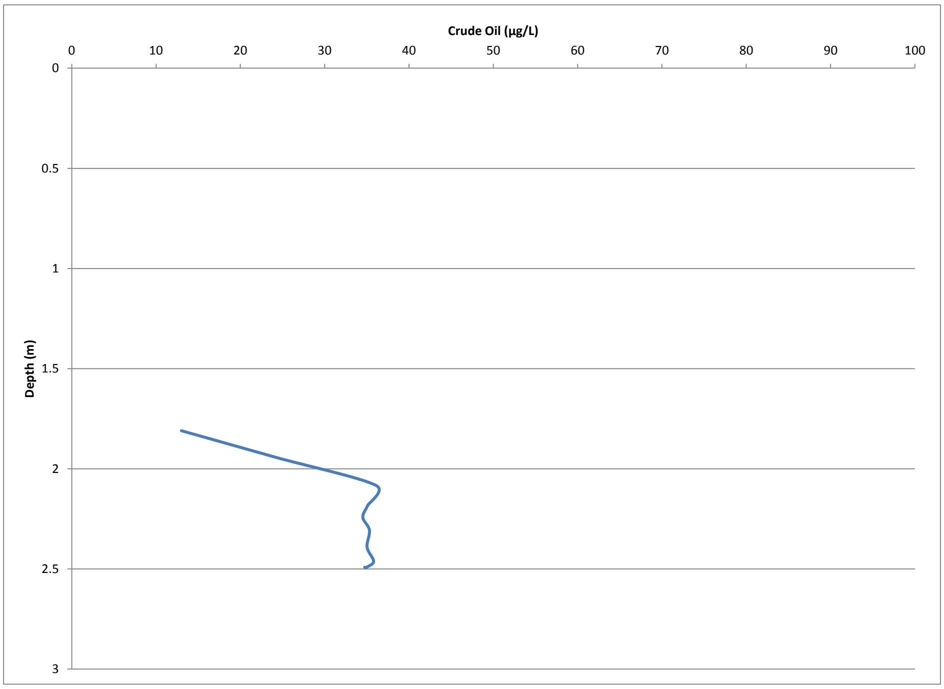


Figure 3-19: Hydrocarbon profile in Darwin Harbour (winter)

3.2 Water quality

3.2.1 Nutrients and pigments

The ANZECC & ARMCANZ (2000b) default trigger values for chemical stressors for tropical Australia for slightly disturbed offshore marine ecosystems are listed in **Table 3-3** to Table 3-6. The nutrient concentrations measured in samples from the shallow depths at each of the permit area, Evans Shoal, Tassie Shoal and Lynedoch Bank sites were around the default trigger values, but most of the samples from deeper waters had nutrient concentrations that were well above the default trigger values (with the exception of ammonium concentrations which were at or below the laboratory LOR at most sites and depths).

Nitrogen

Total nitrogen is comprised of ammonium, nitrate+nitrite and organic nitrogen. At most sites there was no detectable ammonium at any depth (**Table 3-3** to Table 3-6). Nitrate+nitrite concentrations were lowest in the surface water at all sites. All results indicate increasing nitrate+nitrite concentrations with depth. In general, nitrogen concentrations in the surface layers were low and mainly comprised of organic nitrogen while the bottom layers were higher and mainly comprised of nitrate+nitrite.

The sites where total nitrogen ammonium and nitrate+nitrite were detected during each sampling event and any trends in the surveys are discussed below.

Winter

The majority of the results from the winter survey did not detect ammonium at any depth with the exceptions of sites SP2-S, SP7-B, SP11-B and SP14 (all depths). These higher results are unusual in relation to the other samples. There was contamination of both ammonium and nitrate-nitrite in the field blank, therefore it is assumed that these samples have been contaminated, possibly in the filtering process.

Nitrate+nitrite concentrations were lowest in the surface water at all sites deeper than 200 m. At these deeper sites the nitrate-nitrite concentrations in the mid water sample were comparatively high and ranged from 170 to 250 µg/L and they were higher again in the bottom water and ranged from 330 to 400 µg/L. For the sites of approximately 100 m depth, the nitrate+nitrite concentrations in the surface and mid waters were low (< 5 µg/L), while the bottom water was higher (140 to 180 µg/L). The nitrate-nitrite concentrations at the shallow sites (< 30 m) had comparably lower nitrate-nitrite concentrations in both the surface and bottom water (≤ 7 µg/L). Therefore, the deeper the depth the sample was taken the higher the nitrate-nitrite concentration.

Total nitrogen concentrations were low in the surface samples with concentrations ranging between 80 and 110 µg/L at all sites. Again the total nitrogen concentrations increased as the depth of the sample increased, with the concentrations in the bottom water of the deepest sites (SP1, SP2, SP3 and SP6) ranged from 380 to 400 µg/L.

Summer

While just over half the sites there was little or no detectable ammonium at any depth, sites SP2-M, SP2-B, SP4-B, SP5-B, SP6-S, SP6-M, SP6-B, SP7-S, SP8-M, SP8-B, SP9-S, SP9-M, SP9-B, SP10-B, SP11-S, SP12-S, SP12-M, SP12-B, SP13-S and SP14-S had detectable results. This was unusual in relation to the other samples (in that there was no pattern to the results, e.g. only detectable results in the bottom water) and samples taken on previous occasions (in which ammonium at all depths were below laboratory detection limits). This indicates these samples have been contaminated, possibly via a connection to the Niskin bottle that enables bottles to be filled directly.

Nitrate+nitrite concentrations were lowest in the surface water at all sites. All surface water values measured during the survey were below the ANZECC & ARMCANZ (2000a) summer trigger value of 4 µg/L. At the deepest sites the nitrate+nitrite concentrations in the mid-water sample were comparatively high and ranged from 150 to 230 µg/L, and in the bottom water sample ranged from 280 to 380 µg/L. For the sites of approximately 100 m depth, the nitrate-nitrite concentrations in the surface and mid-waters were low (≤5 µg/L) and higher in bottom waters (180–210 µg/L). The nitrate+nitrite concentrations at the shallow sites (<30 m) were low and similar in both the surface and bottom water (≤2 µg/L).

Total nitrogen concentrations were low in the surface samples with concentrations ranging between 80 and 120 µg/L at all sites. Again, total nitrogen concentrations increased with depth, with the highest concentrations recorded in the bottom water of the deepest sites (SP1, SP2, SP3 and SP6), ranging from 400 to 420 µg/L.

Autumn

Detectable ammonia results were recorded at sites SP15-S, SP15-B and SP17-B. At least one of these was considered to be due to contamination in the filtering process. All surface water values measured during this survey were below this level. At the deepest sites, the nitrate+nitrite concentrations were relatively high in the mid-water samples, ranging from 64 µg/L to 200 µg/L, and even higher in the bottom water samples, ranging from 310 µg/L to 360 µg/L. For the sites of approximately 100 m depth, the nitrate+nitrite concentrations in the surface and mid-waters were low (<2 µg/L) but concentrations were higher in the bottom waters (74 µg/L to 120 µg/L). The nitrate+nitrite concentrations at the shallow sites (<30 m) were low and similar in both the surface and bottom water (<2 µg/L).

Total nitrogen concentrations were low in the surface samples with concentrations ranging between 80 and 100 µg/L at all sites. Again, total nitrogen concentrations increased with depth, with the highest concentrations recorded in the bottom water of the deepest sites (SP1, SP2, SP3 and SP6), ranging from 350 µg/L to 360 µg/L.

Phosphorus

Total phosphorus consists of orthophosphate and organic phosphate. Orthophosphate concentrations in the surface water samples at all sites were ≤5 µg/L (**Table 3-3** to **Table 3-6**).

The sites where total phosphorus was detected during each sampling event and any trends in the surveys are discussed below.

Winter

Orthophosphate concentrations in the surface water samples at all sites were ≤5 µg/L. The bottom water of the shallowest sites or the middle water of the sites in approximately 100 m water depth had orthophosphate concentrations similar to the surface those in the surface water. The middle waters of the deepest sites were higher ranging from 26 to 34 µg/L, whilst the bottom water was higher again ranging from 51 µg/L o 61 µg/L. The total phosphorus concentrations were similar to the orthophosphate concentrations in that they increased with an increase in depth. Therefore, phosphorus concentrations in the surface layers were low and mainly comprised of organic phosphorus and the bottom layers were high and mainly comprised of orthophosphate. All surface water samples collected during this survey had orthophosphate concentrations that were at or below the ANZECC & ARMCANZ (2000a) guidelines default winter trigger value of 10 µg/L.

Summer

Orthophosphate concentrations in the surface water samples at all sites were ≤5 µg/L. The bottom water of the shallowest sites and the middle water of sites in approximately 100 m water depth had orthophosphate concentrations similar to those measured in surface waters. The deepest sites had higher concentrations, ranging from 23 to 35 µg/L in the middle waters and from 39 to 56 µg/L in the bottom waters.

All surface water samples collected during this survey had orthophosphate concentrations that were at or below the ANZECC & ARMCANZ (2000a) guidelines default summer trigger value of 5 µg/L.

Autumn

Orthophosphate concentrations in the surface water samples at all sites were ≤3 µg/L. The bottom water of the shallowest sites and the middle water of sites in approximately 100 m water depth had orthophosphate concentrations similar to those measured in surface waters. The deepest sites had higher concentrations, ranging from 15 µg/L to 33 µg/L in the mid-waters and from 53 µg/L to 61 µg/L in the bottom waters.

All surface water samples collected during this survey had orthophosphate concentrations that were at or below the ANZECC & ARMCANZ (2000a) guidelines default winter trigger value.

In summary, total phosphorus concentrations showed similar patterns to the orthophosphate concentrations, increasing with depth, with low phosphorus concentrations in the surface layers (mainly comprising of organic phosphorus) and high concentrations in the bottom layers (mainly comprising of orthophosphate).

Pigments

Chlorophyll *a* concentrations (as a proxy for phytoplankton biomass) in all surface water samples from the permit area, Evans Shoal, Tassie Shoal and Lynedoch Bank were low during all surveys, in the range of ≤0.9 µg/L (**Table 3-3** to **Table 3-6**). Chlorophyll *a* concentrations in samples from water depths greater than 100 m were generally at or below the laboratory detection limits (LOR <0.1 µg/L). During the summer survey, the highest chlorophyll *a* concentrations were mid-water at sites in approximately 100 m of water, suggesting the euphotic zone reached a depth of approximately 50 m during the survey.

Chlorophyll *a* concentrations were at or below the ANZECC & ARMCANZ (2000a) default trigger value of 0.9 µg/L at all sites and all depths during all surveys.

Phaeophytin is the breakdown product of chlorophyll *a* and is analysed more frequently in lakes to determine if phytoplankton blooms are increasing or declining. Phaeophytin concentrations were below the laboratory LOR for all sites and depths during all surveys. There are no ANZECC & ARMCANZ (2000b) default trigger values for phaeophytin.

3.2.2 Metals/metalloids

The metal/metalloid samples were processed as either unfiltered or filtered, with the unfiltered generally defining the total metals in solution, including those bound to particles (considered ‘unavailable’) and those that are bioavailable or possibly toxic to organisms (depending on the type of metal and the concentration). ANZECC & ARMCANZ (2000a) guidelines recommend that unfiltered samples be taken and if metal/metalloids are found to be above recommended concentrations, then filtered samples should also be taken to determine bioavailability of the metal/metalloids. The filtered metals/metalloids generally define those compounds that are bioavailable or possibly toxic to organisms, as all but the very fine particles (< 0.2 µm) are filtered out of the sample. If bioavailable metals/metalloids are found above recommended concentrations, then additional samples should be taken to determine if the detected concentrations are toxic.

The results from the metals/metalloids survey are presented in **Table 3-7** to **Table 3-14**. The trends and exceedences for metals/metalloids associated with each survey are discussed below.

Winter

Of the total metal/metalloids in the water sampled from the various depths at the permit area, Evans Shoal and Tassie Shoal sites, only copper was above the ANZECC & ARMCANZ (2000) trigger value for 99% species protection of 0.3 µg/L (**Table 3-7** to **Table 3-9**).

After filtering, the copper concentrations at four sites (SP2-M, SP7-B, SP10-M and SP14-B) were slightly above 0.3 µg/L (**Table 3-10** to **Table 3-13**). The copper concentrations at sites SP1-S, SP5-S and SP11-S were considered to be high and possibly due to contamination as they were higher than the unfiltered samples. Therefore, they have been excluded from the results.

Of the other total metals, lead, mercury, cadmium and cobalt were below the laboratory LORs at all depths at the permit area, Evans Shoal and Tassie Shoal sampling sites during the winter survey (**Table 3-7** to **Table 3-9**).

Total barium concentrations at all sites and depths ranged from 5.3 µg/L to 7.9 ug/L with the deepest water comprising the highest concentrations (**Table 3-7** to **Table 3-9**). Filtered barium concentrations were similar to total barium concentrations at the permit area, Evans Shoal and Tassie Shoal sampling sites and depths (**Table 3-10** to **Table 3-13**).

Total chromium concentrations were below the laboratory LOR (< 0.2 µg/L) in all surface samples at the permit area, Evans Shoal and Tassie Shoal sites and at the laboratory LOR (or slightly higher for the deepest depths) for all bottom depths greater than 100 m of water (**Table 3-7** to **Table 3-9**). Filtered chromium concentrations were similar to the total chromium concentrations (**Table 3-10** to **Table 3-13**).

Total nickel concentrations were below the laboratory LOR (< 0.3 µg/L) in all surface samples and the majority of middle depth samples that were taken in less than 100 m of water, while bottom water concentrations at all sites deeper than 100 m of water ranged from 0.3–0.4 µg/L (**Table 3-7** to **Table 3-9**). Filtered nickel concentrations were similar to the total concentrations (**Table 3-10** to **Table 3-13**).

There did not appear to be a particular pattern regarding change of total zinc concentrations with depth, as per the other metals. Total zinc concentrations at all depths ranged from below the laboratory LOR to 4 ug/L (**Table 3-7** to **Table 3-9**). Filtered zinc concentrations were similar to total zinc concentrations (**Table 3-10** to **Table 3-13**), but all were below the ANZECC & ARMCANZ (2000) trigger value of 7 µg/L.

Total arsenic and filtered arsenic concentrations were very similar at all depths of the permit area, Evans Shoal and Tassie Shoal sites and ranged from 1.5 µg/L to 2.0 µg/L (**Table 3-10** to **Table 3-13**), which is below the ANZECC & ARMCANZ (2000) trigger value of 4.5 µg/L.

Summer

Of the total metals/metalloids in the water sampled from the various depths at the permit area, Evans Shoal, Tassie Shoal and Lynedoch Bank sites, only copper was above the ANZECC & ARMCANZ (2000a) trigger value of 0.3 µg/L for 99% species protection (**Table 3-7** to **Table 3-10**). After filtering, the copper concentrations at five sites (SP2-S, SP7-S, SP9-M, SP10-B and SP13-S) were slightly above 0.3 µg/L (**Table 3-11** to **Table 3-14**). The high copper concentrations at sites SP8-B, SP11-S and SP12-M were possibly due to contamination as they were higher than the unfiltered samples.

Of the other total metals, cadmium, cobalt, chromium, lead and mercury were all below the laboratory LORs at all depths at the permit area, Evans Shoal, Tassie Shoal and Lynedoch Bank sampling sites during the summer survey (**Table 3-7** to **Table 3-10**).

Total barium concentrations ranged from 5.0 µg/L to 7.0 ug/L at all sites and depths, with the deepest water samples comprising the highest concentrations (**Table 3-7** to **Table 3-10**). Filtered barium concentrations were similar to total barium concentrations at each of permit area, Evans Shoal, Tassie Shoal and Lynedoch Bank sampling sites and depths (**Table 3-11** to **Table 3-14**). There is no ANZECC & ARMCANZ (2000a) trigger value for barium.

Total nickel concentrations were below the laboratory LOR (<0.3 µg/L) in all surface samples and in most mid-water samples in <100 m of water, whereas bottom water concentrations at all sites >100 m of water were 0.3 µg/L–0.5 µg/L (**Table 3-7** to **Table 3-10**). Filtered nickel concentrations were similar to the total concentrations (**Table 3-11** to **Table 3-14**). The ANZECC & ARMCANZ (2000a) trigger value for nickel in marine water protecting 99% of species is 7 µg/L.

There did not appear to be a particular pattern regarding total zinc concentrations with depth. Total zinc concentrations at all depths ranged from below the laboratory LOR to 4 ug/L (**Table 3-7** to **Table 3-10**). Filtered zinc concentrations were similar to total zinc concentrations (**Table 3-11** to **Table 3-14**), and all were below the ANZECC & ARMCANZ (2000a) trigger value of 7 µg/L.

Total arsenic and filtered arsenic concentrations were similar at all depths of all the permit area, Evans Shoal, Tassie Shoal and Lynedoch Bank sites and ranged from 1.5 µg/L to 1.9 µg/L (**Table 3-7** to **Table 3-14**), below the ANZECC & ARMCANZ (2000a) trigger value of 4.5 µg/L.

Autumn

Of the total metals/metalloids in the water sampled from the various depths at the permit area, Evans Shoal, Tassie Shoal and Lynedoch Bank sites, none were above the ANZECC & ARMCANZ (2000a) trigger values for 99% species protection in marine water (**Table 3-7** to **Table 3-10**), where trigger values were available

Copper concentrations were generally below the laboratory LOR for most sites and depths sampled during this survey (**Table 3-7** to **Table 3-10**). No sites had samples that were above the ANZECC & ARMCANZ (2000a) trigger value of 0.3 µg/L but filtered samples for sites SP12-S and SP12-B equalled the trigger value (**Table 3-11** to **Table 3-14**).

Total nickel concentrations were below the laboratory LOR (<0.3 µg/L) in all surface samples and most mid water samples from sites in less than 100 m of water, while bottom water concentrations at all sites deeper than 100 m of water ranged from 0.3 µg/L to 0.5 µg/L (**Table 3-7** to **Table 3-10**).

The total metals, cadmium, cobalt, lead and mercury were all below the laboratory LORs at all depths at the permit area, Evans Shoal, Tassie Shoal and Lynedoch Bank sampling sites during the autumn survey (**Table 3-7** to **Table 3-10**).

Total arsenic and filtered arsenic concentrations were similar at all depths of all the permit area, Evans Shoal, Tassie Shoal and Lynedoch Bank sites and ranged from 1.3 µg/L to 2.1 µg/L (**Table 3-7** to **Table 3-14**), which is below the ANZECC & ARMCANZ (2000a) trigger value of 4.5 µg/L.

Total barium concentrations ranged from 5.0 µg/L to 8.2 µg/L at all sites and depths, with the deepest water samples comprising the highest concentrations (**Table 3-7** to **Table 3-10**). Filtered barium concentrations were similar to total barium concentrations at each of permit area, Evans Shoal, Tassie Shoal and Lynedoch Bank sampling sites and depths (**Table 3-11** to **Table 3-14**). There is no ANZECC & ARMCANZ (2000a) trigger value for barium but there are guideline values for drinking water NHMRC & ARMCANZ (2011). Barium has a human health guideline for drinking water of 2000 µg/L, much higher than the concentrations reported in this survey. In Australian drinking water supplies, barium ranges from <2 µg /L to 1,100 µg /L.

Total chromium and filtered chromium concentrations were below LOR in the surface water of all sites in and around permit area, Evans Shoal, Tassie Shoal and Lynedoch Bank (**Table 3-7** to **Table 3-14**). Chromium concentrations were slightly above the LOR in samples from the deepest sites. All samples were below the ANZECC & ARMCANZ (2000a) trigger value of 7.7 µg/L.

Filtered nickel concentrations were similar to the total concentrations (**Table 3-11** to **Table 3-14**). The ANZECC & ARMCANZ (2000a) trigger value for nickel in marine water protecting 99% of species is 7 µg/L.

There was no trend in total zinc concentrations with depth. Total zinc concentrations at all depths ranged from below the laboratory LOR to 3 ug/L (**Table 3-7** to **Table 3-10**). Filtered zinc concentrations were similar to total zinc concentrations (**Table 3-11** to **Table 3-14**) and all were below the ANZECC & ARMCANZ (2000a) trigger value of 7 µg/L.

Table 3-3: Nutrient concentrations at permit area sites

Parameter	Ammonium			Nitrate+nitrite			Total nitrogen			Orthophosphate			Total phosphorus			Chlorophyll *a*			Phaeophytin		
Units	µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L		
LOR	<3			<2			<50			<2			<5			<0.1			<0.2		
Guideline[1]	9[2] 4[3]			5[2] 4[3]			140[2, 3]			10[2] 5[3]			10[2] 5[3]			0.9[2, 3]			–		
Season / Site	W	S	A	W	S	A	W	S	A	W	S	A	W	S	A	W	S	A	W	S	A
SP1-S	<3	<3	<3	5	<2	<2	90	90	90	5	4	2	15	13	11	0.36	0.1	<0.1	<0.2	<0.2	<0.2
SP1-M	<3	<3	<3	250	230	200	300	300	280	33	35	33	38	42	40	<0.05	<0.1	<0.1	<0.2	<0.2	<0.2
SP1-B	<3	<3	<3	390	380	360	440	420	450	60	56	60	65	62	65	<0.05	<0.1	<0.1	<0.2	<0.2	<0.2
SP2-S	5	<3	<3	120	2	<2	220	110	90	5	4	2	15	13	12	0.43	<0.1	<0.1	<0.2	<0.2	<0.2
SP2-M	<3	3	<3	250	210	150	310	270	230	34	32	26	39	36	33	<0.05	<0.1	<0.1	<0.2	<0.2	<0.2
SP2-B	<3	6	<3	400	370	360	430	420	450	61	54	58	65	59	63	<0.05	<0.1	<0.1	<0.2	<0.2	<0.2
SP3-S	<3	<3	<3	15	<2	<2	110	90	80	5	3	<2	15	14	12	0.50	<0.1	<0.1	<0.2	<0.2	<0.2
SP3-M	<3	<3	<3	240	230	190	280	270	310	35	31	31	41	36	41	<0.05	<0.1	<0.1	<0.2	<0.2	<0.2
SP3-B	<3	<3	<3	380	290	360	420	400	450	59	39	61	64	58	65	<0.05	<0.1	<0.1	<0.2	<0.2	<0.2
SP4-S	<3	<3	<3	5	<2	<2	90	80	80	5	4	2	14	14	12	0.21	0.1	<0.1	<0.2	<0.2	<0.2
SP4-M	<3	<3	<3	180	200	140	240	240	220	28	27	27	34	33	34	0.07	<0.1	<0.1	<0.2	<0.2	<0.2
SP4-B	<3	3	<3	350	340	320	380	360	410	54	47	54	57	51	58	<0.05	<0.1	<0.1	<0.2	<0.2	<0.2
SP5-S	<3	<3	<3	4	<2	<2	80	100	80	4	4	2	13	13	12	0.41	0.1	<0.1	<0.2	<0.2	<0.2
SP5-M	<3	<3	<3	170	230	120	220	260	220	26	34	26	31	40	34	0.08	<0.1	<0.1	<0.2	<0.2	<0.2
SP5-B	<3	5	<3	350	330	320	390	360	420	52	46	53	55	52	58	<0.05	<0.1	<0.1	<0.2	<0.2	<0.2
SP6-S	<3	3	<3	6	<2	<2	90	100	100	5	3	2	14	14	12	0.16	0.1	<0.1	<0.2	<0.2	<0.2
SP6-M	<3	8	<3	220	150	200	270	260	290	34	23	33	38	35	39	<0.05	<0.1	<0.1	<0.2	<0.2	<0.2
SP6-B	3	4	<3	390	280	350	440	400	440	60	43	59	64	57	64	<0.05	<0.1	<0.1	<0.2	<0.2	<0.2

W – winter; S – summer; A – autumn

[1] The ANZECC & ARMCANZ (2000b) default trigger values for chemical stressors for tropical Australia for slightly disturbed offshore marine ecosystems.

[2] Winter values.

[3] Summer values.

Table 3-4: Nutrient concentrations at Evans Shoal sites

Parameter	Ammonium			Nitrate+nitrite			Total nitrogen			Orthophosphate		
Units		µg/L			µg/L			µg/L			µg/L	
Limit of reporting		<3			<2			<50			<2	
Guideline[1]		9[2] 4[3]			5[2] 4[3]			140[2, 3]			10[2] 5[3]	
Season **Site**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**
SP7-S	<3	4	<3	3	2	<2	80	100	90	5	4	2
SP7-B	6	<3	<3	6	2	<2	80	90	80	6	4	2
SP8-S	NS	<3	<3	NS	<2	<2	NS	90	90	NS	4	2
SP8-M	NS	5	<3	NS	<2	<2	NS	80	100	NS	5	2
SP8-B	NS	3	<3	NS	170	2	NS	240	80	NS	25	3
SP9-S	NS	5	<3	NS	2	<2	NS	90	80	NS	5	3
SP9-M	NS	5	<3	NS	190	<2	NS	310	80	NS	28	3
SP9-B	NS	7	<3	NS	180	110	NS	320	200	NS	32	24
SP10-S	<3	<3	<3	6	<2	<2	100	80	100	5	5	2
SP10-M	<3	<3	<3	200	150	64	260	220	160	31	24	15
SP10-B	<3	8	<3	330	300	310	370	350	420	51	43	53

Parameter	Total phosphorus			Chlorophyll *a*			Phaeophytin		
Units		µg/L			µg/L			µg/L	
Limit of reporting		<5			<0.1			<0.2	
Guideline[1]		10[2] 5[3]			0.9[2, 3]			–	
Season **Site**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**
SP7-S	13	12	12	0.22	0.1	<0.1	<0.2	<0.2	<0.2
SP7-B	14	13	12	0.45	0.2	0.2	<0.2	<0.2	<0.2
SP8-S	NS	12	12	NS	0.2	0.3	NS	<0.2	<0.2
SP8-M	NS	14	12	NS	0.3	<0.1	NS	<0.2	<0.2
SP8-B	NS	32	12	NS	0.2	0.2	NS	<0.2	<0.2
SP9-S	NS	14	12	NS	0.1	0.2	NS	<0.2	<0.2
SP9-M	NS	35	12	NS	0.2	0.2	NS	<0.2	<0.2
SP9-B	NS	43	31	NS	<0.1	<0.1	NS	<0.2	<0.2
SP10-S	14	14	12	0.18	0.1	<0.1	<0.2	<0.2	<0.2
SP10-M	36	30	24	0.05	0.2	0.3	<0.2	<0.2	<0.2
SP10-B	54	48	57	<0.05	<0.1	<0.1	<0.2	<0.2	<0.2

W – winter; S – summer; A – autumn

[1] The ANZECC & ARMCANZ (2000b) default trigger values for chemical stressors for tropical Australia for slightly disturbed offshore marine ecosystems.

[2] Winter values.

[3] Summer values.

NS = no sample due to inclement weather conditions.

Table 3-5: Nutrient concentrations at Tassie Shoal sites

Parameter	Ammonium			Nitrate+nitite			Total nitrogen			Orthophosphate			Total phosphorus			Chlorophyll *a*			Phaeophytin		
Units	µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L		
Limit of reporting	<3			<2			<50			<2			<5			<0.1			<0.2		
Guideline[1]	9[2] 4[3]			5[2] 4[3]			140[2, 3]			10[2] 5[3]			10[2] 5[3]			0.9[2, 3]			–		
Season **Site**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**
SP11-S	<3	4	<3	<2	<2	<2	90	90	80	4	3	3	14	13	13	0.21	0.2	<0.1	<0.2	<0.2	<0.2
SP11-B	7	<3	<3	6	<2	4	110	110	90	4	3	3	14	13	13	0.35	0.3	0.1	<0.2	<0.2	<0.2
SP12-S	<3	4	<3	2	<2	<2	90	120	80	4	4	3	14	14	12	0.17	0.2	<0.1	<0.2	<0.2	<0.2
SP12-M	<3	37	<3	<2	3	<2	90	90	90	4	7	2	12	15	13	0.42	0.8	0.1	<0.2	0.2	<0.2
SP12-B	<3	4	<3	180	210	74	240	280	180	29	33	17	34	39	28	0.07	0.2	0.2	<0.2	<0.2	<0.2
SP13-S	<3	9	<3	<2	<2	<2	100	110	80	5	5	2	14	14	13	0.16	0.2	<0.1	<0.2	<0.2	<0.2
SP13-M	<3	<3	<3	4	<2	<2	100	100	90	4	7	3	12	18	14	0.53	0.9	0.2	<0.2	0.4	<0.2
SP13-B	<3	<3	<3	150	200	110	220	260	210	24	30	24	30	38	32	0.10	0.3	0.1	<0.2	0.5	<0.2
SP14-S	7	5	<3	3	<2	<2	100	90	90	4	4	2	13	14	13	0.34	0.2	<0.1	<0.2	<0.2	<0.2
SP14-M	4	<3	<3	2	<2	<2	120	100	90	3	4	3	14	16	13	0.33	0.9	0.3	<0.2	0.4	<0.2
SP14-B	3	<3	<3	140	190	120	230	250	220	23	30	26	29	37	33	0.07	0.3	0.1	<0.2	0.5	<0.2

W – winter; S – summer; A – autumn

[1] The ANZECC & ARMCANZ (2000b) default trigger values for chemical stressors for tropical Australia for slightly disturbed offshore marine ecosystems.

[2] Winter values.

[3] Summer values.

Table 3-6: Nutrient concentrations at Lynedoch Bank sites

Parameter	Ammonium			Nitrate+nitrite			Total nitrogen			Orthophosphate			Total phosphorus			Chlorophyll *a*			Phaeophytin		
Units	µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L		
Limit of reporting	<3			<2			<50			<2			<5			<0.1			<0.2		
Guideline[1]	9[2] 4[3]			5[2] 4[3]			140[2, 3]			10[2] 5[3]			10[2] 5[3]			0.9[2, 3]			–		
Season **Site**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**
SP15-S	NS	<3	4	NS	2	<2	NS	100	90	NS	4	3	NS	13	12	NS	<0.1	<0.1	NS	<0.2	<0.2
SP15-M	NS	<3	<3	NS	5	<2	NS	90	120	NS	6	3	NS	15	14	NS	0.4	0.2	NS	<0.2	<0.2
SP15-B	NS	<3	8	NS	190	110	NS	260	250	NS	30	22	NS	37	36	NS	0.1	<0.1	NS	<0.2	<0.2
SP16-S	NS	<3	<3	NS	<2	<2	NS	80	100	NS	4	2	NS	14	12	NS	<0.1	<0.1	NS	<0.2	<0.2
SP16-B	NS	<3	<3	NS	<2	<2	NS	90	90	NS	4	2	NS	13	12	NS	0.2	<0.1	NS	<0.2	<0.2
SP17-S	NS	<3	<3	NS	<2	<2	NS	100	100	NS	4	2	NS	12	12	NS	<0.1	<0.1	NS	<0.2	<0.2
SP17-M	NS	<3	<3	NS	16	7	NS	100	100	NS	7	5	NS	16	14	NS	0.5	0.3	NS	0.2	<0.2
SP17-B	NS	<3	9	NS	180	150	NS	250	240	NS	30	29	NS	37	35	NS	0.1	<0.1	NS	<0.2	<0.2

W – winter; S – summer; A – autumn

[1] The ANZECC & ARMCANZ (2000b) default trigger values for chemical stressors for tropical Australia for slightly disturbed offshore marine ecosystems.

[2] Winter values.

[3] Summer values.

NS = no sample due to inclement weather conditions.

Table 3-7: Total metal concentrations at permit area sites

Parameter	Arsenic			Barium			Cadmium			Chromium			Cobalt			Copper			Mercury			Nickel			Lead			Zinc		
Units	µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L		
Limit of reporting	<0.5			<0.5			<0.1			<0.2			<0.05			<0.2			<0.1			<0.3			<0.1			<1.0		
Guideline[1]	4.5[2]			–			0.7			7.7[3]			1.0			0.3			0.1			7.0			2.2			7.0		
Season **Site**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**
SP1-S	1.8	1.6	1.9	5.6	5.1	5.9	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	0.3	0.3	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	1	2	1
SP1-M	1.9	1.7	1.9	5.6	5.5	6.1	<0.1	<0.1	<0.1	0.2	<0.2	0.2	<0.05	<0.05	<0.05	<0.2	0.2	0.2	<0.1	<0.1	<0.1	0.4	<0.3	0.3	<0.1	<0.1	<0.1	1	<1	2
SP1-B	2.0	1.9	2.1	7.9	7.0	8.0	<0.1	<0.1	<0.1	0.3	<0.2	0.3	<0.05	<0.05	<0.05	<0.2	0.2	<0.2	<0.1	<0.1	<0.1	0.4	0.3	0.4	<0.1	<0.1	<0.1	<1	1	1
SP2-S	1.7	1.6	1.8	5.5	5.2	5.5	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	**0.5**	**0.5**	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	3	3	1
SP2-M	1.9	1.8	1.8	5.7	5.6	5.8	<0.1	<0.1	<0.1	0.2	<0.2	<0.2	<0.05	<0.05	<0.05	**1.0**	0.3	<0.2	<0.1	<0.1	<0.1	0.3	<0.3	<0.3	<0.1	<0.1	<0.1	4	<1	1
SP2-B	1.9	1.7	2.0	7.8	6.9	8.1	<0.1	<0.1	<0.1	0.3	<0.2	0.2	<0.05	<0.05	<0.05	<0.2	0.3	0.3	<0.1	<0.1	<0.1	0.4	0.4	0.3	<0.1	<0.1	<0.1	<1	3	2
SP3-S	1.7	1.6	1.8	5.3	5.4	5.5	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	0.2	0.2	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	2	1	<1
SP3-M	1.8	1.8	1.8	5.5	5.6	5.9	<0.1	<0.1	<0.1	<0.2	<0.2	0.2	<0.05	<0.05	<0.05	<0.2	<0.2	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	<1	<1	<1
SP3-B	1.8	1.8	2.1	7.5	6.3	8.2	<0.1	<0.1	<0.1	0.3	<0.2	0.2	<0.05	<0.05	<0.05	<0.2	0.3	<0.2	<0.1	<0.1	<0.1	0.3	0.4	0.5	<0.1	<0.1	<0.1	1	<1	<1
SP4-S	1.6	1.6	1.8	5.5	5.2	5.6	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	0.2	**0.5**	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	1	<1	<1
SP4-M	1.8	1.7	1.7	5.7	5.0	5.6	<0.1	<0.1	<0.1	0.2	<0.2	<0.2	<0.05	<0.05	<0.05	0.2	0.3	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	<1	1	1
SP4-B	1.9	1.8	2.0	6.9	6.4	7.5	<0.1	<0.1	<0.1	0.2	<0.2	0.2	<0.05	<0.05	<0.05	0.2	**0.7**	<0.2	<0.1	<0.1	<0.1	0.4	0.5	0.3	<0.1	<0.1	<0.1	<1	4	<1
SP5-S	1.7	1.6	1.6	5.3	5.3	5.0	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	0.3	**0.6**	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	2	3	<1
SP5-M	1.8	1.8	1.8	5.5	5.6	5.8	<0.1	<0.1	<0.1	0.2	<0.2	<0.2	<0.05	<0.05	<0.05	<0.2	<0.2	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	<1	<1	<1
SP5-B	1.7	1.8	1.8	6.8	6.1	6.7	<0.1	<0.1	<0.1	0.2	<0.2	<0.2	<0.05	<0.05	<0.05	**0.4**	0.2	<0.2	<0.1	<0.1	<0.1	0.4	0.3	0.3	<0.1	<0.1	<0.1	2	<1	1
SP6-S	1.6	1.6	1.6	5.5	5.3	5.3	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	**0.4**	0.3	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	2	2	<1
SP6-M	1.8	1.8	1.8	5.6	5.5	5.7	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	0.2	0.3	<0.2	<0.1	<0.1	<0.1	0.3	<0.3	<0.3	<0.1	<0.1	<0.1	<1	2	1
SP6-B	1.9	1.8	1.9	7.7	6.8	7.6	<0.1	<0.1	<0.1	0.2	<0.2	<0.2	<0.05	<0.05	<0.05	0.2	0.2	<0.2	<0.1	<0.1	<0.1	0.4	0.3	0.4	<0.1	<0.1	<0.1	1	2	<1

[1] All trigger values listed are for ANZECC & ARMCANZ (2000a) 99% species protection, while that for cobalt is 95% species protection.
[2] Low reliability trigger value.
[3] Value for Chromium III.
Values in bold are above the ANZECC & ARMCANZ (2000a) trigger value.

Table 3-8: Total metal concentrations at Evans Shoal sites

Parameter	Arsenic			Barium			Cadmium			Chromium			Cobalt			Copper			Mercury			Nickel			Lead			Zinc		
Units	µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L		
Limit of reporting	<0.5			<0.5			<0.1			<0.2			<0.05			<0.2			<0.1			<0.3			<0.1			<1.0		
Guideline[1]	4.5[2]			–			0.7			7.7[3]			1.0			0.3			0.1			7.0			2.2			7.0		
Season Site	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**
SP7-S	1.7	1.7	1.7	5.6	5.4	5.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	0.3	**0.6**	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	0.2	<0.1	1	1	<1
SP7-B	1.7	1.7	1.5	5.5	5.6	5.6	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	**0.5**	**0.4**	<0.2	<0.1	<0.1	<0.1	0.3	<0.3	<0.3	<0.1	<0.1	<0.1	2	2	<1
SP8-S	NS	1.6	1.6	NS	5.3	5.3	NS	<0.1	<0.1	NS	<0.2	<0.2	NS	<0.05	<0.05	NS	0.2	<0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	<0.1	<0.1	NS	1	1
SP8-M	NS	1.7	1.7	NS	5.6	5.5	NS	<0.1	<0.1	NS	<0.2	<0.2	NS	<0.05	<0.05	NS	**0.4**	0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	<0.1	<0.1	NS	2	<1
SP8-B	NS	1.8	1.7	NS	5.9	5.3	NS	<0.1	<0.1	NS	<0.2	<0.2	NS	<0.05	<0.05	NS	0.3	<0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	<0.1	<0.1	NS	2	1
SP9-S	NS	1.8	1.7	NS	5.6	5.4	NS	<0.1	<0.1	NS	<0.2	<0.2	NS	<0.05	<0.05	NS	0.3	<0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	0.2	<0.1	NS	1	2
SP9-M	NS	1.8	1.8	NS	5.8	5.2	NS	<0.1	<0.1	NS	<0.2	<0.2	NS	<0.05	<0.05	NS	**0.4**	<0.2	NS	<0.1	<0.1	NS	0.3	<0.3	NS	<0.1	<0.1	NS	2	<1
SP9-B	NS	1.9	1.9	NS	6.0	5.9	NS	<0.1	<0.1	NS	<0.2	<0.2	NS	<0.05	<0.05	NS	0.3	<0.2	NS	<0.1	<0.1	NS	0.4	<0.3	NS	<0.1	<0.1	NS	2	1
SP10-S	1.6	1.7	1.7	5.5	5.6	5.5	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	0.3	0.2	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	<1	1	<1
SP10-M	1.8	1.9	1.8	5.8	6.0	5.6	<0.1	<0.1	<0.1	0.2	<0.2	<0.2	<0.05	<0.05	<0.05	**0.4**	0.2	<0.2	<0.1	<0.1	<0.1	0.3	0.3	<0.3	<0.1	<0.1	<0.1	2	3	<1
SP10-B	1.8	1.9	1.9	6.7	6.4	7.4	<0.1	<0.1	<0.1	0.2	<0.2	0.2	<0.05	<0.05	<0.05	**0.4**	**0.4**	0.2	<0.1	<0.1	<0.1	0.4	0.4	0.4	<0.1	<0.1	<0.1	2	4	<1

[1] All trigger values listed are for ANZECC & ARMCANZ (2000a) 99% species protection, while that for cobalt is 95% species protection.

[2] Low reliability trigger value.

[3] Value for Chromium III.

Values in bold are above the ANZECC & ARMCANZ (2000a) trigger value.

NS = no sample due to inclement weather conditions.

Table 3-9: Total metal concentrations at Tassie Shoal sites

Parameter		Arsenic			Barium			Cadmium			Chromium			Cobalt			Copper			Mercury			Nickel			Lead			Zinc	
Units		µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L	
Limit of reporting		<0.5			<0.5			<0.1			<0.2			<0.05			<0.2			<0.1			<0.3			<0.1			<1.0	
Guideline[1]		4.5[2]			–			0.7			7.7[3]			1.0			0.3			0.1			7.0			2.2			7.0	
Season / **Site**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**
SP11-S	1.6	1.6	1.9	5.9	5.3	5.3	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	< 0.05	< 0.05	< 0.05	0.3	0.2	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	<1	2	<1
SP11-B	1.6	1.8	1.6	5.5	5.6	5.2	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	< 0.05	< 0.05	< 0.05	0.3	0.3	<0.2	<0.1	<0.1	<0.1	<0.3	0.3	<0.3	<0.1	<0.1	<0.1	1	<1	<1
SP12-S	1.6	1.7	1.6	5.4	5.2	5.2	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	< 0.05	< 0.05	< 0.05	0.2	0.3	0.3	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	<1	2	2
SP12-M	1.6	1.9	1.6	5.5	5.5	5.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	< 0.05	< 0.05	< 0.05	0.3	0.2	0.3	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	<1	1	<1
SP12-B	1.7	1.9	1.8	6.0	5.8	5.8	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	< 0.05	< 0.05	< 0.05	0.2	0.2	0.3	<0.1	<0.1	<0.1	<0.3	0.3	<0.3	<0.1	<0.1	<0.1	<1	3	<1
SP13-S	1.6	1.6	1.6	5.5	5.5	5.2	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	< 0.05	< 0.05	< 0.05	0.3	**0.5**	<0.2	<0.1	<0.1	<0.1	<0.3	0.3	<0.3	<0.1	<0.1	<0.1	1	4	1
SP13-M	1.6	1.7	1.6	5.5	5.8	5.3	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	< 0.05	< 0.05	< 0.05	**0.4**	<0.2	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	1	1	<1
SP13-B	1.7	1.7	1.8	5.9	5.7	6.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.2	< 0.05	< 0.05	< 0.05	<0.2	<0.2	0.3	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	1	1	<1
SP14-S	1.7	1.6	1.7	5.4	5.4	5.5	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	< 0.05	< 0.05	< 0.05	0.2	<0.2	0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	2	<1	<1
SP14-M	1.7	1.7	1.8	5.5	5.8	5.5	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	< 0.05	< 0.05	< 0.05	0.2	<0.2	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	2	<1	<1
SP14-B	1.8	1.8	2.0	6.1	5.8	6.2	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	< 0.05	< 0.05	< 0.05	**0.4**	<0.2	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	4	<1	1

[1] All trigger values listed are for ANZECC & ARMCANZ (2000a) 99% species protection, while that for cobalt is 95% species protection.
[2] Low reliability trigger value.
[3] Value for Chromium III.
Values in bold are above the ANZECC & ARMCANZ (2000a) trigger value.

Table 3-10: Total metal concentrations at Lynedoch Bank sites

Parameter	Arsenic			Barium			Cadmium			Chromium			Cobalt			Copper			Mercury			Nickel			Lead			Zinc		
Units	µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L		
Limit of reporting	<0.5			<0.5			<0.1			<0.2			<0.05			<0.2			<0.1			<0.3			<0.1			<1.0		
Guideline[1]	4.5[2]			–			0.7			7.7[3]			1.0			0.3			0.1			7.0			2.2			7.0		
Season Site	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**
SP15-S	NS	1.5	1.7	NS	5.6	5.5	NS	<0.1	<0.1	NS	<0.2	<0.2	NS	<0.05	<0.05	NS	<0.2	<0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	<0.1	<0.1	NS	<1	3
SP15-M	NS	1.8	1.8	NS	5.7	5.7	NS	<0.1	<0.1	NS	<0.2	<0.2	NS	<0.05	<0.05	NS	<0.2	<0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	<0.1	<0.1	NS	<1	<1
SP15-B	NS	1.7	1.9	NS	5.8	6.3	NS	<0.1	<0.1	NS	0.2	<0.2	NS	<0.05	<0.05	NS	<0.2	0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	<0.1	<0.1	NS	<1	1
SP16-S	NS	1.5	1.9	NS	5.5	5.5	NS	<0.1	<0.1	NS	<0.2	<0.2	NS	<0.05	<0.05	NS	<0.2	0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	<0.1	<0.1	NS	<1	1
SP16-B	NS	1.7	1.9	NS	5.4	5.6	NS	<0.1	<0.1	NS	<0.2	<0.2	NS	<0.05	<0.05	NS	<0.2	<0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	<0.1	<0.1	NS	<1	1
SP17-S	NS	1.7	1.8	NS	5.6	5.6	NS	<0.1	<0.1	NS	<0.2	<0.2	NS	<0.05	<0.05	NS	0.2	0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	<0.1	<0.1	NS	<1	3
SP17-M	NS	1.7	1.7	NS	5.7	5.6	NS	<0.1	<0.1	NS	<0.2	<0.2	NS	<0.05	<0.05	NS	<0.2	<0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	<0.1	<0.1	NS	2	3
SP17-B	NS	1.8	1.9	NS	6.0	6.2	NS	<0.1	<0.1	NS	<0.2	<0.2	NS	<0.05	<0.05	NS	<0.2	<0.2	NS	<0.1	<0.1	NS	0.4	<0.3	NS	<0.1	<0.1	NS	1	1

[1] All trigger values listed are for ANZECC & ARMCANZ (2000a) 99% species protection, while that for cobalt is 95% species protection.
[2] Low reliability trigger value.
[3] Value for Chromium III.
Values in bold are above the ANZECC & ARMCANZ (2000a) trigger value.

NS = no sample due to inclement weather conditions.

Table 3-11: Filtered metal concentrations at permit area sites

Parameter	Arsenic			Barium			Cadmium			Chromium			Cobalt			Copper			Mercury			Nickel			Lead			Zinc		
Units	μg/L			μg/L			μg/L			μg/L			μg/L			μg/L			μg/L			μg/L			μg/L			μg/L		
Limit of reporting	<0.5			<0.5			<0.1			<0.2			<0.05			<0.2			<0.1			<0.3			<0.1			<1.0		
Guideline[1]	4.5[2]			–			0.7			7.7[3]			1.0			0.3			0.1			7.0			2.2			7.0		
Season Site	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**
SP1-S	1.7	1.6	1.6	5.4	5.0	5.4	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	**0.4**	0.2	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	1	2	1
SP1-M	1.9	1.7	1.8	5.6	5.5	6.3	<0.1	<0.1	<0.1	0.2	<0.2	0.2	<0.05	<0.05	<0.05	<0.2	<0.2	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	0.3	<0.1	<0.1	<0.1	1	1	1
SP1-B	1.9	1.7	2.0	8.0	7.1	7.9	<0.1	<0.1	<0.1	0.2	<0.2	0.2	<0.05	<0.05	<0.05	<0.2	0.2	<0.2	<0.1	<0.1	<0.1	0.4	0.3	0.4	<0.1	<0.1	<0.1	<1	1	<1
SP2-S	1.7	1.6	1.7	5.6	5.1	5.6	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	0.3	**0.4**	0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	3	2	1
SP2-M	1.9	1.6	1.9	5.5	5.5	5.7	<0.1	<0.1	<0.1	0.2	<0.2	<0.2	<0.05	<0.05	<0.05	**0.4**	0.2	<0.2	<0.1	<0.1	<0.1	0.3	<0.3	<0.3	<0.1	<0.1	<0.1	3	<1	1
SP2-B	1.9	1.8	1.9	7.5	6.8	8.0	<0.1	<0.1	<0.1	0.2	<0.2	0.2	<0.05	<0.05	<0.05	<0.2	0.3	<0.2	<0.1	<0.1	<0.1	0.4	0.3	0.4	<0.1	<0.1	<0.1	1	4	<1
SP3-S	1.7	1.6	1.7	5.3	5.3	5.5	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	0.2	0.3	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	2	1	<1
SP3-M	1.8	1.7	1.9	5.5	5.3	6.0	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	<0.2	<0.2	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	<1	2	<1
SP3-B	1.8	1.8	2.0	7.5	6.2	8.1	<0.1	<0.1	<0.1	0.2	<0.2	<0.2	<0.05	<0.05	<0.05	<0.2	<0.2	<0.2	<0.1	<0.1	<0.1	0.3	0.3	0.4	<0.1	<0.1	<0.1	1	1	<1
SP4-S	1.7	1.6	1.8	5.6	5.1	5.6	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	<0.2	0.2	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	1	<1	<1
SP4-M	1.7	1.7	1.7	5.6	5.3	5.6	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	0.2	0.3	<0.2	<0.1	<0.1	<0.1	0.3	<0.3	<0.3	<0.1	<0.1	<0.1	<1	1	<1
SP4-B	1.8	1.8	1.8	7.0	6.3	7.4	<0.1	<0.1	<0.1	0.2	<0.2	0.2	<0.05	<0.05	<0.05	<0.2	0.2	<0.2	<0.1	<0.1	<0.1	0.3	0.3	0.3	<0.1	<0.1	<0.1	<1	1	<1
SP5-S	1.7	1.6	1.6	5.3	5.3	5.0	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	**0.5**	0.3	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	0.1	<0.1	<0.1	3	<1	<1
SP5-M	1.8	1.7	1.8	5.6	5.6	6.0	<0.1	<0.1	<0.1	0.2	<0.2	<0.2	<0.05	<0.05	<0.05	<0.2	0.2	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	<1	1	<1
SP5-B	1.8	1.7	1.7	6.7	6.4	6.4	<0.1	<0.1	<0.1	0.2	<0.2	<0.2	<	<	<	0.2	0.2	<0.2	<0.1	<0.1	<0.1	0.3	<0.3	<0.3	<0.1	<0.1	<0.1	1	2	<1

Parameter	Arsenic			Barium			Cadmium			Chromium			Cobalt			Copper			Mercury			Nickel			Lead			Zinc		
Units	µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L		
Limit of reporting	<0.5			<0.5			<0.1			<0.2			<0.05			<0.2			<0.1			<0.3			<0.1			<1.0		
Guideline[1]	4.5[2]			–			0.7			7.7[3]			1.0			0.3			0.1			7.0			2.2			7.0		
Season **Site**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**
													0.05	0.05	0.05															
SP6-S	1.6	1.6	1.6	5.4	5.2	5.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	0.3	0.3	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	1	2	<1
SP6-M	1.8	1.7	1.8	5.5	5.4	5.7	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	0.2	0.3	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	<1	3	1
SP6-B	1.8	1.8	1.8	7.6	6.8	7.5	<0.1	<0.1	<0.1	0.2	<0.2	<0.2	<0.05	<0.05	<0.05	0.3	0.3	<0.2	<0.1	<0.1	<0.1	0.4	0.3	0.4	<0.1	<0.1	<0.1	2	3	<1

[1] All trigger values listed are for ANZECC & ARMCANZ (2000a) 99% species protection, while that for cobalt is 95% species protection.
[2] Low reliability trigger value.
[3] Value for Chromium III.

Table 3-12: Filtered metal concentrations at Evans Shoal sites

Parameter	Arsenic			Barium			Cadmium			Chromium			Cobalt			Copper			Mercury			Nickel			Lead			Zinc		
Units	µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L		
Limit of reporting	<0.5			<0.5			<0.1			<0.2			<0.05			<0.2			<0.1			<0.3			<0.1			<1.0		
Guideline[1]	4.5[2]			–			0.7			7.7[3]			1.0			0.3			0.1			7.0			2.2			7.0		
Season / **Site**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**
SP7-S	1.6	1.6	1.7	5.6	5.4	5.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	0.3	**0.4**	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	0.1	<0.1	2	1	<1
SP7-B	1.5	1.6	1.3	5.4	5.4	5.5	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	**0.4**	0.3	<0.2	<0.1	<0.1	<0.1	0.3	<0.3	<0.3	<0.1	<0.1	<0.1	2	2	<1
SP8-S	NS	1.6	1.6	NS	5.4	5.2	NS	<0.1	<0.1	NS	<0.2	<0.2	<0.05	<0.05	<0.05	NS	0.2	<0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	<0.1	<0.1	NS	<1	<1
SP8-M	NS	1.6	1.6	NS	5.5	5.3	NS	<0.1	<0.1	NS	<0.2	<0.2	<0.05	<0.05	<0.05	NS	0.3	<0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	<0.1	<0.1	NS	2	<1
SP8-B	NS	1.8	1.8	NS	5.6	5.1	NS	<0.1	<0.1	NS	<0.2	<0.2	<0.05	<0.05	<0.05	NS	**0.4**	<0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	<0.1	<0.1	NS	2	<1
SP9-S	NS	1.8	1.8	NS	5.5	5.3	NS	<0.1	<0.1	NS	<0.2	<0.2	<0.05	<0.05	<0.05	NS	0.3	<0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	0.2	<0.1	NS	1	<1
SP9-M	NS	1.8	1.8	NS	5.6	5.0	NS	<0.1	<0.1	NS	<0.2	<0.2	<0.05	<0.05	<0.05	NS	**0.4**	<0.2	NS	<0.1	<0.1	NS	0.3	<0.3	NS	<0.1	<0.1	NS	2	<1
SP9-B	NS	1.9	1.7	NS	6.0	5.7	NS	<0.1	<0.1	NS	<0.2	<0.2	<0.05	<0.05	<0.05	NS	0.3	<0.2	NS	<0.1	<0.1	NS	0.4	<0.3	NS	<0.1	<0.1	NS	3	1
SP10-S	1.7	1.7	1.6	5.4	5.5	5.5	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	0.3	0.2	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	<1	1	<1
SP10-M	1.7	1.8	1.8	5.8	5.9	5.6	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	**0.4**	0.3	<0.2	<0.1	<0.1	<0.1	0.3	<0.3	<0.3	<0.1	<0.1	<0.1	2	3	<1
SP10-B	1.8	1.9	1.9	6.8	6.3	7.1	<0.1	<0.1	<0.1	0.2	<0.2	0.2	<0.05	<0.05	<0.05	0.3	**0.4**	<0.2	<0.1	<0.1	<0.1	0.3	0.4	0.4	<0.1	<0.1	<0.1	1	4	<1

[1] All trigger values listed are for ANZECC & ARMCANZ (2000a) 99% species protection, while that for cobalt is 95% species protection.
[2] Low reliability trigger value.
[3] Value for Chromium III.

NS = no sample due to inclement weather conditions.

Table 3-13: Filtered metal concentrations at Tassie Shoal sites

Parameter	Arsenic			Barium			Cadmium			Chromium			Cobalt			Copper			Mercury			Nickel			Lead			Zinc		
Units	µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L		
Limit of reporting	<0.5			<0.5			<0.1			<0.2			<0.05			<0.2			<0.1			<0.3			<0.1			<1.0		
Guideline[1]	4.5[2]			–			0.7			7.7[3]			1.0			0.3			0.1			7.0			2.2			7.0		
Season / **Site**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**
SP11-S	1.6	1.5	1.8	5.6	5.0	5.5	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	**0.4**	**0.4**	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	1	2	<1
SP11-B	1.6	1.7	1.7	5.4	5.2	5.2	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	0.3	0.3	<0.2	<0.1	<0.1	<0.1	<0.3	0.3	<0.3	<0.1	<0.1	<0.1	3	<1	<1
SP12-S	1.6	1.7	1.7	5.5	5.2	5.2	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	0.2	0.3	0.3	<0.1	<0.1	<0.1	<0.3	0.3	<0.3	<0.1	<0.1	<0.1	1	1	1
SP12-M	1.6	1.8	1.7	5.4	5.5	5.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	0.3	**0.5**	0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	<1	5	1
SP12-B	1.7	1.9	1.8	6.1	5.8	5.8	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	<0.2	0.3	0.3	<0.1	<0.1	<0.1	<0.3	0.3	<0.3	<0.1	<0.1	<0.1	<1	3	<1
SP13-S	1.6	1.7	1.7	5.6	5.7	5.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	0.3	**0.4**	<0.2	<0.1	<0.1	<0.1	<0.3	0.3	<0.3	<0.1	<0.1	<0.1	1	4	<1
SP13-M	1.6	1.6	1.7	5.3	5.7	5.3	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	0.3	<0.2	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	1	<1	<1
SP13-B	1.8	1.6	1.8	6.0	5.7	6.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	<0.2	<0.2	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	1	<1	<1
SP14-S	1.7	1.6	1.7	5.3	5.4	5.4	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	<0.2	<0.2	0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	2	<1	<1
SP14-M	1.7	1.6	1.7	5.2	5.5	5.7	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	<0.2	<0.2	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	1	<1	<1
SP14-B	1.7	1.8	2.0	6.0	5.8	6.2	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.05	<0.05	<0.05	**0.4**	<0.2	<0.2	<0.1	<0.1	<0.1	<0.3	<0.3	<0.3	<0.1	<0.1	<0.1	3	1	<1

[1] All trigger values listed are for ANZECC & ARMCANZ (2000a) 99% species protection, while that for cobalt is 95% species protection.
[2] Low reliability trigger value.
[3] Value for Chromium III.

Table 3-14: Filtered metal concentrations at Lynedoch Bank sites

Parameter	Arsenic			Barium			Cadmium			Chromium			Cobalt			Copper			Mercury			Nickel			Lead			Zinc		
Units	µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L			µg/L		
Limit of reporting	<0.5			<0.5			<0.1			<0.2			<0.05			<0.2			<0.1			<0.3			<0.1			<1.0		
Guideline[1]	4.5[2]			–			0.7			7.7[3]			1.0			0.3			0.1			7.0			2.2			7.0		
Season Site	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**
SP15-S	NS	1.5	1.8	NS	5.6	5.5	NS	<0.1	<0.1	NS	<0.2	<0.2	NS	<0.05	<0.05	NS	<0.2	<0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	<0.1	<0.1	NS	<1	2
SP15-M	NS	1.8	1.8	NS	5.6	5.7	NS	<0.1	<0.1	NS	<0.2	<0.2	NS	<0.05	<0.05	NS	<0.2	<0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	<0.1	<0.1	NS	1	1
SP15-B	NS	1.7	1.9	NS	5.8	6.3	NS	<0.1	<0.1	NS	<0.2	<0.2	NS	<0.05	<0.05	NS	<0.2	<0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	<0.1	<0.1	NS	<1	<1
SP16-S	NS	1.6	1.7	NS	5.6	5.4	NS	<0.1	<0.1	NS	<0.2	<0.2	NS	<0.05	<0.05	NS	<0.2	<0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	<0.1	<0.1	NS	1	1
SP16-B	NS	1.6	1.7	NS	5.4	5.3	NS	<0.1	<0.1	NS	<0.2	<0.2	NS	<0.05	<0.05	NS	<0.2	<0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	<0.1	<0.1	NS	1	1
SP17-S	NS	1.6	1.7	NS	5.7	5.6	NS	<0.1	<0.1	NS	<0.2	<0.2	NS	<0.05	<0.05	NS	<0.2	<0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	<0.1	<0.1	NS	<1	4
SP17-M	NS	1.7	1.7	NS	5.7	5.6	NS	<0.1	<0.1	NS	<0.2	<0.2	NS	<0.05	<0.05	NS	<0.2	<0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	<0.1	<0.1	NS	<1	1
SP17-B	NS	1.7	1.9	NS	5.9	6.3	NS	<0.1	<0.1	NS	<0.2	<0.2	NS	<0.05	<0.05	NS	<0.2	<0.2	NS	<0.1	<0.1	NS	<0.3	<0.3	NS	<0.1	<0.1	NS	<1	2

[1] All trigger values listed are for ANZECC & ARMCANZ (2000a) 99% species protection, while that for cobalt is 95% species protection.
[2] Low reliability trigger value.
[3] Value for Chromium III.

NS = no sample due to inclement weather conditions.

3.2.3 Hydrocarbons

TPHs at all sites and depths in and around the permit area, Evans Shoal Tassie Shoal and Lynedoch Bank were below the laboratory LORs during the summer and autumn surveys. Consequently, PAHs were not analysed. Results for all sites can be found in **Appendix C**. However, as an example, the results for all three depths at SP1 are shown in **Table 3-15**.

During the winter survey, two sites in the permit area (SP5-S and SP6-M) and one site at Evans Shoal (SP14-M) had TPH above the LOR, the results of which are shown in **Table 3-16**. TPH was 130 µg/L for the fraction C_{15}–C_{28} at site SP5-S, 230 µg/L for the fraction C_{15}–C_{28} at site SP6-M and 190 µg/L for the fraction C_{29}–C_{36} at site SP14-M. Hydrocarbons in diesel fuel range from approximately C_{11}–C_{20} (Agency for Toxic Substances and Disease Registry 1999). It is possible that the open Niskin bottle passed through the surface water in which traces of diesel fuel from the boat had been released and contaminated the sample. However, as the TPH at SP14-M was from a higher hydrocarbon fraction it would appear that there were two sources of contamination. If there were areas of natural hydrocarbon seepage that occurred in the sampling area then hydrocarbons would be present in all fractions. In addition, there was little difference in the hydrocarbon profiles (**Section 3.1.9**) between sites, which would also indicate a lack of hydrocarbons in the areas sampled.

There is a low reliability trigger value for TPH C_{10}–C_{36} for 99% species protection of 7 µg/L (ANZECC & ARMCANZ 2000b). However, the laboratory LORs were above this value so it is difficult to determine if any exceedances have occurred. In cases where the trigger values are lower than the LOR the reporting of results should be either ‘detected’ or ‘not detected’ unless a better LOR can be achieved. In the past, TPH was analysed according to carbon chains C_6–C_9, C_{10}–C_{14}, C_{15}–C_{28} and C_{29}–C_{36} but in an attempt to incorporate health and ecological screening levels for petroleum hydrocarbons, the National Environment Protection Council released National Environment Protection Measures (NEPC 2013) which resulted in changes in the carbon chain divisions considered. This was based on analytical factors such as physical and chemical properties and the availability of toxicity data. This new analysis of hydrocarbons is called TRHs and includes BTEXN.

The BTEXN at all depths for permit area, Evans Shoal and Tassie Shoal sites were also below the LOR (**Table 3-15** and **Table 3-16**).

Table 3-15: TPHs, TRHs and BTEXN at site SP1

Compound	LOR (µg/L)	Sample[2]								
		SP1-S (µg/L)			SP1-M (µg/L)			SP1-B (µg/L)		
Season[1]		W	S	A	W	S	A	W	S	A
TPHs										
C_6–C_9	20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C_{10}–C_{14}	50	<50	<20	<50	<50	<20	<50	<50	<20	<50
C_{15}–C_{28}	100	<100	<100	<100	<100	<100	<100	<100	<100	<100
C_{29}–C_{36}	50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C_{10}–C_{36} (sum)	50	<50	<50	<50	<50	<50	<50	<50	<50	<50
TRHs										
C_6–C_{10}	20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C_6–C_{10} minus BTEX	20	<20	<20	<20	<20	<20	<20	<20	<20	<20
>C_{10}–C_{16}	100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C_{16}–C_{34}	100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C_{34}–C_{40}	100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C_{10}–C_{40} (sum)	100	<100	<100	<100	<100	<100	<100	<100	<100	<100
BTEXN										
Benzene	1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	2	<2	<2	<2	<2	<2	<2	<2	<2	<2
meta-& para-xylene	2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ortho-xylene	2	-	-	<2	-	-	<2	-	-	<2
Total xylene	2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of BTEX	1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Naphthalene	5	<5	<5	<5	<5	<5	<5	<5	<5	<5

[1] W = winter, S = summer, A = autumn
[2] -S = near surface water, -M = mid-water, -B = near bottom water.

Table 3-16: TPHs, TRHs and BTEXN at sites SP5-S, SP6-M and SP14-M

Compound	LOR (µg/L)	Sample[2]								
		SP5-S (µg/L)			SP6-M (µg/L)			SP14-M (µg/L)		
Season[1]		W	S	A	W	S	A	W	S	A
TPHs										
C_6–C_9	20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C_{10}–C_{14}	50	<50	<20	<50	<50	<20	<50	<20	<20	<50
C_{15}–C_{28}	100	**140**	<100	**140**	**310**	<100	**310**	<100	<100	<100
C_{29}–C_{36}	50	<50	<50	<50	<50	<50	<50	**190**	<50	**190**
C_{10}–C_{36} (sum)	50	**140**	<50	**140**	**310**	<50	**310**	**190**	<50	**190**
TRHs										
C_6–C_{10}	20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C_6–C_{10} minus BTEX	20	<20	<20	<20	<20	<20	<20	<20	<20	<20
>C_{10}–C_{16}	100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C_{16}–C_{34}	100	**130**	<100	**130**	**230**	<100	**230**	**180**	<100	**180**
>C_{34}–C_{40}	100	<100	<100	<100	<100	<100	<100	**220**	<100	**220**
>C_{10}–C_{40} (sum)	100	**130**	<100	**130**	**230**	<100	**230**	**400**	<100	**400**
BTEXN										
Benzene	1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	2	<2	<2	<2	<2	<2	<2	<2	<2	<2
meta-& para-xylene	2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total xylene	2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of BTEX	1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Naphthalene	5	<5	<5	<5	<5	<5	<5	<5	<5	<5

[1] W = winter, S = summer, A = autumn
[2] -S = near surface water, -M = mid-water, -B = near bottom water.

3.2.4 Naturally occurring radioactive materials

Winter

Radium^{226} was found above the laboratory minimum reporting limit (MRL) at one location during the survey, at SP4-M. Radium^{228} was above the MRL at a number of different sites including SP1-S, SP2-S, SP2-M, SP3-S and SP4-M all within the permit area and SP14-B in the Evans Shoal area. Thorium^{228} concentrations were all below the MRL at all depths for all sites (**Table 3-17**, **Table 3-18** and **Table 3-19**).

Summer

Radium^{226} was found above the laboratory MRL in four samples; SP2-B, SP4-S, SP4–M and SP15-M. Radium^{228} was slightly above the MRL for SP2-B, SP4-B and SP8-B. Thorium^{228} concentrations were all below the MRL at all depths for all sites (**Table 3-17**, **Table 3-18**, **Table 3-19** and **Table 3-20**). There are no ANZECC & ARMCANZ (2000a) trigger values for these radionuclides.

Autumn

Radium^{226} was found above the laboratory MRL in eight samples (SP2-M, SP4-S, SP5-M, SP7-B, SP8-S, SP9-S, SP11-S and SP12-M. Radium^{228} was slightly above the MRL for SP4-S. Thorium^{228} concentrations were all below the MRL at all depths for all sites (**Table 3-17**, **Table 3-18**, **Table 3-19** and **Table 3-20**). There are no ANZECC & ARMCANZ (2000a) trigger values for these radionuclides.

Table 3-17: Naturally occurring radioactive materials at permit area sites

Parameter	Radium^{226}			Radium^{228}			Thorium^{228}		
Units	(Bq/L)			(Bq/L)			(Bq/L)		
Minimum reporting limit (MRL)	0.1			0.1			0.1		
Season[1]	W	S	A	W	S	A	W	S	A
Site/sample[2]									
SP1-S	<0.1	<0.1	<0.1	0.123 ± 0.061	<0.1	<0.1	<0.1	<0.1	<0.1
SP1-M	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP1-B	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP2-S	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP2-M	<0.1	<0.1	0.124 ± 0.014	0.493 ± 0.176	<0.1	<0.1	<0.1	<0.1	<0.1
SP2-B	<0.1	0.114 ± 0.025	<0.1	0.297 ± 0.103	0.116 ± 0.053	<0.1	<0.1	<0.1	<0.1
SP3-S	<0.1	<0.1	<0.1	0.230 ± 0.068	<0.1	<0.1	<0.1	<0.1	<0.1
SP3-M	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP3-B	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP4-S	<0.1	0.115 ± 0.014	0.295 ± 0.053	<0.1	<0.1	0.165 ± 0.064	<0.1	<0.1	<0.1
SP4-M	0.175 ± 0.068	0.107 ± 0.048	<0.1	0.110 ± 0.050	<0.1	<0.1	<0.1	<0.1	<0.1
SP4-B	<0.1	<0.1	<0.1	<0.1	0.109 ± 0.039	<0.1	<0.1	<0.1	<0.1
SP5-S	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP5-M	<0.1	<0.1	0.104 ± 0.014	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP5-B	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP6-S	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP6-M	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP6-B	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

[1] W = winter, S = summer, A = autumn.

[2] -S = near surface water, -M = mid-water, -B = near bottom water.

Table 3-18: Naturally occurring radioactive materials at Evans Shoal sites

Parameter	Radium^{226}			Radium^{228}			Thorium^{228}		
Units	(Bq/L)			(Bq/L)			(Bq/L)		
MRL	0.1			0.1			0.1		
Season[1]	W	S	A	W	S	A	W	S	A
Site/sample[2]									
SP7-S	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP7-B	<0.1	<0.1	0.141 ± 0.025	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP8-S	NS	<0.1	0.136 ± 0.019	NS	<0.1	<0.1	NS	<0.1	<0.1
SP8-M	NS	<0.1	<0.1	NS	<0.1	<0.1	NS	<0.1	<0.1
SP8-B	NS	<0.1	<0.1	NS	0.112 ± 0.020	<0.1	NS	<0.1	<0.1
SP9-S	NS	<0.1	0.113 ± 0.022	NS	<0.1	<0.1	NS	<0.1	<0.1
SP9-M	NS	<0.1	<0.1	NS	<0.1	<0.1	NS	<0.1	<0.1
SP9-B	NS	<0.1	<0.1	NS	<0.1	<0.1	NS	<0.1	<0.1
SP10-S	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP10-M	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP10-B	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

[1] W = winter, S = summer, A = autumn.
[2] -S = near surface water, -M = mid-water, -B = near bottom water.
NS = no sample due to inclement weather conditions.

Table 3-19: Naturally occurring radioactive materials at Tassie Shoal sites

Parameter	Radium^{226}			Radium^{228}			Thorium^{228}		
Units	(Bq/L)			(Bq/L)			(Bq/L)		
MRL	0.1			0.1			0.1		
Season[1]	W	S	A	W	S	A	W	S	A
Site/sample[2]									
SP11-S	<0.1	<0.1	0.172 ± 0.031	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP11-B	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP12-S	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP12-M	<0.1	<0.1	0.105 ± 0.015	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP12-B	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP13-S	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP13-M	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP13-B	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP14-S	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP14-M	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SP14-B	<0.1	<0.1	<0.1	0.249 ± 0.097	<0.1	<0.1	<0.1	<0.1	<0.1

[1] W = winter, S = summer, A = autumn.
[2] -S = near surface water, -M = mid-water, -B = near bottom water.
NS = no sample due to inclement weather conditions.

Table 3-20: Naturally occurring radioactive materials at Lynedoch Bank sites

Parameter	Radium226			Radium228			Thorium228		
Units	(Bq/L)			(Bq/L)			(Bq/L)		
MRL	0.1			0.1			0.1		
Season[1]	W	S	A	W	S	A	W	S	A
Site/sample[2]									
SP15-S	NS	<0.1	<0.1	NS	<0.1	<0.1	NS	<0.1	<0.1
SP15-M	NS	0.133 ± 0.047	<0.1	NS	<0.1	<0.1	NS	<0.1	<0.1
SP15-B	NS	<0.1	<0.1	NS	<0.1	<0.1	NS	<0.1	<0.1
SP16-S	NS	<0.1	<0.1	NS	<0.1	<0.1	NS	<0.1	<0.1
SP16-B	NS	<0.1	<0.1	NS	<0.1	<0.1	NS	<0.1	<0.1
SP17-S	NS	<0.1	<0.1	NS	<0.1	<0.1	NS	<0.1	<0.1
SP17-M	NS	<0.1	<0.1	NS	<0.1	<0.1	NS	<0.1	<0.1
SP17-B	NS	<0.1	<0.1	NS	<0.1	<0.1	NS	<0.1	<0.1

[1] W = winter, S = summer, A = autumn.
[2] -S = near surface water, -M = mid-water, -B = near bottom water.
NS = no sample due to inclement weather conditions.

3.3 Phytoplankton and zooplankton

Winter

Marine phytoplankton from the diatoms (Bacillariophyceae), the blue-green algae (Cyanobacteria), the silicoflagellates (Dictyochophyceae) and dinoflagellates (Dinophyceae) were captured in the plankton net tows in the permit area (SP3, SP5 and SP6), the Evans Shoal area (SP7 and SP10) and the Tassie Shoal area (SP14) (**Table 3-21**). Blue-green algae (comprised solely of *Trichodesmium erythraeum*) were captured in the greatest abundance (greater than 54%) at the majority of sites, however at SP14 the abundance of diatoms was much higher (greater than 92%). The diversity of the diatoms was highest at each site with up to 35 different species being identified. These Classes have been subdivided into the lowest taxonomic order possible in **Appendix C**.

Of the marine zooplankton captured in the plankton net tows, organisms from the Classes Trizonidae and Copepoda were in the highest abundance (**Table 3-22**). The greatest number of species were identified from SP3 with SP5 having the least. The Copepoda Class contain the highest number of different species whereas the majority of other Classes contained only one. These Classes have been subdivided into the lowest taxonomic order possible in **Appendix C**.

Summer

Marine phytoplankton captured at the permit area (SP1, SP3, SP5 and SP6), Evans Shoal (SP7, SP8 and SP10), Tassie Shoal (SP11, SP13 and SP14) and Lynedoch Bank (SP16 and SP17) consisted of diatoms (Bacillariophyceae), cryptomonads (Cryptophyceae), blue-green algae (Cyanobacteria) and dinoflagellates (Dinophyceae) (**Table 3-21**). Blue-green algae (comprised solely of *Trichodesmium erythraeum*) were captured in the greatest abundance (greater than 71%) at all sites. Diatoms were the most diverse group at all sites with up to 27 different species present. These (sub) Classes were identified to the lowest taxonomic order possible (**Appendix C**). This combination of species and diversity was similar to the winter survey. The phytoplankton assemblage composition and diversity in summer was similar to winter, although silicoflagellates (Dictyochophyceae) were more abundant in winter and cryptomonads (Crytophyceae) were only present in summer.

Of the marine zooplankton captured during the summer survey, copepods were the only ones present at every site (**Table 3-23**). Trizonidae, Copepoda and Polycystinea were highest in abundance. The greatest diversity of zooplankton species was observed at SP7, while the lowest diversity was observed at SP5. Copepods displayed the highest number of different species whereas most other Classes contained only one species. These Classes were subdivided into the lowest taxonomic order possible (**Appendix C**).

Autumn

Marine phytoplankton captured at the permit area (SP1, SP3, SP5 and SP6), at Evans Shoal (SP7, SP8 and SP10), at Tassie Shoal (SP11, SP13 and SP14) and at Lynedoch Bank (SP16 and SP17) consisted of diatoms (Bacillariophyceae), green algae (Chlorophyceae), cryptomonads (Cryptophyceae), blue-green algae (Cyanobacteria) and dinoflagellates (Dinophyceae) (**Table 3-21**). Blue-green algae (comprised solely of *Trichodesmium erythraeum*) were captured in the greatest abundance (greater than 44%) at most sites except at Tassie Shoal where they were not present and dinoflagellates were most abundant. These (sub) Classes were identified to the lowest taxonomic order possible (**Appendix C**).

Of all marine zooplankton captured, copepods were the only ones present at every site (**Table 3-24**). Copepoda and Gigartacontidae were highest in abundance. Copepods displayed the highest number of different species whereas the majority of other Classes contained only one species (**Appendix C**).

Table 3-21: Composition (%) of phytoplankton at each site – winter, summer and autumn

Site	Bacillariophyceae			Chlorophyceae			Cryptophyceae			Cyanobacteria			Dinophyceae			Dictyochophyceae		
Season	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**
Permit area																		
SP1		7.17						0.14			91.68	91.67		1.00	8.33			
SP3	44.3	3.57	1.85							54.9	94.95	87.04	0.5	1.49	11.11	0.3		
SP5	28.2	2.67	25.00			50.00				70.8	95.99		0.5	1.34	25.00	0.5		
SP6	10.4	8.83	11.76							88.2	89.05	67.65	1.0	2.11	20.59	0.4		
Evans Shoal																		
SP7	27.3	5.86	4.26							70.3	92.90	82.98	1.8	1.23	12.77	0.6		
SP8		23.78	18.52								76.14	66.67		0.08	14.81			
SP10	20.1	2.10	12.50							78.6	96.50	43.75	1.0	1.40	43.75	0.3		
Tassie Shoal																		
SP11		15.27	46.67								82.00			2.73	53.33			
SP13		4.46	37.50								94.64			0.89	62.50			
SP14	92.3	4.00	12.50					0.2	12.50	6.1	94.57		0.9	1.23	75.00	0.7		
Lynedoch Bank																		
SP16		6.00						0.11			92.30	68.75		1.59	31.25			
SP17		18.37	11.63								71.43	72.09		10.20	16.28			

W – winter; S – summer; A – autumn

Table 3-22: Composition (%) of zooplankton at each site – winter

Phylum	Class	Permit area		Tassie Shoal
		SP3	SP5	SP14
Protista	Appendicularia	1.3	8.7	0.5
	Foraminifera	1.3	0.4	1.9
	Polycystinea			0.9
	Gigartacontidae			0.9
	Trizonidae	23.6	9.7	20.7
	Unknown	0.6		
Crustacea	Copepoda	66.9	80.3	73.1
	Malacostraca	1.9		0.5
	Maxillopoda	0.6		
	Ostracoda	0.6		
Chaetognatha	Sagittoidea	2.6	0.7	0.9
Echinodermata	Ophiuroidea		0.2	0.5
Chordata	Thaliacea	0.6		

Table 3-23: Composition (%) of zooplankton at each site – summer

Phylum	Class	Permit area				Evans Shoal			Tassie Shoal			Lynedoch Bank
		SP1	SP3	SP5	SP6	SP7	SP8	SP10	SP11	SP13	SP14	SP17
Protista	Foraminifera	1.07				0.87			3.85			2.90
	Polycystinea	0.27			8.20	1.74	1.60	66.92				
	Gigartacontidae					1.74	4.79		1.28			
	Spirotrichea								3.85			
	Trizonidae	62.13	56.55			71.30	75.53		34.62	74.86	75.20	33.33
	Unknown		0.69			1.74	0.53			0.18		
Annelida	Polychaeta		0.69				2.66	0.76				
Crustacea	Branchiopoda	0.80	0.69		3.28							1.45
	Cladocera	0.27										
	Copepoda	32.0	35.86	96.08	88.52	16.52	7.98	27.76	51.28	22.59	18.54	55.07
	Malacostraca									0.18		
	Maxillopoda									0.18		
Mollusca	Gastropoda					2.61			1.28	0.36	0.52	
Chaetognatha	Sagittoidea	2.93	5.52	3.92		1.74	6.38	3.42	2.56	1.28	5.74	7.25
Echinodermata	Ophiuroidea					1.74	0.53	1.14		0.36		

Table 3-24: Composition (%) of zooplankton at each site – autumn

Phylum	Class	Permit area				Evans Shoal			Tassie Shoal			Lynedoch Bank	
		SP1	SP3	SP5	SP6	SP7	SP8	SP10	SP11	SP13	SP14	SP16	SP17
Protista	Foraminifera		0.09	0.07					0.84			0.74	
	Polycystinea									3.64	1.08	0.19	1.35
	Gigartacontidae		98.06	70.32	63.07	9.18	8.42		81.84	82.89	7.53	93.60	87.58
	Unknown	0.49	0.06	0.29	0.57	0.51	1.32		0.08	5.70		0.08	0.31
Annelida	Polychaetea	3.44	0.03			13.78	5.53	0.42	0.08				
Arthropoda	Branchiopoda								0.08	0.10			
	Copepoda	93.12	1.35	28.29	19.32	69.90	81.58	95.34	17.10	7.57	88.17	1.24	7.25
	Maxillopoda					2.55							
Chaetognatha	Sagittoidea	0.25	0.13	0.43	3.98		0.26	2.54				0.50	
Urochordata	Appendicularia	2.70	0.28	0.61	13.07	4.08	2.89	1.69		0.10	3.23	3.65	3.52

4. Discussion

Three baseline water quality surveys were undertaken as part of the Barossa marine studies program with the aim of incorporating seasonality (winter, summer and a transition season (i.e. autumn)) into our understanding of marine water conditions in the permit area and broader surrounding area. In general, the sites surveyed ranged in depth from around 10 m–30 m on top of shoals and banks through to approximately 280 m in the permit area.

Dissolved oxygen was high in the surface water (90%–100% saturation at all sites and each season) decreasing to approximately 35% saturation in the bottom water of the deepest sites. The dissolved oxygen of the shallowest sites stayed constant from surface to bottom waters. Dissolved oxygen was highest near the ocean surface, where light for photosynthesis is strongest and oxygen exchange between the atmosphere and the ocean is at a maximum. Waves, wind and currents act to mix dissolved oxygen through the upper section of the water column. These processes become progressively weaker as depth increases. Below the upper mixed layer the oxygen content decreased with an increase in depth due to oxidation of organic matter resulting in the consumption of oxygen.

There was very little difference in salinity between the surface water and the bottom water at all sites during all seasons. Salinity at the surface waters were approximately 34 PSU, which was approximately 0.7 PSU lower than the bottom water of the deepest sites. As these sites were remote from any large land masses, the only potential factors affecting surface water salinity are climatic ones, i.e. precipitation or evaporation.

Surface water temperatures ranged from approximately 27°C in winter to approximately 30°C in summer and autumn, gradually decreasing with depth to approximately 11°C–13°C in the bottom water of the deepest sites. Other studies have shown that mean monthly temperatures in the central Timor Sea are typically between 26°C and 30°C decreasing to approximately 12°C at 300 m, with waters expected to be stratified all year round, but with the thermocline nearer the surface (50 m depth) in summer, compared to winter (100 m depth) (Woodside 1999). For those sites with sufficient depth, a thermocline was observed to occur with the depth changing between the surveys. The zone above the thermocline is called the ‘mixed layer’ in which horizontal and vertical mixing occurs and the zone below the thermocline is called the ‘deep zone’. Stable temperature gradients act as barriers to vertical mixing and if wind-generated turbulence is insufficient to break down this gradient then no mixing will take place across the thermocline. The depth of the thermocline was similar in the winter and autumn surveys (occurring between approximately 70 m and 150 m) and deeper than the summer survey (present between 40 m and 70 m). This is thought to be due to strong, continual winds during winter and autumn, causing the depth of the mixed layer to be greater.

Turbidity was very low throughout the water column at each site and during each season (<0.2 NTU). Approximately 20 m–50 m (depending on the site) above the seabed the turbidity was slightly elevated and increased with depth, possibly caused by the action of currents passing over the seabed causing some turbulence and resuspension of sediments.

TSS concentrations were generally low (≤1 mg/L) or below laboratory detection limits at the sites sampled during winter and summer. No sampling of TSS was undertaken during the autumn survey.

The pH in the surface waters ranged from approximately 8.1–8.3 pH units while the pH at the seabed was ranged from approximately 7.7–7.9 pH units. The shape of the profiles for pH and dissolved oxygen were similar, with a decrease in pH occurring near the top of the thermocline, due to oxidation of organic matter. When dead organisms fall from the surface layers and start decaying they liberate carbon dioxide, which dissolves into the water producing carbonic acid that undergoes almost instantaneous ionisation into hydrogen ions and thus decreasing pH (Hinga 2002). Pressure and temperature also play a part as they affect the various equilibrium constants. In surface water, photosynthesis consumes carbon dioxide and therefore less dissociation of carbon dioxide into hydrogen ions occurs.

Chlorophyll *a* concentrations were low throughout the water column at each site and during each season, less than the ANZECC & ARMCANZ (2000b) trigger value of 0.9 µg/L. Chlorophyll *a* concentrations peaked at shallower depths during winter (30–50 m) and deeper depths during summer and autumn (50 m–70 m). During summer the zone of maximum productivity lies some distance below the surface probably due to optimising the requirement for light and nutrients. Nutrient concentrations increase with depth and light penetration is greater in summer therefore the depth of maximum productivity would be greater in summer than winter.

Trichodesmium erythraeum (a blue-green alga) was the phytoplankton species captured in highest abundance at the majority of sites during each season. *Trichodesmium* spp. occur in large numbers in tropical areas of the Indian Ocean, where their ability to fix nitrogen enables them to thrive when nutrient concentrations are low (Riley and Chester 1971). Dinoflagellates were the most diverse group during the autumn survey, whereas diatoms were the most diverse group during the summer and winter surveys. The phytoplankton assemblage composition in autumn was similar to summer and winter, although silicoflagellates were only present during winter and cryptomonads were only present during summer and autumn.

Copepods were the most abundant zooplankton collected during each season. Copepods also displayed the highest species diversity whereas the majority of other Classes contained only one species.

Inorganic nutrients orthophosphate, ammonium and nitrite+nitrate are released when organic compounds decay. Nitrification is the term given to the oxidation process which converts ammonium (formed by the bacterial decay of marine organisms or excreted by marine animals) into nitrite and then nitrate. Oxygen is consumed during these processes, which was evident in the bottom water of the deepest sites in the permit area where phosphorus and nitrate concentrations were high and oxygen levels were low.

Metals are also released when organic materials decay. Although the metal concentrations analysed in samples collected during the surveys were very low, there were slight increases in arsenic, barium chromium and nickel in the bottom waters of the deepest sites at the permit area and Evans Shoal. The distribution of some metals in seawater have been reported to be significantly influenced by the uptake of phytoplankton in the surface waters, subsequent decomposition of the organic matter produced and remineralisation in deep waters (Abe 2004). There were no dissolved metal samples collected that exceeded the ANZECC & ARMCANZ (2000a) trigger values for 99% species protection except for the copper concentrations at four sites during winter and five sites during summer, which exceeded the ANZECC & ARMCANZ (2000a) trigger value of 0.3 µg/L.

TPHs/TRHs and BTEXN were below the laboratory reporting limits at all sites and depths for each season. The only exceptions to this were the presence of hydrocarbons at two sites in the permit area and one site at Evans Shoal during the winter survey, in which the TPH was above the LOR. However, it is thought that the concentration of hydrocarbons at these sites were due to small operational releases from the vessel, as areas of natural hydrocarbon seepage would be present in all fractions, not the fractions obtained during sampling. In addition, there was little difference in the hydrocarbon profiles between sites, which would also indicate a lack of natural hydrocarbon sources in the areas sampled. Therefore, overall, there was little difference in the hydrocarbon profiles between sites, which indicates a lack of hydrocarbons in the areas sampled.

Radium^{226} and radium^{228} were above the minimum reporting limit at a number of sites during the three surveys, while thorium^{228} was not detected at any site. There are no ANZECC & ARMCANZ (2000a) trigger values associated with NORMs but there are guideline values for drinking water NHMRC & ARMCANZ (2011). Typical values for radium^{226} and radium^{228} in Australian drinking water supplies derived from groundwater sources, vary considerably depending on the aquifer and it is not uncommon in small supplies to find concentrations up to and exceeding 0.5 Bq/L. According to the guidelines, concentrations of radium^{226} should not be above 4.89 Bq/L and radium^{228} should not be above 1.98 Bq/L. All concentrations at all sites sampled during the three seasonal surveys were low (<0.49 Bq/L only slightly above the MRL of 0.10 Bq/L) and were lower than the threshold concentrations cited above.

In summary, the results of the three seasonal surveys (winter, summer and autumn) contribute to an appropriate baseline characterisation of the water quality in the study area.

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Appendix A. SBE 19plus V2 Calibration Certificate

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SBE 19 Plus V2 - 600m (19P-7123) - Salinity, Temperature, DO, pH, Turbidity and PAR check

Client: Jacobs Group (Australia) Pty Ltd

Address: 263 Adelaide Terrace, Perth WA 6000

Contact: Celeste Wilson   Email: Celeste.Wilson@jacobs.com

Phone: 9469 4438

Analyst: K.Wienczugow

Date: 26/03/2015

Job: Conoco Phillips Barossa

Table 1 Salinity Calibration Check

SBE 19 Plus V2 - 600m	[1]Laboratory Salinity Check Water	[2]Laboratory SBE 19 Plus V2 Comparison	SBE 19 Plus V2 - 600m	Tolerance ± 0.1psu	Date Checked / Name
Serial No: 19P-7123	Salinity (psu ± 0.1)	Salinity (psu)	Salinity Reading (psu)	Pass/Fail	
	32.7 ± 0.1	32.757	32.728	Pass	26/3/2015 K.Wienczugow

[1]Laboratory salinity check water was prepared by calibrating against IAPSO standard seawater 35.00 psu. [2]MAFRL's SBE 19 *Plus V2 - 100m* CTD was tested as an additional comparitive measure.

Table 2 Temperature Calibration Check

SBE 19 Plus V2 - 600m	[3]Laboratory Temperature Check	[2]Laboratory SBE 19 Plus V2 Comparison	SBE 19 Plus V2 - 600m	Tolerance ± 0.1°C	Date Checked / Name
Serial No: 19P-7123	Temperature (± 0.1 °C)	Temperature (°C)	Temperature Reading (°C)	Pass/Fail	
	22.7 ± 0.1	22.672	22.685	Pass	26/3/2015 K.Wienczugow

[3]Laboratory temperature check made with a NATA accredited -5.0 to 50.0°C immersion thermometer (Serial number: 0681667). [2]MAFRL's SBE 19 *Plus V2* - 100m CTD was tested as an additional comparitive measure.

Table 3 pH Calibration Check

Model: SBE 18-I	[4]Laboratory pH Check		SBE 19 Plus V2 - 600m	Tolerance ± 0.1 pH Unit	Date Calibrated / Name
Serial Number:180946	pH Standard (± 0.1)		pH Reading	Pass/Fail	
	4.01 @ 25°C		3.99	Pass	26/3/2015 K.Wienczugow
	7.00 @ 25°C		7.03	Pass	26/3/2015 K.Wienczugow
	10.01 @ 25°C		9.99	Pass	26/3/2015 K.Wienczugow

[4]pH calibration performed with pH standards (opened 11/3/2015) according to Sea-Bird Application note 18-1 for pH sensor calibration (Slope = 4.6006, Offset = 2.5179)

Table 4 DO Calibration Check

Model: SBE 43		[5]Laboratory SBE 19 Plus V2 Comparison	SBE 19 Plus V2 - 600m	Tolerance ± 2%	Date Checked / Name
Serial Number:432365		Dissolved Oxygen (%)	Dissolved Oxygen Reading (%)	Pass/Fail	
		99.9	98.8	Pass	26/3/2015 K.Wienczugow
		80.4	79.1	Pass	26/3/2015 K.Wienczugow

[5]Dissolve Oxygen calibration check performed in air saturated water and in a reduced oxygen water environment and compared against cleaned calibrated SBE 43 DO sensor from MAFRL's SBE 19 Plus V2 - 100m CTD.

Signatory:

Date: 26/3/2015

*Please note this report is not covered by NATA accreditation

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SBE 19 Plus V2 - 600m (19P-7123) - Salinity, Temperature, DO, pH, Turbidity and PAR check

Client: Jacobs Group (Australia) Pty Ltd
Address: 263 Adelaide Terrace, Perth WA 6000
Contact: Celeste Wilson Email: Celeste.Wilson@jacobs.com Phone: 9469 4438

Analyst: K.Wienczugow
Date: 26/03/2015
Job: Conoco Phillips Barossa

Table 5 Turbidity Calibration Check

Model: Wetlabs NTURT	[6]Laboratory Turbidity Standard		[7]SBE 19 Plus V2 - 600m	Tolerance ± 5%	Date Calibrated / Name
Serial Number: 201	Turbidity (NTU ± 0.01)		Turbidity Reading (NTU)	Pass/Fail	
	0.0		0.04	Pass	26/3/2015 K.Wienczugow
	5.0		5.11	Pass	26/3/2015 K.Wienczugow
	10.0		9.97	Pass	26/3/2015 K.Wienczugow

[6]Zero NTU standard prepared from 0.2µm filtered deionised distilled water. Freshly prepared primary formazin standard 4000 NTU was diluted for a three point check carried out in a non reflective black plastic bucket.

[7]Average readings were calculated using Sea Save software and Wetlabs calibration coefficients optimised for maximum accuracy below 20 NTU (Scale factor = 6.000, Dark output = 0.096).

Table 4 PAR Calibration Check

Model: Satlantic PAR LOG-s	[8]Laboratory Reference Lamp		[9]SBE 19 Plus V2 - 600m	Tolerance ±5%	Date Checked / Name
Serial Number:126	PAR (µmol $s^{-1}m^{-2}$)		PAR (µmol $s^{-1}m^{-2}$)	Pass/Fail	
	267		255 ±13	Pass	26/3/2015 K.Wienczugow
	0 (dark)		0	Pass	26/3/2015 K.Wienczugow

[8]Quartz Tungsten Halogen Reference Lamp operated at 3150°K from a LI-1800-02 Optical Radiation Calibrator. Reference lamp output has been corrected for the immersion effect with a multiplier of 1.322 for in-water operation.

[9]A certified LICOR LI-192SA Underwater Quantum Sensor (Serial number: 8207) was used as a control to check the output of the tungsten reference lamp used for verifying PAR against the Satlantic PAR cosine log sensor.

Signatory:

Date: 26/3/2015

Appendix B. Plankton Transect Coordinates

Table B.1: GPS coordinates of the start and finish of the plankton transects – winter

Site name	Sample type	Coordinates (DDD° MM.MMM')[1]	
		Latitude	Longitude
SP3 start		9° 44' 55.592" S	130° 20' 31.955" E
SP3 finish	Phytoplankton and zooplankton	9° 45' 41.250" S	130° 10' 38.260" E
SP5 start		9° 53' 17.222" S	130° 24' 19.322" E
SP5 finish	Phytoplankton and zooplankton	9° 53' 16.390" S	130° 24' 09.370" E
SP6 start		9° 48' 44.030" S	129° 58' 5.259" E
SP6 finish	Phytoplankton and zooplankton	9° 48' 43.920" S	129° 57' 55.440" E
SP7 start		9° 55' 2.690" S	129° 33' 38.636" E
SP7 finish	Phytoplankton and zooplankton	9° 55' 02.170" S	129° 33' 28.950" E
SP10 start		9° 51' 25.533" S	129° 32' 5.302" E
SP10 finish	Phytoplankton and zooplankton	9° 51' 25.320" S	129° 31' 55.390" E
SP14 start		10° 14' 57.851" S	129° 46' 5.394" E
SP14 finish	Phytoplankton and zooplankton	10° 14' 52.570" S	129° 45' 58.170" E

Table B.2: GPS coordinates of the start and finish of the plankton transects – summer

Site name	Sample type	Coordinates (DDD° MM.MMM')[1]	
		Latitude	Longitude
SP1 start		9° 43' 30.000" S	130° 28' 54.300" E
SP1 finish	Phytoplankton and zooplankton	9° 43' 35.400" S	130° 29' 00.840" E
SP3 start		9° 45' 44.040" S	130° 10' 47.340" E
SP3 finish	Phytoplankton and zooplankton	9° 45' 47.760" S	130° 10' 56.520" E
SP5 start		9° 53' 19.320" S	130° 24' 21.300" E
SP5 finish	Phytoplankton and zooplankton	9° 53' 23.280" S	130° 24' 30.360" E
SP6 start		9° 48' 44.760" S	129° 58' 05.220" E
SP6 finish	Phytoplankton and zooplankton	9° 48' 50.520" S	129° 58' 13.200" E
SP7 start		9° 55' 06.720" S	129° 33' 37.920" E
SP7 finish	Phytoplankton and zooplankton	9° 55' 16.800" S	129° 33' 38.400" E
SP8 start		9° 57' 08.520" S	129° 32' 04.500" E
SP8 finish	Phytoplankton and zooplankton	9° 57' 13.560" S	129° 32' 13.380" E
SP10 start		9° 51' 39.600" S	129° 31' 51.840" E
SP10 finish	Phytoplankton and zooplankton	9° 51' 47.640" S	129° 31' 57.720" E
SP11 start		10° 08' 03.540" S	129° 32' 52.260" E
SP11 finish	Phytoplankton and zooplankton	10° 08' 06.180" S	129° 33' 01.440" E
SP13 start		10° 11' 40.680" S	129° 39' 42.960" E
SP13 finish	Phytoplankton and zooplankton	10° 11' 39.240" S	129° 39' 33.000" E
SP14 start		10° 14' 58.080" S	129° 46' 05.940" E
SP14 finish	Phytoplankton and zooplankton	10° 14' 48.420" S	129° 46' 03.600" E
SP16 start		10° 01' 37.120" S	130° 48' 36.420" E
SP16 finish	Phytoplankton and zooplankton	10° 01' 49.500" S	130° 48' 42.120" E
SP17 start		10° 02' 25.920" S	130° 50' 15.960" E
SP17 finish	Phytoplankton and zooplankton	10° 02' 31.680" S	130° 50' 24.120" E

Table B.3: GPS coordinates of the start and finish of the plankton transects – autumn

Site name	Sample type	Coordinates (DDD° MM.MMM')[1]	
		Latitude	Longitude
SP1 start		9° 43.999'S	130° 28.860'E
SP1 finish	Phytoplankton and zooplankton	9° 43.447'S	130° 28.706'E
SP3 start		9° 45.732'S	130° 10.800'E
SP3 finish	Phytoplankton and zooplankton	9° 45.729'S	130° 10.633'E
SP5 start		9° 53.289'S	130° 24.292'E
SP5 finish	Phytoplankton and zooplankton	9° 53.312'S	130° 24.129'E
SP6 start		9° 48.732'S	129° 57.923'E
SP6 finish	Phytoplankton and zooplankton	9° 48.726'S	129° 57.922'E
SP7 start		9° 55.061'S	129° 33.670'E
SP7 finish	Phytoplankton and zooplankton	9° 54.922'S	129° 33.580'E
SP8 start		9° 57.132'S	129° 32.098'E
SP8 finish	Phytoplankton and zooplankton	9° 57.135'S	129° 31.929'E
SP10 start		9° 51.430'S	129° 32.085'E
SP10 finish	Phytoplankton and zooplankton	9° 51.505'S	129° 31.935'E
SP11 start		10° 07.995'S	129° 33.000'E
SP11 finish	Phytoplankton and zooplankton	10° 08.025'S	129° 32.840'E
SP13 start		10° 11.727'S	129° 39.762'E
SP13 finish	Phytoplankton and zooplankton	10° 11.563'S	129° 39.759'E
SP14 start		10° 14.964'S	129° 46.090'E
SP14 finish	Phytoplankton and zooplankton	10° 14.870'S	129° 45.951'E
SP16 start		10° 01.636'S	130° 48.579'E
SP16 finish	Phytoplankton and zooplankton	10° 01.587'S	130° 48.417'E
SP17 start		10° 02.433' S	130° 50.267'E
SP17 finish	Phytoplankton and zooplankton	10° 02.428' S	130° 50.101'E

[1] Datum = GDA94.

Appendix C. Analytical Laboratory Reports

Appendix C1. Winter

CERTIFICATE OF ANALYSIS

Work Order	: **EP1404964**	Page	: 1 of 10
Client	: **JACOBS GROUP (AUSTRALIA) PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: CELESTE WILSON	Contact	: Scott James
Address	: P O BOX H615 PERTH WA, AUSTRALIA 6001	Address	: 10 Hod Way Malaga WA Australia 6090
E-mail	: cxxwilson@skm.com.au	E-mail	: perth.enviro.services@alsglobal.com
Telephone	: +61 08 9469 4400	Telephone	: +61-8-9209 7655
Facsimile	: +61 08 9469 4488	Facsimile	: +61-8-9209 7600
Project	: Jacobs Project Number WV04831 104	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 01-JUL-2014
Sampler	: G.C.	Issue Date	: 08-JUL-2014
Site	: ----		
		No. of samples received	: 36
Quote number	: EP/370/14	No. of samples analysed	: 34

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Agnes Szilagyi	Senior Organic Chemist	Perth Organics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	SP1-S	SP1-M	SP1-B	SP2-S	SP2-M
			Client sampling date / time	28-JUN-2014 18:10	28-JUN-2014 18:10	28-JUN-2014 18:10	28-JUN-2014 19:30	28-JUN-2014 19:30
Compound	*CAS Number*	*LOR*	*Unit*	**EP1404964-001**	**EP1404964-002**	**EP1404964-003**	**EP1404964-004**	**EP1404964-005**
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ **Total Xylenes**	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**78.8**	**87.7**	**99.0**	**92.7**	**97.9**
Toluene-D8	2037-26-5	0.1	%	**113**	**110**	**106**	**105**	**105**
4-Bromofluorobenzene	460-00-4	0.1	%	**80.4**	**83.1**	**87.4**	**83.2**	**85.6**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	SP2-B	SP3-S	SP3-M	SP3-B	SP4-S
			Client sampling date / time	28-JUN-2014 19:30	29-JUN-2014 08:50	29-JUN-2014 08:50	29-JUN-2014 08:50	29-JUN-2014 07:15
Compound	CAS Number	LOR	Unit	EP1404964-006	EP1404964-007	EP1404964-008	EP1404964-009	EP1404964-010
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**88.1**	**98.8**	**108**	**102**	**105**
Toluene-D8	2037-26-5	0.1	%	**110**	**105**	**104**	**105**	**104**
4-Bromofluorobenzene	460-00-4	0.1	%	**83.6**	**86.0**	**88.6**	**87.1**	**87.9**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)

Compound	CAS Number	LOR	Unit	SP4-M	SP4-B	SP5-S	SP5-M	SP5-B
			Client sampling date / time	29-JUN-2014 07:15	29-JUN-2014 07:15	28-JUN-2014 16:30	28-JUN-2014 16:30	28-JUN-2014 16:30
				EP1404964-011	EP1404964-012	EP1404964-013	EP1404964-014	EP1404964-015
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	**140**	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	**140**	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	**130**	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	**130**	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**84.0**	**100**	**104**	**84.1**	**113**
Toluene-D8	2037-26-5	0.1	%	**113**	**106**	**104**	**112**	**106**
4-Bromofluorobenzene	460-00-4	0.1	%	**81.0**	**86.5**	**88.6**	**80.1**	**89.8**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)

Compound	CAS Number	LOR	Unit	SP6-S	SP6-M	SP6-B	SP7-S	SP7-B
			Client sampling date / time	29-JUN-2014 11:00	29-JUN-2014 11:00	29-JUN-2014 11:00	29-JUN-2014 15:05	29-JUN-2014 15:05
				EP1404964-016	EP1404964-017	EP1404964-018	EP1404964-019	EP1404964-020
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	**310**	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	**310**	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	**230**	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	**230**	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**81.8**	**81.2**	**104**	**103**	**102**
Toluene-D8	2037-26-5	0.1	%	**114**	**115**	**108**	**106**	**106**
4-Bromofluorobenzene	460-00-4	0.1	%	**81.2**	**81.6**	**88.4**	**87.9**	**87.8**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	SP10-S	SP10-M	SP10-B	SP11-S	SP11-B
			Client sampling date / time	29-JUN-2014 15:00	29-JUN-2014 15:00	29-JUN-2014 15:00	29-JUN-2014 08:15	29-JUN-2014 08:15
Compound	CAS Number	LOR	Unit	EP1404964-021	EP1404964-022	EP1404964-023	EP1404964-024	EP1404964-025
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**93.8**	**83.2**	**78.2**	**78.9**	**81.6**
Toluene-D8	2037-26-5	0.1	%	**110**	**113**	**113**	**116**	**113**
4-Bromofluorobenzene	460-00-4	0.1	%	**85.8**	**76.7**	**79.5**	**78.2**	**75.9**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	SP12-S	SP12-M	SP12-B	SP13-S	SP13-M
			Client sampling date / time	29-JUN-2014 17:30	29-JUN-2014 17:30	29-JUN-2014 17:30	29-JUN-2014 19:15	29-JUN-2014 19:15
Compound	CAS Number	LOR	Unit	EP1404964-026	EP1404964-027	EP1404964-028	EP1404964-029	EP1404964-030
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**105**	**104**	**101**	**102**	**92.8**
Toluene-D8	2037-26-5	0.1	%	**106**	**105**	**108**	**105**	**109**
4-Bromofluorobenzene	460-00-4	0.1	%	**86.1**	**87.8**	**87.5**	**86.2**	**81.9**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	SP13-B	SP14-S	SP14-M	SP14-B	----
			Client sampling date / time	29-JUN-2014 19:15	26-JUN-2014 17:30	26-JUN-2014 17:30	26-JUN-2014 17:30	----
Compound	CAS Number	LOR	Unit	EP1404964-031	EP1404964-032	EP1404964-033	EP1404964-034	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	----
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	----
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	----
C29 - C36 Fraction	----	50	µg/L	<50	<50	**190**	<50	----
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	**190**	<50	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	----
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	----
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	----
>C16 - C34 Fraction	----	100	µg/L	<100	<100	**180**	<100	----
>C34 - C40 Fraction	----	100	µg/L	<100	<100	**220**	<100	----
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	**400**	<100	----
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	----
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	----
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	----
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	----
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	----
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	----
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**103**	**82.2**	**123**	**113**	----
Toluene-D8	2037-26-5	0.1	%	**107**	**114**	**105**	**102**	----
4-Bromofluorobenzene	460-00-4	0.1	%	**87.6**	**79.0**	**89.4**	**89.7**	----

Surrogate Control Limits

Sub-Matrix: **WATER**

Compound	CAS Number	Recovery Limits (%) Low	High
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	60.5	141.2
Toluene-D8	2037-26-5	73.4	126
4-Bromofluorobenzene	460-00-4	59.6	125.3

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Murdoch UNIVERSITY

WATER QUALITY DATA

Contact: Celeste Wilson
Customer: Jacobs
Address: Level 11, Durack Centre, 263 Adelaide Terrace, Perth WA 6001

Date of Issue: 15/07/2014
Date Received: 01/07/2014
Our Reference: SKM14-24 - 2
Your Reference: WV04831.104

METHOD SAMPLE CODE	Sampling Date	2000 AMMONIA µg.N/L	4100 ORTHO-P µg.P/L	2100 NO3+NO2 µg.N/L	4700 TOTAL-P µg.P/L	2700 TOTAL-N µg.N/L	3000 CHLOROPHYLL'a' µg/L	3000 PHAEOPHYTIN'a' µg/L	2540D TSS mg/L
Reporting Limit		<3	<2	<2	<5	<50	<0.05	<0.2	<1
File			14070202,0203		14070401		14070801		140703
SP1S	28/06/2014	<3	5	5	15	90	0.36	<0.2	
SP1M	28/06/2014	<3	33	250	38	300	<0.05	<0.2	
SP1B	28/06/2014	<3	60	390	65	440	<0.05	<0.2	
SP2S	28/06/2014	5	5	120	15	220	0.43	<0.2	<0.5
SP2M	28/06/2014	<3	34	250	39	310	<0.05	<0.2	
SP2B	28/06/2014	<3	61	400	65	430	<0.05	<0.2	
SP3S	29/06/2014	<3	5	15	15	110	0.50	<0.2	<0.5
SP3M	29/06/2014	<3	35	240	41	280	<0.05	<0.2	
SP3B	29/06/2014	<3	59	380	64	420	<0.05	<0.2	
SP4S	29/06/2014	<3	5	5	14	90	0.21	<0.2	
SP4M	29/06/2014	<3	28	180	34	240	0.07	<0.2	
SP4B	29/06/2014	<3	54	350	57	380	<0.05	<0.2	
SP5S	28/06/2014	<3	4	4	13	80	0.41	<0.2	
SP5M	28/06/2014	<3	26	170	31	220	0.08	<0.2	
SP5B	28/06/2014	<3	52	350	55	390	<0.05	<0.2	
SP6S	29/06/2014	<3	5	6	14	90	0.16	<0.2	<0.5
SP6M	29/06/2014	<3	34	220	38	270	<0.05	<0.2	
SP6B	29/06/2014	3	60	390	64	440	<0.05	<0.2	
SP7S	29/06/2014	<3	5	3	13	80	0.22	<0.2	
SP7B	29/06/2014	6	6	6	14	80	0.45	<0.2	

Signatory: Jamie Woodward
Date: 15/07/2014

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Marine and Freshwater Research Laboratory Environmental Science
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Customer: Jacobs
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Date of Issue: 15/07/2014
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Our Reference: SKM14-24 - 2
Your Reference: WV04831.104

METHOD SAMPLE CODE	Sampling Date	2000 AMMONIA µg.N/L	4100 ORTHO-P µg.P/L	2100 NO3+NO2 µg.N/L	4700 TOTAL-P µg.P/L	2700 TOTAL-N µg.N/L	3000 CHLOROPHYLL'a' µg/L	3000 PHAEOPHYTIN'a' µg/L	2540D TSS mg/L
Reporting Limit		**<3**	**<2**	**<2**	**<5**	**<50**	**<0.05**	**<0.2**	**<1**
File			**14070202,0203**		**14070401**		**14070801**		**140703**
SP10S	29/06/2014	<3	5	6	14	100	0.18	<0.2	
SP10M	29/06/2014	<3	31	200	36	260	0.05	<0.2	
SP10B	29/06/2014	<3	51	330	54	370	<0.05	<0.2	
SP11S	29/06/2014	<3	4	<2	14	90	0.21	<0.2	
SP11B	29/06/2014	7	4	6	14	110	0.35	<0.2	
SP12S	29/06/2014	<3	4	2	14	90	0.17	<0.2	<0.5
SP12M	29/06/2014	<3	4	<2	12	90	0.42	<0.2	
SP12B	29/06/2014	<3	29	180	34	240	0.07	<0.2	
SP13S	29/06/2014	<3	5	<2	14	100	0.16	<0.2	
SP13M	29/06/2014	<3	4	4	12	100	0.53	<0.2	
SP13B	29/06/2014	<3	24	150	30	220	0.10	<0.2	
SP14S	26/06/2014	7	4	3	13	100	0.34	<0.2	
SP14M	26/06/2014	4	3	2	14	120	0.33	<0.2	
SP14B	26/06/2014	3	23	140	29	230	0.07	<0.2	
Transport Blank		<3	<2	<2	<5	<50			
Field Blank		9	<2	8	<5	<50	<0.05	<0.2	

Signatory: Jamie Woodward
Date: 15/07/2014

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Date of Issue: 15/07/2014
Date Received: 01/07/2014
Our Reference: SKM14-24 - 2
Your Reference: WV04831.104

METHOD SAMPLE CODE	Sampling Date	MS001 Filtered Cr µg/L	MS001 Filtered Co µg/L	MS001 Filtered Ni µg/L	MS001 Filtered Cu µg/L	MS001 Filtered Zn µg/L	MS001 Filtered As µg/L	MS001 Filtered Cd µg/L	MS001 Filtered Ba µg/L	MS001 Filtered Pb µg/L	ICP006 Hg mg/L
Reporting Limit		**<0.2**	**<0.05**	**<0.3**	**<0.2**	**<1**	**<0.5**	**<0.1**	**<0.5**	**<0.1**	**<0.0001**
File											**14070401-02**
SP1S	28/06/2014	<0.2	<0.05	<0.3	0.4	1	1.7	<0.1	5.4	<0.1	<0.0001
SP1M	28/06/2014	0.2	<0.05	<0.3	<0.2	1	1.9	<0.1	5.6	<0.1	<0.0001
SP1B	28/06/2014	0.2	<0.05	0.4	<0.2	<1	1.9	<0.1	8.0	<0.1	<0.0001
SP2S	28/06/2014	<0.2	<0.05	<0.3	0.3	3	1.7	<0.1	5.6	<0.1	<0.0001
SP2M	28/06/2014	0.2	<0.05	0.3	0.4	3	1.9	<0.1	5.5	<0.1	<0.0001
SP2B	28/06/2014	0.2	<0.05	0.4	<0.2	1	1.9	<0.1	7.5	<0.1	<0.0001
SP3S	29/06/2014	<0.2	<0.05	<0.3	0.2	2	1.7	<0.1	5.3	<0.1	<0.0001
SP3M	29/06/2014	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.5	<0.1	<0.0001
SP3B	29/06/2014	0.2	<0.05	0.3	<0.2	1	1.8	<0.1	7.5	<0.1	<0.0001
SP4S	29/06/2014	<0.2	<0.05	<0.3	<0.2	1	1.7	<0.1	5.6	<0.1	<0.0001
SP4M	29/06/2014	<0.2	<0.05	0.3	0.2	<1	1.7	<0.1	5.6	<0.1	<0.0001
SP4B	29/06/2014	0.2	<0.05	0.3	<0.2	<1	1.8	<0.1	7.0	<0.1	<0.0001
SP5S	28/06/2014	<0.2	<0.05	<0.3	0.5	3	1.7	<0.1	5.3	0.1	<0.0001
SP5M	28/06/2014	0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.6	<0.1	<0.0001
SP5B	28/06/2014	0.2	<0.05	0.3	0.2	1	1.8	<0.1	6.7	<0.1	<0.0001
SP6S	29/06/2014	<0.2	<0.05	<0.3	0.3	1	1.6	<0.1	5.4	<0.1	<0.0001
SP6M	29/06/2014	<0.2	<0.05	<0.3	0.2	<1	1.8	<0.1	5.5	<0.1	<0.0001
SP6B	29/06/2014	0.2	<0.05	0.4	0.3	2	1.8	<0.1	7.6	<0.1	<0.0001
SP7S	29/06/2014	<0.2	<0.05	<0.3	0.3	2	1.6	<0.1	5.6	<0.1	<0.0001
SP7B	29/06/2014	<0.2	<0.05	0.3	0.4	2	1.5	<0.1	5.4	<0.1	<0.0001

Signatory: Jamie Woodward
Date: 15/07/2014

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Date of Issue: 15/07/2014
Date Received: 01/07/2014
Our Reference: SKM14-24 - 2
Your Reference: WV04831.104

METHOD	Sampling	MS001	MS001	MS001	MS001	MS001	MS001	MS001	MS001	MS001	ICP006
SAMPLE CODE	Date	Filtered Cr	Filtered Co	Filtered Ni	Filtered Cu	Filtered Zn	Filtered As	Filtered Cd	Filtered Ba	Filtered Pb	Hg
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L
Reporting Limit		<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.5	<0.1	<0.0001
File											14070401-02
SP10S	29/06/2014	<0.2	<0.05	<0.3	0.3	<1	1.7	<0.1	5.4	<0.1	<0.0001
SP10M	29/06/2014	<0.2	<0.05	0.3	0.4	2	1.7	<0.1	5.8	<0.1	<0.0001
SP10B	29/06/2014	0.2	<0.05	0.3	0.3	1	1.8	<0.1	6.8	<0.1	<0.0001
SP11S	29/06/2014	<0.2	<0.05	<0.3	0.4	1	1.6	<0.1	5.6	<0.1	<0.0001
SP11B	29/06/2014	<0.2	<0.05	<0.3	0.3	3	1.6	<0.1	5.4	<0.1	<0.0001
SP12S	29/06/2014	<0.2	<0.05	<0.3	0.2	1	1.6	<0.1	5.5	<0.1	<0.0001
SP12M	29/06/2014	<0.2	<0.05	<0.3	0.3	<1	1.6	<0.1	5.4	<0.1	<0.0001
SP12B	29/06/2014	<0.2	<0.05	<0.3	<0.2	<1	1.7	<0.1	6.1	<0.1	<0.0001
SP13S	29/06/2014	<0.2	<0.05	<0.3	0.3	1	1.6	<0.1	5.6	<0.1	<0.0001
SP13M	29/06/2014	<0.2	<0.05	<0.3	0.3	1	1.6	<0.1	5.3	<0.1	<0.0001
SP13B	29/06/2014	<0.2	<0.05	<0.3	<0.2	1	1.8	<0.1	6.0	<0.1	<0.0001
SP14S	26/06/2014	<0.2	<0.05	<0.3	<0.2	2	1.7	<0.1	5.3	<0.1	<0.0001
SP14M	26/06/2014	<0.2	<0.05	<0.3	<0.2	1	1.7	<0.1	5.2	<0.1	<0.0001
SP14B	26/06/2014	<0.2	<0.05	<0.3	0.4	3	1.7	<0.1	6.0	<0.1	<0.0001
Transport Blank		<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.5	<0.1	<0.0001
Field Blank		<0.2	<0.05	<0.3	<0.2	1	<0.5	<0.1	<0.5	<0.1	<0.0001

Signatory: Jamie Woodward
Date: 15/07/2014

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Date of Issue: 15/07/2014
Date Received: 01/07/2014
Our Reference: SKM14-24 - 2
Your Reference: WV04831.104

METHOD SAMPLE CODE	Sampling Date	MS001 Unfiltered Cr µg/L	MS001 Unfiltered Co µg/L	MS001 Unfiltered Ni µg/L	MS001 Unfiltered Cu µg/L	MS001 Unfiltered Zn µg/L	MS001 Unfiltered As µg/L	MS001 Unfiltered Cd µg/L	MS001 Unfiltered Ba µg/L	MS001 Unfiltered Pb µg/L	ICP006 Unfiltered Hg mg/L
Reporting Limit		**<0.2**	**<0.05**	**<0.3**	**<0.2**	**<1**	**<0.5**	**<0.1**	**<0.5**	**<0.1**	**<0.0001**
File											**14070901-02**
SP1S	28/06/2014	<0.2	<0.05	<0.3	0.3	1	1.8	<0.1	5.6	<0.1	<0.0001
SP1M	28/06/2014	0.2	<0.05	0.4	<0.2	1	1.9	<0.1	5.6	<0.1	<0.0001
SP1B	28/06/2014	0.3	<0.05	0.4	<0.2	<1	2.0	<0.1	7.9	<0.1	<0.0001
SP2S	28/06/2014	<0.2	<0.05	<0.3	0.5	3	1.7	<0.1	5.5	<0.1	<0.0001
SP2M	28/06/2014	0.2	<0.05	0.3	1.0	4	1.9	<0.1	5.7	<0.1	<0.0001
SP2B	28/06/2014	0.3	<0.05	0.4	<0.2	<1	1.9	<0.1	7.8	<0.1	<0.0001
SP3S	29/06/2014	<0.2	<0.05	<0.3	0.2	2	1.7	<0.1	5.3	<0.1	<0.0001
SP3M	29/06/2014	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.5	<0.1	<0.0001
SP3B	29/06/2014	0.3	<0.05	0.3	<0.2	1	1.8	<0.1	7.5	<0.1	<0.0001
SP4S	29/06/2014	<0.2	<0.05	<0.3	0.2	1	1.6	<0.1	5.5	<0.1	<0.0001
SP4M	29/06/2014	0.2	<0.05	<0.3	0.2	<1	1.8	<0.1	5.7	<0.1	<0.0001
SP4B	29/06/2014	0.2	<0.05	0.4	0.2	<1	1.9	<0.1	6.9	<0.1	<0.0001
SP5S	28/06/2014	<0.2	<0.05	<0.3	0.3	2	1.7	<0.1	5.3	<0.1	<0.0001
SP5M	28/06/2014	0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.5	<0.1	<0.0001
SP5B	28/06/2014	0.2	<0.05	0.4	0.4	2	1.7	<0.1	6.8	<0.1	<0.0001
SP6S	29/06/2014	<0.2	<0.05	<0.3	0.4	2	1.6	<0.1	5.5	<0.1	<0.0001
SP6M	29/06/2014	<0.2	<0.05	0.3	0.2	<1	1.8	<0.1	5.6	<0.1	<0.0001
SP6B	29/06/2014	0.2	<0.05	0.4	0.2	1	1.9	<0.1	7.7	<0.1	<0.0001
SP7S	29/06/2014	<0.2	<0.05	<0.3	0.3	1	1.7	<0.1	5.6	<0.1	<0.0001
SP7B	29/06/2014	<0.2	<0.05	0.3	0.5	2	1.7	<0.1	5.5	<0.1	<0.0001

Signatory: Jamie Woodward
Date: 15/07/2014

All test items tested as received. Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory
Environmental Science
Tel: +61 8 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
Accredited for compliance with ISO/IEC 17025.
The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

Murdoch UNIVERSITY

WATER QUALITY DATA

Contact: Celeste Wilson
Customer: Jacobs
Address: Level 11, Durack Centre, 263 Adelaide Terrace, Perth WA 6001

Date of Issue: 15/07/2014
Date Received: 01/07/2014
Our Reference: SKM14-24 - 2
Your Reference: WV04831.104

METHOD SAMPLE CODE	Sampling Date	MS001 Unfiltered Cr µg/L	MS001 Unfiltered Co µg/L	MS001 Unfiltered Ni µg/L	MS001 Unfiltered Cu µg/L	MS001 Unfiltered Zn µg/L	MS001 Unfiltered As µg/L	MS001 Unfiltered Cd µg/L	MS001 Unfiltered Ba µg/L	MS001 Unfiltered Pb µg/L	ICP006 Unfiltered Hg mg/L
Reporting Limit		**<0.2**	**<0.05**	**<0.3**	**<0.2**	**<1**	**<0.5**	**<0.1**	**<0.5**	**<0.1**	**<0.0001**
File											**14070901-02**
SP10S	29/06/2014	<0.2	<0.05	<0.3	0.3	<1	1.6	<0.1	5.5	<0.1	<0.0001
SP10M	29/06/2014	0.2	<0.05	0.3	0.4	2	1.8	<0.1	5.8	<0.1	<0.0001
SP10B	29/06/2014	0.2	<0.05	0.4	0.4	2	1.8	<0.1	6.7	<0.1	<0.0001
SP11S	29/06/2014	<0.2	<0.05	<0.3	0.3	<1	1.6	<0.1	5.9	<0.1	<0.0001
SP11B	29/06/2014	<0.2	<0.05	<0.3	0.3	1	1.6	<0.1	5.5	<0.1	<0.0001
SP12S	29/06/2014	<0.2	<0.05	<0.3	0.2	<1	1.6	<0.1	5.4	<0.1	<0.0001
SP12M	29/06/2014	<0.2	<0.05	<0.3	0.3	<1	1.6	<0.1	5.5	<0.1	<0.0001
SP12B	29/06/2014	0.2	<0.05	<0.3	0.2	<1	1.7	<0.1	6.0	<0.1	<0.0001
SP13S	29/06/2014	<0.2	<0.05	<0.3	0.3	1	1.6	<0.1	5.5	<0.1	<0.0001
SP13M	29/06/2014	<0.2	<0.05	<0.3	0.4	1	1.6	<0.1	5.5	<0.1	<0.0001
SP13B	29/06/2014	<0.2	<0.05	<0.3	<0.2	1	1.7	<0.1	5.9	<0.1	<0.0001
SP14S	26/06/2014	<0.2	<0.05	<0.3	0.2	2	1.7	<0.1	5.4	<0.1	<0.0001
SP14M	26/06/2014	<0.2	<0.05	<0.3	0.2	2	1.7	<0.1	5.5	<0.1	<0.0001
SP14B	26/06/2014	<0.2	<0.05	<0.3	0.4	4	1.8	<0.1	6.1	<0.1	<0.0001
Transport Blank		<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.5	<0.1	<0.0001
Field Blank		<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.5	<0.1	<0.0001

Signatory: Jamie Woodward
Date: 15/07/2014

All test items tested as received. Spare test items will be held for two months unless otherwise requested.

15 August 2014

Ref: 7956
Contract: PB 22767

Sinclair Knight Merz – JACOBS PROJECT
7th Floor Durack Centre
PERTH WA 6000

Attn: Celeste Wilson

ANALYTICAL REPORT

The results (to 95%, 2σ confidence level) for Radium-226, Radium-228 and Thorium-228 analyses of thirty four (34) liquid samples, as received at our laboratory on 11 July 2014, are detailed on page two and three of this report.

MDL:	Radium-226	0.100Bq/l	Radium-228	0.100Bq/l
	Thorium-228	0.100Bq/l		
Method:	LTP No. 4(a)	Gamma Spectrometry Analysis		

Madassar A. Qureshi
Authorised Signatory

WRS No	Client Sample ID	Ra-226 (Bq/l)	Ra-228 (Bq/l)	Th-228 (Bq/l)
7956-1	SP1-S 28/06/2014	<MDL	0.123 ± 0.061	<MDL
7956-2	SP1-M 28/06/2014	<MDL	<MDL	<MDL
7956-3	SP1-B 28/06/2014	<MDL	<MDL	<MDL
7956-4	SP2-S 28/06/2014	<MDL	<MDL	<MDL
7956-5	SP2-M 28/06/2014	<MDL	0.493 ± 0.176	<MDL
7956-6	SP2-B 28/06/2014	<MDL	0.297 ± 0.103	<MDL
7956-7	SP3-S 29/06/2014	<MDL	0.230 ± 0.068	<MDL
7956-8	SP3-M 29/06/2014	<MDL	<MDL	<MDL
7956-9	SP3-B 29/06/2014	<MDL	<MDL	<MDL
7956-10	SP4-S 29/06/2014	<MDL	<MDL	<MDL
7956-10D	SP4-S 29/06/2014	<MDL	<MDL	<MDL
7956-11	SP4-M 29/06/2014	0.175 ± 0.068	0.110 ± 0.050	<MDL
7956-12	SP4-B 29/06/2014	<MDL	<MDL	<MDL
7956-13	SP5-S 28/06/2014	<MDL	0.257 ± 0.040	<MDL
7956-14	SP5-M 28/06/2014	<MDL	<MDL	<MDL
7956-15	SP5-B 28/06/2014	<MDL	<MDL	<MDL
7956-16	SP6-S 29/06/2014	<MDL	0.157 ± 0.044	<MDL
7956-17	SP6-M 29/06/2014	<MDL	<MDL	<MDL
7956-18	SP6-B 29/06/2014	<MDL	<MDL	<MDL
7956-19	SP7-S 29/06/2014	<MDL	<MDL	<MDL
7956-20	SP7-B 29/06/2014	<MDL	<MDL	<MDL
7956-20D	SP7-B 29/06/2014	<MDL	<MDL	<MDL
7956-21	SP10-S 29/06/2014	<MDL	<MDL	<MDL
7956-22	SP10-M 29/06/2014	<MDL	<MDL	<MDL
7956-23	SP10-B 29/06/2014	<MDL	<MDL	<MDL

Realtime Group Limited solutions for today and tomorrow

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Mackay Qld 4740
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Fax: 61 7 4955 7338

WRS No	Client Sample ID	Ra-226 (Bq/l)	Ra-228 (Bq/l)	Th-228 (Bq/l)
7956-24	SP11-S 29/06/2014	<MDL	<MDL	<MDL
7956-25	SP11-B 29/06/2014	<MDL	<MDL	<MDL
7956-26	SP12-S 29/06/2014	<MDL	<MDL	<MDL
7956-27	SP12-M 29/06/2014	<MDL	<MDL	<MDL
7956-28	SP12-B 29/06/2014	<MDL	<MDL	<MDL
7956-29	SP13-S 29/06/2014	<MDL	<MDL	<MDL
7956-30	SP13-M 29/06/2014	<MDL	<MDL	<MDL
7956-30D	SP13-M 29/06/2014	<MDL	<MDL	<MDL
7956-31	SP13-B 29/06/2014	<MDL	<MDL	<MDL
7956-32	SP14-S 26/06/2014	<MDL	<MDL	<MDL
7956-33	SP14-M 26/06/2014	<MDL	<MDL	<MDL
7956-34	SP14-B 26/06/2014	<MDL	0.249 ± 0.097	<MDL

The reported expanded uncertainty of measurement is stated as the standard uncertainty of the measurement ± 5.6 %, multiplied by the coverage factor k=2, which corresponds to a coverage probability of approximately 95%.

Realtime Group Limited solutions for today and tomorrow

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DATA REPORT

Project
WV04831.104
Timor Sea

Customer
Sinclair Knight Merz
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

Report Date
12/08/2014

DSID
24338

Batch Number
140702111432

Sample ID
SP3

Date Collected
29/06/2014

Monitoring Point
SP3

Sample Type
Phytoplankton

Date Received
2/07/2014

Functional Location ID
SP3

Method (Detection Limit)
Raw Count (1)

Analysis Date
12/08/2014

Units Reported Cell Density:Cells^{-1} Biovolume: mm ^{3} L $^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Concentrated (phytoplankton net) sample.
Qualitative analysis.
Sedgewick Rafter Chamber (1 ml) - 1 Long transect analysed.

Field Data Recording

Total Density
743.0 Cells^{-1}

Total Counted
743

Uncertainty
7.3%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Asterolampra sp. 002	2		0.27
Chaetoceros spp.	131		17.63
Coscinodiscus nitidis	1		0.13
Coscinodiscus sp. 002	1		0.13
Cylindrotheca closterium	76		10.23
Detonula sp. 001	4		0.54
Fragilariopsis kergulensis	14		1.88
Guinardia striata	3		0.40
Leptocylindrus danicus	5		0.67
Leptocylindrus minimus	4		0.54
Navicula spp.	3		0.40
Nitzschia longissima	14		1.88
Nitzschia spp.	12		1.62
Planktoniella sol	1		0.13
Pseudonitzschia delicatissima group	9		1.21
Pseudonitzschia seriata group	1		0.13
Rhizosolenia spp.	1		0.13
Thalassiosira pseudonana	11		1.48
Thalassiosira sp. 004	26		3.50
Thalassiothrix sp. 001	10		1.35
	329	**0.0000**	**44.28**

Species Name	Density	BioVolume	%
Cyanobacteria			
Trichodesmium erythraeum	408		54.91
	408	**0.0000**	**54.91**
Dictyochophyceae			
Dictyocha fibula var. rhombica	1		0.13
Dictyocha octonaria	1		0.13
	2	**0.0000**	**0.27**
Dinophyceae			
Ceratium spp.	1		0.13
Prorocentrum dentatum	2		0.27
Scrippsiella trochoidea	1		0.13
	4	**0.0000**	**0.54**

End Of Report

This report contains coloured shading. Dalcon Environmental intends that this report be viewed and/or printed in colour.

Dalcon Environmental Pty Ltd makes no claim that the taxa list provided herein is exhaustive. Some taxa, including potentially problematic taxa, may be present in the sample but not recorded during analysis, this is particularly the case for small or inconspicuous taxa or taxa present in low numbers. Guidance presented herein is based on published research , whilst Dalcon Environmental make every attempt to remain up to date, it is possible that scientific consensus may differ from that presented herein.

Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

Project
WV04831.104
Timor Sea

Customer
Sinclair Knight Merz
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

DSID
24339

Report Date
12/08/2014

Batch Number
140702111615

Sample ID
SP5

Date Collected
28/06/2014

Monitoring Point
SP5

Sample Type
Phytoplankton

Date Received
2/07/2014

Functional Location ID
SP5

Method (Detection Limit)
Raw Count (1)

Analysis Date
12/08/2014

Units Reported Cell Density:Cells^{-1} Biovolume: mm^{3} L^{-1} %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Concentrated (phytoplankton net) sample.
Qualitative analysis.
Sedgewick Rafter Chamber (1 ml) - 1 Long transect analysed.

Field Data Recording

Total Density
1,243.0 Cells^{-1}

Total Counted
1,243

Uncertainty
5.7%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Asterolampra sp. 001	1		0.08
Asterolampra sp. 002	1		0.08
Bacteriastrum hyalinum	10		0.80
Cerataulina sp. 004	9		0.72
Chaetoceros spp.	114		9.17
Climacodium frauenfeldianum	4		0.32
Coscinodiscus nitidis	5		0.40
Cylindrotheca closterium	88		7.08
Diatom 189	1		0.08
Eucampia cornuta	4		0.32
Fragilariopsis kergulensis	3		0.24
Navicula spp.	3		0.24
Nitzschia longissima	30		2.41
Nitzschia spp.	2		0.16
Pseudonitzschia delicatissima group	14		1.13
Pseudonitzschia seriata group	8		0.64
Rhizosolenia setigera	7		0.56
Rhizosolenia spp.	5		0.40
Thalassionema frauenfeldii	12		0.97
Thalassiosira pseudonana	7		0.56
Thalassiosira sp. 004	7		0.56

Species Name	Density	BioVolume	%
Thalassiothrix sp. 001	15		1.21
	350	**0.0000**	**28.16**
Cyanobacteria			
Trichodesmium erythraeum	880		70.80
	880	**0.0000**	**70.80**
Dictyochophyceae			
Dictyocha fibula var. rhombica	6		0.48
	6	**0.0000**	**0.48**
Dinophyceae			
Ceratium breve	2		0.16
Ornithocercus splendicus	3		0.24
Protoperidinium roseum	1		0.08
Protoperidinium sp. 037	1		0.08
	7	**0.0000**	**0.56**

End Of Report

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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Project
WV04831.104
Timor Sea

Customer
Sinclair Knight Merz
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

Report Date
12/08/2014

DSID
24340

Batch Number
140702111733

Monitoring Point
SP6 - Barossa WV04831

Functional Location ID
SP6

Sample ID
SP6

Sample Type
Phytoplankton

Method (Detection Limit)
Raw Count (1)

Date Collected
29/06/2014

Date Received
2/07/2014

Analysis Date
12/08/2014

Units Reported Cell Density:Cells^{-1} Biovolume: mm ^{3} L $^{-1}$ %: Percentage of total cells counted

Sampler Notes

Field Data Recording

Laboratory Notes
Concentrated (phytoplankton net) sample.
Qualitative analysis.
Sedgewick Rafter Chamber (1 ml) - 1 Long transect analysed.

Total Density
1,043.0 Cells^{-1}

Total Counted
1,043

Uncertainty
6.2%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Bacteriastrum hyalinum	2		0.19
Cerataulina pelagica	2		0.19
Chaetoceros spp.	45		4.31
Climacodium frauenfeldianum	6		0.58
Coscinodiscus nitidis	1		0.10
Coscinodiscus sp. 002	1		0.10
Cylindrotheca closterium	5		0.48
Eucampia sp. 001	2		0.19
Fragilariopsis kergulensis	2		0.19
Navicula spp.	1		0.10
Nitzschia longissima	5		0.48
Proboscia alata	1		0.10
Pseudonitzschia delicatissima group	2		0.19
Rhizosolenia spp.	4		0.38
Thalassiosira sp. 004	7		0.67
Thalassiothrix sp. 001	22		2.11
	108	**0.0000**	**10.35**
Cyanobacteria			
Trichodesmium erythraeum	920		88.21
	920	**0.0000**	**88.21**

Species Name	Density	BioVolume	%
Dictyochophyceae			
Dictyocha fibula var. rhombica	3		0.29
Dictyocha octonaria	1		0.10
	4	**0.0000**	**0.38**
Dinophyceae			
Ceratium buceros	2		0.19
Ceratium furca	4		0.38
Ceratium lineatum	2		0.19
Protoperidinium roseum	1		0.10
Pyrocystis lunula	1		0.10
Scrippsiella trochoidea	1		0.10
	11	**0.0000**	**1.05**

End Of Report

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

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Project
WV04831.104
Timor Sea

Customer
Sinclair Knight Merz
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

Report Date
12/08/2014

DSID
24341

Batch Number
140702111841

Sample ID
SP7

Date Collected
29/06/2014

Monitoring Point
SP6 - Barossa WV04831

Sample Type
Phytoplankton

Date Received
2/07/2014

Functional Location ID
SP6

Method (Detection Limit)
Raw Count (1)

Analysis Date
12/08/2014

Units Reported Cell Density:Cells^{-1} Biovolume: mm ^{3} L $^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Concentrated (phytoplankton net) sample.
Qualitative analysis.
Sedgewick Rafter Chamber (1 ml) - 1 Long transect analysed.

Field Data Recording

Total Density
725.0 Cells^{-1}

Total Counted
725

Uncertainty
7.4%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Asterolampra sp. 002	1		0.14
Bacteriastrum hyalinum	6		0.83
Bacteriastrum sp. 018	4		0.55
Cerataulina pelagica	8		1.10
Chaetoceros spp.	104		14.34
Climacodium frauenfeldianum	8		1.10
Coscinodiscus nitidis	10		1.38
Coscinodiscus sp. 002	4		0.55
Cylindrotheca closterium	2		0.28
Dactyliosolen antarcticus	11		1.52
Fragilariopsis kergulensis	4		0.55
Hemiaulus sp. 001	1		0.14
Lithodesmium sp. 001	2		0.28
Nitzschia longissima	4		0.55
Pseudonitzschia delicatissima group	5		0.69
Rhizosolenia spp.	10		1.38
Thalassiosira sp. 004	7		0.97
Thalassiothrix sp. 001	7		0.97
	198	**0.0000**	**27.31**
Cyanobacteria			

Species Name	Density	BioVolume	%
Trichodesmium erythraeum	510		70.34
	510	**0.0000**	**70.34**
Dictyochophyceae			
Dictyocha fibula var. rhombica	2		0.28
Dictyocha octonaria	2		0.28
	4	**0.0000**	**0.55**
Dinophyceae			
Ceratium breve	1		0.14
Ceratium buceros	1		0.14
Ceratium furca	2		0.28
Ceratium lineatum	3		0.41
Ceratium sp. 054	1		0.14
Dinophysis miles	1		0.14
Ornithocercus splendicus	1		0.14
Phalacroma rotundatum	1		0.14
Protoperidinium roseum	1		0.14
Protoperidinium sp. 032	1		0.14
	13	**0.0000**	**1.79**

End Of Report

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

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Project
WV04831.104
Timor Sea

Customer
Sinclair Knight Merz
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

Report Date
12/08/2014

DSID
24342

Batch Number
140702111947

Sample ID
SP10

Date Collected
29/06/2014

Monitoring Point
Barossa

Sample Type
Phytoplankton

Date Received
2/07/2014

Functional Location ID
SP10

Method (Detection Limit)
Raw Count (1)

Analysis Date
12/08/2014

Units Reported Cell Density:Cells^{-1} Biovolume: mm ^{3} L $^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Concentrated (phytoplankton net) sample.
Qualitative analysis.
Sedgewick Rafter Chamber (1 ml) - 1 Long transect analysed.

Field Data Recording

Total Density
1,800.0 Cells^{-1}

Total Counted
1,800

Uncertainty
4.7%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Bacteriastrum hyalinum	5		0.28
Bacteriastrum sp. 018	14		0.78
Cerataulina sp. 004	3		0.17
Chaetoceros spp.	194		10.78
Climacodium frauenfeldianum	72		4.00
Coscinodiscus centralis	1		0.06
Coscinodiscus nitidis	4		0.22
Cylindrotheca closterium	3		0.17
Detonula sp. 001	2		0.11
Diatom 085	3		0.17
Diatom 189	1		0.06
Nitzschia longissima	3		0.17
Proboscia alata	3		0.17
Pseudonitzschia delicatissima group	6		0.33
Pseudonitzschia seriata group	5		0.28
Rhizosolenia setigera	3		0.17
Rhizosolenia spp.	7		0.39
Skeletonema spp.	6		0.33
Thalassiosira sp. 004	16		0.89
Thalassiothrix sp. 001	11		0.61
	362	**0.0000**	**20.11**

Species Name	Density	BioVolume	%
Cyanobacteria			
Trichodesmium erythraeum	1,415		78.61
	1,415	**0.0000**	**78.61**
Dictyochophyceae			
Dictyocha fibula var. rhombica	5		0.28
Dictyocha octonaria	1		0.06
	6	**0.0000**	**0.33**
Dinophyceae			
Ceratium breve	1		0.06
Ceratium furca	2		0.11
Ceratium lineatum	1		0.06
Ceratium sp. 027	3		0.17
Ceratium sp. 054	1		0.06
Ornithocercus splendicus	1		0.06
Oxytoxum scolopax	1		0.06
Prorocentrum mexicanum	1		0.06
Prorocentrum sp. 012	1		0.06
Protoperidinium sp. 018	1		0.06
Protoperidinium sp. 024	1		0.06
Protoperidinium steinii	2		0.11
Scrippsiella trochoidea	1		0.06
	17	**0.0000**	**0.94**

End Of Report

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

DATA REPORT

A// 3 Yeeda Way
Malaga, WA 6090

P// (08) 9271 6776

F// (08) 9248 9120

Project
WV04831.104
Timor Sea

Customer
Sinclair Knight Merz
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

Report Date
12/08/2014

DSID
24343

Batch Number
140702112054

Sample ID
SP14

Date Collected
26/06/2014

Monitoring Point
WV04831

Sample Type
Phytoplankton

Date Received
2/07/2014

Functional Location ID
SP14

Method (Detection Limit)
Raw Count (1)

Analysis Date
12/08/2014

Units Reported Cell Density:Cells^{-1} Biovolume: mm ^{3} L $^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Concentrated (phytoplankton net) sample.
Qualitative analysis.
Sedgewick Rafter Chamber (1 ml) - 1 Long transect analysed.

Field Data Recording

Total Density
2,327.0 Cells^{-1}

Total Counted
2,327

Uncertainty
4.1%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Bacteriastrum hyalinum	336		14.44
Bacteriastrum sp. 018	54		2.32
Cerataulina pelagica	11		0.47
Cerataulina sp. 004	7		0.30
Chaetoceros spp.	1,038		44.61
Climacodium frauenfeldianum	28		1.20
Corethron criophilum	1		0.04
Corethron sp. 004	1		0.04
Coscinodiscus centralis	5		0.21
Coscinodiscus nitidis	47		2.02
Coscinodiscus sp. 002	2		0.09
Cylindrotheca closterium	11		0.47
Dactyliosolen antarcticus	2		0.09
Dactyliosolen phuketensis	2		0.09
Detonula sp. 001	3		0.13
Diatom 125	69		2.97
Diatom 301	1		0.04
Eucampia cornuta	12		0.52
Eucampia sp. 001	1		0.04
Fragilariopsis kergulensis	31		1.33
Guinardia striata	9		0.39

Species Name	Density	BioVolume	%
Hemiaulus sp. 001	41		1.76
Hemiaulus sp. 006	1		0.04
Leptocylindrus danicus	7		0.30
Meuniera membranacea	6		0.26
Navicula spp.	1		0.04
Nitzschia longissima	8		0.34
Pleurosigma salinarum	1		0.04
Proboscia alata	21		0.90
Pseudo-nitzschia "seriata group"	5		0.21
Pseudonitzschia delicatissima group	3		0.13
Rhizosolenia spp.	63		2.71
Thalassionema frauenfeldii	291		12.51
Thalassiosira sp. 004	8		0.34
Thalassiothrix sp. 001	21		0.90
	2,148	**0.0000**	**92.31**
Cyanobacteria			
Trichodesmium erythraeum	142		6.10
	142	**0.0000**	**6.10**
Dictyochophyceae			
Dictyocha fibula var. rhombica	13		0.56
Dictyocha octonaria	4		0.17
	17	**0.0000**	**0.73**
Dinophyceae			
Amphisolenia sp. 002	1		0.04
Ceratium buceros	1		0.04
Ceratium candelabrum	1		0.04
Ceratium declinatum	1		0.04
Ceratium furca	1		0.04
Ceratium lineatum	2		0.09
Ceratium sp. 032	1		0.04
Ceratium sp. 054	1		0.04
Ornithocercus splendicus	2		0.09
Oxytoxum scolopax	1		0.04
Phalacroma rotundatum	1		0.04
Prorocentrum micans	1		0.04
Prorocentrum sp. 009	2		0.09
Protoperidinium steinii	3		0.13
Scrippsiella trochoidea	1		0.04
	20	**0.0000**	**0.86**

Species Name	Density	BioVolume	%

End Of Report

Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

Project
WV04831.104
Timor Sea

Customer
Sinclair Knight Merz
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

Report Date
8/08/2014

DSID
24344

Batch Number
140702112203

Sample ID
SP3

Date Collected
29/06/2014

Monitoring Point
SP3

Sample Type
Zooplankton

Date Received
2/07/2014

Functional Location ID
SP3

Method (Detection Limit)
Raw Count (1)

Analysis Date
30/07/2014

Units Reported: Cell Density:Individuals^{-1} Biovolume: mm^{3} L^{-1} %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Original sample volume = 84 ml.
Sample diluted 25x prior to analysis.
3 x 1ml sub-samples (Sedgewick-Rafter Chamber) analysed.

Field Data Recording

Total Density
157.0 Individuals^{-1}

Total Counted
157

Uncertainty
16.0%

Species Name	Density	BioVolume	%
Appendicularia			
Appendicularian	2		1.27
	2	**0.0000**	**1.27**
Copepoda			
Acartiidae	6		3.82
Calanidae	36		22.93
Copepod Nauplius	14		8.92
Corycaeidae	15		9.55
Macrosetella sp. 001	4		2.55
Oithonidae	12		7.64
Oncaeidae	5		3.18
Paracalanidae	8		5.10
Sulcanidae	4		2.55
Temoridae	1		0.64
	105	**0.0000**	**66.88**
Foraminifera			
Foraminiferida	2		1.27
	2	**0.0000**	**1.27**
Malacostraca			

Species Name	Density	BioVolume	%
Anomuran zoea larva	3		1.91
	3	**0.0000**	**1.91**
Maxillopoda			
Cirripede nauplius	1		0.64
	1	**0.0000**	**0.64**
Ostracoda			
Cypridinidae	1		0.64
	1	**0.0000**	**0.64**
Sagittoidea			
Chaetognath	4		2.55
	4	**0.0000**	**2.55**
Thaliacea			
Salpidae	1		0.64
	1	**0.0000**	**0.64**
Trizonidae			
Trizonidae	37		23.57
	37	**0.0000**	**23.57**
Unknown			
Protozoa 047	1		0.64
	1	**0.0000**	**0.64**

End Of Report

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

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Malaga, WA 6090
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Project
WV04831.104
Timor Sea

Customer
Sinclair Knight Merz
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

Report Date
8/08/2014

DSID
24345

Batch Number
140702112325

Sample ID
SP5

Date Collected
28/06/2014

Monitoring Point
SP5

Sample Type
Zooplankton

Date Received
2/07/2014

Functional Location ID
SP5

Method (Detection Limit)
Raw Count (1)

Analysis Date
6/08/2014

Units Reported Cell Density:Individuals^{-1} Biovolume: mm ^{3} L $^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Original sample volume = 66 ml.
Sample diluted 10x prior to analysis.
3 x 1ml sub-samples (Sedgewick-Rafter Chamber) analysed.

Field Data Recording

Total Density
527.0 Individuals^{-1}

Total Counted
527

Uncertainty
8.7%

Species Name	Density	BioVolume	%
Appendicularia			
Appendicularian	46		8.73
	46	**0.0000**	**8.73**
Copepoda			
Acartiidae	145		27.51
Calanidae	113		21.44
Copepod Nauplius	97		18.41
Corycaeidae	19		3.61
Macrosetella sp. 001	5		0.95
Microsetella	9		1.71
Oithonidae	21		3.98
Oncaeidae	1		0.19
Paracalanidae	1		0.19
Pontellidae nauplius	2		0.38
Sulcanidae	10		1.90
	423	**0.0000**	**80.27**
Foraminifera			
Foraminiferida	2		0.38
	2	**0.0000**	**0.38**

Species Name	Density	BioVolume	%
Ophiuroidea			
Echinoderm Ophiopluteus Larva	1		0.19
	1	**0.0000**	**0.19**
Sagittoidea			
Chaetognath	4		0.76
	4	**0.0000**	**0.76**
Trizonidae			
Trizonidae	51		9.68
	51	**0.0000**	**9.68**

End Of Report

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

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Project
WV04831.104
Timor Sea

Customer
Sinclair Knight Merz
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

Report Date
8/08/2014

DSID
24346

Batch Number
140702112444

Sample ID
SP14

Date Collected
26/06/2014

Monitoring Point
WV04831

Sample Type
Zooplankton

Date Received
2/07/2014

Functional Location ID
SP14

Method (Detection Limit)
Raw Count (1)

Analysis Date
30/07/2014

Units Reported: Cell Density:Individuals^{-1} Biovolume: mm ^{3} L $^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Original sample volume = 66 ml.
Sample diluted 100x prior to analysis.
3 x 1ml sub-samples (Sedgewick-Rafter Chamber) analysed.

Field Data Recording

Total Density
212.0 Individuals^{-1}

Total Counted
212

Uncertainty
13.7%

Species Name	Density	BioVolume	%
Appendicularia			
Appendicularian	1		0.47
	1	**0.0000**	**0.47**
Copepoda			
Acartiidae	31		14.62
Calanidae	53		25.00
Copepod Nauplius	44		20.75
Corycaeidae	2		0.94
Macrosetella sp. 001	7		3.30
Microsetella	8		3.77
Oncaeidae	1		0.47
Paracalanidae	5		2.36
Sulcanidae	4		1.89
	155	**0.0000**	**73.11**
Foraminifera			
Foraminiferida	4		1.89
	4	**0.0000**	**1.89**
Gigartacontidae			
Gigartacontidae	2		0.94

Species Name	Density	BioVolume	%
	2	**0.0000**	**0.94**
Malacostraca			
Hyperiidae	1		0.47
	1	**0.0000**	**0.47**
Ophiuroidea			
Echinoderm Ophiopluteus Larva	1		0.47
	1	**0.0000**	**0.47**
Polycystinea			
Theoperidae	2		0.94
	2	**0.0000**	**0.94**
Sagittoidea			
Chaetognath	2		0.94
	2	**0.0000**	**0.94**
Trizonidae			
Trizonidae	44		20.75
	44	**0.0000**	**20.75**

End Of Report

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

Appendix C1. Summer

CERTIFICATE OF ANALYSIS

Work Order	: **EP1500461**	Page	: 1 of 13
Client	: **JACOBS GROUP (AUSTRALIA) PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: MR CHRIS TEASDALE	Contact	: Scott James
Address	: P O BOX H615 PERTH WA, AUSTRALIA 6001	Address	: 10 Hod Way Malaga WA Australia 6090
E-mail	: cteasdale@globalskm.com	E-mail	: perth.enviro.services@alsglobal.com
Telephone	: +61 08 9469 4400	Telephone	: +61-8-9209 7655
Facsimile	: +61 08 9469 4488	Facsimile	: +61-8-9209 7600
Project	: IW021200	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: IW021200.104		
C-O-C number	: ----	Date Samples Received	: 23-JAN-2015
Sampler	: K.R.	Issue Date	: 29-JAN-2015
Site	: ----		
		No. of samples received	: 48
Quote number	: EP/370/14	No. of samples analysed	: 48

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Agnes Szilagyi	Senior Organic Chemist	Perth Organics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	SP1-S	SP1-M	SP1-B	SP2-S	SP2-M
			Client sample ID	SP1-S	SP1-M	SP1-B	SP2-S	SP2-M
			Client sampling date / time	20-JAN-2015 08:25	20-JAN-2015 08:25	20-JAN-2015 08:25	20-JAN-2015 07:00	20-JAN-2015 07:00
				EP1500461-001	**EP1500461-002**	**EP1500461-003**	**EP1500461-004**	**EP1500461-005**
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ **Total Xylenes**	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**94.5**	**105**	**104**	**99.8**	**103**
Toluene-D8	2037-26-5	0.1	%	**101**	**96.6**	**98.5**	**99.2**	**98.1**
4-Bromofluorobenzene	460-00-4	0.1	%	**96.7**	**98.6**	**97.9**	**97.3**	**96.0**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)

Client sample ID				SP2-B	SP3-S	SP3-M	SP3-B	SP4-S
Client sampling date / time				20-JAN-2015 07:00	19-JAN-2015 14:10	19-JAN-2015 14:10	19-JAN-2015 14:10	19-JAN-2015 15:20
Compound	CAS Number	LOR	Unit	EP1500461-006	EP1500461-007	EP1500461-008	EP1500461-009	EP1500461-010
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**99.5**	**98.1**	**100**	**101**	**99.1**
Toluene-D8	2037-26-5	0.1	%	**99.3**	**101**	**99.3**	**98.3**	**99.9**
4-Bromofluorobenzene	460-00-4	0.1	%	**95.4**	**95.1**	**94.8**	**95.1**	**94.8**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)

Compound	CAS Number	LOR	Unit	SP4-M	SP4-B	SP5-S	SP5-M	SP5-B
			Client sampling date / time	19-JAN-2015 15:20	19-JAN-2015 15:20	19-JAN-2015 16:45	19-JAN-2015 16:45	19-JAN-2015 16:45
				EP1500461-011	EP1500461-012	EP1500461-013	EP1500461-014	EP1500461-015
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**96.4**	**102**	**101**	**99.1**	**101**
Toluene-D8	2037-26-5	0.1	%	**101**	**99.1**	**99.7**	**100**	**99.2**
4-Bromofluorobenzene	460-00-4	0.1	%	**93.6**	**93.5**	**93.8**	**93.5**	**93.8**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	SP6-S	SP6-M	SP6-B	SP7-S	SP7-B
			Client sampling date / time	19-JAN-2015 12:10	19-JAN-2015 12:10	19-JAN-2015 12:10	18-JAN-2015 11:30	18-JAN-2015 11:30
Compound	CAS Number	LOR	Unit	EP1500461-016	EP1500461-017	EP1500461-018	EP1500461-019	EP1500461-020
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**97.9**	**94.8**	**94.2**	**95.6**	**100**
Toluene-D8	2037-26-5	0.1	%	**101**	**102**	**102**	**101**	**99.4**
4-Bromofluorobenzene	460-00-4	0.1	%	**92.3**	**91.4**	**90.7**	**91.6**	**92.8**

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)

					Client sample ID	SP8-S	SP8-M	SP8-B	SP9-S	SP9-M
					Client sampling date / time	18-JAN-2015 14:30	18-JAN-2015 14:30	18-JAN-2015 14:30	18-JAN-2015 13:30	18-JAN-2015 13:30
	Compound	CAS Number	LOR	Unit		EP1500461-021	EP1500461-022	EP1500461-023	EP1500461-024	EP1500461-025
	EP080/071: Total Petroleum Hydrocarbons									
	C6 - C9 Fraction	----	20	µg/L		<20	<20	<20	<20	<20
	C10 - C14 Fraction	----	50	µg/L		<50	<50	<50	<50	<50
	C15 - C28 Fraction	----	100	µg/L		<100	<100	<100	<100	<100
	C29 - C36 Fraction	----	50	µg/L		<50	<50	<50	<50	<50
^	C10 - C36 Fraction (sum)	----	50	µg/L		<50	<50	<50	<50	<50
	EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions									
	C6 - C10 Fraction	C6_C10	20	µg/L		<20	<20	<20	<20	<20
^	C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L		<20	<20	<20	<20	<20
	>C10 - C16 Fraction	>C10_C16	100	µg/L		<100	<100	<100	<100	<100
	>C16 - C34 Fraction	----	100	µg/L		<100	<100	<100	<100	<100
	>C34 - C40 Fraction	----	100	µg/L		<100	<100	<100	<100	<100
^	>C10 - C40 Fraction (sum)	----	100	µg/L		<100	<100	<100	<100	<100
^	>C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L		<100	<100	<100	<100	<100
	EP080: BTEXN									
	Benzene	71-43-2	1	µg/L		<1	<1	<1	<1	<1
	Toluene	108-88-3	2	µg/L		<2	<2	<2	<2	<2
	Ethylbenzene	100-41-4	2	µg/L		<2	<2	<2	<2	<2
	meta- & para-Xylene	108-38-3 106-42-3	2	µg/L		<2	<2	<2	<2	<2
	ortho-Xylene	95-47-6	2	µg/L		<2	<2	<2	<2	<2
^	Total Xylenes	1330-20-7	2	µg/L		<2	<2	<2	<2	<2
^	Sum of BTEX	----	1	µg/L		<1	<1	<1	<1	<1
	Naphthalene	91-20-3	5	µg/L		<5	<5	<5	<5	<5
	EP080S: TPH(V)/BTEX Surrogates									
	1.2-Dichloroethane-D4	17060-07-0	0.1	%		**97.3**	**95.5**	**97.8**	**95.2**	**103**
	Toluene-D8	2037-26-5	0.1	%		**101**	**101**	**101**	**101**	**98.2**
	4-Bromofluorobenzene	460-00-4	0.1	%		**89.1**	**89.7**	**89.8**	**88.9**	**92.2**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	SP9-B	SP10-S	SP10-M	SP10-B	SP11-S
			Client sampling date / time	18-JAN-2015 13:30	18-JAN-2015 09:16	18-JAN-2015 09:16	18-JAN-2015 09:16	18-JAN-2015 16:55
Compound	CAS Number	LOR	Unit	EP1500461-026	EP1500461-027	EP1500461-028	EP1500461-029	EP1500461-030
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	97.3	98.0	96.3	97.8	94.8
Toluene-D8	2037-26-5	0.1	%	101	101	100	102	102
4-Bromofluorobenzene	460-00-4	0.1	%	90.6	89.6	89.5	89.0	89.4

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)

Compound	CAS Number	LOR	Unit	SP11-B	SP12-S	SP12-M	SP12-B	SP13-S
Client sampling date / time				18-JAN-2015 16:55	18-JAN-2015 15:50	18-JAN-2015 15:50	18-JAN-2015 15:50	19-JAN-2015 07:20
				EP1500461-031	EP1500461-032	EP1500461-033	EP1500461-034	EP1500461-035
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**97.1**	**99.4**	**96.0**	**101**	**100**
Toluene-D8	2037-26-5	0.1	%	**101**	**100**	**100**	**99.4**	**99.4**
4-Bromofluorobenzene	460-00-4	0.1	%	**89.0**	**89.0**	**88.4**	**90.4**	**91.0**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	SP13-M	SP13-B	SP14-S	SP14-M	SP14-B
			Client sampling date / time	19-JAN-2015 07:20	19-JAN-2015 07:20	19-JAN-2015 08:40	19-JAN-2015 08:40	19-JAN-2015 08:40
Compound	CAS Number	LOR	Unit	EP1500461-036	EP1500461-037	EP1500461-038	EP1500461-039	EP1500461-040
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**101**	**94.8**	**101**	**100**	**95.7**
Toluene-D8	2037-26-5	0.1	%	**99.2**	**100**	**98.7**	**99.5**	**103**
4-Bromofluorobenzene	460-00-4	0.1	%	**89.0**	**88.5**	**88.6**	**89.5**	**99.5**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	SP15-S	SP15-M	SP15-B	SP16-S	SP16-B
			Client sampling date / time	20-JAN-2015 11:00	20-JAN-2015 11:00	20-JAN-2015 11:00	20-JAN-2015 13:10	20-JAN-2015 13:10
Compound	CAS Number	LOR	Unit	EP1500461-041	EP1500461-042	EP1500461-043	EP1500461-044	EP1500461-045
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**94.7**	**104**	**105**	**106**	**102**
Toluene-D8	2037-26-5	0.1	%	**102**	**98.6**	**101**	**100**	**101**
4-Bromofluorobenzene	460-00-4	0.1	%	**93.4**	**88.4**	**90.1**	**92.6**	**88.6**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)

Compound	CAS Number	LOR	Unit	SP17-S	SP17-M	SP17-B	----	----
Client sampling date / time				20-JAN-2015 14:35	20-JAN-2015 14:35	20-JAN-2015 14:35	----	----
				EP1500461-046	**EP1500461-047**	**EP1500461-048**	**----**	**----**
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	----	----
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	----	----
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	----	----
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	----	----
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	----	----
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	----	----
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	----	----
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	----	----
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	----	----
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	----	----
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	----	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	----	----
Toluene	108-88-3	2	µg/L	<2	<2	<2	----	----
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	----	----
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	----	----
^ **Total Xylenes**	1330-20-7	2	µg/L	<2	<2	<2	----	----
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	----	----
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**104**	**107**	**109**	----	----
Toluene-D8	2037-26-5	0.1	%	**100**	**98.1**	**97.6**	----	----
4-Bromofluorobenzene	460-00-4	0.1	%	**88.4**	**89.4**	**86.8**	----	----

Surrogate Control Limits

Sub-Matrix: **WATER**

Compound	CAS Number	Recovery Limits (%) Low	High
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	60.5	141.2
Toluene-D8	2037-26-5	73.4	126
4-Bromofluorobenzene	460-00-4	59.6	125.3

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WATER QUALITY DATA

Contact: Celeste Wilson
Customer: Jacobs
Address: Level 11, Durack Centre, 263 Adelaide Terrace, Perth WA 6001

Date of Issue: 17/02/2015
Date Received: 22/01/2015
Our Reference: JAC14-12
Your Reference: IW021200.104

METHOD	Sampling	2000	4100	2100	4700	2700	3000	3000	2540D
SAMPLE CODE	Date	AMMONIA	ORTHO-P	NO3+NO2	TOTAL-P	TOTAL-N	CHLOROPHYLL'a'	PHAEOPHYTIN'a'	TSS
		µg.N/L	µg.P/L	µg.N/L	µg.P/L	µg.N/L	µg/L	µg/L	mg/L
Reporting Limit		<3	<2	<2	<5	<50	<0.1	<0.2	<0.5
File			15012902,020901			15020301,1201		15012803	150127
SP1-S	20/01/2015	<3	4	<2	13	90	0.1	<0.2	
SP1-M	20/01/2015	<3	35	230	42	300	<0.1	<0.2	
SP1-B	20/01/2015	<3	56	380	62	420	<0.1	<0.2	
SP2-S	20/01/2015	<3	4	2	13	110	<0.1	<0.2	<0.5
SP2-M	20/01/2015	3	32	210	36	270	<0.1	<0.2	
SP2-B	20/01/2015	6	54	370	59	420	<0.1	<0.2	
SP3-S	19/01/2015	<3	3	<2	14	90	<0.1	<0.2	0.8
SP3-M	19/01/2015	<3	31	230	36	270	<0.1	<0.2	
SP3-B	19/01/2015	<3	39	290	58	400	<0.1	<0.2	
SP4-S	19/01/2015	<3	4	<2	14	80	0.1	<0.2	
SP4-M	19/01/2015	<3	27	200	33	240	<0.1	<0.2	
SP4-B	19/01/2015	3	47	340	51	360	<0.1	<0.2	
SP5-S	19/01/2015	<3	4	<2	13	100	0.1	<0.2	
SP5-M	19/01/2015	<3	34	230	40	260	<0.1	<0.2	
SP5-B	19/01/2015	5	46	330	52	360	<0.1	<0.2	
SP6-S	19/01/2015	3	3	<2	14	100	0.1	<0.2	<0.5
SP6-M	19/01/2015	8	23	150	35	260	<0.1	<0.2	
SP6-B	19/01/2015	4	43	280	57	400	<0.1	<0.2	
SP7-S	18/01/2015	4	4	2	12	100	0.1	<0.2	0.7
SP7-B	18/01/2015	<3	4	2	13	90	0.2	<0.2	

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Signatory: Jamie Woodward
Date: 17/02/2015

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METHOD SAMPLE CODE	Sampling Date	2000 AMMONIA µg.N/L	4100 ORTHO-P µg.P/L	2100 NO3+NO2 µg.N/L	4700 TOTAL-P µg.P/L	2700 TOTAL-N µg.N/L	3000 CHLOROPHYLL'a' µg/L	3000 PHAEOPHYTIN'a' µg/L	2540D TSS mg/L
Reporting Limit		**<3**	**<2**	**<2**	**<5**	**<50**	**<0.1**	**<0.2**	**<0.5**
File			**15012902,020901**		**15020301,1201**		**15012803**		**150127**
SP8-S	18/01/2015	<3	4	<2	12	90	0.2	<0.2	
SP8-M	18/01/2015	5	5	<2	14	80	0.3	<0.2	
SP8-B	18/01/2015	3	25	170	32	240	0.2	<0.2	
SP9-S	18/01/2015	5	5	2	14	90	0.1	<0.2	
SP9-M	18/01/2015	5	28	190	35	310	0.2	<0.2	
SP9-B	18/01/2015	7	32	180	43	320	<0.1	<0.2	
SP10-S	18/01/2015	<3	5	<2	14	80	0.1	<0.2	
SP10-M	18/01/2015	<3	24	150	30	220	0.2	<0.2	
SP10-B	18/01/2015	8	43	300	48	350	<0.1	<0.2	
SP11-S	18/01/2015	4	3	<2	13	90	0.2	<0.2	
SP11-B	18/01/2015	<3	3	<2	13	110	0.3	<0.2	
SP12-S	18/01/2015	4	4	<2	14	120	0.2	<0.2	0.8
SP12-M	18/01/2015	37	7	3	15	90	0.8	0.2	
SP12-B	18/01/2015	4	33	210	39	280	0.2	<0.2	
SP13-S	19/01/2015	9	5	<2	14	110	0.2	<0.2	
SP13-M	19/01/2015	<3	7	<2	18	100	0.9	0.4	
SP13-B	19/01/2015	<3	30	200	38	260	0.3	0.5	
SP14-S	19/01/2015	5	4	<2	14	90	0.2	<0.2	
SP14-M	19/01/2015	<3	4	<2	16	100	0.9	0.4	
SP14-B	19/01/2015	<3	30	190	37	250	0.3	0.5	

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Date: 17/02/2015

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METHOD	Sampling	2000	4100	2100	4700	2700	3000	3000	2540D
SAMPLE CODE	Date	AMMONIA	ORTHO-P	NO3+NO2	TOTAL-P	TOTAL-N	CHLOROPHYLL'a'	PHAEOPHYTIN'a'	TSS
		µg.N/L	µg.P/L	µg.N/L	µg.P/L	µg.N/L	µg/L	µg/L	mg/L
Reporting Limit		<3	<2	<2	<5	<50	<0.1	<0.2	<0.5
File			15012902,020901		15020301,1201		15012803		150127
SP15-S	20/01/2015	<3	4	2	13	100	<0.1	<0.2	
SP15-M	20/01/2015	<3	6	5	15	90	0.4	<0.2	
SP15-B	20/01/2015	<3	30	190	37	260	0.1	<0.2	
SP16-S	20/01/2015	<3	4	<2	14	80	<0.1	<0.2	1.0
SP16-B	20/01/2015	<3	4	<2	13	90	0.2	<0.2	
SP17-S	20/01/2015	<3	4	<2	12	100	<0.1	<0.2	
SP17-M	20/01/2015	<3	7	16	16	100	0.5	0.2	
SP17-B	20/01/2015	<3	30	180	37	250	0.1	<0.2	
Field Blank	20/01/2015	<3	<2	<2	<5	<50	<0.1	<0.2	
Trans Blank	20/01/2015	<3	<2	<2	<5	<50	<0.1	<0.2	

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Date: 17/02/2015

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Our Reference: JAC14-12
Your Reference: IW021200.104

METHOD	Sampling	MS001	MS001	MS001	MS001	MS001	MS001	MS001	MS001	MS001	ICP006
SAMPLE CODE	Date	Filtered Cr	Filtered Co	Filtered Ni	Filtered Cu	Filtered Zn	Filtered As	Filtered Cd	Filtered Ba	Filtered Pb	Hg
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L
Reporting Limit		<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.5	<0.1	<0.0001
File											15012901-02
SP1-S	20/01/2015	<0.2	<0.05	<0.3	0.2	2	1.6	<0.1	5.0	<0.1	<0.0001
SP1-M	20/01/2015	<0.2	<0.05	<0.3	<0.2	1	1.7	<0.1	5.5	<0.1	<0.0001
SP1-B	20/01/2015	<0.2	<0.05	0.3	0.2	1	1.7	<0.1	7.1	<0.1	<0.0001
SP2-S	20/01/2015	<0.2	<0.05	<0.3	0.4	2	1.6	<0.1	5.1	<0.1	<0.0001
SP2-M	20/01/2015	<0.2	<0.05	<0.3	0.2	<1	1.6	<0.1	5.5	<0.1	<0.0001
SP2-B	20/01/2015	<0.2	<0.05	0.3	0.3	4	1.8	<0.1	6.8	<0.1	<0.0001
SP3-S	19/01/2015	<0.2	<0.05	<0.3	0.3	1	1.6	<0.1	5.3	<0.1	<0.0001
SP3-M	19/01/2015	<0.2	<0.05	<0.3	<0.2	2	1.7	<0.1	5.3	<0.1	<0.0001
SP3-B	19/01/2015	<0.2	<0.05	0.3	<0.2	1	1.8	<0.1	6.2	<0.1	<0.0001
SP4-S	19/01/2015	<0.2	<0.05	<0.3	0.2	<1	1.6	<0.1	5.1	<0.1	<0.0001
SP4-M	19/01/2015	<0.2	<0.05	<0.3	0.3	1	1.7	<0.1	5.3	<0.1	<0.0001
SP4-B	19/01/2015	<0.2	<0.05	0.3	0.2	1	1.8	<0.1	6.3	<0.1	<0.0001
SP5-S	19/01/2015	<0.2	<0.05	<0.3	0.3	<1	1.6	<0.1	5.3	<0.1	<0.0001
SP5-M	19/01/2015	<0.2	<0.05	<0.3	0.2	1	1.7	<0.1	5.6	<0.1	<0.0001
SP5-B	19/01/2015	<0.2	<0.05	<0.3	0.2	2	1.7	<0.1	6.4	<0.1	<0.0001
SP6-S	19/01/2015	<0.2	<0.05	<0.3	0.3	2	1.6	<0.1	5.2	<0.1	<0.0001
SP6-M	19/01/2015	<0.2	<0.05	<0.3	0.3	3	1.7	<0.1	5.4	<0.1	<0.0001
SP6-B	19/01/2015	<0.2	<0.05	0.3	0.3	3	1.8	<0.1	6.8	<0.1	<0.0001
SP7-S	18/01/2015	<0.2	<0.05	<0.3	0.4	1	1.6	<0.1	5.4	0.1	<0.0001
SP7-B	18/01/2015	<0.2	<0.05	<0.3	0.3	2	1.6	<0.1	5.4	<0.1	<0.0001

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Signatory: Jamie Woodward
Date: 17/02/2015

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Date of Issue: 17/02/2015
Date Received: 22/01/2015
Our Reference: JAC14-12
Your Reference: IW021200.104

METHOD SAMPLE CODE	Sampling Date	MS001 Filtered Cr µg/L	MS001 Filtered Co µg/L	MS001 Filtered Ni µg/L	MS001 Filtered Cu µg/L	MS001 Filtered Zn µg/L	MS001 Filtered As µg/L	MS001 Filtered Cd µg/L	MS001 Filtered Ba µg/L	MS001 Filtered Pb µg/L	ICP006 Hg mg/L
Reporting Limit		**<0.2**	**<0.05**	**<0.3**	**<0.2**	**<1**	**<0.5**	**<0.1**	**<0.5**	**<0.1**	**<0.0001**
File											**15012901-02**
SP8-S	18/01/2015	<0.2	<0.05	<0.3	0.2	<1	1.6	<0.1	5.4	<0.1	<0.0001
SP8-M	18/01/2015	<0.2	<0.05	<0.3	0.3	2	1.6	<0.1	5.5	<0.1	<0.0001
SP8-B	18/01/2015	<0.2	<0.05	<0.3	0.4	2	1.8	<0.1	5.6	<0.1	<0.0001
SP9-S	18/01/2015	<0.2	<0.05	<0.3	0.3	1	1.8	<0.1	5.5	0.2	<0.0001
SP9-M	18/01/2015	<0.2	<0.05	0.3	0.4	2	1.8	<0.1	5.6	<0.1	<0.0001
SP9-B	18/01/2015	<0.2	<0.05	0.4	0.3	3	1.9	<0.1	6.0	<0.1	<0.0001
SP10-S	18/01/2015	<0.2	<0.05	<0.3	0.2	1	1.7	<0.1	5.5	<0.1	<0.0001
SP10-M	18/01/2015	<0.2	<0.05	<0.3	0.3	3	1.8	<0.1	5.9	<0.1	<0.0001
SP10-B	18/01/2015	<0.2	<0.05	0.4	0.4	4	1.9	<0.1	6.3	<0.1	<0.0001
SP11-S	18/01/2015	<0.2	<0.05	<0.3	0.4	2	1.5	<0.1	5.0	<0.1	<0.0001
SP11-B	18/01/2015	<0.2	<0.05	0.3	0.3	<1	1.7	<0.1	5.2	<0.1	<0.0001
SP12-S	18/01/2015	<0.2	<0.05	0.3	0.3	1	1.7	<0.1	5.2	<0.1	<0.0001
SP12-M	18/01/2015	<0.2	<0.05	<0.3	0.5	5	1.8	<0.1	5.5	<0.1	<0.0001
SP12-B	18/01/2015	<0.2	<0.05	0.3	0.3	3	1.9	<0.1	5.8	<0.1	<0.0001
SP13-S	19/01/2015	<0.2	<0.05	0.3	0.4	4	1.7	<0.1	5.7	<0.1	<0.0001
SP13-M	19/01/2015	<0.2	<0.05	<0.3	<0.2	<1	1.6	<0.1	5.7	<0.1	<0.0001
SP13-B	19/01/2015	<0.2	<0.05	<0.3	<0.2	<1	1.6	<0.1	5.7	<0.1	<0.0001
SP14-S	19/01/2015	<0.2	<0.05	<0.3	<0.2	<1	1.6	<0.1	5.4	<0.1	<0.0001
SP14-M	19/01/2015	<0.2	<0.05	<0.3	<0.2	<1	1.6	<0.1	5.5	<0.1	<0.0001
SP14-B	19/01/2015	<0.2	<0.05	<0.3	<0.2	1	1.8	<0.1	5.8	<0.1	<0.0001

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Date: 17/02/2015

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Date of Issue: 17/02/2015
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Our Reference: JAC14-12
Your Reference: IW021200.104

METHOD	Sampling	MS001	MS001	MS001	MS001	MS001	MS001	MS001	MS001	MS001	ICP006
SAMPLE CODE	Date	Filtered Cr	Filtered Co	Filtered Ni	Filtered Cu	Filtered Zn	Filtered As	Filtered Cd	Filtered Ba	Filtered Pb	Hg
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L
Reporting Limit		**<0.2**	**<0.05**	**<0.3**	**<0.2**	**<1**	**<0.5**	**<0.1**	**<0.5**	**<0.1**	**<0.0001**
File											**15012901-02**
SP15-S	20/01/2015	<0.2	<0.05	<0.3	<0.2	<1	1.5	<0.1	5.6	<0.1	<0.0001
SP15-M	20/01/2015	<0.2	<0.05	<0.3	<0.2	1	1.8	<0.1	5.6	<0.1	<0.0001
SP15-B	20/01/2015	<0.2	<0.05	<0.3	<0.2	<1	1.7	<0.1	5.8	<0.1	<0.0001
SP16-S	20/01/2015	<0.2	<0.05	<0.3	<0.2	1	1.6	<0.1	5.6	<0.1	<0.0001
SP16-B	20/01/2015	<0.2	<0.05	<0.3	<0.2	1	1.6	<0.1	5.4	<0.1	<0.0001
SP17-S	20/01/2015	<0.2	<0.05	<0.3	<0.2	<1	1.6	<0.1	5.7	<0.1	<0.0001
SP17-M	20/01/2015	<0.2	<0.05	<0.3	<0.2	<1	1.7	<0.1	5.7	<0.1	<0.0001
SP17-B	20/01/2015	<0.2	<0.05	<0.3	<0.2	<1	1.7	<0.1	5.9	<0.1	<0.0001
Field Blank	20/01/2015	<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.5	<0.1	<0.0001
Trans Blank	20/01/2015	<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.5	<0.1	<0.0001

Signatory: Jamie Woodward
Date: 17/02/2015

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Our Reference: JAC14-12
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METHOD SAMPLE CODE	Sampling Date	MS001 Unfiltered Cr µg/L	MS001 Unfiltered Co µg/L	MS001 Unfiltered Ni µg/L	MS001 Unfiltered Cu µg/L	MS001 Unfiltered Zn µg/L	MS001 Unfiltered As µg/L	MS001 Unfiltered Cd µg/L	MS001 Unfiltered Ba µg/L	MS001 Unfiltered Pb µg/L	ICP006 Total Ext Hg mg/L
Reporting Limit		<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.5	<0.1	<0.0001
File											15013001-02
SP1-S	20/01/2015	<0.2	<0.05	<0.3	0.3	2	1.6	<0.1	5.1	<0.1	<0.0001
SP1-M	20/01/2015	<0.2	<0.05	<0.3	0.2	<1	1.7	<0.1	5.5	<0.1	<0.0001
SP1-B	20/01/2015	<0.2	<0.05	0.3	0.2	1	1.9	<0.1	7.0	<0.1	<0.0001
SP2-S	20/01/2015	<0.2	<0.05	<0.3	0.5	3	1.6	<0.1	5.2	<0.1	<0.0001
SP2-M	20/01/2015	<0.2	<0.05	<0.3	0.3	<1	1.8	<0.1	5.6	<0.1	<0.0001
SP2-B	20/01/2015	<0.2	<0.05	0.4	0.3	3	1.7	<0.1	6.9	<0.1	<0.0001
SP3-S	19/01/2015	<0.2	<0.05	<0.3	0.2	1	1.6	<0.1	5.4	<0.1	<0.0001
SP3-M	19/01/2015	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.6	<0.1	<0.0001
SP3-B	19/01/2015	<0.2	<0.05	0.4	0.3	<1	1.8	<0.1	6.3	<0.1	<0.0001
SP4-S	19/01/2015	<0.2	<0.05	<0.3	0.5	<1	1.6	<0.1	5.2	<0.1	<0.0001
SP4-M	19/01/2015	<0.2	<0.05	<0.3	0.3	1	1.7	<0.1	5.0	<0.1	<0.0001
SP4-B	19/01/2015	<0.2	<0.05	0.5	0.7	4	1.8	<0.1	6.4	<0.1	<0.0001
SP5-S	19/01/2015	<0.2	<0.05	<0.3	0.6	3	1.6	<0.1	5.3	<0.1	<0.0001
SP5-M	19/01/2015	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.6	<0.1	<0.0001
SP5-B	19/01/2015	<0.2	<0.05	0.3	0.2	<1	1.8	<0.1	6.1	<0.1	<0.0001
SP6-S	19/01/2015	<0.2	<0.05	<0.3	0.3	2	1.6	<0.1	5.3	<0.1	<0.0001
SP6-M	19/01/2015	<0.2	<0.05	<0.3	0.3	2	1.8	<0.1	5.5	<0.1	<0.0001
SP6-B	19/01/2015	<0.2	<0.05	0.3	0.2	2	1.8	<0.1	6.8	<0.1	<0.0001
SP7-S	18/01/2015	<0.2	<0.05	<0.3	0.6	1	1.7	<0.1	5.4	0.2	<0.0001
SP7-B	18/01/2015	<0.2	<0.05	<0.3	0.4	2	1.7	<0.1	5.6	<0.1	<0.0001

Signatory: Jamie Woodward
Date: 17/02/2015

All test items tested as received. Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory
Environmental Science
Tel: +61 8 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
Accredited for compliance with ISO/IEC 17025.
The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

Murdoch University

WATER QUALITY DATA

Contact: Celeste Wilson
Customer: Jacobs
Address: Level 11, Durack Centre, 263 Adelaide Terrace, Perth WA 6001

Date of Issue: 17/02/2015
Date Received: 22/01/2015
Our Reference: JAC14-12
Your Reference: IW021200.104

METHOD SAMPLE CODE	Sampling Date	MS001 Unfiltered Cr µg/L	MS001 Unfiltered Co µg/L	MS001 Unfiltered Ni µg/L	MS001 Unfiltered Cu µg/L	MS001 Unfiltered Zn µg/L	MS001 Unfiltered As µg/L	MS001 Unfiltered Cd µg/L	MS001 Unfiltered Ba µg/L	MS001 Unfiltered Pb µg/L	ICP006 Total Ext Hg mg/L
Reporting Limit		<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.5	<0.1	<0.0001
File											15013001-02
SP8-S	18/01/2015	<0.2	<0.05	<0.3	0.2	1	1.6	<0.1	5.3	<0.1	<0.0001
SP8-M	18/01/2015	<0.2	<0.05	<0.3	0.4	2	1.7	<0.1	5.6	<0.1	<0.0001
SP8-B	18/01/2015	<0.2	<0.05	<0.3	0.3	2	1.8	<0.1	5.9	<0.1	<0.0001
SP9-S	18/01/2015	<0.2	<0.05	<0.3	0.3	1	1.8	<0.1	5.6	0.2	<0.0001
SP9-M	18/01/2015	<0.2	<0.05	0.3	0.4	2	1.8	<0.1	5.8	<0.1	<0.0001
SP9-B	18/01/2015	<0.2	<0.05	0.4	0.3	2	1.9	<0.1	6.0	<0.1	<0.0001
SP10-S	18/01/2015	<0.2	<0.05	<0.3	0.2	1	1.7	<0.1	5.6	<0.1	<0.0001
SP10-M	18/01/2015	<0.2	<0.05	0.3	0.2	3	1.9	<0.1	6.0	<0.1	<0.0001
SP10-B	18/01/2015	<0.2	<0.05	0.4	0.4	4	1.9	<0.1	6.4	<0.1	<0.0001
SP11-S	18/01/2015	<0.2	<0.05	<0.3	0.2	2	1.6	<0.1	5.3	<0.1	<0.0001
SP11-B	18/01/2015	<0.2	<0.05	0.3	0.3	<1	1.8	<0.1	5.6	<0.1	<0.0001
SP12-S	18/01/2015	<0.2	<0.05	<0.3	0.3	2	1.7	<0.1	5.2	<0.1	<0.0001
SP12-M	18/01/2015	<0.2	<0.05	<0.3	0.2	1	1.9	<0.1	5.5	<0.1	<0.0001
SP12-B	18/01/2015	<0.2	<0.05	0.3	0.2	3	1.9	<0.1	5.8	<0.1	<0.0001
SP13-S	19/01/2015	<0.2	<0.05	0.3	0.5	4	1.6	<0.1	5.5	<0.1	<0.0001
SP13-M	19/01/2015	<0.2	<0.05	<0.3	<0.2	1	1.7	<0.1	5.8	<0.1	<0.0001
SP13-B	19/01/2015	0.2	<0.05	<0.3	<0.2	1	1.7	<0.1	5.7	<0.1	<0.0001
SP14-S	19/01/2015	<0.2	<0.05	<0.3	<0.2	<1	1.6	<0.1	5.4	<0.1	<0.0001
SP14-M	19/01/2015	<0.2	<0.05	<0.3	<0.2	<1	1.7	<0.1	5.8	<0.1	<0.0001
SP14-B	19/01/2015	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.8	<0.1	<0.0001

Signatory: Jamie Woodward
Date: 17/02/2015

All test items tested as received. Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory
Environmental Science
Tel: +61 8 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
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The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

WATER QUALITY DATA

Contact: Celeste Wilson
Customer: Jacobs
Address: Level 11, Durack Centre, 263 Adelaide Terrace, Perth WA 6001

Date of Issue: 17/02/2015
Date Received: 22/01/2015
Our Reference: JAC14-12
Your Reference: IW021200.104

METHOD SAMPLE CODE	Sampling Date	MS001 Unfiltered Cr µg/L	MS001 Unfiltered Co µg/L	MS001 Unfiltered Ni µg/L	MS001 Unfiltered Cu µg/L	MS001 Unfiltered Zn µg/L	MS001 Unfiltered As µg/L	MS001 Unfiltered Cd µg/L	MS001 Unfiltered Ba µg/L	MS001 Unfiltered Pb µg/L	ICP006 Total Ext Hg mg/L
Reporting Limit		**<0.2**	**<0.05**	**<0.3**	**<0.2**	**<1**	**<0.5**	**<0.1**	**<0.5**	**<0.1**	**<0.0001**
File											**15013001-02**
SP15-S	20/01/2015	<0.2	<0.05	<0.3	<0.2	<1	1.5	<0.1	5.6	<0.1	<0.0001
SP15-M	20/01/2015	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.7	<0.1	<0.0001
SP15-B	20/01/2015	0.2	<0.05	<0.3	<0.2	<1	1.7	<0.1	5.8	<0.1	<0.0001
SP16-S	20/01/2015	<0.2	<0.05	<0.3	<0.2	<1	1.5	<0.1	5.5	<0.1	<0.0001
SP16-B	20/01/2015	<0.2	<0.05	<0.3	<0.2	<1	1.7	<0.1	5.4	<0.1	<0.0001
SP17-S	20/01/2015	<0.2	<0.05	<0.3	0.2	<1	1.7	<0.1	5.6	<0.1	<0.0001
SP17-M	20/01/2015	<0.2	<0.05	<0.3	<0.2	2	1.7	<0.1	5.7	<0.1	<0.0001
SP17-B	20/01/2015	<0.2	<0.05	0.4	<0.2	1	1.8	<0.1	6.0	<0.1	<0.0001
Field Blank	20/01/2015	<0.2	<0.05	<0.3	<0.2	1	<0.5	<0.1	<0.5	<0.1	<0.0001
Trans Blank	20/01/2015	<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.5	<0.1	<0.0001

Signatory: Jamie Woodward
Date: 17/02/2015

All test items tested as received. Spare test items will be held for two months unless otherwise requested.

Western Radiation Services
analytical laboratory & consulting

NATA
WORLD RECOGNISED ACCREDITATION
Accredited Laboratory
No. 14174

ABN: 64 135 436 092

18 March 2015

Sinclair Knight Merz – JACOBS PROJECT
7th Floor Durack Centre
PERTH WA 6000

Attn: Celeste Wilson
Jacobs Project#:WV04831.104

ANALYTICAL REPORT

The results (to 95%, 2σ confidence level) for Radium-226, Radium-228 and Thorium-228 analyses of forty eight(48) liquid samples, as received at our laboratory on 10 February 2015, are detailed on page two and three of this report.

MDL:	Radium-226	0.100 Bq/l	Radium-228	0.100 Bq/l
	Thorium-228	0.100 Bq/l		

Method:	LTP No. 4(a)	Gamma Spectrometry Analysis

Madassar A. Qureshi
Authorised Signatory

WRS No	Client Sample ID	Ra-226 (Bq/l)	Ra-228 (Bq/l)	Th-228 (Bq/l)
9189-1	SP1-S 20/01/2015	<MDL	<MDL	<MDL
9189-2	SP1-M 20/01/2015	<MDL	<MDL	<MDL
9189-3	SP1-B 20/01/2015	<MDL	<MDL	<MDL
9189-4	SP2-S 20/01/2015	<MDL	<MDL	<MDL
9189-5	SP2-M 20/01/2015	<MDL	<MDL	<MDL
9189-6	SP2-B 20/01/2015	0.114 ± 0.025	0.116 ± 0.053	<MDL
9189-7	SP3-S 19/01/2015	<MDL	<MDL	<MDL
9189-8	SP3-M 19/01/2015	<MDL	<MDL	<MDL
9189-9	SP3-B 19/01/2015	<MDL	<MDL	<MDL
9189-10	SP4-S 19/01/2015	0.115 ± 0.014	<MDL	<MDL
9189-10D	SP4-S 19/01/2015	0.118 ± 0.015	<MDL	<MDL
9189-11	SP4-M 19/01/2015	0.107 ± 0.048	<MDL	<MDL
9189-12	SP4-B 19/01/2015	<MDL	0.109 ± 0.039	<MDL
9189-13	SP5-S 19/01/2015	<MDL	<MDL	<MDL
9189-14	SP5-M 19/01/2015	<MDL	<MDL	<MDL
9189-15	SP5-B 19/01/2015	<MDL	<MDL	<MDL
9189-16	SP6-S 19/01/2015	<MDL	<MDL	<MDL
9189-17	SP6-M 19/01/2015	<MDL	<MDL	<MDL
9189-18	SP6-B 19/01/2015	<MDL	<MDL	<MDL
9189-19	SP7-S 18/01/2015	<MDL	<MDL	<MDL
9189-20	SP7-B 18/01/2015	<MDL	<MDL	<MDL
9189-20D	SP7-B 18/01/2015	<MDL	<MDL	<MDL
9189-21	SP8-S 18/01/2015	<MDL	<MDL	<MDL
9189-22	SP8-M 18/01/2015	<MDL	<MDL	<MDL
9189-23	SP8-B 18/01/2015	<MDL	0.112 ± 0.020	<MDL
9189-24	SP9-S 18/01/2015	<MDL	<MDL	<MDL
9189-25	SP9-M 18/01/2015	<MDL	<MDL	<MDL
9189-26	SP9-B 18/01/2015	<MDL	<MDL	<MDL

Realtime Group Limited solutions for today and tomorrow

Perth Office: 24 Brennan Way, Belmont W.A. 6104
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Email: admin@westernradiation.com.au

WRS No	Client Sample ID	Ra-226 (Bq/g)	Ra-228 (Bq/g)	Th-228 (Bq/l)
9189-27	SP10-S 18/01/2015	<MDL	<MDL	<MDL
9189-28	SP10-M 18/01/2015	<MDL	<MDL	<MDL
9189-29	SP10-B 18/01/2015	<MDL	<MDL	<MDL
9189-30	SP11-S 18/01/2015	<MDL	<MDL	<MDL
9189-30D	SP11-S 18/01/2015	<MDL	<MDL	<MDL
9189-31	SP11-B 18/01/2015	<MDL	<MDL	<MDL
9189-32	SP12-S 18/01/2015	<MDL	<MDL	<MDL
9189-33	SP12-M 18/01/2015	<MDL	<MDL	<MDL
9189-34	SP12-B 18/01/2015	<MDL	<MDL	<MDL
9189-35	SP13-S 19/01/2015	<MDL	<MDL	<MDL
9189-36	SP13-M 19/01/2015	<MDL	<MDL	<MDL
9189-37	SP13-B 19/01/2015	<MDL	<MDL	<MDL
9189-38	SP14-S 19/01/2015	<MDL	<MDL	<MDL
9189-39	SP14-M 19/01/2015	<MDL	<MDL	<MDL
9189-40	SP14-B 19/01/2015	<MDL	<MDL	<MDL
9189-40D	SP14-B 19/01/2015	<MDL	<MDL	<MDL
9189-41	SP15-S 20/01/2015	<MDL	<MDL	<MDL
9189-42	SP15-M 20/01/2015	0.133 ± 0.047	<MDL	<MDL
9189-43	SP15-B 20/01/2015	<MDL	<MDL	<MDL
9189-44	SP16-S 20/01/2015	<MDL	<MDL	<MDL
9189-45	SP16-B 20/01/2015	<MDL	<MDL	<MDL
9189-46	SP17-S 20/01/2015	<MDL	<MDL	<MDL
9189-47	SP17-M 20/01/2015	<MDL	<MDL	<MDL
9189-48	SP17-B 20/01/2015	<MDL	<MDL	<MDL

The reported expanded uncertainty of measurement is stated as the standard uncertainty of the measurement ± 5.6 %, multiplied by the coverage factor k=2, which corresponds to a coverage probability of approximately 95%.

Realtime Group Limited solutions for today and tomorrow

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Email:admin@westernradiation.com.au

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Malaga, WA 6090

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DATA REPORT

Project
BAROSSA
COP-Barossa WQ Trip

Customer
Jacobs Group (Australia) Pty Ltd
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

DSID
26281

Report Date
26/03/2015

Batch Number
150123145338

Sample ID
SP1-S - PHYTO

Date Collected
20/01/2015

Monitoring Point
Timor Sea

Sample Type
Phytoplankton

Date Received
23/01/2015

Functional Location ID
Timor Sea

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
18/03/2015

Units Reported Cell Density:cells L^{-1} Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density
127,551.0 cells L^{-1}

Total Counted
697

Uncertainty
7.6%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Bacteriastrum hyalinum	549		0.43
Cerataulina pelagica	366		0.29
Chaetoceros spp.	2,379		1.87
Dactyliosolen phuketensis	183		0.14
Entomoneis tenuistriata	183		0.14
Nitzschia longissima	366		0.29
Planktoniella sol	183		0.14
Pseudo-nitzschia "delicatissima group"	2,013		1.58
Pseudo-nitzschia "seriata group"	549		0.43
Rhizosolenia setigera	183		0.14
Rhizosolenia shrubsolei	183		0.14
Rhizosolenia striata	366		0.29
Skeletonema sp.	549		0.43
Thalassionema frauenfeldii	549		0.43
Thalassiothrix sp. 001	549		0.43
	9,150	**0.0000**	**7.17**

Species Name	Density	BioVolume	%
Cryptophyceae			
Cryptophyte 014	183		0.14
	183	**0.0000**	**0.14**

Species Name	Density	BioVolume	%
Cyanobacteria			
Trichodesmium erythraeum	116,937		91.68
	116,937	**0.0000**	**91.68**

Species Name	Density	BioVolume	%
Dinophyceae			
Ceratium buceros	183		0.14
Ceratium sp. 033	366		0.29
Dinophysis caudata var. pediculata	366		0.29
Protoperidinium sp. 018	366		0.29
	1,281	**0.0000**	**1.00**

End Of Report

This report contains coloured shading. Dalcon Environmental intends that this report be viewed and/or printed in colour.

Dalcon Environmental Pty Ltd makes no claim that the taxa list provided herein is exhaustive. Some taxa, including potentially problematic taxa, may be present in the sample but not recorded during analysis, this is particularly the case for small or inconspicuous taxa or taxa present in low numbers. Guidance presented herein is based on published research , whilst Dalcon Environmental make every attempt to remain up to date, it is possible that scientific consensus may differ from that presented herein.

Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

Species Name	Density	BioVolume	%

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Potentially toxic species
Potentially harmful (non-toxic) species

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www.dalconenvironmental.com.au

DATA REPORT

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Project
BAROSSA
COP-Barossa WQ Trip

Customer
Jacobs Group (Australia) Pty Ltd
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

DSID
26282

Report Date
26/03/2015

Batch Number
150123145338

Sample ID
SP3-S - PHYTO

Date Collected
19/01/2015

Monitoring Point
Timor Sea

Sample Type
Phytoplankton

Date Received
23/01/2015

Functional Location ID
Timor Sea

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
18/03/2015

Units Reported Cell Density:cells L^{-1} Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density
123,159.0 cells L^{-1}

Total Counted
673

Uncertainty
7.7%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Bacteriastrum hyalinum	366		0.30
Cerataulina pelagica	366		0.30
Chaetoceros spp.	1,647		1.34
Cylindrotheca closterium	366		0.30
Nitzschia longissima	366		0.30
Proboscia alata	183		0.15
Pseudo-nitzschia "seriata group"	549		0.45
Rhizosolenia setigera	183		0.15
Thalassiothrix sp. 001	366		0.30
	4,392	**0.0000**	**3.57**
Cyanobacteria			
Trichodesmium erythraeum	116,937		94.95
	116,937	**0.0000**	**94.95**
Dinophyceae			
Ceratium furca	366		0.30
Ceratium sp. 037	183		0.15
Dinophysis caudata var. pediculata	183		0.15
Protoperidinium grande	366		0.30
Protoperidinium sp. 018	549		0.45

Species Name	Density	BioVolume	%
Protoperidinium sp. 032	183		0.15
	1,830	**0.0000**	**1.49**

End Of Report

Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

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Project
BAROSSA
COP-Barossa WQ Trip

Customer
Jacobs Group (Australia) Pty Ltd
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

DSID
26283

Report Date
26/03/2015

Batch Number
150123145338

Sample ID
SP5-S - PHYTO

Date Collected
19/01/2015

Monitoring Point
Timor Sea

Sample Type
Phytoplankton

Date Received
23/01/2015

Functional Location ID
Timor Sea

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
18/03/2015

Units Reported Cell Density:cells L^{-1} Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density
136,884.0 cells L^{-1}

Total Counted
748

Uncertainty
7.3%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Bacteriastrum hyalinum	183		0.13
Cerataulina pelagica	366		0.27
Chaetoceros spp.	1,281		0.94
Cylindrotheca closterium	183		0.13
Nitzschia longissima	366		0.27
Proboscia alata	183		0.13
Skeletonema costatum	549		0.40
Thalassiothrix sp. 001	549		0.40
	3,660	**0.0000**	**2.67**
Cyanobacteria			
Trichodesmium erythraeum	131,394		95.99
	131,394	**0.0000**	**95.99**
Dinophyceae			
Ceratium furca	183		0.13
Ceratium sp. 040	183		0.13
Ceratium sp. 048	366		0.27
Dinophysis sp. 020	183		0.13
Prorocentrum sp. 005	183		0.13
Protoperidinium sp. 018	183		0.13

Species Name	Density	BioVolume	%
Protoperidinium sp. 046	183		0.13
Scrippsiella trochoidea	366		0.27
	1,830	**0.0000**	**1.34**

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

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Project
BAROSSA
COP-Barossa WQ Trip

Customer
Jacobs Group (Australia) Pty Ltd
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

DSID
26284

Report Date
26/03/2015

Batch Number
150123145338

Sample ID
SP6-S - PHYTO

Date Collected
19/01/2015

Monitoring Point
Timor Sea

Sample Type
Phytoplankton

Date Received
23/01/2015

Functional Location ID
Timor Sea

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
17/03/2015

Units Reported Cell Density:cells L^{-1} Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density
147,132.0 cells L^{-1}

Total Counted
804

Uncertainty
7.1%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Bacteriastrum hyalinum	549		0.37
Cerataulina pelagica	549		0.37
Chaetoceros spp.	3,843		2.61
Climacodium frauenfeldianum	732		0.50
Cylindrotheca closterium	366		0.25
Nitzschia longissima	549		0.37
Proboscia alata	366		0.25
Pseudo-nitzschia "delicatissima group"	2,196		1.49
Thalassiothrix sp. 001	3,843		2.61
	12,993	**0.0000**	**8.83**
Cyanobacteria			
Trichodesmium erythraeum	131,028		89.05
	131,028	**0.0000**	**89.05**
Dinophyceae			
Ceratium furca	549		0.37
Ceratium sp. 040	183		0.12
Dinoflagellate 036	549		0.37
Dinophysis sp. 020	183		0.12
Gyrodinium sp. 016	183		0.12

Species Name	Density	BioVolume	%
Prorocentrum sp. 005	183		0.12
Protoperidinium sp. 018	549		0.37
Scrippsiella trochoidea	732		0.50
	3,111	**0.0000**	**2.11**

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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Project
BAROSSA
COP-Barossa WQ Trip

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Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

DSID
26285

Report Date
26/03/2015

Batch Number
150123145338

Sample ID
SP7-S - PHYTO

Date Collected
18/01/2015

Monitoring Point
Timor Sea

Sample Type
Phytoplankton

Date Received
23/01/2015

Functional Location ID
Timor Sea

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
26/03/2015

Units Reported Cell Density:cells L^{-1} Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density
59,292.0 cells L^{-1}

Total Counted
324

Uncertainty
11.1%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Bacteriastrum hyalinum	183		0.31
Chaetoceros spp.	915		1.54
Leptocylindrus danicus	732		1.23
Pseudo-nitzschia "delicatissima group"	1,647		2.78
	3,477	**0.0000**	**5.86**
Cyanobacteria			
Trichodesmium erythraeum	55,083		92.90
	55,083	**0.0000**	**92.90**
Dinophyceae			
Dinoflagellate 036	366		0.62
Gymnodinium sp. 024	183		0.31
Scrippsiella trochoidea	183		0.31
	732	**0.0000**	**1.23**

End Of Report

Shading Key

Species Name	Density	BioVolume	%

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Potentially toxic species
Potentially harmful (non-toxic) species

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Project
BAROSSA
COP-Barossa WQ Trip

Customer
Jacobs Group (Australia) Pty Ltd
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID

DSID
26286

Report Date
26/03/2015

Batch Number
150123145338

Sample ID
SP8-S - PHYTO

Date Collected
18/01/2015

Monitoring Point
Timor Sea

Sample Type
Phytoplankton

Date Received
23/01/2015

Functional Location ID
Timor Sea

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
26/03/2015

Units Reported Cell Density:cells L^{-1} Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density
452,559.0 cells L^{-1}

Total Counted
2,473

Uncertainty
4.0%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Bacteriastrum hyalinum	2,379		0.53
Chaetoceros spp.	73,749		16.30
Climacodium sp. 002	183		0.04
Cylindrotheca closterium	183		0.04
Dactyliosolen phuketensis	183		0.04
Detonula sp. 001	1,281		0.28
Guinardia flaccida	549		0.12
Guinardia striata	366		0.08
Leptocylindrus danicus	366		0.08
Navicula transitrans var. derasa	183		0.04
Nitzschia longissima	1,098		0.24
Odontella sinensis	183		0.04
Proboscia alata	1,281		0.28
Pseudo-nitzschia "delicatissima group"	6,039		1.33
Pseudo-nitzschia "seriata group"	16,287		3.60
Rhizosolenia setigera	915		0.20
Rhizosolenia shrubsolei	183		0.04
Rhizosolenia striata	1,281		0.28
Skeletonema costatum	915		0.20
	107,604	**0.0000**	**23.78**

Species Name	Density	BioVolume	%
Cyanobacteria			
Trichodesmium erythraeum	344,589		76.14
	344,589	**0.0000**	**76.14**

Species Name	Density	BioVolume	%
Dinophyceae			
Ceratium fusus	183		0.04
Prorocentrum sp. 005	183		0.04
	366	**0.0000**	**0.08**

End Of Report

Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

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Project
BAROSSA
COP-Barossa WQ Trip

Customer
Jacobs Group (Australia) Pty Ltd
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

DSID
26287

Report Date
26/03/2015

Batch Number
150123145338

Sample ID
SP10-S - PHYTO

Date Collected
18/01/2015

Monitoring Point
Timor Sea

Sample Type
Phytoplankton

Date Received
23/01/2015

Functional Location ID
Timor Sea

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
18/03/2015

Units Reported Cell Density:cells L^{-1} Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density
78,324.0 cells L^{-1}

Total Counted
428

Uncertainty
9.7%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Chaetoceros spp.	549		0.70
Cylindrotheca closterium	183		0.23
Entomoneis tenuistriata	183		0.23
Navicula spp.	183		0.23
Thalassiothrix sp. 001	549		0.70
	1,647	**0.0000**	**2.10**
Cyanobacteria			
Trichodesmium erythraeum	75,579		96.50
	75,579	**0.0000**	**96.50**
Dinophyceae			
Ceratium sp. 039	183		0.23
Heterocapsa sp. 001	183		0.23
Katodinium rotundatum	183		0.23
Protoperidinium grande	366		0.47
Protoperidinium sp. 018	183		0.23
	1,098	**0.0000**	**1.40**

Species Name	Density	BioVolume	%

End Of Report

Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

Project	Customer	Analyst ID	DSID
BARОSSA COP-Barossa WQ Trip	Jacobs Group (Australia) Pty Ltd Level 7, Durack Centre 263 Adelaide Terrace Perth, WA 6000	stuart **Report Date** 26/03/2015	26288

Batch Number
150123145338

Sample ID
SP11-S - PHYTO

Date Collected
18/01/2015

Monitoring Point
Timor Sea

Sample Type
Phytoplankton

Date Received
23/01/2015

Functional Location ID
Timor Sea

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
18/03/2015

Units Reported Cell Density:cells L^{-1} Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density
180,987.0 cells L^{-1}

Total Counted
989

Uncertainty
6.4%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Amphora sp. 008	183		0.10
Amphora sp. 074	183		0.10
Bacteriastrum hyalinum	2,013		1.11
Cerataulina pelagica	549		0.30
Chaetoceros spp.	2,379		1.31
Climacodium frauenfeldianum	549		0.30
Coscinodiscus spp.	366		0.20
Cylindrotheca closterium	183		0.10
Detonula sp. 001	549		0.30
Eucampia sp. 006	549		0.30
Guinardia striata	366		0.20
Hemiaulus sinensis	549		0.30
Leptocylindrus danicus	1,098		0.61
Nitzschia longissima	1,647		0.91
Odontella sinensis	183		0.10
Paralia sulcata	183		0.10
Planktoniella sol	366		0.20
Proboscia alata	183		0.10
Pseudo-nitzschia "delicatissima group"	3,843		2.12
Pseudo-nitzschia "seriata group"	4,209		2.33
Rhizosolenia setigera	183		0.10

Species Name	Density	BioVolume	%
Rhizosolenia shrubsolei	366		0.20
Rhizosolenia striata	915		0.51
Skeletonema costatum	549		0.30
Thalassionema frauenfeldii	3,477		1.92
Thalassionema nitzschioides	1,464		0.81
Thalassiothrix sp. 001	549		0.30
	27,633	**0.0000**	**15.27**
Cyanobacteria			
Trichodesmium erythraeum	148,413		82.00
	148,413	**0.0000**	**82.00**
Dinophyceae			
Ceratium buceros	183		0.10
Ceratium furca	915		0.51
Ceratium lineatum	183		0.10
Ceratium sp. 031	183		0.10
Ceratium sp. 033	183		0.10
Ceratium sp. 048	183		0.10
Ornithocercus sp. 003	183		0.10
Prorocentrum micans	183		0.10
Protoperidinium crassipes	366		0.20
Protoperidinium grande	1,281		0.71
Protoperidinium roseum	183		0.10
Protoperidinium sp. 018	366		0.20
Protoperidinium steinii	366		0.20
Pyrophacus sp. 001	183		0.10
	4,941	**0.0000**	**2.73**

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

Project	Customer	Analyst ID	DSID
BARROSSA COP-Barossa WQ Trip	Jacobs Group (Australia) Pty Ltd Level 7, Durack Centre 263 Adelaide Terrace Perth, WA 6000	stuart **Report Date** 26/03/2015	26289

Batch Number 150123145338
Sample ID SP13-S - PHYTO
Date Collected 19/01/2015

Monitoring Point Timor Sea
Sample Type Phytoplankton
Date Received 23/01/2015

Functional Location ID Timor Sea
Method (Detection Limit) Utermohl Tube (New) (183)
Analysis Date 18/03/2015

Units Reported Cell Density:cells L^{-1} Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density 61,488.0 cells L^{-1}
Total Counted 336
Uncertainty 10.9%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Adoneis sp. 001	183		0.30
Chaetoceros spp.	1,281		2.08
Climacodium frauenfeldianum	366		0.60
Cylindrotheca closterium	366		0.60
Navicula transitrans var. derasa	183		0.30
Nitzschia longissima	366		0.60
	2,745	**0.0000**	**4.46**
Cyanobacteria			
Trichodesmium erythraeum	58,194		94.64
	58,194	**0.0000**	**94.64**
Dinophyceae			
Ceratium sp. 036	183		0.30
Ornithocercus sp. 002	183		0.30
Phalacroma rotundatum	183		0.30
	549	**0.0000**	**0.89**

End Of Report

Species Name	Density	BioVolume	%

Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

Project	Customer	Analyst ID	DSID
BAROSSA COP-Barossa WQ Trip	Jacobs Group (Australia) Pty Ltd Level 7, Durack Centre 263 Adelaide Terrace Perth, WA 6000	stuart **Report Date** 26/03/2015	26290

Batch Number 150123145338	**Sample ID** SP14-S - PHYTO	**Date Collected** 19/01/2015
Monitoring Point Timor Sea	**Sample Type** Phytoplankton	**Date Received** 23/01/2015
Functional Location ID Timor Sea	**Method (Detection Limit)** Utermohl Tube (New) (183)	**Analysis Date** 17/03/2015

Units Reported Cell Density:cells L^{-1} Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density	Total Counted	Uncertainty
178,608.0 cells L^{-1}	976	6.4%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Bacteriastrum hyalinum	183		0.10
Cerataulina pelagica	549		0.31
Chaetoceros spp.	1,281		0.72
Guinardia striata	366		0.20
Leptocylindrus danicus	1,098		0.61
Proboscia alata	183		0.10
Pseudo-nitzschia "delicatissima group"	1,464		0.82
Rhizosolenia setigera	366		0.20
Rhizosolenia sp. 024	183		0.10
Skeletonema costatum	549		0.31
Thalassiothrix sp. 001	915		0.51
	7,137	**0.0000**	**4.00**
Cryptophyceae			
Cryptophyte 004	366		0.20
	366	**0.0000**	**0.20**
Cyanobacteria			
Trichodesmium erythraeum	168,909		94.57
	168,909	**0.0000**	**94.57**

Species Name	Density	BioVolume	%
Dinophyceae			
Dinoflagellate 036	549		0.31
Gymnodinium sp. 029	183		0.10
Heterocapsa sp. 001	183		0.10
Karenia papilionaceae	366		0.20
Prorocentrum micans	183		0.10
Protoperidinium roseum	183		0.10
Scrippsiella trochoidea	549		0.31
	2,196	**0.0000**	**1.23**

End Of Report

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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Project
BAROSSA
COP-Barossa WQ Trip

Customer
Jacobs Group (Australia) Pty Ltd
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

DSID
26291

Report Date
26/03/2015

Batch Number
150123145338

Sample ID
SP16-S - PHYTO

Date Collected
20/01/2015

Monitoring Point
Timor Sea

Sample Type
Phytoplankton

Date Received
23/01/2015

Functional Location ID
Timor Sea

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
17/03/2015

Units Reported Cell Density:cells L^{-1} Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density
161,589.0 cells L^{-1}

Total Counted
883

Uncertainty
6.7%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Bacteriastrum hyalinum	183		0.11
Cerataulina pelagica	549		0.34
Chaetoceros spp.	2,013		1.25
Guinardia striata	366		0.23
Leptocylindrus danicus	1,281		0.79
Pseudo-nitzschia "delicatissima group"	2,196		1.36
Rhizosolenia setigera	549		0.34
Skeletonema costatum	549		0.34
Thalassiothrix sp. 001	2,013		1.25
	9,699	**0.0000**	**6.00**
Cryptophyceae			
Cryptophyte 004	183		0.11
	183	**0.0000**	**0.11**
Cyanobacteria			
Trichodesmium erythraeum	149,145		92.30
	149,145	**0.0000**	**92.30**
Dinophyceae			
Dinoflagellate 036	915		0.57

Species Name	Density	BioVolume	%
Heterocapsa sp. 001	366		0.23
Karenia papilionaceae	549		0.34
Prorocentrum micans	183		0.11
Scrippsiella trochoidea	549		0.34
	2,562	**0.0000**	**1.59**

End Of Report

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

Project
BAROSSA
COP-Barossa WQ Trip

Customer
Jacobs Group (Australia) Pty Ltd
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

DSID
26292

Report Date
26/03/2015

Batch Number
150123145338

Sample ID
SP17-S - PHYTO

Date Collected
20/01/2015

Monitoring Point
Timor Sea

Sample Type
Phytoplankton

Date Received
23/01/2015

Functional Location ID
Timor Sea

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
26/03/2015

Units Reported Cell Density:cells L^{-1} Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density
8,967.0 cells L^{-1}

Total Counted
49

Uncertainty
28.6%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Chaetoceros spp.	549		6.12
Nitzschia longissima	183		2.04
Nitzschia spp.	732		8.16
Proboscia alata	183		2.04
	1,647	**0.0000**	**18.37**
Cyanobacteria			
Trichodesmium erythraeum	6,405		71.43
	6,405	**0.0000**	**71.43**
Dinophyceae			
Dinoflagellate 036	366		4.08
Gymnodinium sp. 009	183		2.04
Gymnodinium sp. 015	366		4.08
	915	**0.0000**	**10.20**

End Of Report

Shading Key

Species Name	Density	BioVolume	%

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Potentially toxic species
Potentially harmful (non-toxic) species

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A// 3 Yeeda Way
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DATA REPORT

Project
BAROSSA
COP-Barossa WQ Trip

Customer
Jacobs Group (Australia) Pty Ltd
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

Report Date
29/03/2015

DSID
26293

Batch Number
150123150348

Sample ID
SP1-S - ZOOP

Date Collected
20/01/2015

Monitoring Point
Timor Sea

Sample Type
Zooplankton

Date Received
23/01/2015

Functional Location ID
Timor Sea

Method (Detection Limit)
Raw Count (1)

Analysis Date
26/03/2015

Units Reported: Cell Density:Individuals^{-1} Biovolume: mm^{3} L^{-1} %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Sample analysed diluted 10x
Number of chambers (1 ml) counted = 1
Total volume of sample = 60 ml

Field Data Recording

Total Density
375.0 Individuals^{-1}

Total Counted
375

Uncertainty
10.3%

Species Name	Density	BioVolume	%
Branchiopoda			
Podonidae	2		0.53
Polyphemidae	1		0.27
	3	**0.0000**	**0.80**
Cladocera			
Penilia avirostris	1		0.27
	1	**0.0000**	**0.27**
Copepoda			
Acartiidae	3		0.80
Calanidae	55		14.67
Candacidae	3		0.80
Copepod Nauplius	27		7.20
Corycaeidae	5		1.33
Macrosetella sp. 001	2		0.53
Microsetella	2		0.53
Oncaeidae	7		1.87
Paracalanidae	3		0.80
Pontellidae nauplius	11		2.93
Sulcanidae	2		0.53
	120	**0.0000**	**32.00**

Species Name	Density	BioVolume	%
Foraminifera			
Foraminiferida	4		1.07
	4	**0.0000**	**1.07**
Polycystinea			
Theoperidae	1		0.27
	1	**0.0000**	**0.27**
Sagittoidea			
Chaetognath	11		2.93
	11	**0.0000**	**2.93**
Trizonidae			
Trizonidae	233		62.13
	233	**0.0000**	**62.13**
Unknown			
Protozoa 047	2		0.53
	2	**0.0000**	**0.53**

End Of Report

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

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Project
BAROSSA
COP-Barossa WQ Trip

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Jacobs Group (Australia) Pty Ltd
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263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

Report Date
29/03/2015

DSID
26294

Batch Number
150123150348

Sample ID
SP3-S - ZOOP

Date Collected
19/01/2015

Monitoring Point
Timor Sea

Sample Type
Zooplankton

Date Received
23/01/2015

Functional Location ID
Timor Sea

Method (Detection Limit)
Raw Count (1)

Analysis Date
28/03/2015

Units Reported: Cell Density:Individuals^{-1} Biovolume: mm ^{3} L^{-1} %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Sample analysed diluted 10x
Number of chambers (1 ml) counted = 1
Total volume of sample = 61 ml

Field Data Recording

Total Density
145.0 Individuals^{-1}

Total Counted
145

Uncertainty
16.6%

Species Name	Density	BioVolume	%
Branchiopoda			
Polyphemidae	1		0.69
	1	**0.0000**	**0.69**
Copepoda			
Calanidae	17		11.72
Copepod Nauplius	17		11.72
Corycaeidae	7		4.83
Oncaeidae	1		0.69
Paracalanidae	5		3.45
Pontellidae nauplius	1		0.69
Sulcanidae	4		2.76
	52	**0.0000**	**35.86**
Polychaeta			
Polychaete larva	1		0.69
	1	**0.0000**	**0.69**
Sagittoidea			
Chaetognath	8		5.52
	8	**0.0000**	**5.52**

Species Name	Density	BioVolume	%
Trizonidae			
Trizonidae	82		56.55
	82	**0.0000**	**56.55**
Unknown			
Protozoa 047	1		0.69
	1	**0.0000**	**0.69**

End Of Report

Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

Project
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COP-Barossa WQ Trip

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263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

Report Date
29/03/2015

DSID
26295

Batch Number
150123150348

Sample ID
SP5-S - ZOOP

Date Collected
19/01/2015

Monitoring Point
Timor Sea

Sample Type
Zooplankton

Date Received
23/01/2015

Functional Location ID
Timor Sea

Method (Detection Limit)
Raw Count (1)

Analysis Date
28/03/2015

Units Reported: Cell Density: $Individuals^{-1}$ Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Sample analysed diluted 10x
Number of chambers (1 ml) counted = 1
Total volume of sample = 67 ml

Field Data Recording

Total Density
102.0 $Individuals^{-1}$

Total Counted
102

Uncertainty
19.8%

Species Name	Density	BioVolume	%
Copepoda			
Acartiidae	9		8.82
Calanidae	59		57.84
Candacidae	1		0.98
Copepod Nauplius	6		5.88
Corycaeidae	4		3.92
Macrosetella sp. 001	3		2.94
Microsetella	11		10.78
Oncaeidae	1		0.98
Paracalanidae	3		2.94
Sulcanidae	1		0.98
	98	**0.0000**	**96.08**
Sagittoidea			
Chaetognath	4		3.92
	4	**0.0000**	**3.92**

End Of Report

Shading Key

Species Name	Density	BioVolume	%

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Potentially toxic species

Potentially harmful (non-toxic) species

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DATA REPORT

Project
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COP-Barossa WQ Trip

Customer
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263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

DSID
26296

Report Date
29/03/2015

Batch Number
150123150348

Sample ID
SP6-S - ZOOP

Date Collected
19/01/2015

Monitoring Point
Timor Sea

Sample Type
Zooplankton

Date Received
23/01/2015

Functional Location ID
Timor Sea

Method (Detection Limit)
Raw Count (1)

Analysis Date
28/03/2015

Units Reported Cell Density:Individuals^{-1} Biovolume: mm ^{3} L $^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Sample analysed diluted 10x
Number of chambers (1 ml) counted = 3
Total volume of sample = 121 ml

Field Data Recording

Total Density
61.0 Individuals^{-1}

Total Counted
61

Uncertainty
25.6%

Species Name	Density	BioVolume	%
Branchiopoda			
Polyphemidae	2		3.28
	2	**0.0000**	**3.28**
Copepoda			
Acartiidae	1		1.64
Calanidae	15		24.59
Copepod Nauplius	21		34.43
Corycaeidae	10		16.39
Microsetella	4		6.56
Oncaeidae	3		4.92
	54	**0.0000**	**88.52**
Polycystinea			
Theoperidae	5		8.20
	5	**0.0000**	**8.20**

End Of Report

Shading Key

Species Name	Density	BioVolume	%

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Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

Project
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COP-Barossa WQ Trip

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Perth, WA 6000

Analyst ID
stuart

DSID
26297

Report Date
29/03/2015

Batch Number
150123150348

Sample ID
SP7-S - ZOOP

Date Collected
18/01/2015

Monitoring Point
Timor Sea

Sample Type
Zooplankton

Date Received
23/01/2015

Functional Location ID
Timor Sea

Method (Detection Limit)
Raw Count (1)

Analysis Date
28/03/2015

Units Reported: Cell Density:Individuals^{-1} Biovolume: mm^{3} L^{-1} %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Sample analysed diluted 10x
Number of chambers (1 ml) counted = 1
Total volume of sample = 90 ml

Field Data Recording

Total Density
115.0 Individuals^{-1}

Total Counted
115

Uncertainty
18.7%

Species Name	Density	BioVolume	%
Copepoda			
Acartiidae	1		0.87
Calanidae	3		2.61
Copepod Nauplius	6		5.22
Corycaeidae	2		1.74
Microsetella	1		0.87
Oncaeidae	2		1.74
Pontellidae nauplius	1		0.87
Sulcanidae	3		2.61
	19	**0.0000**	**16.52**
Foraminifera			
Foraminiferida	1		0.87
	1	**0.0000**	**0.87**
Gastropoda			
Cavolinidae	3		2.61
	3	**0.0000**	**2.61**
Gigartacontidae			
Gigartacontidae	2		1.74
	2	**0.0000**	**1.74**

Species Name	Density	BioVolume	%
Ophiuroidea			
Echinoderm Ophiopluteus Larva	2		1.74
	2	**0.0000**	**1.74**
Polycystinea			
Theoperidae	2		1.74
	2	**0.0000**	**1.74**
Sagittoidea			
Chaetognath	2		1.74
	2	**0.0000**	**1.74**
Trizonidae			
Trizonidae	82		71.30
	82	**0.0000**	**71.30**
Unknown			
Protozoa 047	2		1.74
	2	**0.0000**	**1.74**

End Of Report

Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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Project
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Analyst ID
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DSID
26298

Report Date
29/03/2015

Batch Number
150123150348

Sample ID
SP8-S - ZOOP

Date Collected
18/01/2015

Monitoring Point
Timor Sea

Sample Type
Zooplankton

Date Received
23/01/2015

Functional Location ID
Timor Sea

Method (Detection Limit)
Raw Count (1)

Analysis Date
26/03/2015

Units Reported: Cell Density:Individuals^{-1} Biovolume: mm ^{3} L $^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Sample analysed diluted 10x
Number of chambers (1 ml) counted = 1
Total volume of sample = 125 ml

Field Data Recording

Total Density
188.0 Individuals^{-1}

Total Counted
188

Uncertainty
14.6%

Species Name	Density	BioVolume	%
Copepoda			
Calanidae	2		1.06
Copepod Nauplius	5		2.66
Macrosetella sp. 001	2		1.06
Microsetella	1		0.53
Oncaeidae	5		2.66
	15	**0.0000**	**7.98**
Gigartacontidae			
Gigartacontidae	9		4.79
	9	**0.0000**	**4.79**
Ophiuroidea			
Echinoderm Ophiopluteus Larva	1		0.53
	1	**0.0000**	**0.53**
Polychaeta			
Polychaete larva	5		2.66
	5	**0.0000**	**2.66**
Polycystinea			
Theoperidae	3		1.60

Species Name	Density	BioVolume	%
	3	**0.0000**	**1.60**
Sagittoidea			
Chaetognath	12		6.38
	12	**0.0000**	**6.38**
Trizonidae			
Trizonidae	142		75.53
	142	**0.0000**	**75.53**
Unknown			
Protozoa 047	1		0.53
	1	**0.0000**	**0.53**

End Of Report

Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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Project
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COP-Barossa WQ Trip

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Jacobs Group (Australia) Pty Ltd
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263 Adelaide Terrace
Perth, WA 6000

Analyst ID

DSID
26299

Report Date
29/03/2015

Batch Number
150123150348

Sample ID
SP10-S - ZOOP

Date Collected
18/01/2015

Monitoring Point
Timor Sea

Sample Type
Zooplankton

Date Received
23/01/2015

Functional Location ID
Timor Sea

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
29/03/2015

Units Reported: Cell Density:Individuals^{-1} Biovolume: mm^{3} L^{-1} %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Sample analysed diluted 10x
Number of chambers (1 ml) counted = 1
Total volume of sample = 55 ml

Field Data Recording

Total Density
48,129.0 Individuals^{-1}

Total Counted
263

Uncertainty
12.3%

Species Name	Density	BioVolume	%
Copepoda			
Acartiidae	549		1.14
Calanidae	4,575		9.51
Copepod Nauplius	3,660		7.60
Corycaeidae	2,013		4.18
Oncaeidae	915		1.90
Pontellidae nauplius	366		0.76
Sulcanidae	1,281		2.66
	13,359	**0.0000**	**27.76**
Ophiuroidea			
Echinoderm Ophiopluteus Larva	549		1.14
	549	**0.0000**	**1.14**
Polychaeta			
Polychaete larva	366		0.76
	366	**0.0000**	**0.76**
Polycystinea			
Theoperidae	32,208		66.92
	32,208	**0.0000**	**66.92**

Species Name	Density	BioVolume	%
Sagittoidea			
Chaetognath	1,647		3.42
	1,647	**0.0000**	**3.42**

End Of Report

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

Project
BAROSSA
COP-Barossa WQ Trip

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Perth, WA 6000

Analyst ID
stuart

DSID
26300

Report Date
29/03/2015

Batch Number
150123150348

Sample ID
SP11-S - ZOOP

Date Collected
18/01/2015

Monitoring Point
Timor Sea

Sample Type
Zooplankton

Date Received
23/01/2015

Functional Location ID
Timor Sea

Method (Detection Limit)
Raw Count (1)

Analysis Date
26/03/2015

Units Reported Cell Density: Individuals^{-1} Biovolume: mm^{3} L^{-1} %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Sample analysed diluted 10x
Number of chambers (1 ml) counted = 1
Total volume of sample = 400 ml

Field Data Recording

Total Density
78.0 Individuals^{-1}

Total Counted
78

Uncertainty
22.6%

Species Name	Density	BioVolume	%
Copepoda			
Acartiidae	1		1.28
Calanidae	1		1.28
Copepod Nauplius	37		47.44
Sulcanidae	1		1.28
	40	**0.0000**	**51.28**
Foraminifera			
Foraminiferida	3		3.85
	3	**0.0000**	**3.85**
Gastropoda			
Cavolinidae	1		1.28
	1	**0.0000**	**1.28**
Gigartacontidae			
Gigartacontidae	1		1.28
	1	**0.0000**	**1.28**
Sagittoidea			
Chaetognath	2		2.56
	2	**0.0000**	**2.56**

Species Name	Density	BioVolume	%
Spirotrichea			
Tintinnid	3		3.85
	3	**0.0000**	**3.85**
Trizonidae			
Trizonidae	27		34.62
	27	**0.0000**	**34.62**
Unknown			
Protozoa 047	1		1.28
	1	**0.0000**	**1.28**

End Of Report

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

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Project
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Analyst ID
stuart

DSID
26301

Report Date
29/03/2015

Batch Number
150123150348

Sample ID
SP13-S - ZOOP

Date Collected
19/01/2015

Monitoring Point
Timor Sea

Sample Type
Zooplankton

Date Received
23/01/2015

Functional Location ID
Timor Sea

Method (Detection Limit)
Raw Count (1)

Analysis Date
29/03/2015

Units Reported: Cell Density:Individuals^{-1} Biovolume: mm ^{3} L $^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Sample analysed diluted 10x
Number of chambers (1 ml) counted = 1
Total volume of sample = 80 ml

Field Data Recording

Total Density
549.0 Individuals^{-1}

Total Counted
549

Uncertainty
8.5%

Species Name	Density	BioVolume	%
Copepoda			
Acartiidae	62		11.29
Calanidae	14		2.55
Candacidae	1		0.18
Copepod Nauplius	29		5.28
Corycaeidae	5		0.91
Macrosetella sp. 001	1		0.18
Microsetella	4		0.73
Oncaeidae	3		0.55
Sulcanidae	5		0.91
	124	**0.0000**	**22.59**
Gastropoda			
Cavoliniidae	2		0.36
	2	**0.0000**	**0.36**
Malacostraca			
Anomuran zoea larva	1		0.18
	1	**0.0000**	**0.18**
Maxillopoda			
Cirripede nauplius	1		0.18

Species Name	Density	BioVolume	%
	1	**0.0000**	**0.18**
Ophiuroidea			
Echinoderm Ophiopluteus Larva	2		0.36
	2	**0.0000**	**0.36**
Sagittoidea			
Chaetognath	7		1.28
	7	**0.0000**	**1.28**
Trizonidae			
Trizonidae	411		74.86
	411	**0.0000**	**74.86**
Unknown			
Protozoa 047	1		0.18
	1	**0.0000**	**0.18**

End Of Report

Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

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Project
BAROSSA
COP-Barossa WQ Trip

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Analyst ID
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DSID
26302

Report Date
29/03/2015

Batch Number
150123150348

Sample ID
SP14-S - ZOOP

Date Collected
19/01/2015

Monitoring Point
Timor Sea

Sample Type
Zooplankton

Date Received
23/01/2015

Functional Location ID
Timor Sea

Method (Detection Limit)
Raw Count (1)

Analysis Date
29/03/2015

Units Reported: Cell Density:Individuals^{-1} Biovolume: mm ^{3} L^{-1} %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Sample analysed diluted 10x
Number of chambers (1 ml) counted = 1
Total volume of sample = 90 ml

Field Data Recording

Total Density
383.0 Individuals^{-1}

Total Counted
383

Uncertainty
10.2%

Species Name	Density	BioVolume	%
Copepoda			
Acartiidae	18		4.70
Calanidae	3		0.78
Copepod Nauplius	38		9.92
Corycaeidae	4		1.04
Macrosetella sp. 001	3		0.78
Microsetella	2		0.52
Oncaeidae	2		0.52
Sulcanidae	1		0.26
	71	**0.0000**	**18.54**
Gastropoda			
Cavoliniidae	2		0.52
	2	**0.0000**	**0.52**
Sagittoidea			
Chaetognath	22		5.74
	22	**0.0000**	**5.74**
Trizonidae			
Trizonidae	288		75.20
	288	**0.0000**	**75.20**

Species Name	Density	BioVolume	%

End Of Report

This report contains coloured shading. Dalcon Environmental intends that this report be viewed and/or printed in colour.

Dalcon Environmental Pty Ltd makes no claim that the taxa list provided herein is exhaustive. Some taxa, including potentially problematic taxa, may be present in the sample but not recorded during analysis, this is particularly the case for small or inconspicuous taxa or taxa present in low numbers. Guidance presented herein is based on published research , whilst Dalcon Environmental make every attempt to remain up to date, it is possible that scientific consensus may differ from that presented herein.

Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

dalcon environmental

www.dalconenvironmental.com.au

DATA REPORT

A// 3 Yeeda Way
Malaga, WA 6090

P// (08) 9271 6776

F// (08) 9248 9120

Project
BAROSSA
COP-Barossa WQ Trip

Customer
Jacobs Group (Australia) Pty Ltd
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

Report Date
29/03/2015

DSID
26303

Batch Number
150123150348

Sample ID
SP17-S - ZOOP

Date Collected
20/01/2015

Monitoring Point
Timor Sea

Sample Type
Zooplankton

Date Received
23/01/2015

Functional Location ID
Timor Sea

Method (Detection Limit)
Raw Count (1)

Analysis Date
28/03/2015

Units Reported: Cell Density:Individuals^{-1} Biovolume: mm ^{3} L^{-1} %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Sample analysed diluted 10x
Number of chambers (1 ml) counted = 1
Total volume of sample = 68 ml

Field Data Recording

Total Density
69.0 Individuals^{-1}

Total Counted
69

Uncertainty
24.1%

Species Name	Density	BioVolume	%
Branchiopoda			
Polyphemidae	1		1.45
	1	**0.0000**	**1.45**
Copepoda			
Acartiidae	1		1.45
Calanidae	4		5.80
Copepod Nauplius	28		40.58
Corycaeidae	1		1.45
Macrosetella sp. 001	1		1.45
Microsetella	1		1.45
Oncaeidae	1		1.45
Pontellidae nauplius	1		1.45
	38	**0.0000**	**55.07**
Foraminifera			
Foraminiferida	2		2.90
	2	**0.0000**	**2.90**
Sagittoidea			
Chaetognath	5		7.25
	5	**0.0000**	**7.25**

Species Name	Density	BioVolume	%
Trizonidae			
Trizonidae	23		33.33
	23	**0.0000**	**33.33**

End Of Report

Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

This report contains coloured shading. Dalcon Environmental intends that this report be viewed and/or printed in colour.

Dalcon Environmental Pty Ltd makes no claim that the taxa list provided herein is exhaustive. Some taxa, including potentially problematic taxa, may be present in the sample but not recorded during analysis, this is particularly the case for small or inconspicuous taxa or taxa present in low numbers. Guidance presented herein is based on published research , whilst Dalcon Environmental make every attempt to remain up to date, it is possible that scientific consensus may differ from that presented herein.

Appendix C1. Autumn

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EP1502864**	Page	: 1 of 14
Client	: **JACOBS GROUP (AUSTRALIA) PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: MR CHRIS TEASDALE	Contact	: Scott James
Address	: P O BOX H615 PERTH WA, AUSTRALIA 6001	Address	: 10 Hod Way Malaga WA Australia 6090
E-mail	: cteasdale@globalskm.com	E-mail	: perth.enviro.services@alsglobal.com
Telephone	: +61 08 9469 4400	Telephone	: +61-8-9209 7655
Facsimile	: +61 08 9469 4488	Facsimile	: +61-8-9209 7600
Project	: COP Barossa Envt l Studies Trip 4 IW021200	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: IW021200.104		
C-O-C number	: ----	Date Samples Received	: 16-APR-2015
Sampler	: AC	Issue Date	: 24-APR-2015
Site	: ----		
		No. of samples received	: 54
Quote number	: EP/286/15	No. of samples analysed	: 54

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

NATA

WORLD RECOGNISED ACCREDITATION

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Rassem Ayoubi	Senior Organic Chemist	Perth Organics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	SP1-S	SP1-M	SP1-B	SP2-S	SP2-M
			Client sampling date / time	12-APR-2015 16:45	12-APR-2015 16:45	12-APR-2015 16:45	12-APR-2015 18:00	12-APR-2015 18:00
Compound	CAS Number	LOR	Unit	EP1502864-001	EP1502864-002	EP1502864-003	EP1502864-004	EP1502864-005
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**82.8**	**99.3**	**100**	**96.4**	**89.0**
Toluene-D8	2037-26-5	0.1	%	**109**	**102**	**104**	**104**	**106**
4-Bromofluorobenzene	460-00-4	0.1	%	**94.8**	**98.6**	**93.4**	**90.6**	**90.9**

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	SP2-B	SP3-S	SP3-M	SP3-B	SP4-S
			Client sampling date / time	12-APR-2015 18:00	13-APR-2015 10:10	13-APR-2015 10:10	13-APR-2015 10:10	13-APR-2015 08:58
				EP1502864-006	**EP1502864-007**	**EP1502864-008**	**EP1502864-009**	**EP1502864-010**
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ **Total Xylenes**	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**98.7**	**102**	**99.9**	**99.8**	**97.8**
Toluene-D8	2037-26-5	0.1	%	**103**	**101**	**104**	**102**	**104**
4-Bromofluorobenzene	460-00-4	0.1	%	**91.5**	**91.9**	**92.7**	**90.6**	**90.0**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	SP4-M	SP4-B	SP5-S	SP5-M	SP5-B
			Client sampling date / time	13-APR-2015 08:58	13-APR-2015 08:58	13-APR-2015 07:08	13-APR-2015 07:08	13-APR-2015 07:08
Compound	CAS Number	LOR	Unit	EP1502864-011	EP1502864-012	EP1502864-013	EP1502864-014	EP1502864-015
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**97.4**	**84.7**	**82.4**	**88.0**	**82.7**
Toluene-D8	2037-26-5	0.1	%	**104**	**110**	**110**	**107**	**110**
4-Bromofluorobenzene	460-00-4	0.1	%	**90.2**	**98.7**	**95.9**	**97.2**	**93.8**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)

Compound	CAS Number	LOR	Unit	SP6-S	SP6-M	SP6-B	SP7-S	SP7-B
			Client sampling date / time	13-APR-2015 13:38	13-APR-2015 13:38	13-APR-2015 13:38	13-APR-2015 17:55	13-APR-2015 17:55
				EP1502864-016	**EP1502864-017**	**EP1502864-018**	**EP1502864-019**	**EP1502864-020**
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ **Total Xylenes**	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**91.6**	**87.9**	**85.6**	**88.7**	**92.6**
Toluene-D8	2037-26-5	0.1	%	**106**	**108**	**109**	**107**	**107**
4-Bromofluorobenzene	460-00-4	0.1	%	**94.7**	**94.5**	**93.4**	**91.7**	**96.5**

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	SP8-S	SP8-M	SP8-B	SP9-S	SP9-M
Client sampling date / time				14-APR-2015 07:51	14-APR-2015 07:51	14-APR-2015 07:51	14-APR-2015 07:12	14-APR-2015 07:12
				EP1502864-021	**EP1502864-022**	**EP1502864-023**	**EP1502864-024**	**EP1502864-025**
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**87.5**	**87.0**	**90.2**	**88.0**	**83.6**
Toluene-D8	2037-26-5	0.1	%	**106**	**105**	**104**	**106**	**106**
4-Bromofluorobenzene	460-00-4	0.1	%	**97.5**	**93.6**	**93.8**	**93.3**	**90.4**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)

Compound	CAS Number	LOR	Unit	SP9-B	SP10-S	SP10-M	SP10-B	SP11-S
Client sampling date / time				14-APR-2015 07:12	13-APR-2015 16:45	13-APR-2015 16:45	13-APR-2015 16:45	14-APR-2015 10:10
				EP1502864-026	EP1502864-027	EP1502864-028	EP1502864-029	EP1502864-030
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**84.6**	**87.3**	**88.3**	**88.4**	**91.6**
Toluene-D8	2037-26-5	0.1	%	**107**	**104**	**106**	**105**	**104**
4-Bromofluorobenzene	460-00-4	0.1	%	**92.4**	**93.3**	**92.4**	**92.9**	**93.0**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	SP11-B	SP12-S	SP12-M	SP12-B	SP13-S
			Client sampling date / time	14-APR-2015 10:10	14-APR-2015 08:55	14-APR-2015 08:55	14-APR-2015 08:55	14-APR-2015 11:06
Compound	*CAS Number*	*LOR*	*Unit*	EP1502864-031	EP1502864-032	EP1502864-033	EP1502864-034	EP1502864-035
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**89.5**	**85.5**	**89.8**	**89.0**	**86.4**
Toluene-D8	2037-26-5	0.1	%	**106**	**106**	**105**	**108**	**105**
4-Bromofluorobenzene	460-00-4	0.1	%	**90.7**	**89.8**	**92.4**	**88.7**	**89.0**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	SP13-M	SP13-B	SP14-S	SP14-M	SP14-B
			Client sampling date / time	14-APR-2015 11:06	14-APR-2015 11:06	14-APR-2015 12:46	14-APR-2015 12:46	14-APR-2015 12:46
Compound	*CAS Number*	*LOR*	*Unit*	**EP1502864-036**	**EP1502864-037**	**EP1502864-038**	**EP1502864-039**	**EP1502864-040**
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ **Total Xylenes**	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**88.9**	**86.5**	**81.8**	**92.9**	**89.4**
Toluene-D8	2037-26-5	0.1	%	**105**	**107**	**108**	**103**	**106**
4-Bromofluorobenzene	460-00-4	0.1	%	**89.8**	**89.8**	**87.7**	**91.1**	**87.2**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	SP15-S	SP15-M	SP15-B	SP16-S	SP16-B
			Client sampling date / time	12-APR-2015 14:38	12-APR-2015 14:38	12-APR-2015 14:38	12-APR-2015 13:30	12-APR-2015 13:30
Compound	CAS Number	LOR	Unit	EP1502864-041	EP1502864-042	EP1502864-043	EP1502864-044	EP1502864-045
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**98.4**	**90.7**	**93.2**	**99.4**	**97.5**
Toluene-D8	2037-26-5	0.1	%	**98.9**	**103**	**101**	**99.4**	**101**
4-Bromofluorobenzene	460-00-4	0.1	%	**95.6**	**93.7**	**92.1**	**93.2**	**92.8**

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	SP17-S	SP17-M	SP17-B	FIELD BLANK	TRANS BLANK
			Client sampling date / time	12-APR-2015 11:10	12-APR-2015 11:10	12-APR-2015 11:10	14-APR-2015 13:30	14-APR-2015 13:30
				EP1502864-046	**EP1502864-047**	**EP1502864-048**	**EP1502864-049**	**EP1502864-050**
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ **Total Xylenes**	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**102**	**100**	**104**	**102**	**98.9**
Toluene-D8	2037-26-5	0.1	%	**97.6**	**98.7**	**97.1**	**97.1**	**98.9**
4-Bromofluorobenzene	460-00-4	0.1	%	**93.7**	**90.5**	**93.7**	**93.4**	**90.9**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	SP9-S LAB BLANK	SP8-M LAB BLANK	SP12-S LAB BLANK	SP11-S LAB BLANK	----
			Client sampling date / time	14-APR-2015 07:12	14-APR-2015 07:51	14-APR-2015 08:55	14-APR-2015 10:00	----
Compound	CAS Number	LOR	Unit	EP1502864-051	EP1502864-052	EP1502864-053	EP1502864-054	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	----
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	----
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	----
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	----
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	----
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	----
>C10 - C16 Fraction	>C10_C16	100	µg/L	<100	<100	<100	<100	----
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	----
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	----
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	----
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	----
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	----
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	----
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	----
^ **Total Xylenes**	1330-20-7	2	µg/L	<2	<2	<2	<2	----
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	----
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**90.3**	**90.3**	**103**	**103**	----
Toluene-D8	2037-26-5	0.1	%	**102**	**101**	**97.9**	**98.4**	----
4-Bromofluorobenzene	460-00-4	0.1	%	**85.8**	**86.8**	**90.4**	**90.2**	----

Surrogate Control Limits

Sub-Matrix: **WATER**

Compound	*CAS Number*	*Recovery Limits (%)* Low	High
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	60.5	141.2
Toluene-D8	2037-26-5	73.4	126
4-Bromofluorobenzene	460-00-4	59.6	125.3

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WORLD RECOGNISED ACCREDITATION
Accreditation Number: 10603
Accredited for compliance with ISO/IEC 17025.
The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

Murdoch UNIVERSITY

WATER QUALITY DATA

Contact: Celeste Wilson
Customer: Jacobs
Address: Level 11, Durack Centre, 263 Adelaide Terrace, Perth WA 6001

Date of Issue: 15/05/2015
Date Received: 16/04/2015
Our Reference: JAC15-6
Your Reference: IW021200.104

METHOD	Sampling	2000	4100	2100	4700	2700	3000	3000
SAMPLE CODE	Date	AMMONIA	ORTHO-P	NO3+NO2	TOTAL-P	TOTAL-N	CHLOROPHYLL'a'	PHAEOPHYTIN'a'
		µg.N/L	µg.P/L	µg.N/L	µg.P/L	µg.N/L	µg/L	µg/L
Reporting Limit		<3	<2	<2	<5	<50	<0.1	<0.2
File			15042201		15042301		15042301	
SP1-S	12/04/2015	<3	2	<2	11	90	<0.1	<0.2
SP1-M	12/04/2015	<3	33	200	40	280	<0.1	<0.2
SP1-B	12/04/2015	<3	60	360	65	450	<0.1	<0.2
SP2-S	12/04/2015	<3	2	<2	12	90	<0.1	<0.2
SP2-M	12/04/2015	<3	26	150	33	230	<0.1	<0.2
SP2-B	12/04/2015	<3	58	360	63	450	<0.1	<0.2
SP3-S	13/04/2015	<3	<2	<2	12	80	<0.1	<0.2
SP3-M	13/04/2015	<3	31	190	41	310	<0.1	<0.2
SP3-B	13/04/2015	<3	61	360	65	450	<0.1	<0.2
SP4-S	13/04/2015	<3	2	<2	12	80	<0.1	<0.2
SP4-M	13/04/2015	<3	27	140	34	220	<0.1	<0.2
SP4-B	13/04/2015	<3	54	320	58	410	<0.1	<0.2
SP5-S	13/04/2015	<3	2	<2	12	80	<0.1	<0.2
SP5-M	13/04/2015	<3	26	120	34	220	<0.1	<0.2
SP5-B	13/04/2015	<3	53	320	58	420	<0.1	<0.2
SP6-S	13/04/2015	<3	2	<2	12	100	<0.1	<0.2
SP6-M	13/04/2015	<3	33	200	39	290	<0.1	<0.2
SP6-B	13/04/2015	<3	59	350	64	440	<0.1	<0.2
SP7-S	13/04/2015	<3	2	<2	12	90	<0.1	<0.2
SP7-B	13/04/2015	<3	2	<2	12	80	0.2	<0.2

Signatory: Jamie Woodward
Date: 15/05/2015

All test items tested as received. Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory
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Accreditation Number: 10603
Accredited for compliance with ISO/IEC 17025.
The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

Murdoch University

WATER QUALITY DATA

Contact: Celeste Wilson
Customer: Jacobs
Address: Level 11, Durack Centre, 263 Adelaide Terrace, Perth WA 6001

Date of Issue: 15/05/2015
Date Received: 16/04/2015
Our Reference: JAC15-6
Your Reference: IW021200.104

METHOD SAMPLE CODE	Sampling Date	2000 AMMONIA µg.N/L	4100 ORTHO-P µg.P/L	2100 NO3+NO2 µg.N/L	4700 TOTAL-P µg.P/L	2700 TOTAL-N µg.N/L	3000 CHLOROPHYLL'a' µg/L	3000 PHAEOPHYTIN'a' µg/L
Reporting Limit		**<3**	**<2**	**<2**	**<5**	**<50**	**<0.1**	**<0.2**
File			**15042201**		**15042301**		**15042301**	
SP8-S	14/04/2015	<3	2	<2	12	90	0.3	<0.2
SP8-M	14/04/2015	<3	2	<2	12	100	<0.1	<0.2
SP8-B	14/04/2015	<3	3	2	12	80	0.2	<0.2
SP9-S	14/04/2015	<3	3	<2	12	80	0.2	<0.2
SP9-M	14/04/2015	<3	3	<2	12	80	0.2	<0.2
SP9-B	14/04/2015	<3	24	110	31	200	<0.1	<0.2
SP10-S	13/04/2015	<3	2	<2	12	100	<0.1	<0.2
SP10-M	13/04/2015	<3	15	64	24	160	0.3	<0.2
SP10-B	13/04/2015	<3	53	310	57	420	<0.1	<0.2
SP11-S	14/04/2015	<3	3	<2	13	80	<0.1	<0.2
SP11--B	14/04/2015	<3	3	4	13	90	0.1	<0.2
SP12-S	14/04/2015	<3	3	<2	12	80	<0.1	<0.2
SP12-M	14/04/2015	<3	2	<2	13	90	0.1	<0.2
SP12-B	14/04/2015	<3	17	74	28	180	0.2	<0.2
SP13-S	14/04/2015	<3	2	<2	13	80	<0.1	<0.2
SP13-M	14/04/2015	<3	3	<2	14	90	0.2	<0.2
SP13-B	14/04/2015	<3	24	110	32	210	0.1	<0.2
SP14-S	13/04/2015	<3	2	<2	13	90	<0.1	<0.2
SP14-M	13/04/2015	<3	3	<2	13	90	0.3	<0.2
SP14-B	13/04/2015	<3	26	120	33	220	0.1	<0.2

Signatory: Jamie Woodward
Date: 15/05/2015

All test items tested as received. Spare test items will be held for two months unless otherwise requested.

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Accreditation Number: 10603
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Murdoch UNIVERSITY

WATER QUALITY DATA

Contact: Celeste Wilson
Customer: Jacobs
Address: Level 11, Durack Centre, 263 Adelaide Terrace, Perth WA 6001

Date of Issue: 15/05/2015
Date Received: 16/04/2015
Our Reference: JAC15-6
Your Reference: IW021200.104

METHOD SAMPLE CODE	Sampling Date	2000 AMMONIA µg.N/L	4100 ORTHO-P µg.P/L	2100 NO3+NO2 µg.N/L	4700 TOTAL-P µg.P/L	2700 TOTAL-N µg.N/L	3000 CHLOROPHYLL'a' µg/L	3000 PHAEOPHYTIN'a' µg/L
Reporting Limit		**<3**	**<2**	**<2**	**<5**	**<50**	**<0.1**	**<0.2**
File			**15042201**			**15042301**		**15042301**
SP15-S	12/04/2015	4	3	<2	12	90	<0.1	<0.2
SP15-M	12/04/2015	<3	3	<2	14	120	0.2	<0.2
SP15-B	12/04/2015	8	22	110	36	250	<0.1	<0.2
SP16-S	12/04/2015	<3	2	<2	12	100	<0.1	<0.2
SP16-B	12/04/2015	<3	2	<2	12	90	<0.1	<0.2
SP17-S	12/04/2015	<3	2	<2	12	100	<0.1	<0.2
SP17-M	12/04/2015	<3	5	7	14	100	0.3	<0.2
SP17-B	12/04/2015	9	29	150	35	240	<0.1	<0.2
Field Blank	14/04/2015	<3	<2	<2	<5	<50	<0.1	<0.2
Trans Blank	14/04/2015	<3	<2	<2	<5	<50	<0.1	<0.2

Signatory: Jamie Woodward
Date: 15/05/2015

All test items tested as received. Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater
Research Laboratory
Environmental Science
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Accreditation Number: 10603
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Murdoch University

WATER QUALITY DATA

Contact: Celeste Wilson
Customer: Jacobs
Address: Level 11, Durack Centre, 263 Adelaide Terrace, Perth WA 6001

Date of Issue: 15/05/2015
Date Received: 16/04/2015
Our Reference: JAC15-6
Your Reference: IW021200.104

METHOD SAMPLE CODE	Sampling Date	MS001 Filtered Cr µg/L	MS001 Filtered Co µg/L	MS001 Filtered Ni µg/L	MS001 Filtered Cu µg/L	MS001 Filtered Zn µg/L	MS001 Filtered As µg/L	MS001 Filtered Cd µg/L	MS001 Filtered Ba µg/L	MS001 Filtered Pb µg/L	ICP006 Hg mg/L
Reporting Limit		**<0.2**	**<0.05**	**<0.3**	**<0.2**	**<1**	**<0.5**	**<0.1**	**<0.5**	**<0.1**	**<0.0001**
File											**15042203-04**
SP1-S	12/04/2015	<0.2	<0.05	<0.3	<0.2	1	1.6	<0.1	5.4	<0.1	<0.0001
SP1-M	12/04/2015	0.2	<0.05	0.3	<0.2	1	1.8	<0.1	6.3	<0.1	<0.0001
SP1-B	12/04/2015	0.2	<0.05	0.4	<0.2	<1	2.0	<0.1	7.9	<0.1	<0.0001
SP2-S	12/04/2015	<0.2	<0.05	<0.3	0.2	1	1.7	<0.1	5.6	<0.1	<0.0001
SP2-M	12/04/2015	<0.2	<0.05	<0.3	<0.2	1	1.9	<0.1	5.7	<0.1	<0.0001
SP2-B	12/04/2015	0.2	<0.05	0.4	<0.2	<1	1.9	<0.1	8.0	<0.1	<0.0001
SP3-S	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.7	<0.1	5.5	<0.1	<0.0001
SP3-M	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.9	<0.1	6.0	<0.1	<0.0001
SP3-B	13/04/2015	<0.2	<0.05	0.4	<0.2	<1	2.0	<0.1	8.1	<0.1	<0.0001
SP4-S	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.6	<0.1	<0.0001
SP4-M	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.7	<0.1	5.6	<0.1	<0.0001
SP4-B	13/04/2015	0.2	<0.05	0.3	<0.2	<1	1.8	<0.1	7.4	<0.1	<0.0001
SP5-S	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.6	<0.1	5.0	<0.1	<0.0001
SP5-M	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	6.0	<0.1	<0.0001
SP5-B	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.7	<0.1	6.4	<0.1	<0.0001
SP6-S	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.6	<0.1	5.1	<0.1	<0.0001
SP6-M	13/04/2015	<0.2	<0.05	<0.3	<0.2	1	1.8	<0.1	5.7	<0.1	<0.0001
SP6-B	13/04/2015	<0.2	<0.05	0.4	<0.2	<1	1.8	<0.1	7.5	<0.1	<0.0001
SP7-S	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.7	<0.1	5.1	<0.1	<0.0001
SP7-B	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.3	<0.1	5.5	<0.1	<0.0001

Signatory: Jamie Woodward
Date: 15/05/2015

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Marine and Freshwater Research Laboratory
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WATER QUALITY DATA

Contact: Celeste Wilson
Customer: Jacobs
Address: Level 11, Durack Centre, 263 Adelaide Terrace, Perth WA 6001

Date of Issue: 15/05/2015
Date Received: 16/04/2015
Our Reference: JAC15-6
Your Reference: IW021200.104

METHOD SAMPLE CODE	Sampling Date	MS001 Filtered Cr µg/L	MS001 Filtered Co µg/L	MS001 Filtered Ni µg/L	MS001 Filtered Cu µg/L	MS001 Filtered Zn µg/L	MS001 Filtered As µg/L	MS001 Filtered Cd µg/L	MS001 Filtered Ba µg/L	MS001 Filtered Pb µg/L	ICP006 Hg mg/L
Reporting Limit		**<0.2**	**<0.05**	**<0.3**	**<0.2**	**<1**	**<0.5**	**<0.1**	**<0.5**	**<0.1**	**<0.0001**
File											**15042203-04**
SP8-S	14/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.6	<0.1	5.2	<0.1	<0.0001
SP8-M	14/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.6	<0.1	5.3	<0.1	<0.0001
SP8-B	14/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.1	<0.1	<0.0001
SP9-S	14/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.3	<0.1	<0.0001
SP9-M	14/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.0	<0.1	<0.0001
SP9-B	14/04/2015	<0.2	<0.05	<0.3	<0.2	1	1.7	<0.1	5.7	<0.1	<0.0001
SP10-S	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.6	<0.1	5.5	<0.1	<0.0001
SP10-M	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.6	<0.1	<0.0001
SP10-B	13/04/2015	0.2	<0.05	0.4	<0.2	<1	1.9	<0.1	7.1	<0.1	<0.0001
SP11-S	14/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.5	<0.1	<0.0001
SP11--B	14/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.7	<0.1	5.2	<0.1	<0.0001
SP12-S	14/04/2015	<0.2	<0.05	<0.3	0.3	1	1.7	<0.1	5.2	<0.1	<0.0001
SP12-M	14/04/2015	<0.2	<0.05	<0.3	0.2	1	1.7	<0.1	5.1	<0.1	<0.0001
SP12-B	14/04/2015	<0.2	<0.05	<0.3	0.3	<1	1.8	<0.1	5.8	<0.1	<0.0001
SP13-S	14/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.7	<0.1	5.1	<0.1	<0.0001
SP13-M	14/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.7	<0.1	5.3	<0.1	<0.0001
SP13-B	14/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	6.1	<0.1	<0.0001
SP14-S	13/04/2015	<0.2	<0.05	<0.3	0.2	<1	1.7	<0.1	5.4	<0.1	<0.0001
SP14-M	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.7	<0.1	5.7	<0.1	<0.0001
SP14-B	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	2.0	<0.1	6.2	<0.1	<0.0001

Signatory: Jamie Woodward
Date: 15/05/2015

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Murdoch UNIVERSITY

WATER QUALITY DATA

Contact: Celeste Wilson
Customer: Jacobs
Address: Level 11, Durack Centre, 263 Adelaide Terrace, Perth WA 6001

Date of Issue: 15/05/2015
Date Received: 16/04/2015
Our Reference: JAC15-6
Your Reference: IW021200.104

METHOD SAMPLE CODE	Sampling Date	MS001 Filtered Cr µg/L	MS001 Filtered Co µg/L	MS001 Filtered Ni µg/L	MS001 Filtered Cu µg/L	MS001 Filtered Zn µg/L	MS001 Filtered As µg/L	MS001 Filtered Cd µg/L	MS001 Filtered Ba µg/L	MS001 Filtered Pb µg/L	ICP006 Hg mg/L
Reporting Limit		**<0.2**	**<0.05**	**<0.3**	**<0.2**	**<1**	**<0.5**	**<0.1**	**<0.5**	**<0.1**	**<0.0001**
File											**15042203-04**
SP15-S	12/04/2015	<0.2	<0.05	<0.3	<0.2	2	1.8	<0.1	5.5	<0.1	<0.0001
SP15-M	12/04/2015	<0.2	<0.05	<0.3	<0.2	1	1.8	<0.1	5.7	<0.1	<0.0001
SP15-B	12/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.9	<0.1	6.3	<0.1	<0.0001
SP16-S	12/04/2015	<0.2	<0.05	<0.3	<0.2	1	1.7	<0.1	5.4	<0.1	<0.0001
SP16-B	12/04/2015	<0.2	<0.05	<0.3	<0.2	1	1.7	<0.1	5.3	<0.1	<0.0001
SP17-S	12/04/2015	<0.2	<0.05	<0.3	<0.2	4	1.7	<0.1	5.6	<0.1	<0.0001
SP17-M	12/04/2015	<0.2	<0.05	<0.3	<0.2	1	1.7	<0.1	5.6	<0.1	<0.0001
SP17-B	12/04/2015	<0.2	<0.05	<0.3	<0.2	2	1.9	<0.1	6.3	<0.1	<0.0001
Field Blank	14/04/2015	<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.5	<0.1	<0.0001
Trans Blank	14/04/2015	<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.5	<0.1	<0.0001

Signatory: Jamie Woodward
Date: 15/05/2015

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Date of Issue: 15/05/2015
Date Received: 16/04/2015
Our Reference: JAC15-6
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METHOD SAMPLE CODE	Sampling Date	MS001 Unfiltered Cr µg/L	MS001 Unfiltered Co µg/L	MS001 Unfiltered Ni µg/L	MS001 Unfiltered Cu µg/L	MS001 Unfiltered Zn µg/L	MS001 Unfiltered As µg/L	MS001 Unfiltered Cd µg/L	MS001 Unfiltered Ba µg/L	MS001 Unfiltered Pb µg/L	ICP006 Total Ext Hg mg/L
Reporting Limit		<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.5	<0.1	<0.0001
File											15042201-03
SP1-S	12/04/2015	<0.2	<0.05	<0.3	<0.2	1	1.9	<0.1	5.9	<0.1	<0.0001
SP1-M	12/04/2015	0.2	<0.05	0.3	0.2	2	1.9	<0.1	6.1	<0.1	<0.0001
SP1-B	12/04/2015	0.3	<0.05	0.4	<0.2	1	2.1	<0.1	8.0	<0.1	<0.0001
SP2-S	12/04/2015	<0.2	<0.05	<0.3	<0.2	1	1.8	<0.1	5.5	<0.1	<0.0001
SP2-M	12/04/2015	<0.2	<0.05	<0.3	<0.2	1	1.8	<0.1	5.8	<0.1	<0.0001
SP2-B	12/04/2015	0.2	<0.05	0.3	0.3	2	2.0	<0.1	8.1	<0.1	<0.0001
SP3-S	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.5	<0.1	<0.0001
SP3-M	13/04/2015	0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.9	<0.1	<0.0001
SP3-B	13/04/2015	0.2	<0.05	0.5	<0.2	<1	2.1	<0.1	8.2	<0.1	<0.0001
SP4-S	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.6	<0.1	<0.0001
SP4-M	13/04/2015	<0.2	<0.05	<0.3	<0.2	1	1.7	<0.1	5.6	<0.1	<0.0001
SP4-B	13/04/2015	0.2	<0.05	0.3	<0.2	<1	2.0	<0.1	7.5	<0.1	<0.0001
SP5-S	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.6	<0.1	5.0	<0.1	<0.0001
SP5-M	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.8	<0.1	<0.0001
SP5-B	13/04/2015	<0.2	<0.05	0.3	<0.2	1	1.8	<0.1	6.7	<0.1	<0.0001
SP6-S	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.6	<0.1	5.3	<0.1	<0.0001
SP6-M	13/04/2015	<0.2	<0.05	<0.3	<0.2	1	1.8	<0.1	5.7	<0.1	<0.0001
SP6-B	13/04/2015	<0.2	<0.05	0.4	<0.2	<1	1.9	<0.1	7.6	<0.1	<0.0001
SP7-S	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.7	<0.1	5.1	<0.1	<0.0001
SP7-B	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.5	<0.1	5.6	<0.1	<0.0001

Signatory: Jamie Woodward
Date: 15/05/2015

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WATER QUALITY DATA

Contact: Celeste Wilson
Customer: Jacobs
Address: Level 11, Durack Centre, 263 Adelaide Terrace, Perth WA 6001

Date of Issue: 15/05/2015
Date Received: 16/04/2015
Our Reference: JAC15-6
Your Reference: IW021200.104

METHOD SAMPLE CODE	Sampling Date	MS001 Unfiltered Cr µg/L	MS001 Unfiltered Co µg/L	MS001 Unfiltered Ni µg/L	MS001 Unfiltered Cu µg/L	MS001 Unfiltered Zn µg/L	MS001 Unfiltered As µg/L	MS001 Unfiltered Cd µg/L	MS001 Unfiltered Ba µg/L	MS001 Unfiltered Pb µg/L	ICP006 Total Ext Hg mg/L
Reporting Limit		**<0.2**	**<0.05**	**<0.3**	**<0.2**	**<1**	**<0.5**	**<0.1**	**<0.5**	**<0.1**	**<0.0001**
File											**15042201-03**
SP8-S	14/04/2015	<0.2	<0.05	<0.3	<0.2	1	1.6	<0.1	5.3	<0.1	<0.0001
SP8-M	14/04/2015	<0.2	<0.05	<0.3	0.2	<1	1.7	<0.1	5.5	<0.1	<0.0001
SP8-B	14/04/2015	<0.2	<0.05	<0.3	<0.2	1	1.7	<0.1	5.3	<0.1	<0.0001
SP9-S	14/04/2015	<0.2	<0.05	<0.3	<0.2	2	1.7	<0.1	5.4	<0.1	<0.0001
SP9-M	14/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.2	<0.1	<0.0001
SP9-B	14/04/2015	<0.2	<0.05	<0.3	<0.2	1	1.9	<0.1	5.9	<0.1	<0.0001
SP10-S	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.7	<0.1	5.5	<0.1	<0.0001
SP10-M	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.6	<0.1	<0.0001
SP10-B	13/04/2015	0.2	<0.05	0.4	0.2	<1	1.9	<0.1	7.4	<0.1	<0.0001
SP11-S	14/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.9	<0.1	5.3	<0.1	<0.0001
SP11--B	14/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.6	<0.1	5.2	<0.1	<0.0001
SP12-S	14/04/2015	<0.2	<0.05	<0.3	0.3	2	1.6	<0.1	5.2	<0.1	<0.0001
SP12-M	14/04/2015	<0.2	<0.05	<0.3	0.3	<1	1.6	<0.1	5.1	<0.1	<0.0001
SP12-B	14/04/2015	<0.2	<0.05	<0.3	0.3	<1	1.8	<0.1	5.8	<0.1	<0.0001
SP13-S	14/04/2015	<0.2	<0.05	<0.3	<0.2	1	1.6	<0.1	5.2	<0.1	<0.0001
SP13-M	14/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.6	<0.1	5.3	<0.1	<0.0001
SP13-B	14/04/2015	<0.2	<0.05	<0.3	0.3	<1	1.8	<0.1	6.1	<0.1	<0.0001
SP14-S	13/04/2015	<0.2	<0.05	<0.3	0.2	<1	1.7	<0.1	5.5	<0.1	<0.0001
SP14-M	13/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.5	<0.1	<0.0001
SP14-B	13/04/2015	<0.2	<0.05	<0.3	<0.2	1	2.0	<0.1	6.2	<0.1	<0.0001

Signatory: Jamie Woodward
Date: 15/05/2015

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METHOD SAMPLE CODE	Sampling Date	MS001 Unfiltered Cr µg/L	MS001 Unfiltered Co µg/L	MS001 Unfiltered Ni µg/L	MS001 Unfiltered Cu µg/L	MS001 Unfiltered Zn µg/L	MS001 Unfiltered As µg/L	MS001 Unfiltered Cd µg/L	MS001 Unfiltered Ba µg/L	MS001 Unfiltered Pb µg/L	ICP006 Total Ext Hg mg/L
Reporting Limit		**<0.2**	**<0.05**	**<0.3**	**<0.2**	**<1**	**<0.5**	**<0.1**	**<0.5**	**<0.1**	**<0.0001**
File											**15042201-03**
SP15-S	12/04/2015	<0.2	<0.05	<0.3	<0.2	3	1.7	<0.1	5.5	<0.1	<0.0001
SP15-M	12/04/2015	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	5.7	<0.1	<0.0001
SP15-B	12/04/2015	<0.2	<0.05	<0.3	0.2	1	1.9	<0.1	6.3	<0.1	<0.0001
SP16-S	12/04/2015	<0.2	<0.05	<0.3	0.2	1	1.9	<0.1	5.5	<0.1	<0.0001
SP16-B	12/04/2015	<0.2	<0.05	<0.3	<0.2	1	1.9	<0.1	5.6	<0.1	<0.0001
SP17-S	12/04/2015	<0.2	<0.05	<0.3	0.2	3	1.8	<0.1	5.6	<0.1	<0.0001
SP17-M	12/04/2015	<0.2	<0.05	<0.3	<0.2	3	1.7	<0.1	5.6	<0.1	<0.0001
SP17-B	12/04/2015	<0.2	<0.05	<0.3	<0.2	1	1.9	<0.1	6.2	<0.1	<0.0001
Field Blank	14/04/2015	<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.5	<0.1	<0.0001
Trans Blank	14/04/2015	<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.5	<0.1	<0.0001

Signatory: Jamie Woodward
Date: 15/05/2015

All test items tested as received. Spare test items will be held for two months unless otherwise requested.

Western Radiation Services
analytical laboratory & consulting

NATA
WORLD RECOGNISED ACCREDITATION
Accredited Laboratory No. 14174

ABN: 64 135 436 092

3 June 2015

Sinclair Knight Merz – JACOBS PROJECT
7th Floor Durack Centre
PERTH WA 6000

Attn: Alaina Clark/Marine Scientist

ANALYTICAL REPORT

The results (to 95%, 2σ confidence level) for Radium-226, Radium-228 and Thorium-228 analyses of forty eight (48) liquid samples, as received at our laboratory on 29 April 2015, are detailed on page two and three of this report.

MDL:	Radium-226	0.100 Bq/l	Radium-228	0.100 Bq/l
	Thorium-228	0.100 Bq/l		

Method:	LTP No. 4(a)	Gamma Spectrometry Analysis

Madassar A. Qureshi
Authorised Signatory

Perth Office: 24 Brennan Way, Belmont W.A. 6104
Tel: 61 8 9475 0099 |**Fax:** 61 8 9475 0165
A/H: 61 (0) 439 970 660

WRS No	Client Sample ID	Ra-226 (Bq/l)	Ra-228 (Bq/l)	Th-228 (Bq/l)
9278-1	SP1-S	<MDL	<MDL	<MDL
9278-2	SP1-M	<MDL	<MDL	<MDL
9278-3	SP1-B	<MDL	<MDL	<MDL
9278-4	SP2-S	<MDL	<MDL	<MDL
9278-5	SP2-M	0.124 ± 0.014	<MDL	<MDL
9278-6	SP2-B	<MDL	<MDL	<MDL
9278-7	SP3-S	<MDL	<MDL	<MDL
9278-8	SP3-M	<MDL	<MDL	<MDL
9278-9	SP3-B	<MDL	<MDL	<MDL
9278-10	SP4-S	0.295 ± 0.053	0.148 ± 0.045	<MDL
9278-10D	SP4-S	0.263 ± 0.049	0.165 ± 0.064	<MDL
9278-11	SP4-M	<MDL	<MDL	<MDL
9278-12	SP4-B	<MDL	<MDL	<MDL
9278-13	SP5-S	<MDL	<MDL	<MDL
9278-14	SP5-M	0.104 ± 0.014	<MDL	<MDL
9278-15	SP5-B	<MDL	<MDL	<MDL
9278-16	SP6-S	<MDL	<MDL	<MDL
9278-17	SP6-M	<MDL	<MDL	<MDL
9278-18	SP6-B	<MDL	<MDL	<MDL
9278-19	SP7-S	<MDL	<MDL	<MDL
9278-20	SP7-B	0.137 ± 0.024	<MDL	<MDL
9278-20D	SP7-B	0.141 ± 0.025	<MDL	<MDL
9278-21	SP8-S	0.136 ± 0.019	<MDL	<MDL
9278-22	SP8-M	<MDL	<MDL	<MDL
9278-23	SP8-B	<MDL	<MDL	<MDL
9278-24	SP9-S	0.113 ± 0.022	<MDL	<MDL
9278-25	SP9-M	<MDL	<MDL	<MDL
9278-26	SP9-B	<MDL	<MDL	<MDL

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Tel: 61 8 9475 0099 |**Fax:** 61 8 9475 0165
A/H: 61 (0) 439 970 660

WRS No	Client Sample ID	Ra-226 (Bq/l)	Ra-228 (Bq/l)	Th-228 (Bq/l)
9278-27	SP10-S	<MDL	<MDL	<MDL
9278-28	SP10-M	<MDL	<MDL	<MDL
9278-29	SP10-B	<MDL	<MDL	<MDL
9278-30	SP11-S	0.136 ± 0.030	<MDL	<MDL
9278-30D	SP11-S	0.172 ± 0.031	<MDL	<MDL
9278-31	SP11-B	<MDL	<MDL	<MDL
9278-32	SP12-S	<MDL	<MDL	<MDL
9278-33	SP12-M	0.105 ± 0.015	<MDL	<MDL
9278-34	SP12-B	<MDL	<MDL	<MDL
9278-35	SP13-S	<MDL	<MDL	<MDL
9278-36	SP13-M	<MDL	<MDL	<MDL
9278-37	SP13-B	<MDL	<MDL	<MDL
9278-38	SP14-S	<MDL	<MDL	<MDL
9278-39	SP14-M	<MDL	<MDL	<MDL
9278-40	SP14-B	<MDL	<MDL	<MDL
9278-40D	SP14-B	<MDL	<MDL	<MDL
9278-41	SP15-S	<MDL	<MDL	<MDL
9278-42	SP15-M	<MDL	<MDL	<MDL
9278-43	SP15-B	<MDL	<MDL	<MDL
9278-44	SP16-S	<MDL	<MDL	<MDL
9278-45	SP16-B	<MDL	<MDL	<MDL
9278-46	SP17-S	<MDL	<MDL	<MDL
9278-47	SP17-M	<MDL	<MDL	<MDL
9278-48	SP17-B	<MDL	<MDL	<MDL

The reported expanded uncertainty of measurement is stated as the standard uncertainty of the measurement ± 5.6 %, multiplied by the coverage factor k=2, which corresponds to a coverage probability of approximately 95%.

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DATA REPORT

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Project
BAROSSA
COP-Barossa WQ Trip

Customer
Jacobs Group (Australia) Pty Ltd
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

DSID
27560

Report Date
1/06/2015

Batch Number
150420110337

Sample ID
SP1-S

Date Collected
12/04/2015

Monitoring Point

Sample Type
Phytoplankton

Date Received
20/04/2015

Functional Location ID
SP1-S

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
29/05/2015

Units Reported Cell Density:cells L^{-1} Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density
21,960.0 cells L^{-1}

Total Counted
120

Uncertainty
18.3%

Species Name	Density	BioVolume	%
Cyanobacteria			
Trichodesmium erythraeum	20,130		91.67
	20,130	**0.0000**	**91.67**
Dinophyceae			
Dinoflagellate 003	183		0.83
Dinoflagellate 036	1,098		5.00
Gyrodinium sp. 002	183		0.83
Heterocapsa sp. 001	183		0.83
Scrippsiella trochoidea	183		0.83
	1,830	**0.0000**	**8.33**

End Of Report

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

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Project
BAROSSA
COP-Barossa WQ Trip

Customer
Jacobs Group (Australia) Pty Ltd
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

Report Date
1/06/2015

DSID
27561

Batch Number
150420110513

Sample ID
SP3-S

Date Collected
13/04/2015

Monitoring Point

Sample Type
Phytoplankton

Date Received
20/04/2015

Functional Location ID
SP3-S

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
1/06/2015

Units Reported Cell Density:cells L^{-1} Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density
9,882.0 cells L^{-1}

Total Counted
54

Uncertainty
27.2%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Nitzschia spp.	183		1.85
	183	**0.0000**	**1.85**
Cyanobacteria			
Trichodesmium erythraeum	8,601		87.04
	8,601	**0.0000**	**87.04**
Dinophyceae			
Dinoflagellate 003	183		1.85
Dinoflagellate 036	366		3.70
Dinoflagellate 081	183		1.85
Prorocentrum dentatum	183		1.85
Protoperidinium steinii	183		1.85
	1,098	**0.0000**	**11.11**

End Of Report

Shading Key

Species Name	Density	BioVolume	%

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Potentially toxic species
Potentially harmful (non-toxic) species

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Project
BAROSSA
COP-Barossa WQ Trip

Customer
Jacobs Group (Australia) Pty Ltd
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

Report Date
1/06/2015

DSID
27562

Batch Number
150420110600

Sample ID
SP5-S

Date Collected
13/04/2015

Monitoring Point

Sample Type
Phytoplankton

Date Received
20/04/2015

Functional Location ID
SP5-S

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
1/06/2015

Units Reported Cell Density:cells L^{-1} Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density
5,856.0 cells L^{-1}

Total Counted
32

Uncertainty
35.4%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Navicula spp.	549		9.38
Nitzschia spp.	915		15.63
	1,464	**0.0000**	**25.00**
Chlorophyceae			
Chlorophyte 002	2,928		50.00
	2,928	**0.0000**	**50.00**
Dinophyceae			
Dinoflagellate 003	366		6.25
Dinoflagellate 036	732		12.50
Heterocapsa sp. 001	366		6.25
	1,464	**0.0000**	**25.00**

End Of Report

Shading Key

Species Name	Density	BioVolume	%

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Potentially toxic species

Potentially harmful (non-toxic) species

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DATA REPORT

Project	Customer	Analyst ID	DSID
BARROSSA	Jacobs Group (Australia) Pty Ltd Level 7, Durack Centre 263 Adelaide Terrace Perth, WA 6000	stuart	27563
COP-Barossa WQ Trip		**Report Date** 1/06/2015	

Batch Number
150420110644

Sample ID
SP6-S

Date Collected
13/04/2015

Monitoring Point

Sample Type
Phytoplankton

Date Received
20/04/2015

Functional Location ID
SP6-S

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
1/06/2015

Units Reported Cell Density:cells L^{-1} Biovolume: $mm^3\ L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density
6,222.0 cells L^{-1}

Total Counted
34

Uncertainty
34.3%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Chaetoceros spp.	549		8.82
Nitzschia spp.	183		2.94
	732	**0.0000**	**11.76**
Cyanobacteria			
Trichodesmium erythraeum	4,209		67.65
	4,209	**0.0000**	**67.65**
Dinophyceae			
Dinoflagellate 003	183		2.94
Dinoflagellate 036	549		8.82
Dinoflagellate 081	183		2.94
Heterocapsa sp. 001	366		5.88
	1,281	**0.0000**	**20.59**

End Of Report

Shading Key

Species Name	Density	BioVolume	%

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Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

Project
BAROSSA
COP-Barossa WQ Trip

Customer
Jacobs Group (Australia) Pty Ltd
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

Report Date
1/06/2015

DSID
27564

Batch Number
150420110734

Sample ID
SP7-S

Date Collected
13/04/2015

Monitoring Point

Sample Type
Phytoplankton

Date Received
20/04/2015

Functional Location ID
SP7-S

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
29/05/2015

Units Reported Cell Density:cells L^{-1} Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density
8,601.0 cells L^{-1}

Total Counted
47

Uncertainty
29.2%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Chaetoceros spp.	366		4.26
	366	**0.0000**	**4.26**
Cyanobacteria			
Trichodesmium erythraeum	7,137		82.98
	7,137	**0.0000**	**82.98**
Dinophyceae			
Dinoflagellate 003	549		6.38
Dinoflagellate 036	183		2.13
Heterocapsa sp. 001	183		2.13
Scrippsiella trochoidea	183		2.13
	1,098	**0.0000**	**12.77**

End Of Report

Shading Key

Species Name	Density	BioVolume	%

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Potentially toxic species

Potentially harmful (non-toxic) species

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DATA REPORT

Project
BAROSSA
COP-Barossa WQ Trip

Customer
Jacobs Group (Australia) Pty Ltd
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

Report Date
1/06/2015

DSID
27565

Batch Number
150420110817

Sample ID
SP8-S

Date Collected
14/04/2015

Monitoring Point

Sample Type
Phytoplankton

Date Received
20/04/2015

Functional Location ID
SP8-S

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
29/05/2015

Units Reported   Cell Density:cells L^{-1} Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density
4,941.0 cells L^{-1}

Total Counted
27

Uncertainty
38.5%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Chaetoceros spp.	366		7.41
Leptocylindrus danicus	183		3.70
Navicula spp.	366		7.41
	915	**0.0000**	**18.52**
Cyanobacteria			
Trichodesmium erythraeum	3,294		66.67
	3,294	**0.0000**	**66.67**
Dinophyceae			
Dinoflagellate 003	366		7.41
Dinoflagellate 036	183		3.70
Gyrodinium sp. 002	183		3.70
	732	**0.0000**	**14.81**

End Of Report

Shading Key

Species Name	Density	BioVolume	%

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Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

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Project
BAROSSA
COP-Barossa WQ Trip

Customer
Jacobs Group (Australia) Pty Ltd
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

DSID
27566

Report Date
1/06/2015

Batch Number
150420110901

Sample ID
SP10-S

Date Collected
13/04/2015

Monitoring Point

Sample Type
Phytoplankton

Date Received
20/04/2015

Functional Location ID
SP10-S

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
1/06/2015

Units Reported Cell Density:cells L^{-1} Biovolume: mm^{3} L^{-1} %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density
2,928.0 cells L^{-1}

Total Counted
16

Uncertainty
50.0%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Cylindrotheca closterium	183		6.25
Nitzschia spp.	183		6.25
	366	**0.0000**	**12.50**
Cyanobacteria			
Trichodesmium erythraeum	1,281		43.75
	1,281	**0.0000**	**43.75**
Dinophyceae			
Dinoflagellate 003	549		18.75
Dinoflagellate 036	183		6.25
Heterocapsa sp. 001	183		6.25
Scrippsiella trochoidea	366		12.50
	1,281	**0.0000**	**43.75**

End Of Report

Shading Key

Species Name	Density	BioVolume	%

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Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

Project
BAROSSA
COP-Barossa WQ Trip

Customer
Jacobs Group (Australia) Pty Ltd
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

DSID
27567

Report Date
1/06/2015

Batch Number
150420110940

Sample ID
SP11-S

Date Collected
14/04/2015

Monitoring Point

Sample Type
Phytoplankton

Date Received
20/04/2015

Functional Location ID
SP11-S

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
1/06/2015

Units Reported Cell Density:cells L^{-1} Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density
2,745.0 cells L^{-1}

Total Counted
15

Uncertainty
51.6%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Chaetoceros spp.	549		20.00
Cylindrotheca closterium	183		6.67
Nitzschia spp.	549		20.00
	1,281	**0.0000**	**46.67**
Dinophyceae			
Dinoflagellate 003	366		13.33
Dinoflagellate 036	549		20.00
Dinoflagellate 081	366		13.33
Gyrodinium sp. 002	183		6.67
	1,464	**0.0000**	**53.33**

End Of Report

Shading Key

Species Name	Density	BioVolume	%

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Potentially toxic species
Potentially harmful (non-toxic) species

DATA REPORT

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Project
BAROSSA
COP-Barossa WQ Trip

Customer
Jacobs Group (Australia) Pty Ltd
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

Report Date
1/06/2015

DSID
27568

Batch Number
150420111019

Sample ID
SP13-S

Date Collected
14/04/2015

Monitoring Point

Sample Type
Phytoplankton

Date Received
20/04/2015

Functional Location ID
SP13-S

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
1/06/2015

Units Reported Cell Density:cells L^{-1} Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density
1,464.0 cells L^{-1}

Total Counted
8

Uncertainty
70.7%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Cylindrotheca closterium	366		25.00
Nitzschia spp.	183		12.50
	549	**0.0000**	**37.50**
Dinophyceae			
Dinoflagellate 003	366		25.00
Dinoflagellate 036	183		12.50
Dinoflagellate 081	183		12.50
Gyrodinium sp. 002	183		12.50
	915	**0.0000**	**62.50**

End Of Report

Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

Project
BAROSSA
COP-Barossa WQ Trip

Customer
Jacobs Group (Australia) Pty Ltd
Level 7, Durack Centre
263 Adelaide Terrace
Perth, WA 6000

Analyst ID
stuart

DSID
27569

Report Date
1/06/2015

Batch Number
150420111058

Sample ID
SP14-S

Date Collected
14/04/2015

Monitoring Point

Sample Type
Phytoplankton

Date Received
20/04/2015

Functional Location ID
SP14-S

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
1/06/2015

Units Reported Cell Density:cells L^{-1} Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density
1,464.0 cells L^{-1}

Total Counted
8

Uncertainty
70.7%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Nitzschia spp.	183		12.50
	183	**0.0000**	**12.50**
Cryptophyceae			
Cryptophyte 014	183		12.50
	183	**0.0000**	**12.50**
Dinophyceae			
Dinoflagellate 003	183		12.50
Dinoflagellate 036	183		12.50
Dinoflagellate 081	549		37.50
Gyrodinium sp. 002	183		12.50
	1,098	**0.0000**	**75.00**

End Of Report

Shading Key

Species Name	Density	BioVolume	%

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Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

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Analyst ID
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Report Date
1/06/2015

DSID
27570

Batch Number
150420111139

Sample ID
SP16-S

Date Collected
12/04/2015

Monitoring Point

Sample Type
Phytoplankton

Date Received
20/04/2015

Functional Location ID
SP16-S

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
1/06/2015

Units Reported Cell Density:cells L^{-1} Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density
2,928.0 cells L^{-1}

Total Counted
16

Uncertainty
50.0%

Species Name	Density	BioVolume	%
Cyanobacteria			
Trichodesmium erythraeum	2,013		68.75
	2,013	**0.0000**	**68.75**
Dinophyceae			
Dinoflagellate 003	549		18.75
Dinoflagellate 036	183		6.25
Heterocapsa sp. 001	183		6.25
	915	**0.0000**	**31.25**

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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Analyst ID
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Report Date
1/06/2015

DSID
27571

Batch Number
150420111222

Sample ID
SP17-S

Date Collected
12/04/2015

Monitoring Point

Sample Type
Phytoplankton

Date Received
20/04/2015

Functional Location ID
SP17-S

Method (Detection Limit)
Utermohl Tube (New) (183)

Analysis Date
1/06/2015

Units Reported Cell Density:cells L^{-1} Biovolume: $mm^3 L^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
No exceedances of WASQAP (2011) guideline values.

Field Data Recording

Total Density
7,869.0 cells L^{-1}

Total Counted
43

Uncertainty
30.5%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Chaetoceros spp.	549		6.98
Nitzschia spp.	366		4.65
	915	**0.0000**	**11.63**
Cyanobacteria			
Trichodesmium erythraeum	5,673		72.09
	5,673	**0.0000**	**72.09**
Dinophyceae			
Dinoflagellate 003	549		6.98
Dinoflagellate 036	366		4.65
Heterocapsa sp. 001	366		4.65
	1,281	**0.0000**	**16.28**

End Of Report

Shading Key

Species Name	Density	BioVolume	%

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Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

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Analyst ID

DSID
27585

Report Date
1/06/2015

Batch Number
150420113150

Sample ID
SP1-S

Date Collected
12/04/2015

Monitoring Point

Sample Type
Zooplankton

Date Received
20/04/2015

Functional Location ID
SP1-S

Method (Detection Limit)
Raw Count (1)

Analysis Date
29/05/2015

Units Reported: Cell Density:Individuals^{-1} Biovolume: mm^{3} L^{-1} %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Initial sample volume = 100 ml
Sample diluted 10x prior to analysis
3 replicate samples, 1 ml each, analysed

Field Data Recording

Total Density
407.0 Individuals^{-1}

Total Counted
407

Uncertainty
9.9%

Species Name	Density	BioVolume	%
Appendicularia			
Appendicularian	11		2.70
	11	**0.0000**	**2.70**
Copepoda			
Acartiidae	34		8.35
Calanidae	157		38.57
Copepod Nauplius	101		24.82
Corycaeidae	47		11.55
Macrosetella sp. 001	5		1.23
Microsetella	3		0.74
Oncaeidae	10		2.46
Paracalanidae	2		0.49
Pontellidae nauplius	14		3.44
Sulcanidae	6		1.47
	379	**0.0000**	**93.12**
Polychaeta			
Polychaete larva	14		3.44
	14	**0.0000**	**3.44**
Sagittoidea			

Species Name	Density	BioVolume	%
Chaetognath	1		0.25
	1	**0.0000**	**0.25**
Unknown			
Protozoa 047	1		0.25
Protozoa 056	1		0.25
	2	**0.0000**	**0.49**

End Of Report

Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

Project
BAROSSA
COP-Barossa WQ Trip

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Analyst ID
stuart

Report Date
1/06/2015

DSID
27586

Batch Number
150420113235

Sample ID
SP3-S

Date Collected
13/04/2015

Monitoring Point

Sample Type
Zooplankton

Date Received
20/04/2015

Functional Location ID
SP3-S

Method (Detection Limit)
Raw Count (1)

Analysis Date
28/05/2015

Units Reported Cell Density:Individuals^{-1} Biovolume: mm ^{3} L $^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Initial sample volume = 106 ml
Sample diluted 10x prior to analysis
3 replicate samples, 1 ml each, analysed

Field Data Recording

Total Density
3,188.0 Individuals^{-1}

Total Counted
3,188

Uncertainty
3.5%

Species Name	Density	BioVolume	%
Appendicularia			
Appendicularian	9		0.28
	9	**0.0000**	**0.28**
Copepoda			
Acartiidae	13		0.41
Calanidae	2		0.06
Copepod Nauplius	9		0.28
Corycaeidae	15		0.47
Oncaeidae	3		0.09
Sulcanidae	1		0.03
	43	**0.0000**	**1.35**
Foraminifera			
Foraminiferida	3		0.09
	3	**0.0000**	**0.09**
Gigartacontidae			
Gigartacontidae	3,126		98.06
	3,126	**0.0000**	**98.06**
Polychaeta			

Species Name	Density	BioVolume	%
Polychaete larva	1		0.03
	1	**0.0000**	**0.03**
Sagittoidea			
Chaetognath	4		0.13
	4	**0.0000**	**0.13**
Unknown			
Protozoa 047	2		0.06
	2	**0.0000**	**0.06**

End Of Report

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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Project
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Report Date
1/06/2015

DSID
27587

Batch Number
150420113313

Sample ID
SP5-S

Date Collected
13/04/2015

Monitoring Point

Sample Type
Zooplankton

Date Received
20/04/2015

Functional Location ID
SP5-S

Method (Detection Limit)
Raw Count (1)

Analysis Date
28/05/2015

Units Reported: Cell Density:Individuals^{-1} Biovolume: mm ^{3} L $^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Initial sample volume = 86 ml
Sample diluted 10x prior to analysis
3 replicate samples, 1 ml each, analysed

Field Data Recording

Total Density
2,807.0 Individuals^{-1}

Total Counted
2,807

Uncertainty
3.8%

Species Name	Density	BioVolume	%
Appendicularia			
Appendicularian	17		0.61
	17	**0.0000**	**0.61**
Copepoda			
Acartiidae	103		3.67
Calanidae	333		11.86
Copepod Nauplius	151		5.38
Corycaeidae	55		1.96
Macrosetella sp. 001	12		0.43
Microsetella	16		0.57
Oncaeidae	56		2.00
Paracalanidae	15		0.53
Pontellidae nauplius	22		0.78
Sulcanidae	31		1.10
	794	**0.0000**	**28.29**
Foraminifera			
Foraminiferida	2		0.07
	2	**0.0000**	**0.07**
Gigartacontidae			

Species Name	Density	BioVolume	%
Gigartacontidae	1,974		70.32
	1,974	**0.0000**	**70.32**
Sagittoidea			
Chaetognath	12		0.43
	12	**0.0000**	**0.43**
Unknown			
Protozoa 047	8		0.29
	8	**0.0000**	**0.29**

End Of Report

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

Project
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COP-Barossa WQ Trip

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Perth, WA 6000

Analyst ID
stuart

Report Date
1/06/2015

DSID
27588

Batch Number
150420113358

Sample ID
SP6-S

Date Collected
13/04/2015

Monitoring Point

Sample Type
Zooplankton

Date Received
20/04/2015

Functional Location ID
SP6-S

Method (Detection Limit)
Raw Count (1)

Analysis Date
28/05/2015

Units Reported: Cell Density:Individuals^{-1} Biovolume: mm ^{3} L $^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Initial sample volume = 102 ml
Sample diluted 10x prior to analysis
3 replicate samples, 1 ml each, analysed

Field Data Recording

Total Density
176.0 Individuals^{-1}

Total Counted
176

Uncertainty
15.1%

Species Name	Density	BioVolume	%
Appendicularia			
Appendicularian	23		13.07
	23	**0.0000**	**13.07**
Copepoda			
Acartiidae	9		5.11
Calanidae	10		5.68
Copepod Nauplius	8		4.55
Corycaeidae	3		1.70
Oncaeidae	3		1.70
Sulcanidae	1		0.57
	34	**0.0000**	**19.32**
Gigartacontidae			
Gigartacontidae	111		63.07
	111	**0.0000**	**63.07**
Sagittoidea			
Chaetognath	7		3.98
	7	**0.0000**	**3.98**
Unknown			

Species Name	Density	BioVolume	%
Protozoa 047	1		0.57
	1	**0.0000**	**0.57**

End Of Report

Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

Project
BAROSSA
COP-Barossa WQ Trip

Customer
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Level 7, Durack Centre
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Perth, WA 6000

Analyst ID
stuart

DSID
27589

Report Date
1/06/2015

Batch Number
150420113438

Sample ID
SP7-S

Date Collected
13/04/2015

Monitoring Point

Sample Type
Zooplankton

Date Received
20/04/2015

Functional Location ID
SP7-S

Method (Detection Limit)
Raw Count (1)

Analysis Date
29/05/2015

Units Reported: Cell Density:Individuals^{-1} Biovolume: mm^{3} L^{-1} %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Initial sample volume = 99 ml
Sample diluted 10x prior to analysis
3 replicate samples, 1 ml each, analysed

Field Data Recording

Total Density
196.0 Individuals^{-1}

Total Counted
196

Uncertainty
14.3%

Species Name	Density	BioVolume	%
Appendicularia			
Appendicularian	8		4.08
	8	**0.0000**	**4.08**
Copepoda			
Acartiidae	6		3.06
Calanidae	56		28.57
Copepod Nauplius	13		6.63
Corycaeidae	41		20.92
Microsetella	10		5.10
Oncaeidae	9		4.59
Paracalanidae	2		1.02
	137	**0.0000**	**69.90**
Gigartacontidae			
Gigartacontidae	18		9.18
	18	**0.0000**	**9.18**
Maxillopoda			
Cirripede nauplius	5		2.55
	5	**0.0000**	**2.55**

Species Name	Density	BioVolume	%
Polychaeta			
Polychaete larva	27		13.78
	27	**0.0000**	**13.78**
Unknown			
Protozoa 047	1		0.51
	1	**0.0000**	**0.51**

End Of Report

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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Project
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Analyst ID
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DSID
27590

Report Date
1/06/2015

Batch Number
150420113516

Sample ID
SP8-S

Date Collected
14/04/2015

Monitoring Point

Sample Type
Zooplankton

Date Received
20/04/2015

Functional Location ID
SP8-S

Method (Detection Limit)
Raw Count (1)

Analysis Date
28/05/2015

Units Reported: Cell Density:Individuals^{-1} Biovolume: mm ^{3} L^{-1} %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Initial sample volume = 91 ml
Sample diluted 10x prior to analysis
3 replicate samples, 1 ml each, analysed

Field Data Recording

Total Density
380.0 Individuals^{-1}

Total Counted
380

Uncertainty
10.3%

Species Name	Density	BioVolume	%
Appendicularia			
Appendicularian	11		2.89
	11	**0.0000**	**2.89**
Copepoda			
Acartiidae	29		7.63
Calanidae	151		39.74
Copepod Nauplius	62		16.32
Corycaeidae	33		8.68
Microsetella	16		4.21
Oncaeidae	8		2.11
Paracalanidae	6		1.58
Pontellidae nauplius	5		1.32
	310	**0.0000**	**81.58**
Gigartacontidae			
Gigartacontidae	32		8.42
	32	**0.0000**	**8.42**
Polychaeta			
Polychaete larva	21		5.53
	21	**0.0000**	**5.53**

Species Name	Density	BioVolume	%
Sagittoidea			
Chaetognath	1		0.26
	1	**0.0000**	**0.26**
Unknown			
Protozoa 047	5		1.32
	5	**0.0000**	**1.32**

End Of Report

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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Project
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COP-Barossa WQ Trip

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Perth, WA 6000

Analyst ID
stuart

Report Date
1/06/2015

DSID
27591

Batch Number
150420113557

Sample ID
SP10-S

Date Collected
13/04/2015

Monitoring Point

Sample Type
Zooplankton

Date Received
20/04/2015

Functional Location ID
SP10-S

Method (Detection Limit)
Raw Count (1)

Analysis Date
28/05/2015

Units Reported: Cell Density: Individuals^{-1} Biovolume: mm^{3} L^{-1} %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Initial sample volume = 106 ml
Sample diluted 10x prior to analysis
3 replicate samples, 1 ml each, analysed

Field Data Recording

Total Density
236.0 Individuals^{-1}

Total Counted
236

Uncertainty
13.0%

Species Name	Density	BioVolume	%
Appendicularia			
Appendicularian	4		1.69
	4	**0.0000**	**1.69**
Copepoda			
Acartiidae	23		9.75
Calanidae	77		32.63
Copepod Nauplius	55		23.31
Corycaeidae	39		16.53
Macrosetella sp. 001	1		0.42
Microsetella	1		0.42
Oncaeidae	18		7.63
Paracalanidae	3		1.27
Sulcanidae	8		3.39
	225	**0.0000**	**95.34**
Polychaeta			
Polychaete larva	1		0.42
	1	**0.0000**	**0.42**
Sagittoidea			
Chaetognath	6		2.54

Species Name	Density	BioVolume	%
	6	0.0000	2.54

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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DATA REPORT

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Analyst ID
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Report Date
1/06/2015

DSID
27592

Batch Number
150420113641

Sample ID
SP11-S

Date Collected
14/04/2015

Monitoring Point

Sample Type
Zooplankton

Date Received
20/04/2015

Functional Location ID
SP11-S

Method (Detection Limit)
Raw Count (1)

Analysis Date
28/05/2015

Units Reported: Cell Density:Individuals^{-1} Biovolume: mm^3 L^{-1} %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Initial sample volume = 106 ml
Sample diluted 10x prior to analysis
3 replicate samples, 1 ml each, analysed

Field Data Recording

Total Density
1,316.0 Individuals^{-1}

Total Counted
1,316

Uncertainty
5.5%

Species Name	Density	BioVolume	%
Branchiopoda			
Polyphemidae	1		0.08
	1	**0.0000**	**0.08**
Copepoda			
Acartiidae	21		1.60
Calanidae	73		5.55
Copepod Nauplius	45		3.42
Corycaeidae	41		3.12
Macrosetella sp. 001	16		1.22
Microsetella	12		0.91
Oncaeidae	17		1.29
	225	**0.0000**	**17.10**
Foraminifera			
Foraminiferida	11		0.84
	11	**0.0000**	**0.84**
Gigartacontidae			
Gigartacontidae	1,077		81.84
	1,077	**0.0000**	**81.84**

Species Name	Density	BioVolume	%
Polychaeta			
Polychaete larva	1		0.08
	1	**0.0000**	**0.08**

Species Name	Density	BioVolume	%
Unknown			
Protozoa 047	1		0.08
	1	**0.0000**	**0.08**

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Shading Key
Potentially toxic species
Potentially harmful (non-toxic) species

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Analyst ID
stuart

DSID
27593

Report Date
1/06/2015

Batch Number
150420113723

Sample ID
SP13-S

Date Collected
14/04/2015

Monitoring Point

Sample Type
Zooplankton

Date Received
20/04/2015

Functional Location ID
SP13-S

Method (Detection Limit)
Raw Count (1)

Analysis Date
29/05/2015

Units Reported Cell Density:Individuals^{-1} Biovolume: mm ^{3} L $^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Initial sample volume = 75 ml
Sample diluted 10x prior to analysis
3 replicate samples, 1 ml each, analysed

Field Data Recording

Total Density
1,017.0 Individuals^{-1}

Total Counted
1,017

Uncertainty
6.3%

Species Name	Density	BioVolume	%
Appendicularia			
Appendicularian	1		0.10
	1	**0.0000**	**0.10**
Branchiopoda			
Podonidae	1		0.10
	1	**0.0000**	**0.10**
Copepoda			
Acartiidae	1		0.10
Calanidae	7		0.69
Copepod Nauplius	40		3.93
Corycaeidae	17		1.67
Microsetella	6		0.59
Oncaeidae	4		0.39
Pontellidae nauplius	2		0.20
	77	**0.0000**	**7.57**
Gigartacontidae			
Gigartacontidae	843		82.89
	843	**0.0000**	**82.89**

Species Name	Density	BioVolume	%
Polycystinea			
Theoperidae	37		3.64
	37	**0.0000**	**3.64**
Unknown			
Protozoa 047	6		0.59
Protozoa 056	52		5.11
	58	**0.0000**	**5.70**

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Analyst ID
stuart

Report Date
1/06/2015

DSID
27594

Batch Number
150420113821

Sample ID
SP14-S

Date Collected
14/04/2015

Monitoring Point

Sample Type
Zooplankton

Date Received
20/04/2015

Functional Location ID
SP14-S

Method (Detection Limit)
Raw Count (1)

Analysis Date
29/05/2015

Units Reported: Cell Density:Individuals^{-1} Biovolume: mm^{3} L^{-1} %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Initial sample volume = 105 ml
Sample diluted 10x prior to analysis
3 replicate samples, 1 ml each, analysed

Field Data Recording

Total Density
93.0 Individuals^{-1}

Total Counted
93

Uncertainty
20.7%

Species Name	Density	BioVolume	%
Appendicularia			
Appendicularian	3		3.23
	3	**0.0000**	**3.23**
Copepoda			
Acartiidae	14		15.05
Calanidae	4		4.30
Copepod Nauplius	16		17.20
Corycaeidae	37		39.78
Microsetella	6		6.45
Paracalanidae	5		5.38
	82	**0.0000**	**88.17**
Gigartacontidae			
Gigartacontidae	7		7.53
	7	**0.0000**	**7.53**
Polycystinea			
Theoperidae	1		1.08
	1	**0.0000**	**1.08**

Species Name	Density	BioVolume	%

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Analyst ID
stuart

Report Date
1/06/2015

DSID
27595

Batch Number
150420113908

Sample ID
SP16-S

Date Collected
12/04/2015

Monitoring Point

Sample Type
Zooplankton

Date Received
20/04/2015

Functional Location ID
SP16-S

Method (Detection Limit)
Raw Count (1)

Analysis Date
29/05/2015

Units Reported: Cell Density:Individuals^{-1} Biovolume: mm ^{3} L $^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Initial sample volume = 117 ml
Sample diluted 10x prior to analysis
3 replicate samples, 1 ml each, analysed

Field Data Recording

Total Density
2,577.0 Individuals^{-1}

Total Counted
2,577

Uncertainty
3.9%

Species Name	Density	BioVolume	%
Appendicularia			
Appendicularian	94		3.65
	94	**0.0000**	**3.65**
Copepoda			
Acartiidae	2		0.08
Calanidae	16		0.62
Copepod Nauplius	12		0.47
Microsetella	2		0.08
	32	**0.0000**	**1.24**
Foraminifera			
Foraminiferida	19		0.74
	19	**0.0000**	**0.74**
Gigartacontidae			
Gigartacontidae	2,412		93.60
	2,412	**0.0000**	**93.60**
Polycystinea			
Theoperidae	5		0.19
	5	**0.0000**	**0.19**

Species Name	Density	BioVolume	%
Sagittoidea			
Chaetognath	13		0.50
	13	**0.0000**	**0.50**
Unknown			
Protozoa 047	1		0.04
Protozoa 056	1		0.04
	2	**0.0000**	**0.08**

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DSID
27596

Report Date
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Batch Number
150420113957

Sample ID
SP17-S

Date Collected
12/04/2015

Monitoring Point

Sample Type
Zooplankton

Date Received
20/04/2015

Functional Location ID
SP17-S

Method (Detection Limit)
Raw Count (1)

Analysis Date
29/05/2015

Units Reported: Cell Density:Individuals $^{-1}$ Biovolume: mm ^{3} L $^{-1}$ %: Percentage of total cells counted

Sampler Notes

Laboratory Notes
Initial sample volume = 83 ml
Sample diluted 10x prior to analysis
3 replicate samples, 1 ml each, analysed

Field Data Recording

Total Density
966.0 Individuals $^{-1}$

Total Counted
966

Uncertainty
6.4%

Species Name	Density	BioVolume	%
Appendicularia			
Appendicularian	34		3.52
	34	**0.0000**	**3.52**
Copepoda			
Calanidae	3		0.31
Copepod Nauplius	29		3.00
Corycaeidae	10		1.04
Oncaeidae	21		2.17
Pontellidae nauplius	7		0.72
	70	**0.0000**	**7.25**
Gigartacontidae			
Gigartacontidae	846		87.58
	846	**0.0000**	**87.58**
Polycystinea			
Theoperidae	13		1.35
	13	**0.0000**	**1.35**
Unknown			
Protozoa 047	3		0.31

Species Name	Density	BioVolume	%
	3	**0.0000**	**0.31**

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Potentially harmful (non-toxic) species

Appendix C.

Sediment quality and infauna field survey report (Jacobs 2016b)

Barossa Environmental Studies

ConocoPhillips

Sediment Quality and Infauna Field Survey Report

WV04831-NMS-RP-0027 | Rev 2

19 August 2016

Barossa Environmental Studies

Project no:	WV04831 (IW021200)
Document title:	Sediment Quality and Infauna Field Survey Report
Document No.:	WV04831-NMS-RP-0027
Revision:	Rev 2
Date:	1 June 2015
Client name:	ConocoPhillips
Project manager:	Arne de Vos
Author:	Dr Garnet Hooper
File name:	http://dmca-apac.skmconsulting.com/sites/WV04831/DmcaConsult/Deliverables/SQ Technical Report/WV04831-NMS-RP-0027_Sediment Quality and Infauna.docx

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Document history and status

Revision	Date	Description	Review	Approved
Rev A	12/06/2015	Technical Review	P Erftemeijer	C Teasdale
Rev A	12/06/2015	Editorial Review	J Phillips	C Teasdale
Rev 0	17/06/2015	Issue to client	C Teasdale	C Teasdale
Rev 1	06/08/2015	Client comments addressed	C Teasdale	T Mitchell
Rev 2	19/08/2016	Revised Final	C Wilson	A de Vos

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The sole purpose of this report and the associated services performed by Jacobs is to undertake the studies in accordance with the scope of services set out in the contract between Jacobs and the Client. That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

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Abbreviations

ALS	Australian Laboratory Services Pty Ltd
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agricultural and Resource Management Council of Australia and New Zealand
aRPD	apparent redox potential discontinuity
BEST	Bio-Env and stepwise
BETXN	benzene, toluene, ethylbenzene, xylenes (meta-, para- and ortho-xylene) and naphthalene
BHQ	benthic habitat quality
Bio-Env	biological-environmental
BPPH	benthic primary producer habitat
Bq/g	becquerels per gram
ConocoPhillips	ConocoPhillips Australia Exploration Pty Ltd
DW	dry weight
(g)mS	slightly gravelly muddy sand
(g)S	slightly gravelly sand
gS	gravelly sand
(g)sM	slightly gravelly sandy mud
GPS	global positioning system
ISQG	interim sediment quality guidelines
LOR	limit of reporting
MAFRL	Marine and Freshwater Research Laboratory (Murdoch University)
mg/kg	milligrams per kilogram
MRL	minimum reporting limit
N/A	not applicable
NATA	National Association of Testing Authorities
NAGD	national assessment guidelines for dredging
NEPM	National Environment Protection Measure(s)
n-MDS	non-metric multi-dimensional scaling
NORM	naturally occurring radioactive material
NS	no sample
NT	Northern Territory
PAH	polycyclic aromatic hydrocarbons
PCA	principal components analysis

PRIMER	Plymouth routines in marine environmental research
PSD	particle size distribution
QA/QC	quality assurance/quality control
S	*pertaining to Folk classification* - sand
S	*pertaining to infaunal descriptive statistics* - species richness
SIMPROF	similarity profile
sM	sandy mud
SP1	sampling point 1
Sp.	species (singular)
SPI	sediment profile imagery
Spp.	species (plural)
TBT	tributyltin
TKN	total kjeldahl nitrogen
TOC	total organic carbon
TP	total phosphorus
TPH	total petroleum hydrocarbon
TRH	total recoverable hydrocarbon
µg	microgram

Executive Summary

ConocoPhillips Australia Exploration Pty Ltd (ConocoPhillips) are proposing to develop natural gas resources as part of the Barossa area development, located in waters up to 300 m deep in the Bonaparte Basin, in Commonwealth waters offshore of northern Australia. To develop a robust understanding of the existing marine environmental values of the area to inform any future approvals, a targeted baseline marine studies program is being progressed within and surrounding the Barossa field.

A key component of the baseline marine studies program is a sediment quality and infauna survey that was undertaken from 8 to 14 April 2015, during the autumn or tropical transitional season.

Seventeen water quality sampling sites were positioned to provide representative coverage of the permit area and areas of regional interest such as shoals and banks. Sites were located in the permit area (five sites, labelled SP1 to SP5), around Evans Shoal (four sites, SP7 to SP10), around Tassie Shoal (four sites, SP11 to SP14), around Lynedoch Bank (three sites, SP15 to SP17) and between the permit area and Evans Shoal (one site, SP6). Sites surveyed ranged in depth from around 10 m–30 m on top of shoals and banks through to approximately 280 m in the permit area.

Sediment samples were collected from each site for analysis of nutrients, metals/metalloids, hydrocarbons, naturally occurring radioactive materials, particle size distribution and infaunal community composition. Sampling sites ranged in depth from around 70 m at the shoals and banks through to approximately 280 m in the permit area. Shallow sampling sites on the shoals and banks were found to be unsuitable for sediment sampling due to the density of coral/biota cover and lack of consistent sediment patches.

Key conclusions from the sediment quality and infauna survey include:

- Of the metals and metalloids tested, only cobalt and nickel were recorded above the ANZECC & ARMCANZ (2000b) Interim Sediment Quality Guideline (ISQG) - low reliability trigger values. Cobalt was commonly recorded above the ISQG-low reliability trigger value level at all sites except one site at Evans Shoal. Nickel concentrations were recorded at or above the ISQG-low trigger value at two sites within the permit area. Nickel is commonly found in high levels in sediments in Australia (Commonwealth of Australia 2009) and both nickel and cobalt were found at levels greater than the ISQG-low reliability trigger value in deep offshore waters in the Browse Basin (approximately 30 km north-east of Seringapatam Reef) (SKM 2014).

- Tributyltin and hydrocarbons were below the laboratory reporting limits at all sites. Although historic exploration has been undertaken in the permit area, potential impacts from these activities were not detected in the data.

- Radium^{226} concentrations were recorded above the minimum reporting limit at two sites (one in the permit area and one to the west of the permit area), but at levels well below the ANZECC & ARMCANZ (2000b) ISQG-low reliability trigger value for radionuclides. Radium^{228} and thorium^{228} were not detected at any site.

- The highest total nitrogen and total organic carbon concentrations were associated with the permit area sediments, which were the deepest and the finest sediment habitats sampled. Lowest levels were recorded at the shoals. A converse trend was generally observed for sediment total phosphorus concentrations.

- A gradual transition in sediment composition was observed over broad spatial scales (tens of kilometres), particularly between the permit area and the sediments of the shallow shoals. There was a lesser trend of an east-west transition in sediment type in the permit area, with finer sediments (sandy muds) in the east to coarser muddy sands in the west.

- While infaunal communities varied across the survey sites, the sites sampled are considered indicative of the benthic infaunal communities that are likely to occur in the study area. Communities ranged from a relatively depauperate faunal community (only three individuals representing three taxa per 0.1 m^2) at a site on Evans Shoal to a diverse and abundant community (63 individuals representing 42 taxa) in the sediments at another site on Evans Shoal.

- The profile images from the Sediment Profile Imagery (SPI) system, deployed at a single site in the permit area, described a consistently fine and unlayered sediment throughout the upper approximately 18 cm of the sediment profile, with slightly coarser material at the surface. Bioturbation was evident in the form of burrows and feeding voids. The particle size analysis of SPI images yielded average particle sizes in the same size class (63–125 µm, or very fine sand) as the median grain size derived from the laboratory analysis of particle size distribution samples.

In summary, the results of the sediment survey contributed to an appropriate baseline characterisation of the sediment quality in the study area, and provided an indication of the composition of infaunal communities that are found in the area.

1. Introduction

1.1 Background

ConocoPhillips Australia Exploration Pty Ltd (ConocoPhillips), as proponent on behalf of the current and future joint ventures, are proposing to develop natural gas resources as part of the Barossa area development, located approximately 300 kilometres (km) north of Darwin, Northern Territory (NT).

To facilitate the environmental approvals process for any future development of the Barossa field and surrounds, a robust understanding of the existing state of the key environmental values and sensitivities will be necessary. This understanding will be gained from a series of studies and surveys to assess and monitor the baseline state of environmental factors such as water quality, sediment quality, noise, metocean conditions and benthic habitats within petroleum retention lease permit NT/RL5 (referred to as the permit area in this report) and across a broader geographical area. The field studies assessing these factors commenced in June 2014.

1.2 Overview of existing regional environment

The Barossa area is located in the North Marine Region (Department of Sustainability, Environment, Water, Population and Communities 2012), which comprises the Commonwealth waters of the Gulf of Carpentaria, Timor Sea and Arafura Sea as far west as the NT and Western Australian border. The North Marine Region contains internationally significant breeding and/or feeding grounds for a number of listed threatened and migratory marine species including nearshore dolphins, turtles, dugongs, seabirds and migratory shorebirds afforded protection under national legislation and international conventions.

The Timor and Arafura Seas support a variety of shark, pelagic finfish and crustacean species of commercial and recreational game-fishing importance, e.g. trawl and various finfish fisheries. The shelf break and slope of the Arafura Shelf is characterised by patch reefs and hard substrate pinnacles that support a diverse array of invertebrate groups, with polychaetes and crustaceans being the most prolific (Heyward et al. 1997, CEE 2002). Surveys indicate that between 50 m and 200 m depth, the benthos consists of predominantly soft, easily resuspended sediments (Heyward et al. 1997, URS 2005, 2007). The diversity and coverage of epibenthos is low and organisms present are predominantly sponges, gorgonians and soft corals (Heyward et al. 1997, URS 2005, 2007).

Numerous shoals (submerged calcareous banks or ‘seamounts’) exist in the broader region around the permit area; the closest being Evans Shoal, 60 km to the west and Tassie Shoal, 70 km south-west, and Lynedoch Bank, 40 km to the south-east. In addition, the new Oceanic Shoals Commonwealth marine reserve (multiple use zone) lies to the south and south-east of the permit area.

1.3 Objectives

A sediment quality and infauna survey is a key component of the Barossa marine baseline studies program.

Baseline studies were undertaken with reference to the permit area, as shown in **Figure 1-1**. While this represents the area of primary interest as part of ConocoPhillips’ staged field development, the broader surrounds were also characterised, including the nearest seabed features of regional interest to the Barossa area (i.e. Evans Shoal, Tassie Shoal and Lynedoch Bank).

The specific objectives of the sediment quality and infauna survey were to:

- determine the sediment quality of the marine benthos within the permit area and in the vicinity of Evans Shoal, Tassie Shoal and Lynedoch Bank
- determine the infaunal community composition throughout the study area.

This report summarises the results of the sediment quality and infauna survey, undertaken in mid-April 2015 during the northern Australian (tropical transitional) autumn.

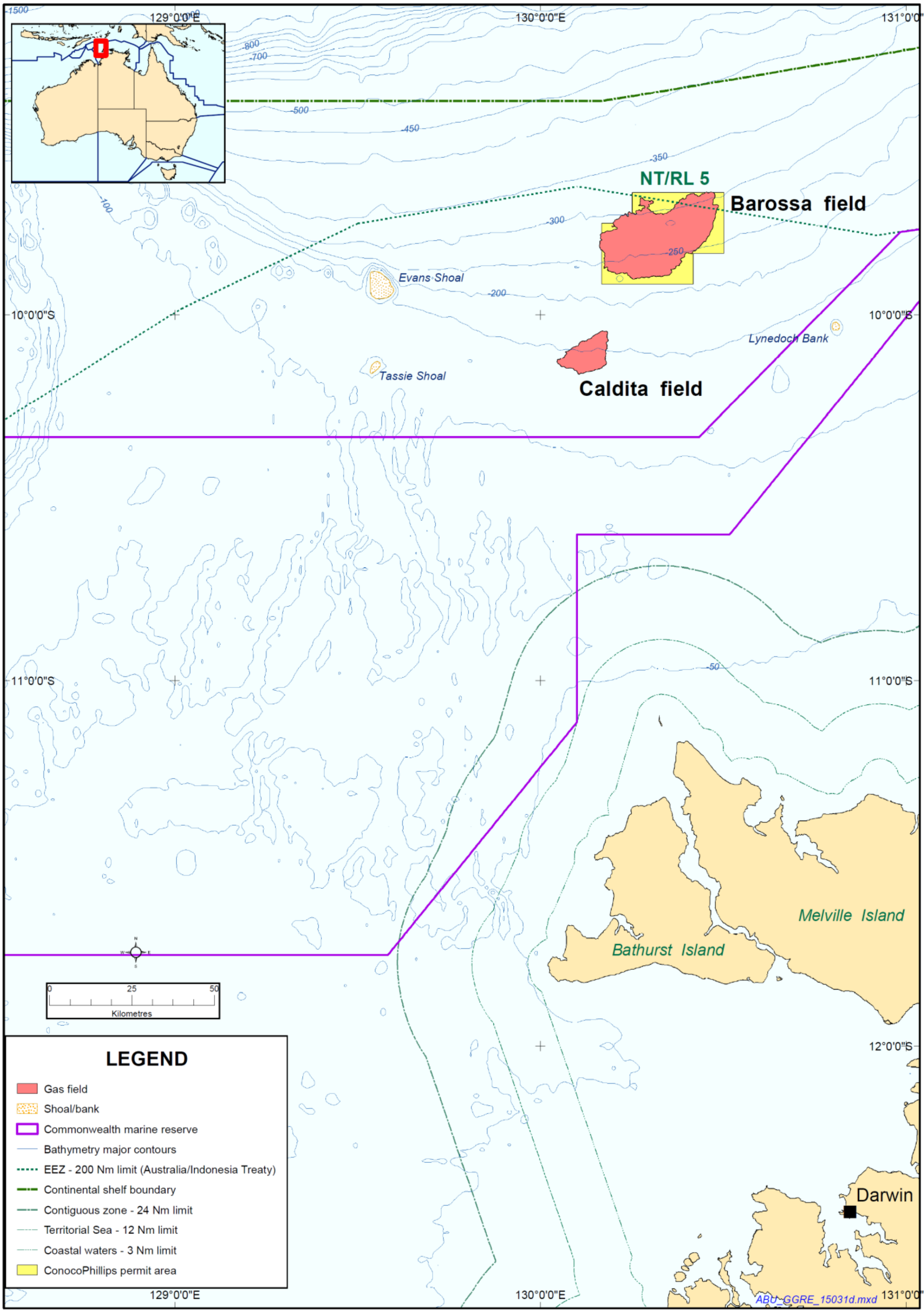


Figure 1-1: Barossa field location

2. Methods

The methods employed during the sediment quality survey follow those detailed in the *Barossa Environmental Studies: Sediment Quality and Infauna Field Sampling Plan Method Statement* (Jacobs 2015a). An overview of the methods is provided in the sections below.

2.1 Sampling sites

Seventeen sampling sites (**Figure 2-2**) were identified to provide coverage of the permit area and of areas of regional interest such as shoals and banks. Sites were located in:

- the permit area (five sites, labelled SP1 to SP5)
- Evans Shoal, approximately 60 km west of the permit area (four sites, SP7 to SP10)
- Tassie Shoal, approximately 70 km south-west of the permit area (four sites, SP11 to SP14)
- Lynedoch Bank, approximately 40 km south-east of the permit area (three sites, SP15 to SP17)
- between the permit area and Evans Shoal, approximately 20 km west of the permit area (one site, SP6).

2.2 Sediment sampling

2.2.1 Sample collection

In water depths less than 100 m, and where remotely operated vehicle imagery had not already been collected as part of the benthic habitat survey (Jacobs 2015b), a GoPro Hero 3+ camera and Mangrove VC-4L6 underwater video light were deployed to obtain imagery of the seabed to assess potential for grab sampling success and potential environmental risk of sampling. Grab samples were not collected at sites lacking large areas of sediment (due to the low chance of success) and/or where coral/benthic primary producer habitat (BPPH) cover was identified to be relatively common and at high risk of damage from grab sampling operations.

Three replicate sediment samples were collected at each site where feasible using a 0.1 m^2 or 0.2 m^2 van Veen grab (**Figure 2-1**) deployed from the stern of the survey vessel *Warrego* via the vessel's A-frame. Of the three replicates, two were collected for contaminants, nutrients and particle size distribution (PSD) sampling, and the third grab collected for infaunal sampling. The grab was thoroughly cleaned with Decon 90 prior to deployment at each sampling site.

If no sample was obtained following three replicate deployments, sites were moved at least 500 m and the direction from the original site location noted in the new site label.

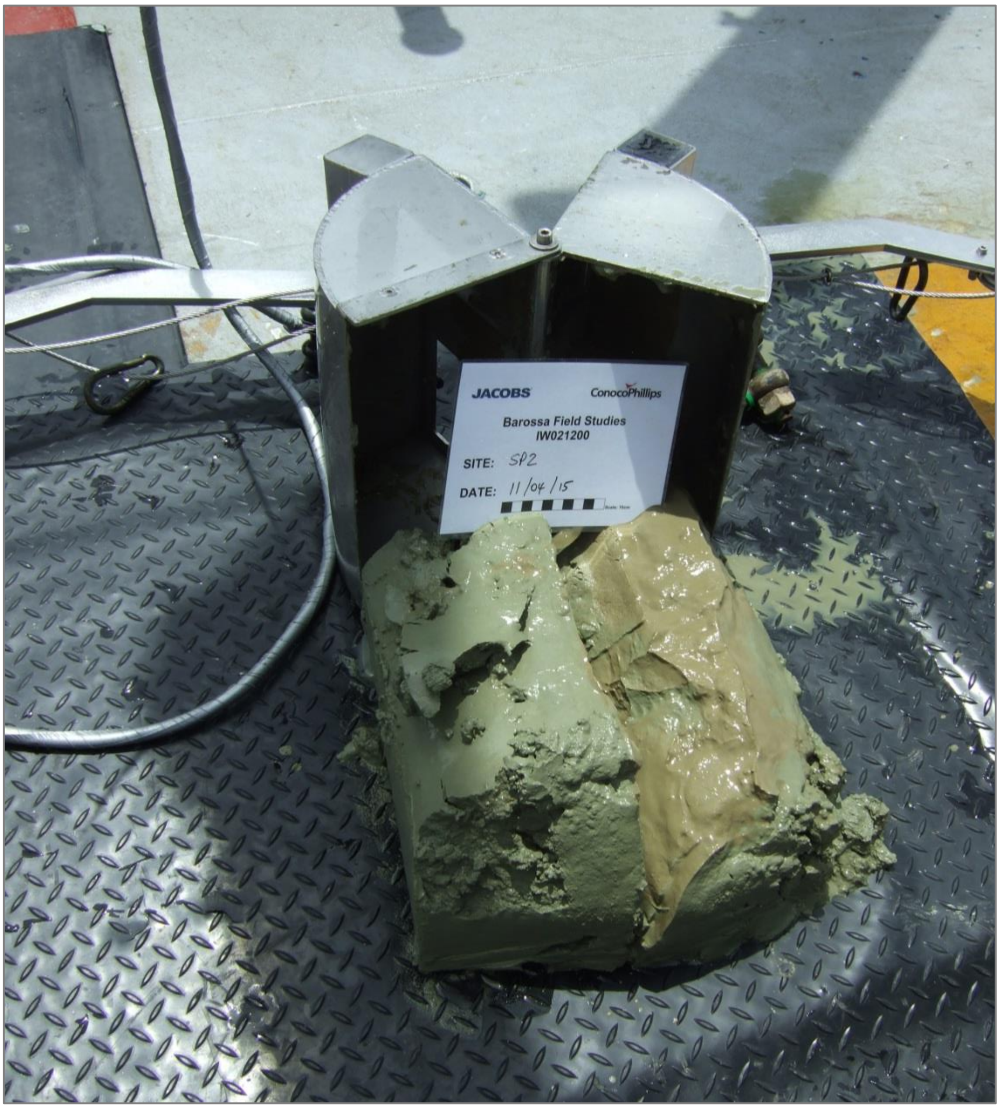


Figure 2-1: van Veen grab with infaunal sediment sample from site SP2

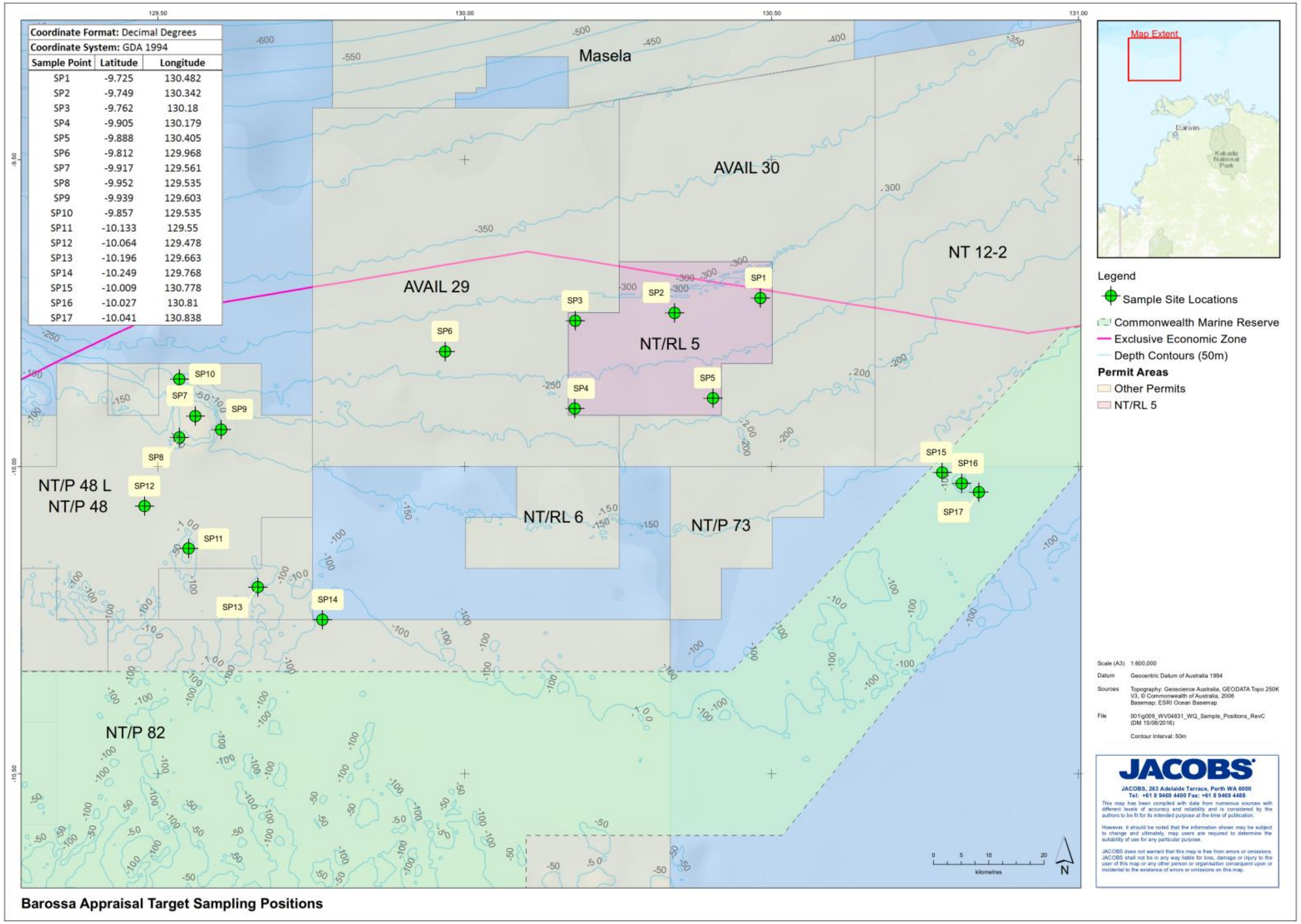


Figure 2-2: Barossa appraisal target sampling positions

2.2.2 Sample processing, preservation and storage

Sampling data were recorded on a field sheet with date, time, position, depth and in situ observations for each grab sampling attempt (see **Appendix A**). Sediment descriptions, descriptions of sediment features (e.g. worm tubes) or biota were also noted, along with type(s) of sample collected for each attempt. Contaminants samples were taken from the surface (upper approximately 5 cm) of sediment from two replicate grab samples per sampling site, where possible. Sediment within the grab was carefully removed and transferred to a glass bowl using plastic sampling utensils that had been pre-cleaned with Decon 90. Sediment within 5 mm of the side of the grab was not sampled to minimise risk of contamination. The sediment was then carefully homogenised in the glass bowl before transfer to appropriate sample jars.

Two replicate grabs samples were collected from which 70 ml of sediment were collected for metals, nutrients and TOC. A 150 ml sample was collected for hydrocarbons and TBT, with 250 ml collected for naturally occurring radioactive materials (NORMs). These samples were processed on board the vessel by filling sample jars to the neck, leaving minimal sufficient air space to allow expansion of the frozen sediment. The contaminants sampling did not require the full sample surface, which allowed collection of a representative PSD sample from one of the same grab samples as the contaminants. A single replicate 300–500 ml sample of sediment was collected for particle size distribution (PSD) analysis, placed in a plastic ziplock bag and frozen.

A third replicate comprising a whole grab sample was collected for infaunal analysis and transferred into a 500 µm box sieve. The sample was then photographed with a slate identifying sample site name and date in view, and then sieved by washing through with seawater from a deck hose. The potential risk of transfer of pelagic biota >500 µm into the sample from the deck hose during processing is mitigated through rationalisation of pelagic biota out of the dataset prior to analysis (**Section 2.2.4**). The remaining material in the sieve was transferred to ziplock bags, into which 80% ethanol was then added. The sample was then gently mixed to make sure that the preservative adequately penetrated the sediment.

Samples were stored in laboratory-supplied jars or ziplock bags, and labelled with the site name, replicate number, the date and time of sampling, and the analysis required. An additional label on waterproof paper was added into the infaunal sample to mitigate for risk of the ethanol degrading the external label during processing. All samples were preserved and handled in accordance with the requirements of the analytical laboratories.

The location of the sampling sites was considered remote and, therefore, the preservation techniques were selected to achieve the maximum holding times for each parameter (**Table 2-1**). For example, the holding time for total recoverable hydrocarbons (TRHs) is 14 days; therefore, these samples were transported to Perth and hand-delivered to the appropriate laboratory in time to meet the holding time requirements.

Samples were then stored appropriately until delivery to the appropriate National Association of Testing Authorities (NATA) accredited laboratory (**Table 2-2**), with supporting chain of custody form requesting the analysis required.

2.2.3 Sample analysis

Analytes and their respective laboratory limits of reporting (LOR), 99% species protection guideline trigger value (ANZECC & ARMCANZ 2000a) and low reliability values for contaminants having insufficient data to derive reliable national guidelines (ANZECC & ARMCANZ 2000b) are presented in **Table 2-1**. All geochemical analyses were undertaken using standard methods at NATA accredited laboratories.

Particle size distribution analysis of sediments was undertaken via laser diffraction and sieving. Full PSD analysis was completed for appropriate differentiation of coarse sediment components, which may be an important factor in an area with such a diverse range of particulate substrate habitats (from shallow offshore shoals to deep offshore sediments). This analysis consisted of:

i) Laser diffraction of particle sizes ≤500 µm. This characterised the finer sediments and allowed comparison with existing ConocoPhillips data.

ii) Wet/dry sieving of sediments for the following size classes: <500 µm, 500 µm, 1 mm, 2 mm, 4 mm, 8 mm and >16 mm (i.e. remaining fraction retained on the 16 mm sieve). This appropriately characterised the coarser component of sediments and allowed comparison with existing ConocoPhillips PSD data.

2.2.4 Data analysis

Sediment analyte concentrations were compared to ANZECC & ARMCANZ (2000b) trigger values for Western Australian tropical offshore sediments. All other values were compared to ANZECC & ARMCANZ (2000a) Interim Sediment Quality Guideline (ISQG) low reliability trigger values for marine sediments with a 99% level of species protection where available. Where no ANZECC & ARMCANZ ISQG trigger value is available, comparison was made with other guideline levels, i.e. the National Assessment Guidelines for Dredging (NAGD) where relevant (Commonwealth of Australia 2009).

Multivariate analysis of data was undertaken using the Plymouth Routines In Multivariate Ecological Research (PRIMER) v6 software (Clarke and Gorley 2006). The DIVERSE routine was used to provide the descriptive statistics of infaunal data for each sample collected. After appropriate transformation / normalisation, resemblance matrices were derived using either Bray-Curtis (for infauna) or Euclidean distance (for environmental data). The “Cluster” routine with SIMPROF (similarity profile) permutational tests were used to identify groupings of samples based on survey data. Non-metric Multi-Dimensional Scaling (n-MDS) was used to represent the distribution of samples in 2-dimensional space, and therefore represent the relative similarity (or dissimilarity) of samples to each other. The principal components analysis (PCA) routine was used to further analyse environmental data to determine the effect of input variables (e.g. principal sediment components such as %silt, %sand or %gravel) on the distribution of the sample data in the PCA plot. The Bio-Env option in the Bio-Env and stepwise (BEST) routine was used to determine the environmental variables that had the greatest influence on the distribution of infaunal data. Following this step the Relate routine was used to determine the statistical significance of the combination of variables identified from the BEST analysis.

The physical character of sediments from each sample was then described in terms of the Folk sediment classification, skewness, kurtosis, and sorting. These data facilitate the understanding of the relationship between physical sediment characteristics and other data from the same site (e.g. contaminants, biota).

Infaunal data were rationalised prior to analysis. Taxa were checked for correct nomenclature and full taxonomic classification using the “match taxa” tool provided by the World Register of Marine Species (2015). Following this step, the taxa were then reviewed for the occurrence of pelagic taxa (e.g. Ctenophores, Chaetognatha) that often appear in grab samples but do not represent the benthic ecological community. If pelagic taxa were identified in the infaunal dataset, they were excluded from statistical analysis as “ecological noise”. Similarly, all individuals identified as “juveniles” were excluded. Juvenile stages are ephemeral and can exhibit significant post-settlement mortality (OSPAR Commission 2003). Inclusion of juvenile life stages can dominate the analysis due to the impact on abundance of relevant species, and the ephemeral nature of juveniles provides an unrealistic assessment of the benthic infaunal communities at the sample location. This can either generate or mask trends in change in benthic communities over time.

Table 2-1: Analytical LOR, guideline trigger values and sample storage, preservation and holding times

Test parameter	Guideline[1]	LOR	Storage container	Preservation	Holding time
Aluminium (Al) (mg/kg DW)	No value	<20	Glass jar	Freeze	180 days
Arsenic (As) (mg/kg DW)	20	<2	Glass jar	Freeze	180 days
Barium (Ba) (mg/kg DW)	No value	<0.1	Glass jar	Freeze	180 days
Cadmium (Cd) (mg/kg DW)	1.5	<0.1	Glass jar	Freeze	180 days
Chromium (Cr) (mg/kg DW)	80	<0.2	Glass jar	Freeze	180 days
Cobalt (Co) (mg/kg DW)	1.0[2]	<0.2	Glass jar	Freeze	180 days
Copper (Cu) (mg/kg DW)	65	<0.2	Glass jar	Freeze	180 days
Iron (Fe) (mg/kg DW)	No value	<5	Glass jar	Freeze	180 days
Mercury (Hg) (mg/kg DW)	0.15	<0.01	Glass jar	Freeze	28 days
Nickel (Ni) (mg/kg DW)	21[2]	<0.7	Glass jar	Freeze	180 days
Lead (Pb) (mg/kg DW)	50	<1	Glass jar	Freeze	180 days
Zinc (Zn) (mg/kg DW)	200	<0.5	Glass jar	Freeze	180 days
Tributyltin (TBT) (µg Sn/kg DW)[3]	9	<0.5	Glass jar	Freeze	56 days
TRH (C_{10}–C_{36}) (mg/kg DW)[3]	550[4]	<3 - <50	Glass jar	Freeze	14 days
Total PAHs (µg/kg DW)[3]	10,000	<3 - <10	Glass jar	Freeze	180 days
BTEXN (µg/g DW)[3]	5–500[2]	<0.2 - <1	Glass jar	Freeze	14 days
$Radium^{226}$ (Bq/g DW)		<0.03	Glass jar	Freeze	180 days
$Radium^{228}$ (Bq/g DW)	35 combined	<0.03	Glass jar	Freeze	180 days
$Thorium^{228}$ (Bq/g DW)		<0.03	Glass jar	Freeze	180 days
Total Kjeldahl nitrogen (TKN) (%)	N/A	<0.1	Glass jar	Freeze	14 days
Total phosphorus (TP) (%)	N/A	<0.05	Glass jar	Freeze	14 days
Total organic carbon (TOC) (%)	N/A	<0.2	Glass jar	Freeze	14 days
Moisture content (%)	N/A	N/A	Glass jar	Freeze	N/A
PSD	N/A	N/A	Plastic ziplock bag	Freeze	N/A
Infauna	N/A	N/A	Plastic ziplock bag	80% ethanol	N/A

[1] ANZECC & ARMCANZ (2000a) 99% species protection value unless otherwise specified
[2] ANZECC & ARMCANZ (2000b) ISQG-low reliability trigger value
[3] Normalised to 1% organic carbon
[4] National Assessment Guidelines for Dredging (NAGD) Guidance Levels (Commonwealth of Australia 2009)[a]
mg/kg = milligrams per kilogram, DW = dry weight, Bq/g = Becquerel per gram, µg = microgram, N/A = Not applicable

Table 2-2: Analytes and the corresponding analytical laboratory

Parameter	Laboratory
Metals and metalloids (Al, As, Ba, Cd, Cr, Co, Cu, Fe, Hg, Ni, Pb, Zn)	MAFRL[1]
Nutrients (TKN, TP)	MAFRL
Total organic carbon (TOC)	MAFRL
Particle size distribution (PSD)	MAFRL
Total recoverable hydrocarbons (TRHs)	ALS[2]
Benzene, toluene, ethylbenzene, xylenes (meta-, para- and ortho-xylene) and naphthalene (BTEXN)	ALS
Polycyclic aromatic hydrocarbons (PAHs; only where TPHs detected)	ALS
Tributyltin (TBT)	ALS
NORMs ($radium^{226}$, $radium^{228}$ and $thorium^{228}$)	Radiation Safety Services
Infaunal taxonomy	Dardanus Scientific

[1] MAFRL – Marine and Freshwater Research Laboratory
[2] ALS – Australian Laboratory Services

2.2.5 Quality control procedures

To test for potential sample contamination during collection, storage or transport, low analyte concentration water samples were provided by the laboratories to be split in two ways:

- transport blank: to estimate any contamination introduced to the sample during the transportation and storage stage, low analyte water was poured directly into the sample containers on site
- field blank: to estimate any contamination introduced to the sample during the collection procedure. This involved following the same sampling procedure using the low analyte water instead of the sample sediment.

Quality control procedures that related to the sediment sampling were:

- sun cream/zinc and any other potential anthropogenic contaminants were avoided by the personnel in contact with the sediment sampling equipment
- smoking was prohibited in the sampling area
- Decon 90-cleaned latex gloves were worn at all times when handling sediment samples. Gloves were cleaned between each replicate.
- sampling utensils (i.e. plastic spoons, glass bowls) were Decon 90-cleaned between replicates just prior to taking samples
- samples were processed on an open area of the deck as far from sources of potential contamination (e.g. the A-frame, vessel exhaust fumes) as possible
- as far as possible, the insides of the sample jar and did not come in contact with any potentially contaminated surfaces or substances (such as hands, workbenches or vessel emissions)
- hands did not come into contact with the insides or lip of the sample jars.

Procedural and record-keeping quality control measures implemented were:

- global positioning system (GPS) waypoints were recorded for all sampling attempts from the vessel when the grab reached the sea bed
- water depths, times, dates, samples collected and in situ observations were also recorded onto field logsheets
- photographs were taken of sediment samples collected
- appropriate chain of custody forms to accompany samples were completed for each laboratory
- any changes to the field procedures were documented.

2.3 Sediment Profile Imagery

2.3.1 Deployment and image capture

Due to incoming poor weather, the Sediment Profile Imagery (SPI) camera system (**Figure 2-3**) was deployed only at site SP3 in the permit area (**Figure 2-2**).

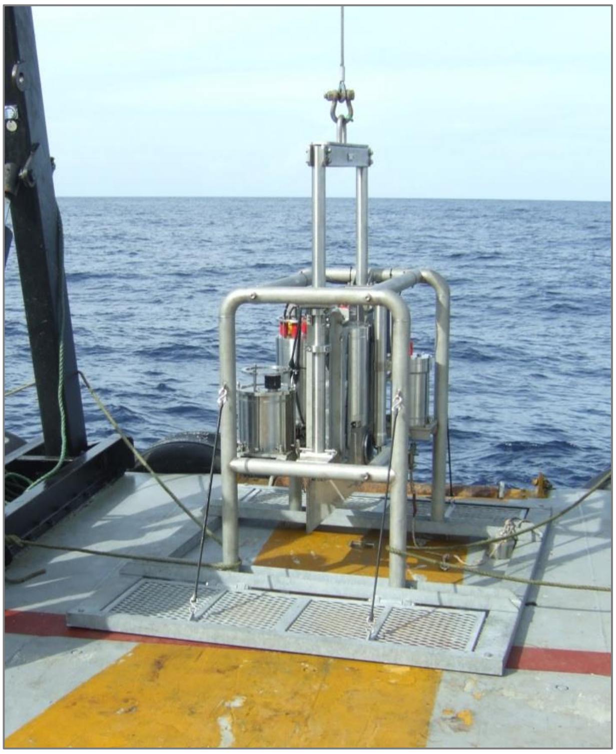


Figure 2-3: SPI system prior to deployment

The SPI system was deployed from the A-frame, and once on the seabed it was left to rest for one minute to allow the profile image to be taken. Time, depth and position were taken each time the SPI was on the seabed. The SPI was then raised approximately 5 m from the seabed and held for one minute to allow the electronics to re-set. The unit was then lowered to the seabed. This was repeated to allow five photograph attempts on the seabed. The unit was then raised to the surface and images checked and downloaded on deck. Three independent images were successfully collected at this site. Deteriorating weather conditions and work priorities did not allow for further deployment at other sites. Once downloaded, images were backed up on an external hard drive for return to Perth.

2.3.2 Image analysis

Images were subject to quality assurance/quality control (QA/QC) procedures, then analysed in the office for the following parameters:

- depth of penetration of the prism
- sediment surface features
- depth of the apparent Redox Potential Discontinuity (aRPD)
- occurrence of methane gas pockets
- bioturbation, including burrows and feeding voids
- Benthic Habitat Quality (BHQ) index
- successional stage (based on BHQ index scores, after Nilsson and Rosenberg (2000)
- average particle size (diameter).

3. Results

3.1 Sediment quality

Sediment survey logs, showing sampling data for all sampling attempts (e.g. date, geographic position, sample descriptions) can be found in **Appendix A**. Photographs of sediment samples can be found in **Appendix B**. A summary of samples collected is presented in **Table 3-1**.

Table 3-1: Number of replicate samples successfully collected at each site

Site	Latitude[2]	Longitude[2]	Metals	Hydrocarbons	NORMs	PSD	Infauna
SP1	-9.725 °	130.482 °	2	2	2	1	1
SP2	-9.749 °	130.342 °	2	2	2	1	1
SP3	-9.762 °	130.180 °	2	2	2	1	1
SP4[1]	-9.905 °	130.179 °	1	1	1	1	0
SP5[1]	-9.888 °	130.405 °	2	2	2	1	1
SP6E	-9.812 °	129.968 °	2	2	2	1	1
SP7	-9.917 °	129.561 °			NS		
SP8	-9.952 °	129.535 °	2	2	2	1	1
SP9	-9.939 °	129.603 °	1	0	0	1	0
SP10N	-9.857 °	129.535 °	2	2	2	1	1
SP11	-10.133 °	129.550 °			NS		
SP12	-10.064 °	129.478 °	2	2	2	1	1
SP13	-10.196 °	129.663 °	2	2	2	1	1
SP14	-10.249 °	129.768 °	2	2	2	1	1
SP15	-10.009 °	130.778 °	2	2	2	1	1
SP16	-10.027 °	130.810 °			NS		
SP17[1]	-10.041 °	130.838 °	1	1	1	1	0

[1] Samples at SP4, SP5 and SP17 were collected using the 0.2 m^2 van Veen grab. All other samples were collected using the 0.1 m^2 van Veen grab.

[2] GPS co-ordinates presented in decimal degrees. Datum used was WGS84.

NS = No sample

Samples were not collected at sites SP7, SP11 and SP16 due to the occurrence of BPPH. Benthic habitat surveys at SP11 and SP16 had previously collected imagery of benthic habitats, and GoPro imagery was collected at site SP7. Grab sampling at these locations posed a high risk of environmental damage, with low or negligible chance of sampling success (**Figure 3-1**). GoPro imagery was also captured at SP8 as this was less than 100 m water depth, but in this case the substrate was identified as being suitable for sampling (**Figure 3-2**).

Sites SP6 and SP10 were relocated by at least 500 m due to three failed grab sampling attempts at the original locations. These sites were moved to the east and north, and hence renamed SP6E and SP10N, respectively.

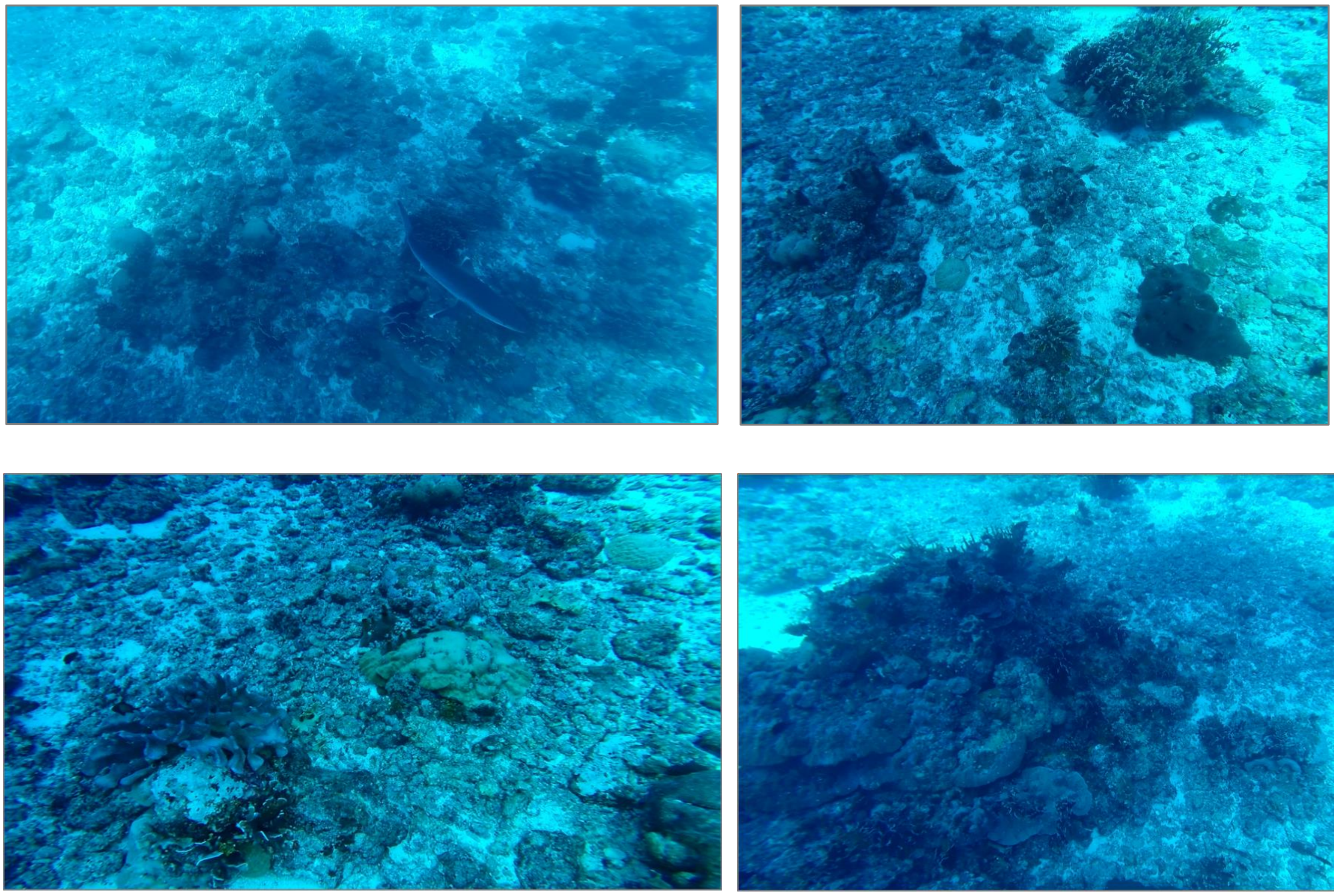


Figure 3-1: Hard substrate coral and sponge habitats at site SP7

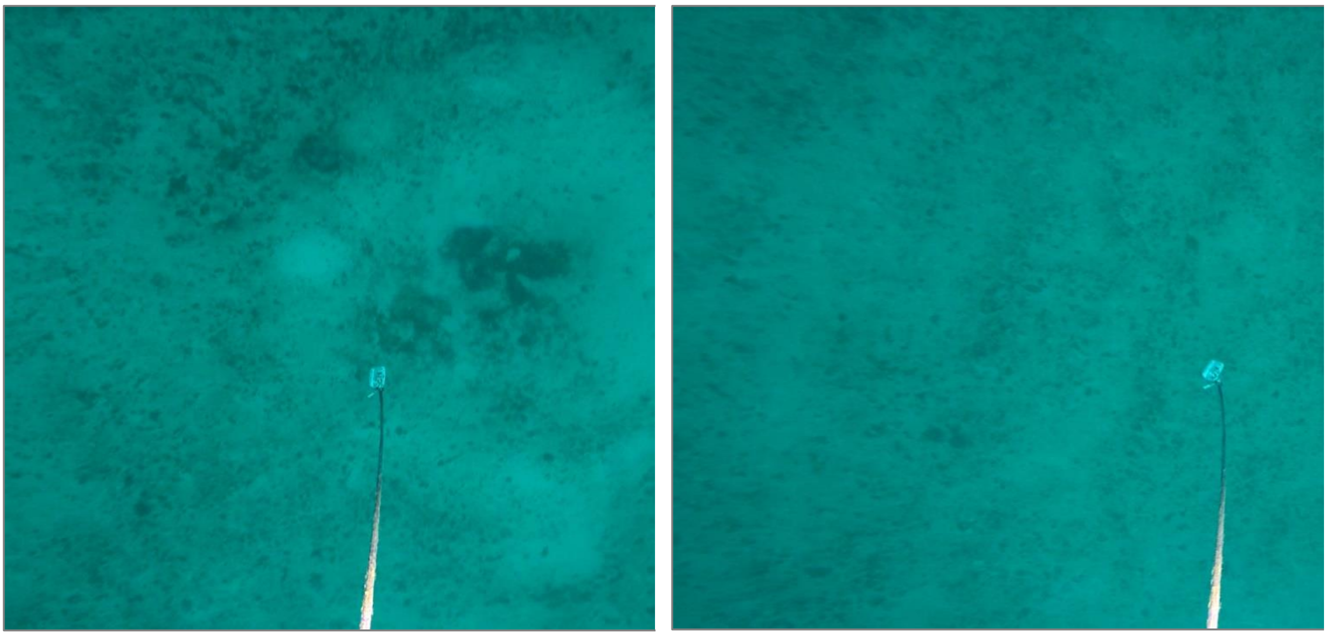


Figure 3-2: Sediment suitable for sampling at site SP8

3.1.1 Metals and metalloids

Of the total metals/metalloids in the sediments sampled from the permit area, Evans Shoal, Tassie Shoal and Lynedoch Bank sites, only cobalt and nickel were recorded were above the ANZECC & ARMCANZ (2000b) ISQG-low reliability trigger value, where trigger values were available (**Table 3-2**). Cobalt was recorded up to seven-fold above the ISQG-low reliability trigger value level of 1.0 mg/kg at all sites except SP8. Nickel concentrations were recorded at or slightly above the ISQG-low trigger value (21 mg/kg DW) at two of the sites (SP1 and SP2). It should be noted that cobalt and nickel (both of which are often strongly associated) tend to complex strongly with organic molecules and are likely to be largely unavailable for biological uptake (Wenziker et al. 2006). None of these levels of cobalt and nickel are indicative of contamination and can be considered to represent the locally specific, naturally occurring background concentrations. High levels of cobalt and nickel are commonly found in sediments in Australia (Commonwealth of Australia 2009).

Concentrations of the metals and metalloids aluminium, barium, chromium, cobalt, copper, iron, mercury, nickel, lead and zinc were generally 2–3 times greater in the deep water permit area than in the shallow water sediments at the shoals.

Total arsenic concentrations were similar at all stations of all the permit area, Evans Shoal, Tassie Shoal and Lynedoch Bank sites and ranged from 3 to 5 mg/kg, well below the ANZECC & ARMCANZ (2000b) ISQG-low reliability trigger value of 20 mg/kg.

Total cadmium concentrations ranged from 0.1 to 0.3 mg/kg at all sites, well below the ANZECC & ARMCANZ (2000b) ISQG-low reliability trigger value of 1.5 mg/kg.

Table 3-2: Total metal and metalloid concentrations

Parameter	Aluminium	Arsenic	Barium	Cadmium	Chromium	Cobalt	Copper	Iron	Mercury	Nickel	Lead	Zinc
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Limit of reporting	<20	<2	<0.1	<0.1	<0.2	<0.2	<0.2	<5	<0.01	<0.7	<1	<0.5
Guideline[1]	No value	20	No value	1.5	80	1.0	65	No value	0.15	21	50	200
Site												
SP1 1[2]	15000	3	21	0.3	28	**6.7**[3]	13	16000	0.03	21	6	48
SP1 2	16000	3	21	0.2	29	**7.2**	14	16000	0.03	21	6	47
SP2 1	16000	2	33	0.2	31	**7.5**	15	16000	0.03	**23**	7	51
SP2 2	16000	2	29	0.3	31	**7.1**	14	16000	0.03	**23**	7	50
SP3 1	14000	2	23	0.3	27	**6.5**	11	15000	0.03	19	6	46
SP3 2	13000	2	25	0.2	25	**6.2**	10	15000	0.04	17	5	43
SP4 1	9300	3	9.1	0.2	27	**5.6**	4.7	17000	0.03	14	5	51
SP5 1	8400	2	11	0.2	20	**4.7**	5.3	13000	0.02	11	4	38
SP5 2	8200	3	12	0.2	21	**4.9**	5.5	13000	0.03	12	5	40
SP6E 1	8300	3	14	0.2	20	**4.9**	5.6	13000	0.03	12	4	36
SP6E 2	9400	3	15	0.1	22	**5.2**	6.0	13000	0.03	12	4	38
SP8 1	560	2	5.6	0.2	5.0	0.7	0.9	520	<0.01	1.1	<1	2.3
SP8 2	550	3	5.9	0.2	5.2	0.7	1.0	550	<0.01	1.3	1	2.3
SP9 1	2000	5	7.0	0.2	7.4	**1.9**	1.7	2800	<0.01	4.2	4	6.9
SP10N 1	2900	4	7.8	0.2	7.9	**1.8**	2.4	3900	0.01	4.6	3	10
SP10N 2	3100	3	7.7	0.3	8.5	**1.7**	2.5	4300	0.01	4.5	3	11
SP12 1	4200	3	21	0.3	10	**2.1**	2.6	5300	0.01	5.4	2	11
SP12 2	4400	4	28	0.2	11	**2.1**	3.0	5800	0.01	5.7	2	12
SP13 1	3300	3	9.8	0.2	8.9	**1.8**	1.8	4200	<0.01	4.6	2	8.5
SP13 2	2700	3	9.4	0.2	7.7	**1.5**	1.6	3500	<0.01	3.7	2	7.3
SP14 1	4600	3	8.7	0.2	11	**2.3**	2.7	5800	0.01	6.1	3	13
SP14 2	4500	3	8.1	0.2	11	**2.3**	2.7	5800	0.01	5.9	3	12
SP15 1	3400	4	8.8	0.2	7.7	**1.9**	2.9	5500	<0.01	5.1	3	11
SP15 2	2800	5	8.4	0.2	7.2	**1.8**	2.6	5000	<0.01	5.0	2	9.8
SP17 1	5500	3	8.0	0.3	11	**3.1**	3.5	7600	<0.01	7.2	3	18

[1] See **Table 2-1** for information on guidelines.
[2] SP1 1 refers to replicate 1 at site SP1
[3] Values in bold exceed the relevant guideline value

3.1.2 Tributyltin

Tributyltin concentrations at all sites were below the limit of reporting (LOR) (**Table 3-3**) and hence well below the ANZECC & ARMCANZ (2000b) ISQG-low reliability trigger value of 9 µgSn/kg. Monobutyltin and dibutyltin concentrations were also below the LOR. Tripropyltin concentrations ranged from 8.8% at SP3 to 100% at SP6E. There are no guideline values for monobutyltin, dibutyltin or tripropyltin.

Table 3-3: Monobutyltin, dibutyltin, tributyltin and tripropyltin concentrations

Parameter	Monobutyltin	Dibutyltin	Tributyltin	Tripropyltin
Units	µgSn/kg	µgSn/kg	µgSn/kg	%
Limit of reporting	1	1	0.5	0.1
Guideline[1]	N/A	N/A	9	N/A
Site				
SP1 1	<1	<1	<0.5	86.8
SP1 2	<1	<1	<0.5	68.2
SP2 1	<1	<1	<0.5	12.2
SP2 2	<1	<1	<0.5	74.1
SP3 1	<1	<1	<0.5	8.8
SP3 2	<1	<1	<0.5	66.6
SP4 1	<1	<1	<0.5	79.2
SP5 1	<1	<1	<0.5	92.2
SP5 2	<1	<1	<0.5	83.5
SP6E 1	<1	<1	<0.5	89.9
SP6E 2	<1	<1	<0.5	100
SP8 1	<1	<1	<0.5	69.8
SP8 2	<1	<1	<0.5	20.1
SP9 1	NS[2]	NS	NS	NS
SP10N 1	1	<1	<0.5	97.2
SP10N 2	<1	<1	<0.5	99.1
SP12 1	<1	<1	<0.5	85.5
SP12 2	<1	<1	<0.5	95.0
SP13 1	<1	<1	<0.5	54.8
SP13 2	<1	<1	<0.5	87.2
SP14 1	<1	<1	<0.5	88.2
SP14 2	<1	<1	<0.5	70.7
SP15 1	<1	<1	<0.5	80.3
SP15 2	<1	<1	<0.5	69.8
SP17 1	<1	<1	<0.5	86.8

[1] ANZECC & ARMCANZ (2000b) ISQG-Low reliability trigger value
[2] NS = No sample

3.1.3 Hydrocarbons

Historically, total petroleum hydrocarbons (TPHs) were analysed according to carbon chains C_6–C_9, C_{10}–C_{14}, C_{15}–C_{28} and C_{29}–C_{36}. In an attempt to incorporate health and ecological screening levels for petroleum hydrocarbons, the National Environment Protection Council released draft National Environment Protection Measures (NEPC 2013) that resulted in changes in the carbon chain divisions considered. This was based on analytical factors such as physical and chemical properties and the availability of toxicity data. This new analysis of hydrocarbons is called total recoverable hydrocarbons (TRHs) and includes benzene, toluene, ethylbenzene, meta-, para-, and ortho-xylene and naphthalene (BTEXN).

TPH, TRH and BTEXN concentrations were below the laboratory LOR at all sites and depths in and around the Permit Zone, Evans Shoal, Tassie Shoal and Lynedoch Bank (**Table 3-4**). Consequently, polycyclic aromatic hydrocarbons (PAHs) were not analysed.

Table 3-4: Total petroleum hydrocarbons, total recoverable hydrocarbons and BTEXN (in mg/kg DW) at site SP1

Compound[1]	LOR[2]	SP1 1	SP1 2	SP2 1	SP2 2	SP3 1	SP3 2	SP4 1	SP5 1	SP5 2	SP6E 1	SP6E 2	SP8 1	SP8 2	SP9 1	SP10N 1	SP10N 2	SP12 1	SP12 2	SP13 1	SP13 2	SP14 1	SP14 2	SP15 1	SP15 2	SP17 1
Moisture content (%)	1.0a	62.7	63.3	65.5	63.7	60.4	62.7	45.5	50.1	50.8	52.2	52.9	29.0	28.7	NS[3]	33.2	36.3	40.6	41.7	34.0	30.4	40.0	39.7	31.8	29.4	42.7
TPH[3]																										
C_6–C_9	10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	NS	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
C_{10}–C_{14}	3	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	NS	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
C_{15}–C_{28}	3	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	NS	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
C_{29}–C_{36}	5	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	NS	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8
C_{10}–C_{36} (sum)	3	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	NS	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
TRH[3]																										
C_6–C_{10}	10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	NS	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
C_6–C_{10} minus BTEX	10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	NS	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
>C_{10}–C_{16}	3	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	NS	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
>C_{10}–C_{16} fraction minus naphthalene	50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	NS	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
>C_{16}–C_{34}	3	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	NS	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
>C_{34}–C_{40}	5	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	NS	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8
>C_{10}–C_{40} (sum)	3	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	NS	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
BTEXN																										
Benzene	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	NS	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	NS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	NS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
meta-& para-xylene	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	NS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ortho-xylene	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	NS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total xylenes	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	NS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Sum of BTEX	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	NS	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	NS	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

[1] in mg/kg
[2] Limit of reporting
[3] NS = No sample

3.1.4 Naturally occurring radioactive materials

Radium^{226} was found above the laboratory minimum reporting limit (MRL) in three samples – SP4 1, SP6E 1 and SP6E 2 (**Table 3-5**). Radium^{228} and thorium^{228} concentrations were all below the MRL at all sites. All of these NORMs were below the ANZECC & ARMCANZ (2000b) ISQG-low reliability trigger value for radionuclides (sum of gross alpha and gross beta) of 35 Bq/g at all sampling sites.

Table 3-5: Naturally occurring radioactive materials

Parameter	Radium^{226}	Radium^{228}	Thorium^{228}
Units	Bq/g	Bq/g	Bq/g
MRL	0.03	0.03	0.03
Site			
SP1 1	<0.03	<0.03	<0.03
SP1 2	<0.03	<0.03	<0.03
SP2 1	<0.03	<0.03	<0.03
SP2 2	<0.03	<0.03	<0.03
SP3 1	<0.03	<0.03	<0.03
SP3 2	<0.03	<0.03	<0.03
SP4 1	0.068	<0.03	<0.03
SP5 1	<0.03	<0.03	<0.03
SP5 2	<0.03	<0.03	<0.03
SP6E 1	0.041	<0.03	<0.03
SP6E 2	0.034	<0.03	<0.03
SP8 1	<0.03	<0.03	<0.03
SP8 2	<0.03	<0.03	<0.03
SP9 1	NS	NS	NS
SP10N 1	<0.03	<0.03	<0.03
SP10N 2	<0.03	<0.03	<0.03
SP12 1	<0.03	<0.03	<0.03
SP12 2	<0.03	<0.03	<0.03
SP13 1	<0.03	<0.03	<0.03
SP13 2	<0.03	<0.03	<0.03
SP14 1	<0.03	<0.03	<0.03
SP14 2	<0.03	<0.03	<0.03
SP15 1	<0.03	<0.03	<0.03
SP15 2	<0.03	<0.03	<0.03
SP17 1	<0.03	<0.03	<0.03

NS = No sample

3.1.5 Nutrients

Total Kjeldahl nitrogen (TKN) concentrations ranged from 0.2 mg N/g at SP8 and SP13, to 2.1 mg N/g at SP2 (**Table 3-6**). TKN concentrations were generally greatest in the northern permit area, 2–3 times lower in the southern permit area, and lowest (4–10 times lower) in the vicinity of the shoals.

Total phosphorus (TP) concentrations ranged from 0.31 mg P/g at SP8 to 2.8 mg P/g at SP4. The spatial pattern in distribution of TP concentrations was less clear than for other nutrients, with greatest concentrations (with the exception of SP4) occurring at sites SP12 to SP17 (at Tassie Shoal and Lynedoch Bank), lower concentrations in the permit area and deeper waters adjacent to the shoals (except SP4) and lowest concentrations at SP8 on Evans Shoal.

Total organic carbon (TOC) concentrations ranged from <0.2% at SP13 (below the laboratory LOR) to 1.5% at SP2. TOC levels were 3–5 times higher in the northern (deeper) permit area.

There are no ANZECC & ARMCANZ (2000a, b) trigger values for nutrients.

Table 3-6: Nutrient concentrations

Parameter	TKN	TP	TOC
Units	mg N/g	mg P/g	% C
LOR	<0.1	<0.05	<0.2
Guideline	N/A	N/A	N/A
Site			
SP1 1	1.9	0.74	1.4
SP1 2	2.0	0.78	1.4
SP2 1	2.1	0.78	1.5
SP2 2	2.1	0.78	1.5
SP3 1	1.6	0.81	1.2
SP3 2	1.5	0.80	1.1
SP4 1	0.5	2.8	0.4
SP5 1	0.6	0.98	0.5
SP5 2	0.7	0.89	0.5
SP6E 1	0.8	1.6	0.6
SP6E 2	0.9	1.6	0.6
SP8 1	0.2	0.31	0.3
SP8 2	0.3	0.31	0.2
SP9 1	0.3	0.79	0.2
SP10N 1	0.3	0.79	0.2
SP10N 2	0.3	0.90	0.3
SP12 1	0.4	1.2	0.3
SP12 2	0.5	1.1	0.4
SP13 1	0.2	1.4	0.2
SP13 2	0.2	1.4	<0.2
SP14 1	0.4	1.9	0.3
SP14 2	0.4	1.9	0.3
SP15 1	0.3	1.8	0.3
SP15 2	0.3	2.0	0.2
SP17 1	0.5	1.3	0.3

3.1.6 Multivariate analysis of sediment quality data

Data for metals/metalloids and nutrients were combined and normalised for multivariate analysis. Data that were consistently or wholly below the laboratory LOR or MRL (i.e. TBT, TPH, TRH, BTEXN and NORMs) were excluded from the analysis. Analysis using PRIMER v6 was based on Euclidean distance resemblance. Cluster analysis with SIMPROF identified five significant groups derived from the sediment quality variables analysed (**Figure 3-3** and **Figure 3-4**):

1. Group A corresponded to the northern (deepest) permit area sites
2. Group B included the southern permit area sites (SP4 and SP5) and SP6E (approximately 20 km west of the permit area)
3. Group C are from Tassie Shoal sites
4. Group D are from SP8 on Evans Shoal
5. Group E comprises samples from Evans Shoal, Tassie Shoal and Lynedoch Bank.

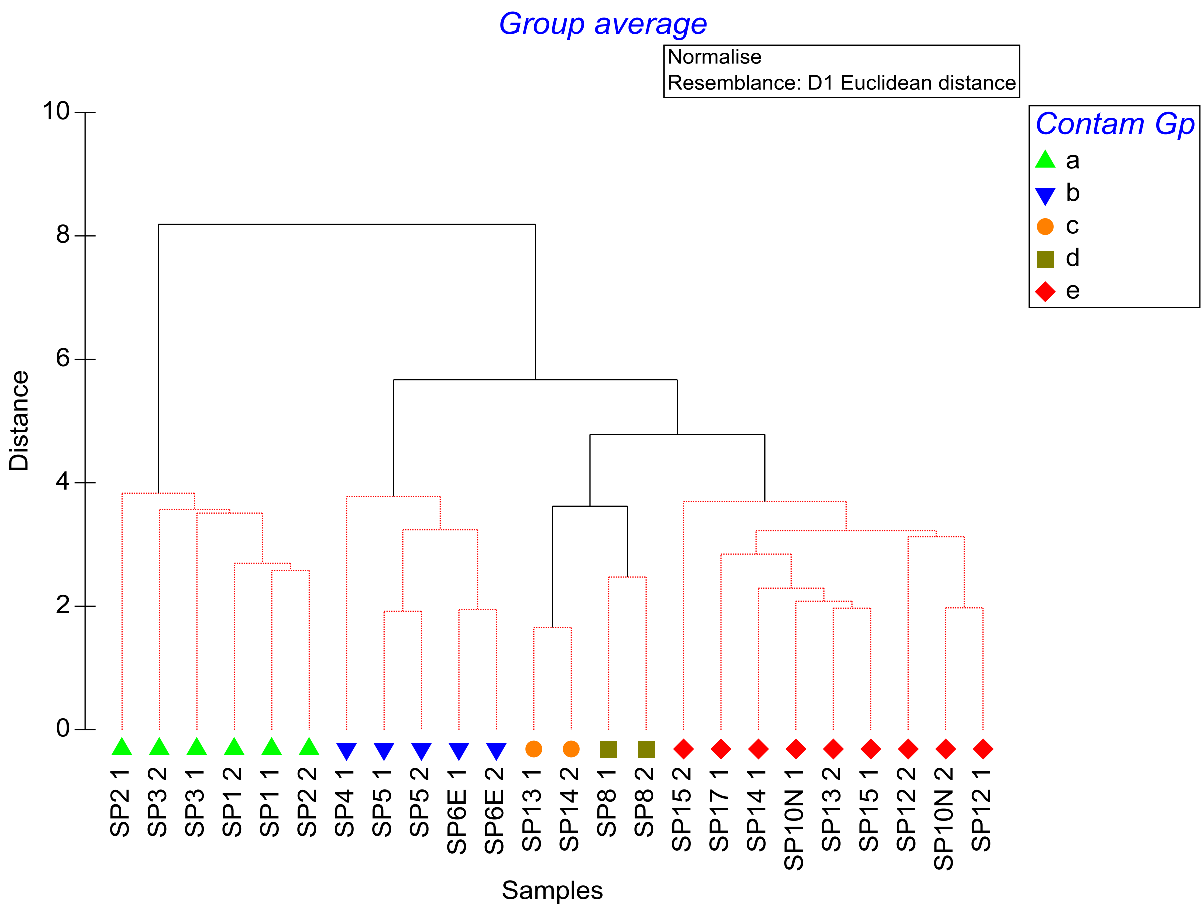


Figure 3-3: Grouping of sites based on similarity in sediment quality

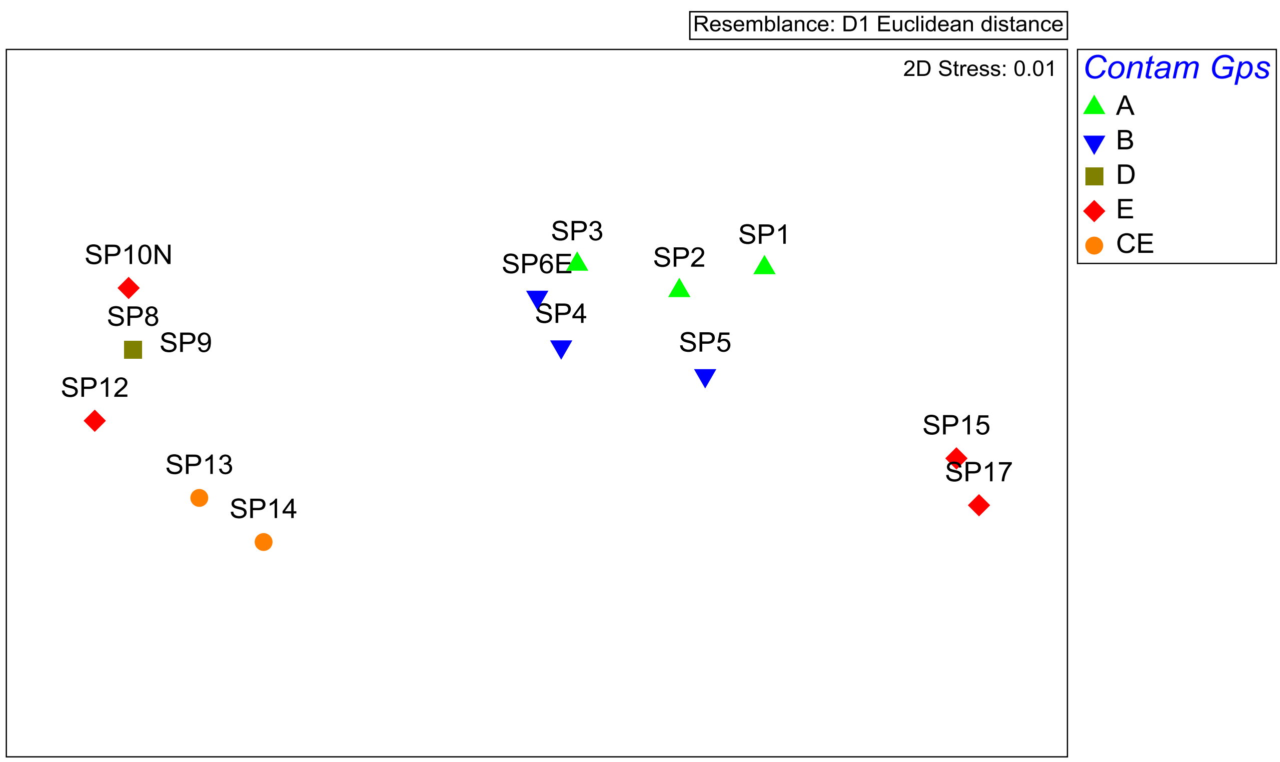


Figure 3-4: Distribution of sediment quality throughout the study area

3.1.7 Particle size distributions

Laboratory PSD results can be found in **Appendix C**. Prior to statistical analysis, data were analysed to characterise sediment samples in terms of Folk sediment classification, sorting, skewness and kurtosis (**Table 3-7**).

Folk sediment classifications provide a high-level description of sediment characteristics. The description is provided in the form of a code, which is made of abbreviations for principal sediment components. The code describes the sediment starting with the least characteristic component and finishing with the most characteristic component (which is capitalised), where:

m/M = muddy / Mud (which is synonymous with silt/clay)

s/S = sandy / Sand

g/G = gravelly or Gravel

() = slightly

For example:

(g)mS = slightly gravelly muddy Sand

smG = sandy muddy Gravel

Folk classifications ranged from sandy mud (sM) at SP2 in the northern (deepest) section of the permit area, to gravelly sand (gS) at SP8 and SP9 (Evans Shoal) (**Figure 3-5**). Folk classifications were also derived from the URS (2005) Caldita-1 pre-drilling environmental survey PSD data to increase the data density in the southern area between the permit area and the shoals. Although the Folk classifications from the Caldita-1 data (approximately 35 km south of the Barossa field) are likely to underestimate the gravel component due to the difference in PSD analysis method used, the data were generally a good fit and provide a useful contribution to the characterisation of the environment (**Figure 3-5**).

Sediments were found to contain a gravel component in the eastern permit area (SP1 and SP5) and became coarser towards the shoals (muddy sands as opposed to sandy muds) (Figure 3-5). Sites in and adjacent to the western permit area were also coarser than SP2, but lacked a gravel component (**Table 3-7**). Sediments were coarser in a southerly direction from the western permit area to Caldita (Caldita-1 is between C5000N to C5000S), transitioning from muddy sands to sands. Sediments at the shoals are generally slightly gravelly sands, with a >10% mud component on the shoal flats. Sites at the shallow shoals were gravelly sands, consisting of <10% mud component and >20% gravel.

Sorting describes the distribution of grain sizes within sediments. Poorly sorted sediments indicate that the sediment is comprised of a wide range of different particle sizes, whereas well sorted sediments are comprised of a small size range of similar particle sizes. This has implications for both the physico-chemical (e.g. pore water flow, oxygenation) and biological characteristics of sediments (based on available ecological niches, available oxygen, energy required to move through sediments, etc.). Sediments in the study area ranged from moderately sorted in the northern (deepest) part of the permit area (SP1 and SP2) to very poorly sorted at the shallow Evans Shoal sites (SP8 and SP9). All other sites were characterised as having poorly sorted sediments (**Table 3-7**)

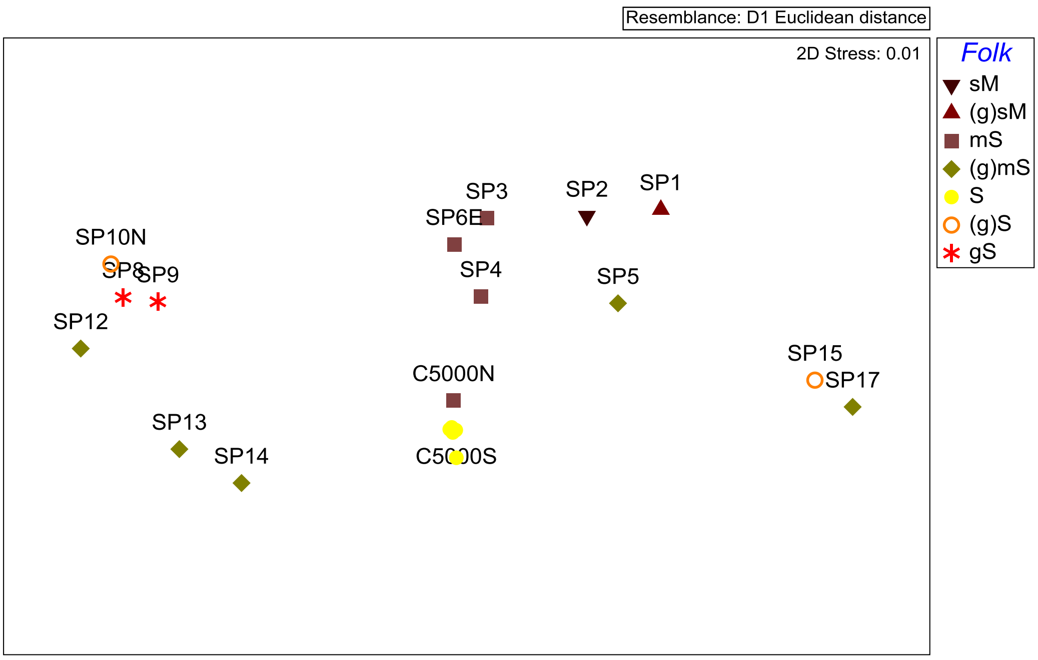
Skewness and kurtosis describe the distribution curve of the sediment particle size distribution, relative to the bell-shaped normal curve. Skewness describes dominance of finer (left or fine skewed) or coarser particle sizes (right or coarse skewed) in the sample, rather than an even distribution. Kurtosis describes the relative dominance of different particle sizes. A leptokurtic ("sharp" or "pointy") curve describes a sediment sample that is highly dominated by a small number of similar size classes. A platykurtic curve describes a sediment sample that has a relatively even representation of particle sizes across the size range. Sediments in the permit area ranged from strongly fine skewed and leptokurtic at SP2 to coarse skewed and mesokurtic at SP4 (**Table 3-7**)

Cluster analysis of Euclidean distance resemblance based on square root transformed PSD data identified four main groups of sediments (**Figure 3-6**). Group A consisted of the northern (deepest) permit area sites (SP1 to SP3). Group B consisted of the shallow Evans Shoal sites (SP9 and SP9) and the seaward shoal slope sites (SP10N and SP15). Group C was comprised of the remaining permit area sites (SP4 and SP5) and SP6E adjacent to the permit area. The final group (Group D) comprised of the shoal flat, Tassie Shoal and shallow Lynedoch Bank sites (SP12, SP13, SP14 and SP17, respectively). The spatial distribution of PSD groups is presented in **Figure 3-7**.

Two-dimensional n-MDS ordination (Figure 3-8) showed an almost linear pattern of distribution of the four groups of sites from the coarsest sediments on the left and the finest sediments on the right.

Table 3-7: Sediment sample particle size characteristics

Site	% Silt/clay (<63 µm)	% Sand (0.063–4 mm)	% Gravel (4–64 mm)	Folk classification	Sorting	Skewness	Kurtosis[1]
SP1	56.99	42.88	0.13	(g)sM	Moderately sorted	Strongly fine skewed	Mesokurtic
SP2	66.35	33.65	0.00	sM	Moderately sorted	Strongly fine skewed	Leptokurtic
SP3	45.16	54.84	0.00	mS	Poorly sorted	Strongly fine skewed	Platykurtic
SP4	16.45	83.55	0.00	mS	Poorly sorted	Coarse skewed	Mesokurtic
SP5	24.65	75.30	0.05	(g)mS	Poorly sorted	Symmetrical	Platykurtic
SP6E	26.21	73.79	0.00	mS	Poorly sorted	Symmetrical	Platykurtic
SP8	4.88	71.48	23.64	gS	Very poorly sorted	Fine skewed	Platykurtic
SP9	5.47	67.37	27.15	gS	Very poorly sorted	Fine skewed	Platykurtic
SP10N	5.93	93.02	1.04	(g)S	Poorly sorted	Symmetrical	Leptokurtic
SP12	15.99	83.59	0.42	(g)mS	Poorly sorted	Fine skewed	Platykurtic
SP13	10.94	87.66	1.39	(g)mS	Poorly sorted	Symmetrical	Platykurtic
SP14	12.36	86.59	1.04	(g)mS	Poorly sorted	Symmetrical	Mesokurtic
SP15	5.93	90.34	3.73	(g)S	Poorly sorted	Fine skewed	Mesokurtic
SP17	13.76	85.94	0.29	(g)mS	Poorly sorted	Fine skewed	Mesokurtic



NB: Includes PSD data from Caldita-1 (C5000N and C5000S) (URS 2005)

Figure 3-5: Distribution of Folk sediment classifications throughout the sampling area

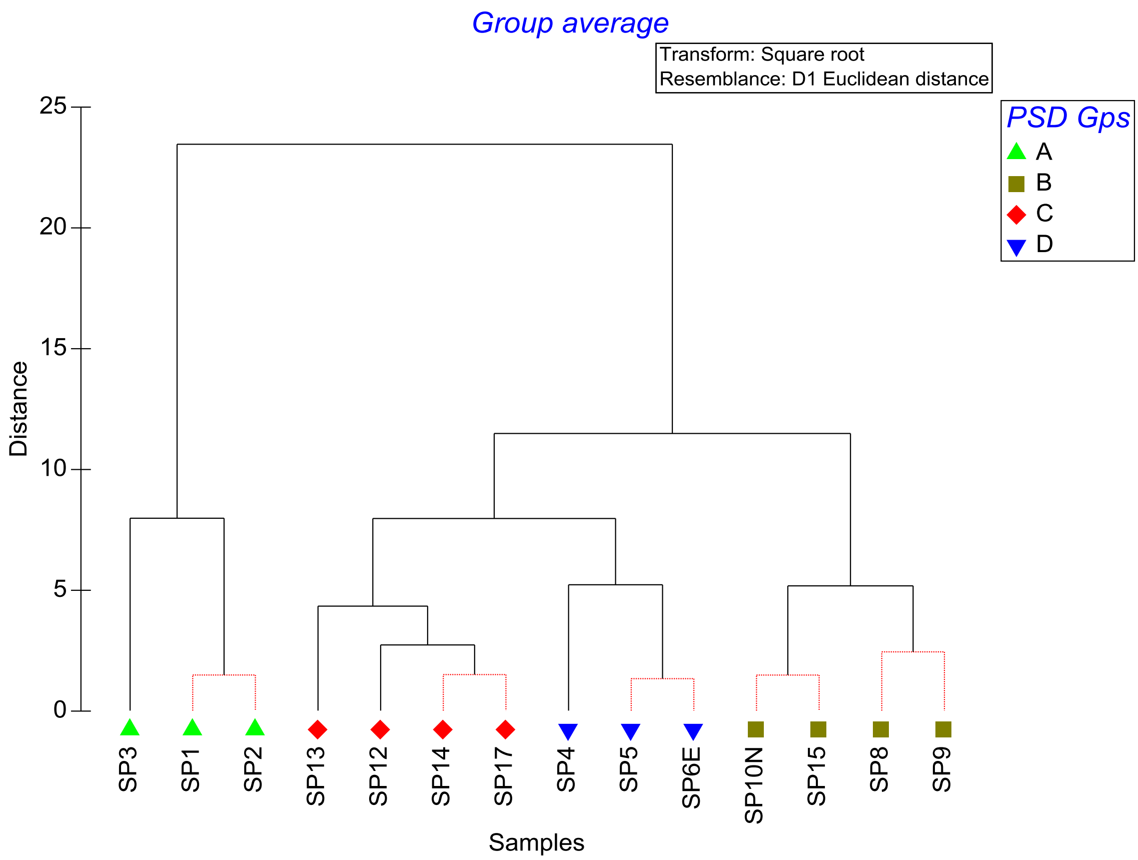


Figure 3-6: Grouping of sites based on sediment particle size characteristics

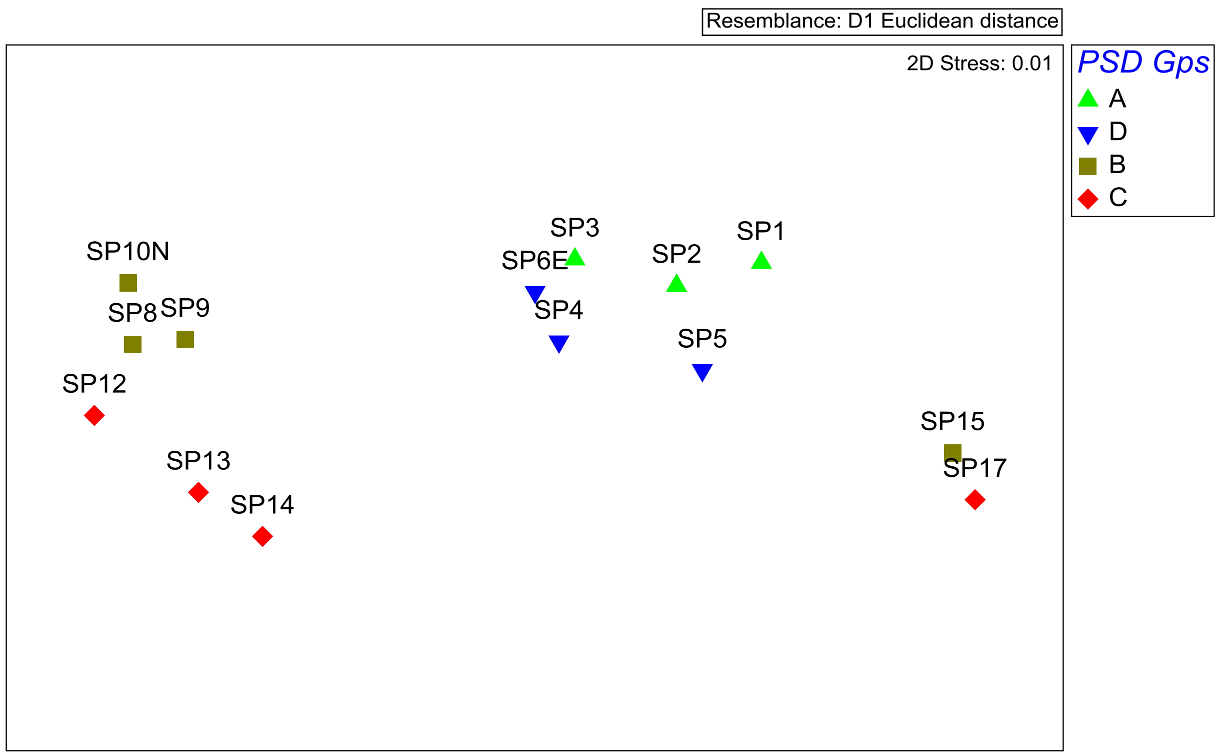


Figure 3-7: Distribution of PSD groups throughout the study area

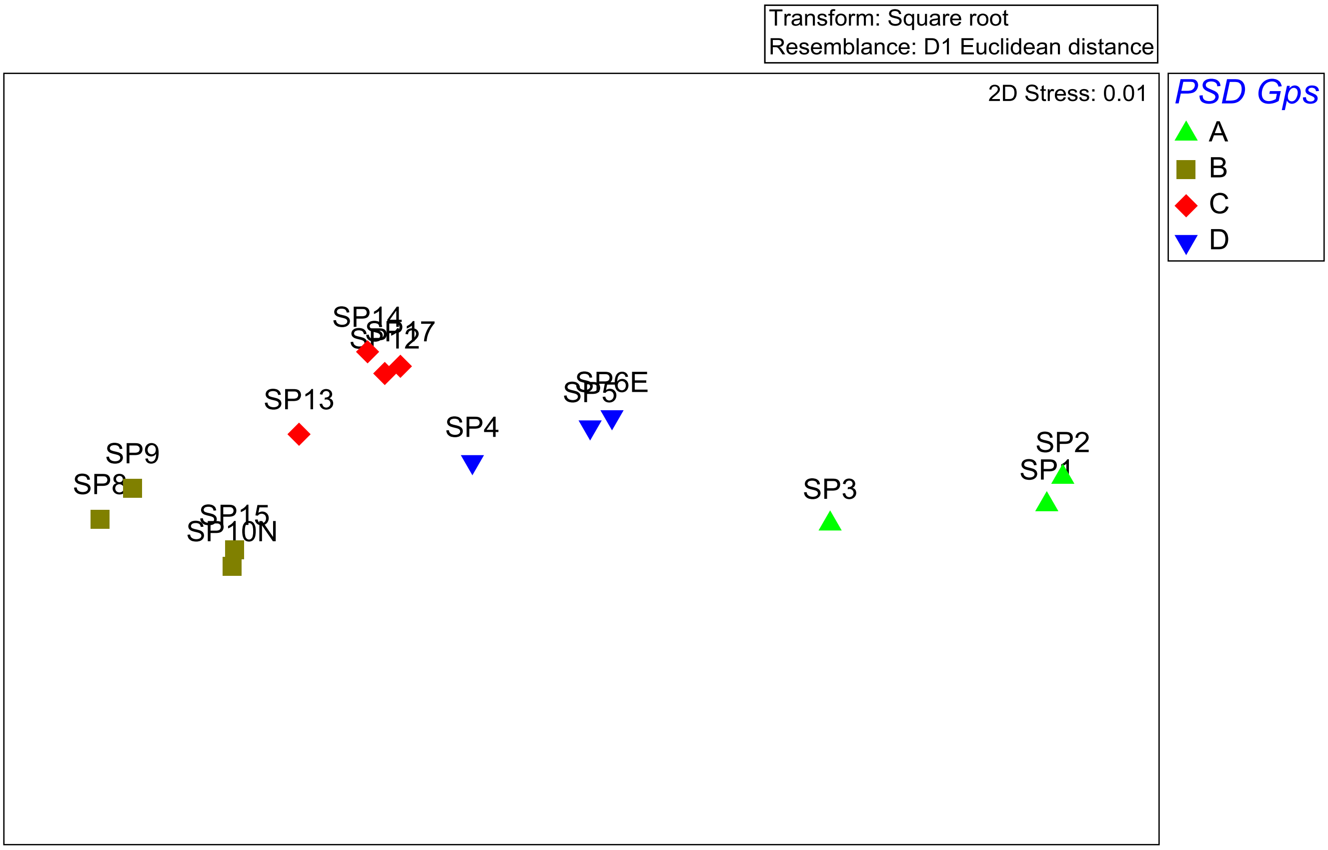


Figure 3-8: Sediment particle size characteristics overlaid with PSD groups

Comparison of PSD groups with the sediment quality groupings identified in Section **3.1.6** indicated similar spatial distributions. To determine if there was a clear relationship between PSD and contaminants, an n-MDS ordination of contaminants data overlaid with contaminant groups (**Figure 3-9**) was compared with the same n-MDS but overlaid with the PSD groupings (**Figure 3-10**). This clearly showed a direct relationship between PSD and contaminants, with contaminant Group A matching PSD Group A, and contaminant Group B matching PSD Group D.

To further investigate the drivers for variation in sediment composition in the study area, a Principal Component Analysis (PCA) based on PSD data combined into silt/clay, sand, gravel and cobble size classes was overlaid with PSD groups (**Figure 3-11**). This showed that the main drivers of sediment heterogeneity were the silt/clay and sand fractions. The influence of the gravel fraction was only particular of note at SP8 (and presumably SP9 if a PSD sample had been successfully collected). **Figure 3-12** illustrates the relationship between silt/clay, sand and gravel fractions in the transitional gradient of Folk sediment classifications of sites for the study area.

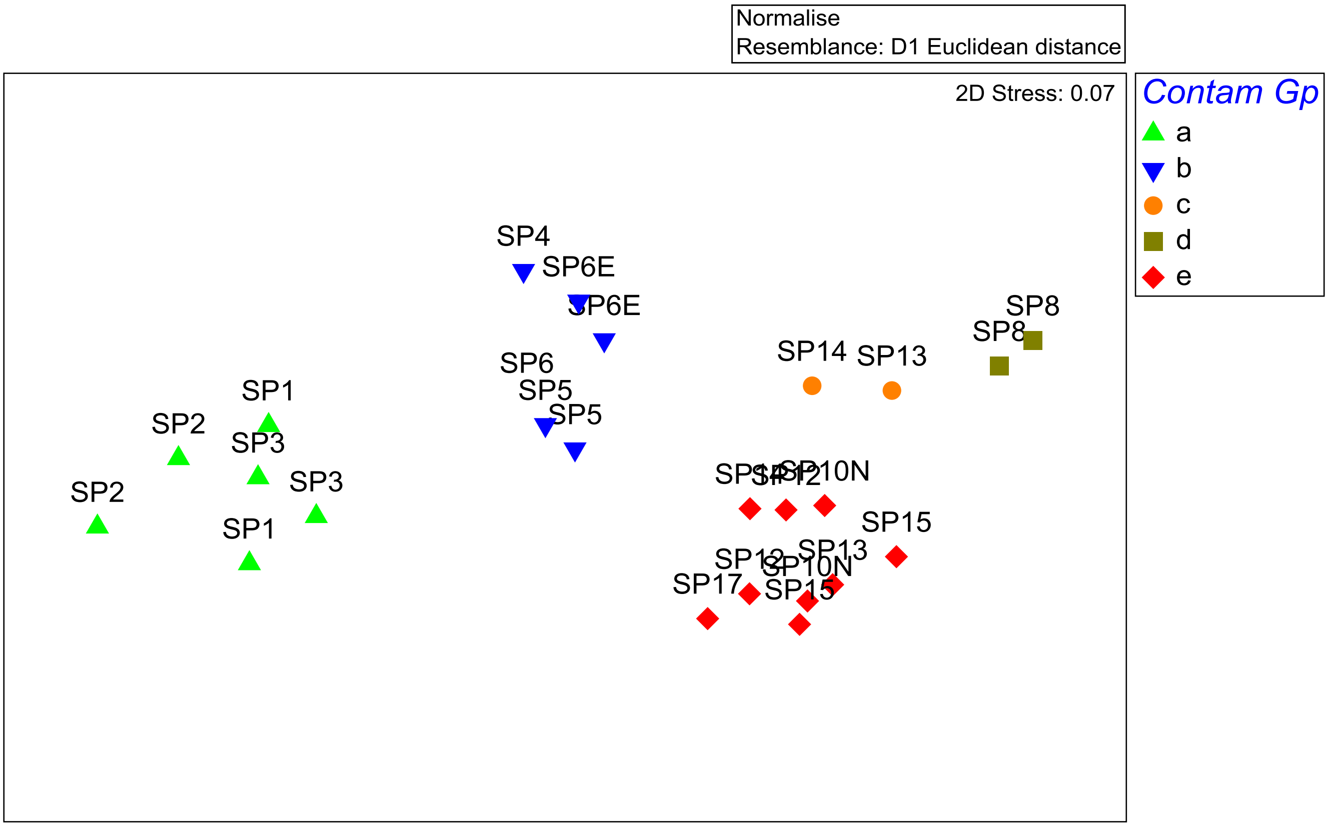


Figure 3-9: Sediment quality characteristics overlaid with contaminant groups

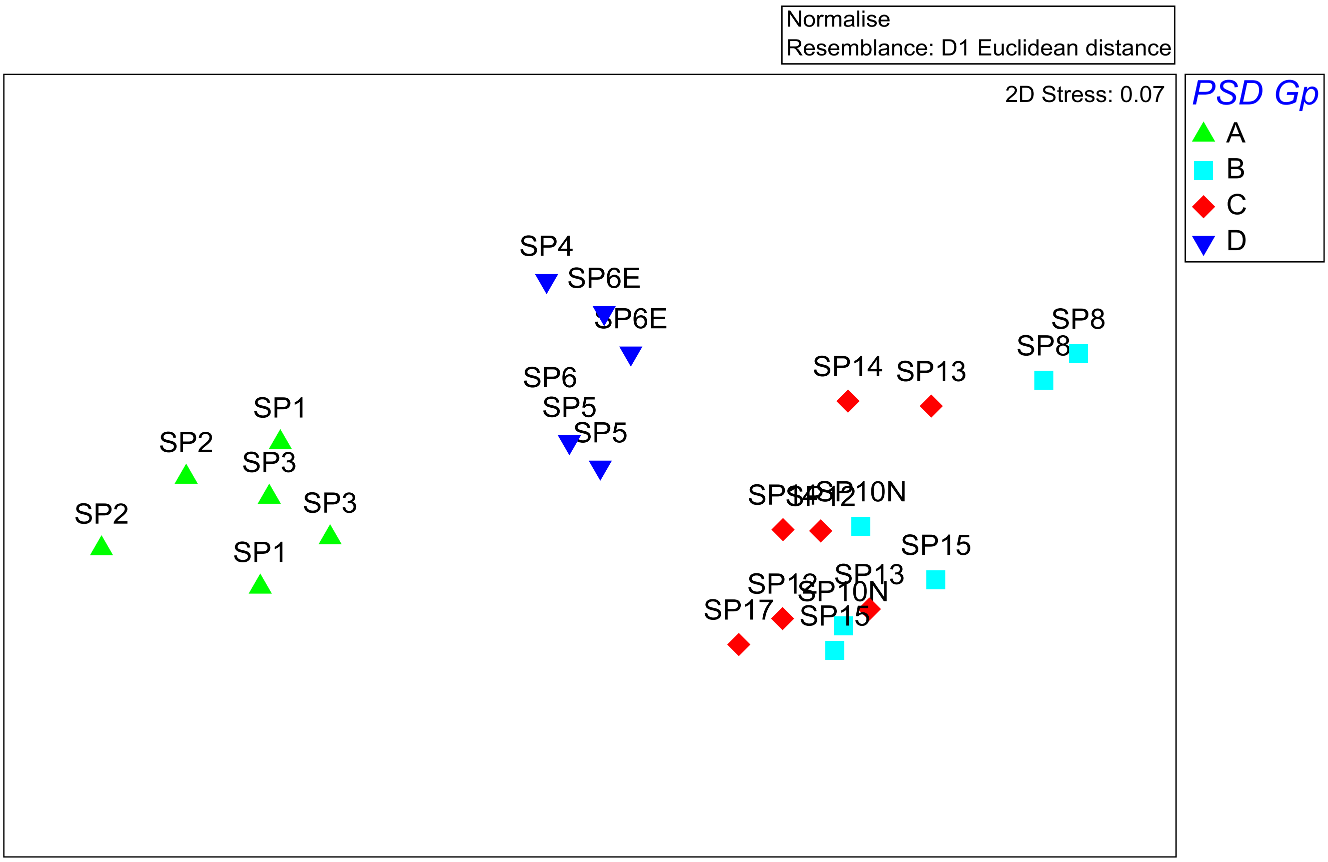


Figure 3-10: Sediment contaminant characteristics overlaid with PSD groups

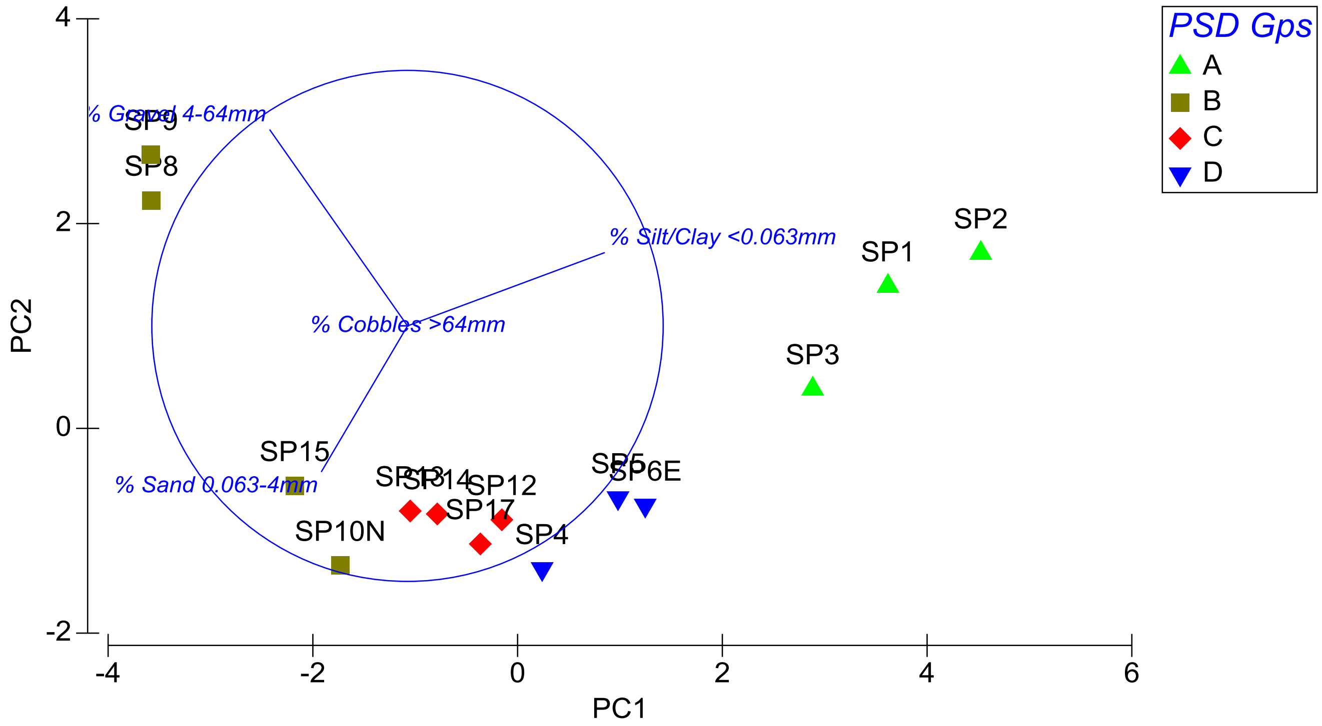


Figure 3-11: Principal components analysis plot of PSD data, overlaid with PSD groups

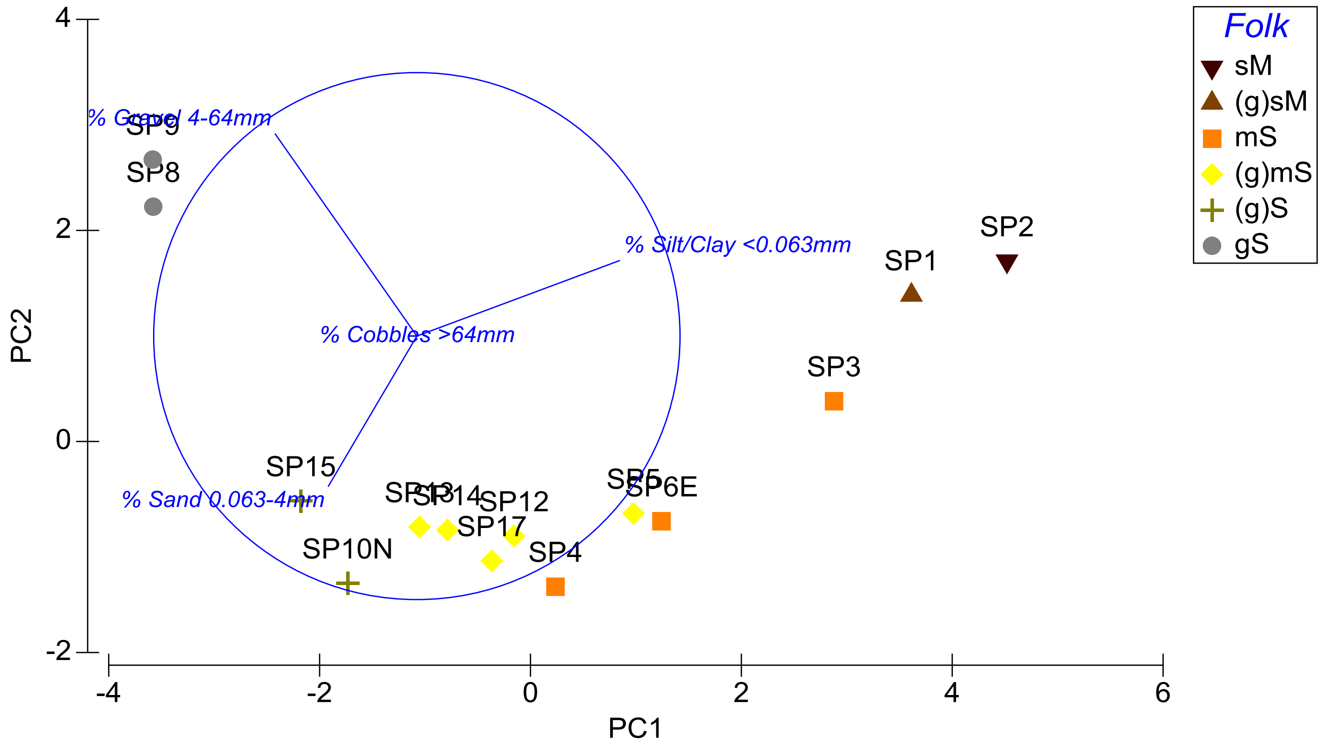


Figure 3-12: Principal components analysis plot of PSD data, overlaid with Folk sediment classifications

The relationship between PSD and contaminants demonstrated in **Section 3.1.6** is demonstrated further by overlaying contaminant groups over the PSD PCA (**Figure 3-13**), with contaminant group A being associated with a high silt/clay and low sand/gravel component. Group D, conversely, was associated with a high gravel and low silt component.

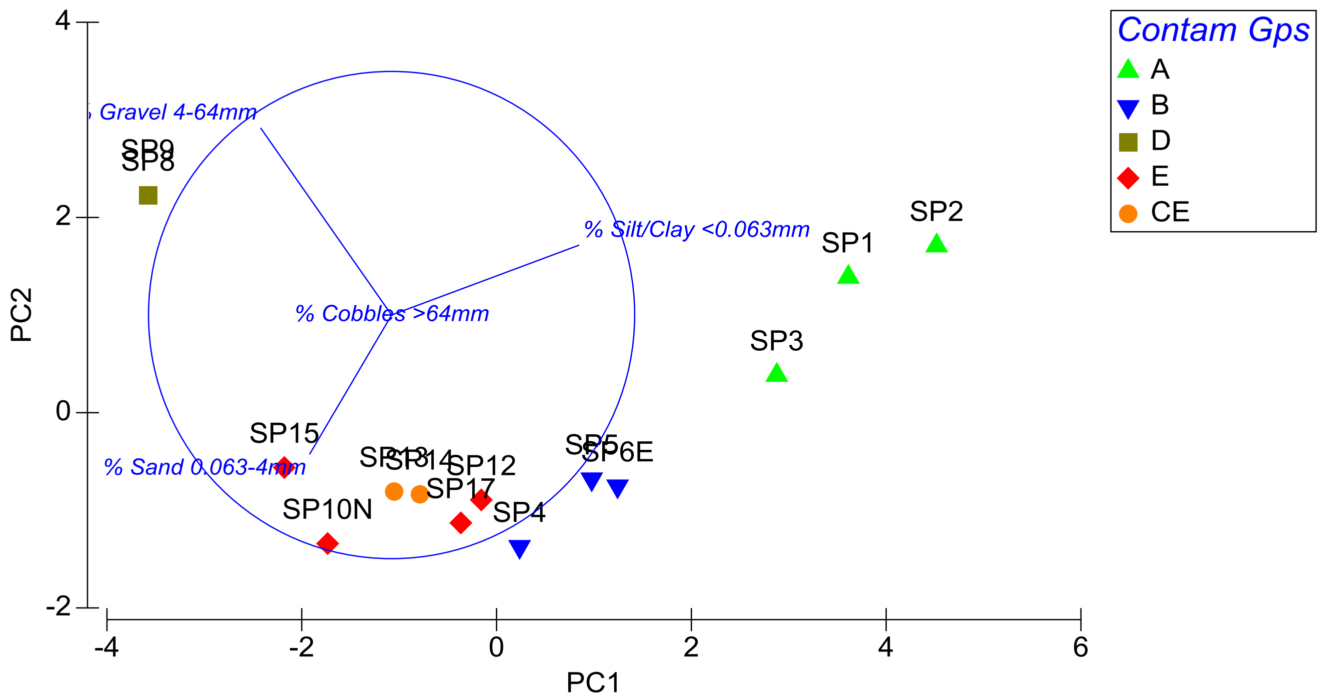


Figure 3-13: Principal components analysis plot of PSD data, overlaid with sediment quality groups

3.2 Infauna

3.2.1 Descriptive statistics

Fourteen infaunal samples were successfully collected. The infaunal data can be found in **Appendix C**. Descriptive statistics of the infaunal community data describing the number of species (S), abundance (N), Margalef's species richness (d), Pielou's evenness (J'), Shannon-Weiner diversity (H') and Simpson's alpha diversity index (1-λ') are presented in **Table 3-8**. The number of species (S) ranged from 3 at SP10N to 42 at SP8. Abundance (N) ranged from three individuals at SP10N to 63 individuals at SP8. Species richness (d) and Shannon-Weiner diversity (H') were consequently lowest at SP10N (1.8 and 1.1, respectively) and highest at SP8 (9.9 and 3.56, respectively). Evenness (J') and alpha diversity (1-λ') were lowest at SP1 and highest at sites where each taxa was represented by a single individual (i.e. SP2, SP10N and SP12).

Table 3-8: Infaunal community descriptive statistics

Site	S[1]	N[1]	d[1]	J'[1]	H'(log_e)[1]	1- λ '[1]
SP1	6	9	2.3	0.88	1.58	0.83
SP2	5	5	2. 5	1.00	1.61	1.00
SP3	6	7	2.6	0.98	1.75	0.95
SP5	9	15	3.0	0.92	2.03	0.90
SP6E	8	13	2.7	0.91	1.88	0.88
SP8	42	63	9.9	0.96	3.56	0.98
SP10N	3	3	1.8	1.00	1.10	1.00
SP12	15	19	4.8	0.97	2.63	0.97
SP13	12	12	4.4	1.00	2.48	1.00
SP14	24	33	6.6	0.96	3.06	0.98
SP15	39	56	9.4	0.96	3.52	0.98

[1] S = species richness, N = abundance, d = Margalef's species richness, J' = Pielou's evenness, H' = Shannon-Weiner diversity, 1- λ' = Simpson's index

Sediments at the permit zone were characterised by burrowing taxa and demersal fish, namely foraminifera (an amoeboid protist), nematodes, *Bregmaceros* sp. (codlets), tube-forming Onuphid polychaetes and the superb nut shell *Ennucula superba*. The coarser Tassie Shoal sediments were characterised by syllid polychaetes, tanaid crustaceans, foraminifera, brittlestars and fibularid echinoderms (urchins). Lynedoch Bank (SP15) was characterised by biota that were characteristic of both the permit area and Tassie Shoal, namely nematodes, tanaid crustaceans, and tube-dwelling onuphid polychaetes, but this site was relatively species-rich, and was also characterised by lumbrinerid polychaetes, brittlestars (*Amphioplus* sp.), tube-dwelling chaetopterid polychaetes and mud shrimp (callianassids). This suggested that mixed sediment habitats, comprising coarse and fine sediments, were present at this site. The variability between infaunal communities at Evans Shoal resulted in characteristic taxa being identified at the phylum level, with sediments being dominated by molluscs (e.g. laevidentaliidae), crustaceans (e.g. tanaids, amphipods, isopods, callianassids) and annelid worms (e.g. syllids, *Nematonereis* sp., lumbrinerids).

The infaunal community composition at the phylum level is presented in **Table 3-9**. Note that the infaunal community included foraminifera, which are amoeboid protists. Cluster analysis of infaunal data (**Figure 3-14**) identified that only site SP10N was significantly different to the other sites due to the high degree of variability between remaining sites. Site SP10N had only three individuals from three taxa.

The macrofaunal and infaunal assemblages of the study area were found to be diverse, with 235 individuals representing 124 taxa recorded from 11 grab samples.

3.2.2 Qualitative observations of infauna from grab samples

In situ observations and photographs of conspicuous biota and features were recorded at three sites (SP2, SP8 and SP15) and provide additional qualitative information about the ecology of these three sites.

A photograph of biota in the grab sample (for physico-chemical analysis) from SP8 shows the diversity of this site (**Figure 3-15a**). Biota present were a stomatopod (mantis shrimp), shrimp, several *Lithothamnion thalli* (coralline red algae) and a clump of predominantly biogenic material that included hydroids, bryozoan, ascidians, sponges, red and green algae, and polychaete tubes (**Figure 3-15a**). Also observed in the grab samples from this site were caprellid amphipods (skeleton shrimps), squat lobsters (*Galathea* sp.) and a spider crab (see logsheets in **Appendix B**).

Samples from SP15 were noted to contain large shells (e.g. scallops and other bivalves), gastropod mollusc shells, large pieces of shell hash, and large old calcareous worm tubes (**Figure 3-15b**).

In a grab sample from SP2 in the permit area, a large polychaete (>15 cm long) in a mud tube was collected (**Figure 3-15**c). Polychaetes such as this generally adopt multiple feeding strategies, including carnivory, scavenging, and even filter feeding by producing a mucus plug in their tube. As the tube is irrigated by movement of the worm in the tube, particles are sucked into the mucus and become trapped. The worm then ingests the mucus plug, and digests the trapped organic particles.

Table 3-9: Number of individuals from different phyla at each sampling site

Phylum	SP1	SP2	SP3	SP4	SP5	SP6E	SP8	SP9	SP10N	SP12	SP13	SP14	SP15	SP17
Mollusca	4	1	0	0	2	0	2	0	1	1	2	0	0	0
Cnidaria	0	0	0	0	1	0	12	0	0	0	0	5	0	0
Echinodermata	0	0	1	0	1	0	0	0	0	3	2	3	5	0
Crustacea	1	2	1	0	2	4	26	0	1	6	2	16	16	0
Foraminifera	1	0	0	0	6	1	0	0	0	2	0	2	0	0
Annelida	2	1	5	0	0	3	8	0	1	6	6	5	27	0
Nematoda	0	0	0	0	3	4	0	0	0	0	0	0	5	0
Echiura	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Nemertea	0	0	0	0	0	0	0	0	0	1	0	0	1	0
Arthropoda	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Porifera	0	0	0	0	0	0	13	0	0	0	0	0	2	0
Chordata	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Bryozoa	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Sipuncula	0	0	0	0	0	0	1	0	0	0	0	0	0	0

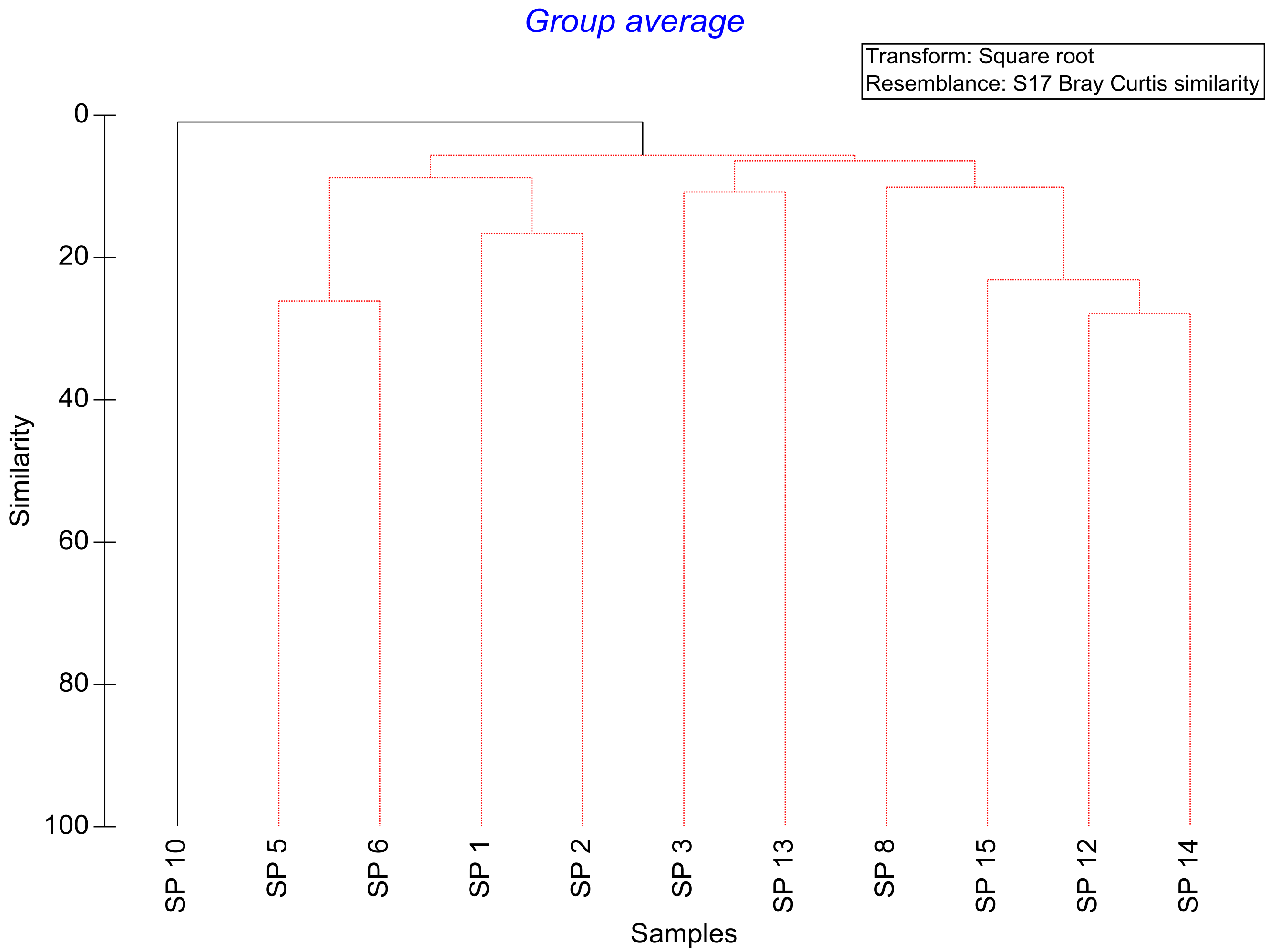
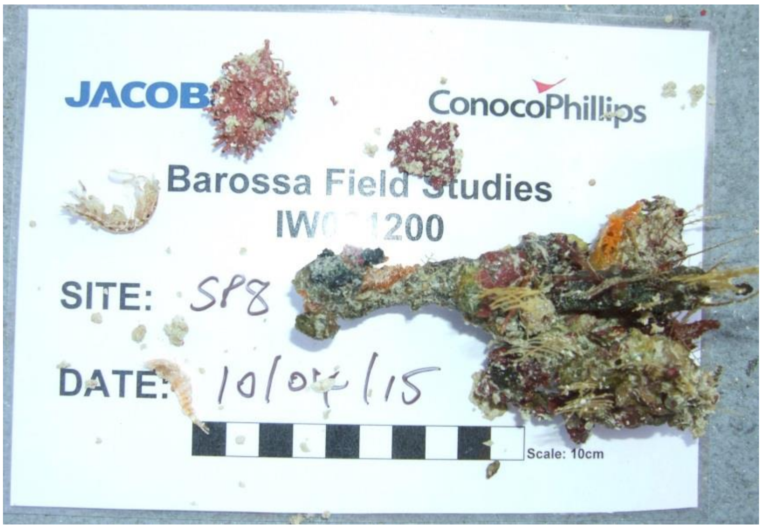


Figure 3-14: Grouping of sites based on similarity of infaunal data

a)



b)

c)

Figure 3-15: Biota collected in a physico-chemical grab sample from SP8 (a), SP15 (b) and SP2 (c)

3.2.3 Multivariate comparison of infaunal data with PSD data

To investigate the relationship between the biological environment and the physical environment, species richness (S), abundance (N) and the abundance of each Phylum was overlaid as a bubble plot over the PSD Principal Components Analysis plot (originally presented in **Figure 3-11**). A general trend of increasing species richness (**Figure 3-16**) and abundance (**Figure 3-17**) with increasing contribution of the coarse sediment component were observed. For many phyla there was also an evident trend of increasing abundance with increasing contribution of the coarse sediment fraction (e.g. annelid worms and crustaceans) (**Figure 3-18** and **Figure 3-19**). However, in some cases this trend was reversed (e.g. Mollusca), where greatest abundances were associated with finer sediments (**Figure 3-20**). Review of relationships between PSD and other phyla indicated that some biota were associated with a more restricted range of sediment types. For example, foraminifera were associated with sediments with a greater fines fraction (**Figure 3-21**), echinoderms were associated with mixed sediments not dominated by a fines or coarse component (**Figure 3-22**), and sessile or encrusting phyla such as cnidarians (anemones, sea pens and corals) and sponges (Porifera) were associated with sediments with a strong coarse component (**Figure 3-23** and **Figure 3-24**).

The PRIMER routine Bio-Env was used to identify the environmental variables that were likely to have had the greatest influence on the distribution of infauna within the study area. Results showed that depth and silt/clay (<63 µm) component had the greatest combined influence on infaunal distribution, although this was not considered significant (Global R = 0.404, significance 6.5%). The RELATE routine was used to compare the distribution of samples based on environmental variables (Latitude, Longitude, depth, %gravel, %sand and %silt) with the distribution based on infaunal community to determine whether there was a relationship between environmental and biological parameters at a broader level. Results indicated that there was a significant relationship between environmental variables and infaunal communities (Rho = 0.3332, significance level of sample statistic = 0.9%), but with low Rho value and Bio-Env Global R values indicating that there was likely to be a lot of overlap between the effects of different environmental variables.

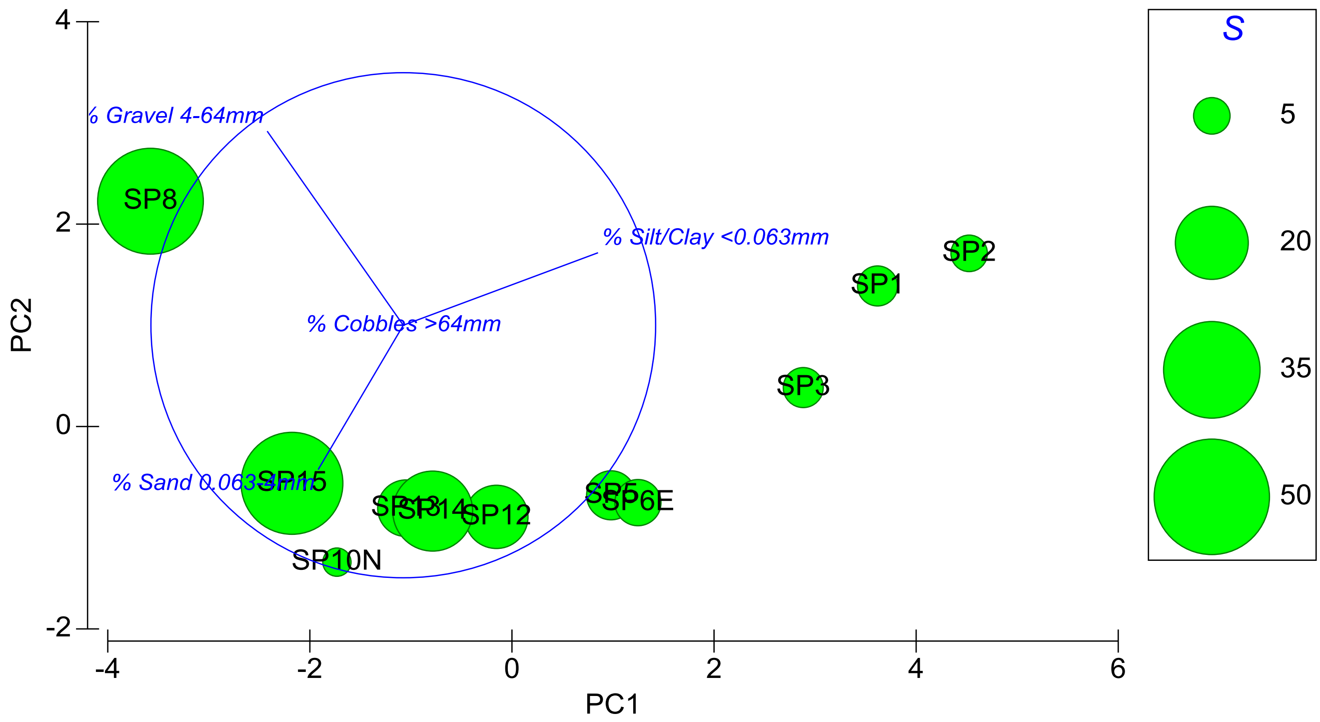


Figure 3-16: Infaunal species richness (S) overlaid over PSD principal components analysis plot

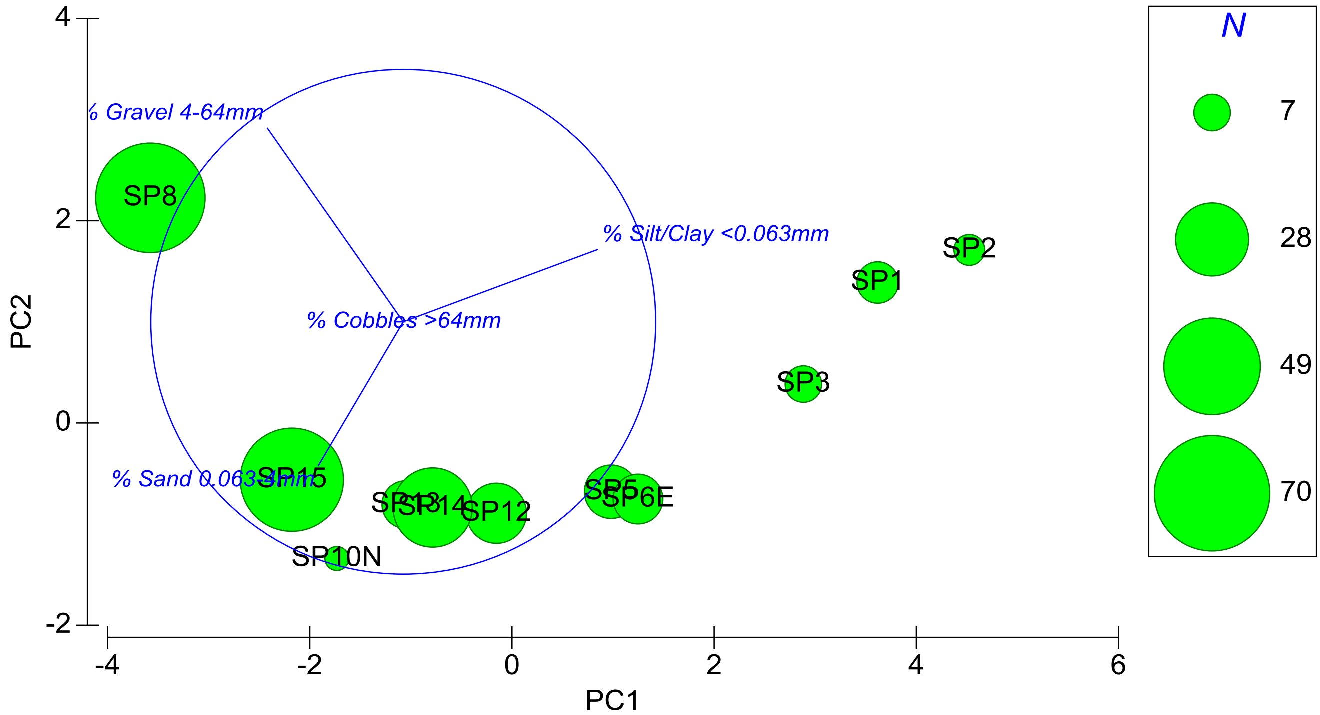


Figure 3-17: Infaunal abundance (N) overlaid over PSD principal components analysis plot

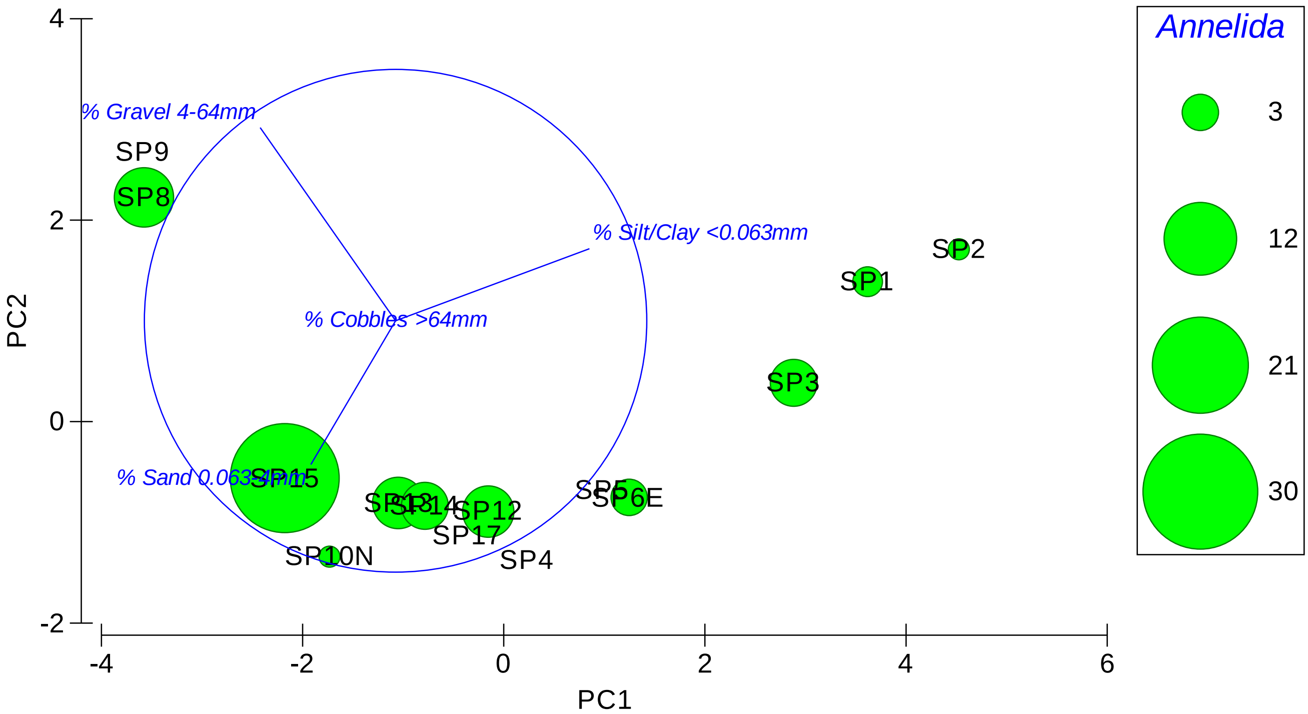


Figure 3-18: Annelid worm abundance overlaid over PSD principal components analysis plot

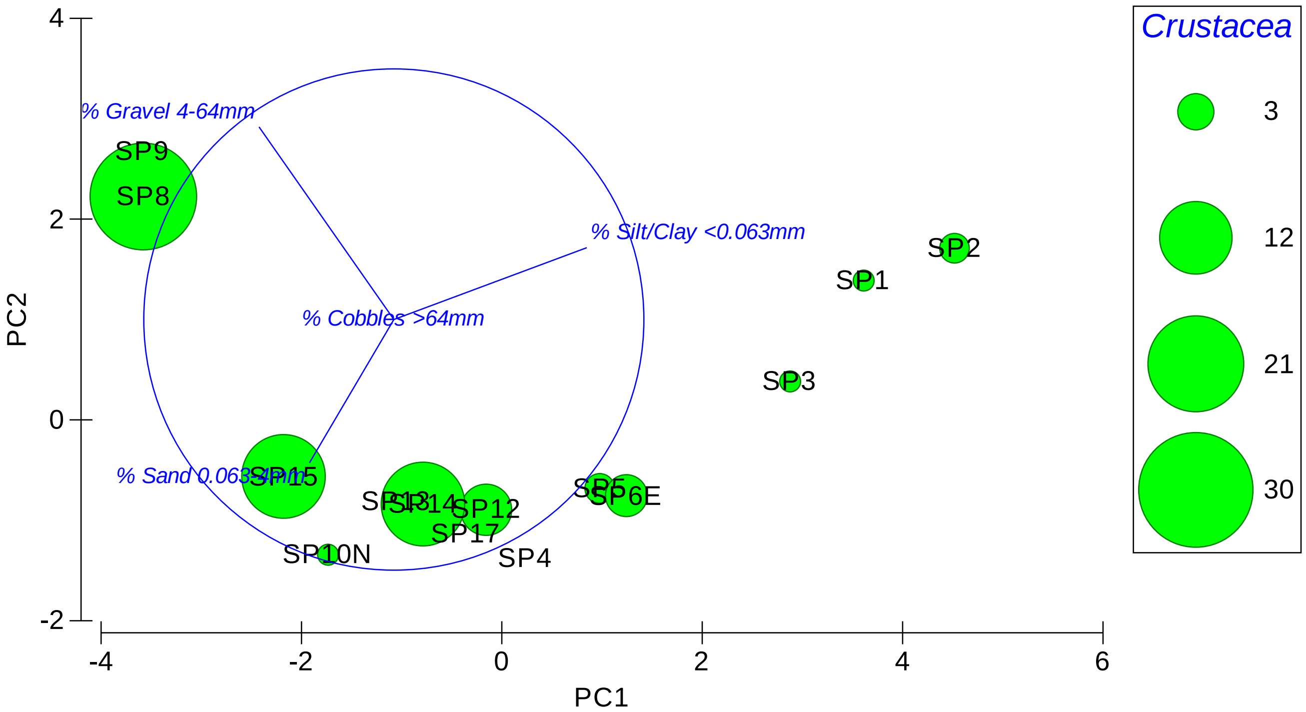


Figure 3-19: Crustacean abundance overlaid over PSD principal components analysis plot

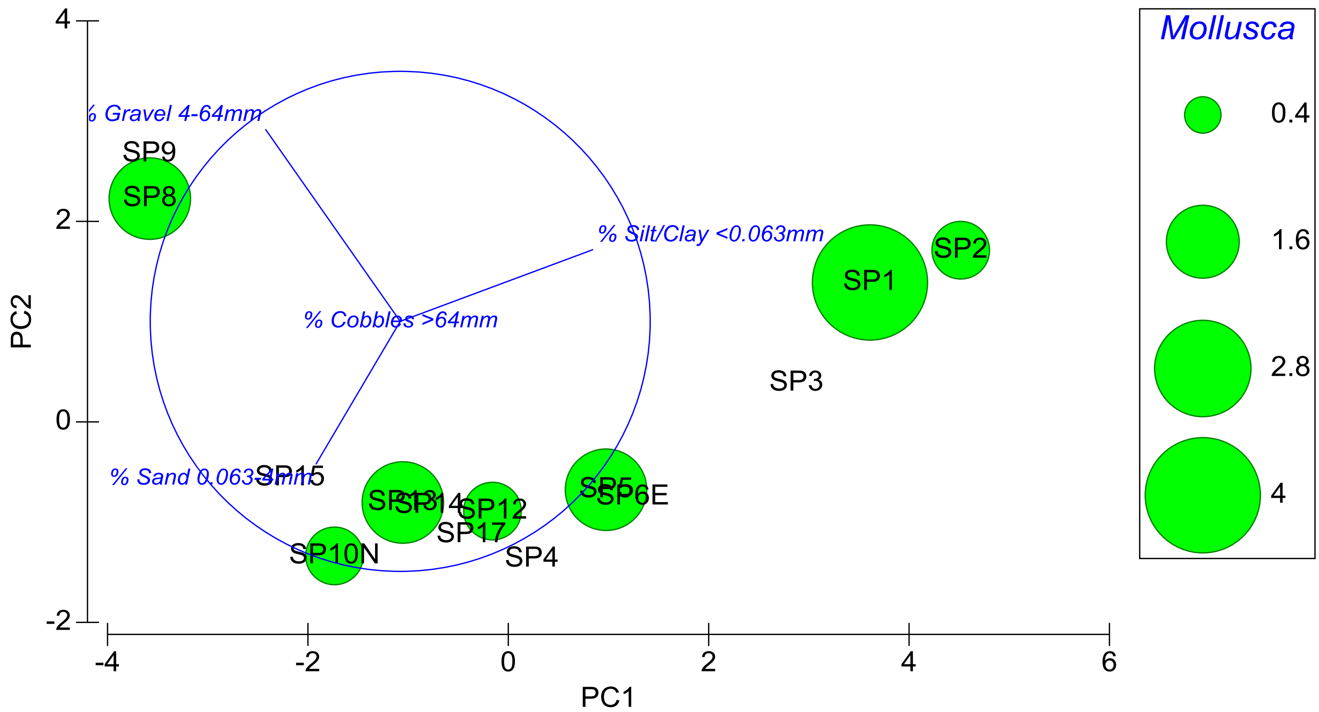


Figure 3-20: Molluscan abundance overlaid over PSD principal components analysis plot

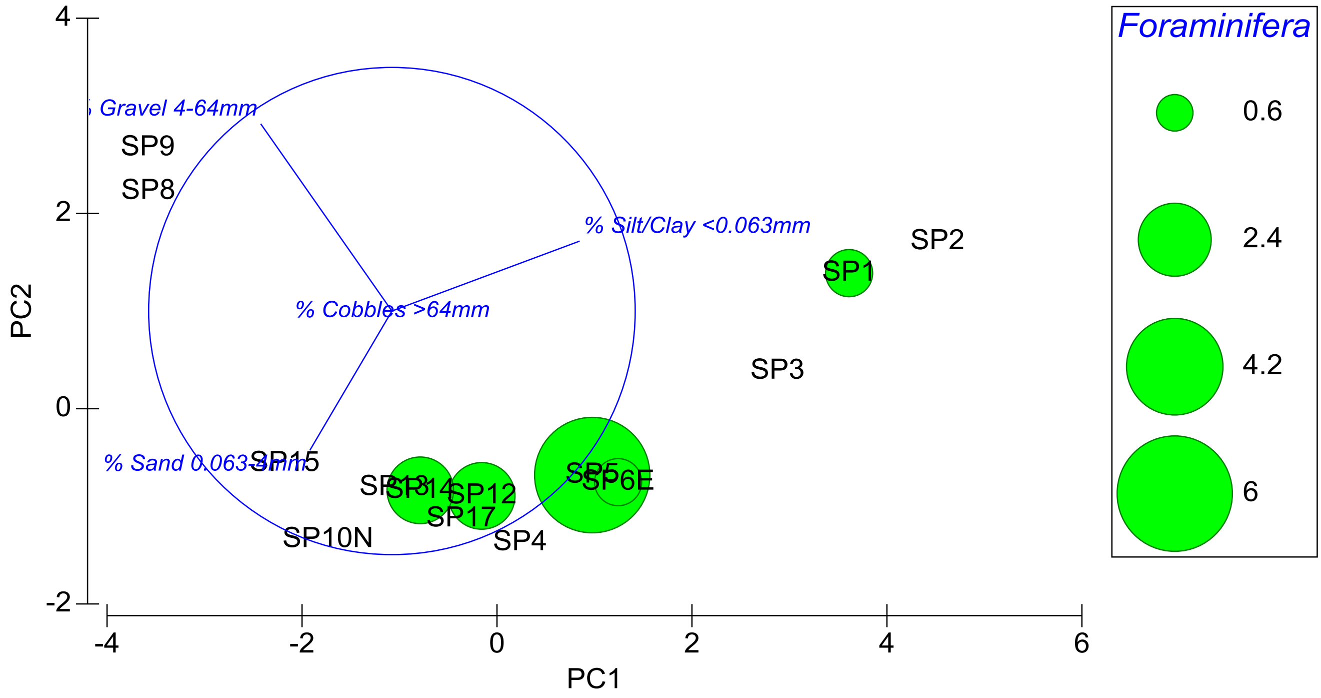


Figure 3-21: Foraminifera abundance overlaid over PSD principal components analysis plot

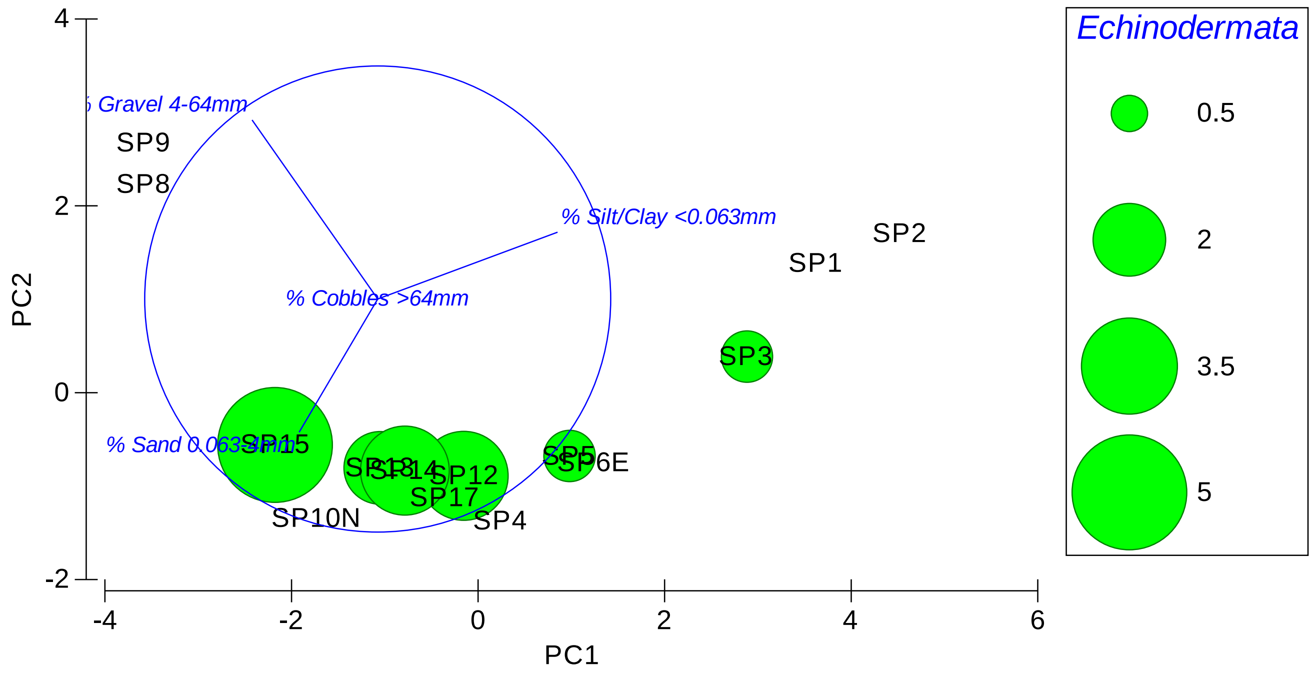


Figure 3-22: Echinoderm abundance overlaid over PSD principal components analysis plot

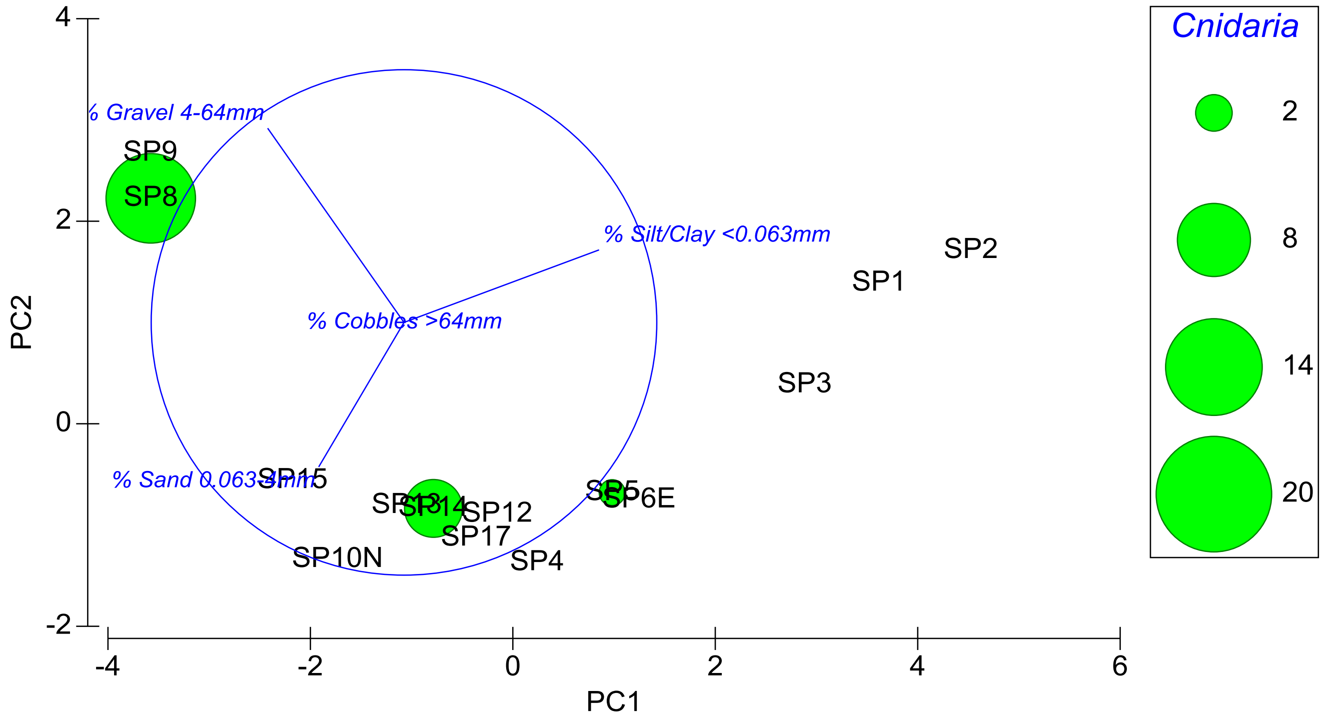


Figure 3-23: Cnidarian abundance overlaid over PSD principal components analysis plot

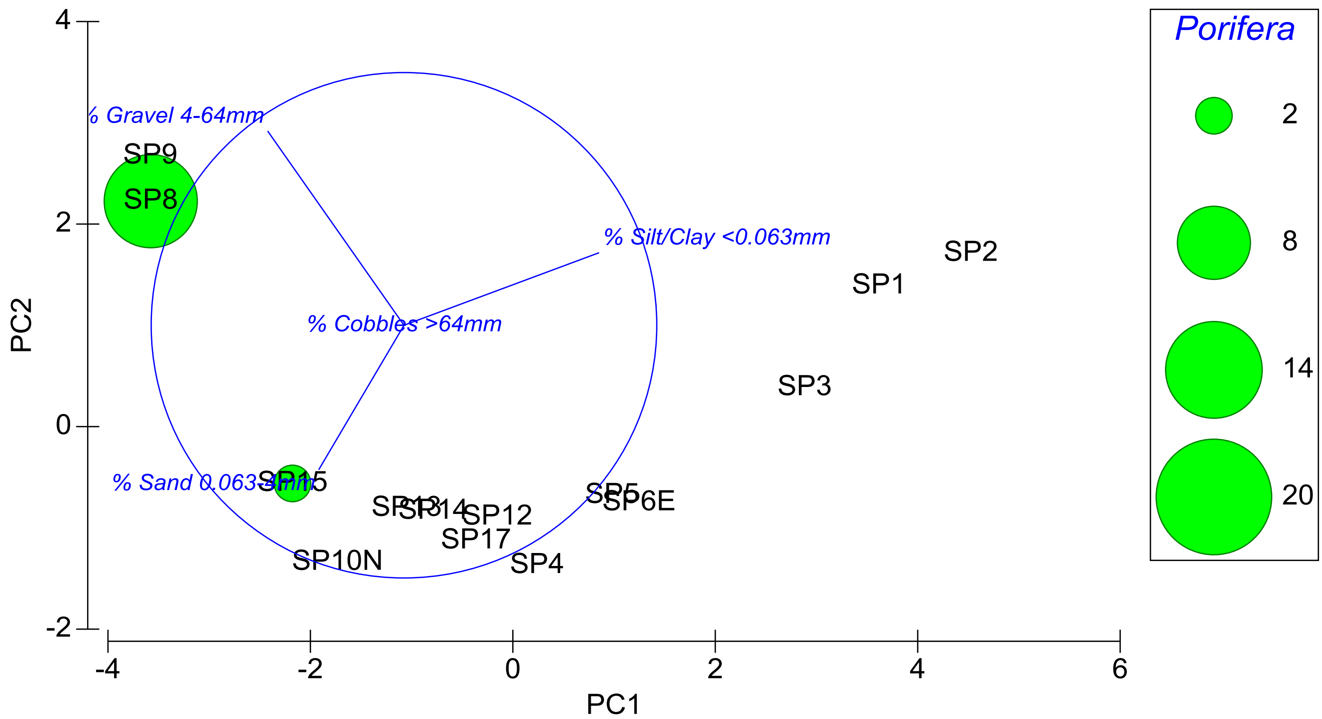


Figure 3-24: Porifera (sponge) occurrence overlaid over PSD principal components analysis plot

3.3 Sediment Profile Imagery

Three images were successfully obtained from the single deployment of the SPI system at SP3 (in the permit area). QA/QC review of the images identified that the sediment surface was not captured in the images due to over-penetration of the prism.

The quality of the images was sufficient for analysis, although depth measurements were recorded as "greater than" (>) as there was no point of reference other than the top of the images. Normally the point of reference used is the sediment surface. The surface of the sediment was not captured due to the soft nature of the sediment. Normally, the first deployment images are reviewed and the maximum penetration depth adjusted on the frame to enable capture of the sediment surface for subsequent deployments. The maximum penetration depth was >17.5 cm (**Table 3-10**), with no evidence of smearing in the images. The apparent Redox Potential Discontinuity (aRPD) layer was not clearly evident, most likely due to the relatively consistent sediment composition throughout the sediment profile in the images. A relatively thin coarser layer was evident in the upper profile, with the majority of the profile consisting of consolidated fine (silt/clay) particles with fine sand and small particles of broken shell. Evidence of bioturbation was recorded in all three images, through the identification of burrows (1) and feeding voids (7) (e.g. **Figure 3-25**). Limited assessment of the Benthic Habitat Quality (BHQ) index (Nilsson and Rosenberg 1997, 2000) could be undertaken, due to the lack of sediment surface in the images. Results were indicative of benthic infaunal successional stage III, which identifies an undisturbed habitat (Pearson and Rosenberg 1978). No evidence of methane gas pockets or hydrocarbons was identified.

The smallest particle size identified from analysis of the images was 55 µm. This defined the lowest limit of resolution of this method.

Table 3-10: Results of analysis of images obtained using the Sediment Profile Imagery system

Parameter	Profile Image 1	Profile Image 2	Profile Image 3
Min. penetration depth (cm)	Not measurable	Not measurable	Not measurable
Max. penetration depth (cm)	>17.6	>17.7	>17.7
Min. aRPD depth (cm)	Not identified	Not identified	Not identified
Max. aRPD depth (cm)	Not identified	Not identified	Not identified
Max. burrow depth (cm)	>4.9	N/A	N/A
Min. feeding void 1 depth (cm)	>12.8	>9.5	>4.2
Max. feeding void 1 depth (cm)	>13.1	>10.1	>4.7
Min. feeding void 2 depth (cm)	N/A	>11.1	>10.3
Max. feeding void 2 depth (cm)	N/A	>11.3	>11.2
Min. feeding void 3 depth (cm)	N/A	>13.4	>10.3
Max. feeding void 3 depth (cm)	N/A	>14.1	>10.7
Successional stage	III	III	III
Benthic Habitat Quality (BHQ) index:			
A =	N/A	N/A	N/A
B =	3	3	3
C =	N/A	N/A	N/A
Average particle size (mm)	0.080	0.087	0.094
Particle count	132443	102386	47805
Total area (%)	2.818	3.283	3.07

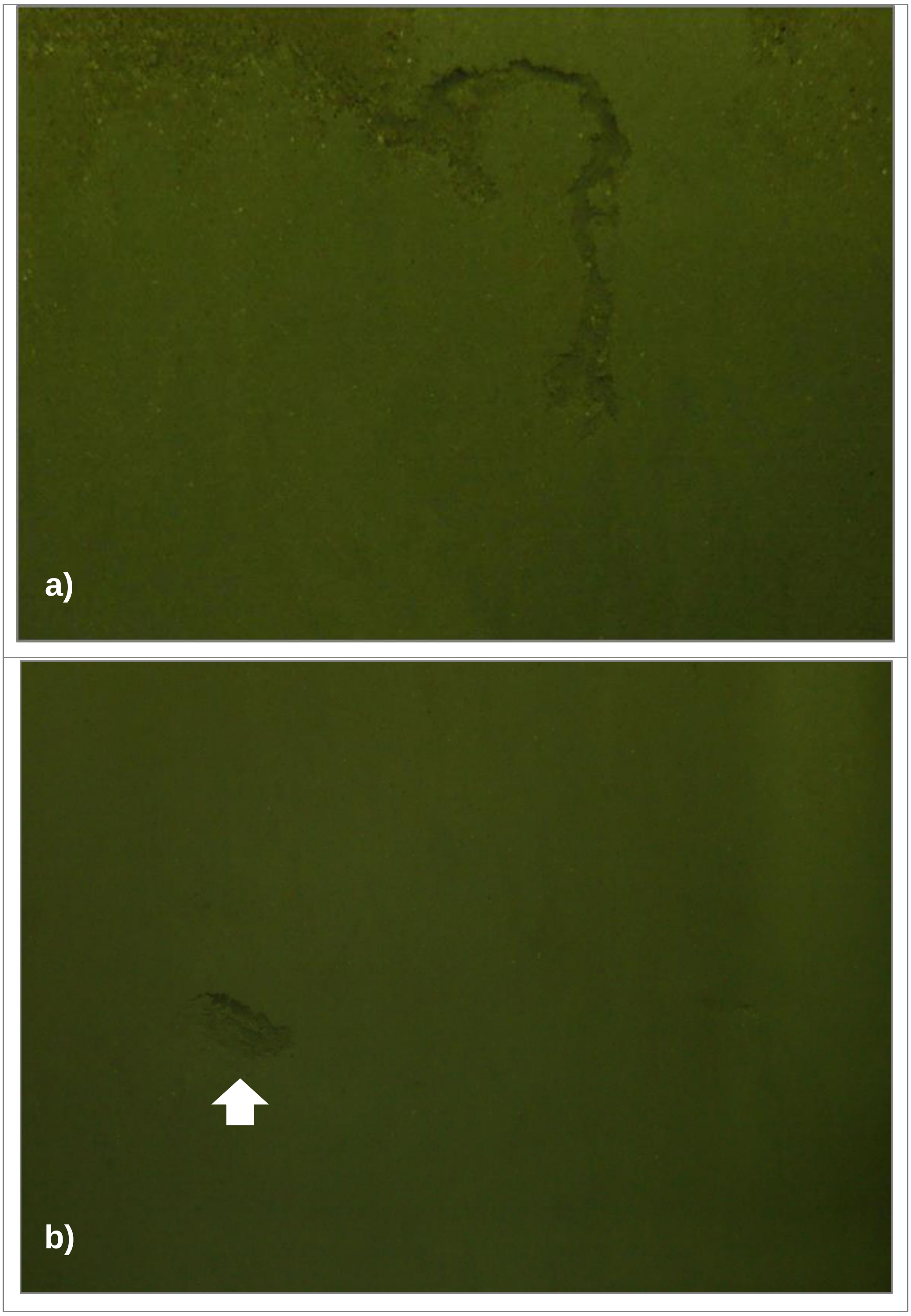


Figure 3-25: Burrow (a) and feeding void (b) in SPI image from site SP3

4. Discussion

This survey provides baseline information on sediment quality and a characterisation of seabed habitats in and around the permit area. In general, the sites surveyed ranged in depth from around 70 m at the shoals and banks to approximately 280 m in the permit area. Shallower sampling sites on the shoals and banks (with minimum depths of <10 m in places) were found to be unsuitable for sediment sampling due to the density of coral/biota cover and lack of consistent sediment patches (following review of remotely operated vehicle or GoPro imagery). Therefore, to mitigate environmental risk, sampling was not undertaken at such sites.

Of the metals and metalloids tested, only cobalt and nickel were recorded above the ANZECC & ARMCANZ (2000b) ISQG-low reliability trigger values. Cobalt was commonly recorded above the ISQG-low reliability trigger value level of 1.0 mg/kg (at all sites except SP8 in the permit area). Nickel concentrations were recorded at or slightly above the ISQG-low trigger value (21 mg/kg DW) at SP1 and SP2 (within the permit area), respectively. Nickel is commonly recorded at high levels in Australian sediments (Commonwealth of Australia 2009).

Tributyltin and hydrocarbons (TPHs, TRHs and BTEXN) were below the laboratory reporting limits at all sites. Although historic exploration has been undertaken in the permit area, potential impacts from these activities were not detected at the sampling locations.

$Radium^{226}$ concentrations were recorded above the minimum reporting limit at SP4 (within the permit area) and SP6E (approximately 20 km to the west of the permit area), but at levels well below the ANZECC & ARMCANZ (2000b) ISQG-low reliability trigger value for radionuclides (sum of gross alpha and gross beta) of 35 Bq/g. $Radium^{228}$ and $thorium^{228}$ were not detected at any site.

Nitrogen, phosphorus and organic carbon are released when organic compounds decay. The highest concentrations of nitrogen and organic carbon were associated with the permit area sediments, which were the deepest and the finest sediment habitats sampled. Deep water sediment habitats are predominantly depositional, as indicated by their relatively high PSD fines component and nutrient content. The benthic biological communities of these habitats are consumers rather than (primary) producers. They utilise the increased nutrient component of sediments through adoption of detritus or deposit feeding strategies, which may be used in combination with other feeding strategies (e.g. carnivory, scavenging or filter feeding).

The sediment type identified during this study were comparable with those found in local and broader regional seabed habitat mapping studies undertaken in the Eastern Joseph Bonaparte Gulf and Timor Sea (URS 2005 and 2008, Fugro 2006a, b, Anderson et al. 2011, Przeslawski et al. 2011). The study area was characterised by a gradual transition in sediment composition over broad spatial scales (tens of kilometres), and in particular between the permit area and the sediments of the shallow shoals. This common trend is often related to depth (and therefore current velocities at the sediment–water interface) and prevailing current or weather direction (e.g. fetch). There was a lesser trend of an east–west transition in sediment type in the permit area, with finer sediments (sandy muds) in the east to coarser muddy sands in the west. This is likely to be related to the prevailing current direction, which flows along a south-eastward to north-westward axis near the seabed (Fugro 2015). The use of Folk sediment classifications was useful in mapping the different sediment types, and clearly illustrated the transition in sediments from finer deep sediments to coarse shallow water sediments.

Infaunal communities were variable throughout the study area and are considered indicative of the benthic infaunal communities that are likely to occur in the study area. Foraminifera (amoeboid protists) were recorded at a number of the permit area sites. These were testate (i.e. have a shell) and were found to be within the macrofaunal size class. These were also found in deep offshore water sediments sampled during a study in the Browse Basin (approximately 30 km north-west of Seringapatam Reef) (SKM 2014). Relatively depauperate faunal communities (only three individuals representing three taxa per 0.1 m^2) were found at site SP10N (which consisted of slightly gravelly sand, with approximately 1% gravel) on or adjacent to the steep shoal slope at Evans Shoal. In contrast, the coarser gravelly sand sediments (approximately 24% gravel) at site SP8 in the permit area were found to be diverse (42 taxa), with an abundance of 63 individuals per 0.1 m^2. The relationship between coarse sediments, high infaunal abundances and species richness has been previously identified in the north-west shelf. Huang et al. (2013) noted that greater species richness and total abundance were associated with coarse-grained, heterogeneous sediments. The infaunal data from this study was found to have a greater number of taxa than recorded from the Browse Basin study (SKM 2014), with a total of 124 taxa from

11 samples in comparison with 67 taxa from 14 samples, respectively. This can be explained by the ratio of samples collected in deep water (12 of 14 samples taken in >400 m in the Browse Basin study area; 5 of 11 samples collected in water depths of >200 m in the current study area). Shallower sites were found to have greater species richness (**Section 3.2.1**). Analysis of PSD from both the current study area and the Browse Basin study showed that the shallower sediments associated with reef, shoals and banks were coarser in nature. Increased light and food availability (due to increased productivity) in the shallow photic zone is also likely to be a contributing factor. The range of infaunal abundances and number of species was greater than that found in the Browse Basin study (from 3 to 63 individuals and 3 to 42 species per 0.1m^2 compared with 2 to 48 individuals and 2 to 15 species from the Browse Basin). It must be noted, however, that the Browse Basin deep samples were collected using a 0.1 m^2 box core, and the shallow samples using a 0.025 m^2 petit ponar grab, so the upper range of infaunal abundance and number of species are likely to be higher for Browse (and potentially more comparable with shallow-water samples collected in the current study). The characteristics of the infaunal community recorded in the study area were comparable with those from other studies in North-West Australia. For example, infaunal data recorded from the Carnarvon Shelf in North-West Australia varied from 4 to 97 individuals per 0.1 m^2 and from 4 to 48 species per 0.1 m^2 across the region studied (Przeslawski et al. 2013).

In situ observations and photographs of conspicuous biota collected in grab samples provided important ecological context to the infaunal data (Olenin and Ducrotoy 2006). Aggregations of encrusting and sessile biota (comprising of sponges, ascidians, hydroids, polychaete tubes, red and green algae; for example, as recorded from site SP8 at Evans Shoal) increase the availability of niches for colonisation by a wide range of cryptic biota. Large tube-dwelling infaunal crustacea were also recorded from this site, such as mantis shrimp and shrimp. Large shell hash were recorded at SP15 at Lynedoch Bank, which was found to have the second highest species richness and abundance. Large pieces of shell material and calcareous structures are of ecological importance to particulate sediment biota. They can provide niches for colonisation by encrusting or cryptic biota, such as squat lobsters and other crustaceans, and can also help consolidate sediments. Sediment descriptions and deck sample photographs were considered as part of the interpretation of the PSD and infaunal data, as larger sediment components (e.g. shell hash, cobbles) and biological aggregations are not necessarily incorporated in the PSD and infaunal data. Large particle sizes (large shell hash and cobbles) are often excluded from the sample collected for PSD analysis due to either the low number per surface area sampled or (most commonly) as they take up too large proportion of the sample volume, which would skew the data. Aggregations may be excluded or under-represented by infaunal analysis as colonial organisms may be counted as individuals (under-representing their contribution), or excluded if they do not happen to occur in the sample randomly chosen for infaunal analysis. Therefore, capturing these ecological components through sediment descriptions and deck photos provided additional context in identifying relationships between habitat composition and infaunal diversity and abundance (e.g. at site SP8 in the permit area).

Although only deployed once at one site in the permit area (SP3), the SPI system provided some additional contextual information on undisturbed sediment profiles (e.g. structure) and bioturbation. The images indicated that the site was undisturbed, based on the key features recorded (e.g. burrows, feeding voids and lack of hydrocarbons or methane gas pockets). Particle size analysis from the three SPI images determined that average particle size was 87 µm. The median grain size from PSD analysis on a sediment sample taken in the vicinity was 70 µm. These values are sufficiently similar that they would have been characterised in the same size fraction using the PSD analysis, i.e. very fine sand (63 µm–125 µm).

In summary, the results of the sediment survey contributed to an appropriate baseline characterisation of the sediment quality in the study area, and provided an indication of the composition of infaunal communities that are found in the area.

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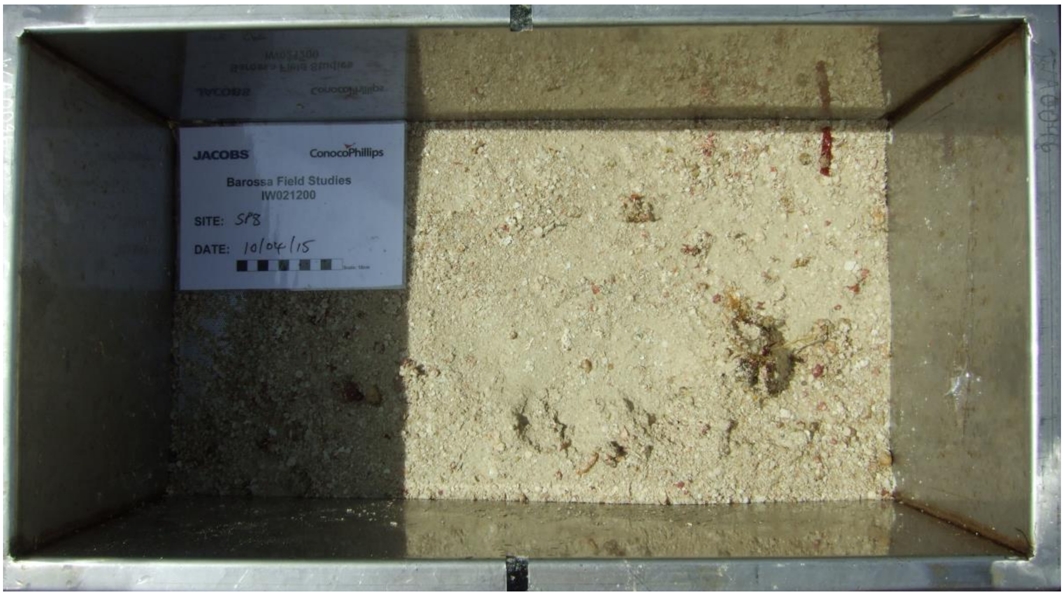
Appendix A. Sediment Survey Field Logsheets

Log sheet No.	Site	Sample	Date	Equipment	Sample?	Time	Waypoint	S	E	S deg.decdeg	E deg.decdeg	Depth	Proportion of grab	Organics/metals	Hydrocarbons	NORMs	PSD	Infauna	Sediment composition	Sediment features	Conspicuous fauna	Photo?	Comments
1	SP17	1	8/04/2015	$0.2m^2$ van Veen	N	17:06	1461	ND	ND	ND	ND	116	N/A	N	N	N	N	N	N/A	N/A	N/A	N	
1	SP17	2	8/04/2015	$0.2m^2$ van Veen	N	17:32	1462	10° 02.439	130° 50.273	10.03772333	130.8360633	115	N/A	N	N	N	N	N	N/A	N/A	N/A	N	
1	SP17	3	8/04/2015	$0.2m^2$ van Veen	Y	18:07	1463	10° 02.439	130° 50.270	10.03772333	130.8360333	115	1/3	Y	Y	Y	> 300	N	Green-grey silty sand with few small shell fragments. Thin veneer of slightly orange-brown coarser layer on surface.	Tubes	Annelid worm	N	
2	SP5	1	9/04/2015	$0.2m^2$ van Veen	Y	7:28	1467	09° 53.293	130° 24.373	9.886263333	130.40373	211	> 1/2	Y	Y	Y	> 300	N	Green-grey silty sand with few small shell fragments. Slightly coarser than SP17. Slightly orange thin veneer.	None	None	N	
2	SP5	2	9/04/2015	$0.2m^2$ van Veen	Y	8:11	1468	09° 53.315	130° 24.411	9.886483333	130.40411	211	> 1/2	Y	Y	Y	N	N	As above	None	Polychaete	N	
2	SP5	3	9/04/2015	$0.2m^2$ van Veen	N	8:46	1469	09° 53.230	130° 24.403	9.885633333	130.40403	211	N/A	N	N	N	N	N	N/A	N/A	N/A	N	
3	SP5	1	9/04/2015	$0.2m^2$ van Veen	Y	9:08	1470	09° 53.237	130° 24.347	9.885703333	130.40347	211	> 1/2	N	N	N	N	Y	As previous, shell fragments	Tubes	Pectenarid polychaetes, solitary corals	Y	
3	SP4	2	9/04/2015	$0.2m^2$ van Veen	Y	11:58	1471	09° 54.226	130° 10.741	9.90226	130.1740767	220	> 1/2	Y	Y	Y	> 300	N	Olive coloured silty sand, some shell fragments	None	None	N	
3	SP4	3	9/04/2015	$0.2m^2$ van Veen	N (lost grab)	12:25	1472	09° 54.242	130° 10.774	9.90242	130.1744067	220	N/A	N	N	N	N	N	N/A	N/A	N/A	N	
4	SP6	1	9/04/2015	$0.1m^2$ van Veen	N	17:59	1473	09° 48.744	129° 58.030	9.80744	129.9669667	269	Scrapings	N	N	N	N	N	N/A	N/A	N/A	N	
4	SP6	2	9/04/2015	$0.1m^2$ van Veen	N	18:36	1474	09° 48.736	129° 58.169	9.80736	129.9683567	270	Scrapings	N	N	N	N	N	N/A	N/A	N/A	N	Moved site to the East
4	SP9	1	10/04/2015	$0.1m^2$ van Veen	N	7:34	1475	09° 56.447	129° 36.255	9.937803333	129.60255	161	Scrapings	N	N	N	N	N	Coral gravel/pebbles	None	1 dead solitary coral	N	
5	SP9	2	10/04/2015	$0.1m^2$ van Veen	Y	7:50	1476	09° 56.490	129° 36.173	9.938233333	129.60173	169	~ 1.5 cm thickness	N	N	N	Y	N	Coral gravel/pebbles	Tubes, casts	Polychaete tubes	Y	
5	SP9	3	10/04/2015	$0.1m^2$ van Veen	Y	8:15	1477	09° 56.443	129° 36.283	9.937763333	129.60283	169	~ 1 cm thickness	Y	N	N	N	N	Coarse shelly coral gravel/pebbles with some coarse sand	Tubes, casts	None	N	
5	SP10	1	10/04/2015	$0.1m^2$ van Veen	N	8:55	1478	09° 51.426	129° 32.118	9.85426	129.5345133	200	No sample	N	N	N	N	N	Few small shells	N/A	None	N	
6	SP10	2	10/04/2015	$0.1m^2$ van Veen	N	9:36	1479	09° 51.422	129° 32.106	9.85422	129.5343933	201	No sample	N	N	N	N	N	Few small shells	N/A	None	N	Moved site ~500 m North
6	SP10 N	1	10/04/2015	$0.1m^2$ van Veen	Y	10:45	1480	09° 51.074	129° 31.956	9.85074	129.5262267	242	1/3	Y	Y	Y	> 300	N	Sandy with small shell fragments; brownish in colour	None	None	N	
6	SP10 N	2	10/04/2015	$0.1m^2$ van Veen	Y	11:25	1481	09° 51.071	129° 32.037	9.85071	129.5337033	242	1/2	Y	Y	Y	N	N	Sandy with small shell fragments; brownish in colour	None	None	N	
7	SP10 N	3	10/04/2015	$0.1m^2$ van Veen	Y	12:05	1482	09° 51.065	129° 31.923	9.85065	129.5258967	242	1/2	N	N	N	N	Y	Sandy with small shell fragments; brownish in colour	Tubes, casts	*Pectinaria* sp.	Y	
7	SP8	1	10/04/2015	GoPro	N/A	14:02	1483	09° 57.108	129° 32.095	9.95108	129.5342833	69	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	GoPro video
7	SP8	1	10/04/2015	$0.1m^2$ van Veen	Y	14:25	1484	09° 57.112	129° 32.113	9.95112	129.5344633	69	> 1/2	Y	Y	Y	> 300	N	Coarse sand, shell (lots) and coralline algae thalli (dead framents)	None	Caprellid, amphipod, shrimp, red algae, coralline algae thalli	N	
8	SP8	2	10/04/2015	$0.1m^2$ van Veen	Y	14:45	1485	09° 57.106	129° 32.101	9.95106	129.5343433	69	1/2	Y	Y	Y	N	N	Coarse sand and shell fragments	Tubes, casts	Mantis shrimp (stomatopod), Galathea sp., sponges, spider crab, hydroids, ascidean	Y	Labelled photo of biota, not sediment sample
8	SP8	3	10/04/2015	$0.1m^2$ van Veen	Y	15:05	1486	09° 57.135	129° 32.121	9.95135	129.5345433	69	1/2	N	N	N	N	Y	Coarse sand, shell fragments and lithothamnion thalli	Tubes, casts	Galathea sp., sponges, hydroids, polychaete worm tubes	Y	
8	SP12	1	10/04/2015	$0.1m^2$ van Veen	Y	16:15	1487	10° 03.845	129° 28.678	10.05845	129.4734467	108	> 2/3	Y	Y	Y	> 300	N	Silty sand and some shell fragments	Tubes	polychaete tubes	N	
9	SP12	2	10/04/2015	$0.1m^2$ van Veen	Y	16:25	1488	10° 03.842	129° 28.658	10.05842	129.4732467	107	2/3	Y	Y	Y	N	N	Silty sand and some shell fragments	None	None	N	
9	SP12	3	10/04/2015	$0.1m^2$ van Veen	Y	16:52	1489	10° 03.855	129° 28.679	10.05855	129.4734567	107	2/3	N	N	N	N	Y	Silty sand and some shell fragments	None	Shrimp, sponge	Y	
9	SP1	1	11/04/2015	$0.1m^2$ van Veen	Y	7:27	1492	09° 43.460	130° 28.922	9.721266667	130.4758867	276	Full	Y	Y	Y	> 300	N	Very slightly sandy silt clay	Tubes, casts	Polychaete, Pectenid polychaete	N	
10	SP1	2	11/04/2015	$0.1m^2$ van Veen	Y	8:01	1493	09° 43.324	130° 28.997	9.719906667	130.4766367	277	Full	Y	Y	Y	N	N	Very slightly sandy silt clay	Tubes, casts	Polychaetes	N	
10	SP1	3	11/04/2015	$0.1m^2$ van Veen	Y	8:32	1496	09° 43.454	130° 29.004	9.721206667	130.4833733	277	Full	N	N	N	N	Y	Very slightly sandy silt clay	Tubes, casts	Polychaetes (including bamboo worms, Pectenids), fish	Y	
10	SP2	1	11/04/2015	$0.1m^2$ van Veen	N	11:19	1497	09° 44.885	130° 20.571	9.742183333	130.3390433	279	N/A	N	N	N	N	N	N/A	N/A	N/A	N	Grab failed to close
11	SP2	2	11/04/2015	$0.1m^2$ van Veen	Y	11:42	1498	09° 44.929	130° 20.534	9.742623333	130.3386733	277	Full	Y	Y	Y	> 300	N	Very slightly sandy silt clay	Burrows, tubes, casts	Polychaetes	Y	Labelled photo of biota, not sediment sample
11	SP2	3	11/04/2015	$0.1m^2$ van Veen	Y	12:15	1499	09° 44.895	130° 20.579	9.742283333	130.3391233	277	Full	Y	Y	Y	N	N	Very slightly sandy silt clay	Burrows, tubes, casts	Polychaetes	N	
11	SP2	4	11/04/2015	$0.1m^2$ van Veen	Y	13:51	1500	09° 44.902	130° 20.558	9.742353333	130.3389133	277	Full	N	N	N	N	Y	Very slightly sandy silt clay	Burrows, tubes, casts	None	Y	
12	SP3	1	11/04/2015	$0.1m^2$ van Veen	Y	14:28	1501	09° 45.702	130° 10.791	9.75702	130.1745767	279	Full	Y	Y	Y	> 300	N	Very slightly sandy silt clay - layer with shell at around 10cm depth	Tubes, casts	Polychaetes	N	
12	SP3	2	11/04/2015	$0.1m^2$ van Veen	Y	14:56	1502	09° 45.733	130° 10.801	9.75733	130.1746767	279	Full	N	N	N	N	Y	Very slightly sandy silt clay - layer with shell at around 10cm depth	Burrows, tubes, casts	Polychaete tubes	Y	
12	SP3	3	11/04/2015	$0.1m^2$ van Veen	Y	15:23	1503	09° 45.738	130° 10.784	9.75738	130.1745067	279	Full	Y	Y	Y	N	N	Very slightly sandy silt clay - Some fine sand/shell and thin orange/brown veneer.	Tubes, casts	None	N	
13	SP3	1	11/04/2015	SPI	N	16:33	1504	09° 45.699	130° 10.807	9.75699	130.1747367	279	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No Image	
13	SP3	2	11/04/2015	SPI	Y	16:35	1505	09° 45.681	130° 10.806	9.75681	130.1747267	279	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Profile Image	Sediment/water interface not captured. Plan view camera failed to fire.
13	SP3	3	11/04/2015	SPI	N	16:39	1506	09° 45.667	130° 10.796	9.75667	130.1746267	279	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No Image	
13	SP3	4	11/04/2015	SPI	Y	16:43	1507	09° 45.656	130° 10.787	9.75656	130.1745367	279	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Profile Image	Sediment/water interface not captured. Plan view camera failed to fire.
13	SP3	5	11/04/2015	SPI	Y	16:46	1508	09° 45.643	130° 10.799	9.75643	130.1746567	279	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Profile Image	Sediment/water interface not captured. Plan view camera failed to fire.
13	SP3	6	11/04/2015	SPI	N	17:06	1509	09° 45.550	130° 10.699	9.7555	130.1736567	279	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No Image	
13	SP6 E	1	11/04/2015	$0.1m^2$ van Veen	N	18:07	1510	09° 49.119	130° 07.728	9.817856667	130.1239467	260	N/A	N	N	N	N	N	N/A	N/A	N/A	N	No sample
13	SP6 E	2	11/04/2015	$0.1m^2$ van Veen	Y	18:27	1511	09° 49.014	130° 07.719	9.816806667	130.1238567	260	Full	Y	Y	Y	> 300	N	Coarser silt/clay	Tubes, casts	Polychaete tubes	N	
15	SP6 E	3	11/04/2015	$0.1m^2$ van Veen	Y	18:53	1512	09° 48.885	130° 07.721	9.80885	130.1238767	261	Full	N	N	N	N	Y	Slightly sandy/shelly silty mud	Tubes, casts	Polychaete tubes	Y	
15	SP6 E	4	11/04/2015	$0.1m^2$ van Veen	Y	19:15	1513	09° 48.845	130° 07.799	9.80845	130.1246567	260	Full	Y	Y	Y	N	N	Slightly sandy/shelly silty mud	Burrows, tubes, casts	Polychaetes	N	
15	SP15	1	12/04/2015	$0.1m^2$ van Veen	Y	7:20	1514	10° 00.547	130° 46.668	10.00547	130.7733467	123	1/2	Y	Y	Y	> 300	N	Shelly silty coarse sand	None	Polychaetes, shell and encrusting tubeworms	N	
16	SP15	2	12/04/2015	$0.1m^2$ van Veen	Y	7:41	1515	10° 00.516	130° 46.696	10.00516	130.7736267	123	1/2	Y	Y	Y	N	N	Shelly silty coarse sand	Tubes	Brittlestar, polychaetes	N	
16	SP15	3	12/04/2015	$0.1m^2$ van Veen	Y	7:57	1516	10° 00.527	130° 46.654	10.00527	130.7732067	123	1/3	N	N	N	N	Y	Shelly silty coarse sand	Tubes	Polychaete tubes	Y	
17	SP14	1	14/04/2015	$0.1m^2$ van Veen	Y	14:14	1522	10° 14.872	129° 46.156	10.24205333	130.7682267	99	1/2	Y	Y	Y	N	N	Silty sand	None	None	N	Slightly washed out
17	SP14	2	14/04/2015	$0.1m^2$ van Veen	Y	14:23	1523	10° 14.948	129° 46.074	10.24281333	130.7674067	99	1/2	Y	Y	Y	> 300	N	Silty sand	Tubes	Polychaete tubes	N	
17	SP14	3	14/04/2015	$0.1m^2$ van Veen	Y	14:43	1524	10° 14.961	129° 46.117	10.24294333	130.7678367	99	1/2	N	N	N	N	Y	Silty sand	Tubes	Polychaetes	Y	
18	SP13	1	14/04/2015	$0.1m^2$ van Veen	Y	15:42	1525	10° 11.659	129° 39.847	10.18992333	130.65847	98	1/2	Y	Y	Y	> 300	N	Slightly silty sand, shelly	None	Prawns	N	
18	SP13	2	14/04/2015	$0.1m^2$ van Veen	Y	16:01	1526	10° 11.589	129° 39.857	10.18922333	130.65857	98	1/2	Y	Y	Y	N	N	Slightly silty sand, shelly	Tubes	Prawns, polychaetes	N	
18	SP13	3	14/04/2015	$0.1m^2$ van Veen	Y	16:17	1527	10° 11.747	129° 39.754	10.19080333	130.65754	98	1/2	N	N	N	N	Y	Slightly silty sand, shelly	Tubes	Brittlestar, polychaetes	Y	

Appendix B. Photographs of Grab Samples and SPI Profile Images

Sample location	Photograph
SP1	
SP2	

SP3	
SP4	(no image)
SP5	

<table>
<tr><td>SP6E</td><td>
</td></tr>
<tr><td>SP7</td><td>No sample</td></tr>
<tr><td>SP8</td><td>
</td></tr>
</table>

SP9	
SP10	
SP11	No sample

SP12	JACOBS ConocoPhillips Barossa Field Studies IW021200 SITE: SP12 DATE: 10/04/15
SP13	JACOBS ConocoPhillips Barossa Field Studies IW021200 SITE: SP13

<table>
<tr><td>SP14</td><td>
</td></tr>
<tr><td>SP15</td><td>
</td></tr>
<tr><td>SP16</td><td>No sample</td></tr>
</table>

SP17	ConocoPhillips JACOBS Barossa Field Studies IW021200 SITE: DATE:

SP3 SPI image 1	

SP3 SPI image 2	

SP3 SPI image 3	

Appendix C. Analytical Laboratory Reports

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EP1502881**	Page	: 1 of 13
Client	: **JACOBS GROUP (AUSTRALIA) PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: MR CHRIS TEASDALE	Contact	: Scott James
Address	: P O BOX H615 PERTH WA, AUSTRALIA 6001	Address	: 10 Hod Way Malaga WA Australia 6090
E-mail	: cteasdale@globalskm.com	E-mail	: perth.enviro.services@alsglobal.com
Telephone	: +61 08 9469 4400	Telephone	: +61-8-9209 7655
Facsimile	: +61 08 9469 4488	Facsimile	: +61-8-9209 7600
Project	: IW021200	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 16-APR-2015
Sampler	: G.H.	Issue Date	: 06-MAY-2015
Site	: ----		
		No. of samples received	: 29
Quote number	: EN/003/14	No. of samples analysed	: 25

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Matt Frost	Senior Organic Chemist	Brisbane Organics
Rassem Ayoubi	Senior Organic Chemist	Perth Inorganics
Rassem Ayoubi	Senior Organic Chemist	Perth Organics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **EP080: Poor matrix spike recoveries due to matrix effects. Confirmed by re-extraction and re-analysis.**
- **EP090: Particular samples shows poor surrogate recovery due to matrix interference. Confirmed by re-extraction and re-analysis.**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	SP1 1	SP1 2	SP2 1	SP2 2	SP3 1
			Client sampling date / time	11-APR-2015 07:27	11-APR-2015 08:01	11-APR-2015 11:42	11-APR-2015 12:15	11-APR-2015 14:28
Compound	CAS Number	LOR	Unit	EP1502881-001	EP1502881-002	EP1502881-003	EP1502881-004	EP1502881-005
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	**62.7**	**63.3**	**65.5**	**63.7**	**60.4**
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	10	mg/kg	<10	<10	<10	<10	<10
C10 - C14 Fraction	----	50	mg/kg	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
^ C10 - C36 Fraction (sum)	----	50	mg/kg	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	10	mg/kg	<10	<10	<10	<10	<10
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	10	mg/kg	<10	<10	<10	<10	<10
>C10 - C16 Fraction	>C10_C16	50	mg/kg	<50	<50	<50	<50	<50
>C16 - C34 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	50	mg/kg	<50	<50	<50	<50	<50
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	50	mg/kg	<50	<50	<50	<50	<50
EP080: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	100-41-4	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
meta- & para-Xylene	108-38-3 106-42-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
ortho-Xylene	95-47-6	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	1330-20-7	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Naphthalene	91-20-3	1	mg/kg	<1	<1	<1	<1	<1
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**64.2**	**70.9**	**66.7**	**70.6**	**72.9**
Toluene-D8	2037-26-5	0.1	%	**68.1**	**74.1**	**66.4**	**72.3**	**72.6**
4-Bromofluorobenzene	460-00-4	0.1	%	**69.7**	**74.4**	**66.6**	**74.6**	**73.4**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	SP1 1	SP1 2	SP2 1	SP2 2	SP3 1
			Client sampling date / time	11-APR-2015 07:27	11-APR-2015 08:01	11-APR-2015 11:42	11-APR-2015 12:15	11-APR-2015 14:28
Compound	CAS Number	LOR	Unit	EP1502881-001	EP1502881-002	EP1502881-003	EP1502881-004	EP1502881-005
EP090S: Organotin Surrogate								
Tripropyltin	----	0.1	%	86.8	68.2	12.2	74.1	8.8

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	SP3 2	SP4 1	SP5 1	SP5 2	SP6 1
			Client sampling date / time	11-APR-2015 15:23	09-APR-2015 11:58	09-APR-2015 07:28	09-APR-2015 08:11	09-APR-2015 18:27
Compound	CAS Number	LOR	Unit	EP1502881-006	EP1502881-007	EP1502881-008	EP1502881-009	EP1502881-010
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	**62.7**	**45.5**	**50.1**	**50.8**	**52.7**
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	10	mg/kg	<10	<10	<10	<10	<10
C10 - C14 Fraction	----	50	mg/kg	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
^ C10 - C36 Fraction (sum)	----	50	mg/kg	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	10	mg/kg	<10	<10	<10	<10	<10
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	10	mg/kg	<10	<10	<10	<10	<10
>C10 - C16 Fraction	>C10_C16	50	mg/kg	<50	<50	<50	<50	<50
>C16 - C34 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	50	mg/kg	<50	<50	<50	<50	<50
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	50	mg/kg	<50	<50	<50	<50	<50
EP080: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	100-41-4	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
meta- & para-Xylene	108-38-3 106-42-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
ortho-Xylene	95-47-6	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	1330-20-7	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Naphthalene	91-20-3	1	mg/kg	<1	<1	<1	<1	<1
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**73.5**	**74.0**	**75.1**	**74.0**	**77.1**
Toluene-D8	2037-26-5	0.1	%	**67.8**	**74.8**	**72.6**	**72.8**	**72.5**
4-Bromofluorobenzene	460-00-4	0.1	%	**65.7**	**75.2**	**72.0**	**75.6**	**73.1**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			Client sample ID	SP3 2	SP4 1	SP5 1	SP5 2	SP6 1
			Client sampling date / time	11-APR-2015 15:23	09-APR-2015 11:58	09-APR-2015 07:28	09-APR-2015 08:11	09-APR-2015 18:27
Compound	CAS Number	LOR	Unit	EP1502881-006	EP1502881-007	EP1502881-008	EP1502881-009	EP1502881-010
EP090S: Organotin Surrogate								
Tripropyltin	----	0.1	%	66.6	79.2	92.2	83.5	97.9

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	SP8 1	SP8 2	SP10N 1	SP10N 2	SP12 1
			Client sampling date / time	10-APR-2015 14:25	10-APR-2015 14:45	10-APR-2015 10:45	10-APR-2015 11:25	10-APR-2015 16:15
				EP1502881-012	**EP1502881-013**	**EP1502881-014**	**EP1502881-015**	**EP1502881-016**
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	**29.0**	**28.7**	**33.2**	**36.3**	**40.6**
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	10	mg/kg	<10	<10	<10	<10	<10
C10 - C14 Fraction	----	50	mg/kg	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
^ **C10 - C36 Fraction (sum)**	----	50	mg/kg	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	10	mg/kg	<10	<10	<10	<10	<10
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	10	mg/kg	<10	<10	<10	<10	<10
>C10 - C16 Fraction	>C10_C16	50	mg/kg	<50	<50	<50	<50	<50
>C16 - C34 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	50	mg/kg	<50	<50	<50	<50	<50
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	50	mg/kg	<50	<50	<50	<50	<50
EP080: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	100-41-4	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
meta- & para-Xylene	108-38-3 106-42-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
ortho-Xylene	95-47-6	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ **Sum of BTEX**	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ **Total Xylenes**	1330-20-7	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Naphthalene	91-20-3	1	mg/kg	<1	<1	<1	<1	<1
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	**1**	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**87.4**	**88.1**	**76.8**	**83.6**	**82.1**
Toluene-D8	2037-26-5	0.1	%	**80.4**	**83.1**	**69.4**	**74.4**	**74.4**
4-Bromofluorobenzene	460-00-4	0.1	%	**78.6**	**78.5**	**68.8**	**71.7**	**72.0**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	SP8 1	SP8 2	SP10N 1	SP10N 2	SP12 1
			Client sampling date / time	10-APR-2015 14:25	10-APR-2015 14:45	10-APR-2015 10:45	10-APR-2015 11:25	10-APR-2015 16:15
Compound	CAS Number	LOR	Unit	EP1502881-012	EP1502881-013	EP1502881-014	EP1502881-015	EP1502881-016
EP090S: Organotin Surrogate								
Tripropyltin	----	0.1	%	69.8	20.1	97.2	99.1	85.5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

Compound	CAS Number	LOR	Unit	SP12 2	SP15 1	SP15 2	SP17 1	SP14 1
Client sampling date / time				10-APR-2015 16:25	12-APR-2015 07:20	12-APR-2015 07:41	08-APR-2015 18:07	14-APR-2015 14:14
				EP1502881-017	EP1502881-018	EP1502881-019	EP1502881-020	EP1502881-021
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	**41.7**	**31.8**	**29.4**	**42.7**	**40.0**
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	10	mg/kg	<10	<10	<10	<10	<10
C10 - C14 Fraction	----	50	mg/kg	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
^ C10 - C36 Fraction (sum)	----	50	mg/kg	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	10	mg/kg	<10	<10	<10	<10	<10
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	10	mg/kg	<10	<10	<10	<10	<10
>C10 - C16 Fraction	>C10_C16	50	mg/kg	<50	<50	<50	<50	<50
>C16 - C34 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	50	mg/kg	<50	<50	<50	<50	<50
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	50	mg/kg	<50	<50	<50	<50	<50
EP080: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	100-41-4	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
meta- & para-Xylene	108-38-3 106-42-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
ortho-Xylene	95-47-6	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	1330-20-7	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Naphthalene	91-20-3	1	mg/kg	<1	<1	<1	<1	<1
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**80.4**	**76.1**	**83.0**	**75.9**	**79.2**
Toluene-D8	2037-26-5	0.1	%	**73.1**	**67.0**	**74.5**	**67.0**	**71.5**
4-Bromofluorobenzene	460-00-4	0.1	%	**68.5**	**67.4**	**73.2**	**66.2**	**70.9**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	SP12 2	SP15 1	SP15 2	SP17 1	SP14 1
			Client sampling date / time	10-APR-2015 16:25	12-APR-2015 07:20	12-APR-2015 07:41	08-APR-2015 18:07	14-APR-2015 14:14
Compound	CAS Number	LOR	Unit	EP1502881-017	EP1502881-018	EP1502881-019	EP1502881-020	EP1502881-021
EP090S: Organotin Surrogate								
Tripropyltin	----	0.1	%	95.0	80.3	69.8	86.8	88.2

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

Compound	CAS Number	LOR	Unit	SP14 2	SP13 1	SP13 2	SP6E 1	SP6E 2
			Client sampling date / time	14-APR-2015 14:28	14-APR-2015 15:42	14-APR-2015 16:01	11-APR-2015 15:00	11-APR-2015 15:00
				EP1502881-022	EP1502881-023	EP1502881-024	EP1502881-025	EP1502881-030
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	**39.7**	**34.0**	**30.4**	**52.2**	**52.9**
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	10	mg/kg	<10	<10	<10	<10	<10
C10 - C14 Fraction	----	50	mg/kg	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
^ C10 - C36 Fraction (sum)	----	50	mg/kg	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	10	mg/kg	<10	<10	<10	<10	<10
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	10	mg/kg	<10	<10	<10	<10	<10
>C10 - C16 Fraction	>C10_C16	50	mg/kg	<50	<50	<50	<50	<50
>C16 - C34 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	mg/kg	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	50	mg/kg	<50	<50	<50	<50	<50
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	50	mg/kg	<50	<50	<50	<50	<50
EP080: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	100-41-4	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
meta- & para-Xylene	108-38-3 106-42-3	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
ortho-Xylene	95-47-6	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	1330-20-7	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Naphthalene	91-20-3	1	mg/kg	<1	<1	<1	<1	<1
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**85.8**	**89.3**	**77.4**	**88.3**	**86.8**
Toluene-D8	2037-26-5	0.1	%	**77.2**	**78.9**	**66.3**	**77.5**	**75.8**
4-Bromofluorobenzene	460-00-4	0.1	%	**82.2**	**81.8**	**70.9**	**78.9**	**79.0**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)

			Client sample ID	SP14 2	SP13 1	SP13 2	SP6E 1	SP6E 2
			Client sampling date / time	14-APR-2015 14:28	14-APR-2015 15:42	14-APR-2015 16:01	11-APR-2015 15:00	11-APR-2015 15:00
Compound	CAS Number	LOR	Unit	EP1502881-022	EP1502881-023	EP1502881-024	EP1502881-025	EP1502881-030
EP090S: Organotin Surrogate								
Tripropyltin	----	0.1	%	70.7	54.8	87.2	89.9	100

Surrogate Control Limits

Sub-Matrix: **SOIL**

Compound	CAS Number	Recovery Limits (%)	
		Low	High
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	63.2	132
Toluene-D8	2037-26-5	66.0	125.4
4-Bromofluorobenzene	460-00-4	60.4	124
EP090S: Organotin Surrogate			
Tripropyltin	----	35	130

ALS Environmental

QUALITY CONTROL REPORT

Work Order	: **EP1502881**	Page	: 1 of 9
Client	: **JACOBS GROUP (AUSTRALIA) PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: MR CHRIS TEASDALE	Contact	: Scott James
Address	: P O BOX H615 PERTH WA, AUSTRALIA 6001	Address	: 10 Hod Way Malaga WA Australia 6090
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Telephone	: +61 08 9469 4400	Telephone	: +61-8-9209 7655
Facsimile	: +61 08 9469 4488	Facsimile	: +61-8-9209 7600
Project	: IW021200	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Site	: ----		
C-O-C number	: ----	Date Samples Received	: 16-APR-2015
Sampler	: G.H.	Issue Date	: 06-MAY-2015
Order number	: ----		
		No. of samples received	: 29
Quote number	: EN/003/14	No. of samples analysed	: 25

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

NATA WORLD RECOGNISED ACCREDITATION

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out ir compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Matt Frost	Senior Organic Chemist	Brisbane Organics
Rassem Ayoubi	Senior Organic Chemist	Perth Inorganics
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General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

Key :
- Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
- CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
- LOR = Limit of reporting
- RPD = Relative Percentage Difference
- # = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **SOIL**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
EA055: Moisture Content (QC Lot: 3907064)									
EP1502881-001	SP1 1	EA055-103: Moisture Content (dried @ 103°C)	----	1.0	%	62.7	62.8	0.3	0% - 20%
EP1502881-010	SP6 1	EA055-103: Moisture Content (dried @ 103°C)	----	1.0	%	52.7	52.7	0.0	0% - 20%
EA055: Moisture Content (QC Lot: 3907065)									
EP1502881-022	SP14 2	EA055-103: Moisture Content (dried @ 103°C)	----	1.0	%	39.7	39.7	0.0	0% - 20%
EP080/071: Total Petroleum Hydrocarbons (QC Lot: 3904677)									
EP1502881-001	SP1 1	EP071: C15 - C28 Fraction	----	100	mg/kg	<100	<100	0.0	No Limit
		EP071: C29 - C36 Fraction	----	100	mg/kg	<100	<100	0.0	No Limit
		EP071: C10 - C14 Fraction	----	50	mg/kg	<50	<50	0.0	No Limit
EP1502881-012	SP8 1	EP071: C15 - C28 Fraction	----	100	mg/kg	<100	<100	0.0	No Limit
		EP071: C29 - C36 Fraction	----	100	mg/kg	<100	<100	0.0	No Limit
		EP071: C10 - C14 Fraction	----	50	mg/kg	<50	<50	0.0	No Limit
EP080/071: Total Petroleum Hydrocarbons (QC Lot: 3904678)									
EP1502899-001	Anonymous	EP071: C15 - C28 Fraction	----	100	mg/kg	<100	<100	0.0	No Limit
		EP071: C29 - C36 Fraction	----	100	mg/kg	<100	<100	0.0	No Limit
		EP071: C10 - C14 Fraction	----	50	mg/kg	<50	<50	0.0	No Limit
EP080/071: Total Petroleum Hydrocarbons (QC Lot: 3904680)									
EP1502881-001	SP1 1	EP080: C6 - C9 Fraction	----	10	mg/kg	<10	<10	0.0	No Limit
EP1502881-012	SP8 1	EP080: C6 - C9 Fraction	----	10	mg/kg	<10	<10	0.0	No Limit
EP080/071: Total Petroleum Hydrocarbons (QC Lot: 3904681)									
EP1502899-001	Anonymous	EP080: C6 - C9 Fraction	----	10	mg/kg	<10	<10	0.0	No Limit
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QC Lot: 3904677)									
EP1502881-001	SP1 1	EP071: >C16 - C34 Fraction	----	100	mg/kg	<100	<100	0.0	No Limit
		EP071: >C34 - C40 Fraction	----	100	mg/kg	<100	<100	0.0	No Limit
		EP071: >C10 - C16 Fraction	>C10_C16	50	mg/kg	<50	<50	0.0	No Limit
EP1502881-012	SP8 1	EP071: >C16 - C34 Fraction	----	100	mg/kg	<100	<100	0.0	No Limit
		EP071: >C34 - C40 Fraction	----	100	mg/kg	<100	<100	0.0	No Limit
		EP071: >C10 - C16 Fraction	>C10_C16	50	mg/kg	<50	<50	0.0	No Limit
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QC Lot: 3904678)									
EP1502899-001	Anonymous	EP071: >C16 - C34 Fraction	----	100	mg/kg	<100	<100	0.0	No Limit
		EP071: >C34 - C40 Fraction	----	100	mg/kg	<100	<100	0.0	No Limit
		EP071: >C10 - C16 Fraction	>C10_C16	50	mg/kg	<50	<50	0.0	No Limit
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QC Lot: 3904680)									
EP1502881-001	SP1 1	EP080: C6 - C10 Fraction	C6_C10	10	mg/kg	<10	<10	0.0	No Limit
EP1502881-012	SP8 1	EP080: C6 - C10 Fraction	C6_C10	10	mg/kg	<10	<10	0.0	No Limit

Sub-Matrix: **SOIL**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
				Laboratory Duplicate (DUP) Report					
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QC Lot: 3904681)									
EP1502899-001	Anonymous	EP080: C6 - C10 Fraction	C6_C10	10	mg/kg	<10	<10	0.0	No Limit
EP080: BTEXN (QC Lot: 3904680)									
EP1502881-001	SP1 1	EP080: Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	0.0	No Limit
		EP080: Toluene	108-88-3	0.5	mg/kg	<0.5	<0.5	0.0	No Limit
		EP080: Ethylbenzene	100-41-4	0.5	mg/kg	<0.5	<0.5	0.0	No Limit
		EP080: meta- & para-Xylene	108-38-3 106-42-3	0.5	mg/kg	<0.5	<0.5	0.0	No Limit
		EP080: ortho-Xylene	95-47-6	0.5	mg/kg	<0.5	<0.5	0.0	No Limit
		EP080: Naphthalene	91-20-3	1	mg/kg	<1	<1	0.0	No Limit
EP1502881-012	SP8 1	EP080: Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	0.0	No Limit
		EP080: Toluene	108-88-3	0.5	mg/kg	<0.5	<0.5	0.0	No Limit
		EP080: Ethylbenzene	100-41-4	0.5	mg/kg	<0.5	<0.5	0.0	No Limit
		EP080: meta- & para-Xylene	108-38-3 106-42-3	0.5	mg/kg	<0.5	<0.5	0.0	No Limit
		EP080: ortho-Xylene	95-47-6	0.5	mg/kg	<0.5	<0.5	0.0	No Limit
		EP080: Naphthalene	91-20-3	1	mg/kg	<1	<1	0.0	No Limit
EP080: BTEXN (QC Lot: 3904681)									
EP1502899-001	Anonymous	EP080: Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	0.0	No Limit
		EP080: Toluene	108-88-3	0.5	mg/kg	<0.5	<0.5	0.0	No Limit
		EP080: Ethylbenzene	100-41-4	0.5	mg/kg	<0.5	<0.5	0.0	No Limit
		EP080: meta- & para-Xylene	108-38-3 106-42-3	0.5	mg/kg	<0.5	<0.5	0.0	No Limit
		EP080: ortho-Xylene	95-47-6	0.5	mg/kg	<0.5	<0.5	0.0	No Limit
		EP080: Naphthalene	91-20-3	1	mg/kg	<1	<1	0.0	No Limit
EP090: Organotin Compounds (QC Lot: 3910186)									
EP1502881-007	SP4 1	EP090: Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	0.0	No Limit
		EP090: Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	0.0	No Limit
		EP090: Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	0.0	No Limit
EP090: Organotin Compounds (QC Lot: 3910452)									
EP1502881-001	SP1 1	EP090: Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	0.0	No Limit
		EP090: Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	0.0	No Limit
		EP090: Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	0.0	No Limit
EP1502881-018	SP15 1	EP090: Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	0.0	No Limit
		EP090: Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	0.0	No Limit
		EP090: Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	0.0	No Limit

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Spike (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **SOIL**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EP080/071: Total Petroleum Hydrocarbons (QCLot: 3904677)								
EP071: C10 - C14 Fraction	----	25	mg/kg	<50	1192 mg/kg	87.6	47	135
EP071: C15 - C28 Fraction	----	50	mg/kg	<100	2699 mg/kg	90.5	63	129
EP071: C29 - C36 Fraction	----	50	mg/kg	<100	437 mg/kg	75.1	53	135
EP080/071: Total Petroleum Hydrocarbons (QCLot: 3904678)								
EP071: C10 - C14 Fraction	----	25	mg/kg	<50	1192 mg/kg	99.6	47	135
EP071: C15 - C28 Fraction	----	50	mg/kg	<100	2699 mg/kg	99.6	63	129
EP071: C29 - C36 Fraction	----	50	mg/kg	<100	437 mg/kg	88.8	53	135
EP080/071: Total Petroleum Hydrocarbons (QCLot: 3904680)								
EP080: C6 - C9 Fraction	----	10	mg/kg	<10	32 mg/kg	103	64	134
EP080/071: Total Petroleum Hydrocarbons (QCLot: 3904681)								
EP080: C6 - C9 Fraction	----	10	mg/kg	<10	32 mg/kg	99.1	64	134
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QCLot: 3904677)								
EP071: >C10 - C16 Fraction	>C10_C16	50	mg/kg	<50	1913 mg/kg	89.8	61	133
EP071: >C16 - C34 Fraction	----	100	mg/kg	<100	2245 mg/kg	90.5	63	135
EP071: >C34 - C40 Fraction	----	100	mg/kg	<100	151 mg/kg	63.1	50	140
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QCLot: 3904678)								
EP071: >C10 - C16 Fraction	>C10_C16	50	mg/kg	<50	1913 mg/kg	99.0	61	133
EP071: >C16 - C34 Fraction	----	100	mg/kg	<100	2245 mg/kg	101	63	135
EP071: >C34 - C40 Fraction	----	100	mg/kg	<100	151 mg/kg	93.2	50	140
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QCLot: 3904680)								
EP080: C6 - C10 Fraction	C6_C10	10	mg/kg	<10	37 mg/kg	102	61	143
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QCLot: 3904681)								
EP080: C6 - C10 Fraction	C6_C10	10	mg/kg	<10	37 mg/kg	99.2	61	143
EP080: BTEXN (QCLot: 3904680)								
EP080: Benzene	71-43-2	0.2	mg/kg	<0.2	2 mg/kg	98.0	73	127
EP080: Toluene	108-88-3	0.5	mg/kg	<0.5	2 mg/kg	98.8	72	126
EP080: Ethylbenzene	100-41-4	0.5	mg/kg	<0.5	2 mg/kg	97.6	73	125

Sub-Matrix: **SOIL**

Method: Compound	CAS Number	LOR	Unit	Method Blank (MB) Report Result	Laboratory Control Spike (LCS) Report Spike Concentration	Spike Recovery (%) LCS	Recovery Limits (%) Low	Recovery Limits (%) High
EP080: BTEXN (QCLot: 3904680) - continued								
EP080: meta- & para-Xylene	108-38-3 106-42-3	0.5	mg/kg	<0.5	4 mg/kg	97.2	72	126
EP080: ortho-Xylene	95-47-6	0.5	mg/kg	<0.5	2 mg/kg	95.2	75	125
EP080: Naphthalene	91-20-3	1	mg/kg	<1	2 mg/kg	92.2	63	133
EP080: BTEXN (QCLot: 3904681)								
EP080: Benzene	71-43-2	0.2	mg/kg	<0.2	2 mg/kg	94.2	73	127
EP080: Toluene	108-88-3	0.5	mg/kg	<0.5	2 mg/kg	96.4	72	126
EP080: Ethylbenzene	100-41-4	0.5	mg/kg	<0.5	2 mg/kg	98.5	73	125
EP080: meta- & para-Xylene	108-38-3 106-42-3	0.5	mg/kg	<0.5	4 mg/kg	98.9	72	126
EP080: ortho-Xylene	95-47-6	0.5	mg/kg	<0.5	2 mg/kg	95.6	75	125
EP080: Naphthalene	91-20-3	1	mg/kg	<1	2 mg/kg	95.3	63	133
EP090: Organotin Compounds (QCLot: 3910186)								
EP090: Monobutyltin	78763-54-9	1.0	µgSn/kg	<1	1.25 µgSn/kg	95.8	36	128
EP090: Dibutyltin	1002-53-5	1.0	µgSn/kg	<1	1.25 µgSn/kg	85.6	42	132
EP090: Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	1.25 µgSn/kg	85.7	52	139
EP090: Organotin Compounds (QCLot: 3910452)								
EP090: Monobutyltin	78763-54-9	1.0	µgSn/kg	<1	1.25 µgSn/kg	93.9	36	128
EP090: Dibutyltin	1002-53-5	1.0	µgSn/kg	<1	1.25 µgSn/kg	80.7	42	132
EP090: Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	1.25 µgSn/kg	80.3	52	139

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **SOIL**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Matrix Spike (MS) Report Spike Concentration	SpikeRecovery(%) MS	Recovery Limits (%) Low	Recovery Limits (%) High
EP080/071: Total Petroleum Hydrocarbons (QCLot: 3904677)							
EP1502881-002	SP1 2	EP071: C10 - C14 Fraction	----	1192 mg/kg	86.4	64.7	126
		EP071: C15 - C28 Fraction	----	2699 mg/kg	89.6	61.7	124
		EP071: C29 - C36 Fraction	----	437 mg/kg	72.9	64.6	131
EP080/071: Total Petroleum Hydrocarbons (QCLot: 3904678)							
EP1502899-001	Anonymous	EP071: C10 - C14 Fraction	----	1192 mg/kg	94.4	64.7	126

Sub-Matrix: **SOIL**

				Matrix Spike (MS) Report			
				Spike	SpikeRecovery(%)	Recovery Limits (%)	
Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Concentration	MS	Low	High
EP080/071: Total Petroleum Hydrocarbons (QCLot: 3904678) - continued							
EP1502899-001	Anonymous	EP071: C15 - C28 Fraction	----	2699 mg/kg	92.8	61.7	124
		EP071: C29 - C36 Fraction	----	437 mg/kg	84.2	64.6	131
EP080/071: Total Petroleum Hydrocarbons (QCLot: 3904680)							
EP1502881-002	SP1 2	EP080: C6 - C9 Fraction	----	24 mg/kg	# 56.7	69.1	135
EP080/071: Total Petroleum Hydrocarbons (QCLot: 3904681)							
EP1502899-001	Anonymous	EP080: C6 - C9 Fraction	----	24 mg/kg	94.6	69.1	135
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QCLot: 3904677)							
EP1502881-002	SP1 2	EP071: >C10 - C16 Fraction	>C10_C16	1913 mg/kg	89.1	64.7	126
		EP071: >C16 - C34 Fraction	----	2245 mg/kg	89.2	61.7	124
		EP071: >C34 - C40 Fraction	----	151 mg/kg	66.5	64.6	131
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QCLot: 3904678)							
EP1502899-001	Anonymous	EP071: >C10 - C16 Fraction	>C10_C16	1913 mg/kg	93.9	64.7	126
		EP071: >C16 - C34 Fraction	----	2245 mg/kg	94.0	61.7	124
		EP071: >C34 - C40 Fraction	----	151 mg/kg	85.6	64.6	131
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QCLot: 3904680)							
EP1502881-002	SP1 2	EP080: C6 - C10 Fraction	C6_C10	29 mg/kg	# 55.4	69.1	135
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QCLot: 3904681)							
EP1502899-001	Anonymous	EP080: C6 - C10 Fraction	C6_C10	29 mg/kg	91.9	69.1	135
EP080: BTEXN (QCLot: 3904680)							
EP1502881-002	SP1 2	EP080: Benzene	71-43-2	2 mg/kg	# 63.1	76.4	118
		EP080: Toluene	108-88-3	2 mg/kg	# 65.7	67.4	127
EP080: BTEXN (QCLot: 3904681)							
EP1502899-001	Anonymous	EP080: Benzene	71-43-2	2 mg/kg	87.3	76.4	118
		EP080: Toluene	108-88-3	2 mg/kg	90.9	67.4	127
EP090: Organotin Compounds (QCLot: 3910186)							
EP1502881-008	SP5 1	EP090: Monobutyltin	78763-54-9	1.25 µgSn/kg	38.4	35	130
		EP090: Dibutyltin	1002-53-5	1.25 µgSn/kg	80.6	20	130
		EP090: Tributyltin	56573-85-4	1.25 µgSn/kg	80.1	20	130
EP090: Organotin Compounds (QCLot: 3910452)							
EP1502881-002	SP1 2	EP090: Monobutyltin	78763-54-9	1.25 µgSn/kg	# 23.6	35	130
		EP090: Dibutyltin	1002-53-5	1.25 µgSn/kg	67.1	20	130
		EP090: Tributyltin	56573-85-4	1.25 µgSn/kg	77.9	20	130

Matrix Spike (MS) and Matrix Spike Duplicate (MSD) Report

The quality control term Matrix Spike (MS) and Matrix Spike Duplicate (MSD) refers to intralaboratory split samples spiked with a representative set of target analytes. The purpose of these QC parameters are to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **SOIL**

				Matrix Spike (MS) and Matrix Spike Duplicate (MSD) Report						
				Spike	Spike Recovery (%)		Recovery Limits (%)		RPDs (%)	
Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Concentration	MS	MSD	Low	High	Value	Control Limit
EP080/071: Total Petroleum Hydrocarbons (QCLot: 3904677)										
EP1502881-002	SP1 2	EP071: C10 - C14 Fraction	----	1192 mg/kg	86.4	----	64.7	126	----	----
		EP071: C15 - C28 Fraction	----	2699 mg/kg	89.6	----	61.7	124	----	----
		EP071: C29 - C36 Fraction	----	437 mg/kg	72.9	----	64.6	131	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QCLot: 3904677)										
EP1502881-002	SP1 2	EP071: >C10 - C16 Fraction	>C10_C16	1913 mg/kg	89.1	----	64.7	126	----	----
		EP071: >C16 - C34 Fraction	----	2245 mg/kg	89.2	----	61.7	124	----	----
		EP071: >C34 - C40 Fraction	----	151 mg/kg	66.5	----	64.6	131	----	----
EP080/071: Total Petroleum Hydrocarbons (QCLot: 3904678)										
EP1502899-001	Anonymous	EP071: C10 - C14 Fraction	----	1192 mg/kg	94.4	----	64.7	126	----	----
		EP071: C15 - C28 Fraction	----	2699 mg/kg	92.8	----	61.7	124	----	----
		EP071: C29 - C36 Fraction	----	437 mg/kg	84.2	----	64.6	131	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QCLot: 3904678)										
EP1502899-001	Anonymous	EP071: >C10 - C16 Fraction	>C10_C16	1913 mg/kg	93.9	----	64.7	126	----	----
		EP071: >C16 - C34 Fraction	----	2245 mg/kg	94.0	----	61.7	124	----	----
		EP071: >C34 - C40 Fraction	----	151 mg/kg	85.6	----	64.6	131	----	----
EP080/071: Total Petroleum Hydrocarbons (QCLot: 3904680)										
EP1502881-002	SP1 2	EP080: C6 - C9 Fraction	----	24 mg/kg	# 56.7	----	69.1	135	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QCLot: 3904680)										
EP1502881-002	SP1 2	EP080: C6 - C10 Fraction	C6_C10	29 mg/kg	# 55.4	----	69.1	135	----	----
EP080: BTEXN (QCLot: 3904680)										
EP1502881-002	SP1 2	EP080: Benzene	71-43-2	2 mg/kg	# 63.1	----	76.4	118	----	----
		EP080: Toluene	108-88-3	2 mg/kg	# 65.7	----	67.4	127	----	----
EP080/071: Total Petroleum Hydrocarbons (QCLot: 3904681)										
EP1502899-001	Anonymous	EP080: C6 - C9 Fraction	----	24 mg/kg	94.6	----	69.1	135	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QCLot: 3904681)										
EP1502899-001	Anonymous	EP080: C6 - C10 Fraction	C6_C10	29 mg/kg	91.9	----	69.1	135	----	----
EP080: BTEXN (QCLot: 3904681)										
EP1502899-001	Anonymous	EP080: Benzene	71-43-2	2 mg/kg	87.3	----	76.4	118	----	----
		EP080: Toluene	108-88-3	2 mg/kg	90.9	----	67.4	127	----	----
EP090: Organotin Compounds (QCLot: 3910186)										
EP1502881-008	SP5 1	EP090: Monobutyltin	78763-54-9	1.25 µgSn/kg	38.4	----	35	130	----	----

Sub-Matrix: **SOIL**

				Matrix Spike (MS) and Matrix Spike Duplicate (MSD) Report						
				Spike	Spike Recovery (%)		Recovery Limits (%)		RPDs (%)	
Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Concentration	MS	MSD	Low	High	Value	Control Limit
EP090: Organotin Compounds (QCLot: 3910186) - continued										
EP1502881-008	SP5 1	EP090: Dibutyltin	1002-53-5	1.25 µgSn/kg	80.6	----	20	130	----	----
		EP090: Tributyltin	56573-85-4	1.25 µgSn/kg	80.1	----	20	130	----	----
EP090: Organotin Compounds (QCLot: 3910452)										
EP1502881-002	SP1 2	EP090: Monobutyltin	78763-54-9	1.25 µgSn/kg	# 23.6	----	35	130	----	----
		EP090: Dibutyltin	1002-53-5	1.25 µgSn/kg	67.1	----	20	130	----	----
		EP090: Tributyltin	56573-85-4	1.25 µgSn/kg	77.9	----	20	130	----	----

INTERPRETIVE QUALITY CONTROL REPORT

Work Order	: **EP1502881**	Page	: 1 of 8
Client	: JACOBS GROUP (AUSTRALIA) PTY LTD	Laboratory	: Environmental Division Perth
Contact	: MR CHRIS TEASDALE	Contact	: Scott James
Address	: P O BOX H615 PERTH WA, AUSTRALIA 6001	Address	: 10 Hod Way Malaga WA Australia 6090
E-mail	: cteasdale@globalskm.com	E-mail	: perth.enviro.services@alsglobal.com
Telephone	: +61 08 9469 4400	Telephone	: +61-8-9209 7655
Facsimile	: +61 08 9469 4488	Facsimile	: +61-8-9209 7600
Project	: IW021200	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Site	: ----		
C-O-C number	: ----	Date Samples Received	: 16-APR-2015
Sampler	: G.H.	Issue Date	: 06-MAY-2015
Order number	: ----		
		No. of samples received	: 29
Quote number	: EN/003/14	No. of samples analysed	: 25

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Interpretive Quality Control Report contains the following information:

- Analysis Holding Time Compliance
- Quality Control Parameter Frequency Compliance
- Brief Method Summaries
- Summary of Outliers

Analysis Holding Time Compliance

This report summarizes extraction / preparation and analysis times and compares each with recommended holding times (USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method		Sample Date	Extraction / Preparation			Analysis		
Container / Client Sample ID(s)			Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EA055: Moisture Content								
Soil Glass Jar - Unpreserved (EA055-103)								
SP17 1		**08-APR-2015**	**----**	----	----	**21-APR-2015**	22-APR-2015	✓
Soil Glass Jar - Unpreserved (EA055-103)								
SP4 1, SP5 2,	SP5 1, SP6 1	**09-APR-2015**	**----**	----	----	**21-APR-2015**	23-APR-2015	✓
Soil Glass Jar - Unpreserved (EA055-103)								
SP8 1, SP10N 1, SP12 1,	SP8 2, SP10N 2, SP12 2	**10-APR-2015**	**----**	----	----	**21-APR-2015**	24-APR-2015	✓
Soil Glass Jar - Unpreserved (EA055-103)								
SP1 1, SP2 1, SP3 1, SP6E 1,	SP1 2, SP2 2, SP3 2, SP6E 2	**11-APR-2015**	**----**	----	----	**21-APR-2015**	25-APR-2015	✓
Soil Glass Jar - Unpreserved (EA055-103)								
SP15 1,	SP15 2	**12-APR-2015**	**----**	----	----	**21-APR-2015**	26-APR-2015	✓
Soil Glass Jar - Unpreserved (EA055-103)								
SP14 1, SP13 1,	SP14 2, SP13 2	**14-APR-2015**	**----**	----	----	**21-APR-2015**	28-APR-2015	✓

Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)		Sample Date	Extraction / Preparation: Date extracted	Due for extraction	Evaluation	Analysis: Date analysed	Due for analysis	Evaluation
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
Soil Glass Jar - Unpreserved (EP071) SP17 1		**08-APR-2015**	**20-APR-2015**	22-APR-2015	✓	**21-APR-2015**	30-MAY-2015	✓
Soil Glass Jar - Unpreserved (EP071) SP4 1, SP5 2,	SP5 1, SP6 1	**09-APR-2015**	**20-APR-2015**	23-APR-2015	✓	**21-APR-2015**	30-MAY-2015	✓
Soil Glass Jar - Unpreserved (EP071) SP8 1, SP10N 1, SP12 1,	SP8 2, SP10N 2, SP12 2	**10-APR-2015**	**20-APR-2015**	24-APR-2015	✓	**21-APR-2015**	30-MAY-2015	✓
Soil Glass Jar - Unpreserved (EP071) SP1 1, SP2 1, SP3 1, SP6E 1,	SP1 2, SP2 2, SP3 2, SP6E 2	**11-APR-2015**	**20-APR-2015**	25-APR-2015	✓	**21-APR-2015**	30-MAY-2015	✓
Soil Glass Jar - Unpreserved (EP071) SP15 1,	SP15 2	**12-APR-2015**	**20-APR-2015**	26-APR-2015	✓	**21-APR-2015**	30-MAY-2015	✓
Soil Glass Jar - Unpreserved (EP071) SP14 1, SP13 1,	SP14 2, SP13 2	**14-APR-2015**	**20-APR-2015**	28-APR-2015	✓	**21-APR-2015**	30-MAY-2015	✓
EP080: BTEXN								
Soil Glass Jar - Unpreserved (EP080) SP17 1		**08-APR-2015**	**20-APR-2015**	22-APR-2015	✓	**21-APR-2015**	22-APR-2015	✓
Soil Glass Jar - Unpreserved (EP080) SP4 1, SP5 2,	SP5 1, SP6 1	**09-APR-2015**	**20-APR-2015**	23-APR-2015	✓	**21-APR-2015**	23-APR-2015	✓
Soil Glass Jar - Unpreserved (EP080) SP8 1, SP10N 1, SP12 1,	SP8 2, SP10N 2, SP12 2	**10-APR-2015**	**20-APR-2015**	24-APR-2015	✓	**21-APR-2015**	24-APR-2015	✓
Soil Glass Jar - Unpreserved (EP080) SP1 1, SP2 1, SP3 1,	SP1 2, SP2 2, SP3 2	**11-APR-2015**	**20-APR-2015**	25-APR-2015	✓	**21-APR-2015**	25-APR-2015	✓
Soil Glass Jar - Unpreserved (EP080) SP6E 1,	SP6E 2	**11-APR-2015**	**21-APR-2015**	25-APR-2015	✓	**21-APR-2015**	25-APR-2015	✓
Soil Glass Jar - Unpreserved (EP080) SP15 1,	SP15 2	**12-APR-2015**	**20-APR-2015**	26-APR-2015	✓	**21-APR-2015**	26-APR-2015	✓
Soil Glass Jar - Unpreserved (EP080) SP14 1		**14-APR-2015**	**20-APR-2015**	28-APR-2015	✓	**21-APR-2015**	28-APR-2015	✓
Soil Glass Jar - Unpreserved (EP080) SP14 2, SP13 2	SP13 1,	**14-APR-2015**	**21-APR-2015**	28-APR-2015	✓	**21-APR-2015**	28-APR-2015	✓

Matrix: **SOIL**

Evaluation: ✗ = Holding time breach ; ✓ = Within holding time.

Method / *Container / Client Sample ID(s)*	*Sample Date*	*Extraction / Preparation*			*Analysis*		
		Date extracted	*Due for extraction*	*Evaluation*	*Date analysed*	*Due for analysis*	*Evaluation*
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions							
Soil Glass Jar - Unpreserved (EP080) SP17 1	**08-APR-2015**	**20-APR-2015**	22-APR-2015	✓	**21-APR-2015**	22-APR-2015	✓
Soil Glass Jar - Unpreserved (EP080) SP4 1, SP5 1, SP5 2, SP6 1	**09-APR-2015**	**20-APR-2015**	23-APR-2015	✓	**21-APR-2015**	23-APR-2015	✓
Soil Glass Jar - Unpreserved (EP080) SP8 1, SP8 2, SP10N 1, SP10N 2, SP12 1, SP12 2	**10-APR-2015**	**20-APR-2015**	24-APR-2015	✓	**21-APR-2015**	24-APR-2015	✓
Soil Glass Jar - Unpreserved (EP080) SP1 1, SP1 2, SP2 1, SP2 2, SP3 1, SP3 2	**11-APR-2015**	**20-APR-2015**	25-APR-2015	✓	**21-APR-2015**	25-APR-2015	✓
Soil Glass Jar - Unpreserved (EP080) SP6E 1, SP6E 2	**11-APR-2015**	**21-APR-2015**	25-APR-2015	✓	**21-APR-2015**	25-APR-2015	✓
Soil Glass Jar - Unpreserved (EP080) SP15 1, SP15 2	**12-APR-2015**	**20-APR-2015**	26-APR-2015	✓	**21-APR-2015**	26-APR-2015	✓
Soil Glass Jar - Unpreserved (EP080) SP14 1	**14-APR-2015**	**20-APR-2015**	28-APR-2015	✓	**21-APR-2015**	28-APR-2015	✓
Soil Glass Jar - Unpreserved (EP080) SP14 2, SP13 1, SP13 2	**14-APR-2015**	**21-APR-2015**	28-APR-2015	✓	**21-APR-2015**	28-APR-2015	✓
EP090: Organotin Compounds							
Soil Glass Jar - Unpreserved (EP090) SP17 1	**08-APR-2015**	**23-APR-2015**	22-APR-2015	✗	**04-MAY-2015**	02-JUN-2015	✓
Soil Glass Jar - Unpreserved (EP090) SP4 1, SP5 1, SP5 2, SP6 1	**09-APR-2015**	**23-APR-2015**	23-APR-2015	✓	**04-MAY-2015**	02-JUN-2015	✓
Soil Glass Jar - Unpreserved (EP090) SP8 1, SP8 2, SP10N 1, SP10N 2, SP12 1, SP12 2	**10-APR-2015**	**23-APR-2015**	24-APR-2015	✓	**04-MAY-2015**	02-JUN-2015	✓
Soil Glass Jar - Unpreserved (EP090) SP1 1, SP1 2, SP2 1, SP2 2, SP3 1, SP3 2, SP6E 1, SP6E 2	**11-APR-2015**	**23-APR-2015**	25-APR-2015	✓	**04-MAY-2015**	02-JUN-2015	✓
Soil Glass Jar - Unpreserved (EP090) SP15 1, SP15 2	**12-APR-2015**	**23-APR-2015**	26-APR-2015	✓	**04-MAY-2015**	02-JUN-2015	✓
Soil Glass Jar - Unpreserved (EP090) SP14 1, SP14 2, SP13 1, SP13 2	**14-APR-2015**	**23-APR-2015**	28-APR-2015	✓	**04-MAY-2015**	02-JUN-2015	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **SOIL**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Moisture Content	EA055-103	3	25	**12.0**	**10.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Organotin Analysis	EP090	3	18	**16.7**	**10.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
TRH - Semivolatile Fraction	EP071	3	26	**11.5**	**10.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
TRH Volatiles/BTEX	EP080	3	26	**11.5**	**10.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Laboratory Control Samples (LCS)							
Organotin Analysis	EP090	2	18	**11.1**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
TRH - Semivolatile Fraction	EP071	2	26	**7.7**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
TRH Volatiles/BTEX	EP080	2	26	**7.7**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Method Blanks (MB)							
Organotin Analysis	EP090	2	18	**11.1**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
TRH - Semivolatile Fraction	EP071	2	26	**7.7**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
TRH Volatiles/BTEX	EP080	2	26	**7.7**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Matrix Spikes (MS)							
Organotin Analysis	EP090	2	18	**11.1**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
TRH - Semivolatile Fraction	EP071	2	26	**7.7**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
TRH Volatiles/BTEX	EP080	2	26	**7.7**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	*Method*	*Matrix*	*Method Descriptions*
Moisture Content	EA055-103	SOIL	In-house. A gravimetric procedure based on weight loss over a 12 hour drying period at 103-105 degrees C. This method is compliant with NEPM (2013) Schedule B(3) Section 7.1 and Table 1 (14 day holding time).
TRH - Semivolatile Fraction	EP071	SOIL	(USEPA SW 846 - 8015A) Sample extracts are analysed by Capillary GC/FID and quantified against alkane standards over the range C10 - C40.
TRH Volatiles/BTEX	EP080	SOIL	(USEPA SW 846 - 8260B) Extracts are analysed by Purge and Trap, Capillary GC/MS. Quantification is by comparison against an established 5 point calibration curve.
Organotin Analysis	EP090	SOIL	(USEPA SW 846 - 8270D) Prepared sample extracts are analysed by GC/MS coupled with high volume injection, and quanitified against an established calibration curve.

Preparation Methods	*Method*	*Matrix*	*Method Descriptions*
Methanolic Extraction of Soils for Purge and Trap	ORG16	SOIL	(USEPA SW 846 - 5030A) 5g of solid is shaken with surrogate and 10mL methanol prior to analysis by Purge and Trap - GC/MS.
Tumbler Extraction of Solids	ORG17	SOIL	In-house, Mechanical agitation (tumbler). 10g of sample, Na2SO4 and surrogate are extracted with 30mL 1:1 DCM/Acetone by end over end tumble. The solvent is decanted, dehydrated and concentrated (by KD) to the desired volume for analysis.
Organotin Sample Preparation	ORG35	SOIL	In house. 20g sample is spiked with surrogate and leached in a methanol:acetic acid:UHP water mix and vacuum filtered. Reagents and solvents are added to the sample and the mixture tumbled. The butyltin compounds are simultaneously derivatised and extracted. The extract is further extracted with petroleum ether. The resultant extracts are combined and concentrated for analysis.

Summary of Outliers

Outliers : Quality Control Samples

The following report highlights outliers flagged in the Quality Control (QC) Report. Surrogate recovery limits are static and based on USEPA SW846 or ALS-QWI/EN/38 (in the absence of specific USEPA limits). This report displays QC Outliers (breaches) only.

Duplicates, Method Blanks, Laboratory Control Samples and Matrix Spikes

Matrix: **SOIL**

Compound Group Name	Laboratory Sample ID	Client Sample ID	Analyte	CAS Number	Data	Limits	Comment
Matrix Spike (MS) Recoveries							
EP080/071: Total Petroleum Hydrocarbons	EP1502881-002	SP1 2	**C6 - C9 Fraction**	----	56.7 %	69.1-135%	**Recovery less than lower data quality objective**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2	EP1502881-002	SP1 2	**C6 - C10 Fraction**	C6_C10	55.4 %	69.1-135%	**Recovery less than lower data quality objective**
EP080: BTEXN	EP1502881-002	SP1 2	**Benzene**	71-43-2	63.1 %	76.4-118%	**Recovery less than lower data quality objective**
EP080: BTEXN	EP1502881-002	SP1 2	**Toluene**	108-88-3	65.7 %	67.4-127%	**Recovery less than lower data quality objective**
EP090: Organotin Compounds	EP1502881-002	SP1 2	**Monobutyltin**	78763-54-9	23.6 %	35-130%	**Recovery less than lower data quality objective**

- **For all matrices, no Method Blank value outliers occur.**
- **For all matrices, no Duplicate outliers occur.**
- **For all matrices, no Laboratory Control outliers occur.**

Regular Sample Surrogates

Sub-Matrix: **SOIL**

Compound Group Name	Laboratory Sample ID	Client Sample ID	Analyte	CAS Number	Data	Limits	Comment
Samples Submitted							
EP090S: Organotin Surrogate	EP1502881-003	SP2 1	**Tripropyltin**	----	12.2 %	35-130 %	**Recovery less than lower data quality objective**
EP090S: Organotin Surrogate	EP1502881-005	SP3 1	**Tripropyltin**	----	8.8 %	35-130 %	**Recovery less than lower data quality objective**
EP090S: Organotin Surrogate	EP1502881-013	SP8 2	**Tripropyltin**	----	20.1 %	35-130 %	**Recovery less than lower data quality objective**

Outliers : Analysis Holding Time Compliance

This report displays Holding Time breaches only. Only the respective Extraction / Preparation and/or Analysis component is/are displayed.

Matrix: **SOIL**

Method	*Extraction / Preparation*			*Analysis*		
Container / Client Sample ID(s)	*Date extracted*	*Due for extraction*	***Days overdue***	*Date analysed*	*Due for analysis*	***Days overdue***
EP090: Organotin Compounds						

Matrix: **SOIL**

Method	*Extraction / Preparation*			*Analysis*		
Container / Client Sample ID(s)	*Date extracted*	*Due for extraction*	***Days overdue***	*Date analysed*	*Due for analysis*	***Days overdue***
EP090: Organotin Compounds - Analysis Holding Time Compliance						
Soil Glass Jar - Unpreserved						
SP17 1	23-APR-2015	22-APR-2015	**1**	----	----	----

Outliers : Frequency of Quality Control Samples

The following report highlights breaches in the Frequency of Quality Control Samples.

- **No Quality Control Sample Frequency Outliers exist.**

CERTIFICATE OF ANALYSIS

Work Order	: **EP1510035**	Page	: 1 of 7
Client	: **JACOBS GROUP (AUSTRALIA) PTY LTD**	Laboratory	: Environmental Division Perth
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Telephone	: +61 08 9469 4400	Telephone	: +61-8-9209 7655
Facsimile	: +61 08 9469 4488	Facsimile	: +61-8-9209 7600
Project	: Ex EP1502281 IW021200	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----	Date Samples Received	: 16-Apr-2015 18:00
C-O-C number	: ----	Date Analysis Commenced	: 20-Apr-2015
Sampler	: GARNET HOOPER	Issue Date	: 19-May-2015 12:17
Site	: ----		
		No. of samples received	: 25
Quote number	: ----	No. of samples analysed	: 25

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Rassem Ayoubi	Senior Organic Chemist	Perth Inorganics
Rassem Ayoubi	Senior Organic Chemist	Perth Organics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.

- EP071-SD: LOR raised due to high moisture content.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	SP1 1-1	SP1 2-1	SP2 1-1	SP2 2-1	SP3 1-1
			Client sampling date / time	11-Apr-2015 07:27	11-Apr-2015 08:01	11-Apr-2015 11:42	11-Apr-2015 12:15	11-Apr-2015 14:28
Compound	CAS Number	LOR	Unit	EP1510035-001	EP1510035-002	EP1510035-003	EP1510035-004	EP1510035-005
				Result	Result	Result	Result	Result
EA055: Moisture Content								
^ **Moisture Content (dried @ 103°C)**	----	1	%	**62.7**	**63.3**	**65.5**	**63.7**	**60.4**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	>C10_C16	3	mg/kg	<4	<4	<4	<4	<4
>C16 - C34 Fraction	----	3	mg/kg	<4	<4	<4	<4	<4
>C34 - C40 Fraction	----	5	mg/kg	<8	<8	<8	<8	<8
^ **>C10 - C40 Fraction (sum)**	----	3	mg/kg	<4	<4	<4	<4	<4
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C10 - C14 Fraction	----	3	mg/kg	<4	<4	<4	<4	<4
C15 - C28 Fraction	----	3	mg/kg	<4	<4	<4	<4	<4
C29 - C36 Fraction	----	5	mg/kg	<8	<8	<8	<8	<8
^ **C10 - C36 Fraction (sum)**	----	3	mg/kg	<4	<4	<4	<4	<4

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	SP3 2-1	SP4 1-1	SP5 1-1	SP5 2-1	SP6 1-1
			Client sampling date / time	09-Apr-2015 15:23	09-Apr-2015 11:58	09-Apr-2015 07:28	09-Apr-2015 08:11	09-Apr-2015 18:27
Compound	CAS Number	LOR	Unit	EP1510035-006	EP1510035-007	EP1510035-008	EP1510035-009	EP1510035-010
				Result	Result	Result	Result	Result
EA055: Moisture Content								
^ **Moisture Content (dried @ 103°C)**	----	1	%	**62.7**	**45.5**	**50.1**	**50.8**	**52.7**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	>C10_C16	3	mg/kg	<4	<4	<4	<4	<4
>C16 - C34 Fraction	----	3	mg/kg	<4	<4	<4	<4	<4
>C34 - C40 Fraction	----	5	mg/kg	<8	<8	<8	<8	<8
^ **>C10 - C40 Fraction (sum)**	----	3	mg/kg	<4	<4	<4	<4	<4
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C10 - C14 Fraction	----	3	mg/kg	<4	<4	<4	<4	<4
C15 - C28 Fraction	----	3	mg/kg	<4	<4	<4	<4	<4
C29 - C36 Fraction	----	5	mg/kg	<8	<8	<8	<8	<8
^ **C10 - C36 Fraction (sum)**	----	3	mg/kg	<4	<4	<4	<4	<4

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	SP8 1-1	SP8 2-1	SPION 1-1	SPION 2-1	SP12 1-1
			Client sampling date / time	10-Apr-2015 14:45	11-Apr-2015 14:45	10-Apr-2015 10:45	10-Apr-2015 11:25	10-Apr-2015 16:15
Compound	CAS Number	LOR	Unit	EP1510035-011	EP1510035-012	EP1510035-013	EP1510035-014	EP1510035-015
				Result	Result	Result	Result	Result
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1	%	**29.0**	**28.7**	**33.2**	**36.3**	**40.6**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	>C10_C16	3	mg/kg	<4	<4	<4	<4	<4
>C16 - C34 Fraction	----	3	mg/kg	<4	<4	<4	<4	<4
>C34 - C40 Fraction	----	5	mg/kg	<8	<8	<8	<8	<8
^ >C10 - C40 Fraction (sum)	----	3	mg/kg	<4	<4	<4	<4	<4
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C10 - C14 Fraction	----	3	mg/kg	<4	<4	<4	<4	<4
C15 - C28 Fraction	----	3	mg/kg	<4	<4	<4	<4	<4
C29 - C36 Fraction	----	5	mg/kg	<8	<8	<8	<8	<8
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<4	<4	<4	<4	<4

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	SP12 2-1	SP15 1-1	SP15 2-1	SP17 1-1	SP14 1-1
			Client sampling date / time	10-Apr-2015 16:25	12-Apr-2015 07:20	12-Apr-2015 07:41	08-Apr-2015 18:07	14-Apr-2015 14:14
Compound	CAS Number	LOR	Unit	EP1510035-016	EP1510035-017	EP1510035-018	EP1510035-019	EP1510035-020
				Result	Result	Result	Result	Result
EA055: Moisture Content								
^ **Moisture Content (dried @ 103°C)**	----	1	%	**41.7**	**31.8**	**29.4**	**42.7**	**40.0**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	>C10_C16	3	mg/kg	<4	<4	<4	<4	<4
>C16 - C34 Fraction	----	3	mg/kg	<4	<4	<4	<4	<4
>C34 - C40 Fraction	----	5	mg/kg	<8	<8	<8	<8	<8
^ **>C10 - C40 Fraction (sum)**	----	3	mg/kg	<4	<4	<4	<4	<4
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C10 - C14 Fraction	----	3	mg/kg	<4	<4	<4	<4	<4
C15 - C28 Fraction	----	3	mg/kg	<4	<4	<4	<4	<4
C29 - C36 Fraction	----	5	mg/kg	<8	<8	<8	<8	<8
^ **C10 - C36 Fraction (sum)**	----	3	mg/kg	<4	<4	<4	<4	<4

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	SP14 2-1	SP13 1-1	SP13 2-1	SP6E 1-1	SPGE 2-1
			Client sampling date / time	14-Apr-2015 14:28	14-Apr-2015 15:42	14-Apr-2015 16:01	[11-Apr-2015]	[11-Apr-2015]
Compound	CAS Number	LOR	Unit	EP1510035-021	EP1510035-022	EP1510035-023	EP1510035-024	EP1510035-025
				Result	Result	Result	Result	Result
EA055: Moisture Content								
^ **Moisture Content (dried @ 103°C)**	----	1	%	**39.7**	**34.0**	**30.4**	**52.2**	**52.9**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	>C10_C16	3	mg/kg	<4	<4	<4	<4	<4
>C16 - C34 Fraction	----	3	mg/kg	<4	<4	<4	<4	<4
>C34 - C40 Fraction	----	5	mg/kg	<8	<8	<8	<8	<8
^ **>C10 - C40 Fraction (sum)**	----	3	mg/kg	<4	<4	<4	<4	<4
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C10 - C14 Fraction	----	3	mg/kg	<4	<4	<4	<4	<4
C15 - C28 Fraction	----	3	mg/kg	<4	<4	<4	<4	<4
C29 - C36 Fraction	----	5	mg/kg	<8	<8	<8	<8	<8
^ **C10 - C36 Fraction (sum)**	----	3	mg/kg	<4	<4	<4	<4	<4

QUALITY CONTROL REPORT

Work Order	: **EP1510035**	Page	: 1 of 4
Client	: **JACOBS GROUP (AUSTRALIA) PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: MR CHRIS TEASDALE	Contact	: Customer Services EP
Address	: P O BOX H615 PERTH WA, AUSTRALIA 6001	Address	: 10 Hod Way Malaga WA Australia 6090
E-mail	: cteasdale@globalskm.com	E-mail	: ALSEnviro.Perth@alsglobal.com
Telephone	: +61 08 9469 4400	Telephone	: +61-8-9209 7655
Facsimile	: +61 08 9469 4488	Facsimile	: +61-8-9209 7600
Project	: Ex EP1502281 IW021200	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----	Date Samples Received	: 16-Apr-2015
C-O-C number	: ----	Date Analysis Commenced	: 20-Apr-2015
Sampler	: GARNET HOOPER	Issue Date	: 19-May-2015
Site	: ----	No. of samples received	: 25
Quote number	: ----	No. of samples analysed	: 25

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted.

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Rassem Ayoubi	Senior Organic Chemist	Perth Inorganics
Rassem Ayoubi	Senior Organic Chemist	Perth Organics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis. Where the LOR of a reported result differs from standard LOR, this may be due to high

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
RPD = Relative Percentage Difference
# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR:- 0% - 50%; Result > 20 times LOR:0% - 20%.

Sub-Matrix: **SOIL**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
EA055: Moisture Content (QC Lot: 98331)									
EP1510035-001	SP1 1-1	EA055-103: Moisture Content (dried @ 103°C)	----	1	%	62.7	62.7	0.00	0% - 20%
EP1510035-010	SP6 1-1	EA055-103: Moisture Content (dried @ 103°C)	----	1	%	52.7	52.7	0.00	0% - 20%
EA055: Moisture Content (QC Lot: 98332)									
EP1510035-021	SP14 2-1	EA055-103: Moisture Content (dried @ 103°C)	----	1	%	39.7	39.7	0.00	0% - 20%
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QC Lot: 97566)									
EP1510035-001	SP1 1-1	EP071-SD: >C10 - C16 Fraction	>C10_C16	3	mg/kg	<4	<4	0.00	No Limit
		EP071-SD: >C10 - C40 Fraction (sum)	----	3	mg/kg	<4	<4	0.00	No Limit
		EP071-SD: >C16 - C34 Fraction	----	3	mg/kg	<4	<4	0.00	No Limit
		EP071-SD: >C34 - C40 Fraction	----	5	mg/kg	<8	<8	0.00	No Limit
EP1510035-011	SP8 1-1	EP071-SD: >C10 - C16 Fraction	>C10_C16	3	mg/kg	<4	<4	0.00	No Limit
		EP071-SD: >C10 - C40 Fraction (sum)	----	3	mg/kg	<4	<4	0.00	No Limit
		EP071-SD: >C16 - C34 Fraction	----	3	mg/kg	<4	<4	0.00	No Limit
		EP071-SD: >C34 - C40 Fraction	----	5	mg/kg	<8	<8	0.00	No Limit
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons (QC Lot: 97566)									
EP1510035-001	SP1 1-1	EP071-SD: C10 - C14 Fraction	----	3	mg/kg	<4	<4	0.00	No Limit
		EP071-SD: C10 - C36 Fraction (sum)	----	3	mg/kg	<4	<4	0.00	No Limit
		EP071-SD: C15 - C28 Fraction	----	3	mg/kg	<4	<4	0.00	No Limit
		EP071-SD: C29 - C36 Fraction	----	5	mg/kg	<8	<8	0.00	No Limit
EP1510035-011	SP8 1-1	EP071-SD: C10 - C14 Fraction	----	3	mg/kg	<4	<4	0.00	No Limit
		EP071-SD: C10 - C36 Fraction (sum)	----	3	mg/kg	<4	<4	0.00	No Limit
		EP071-SD: C15 - C28 Fraction	----	3	mg/kg	<4	<4	0.00	No Limit
		EP071-SD: C29 - C36 Fraction	----	5	mg/kg	<8	<8	0.00	No Limit

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Sample (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **SOIL**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QCLot: 97566)								
EP071-SD: >C10 - C16 Fraction	>C10_C16	3	mg/kg	<4	202 mg/kg	83.3	70	130
EP071-SD: >C10 - C40 Fraction (sum)	----	3	mg/kg	<4	----	----	----	----
EP071-SD: >C16 - C34 Fraction	----	3	mg/kg	<4	258 mg/kg	88.4	70	130
EP071-SD: >C34 - C40 Fraction	----	5	mg/kg	<8	18 mg/kg	96.2	70	130
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QCLot: 97567)								
EP071-SD: >C10 - C16 Fraction	>C10_C16	3	mg/kg	<4	202 mg/kg	83.8	70	130
EP071-SD: >C10 - C40 Fraction (sum)	----	3	mg/kg	<4	----	----	----	----
EP071-SD: >C16 - C34 Fraction	----	3	mg/kg	<4	258 mg/kg	89.4	70	130
EP071-SD: >C34 - C40 Fraction	----	5	mg/kg	<8	18 mg/kg	100	70	130
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons (QCLot: 97566)								
EP071-SD: C10 - C14 Fraction	----	3	mg/kg	<4	138 mg/kg	82.9	70	130
EP071-SD: C10 - C36 Fraction (sum)	----	3	mg/kg	<4	----	----	----	----
EP071-SD: C15 - C28 Fraction	----	3	mg/kg	<4	290 mg/kg	94.6	70	130
EP071-SD: C29 - C36 Fraction	----	5	mg/kg	<8	51 mg/kg	104	70	130
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons (QCLot: 97567)								
EP071-SD: C10 - C14 Fraction	----	3	mg/kg	<4	138 mg/kg	83.5	70	130
EP071-SD: C10 - C36 Fraction (sum)	----	3	mg/kg	<4	----	----	----	----
EP071-SD: C15 - C28 Fraction	----	3	mg/kg	<4	290 mg/kg	96.1	70	130
EP071-SD: C29 - C36 Fraction	----	5	mg/kg	<8	51 mg/kg	120	70	130

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

- **No Matrix Spike (MS) or Matrix Spike Duplicate (MSD) Results are required to be reported.**

QA/QC Compliance Assessment for DQO Reporting

Work Order	: **EP1510035**	Page	: 1 of 5
Client	: **JACOBS GROUP (AUSTRALIA) PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: MR CHRIS TEASDALE	Telephone	: +61-8-9209 7655
Project	: Ex EP1502281 IW021200	Date Samples Received	: 16-Apr-2015
Site	: ----	Issue Date	: 19-May-2015
Sampler	: GARNET HOOPER	No. of samples received	: 25
Order number	: ----	No. of samples analysed	: 25

This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.

Brief method summaries and references are also provided to assist in traceability.

Summary of Outliers

Outliers : Quality Control Samples

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **NO Laboratory Control outliers occur.**
- **NO Matrix Spike outliers occur.**
- **For all regular sample matrices, NO surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

- **NO Analysis Holding Time Outliers exist.**

Outliers : Frequency of Quality Control Samples

- **Quality Control Sample Frequency Outliers exist - please see following pages for full details.**

Outliers : Frequency of Quality Control Samples

Matrix: **SOIL**

Quality Control Sample Type / Method	Count QC	Count Regular	Rate (%) Actual	Rate (%) Expected	Quality Control Specification
Laboratory Duplicates (DUP)					
TPH - Semivolatile Fraction	0	5	0.00	10.00	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Matrix Spikes (MS)					
TPH - Semivolatile Fraction	0	20	0.00	5.00	NEPM 2013 Schedule B(3) and ALS QCS3 requirement

Analysis Holding Time Compliance

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)		Sample Date	Extraction / Preparation: Date extracted	Due for extraction	Evaluation	Analysis: Date analysed	Due for analysis	Evaluation
EA055: Moisture Content								
Soil Glass Jar - Unpreserved (EA055-103)								
SP17 1-1		**08-Apr-2015**	**----**	----	----	**21-Apr-2015**	22-Apr-2015	✓
Soil Glass Jar - Unpreserved (EA055-103)								
SP3 2-1,	SP4 1-1,	**09-Apr-2015**	**----**	----	----	**21-Apr-2015**	23-Apr-2015	✓
SP5 1-1,	SP5 2-1,							
SP6 1-1								
Soil Glass Jar - Unpreserved (EA055-103)								
SP8 1-1,	SPION 1-1,	**10-Apr-2015**	**----**	----	----	**21-Apr-2015**	24-Apr-2015	✓
SPION 2-1,	SP12 1-1,							
SP12 2-1								
Soil Glass Jar - Unpreserved (EA055-103)								
SP1 1-1,	SP1 2-1,	**11-Apr-2015**	**----**	----	----	**21-Apr-2015**	25-Apr-2015	✓
SP2 1-1,	SP2 2-1,							
SP3 1-1,	SP8 2-1,							
SP6E 1-1,	SPGE 2-1							
Soil Glass Jar - Unpreserved (EA055-103)								
SP15 1-1,	SP15 2-1	**12-Apr-2015**	**----**	----	----	**21-Apr-2015**	26-Apr-2015	✓
Soil Glass Jar - Unpreserved (EA055-103)								
SP14 1-1,	SP14 2-1,	**14-Apr-2015**	**----**	----	----	**21-Apr-2015**	28-Apr-2015	✓
SP13 1-1,	SP13 2-1							

Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method Container / Client Sample ID(s)		Sample Date	Extraction / Preparation			Analysis		
			Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
Soil Glass Jar - Unpreserved (EP071-SD)								
SP17 1-1		**08-Apr-2015**	**20-Apr-2015**	22-Apr-2015	✓	**14-May-2015**	30-May-2015	✓
Soil Glass Jar - Unpreserved (EP071-SD)								
SP3 2-1, SP5 1-1, SP6 1-1	SP4 1-1, SP5 2-1,	**09-Apr-2015**	**20-Apr-2015**	23-Apr-2015	✓	**14-May-2015**	30-May-2015	✓
Soil Glass Jar - Unpreserved (EP071-SD)								
SP8 1-1, SPION 2-1, SP12 2-1	SPION 1-1, SP12 1-1,	**10-Apr-2015**	**20-Apr-2015**	24-Apr-2015	✓	**14-May-2015**	30-May-2015	✓
Soil Glass Jar - Unpreserved (EP071-SD)								
SP1 1-1, SP2 1-1, SP3 1-1, SP6E 1-1,	SP1 2-1, SP2 2-1, SP8 2-1, SPGE 2-1	**11-Apr-2015**	**20-Apr-2015**	25-Apr-2015	✓	**14-May-2015**	30-May-2015	✓
Soil Glass Jar - Unpreserved (EP071-SD)								
SP15 1-1,	SP15 2-1	**12-Apr-2015**	**20-Apr-2015**	26-Apr-2015	✓	**14-May-2015**	30-May-2015	✓
Soil Glass Jar - Unpreserved (EP071-SD)								
SP14 1-1, SP13 1-1,	SP14 2-1, SP13 2-1	**14-Apr-2015**	**20-Apr-2015**	28-Apr-2015	✓	**14-May-2015**	30-May-2015	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **SOIL**

Evaluation: ✗ = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Moisture Content	EA055-103	2	20	**10.00**	**10.00**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
TPH - Semivolatile Fraction	EP071-SD	2	20	**10.00**	**10.00**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Laboratory Control Samples (LCS)							
TPH - Semivolatile Fraction	EP071-SD	1	20	**5.00**	**5.00**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Method Blanks (MB)							
TPH - Semivolatile Fraction	EP071-SD	1	20	**5.00**	**5.00**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Matrix Spikes (MS)							
TPH - Semivolatile Fraction	EP071-SD	0	20	**0.00**	**5.00**	✗	NEPM 2013 Schedule B(3) and ALS QCS3 requirement

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	*Method*	*Matrix*	*Method Descriptions*
Moisture Content	EA055-103	SOIL	In-house. A gravimetric procedure based on weight loss over a 12 hour drying period at 103-105 degrees C. This method is compliant with NEPM (2013) Schedule B(3) Section 7.1 and Table 1 (14 day holding time).
TPH - Semivolatile Fraction	EP071-SD	SOIL	(USEPA SW 846 - 8270B) Extracts are analysed by Capillary GC/FID and quantification is by comparison against an established 5 point calibration curve. This method is compliant with NEPM (2013) Schedule B(3) (Method 504)

Marine and Freshwater Research Laboratory
Environmental Science
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WORLD RECOGNISED ACCREDITATION

Accreditation Number: 10603
Accredited for compliance with ISO/IEC 17025.
The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

Murdoch UNIVERSITY

SEDIMENT DATA

Contact: Garnet Hooper
Customer: Jacobs
Address: Level 11, Durack Centre, 263 Adelaide Terrace, Perth WA 6001

Date of Issue: 13/05/2015
Date Received: 16/04/2015
Our Reference: JAC15-8
Your Reference: IW021200

METHOD SAMPLE CODE	Sampling Date	2600 TKN mg.N/g	4500 TOTAL P mg.P/g	6200 TOC % C	ICP002 Total Ext Al mg/kg	ICP002 Total Ext As mg/kg	ICP002 Total Ext Ba mg/kg	ICP002 Total Ext Cd mg/kg	ICP002 Total Ext Co mg/kg
Reporting Limit		<0.1	<0.05	<0.2	<20	<2	<0.1	<0.1	<0.2
File		15042901	15042901	15050101-1101	15050101	15050101	15050101	15050101	15050101
SP1 1-1	11/04/2015	1.9	0.74	1.4	15000	3	21	0.3	6.7
SP1 2-1	11/04/2015	2.0	0.78	1.4	16000	3	21	0.2	7.2
SP2 1-1	11/04/2015	2.1	0.78	1.5	16000	2	33	0.2	7.5
SP2 2-1	11/04/2015	2.1	0.78	1.5	16000	2	29	0.3	7.1
SP3 1-1	11/04/2015	1.6	0.81	1.2	14000	2	23	0.3	6.5
SP3 2-1	11/04/2015	1.5	0.80	1.1	13000	2	25	0.2	6.2
SP4 1-1	09/04/2015	0.5	2.8	0.4	9300	3	9.1	0.2	5.6
SP5 1-1	09/04/2015	0.6	0.98	0.5	8400	2	11	0.2	4.7
SP5 2-1	09/04/2015	0.7	0.89	0.5	8200	3	12	0.2	4.9
SP6E 1-1	09/04/2015	0.8	1.6	0.6	8300	3	14	0.2	4.9
SP6E 2-1	09/04/2015	0.9	1.6	0.6	9400	3	15	0.1	5.2
SP8 1-1	10/04/2015	0.2	0.31	0.3	560	2	5.6	0.2	0.7
SP8 2-1	10/04/2015	0.3	0.31	0.2	550	3	5.9	0.2	0.7
SP9 1-1	10/04/2015	0.3	0.79	0.2	2000	5	7.0	0.2	1.9
SP10N 1-1	10/04/2015	0.3	0.79	0.2	2900	4	7.8	0.2	1.8
SP10N 2-1	10/04/2015	0.3	0.90	0.3	3100	3	7.7	0.3	1.7
SP12 1-1	10/04/2015	0.4	1.2	0.3	4200	3	21	0.3	2.1
SP12 2-1	10/04/2015	0.5	1.1	0.4	4400	4	28	0.2	2.1
SP13 1-1	14/04/2015	0.2	1.4	0.2	3300	3	9.8	0.2	1.8
SP13 2-1	14/04/2015	0.2	1.4	<0.2	2700	3	9.4	0.2	1.5
SP14 1-1	14/04/2015	0.4	1.9	0.3	4600	3	8.7	0.2	2.3

Signatory: Jamie Woodward
Date: 13/05/2015

All test items tested as received. Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory
Environmental Science
Tel: +61 8 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
Accredited for compliance with ISO/IEC 17025.
The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

SEDIMENT DATA

Contact: Garnet Hooper
Customer: Jacobs
Address: Level 11, Durack Centre, 263 Adelaide Terrace, Perth WA 6001

Date of Issue: 13/05/2015
Date Received: 16/04/2015
Our Reference: JAC15-8
Your Reference: IW021200

METHOD SAMPLE CODE	Sampling Date	2600 TKN mg.N/g	4500 TOTAL P mg.P/g	6200 TOC % C	ICP002 Total Ext Al mg/kg	ICP002 Total Ext As mg/kg	ICP002 Total Ext Ba mg/kg	ICP002 Total Ext Cd mg/kg	ICP002 Total Ext Co mg/kg
Reporting Limit		<0.1	<0.05	<0.2	<20	<2	<0.1	<0.1	<0.2
File		15042901	15042901	15050101-1101	15050101	15050101	15050101	15050101	15050101
SP14 2-1	14/04/2015	0.4	1.9	0.3	4500	3	8.1	0.2	2.3
SP15 1-1	12/04/2015	0.3	1.8	0.3	3400	4	8.8	0.2	1.9
SP15 2-1	12/04/2015	0.3	2.0	0.2	2800	5	8.4	0.2	1.8
SP17 1-1	08/04/2015	0.5	1.3	0.3	5500	3	8.0	0.3	3.1
SP6 1-1	09/04/2015	0.9	1.7	0.6	9600	3	15	0.1	4.8
TB1	12/04/2015	<0.1	<0.05	<0.2	<20	<2	<0.1	<0.1	<0.2
MB1	12/04/2015	<0.1	<0.05	<0.2	<20	<2	<0.1	<0.1	<0.2

Note: Ba by ICP002 is outside the scope of accreditation. Results expressed on a dry weight basis

Signatory: Jamie Woodward
Date: 13/05/2015

All test items tested as received. Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory
Environmental Science
Tel: +61 8 93602907 Address: 90 South St, Murdoch, WA, 6150

NATA WORLD RECOGNISED ACCREDITATION
Accreditation Number: 10603
Accredited for compliance with ISO/IEC 17025.
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Murdoch UNIVERSITY

SEDIMENT DATA

Contact: Garnet Hooper
Customer: Jacobs
Address: Level 11, Durack Centre, 263 Adelaide Terrace, Perth WA 6001

Date of Issue: 13/05/2015
Date Received: 16/04/2015
Our Reference: JAC15-8
Your Reference: IW021200

METHOD SAMPLE CODE	Sampling Date	ICP002 Total Ext Cr mg/kg	ICP002 Total Ext Cu mg/kg	ICP002 Total Ext Fe mg/kg	ICP002 Total Ext Ni mg/kg	ICP002 Total Ext Pb mg/kg	ICP002 Total Ext Zn mg/kg	ICP007 Total Ext Hg mg/kg
Reporting Limit		<0.2	<0.2	<5	<0.7	<1	<0.5	<0.01
File		15050101	15050101	15050101	15050101	15050101	15050101	15050602-0701
SP1 1-1	11/04/2015	28	13	16000	21	6	48	0.03
SP1 2-1	11/04/2015	29	14	16000	21	6	47	0.03
SP2 1-1	11/04/2015	31	15	16000	23	7	51	0.03
SP2 2-1	11/04/2015	31	14	16000	23	7	50	0.03
SP3 1-1	11/04/2015	27	11	15000	19	6	46	0.03
SP3 2-1	11/04/2015	25	10	15000	17	5	43	0.04
SP4 1-1	09/04/2015	27	4.7	17000	14	5	51	0.03
SP5 1-1	09/04/2015	20	5.3	13000	11	4	38	0.02
SP5 2-1	09/04/2015	21	5.5	13000	12	5	40	0.03
SP6E 1-1	09/04/2015	20	5.6	13000	12	4	36	0.03
SP6E 2-1	09/04/2015	22	6.0	13000	12	4	38	0.03
SP8 1-1	10/04/2015	5.0	0.9	520	1.1	<1	2.3	<0.01
SP8 2-1	10/04/2015	5.2	1.0	550	1.3	1	2.3	<0.01
SP9 1-1	10/04/2015	7.4	1.7	2800	4.2	4	6.9	<0.01
SP10N 1-1	10/04/2015	7.9	2.4	3900	4.6	3	10	0.01
SP10N 2-1	10/04/2015	8.5	2.5	4300	4.5	3	11	0.01
SP12 1-1	10/04/2015	10	2.6	5300	5.4	2	11	0.01
SP12 2-1	10/04/2015	11	3.0	5800	5.7	2	12	0.01
SP13 1-1	14/04/2015	8.9	1.8	4200	4.6	2	8.5	<0.01
SP13 2-1	14/04/2015	7.7	1.6	3500	3.7	2	7.3	<0.01
SP14 1-1	14/04/2015	11	2.7	5800	6.1	3	13	0.01

All test items tested as received. Spare test items will be held for two months unless otherwise requested.

Signatory: Jamie Woodward
Date: 13/05/2015

Marine and Freshwater Research Laboratory
Environmental Science
Tel: +61 8 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
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The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

SEDIMENT DATA

Contact: Garnet Hooper
Customer: Jacobs
Address: Level 11, Durack Centre, 263 Adelaide Terrace, Perth WA 6001

Date of Issue: 13/05/2015
Date Received: 16/04/2015
Our Reference: JAC15-8
Your Reference: IW021200

METHOD SAMPLE CODE	Sampling Date	ICP002 Total Ext Cr mg/kg	ICP002 Total Ext Cu mg/kg	ICP002 Total Ext Fe mg/kg	ICP002 Total Ext Ni mg/kg	ICP002 Total Ext Pb mg/kg	ICP002 Total Ext Zn mg/kg	ICP007 Total Ext Hg mg/kg
Reporting Limit		**<0.2**	**<0.2**	**<5**	**<0.7**	**<1**	**<0.5**	**<0.01**
File		**15050101**	**15050101**	**15050101**	**15050101**	**15050101**	**15050101**	**15050602-0701**
SP14 2-1	14/04/2015	11	2.7	5800	5.9	3	12	0.01
SP15 1-1	12/04/2015	7.7	2.9	5500	5.1	3	11	<0.01
SP15 2-1	12/04/2015	7.2	2.6	5000	5.0	2	9.8	<0.01
SP17 1-1	08/04/2015	11	3.5	7600	7.2	3	18	<0.01
SP6 1-1	09/04/2015	22	6.2	14000	13	5	40	0.03
TB1	12/04/2015	<0.2	<0.2	<5	<0.7	<1	<0.5	<0.01
MB1	12/04/2015	<0.2	<0.2	<5	<0.7	<1	<0.5	<0.01

Signatory: Jamie Woodward
Date: 13/05/2015

All test items tested as received. Spare test items will be held for two months unless otherwise requested.

PARTICLE SIZE ANALYSIS REPORT
Size distribution analysis by laser diffraction (<500µm) and wet sieving (500-16000µm)

Customer: Jacobs
Contact: Garnett Hooper
Address: Level 11, 263 Adelaide Tce, Perth WA 6001
Date Received: 16/04/2015
Date of Issue: 29/04/2015

Summary Report

Sample Name:	SP1
Sampling Date:	11/04/2015
Sample Type:	Sediment
MAFRL Job Code:	JAC15-7
Client Reference:	IW021200
Analysis Date	17-Apr-15
Intrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300
Wentworth Aggregate Classification	
Clay % (<4µm)	17.79
Fine Silt % (4-16µm)	19.32
Medium Silt % (16-31µm)	10.16
Course Silt % (31-62µm)	19.54
Fine sand % (62-250µm)	28.36
Medium sand % (250-500µm)	3.57
Coarse sand % (500-2000µm)	1.26
Pebbles/Cobbles/Boulders (>2000µm)	0.00
SOP Name	SOP-LV-3REPS-skm.msop
Analysis Model	General Purpose
Result Units	Volume

Extended range by sieving

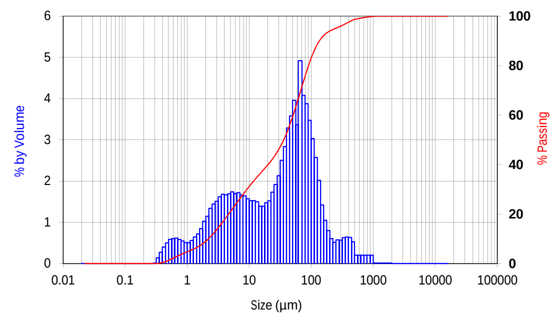
Extended size, µm	Extended percent retained at size
500	1.21
1000	0.06
2000	0.00
4000	0.00
8000	0.00
16000	0.00

Sample visual assessment
Mud with a small amount of sand present

Size Fractions Table

Differential Data				Cumulative Data	
Lower Size (µm)	Upper Size (µm)	% in Interval	% in Interval after scaling	Size (µm)	% Passing
0.020	0.022	0.00	0.00	0.022	0.00
0.022	0.025	0.00	0.00	0.025	0.00
0.025	0.028	0.00	0.00	0.028	0.00
0.028	0.032	0.00	0.00	0.032	0.00
0.032	0.036	0.00	0.00	0.036	0.00
0.036	0.040	0.00	0.00	0.040	0.00
0.040	0.045	0.00	0.00	0.045	0.00
0.045	0.050	0.00	0.00	0.050	0.00
0.050	0.056	0.00	0.00	0.056	0.00
0.056	0.063	0.00	0.00	0.063	0.00
0.063	0.071	0.00	0.00	0.071	0.00
0.071	0.080	0.00	0.00	0.080	0.00
0.080	0.089	0.00	0.00	0.089	0.00
0.089	0.100	0.00	0.00	0.100	0.00
0.100	0.112	0.00	0.00	0.112	0.00
0.112	0.126	0.00	0.00	0.126	0.00
0.126	0.142	0.00	0.00	0.142	0.00
0.142	0.159	0.00	0.00	0.159	0.00
0.159	0.178	0.00	0.00	0.178	0.00
0.178	0.200	0.00	0.00	0.200	0.00
0.200	0.224	0.00	0.00	0.224	0.00
0.224	0.252	0.00	0.00	0.252	0.00
0.252	0.283	0.00	0.00	0.283	0.00
0.283	0.317	0.01	0.01	0.317	0.01
0.317	0.356	0.14	0.14	0.356	0.15
0.356	0.399	0.27	0.27	0.399	0.43
0.399	0.448	0.40	0.40	0.448	0.83
0.448	0.502	0.50	0.50	0.502	1.33
0.502	0.564	0.59	0.59	0.564	1.91
0.564	0.632	0.61	0.61	0.632	2.52
0.632	0.710	0.62	0.62	0.710	3.14
0.710	0.796	0.58	0.58	0.796	3.72
0.796	0.893	0.55	0.55	0.893	4.26
0.893	1.000	0.51	0.51	1.000	4.77
1.000	1.120	0.50	0.50	1.120	5.28
1.120	1.260	0.56	0.56	1.260	5.84
1.260	1.420	0.64	0.64	1.420	6.48
1.420	1.590	0.72	0.72	1.590	7.20
1.590	1.780	0.85	0.85	1.780	8.04
1.780	2.000	1.02	1.02	2.000	9.06
2.000	2.240	1.15	1.14	2.240	10.21
2.240	2.520	1.34	1.34	2.520	11.54
2.520	2.830	1.45	1.44	2.830	12.99
2.830	3.170	1.51	1.51	3.170	14.50
3.170	3.560	1.62	1.62	3.560	16.11
3.560	4.000	1.68	1.68	4.000	17.79
4.000	4.480	1.67	1.67	4.480	19.46
4.480	5.020	1.69	1.69	5.020	21.15
5.020	5.640	1.74	1.74	5.640	22.88
5.640	6.320	1.70	1.70	6.320	24.58
6.320	7.100	1.72	1.72	7.100	26.30
7.100	7.960	1.67	1.67	7.960	27.96
7.960	8.930	1.64	1.64	8.930	29.60
8.930	10.000	1.57	1.57	10.000	31.17
10.000	11.200	1.53	1.52	11.200	32.70
11.200	12.600	1.53	1.52	12.600	34.22
12.600	14.200	1.50	1.50	14.200	35.72
14.200	15.900	1.39	1.39	15.900	37.11
15.900	17.800	1.39	1.39	17.800	38.50
17.800	20.000	1.48	1.47	20.000	39.97
20.000	22.400	1.52	1.52	22.400	41.49
22.400	25.200	1.73	1.73	25.200	43.22
25.200	28.300	1.92	1.92	28.300	45.14
28.300	31.700	2.14	2.13	31.700	47.27
31.700	35.600	2.51	2.50	35.600	49.78
35.600	39.900	2.84	2.84	39.900	52.61
39.900	44.800	3.29	3.29	44.800	55.90
44.800	50.200	3.59	3.58	50.200	59.48
50.200	56.400	3.96	3.96	56.400	63.44
56.400	62.000	3.37	3.37	62.000	66.81
62.000	71.000	4.93	4.92	71.000	71.73
71.000	79.600	4.08	4.08	79.600	75.81
79.600	89.300	3.88	3.88	89.300	79.69
89.300	100.000	3.48	3.47	100.000	83.16
100.000	112.000	3.04	3.03	112.000	86.19
112.000	126.000	2.58	2.57	126.000	88.76
126.000	142.000	2.02	2.02	142.000	90.78
142.000	159.000	1.42	1.42	159.000	92.20
159.000	178.000	1.05	1.05	178.000	93.25
178.000	200.000	0.80	0.80	200.000	94.05
200.000	224.000	0.61	0.60	224.000	94.65
224.000	250.000	0.51	0.51	250.000	95.17
250.000	283.000	0.58	0.57	283.000	95.74
283.000	317.000	0.57	0.57	317.000	96.31
317.000	356.000	0.63	0.63	356.000	96.93
356.000	399.000	0.64	0.64	399.000	97.58
399.000	448.000	0.63	0.63	448.000	98.21
448.000	500.000	0.53	0.53	500.000	98.74
500.00	1000.00	1.21	1.21	1000.00	99.94
1000.00	2000.00	0.06	0.06	2000.00	100.00
2000.00	4000.00	0.00	0.00	4000.00	100.00
4000.00	8000.00	0.00	0.00	8000.00	100.00
8000.00	16000.00	0.00	0.00	16000.00	100.00
>16000		0.00	0.00		100.00
		1.26	98.74		
		98.88			
			100.00		

Size Fractions Graph



PARTICLE SIZE ANALYSIS REPORT
Size distribution analysis by laser diffraction (<500µm) and wet sieving (500-16000µm)

Customer: Jacobs
Contact: Garnett Hooper
Address: Level 11, 263 Adelaide Tce, Perth WA 6001
Date Received: 16/04/2015
Date of Issue: 29/04/2015

Summary Report

Sample Name:	SP2
Sampling Date:	11/04/2015
Sample Type:	Sediment
MAFRL Job Code:	JAC15-7
Client Reference:	IW021200
Analysis Date	17-Apr-15
Intrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300
Wentworth Aggregate Classification	
Clay % (<4µm)	19.13
Fine Silt % (4-16µm)	21.44
Medium Silt % (16-31µm)	9.83
Course Silt % (31-62µm)	15.96
Fine sand % (62-250µm)	24.10
Medium sand % (250-500µm)	7.06
Coarse sand % (500-2000µm)	2.49
Pebbles/Cobbles/Boulders (>2000µm)	0.00
SOP Name	SOP-LV-3REPS-skm.msop
Analysis Model	General Purpose
Result Units	Volume

Extended range by sieving

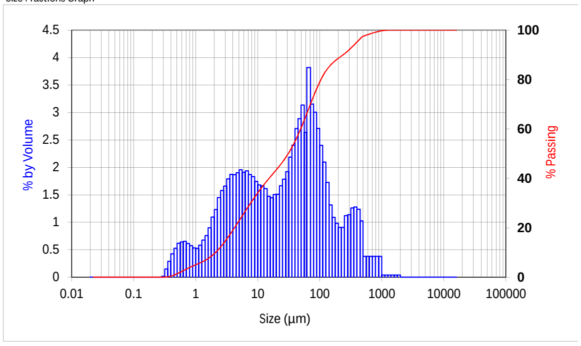
Extended size, µm	Extended percent retained at size
500	2.27
1000	0.22
2000	0.00
4000	0.00
8000	0.00
16000	0.00

Sample visual assessment
Mud with a small amount of sand present

Size Fractions Table

Differential Data				Cumulative Data	
Lower Size (µm)	Upper Size (µm)	% in Interval	% in Interval after scaling	Size (µm)	% Passing
0.020	0.022	0.00	0.00	0.022	0.00
0.022	0.025	0.00	0.00	0.025	0.00
0.025	0.028	0.00	0.00	0.028	0.00
0.028	0.032	0.00	0.00	0.032	0.00
0.032	0.036	0.00	0.00	0.036	0.00
0.036	0.040	0.00	0.00	0.040	0.00
0.040	0.045	0.00	0.00	0.045	0.00
0.045	0.050	0.00	0.00	0.050	0.00
0.050	0.056	0.00	0.00	0.056	0.00
0.056	0.063	0.00	0.00	0.063	0.00
0.063	0.071	0.00	0.00	0.071	0.00
0.071	0.080	0.00	0.00	0.080	0.00
0.080	0.089	0.00	0.00	0.089	0.00
0.089	0.100	0.00	0.00	0.100	0.00
0.100	0.112	0.00	0.00	0.112	0.00
0.112	0.126	0.00	0.00	0.126	0.00
0.126	0.142	0.00	0.00	0.142	0.00
0.142	0.159	0.00	0.00	0.159	0.00
0.159	0.178	0.00	0.00	0.178	0.00
0.178	0.200	0.00	0.00	0.200	0.00
0.200	0.224	0.00	0.00	0.224	0.00
0.224	0.252	0.00	0.00	0.252	0.00
0.252	0.283	0.00	0.00	0.283	0.00
0.283	0.317	0.01	0.01	0.317	0.01
0.317	0.356	0.15	0.15	0.356	0.16
0.356	0.399	0.29	0.29	0.399	0.45
0.399	0.448	0.43	0.42	0.448	0.87
0.448	0.502	0.53	0.53	0.502	1.40
0.502	0.564	0.62	0.62	0.564	2.02
0.564	0.632	0.64	0.64	0.632	2.66
0.632	0.710	0.65	0.65	0.710	3.31
0.710	0.796	0.61	0.61	0.796	3.92
0.796	0.893	0.58	0.57	0.893	4.49
0.893	1.000	0.53	0.53	1.000	5.02
1.000	1.120	0.53	0.52	1.120	5.55
1.120	1.260	0.58	0.58	1.260	6.13
1.260	1.420	0.68	0.67	1.420	6.80
1.420	1.590	0.76	0.76	1.590	7.56
1.590	1.780	0.90	0.90	1.780	8.46
1.780	2.000	1.10	1.09	2.000	9.55
2.000	2.240	1.24	1.23	2.240	10.78
2.240	2.520	1.46	1.45	2.520	12.23
2.520	2.830	1.58	1.58	2.830	13.81
2.830	3.170	1.67	1.66	3.170	15.47
3.170	3.560	1.80	1.79	3.560	17.26
3.560	4.000	1.88	1.87	4.000	19.13
4.000	4.480	1.87	1.86	4.480	20.99
4.480	5.020	1.91	1.90	5.020	22.89
5.020	5.640	1.97	1.96	5.640	24.85
5.640	6.320	1.92	1.91	6.320	26.76
6.320	7.100	1.94	1.93	7.100	28.69
7.100	7.960	1.88	1.87	7.960	30.56
7.960	8.930	1.84	1.83	8.930	32.39
8.930	10.000	1.75	1.74	10.000	34.14
10.000	11.200	1.69	1.68	11.200	35.81
11.200	12.600	1.67	1.66	12.600	37.48
12.600	14.200	1.62	1.61	14.200	39.09
14.200	15.900	1.48	1.47	15.900	40.56
15.900	17.800	1.45	1.45	17.800	42.01
17.800	20.000	1.51	1.50	20.000	43.51
20.000	22.400	1.52	1.51	22.400	45.02
22.400	25.200	1.67	1.67	25.200	46.69
25.200	28.300	1.79	1.78	28.300	48.47
28.300	31.700	1.93	1.92	31.700	50.39
31.700	35.600	2.20	2.19	35.600	52.58
35.600	39.900	2.41	2.40	39.900	54.98
39.900	44.800	2.72	2.71	44.800	57.69
44.800	50.200	2.90	2.89	50.200	60.58
50.200	56.400	3.15	3.14	56.400	63.71
56.400	62.000	2.65	2.64	62.000	66.35
62.000	71.000	3.84	3.82	71.000	70.17
71.000	79.600	3.17	3.15	79.600	73.32
79.600	89.300	3.02	3.00	89.300	76.32
89.300	100.000	2.72	2.71	100.000	79.03
100.000	112.000	2.41	2.40	112.000	81.43
112.000	126.000	2.10	2.09	126.000	83.53
126.000	142.000	1.73	1.73	142.000	85.25
142.000	159.000	1.32	1.32	159.000	86.57
159.000	178.000	1.09	1.09	178.000	87.66
178.000	200.000	0.98	0.98	200.000	88.64
200.000	224.000	0.91	0.90	224.000	89.54
224.000	250.000	0.91	0.90	250.000	90.45
250.000	283.000	1.13	1.12	283.000	91.57
283.000	317.000	1.14	1.14	317.000	92.71
317.000	356.000	1.27	1.26	356.000	93.97
356.000	399.000	1.28	1.28	399.000	95.24
399.000	448.000	1.24	1.24	448.000	96.48
448.000	500.000	1.03	1.02	500.000	97.51
500.00	1000.00	2.27	2.27	1000.00	99.78
1000.00	2000.00	0.22	0.22	2000.00	100.00
2000.00	4000.00	0.00	0.00	4000.00	100.00
4000.00	8000.00	0.00	0.00	8000.00	100.00
8000.00	16000.00	0.00	0.00	16000.00	100.00
>16000		0.00	0.00		100.00
		2.49	97.51		
		97.95			
			100.00		

Size Fractions Graph



PARTICLE SIZE ANALYSIS REPORT

Size distribution analysis by laser diffraction (<500µm) and wet sieving (500-16000µm)

Customer: Jacobs
Contact: Garnett Hooper
Address: Level 11, 263 Adelaide Tce, Perth WA 6001
Date Received: 16/04/2015
Date of Issue: 29/04/2015

Marine and Freshwater Research Laboratory Environmental Science | Murdoch UNIVERSITY

Summary Report

Sample Name:	SP3
Sampling Date:	11/04/2015
Sample Type:	Sediment
MAFRL Job Code:	JAC15-7
Client Reference:	IW021200
Analysis Date	17-Apr-15
Intrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300
Wentworth Aggregate Classification	
Clay % (<4µm)	11.79
Fine Silt % (4-16µm)	13.00
Medium Silt % (16-31µm)	6.74
Course Silt % (31-62µm)	13.64
Fine sand % (62-250µm)	31.63
Medium sand % (250-500µm)	16.54
Coarse sand % (500-2000µm)	6.18
Pebbles/Cobbles/Boulders (>2000µm)	0.48
SOP Name	SOP-LV-3REPS-skm.msop
Analysis Model	General Purpose
Result Units	Volume

Extended range by sieving

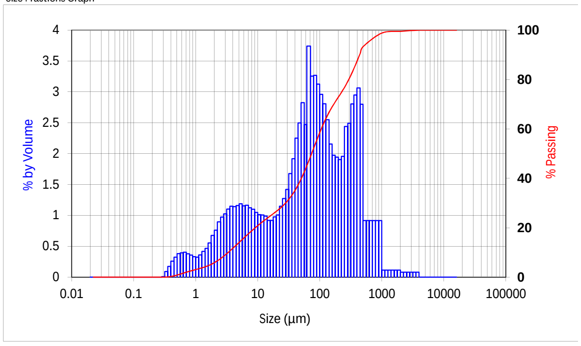
Extended size, µm	Extended percent retained at size
500	5.49
1000	0.69
2000	0.48
4000	0.00
8000	0.00
16000	0.00

Sample visual assessment
Mud with a small amount of sand present

Size Fractions Table

Differential Data				Cumulative Data	
Lower Size (µm)	Upper Size (µm)	% in Interval	% in Interval after scaling	Size (µm)	% Passing
0.020	0.022	0.00	0.00	0.022	0.00
0.022	0.025	0.00	0.00	0.025	0.00
0.025	0.028	0.00	0.00	0.028	0.00
0.028	0.032	0.00	0.00	0.032	0.00
0.032	0.036	0.00	0.00	0.036	0.00
0.036	0.040	0.00	0.00	0.040	0.00
0.040	0.045	0.00	0.00	0.045	0.00
0.045	0.050	0.00	0.00	0.050	0.00
0.050	0.056	0.00	0.00	0.056	0.00
0.056	0.063	0.00	0.00	0.063	0.00
0.063	0.071	0.00	0.00	0.071	0.00
0.071	0.080	0.00	0.00	0.080	0.00
0.080	0.089	0.00	0.00	0.089	0.00
0.089	0.100	0.00	0.00	0.100	0.00
0.100	0.112	0.00	0.00	0.112	0.00
0.112	0.126	0.00	0.00	0.126	0.00
0.126	0.142	0.00	0.00	0.142	0.00
0.142	0.159	0.00	0.00	0.159	0.00
0.159	0.178	0.00	0.00	0.178	0.00
0.178	0.200	0.00	0.00	0.200	0.00
0.200	0.224	0.00	0.00	0.224	0.00
0.224	0.252	0.00	0.00	0.252	0.00
0.252	0.283	0.00	0.00	0.283	0.00
0.283	0.317	0.01	0.01	0.317	0.01
0.317	0.356	0.09	0.09	0.356	0.10
0.356	0.399	0.17	0.17	0.399	0.27
0.399	0.448	0.25	0.26	0.448	0.53
0.448	0.502	0.32	0.32	0.502	0.85
0.502	0.564	0.37	0.38	0.564	1.23
0.564	0.632	0.39	0.39	0.632	1.63
0.632	0.710	0.39	0.40	0.710	2.03
0.710	0.796	0.37	0.38	0.796	2.41
0.796	0.893	0.35	0.36	0.893	2.76
0.893	1.000	0.32	0.33	1.000	3.09
1.000	1.120	0.32	0.32	1.120	3.42
1.120	1.260	0.35	0.36	1.260	3.78
1.260	1.420	0.41	0.42	1.420	4.19
1.420	1.590	0.46	0.47	1.590	4.66
1.590	1.780	0.54	0.55	1.780	5.21
1.780	2.000	0.66	0.67	2.000	5.89
2.000	2.240	0.74	0.76	2.240	6.65
2.240	2.520	0.88	0.90	2.520	7.54
2.520	2.830	0.95	0.97	2.830	8.51
2.830	3.170	1.00	1.02	3.170	9.54
3.170	3.560	1.08	1.10	3.560	10.64
3.560	4.000	1.12	1.15	4.000	11.79
4.000	4.480	1.12	1.14	4.480	12.93
4.480	5.020	1.13	1.16	5.020	14.09
5.020	5.640	1.16	1.19	5.640	15.28
5.640	6.320	1.13	1.15	6.320	16.43
6.320	7.100	1.14	1.16	7.100	17.60
7.100	7.960	1.10	1.12	7.960	18.72
7.960	8.930	1.07	1.10	8.930	19.81
8.930	10.000	1.02	1.05	10.000	20.86
10.000	11.200	0.99	1.01	11.200	21.87
11.200	12.600	0.99	1.01	12.600	22.88
12.600	14.200	0.97	0.99	14.200	23.87
14.200	15.900	0.90	0.92	15.900	24.79
15.900	17.800	0.90	0.92	17.800	25.70
17.800	20.000	0.95	0.98	20.000	26.68
20.000	22.400	0.99	1.01	22.400	27.69
22.400	25.200	1.12	1.15	25.200	28.83
25.200	28.300	1.24	1.27	28.300	30.11
28.300	31.700	1.39	1.42	31.700	31.53
31.700	35.600	1.64	1.68	35.600	33.20
35.600	39.900	1.87	1.92	39.900	35.12
39.900	44.800	2.20	2.25	44.800	37.37
44.800	50.200	2.44	2.50	50.200	39.87
50.200	56.400	2.76	2.83	56.400	42.69
56.400	62.000	2.42	2.47	62.000	45.16
62.000	71.000	3.66	3.74	71.000	48.90
71.000	79.600	3.18	3.25	79.600	52.16
79.600	89.300	3.20	3.27	89.300	55.43
89.300	100.000	3.06	3.13	100.000	58.55
100.000	112.000	2.89	2.96	112.000	61.51
112.000	126.000	2.75	2.81	126.000	64.32
126.000	142.000	2.49	2.55	142.000	66.87
142.000	159.000	2.11	2.15	159.000	69.02
159.000	178.000	1.93	1.97	178.000	70.99
178.000	200.000	1.90	1.94	200.000	72.94
200.000	224.000	1.86	1.90	224.000	74.84
224.000	250.000	1.91	1.96	250.000	76.80
250.000	283.000	2.39	2.44	283.000	79.24
283.000	317.000	2.44	2.49	317.000	81.73
317.000	356.000	2.74	2.80	356.000	84.53
356.000	399.000	2.88	2.95	399.000	87.48
399.000	448.000	3.00	3.06	448.000	90.54
448.000	500.000	2.74	2.80	500.000	93.34
500.00	1000.00	5.49	5.49	1000.00	98.83
1000.00	2000.00	0.69	0.69	2000.00	99.52
2000.00	4000.00	0.48	0.48	4000.00	100.00
4000.00	8000.00	0.00	0.00	8000.00	100.00
8000.00	16000.00	0.00	0.00	16000.00	100.00
>16000		0.00	0.00		100.00
		6.66	93.34		
		91.29			
			100.00		

Size Fractions Graph



PARTICLE SIZE ANALYSIS REPORT
Size distribution analysis by laser diffraction (<500µm) and wet sieving (500-16000µm)

Customer: Jacobs
Contact: Garnett Hooper
Address: Level 11, 263 Adelaide Tce, Perth WA 6001
Date Received: 16/04/2015
Date of Issue: 29/04/2015

Marine and Freshwater Research Laboratory Environmental Science | Murdoch UNIVERSITY

Summary Report

Sample Name:	SP4
Sampling Date:	9/04/2015
Sample Type:	Sediment
MAFRL Job Code:	JAC15-7
Client Reference:	IW021200
Analysis Date	20-Apr-15
Intrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300
Wentworth Aggregate Classification	
Clay % (<4µm)	4.57
Fine Silt % (4-16µm)	5.06
Medium Silt % (16-31µm)	2.78
Course Silt % (31-62µm)	4.04
Fine sand % (62-250µm)	36.27
Medium sand % (250-500µm)	30.67
Coarse sand % (500-2000µm)	14.56
Pebbles/Cobbles/Boulders (>2000µm)	2.04
SOP Name	SOP-3REPS-skm.msop
Analysis Model	General Purpose
Result Units	Volume

Extended range by sieving

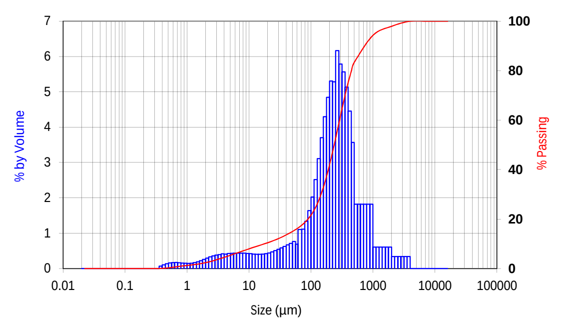
Extended size, µm	Extended percent retained at size
500	10.92
1000	3.65
2000	2.04
4000	0.00
8000	0.00
16000	0.00

Sample visual assessment
Sandy mud with some coral and shell present. A large bit of shell was removed from the sample prior to homogenisation as it was not representetive of the sample.

Size Fractions Table

Differential Data				Cumulative Data	
Lower Size (µm)	Upper Size (µm)	% in Interval	% in Interval after scaling	Size (µm)	% Passing
0.020	0.022	0.00	0.00	0.022	0.00
0.022	0.025	0.00	0.00	0.025	0.00
0.025	0.028	0.00	0.00	0.028	0.00
0.028	0.032	0.00	0.00	0.032	0.00
0.032	0.036	0.00	0.00	0.036	0.00
0.036	0.040	0.00	0.00	0.040	0.00
0.040	0.045	0.00	0.00	0.045	0.00
0.045	0.050	0.00	0.00	0.050	0.00
0.050	0.056	0.00	0.00	0.056	0.00
0.056	0.063	0.00	0.00	0.063	0.00
0.063	0.071	0.00	0.00	0.071	0.00
0.071	0.080	0.00	0.00	0.080	0.00
0.080	0.089	0.00	0.00	0.089	0.00
0.089	0.100	0.00	0.00	0.100	0.00
0.100	0.112	0.00	0.00	0.112	0.00
0.112	0.126	0.00	0.00	0.126	0.00
0.126	0.142	0.00	0.00	0.142	0.00
0.142	0.159	0.00	0.00	0.159	0.00
0.159	0.178	0.00	0.00	0.178	0.00
0.178	0.200	0.00	0.00	0.200	0.00
0.200	0.224	0.00	0.00	0.224	0.00
0.224	0.252	0.00	0.00	0.252	0.00
0.252	0.283	0.00	0.00	0.283	0.00
0.283	0.317	0.00	0.00	0.317	0.00
0.317	0.356	0.00	0.00	0.356	0.00
0.356	0.399	0.07	0.07	0.399	0.07
0.399	0.448	0.11	0.10	0.448	0.17
0.448	0.502	0.15	0.13	0.502	0.31
0.502	0.564	0.17	0.16	0.564	0.46
0.564	0.632	0.18	0.17	0.632	0.63
0.632	0.710	0.19	0.17	0.710	0.80
0.710	0.796	0.18	0.16	0.796	0.96
0.796	0.893	0.17	0.16	0.893	1.12
0.893	1.002	0.16	0.15	1.002	1.27
1.002	1.125	0.16	0.14	1.125	1.41
1.125	1.262	0.16	0.15	1.262	1.56
1.262	1.416	0.18	0.17	1.416	1.73
1.416	1.589	0.21	0.19	1.589	1.92
1.589	1.783	0.24	0.22	1.783	2.14
1.783	2.000	0.28	0.26	2.000	2.40
2.000	2.244	0.32	0.29	2.244	2.69
2.244	2.518	0.36	0.33	2.518	3.02
2.518	2.825	0.39	0.36	2.825	3.38
2.825	3.170	0.42	0.38	3.170	3.76
3.170	3.557	0.43	0.40	3.557	4.15
3.557	4.000	0.46	0.42	4.000	4.57
4.000	4.477	0.45	0.41	4.477	4.98
4.477	5.024	0.46	0.42	5.024	5.40
5.024	5.637	0.47	0.43	5.637	5.83
5.637	6.325	0.47	0.43	6.325	6.26
6.325	7.096	0.48	0.44	7.096	6.70
7.096	7.962	0.48	0.44	7.962	7.14
7.962	8.934	0.47	0.43	8.934	7.57
8.934	10.024	0.47	0.43	10.024	8.00
10.024	11.247	0.46	0.42	11.247	8.42
11.247	12.619	0.45	0.41	12.619	8.83
12.619	14.159	0.44	0.40	14.159	9.23
14.159	15.887	0.44	0.40	15.887	9.63
15.887	17.825	0.44	0.41	17.825	10.03
17.825	20.000	0.46	0.42	20.000	10.45
20.000	22.440	0.48	0.44	22.440	10.89
22.440	25.179	0.51	0.47	25.179	11.36
25.179	28.251	0.55	0.50	28.251	11.87
28.251	31.698	0.59	0.54	31.698	12.41
31.698	35.566	0.64	0.58	35.566	12.99
35.566	39.905	0.68	0.63	39.905	13.62
39.905	44.774	0.73	0.67	44.774	14.29
44.774	50.238	0.78	0.71	50.238	15.00
50.238	56.368	0.84	0.76	56.368	15.76
56.368	62.000	0.75	0.69	62.000	16.45
62.000	70.963	1.21	1.10	70.963	17.55
70.963	79.621	1.22	1.11	79.621	18.67
79.621	89.337	1.46	1.34	89.337	20.00
89.337	100.237	1.79	1.64	100.237	21.64
100.237	112.468	2.22	2.03	112.468	23.67
112.468	126.191	2.75	2.51	126.191	26.18
126.191	141.589	3.41	3.11	141.589	29.29
141.589	158.866	4.05	3.70	158.866	33.00
158.866	178.250	4.70	4.29	178.250	37.29
178.250	200.000	5.30	4.84	200.000	42.14
200.000	224.404	5.81	5.31	224.404	47.44
224.404	250.000	5.78	5.28	250.000	52.72
250.000	282.508	6.75	6.17	282.508	58.89
282.508	316.979	6.33	5.79	316.979	64.68
316.979	355.656	6.09	5.56	355.656	70.24
355.656	399.052	5.62	5.13	399.052	75.37
399.052	447.744	4.88	4.46	447.744	79.83
447.744	500.000	3.90	3.57	500.000	83.40
500.00	1000.00	10.92	10.92	1000.00	94.31
1000.00	2000.00	3.65	3.65	2000.00	97.96
2000.00	4000.00	2.04	2.04	4000.00	100.00
4000.00	8000.00	0.00	0.00	8000.00	100.00
8000.00	16000.00	0.00	0.00	16000.00	100.00
>16000		0.00	0.00		100.00
		16.60	83.40		
		91.29			
			100.00		

Size Fractions Graph



PARTICLE SIZE ANALYSIS REPORT
Size distribution analysis by laser diffraction (<500µm) and wet sieving (500-16000µm)

Customer: Jacobs
Contact: Garnett Hooper
Address: Level 11, 263 Adelaide Tce, Perth WA 6001
Date Received: 16/04/2015
Date of Issue: 29/04/2015

Marine and Freshwater Research Laboratory Environmental Science | Murdoch UNIVERSITY

Summary Report

Sample Name:	SP5
Sampling Date:	9/04/2015
Sample Type:	Sediment
MAFRL Job Code:	JAC15-7
Client Reference:	IW021200
Analysis Date	20-Apr-15
Intrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300
Wentworth Aggregate Classification	
Clay % (<4µm)	6.02
Fine Silt % (4-16µm)	6.99
Medium Silt % (16-31µm)	4.13
Course Silt % (31-62µm)	7.52
Fine sand % (62-250µm)	37.60
Medium sand % (250-500µm)	24.07
Coarse sand % (500-2000µm)	12.68
Pebbles/Cobbles/Boulders (>2000µm)	1.00
SOP Name	SOP-3REPS-skm.msop
Analysis Model	General Purpose
Result Units	Volume

Extended range by sieving

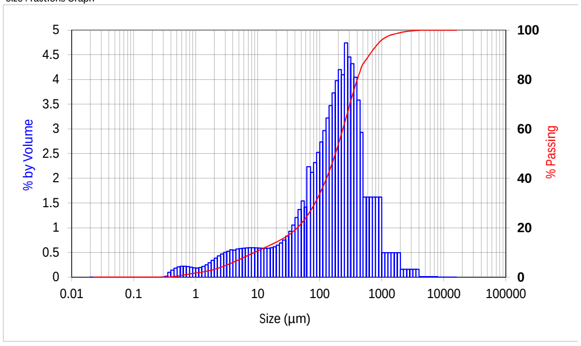
Extended size, µm	Extended percent retained at size
500	9.72
1000	2.96
2000	0.95
4000	0.05
8000	0.00
16000	0.00

Sample visual assessment
Muddy sand with some shell present.

Size Fractions Table

Differential Data				Cumulative Data	
Lower Size (µm)	Upper Size (µm)	% in Interval	% in Interval after scaling	Size (µm)	% Passing
0.020	0.022	0.00	0.00	0.022	0.00
0.022	0.025	0.00	0.00	0.025	0.00
0.025	0.028	0.00	0.00	0.028	0.00
0.028	0.032	0.00	0.00	0.032	0.00
0.032	0.036	0.00	0.00	0.036	0.00
0.036	0.040	0.00	0.00	0.040	0.00
0.040	0.045	0.00	0.00	0.045	0.00
0.045	0.050	0.00	0.00	0.050	0.00
0.050	0.056	0.00	0.00	0.056	0.00
0.056	0.063	0.00	0.00	0.063	0.00
0.063	0.071	0.00	0.00	0.071	0.00
0.071	0.080	0.00	0.00	0.080	0.00
0.080	0.089	0.00	0.00	0.089	0.00
0.089	0.100	0.00	0.00	0.100	0.00
0.100	0.112	0.00	0.00	0.112	0.00
0.112	0.126	0.00	0.00	0.126	0.00
0.126	0.142	0.00	0.00	0.142	0.00
0.142	0.159	0.00	0.00	0.159	0.00
0.159	0.178	0.00	0.00	0.178	0.00
0.178	0.200	0.00	0.00	0.200	0.00
0.200	0.224	0.00	0.00	0.224	0.00
0.224	0.252	0.00	0.00	0.252	0.00
0.252	0.283	0.00	0.00	0.283	0.00
0.283	0.317	0.00	0.00	0.317	0.00
0.317	0.356	0.02	0.02	0.356	0.02
0.356	0.399	0.10	0.10	0.399	0.11
0.399	0.448	0.15	0.14	0.448	0.26
0.448	0.502	0.19	0.18	0.502	0.44
0.502	0.564	0.22	0.21	0.564	0.64
0.564	0.632	0.24	0.22	0.632	0.86
0.632	0.710	0.24	0.22	0.710	1.08
0.710	0.796	0.23	0.21	0.796	1.30
0.796	0.893	0.21	0.20	0.893	1.50
0.893	1.002	0.20	0.19	1.002	1.68
1.002	1.125	0.20	0.18	1.125	1.87
1.125	1.262	0.21	0.19	1.262	2.06
1.262	1.416	0.23	0.22	1.416	2.28
1.416	1.589	0.27	0.25	1.589	2.53
1.589	1.783	0.31	0.29	1.783	2.82
1.783	2.000	0.36	0.34	2.000	3.16
2.000	2.244	0.41	0.39	2.244	3.54
2.244	2.518	0.46	0.43	2.518	3.97
2.518	2.825	0.50	0.47	2.825	4.44
2.825	3.170	0.54	0.50	3.170	4.94
3.170	3.557	0.56	0.52	3.557	5.47
3.557	4.000	0.59	0.55	4.000	6.02
4.000	4.477	0.59	0.55	4.477	6.56
4.477	5.024	0.61	0.57	5.024	7.13
5.024	5.637	0.62	0.58	5.637	7.71
5.637	6.325	0.63	0.58	6.325	8.29
6.325	7.096	0.63	0.59	7.096	8.88
7.096	7.962	0.64	0.59	7.962	9.48
7.962	8.934	0.64	0.59	8.934	10.07
8.934	10.024	0.64	0.59	10.024	10.67
10.024	11.247	0.63	0.59	11.247	11.25
11.247	12.619	0.63	0.58	12.619	11.84
12.619	14.159	0.63	0.58	14.159	12.42
14.159	15.887	0.63	0.59	15.887	13.01
15.887	17.825	0.64	0.60	17.825	13.60
17.825	20.000	0.66	0.61	20.000	14.22
20.000	22.440	0.69	0.65	22.440	14.86
22.440	25.179	0.74	0.69	25.179	15.56
25.179	28.251	0.81	0.75	28.251	16.31
28.251	31.698	0.89	0.83	31.698	17.14
31.698	35.566	1.00	0.93	35.566	18.06
35.566	39.905	1.13	1.05	39.905	19.12
39.905	44.774	1.29	1.21	44.774	20.32
44.774	50.238	1.47	1.37	50.238	21.69
50.238	56.368	1.66	1.54	56.368	23.23
56.368	62.000	1.52	1.42	62.000	24.65
62.000	70.963	2.40	2.24	70.963	26.89
70.963	79.621	2.27	2.12	79.621	29.01
79.621	89.337	2.49	2.32	89.337	31.33
89.337	100.237	2.71	2.52	100.237	33.85
100.237	112.468	2.93	2.73	112.468	36.58
112.468	126.191	3.18	2.96	126.191	39.55
126.191	141.589	3.46	3.22	141.589	42.77
141.589	158.866	3.73	3.47	158.866	46.24
158.866	178.250	4.00	3.73	178.250	49.97
178.250	200.000	4.27	3.98	200.000	53.95
200.000	224.404	4.51	4.20	224.404	58.15
224.404	250.000	4.40	4.10	250.000	62.25
250.000	282.508	5.09	4.74	282.508	66.99
282.508	316.979	4.78	4.45	316.979	71.44
316.979	355.656	4.64	4.32	355.656	75.76
355.656	399.052	4.34	4.05	399.052	79.81
399.052	447.744	3.85	3.58	447.744	83.39
447.744	500.000	3.14	2.93	500.000	86.32
500.00	1000.00	9.72	9.72	1000.00	96.04
1000.00	2000.00	2.96	2.96	2000.00	99.00
2000.00	4000.00	0.95	0.95	4000.00	99.95
4000.00	8000.00	0.05	0.05	8000.00	100.00
8000.00	16000.00	0.00	0.00	16000.00	100.00
>16000		0.00	0.00		100.00
		13.68	86.32		
		92.63			
			100.00		

Size Fractions Graph



PARTICLE SIZE ANALYSIS REPORT
Size distribution analysis by laser diffraction (<500µm) and wet sieving (500-16000µm)

Customer: Jacobs
Contact: Garnett Hooper
Address: Level 11, 263 Adelaide Tce, Perth WA 6001
Date Received: 16/04/2015
Date of Issue: 29/04/2015

Summary Report

Sample Name:	SP6E
Sampling Date:	9/04/2015
Sample Type:	Sediment
MAFRL Job Code:	JAC15-7
Client Reference:	IW021200
Analysis Date	22-Apr-15
Intrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300
Wentworth Aggregate Classification	
Clay % (<4µm)	6.44
Fine Silt % (4-16µm)	6.45
Medium Silt % (16-31µm)	3.73
Course Silt % (31-62µm)	9.59
Fine sand % (62-250µm)	38.38
Medium sand % (250-500µm)	21.53
Coarse sand % (500-2000µm)	12.56
Pebbles/Cobbles/Boulders (>2000µm)	1.32
SOP Name	SOP-LV-3REPS-skm.msop
Analysis Model	General Purpose
Result Units	Volume

Extended range by sieving

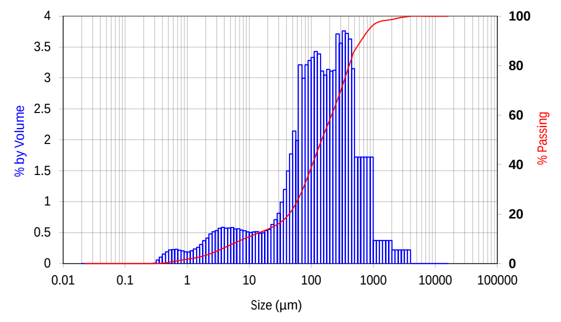
Extended size, µm	Extended percent retained at size
500	10.32
1000	2.24
2000	1.32
4000	0.00
8000	0.00
16000	0.00

Sample visual assessment
Sand with shell and mud present.

Size Fractions Table

Differential Data				Cumulative Data	
Lower Size (µm)	Upper Size (µm)	% in Interval	% in Interval after scaling	Size (µm)	% Passing
0.020	0.022	0.00	0.00	0.022	0.00
0.022	0.025	0.00	0.00	0.025	0.00
0.025	0.028	0.00	0.00	0.028	0.00
0.028	0.032	0.00	0.00	0.032	0.00
0.032	0.036	0.00	0.00	0.036	0.00
0.036	0.040	0.00	0.00	0.040	0.00
0.040	0.045	0.00	0.00	0.045	0.00
0.045	0.050	0.00	0.00	0.050	0.00
0.050	0.056	0.00	0.00	0.056	0.00
0.056	0.063	0.00	0.00	0.063	0.00
0.063	0.071	0.00	0.00	0.071	0.00
0.071	0.080	0.00	0.00	0.080	0.00
0.080	0.089	0.00	0.00	0.089	0.00
0.089	0.100	0.00	0.00	0.100	0.00
0.100	0.112	0.00	0.00	0.112	0.00
0.112	0.126	0.00	0.00	0.126	0.00
0.126	0.142	0.00	0.00	0.142	0.00
0.142	0.159	0.00	0.00	0.159	0.00
0.159	0.178	0.00	0.00	0.178	0.00
0.178	0.200	0.00	0.00	0.200	0.00
0.200	0.224	0.00	0.00	0.224	0.00
0.224	0.252	0.00	0.00	0.252	0.00
0.252	0.283	0.00	0.00	0.283	0.00
0.283	0.317	0.01	0.00	0.317	0.01
0.317	0.356	0.06	0.06	0.356	0.06
0.356	0.399	0.11	0.10	0.399	0.16
0.399	0.448	0.16	0.15	0.448	0.32
0.448	0.502	0.20	0.19	0.502	0.50
0.502	0.564	0.23	0.22	0.564	0.72
0.564	0.632	0.24	0.23	0.632	0.95
0.632	0.710	0.24	0.23	0.710	1.18
0.710	0.796	0.23	0.22	0.796	1.39
0.796	0.893	0.21	0.20	0.893	1.60
0.893	1.000	0.20	0.19	1.000	1.79
1.000	1.120	0.20	0.19	1.120	1.97
1.120	1.260	0.22	0.21	1.260	2.18
1.260	1.420	0.25	0.24	1.420	2.41
1.420	1.590	0.28	0.26	1.590	2.68
1.590	1.780	0.32	0.31	1.780	2.98
1.780	2.000	0.39	0.37	2.000	3.35
2.000	2.240	0.43	0.41	2.240	3.76
2.240	2.520	0.50	0.48	2.520	4.24
2.520	2.830	0.54	0.51	2.830	4.76
2.830	3.170	0.56	0.53	3.170	5.29
3.170	3.560	0.60	0.57	3.560	5.86
3.560	4.000	0.61	0.58	4.000	6.44
4.000	4.480	0.60	0.57	4.480	7.01
4.480	5.020	0.60	0.57	5.020	7.59
5.020	5.640	0.61	0.58	5.640	8.17
5.640	6.320	0.59	0.56	6.320	8.73
6.320	7.100	0.59	0.56	7.100	9.29
7.100	7.960	0.57	0.54	7.960	9.83
7.960	8.930	0.56	0.53	8.930	10.36
8.930	10.000	0.54	0.51	10.000	10.87
10.000	11.200	0.53	0.50	11.200	11.37
11.200	12.600	0.54	0.51	12.600	11.88
12.600	14.200	0.54	0.52	14.200	12.40
14.200	15.900	0.51	0.49	15.900	12.89
15.900	17.800	0.52	0.50	17.800	13.38
17.800	20.000	0.56	0.53	20.000	13.92
20.000	22.400	0.58	0.55	22.400	14.47
22.400	25.200	0.66	0.63	25.200	15.10
25.200	28.300	0.75	0.71	28.300	15.81
28.300	31.700	0.85	0.81	31.700	16.62
31.700	35.600	1.05	0.99	35.600	17.61
35.600	39.900	1.26	1.20	39.900	18.81
39.900	44.800	1.57	1.50	44.800	20.31
44.800	50.200	1.86	1.77	50.200	22.08
50.200	56.400	2.25	2.14	56.400	24.22
56.400	62.000	2.09	1.99	62.000	26.21
62.000	71.000	3.38	3.21	71.000	29.42
71.000	79.600	3.15	3.00	79.600	32.42
79.600	89.300	3.38	3.21	89.300	35.63
89.300	100.000	3.45	3.28	100.000	38.91
100.000	112.000	3.50	3.33	112.000	42.24
112.000	126.000	3.61	3.43	126.000	45.67
126.000	142.000	3.56	3.39	142.000	49.06
142.000	159.000	3.27	3.11	159.000	52.17
159.000	178.000	3.21	3.05	178.000	55.22
178.000	200.000	3.30	3.14	200.000	58.36
200.000	224.000	3.27	3.11	224.000	61.46
224.000	250.000	3.29	3.12	250.000	64.59
250.000	283.000	3.90	3.71	283.000	68.30
283.000	317.000	3.75	3.56	317.000	71.86
317.000	356.000	3.96	3.76	356.000	75.62
356.000	399.000	3.91	3.72	399.000	79.34
399.000	448.000	3.82	3.63	448.000	82.97
448.000	500.000	3.31	3.15	500.000	86.12
500.00	1000.00	10.32	10.32	1000.00	96.44
1000.00	2000.00	2.24	2.24	2000.00	98.68
2000.00	4000.00	1.32	1.32	4000.00	100.00
4000.00	8000.00	0.00	0.00	8000.00	100.00
8000.00	16000.00	0.00	0.00	16000.00	100.00
>16000		0.00	0.00		100.00
		13.88	86.12		
		90.61			
			100.00		

Size Fractions Graph



PARTICLE SIZE ANALYSIS REPORT
Size distribution analysis by laser diffraction (<500µm) and wet sieving (500-16000µm)

Customer: Jacobs
Contact: Garnett Hooper
Address: Level 11, 263 Adelaide Tce, Perth WA 6001
Date Received: 16/04/2015
Date of Issue: 29/04/2015

Marine and Freshwater Research Laboratory Environmental Science | Murdoch UNIVERSITY

Summary Report

Sample Name:	SP8
Sampling Date:	10/04/2015
Sample Type:	Sediment
MAFRL Job Code:	JAC15-7
Client Reference:	IW021200
Analysis Date	20-Apr-15
Intrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300
Wentworth Aggregate Classification	
Clay % (<4µm)	0.35
Fine Silt % (4-16µm)	0.98
Medium Silt % (16-31µm)	1.12
Course Silt % (31-62µm)	2.44
Fine sand % (62-250µm)	22.24
Medium sand % (250-500µm)	12.61
Coarse sand % (500-2000µm)	26.43
Pebbles/Cobbles/Boulders (>2000µm)	33.84
SOP Name	SOP-3REPS-skm.msop
Analysis Model	General Purpose
Result Units	Volume

Extended range by sieving

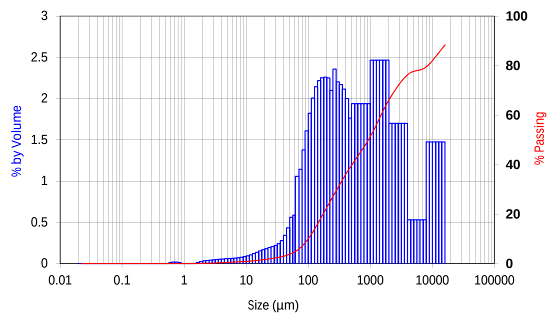
Extended size, µm	Extended percent retained at size
500	11.63
1000	14.80
2000	10.20
4000	3.18
8000	8.84
16000	11.62

Sample visual assessment
Shelly sand with mud and rock present.

Size Fractions Table

Differential Data				Cumulative Data	
Lower Size (µm)	Upper Size (µm)	% in Interval	% in Interval after scaling	Size (µm)	% Passing
0.020	0.022	0.00	0.00	0.022	0.00
0.022	0.025	0.00	0.00	0.025	0.00
0.025	0.028	0.00	0.00	0.028	0.00
0.028	0.032	0.00	0.00	0.032	0.00
0.032	0.036	0.00	0.00	0.036	0.00
0.036	0.040	0.00	0.00	0.040	0.00
0.040	0.045	0.00	0.00	0.045	0.00
0.045	0.050	0.00	0.00	0.050	0.00
0.050	0.056	0.00	0.00	0.056	0.00
0.056	0.063	0.00	0.00	0.063	0.00
0.063	0.071	0.00	0.00	0.071	0.00
0.071	0.080	0.00	0.00	0.080	0.00
0.080	0.089	0.00	0.00	0.089	0.00
0.089	0.100	0.00	0.00	0.100	0.00
0.100	0.112	0.00	0.00	0.112	0.00
0.112	0.126	0.00	0.00	0.126	0.00
0.126	0.142	0.00	0.00	0.142	0.00
0.142	0.159	0.00	0.00	0.159	0.00
0.159	0.178	0.00	0.00	0.178	0.00
0.178	0.200	0.00	0.00	0.200	0.00
0.200	0.224	0.00	0.00	0.224	0.00
0.224	0.252	0.00	0.00	0.252	0.00
0.252	0.283	0.00	0.00	0.283	0.00
0.283	0.317	0.00	0.00	0.317	0.00
0.317	0.356	0.00	0.00	0.356	0.00
0.356	0.399	0.00	0.00	0.399	0.00
0.399	0.448	0.00	0.00	0.448	0.00
0.448	0.502	0.00	0.00	0.502	0.00
0.502	0.564	0.00	0.00	0.564	0.00
0.564	0.632	0.02	0.01	0.632	0.01
0.632	0.710	0.04	0.02	0.710	0.03
0.710	0.796	0.04	0.02	0.796	0.04
0.796	0.893	0.02	0.01	0.893	0.06
0.893	1.002	0.00	0.00	1.002	0.06
1.002	1.125	0.00	0.00	1.125	0.06
1.125	1.262	0.00	0.00	1.262	0.06
1.262	1.416	0.00	0.00	1.416	0.06
1.416	1.589	0.00	0.00	1.589	0.06
1.589	1.783	0.03	0.01	1.783	0.07
1.783	2.000	0.05	0.02	2.000	0.10
2.000	2.244	0.07	0.03	2.244	0.13
2.244	2.518	0.08	0.04	2.518	0.16
2.518	2.825	0.09	0.04	2.825	0.20
2.825	3.170	0.10	0.04	3.170	0.25
3.170	3.557	0.11	0.05	3.557	0.30
3.557	4.000	0.12	0.05	4.000	0.35
4.000	4.477	0.12	0.05	4.477	0.40
4.477	5.024	0.13	0.06	5.024	0.46
5.024	5.637	0.13	0.06	5.637	0.52
5.637	6.325	0.14	0.06	6.325	0.58
6.325	7.096	0.14	0.07	7.096	0.65
7.096	7.962	0.15	0.07	7.962	0.72
7.962	8.934	0.17	0.08	8.934	0.79
8.934	10.024	0.18	0.08	10.024	0.88
10.024	11.247	0.20	0.09	11.247	0.97
11.247	12.619	0.23	0.11	12.619	1.07
12.619	14.159	0.27	0.12	14.159	1.19
14.159	15.887	0.30	0.14	15.887	1.33
15.887	17.825	0.34	0.15	17.825	1.48
17.825	20.000	0.37	0.17	20.000	1.65
20.000	22.440	0.40	0.18	22.440	1.83
22.440	25.179	0.43	0.19	25.179	2.02
25.179	28.251	0.45	0.20	28.251	2.23
28.251	31.698	0.48	0.22	31.698	2.45
31.698	35.566	0.53	0.24	35.566	2.69
35.566	39.905	0.61	0.28	39.905	2.96
39.905	44.774	0.75	0.34	44.774	3.31
44.774	50.238	0.95	0.43	50.238	3.74
50.238	56.368	1.23	0.56	56.368	4.30
56.368	62.000	1.29	0.59	62.000	4.88
62.000	70.963	2.33	1.06	70.963	5.94
70.963	79.621	2.52	1.14	79.621	7.08
79.621	89.337	3.03	1.38	89.337	8.46
89.337	100.237	3.54	1.61	100.237	10.07
100.237	112.468	4.02	1.82	112.468	11.89
112.468	126.191	4.42	2.01	126.191	13.90
126.191	141.589	4.72	2.14	141.589	16.04
141.589	158.866	4.89	2.22	158.866	18.26
158.866	178.250	4.96	2.25	178.250	20.51
178.250	200.000	4.98	2.26	200.000	22.77
200.000	224.404	4.96	2.25	224.404	25.02
224.404	250.000	4.62	2.10	250.000	27.12
250.000	282.508	5.20	2.36	282.508	29.48
282.508	316.979	4.85	2.20	316.979	31.68
316.979	355.656	4.78	2.17	355.656	33.85
355.656	399.052	4.66	2.11	399.052	35.97
399.052	447.744	4.41	2.00	447.744	37.97
447.744	500.000	3.89	1.76	500.000	39.73
500.00	1000.00	11.63	11.63	1000.00	51.36
1000.00	2000.00	14.80	14.80	2000.00	66.16
2000.00	4000.00	10.20	10.20	4000.00	76.36
4000.00	8000.00	3.18	3.18	8000.00	79.54
8000.00	16000.00	8.84	8.84	16000.00	88.38
>16000		11.62	11.62		100.00
		60.27	39.73		
		87.53			
			100.00		

Size Fractions Graph



PARTICLE SIZE ANALYSIS REPORT

Size distribution analysis by laser diffraction (<500µm) and wet sieving (500-16000µm)

Customer: Jacobs
Contact: Garnett Hooper
Address: Level 11, 263 Adelaide Tce, Perth WA 6001
Date Received: 16/04/2015
Date of Issue: 29/04/2015

Summary Report

Sample Name:	SP9
Sampling Date:	10/04/2015
Sample Type:	Sediment
MAFRL Job Code:	JAC15-7
Client Reference:	IW021200
Analysis Date	20-Apr-15
Intrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300
Wentworth Aggregate Classification	
Clay % (<4µm)	0.95
Fine Silt % (4-16µm)	1.36
Medium Silt % (16-31µm)	1.17
Course Silt % (31-62µm)	2.00
Fine sand % (62-250µm)	23.44
Medium sand % (250-500µm)	16.38
Coarse sand % (500-2000µm)	18.71
Pebbles/Cobbles/Boulders (>2000µm)	35.99
SOP Name	SOP-3REPS-skm.msop
Analysis Model	General Purpose
Result Units	Volume

Extended range by sieving

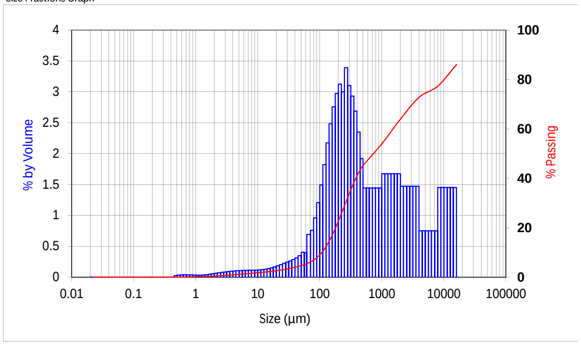
Extended size, µm	Extended percent retained at size
500	8.66
1000	10.05
2000	8.84
4000	4.51
8000	8.71
16000	13.94

Sample visual assessment
Sand with rock, coral, shell and mud present.

Size Fractions Table

Differential Data				Cumulative Data	
Lower Size (µm)	Upper Size (µm)	% in Interval	% in Interval after scaling	Size (µm)	% Passing
0.020	0.022	0.00	0.00	0.022	0.00
0.022	0.025	0.00	0.00	0.025	0.00
0.025	0.028	0.00	0.00	0.028	0.00
0.028	0.032	0.00	0.00	0.032	0.00
0.032	0.036	0.00	0.00	0.036	0.00
0.036	0.040	0.00	0.00	0.040	0.00
0.040	0.045	0.00	0.00	0.045	0.00
0.045	0.050	0.00	0.00	0.050	0.00
0.050	0.056	0.00	0.00	0.056	0.00
0.056	0.063	0.00	0.00	0.063	0.00
0.063	0.071	0.00	0.00	0.071	0.00
0.071	0.080	0.00	0.00	0.080	0.00
0.080	0.089	0.00	0.00	0.089	0.00
0.089	0.100	0.00	0.00	0.100	0.00
0.100	0.112	0.00	0.00	0.112	0.00
0.112	0.126	0.00	0.00	0.126	0.00
0.126	0.142	0.00	0.00	0.142	0.00
0.142	0.159	0.00	0.00	0.159	0.00
0.159	0.178	0.00	0.00	0.178	0.00
0.178	0.200	0.00	0.00	0.200	0.00
0.200	0.224	0.00	0.00	0.224	0.00
0.224	0.252	0.00	0.00	0.252	0.00
0.252	0.283	0.00	0.00	0.283	0.00
0.283	0.317	0.00	0.00	0.317	0.00
0.317	0.356	0.00	0.00	0.356	0.00
0.356	0.399	0.00	0.00	0.399	0.00
0.399	0.448	0.00	0.00	0.448	0.00
0.448	0.502	0.05	0.02	0.502	0.02
0.502	0.564	0.07	0.03	0.564	0.06
0.564	0.632	0.07	0.04	0.632	0.09
0.632	0.710	0.08	0.04	0.710	0.13
0.710	0.796	0.07	0.04	0.796	0.17
0.796	0.893	0.07	0.03	0.893	0.20
0.893	1.002	0.07	0.03	1.002	0.24
1.002	1.125	0.06	0.03	1.125	0.27
1.125	1.262	0.06	0.03	1.262	0.30
1.262	1.416	0.07	0.03	1.416	0.33
1.416	1.589	0.08	0.04	1.589	0.37
1.589	1.783	0.09	0.05	1.783	0.42
1.783	2.000	0.11	0.05	2.000	0.47
2.000	2.244	0.12	0.06	2.244	0.54
2.244	2.518	0.14	0.07	2.518	0.60
2.518	2.825	0.15	0.08	2.825	0.68
2.825	3.170	0.17	0.08	3.170	0.76
3.170	3.557	0.18	0.09	3.557	0.85
3.557	4.000	0.19	0.10	4.000	0.95
4.000	4.477	0.19	0.10	4.477	1.05
4.477	5.024	0.20	0.10	5.024	1.15
5.024	5.637	0.21	0.11	5.637	1.26
5.637	6.325	0.21	0.11	6.325	1.36
6.325	7.096	0.22	0.11	7.096	1.47
7.096	7.962	0.22	0.11	7.962	1.58
7.962	8.934	0.22	0.11	8.934	1.70
8.934	10.024	0.23	0.11	10.024	1.81
10.024	11.247	0.23	0.12	11.247	1.92
11.247	12.619	0.24	0.12	12.619	2.04
12.619	14.159	0.25	0.13	14.159	2.17
14.159	15.887	0.27	0.14	15.887	2.31
15.887	17.825	0.30	0.15	17.825	2.46
17.825	20.000	0.33	0.17	20.000	2.62
20.000	22.440	0.36	0.18	22.440	2.81
22.440	25.179	0.40	0.20	25.179	3.01
25.179	28.251	0.44	0.22	28.251	3.23
28.251	31.698	0.48	0.24	31.698	3.47
31.698	35.566	0.52	0.26	35.566	3.74
35.566	39.905	0.57	0.28	39.905	4.02
39.905	44.774	0.62	0.31	44.774	4.33
44.774	50.238	0.69	0.35	50.238	4.68
50.238	56.368	0.80	0.40	56.368	5.08
56.368	62.000	0.78	0.39	62.000	5.47
62.000	70.963	1.37	0.69	70.963	6.16
70.963	79.621	1.51	0.76	79.621	6.92
79.621	89.337	1.91	0.96	89.337	7.88
89.337	100.237	2.40	1.21	100.237	9.09
100.237	112.468	2.97	1.49	112.468	10.58
112.468	126.191	3.63	1.82	126.191	12.40
126.191	141.589	4.33	2.17	141.589	14.57
141.589	158.866	4.95	2.48	158.866	17.06
158.866	178.250	5.49	2.76	178.250	19.82
178.250	200.000	5.92	2.98	200.000	22.79
200.000	224.404	6.23	3.13	224.404	25.92
224.404	250.000	5.98	3.00	250.000	28.92
250.000	282.508	6.75	3.39	282.508	32.31
282.508	316.979	6.18	3.10	316.979	35.41
316.979	355.656	5.84	2.93	355.656	38.34
355.656	399.052	5.35	2.69	399.052	41.03
399.052	447.744	4.68	2.35	447.744	43.38
447.744	500.000	3.82	1.92	500.000	45.30
500.00	1000.00	8.66	8.66	1000.00	53.96
1000.00	2000.00	10.05	10.05	2000.00	64.01
2000.00	4000.00	8.84	8.84	4000.00	72.85
4000.00	8000.00	4.51	4.51	8000.00	77.35
8000.00	16000.00	8.71	8.71	16000.00	86.06
>16000		13.94	13.94		100.00
		54.70	45.30		
		90.21			
			100.00		

Size Fractions Graph



PARTICLE SIZE ANALYSIS REPORT
Size distribution analysis by laser diffraction (<500µm) and wet sieving (500-16000µm)

Customer: Jacobs
Contact: Garnett Hooper
Address: Level 11, 263 Adelaide Tce, Perth WA 6001
Date Received: 16/04/2015
Date of Issue: 29/04/2015

Summary Report

Sample Name:	SP10N
Sampling Date:	10/04/2015
Sample Type:	Sediment
MAFRL Job Code:	JAC15-7
Client Reference:	IW021200
Analysis Date	20-Apr-15
Intrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300
Wentworth Aggregate Classification	
Clay % (<4µm)	1.37
Fine Silt % (4-16µm)	1.84
Medium Silt % (16-31µm)	1.13
Course Silt % (31-62µm)	1.59
Fine sand % (62-250µm)	27.24
Medium sand % (250-500µm)	38.17
Coarse sand % (500-2000µm)	21.71
Pebbles/Cobbles/Boulders (>2000µm)	6.95
SOP Name	SOP-3REPS-skm.msop
Analysis Model	General Purpose
Result Units	Volume

Extended range by sieving

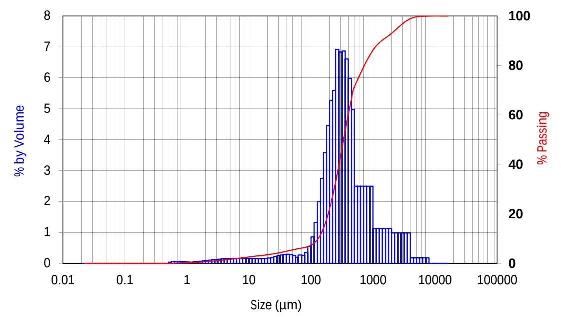
Extended size, µm	Extended percent retained at size
500	14.95
1000	6.75
2000	5.90
4000	1.04
8000	0.00
16000	0.00

Sample visual assessment
Sand with rock, coral, shell and mud present.

Size Fractions Table

Differential Data				Cumulative Data	
Lower Size (µm)	Upper Size (µm)	% in Interval	% in Interval after scaling	Size (µm)	% Passing
0.020	0.022	0.00	0.00	0.022	0.00
0.022	0.025	0.00	0.00	0.025	0.00
0.025	0.028	0.00	0.00	0.028	0.00
0.028	0.032	0.00	0.00	0.032	0.00
0.032	0.036	0.00	0.00	0.036	0.00
0.036	0.040	0.00	0.00	0.040	0.00
0.040	0.045	0.00	0.00	0.045	0.00
0.045	0.050	0.00	0.00	0.050	0.00
0.050	0.056	0.00	0.00	0.056	0.00
0.056	0.063	0.00	0.00	0.063	0.00
0.063	0.071	0.00	0.00	0.071	0.00
0.071	0.080	0.00	0.00	0.080	0.00
0.080	0.089	0.00	0.00	0.089	0.00
0.089	0.100	0.00	0.00	0.100	0.00
0.100	0.112	0.00	0.00	0.112	0.00
0.112	0.126	0.00	0.00	0.126	0.00
0.126	0.142	0.00	0.00	0.142	0.00
0.142	0.159	0.00	0.00	0.159	0.00
0.159	0.178	0.00	0.00	0.178	0.00
0.178	0.200	0.00	0.00	0.200	0.00
0.200	0.224	0.00	0.00	0.224	0.00
0.224	0.252	0.00	0.00	0.252	0.00
0.252	0.283	0.00	0.00	0.283	0.00
0.283	0.317	0.00	0.00	0.317	0.00
0.317	0.356	0.00	0.00	0.356	0.00
0.356	0.399	0.00	0.00	0.399	0.00
0.399	0.448	0.00	0.00	0.448	0.00
0.448	0.502	0.00	0.00	0.502	0.00
0.502	0.564	0.04	0.03	0.564	0.03
0.564	0.632	0.07	0.06	0.632	0.09
0.632	0.710	0.07	0.06	0.710	0.15
0.710	0.796	0.07	0.06	0.796	0.21
0.796	0.893	0.07	0.06	0.893	0.27
0.893	1.002	0.06	0.05	1.002	0.32
1.002	1.125	0.05	0.04	1.125	0.35
1.125	1.262	0.05	0.04	1.262	0.39
1.262	1.416	0.06	0.05	1.416	0.44
1.416	1.589	0.07	0.06	1.589	0.50
1.589	1.783	0.08	0.07	1.783	0.57
1.783	2.000	0.10	0.08	2.000	0.65
2.000	2.244	0.11	0.09	2.244	0.75
2.244	2.518	0.13	0.11	2.518	0.85
2.518	2.825	0.14	0.12	2.825	0.97
2.825	3.170	0.15	0.13	3.170	1.09
3.170	3.557	0.16	0.13	3.557	1.22
3.557	4.000	0.17	0.14	4.000	1.37
4.000	4.477	0.17	0.14	4.477	1.51
4.477	5.024	0.18	0.15	5.024	1.66
5.024	5.637	0.18	0.15	5.637	1.81
5.637	6.325	0.19	0.16	6.325	1.97
6.325	7.096	0.19	0.16	7.096	2.13
7.096	7.962	0.19	0.16	7.962	2.29
7.962	8.934	0.19	0.16	8.934	2.45
8.934	10.024	0.19	0.16	10.024	2.61
10.024	11.247	0.19	0.16	11.247	2.76
11.247	12.619	0.18	0.15	12.619	2.91
12.619	14.159	0.18	0.15	14.159	3.06
14.159	15.887	0.18	0.15	15.887	3.21
15.887	17.825	0.18	0.15	17.825	3.36
17.825	20.000	0.19	0.16	20.000	3.51
20.000	22.440	0.21	0.17	22.440	3.68
22.440	25.179	0.23	0.19	25.179	3.88
25.179	28.251	0.26	0.22	28.251	4.10
28.251	31.698	0.30	0.25	31.698	4.34
31.698	35.566	0.33	0.27	35.566	4.61
35.566	39.905	0.35	0.29	39.905	4.90
39.905	44.774	0.35	0.29	44.774	5.20
44.774	50.238	0.34	0.28	50.238	5.48
50.238	56.368	0.31	0.26	56.368	5.74
56.368	62.000	0.24	0.20	62.000	5.93
62.000	70.963	0.32	0.27	70.963	6.20
70.963	79.621	0.31	0.26	79.621	6.46
79.621	89.337	0.42	0.35	89.337	6.81
89.337	100.237	0.65	0.54	100.237	7.36
100.237	112.468	1.02	0.85	112.468	8.21
112.468	126.191	1.59	1.32	126.191	9.53
126.191	141.589	2.40	1.99	141.589	11.52
141.589	158.866	3.30	2.75	158.866	14.27
158.866	178.250	4.31	3.59	178.250	17.86
178.250	200.000	5.35	4.45	200.000	22.31
200.000	224.404	6.34	5.27	224.404	27.58
224.404	250.000	6.72	5.59	250.000	33.18
250.000	282.508	8.32	6.92	282.508	40.10
282.508	316.979	8.21	6.83	316.979	46.93
316.979	355.656	8.25	6.86	355.656	53.79
355.656	399.052	7.94	6.61	399.052	60.40
399.052	447.744	7.19	5.98	447.744	66.38
447.744	500.000	5.97	4.97	500.000	71.35
500.00	1000.00	14.95	14.95	1000.00	86.30
1000.00	2000.00	6.75	6.75	2000.00	93.05
2000.00	4000.00	5.90	5.90	4000.00	98.96
4000.00	8000.00	1.04	1.04	8000.00	100.00
8000.00	16000.00	0.00	0.00	16000.00	100.00
>16000		0.00	0.00		100.00
		28.65	71.35		
		85.74			
			100.00		

Size Fractions Graph



PARTICLE SIZE ANALYSIS REPORT
Size distribution analysis by laser diffraction (<500µm) and wet sieving (500-16000µm)

Customer: Jacobs
Contact: Garnett Hooper
Address: Level 11, 263 Adelaide Tce, Perth WA 6001
Date Received: 16/04/2015
Date of Issue: 29/04/2015

Marine and Freshwater Research Laboratory Environmental Science | Murdoch UNIVERSITY

Summary Report

Sample Name:	SP12
Sampling Date:	10/04/2015
Sample Type:	Sediment
MAFRL Job Code:	JAC15-7
Client Reference:	IW021200
Analysis Date	20-Apr-15
Intrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300
Wentworth Aggregate Classification	
Clay % (<4µm)	2.04
Fine Silt % (4-16µm)	2.76
Medium Silt % (16-31µm)	2.88
Course Silt % (31-62µm)	8.32
Fine sand % (62-250µm)	37.83
Medium sand % (250-500µm)	11.17
Coarse sand % (500-2000µm)	29.75
Pebbles/Cobbles/Boulders (>2000µm)	5.26
SOP Name	SOP-3REPS-skm.msop
Analysis Model	General Purpose
Result Units	Volume

Extended range by sieving

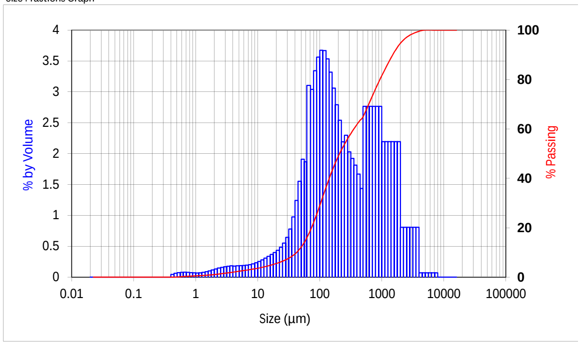
Extended size, µm	Extended percent retained at size
500	16.60
1000	13.16
2000	4.85
4000	0.42
8000	0.00
16000	0.00

Sample visual assessment
Sand with shell and mud present.

Size Fractions Table

Differential Data				Cumulative Data	
Lower Size (µm)	Upper Size (µm)	% in Interval	% in Interval after scaling	Size (µm)	% Passing
0.020	0.022	0.00	0.00	0.022	0.00
0.022	0.025	0.00	0.00	0.025	0.00
0.025	0.028	0.00	0.00	0.028	0.00
0.028	0.032	0.00	0.00	0.032	0.00
0.032	0.036	0.00	0.00	0.036	0.00
0.036	0.040	0.00	0.00	0.040	0.00
0.040	0.045	0.00	0.00	0.045	0.00
0.045	0.050	0.00	0.00	0.050	0.00
0.050	0.056	0.00	0.00	0.056	0.00
0.056	0.063	0.00	0.00	0.063	0.00
0.063	0.071	0.00	0.00	0.071	0.00
0.071	0.080	0.00	0.00	0.080	0.00
0.080	0.089	0.00	0.00	0.089	0.00
0.089	0.100	0.00	0.00	0.100	0.00
0.100	0.112	0.00	0.00	0.112	0.00
0.112	0.126	0.00	0.00	0.126	0.00
0.126	0.142	0.00	0.00	0.142	0.00
0.142	0.159	0.00	0.00	0.159	0.00
0.159	0.178	0.00	0.00	0.178	0.00
0.178	0.200	0.00	0.00	0.200	0.00
0.200	0.224	0.00	0.00	0.224	0.00
0.224	0.252	0.00	0.00	0.252	0.00
0.252	0.283	0.00	0.00	0.283	0.00
0.283	0.317	0.00	0.00	0.317	0.00
0.317	0.356	0.00	0.00	0.356	0.00
0.356	0.399	0.00	0.00	0.399	0.00
0.399	0.448	0.06	0.04	0.448	0.04
0.448	0.502	0.09	0.06	0.502	0.11
0.502	0.564	0.11	0.07	0.564	0.18
0.564	0.632	0.11	0.08	0.632	0.26
0.632	0.710	0.11	0.08	0.710	0.34
0.710	0.796	0.11	0.08	0.796	0.41
0.796	0.893	0.10	0.07	0.893	0.49
0.893	1.002	0.10	0.07	1.002	0.55
1.002	1.125	0.10	0.07	1.125	0.62
1.125	1.262	0.10	0.07	1.262	0.69
1.262	1.416	0.11	0.08	1.416	0.77
1.416	1.589	0.13	0.09	1.589	0.86
1.589	1.783	0.15	0.10	1.783	0.96
1.783	2.000	0.17	0.12	2.000	1.08
2.000	2.244	0.19	0.13	2.244	1.21
2.244	2.518	0.21	0.15	2.518	1.35
2.518	2.825	0.23	0.16	2.825	1.51
2.825	3.170	0.24	0.17	3.170	1.68
3.170	3.557	0.25	0.18	3.557	1.86
3.557	4.000	0.27	0.18	4.000	2.04
4.000	4.477	0.26	0.18	4.477	2.22
4.477	5.024	0.27	0.18	5.024	2.40
5.024	5.637	0.27	0.19	5.637	2.59
5.637	6.325	0.27	0.19	6.325	2.78
6.325	7.096	0.28	0.19	7.096	2.97
7.096	7.962	0.29	0.20	7.962	3.17
7.962	8.934	0.31	0.22	8.934	3.39
8.934	10.024	0.34	0.23	10.024	3.62
10.024	11.247	0.37	0.25	11.247	3.87
11.247	12.619	0.41	0.28	12.619	4.15
12.619	14.159	0.45	0.31	14.159	4.46
14.159	15.887	0.49	0.34	15.887	4.80
15.887	17.825	0.53	0.37	17.825	5.16
17.825	20.000	0.58	0.40	20.000	5.56
20.000	22.440	0.63	0.44	22.440	6.00
22.440	25.179	0.70	0.48	25.179	6.48
25.179	28.251	0.80	0.55	28.251	7.03
28.251	31.698	0.93	0.64	31.698	7.67
31.698	35.566	1.13	0.78	35.566	8.45
35.566	39.905	1.41	0.97	39.905	9.42
39.905	44.774	1.80	1.24	44.774	10.66
44.774	50.238	2.25	1.55	50.238	12.22
50.238	56.368	2.76	1.91	56.368	14.12
56.368	62.000	2.71	1.87	62.000	15.99
62.000	70.963	4.50	3.10	70.963	19.10
70.963	79.621	4.41	3.04	79.621	22.14
79.621	89.337	4.84	3.34	89.337	25.48
89.337	100.237	5.16	3.56	100.237	29.04
100.237	112.468	5.32	3.67	112.468	32.72
112.468	126.191	5.32	3.67	126.191	36.38
126.191	141.589	5.12	3.53	141.589	39.92
141.589	158.866	4.81	3.32	158.866	43.24
158.866	178.250	4.43	3.06	178.250	46.30
178.250	200.000	4.04	2.79	200.000	49.09
200.000	224.404	3.68	2.54	224.404	51.63
224.404	250.000	3.18	2.19	250.000	53.82
250.000	282.508	3.33	2.30	282.508	56.12
282.508	316.979	2.94	2.03	316.979	58.14
316.979	355.656	2.78	1.92	355.656	60.07
355.656	399.052	2.63	1.81	399.052	61.88
399.052	447.744	2.42	1.67	447.744	63.55
447.744	500.000	2.08	1.44	500.000	64.99
500.00	1000.00	16.60	16.60	1000.00	81.58
1000.00	2000.00	13.16	13.16	2000.00	94.74
2000.00	4000.00	4.85	4.85	4000.00	99.58
4000.00	8000.00	0.42	0.42	8000.00	100.00
8000.00	16000.00	0.00	0.00	16000.00	100.00
>16000		0.00	0.00		100.00
		35.01	64.99		
		94.17			
			100.00		

Size Fractions Graph



PARTICLE SIZE ANALYSIS REPORT
Size distribution analysis by laser diffraction (<500µm) and wet sieving (500-16000µm)

Customer: Jacobs
Contact: Garnett Hooper
Address: Level 11, 263 Adelaide Tce, Perth WA 6001
Date Received: 16/04/2015
Date of Issue: 29/04/2015

Marine and Freshwater Research Laboratory Environmental Science
Murdoch UNIVERSITY

Summary Report

Sample Name:	SP13
Sampling Date:	14/04/2015
Sample Type:	Sediment
MAFRL Job Code:	JAC15-7
Client Reference:	IW021200
Analysis Date	22-Apr-15
Intrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300
Wentworth Aggregate Classification	
Clay % (<4µm)	1.48
Fine Silt % (4-16µm)	1.56
Medium Silt % (16-31µm)	1.86
Course Silt % (31-62µm)	6.05
Fine sand % (62-250µm)	32.36
Medium sand % (250-500µm)	19.45
Coarse sand % (500-2000µm)	31.42
Pebbles/Cobbles/Boulders (>2000µm)	5.82
SOP Name	SOP-LV-3REPS-skm.msop
Analysis Model	General Purpose
Result Units	Volume

Extended range by sieving

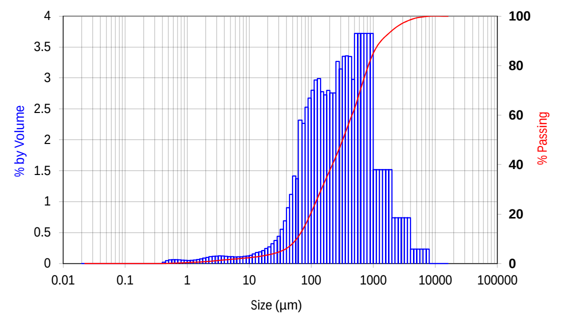
Extended size, µm	Extended percent retained at size
500	22.32
1000	9.10
2000	4.43
4000	1.39
8000	0.00
16000	0.00

Sample visual assessment
Sand with coral, shell and mud present.

Size Fractions Table

Differential Data				Cumulative Data	
Lower Size (µm)	Upper Size (µm)	% in Interval	% in Interval after scaling	Size (µm)	% Passing
0.020	0.022	0.00	0.00	0.022	0.00
0.022	0.025	0.00	0.00	0.025	0.00
0.025	0.028	0.00	0.00	0.028	0.00
0.028	0.032	0.00	0.00	0.032	0.00
0.032	0.036	0.00	0.00	0.036	0.00
0.036	0.040	0.00	0.00	0.040	0.00
0.040	0.045	0.00	0.00	0.045	0.00
0.045	0.050	0.00	0.00	0.050	0.00
0.050	0.056	0.00	0.00	0.056	0.00
0.056	0.063	0.00	0.00	0.063	0.00
0.063	0.071	0.00	0.00	0.071	0.00
0.071	0.080	0.00	0.00	0.080	0.00
0.080	0.089	0.00	0.00	0.089	0.00
0.089	0.100	0.00	0.00	0.100	0.00
0.100	0.112	0.00	0.00	0.112	0.00
0.112	0.126	0.00	0.00	0.126	0.00
0.126	0.142	0.00	0.00	0.142	0.00
0.142	0.159	0.00	0.00	0.159	0.00
0.159	0.178	0.00	0.00	0.178	0.00
0.178	0.200	0.00	0.00	0.200	0.00
0.200	0.224	0.00	0.00	0.224	0.00
0.224	0.252	0.00	0.00	0.252	0.00
0.252	0.283	0.00	0.00	0.283	0.00
0.283	0.317	0.00	0.00	0.317	0.00
0.317	0.356	0.00	0.00	0.356	0.00
0.356	0.399	0.00	0.00	0.399	0.00
0.399	0.448	0.03	0.02	0.448	0.02
0.448	0.502	0.06	0.05	0.502	0.07
0.502	0.564	0.08	0.06	0.564	0.12
0.564	0.632	0.08	0.06	0.632	0.19
0.632	0.710	0.09	0.06	0.710	0.25
0.710	0.796	0.08	0.06	0.796	0.31
0.796	0.893	0.08	0.06	0.893	0.36
0.893	1.000	0.07	0.05	1.000	0.41
1.000	1.120	0.07	0.05	1.120	0.46
1.120	1.260	0.07	0.05	1.260	0.51
1.260	1.420	0.08	0.06	1.420	0.57
1.420	1.590	0.09	0.06	1.590	0.63
1.590	1.780	0.10	0.07	1.780	0.71
1.780	2.000	0.12	0.09	2.000	0.80
2.000	2.240	0.13	0.10	2.240	0.89
2.240	2.520	0.15	0.11	2.520	1.00
2.520	2.830	0.16	0.12	2.830	1.12
2.830	3.170	0.16	0.12	3.170	1.24
3.170	3.560	0.17	0.12	3.560	1.36
3.560	4.000	0.17	0.12	4.000	1.48
4.000	4.480	0.16	0.12	4.480	1.60
4.480	5.020	0.15	0.11	5.020	1.71
5.020	5.640	0.15	0.11	5.640	1.82
5.640	6.320	0.15	0.11	6.320	1.93
6.320	7.100	0.15	0.11	7.100	2.04
7.100	7.960	0.15	0.11	7.960	2.15
7.960	8.930	0.16	0.12	8.930	2.26
8.930	10.000	0.17	0.12	10.000	2.39
10.000	11.200	0.18	0.13	11.200	2.52
11.200	12.600	0.21	0.16	12.600	2.67
12.600	14.200	0.24	0.18	14.200	2.85
14.200	15.900	0.26	0.19	15.900	3.04
15.900	17.800	0.29	0.21	17.800	3.25
17.800	20.000	0.34	0.24	20.000	3.49
20.000	22.400	0.37	0.27	22.400	3.76
22.400	25.200	0.44	0.32	25.200	4.09
25.200	28.300	0.51	0.37	28.300	4.46
28.300	31.700	0.60	0.44	31.700	4.90
31.700	35.600	0.76	0.55	35.600	5.45
35.600	39.900	0.95	0.69	39.900	6.14
39.900	44.800	1.24	0.90	44.800	7.04
44.800	50.200	1.54	1.12	50.200	8.16
50.200	56.400	1.95	1.41	56.400	9.57
56.400	62.000	1.89	1.37	62.000	10.94
62.000	71.000	3.19	2.32	71.000	13.26
71.000	79.600	3.12	2.26	79.600	15.53
79.600	89.300	3.48	2.53	89.300	18.05
89.300	100.000	3.68	2.67	100.000	20.73
100.000	112.000	3.86	2.80	112.000	23.53
112.000	126.000	4.09	2.97	126.000	26.50
126.000	142.000	4.12	2.99	142.000	29.49
142.000	159.000	3.83	2.78	159.000	32.27
159.000	178.000	3.76	2.73	178.000	34.99
178.000	200.000	3.86	2.80	200.000	37.79
200.000	224.000	3.80	2.76	224.000	40.55
224.000	250.000	3.80	2.76	250.000	43.31
250.000	283.000	4.50	3.27	283.000	46.58
283.000	317.000	4.33	3.15	317.000	49.72
317.000	356.000	4.62	3.35	356.000	53.07
356.000	399.000	4.63	3.36	399.000	56.43
399.000	448.000	4.61	3.35	448.000	59.78
448.000	500.000	4.10	2.98	500.000	62.76
500.00	1000.00	22.32	22.32	1000.00	85.07
1000.00	2000.00	9.10	9.10	2000.00	94.18
2000.00	4000.00	4.43	4.43	4000.00	98.61
4000.00	8000.00	1.39	1.39	8000.00	100.00
8000.00	16000.00	0.00	0.00	16000.00	100.00
>16000		0.00	0.00		100.00
		37.24	62.76		
		86.44			
			100.00		

Size Fractions Graph



PARTICLE SIZE ANALYSIS REPORT
Size distribution analysis by laser diffraction (<500µm) and wet sieving (500-16000µm)

Customer: Jacobs
Contact: Garnett Hooper
Address: Level 11, 263 Adelaide Tce, Perth WA 6001
Date Received: 16/04/2015
Date of Issue: 29/04/2015

Summary Report

Sample Name:	SP14
Sampling Date:	14/04/2015
Sample Type:	Sediment
MAFRL Job Code:	JAC15-7
Client Reference:	IW021200
Analysis Date	22-Apr-15
Intrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300
Wentworth Aggregate Classification	
Clay % (<4µm)	1.73
Fine Silt % (4-16µm)	1.83
Medium Silt % (16-31µm)	2.30
Course Silt % (31-62µm)	6.51
Fine sand % (62-250µm)	49.64
Medium sand % (250-500µm)	21.32
Coarse sand % (500-2000µm)	14.26
Pebbles/Cobbles/Boulders (>2000µm)	2.41
SOP Name	SOP-LV-3REPS-skm.msop
Analysis Model	General Purpose
Result Units	Volume

Extended range by sieving

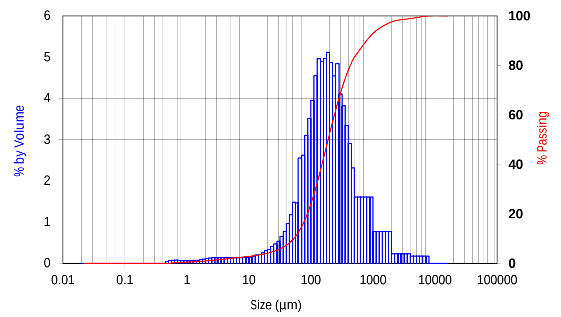
Extended size, µm	Extended percent retained at size
500	9.63
1000	4.63
2000	1.37
4000	1.04
8000	0.00
16000	0.00

Sample visual assessment
Sand with shell and mud present.

Size Fractions Table

Differential Data				Cumulative Data	
Lower Size (µm)	Upper Size (µm)	% in Interval	% in Interval after scaling	Size (µm)	% Passing
0.020	0.022	0.00	0.00	0.022	0.00
0.022	0.025	0.00	0.00	0.025	0.00
0.025	0.028	0.00	0.00	0.028	0.00
0.028	0.032	0.00	0.00	0.032	0.00
0.032	0.036	0.00	0.00	0.036	0.00
0.036	0.040	0.00	0.00	0.040	0.00
0.040	0.045	0.00	0.00	0.045	0.00
0.045	0.050	0.00	0.00	0.050	0.00
0.050	0.056	0.00	0.00	0.056	0.00
0.056	0.063	0.00	0.00	0.063	0.00
0.063	0.071	0.00	0.00	0.071	0.00
0.071	0.080	0.00	0.00	0.080	0.00
0.080	0.089	0.00	0.00	0.089	0.00
0.089	0.100	0.00	0.00	0.100	0.00
0.100	0.112	0.00	0.00	0.112	0.00
0.112	0.126	0.00	0.00	0.126	0.00
0.126	0.142	0.00	0.00	0.142	0.00
0.142	0.159	0.00	0.00	0.159	0.00
0.159	0.178	0.00	0.00	0.178	0.00
0.178	0.200	0.00	0.00	0.200	0.00
0.200	0.224	0.00	0.00	0.224	0.00
0.224	0.252	0.00	0.00	0.252	0.00
0.252	0.283	0.00	0.00	0.283	0.00
0.283	0.317	0.00	0.00	0.317	0.00
0.317	0.356	0.00	0.00	0.356	0.00
0.356	0.399	0.00	0.00	0.399	0.00
0.399	0.448	0.00	0.00	0.448	0.00
0.448	0.502	0.05	0.05	0.502	0.05
0.502	0.564	0.08	0.07	0.564	0.12
0.564	0.632	0.08	0.07	0.632	0.19
0.632	0.710	0.09	0.08	0.710	0.27
0.710	0.796	0.08	0.07	0.796	0.34
0.796	0.893	0.08	0.07	0.893	0.41
0.893	1.000	0.07	0.06	1.000	0.47
1.000	1.120	0.07	0.06	1.120	0.53
1.120	1.260	0.07	0.06	1.260	0.59
1.260	1.420	0.08	0.07	1.420	0.66
1.420	1.590	0.08	0.07	1.590	0.74
1.590	1.780	0.10	0.09	1.780	0.82
1.780	2.000	0.11	0.10	2.000	0.92
2.000	2.240	0.13	0.11	2.240	1.03
2.240	2.520	0.14	0.13	2.520	1.16
2.520	2.830	0.15	0.14	2.830	1.30
2.830	3.170	0.16	0.14	3.170	1.44
3.170	3.560	0.16	0.14	3.560	1.58
3.560	4.000	0.16	0.14	4.000	1.73
4.000	4.480	0.16	0.14	4.480	1.86
4.480	5.020	0.15	0.14	5.020	2.00
5.020	5.640	0.15	0.14	5.640	2.14
5.640	6.320	0.15	0.13	6.320	2.27
6.320	7.100	0.15	0.13	7.100	2.40
7.100	7.960	0.15	0.13	7.960	2.53
7.960	8.930	0.15	0.14	8.930	2.67
8.930	10.000	0.16	0.14	10.000	2.81
10.000	11.200	0.17	0.15	11.200	2.96
11.200	12.600	0.20	0.17	12.600	3.13
12.600	14.200	0.23	0.20	14.200	3.33
14.200	15.900	0.25	0.22	15.900	3.55
15.900	17.800	0.28	0.25	17.800	3.80
17.800	20.000	0.34	0.30	20.000	4.10
20.000	22.400	0.38	0.34	22.400	4.44
22.400	25.200	0.46	0.41	25.200	4.85
25.200	28.300	0.53	0.47	28.300	5.32
28.300	31.700	0.60	0.54	31.700	5.86
31.700	35.600	0.73	0.65	35.600	6.50
35.600	39.900	0.86	0.77	39.900	7.27
39.900	44.800	1.09	0.97	44.800	8.24
44.800	50.200	1.32	1.17	50.200	9.42
50.200	56.400	1.66	1.48	56.400	10.90
56.400	62.000	1.64	1.46	62.000	12.36
62.000	71.000	2.86	2.55	71.000	14.91
71.000	79.600	2.94	2.62	79.600	17.54
79.600	89.300	3.48	3.10	89.300	20.64
89.300	100.000	3.94	3.51	100.000	24.15
100.000	112.000	4.44	3.95	112.000	28.10
112.000	126.000	5.10	4.55	126.000	32.65
126.000	142.000	5.56	4.96	142.000	37.61
142.000	159.000	5.49	4.89	159.000	42.50
159.000	178.000	5.57	4.97	178.000	47.47
178.000	200.000	5.74	5.12	200.000	52.59
200.000	224.000	5.46	4.87	224.000	57.46
224.000	250.000	5.10	4.55	250.000	62.01
250.000	283.000	5.43	4.84	283.000	66.84
283.000	317.000	4.60	4.10	317.000	70.95
317.000	356.000	4.28	3.82	356.000	74.77
356.000	399.000	3.75	3.34	399.000	78.11
399.000	448.000	3.26	2.90	448.000	81.01
448.000	500.000	2.59	2.31	500.000	83.33
500.00	1000.00	9.63	9.63	1000.00	92.96
1000.00	2000.00	4.63	4.63	2000.00	97.59
2000.00	4000.00	1.37	1.37	4000.00	98.96
4000.00	8000.00	1.04	1.04	8000.00	100.00
8000.00	16000.00	0.00	0.00	16000.00	100.00
>16000		0.00	0.00		100.00
		16.67	83.33		
		93.48			
			100.00		

Size Fractions Graph



PARTICLE SIZE ANALYSIS REPORT
Size distribution analysis by laser diffraction (<500µm) and wet sieving (500-16000µm)

Customer: Jacobs
Contact: Garnett Hooper
Address: Level 11, 263 Adelaide Tce, Perth WA 6001
Date Received: 16/04/2015
Date of Issue: 29/04/2015

Marine and Freshwater Research Laboratory Environmental Science

Murdoch UNIVERSITY

Summary Report

Sample Name:	SP15
Sampling Date:	12/04/2015
Sample Type:	Sediment
MAFRL Job Code:	JAC15-7
Client Reference:	IW021200
Analysis Date	22-Apr-15
Intrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300
Wentworth Aggregate Classification	
Clay % (<4µm)	1.59
Fine Silt % (4-16µm)	1.63
Medium Silt % (16-31µm)	0.97
Course Silt % (31-62µm)	1.74
Fine sand % (62-250µm)	28.95
Medium sand % (250-500µm)	29.18
Coarse sand % (500-2000µm)	21.25
Pebbles/Cobbles/Boulders (>2000µm)	14.69
SOP Name	SOP-LV-3REPS-skm.msop
Analysis Model	General Purpose
Result Units	Volume

Extended range by sieving

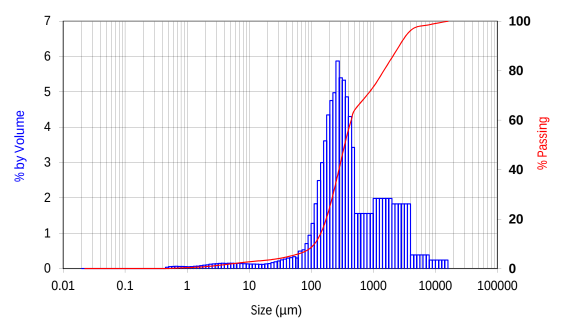
Extended size, µm	Extended percent retained at size
500	9.34
1000	11.91
2000	10.96
4000	2.29
8000	1.44
16000	0.00

Sample visual assessment
Sand with coral, shell and mud present.

Size Fractions Table

Differential Data				Cumulative Data	
Lower Size (µm)	Upper Size (µm)	% in Interval	% in Interval after scaling	Size (µm)	% Passing
0.020	0.022	0.00	0.00	0.022	0.00
0.022	0.025	0.00	0.00	0.025	0.00
0.025	0.028	0.00	0.00	0.028	0.00
0.028	0.032	0.00	0.00	0.032	0.00
0.032	0.036	0.00	0.00	0.036	0.00
0.036	0.040	0.00	0.00	0.040	0.00
0.040	0.045	0.00	0.00	0.045	0.00
0.045	0.050	0.00	0.00	0.050	0.00
0.050	0.056	0.00	0.00	0.056	0.00
0.056	0.063	0.00	0.00	0.063	0.00
0.063	0.071	0.00	0.00	0.071	0.00
0.071	0.080	0.00	0.00	0.080	0.00
0.080	0.089	0.00	0.00	0.089	0.00
0.089	0.100	0.00	0.00	0.100	0.00
0.100	0.112	0.00	0.00	0.112	0.00
0.112	0.126	0.00	0.00	0.126	0.00
0.126	0.142	0.00	0.00	0.142	0.00
0.142	0.159	0.00	0.00	0.159	0.00
0.159	0.178	0.00	0.00	0.178	0.00
0.178	0.200	0.00	0.00	0.200	0.00
0.200	0.224	0.00	0.00	0.224	0.00
0.224	0.252	0.00	0.00	0.252	0.00
0.252	0.283	0.00	0.00	0.283	0.00
0.283	0.317	0.00	0.00	0.317	0.00
0.317	0.356	0.00	0.00	0.356	0.00
0.356	0.399	0.00	0.00	0.399	0.00
0.399	0.448	0.00	0.00	0.448	0.00
0.448	0.502	0.05	0.04	0.502	0.04
0.502	0.564	0.08	0.06	0.564	0.09
0.564	0.632	0.08	0.06	0.632	0.15
0.632	0.710	0.09	0.06	0.710	0.22
0.710	0.796	0.08	0.06	0.796	0.28
0.796	0.893	0.08	0.06	0.893	0.34
0.893	1.000	0.07	0.05	1.000	0.39
1.000	1.120	0.07	0.05	1.120	0.44
1.120	1.260	0.08	0.05	1.260	0.49
1.260	1.420	0.09	0.06	1.420	0.56
1.420	1.590	0.09	0.07	1.590	0.62
1.590	1.780	0.11	0.08	1.780	0.70
1.780	2.000	0.13	0.10	2.000	0.80
2.000	2.240	0.15	0.11	2.240	0.90
2.240	2.520	0.17	0.12	2.520	1.03
2.520	2.830	0.18	0.13	2.830	1.16
2.830	3.170	0.19	0.14	3.170	1.30
3.170	3.560	0.20	0.15	3.560	1.44
3.560	4.000	0.21	0.15	4.000	1.59
4.000	4.480	0.20	0.15	4.480	1.74
4.480	5.020	0.20	0.15	5.020	1.88
5.020	5.640	0.21	0.15	5.640	2.03
5.640	6.320	0.20	0.14	6.320	2.18
6.320	7.100	0.20	0.15	7.100	2.32
7.100	7.960	0.19	0.14	7.960	2.46
7.960	8.930	0.19	0.14	8.930	2.60
8.930	10.000	0.18	0.13	10.000	2.73
10.000	11.200	0.17	0.13	11.200	2.86
11.200	12.600	0.17	0.12	12.600	2.98
12.600	14.200	0.17	0.12	14.200	3.10
14.200	15.900	0.16	0.12	15.900	3.22
15.900	17.800	0.16	0.12	17.800	3.34
17.800	20.000	0.18	0.13	20.000	3.47
20.000	22.400	0.20	0.14	22.400	3.61
22.400	25.200	0.23	0.17	25.200	3.78
25.200	28.300	0.26	0.19	28.300	3.97
28.300	31.700	0.30	0.21	31.700	4.18
31.700	35.600	0.34	0.25	35.600	4.43
35.600	39.900	0.37	0.27	39.900	4.70
39.900	44.800	0.41	0.29	44.800	4.99
44.800	50.200	0.42	0.31	50.200	5.30
50.200	56.400	0.46	0.33	56.400	5.63
56.400	62.000	0.41	0.30	62.000	5.93
62.000	71.000	0.68	0.49	71.000	6.42
71.000	79.600	0.73	0.53	79.600	6.95
79.600	89.300	0.98	0.71	89.300	7.66
89.300	100.000	1.30	0.94	100.000	8.60
100.000	112.000	1.77	1.28	112.000	9.88
112.000	126.000	2.54	1.83	126.000	11.71
126.000	142.000	3.45	2.49	142.000	14.20
142.000	159.000	4.15	3.00	159.000	17.19
159.000	178.000	5.00	3.61	178.000	20.81
178.000	200.000	6.02	4.35	200.000	25.16
200.000	224.000	6.58	4.75	224.000	29.91
224.000	250.000	6.89	4.97	250.000	34.88
250.000	283.000	8.13	5.87	283.000	40.75
283.000	317.000	7.47	5.40	317.000	46.15
317.000	356.000	7.38	5.33	356.000	51.48
356.000	399.000	6.72	4.86	399.000	56.33
399.000	448.000	5.96	4.30	448.000	60.63
448.000	500.000	4.75	3.43	500.000	64.06
500.00	1000.00	9.34	9.34	1000.00	73.40
1000.00	2000.00	11.91	11.91	2000.00	85.31
2000.00	4000.00	10.96	10.96	4000.00	96.27
4000.00	8000.00	2.29	2.29	8000.00	98.56
8000.00	16000.00	1.44	1.44	16000.00	100.00
>16000		0.00	0.00		100.00
		35.94	64.06		
		88.72			
			100.00		

Size Fractions Graph



PARTICLE SIZE ANALYSIS REPORT
Size distribution analysis by laser diffraction (<500µm) and wet sieving (500-16000µm)

Customer: Jacobs
Contact: Garnett Hooper
Address: Level 11, 263 Adelaide Tce, Perth WA 6001
Date Received: 16/04/2015
Date of Issue: 29/04/2015

Marine and Freshwater Research Laboratory Environmental Science | Murdoch UNIVERSITY

Summary Report

Sample Name:	SP17
Sampling Date:	8/04/2015
Sample Type:	Sediment
MAFRL Job Code:	JAC15-7
Client Reference:	IW021200
Analysis Date	22-Apr-15
Intrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300
Wentworth Aggregate Classification	
Clay % (<4µm)	2.25
Fine Silt % (4-16µm)	2.41
Medium Silt % (16-31µm)	2.22
Course Silt % (31-62µm)	6.88
Fine sand % (62-250µm)	47.33
Medium sand % (250-500µm)	20.26
Coarse sand % (500-2000µm)	16.07
Pebbles/Cobbles/Boulders (>2000µm)	2.58
SOP Name	SOP-LV-3REPS-skm.msop
Analysis Model	General Purpose
Result Units	Volume

Extended range by sieving

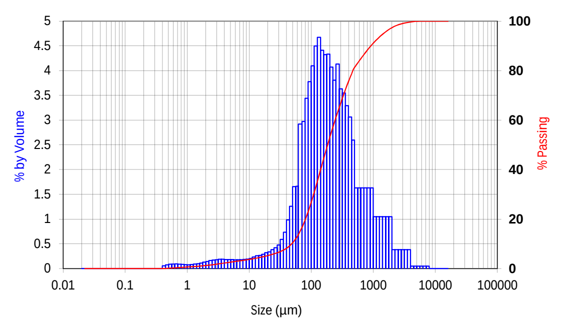
Extended size, µm	Extended percent retained at size
500	9.79
1000	6.28
2000	2.29
4000	0.29
8000	0.00
16000	0.00

Sample visual assessment
Sand with shell and mud present.

Size Fractions Table

Differential Data				Cumulative Data	
Lower Size (µm)	Upper Size (µm)	% in Interval	% in Interval after scaling	Size (µm)	% Passing
0.020	0.022	0.00	0.00	0.022	0.00
0.022	0.025	0.00	0.00	0.025	0.00
0.025	0.028	0.00	0.00	0.028	0.00
0.028	0.032	0.00	0.00	0.032	0.00
0.032	0.036	0.00	0.00	0.036	0.00
0.036	0.040	0.00	0.00	0.040	0.00
0.040	0.045	0.00	0.00	0.045	0.00
0.045	0.050	0.00	0.00	0.050	0.00
0.050	0.056	0.00	0.00	0.056	0.00
0.056	0.063	0.00	0.00	0.063	0.00
0.063	0.071	0.00	0.00	0.071	0.00
0.071	0.080	0.00	0.00	0.080	0.00
0.080	0.089	0.00	0.00	0.089	0.00
0.089	0.100	0.00	0.00	0.100	0.00
0.100	0.112	0.00	0.00	0.112	0.00
0.112	0.126	0.00	0.00	0.126	0.00
0.126	0.142	0.00	0.00	0.142	0.00
0.142	0.159	0.00	0.00	0.159	0.00
0.159	0.178	0.00	0.00	0.178	0.00
0.178	0.200	0.00	0.00	0.200	0.00
0.200	0.224	0.00	0.00	0.224	0.00
0.224	0.252	0.00	0.00	0.252	0.00
0.252	0.283	0.00	0.00	0.283	0.00
0.283	0.317	0.00	0.00	0.317	0.00
0.317	0.356	0.00	0.00	0.356	0.00
0.356	0.399	0.00	0.00	0.399	0.00
0.399	0.448	0.06	0.05	0.448	0.05
0.448	0.502	0.08	0.07	0.502	0.13
0.502	0.564	0.10	0.09	0.564	0.22
0.564	0.632	0.10	0.09	0.632	0.31
0.632	0.710	0.10	0.09	0.710	0.40
0.710	0.796	0.10	0.09	0.796	0.49
0.796	0.893	0.09	0.08	0.893	0.57
0.893	1.000	0.09	0.08	1.000	0.65
1.000	1.120	0.08	0.07	1.120	0.72
1.120	1.260	0.09	0.08	1.260	0.80
1.260	1.420	0.10	0.09	1.420	0.89
1.420	1.590	0.11	0.10	1.590	0.99
1.590	1.780	0.12	0.11	1.780	1.10
1.780	2.000	0.15	0.13	2.000	1.23
2.000	2.240	0.16	0.14	2.240	1.37
2.240	2.520	0.18	0.16	2.520	1.53
2.520	2.830	0.19	0.17	2.830	1.70
2.830	3.170	0.20	0.18	3.170	1.88
3.170	3.560	0.21	0.19	3.560	2.07
3.560	4.000	0.21	0.19	4.000	2.25
4.000	4.480	0.20	0.18	4.480	2.44
4.480	5.020	0.20	0.18	5.020	2.62
5.020	5.640	0.20	0.18	5.640	2.80
5.640	6.320	0.20	0.18	6.320	2.98
6.320	7.100	0.20	0.18	7.100	3.15
7.100	7.960	0.20	0.18	7.960	3.33
7.960	8.930	0.21	0.18	8.930	3.52
8.930	10.000	0.21	0.19	10.000	3.71
10.000	11.200	0.23	0.20	11.200	3.91
11.200	12.600	0.26	0.23	12.600	4.14
12.600	14.200	0.29	0.26	14.200	4.40
14.200	15.900	0.30	0.27	15.900	4.66
15.900	17.800	0.32	0.29	17.800	4.95
17.800	20.000	0.36	0.32	20.000	5.27
20.000	22.400	0.38	0.34	22.400	5.61
22.400	25.200	0.43	0.38	25.200	5.99
25.200	28.300	0.47	0.42	28.300	6.41
28.300	31.700	0.53	0.48	31.700	6.88
31.700	35.600	0.66	0.59	35.600	7.47
35.600	39.900	0.82	0.73	39.900	8.21
39.900	44.800	1.10	0.98	44.800	9.19
44.800	50.200	1.41	1.26	50.200	10.45
50.200	56.400	1.86	1.65	56.400	12.10
56.400	62.000	1.87	1.66	62.000	13.76
62.000	71.000	3.28	2.92	71.000	16.69
71.000	79.600	3.34	2.97	79.600	19.66
79.600	89.300	3.86	3.44	89.300	23.10
89.300	100.000	4.24	3.78	100.000	26.88
100.000	112.000	4.60	4.10	112.000	30.97
112.000	126.000	5.05	4.50	126.000	35.47
126.000	142.000	5.24	4.67	142.000	40.15
142.000	159.000	4.95	4.41	159.000	44.56
159.000	178.000	4.85	4.32	178.000	48.88
178.000	200.000	4.86	4.33	200.000	53.21
200.000	224.000	4.57	4.07	224.000	57.28
224.000	250.000	4.27	3.81	250.000	61.09
250.000	283.000	4.64	4.13	283.000	65.22
283.000	317.000	4.07	3.63	317.000	68.85
317.000	356.000	3.98	3.55	356.000	72.40
356.000	399.000	3.69	3.29	399.000	75.69
399.000	448.000	3.44	3.06	448.000	78.76
448.000	500.000	2.91	2.60	500.000	81.35
500.00	1000.00	9.79	9.79	1000.00	91.14
1000.00	2000.00	6.28	6.28	2000.00	97.42
2000.00	4000.00	2.29	2.29	4000.00	99.71
4000.00	8000.00	0.29	0.29	8000.00	100.00
8000.00	16000.00	0.00	0.00	16000.00	100.00
>16000		0.00	0.00		100.00
		18.65	81.35		
		91.29			
			100.00		

Size Fractions Graph



Marine and Freshwater Research Laboratory
Environmental Science
Tel: +61 8 93602907 Address: 90 South St, Murdoch, WA, 6150

WORLD RECOGNISED ACCREDITATION
Accreditation Number: 10603
Accredited for compliance with ISO/IEC 17025.
The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

Murdoch UNIVERSITY

SEDIMENT DATA

Contact: Garnet Hooper
Customer: Jacobs
Address: Level 11, Durack Centre, 263 Adelaide Terrace, Perth WA 6001

Date of Issue: 13/05/2015
Date Received: 16/04/2015
Our Reference: JAC15-8
Your Reference: IW021200

METHOD SAMPLE CODE Reporting Limit	Sampling Date	2600 TKN mg.N/g <0.1	4500 TOTAL P mg.P/g <0.05	6200 TOC % C <0.2	ICP002 Total Ext Al mg/kg <20	ICP002 Total Ext As mg/kg <2	ICP002 Total Ext Ba mg/kg <0.1	ICP002 Total Ext Cd mg/kg <0.1	ICP002 Total Ext Co mg/kg <0.2
File		15042901	15042901	15050101-1101	15050101	15050101	15050101	15050101	15050101
SP1 1-1	11/04/2015	1.9	0.74	1.4	15000	3	21	0.3	6.7
SP1 2-1	11/04/2015	2.0	0.78	1.4	16000	3	21	0.2	7.2
SP2 1-1	11/04/2015	2.1	0.78	1.5	16000	2	33	0.2	7.5
SP2 2-1	11/04/2015	2.1	0.78	1.5	16000	2	29	0.3	7.1
SP3 1-1	11/04/2015	1.6	0.81	1.2	14000	2	23	0.3	6.5
SP3 2-1	11/04/2015	1.5	0.80	1.1	13000	2	25	0.2	6.2
SP4 1-1	09/04/2015	0.5	2.8	0.4	9300	3	9.1	0.2	5.6
SP5 1-1	09/04/2015	0.6	0.98	0.5	8400	2	11	0.2	4.7
SP5 2-1	09/04/2015	0.7	0.89	0.5	8200	3	12	0.2	4.9
SP6E 1-1	09/04/2015	0.8	1.6	0.6	8300	3	14	0.2	4.9
SP6E 2-1	09/04/2015	0.9	1.6	0.6	9400	3	15	0.1	5.2
SP8 1-1	10/04/2015	0.2	0.31	0.3	560	2	5.6	0.2	0.7
SP8 2-1	10/04/2015	0.3	0.31	0.2	550	3	5.9	0.2	0.7
SP9 1-1	10/04/2015	0.3	0.79	0.2	2000	5	7.0	0.2	1.9
SP10N 1-1	10/04/2015	0.3	0.79	0.2	2900	4	7.8	0.2	1.8
SP10N 2-1	10/04/2015	0.3	0.90	0.3	3100	3	7.7	0.3	1.7
SP12 1-1	10/04/2015	0.4	1.2	0.3	4200	3	21	0.3	2.1
SP12 2-1	10/04/2015	0.5	1.1	0.4	4400	4	28	0.2	2.1
SP13 1-1	14/04/2015	0.2	1.4	0.2	3300	3	9.8	0.2	1.8
SP13 2-1	14/04/2015	0.2	1.4	<0.2	2700	3	9.4	0.2	1.5
SP14 1-1	14/04/2015	0.4	1.9	0.3	4600	3	8.7	0.2	2.3

Signatory: Jamie Woodward
Date: 13/05/2015

All test items tested as received. Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory
Environmental Science
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NATA
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SEDIMENT DATA

Contact: Garnet Hooper
Customer: Jacobs
Address: Level 11, Durack Centre, 263 Adelaide Terrace, Perth WA 6001

Date of Issue: 13/05/2015
Date Received: 16/04/2015
Our Reference: JAC15-8
Your Reference: IW021200

METHOD SAMPLE CODE	Sampling Date	2600 TKN mg.N/g	4500 TOTAL P mg.P/g	6200 TOC % C	ICP002 Total Ext Al mg/kg	ICP002 Total Ext As mg/kg	ICP002 Total Ext Ba mg/kg	ICP002 Total Ext Cd mg/kg	ICP002 Total Ext Co mg/kg
Reporting Limit		**<0.1**	**<0.05**	**<0.2**	**<20**	**<2**	**<0.1**	**<0.1**	**<0.2**
File		**15042901**	**15042901**	**15050101-1101**	**15050101**	**15050101**	**15050101**	**15050101**	**15050101**
SP14 2-1	14/04/2015	0.4	1.9	0.3	4500	3	8.1	0.2	2.3
SP15 1-1	12/04/2015	0.3	1.8	0.3	3400	4	8.8	0.2	1.9
SP15 2-1	12/04/2015	0.3	2.0	0.2	2800	5	8.4	0.2	1.8
SP17 1-1	08/04/2015	0.5	1.3	0.3	5500	3	8.0	0.3	3.1
SP6 1-1	09/04/2015	0.9	1.7	0.6	9600	3	15	0.1	4.8
TB1	12/04/2015	<0.1	<0.05	<0.2	<20	<2	<0.1	<0.1	<0.2
MB1	12/04/2015	<0.1	<0.05	<0.2	<20	<2	<0.1	<0.1	<0.2

Note: Ba by ICP002 is outside the scope of accreditation. Results expressed on a dry weight basis

Signatory: Jamie Woodward
Date: 13/05/2015

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SEDIMENT DATA

Contact: Garnet Hooper
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Address: Level 11, Durack Centre, 263 Adelaide Terrace, Perth WA 6001

Date of Issue: 13/05/2015
Date Received: 16/04/2015
Our Reference: JAC15-8
Your Reference: IW021200

METHOD SAMPLE CODE	Sampling Date	ICP002 Total Ext Cr mg/kg	ICP002 Total Ext Cu mg/kg	ICP002 Total Ext Fe mg/kg	ICP002 Total Ext Ni mg/kg	ICP002 Total Ext Pb mg/kg	ICP002 Total Ext Zn mg/kg	ICP007 Total Ext Hg mg/kg
Reporting Limit		<0.2	<0.2	<5	<0.7	<1	<0.5	<0.01
File		15050101	15050101	15050101	15050101	15050101	15050101	15050602-0701
SP1 1-1	11/04/2015	28	13	16000	21	6	48	0.03
SP1 2-1	11/04/2015	29	14	16000	21	6	47	0.03
SP2 1-1	11/04/2015	31	15	16000	23	7	51	0.03
SP2 2-1	11/04/2015	31	14	16000	23	7	50	0.03
SP3 1-1	11/04/2015	27	11	15000	19	6	46	0.03
SP3 2-1	11/04/2015	25	10	15000	17	5	43	0.04
SP4 1-1	09/04/2015	27	4.7	17000	14	5	51	0.03
SP5 1-1	09/04/2015	20	5.3	13000	11	4	38	0.02
SP5 2-1	09/04/2015	21	5.5	13000	12	5	40	0.03
SP6E 1-1	09/04/2015	20	5.6	13000	12	4	36	0.03
SP6E 2-1	09/04/2015	22	6.0	13000	12	4	38	0.03
SP8 1-1	10/04/2015	5.0	0.9	520	1.1	<1	2.3	<0.01
SP8 2-1	10/04/2015	5.2	1.0	550	1.3	1	2.3	<0.01
SP9 1-1	10/04/2015	7.4	1.7	2800	4.2	4	6.9	<0.01
SP10N 1-1	10/04/2015	7.9	2.4	3900	4.6	3	10	0.01
SP10N 2-1	10/04/2015	8.5	2.5	4300	4.5	3	11	0.01
SP12 1-1	10/04/2015	10	2.6	5300	5.4	2	11	0.01
SP12 2-1	10/04/2015	11	3.0	5800	5.7	2	12	0.01
SP13 1-1	14/04/2015	8.9	1.8	4200	4.6	2	8.5	<0.01
SP13 2-1	14/04/2015	7.7	1.6	3500	3.7	2	7.3	<0.01
SP14 1-1	14/04/2015	11	2.7	5800	6.1	3	13	0.01

All test items tested as received. Spare test items will be held for two months unless otherwise requested.

Signatory: Jamie Woodward
Date: 13/05/2015

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SEDIMENT DATA

Contact: Garnet Hooper
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Address: Level 11, Durack Centre, 263 Adelaide Terrace, Perth WA 6001

Date of Issue: 13/05/2015
Date Received: 16/04/2015
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Your Reference: IW021200

METHOD SAMPLE CODE	Sampling Date	ICP002 Total Ext Cr mg/kg	ICP002 Total Ext Cu mg/kg	ICP002 Total Ext Fe mg/kg	ICP002 Total Ext Ni mg/kg	ICP002 Total Ext Pb mg/kg	ICP002 Total Ext Zn mg/kg	ICP007 Total Ext Hg mg/kg
Reporting Limit		**<0.2**	**<0.2**	**<5**	**<0.7**	**<1**	**<0.5**	**<0.01**
File		**15050101**	**15050101**	**15050101**	**15050101**	**15050101**	**15050101**	**15050602-0701**
SP14 2-1	14/04/2015	11	2.7	5800	5.9	3	12	0.01
SP15 1-1	12/04/2015	7.7	2.9	5500	5.1	3	11	<0.01
SP15 2-1	12/04/2015	7.2	2.6	5000	5.0	2	9.8	<0.01
SP17 1-1	08/04/2015	11	3.5	7600	7.2	3	18	<0.01
SP6 1-1	09/04/2015	22	6.2	14000	13	5	40	0.03
TB1	12/04/2015	<0.2	<0.2	<5	<0.7	<1	<0.5	<0.01
MB1	12/04/2015	<0.2	<0.2	<5	<0.7	<1	<0.5	<0.01

Signatory: Jamie Woodward
Date: 13/05/2015

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Genus species	Family	Order	Class	Phylum	SP 1	SP 2	SP 3	SP 5	SP 6	SP 8	SP 10	SP 12	SP 13	SP 14	SP 15
1 Ennucula superba (Hedley:1902)	Nuculidae	Nuculoida	Bivalvia	Mollusca		1		1					1		
2 anemone	anemone family 1	Actinaria	Anthozoa	Cnidaria				1							
3 Amphioplus sp	Amphiuridae	Ophiurida	Ophiuroidea	Echinodermata				1				1			2
4 ostracod 1	ostracod family 1	.	Ostracoda	Crustacea				2							
5 foram 1	.	.		Foraminifera				1							
6 Nuculana watsoni (Smith:1885)	Nuculidae	Nuculoida	Bivalvia	Mollusca				1							
7 foram 2	.	.	.	Foraminifera	1			4	1			2		2	
8 copepod	.	.	Copepoda	Crustacea					3						
9 Paralacydonia paradoxa Fauvel:1913	Lacydoniidae	Phyllodocida	Polychaeta	Annelida					1				1		1
10 nematode	.	.	.	Nematoda				3	4						5
11 lumbrinerid 1	Lumbrineridae	Eunicida	Polychaeta	Annelida					1						
12 Blank															
13 foram 3	.	.	.	Foraminifera				1							
14 spionid 1	Spionidae	Spionida	Polychaeta	Annelida					1						
15 Blank															
16 amphipod 1	amphipod family 1	Amphipoda	Malacostraca	Crustacea					1						
17 echurian	.	.	.	Echiura					1						
18 Blank															
19 Fibularid	Fibularidae	Clypeasteroida	Echinoidea	Echinodermata								1		1	
20 arcturid	Arcturidae	Isopoda	Malacostraca	Crustacea								1			1
21 tanaid	tanaid family 1	Tanaidacea	Malacostraca	Crustacea						3		3		3	4
22 Cuspidaria sp	Cuspidariidae	Pholadomyoida	Gastropoda	Mollusca								1			
23 Poecilochaetus sp	Poecilochaetidae	Spionida	Polychaeta	Annelida								1			
24 nereid	Nereididae	Phyllodocida	Polychaeta	Annelida								2			
25 syllid 1	Syllidae	Phyllodocida	Polychaeta	Annelida						1		1	1	1	1
26 ostracod 2	ostracod family 2	.	Ostracoda	Crustacea							1	1			
27 Arabella sp	Oenoneidae	Eunicida	Polychaeta	Annelida								1			
28 nemertean	nemertean family 1	.	.	Nemertea								1			1
29 Terebellides sp	Trichobranchidae	Terebellida	Polychaeta	Annelida								1			2
30 hermit crab	Diogeniidae	Decapoda	Malacostraca	Crustacea								1		1	1
31 holothurian 1	holothurian family 1	.	Holothurioidea	Echinodermata								1			
32 Dorvilleidae	Dorvilleidae	Eunicida	Polychaeta	Annelida							1				
33 laevidentaliidae	Laevidentaliidae	Dentaliida	Scaphopoda	Mollusca							1				
34 Glycera sp	Glyceridae	Phyllodocida	Polychaeta	Annelida									1		1
35 Magelona sp	Magelonidae	Spionida	Polychaeta	Annelida			2						1		
36 sphaeromatid	Sphaeromatidae	Isopoda	Malacostraca	Crustacea									1		
37 Pyramidella sp	Pyramidellidae	Heterogastropoda	Gastropoda	Mollusca									1		
38 lumbrinerid 2	Lumbrineridae	Eunicida	Polychaeta	Annelida						1			1		
39 brittlestar 2	brittlestar family 1	.	Ophiuroidea	Echinodermata									1	1	
40 brittlestar 3	brittlestar family 1	.	Ophiuroidea	Echinodermata									1		
41 spionid 2	Spionidae	Spionida	Polychaeta	Annelida									1		
42 Blank															
43 gnathid	Gnathidae	Isopoda	Malacostraca	Crustacea									1		
44 Marphysa sp	Eunicidae	Eunicida	Polychaeta	Annelida										1	
45 Platyischnopus sp	Platyischnopidae	Amphipoda	Malacostraca	Crustacea										1	
46 brittlestar 4	brittlestar family 1	.	Ophiuroidea	Echinodermata										1	
47 pycnogonid	.	Pantapodia	Pycnogonida	Arthropoda										2	
48 cumacean 1	cumacean family 1	Cumacea	Malacostraca	Crustacea										1	
49 sea pen	sea pen family 1	Pennatulacea	Anthozoa	Cnidaria										1	
50 ostracod 3	ostracod family 3	.	Ostracoda	Crustacea						1				2	
51 soft coral 1	.	Alcyonacea	Anthozoa	Cnidaria										4	
52 polychaete ? family 1	.	.	Polychaeta	Annelida										1	1
53 shrimp 1	shrimp family 1	Decapoda	Malacostraca	Crustacea										1	
54 amphipod 2	amphipod family 2	Amphipoda	Malacostraca	Crustacea										1	
55 anthurid 1	Anthuridae	Isopoda	Malacostraca	Crustacea										1	1
56 amphipod 3	amphipod family 3	Amphipoda	Malacostraca	Crustacea		1								1	
57 amphipod 4	amphipod family 4	Amphipoda	Malacostraca	Crustacea										2	
58 amphipod 5	amphipod family 5	Amphipoda	Malacostraca	Crustacea						3				1	
59 anthurid 2	Anthuridae	Isopoda	Malacostraca	Crustacea										1	
60 paraonid	Paraonidae	Scolecida	Polychaeta	Annelida										1	1
61 onuphid	Onuphidae	Eunicida	Polychaeta	Annelida	1		1							1	3
62 alpheid 1	Alpheidae	Decapoda	Malacostraca	Crustacea			1								
63 brittlestar 5	brittlestar family 2	.	Ophiuroidea	Echinodermata			1								1
64 lumbrinerid 3	Lumbrineridae	Eunicida	Polychaeta	Annelida			1								3
65 capitellid 1	Capitellidae	Scolecida	Polychaeta	Annelida			1								
66 Owenia fusiformis Delle Chiaje:1844	Oweniidae	Canalipalpata	Polychaeta	Annelida											1
67 sabellid	Sabellidae	Sabellida	Polychaeta	Annelida											1
68 Spiophanes sp	Spionidae	Spionida	Polychaeta	Annelida											1
69 amphipod 6	amphipod family 6	Amphipoda	Malacostraca	Crustacea											1
70 cirratulid	Cirratulidae	Terebellida	Polychaeta	Annelida											1
71 maldanid	Maldanidae	Scolecida	Polychaeta	Annelida											1
72 aphroditid	Aphroditidae	Phyllodocida	Polychaeta	Annelida											1
73 cumacean 2	cumacean family 1	Cumacea	Malacostraca	Crustacea											1
74 syllid 2	Syllidae	Phyllodocida	Polychaeta	Annelida											2
75 janiridae	Janiridae	Isopoda	Malacostraca	Crustacea						3					1
76 chaetopterid	Chaetopteridae	Spionida	Polychaeta	Annelida											2
77 holothurian 2	holothurian family 1	.	Holothurioidea	Echinodermata											1
78 brittlestar 6	brittlestar family 1	.	Ophiuroidea	Echinodermata											1
79 sponge 1	sponge family 1	.	Demospongiae	Porifera											2
80 capitellid 2	Capitellidae	Scolecida	Polychaeta	Annelida											1
81 ampharetid	Ampharetidae	Terebellida	Polychaeta	Annelida											1
82 spionid 3	Spionidae	Spionida	Polychaeta	Annelida		1									1
83 polychaete ? family 2	.	.	Polychaeta	Annelida											1
84 callianassid	Callianassidae	Decapoda	Malacostraca	Crustacea						1					2
85 Axius sp	Axiidae	Decapoda	Malacostraca	Crustacea											1
86 cumacean 3	cumacean family 2	Cumacea	Malacostraca	Crustacea											1
87 amphipod 7	amphipod family 7	Amphipoda	Malacostraca	Crustacea											1
88 amphipod 8	amphipod family 8	Amphipoda	Malacostraca	Crustacea											1
89 cumacean 4	cumacean family 3	Cumacea	Malacostraca	Crustacea		1									
90 Bregmaceros sp	Bregmacerotidae	Gadiformes	Actinopterygii	Chordata	1	1									
91 Sigalionidae	Sigalionidae	Phyllodocida	Polychaeta	Annelida	1										
92 fasciolarid 1	Fasciolariidae	Caenogastropoda	Gastropoda	Mollusca	4										
93 cirolanid	Cirolanidae	Isopoda	Malacostraca	Crustacea						1					
94 amphipod 9	amphipod family 9	Amphipoda	Malacostraca	Crustacea						2					
95 Birubius sp	Phoxocephalidae	Amphipoda	Malacostraca	Crustacea						2					
96 sponge 2	sponge family 2	.	Calcarea	Porifera						1					
97 Dendrophyllium sp & commensal sipunculid	Dendrophylliidae	Scleractina	Anthozoa	Cnidaria						1					
98 Flabellum sp	Flabellidae	Scleractinia	Anthozoa	Cnidaria						1					
99 sponge 3	sponge family 3	.	Demospongiae	Porifera						1					
100 sponge 4	sponge family 4	.	Calcarea	Porifera						1					
101 leucosid	Leucosidae	Decapoda	Malacostraca	Crustacea	1										
102 bryozoa	bryozoa family 1	.	.	Bryozoa						1					
103 hydroid 1	hydroid family 1	Hydroida	Hydrozoa	Cnidaria						4					
104 hydroid 2	hydroid family 2	Hydroida	Hydrozoa	Cnidaria						1					
105 sponge 5	sponge family 5	.	Calcarea	Porifera						3					
106 Aspidosiphon sp	Aspidosiphonidae	Aspidosiphonida	Phascolosomatidea	Sipuncula						1					
107 xanthid	Xanthidae	Decapoda	Malacostraca	Crustacea						1					
108 amphipod 10	amphipod family 10	Amphipoda	Malacostraca	Crustacea						1					
109 fasciolarid 2	Fasciolariidae	Caenogastropoda	Gastropoda	Mollusca						1					
110 sponge 6	.	.	Demospongiae	Porifera						1					
111 sponge 7	.	.	Demospongiae	Porifera						1					
112 sponge 8	.	.	Demospongiae	Porifera						1					
113 sponge 9	.	.	Demospongiae	Porifera						1					
114 sponge 10	.	.	Demospongiae	Porifera						1					
115 sponge 11	.	.	Demospongiae	Porifera						1					
116 sponge 12	.	.	Demospongiae	Porifera						1					
117 Blank	.	.	Demospongiae	Porifera											
118 hydroid 3	hydroid family 3	Hydroida	Hydrozoa	Cnidaria						3					
119 hard coral	.	.	Hexacorallia	Cnidaria						1					
120 soft coral 2	.	Alcyonacea	Anthozoa	Cnidaria						1					
121 alpheid 2	Alpheidae	Decapoda	Malacostraca	Crustacea						1					
122 trochid	Trochidae	Archaeogastropoda	Gastropoda	Mollusca						1					
123 anthurid 3	Anthuridae	Isopoda	Malacostraca	Crustacea						1					
124 anthurid 4	Anthuridae	Isopoda	Malacostraca	Crustacea						2					
125 Nematonereis sp	Eunicidae	Eunicida	Polychaeta	Annelida						5					
126 Ophelina sp	Opheliidae	Scolecida	Polychaeta	Annelida						1					
127 ostracod 4	ostracod family 4	.	Ostracoda	Crustacea						2					
128 ostracod 5	ostracod family 5	.	Ostracoda	Crustacea						1					
129 shrimp 2	shrimp family 1	Decapoda	Malacostraca	Crustacea						1					
arcturid fragment tail only														1	
brittle star incomplete unident							1			1					1
cumacean fragment tail only													1		
isopod fragment only										1					
polychaete fragments					1				14	2	4	3	5	5	6

Appendix D.

Benthic habitat report (Jacobs 2016c)

Barossa Environmental Studies

ConocoPhillips

Benthic Habitat Report

WV04831-NMS-RP-0028 | Rev 2

19 August 2016

Barossa Environmental Studies

Project no: WV04831 (IW021200)
Document title: Benthic Habitat Report
Document no: WV04831-NMS-RP-0028
Revision: 1
Date: 4 August 2015
Client name: ConocoPhillips
Project manager: Arne de Vos
Author: Nadia Aurisch
File name: T:\Transfer\Aug2016\WVES\TMiley\Barossa OPP Tech Appendices\sent to cop\Benthic Habitat Baseline Report 190816.docx

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Document history and status

Revision	Date	Description	By	Review	Approved
Rev A	25/06/15	Draft for editorial review	N. Aurisch	J. Phillips	
Rev A	25/06/15	Draft for technical review	N. Aurisch	G. Hooper	
Rev 0	01/07/15	For client issue	N. Aurisch	C. Teasdale	T. Mitchell
Rev 1	04/07/15	Final, issued for use	N. Aurisch	C. Teasdale	T. Mitchell
Rev 2	19/08/16	Final, minor revisions	W. Chisholm	A. de Vos	A.de Vos

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Executive Summary

ConocoPhillips Australia Exploration Pty Ltd (ConocoPhillips) are proposing to develop natural gas resources as part of the Barossa area development, located in waters up to 300 m deep in the Bonaparte Basin, in Commonwealth waters offshore of northern Australia. To develop a robust understanding of the existing marine environmental values of the area to inform any future approvals, a targeted baseline marine studies program is being progressed within and surrounding the Barossa field. One component of the baseline marine studies program is a benthic habitat survey. This report summarises the results of this survey, undertaken in late March/early April 2015.

Twenty-five benthic habitat sampling sites were positioned to provide representative coverage of the permit area and nearby areas of regional interest such as shoals and banks. Sites were located in the permit area (eight sites), around Evans Shoal (four sites), around Tassie Shoal (three sites), around Lynedoch Bank (four sites), on seamounts west of the permit area (four sites) and scarps south of the permit area (two sites).

The benthic habitat survey took place over five days, from 31 March to 6 April 2015. At each site, a remotely operated vehicle surveyed several transects along the seafloor capturing both video footage and still images.

Generally, the data collected during this survey indicate that the benthic habitats and biota were typical of those expected in offshore environments and were consistent with studies conducted both in areas with similar features and in areas of a similar geographic location. Key conclusions from this benthic habitat survey include:

- The seabed observed in the permit area was predominantly silty sand generally lacking hard substrate. Fauna groups observed included octocorals (particularly sea pens) and decapod crustaceans (mostly prawns and squat lobsters) in relatively low numbers, however bioturbation was frequently observed. Results from the recent infauna survey indicate bioturbation in this area was predominantly caused by polychaetes, crustaceans, bivalves, molluscs, echinoderms and potentially fish. Sites were generally similar to one another.
- The shoals to the west of the permit area (Evans Shoal and Tassie Shoal) and Lynedoch Bank to the east were comprised of typical tropical coral reef habitat. Biotic assemblages at these sites were generally similar to one another and to other submerged shoals and banks in the broader regional area.
- The seamounts to the west of the permit area supported a diverse range of fish and sharks and contained some of the same benthic taxa as the banks and shoals. Communities varied slightly between each of the sites.
- The scarps to the south of the permit area included areas of hard substrate and supported a diverse range of filter feeders and were generally more similar to the seamount features than to the shoals and bank sites.
- The community composition of these three areas (permit area; banks and shoals; and seamounts and scarps) appeared to be reasonably different to one another with the differences appearing to be driven by depth and substrate type. The least diverse sites were the permit area sites, whilst the most diverse sites were the shoals and banks.

An unexpected observation during the survey was the sighting of four grey nurse sharks (including at least one female that appeared to be pregnant) at a seamount to the west of the permit area, in approximately 130 m water depth. This was considered unusual as neither the east or west coast populations are known to extend that far north and are generally associated with shallower, more coastal waters.

The results of this survey have characterised the benthic habitats of the permit area and selected nearby areas of interest.

1. Introduction

1.1 Background

ConocoPhillips Australia Exploration Pty Ltd (ConocoPhillips), as proponent on behalf of the current and future joint venturers, are proposing to develop natural gas resources as part of the Barossa area development, located approximately 300 kilometres (km) north of Darwin, Northern Territory (NT).

To facilitate the environmental approvals process for any future development of the Barossa field and surrounds, a robust understanding of the existing state of the key environmental values and sensitivities will be necessary. This understanding will be gained from a series of studies and surveys to assess and monitor the baseline state of environmental factors such as water quality, sediment quality, underwater noise, metocean conditions and benthic habitats within petroleum retention lease permit NT/RL5 (referred to as the 'permit area' in this report) and across a broader geographical area. The studies assessing these factors commenced in June 2014.

1.2 Overview of existing regional environment

The Barossa area is located in the North Marine Region (Department of Sustainability, Environment, Water, Population and Communities 2012), which comprises the Commonwealth waters of the Gulf of Carpentaria, Timor Sea and Arafura Sea as far west as the NT and Western Australian border. The North Marine Region contains internationally significant breeding and/or feeding grounds for a number of listed threatened and migratory marine species including nearshore dolphins, turtles, dugongs, seabirds and migratory shorebirds afforded protection under national legislation and international conventions.

The Timor and Arafura Seas support a variety of shark, pelagic finfish and crustacean species of commercial and recreational game-fishing importance, e.g. trawl and various finfish fisheries. The shelf break and slope of the Arafura Shelf is characterised by patch reefs and hard substrate pinnacles that support a diverse array of invertebrate groups, with polychaetes and crustaceans being the most prolific (Heyward et al. 1997, Consulting Environmental Engineers 2002). Surveys indicate that between 50 m and 200 m depth, the benthos consists of predominantly soft, easily resuspended sediments (Heyward et al. 1997, URS 2005, 2007). The diversity and coverage of epibenthos is low and organisms present are predominantly sponges, gorgonians and soft corals (Heyward et al. 1997, URS 2005, 2007).

Numerous shoals (submerged calcareous banks or 'seamounts') exist in the broader region around the permit area; Evans Shoal (60 km west), Tassie Shoal (70 km south-west) and Lynedoch Bank (40 km south-east). In addition, the new Oceanic Shoals Commonwealth marine reserve (multiple use zone) lies to the south and south-east of the permit area.

1.3 Objectives

The benthic habitat survey is a key component of the Barossa marine baseline studies program.

Baseline studies were undertaken with reference to the permit area, as shown in **Figure 1-1**. While this represents the area of primary interest as part of ConocoPhillips' staged field development, the broader surrounds were also characterised.

The survey was completed as a single survey as it was not expected that habitats would vary during different seasonal conditions, based on the remote, offshore location of the Barossa field. The objective of the benthic habitat survey was to characterise the benthic habitats and biota within the permit area and in the vicinity of Evans Shoal, Tassie Shoal and Lynedoch Bank; which represent the nearest seabed features of regional interest to the Barossa field.

This report summarises the results of the benthic habitat survey, undertaken in late March/early April 2015.

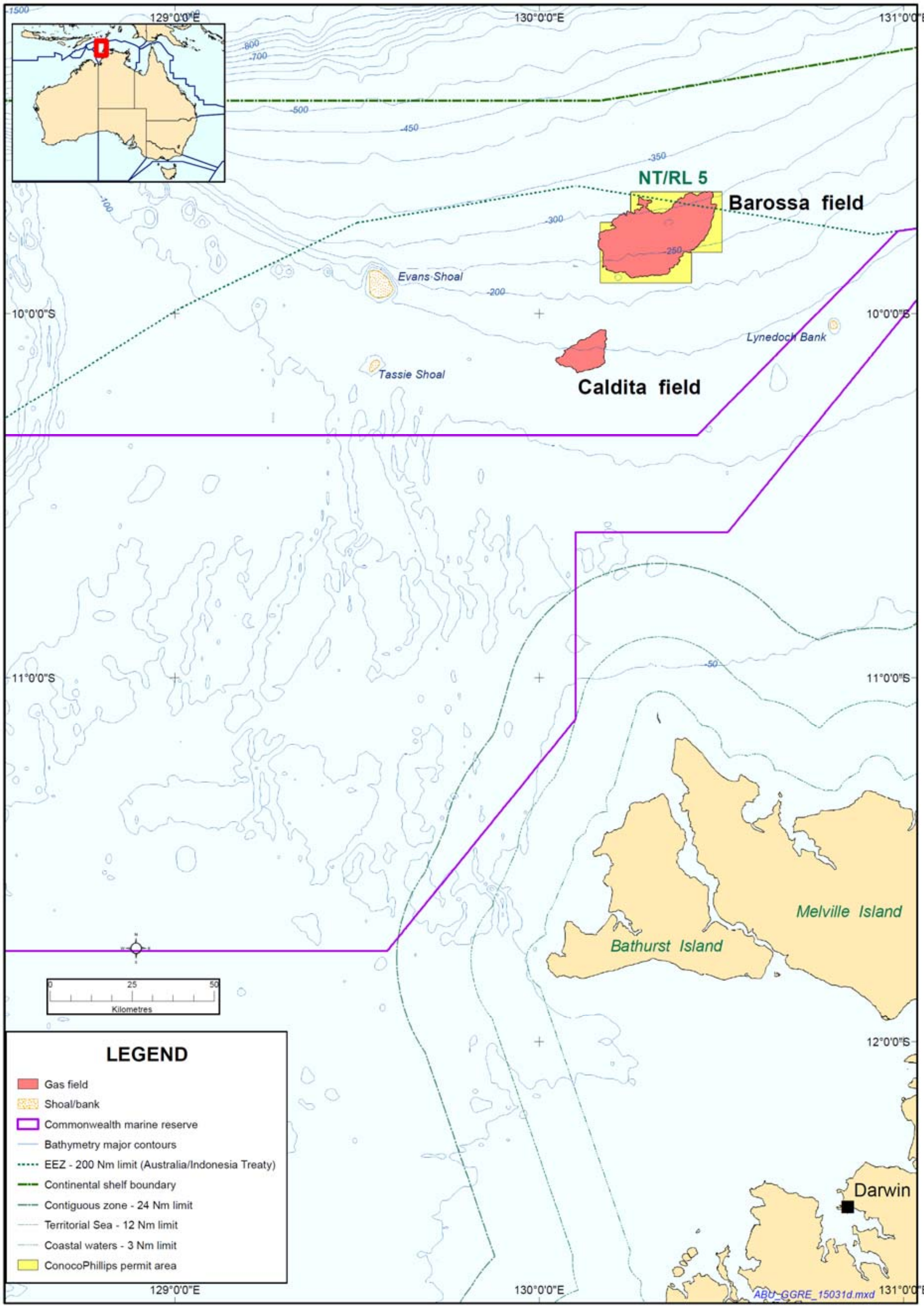


Figure 1-1: Barossa field location

2. Methods

The methods employed during the benthic habitat survey follow those detailed in the *Barossa Environmental Studies: Benthic Habitat Method Statement* (Jacobs 2015). An overview of the methods is provided in the sections below.

2.1 Survey design

The survey was designed to collect data on the distribution of benthic habitats in the immediate vicinity of the permit area, from across the broader region, and from areas of regional interest including shoals and banks and areas with complex topography as a result of the changing bathymetry, e.g. pinnacles/seamounts or scarps. The sampling sites originally identified during design of the study (**Figure 2-1)** were:

- the permit area (eight sites stratified to capture the bathymetric gradient)
- Evans Shoal, approximately 60 km west of the permit area (five sites)
- Tassie Shoal, approximately 70 km south-west of the permit area (three sites)
- Lynedoch Bank, approximately 40 km south-east of the permit area (five sites)
- seamounts, approximately 40 km west of the permit area (three sites)
- scarps, approximately 5–10 km south of the permit area (four sites).

These sites were labelled with a prefix (HM, habitat mapping) and numbered 1–28. Some sites were not visited due to time/weather constraints and are not shown in **Figure 2-1**.

2.2 Sampling sites

Twenty five sites were sampled during the survey (**Table 2-1, Figure 2-1**). Due to weather constraints, five of the original sites were not visited, however, an additional two sites on seamounts to the west of the Barossa field were added to the sampling plan to capture imagery from interesting bathymetric features observed whilst undertaking the field survey. Sites sampled during the field survey are shown in **Table 2-1** and **Figure 2-1**.

2.3 Timing

Benthic habitats were surveyed during a single survey with sampling taking place during daylight hours over 7 days from 31 March to 6 April 2015.

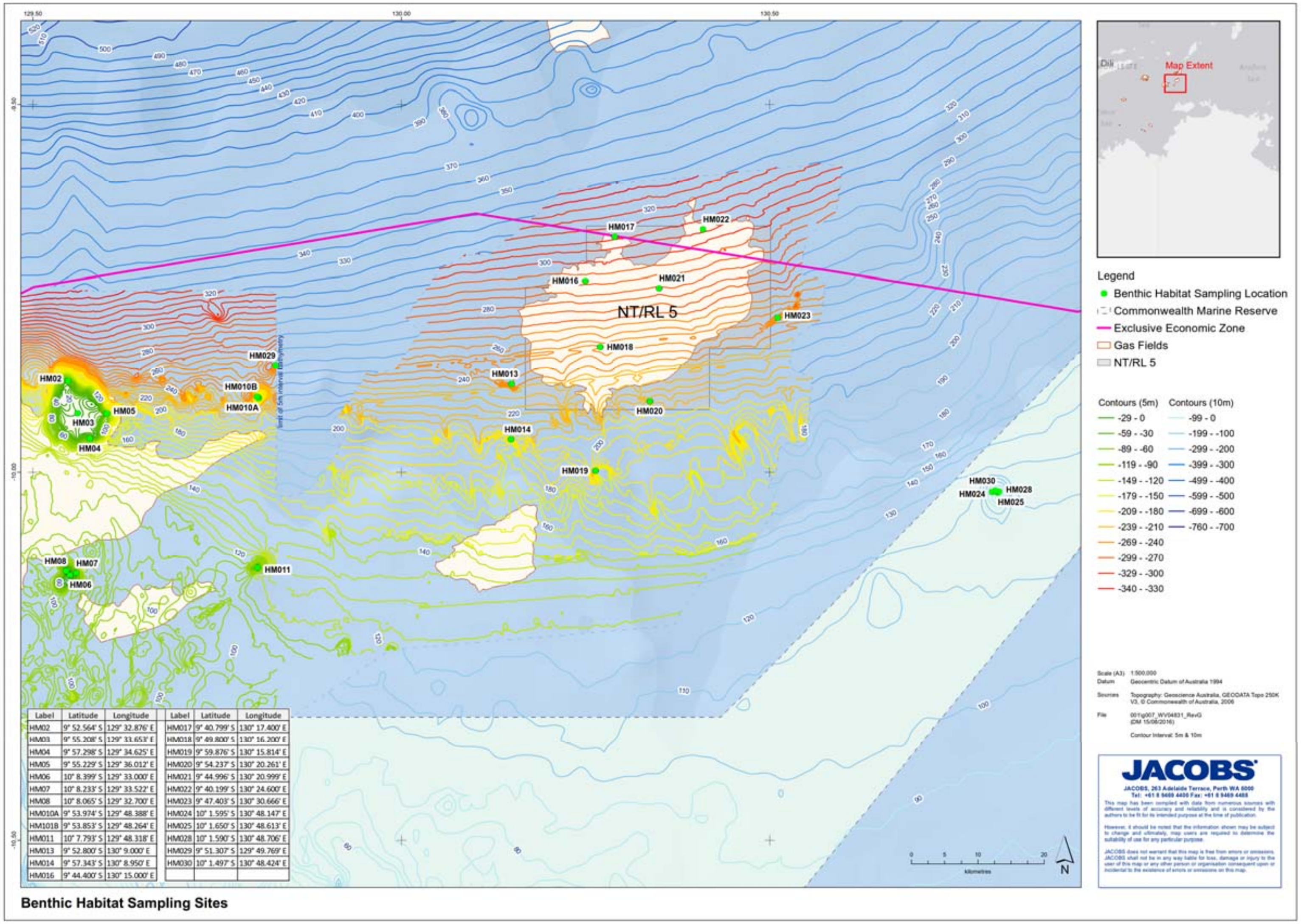
2.4 Sampling equipment

A remotely operated vehicle (ROV) fitted with cameras was used to obtain video footage and digital still images of the seabed for later analysis and data extraction. The ROV was an Ocean Modules V8 Sii, supplied and operated by Intervention Engineering. The ROV was equipped with a high-definition video camera and an 18 megapixel digital single lens reflex (DSLR) camera with four flash units and laser scaling. The ROV was also fitted with four high-intensity lights and positioning was monitored using a Seaprince sonar and two ultra-short baseline (USBL) beacons (Sonardyne Scout Plus and Tritech).

Table 2-1: Benthic habitat sampling site coordinates

Site name	Depth (m)	Coordinates (DD° MM'SS.SSS")[1]	
		Latitude	Longitude
Permit area – 8 sites			
HM013	245	9° 52' 48.0" S	130° 09' 0.0" E
HM016	290	9° 44' 24.0" S	130° 15' 0.0" E
HM017	309	9° 40' 47.94" S	130° 17' 0.0" E
HM018	253	9° 49' 48.0" S	130° 16' 12.0" E
HM020	211	9° 54' 14.22" S	130° 20' 15.66" E
HM021	280	9° 44' 59.76" S	130° 20' 59.94" E
HM022	303	9° 40' 11.94" S	130° 24' 36.0" E
HM023	280	9° 47' 24.18" S	130° 30' 39.96" E
Evans Shoal – 4 sites			
HM02	45–130	9° 52' 33.84" S	129° 32' 52.56" E
HM03	28	9° 55' 12.48" S	129° 33' 39.18" E
HM04	18–55	9° 57' 17.88" S	129° 34' 37.5" E
HM05	83–170	9° 55' 13.74" S	129° 36' 0.72" E
Tassie Shoal – 3 sites			
HM06	15	10° 08' 23.94" S	129° 33" 0.0" E
HM07	28–70	10° 08' 13.98" S	129° 33' 31.32" E
HM08	15	10° 08' 3.9" S	129° 32' 42.0" E
Lynedoch Bank – 4 sites			
HM024	20	10° 01' 35.7" S	130° 48' 8.82" E
HM025	16	10° 01' 39.0" S	130° 48' 36.78" E
HM028	26–83	10° 01' 35.4" S	130° 48' 42.36" E
HM030	16	10° 01' 29.82" S	130° 48' 25.44" E
Seamounts (east of field) – 4 sites			
HM010A	77–140	9° 53' 58.44" S	129° 48' 23.28" E
HM010B	77	9° 53' 51.18" S	129° 48' 15.84" E
HM029	80–220	9° 51' 18.42" S	129° 49' 46.14" E
HM011	50–100	10° 07' 47.58" S	129° 48' 19.08" E
Scarps (south of field) – 2 sites			
HM014	190	9° 57' 20.58" S	130° 08' 57.0" E
HM019	162–185	9° 59' 52.56" S	130° 15' 48.84" E

[1] Coordinate System - GDA 1994



Label	Latitude	Longitude	Label	Latitude	Longitude
HM02	9° 52.564' S	129° 32.876' E	HM017	9° 40.799' S	130° 17.400' E
HM03	9° 55.208' S	129° 33.653' E	HM018	9° 49.800' S	130° 16.200' E
HM04	9° 57.298' S	129° 34.625' E	HM019	9° 59.876' S	130° 15.814' E
HM05	9° 55.229' S	129° 36.012' E	HM020	9° 54.237' S	130° 20.261' E
HM06	10° 8.399' S	129° 33.000' E	HM021	9° 44.996' S	130° 20.999' E
HM07	10° 8.233' S	129° 33.522' E	HM022	9° 40.199' S	130° 24.600' E
HM08	10° 8.065' S	129° 32.700' E	HM023	9° 47.403' S	130° 30.666' E
HM010A	9° 53.974' S	129° 48.388' E	HM024	10° 1.595' S	130° 48.147' E
HM101B	9° 53.853' S	129° 48.264' E	HM025	10° 1.650' S	130° 48.613' E
HM011	10° 7.793' S	129° 48.318' E	HM028	10° 1.590' S	130° 48.706' E
HM013	9° 52.800' S	130° 9.000' E	HM029	9° 51.307' S	129° 49.769' E
HM014	9° 57.343' S	130° 8.950' E	HM030	10° 1.497' S	130° 48.424' E
HM016	9° 44.400' S	130° 15.000' E			

Figure 2-1: Benthic habitat sampling site locations

2.5 Data collection

The ROV was deployed from the Gun Marine Services vessel *Warrego.* The ROV umbilical was attached to a winch line and clump weight, leaving approximately 50 m of umbilical between the ROV and clump weight. The use of the clump weight was to mitigate the potential impact of tidal drag on the ROV umbilical through the water column. The clump weight was lowered and the ROV flown to approximately 5 m above the seabed, after which the ROV continued to descend to 1 m above the seabed. To keep the clump weight stationary (using the data from USBL beacon for guidance), the vessel engaged thrusters and main engines when required to mitigate the effects of currents, wind and waves so that the full transect length could be filmed.

The ROV was then flown along three transects radiating outwards (the direction was dictated by the prevailing conditions) using the clump weight as the origin. Transects were approximately 50 m long, which resulted in approximately 10 minutes of video footage for each transect. Video and digital still imagery of benthic habitats was collected along each transect. At least one transect at each site was an exploratory transect where the ROV was positioned at a height above the seabed to focus on recording video footage in order to capture a broader perspective of the habitats present. The remaining two transects at a site were of fixed direction, with a focus on maintaining a straight heading whilst capturing video and still images of the seabed for any future analysis and quantification of habitat (these still images were not analysed as part of this report). Along these transects, still images were captured every 5 seconds (video footage was captured continuously). Once the three transects had been surveyed, the ROV was recovered to the vessel and moved to the next sampling site.

On the slopes of shoals, banks or seamounts, single transects were flown both across the top of the feature and down the slope. Transects ended when the slope flattened out at the base of the feature or the habitat changed to sand/silt. The vessel would follow the ROV (using the data from the USBL beacon) with the clump weight being raised and lowed as required so that a transect across the full length of the feature could be completed (maximum length was 500 m).

All collected imagery (video and stills) was downloaded and backed up onto an external hard drive for later analysis and classification of the benthic habitats and biota.

2.6 Habitat and biota classification

2.6.1 Qualitative classification

The data captured from each transect was reviewed and if transects from each site was considered representative of the site, then one transect (exploratory) was classified into broad habitat and fauna categories (**Table 2-2**) by a trained marine ecologist.

2.6.2 Presence/absence data

The results from the habitat and biota classification were analysed for similarity between sites. This was done using multidimensional scaling (MDS) in Primer v6. Cluster analysis was based on Bray Curtis similarity of presence/absence of biological data and was used to illustrate similarities of community composition for each site. Observation of habitat type (e.g. hard/soft substrate) was used as part of the interpretation.

2.6.3 Quantitative classification

Still images were captured every 5 seconds along the fixed transects. These images may be used for quantitative and qualitative analysis in the future if required, but this is beyond the scope of this report.

Still images considered to be representative of each habitat type are presented in the habitat descriptions (**Section 3.1**) and images of unidentified fish types are presented in **Appendix A**.

2.6.4 Quality control procedures

Procedural and record-keeping quality control measures implemented were:

- GPS waypoints and water depth were recorded for all sites sampled from the vessel
- site locations and preliminary analysis notes were logged onto field sheets, which were backed up to a hard drive

- any changes to the field procedures were documented.

2.6.5 Limitations

Water clarity and light conditions were limiting factors for image analysis. The water clarity was affected by the substrate type and the amount of particulates in the water column. The finer the substrate type the easier it was for the ROV thrusters and currents to disturb it and introduce particles into the water column. This generally only applied to the deeper water sites that had a predominantly silty sand bottom. The reliance on artificial lighting at deeper sites also meant that objects on the edge of the image frame were harder to accurately identify than objects at the shallow water reef sites if only part of the object was illuminated.

Table 2-2: Habitat and biota classification categories

Teleosts	Other
Type A – Silver, minnow shaped tail	Tunicates/Ascidians
Type B – Rat tail	Sponge - encrusting
Type C – Silver, bullet shaped	Sponge - sub massive
Type D – Bullet shaped, dark minnow tail	Sponge - cup
Type E – Snake head	Sponge - erect
Type F – Tiger stripes	Tube Worms
Type G – Sword fish	Anemones
Type H – Vertical fish	Halimeda
Type I – Triangle fish	Algae
Type J – Mouth prongs	**Echinoderms**
Type K – Pipefish	Feather Stars (Class Crinoidea)
Type L – Gurnaud	Brittle Stars (Class Ophiuroidea)
Type M – Flounder A	Holothurian
Type N – Flounder B	Sea star
Type O – Flounder C	Urchin
Type P – Pink fish	**Octocorals**
Type Q – Flathead	Unidentified - Filter Feeders/non- Photosynthetic Soft Corals
Type R – Goby shape	Sea Pens
Type S – Bulbous Long-tailed transparent	Gorgonians
Unknown teleost	Sea Whips
Family Lutjanidae - snapper	**Corals**
Family Chaetodontidae - butterfly fish	Branching
Family Labridae - wrasse	Digitate
Family Pomacentridae - damsel	Columnar
Family Pomacanthidae - angelfish	Plate
Family Acanthuridae - unicorn fish	Massive
Family Balistidae - triggerfish	Sub-massive
Family Zanclidae - moorish Idol	Encrusting
Family Monacanthidae - leatherjacket	Free-living
Family Holocentridae - squirrel fish	**Decapods**
Family Carangidae	Prawn/Shrimp Group
Family Caesionidae	Long-Antennae Shrimp Group
Family Serranidae	Small Crab/Squat Lobster Group
Family Priacanthidae	Lobster
Reptilia	Hermit crab
Seasnake	**Chondrichthyes**
Mollusc	Shark – whitetip reef
Gastropod	Shark – silvertip
Bivalve	Shark - grey nurse
Actinopterygii	Shark - tawny nurse
Moray eel	Elasmobranch

3. Results

3.1 Habitat descriptions

Habitat descriptions and representative images are provided for each site in the following subsections. Images considered to be representative of deep water fish types are included in **Appendix A**.

3.1.1 Southern permit area

HM013

HM013 was located in 245 m water depth, just outside the south-west boundary of the permit area in an area where seismic survey derived bathymetry indicated a valley. The substrate at HM013 was predominantly silty sand and slightly undulating (<25 cm in height) with widespread bioturbation (i.e. burrows, mounds and tracks). Observed biota included sea pens, anemones (**Figure 3-1**), decapod crustaceans and four types of fish.

HM018

HM018 was located in 253 m water depth in the southern half of the permit area. The substrate at HM018 was predominantly silty sand (**Figure 3-2**) and was slightly undulating (<25 cm in height) with widespread bioturbation. Observed biota included sea pens and decapod crustaceans and six types of fish.

HM020

HM020 was located in 211 m water depth near the southern boundary of the permit area. The substrate at HM020 was predominantly very silty sand and was slightly undulating (<25 cm in height) with widespread bioturbation. Observed biota included sea pens, starfish, decapod crustaceans and five types of fish.

Figure 3-1: Silty sand substrate with burrowing anemone at site HM013

Figure 3-2: Silty sand substrate with teleost (Type A) fish at site HM018

3.1.1.1 Mid permit area

HM016

HM016 was located in 290 m water depth in the north-west of the permit area. The substrate at HM016 was predominantly fine, silty sand and was slightly undulating (<25 cm in height) with widespread bioturbation. Observed biota included sea pens (**Figure 3-3**), anemones, decapod crustaceans and four types of fish.

HM021

HM021 was located in 280 m water depth near the centre of the permit area. The substrate was slightly undulating (<25 cm in height), fine silty sand, with widespread bioturbation. Observed biota included sea pens, decapod crustaceans and one fish type.

HM023

HM023 was located in 280 m water depth just outside the eastern boundary of the permit area where the seismic derived bathymetry indicated a valley. The substrate at HM023 was predominantly silty sand and was slightly undulating (<25 cm in height) with widespread bioturbation. Observed biota included sea pens, soft corals, anemones, starfish, decapod crustaceans and five types of fish (**Figure 3-4**).

Figure 3-3: Silty sand substrate and a sea pen at site HM016

Figure 3-4: Gravelly silty sand substrate with squat lobster, soft coral and teleost (Type K) fish at site HM023

3.1.1.2 Northern permit area

HM017

HM017 was located in 309 m water depth in the north-west corner of the permit area. The substrate at HM017 was predominantly very silty sand and was slightly undulating (<25 cm in height) with widespread bioturbation. Observed biota included anemones, decapod crustaceans and three types of fish (**Figure 3-5**).

HM022

HM022 was located in 303 m water depth near the northern boundary of the permit area. The substrate at HM022 was predominantly silty sand (**Figure 3-6**) and was slightly undulating (<25 cm in height) with widespread bioturbation. Observed biota included a brittle star, sea pens, decapod crustaceans and three types of fish.

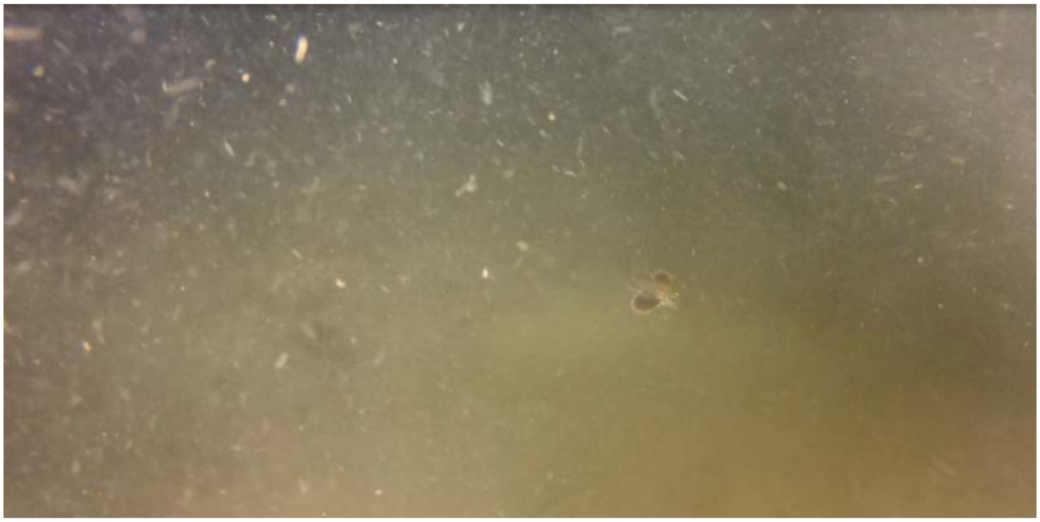


Figure 3-5: Silty sand substrate and a teleost (gurnard - Type L) at site HM017

Figure 3-6: Silty sand substrate with prawn at site HM022

3.1.3 Evans Shoal

HM03 – reef flat

HM03 was located in 28 m water depth in the centre of Evans Shoal (**Figure 3-7**). The substrate was predominantly sand with patchy mixed beds of filter feeders (e.g. sponges and soft corals) and macroalgae. A small bommie was encountered at this site and was covered in hard and soft corals and sponges (**Figure 3-7**), and was inhabited by several taxa of fish including species from families Labridae, (wrasse), Pomacanthidae (damselfish and clownfish), Acanthuridae (surgeonfishes, tangs and unicornfishes), Zanclidae (Moorish idols) and Balistidae (triggerfishes). Small fish (likely Pomacentridae) also inhabited the mixed filter feeder/algal beds. A large leatherjacket (family Monacanthidae) was observed near the sea bed.

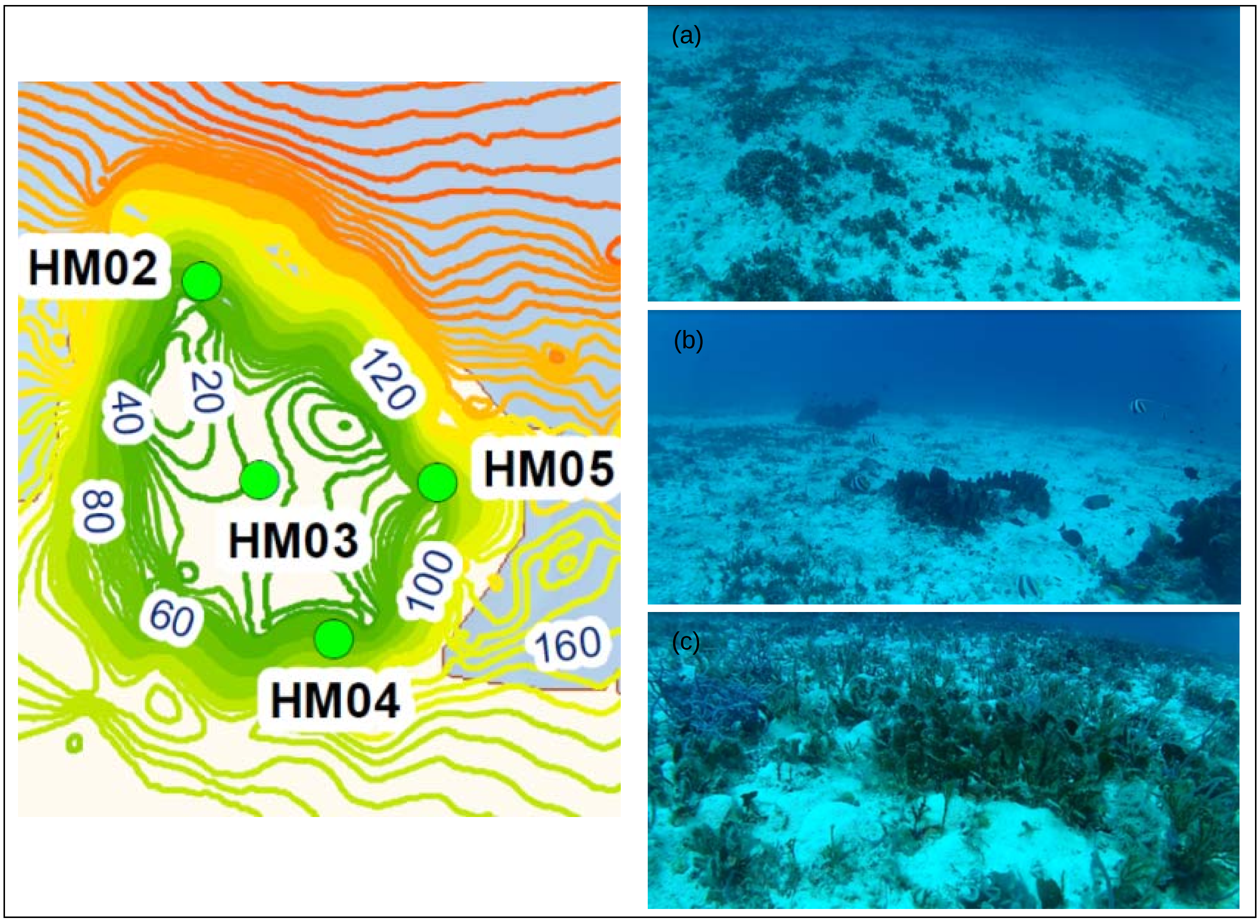


Figure 3-7: Location of sampling site HM03 (left) and indicative habitats comprising (a) sandy substrate with patchy mixed filter feeder/algal beds at HM003, (b) bommie with hard and soft corals, sponges and reef fish and (c) mixed filter feeder and algal beds

HM04 – southern slope

Transects at HM004, south side of Evans Shoal, commenced on the reef flat in 18 m water depth. While the substrate was predominantly sand and rubble, there were areas on the reef flat that had high density coral cover of mostly plate and branching forms (**Figure 3-8**). *Halimeda* spp. (calcareous algae) and soft coral were also recorded. A diverse assemblage of reef fish occurred in these areas and whitetip reef sharks were also observed. The reef crest of the shoal was approximately 32 m deep and was dominated by plate coral (**Figure 3-8**) whereas the upper slope was dominated by sand. At around 42 m water depth, the substrate had nearly 100% cover of plate corals (**Figure 3-8**). At approximately 55 m water depth, the substrate became dominated by macroalgae, including *Halimeda* spp., with scattered sponges and sea cucumbers also present.

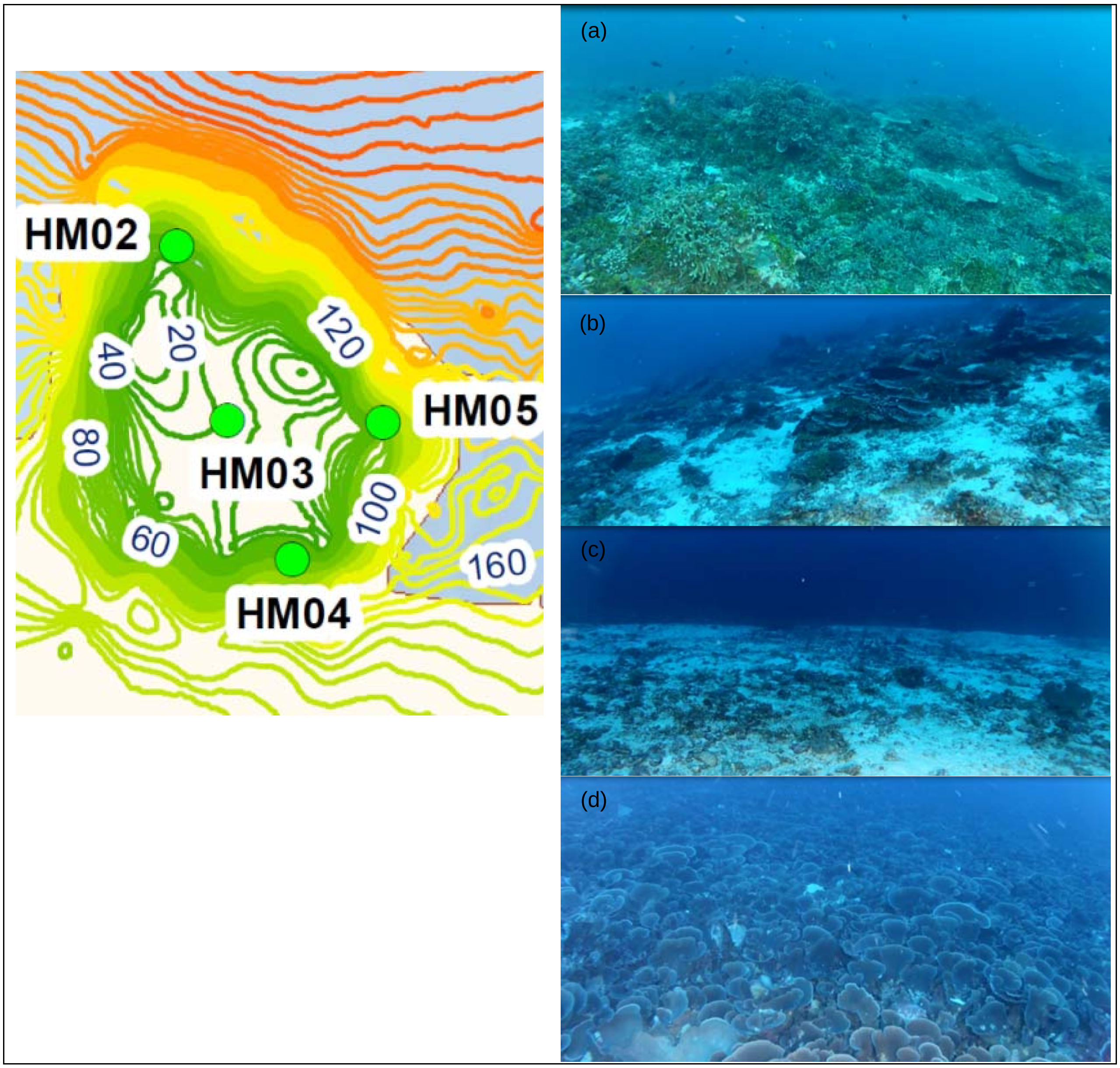


Figure 3-8: Location of sampling site HM04 (left) and habitats observed including (a) reef flat (b) reef crest with plate corals (c) sand, rubble and low-lying epibiota on upper reef slope, and (d) dense plate coral between 42–55 m water depth

HM05

HM05 was located on the eastern slope of Evans Shoal (**Figure 3-9**), with transects starting at approximately 83 m water depth. The submerged reef flat had a predominantly sandy substrate with occasional small macroalgae. Silvertip sharks were observed in this habitat (**Figure 3-9**). The crest of the shoal was approximately 88 m deep and along the edge was a rocky overhang, with various types of filter feeders. The slope itself was quite steep (**Figure 3-9**) and predominantly steep rock faces and rocky overhangs with small sandy ledges. The hard substrate supported filter feeders (such as gorgonians, feather stars, sea whips, sponges) with small reef fish seen in the shelter of the overhangs (**Figure 3-9**).

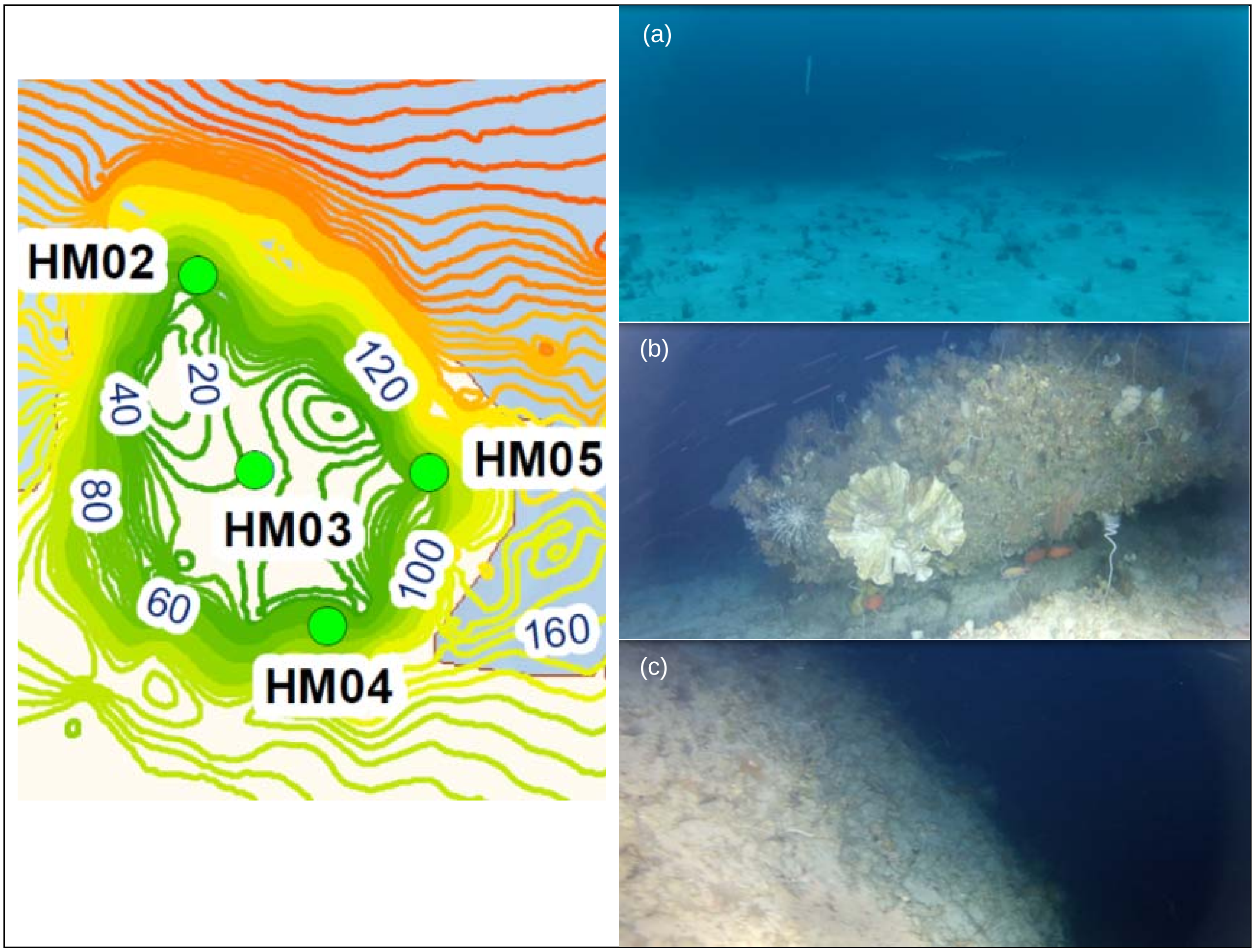


Figure 3-9: Location of sampling site HM05 (left) with habitats at this site found to include (a) sandy upper slope with silvertip shark (b) large boulder on reef slope with soft corals, feather stars, sea whips and squirrel fish, and (c) an example of the steep reef slope profile

HM02 – northern slope

HM02 was located on the northern slope of Evans Shoal (**Figure 3-10**), with transects starting at approximately 45 m water depth. The submerged reef flat alternated between areas dominated by plate coral, sub-massive coral (**Figure 3-10**) and macroalgae (including *Halimeda*) with sponges. Whitetip reef sharks and one tawny nurse shark were observed on the reef flat as were representatives from the fish families Labridae, Pomacentridae and Pomacanthidae. Small discrete piles of rubble were observed and were likely to be triggerfish nests. The crest of the shoal was approximately 80 m deep and was colonised by sponges, filter feeders and algae. The slope was predominantly rock and was reasonably steep and interspersed with small sand-covered ledges (**Figure 3-10**). The hard substrate of the slope supported communities dominated by sponges and filter feeders (such as gorgonians, feather stars, sea whips, sponges). One moray eel (Muraenidae) (**Figure 3-11**) and various species of fish were observed in the rocky overhangs. Representatives of fish families Chaetodontidae (butterflyfish), Carangidae (queenfishes, runners, scads and trevallies), Caesionidae (fusiliers), Serranidae (groupers and reef cod) and Holocentridae (squirrelfish) were also observed close to the reef slope. The slope profile shallowed into a sandy flat at approximately approximately 130 m water depth.

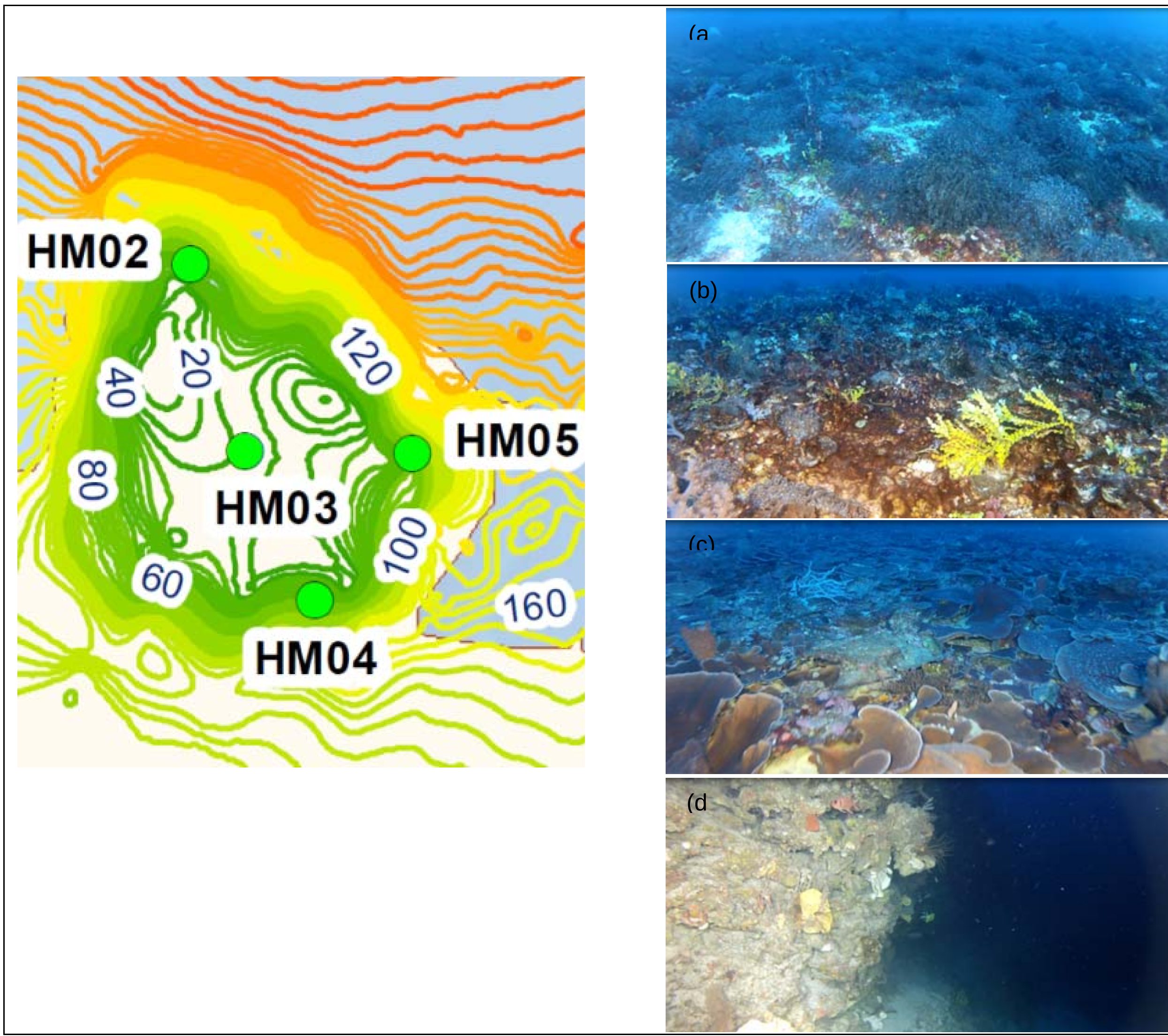


Figure 3-10: Location of sampling site HM02 (left) with representative habitats including (a) hard coral (*Goniopora* with tentacles out) on the reef flat (b) macroalgae and filter feeders on the reef flat (c) plate coral on reef flat and (d) steep rocky slope dominated by sponges and soft corals/filter feeders, with squirrelfish and a sandy ledge below

Figure 3-11: Moray eel in rocky overhang surrounded by sponges and gorgonians on reef slope at site HM02

3.1.4 Tassie Shoal

HM06 – reef top transect

HM06 was located on the submerged reef flat of Tassie Shoal in approximately 15 m water depth (**Figure 3-12**). The substrate consisted of sand, rubble and patchy reef structure. The reef structure was dominated by massive, sub-massive, plate and branching coral forms, and the hard substrate supported a range of sea whips, soft corals, *Halimeda* spp., turf algae and sponges. Feather stars, large clams and a decapod crustacean were recorded. A diverse range of tropical fish species were sighted including representatives from the families Labridae, Pomacentridae, Zanclidae, Pomacanthidae and Acanthuridae.

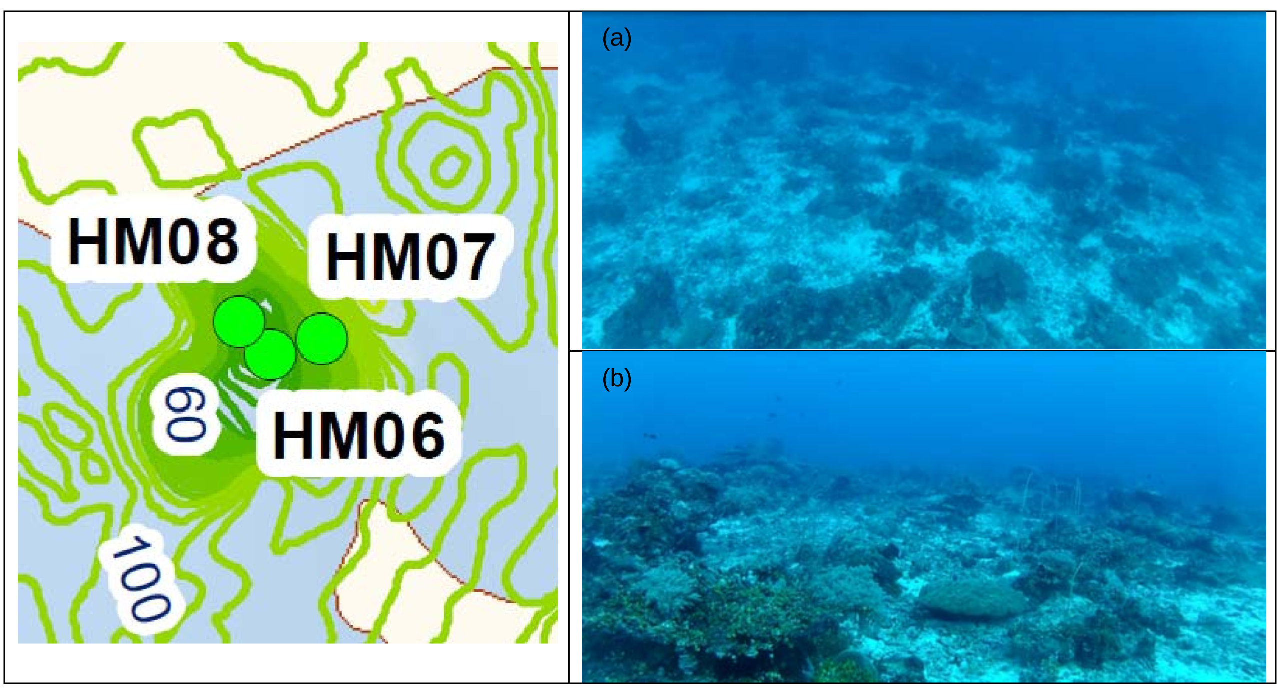


Figure 3-12: Location of sampling site HM06 (left) and images of (a) sand rubble substrate with patchy coral cover and (b) close up of substrate showing hard corals, soft corals, sea whips and *Halimeda* algae

HM07 – eastern slope

HM07 was located on the eastern crest and slope of Tassie Shoal, with the transect commencing in approximately 28 m water depth (**Figure 3-13**). The reef crest was dominated by hard coral, soft coral and sponges. *Halimeda* spp. were also observed, Butterfly fish (family Chaetodontidae), sea snakes and schools of Acanthurids (**Figure 3-13**) and Carangids were observed on both the reef flat and upper slope. The top of the reef slope (30–50 m) was dominated by sponges and soft corals, such as gorgonians and sea whips. A sea snake and a whitetip reef shark were observed at the bottom of the slope at around 48 m. At approximately 50 m the substrate became dominated by sand and rock and at 70 m began to flatten out and become dominated by sand.

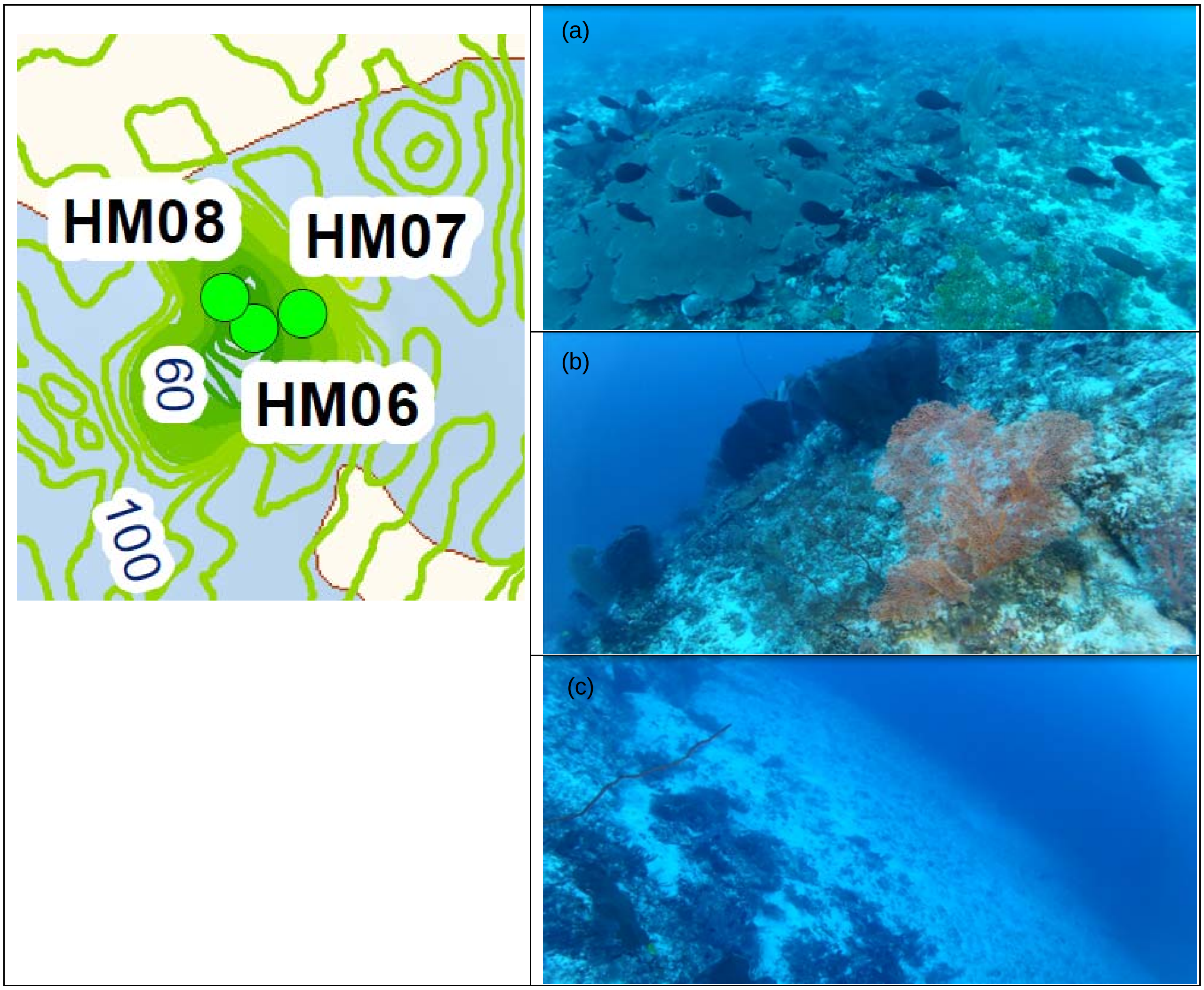


Figure 3-13: Location of sampling site HM07 (left) and images of (a) schools of Acanthurids (b) steep reef profile and predominantly hard substrate with soft corals (gorgonians) and sponges (c) sandy slope with patchy hard corals, whip corals and other filter feeders

HM08 – reef flat

HM08 was located on the submerged reef flat of Tassie Shoal in approximately 15 m water depth (**Figure 3-14**). The substrate was predominantly sand and rubble with hard corals (mostly comprised of plate, branching and massive forms) present although coral cover at this site was noticeably lower than at HM06. The hard substrate also supported a range of sponges, soft corals and *Halimeda* spp., and turf algae were seen growing on dead coral. The types of fish observed at this site appeared to be smaller, site attached fish. Two whitetip reef sharks were also observed.

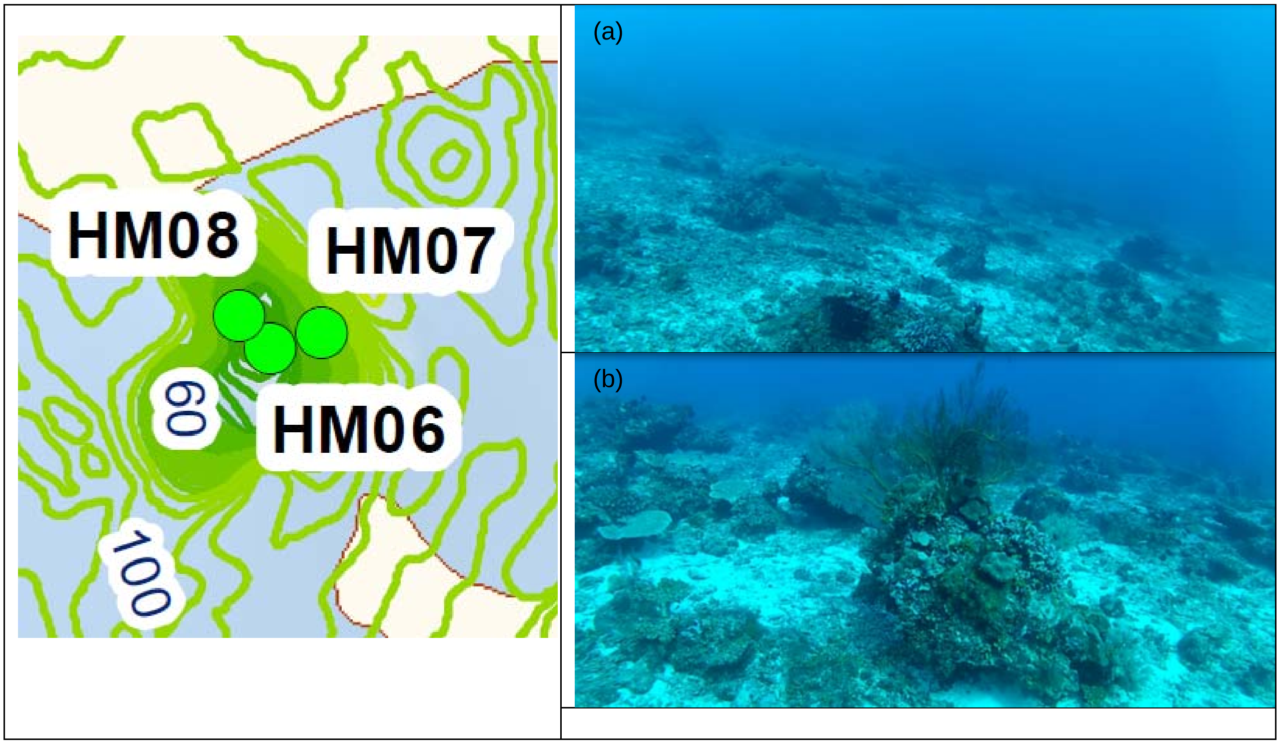


Figure 3-14: Location of sampling site HM08 (left) and images of (a) sand and rubble substrate with hard and soft corals and (b) close up of a coral bommie showing hard and soft corals (gorgonians)

3.1.5 Lynedoch Bank

HM024 – western slope

HM024 was located on the western slope of Lynedoch Bank, with the transect starting on the reef flat in approximately 20 m water depth (**Figure 3-15**). The reef flat was predominantly sand and rubble with hard corals (mostly branching, encrusting and massive forms), sponges and *Halimeda* spp. present. Small triggerfish (Balistidae) were common and sharks (most likely silvertip and whitetip reef sharks) were observed in the periphery of the frame (making identification of some individuals difficult). The reef crest was in approximately 40 m water depth and the slope was again dominated by sand and rubble, with occasional sponges, sea stars, sea cucumbers, and reef fish (Pomacanthidae) (**Figure 3-16**, **Figure 3-17**). The slope flattened out at approximately 70 m deep and became dominated by sand.

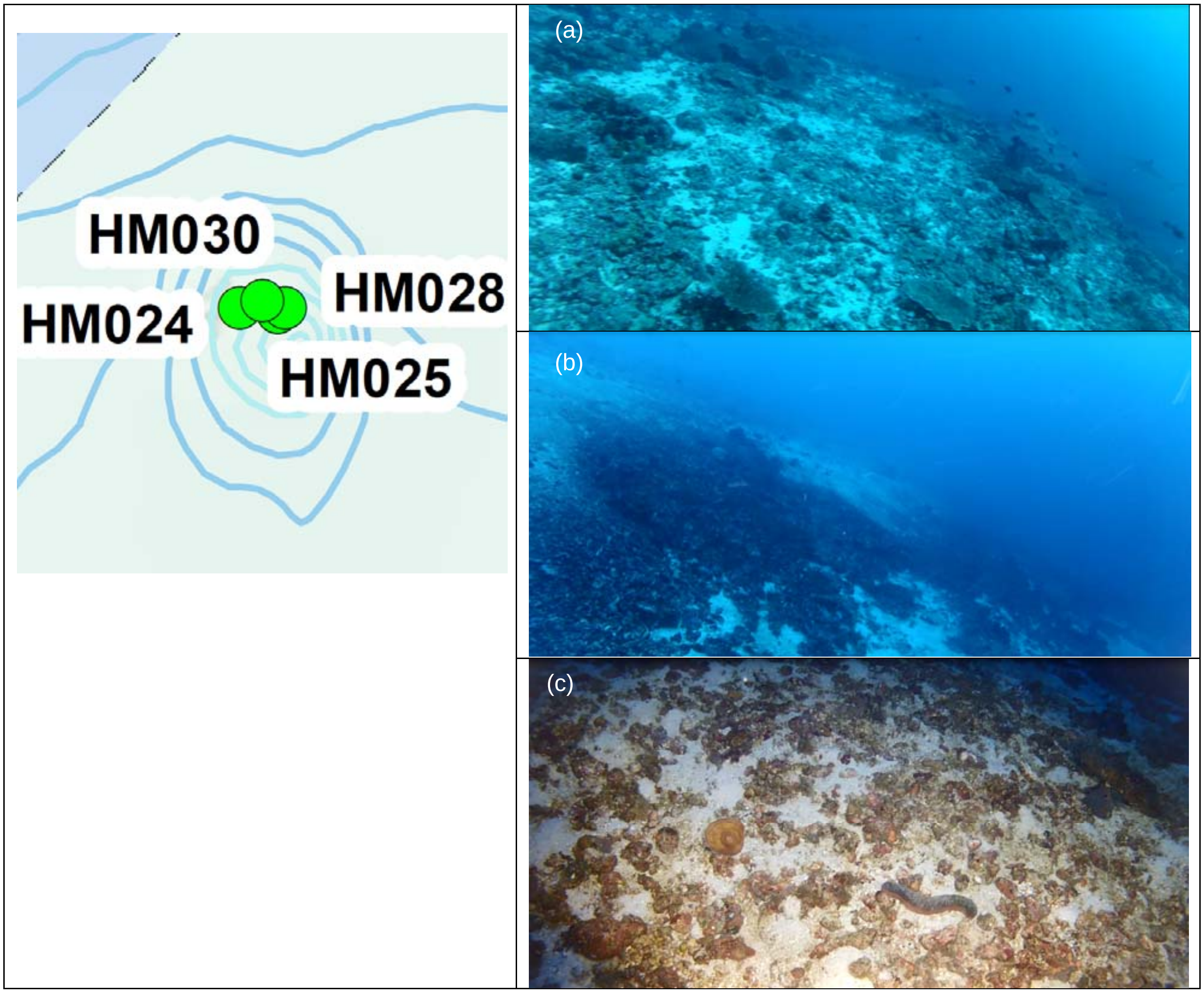


Figure 3-15: Location of sampling site HM024 (left) and images of (a) triggerfish and silvertip shark on reef flat (b) reef slope dominated by sand and rubble and (c) sand/rubble bottom with encrusting coralline algae and bryozoans, sponge and sea cucumber

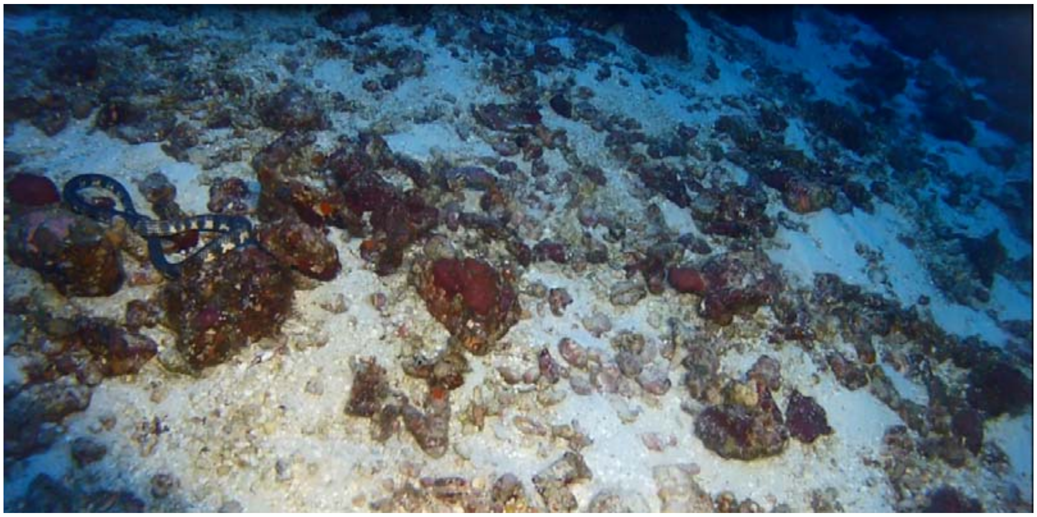


Figure 3-16: Sea snake on slope at site HM024

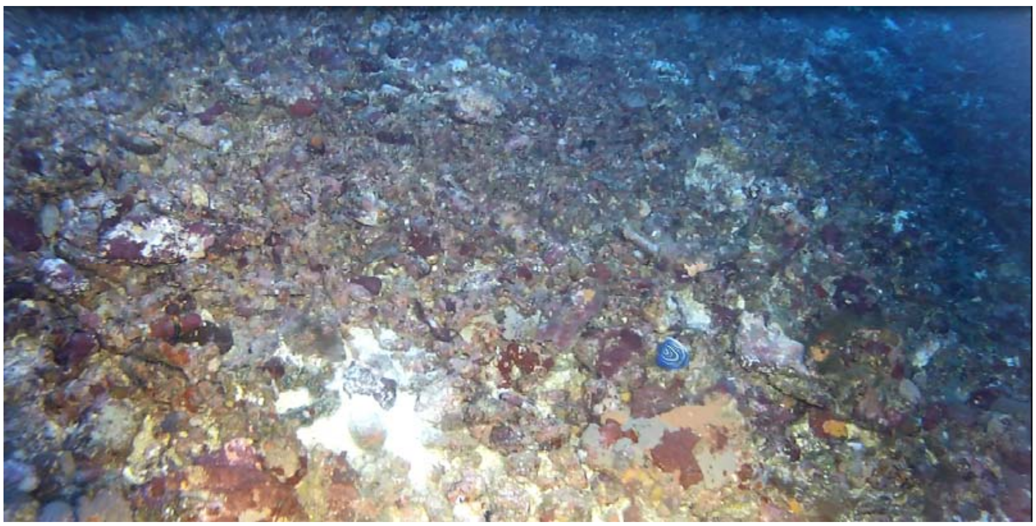


Figure 3-17: Juvenile angelfish on slope at site HM024

HM025 – reef flat

HM025 was located on the submerged reef flat of Lynedoch Bank, in approximately 16 m water depth (**Figure 3-18**). The reef flat was predominantly sand and rubble with hard corals (mostly branching, massive and sub-massive), sponges, soft coral and *Halimeda* spp. present. Small reef fish were common including representatives of the families Chaetodontidae, Labridae and Zanclidae. Whitetip reef sharks, a sea snake and a moray eel were also observed.

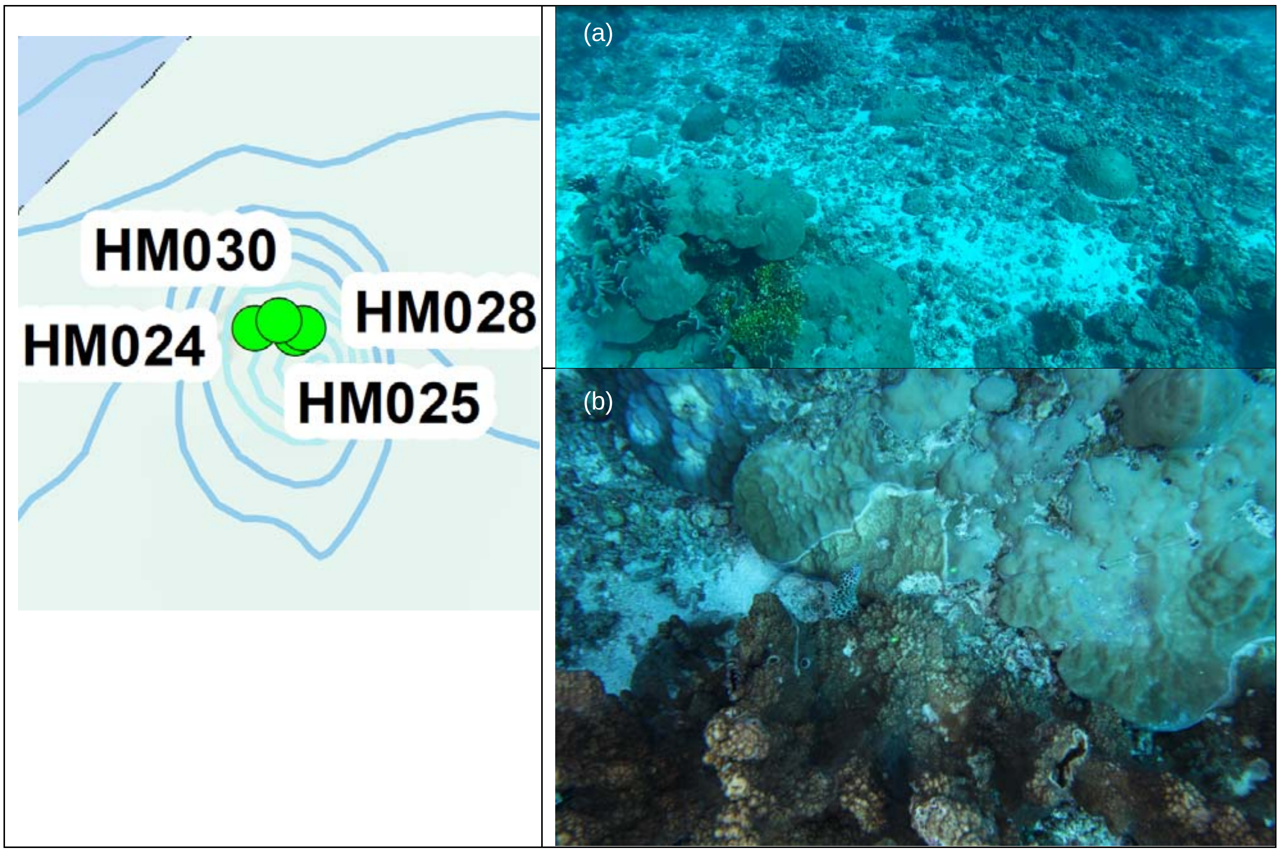


Figure 3-18: Location of sampling site HM025 (left) and images of (a) patchy sand and rubble with hard corals (branching, massive and sub-massive forms), sponges and *Halimeda* spp. and (b) moray eel in hard coral habitat

HM028 – eastern slope

HM028 was located on the eastern slope of Lynedoch Bank, with the transect starting on the reef flat in approximately 26 m water depth (**Figure 3-19**). The reef flat was predominantly sand and rubble with hard corals (mostly branching, encrusting and massive forms) and soft corals present. The reef sloped gently to a depth of approximately 85 m. The slope was predominantly sand and rubble and there was a noticeable low abundance of fish, sharks and other motile biota.

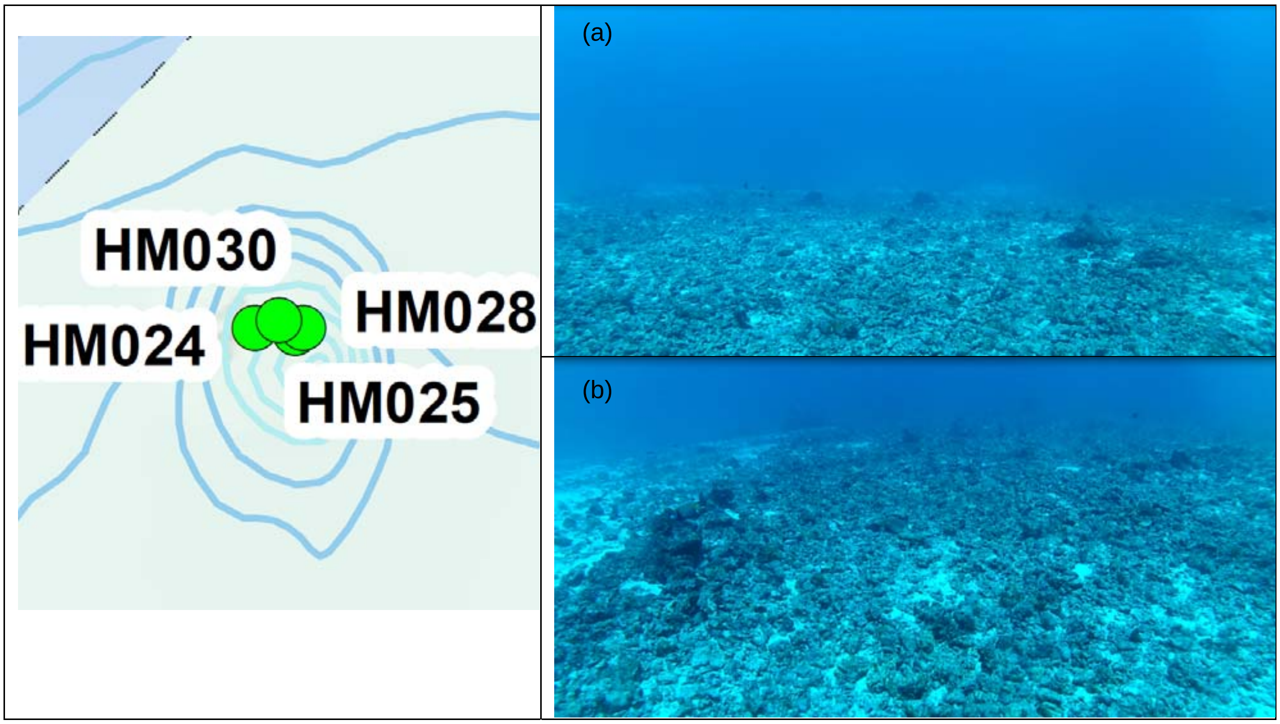


Figure 3-19: Location of sampling site HM028 (left) and images of (a) sand/rubble slope with whitetip reef shark and (b) sand/rubble slope with angelfish

HM030 – reef flat

HM030 was located on the submerged reef flat of Lynedoch Bank, 500 m north-west of HM025 in approximately 16 m water depth (**Figure 3-20**). The substrate on the reef flat was sand and rubble with hard corals (mostly branching and sub-massive forms), sponges and *Halimeda* spp. present. Small triggerfish were common as were other small reef fish including representatives of the families Chaetodontidae, Labridae and Zanclidae. Whitetip reef sharks were also observed.

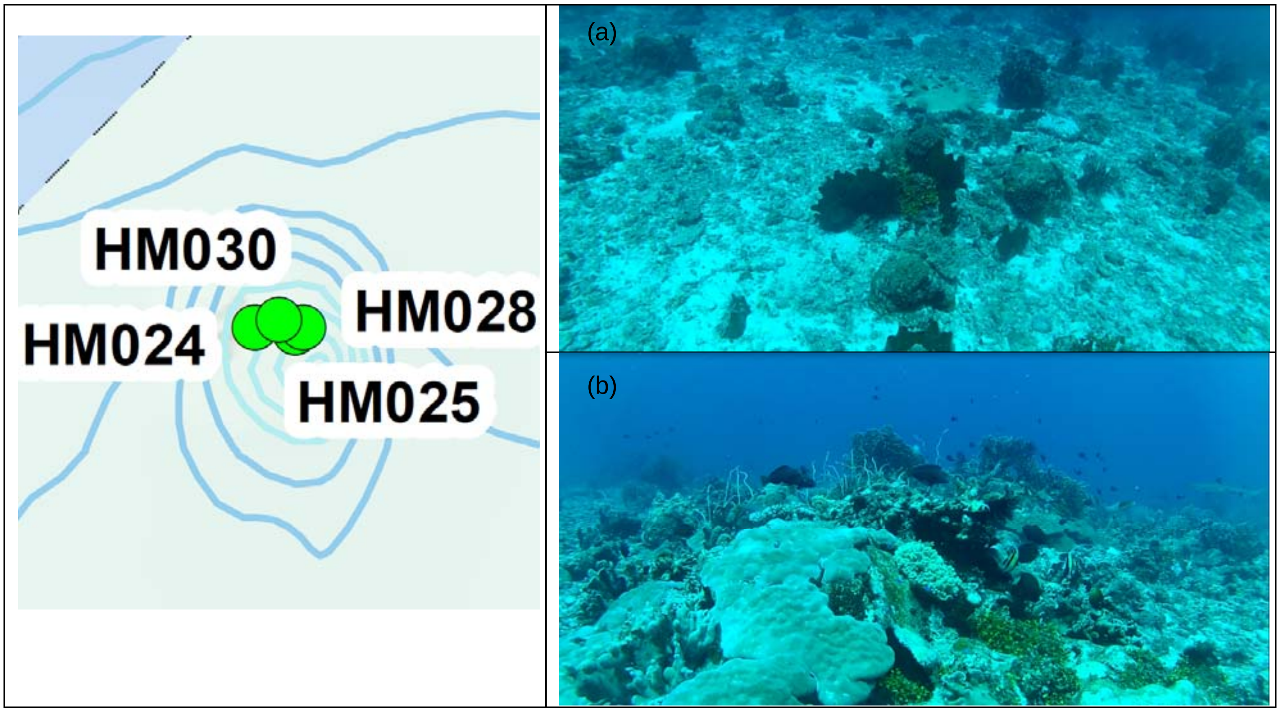


Figure 3-20: Location of sampling site HM030 (left) and images of (a) hard substrate with rubble and a coarse sand veneer with outcrops of hard and soft corals on the reef flat, and (b) hard and soft coral substrate with *Halimeda* sp. algae, reef fish and a whitetip reef shark

3.1.6 Seamounts (west of the permit area)

HM010A

HM010A was located on the south-eastern slope of a seamount approximately 35 km west of the permit area (**Figure 3-21**). The transect started in approximately 77 m water depth and ended at a depth of approximately 170 m. The substrate at the top of the transect was predominantly sand and rubble, with the occasional sea whip and holothurian. Numerous silvertip sharks were observed in this area to a depth of approximately 100 m. The edge of the seamount occurred at approximately 100 m depth. Small discrete piles of rubble were observed and were likely to either be fish nests or as a result of tidal/current action. Gorgonians, sea whips and other soft corals were also recorded. The slope was rock with small patches of sand deposits and sponges and soft corals occurred on the hard substrate. Individual and schools of fish were very common on the slope including representatives of the families Acanthuridae, Lutjanidae, Caesionidae, Serranidae and Zanclidae. At around 130 m depth, a large grey nurse shark with a wide girth was observed, which may have indicated a pregnancy. Three other grey nurse sharks (including at least one male) were also observed cruising back and forth to a depth of approximately 160 m (**Figure 3-21**). The transect ended in sand with large boulders that supported sponges and hard coral.

Figure 3-21: Location of sampling site HM010A (left) and images of (a) piles of rubble potentially from fish nests or tidal /current action, (b) grey nurse shark, and (c) school of trevally (family Carangidae)

HM010B

HM010B was located on the top of the same seamount as HM010A, in approximately 77 m water depth (**Figure 3-22**). The top of the seamount was sand and algae-covered rubble with soft corals and sponges also present. Small triggerfish were very common as were schools of Caranigae and Lutjanidae. Representatives of the families Labridae, Pomacentridae and Zanclidae as well as silvertip sharks were also observed.

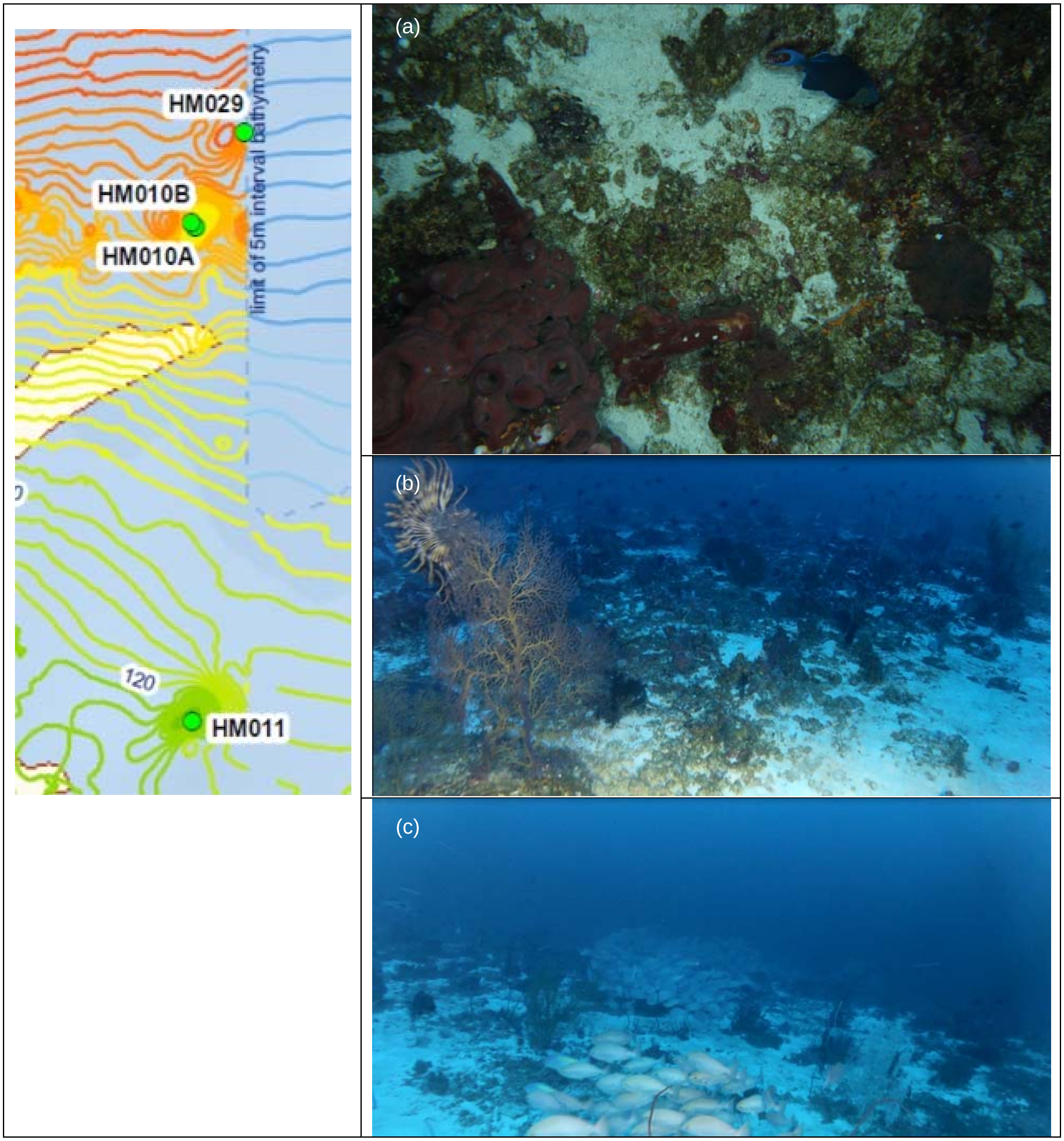


Figure 3-22: Location of sampling site HM010B (left) and images of (a) triggerfish, (b) substrate with soft coral (gorgonians) and feather star, and (c) school of Lutjanidae

HM029

HM029 was located on the eastern slope of a seamount, 6 km north-north-east of HM010A (**Figure 3-23**). The transect started in approximately 80 m water depth and the substrate was predominantly sand, rubble and algae with the occasional sea whip, sponge, soft coral and sea cucumber. Small triggerfish (family Balistidae) were observed in areas with rubble. Gorgonians begin to appear at approximately 90 m water depth, and this habitat continued to the reef edge in approximately 100 m water depth. The slope had a rocky face with coarse sand deposits, with the hard substrate supporting sea whips, sea fans, other soft corals and sponges. At approximately 130 m water depth a school of trevally (family Carangidae), members of the Lutjanidae family and a silvertip shark were recorded. A nautilus shell was found at 178 m depth. At 190 m water depth the substrate was sand with an occasional large boulder. Representatives of the Holocentridae family were observed on these boulders. A small ray was also observed in the sand at 220 m water depth where the transect concluded. It is estimated from the vessel sounder that the seamount continued to a depth of 260 m.

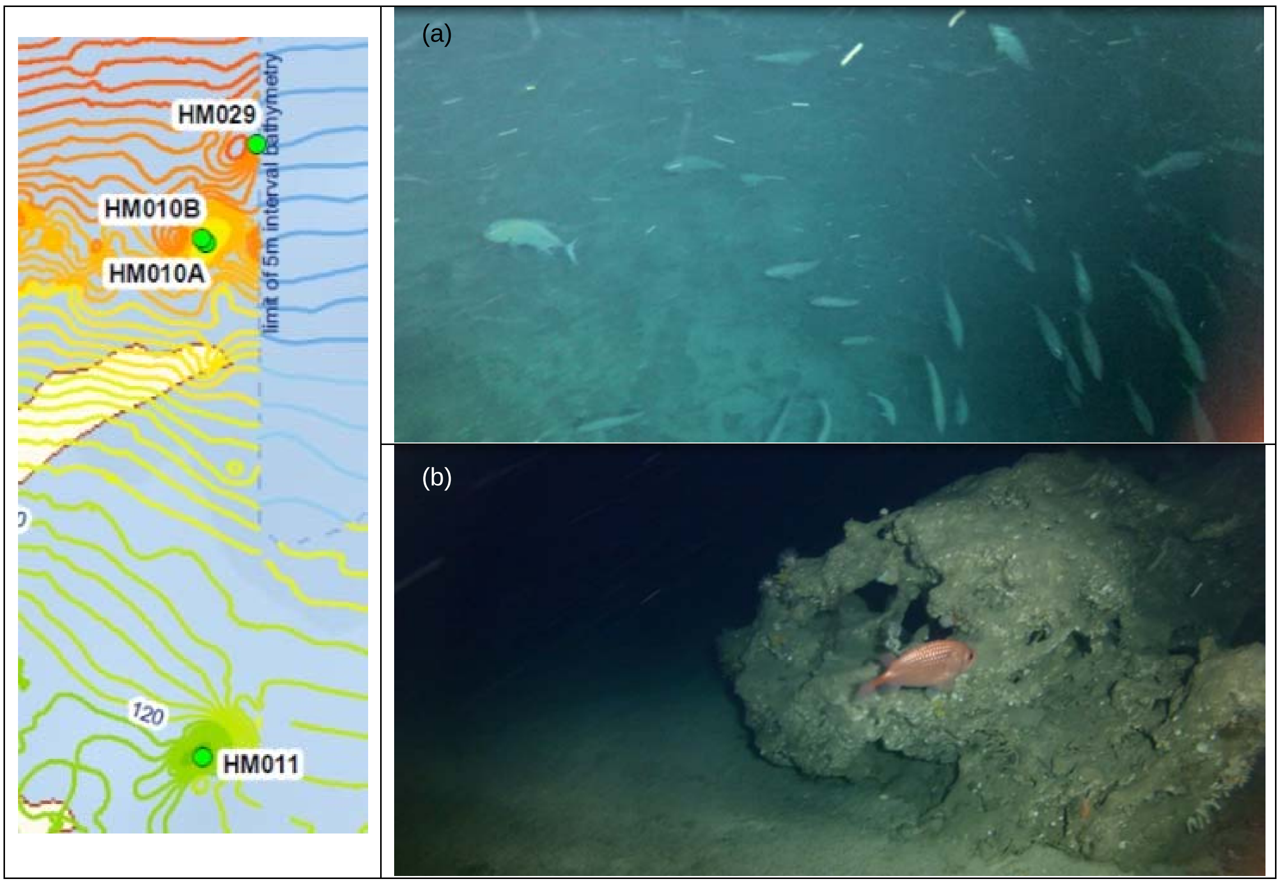


Figure 3-23: Location of sampling site HM029 (left) and images of (a) school of trevally and (b) a squirrel fish (family Holocentridae) near boulders at the base of the slope

HM011

HM011 was located on a seamount, 28 km east of Tassie Shoal (**Figure 3-24**). The top of the seamount was in approximately 50 m water depth and was predominantly sand, rubble, algae and soft coral. Large circular areas were recorded where surface rubble had been removed exposing the sand and clean coral rubble beneath. These appeared to be nests made by trigger fish. Nests were excavated reasonably close together and over a large area, with trigger fish were observed in the vicinity. A silver tip shark and a sea snake were also observed. The lower section of the slope was mostly rock ledges and sand patches, with sea whips, filter feeders and sponges present. Larval or juvenile fish were observed on the edge of the rock ledges at 78 m and 85 m.

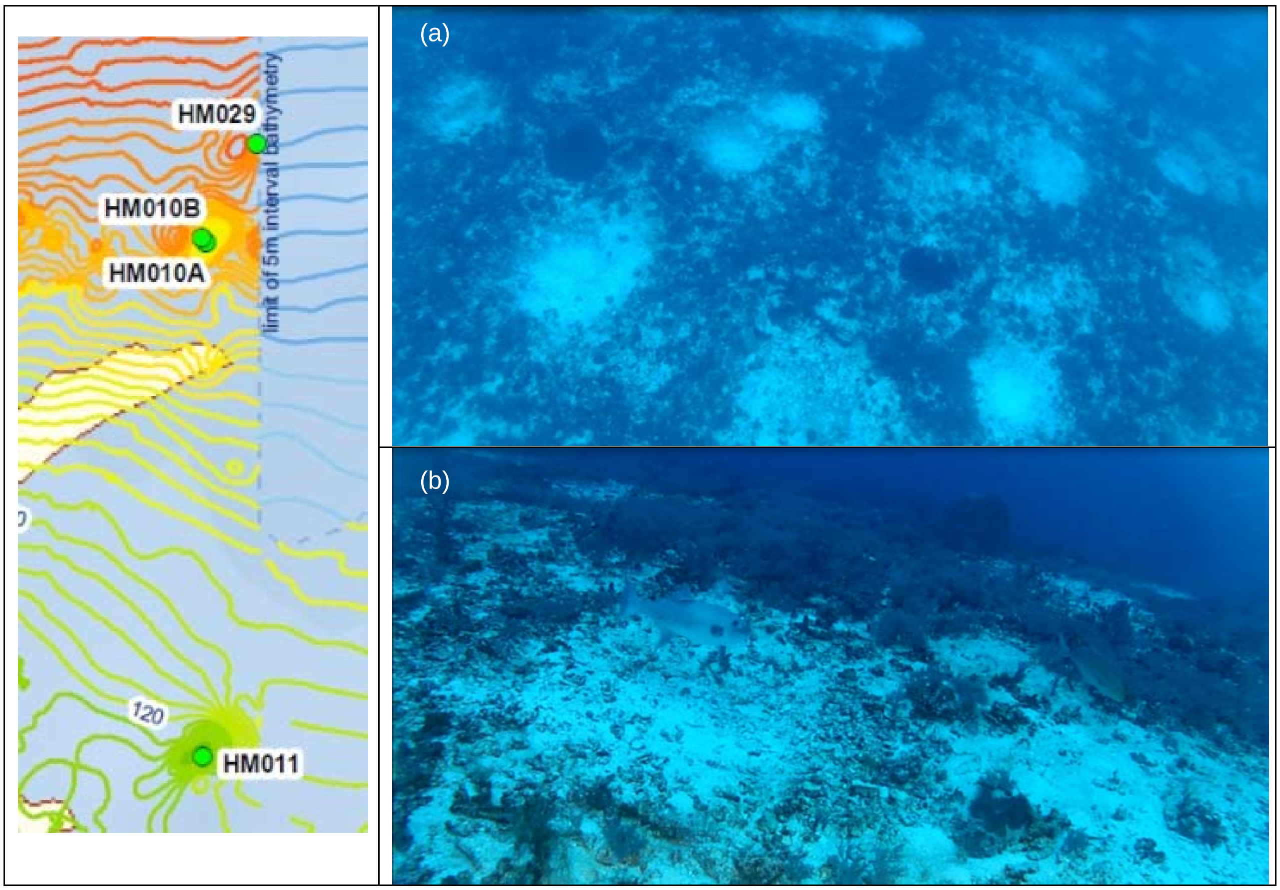


Figure 3-24: Location of sampling site HM011 (left) and images of (a) distribution of triggerfish nests and (b) close up of triggerfish near the nests

3.1.7 Scarps (south of the permit area)

HM019

HM019 was located on a scarp feature 10 km south of the permit area (**Figure 3-25**). The scarp ran in a north-south direction with the shallower side of the scarp (western side) in approximately 160 m water depth and the deeper side of the scarp (eastern side) in approximately 185 m water depth. The higher side appeared to be unbroken rock covered in silty sand and hydroid/bryozoan turf. Gorgonians, sea whips and other filter feeders and sponges were reasonably common on this substrate. The scarp profile was rock boulders and consolidated shell grit and sediment. Feather stars, gorgonians and other filter feeders were present on the slope. The lower side of the scarp was predominantly sand. One deep water snapper species (possibly gold band snapper) was observed in a rocky overhang at the base of the slope and small silver fish and one ray were observed on the sand flat.

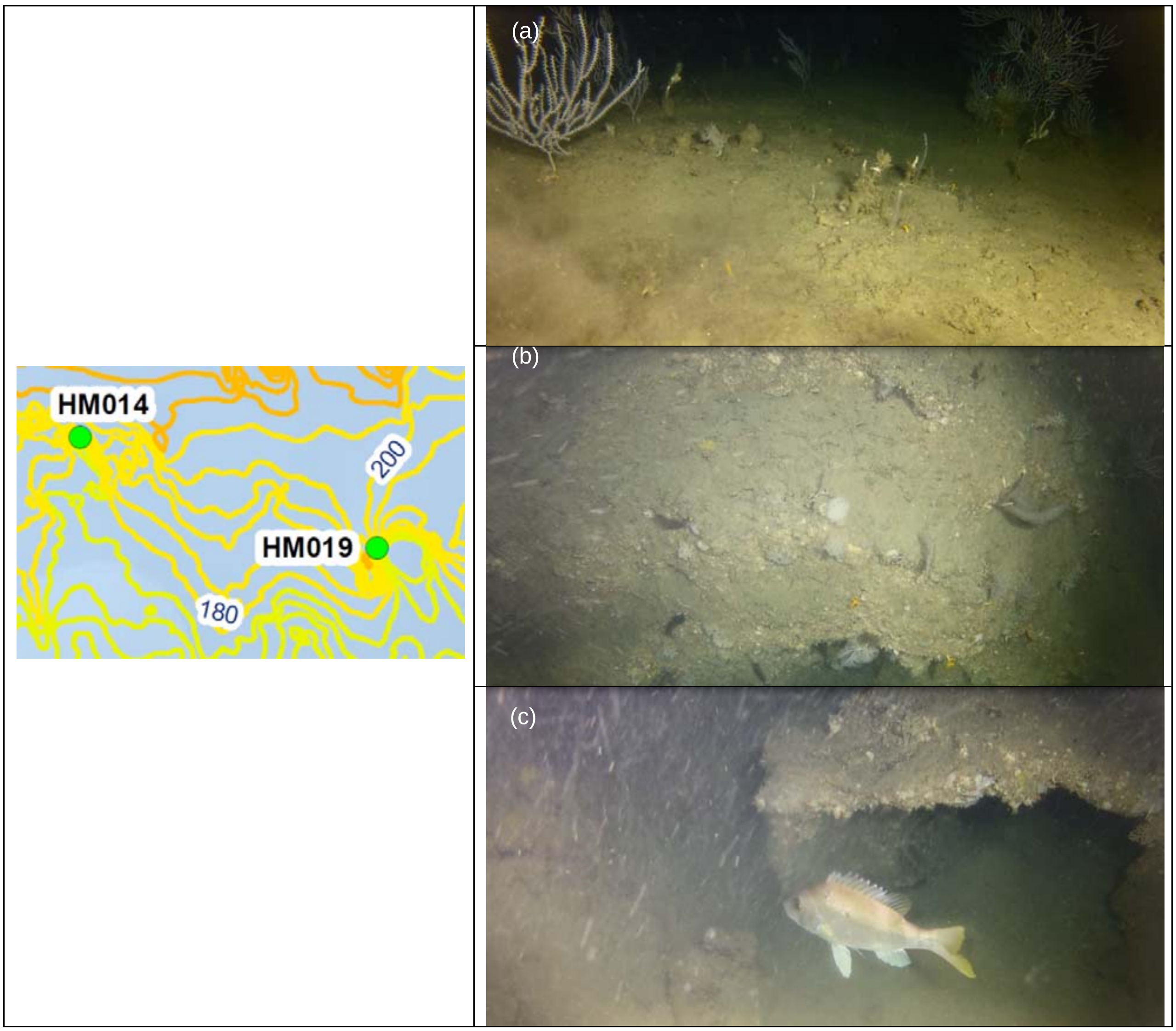


Figure 3-25: Location of sampling site HM019 (left) and images of (a) rocky substrate covered with silty sand with gorgonians and other filter feeders on the high side of the scarp, (b) rocky scarp profile with filter feeders, and (c) deepwater representative from family Lutjanidae in rocky overhang and base of scarp

HM014

HM014 was located on another scarp feature approximately 5 km south of the permit area and 13 km west of HM019 (**Figure 3-26**). The scarp ran in a north-westerly to south-easterly direction with the bottom of the scarp in 190 m water depth. The slope here appeared to be shorter than at HM019 (2–4 m), although the substrate and biota were very similar to that observed at HM019. The shallower side of the scarp (south-western side) appeared to be unbroken rock covered in silty sand and hydroid/bryozoan turf with gorgonians, feather stars and other filter feeders common on this substrate. The scarp profile was comprised of rock boulders and consolidated shell gravel and finer particulate sediment. Feather stars, gorgonians and other filter feeders also appeared on the slope. The deeper side (north-east) of the scarp was predominantly sand.

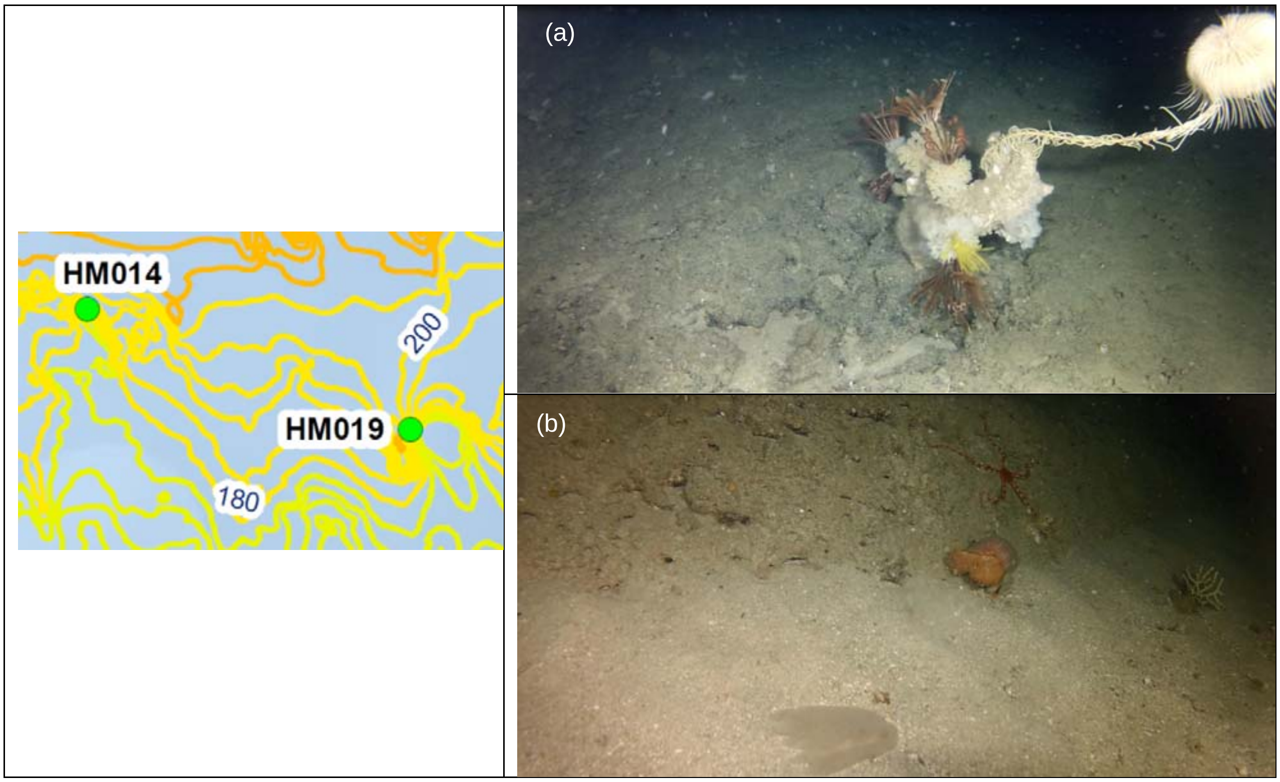


Figure 3-26: Location of sampling site HM014 (left) and images of (a) feather stars on soft coral and (b) crinoid, soft coral and hermit crab at bottom of scarp

3.2 Multidimensional scaling results

MDS was performed on the presence/absence data to determine the similarity between habitats. Raw presence/absence data are provided in **Appendix B**.

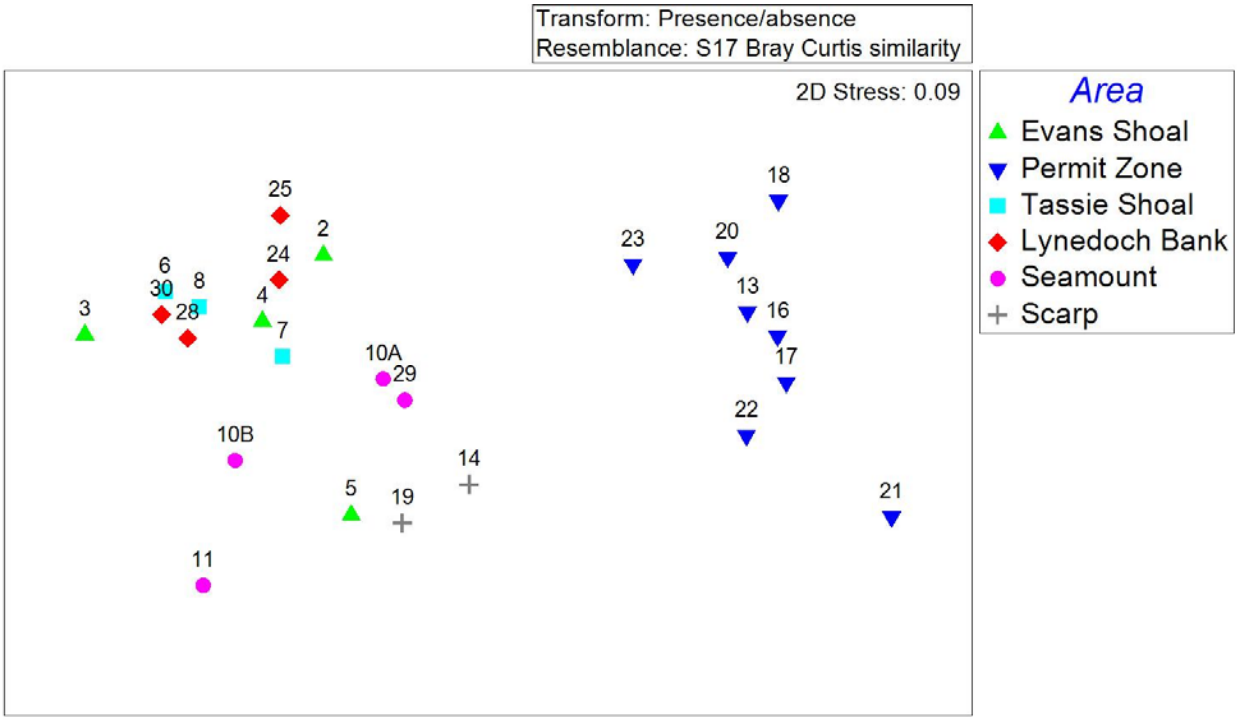


Figure 3-27: MDS plot of sampling sites

The MDS plot (**Figure 3-27**) shows that the sites in the permit area were grouped closely together and away from other sites. This indicates that the permit area sites were similar to each other, but relatively different to the other sites. This is most likely due to the depth and substrate type of these sites. The permit area sites were all deeper than 200 m and the substrate type was predominantly silty sand. The other sites were not clustered as closely together as the permit area sites, indicating more variation among these sites. The shoals and bank sites were generally similar, most likely due to similarities in depth and structure type, meaning reef habitat and biotic assemblages on the reef flats and slopes were reasonably similar. The seamounts and scarps sites appeared to group out separately and potentially due to the depths they occurred at and that they lacked the reef top communities of the banks and shoals (again due to water depth). The eastern slope of Evans Shoal (site HM05) appeared to be more similar to the scarps and seamounts. This slope was noticeably sparser and lacked the diversity in habitats and biota observed on the other slopes, again potentially due to the deeper depth at which this transect started.

4. Discussion

The benthic habitat survey aimed to characterise the distribution of benthic habitats and biota in the immediate vicinity of the Barossa field, from across the broader region, and from areas of regional interest including shoals and banks and areas with complex topography. Sites surveyed ranged in depth from around 10 m–30 m on top of shoals and banks through to 309 m at the deepest site in the permit area.

Three main groupings of benthic habitat types were identified in the MDS plot; the permit area; the banks and shoals; and the seamounts and scarps.

The permit area is located on a plain in 200 m–300 m of water. This area represents the least complex geomorphic features of the Joseph Bonaparte Gulf and the Timor Sea, comprising homogenous flat, soft sediments (Przeslawski et al. 2011). The seabed observed in the permit area was predominantly silty sand lacking in any hard substrate, with relic sea bed features (namely sand waves <25 cm in height) widespread. Due to the lack of hard substrate, the associated epibenthos was expected to be sparse. Fauna groups included octocorals (particularly sea pens) and motile decapod crustaceans (mostly prawns and squat lobsters) and were observed in relatively low numbers. However, it must be noted that bioturbation (burrows, mounds and tracks) was frequently recorded, and many burrow-living decapods (such as prawns) may be more active at dawn, dusk or at night in habitats which lack cover (Taylor and Ko 2011) and hence less likely to be recorded during daylight surveys. These results are similar to those reported in comparable offshore surveys. Surveys around the Greater Poseidon Field in the Browse basin (Jacobs 2013), approximately 970 km south-west of the permit area and in 450 m–550 m water depth, found the substrate was flat, silty sand and that epibenthic macroinvertebrates such as crinoids, filter feeders and decapod crustaceans were common. Surveys for the Sunrise Gas Project (Sinclair Knight Merz 2001), approximately 200 km north-west of the permit area and in 160 m water depth, found that epifauna were sparse and were predominantly comprised of hydroids, sponges and crinoids.

Given the lack of topographic features in the permit area, fish abundance was expected to be low in this survey. Conversely, approximately 20 types of teleost fish were observed within the permit area in varying densities and diversities across the sites. The Greater Poseidon survey (Jacobs 2013) recorded only ten types of teleosts, which may have been a function of the deeper bathymetry or potentially the amount of food sources available (of which bioturbation is one indicator). Prior to this survey, not much was known about the habitat and biota of the permit area. However, based on the bathymetry and expected geomorphological features of the permit area and in comparison with surveys conducted across the wider region, the habitat and biota observed within the permit area was generally as expected. The MDS plot showed that the permit area sites were considerably different from all of the other sites surveyed based on the less diverse habitat features and biota present at these sites.

The shoals to the west of the permit area (Evans Shoal and Tassie Shoal) and the shallow bank to the east (Lynedoch Bank) were expected to be similar in habitat and biota type to other submerged shoals and banks in the broader area. The MDS plot showed that the shoals and bank sites were very similar to one another, likely due to the similar depths at which these features occurred, as well as the consistent substrate type. One exception to this was the eastern slope of Evans Shoal, which was more similar to a scarp feature, most likely due to the depth where this feature occurred, and possibly also due to greater exposure to predominant currents and weather. The substrate on the reef flats was generally sand and algae-covered rubble with communities dominated by hard corals, soft corals and sponges which were present in varying degrees of diversity and abundance. Gorgonians and sea whips often dominated the crests, whereas the hard substrate of the slopes predominantly supported sponges and filter feeders (such as gorgonians, feather stars, sea whips). Of particular note were the northern and southern slopes of Evans Shoal; both slopes supported large areas of dense plate coral (at 40 m–50 m water depth) and the northern slope also supported large areas of dense sub-massive coral in approximately 47 m water depth. These slopes supported a diverse range of fish species typical of reef fish assemblages (families Pomacentridae, Pomacanthidae, Chaetodontidae, Labridae Zanclidae and Ballistidae) as well as pelagic species (families Carangidae and Caesionidae). Whitetip reef and silvertip sharks were also observed at a number of sites. Similarly, Heyward et al. (1997) found some banks of the Big Bank Shoals to be coral-dominated systems with a reefal structure and that as many as 200 species of fish may inhabit each hectare of coral reef in the shoals. In a 2011 GeoScience Australia (GA) survey, raised geomorphic features were found to support sponge and octocoral gardens that in turn provided habitat for other fauna (Przeslawski et al. 2011) and reef-forming hard corals were found on the banks of the Van Diemen Rise (approximately 100 km south-west of the permit area) but were rare in other areas surveyed. These hard coral communities were often dense (up to 90% cover) but overall cover was very low (<1%), whilst octocorals were found to be a major habitat forming taxa on the seafloor across all surveyed sites (Przeslawski et al. 2011). The corals found on the GA survey were diverse and potentially distinct from those found elsewhere in northern Australia and included five species that were on the International Union for Conservation of Nature (IUCN) Red List (considered near threatened, vulnerable and endangered) (Przeslawski et al. 2011). Analysis of the stills images captured during the Barossa benthic habitat survey may be useful to provide robust comparative data on the community composition and cover estimates for comparison with other surveys undertaken in the area. It may also be feasible from the image analysis to determine whether these banks and shoals contain threatened coral species.

The habitat and biota of the seamounts and scarps in the study area were previously unsurveyed. The tops of the seamounts were generally in 50 m–80 m water depth and the substrate was predominantly sand and rubble. The hard substrate of the slope supported epibenthic communities dominated by sponges and filter feeders (such as gorgonians, feather stars, sea whips). Of particular note, at one seamount (HM010A) four grey nurse sharks were observed in approximately 130 m water depth including at least one female that appeared to be pregnant. This was considered unusual as neither the east or west coast populations are known to extend that far north and are generally associated with shallower, more coastal waters (DoE 2015). However, a recently published paper recorded four grey nurse sharks (three female, one male) being caught in the vicinity of Browse Island (offshore Western Australia) and describe the catch as the first known from the Timor Sea (Momigliano and Jaiteh 2015). It is unknown whether the individuals observed during this survey would be linked to the east (listed as critically endangered) or west coast (listed as vulnerable) populations, or another discrete population. Internationally, the species is listed as vulnerable in the IUCN Red List of Threatened Animals (IUCN 2015).

Triggerfish nesting areas were apparent at the seamounts, and the triggerfish appeared to make depressions in the sand and rubble at the top of the southernmost seamount surveyed. Triggerfish were observed in and around these depressions. At a seamount directly west of the Barossa field (HM010A), small, discrete piles of rubble had been accumulated that also may have been fish nests or as the result of tidal/current movement. These piles were also observed on the northern slope of Evans Shoal. The seamounts also appeared to support schools of fish (predominantly from families Lutjanidae, Carangidae and Caesionidae) both on the top of the seamount and at depth. Goldband snapper individuals were tentatively identified at depth at seamount sites, with one individual also observed at the scarps south of the permit area.

The MDS plot showed that the seamount and scarp sites were not as similar to one another as the shoals and bank sites, but this was likely due to the deeper depth of these sites. The substrate on the scarps south of the field appeared to be hard bedrock pavement at the top of the scarp, with a rocky profile along the ridge and sand habitats at the base, with both sites appearing very similar. Not only did the scarps provide hard substrate for filter feeders and sponges, but this is also important information that can be relevant for engineering in the planning of a potential pipeline route to Darwin.

This benthic habits survey identified several different habitat groupings that were predominantly influenced by depth and habitat type. The habitats with the lowest diversity occurred within the permit area, whilst the habitats with the highest diversity occurred at the shoals and banks sites, which were the survey sites located furthest from the permit area.

In summary, the results of this survey further contribute to an appropriate baseline characterisation, to inform risk assessment, of the benthic habitats and biota in the permit area and broader regional surrounds, particularly nearest seabed features of interest.

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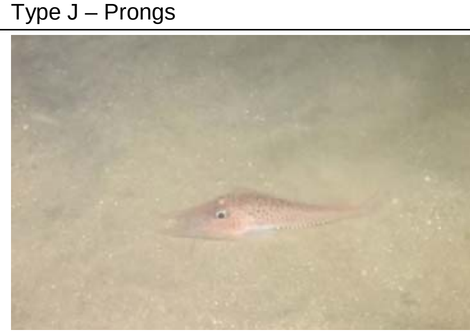
Appendix A. Deepwater fish types

<table>
<tr><td>Type A – Silver, minnow shaped tail</td><td>Type B – Rat tail</td></tr>
<tr><td>
(example from HM020)

(example from HM013)

(example from HM018)

(example from HM018)</td><td>
(example from HM013)</td></tr>
</table>

Type C – Silver, bullet shaped	Type D – Bullet shaped, dark minnow tail
 (example from HM016)	 (example from HM016)
Type E – Snake head	Type F – Tiger stripes
 (example from HM023)	 (example from HM023)
Type G – Sword fish	Type H – Vertical fish
 (example from HM023)	 (example from HM023)
Type I – Triangle fish	Type J – Prongs
 (example from HM018)	 (example from HM020)

Type K – Pipefish	Type L – Gurnaud
 (example from HM016)	 (example from HM017)
Type M – Flounder A	Type N – Flounder B
 (example from HM016)	 (example from HM018)
Type O – Flounder C	Type P – Pink
 (example from HM022)	 (example from HM013)
Type Q – Flathead	Type R – Goby shape
 (example from HM013)	 (example from HM013)

 (example from HM016)  (example from HM020)	 (example from HM018)
Unknown teleost	
 (example from HM013)  (example from HM016)  (example from HM016)	

 (example from HM016)	

Appendix B. Presence/absence site data

PERMIT AREA: Site ID	HM013	HM016	HM017	HM018	HM020	HM021	HM022	HM023
Depth (m)	245	290	309	253	211	280	303	280
Sediment Structure	Soft, Flat (<25cm) Moderately Bioturbated Silty sand	Soft, Flat (<25cm) Moderately Bioturbated Versy silty sand	Soft, Flat (<25cm) Moderately Bioturbated Versy silty sand. Similar to HM016	Soft, Flat (<25cm) Moderately Bioturbated Silty sand	Soft, Flat (<25cm) Moderately Bioturbated Versy silty sand. Similar to HM016	Soft, Flat (<25cm) Moderately Bioturbated Versy silty sand. Similar to HM016	Soft, Flat (<25cm) Moderately Bioturbated Silty sand	Soft, Flat (<25cm) Moderately Bioturbated Silty sand/rubble
Water Clarity/Average Field of View	Medium particulate load / 2–4 m2	High particulate load / 2–4 m2	High particulate load / 2–4 m2	Medium particulate load / 2–4 m2	High particulate load / 2–4 m2	High particulate load / 2–4 m2	Medium particulate load / 2–4 m2	Medium particulate load / 2–4 m2
Other								
Brittle Stars (Class Ophiuroidea)							x	
Feather Stars (Class Crinoidea)								
Tunicates/Ascidians								
Sponge								
Sea Pens	x	x		x	x		x	x
Gorgonians								
Sea Whips								
Unidentified - Filter Feeders/non-Photosynthetic Soft Corals								x
Anemones	x	x	x					x
Tube Worms	x							
Sea cucumber								
Sea star					x			x
Decapods								
Prawn/Shrimp Group	x	x	x		x	x	x	
Long-Antennae Shrimp Group		x				x		
Small Crab/Squat Lobster Group	x	x	x	x				x
Burrowing Lobster								
Decorator Crab								
Teleosts								
Type A – Silver, minnow shaped tail	x							
Type B – Rat tail	x							

PERMIT AREA: Site ID	HM013	HM016	HM017	HM018	HM020	HM021	HM022	HM023
Type C – Silver, bullet shaped	x	x	x	x	x	x	x	x
Type D – Bullet shaped, dark minnow tail		x		x	x			
Type E – Snake head								x
Type F – Tiger stripes								x
Type G – Sword fish								x
Type H – Vertical fish								x
Type I – Triangle fish				x				
Type J – Prongs					x			
Type K – Pipefish		x					x	x
Type L – Gurnaud			x					
Type M – Flounder A		x						
Type N – Flounder B				x				
Type O – Flounder C							x	
Type P – Pink fish	x							
Type Q – Flathead	x	x			x			
Type R – Goby shape	x			x				
Type S – Bulbous Long-tailed transparent				x	x			
Unknown teleost	x	x	x	x	x		x	x
Molluscs								
Octopus								
Squid								
Elasmobranch	x							

EVANS: Site ID	HM003	HM004	HM002	HM005
Depth (m)	28	54	46-130	80 - 170
Sediment Structure	Sand	Sand and reef	Sand and reef	Sand and reef
Water Clarity/Average Field of View	> 20 m	> 20 m	~ 15 m	> 20 m
Other				
Tunicates/Ascidians			x	
Sponge - encrusting			x	
Sponge - sub massive				x
Sponge - cup		x		x
Sponge - erect		x	x	
Non-BPP Zoanthids				
Tube Worms				
Anemones			x	
Halimeda	x	x	x	
Algae	x	x	x	
Echinoderms				
Brittle Stars (Class Ophiuroidea)				
Basket stars (Class Ophiuroidea)				
Feather Stars (Class Crinoidea)			x	x
Holothurian		x	x	
Starfish		x	x	
Octocorals				
Filter Feeder/Non-BPP Soft Corals	x	x	x	x
Sea Pens			x	
Gorgonians		x	x	x
Sea Whips	x	x	x	x
Corals				
Branching		x		
Digitate				
Columnar				
Plate		x	x	
Massive		x		
Sub-massive			x	

EVANS: Site ID	HM003	HM004	HM002	HM005
Encrusting				
Free-living		x	x	
Decapods				
Prawn/Shrimp Group				
Long-Antennae Shrimp Group				
Small Crab/Squat Lobster Group				
Lobster			x	
Decorator Crab				
Teleosts				
Unknown teleost				x
Family Lutjanidae		x		x
Family Chaetodontidae - Butterfly fish		x	x	x
Family Labridae - Wrasse	x	x	x	
Family Pomacentridae	x		x	
Family Pomacanthidae - Angelfish	x		x	
Family Acanthuridae - Unicorn fish	x	x		
Family Balistidae - Triggerfish	x	x		
Family Zanclidae - Moorish Idol	x	x		
Family Monacanthidae - Leatherjacket	x			
Family Holocentridae - squirrel fish				x
Family Carangidae			x	
Family Caesionidae			x	
Family Serranidae			x	x
Chondrichthyes				
Shark - white tip		x	x	
Shark - silver tip				x
Shark - grey nurse				
Shark - tawny nurse			x	
Elasmobranch				
Reptilia				
Seasnake			x	
Cephalopods				

EVANS: Site ID	HM003	HM004	HM002	HM005
Octopus				
Squid				
Bivalve				
Clam				
Mollusc				
Gastropod				x
Actinopterygii				
Moray eel			x	

TASSIE: Site ID	HM006	HM007	HM008
Depth (m)	15	28 - 79	15
Sediment Structure	Platform reef structure (<1 m over 2 m); cobble and boulders	Platform reef structure (<1 m over 2 m); cobble and boulders	Platform reef structure (<1 m over 2 m); cobble and boulders
Water Clarity/Average Field of View	10 m; 40 m2	10 m; 40 m2	10 m; 40 m2
Other			
Tunicates/Ascidians	x	x	x
Sponge - encrusting			
Sponge - massive	x	x	x
Sponge - cup		x	
Sponge - erect		x	
Tube Worms			
Anemones			
Halimeda	x	x	x
Echinoderms			
Brittle Stars (Class Ophiuroidea)			
Basket stars (Class Ophiuroidea)			
Feather Stars (Class Crinoidea)	x	x	x
Holothurian			x
Starfish		x	
Octocorals			
Unidentified - Filter Feeders/non- Photosynthetic Soft Corals			
Filter Feeder/Non-BPP Soft Corals	x	x	x
Sea Pens			
Gorgonians		x	
Sea Whips	x	x	x
Corals			
Branching	x	x	x
Digitate	x		
Columnar	x		x
Plate	x	x	x

TASSIE: Site ID	HM006	HM007	HM008
Massive	x	x	x
Sub-massive	x	x	x
Encrusting	x	x	
Free-living		x	
Decapods			
Prawn/Shrimp Group			
Long-Antennae Shrimp Group			
Small Crab/Squat Lobster Group			
Burrowing Lobster			
Decorator Crab			
Teleosts			
Unknown teleost			
Family Lutjanidae			
Family Chaetodontidae - Butterfly fish		x	
Family Labridae - Wrasse	x		x
Family Pomacentridae	x		x
Family Pomacanthidae - Angelfish	x		
Family Acanthuridae - Unicorn fish	x	x	
Family Balistidae - Triggerfish			x
Family Zanclidae - Moorish Idol	x		
Family Monacanthidae - Leatherjacket			
Family Holocentridae - squirrel fish			
Family Carangidae		x	
Family Caesionidae			
Family Serranidae			
Chondrichthyes			
Shark - white tip		x	x
Shark - silver tip			
Shark - grey nurse			
Elasmobranch			
Reptilia			
Seasnake		x	

TASSIE: Site ID	HM006	HM007	HM008
Molluscs			
Octopus			
Squid			
Clam	x		x
Unidentified gastropod			

LYNEDOCH: Site ID	HM024	HM025	HM028	HM030
Depth (m)	20	16	26-83	16
Sediment Structure	Sand/rubble/reef	Sand/rubble/reef	Sand/rubble/reef	Sand/rubble/reef
Water Clarity/Average Field of View	20	20	20	20
Other				
Tunicates/Ascidians				
Sponge - encrusting	x	x	x	
Sponge - sub massive		x	x	x
Sponge - cup	x			
Sponge - erect				
Non-BPP Zoanthids				
Tube Worms				
Anemones				
Halimeda	x	x	x	x
Algae	x	x	x	
Echinoderms				
Brittle Stars (Class Ophiuroidea)				
Basket stars (Class Ophiuroidea)				
Feather Stars (Class Crinoidea)	x		x	x
Sea cucumber	x	x		
Sea star	x	x		
Octocorals				
Unidentified - Filter Feeders/non- Photosynthetic Soft Corals	x	x	x	x
Sea Pens	x			
Gorgonians				
Sea Whips			x	x
Corals				
Branching	x	x	x	x
Digitate				
Columnar				
Plate	x			
Massive	x	x	x	

LYNEDOCH: Site ID	HM024	HM025	HM028	HM030
Sub-massive	x	x	x	x
Encrusting	x		x	
Free-living	x			
Decapods				
Prawn/Shrimp Group				
Long-Antennae Shrimp Group				
Small Crab/Squat Lobster Group				
Burrowing Lobster				
Decorator Crab				
Teleosts				
Unknown teleost		x		
Family Lutjanidae				
Family Chaetodontidae - Butterfly fish		x		
Family Labridae - Wrasse	x	x		x
Family Pomacentridae		x		x
Family Pomacanthidae - Angelfish	x			x
Family Acanthuridae - Unicorn fish				
Family Balistidae - Triggerfish	x		x	
Family Monacanthidae - Leatherjacket				
Family Zanclidae - Moorish idol		x	x	x
Chondricthyes				
Shark - white tip	x	x	x	x
Shark - silver tip	x			
Shark - grey nurse				
Reptilia				
Seasnake	x			
Cephalopods				
Octopus				
Squid				
Elasmobranch				
Bivalve				
Clam				

LYNEDOCH: Site ID	HM024	HM025	HM028	HM030
Actinopterygii				
Moray eel		x		

SEAMOUNTS: Site ID	HM029	HM010A	HM010B	HM011
Depth (m)	80–220	77 - 140	77	50-100
Sediment Structure	Sand/rock	Sand/rock	Sand/rock	Sand/rock
Water Clarity/Average Field of View	10	10	10	10
Other				
Tunicates/Ascidians		x		
Sponge - encrusting				
Sponge - sub massive	x	x	x	
Sponge - cup			x	x
Sponge - erect	x	x		
Non-BPP Zoanthids				
Tube Worms	x	x		
Anemones	x			
Halimeda				
Algae	x	x	x	
Echinoderms				
Brittle Stars (Class Ophiuroidea)				
Basket stars (Class Ophiuroidea)				
Feather Stars (Class Crinoidea)	x	x	x	
Holothurian	x	x		
Starfish	x	x		
Urchin	x	x		
Octocorals				
Unidentified - Filter Feeders/non- Photosynthetic Soft Corals	x	x	x	x
Sea Pens		x		
Gorgonians	x	x	x	
Sea Whips	x	x	x	x
Corals				
Branching	x			
Digitate				
Columnar				
Plate		x	x	

SEAMOUNTS: Site ID	HM029	HM010A	HM010B	HM011
Massive				
Sub-massive				
Encrusting			x	
Free-living				
Decapods				
Prawn/Shrimp Group	x			
Long-Antennae Shrimp Group				
Small Crab/Squat Lobster Group				
Lobster		x		
Decorator Crab				
Teleosts				
Unknown teleost	x	x		
Family Lutjanidae	x	x		
Family Chaetodontidae - Butterfly fish				
Family Labridae - Wrasse				
Family Pomacentridae			x	
Family Pomacanthidae - Angelfish				
Family Acanthuridae - Unicorn fish		x		
Family Balistidae - Triggerfish	x	x	x	x
Family Carangidae	x	x		
Family Caesionidae		x		
Family Serranidae	x	x		
Family Holocentridae	x			
Family Priacanthidae	x			
Family Monacanthidae - Leatherjacket				
Chondrichthyes				
Shark - white tip				
Shark - silver tip	x	x	x	x
Shark - grey nurse		x		
Elasmobranch	x			
Reptilia				
Seasnake				x

SEAMOUNTS: Site ID	HM029	HM010A	HM010B	HM011
Cephalopods				
Octopus				
Squid				
Bivalve				
Clam				
Mollusc				
Gastropod		x		

SCARPS: Site ID	HM014	HM019
Depth (m)	190	185
Sediment Structure	Coarse/rubble, distinct rocky ridge	Rock with silty, shell grit sand, rocky ridge and sandy bottom
Water Clarity/Average Field of View	Medium bioload / 2–4 m2	Medium bioload / 2–4 m2
Other		
Tunicates/Ascidians	x	x
Sponge - encrusting		
Sponge - sub massive	x	x
Sponge - cup	x	x
Sponge - erect		
Non-BPP Zoanthids		
Tube Worms		x
Anemones	x	
Halimeda		
Algae		
Echinoderms		
Brittle Stars (Class Ophiuroidea)	x	x
Basket stars (Class Ophiuroidea)		
Feather Stars (Class Crinoidea)	x	x
Sea Cucumber		
Sea Star	x	
Octocorals		
Unidentified - Filter Feeders/non- Photosynthetic Soft Corals	x	x
Sea Pens		
Gorgonians		x
Sea Whips		x
Decapods		
Prawn/Shrimp Group		x
Long-Antennae Shrimp Group		
Small Crab/Squat Lobster Group		

SCARPS: Site ID	HM014	HM019
Burrowing Lobster		
Decorator Crab		
Hermit crab	x	
Teleosts		
Unknown teleost	x	
Family Lutjanidae		x
Family Labridae - Wrasse		
Family Pomacentridae		
Family Pomacanthidae - Angelfish		
Family Acanthuridae - Unicorn fish		
Family Balistidae - Triggerfish		
Family Monacanthidae - Leatherjacket		
Chondricthyes		
Shark - white tip		
Shark - silver tip		
Shark - grey nurse		
Shark - tawny nurse		
Elasmobranch		
Reptilia		
Seasnake		
Cephalopods		
Octopus		
Squid		

Appendix E.

Underwater noise monitoring survey (JASCO 2016a)

Passive Acoustic Monitoring of Ambient Noise and Marine Mammals—Barossa Field

July 2014 to July 2015

Submitted to:
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10 August 2016

P001241-001
Document 00997
Version 1.0

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Suggested citation:

McPherson, C., K. Kowarski, J. Delarue, C. Whitt, J. MacDonnell and B. Martin. 2016. *Passive Acoustic Monitoring of Ambient Noise and Marine Mammals—Barossa Field:* . JASCO Document 00997, Version 1.0. Technical report by JASCO Applied Sciences for Jacobs.

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Executive Summary

JASCO Applied Sciences (JASCO) conducted a twelve month—July 2014 to July 2015—baseline acoustic environment characterisation program at and surrounding the Barossa field for Jacobs on behalf of ConocoPhillips. Three JASCO Autonomous Multichannel Acoustic Recorders (AMARs) were deployed close to the seabed at three stations. The AMARs captured data that were analysed to quantify ambient sound levels, the presence of sounds related to anthropogenic activity, and the acoustic presence of marine mammals and fish.

Ambient Sound Levels

The minimum levels of ambient sound (in root-mean-squared sound pressure level) were consistent across all stations. The maximum levels were consistent at the two stations (Station J1 and J3) farthest from the Barossa field where the Mobile Offshore Drilling Unit (MODU) *Nan Hai VI* was operating between October 2014 and March 2015. The closest station (Station J2) showed higher levels, but only during Deployment 1 when the MODU was 8 km away. During Deployment 1 the southernmost station, near the Caldita field (Station J3), had the lowest levels across all exceedance percentiles time periods. However, during Deployment 2 this occurred at the Barossa field (Station J2). The distances from the MODU to the three stations, J1–J3 respectively, was 48 and 71 km, 8 and 15.5 km (Deployment 1), and 36 and 49 km (Deployment 2), for the two drilling locations.

The ambient data showed low levels of diel variations in sound levels attributable to biological events such as fish chorusing, but were otherwise primarily affected by weather events such as wind, at times producing a noticeable diel variation in sound levels, with levels increasing during the day and decreasing at night. During the period April–September when the highest call rates from Omura's a whales were detected, they were the dominant contributor to the soundscape at 26-28 Hz.

Anthropogenic Activity

The amount of shipping was quantified with automated detectors. Shipping was a minor contributor to the soundscape. The MODU *Nan Hai VI* and its support vessels did not change the soundscape considerably from its natural state at a regional level, although at closer ranges (8 and 15.5 km) operations contributed sound levels exceeding natural levels moderately.

Biological Sounds

Automated analysis techniques, including manually validated automated detectors, were used to determine the presence of vocalising marine life. A more detailed analysis based on the automated detection results was conducted to extract more information about the usage of and movements through the region by pygmy blue, Omura's and Bryde's whales. Based on the analysis:

- Omura's whales were detected consistently from April to September inclusive, with a peak in June and July. Based on the year of recordings, the whales seemed to enter the region in a south-west to north-east direction, then maintain a higher presence within the Barossa field area (than compared to the Evans Shoal or Caldita field areas) for the autumn and winter months. They appeared to leave the region in a north-east to south-west direction, reversing their entry path, leaving the area by the start of November. When present they created a pronounced peak at 26-28 Hz that is visible in the spectrograms and power spectral density plots.
- Pygmy blue whales were detected during their northward migration once in August 2014, over a few consecutive days in late May-early June 2015, on the 16 and 30 June, and 1 July 2015. The detections are over 400 km further east than the north-bound migration corridor of pygmy blue whales described in Double et al. (2014). No detections were logged from the south-bound migration, suggesting a different migration path. The highest calling rates of the three monitoring station occurred at the Barossa field, which may reflect its greater depth and proximity to the trench.
- Bryde's whales, distinguished from the Omura's whales through variations in the spatial and temporal occurrence of vocalisations, were present in the region from January to October. They appear to move into the area in a south to north direction during summer and autumn, then utilise the region with a preference for the shallower sections (Evans shoal and Caldita field areas) over the Barossa field region. They then leave the area in a north – south direction, with the last detections in early October.
- Odontocetes were extremely common. Many species were detected on a daily basis, with a primarily nocturnal diel cycle.

- Unknown beaked whale species were detected on four days over the entire program at Stations J2 (Barossa field) and J3 (Caldita field).
- Fish chorused at dawn and dusk over the entire deployment period at all three stations. Their chorusing varied in intensity over the deployment period, but was consistent in diel pattern.

1. Introduction

ConocoPhillips Australia Exploration Pty Ltd (ConocoPhillips), as proponent on behalf of the current and future joint venturers, are proposing to develop the gas and condensate reserves in the Barossa gas field and surrounds, located approximately 300 kilometres (km) north of Darwin, Northern Territory.

To characterise the existing marine environment within and surrounding the Barossa area, ConocoPhillips has undertaken an environmental baseline studies program. Baseline studies were undertaken with reference to petroleum retention lease permit NT/RL5 (referred to as the 'permit area' in this report), as shown in Figure 1. While this represents the area of primary interest as part of ConocoPhillips' staged field development, the broader surrounds were also characterised.

As part of this program, Jacobs contracted JASCO to deliver a long-term acoustic monitoring program, which in part coincided with the 2014–2015 exploration drilling campaign in the Barossa field. This report details the methods (Section 2) and results (Section 3) of this acoustic monitoring program, characterising the baseline acoustic environment within and surrounding the Barossa field whilst also providing data on sound generation from Mobile Offshore Drilling Unit (MODU) and support vessel activities.

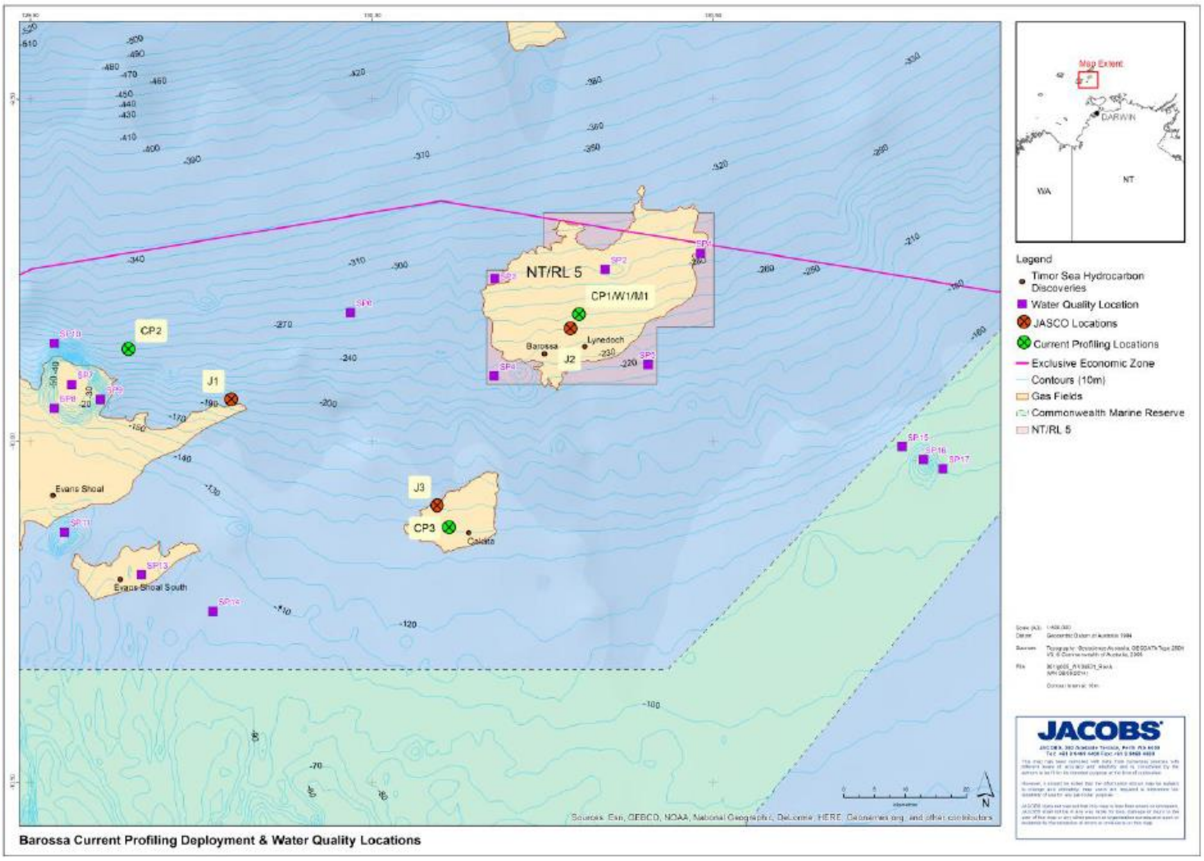


Figure 1. Barossa field and locations of JASCO recorders J1, J2, and J3.

1.1. Acoustic Monitoring Study

This report provides the results from a twelve-month autonomous acoustic monitoring program. The acquired acoustic data were analysed to quantify the acoustic presence of marine mammals (Section 3.2), ambient sound levels (Section 3.3) and the presence of anthropogenic activity such as vessels (Section 3.4), and the. The total sound level data provide a statistical noise floor for current conditions, which is a required input for modelling the area over which noise associated with construction and operation of facilities could be heard by marine life. The recorded total sound levels and current vessel activity levels are inputs for cumulative effects modelling. Finally, the marine mammal presence data documents the seasonal use of sound by marine mammals for foraging, navigation, and socialising.

Current knowledge on marine mammal presence near the Barossa field location is limited and primarily derived from information available from the Australian Government's Department of the Environment (DoE) Protected Matters Search Tool (2015). JASCO's acoustic monitoring study will contribute additional knowledge regarding the spatial and temporal distributions of several marine mammal species in this area, including potential migration pathways.

Data were acquired using three Autonomous Multichannel Acoustic Recorders (AMARs) deployed on the seabed for two six-month periods at three stations (Figure 1).

1.2. Anthropogenic Activity near the Barossa Field

1.2.1. Drilling Activity

A drilling program was conducted by ConocoPhillips at the Barossa field during the monitoring program, with two wells being drilled during this phase of the project. The dates and location of the drilling program were provided by ConocoPhillips (Table 1). The distances from the well to the three acoustic monitoring stations are provided to contextualize the potential for the activities associated with the drilling operation to influence the sound levels at each station.

In association with the drilling activity, there is typically at least one support vessel at the MODU location (e.g., a rig tender), with support vessels periodically supplying the rig with equipment and stores. When a rig or MODU is moved, it is towed using two rig tenders.

Table 1. ConocoPhillips Barossa field MODU drilling locations during monitoring study.

Well	Latitude	Longitude	Mooring Date	Drilling start date	Release date	Distance to stations (km)		
						J1	J2	J3
3	9° 47.736' S	130° 13.678' E	12 Oct 2014	14 Oct 2014	15 Jan 2015	48	8	36
4	9° 47.953' S,	130° 25.678' E	15 Jan 2015	18 Jan 2015	26 Mar 2015	71	15.5	49

1.2.2. Seismic Survey

A seismic survey was detected in the last two weeks of the monitoring program, with pulses detected between 04-15 July 2015. It is most likely that the operator responsible for the survey was CGG, conducting the 2D BandaSeisV in Indonesian waters between Babar Island (part of the Babar Islands group) and Selaru Island (in the Tanimbar Islands group), over 160 km from the closest recording station.

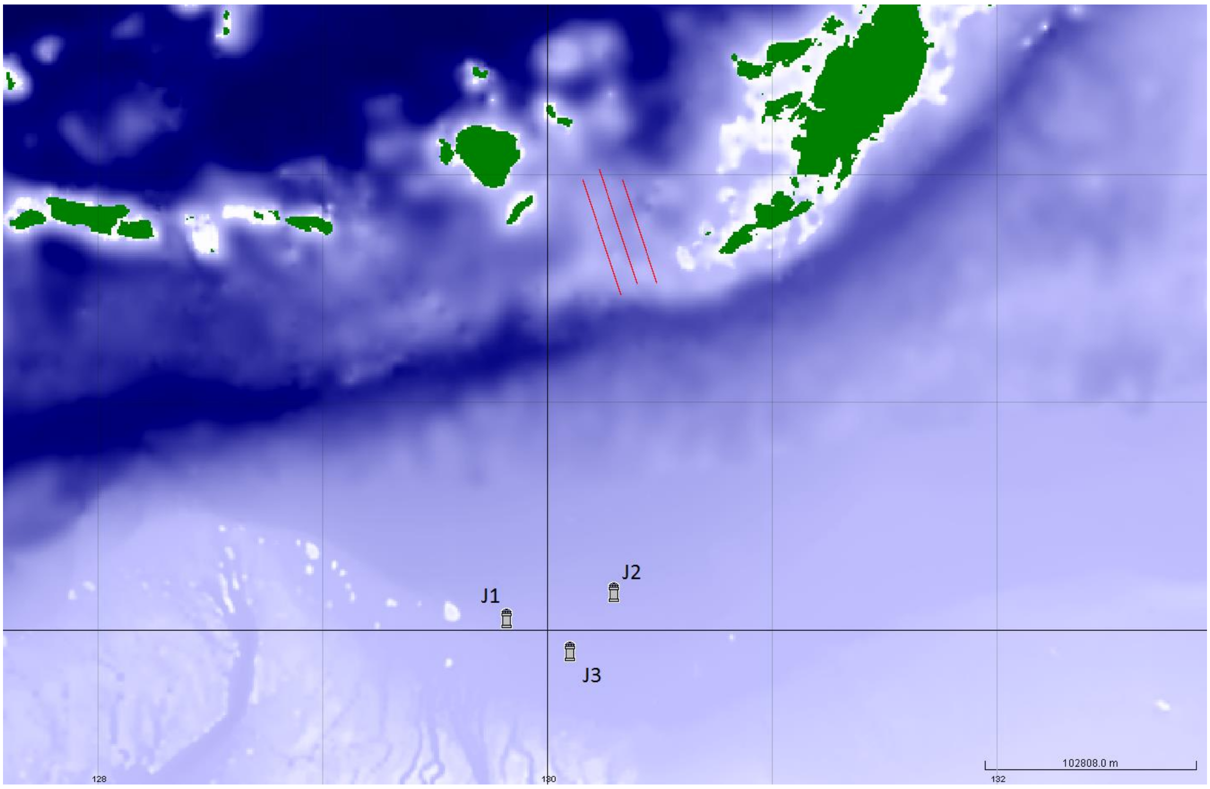


Figure 2. CGG 2D BandaSeisV Seismic survey lines (red lines) and recorder locations.

1.3. Biological Sounds

A search was conducted of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) Protected Matters Database (DoE 2015) determine the species identified by the DoE that may occur in, or may relate to, the Barossa area and surrounds (Table 2). It is believed that blue whales identified as potentially occurring in the Barossa area are in fact pygmy blue whales (*Balaenoptera musculus brevicauda;* Ichihara (1966); Rice (1998)), a sub species of the true blue whale (B. *m. musculus*). In addition to the Protected Matters search results, the Omura's whale (*Balaenoptera omurai;* Wada et al. (2003)), a recently described species basal to the Bryde's/sei whale clade, is also known to be present off northwest Australia (Cerchio et al. 2015) and suspected to be present in the area. This species is not currently listed as a threatened species under the EPBC Act and is therefore not included in the EPBC search tool, and hence not listed in Table 2.

Table 2. EPBC Act Protected Matters Database listing of marine mammals present in the Barossa area and surrounds (DoE 2015).

Species	Common name
Mysticetes	
Balaenoptera bonaerensis	Antarctic minke whale, dark shoulder minke whale
Balaenoptera edeni	Bryde's whale
Balaenoptera musculus	Blue whale
Megaptera novaeangliae	Humpback whale
Large odontocetes	
Orcinus orca	Orca, killer whale
Globicephala macrorhynchus	Short-finned pilot whale
Pseudorca crassidens	False killer whale
Kogia breviceps	Pygmy sperm whale
Kogia simus	Dwarf sperm whale
Physeter macrocephalus	Sperm whale
Ziphius cavirostris	Cuvier's beaked whale, goose-beaked whale
Small odontocetes	
Feresa attenuata	Pygmy killer whale
Peponocephala electra	Melon-headed whale
Delphinus delphis	Common dolphin, short-beaked common dolphin
Grampus griseus	Risso's dolphin, grampus
Lagenodelphis hosei	Fraser's dolphin, Sarawak dolphin
Stenella attenuata	Spotted dolphin, pantropical spotted dolphin
Stenella coeruleoalba	Striped dolphin, euphrosyne dolphin
Stenella longirostris	Long snouted spinner dolphin
Steno bredanensis	Rough-toothed dolphin
Tursiops aduncus	Indian Ocean bottlenose dolphin, spotted bottlenose dolphin
Tursiops aduncus (Arafura/Timor Sea populations)	Spotted bottlenose dolphin
Tursiops truncatus s. str.	Common bottlenose dolphin

2. Methods

2.1. Data Acquisition

Three Autonomous Multichannel Acoustic Recorders (AMARs) were deployed in the Timor Sea for 188–190 days and 179-181 days respectively (Table 3, Figure 3). Each AMAR was fitted with an M8E-V35 dB omnidirectional hydrophone (GeoSpectrum Technologies Inc.; −164 dB re 1 V/µPa sensitivity). For Deployment 1, the AMARs at Station J1 and J3 were each deployed in a mooring configuration that consisted primarily of a bottom-sitting plate fitted with two identical remotely activated pop-up retrieval line canisters (Figure 4). The AMAR at Station J2 was deployed directly on the seabed, tethered to a long ground line along the seabed to a float, anchor and a remotely activated release mechanism to bring the line to the surface for retrieval (Figure 5). A different design was used for Station J2 due to depth limitations on the acoustic release pop-up floatation. For Deployment 2, all three stations used the bottom plate mooring design (Figure 4) due to access to 400 m rated floatation for Station J2.

The bottom plate moorings were deployed by allowing them to sink to the seabed, using additional temporary buoyancy to slow their descent. The AMAR at Station J2 for Deployment 1 was lowered directly to the seabed using the long ground line, after which the vessel moved away to a safe distance to drop the acoustic release, anchor and float. To retrieve the bottom plate moorings, one of the pop-up retrieval line canisters was activated, allowing an integrated float to bring a retrieval line to the surface. At Station J2 (Deployment 1), the acoustic release was triggered to free the float from the anchor and bring the ground line to the surface. After the retrieval line surfaced, the equipment was brought on board using the vessel's winch.

The AMARs sampled on a 30-minute duty cycle: 840 s at 48 ksps, then 65 s at 250 ksps, and then 895s of sleep. The 48 ksps recording channel had a 24-bit resolution with 6 dB of gain resulting in a spectral noise floor of 23 dB re 1 µPa^2/Hz and could resolve a maximum sound pressure level (SPL) of 165 dB re 1 µPa. The 250 ksps data were recorded at 16-bit resolution, with a spectral noise floor of 35 dB re 1 µPa^2/Hz and could resolve a maximum SPL of 171 dB re 1 µPa (no gain). The spectral noise floor represents the quietest sounds that can be recorded, and is directly comparable to the Wenz ocean noise spectra (Figure 10). Acoustic data were stored on internal solid-state flash memory.

Table 3. AMAR deployment and retrieval dates and locations.

Station	Deployment date	Record end / Retrieval date	Latitude (°S)	Longitude (°E)	Water depth (m)	Range to MODU (km)
Deployment 1						
J1	10 Jul 2014	15 Jan 2015	-09°56.9130'	129°48.8280'	179	48
J2	09 Jul 2014		-09°49.9600	130°17.3340'	243	8
J3	11 Jul 2014		-10°05.7188'	130°05.7632'	153	36
Deployment 2						
J1	16 Jan 2015	16 Jul 2015	9° 56.910'	129° 48.8243'	181	71
J2	17 Jan 2015	15 Jul 2015	9° 50.1282'	130° 17.4774'	240	15.5
J3	17 Jan 2015	15 Jul 2015	10° 5.7072'	130° 5.7196'	143	49

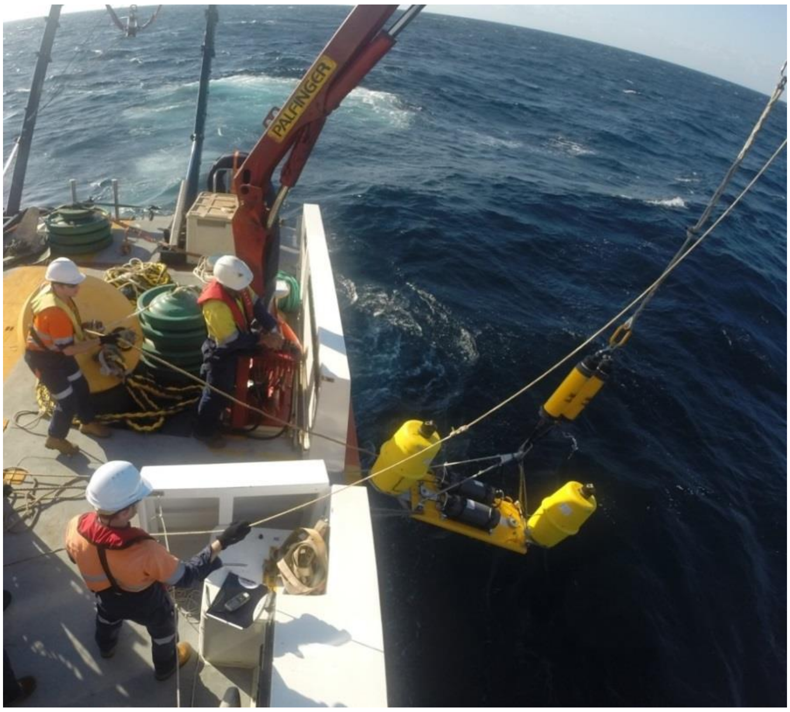


Figure 3. AMAR and mooring float being deployed from the *MV Warrego*.

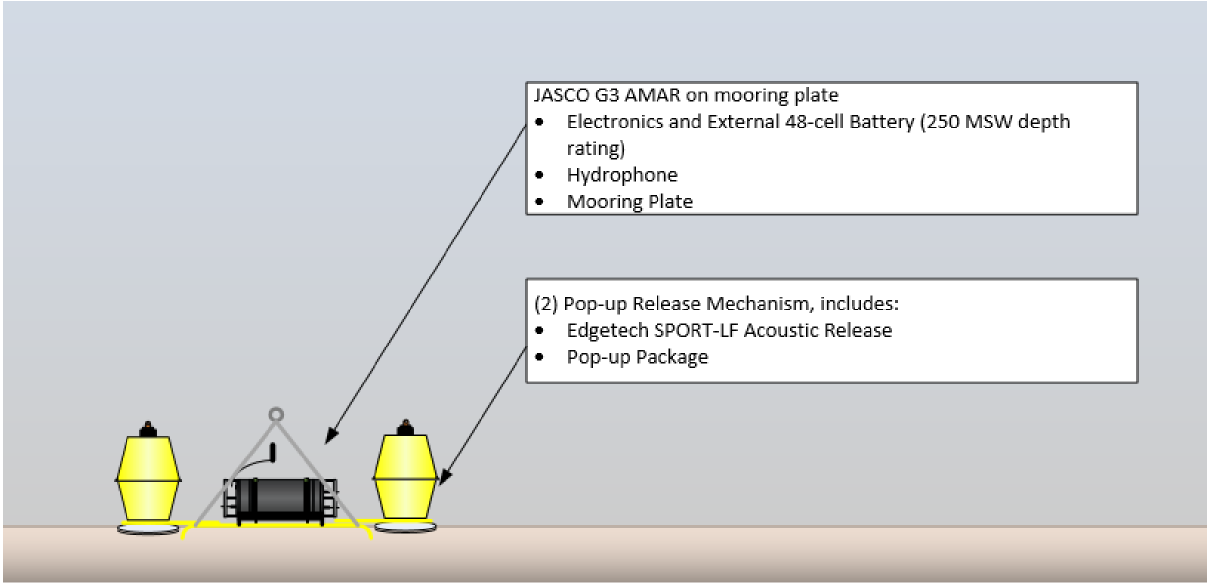


Figure 4. Mooring diagram for AMARs at Stations J1 and J3 Deployment 1, and all stations for Deployment 2.

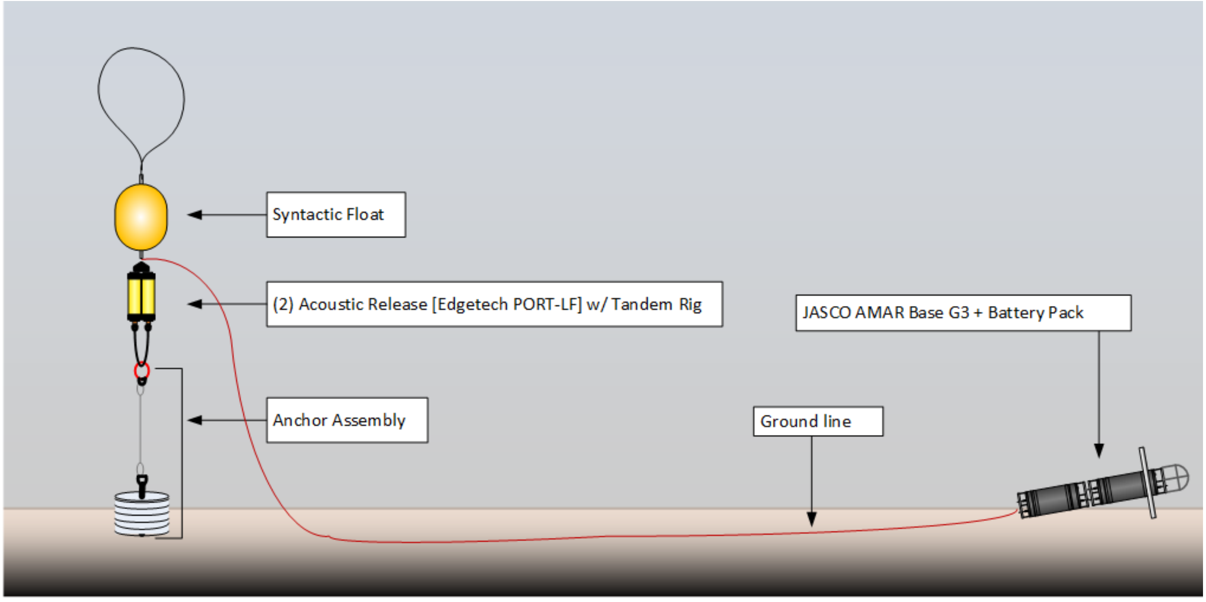


Figure 5. Mooring diagram for AMAR at Station J2, Deployment 1.

2.2. Recorder Calibrations

A GRAS 42AA pistonphone calibrator (Figure 6), which is National Institute of Standards and Technology (NIST) traceable, was used to verify the sensitivity of the recording apparatus as a whole, i.e., the hydrophone, pre-amplifier, and AMARs. Calibration was undertaken in JASCO's warehouse prior to deployment in the field and upon retrieval. The pistonphone and its adapter were placed over the hydrophone and produced a known pressure signal on the hydrophone element (a 250 Hz sinusoid at 133.3 dB re 1 µPa) to verify the pressure response of the recording system. The system sensitivity was measured independently of the software that performed the data analysis, which allowed an independent check on the correct calibration of the analysis software. Both readings were verified for consistency before data analysis was performed.

Figure 6. Split view of (left) a GRAS pistonphone calibrator, (middle) adaptors, and (right) a hydrophone.

2.3. Data Analysis

2.3.1. Marine Mammal Detections

JASCO applied automated analysis techniques to the acoustic data. Automated detectors were employed to detect (if present) calls of pilot whales, killer whales, beaked whales, sperm whales, dolphin clicks, dolphin and other odontocetes' whistles, and moans from various mysticetes including Omura's, Bryde's, blue and humpback whales.

2.3.1.1. Automated Click Detectors

The following list shows the stages of the automated click detector/classifier, based on the zero-crossings in the acoustic time series (refer Figure 7); zero-crossings are the rapid oscillations of the click above and below the signal's normal level.

1. The raw data are high-pass filtered to remove all energy below 8 kHz. 8 kHz removes most energy from other sources like shrimp, vessels, wind and cetacean tonal calls, yet allows the energy from all marine mammal click types to pass.
2. The filtered samples are summed to create a time series with 0.5 ms root-mean-square (rms) time series. Most marine mammal clicks have a duration of 0.05–1 ms (e.g. Au (1993), Baumann-Pickering et al. (2013)).
3. A Teager-Kaiser energy detector identifies possible click events.
4. The high pass filtered data are searched to find the maximum peak signal within 1 ms of the detected peak.
5. The high pass filtered data are then searched backwards and forwards to find the time span where the local data maxima are within 12 dB of the maximum peak. The algorithm allows for two zero-crossings to occur where the local peak is not within 12 dB of the maximum before stopping the search. This defines the time window of the detected click.
6. The classification parameters are extracted. The number of zero crossings within the click, the median time separation between zero crossings, and the slope of the change in time separation between zero crossings are computed. Beaked whales can be identified by the increase in frequency (up sweep) of their clicks. The slope parameter helps to identify beaked whale clicks.
7. The Mahalanobis distance between the extracted classification parameters and the templates of known click types is computed. The covariance matrices for the known click types are stored in an external file and were computed based on 1000 s of manually identified clicks for each species. Each click is classified as a type with the minimum Mahalanobis distance, unless none of them are less than the specified distance threshold.

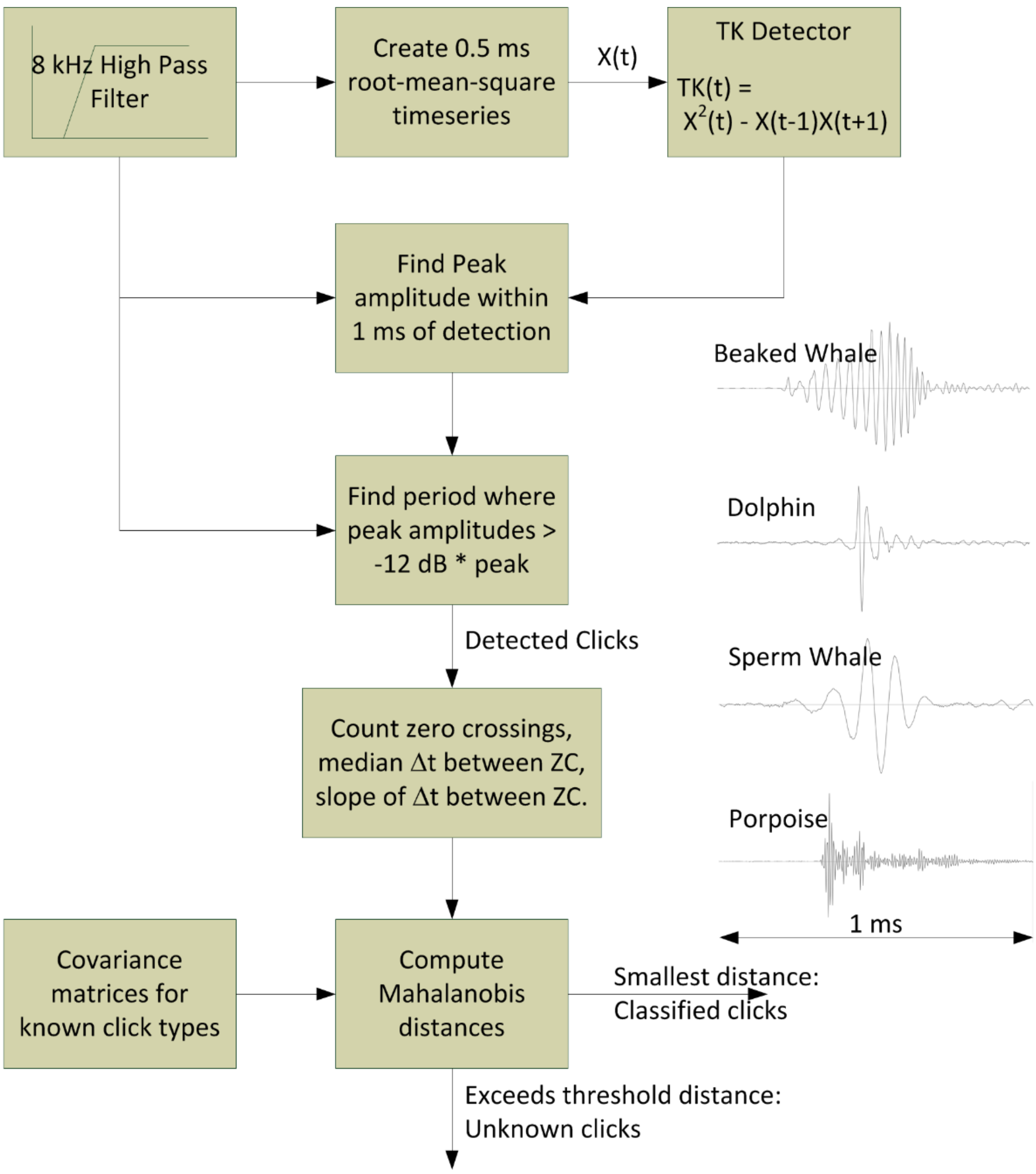


Figure 7. The click detector/classifier and a 1-ms time-series of four click types.

2.3.1.2. Cetacean Tonal Call Detection

The cetacean tonal call detector identifies data likely to contain marine mammal moans, song notes, and whistles. The analysis begins with spectrograms of the appropriate resolution for each mammal call type that are normalised by the median value in each frequency bin for each detection window (Table 4). Contours are formed using the same 3 × 3 kernel used for shipping and seismic airgun analysis. Finally, a call-sorting algorithm determines if the contours match the definition of a mammal call type (Table 5).

Table 4. Fast Fourier Transform (FFT) and detection window settings for marine mammal call detection used in the Barossa analysis. Values are based on JASCO's experience and empirical evaluation of a variety of data sets.

Possible species	Call type	FFT			Detection window (s)	Detection threshold
		Resolution (Hz)	Data duration (s)	Data advance (s)		
Dolphin	Whistle	16	0.032	0.02	30	3
Humpback whale	Moan	2	0.25	0.125	120	3
Bryde's/Omura's whale	Moan	0.5	2	0.25	120	4
Blue whale	Moan	0.5	2	0.125	120	4
Bryde's whale	Downsweep	2	0.25	0.125	120	3

Table 5. Call sorter definitions for the marine mammal calls detected in the Barossa analysis.

Possible species	Call type	Frequency (Hz)	Duration (s)	Bandwidth (Hz)	Other
Pilot whale, killer whale, other dolphin	Whistle	15,000–25,000	0.4–5	>1000	Possibly multiple frequency components, each > 0.4 s long and > 20 Hz bandwidth
Humpback whale	Moan	50–2000	0.5–5	>20	
Omura's/Bryde's whale	Moan	10–70	2–20	>4	
Blue whale	Moan	10–70	10–30	>10	
Bryde's whale	Downsweep	30–200	0.5–3	>10	

2.3.1.3. Validation of Automated Detectors

Automated detectors are often developed and tested with example data files that contain a range of vocalization file types and representative background noise conditions. However, the test files normally cannot cover the full range of possible conditions. Therefore, a selection of files must be manually validated to check on the detector performance and determine the minimum number of detections per sound file required to accept the detector's results. Of the 48 ksps data files, 794 were manually reviewed for the presence/absence of low-frequency baleen whale moans; 387 from deployment 1 and 407 from Deployment 2. Of the 250 ksps data files, 717 were manually reviewed for the presence/absence of high-frequency toothed whale clicks and whistles: 342 from Deployment 1 and 376 from Deployment 2. Files for manual analysis were selected to represent a full range of automated detection results. For each recorder, up to 20 files were selected for each detected species: beaked, sperm, humpback, and baleen whales as well as unidentified small odontocete clicks and whistles. For each species, the following files were randomly selected; 10 files with large numbers of detections, 5 files with a moderate number of detections, and 5 files with a low to moderate number of detections. Files that contained early or late automated detections were primarily selected to help bound the period of occurrence of each species. The automated detector results were checked to note the true presence or absence of every species, as well as vessels and fish. These validated results were fed to a grid search algorithm that maximised the probability of detection and minimised the number of false alarms using the F-score:

$$F = \frac{(1+\beta^2)P*R}{(\beta^2)P+R}; P = \frac{TP}{TP+FP}; R = \frac{TP}{TP+FN}$$

Where P is called the classifier's precision, R is the classifier's recall, TP is the number of correctly detected files (true positives), FP is the number of files that are false detections (false positives), and FN is the number of files that had missed detections (false negatives). P measures exactness; R measures completeness. For instance, a P of 0.9 means that 90% of the detections classified as killer whales for instance were in fact killer whale calls, but says nothing about whether all killer whale vocalisations in the dataset were identified. An R of 0.8 means that 80% of all killer whale calls in the dataset were classified, but says nothing about how many classifications were wrong. Thus, a perfect detector/classifier would have P and R equal to 1. Neither P nor R alone can describe the performance of a detector/classifier on a given dataset; both metrics are required. An F-score of 1 indicates perfect performance–all events are detected with no false alarms. In the equation above β is the relative weight between the recall and precision. A β of 2 means the recall has double the weight of the precision. Conversely, a β of 0.5 means the recall has half the weight of the precision.

The results are the classification threshold, which is defined as the number of detections per file that indicate a valid detection of the species. Table 6 shows the dependence of the classification threshold on the β-parameter and its effect on the precision and recall of the detector and classifier system. To specify that precision (low false alarm rate) was more important than recall, β=0.5 was used.

The classification threshold was used to determine whether mammals were present in each data file. The results were used to generate the presence plots and whisker plots in Section 3.2.The thresholds for other species are contained in Section 3.2.1.

Table 6. Effects of changing the F-score β-parameter on the classification threshold, precision, and recall for the odontocete clicks.

β	Classification threshold	Precision $P = \frac{TP}{TP + FP}$	Recall $R = \frac{TP}{TP + FN}$	F-score
2	25	0.87	0.95	0.93
0.5	50	0.91	0.91	0.91

2.3.1.4. Sound Levels of Mysticete Call Detections

In an effort to observe how the mysticete species moved through the Barossa area, the relative loudness of calls was determined and compared across stations for each call type.

Post-processing in Java extracted the SPL of the detections as well as the SPLs of the time periods immediately before and after each detection. In order to determine the SPL of the actual call, the mean of the SPLs immediately before and after the detection (ambient) was subtracted from the SPL of the detection. Early analysis revealed that the resulting call SPLs could not be reliably compared between stations as they were inherently biased by the threshold setting of the automatic detector that skews them with the ambient. This effect is presented in Figure 8 where the ambient is slightly higher at Station J2 compared to Stations J1 or J3, therefore it appears that the call SPLs are consistently higher at J2 than J1 or J3, when in reality, this is a threshold effect.

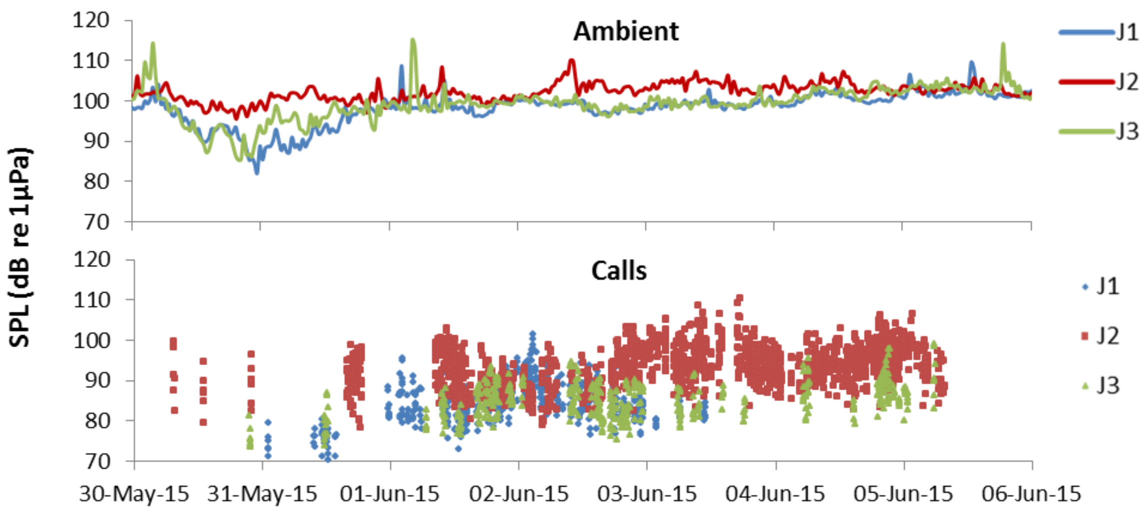


Figure 8. Example line graph of ambient SPL of the 10 to 24,000 Hz band (top) and plot of blue whale call SPL (bottom) at Stations J1, J2, and J3 from 30 May to 6 June 2015 from 30 May to 4 July 2015 at the Barossa area in the Timor Sea.

In order to compare sound levels of calls between stations, the mean station call SPL was subtracted from each call SPL of the associated station. Negative values (those below the mean) were considered to be relatively faint calls and positive values (those above the mean) were considered to be relatively loud calls. In this manner, how call SPLs increased and decreased within and between stations could be reliably observed and presented in a series of plots over time.

2.3.2. Vessel Detections

Vessel detection was performed in two steps. In the first step, narrowband sinusoidal tones (tonals) produced by a ship's propulsion and other rotating machinery (Arveson and Vendittis 2000) are detected in each 840 s file of the 16 ksps data. The tonal detector is based on overlapped FFTs. The number of seconds of data input to the FFT determines its spectral resolution. Arveson and Vendittis (2000) used both 0.5 and 0.125 Hz resolutions. For this study, spectral analysis was performed at 0.125 Hz resolution by using 8 s of real data with a 2 s advance. This frequency resolution separates each tone for easy detection, and the 2 s advance provides suitable temporal resolution. Higher frequency resolutions can reduce detectability of shipping tones, which are often unstable within 1/16 Hz bands for long periods. A 120 s long spectrogram is created with 0.125 Hz frequency resolution and 2 s time resolution (32768-point FFTs, 32000 real data points, 16000-point advance, and Hamming window). A split-window normaliser (Struzinski and Lowe 1984) distinguishes the tonal peaks from the background noise (2 Hz window, 0.75 Hz notch, and detection threshold of 4 times the median). The peaks are joined with a 3 × 3 kernel to create contours. Associations in frequency are made if contours occur at the same time. The event time and number of tones for any event at least 20 s long and 40 Hz in bandwidth are recorded for further analysis.

In the second step, the first step-results of all the 840 s files are combined to detect ship passages. A 'shipping band' is defined at 40–315 Hz and SPL for the band is obtained once per minute. Background estimates of the shipping band SPL and the total SPL are compared to their median values over the 12 hr window, centred on the current time. Shipping is detected when the SPL in the shipping band is at least 3 dB above the median, at least 5 shipping tonals are present, and the SPL in the shipping band is within 8 dB of the total SPL (Figure 9). When these conditions are true, the total per-minute SPL is attributed to shipping.

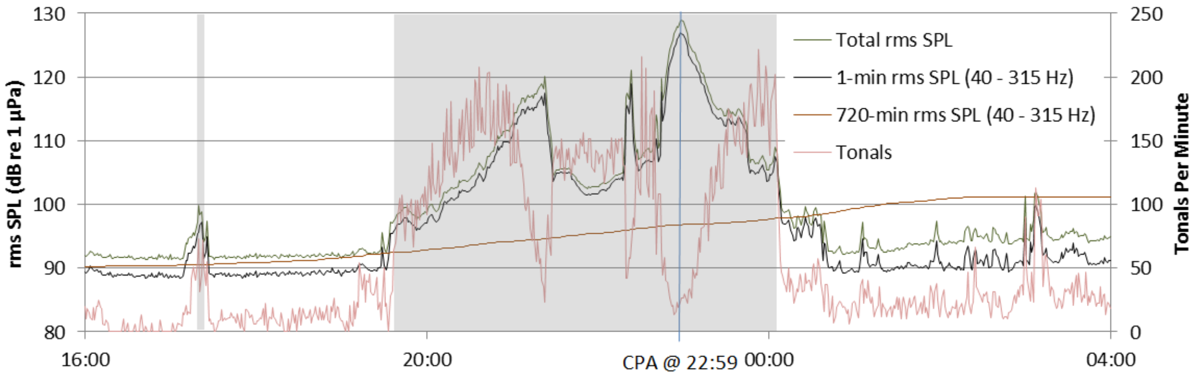


Figure 9. Example of broadband and in-band SPL and the number of 0.125 Hz wide tonals detected per minute as a ship approached a recorder, stopped, and then departed. The shaded area is the time period of shipping detection. All tonals are from the same vessel. Fewer tonals are detected at the ship's closest points of approach (CPA) at 22:59 because of the broadband cavitation noise at CPA and the Doppler shift of the tonals.

2.3.3. Seismic Survey Event Detection

Seismic pulse sequences were detected using correlated detections in spectrogram contours. A 300 s long spectrogram was created using a 4 Hz frequency resolution and a 0.05 s time resolution (Reisz window). Each frequency bin was normalized to the median bin value over the 300 s window. The detection threshold was three times the median value. Contours were created by joining the detected time and frequency bins in the frequency range of 7–1000 Hz using a 5 × 5 kernel. Any contour 0.2–6 s with a bandwidth of at least 60 Hz was kept for further analysis.

An "event" time series is created by summing the normalized value of the frequency bins at each time bin that contains detected contours. The event time series is auto-correlated to look for repeated events. The correlated data space is normalised to its median and a detection threshold of 3 is applied. Peaks larger than their two nearest neighbours are identified and the peaks list is searched for entries with a set repetition interval. The spacing between the minimum and maximum time peaks is appropriately set, typically at 4.8 and 65 s, to allow for the normal range of seismic pulse periods, which are between 5 and 60 s. If at least six regularly spaced peaks occur, the original event time series is searched for all peaks that match the repetition period within a tolerance of 0.25 s. The duration of the 90% SPL window of each peak is determined from the originally sampled time series, and pulses more than 3 s long are rejected.

2.3.4. Total Sound Levels

2.3.4.1. Sound Levels

Underwater sound amplitude is measured in decibels (dB) relative to a fixed reference pressure of p_0 = 1 µPa. Because the perceived loudness of sound, especially impulsive noise such as from seismic airguns, pile driving, and sonar, is not generally proportional to the instantaneous acoustic pressure, several sound level metrics are commonly used to evaluate noise and its effects on marine life.

The zero-to-peak pressure, or PK (dB re 1 µPa), is the maximum instantaneous SPL in a stated frequency band attained by an acoustic pressure signal, $p(t)$:

$$\text{Peak pressure (PK)} = 10\log_{10}\left[\frac{\max\left(\left|p^2(t)\right|\right)}{p_0^2}\right] \quad (1)$$

The peak-to-peak pressure (dB re 1 µPa) is the difference between the maximum and minimum instantaneous SPLs in a stated frequency band attained by an impulse, p(t):

$$\text{Peak-to-peak pressure} = 10\log_{10}\left\{\frac{\left[\max\left(p(t)\right)-\min\left(p(t)\right)\right]^2}{p_0^2}\right\} \tag{2}$$

At high intensities, the PK can be a valid criterion for assessing whether a sound is potentially injurious; however, because the PK does not account for the duration of a noise event, it is a poor indicator of perceived loudness. The root-mean-square (rms) SPL (dB re 1 µPa) is the rms pressure level in a stated frequency band over a time window (T, s) containing the acoustic event:

$$\text{SPL} = 10\log_{10}\left(\frac{1}{T}\int_T p^2(t)dt \Big/ p_0^2\right) \tag{3}$$

The SPL is a measure of the average pressure or of the effective pressure over the duration of an acoustic event, such as the emission of one acoustic pulse, a marine mammal vocalization, the passage a vessel, or a fixed duration in time. Because the window length, T, is the divisor, events more spread out in time have a lower SPL for the same total acoustic energy density.

In studies of impulsive noise, T is often defined as the "90% energy pulse duration" (T_{90}): the interval over which the pulse energy curve rises from 5% to 95% of the total energy. The SPL computed over this T_{90} interval is commonly called the 90% SPL (dB re 1 µPa):

$$\text{90\% SPL} = 10\log_{10}\left(\frac{1}{T_{90}}\int_{T_{90}} p^2(t)dt \Big/ p_0^2\right) \tag{4}$$

The sound exposure level (SEL, dB re 1 µPa²·s) is a measure of the total acoustic energy contained in one or more acoustic events. The SEL for a single event is computed from the time-integral of the squared pressure over the full event duration (T100):

$$\text{SEL} = 10\log_{10}\left(\int_{T_{100}} (p^2(t)-\overline{n^2})dt \Big/ T_0 p_0^2\right) \tag{5}$$

where T_0 is a reference time interval of 1 s. The SEL represents the total acoustic energy received at some location during an acoustic event; it measures the total sound energy to which an organism at that location would be exposed.

SEL is a cumulative metric if it is calculated over periods with multiple acoustic events or fixed periods. For multiple events the cumulative SEL (dB re 1 µPa²·s) can be computed by summing (in linear units) the SELs of the N individual events:

$$\text{Cumulative SEL} = 10\log_{10}\left(\sum_{i=1}^{N} 10^{\frac{\text{SEL}_i}{10}}\right) \tag{6}$$

To compute the SPL and SEL of acoustic events in the presence of high levels of background noise, Equations 4) and 5) are modified to subtract the background noise energy from the event energy:

$$\text{SPL} = 10\log_{10}\left(\frac{1}{T_{90}}\int_{T_{90}} (p^2(t)-\overline{n^2})dt \Big/ p_0^2\right) \tag{7}$$

$$\text{SEL} = 10\log_{10}\left(\int_{T_{100}} (p^2(t)-\overline{n^2})dt \Big/ T_0 p_0^2\right) \tag{8}$$

where $\overline{n^2}$ is the mean square pressure of the background noise generally computed by averaging the squared pressure of a nearby segment of the acoustic recording during which acoustic events are absent (e.g., between pulses).

Because the SPL and SEL are both computed from the integral of square pressure, these metrics are related by a simple expression, which depends only on the duration of the energy time window, T:

$$\text{SPL} = \text{SEL} - 10\log_{10}(T) \tag{9}$$

$$\text{SPL} = \text{SEL} - 10\log_{10}(T_{90}) - 0.458 \tag{10}$$

where the 0.458 dB factor accounts for the SPL containing 90% of the total energy from the per-pulse SEL.

2.3.4.2. Spectral and 1/3-octave-band Analysis

The distribution of a sound's power with frequency is described by the sound's spectrum, which shows the fine-scale features of the frequency distribution of a sound. The spectrum of a sound can be split into a series of adjacent frequency bands. Splitting a spectrum into 1 Hz wide bands yields the "power spectral density" of the sound. These values directly compare to the Wenz curves that represent typical deep-ocean sound levels (Figure 10; Wenz 1962). This splitting of the spectrum into passbands of a constant width of 1 Hz, however, does not represent how animals perceive sound.

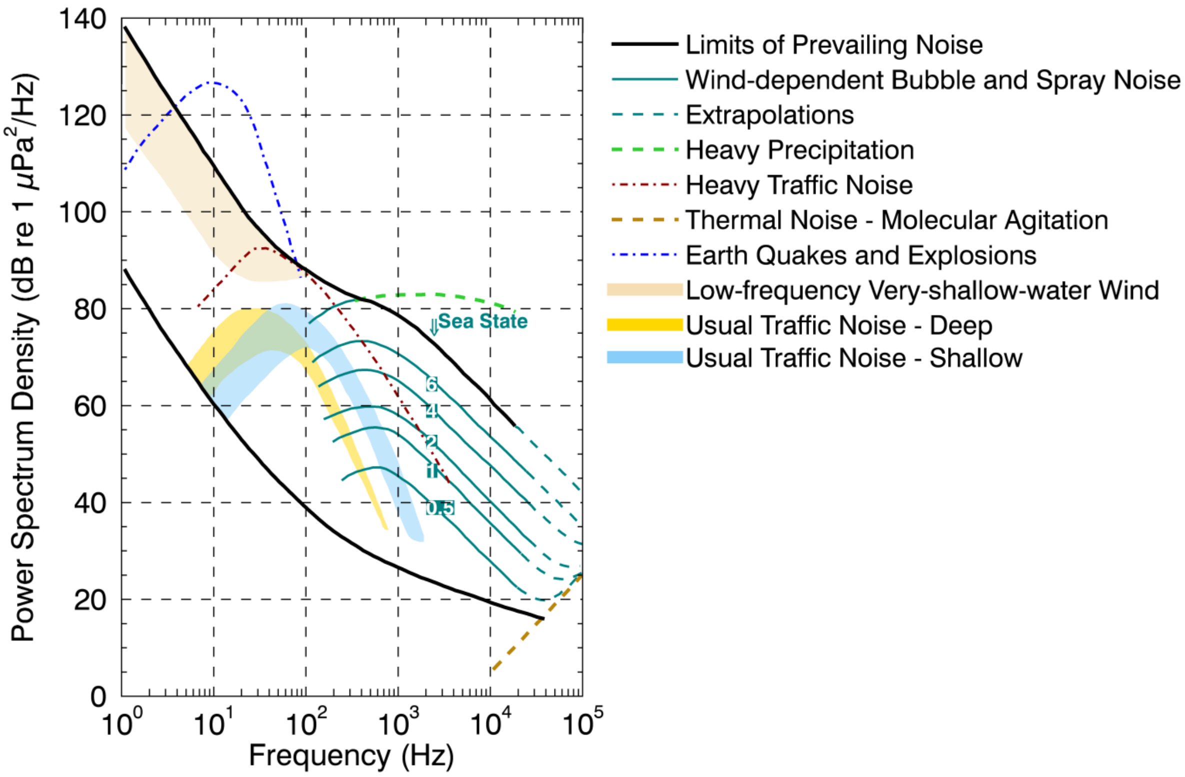


Figure 10. Wenz curves (NRC 2003), adapted from Wenz (1962), describing pressure spectral density levels of marine ambient noise from weather, wind, geologic activity, and commercial shipping.

Because animals perceive exponential increases in frequency rather than linear increases, analysing a sound spectrum with passbands that increase exponentially in size gives more meaningful data. In underwater acoustics, a spectrum is commonly split into 1/3-octave-bands, which are one-third of an octave wide; each octave represents a doubling in sound frequency. The centre frequency of the *i*th 1/3-octave-band, $f_c(i)$, is defined as:

$$f_c(i) = 10^{i/10} \tag{11}$$

and the low (f_{lo}) and high (f_{hi}) frequency limits of the *i*th 1/3-octave-band are defined as:

$$f_{lo} = 10^{-1/20} f_c(i) \quad \text{and} \quad f_{hi} = 10^{1/20} f_c(i) \tag{12}$$

The 1/3-octave-bands become wider with increasing frequency, and on a logarithmic scale the bands appear equally spaced (Figure 11).

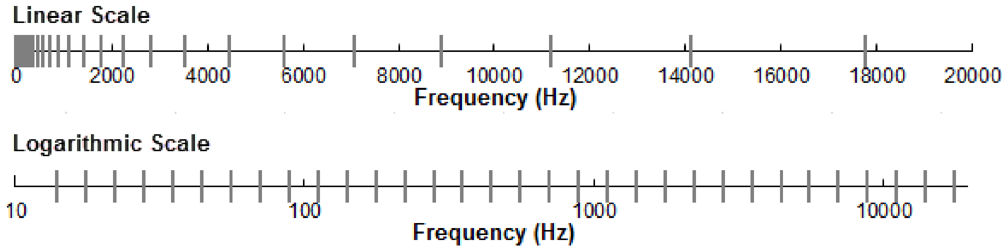


Figure 11. One-third-octave-bands shown on a linear frequency scale and on a logarithmic scale.

The SPL in the *i*th 1/3-octave-band $(L_b^{(i)})$ is computed from the power spectrum *S*(*f*) between f_{lo} and f_{hi}:

$$L_b^{(i)} = 10\log_{10}\left(\int_{f_{lo}}^{f_{hi}} S(f)df\right) \tag{13}$$

Summing the SPL of all the 1/3-octave-bands yields the broadband SPL:

$$\text{Broadband SPL} = 10\log_{10}\sum_i 10^{L_b^{(i)}/10} \tag{14}$$

Figure 12 shows an example of how the 1/3 octave band SPLs compare to the power spectrum of an ambient noise signal. Because the 1/3 octave bands are wider with increasing frequency, the 1/3 octave band SPL is higher than the power spectrum, especially at higher frequencies. Acoustic modelling of 1/3 octave bands require less computation time than 1 Hz bands and still resolves the frequency-dependence of the sound source and the propagation environment.

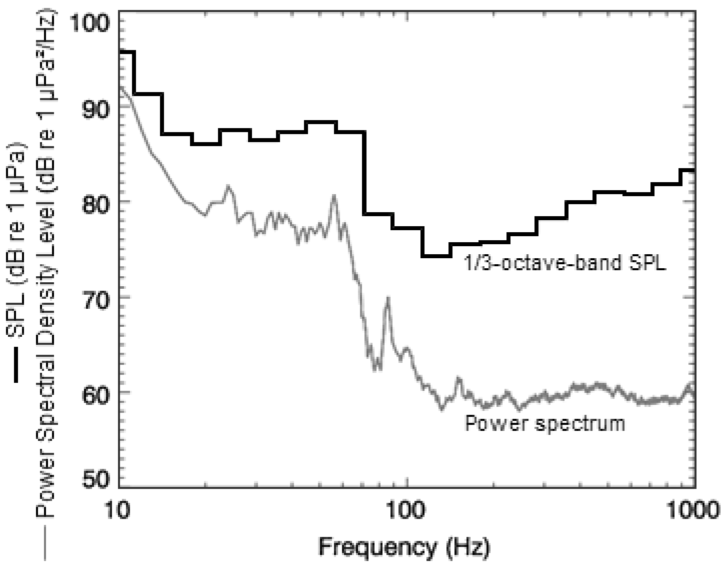


Figure 12. A power spectrum and the corresponding 1/3-octave-band SPLs of ambient noise shown on a logarithmic frequency scale.

2.3.4.3. Sound Level Statistics

Sound level statistics quantify the observed distribution of recorded sound levels. Following standard acoustical practice, the *n*th percentile level (L_n) is the spectral density, SPL or SEL exceeded by *n*% of the data. L_{max} is the maximum recorded sound level. L_{mean} is the linear arithmetic mean of the sound power, which can be significantly different from the median sound level (L_{50}). In this report, the median level is used to compare the most typical sound level between stations, since the median is not as affected by high outliers as the mean sound level. L_5, the level exceeded by only 5% of the data, generally represents the highest typical sound levels measured. Sound levels between L_5 and L_{max} are due to close passes of vessels, intense weather, or other abnormal conditions. L_{95} represents the quietest typical conditions.

3. Results

3.1. Environmental Data

3.1.1. Tide Height

The tidal station closest to the Barossa area is located at Darwin, approximately 300 km south of the Barossa area. Tidal height data were collected from this station (Figures 13 and 14). During Deployment 1, the mean tidal difference was 4.06 m and the minimum tidal range was 0.58 m. the mean tidal difference was 4.10 m and the minimum tidal range was 0.53 m.

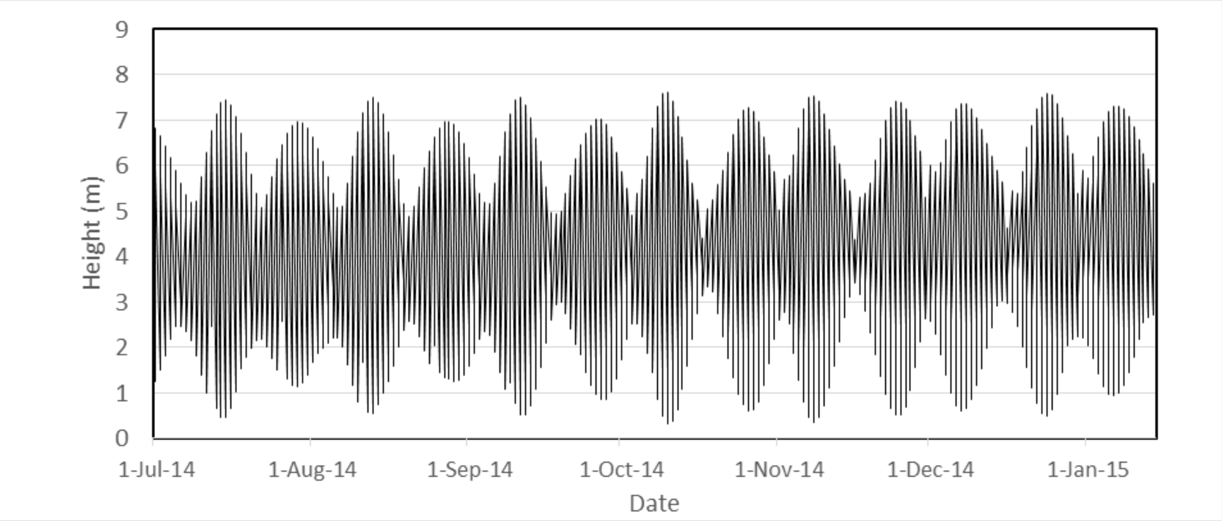


Figure 13. Low and high tide heights (m) at Darwin tidal station 10 July 2014 to 15 January 2015.

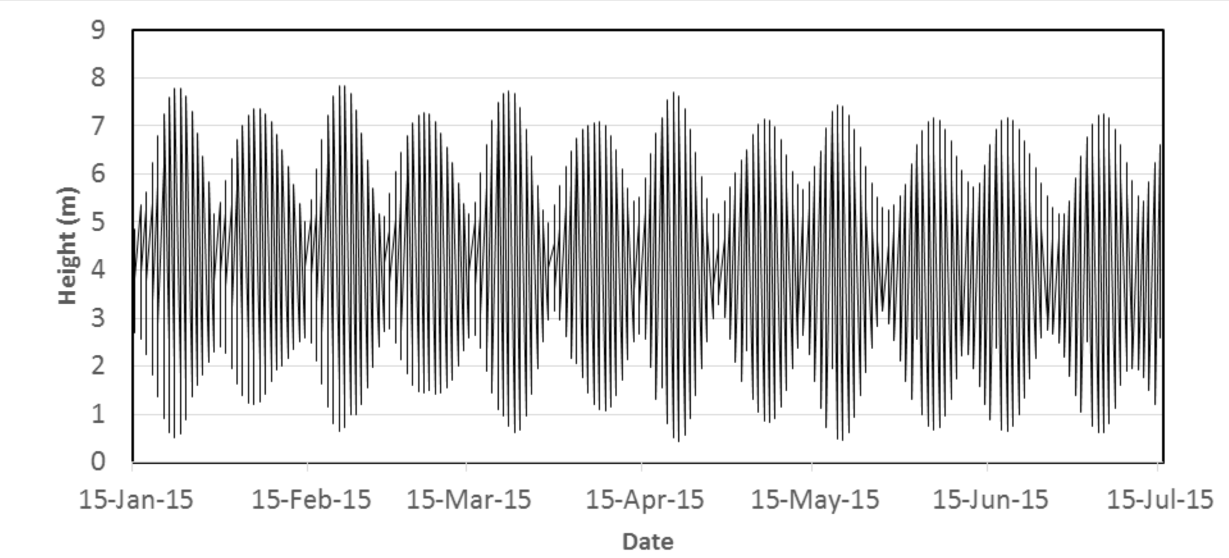


Figure 14. Low and high tide heights (m) at Darwin tidal station 15 January 2015 to 15 July 2015.

3.1.2. Wind Speed

Wind speed data were collected from the Fugro metbouy M1, located at 09° 49.122' S, 130° 18.708' E, close to Station J2, the data is shown in Figure 15. During Deployment 1, the mean wind speed was 6.7 m/s (24.1 km/h), the maximum wind speed of 20.5 m/s (73.84 km/h) was recorded on 31 December 2014. During Deployment 2, the mean wind speed was 7.3 m/s (26.4 km/h), the maximum wind speed of 21 m/s (75.5 km/h) was recorded on 23 March 2015.

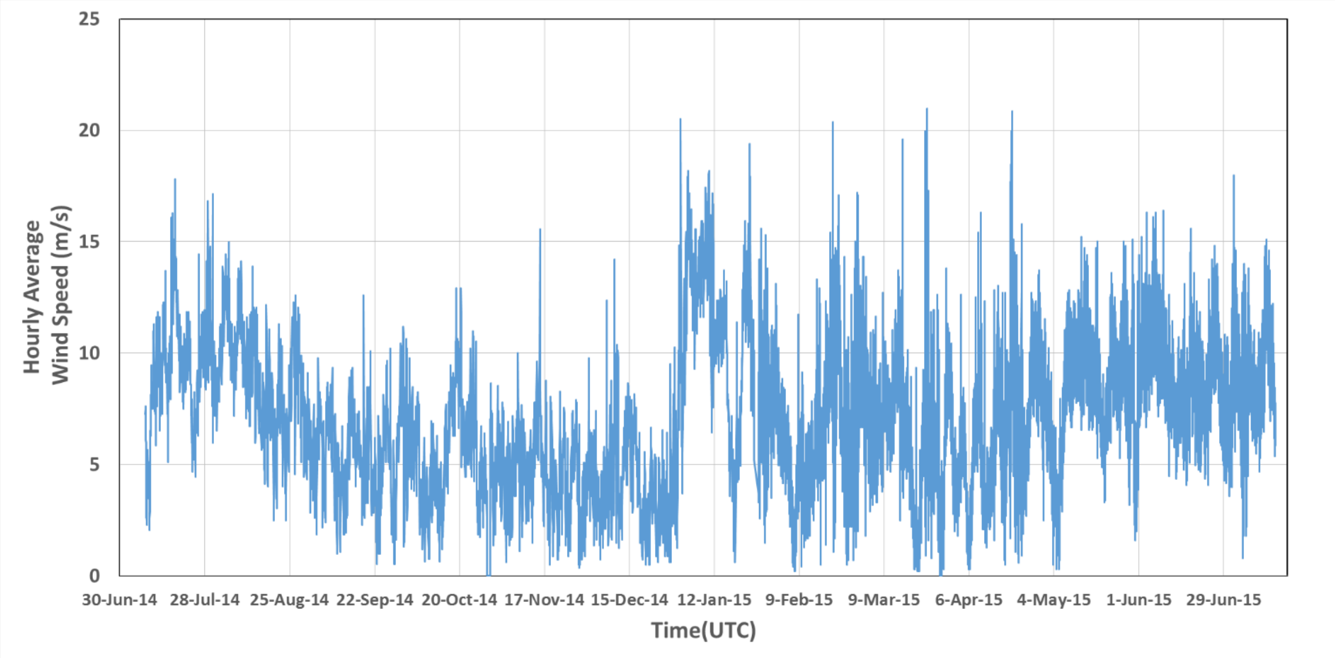


Figure 15. Daily average wind speed recorded at Fugro's M1 metbuoy 8 July 2014 to 15 July 2015.

3.1.3. Wave Height

Wave height data were collected from the Fugro waverider buoy W1, located at 09° 49.115' S, 130° 17.773' E in 260 m of water. During Deployment 1, the mean significant wave height was 1.10 m, while the mean maximum wave height was 1.68 m, the maximum wave height of 5.31 m was recorded on 9 January 2015 (Figure 16). During Deployment 2, the mean significant wave height was 1.28 m, while the overall mean maximum wave height was 2.96 m, the maximum wave height of 5.2 m was recorded on 15 May 2015 (Figure 16).

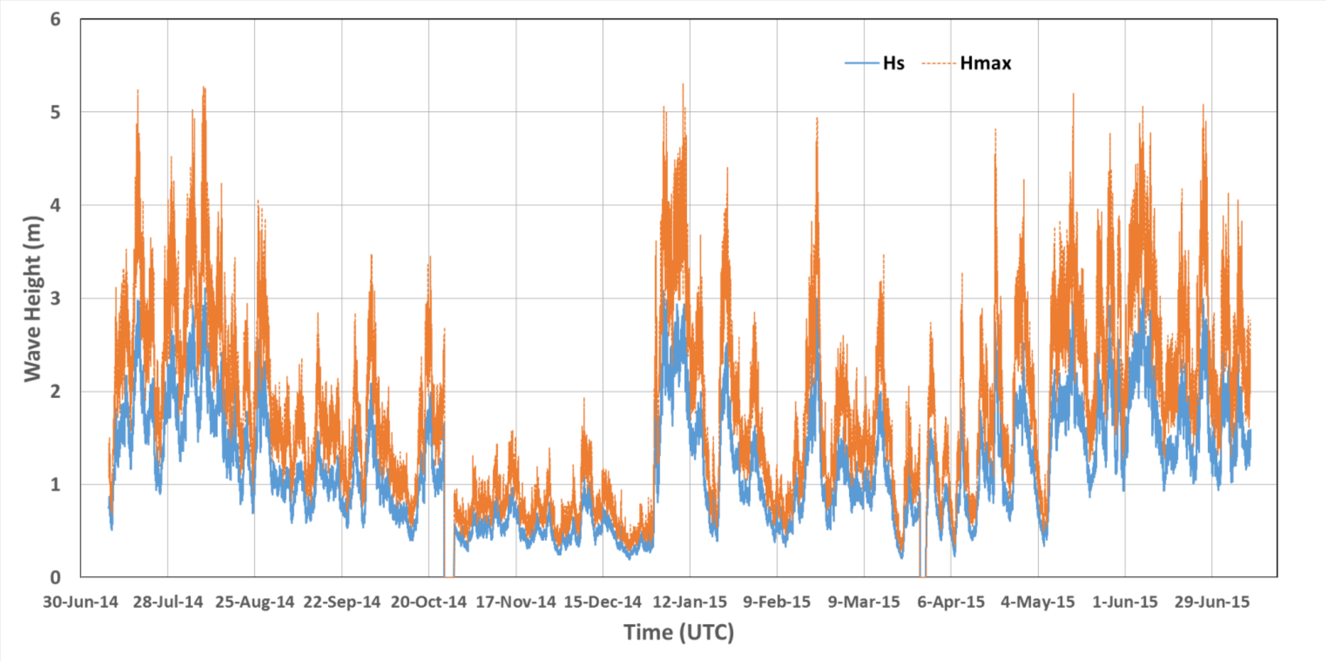


Figure 16. 10-minute wave heights recorded at Fugro's W1 waverider buoy 9 July 2014 to 11 July 2015.

3.2. Marine Fauna

This scope of the acoustic monitoring study did not include detailed manual analysis; instead, JASCO calibrated the automated detection process by manually reviewing 2041 files resulting in over 320 hours of recordings reviewed (Table 7; see Section 2.3.1.3). These files contained pygmy blue whale moans, unidentified baleen whale moans, beaked whale clicks, and unidentified odontocete clicks and whistles. JASCO did not observe humpback whale moans or sperm whale clicks during the manual review.

Table 7. The number of 48 and 250 ksps files manually analysed for deployments 1 and 2 at Stations J1, J2, and J3 recorded in the Timor Sea.

Sampling rate (ksps)	Deployment 1			Deployment 2		
	J1	J2	J3	J1	J2	J3
48 (14min/file)	130	128	129	135	136	136
250 (1min/file)	121	111	110	123	127	125

3.2.1. Detector thresholds

The manual validation results were compared to the automated results for the same files to generate classification thresholds for the manually detected calls (Table 8). The thresholds are the number of automated detections/file (14 min 48 ksps file for mysticete calls and 1 min 250 ksps file for odontocete calls) that provide a high confidence that the species are truly present. The selected thresholds provide a precision of 0.97 for blue whale moans, 0.90 for double-barrel/long calls, 0.55 for downsweeps, 0.75 for beaked whale clicks, 0.92 for odontocete clicks, and 0.88 for whistles (Table 8). These thresholds were applied to the automated detections. Note that the selected thresholds also translate into recall values near 50-60%, which suggest that our method underestimates (conservative) acoustic occurrence and that isolated detections outside of the main period of occurrence could be overlooked.

Table 8. Classification thresholds determined from validating the automated detector outputs. The classification thresholds are the minimum number of detected calls/file required to be confident that detections are not false alarms. The precision (P), recall (R), and F-score (F) before the threshold is applied (original) and after (threshold) is shown.

Vocalisations	$P_{original}$	$R_{original}$	Classification threshold	$P_{threshold}$	$R_{threshold}$	$F_{threshold}$
Pygmy blue whale	0.63	0.82	6	0.97	0.64	0.88
Double-barrel/long monotonic	0.57	0.98	11	0.90	0.60	0.82
Downsweep	0.41	0.61	5	0.55	0.52	0.54
Beaked whale	0.25	0.83	11	0.75	0.50	0.68
Clicks	0.79	0.99	67	0.92	0.89	0.91
Whistles	0.88	0.46	2	0.88	0.46	0.75

3.2.2. Mysticetes

3.2.2.1. Pygmy Blue Whales

3.2.2.1.1. Manual Detections

Pygmy blue whale calls were positively identified during the manual validation of automatic detections based on similarities with previous descriptions (e.g. Gavrilov et al. (2011)). Detections occurred mostly during Deployment 2, when calls were observed over 10 days at Station J1, 7 days at Station J2, and 6 days at Station J3 (Figure 17). One validated detection also occurred at J2 on 2 August 2014. The calls were typically organised into songs, as described by McDonald et al. (2006), Gavrilov et al. (2011). A segment of a pygmy blue whale song composed of two notes is shown in Figure 18. The call has a frequency bandwidth of 77 Hz (15–92 Hz) and a time period of 24 s. Calls had most energy at ~20 Hz and 50–70 Hz and lasted for 15–25 ss. Some calls were detected at all three stations simultaneously (Figure 19). While the time axis is shown as synchronised, the stations have not been synchronised to the point of being able to localise the calling animal.

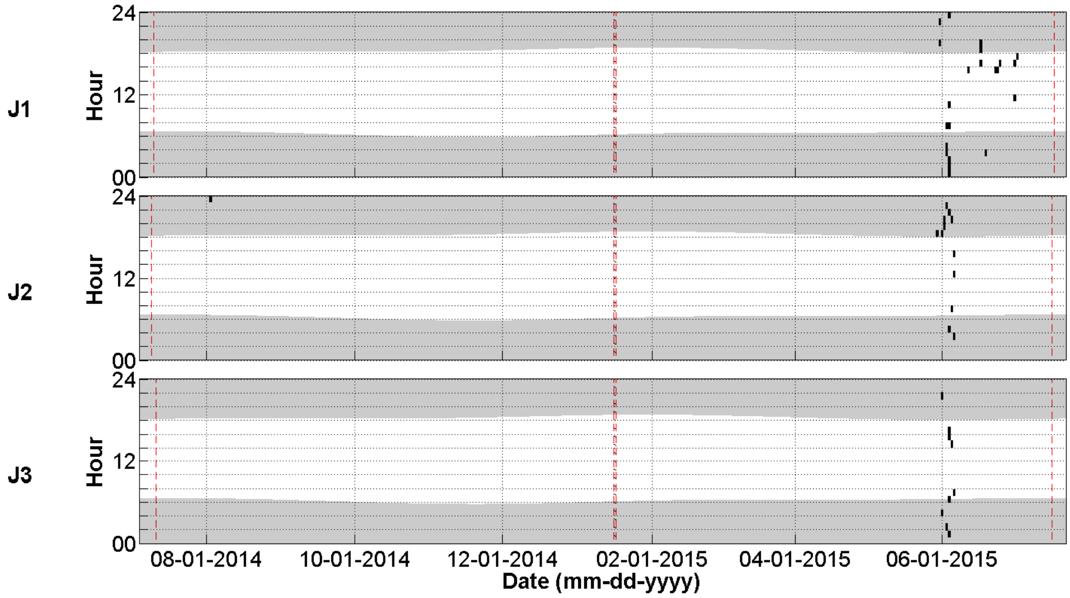


Figure 17. Presence of manually validated pygmy blue whale calls (normalised on a 0.5 h basis) at Stations J1, J2, and J3 from July 2014 to July 2015 in the Timor Sea. The grey areas indicate hours of darkness from sunset to sunrise (Ocean Time Series Group 2009). The red dashed lines indicate the start and end of recording time.

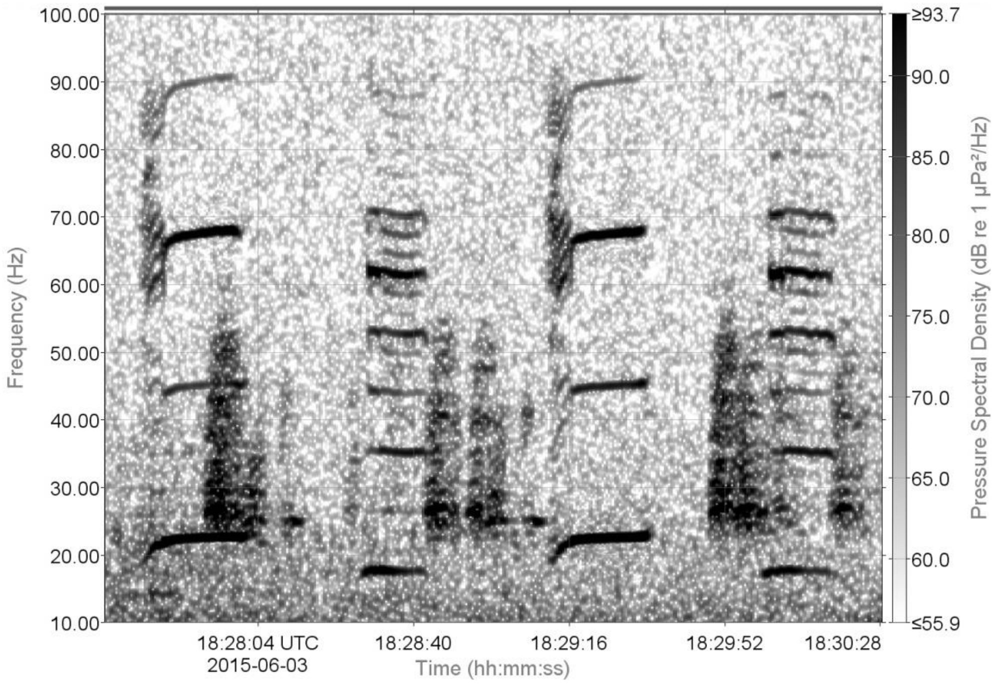


Figure 18. Spectrogram of pygmy blue whale songs showing two repetitions of each call type in sequence and Omura's whale calls in the background, recorded at Station J2 on 3 June 2015 (UTC) (0.0916 Hz frequency resolution, 2 s time window, 0.5 s time step, Hamming window).

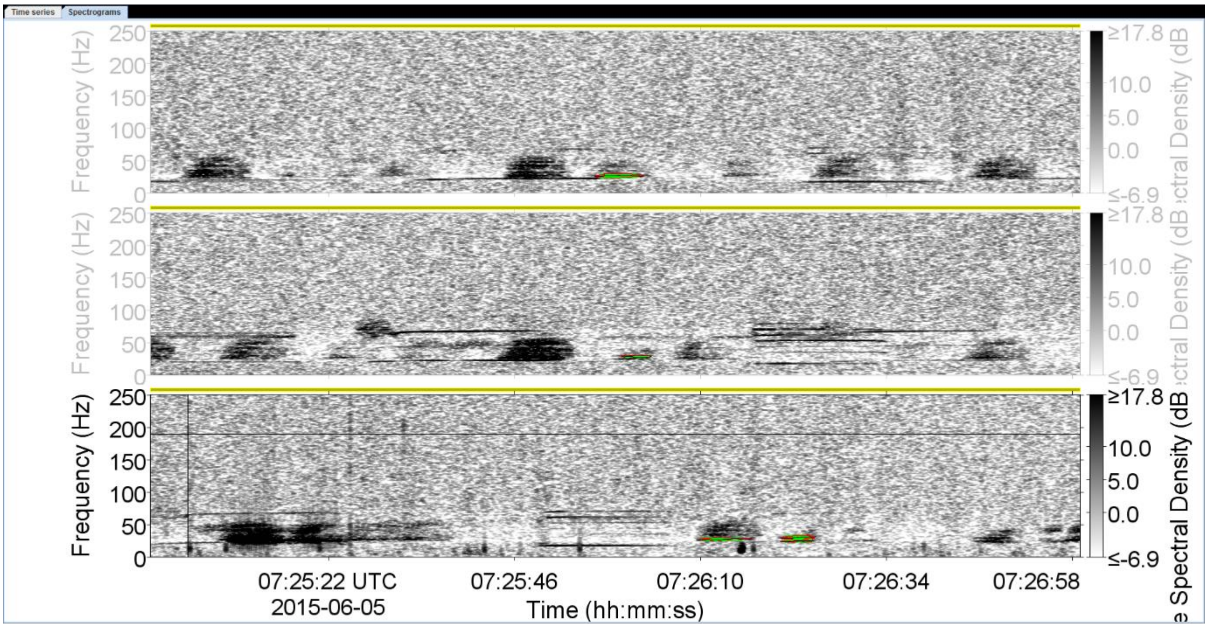


Figure 19. Spectrogram of pygmy blue whale calls recorded at Station (top) J1, (centre) J2 and (bottom) J3 on 5 June 2015 (UTC) (0.5 Hz frequency resolution, 0.5 s time window, 0.05 s time step, and Hamming window).

3.2.2.1.2. Automated Detections

Pygmy blue whales were automatically detected primarily from 29 May to 5 June 2015 (Figures 20 and 21). Detections that occurred outside of this period were verified for pygmy blue whale call absence/presence. A single automated detection at Station J3 on 15 February 2015 was found to be falsely triggered by noise. In contrast, detections on 16 and 30 June 2015 as well as 1 July 2015 were verified as true pygmy blue whale calls. Call detections were greatest at the deepest station, J2, at Barossa field, and lowest at the shallowest station, J3, at Caldita field (Table 9 and Figure 22). No obvious diurnal pattern was observed. It is worth noting that based on manual analysis results and a detector recall of 0.64 (Table 8), the automated detector failed to detect pygmy blue whales on a few days in June when pygmy blue whales were present in the vicinity of Station J1 as determined through manual analysis (Figure 17).

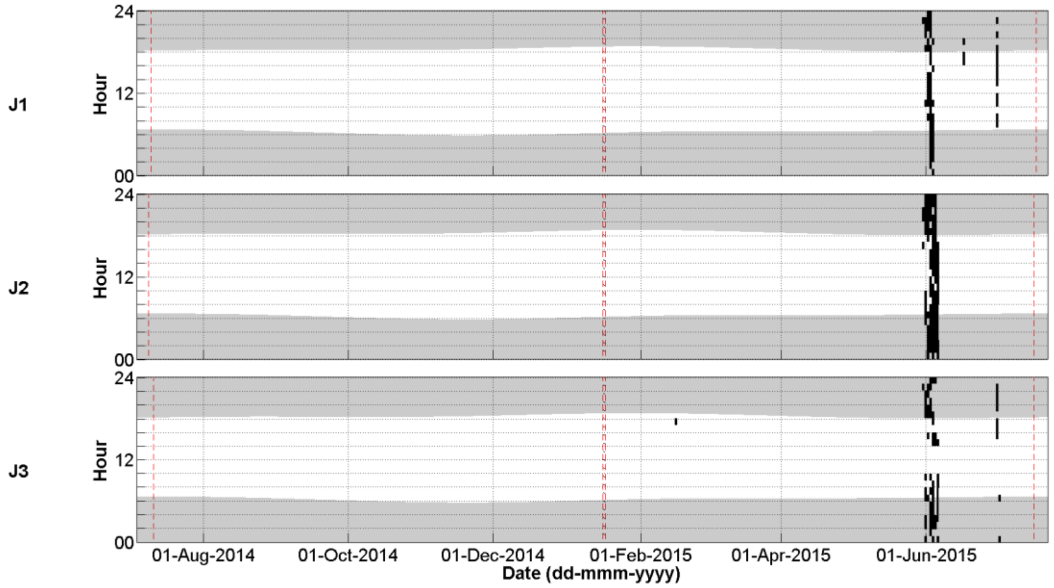


Figure 20. Hourly (expressed as an index) and daily presence of automatically detected pygmy blue whale calls at Stations J1, J2, and J3. Presence of automatically detected pygmy blue whales (normalised on a 1 h basis). The grey areas indicate hours of darkness from sunset to sunrise (Ocean Time Series Group 2009). The red dashed lines indicate the start and end of recording time.

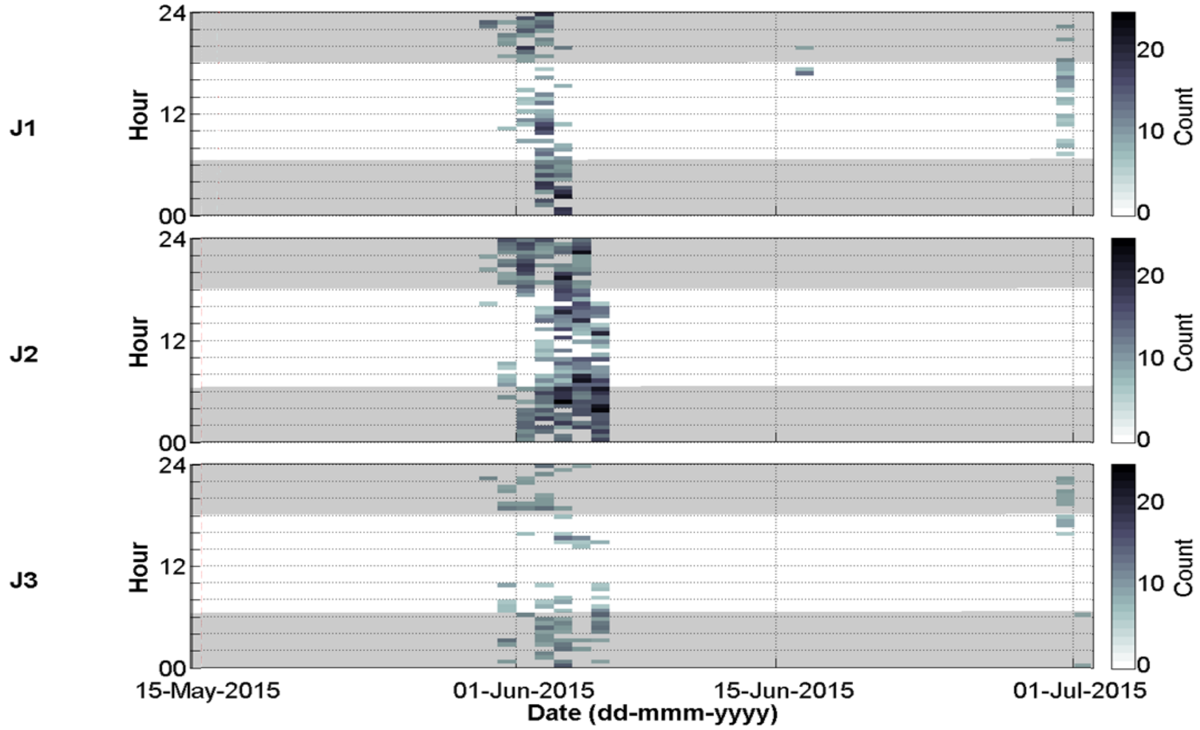


Figure 21. Hourly (expressed as an index) and daily number of automatically detected pygmy blue whale calls at Stations J1, J2, and J3 from 15 May to 1 Jul 2015. Count of automatically detected blue whales (normalised on a 0.5 h basis). The grey areas indicate hours of darkness from sunset to sunrise (Ocean Time Series Group 2009).

Table 9. Pygmy blue whale detection summary

Station	Total detection days	Pygmy blue whale moan detections
Deployment 1, 10–11 Jul 2014 to 15 Jan 2015		
J1	0	0
J2	1	1
J3	0	0
Deployment 2, 16–17 Jan to 15–16 Jul 2015		
J1	7	905
J2	7	2060
J3	9	659

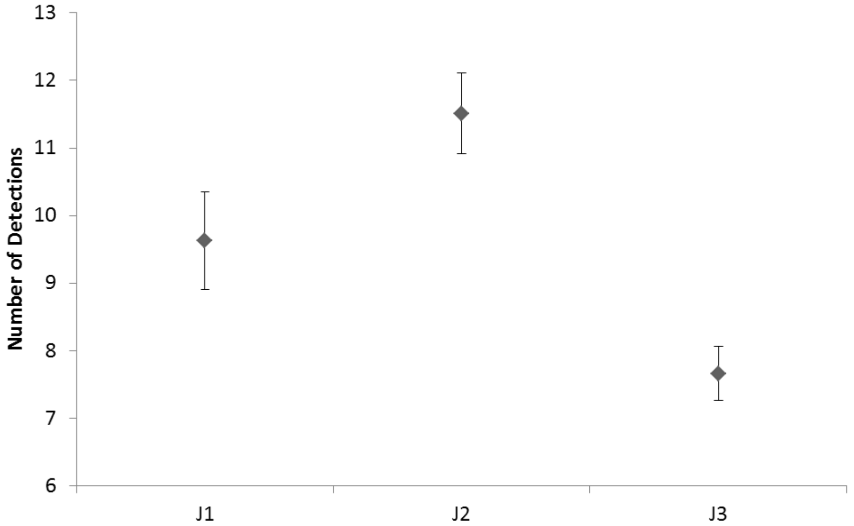


Figure 22. Mean number of pygmy blue whale call detections per 14 min 48 ksps sample for samples with at least 1 detection with 95% confidence intervals for Stations J1, J2, and J3.

A more detailed examination of the June peak in detections revealed that pygmy blue whale call SPLs at all stations had similar variations about the mean station call SPL during the nine days of recordings when calls were detected (Figure 23).

The first main group of calling pygmy blue whales were detected on 31 May initially at Station J1, followed by Station J3, and finally noticeably louder calls were detected at Station J2. Over 5 hours later the second main group was detected, again initially at Station J1, before being detected at Station J3 and finally only Station J2. For the remainder of 1 June and the entirety of 2 June calls were detected almost continuously at all three stations, with detections at Stations J1 and J3 being consistently louder than those of Station J2 for the majority of 2 June. Detections ceased at Station J1 on 3 June. Calls continued to be detected at Station J2, with sporadic detections at Station J3, until the morning of 5 June when the last calling activity was detected at Station J2 (Figure 24).

After the initial detections, pygmy blue whale calls were not detected again until the morning of 16 June at Station J1 (Figure 23). A similar detection event occurred at Station J1 in the night of 29 June (Figures 23 and 25). The final pulse of calls was detected on 30 June at Station J1 followed closely by Station J3. Station J1 calls showed a slight decrease in relative loudness from when they began at 02:23 to when they ceased at 12:01. In contrast, Station J3 calls increased gradually in loudness from when they were first detected at 08:20 to when they were last detected at 15:31 (Figure 25).

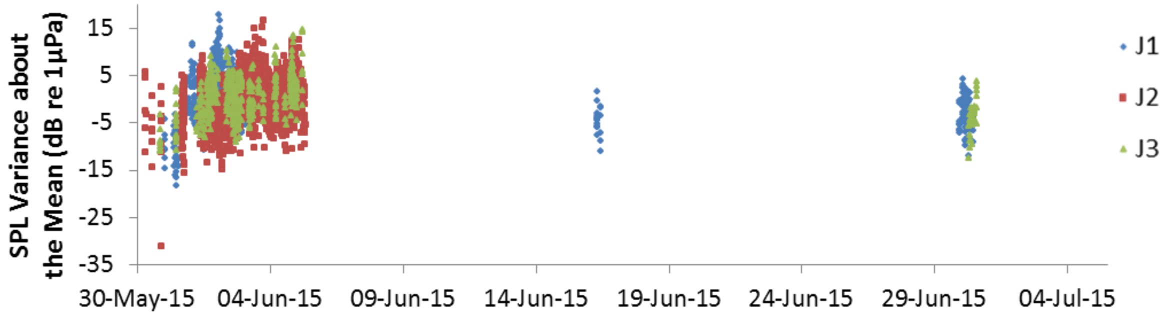


Figure 23. Plot of pygmy blue whale call SPLs above and below the mean call SPL/station for Stations J1, J2, and J3 from 30 May to 4 July 2015.

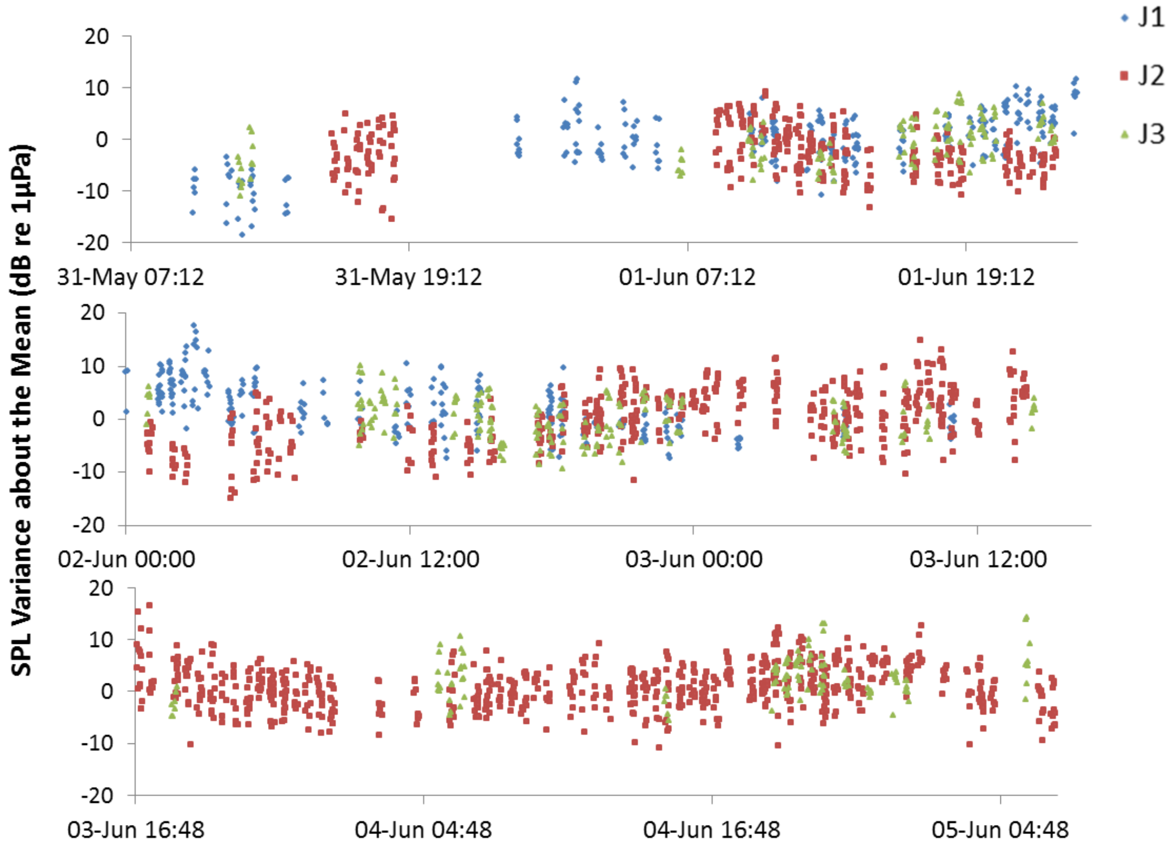


Figure 24. Plot of pygmy blue whale call SPLs above and below the mean call SPL/station for Stations J1, J2, and J3 from 31 May 2015 to 1 June 2015 (top), 2 June to 3 June 2015 (middle), and 3 June to 5 June (bottom).

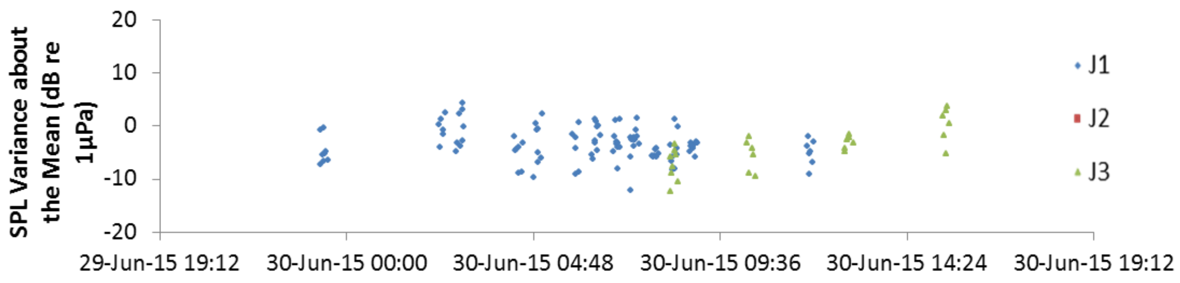


Figure 25. Plot of pygmy blue whale call SPL above and below the mean call SPL/station for stations J1, J2, and J3 from 30 June to 1 July 2015.

3.2.2.1.3. Regional use approximation

To provide some context about the possible migration path of the pygmy blue whales, an estimate of the distance of pygmy blue whales from Station J2 using the minimum, median and maximum received call levels determined through analysis of the automated detections was performed.

Along with the received call levels (Table 10), the source levels from literature of 183 dB re 1 µPa SPL (McCauley et al. 2001) and 179 dB re 1 µPa SPL (Gavrilov et al. 2011) were used. An estimated whale depth of 40 m was selected based on the commonly reported depth of a calling blue whale of 40 m (Thode et al. 2000), and used with a transmission loss curve derived from running JASCO's Marine Operations Noise Model (MONM) over a single transect line at a bearing of 303.96°, taking advantage of the theory of reciprocity. The exact migration path of the whales is unknown, and while a single transect is not accurate, it allows for a comparison of possible distances from Station 2 to the whales. It has been assumed that the whales were migrating offshore from the recorders, in the direction of the trench, the bearing selected is the bearing from Station J2 to the nearest section of the continental slope.

An eigenray is defined as a ray that connects a source position with a receiver position. The principle of reciprocity is applicable for a point-to-point situation, and is where the eigenrays from a source position to the receiver position are the same as when source and receiver change positions. The reflections of the eigenrays at the sea surface and sea floor are symmetric in angles, and therefore the acoustic fields are the same.

The calculated distances of the pygmy blue whales from Station J2 along the selected transect range, are shown in Table 11.

Table 10. Pygmy blue whale call modelling parameters

Call SL (dB)	Received Level (dB)			Call depth (m)	Call Frequency (Hz)	Modelled 1/3 Octave band centre Frequency (Hz)
	Minimum	Median	Maximum			
179	62.8	93.9	110.5	40	20	20
183						

Table 11. Pygmy blue whale distance estimation (km)

Call SL (dB)	Estimated Distance (km)		
	Min. received level	Median received level	Max. received level
179	$8.0x10^4$	$2.3x10^4$	5
183	$>8.0x10^4$	$3.1x10^4$	9

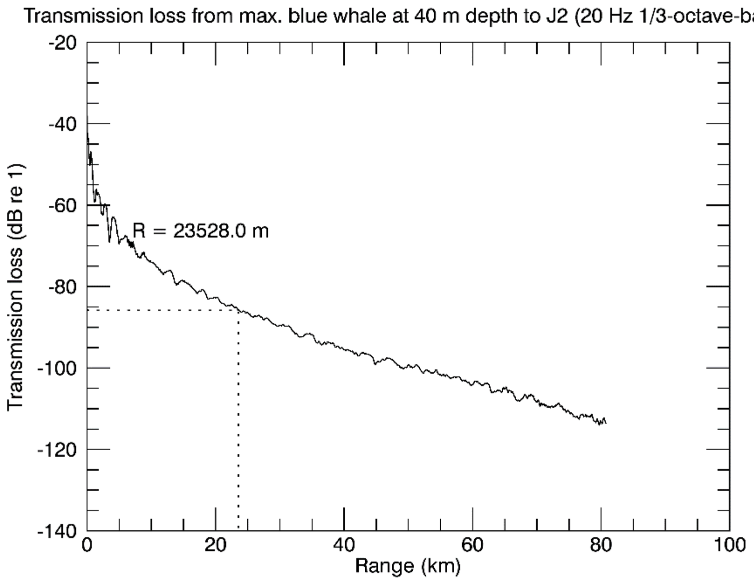


Figure 26. Example transmission loss modelling results for median received pygmy blue whale call using source level 179 dB, using a 1/3 octave band centred at 20 Hz.

3.2.2.2. Omura's and Bryde's Whales

3.2.2.2.1. Manual Detections

Three initially unidentified baleen whale call types were regularly observed: double-barrel moans (Figure 28), long monotonic moans (Figure 30), and downsweeps (Figure 32). The double-barrel calls often occurred in sequence with the monotonic calls suggesting that these two calls were produced by the same species/individuals. Because of their similarities, double-barrel and long calls were both detected by the same automated detector and will therefore be discussed jointly in Section 3.2.2.2.2. Downsweeps almost always occurred within the same file as the other calls, but it was not until a more detailed analysis on the detections occurred that it became apparent they are likely from a different whale to the double-barrel and long monotonic calls. The justification for the attribution of the double-barrel moans and long monotonic calls to Omura's whales and the downsweeps to Bryde's whales is provided in Section 4.1.1.2.

Double-barrel Omura's calls were primarily observed in the months of May-August on 34 days at Station J1, 28 days at J2, and 38 days at J3 (Figure 27). Calls were comprised of three distinct parts: 1) a 6–9 s long 26–28 Hz call, 2) a 2–3 s long 40 Hz call occurring simultaneously above 3) a 2–3 s 26–28 Hz call where calls 1 and 2 were separated by 3–4 s (Figure 28).

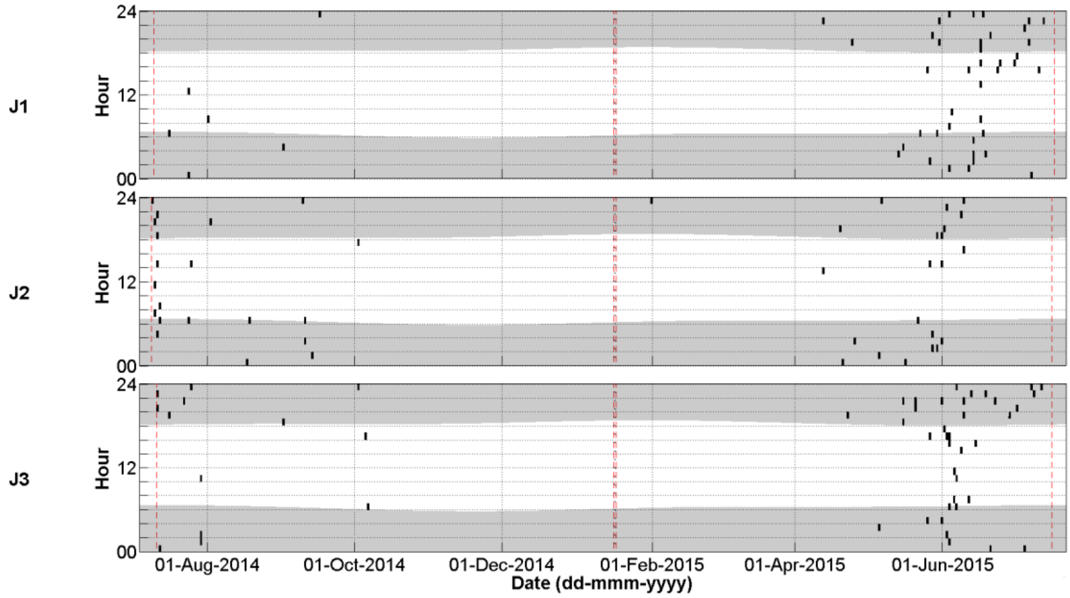


Figure 27. Presence of manually validated double-barrel Omura's whale calls (normalised on a 0.5 h basis) at Stations J1, J2, and J3 from July 2014 to July 2015 in the Timor Sea. The grey areas indicate hours of darkness from sunset to sunrise (Ocean Time Series Group 2009). The red dashed lines indicate the start and end of recording time.

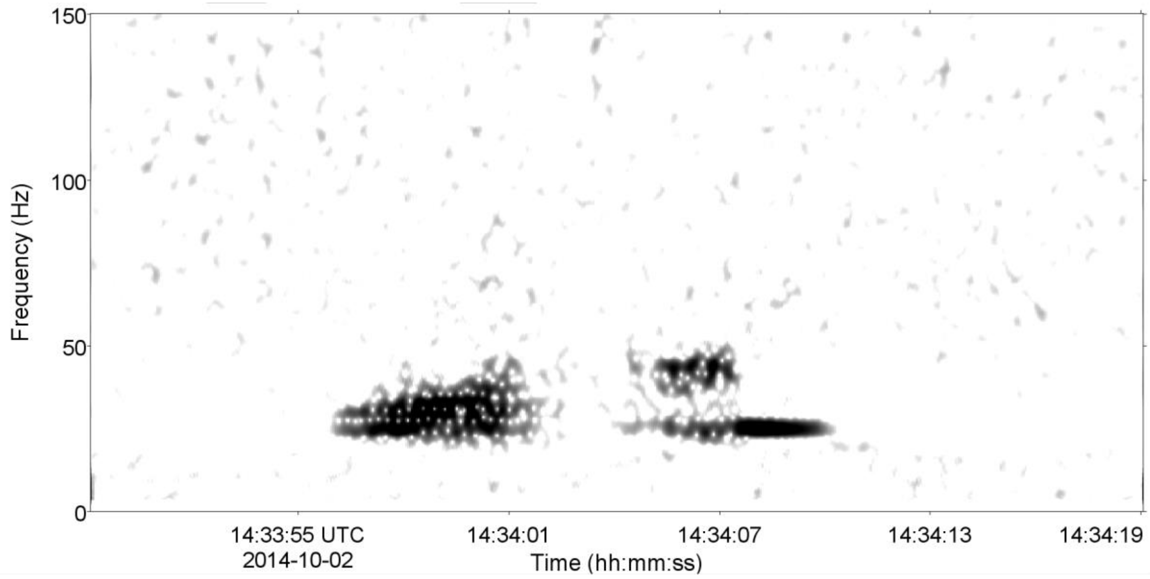


Figure 28 Spectrogram of a double-barrel Omura's whale call recorded at Station J1 on 2 October 2014 (UTC) (0.5 Hz frequency resolution, 0.5 s time window, 0.05 s time step, and Hamming window).

Long monotonic Omura's calls were manually observed on 66 days at Station J1, 73 days at J2, and 58 days at J3. While the call type occurred in all recorded months, it was more abundant in April to August (Figure 29). Long monotonic calls had a centroid frequency of 26–28 Hz and duration of 6–10 s (Figure 30).

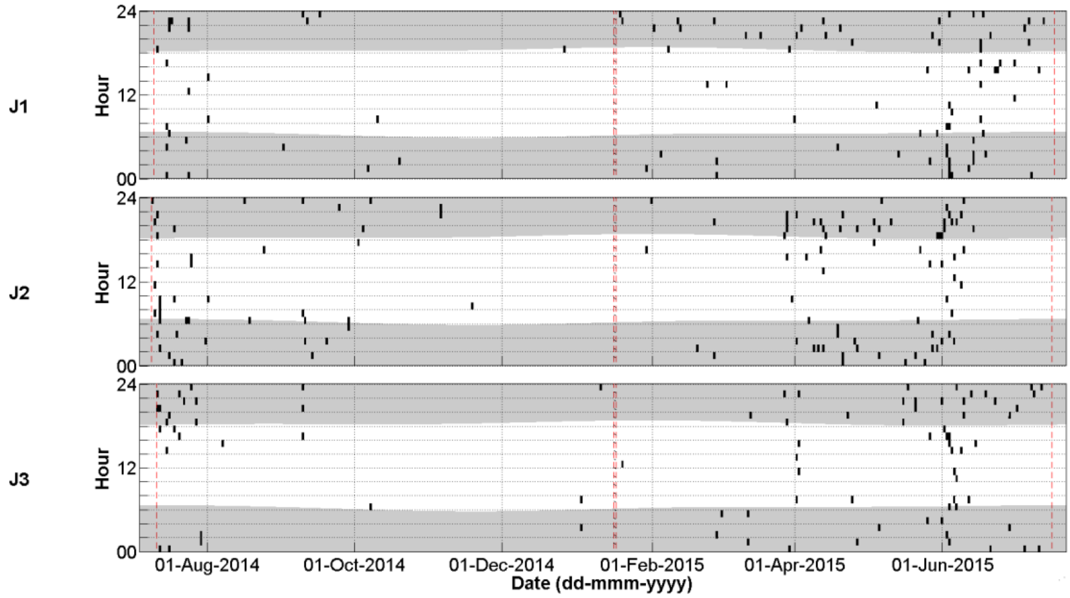


Figure 29. Presence of manually validated long monotonic Omura's whale calls (normalised on a 0.5 h basis) at Stations J1, J2, and J3 from July 2014 to July 2015 in the Timor Sea. The grey areas indicate hours of darkness from sunset to sunrise (Ocean Time Series Group 2009). The red dashed lines indicate the start and end of recording time.

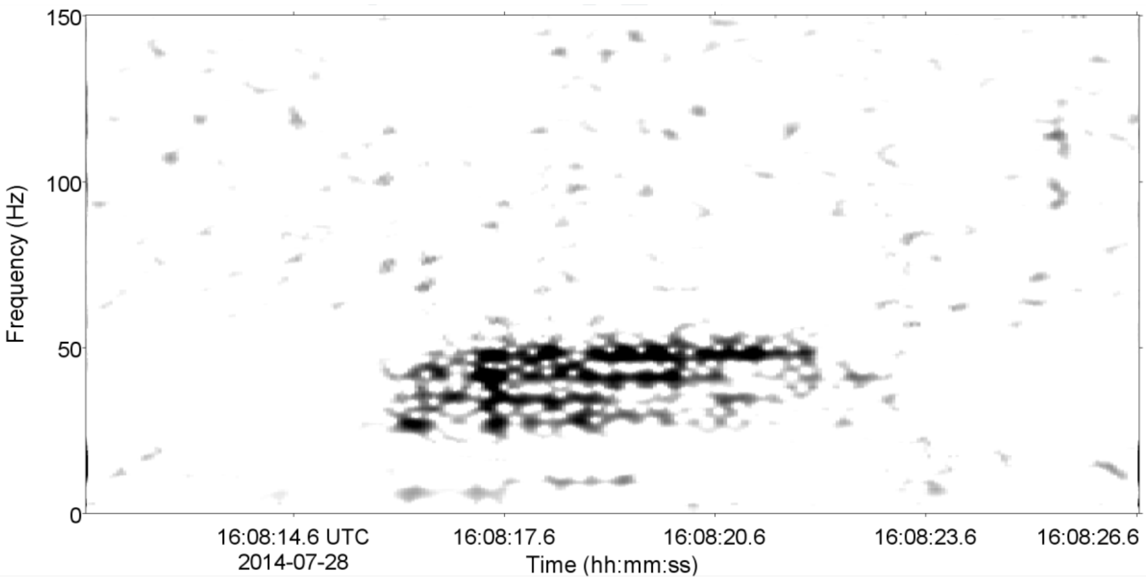


Figure 30. Spectrogram of a long monotonic Omura's whale call recorded at Station J3 on 28 July 2014 (UTC). (0.5 Hz frequency resolution, 0.5 s time window, 0.05 s time step, and Hamming window).

Bryde's whale downsweeping moans were not observed as frequently as either the double-barrel or long monotonic calls. Downsweeps were manually detected on 19 days at Station J1, 16 days at J2, and 10 days at J3. Detections occurred sporadically throughout the year with an increase in early June at Station J2 (Figure 31). A downsweeping moan is shown in Figure 32. These moans decreased from 150 to 40 Hz and lasted for 0.5–2 s.

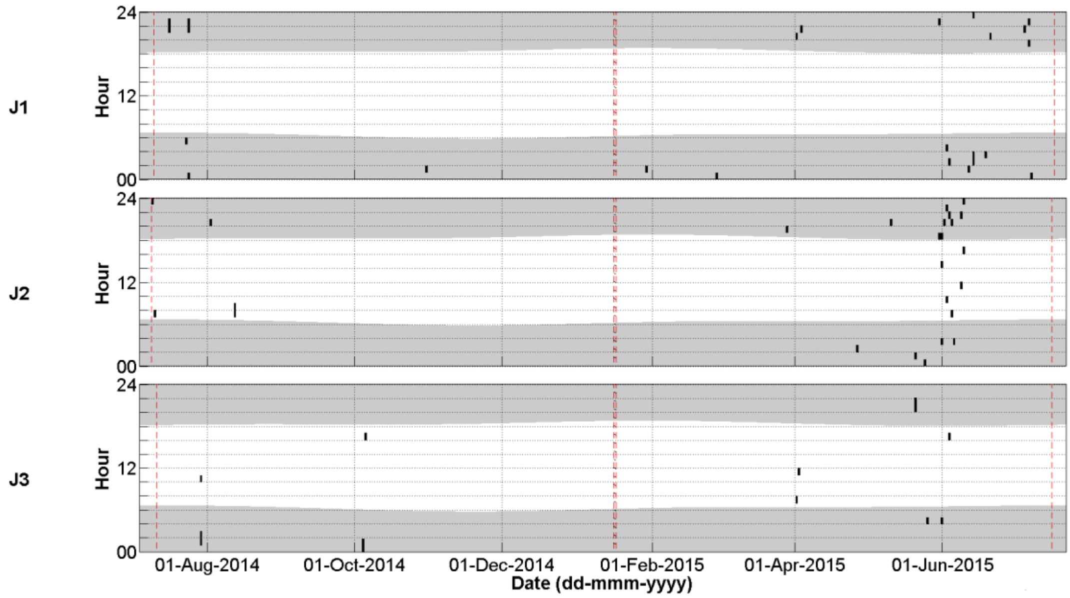


Figure 31. Presence of manually validated downsweeping Bryde's whale calls (normalised on a 0.5 h basis) at Stations J1, J2, and J3 from July 2014 to July 2015 in the Timor Sea The grey areas indicate hours of darkness from sunset to sunrise (Ocean Time Series Group 2009). The red dashed lines indicate the start and end of recording time.

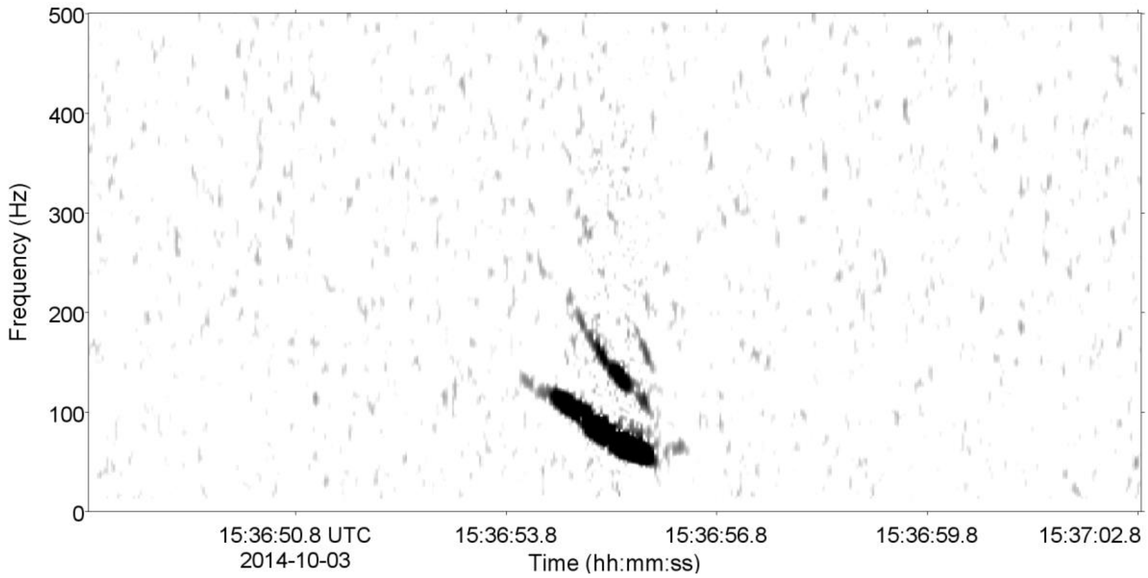


Figure 32. Spectrogram of a downsweeping Bryde's whale call recorded at Station J3 on 3 October 2014 (UTC) (2 Hz frequency resolution, 0.128 s time window, 0.032 s time step, and Hamming window).

3.2.2.2.2. Automated Detections

Detections of the double-barrel/monotonic Omura's calls were higher at Stations J1 (off Evans Shoal) and J2 (at the Barossa field) than Station J3 (Caldita field) for Deployment 1, but higher at Stations J1 and J3 for Deployment 2 (Table 12). The latter is largely due to a hydrophone interference issue at Station J2 (see Section 3.3.1) introducing low frequency noise to the data and preventing the detection of these calls in the associated frequency bands after 10 June. The mean call rate (calls/14 min) was greater during deployment 2 and was consistently higher at the deepest station (J2) than either J1 or J3 during both deployments (Figure 33). Across all stations, detections of Omura's and Bryde's calls were most common from May to July, while after November 1, no Omura's calls were detected until late December (Figure 34), and no Bryde's whale calls were detected from mid-October until early January (Figure 38). No obvious diurnal pattern was observed.

Table 12. Omura's and Bryde's whale detection summary.

Station	Total detection days	Days with Omura's whale double barrel/monotonic calls	Days with Bryde's whale downsweep calls
Deployment 1, 10–11 Jul 2014 to 15 Jan 2015			
J1	59	55	9
J2	58	57	6
J3	34	27	9
Deployment 2, 16–17 Jan to 15–16 Jul 2015			
J1	154	148	51
J2	100	97	16
J3	119	108	28

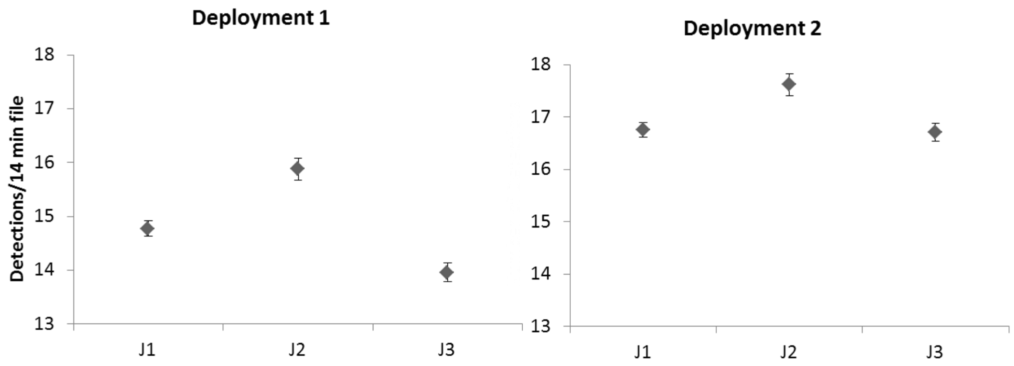


Figure 33. Mean number of Omura's whale double-barrel/monotonic call detections per 14 min 48 ksps sample for samples with at least 1 detection with 95% confidence intervals for Stations J1, J2, and J3 during both deployments.

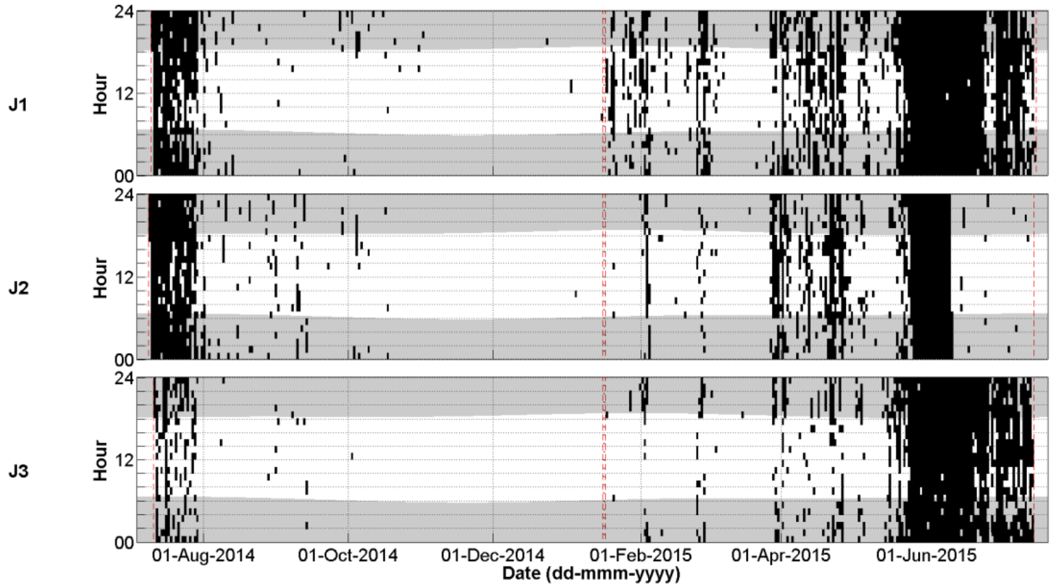


Figure 34. Hourly (expressed as an index) and daily presence of automatically detected Omura's whale double barrel/monotonic calls at Stations J1, J2, and J3. Presence of automatically detected calls normalised on a 1 h basis. The grey areas indicate hours of darkness from sunset to sunrise (Ocean Time Series Group 2009). The red dashed lines indicate the start and end of recording time.

Omura's whale double-barrel/monotonic call SPLs at Stations J1, J2, and J3 overall had similar variation about the mean call SPL/station (Figure 35). From the beginning of the recording period to the end of July 2014 calls were detected continuously at all stations (Figure 35). Call regularity began to decrease in August 2014 with the calls first ending at Station J3 on 2 October, then at Station J2 on 16 October, and lastly at Station J1 on 1 November (Figure 36).

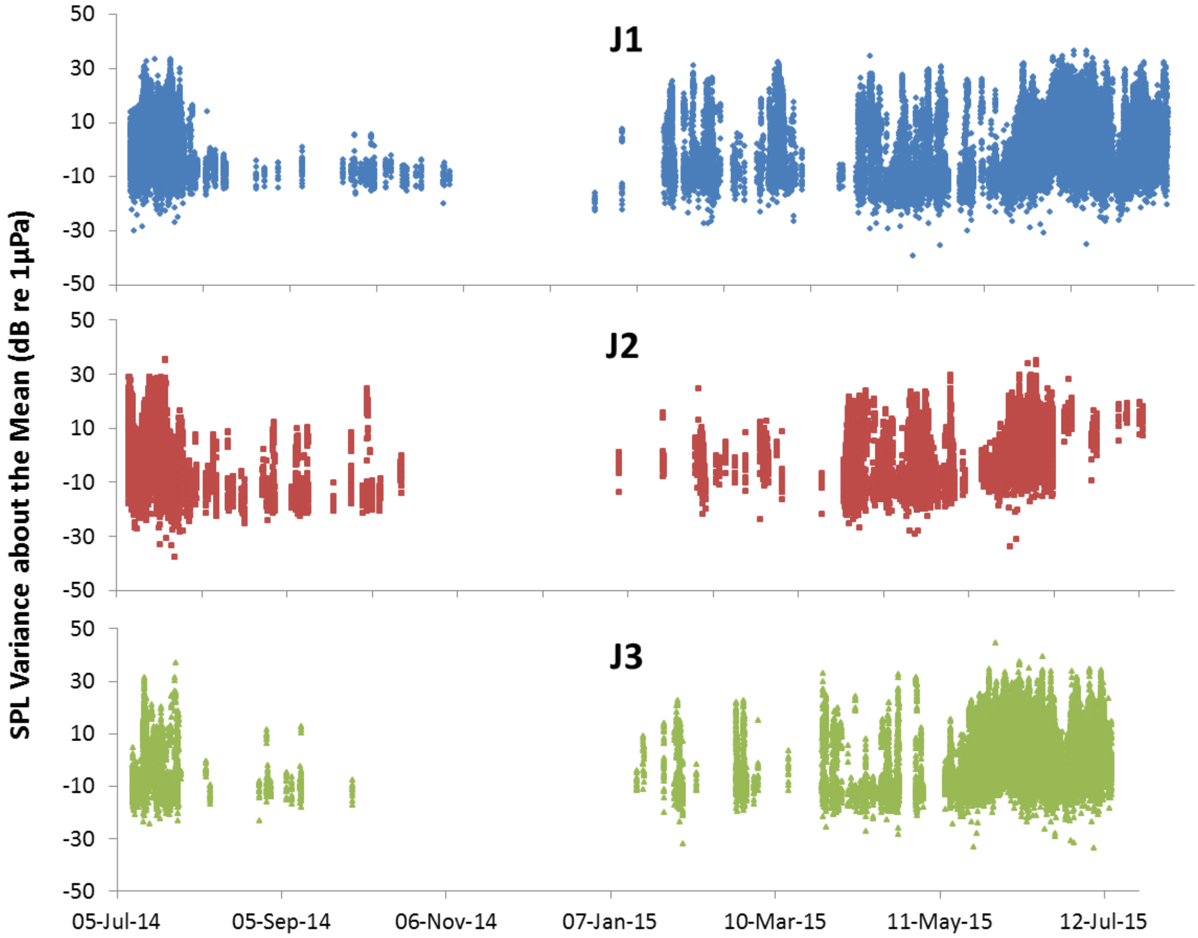


Figure 35. Plot of Omura's whale double-barrel/monotonic call SPL above and below the mean call SPL/station for Stations J1 (top), J2 (middle), and J3 (bottom) from 10 July 2014 to 15 July 2015.

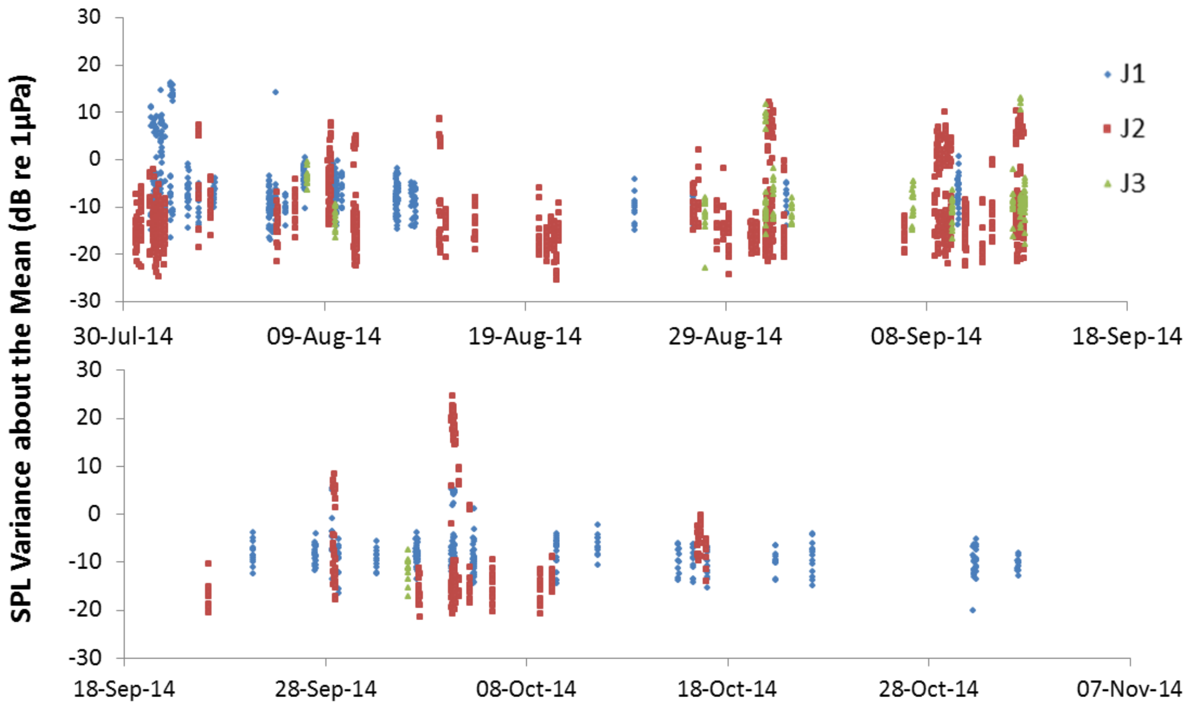


Figure 36. Plot of Omura's whale double-barrel/monotonic call SPL above and below the mean call SPL/station for Stations J1, J2, and J3 from 30 July to 18 September 2014 (top) and 18 Sept to 7 Nov 2014 (bottom).

Omura's whale double-barrel/monotonic calls were not detected again until late 2014 - early 2015 when they first occurred at Station J1 (23 December), followed by Station J2 (4 January) and finally Station J3 (17 January) (Figure 35 and Figure 37). The reoccurrence of double-barrel/monotonic calls came in a number of pulses. The first robust pulse of detections occurred from 17–21 January primarily at Station J1 (Figure 37). The second pulse began three days later when detections occurred at Station J1 from 24–29 January, with detections also at Station J3 on 27 January. The night of 30 January the third pulse was detected at Station J1 followed the next afternoon by detections at Stations J2 and J3, with the detection rate decreasing after 4 February. Detections were sporadic until 22 February when the number of detections increased. This appeared to represent a number of whales moving across the area, with the pulse subsiding on approximately 5 March. Detections were again sparse until 26 March when detections occurred across all stations and remained nearly constant until the end of recording in mid-July.

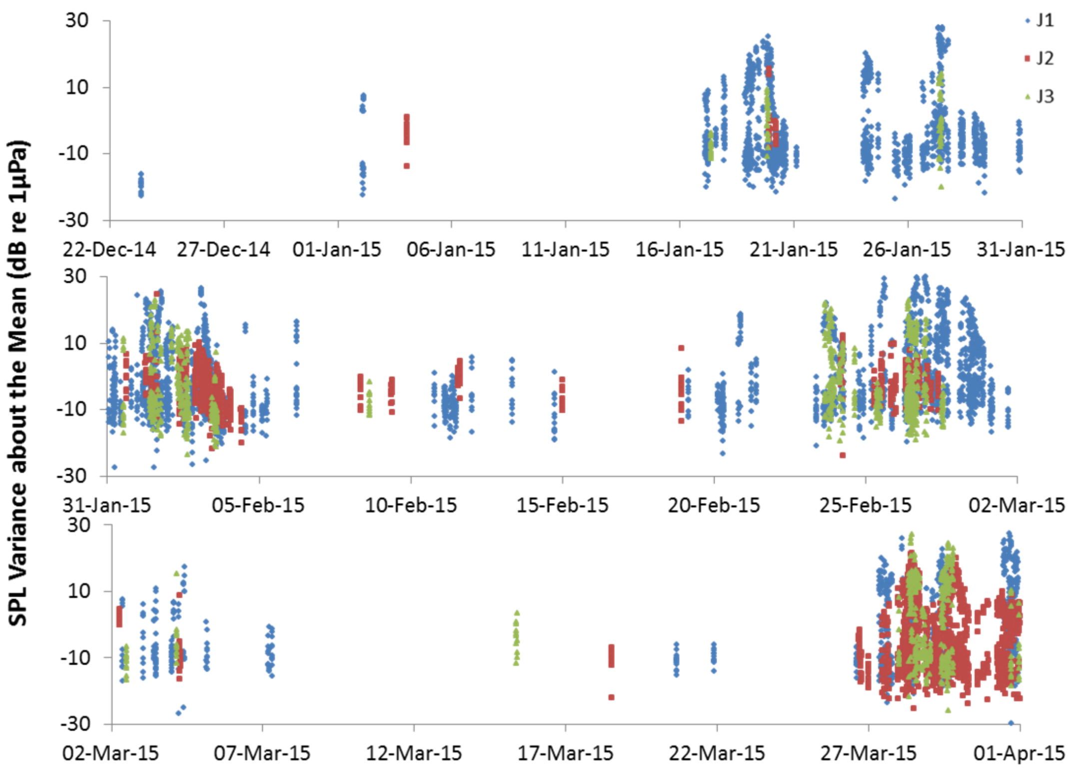


Figure 37. Plot of Omura's whale double-barrel/monotonic call SPL above and below the mean call SPL/station for Stations J1, J2, and J3 from 16 Jan to 10 Feb 2015 (top), 10 February to 7 March 2015 (middle), and 7 March to 1 April 2015 (bottom).

Bryde's whale downsweeping call detections were similar at all stations and more common during Deployment 2 (Figure 38, Table 12). While the mean call rate (detections/14 min) was slightly lower at Station J2 than either Stations J1 or J3, the difference wasn't significant (Figure 39). Calls occurred during two periods: July-October 2014 and January-July 2015 with no obvious diurnal pattern (Figure 44). In 2014 calls were initially detected solely at Station J2 on 9, 11, 12 June. Detections then occurred only at Station J1 on 16, 23, 24 June. Finally, they were detected only at Station J3 on 20 August, 30 September, and 3, 10 October 2014 (Figure 40). Downsweeps did not occur again until 2015 when they were first detected at Station J3 (6, 29 January, and 4, 22 February). Detections also began to occur at Station J1 on 26 February, and by 19 April were taking place semi-regularly at all three stations until the end of recording in mid-July. It is worth noting that in 2015 detected calls were consistently louder at Station J2 than either Station J1 or J3 (Figure 45).

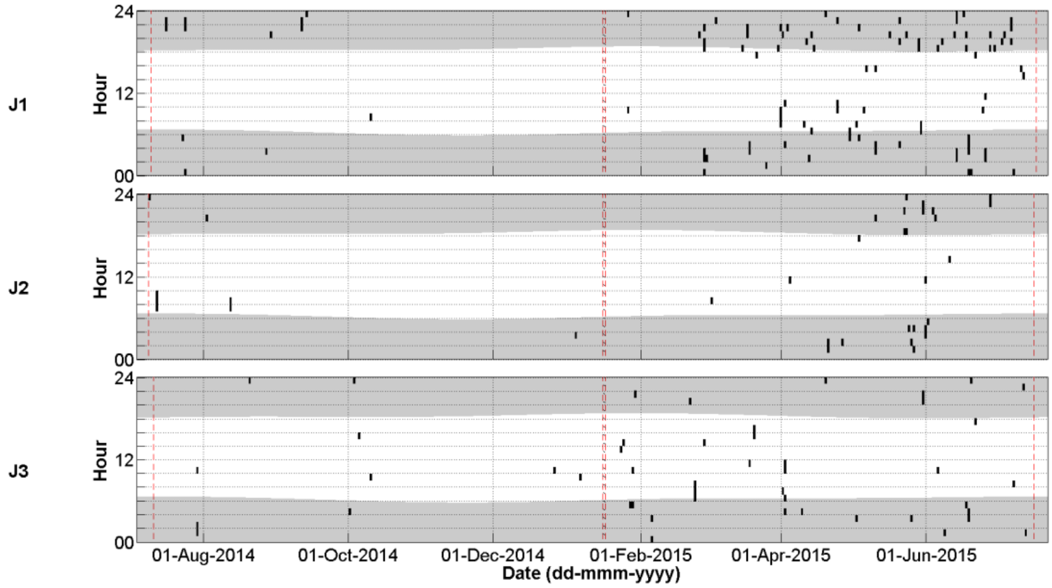


Figure 38. Hourly (expressed as an index) and daily presence of automatically detected Bryde's whale downsweep calls at Stations J1, J2, and J3. Presence of automatically detected calls normalised on a 1 h basis. The grey areas indicate hours of darkness from sunset to sunrise (Ocean Time Series Group 2009). The red dashed lines indicate the start and end of recording time.

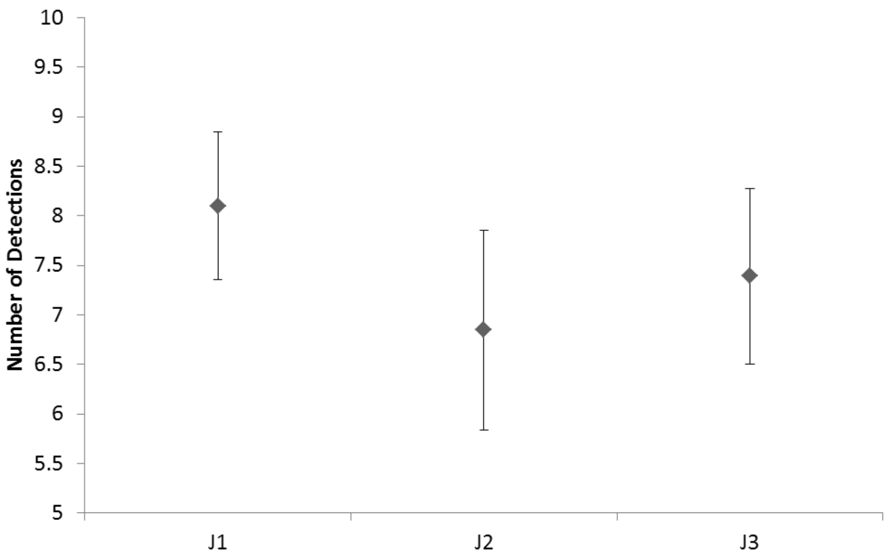


Figure 39 Mean number of Bryde's whale downsweeping call detections per 14 min 48 ksps sample for samples with at least 1 detection with 95% confidence intervals for Stations J1, J2, and J3.

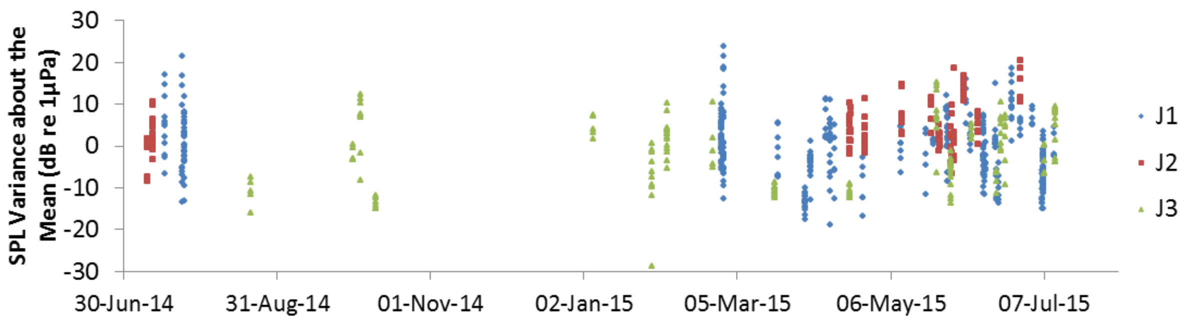


Figure 40. Plot of monotonic call SPL above and below the mean call SPL/station for Stations J1, J2, and J3 from 30 June 2014 to 7 July.

3.2.2.2.3. Regional use approximation

To provide some context about the possible use of the region by Omura's and Bryde's whales, an estimate of the distances from Station J2 using the minimum, median and maximum received call levels determined through analysis of the automated detections was performed.

Along with the received call levels (Table 13), an approximate source level of 155 dB re 1 µPa was used, based on estimates for minke whales (Gedamke et al. 2001), sei whales (McDonald et al. 2005) and Bryde's whales (Širović et al. 2014). The reported call levels for Bryde's whales (Širović et al. 2014) was 155 dB re 1 µPa at 1 m, +/- 14 dB. An estimated whale depth of 30 m was selected for the Omura's and Bryde's whale based upon observations in Cerchio et al. (2015) (mean of 31 m with a standard deviation of 48 m) and the lack of recorded information about the typical dive depth for a Bryde's whale. These inputs were used with a transmission loss curve derived from running JASCO's Marine Operations Noise Model (MONM) over a single transect line at a bearing of 303.96°, taking advantage of the theory of reciprocity. The exact migration path of the whales is unknown, and while a single transect is not accurate, it allows for a comparison of possible distances from Station 2 to the whales. The modelling transect used for the Omura's and Bryde's is the same as used for the pygmy blue for simplicity. A more detailed investigation should select transects for each whale species based upon an analysis of their movements across the region.

The maximum received call levels are within the first range step of the modelling, i.e. between the source at 30 m depth and the receiver at 240 m. Therefore it is assumed that the whales are within this range.

The calculated distances of the whales from Station J2 along the selected transect range, are shown in Table 14.

Table 13. Whale call modelling parameters

Whale call	Estimated Broadband Call SL (dB)	Received Level (dB)			Call depth (m)	Call Frequency (Hz)	Modelled 1/3 Octave band centre Frequency (Hz)
		Minimum	Median	Maximum			
Monotonic call (Omura's)	155	55.6	93.2	128.6	30	26–28	25
Downsweep call (Bryde's)	155	80.4	92.2	109.2	30	150-40	50

Table 14. Whale distance estimation (m)

Whale call	Estimated Broadband Call SL (dB)	Estimated Distance (m)		
		Min. received level	Median received level	Max. received level
Monotonic call (Omura's)	155	3.6×10^3	2160	<240 (water depth)
Downsweep call (Bryde's)	155	5.6×10^3	1,260	<240 (water depth)

3.2.3. Odontocetes

3.2.3.1. Beaked whales

3.2.3.1.1. Manual Detections

Beaked whale clicks were positively identified during manual validation analysis at Station J2 on 3 April 2015 and at Station J3 on 31 August 2014 as well as 3 May and 17 May 2015. Examples of beaked whale clicks that may represent separate species and/or click-types are shown in Figure 23 and Figure 42. Clicks recorded at Station J2 (Figure 42) were higher in frequency (60–140 kHz) and shorter in duration (0.3 ms) than those recorded at Station J3 (Figure 23), which had a duration of ~ 1 ms and ranged from 21–116 kHz.

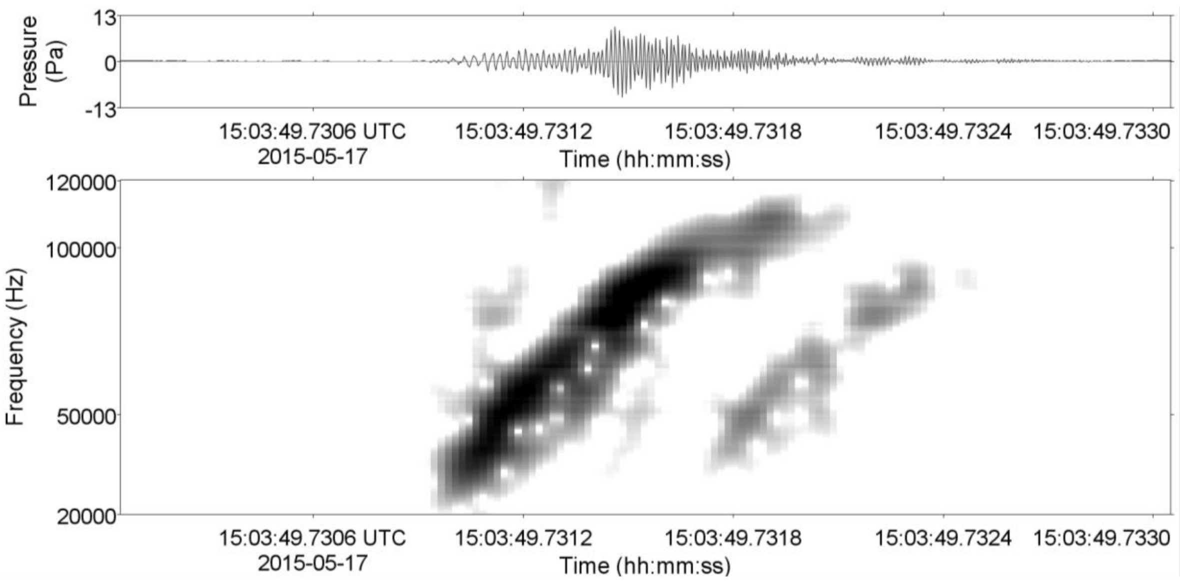


Figure 41. Spectrogram of beaked whale click recorded at Station J3 on 17 May 2015 (UTC) (512 Hz frequency resolution, 0.266 ms time window, 0.02 ms time step, and Hamming window).

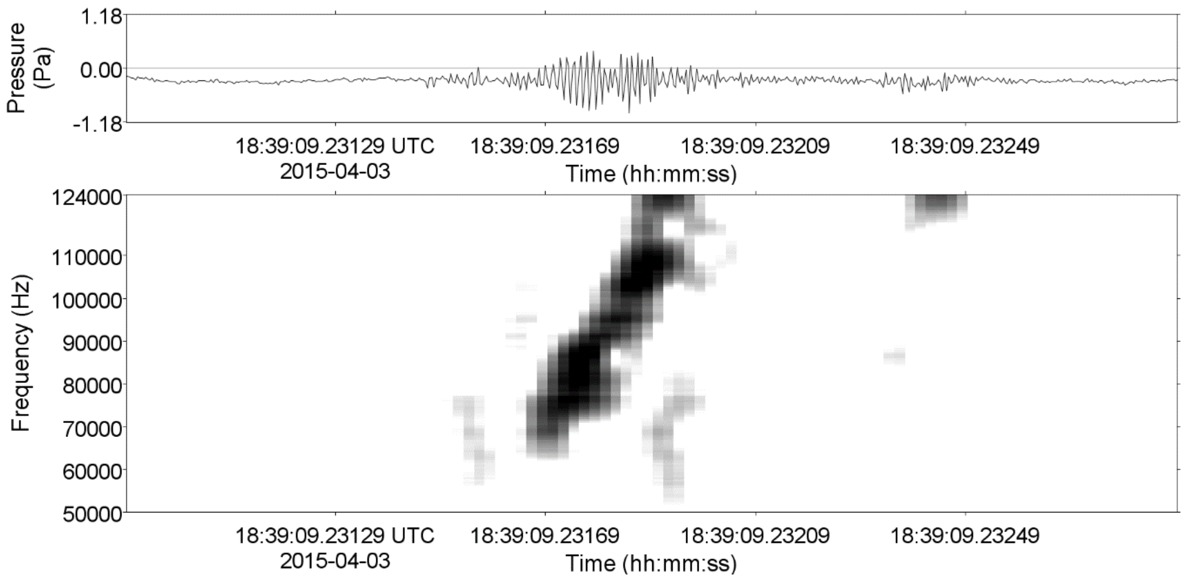


Figure 42. Spectrogram of beaked whale click recorded at Station J2 on 3 April 2015 (UTC) (512 Hz frequency resolution, 0.266 ms time window, 0.02 ms time step, and Hamming window).

3.2.3.1.2. Automated Detections

Beaked whale clicks were automatically detected on three days at Station J3: 31 August 2014, 3 May 2015 and 17 May 2017. These results coincide with the manual analysis results in Section 3.2.3.1, only missing the clicks observed at Station J2 on 3 April 2015. This is reflective of there being few files with beaked whale click detections above the assigned threshold; all files were already reviewed during manual analysis.

3.2.3.2. Unidentified Odontocetes

3.2.3.2.1. Manual Detections

Odontocetes were positively identified during manual validation analysis from July 2014 to July 2015 at all stations (Figure 43). Calls were observed at Station J1 on 123 days (79 with clicks and whistles, 42 with only clicks, and 2 with only whistles), at Station J2 on 145 days (94 with clicks and whistles, 49 with only clicks, and 2 with only whistles), and at Station J3 on 117 days (78 with clicks and whistles, 38 with only clicks, and 1 with only whistles). An example of odontocete clicks and whistles is shown in Figure 44. The centre frequency of clicks ranged from 13–110 kHz. Whistles occurred from 2–20 kHz both in repeated patterns and at random.

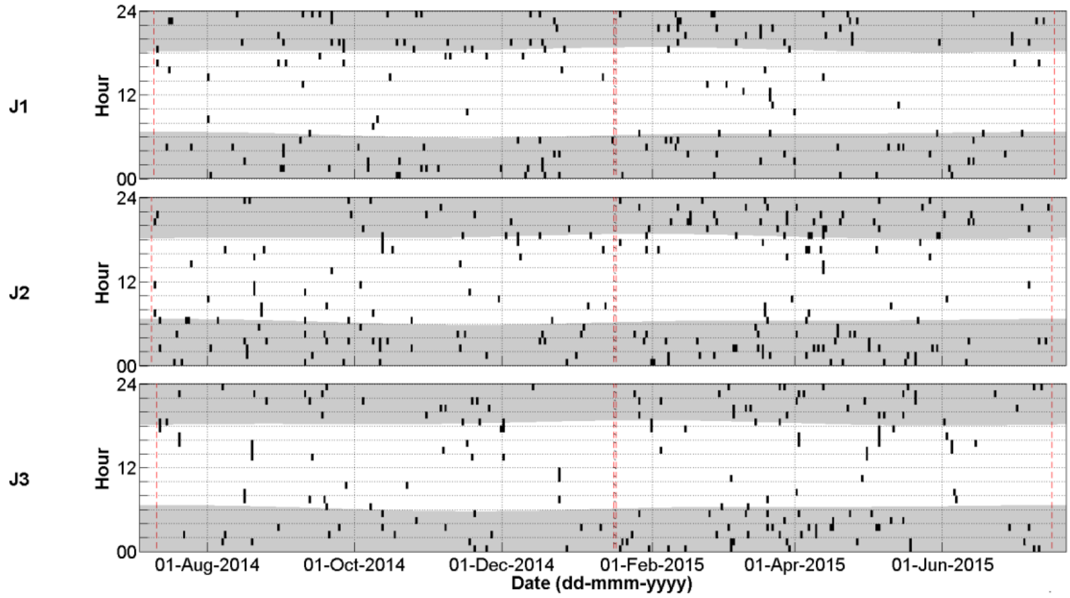


Figure 43. Presence of manually validated odontocete clicks and whistles (normalised on a 1 h basis) at Stations J1, J2, and J3 from July 2014 to July 2015 in the Timor Sea. The grey areas indicate hours of darkness from sunset to sunrise (Ocean Time Series Group 2009). The red dashed lines indicate the start and end of recording time.

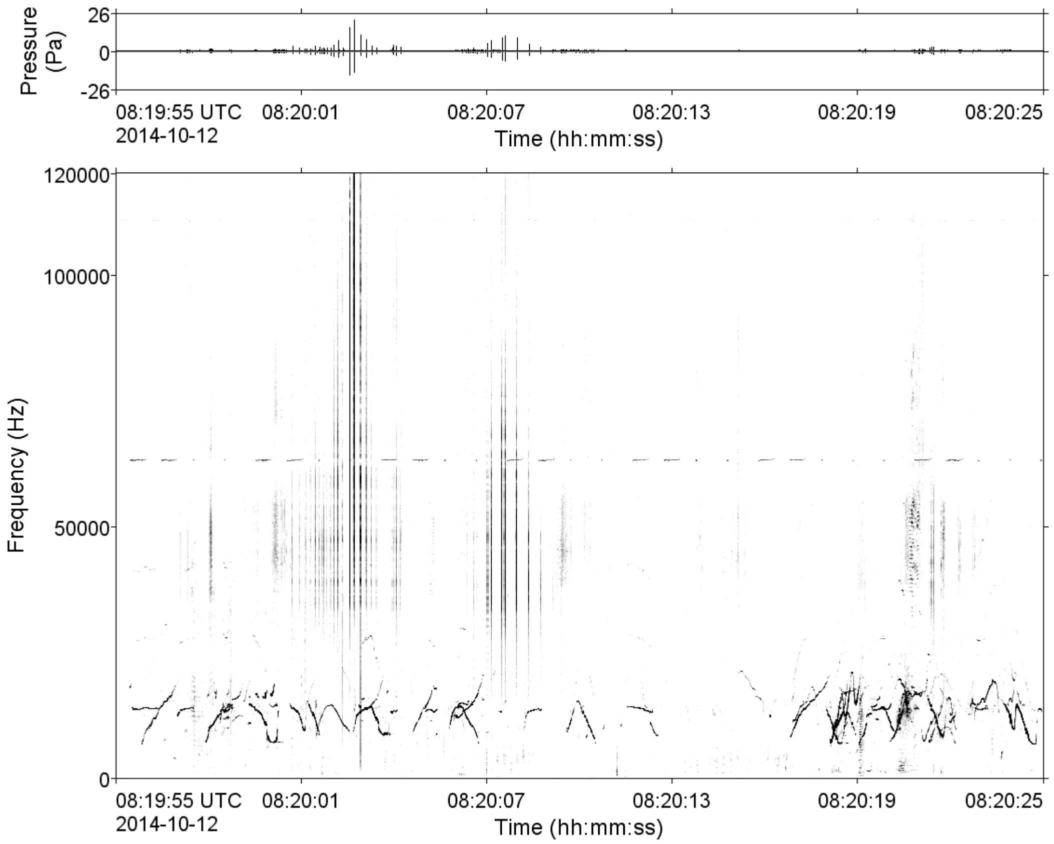


Figure 44. Spectrogram of odontocete clicks and whistles recorded at Station J2 on 12 October 2014 (UTC) (2 Hz frequency resolution, 0.128 s time window, 0.032 s time step, and Hamming window).

3.2.3.2.2. Automated Detections

Odontocetes were detected at Station J1 on 368 out of 371 days: clicks and whistles were detected on 238 days, clicks only were detected on 130 days, and whistles were never detected by themselves. Station J2 had 366 out of 370 days of detections: clicks and whistles were detected on 287 days, clicks only were detected on 77 days, and whistles were detected by themselves on only two days. Detections at Station J3 occurred on 363 out of 368 days: clicks and whistles were detected on 247 days, clicks only were detected on 118 days, and whistles were never detected by themselves. Clicks and whistles were consistently detected throughout the recording period at Stations J2 and J3, predominantly during hours of darkness (Figure 46).

An example of the detectors in operation is shown in Figure 45. The dense nature of detections at Station J1 during Deployment 1 suggests that these results are not real, but rather a product of unknown noise at Station J1 that created a large number of false positives in our click detector (Figure 48). The noise was observed during manual analysis, and is discussed in Section 4.1.2, and attributed to crustaceans such as snapping shrimp, and the noise from the flow through the rocks and the sea fans. The source of the unknown noise seems to decrease during Deployment 2, as by mid deployment the detection rate is similar to the other stations. Based on manually verified click and whistle detections (Figure 43), and automated detections of whistles (Figure 47), odontocetes at Station J1 have been observed in a similar pattern to that of J2 and J3, in that they were present throughout the recording period and especially vocal at night.

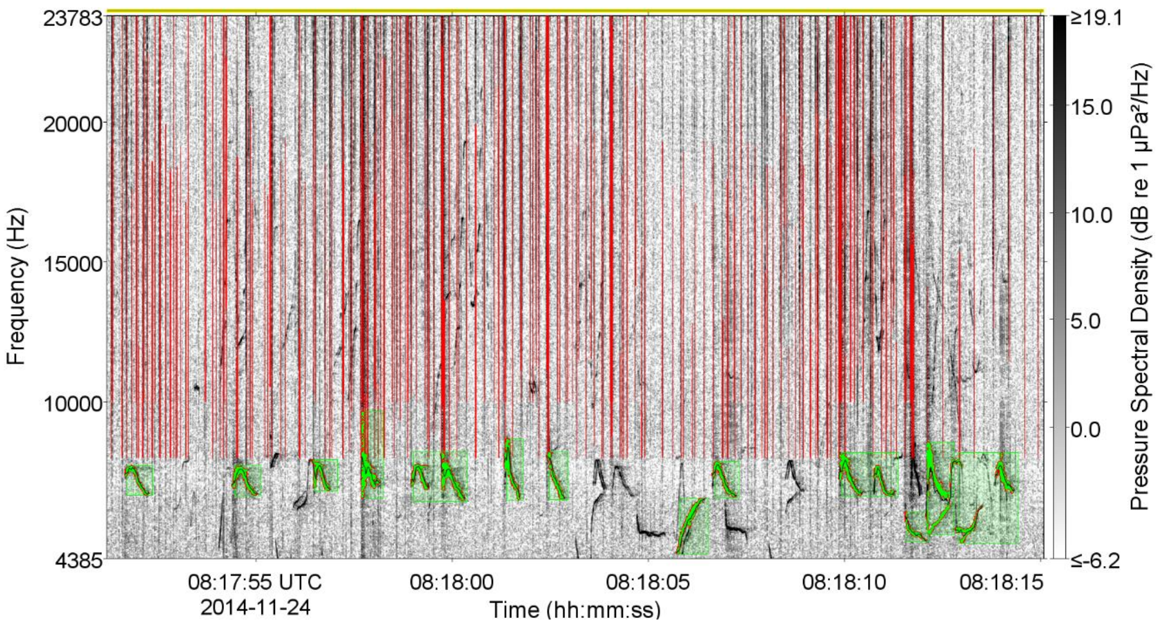


Figure 45. Example click and whistle detections of suspected pilot whales recorded at Station J1 on 24 November 2014 (UTC) (4 Hz frequency resolution, 0.05 s time window, 0.01 s time step, and Hamming window). Click detections are shown as red lines, and whistle detections as green boxes.

Table 15. Odontocete detection summary, both deployments.

Station	Total days	Total days with detections	Days with click and whistle detections	Days with click only detections	Days with whistle only detections
Deployment 1, 10–11 Jul 2014 to 15 Jan 2015					
J1	190	189	117	72	0
J2	191	188	156	31	1
J3	189	185	126	59	0
Deployment 2, 16–17 Jan to 15–16 Jul 2015					
J1	181	179	121	58	0
J2	179	178	131	46	1
J3	179	178	121	57	0

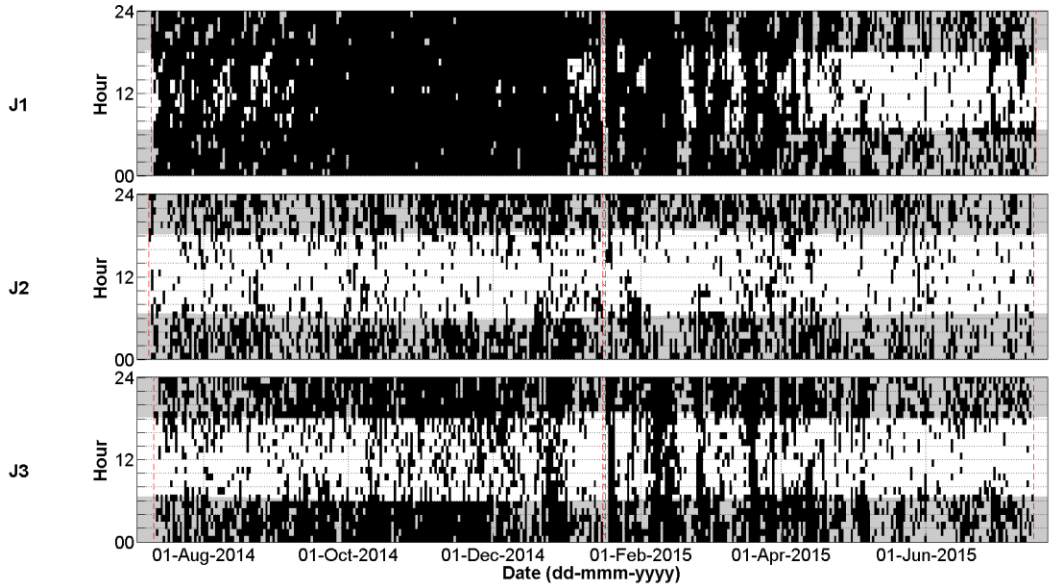


Figure 46. Hourly and daily (expressed as an index) presence of automatically detected odontocete clicks at Stations J1, J2, and J3. Hourly presence of automatically detected odontocete (normalised on a 1 h basis). The grey areas indicate hours of darkness from sunset to sunrise (Ocean Time Series Group 2009). The red dashed lines indicate the start and end of recording time.

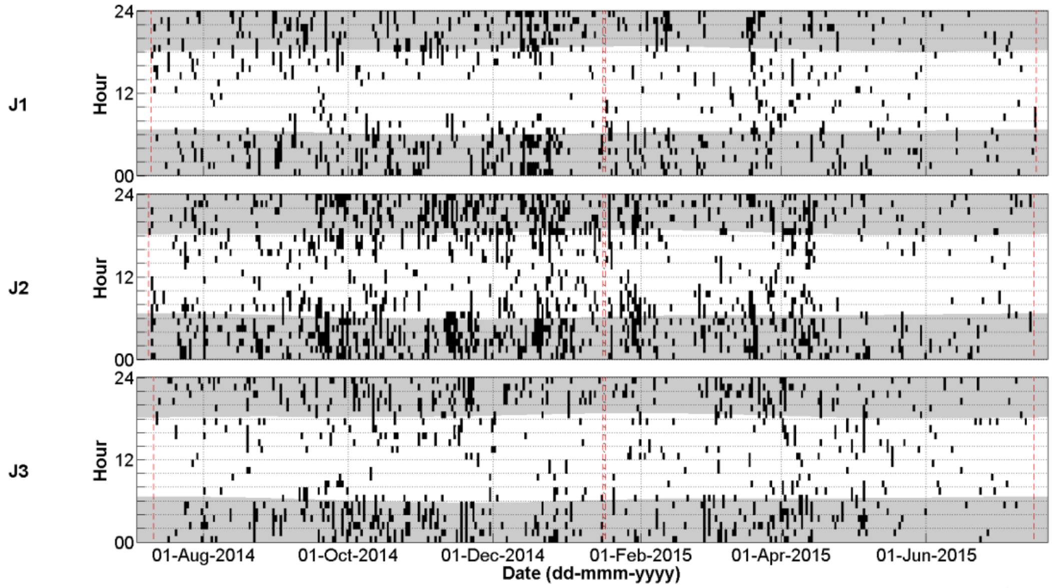


Figure 47. Hourly and daily (expressed as an index) presence of automatically detected odontocete whistles at Stations J1, J2, and J3. Hourly presence of automatically detected odontocete (normalised on a 1 h basis). The grey areas indicate hours of darkness from sunset to sunrise (Ocean Time Series Group 2009). The red dashed lines indicate the start and end of recording time.

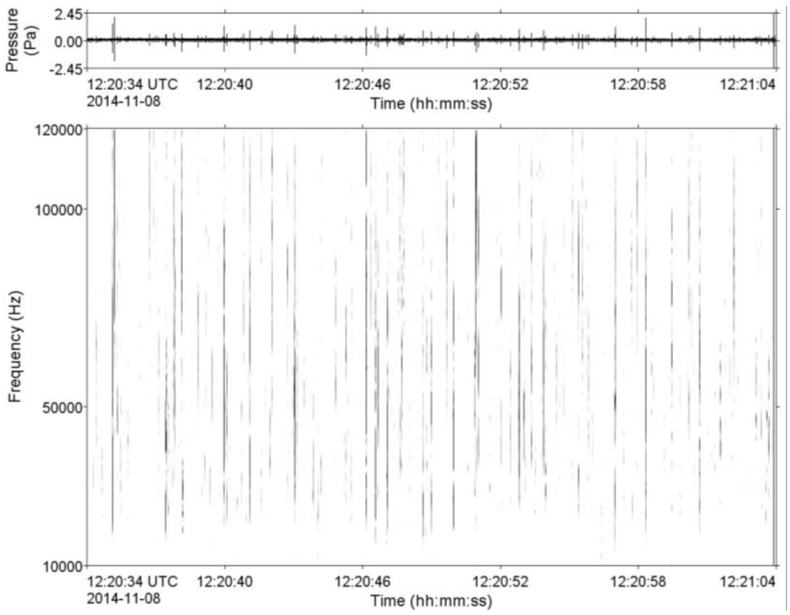


Figure 48. Spectrogram of unknown noise causing false click detections recorded at Station J1 on 8 November 2014 (UTC) (128 Hz frequency resolution, 0.001 s time window, 0.0005 s time step, and Hamming window).

3.2.4. Opportunistic Detections

3.2.4.1. Pilot Whales

Whistles resembling those produced by pilot whales (Sayigh et al. 2013) were observed on 21 September and 24 November 2014 at Station J1 and on 9 October at Station J2. An example of whistles likely produced by pilot whales is shown in Figure 49. These whistles ranged from 10–20 kHz, were 0.4–0.8 s. in duration, and occurred in a repeated pattern.

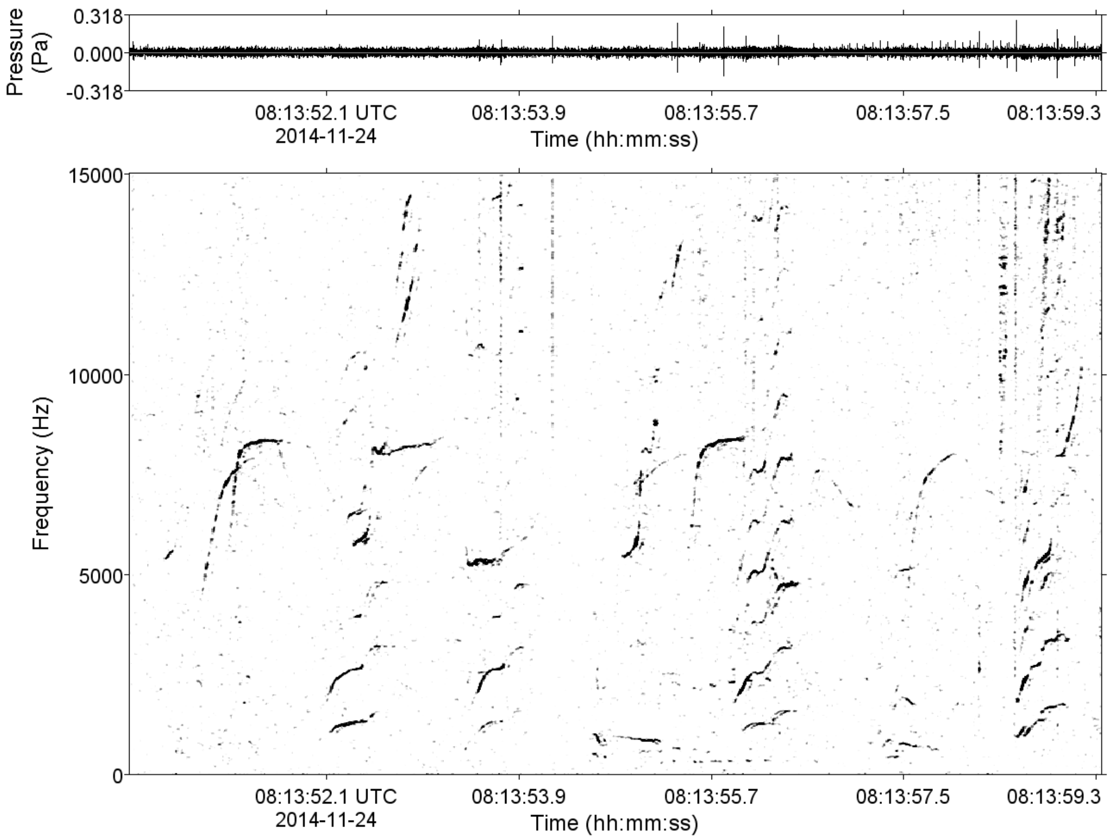


Figure 49. Spectrogram of whistles thought to be produced by pilot whales recorded at Station J1 on 24 November 2014 (UTC) (4 Hz frequency resolution, 0.05 s time window, 0.01 s time step, and Hamming window).

3.2.4.2. Fish

The first fish calls were opportunistically observed on 9 October 2014 at Station J2 as shown in Figure 50.

Fish chorusing can be seen in the weekly spectrograms (Figure 51), through the elevated levels from 200–800 Hz during the dawn chorus, and from 2–4 kHz during the evening chorus. The evening chorus also had a band of energy in the range of 150-200 Hz. These chorusing events can be seen in the example monthly spectrograms from Station J1, despite the presence of elevated levels from weather and the commencement of MODU operations (Figure 52). During Deployment 2, chorusing events were more prevalent at Station J1 than either of the other stations, with Station J3 recording very little fish chorusing activity. Figure 53 shows the monthly spectrograms for April 2015, in which the dawn and dusk choruses are most obvious for Station J1, less so for Station J2, and the dawn chorus is the only chorus present at Station J3, and only noticeable on occasion.

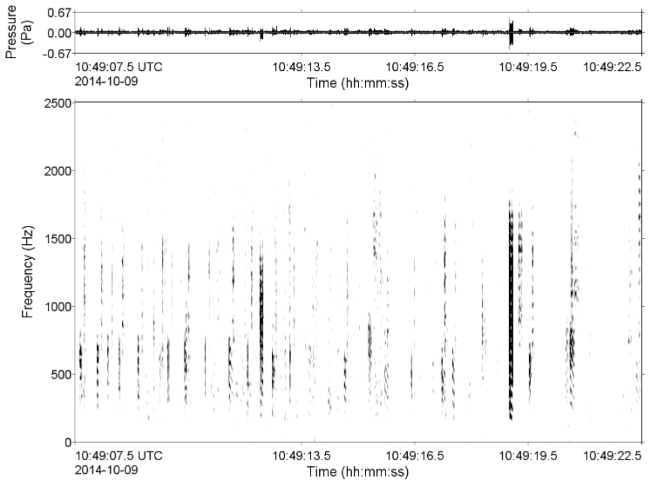


Figure 50. Spectrogram of fish recorded at Station J2 on 9 October 2014 (UTC) (2 Hz frequency resolution, 0.128 s time window, 0.032 s time step, and Hamming window).

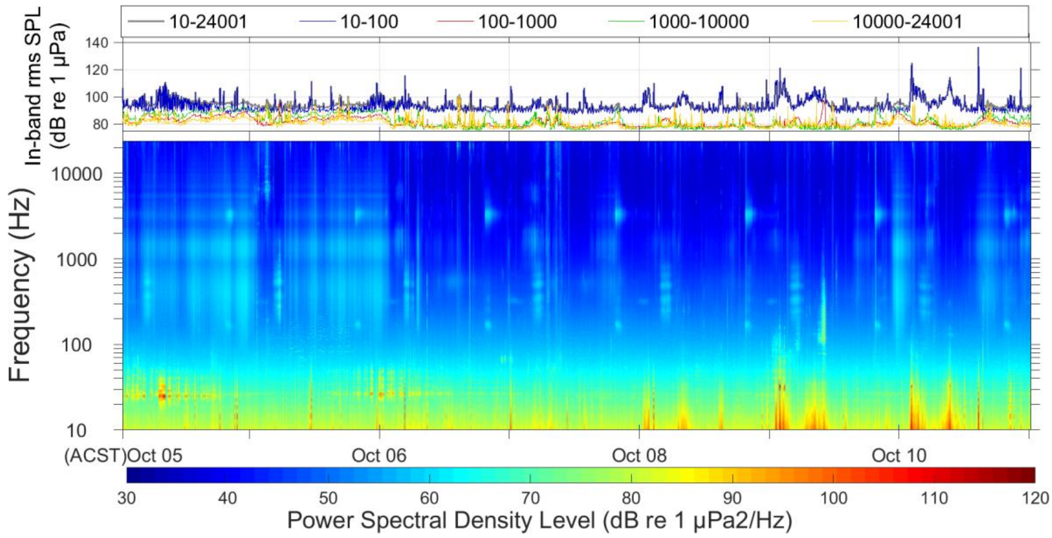


Figure 51 Weekly spectrogram for Station J2 for 4–11 October 2014 showing dawn (200–800 Hz) and evening (2–4 kHz) fish choruses. The evening chorus also has energy at 150-200 Hz.

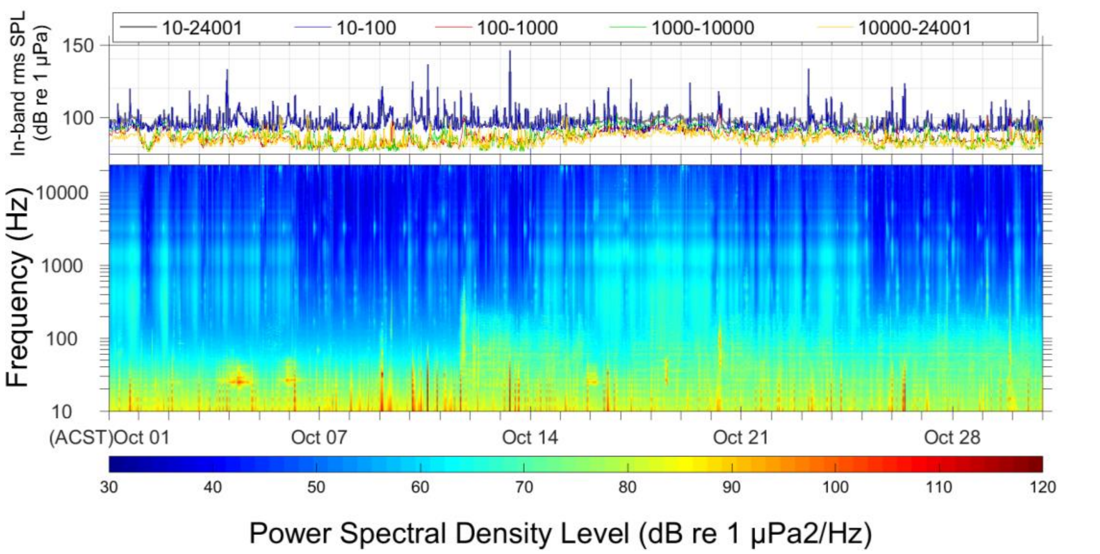


Figure 52. Monthly spectrogram for Station J1 for October 2014 showing dawn and evening fish choruses, and the presence of the MODU from 12 October 2014.

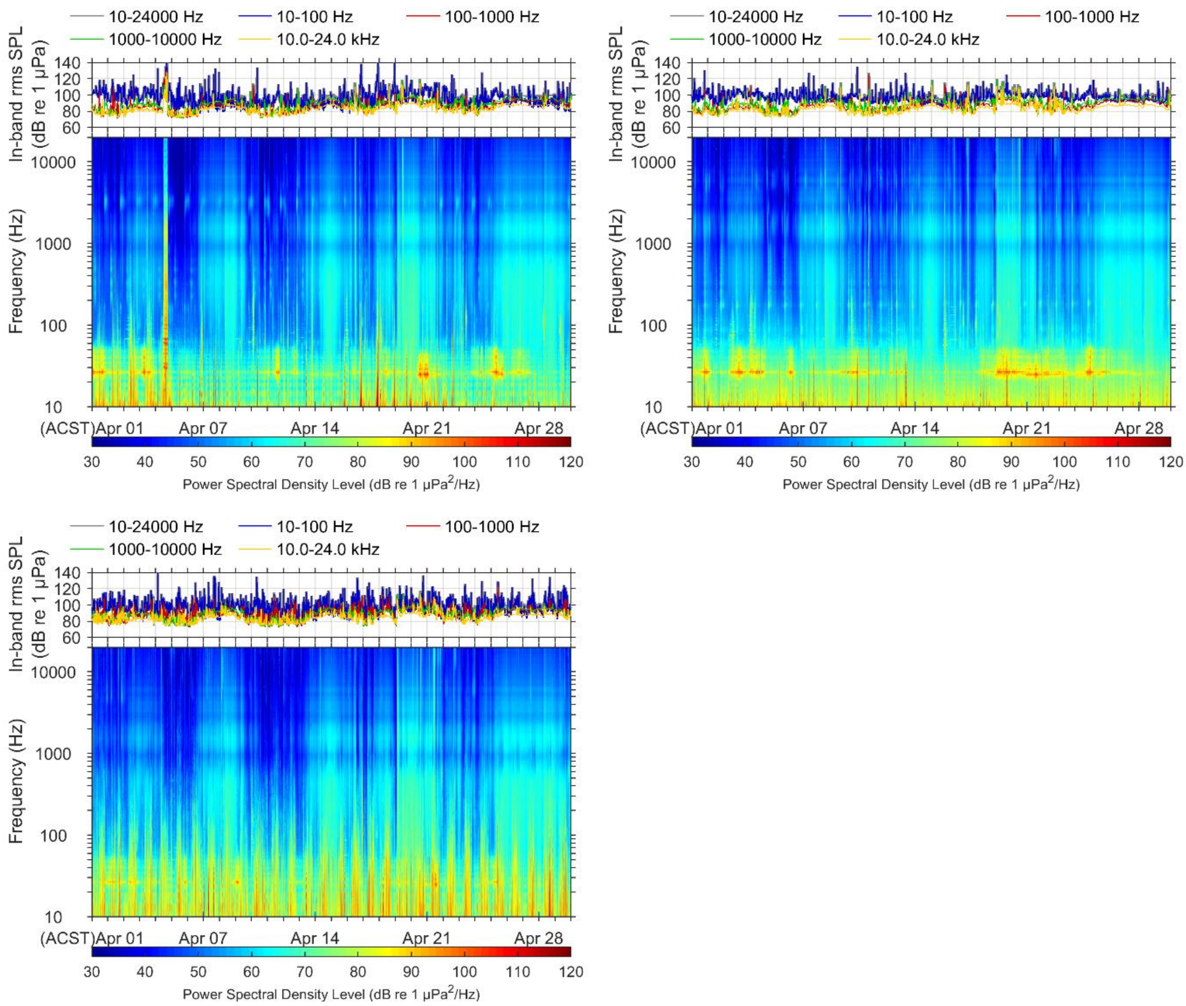


Figure 53. Monthly spectrograms for April 2015 at Station (top left) J1, (top right) J2, and (bottom left) J3.

3.3. Ambient Noise Measurements

The overall ambient sounds are shown as spectrograms and band level plots (Section 3.3.1), sound levels statistics (Section 3.3.2) and power spectral density sound levels (Section 3.3.3). Anthropogenic events are discussed in Section 3.4.

3.3.1. Spectrograms

The spectrogram and band-level plots (Figures 54–59) provide an overview of the sound variability in time and frequency from each station for each deployment presenting an overview of presence and level of contribution from different sources. Short-term events appear as vertical stripes on the spectrograms and spikes on the band level plots. Long-term events affect (increasing or decreasing accordingly) the band level over the event period and appear in the spectrograms as horizontal bands of colour.

During Deployment 1 (Figures 54, 55 and 56) the spectrograms show elevated sound levels at frequencies from 20 Hz–24 kHz from deployment until early September (Stations J2 and J3), or October (Station J1) and again from the start of January until retrieval for all stations. These raised levels are predominantly due to weather events, including the more localised elevation of levels at Station J1 in October. Elevated sound levels from mid-October until retrieval below 200 Hz at Station J1, below 900 Hz at Station J2, and below 300 Hz at J3, were due to the presence of the MODU at Barossa−3 (see Section 3.4.2). It was difficult to differentiate any fish chorusing events at this time scale due to the influence of weather and the MODU. However, these events are more obvious at the monthly level (e.g. Figure 52), and are discussed further in Section 4.1.3. Mysticete calls are apparent below 80 Hz with a peak near 26–28 Hz at all stations intermittently throughout the entire deployment.

The spectrogram and band plots for Deployment 2 are shown in Figures 57, 58 and 59. The spectrograms for 21-23 January 2015 at all stations show elevated sound levels across the entire frequency range, which is an example of storm activity increasing the received sound levels. The MODU at Barossa-4 exploration well location (Section 3.4.2), close to Station J2, raised levels at frequencies below 900 Hz until 26 March, however was barely detected at the other stations. Similar to Deployment 1, it is difficult to differentiate any fish chorusing events at this time scale due to the influence of weather, however the 2–4 kHz evening fish chorus is apparent at Station J1. Energy from odontocete clicks and whistles above 10 kHz increased sound levels at all stations periodically during the entire deployment. Noise levels at Station J2 were influenced by what appears to be benthic organism or crustaceans on the hydrophone from 10 June 2015 (Figure 60). Mysticete detections stopped after June 10 at J2, but odontocete detections were generally unaffected. The period after 10 June 2015 has been excluded from further analysis of sound level statistics.

Mysticete calls (Omura's or Bryde's whales) are significant contributors to the soundscape below 80 Hz with a peak near 26–28 Hz at all stations throughout the entire deployment.

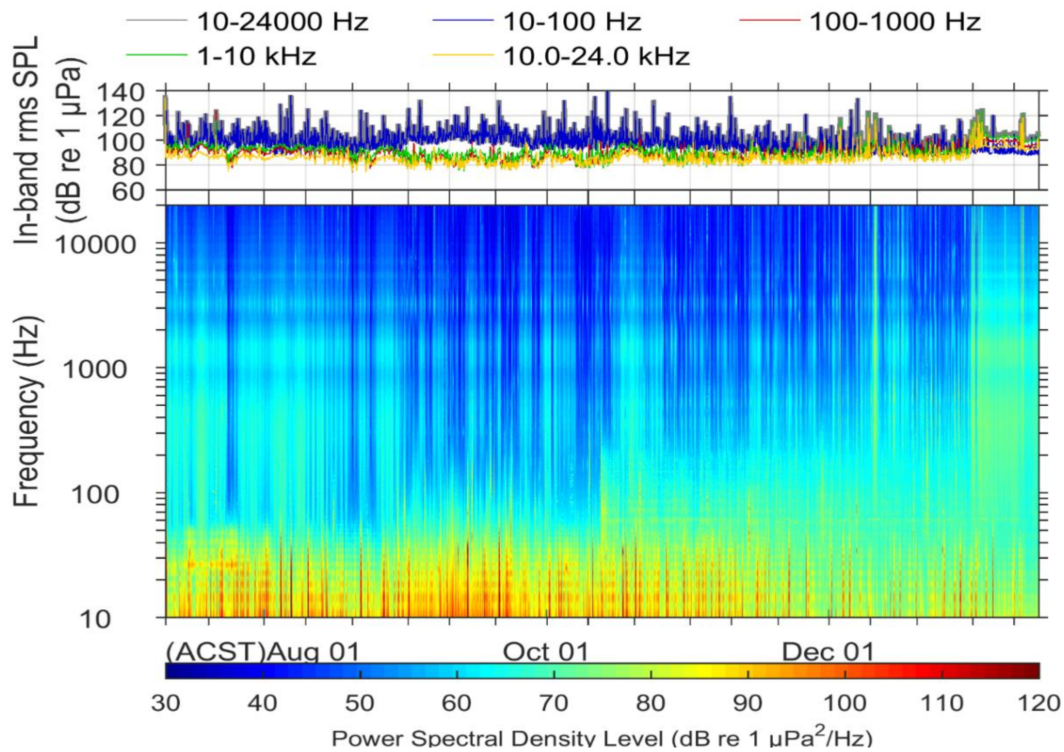


Figure 54. Deployment 1: Sound level summary for Station J1, 10 July 2014 to 15 January 2015. Top: In-band SPLs. Bottom: Spectrogram of power spectral densities. Calls of Omura's or Bryde's whales created a 26–28 Hz tone in this data in July.

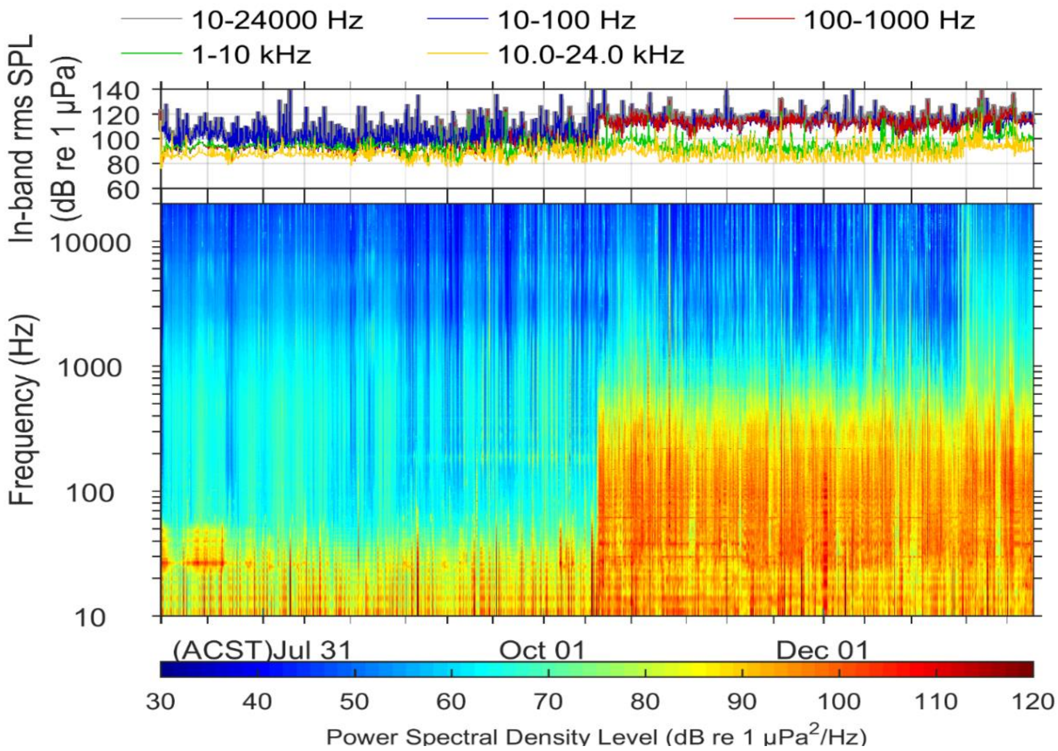


Figure 55. Deployment 1: Sound level summary for Station J2, 10 July 2014 to 15 January 2015. Top: In-band SPLs. Bottom: Spectrogram of power spectral densities. Calls of Omura's or Bryde's whales created a 26–28 Hz tone in this data in July. The arrival of the MODU at Barossa-4 on the 11 October increased sound levels up to 900 Hz.

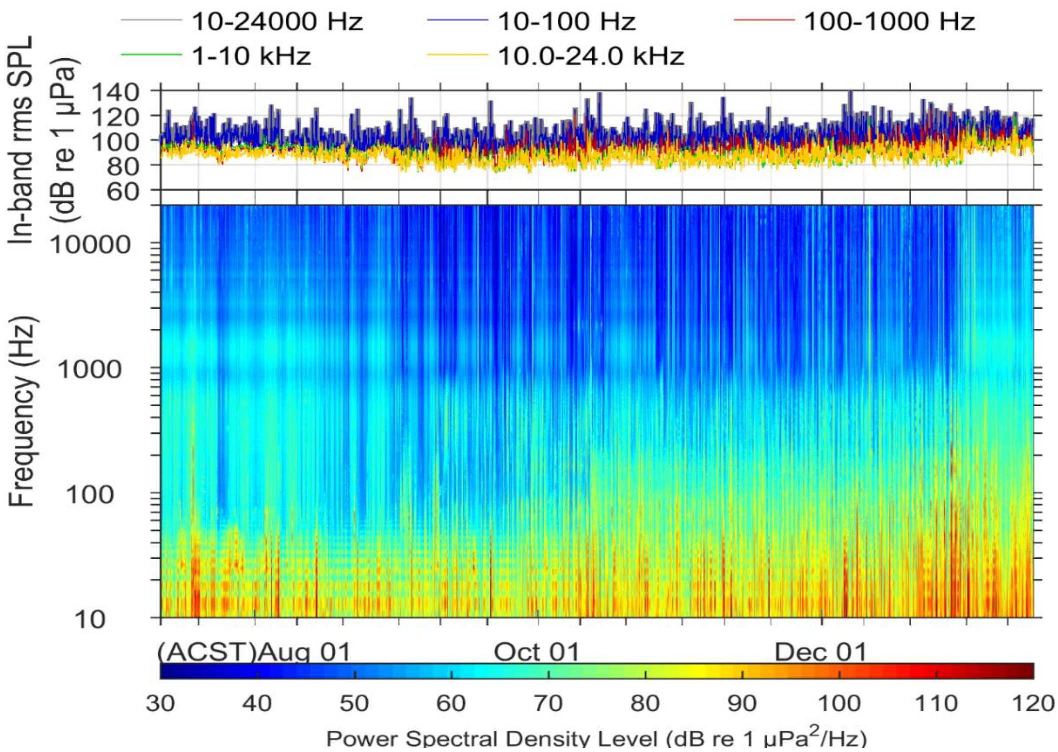


Figure 56. Deployment 1: Sound level summary for Station J3, 10 July 2014 to 15 January 2015. Top: In-band SPLs. Bottom: Spectrogram of power spectral densities.

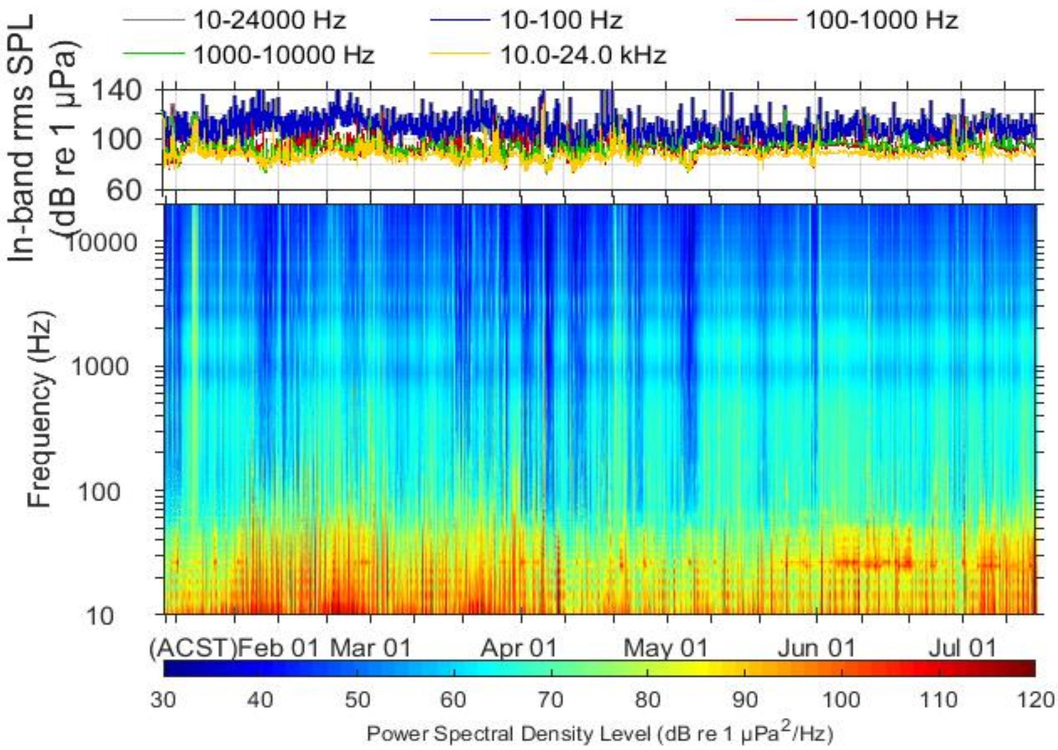


Figure 57. Deployment 2: Sound level summary for Station J1, 16 January to 16 July 2015. Top: In-band SPLs. Bottom: Spectrogram of power spectral densities. Periods of calling from Omura's or Bryde's whales appear at 26–28 Hz throughout the data, but become much more prevalent from May.

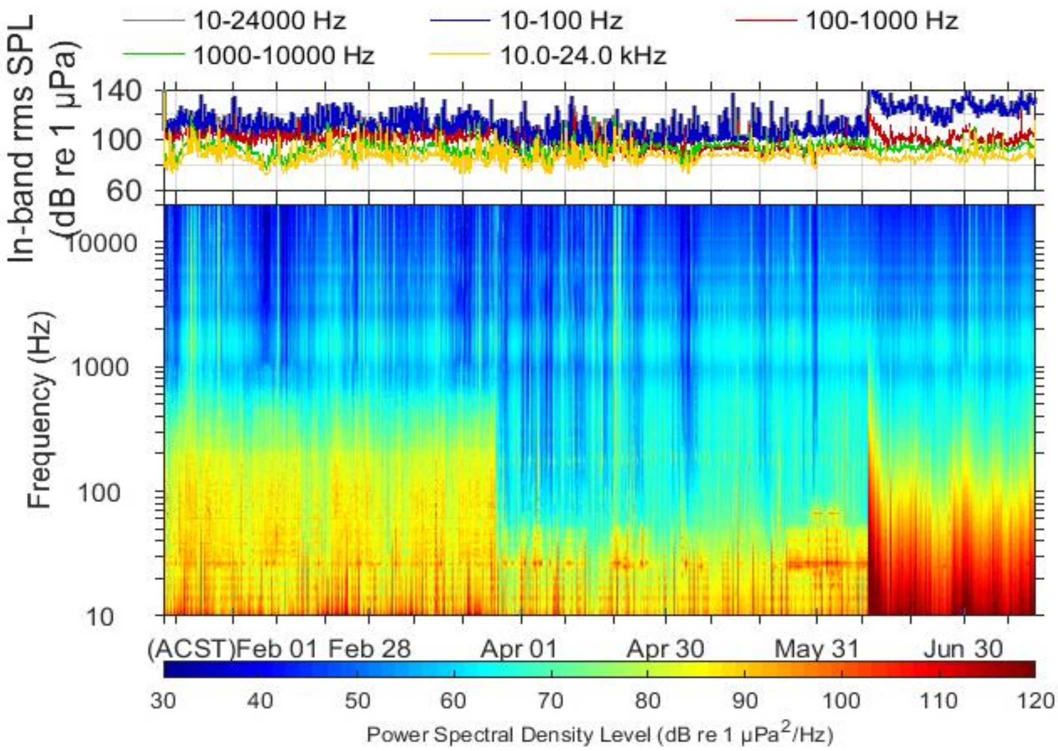


Figure 58. Deployment 2: Sound level summary for Station J2, 17 January to 15 July 2015. Top: In-band SPLs. Bottom: Spectrogram of power spectral densities. Omura's or Brydes whale calls are visible at 26–28 Hz throughout the deployment. The presence of the MODU is clearly seen by the elevated sound levels up to 500-600 Hz until late march. On June 10th an animal, possibly a crustacean took up residence on the hydrophone.

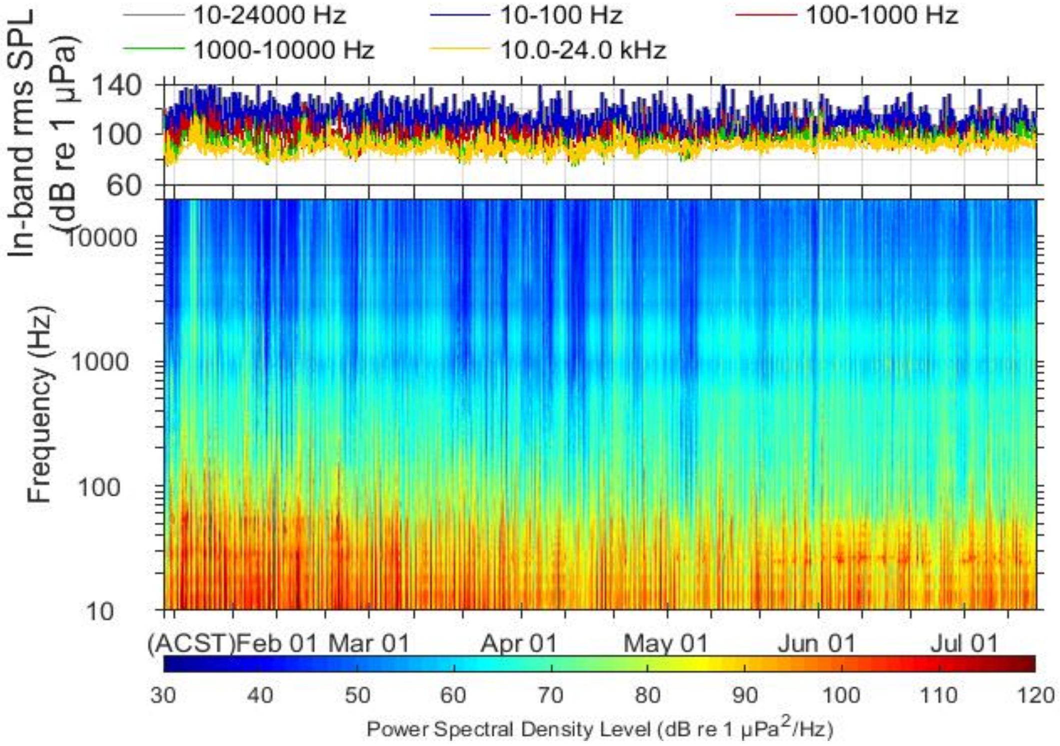


Figure 59. Deployment 2: Sound level summary for Station J3, 17 January to 15 July 2015. Top: In-band SPLs. Bottom: Spectrogram of power spectral densities. The Omura's or Bryde's whale calls at 26–28 Hz are less pronounced on this Station than J1 and J2.

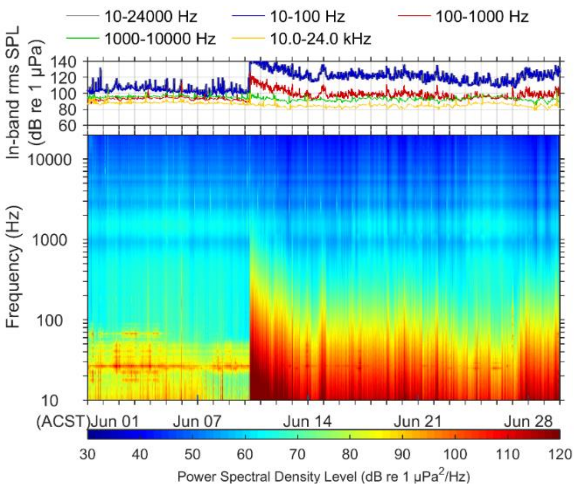


Figure 60. Monthly spectrogram for June 2015 at Station J2 showing Bryde's or Omura's whale calls at 26–28 Hz, as well as the arrival of an animal creating local noise on the hydrophone starting on 10 June.

3.3.2. Statistical analysis

A statistical analysis of the data recorded on the 48 ksps channel was conducted. Figure 61 shows the statistical analysis of sound distributions of the 1-minute SPLs for all stations; the values are shown in Table 16. Exceedance of the 120 dB re 1 µPa level were determined to assist possible impact assessments in the region. The statistics can be contrasted against any modelling studies which compare results against the current interim U.S. National Marine Fisheries Service (NMFS 2014) threshold for behavioural response criteria due to non-pulsed noise 120 dB re 1 µPa.

The Deployment 1 median 1-min SPLs were 95.2, 96.2 and 91.7 dB re 1 µPa at J1, J2 and J3 respectively, while for Deployment 2 they were 97.7, 100.9 and 98.2 dB re 1 µPa. Stations J1 and J3 have the majority of their sound energy in the bands of 100-1000 Hz and 1000-10000 Hz which is associated with wind and wave sound sources as well as the fish choruses. Station J2 has the majority of its sound energy in the band of 10-100 Hz which is generally associated with anthropogenic sound sources like the MODU or seismic surveys. The mysticete calls are also in this band.

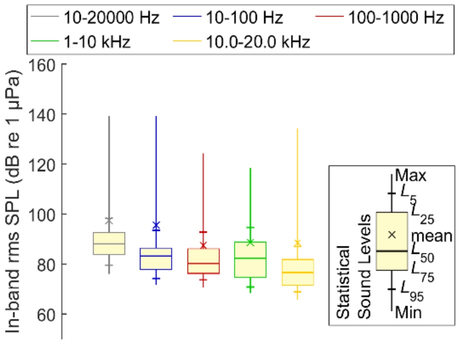
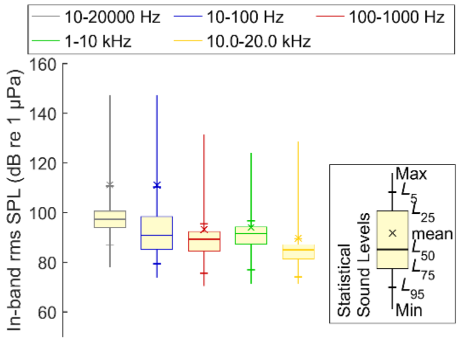
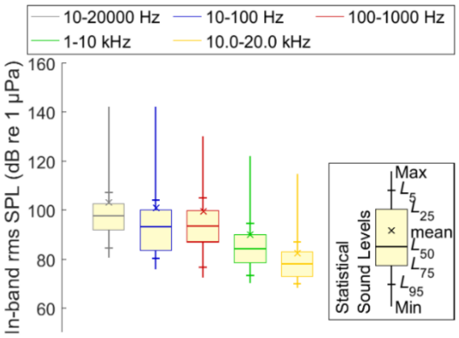
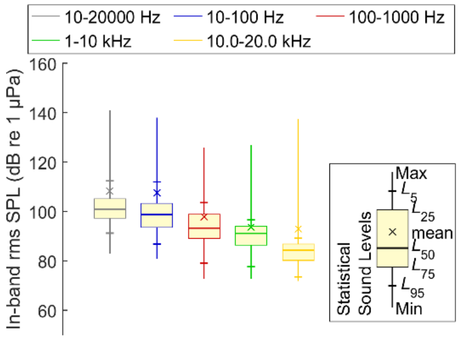
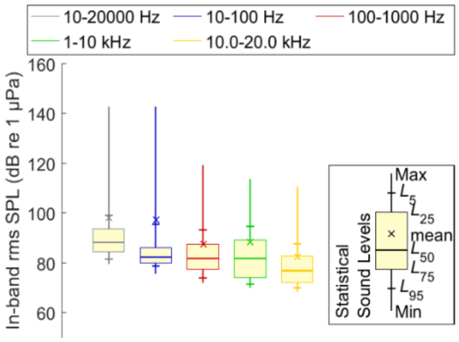
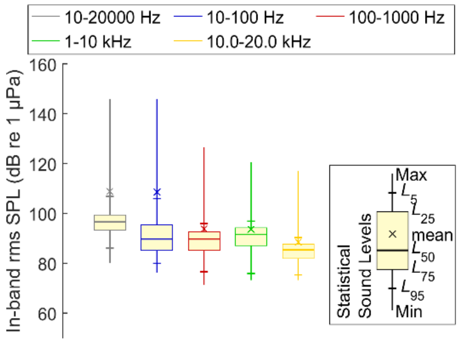
Station	Deployment 1 (10 July 2014 to 15 January 2015)	Deployment 2 (16/17 January to 15/16 July 2015)
J1		
J2		
J3		

Figure 61. The 1-min SPLs for all stations from both deployments.

Table 16. Statistical analysis of sound levels for Stations J1, J2, and J3. SPL units: dB re 1 µPa, Station J2 for the second deployment is only analysed until 10 June 2015.

Sound level statistic	J1		J2		J3	
	PK	1-min SPL	PK	1-min SPL	PK	1-min SPL
Deployment 1 (10 Jul 2014 to 15 Jan 2015)						
Minimum	103.8	83.1	99.2	83.6	101.4	81.1
L_{95}	113.9	90	108.9	91.5	109.1	83.8
L_{75}	120.1	92.4	113.5	96.9	113.3	87.9
L_{50}	125.4	95.2	124.9	106.2	117.3	91.7
L_{25}	131.9	98.4	131.7	117.3	123.6	96.8
L_{5}	144.2	106.6	136.6	121.8	138.3	102.1
Maximum	170.5	146.3	176.2	156.1	170.8	144.6
Mean	141.5	104.8	138.5	117.1	141	103.6
% of 1-min periods when data exceeds 120 dB re 1 µPa	76.32	0.58	58.3	12.67	37.78	0.11
Deployment 2 (16/17 Jan to 15/16 Jul 2015)						
Minimum	100.5	79.1	98.6	82.6	105.4	81.4
L_{95}	110.2	87.7	109.5	91.3	113.3	88.4
L_{75}	114.5	94.1	115	97.6	117.4	95.2
L_{50}	118.6	97.7	118.7	100.9	121.5	98.2
L_{25}	124.6	100.8	122.2	104.7	128.3	101.2
L_{5}	138.7	111.1	128.3	109.2	142.8	110.4
Maximum	165.4	146.5	166.1	142	167.1	147.9
Mean	136.8	109.9	130.3	105.9	142	109.5
% of 1-min periods when data exceeds 120 dB re 1 µPa	43.94	1.12	41.54	0.17	59.91	0.76

Analysis periods relevant to the dominant soundscape contributors for Deployment 1 were defined to analyse the median 1 minute SPLs in a meaningful way. As outlined above, the weather was the dominant contributor from July until early September at Stations J2 and J3, therefore the first period was defined as 10 July –1 September 2014. The next period, 1 September to 10 October 2014, was selected as it lies between the weather reducing in dominance and the MODU commencing operations. The third period, 10 October 2014 to 1 January 2015, was selected as it aligned with the presence of the MODU under similar weather conditions, and the final period 1–15 January 2015 was selected as it encompasses the presence of the MODU under intensified weather conditions.

The median 1 minute SPLs for the periods determined by weather and MODU presence are shown in Table 17, the entire deployment is shown in Table 16 above.

Deployment 2 did not have clearly defined weather periods like Deployment 1, and while the MODU was present, it was only a noticeable contributor to the soundscape at Station J2 due to its proximity, and distance from the other stations. Therefore, the statistical analysis for Deployment 2 was not broken down into periods as it was for Deployment 1, but rather analysed as a whole (see Table 16).

Table 17. Deployment 1, pattern analysis periods, median 1 minute SPLs sound levels (dB re 1 µPa) for Stations J1, J2, and J3. SPL units: dB re 1 µPa.

Station	10 Jul– 1 Sep 2014	1 Sep– 10 Oct 2014	10 Oct 2014– 1 Jan 2015	1–15 Jan 2015
J1	97.3	93.7	93.6	106.4
J2	97.5	95.6	116.9	118.7
J3	96.6	88.1	89.9	98.1

3.3.3. Percentile Power Spectral Density Results

The percentile power spectral density (PSD) results for Deployment 1 are shown in Figures 62–64 for Stations J1–J3. At Stations J1 and J3, the PSDs decay relatively smoothly from 10 Hz to 24,000 Hz (the 24-bit channel recorded bandwidth), while Station J2 exhibits a strong peak centred at 100 Hz. The median (L_{50}) curve at Station J1 decays 9 dB from 100–1000 Hz, and 10 dB from 1000–10,000 Hz. At Station J2 the median level decays 12 dB from 100–1000 and 11 dB from 1000–10,000 and at Station J3 the median level decays 12 dB from 100–1000 and 10 dB from 1000–10,000.

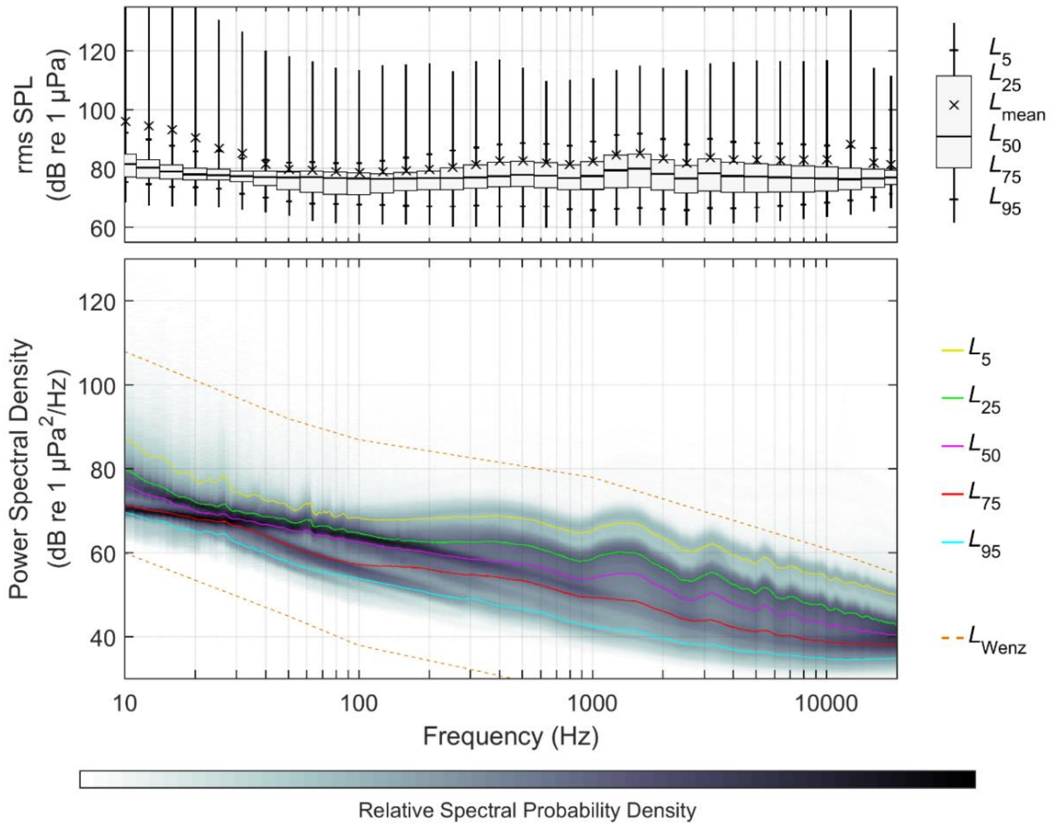


Figure 62. Deployment 1: Percentile power spectral density sound levels at Station J1 for 10 July 2014 to 15 January 2015.

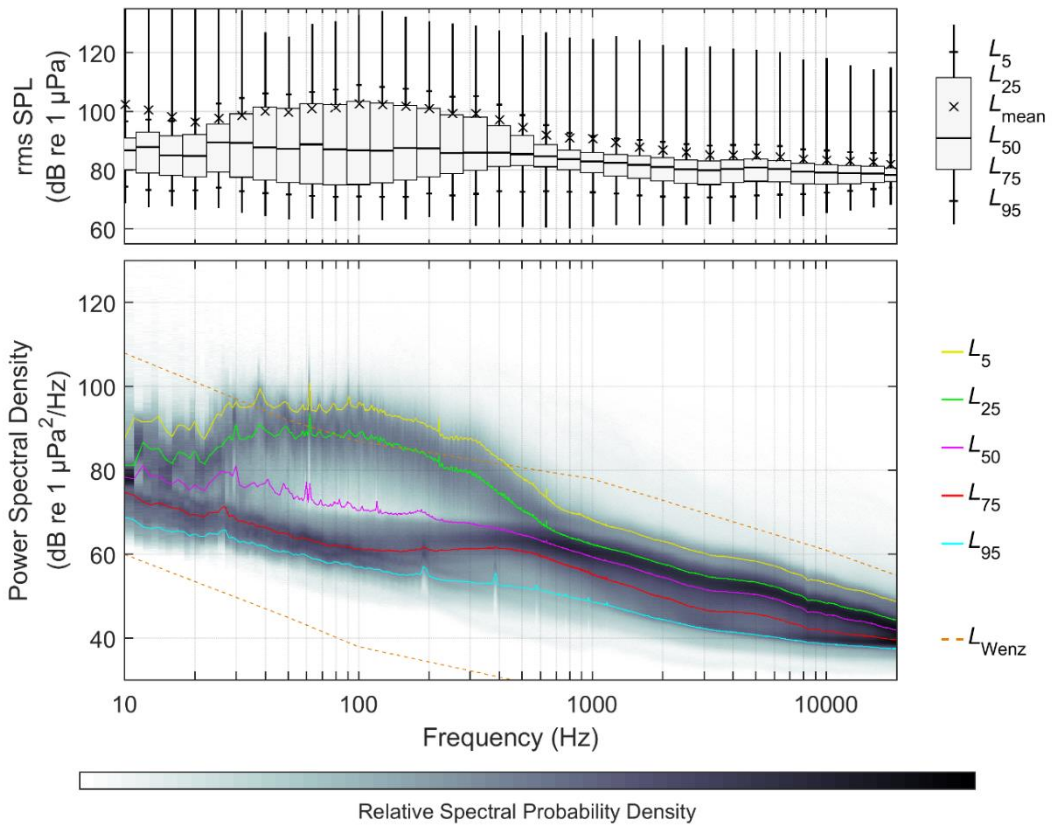


Figure 63. Deployment 1: Percentile power spectral density sound levels at Station J2 for 10 July 2014 to 15 January 2015.

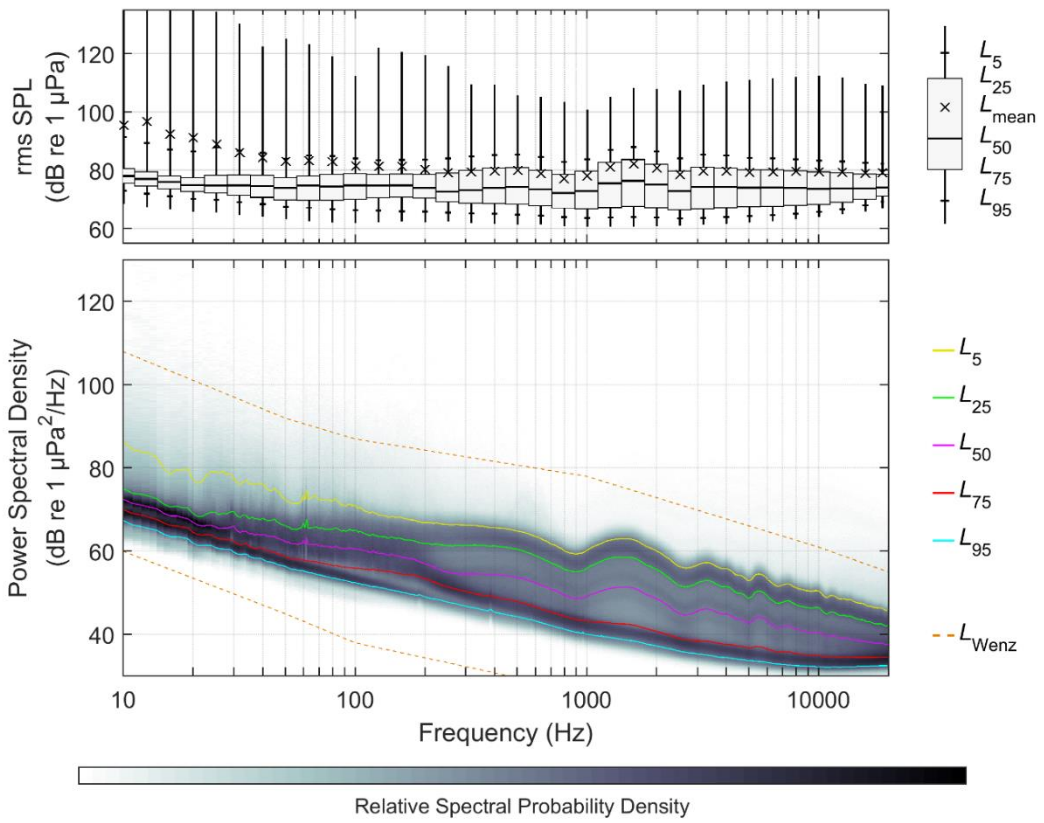


Figure 64. Deployment 1: Percentile power spectral density sound levels at Station J3 for 10 July 2014 to 15 January 2015.

The percentile power spectral density (PSD) results for Deployment 2 are shown in Figures 65–67 for Stations J1–J3. Unlike Deployment 1, none of the PSDs demonstrate a relatively smooth decay over the recorded bandwidth, with more variability present at frequencies below 1 kHz. At frequencies above 1 kHz, the decay pattern is similar at all three stations, and while approximately 5 dB higher than the levels at Stations J1 and J3 from Deployment 1, Station J2 follows the same trend. Peaks are present at all percentiles (except L_5, Station J2) at around 26–28 Hz. The median (L_{50}) curve at Station J1 decays 4 dB from 100–1000 Hz, and 10 dB from 1000–10,000 Hz. At Station J2 the median level decays 16 dB from 100–1000 and 10 dB from 1000–10,000 and at Station J3 the median level decays 9 dB from 100–1000 and 7 dB from 1000–10,000.

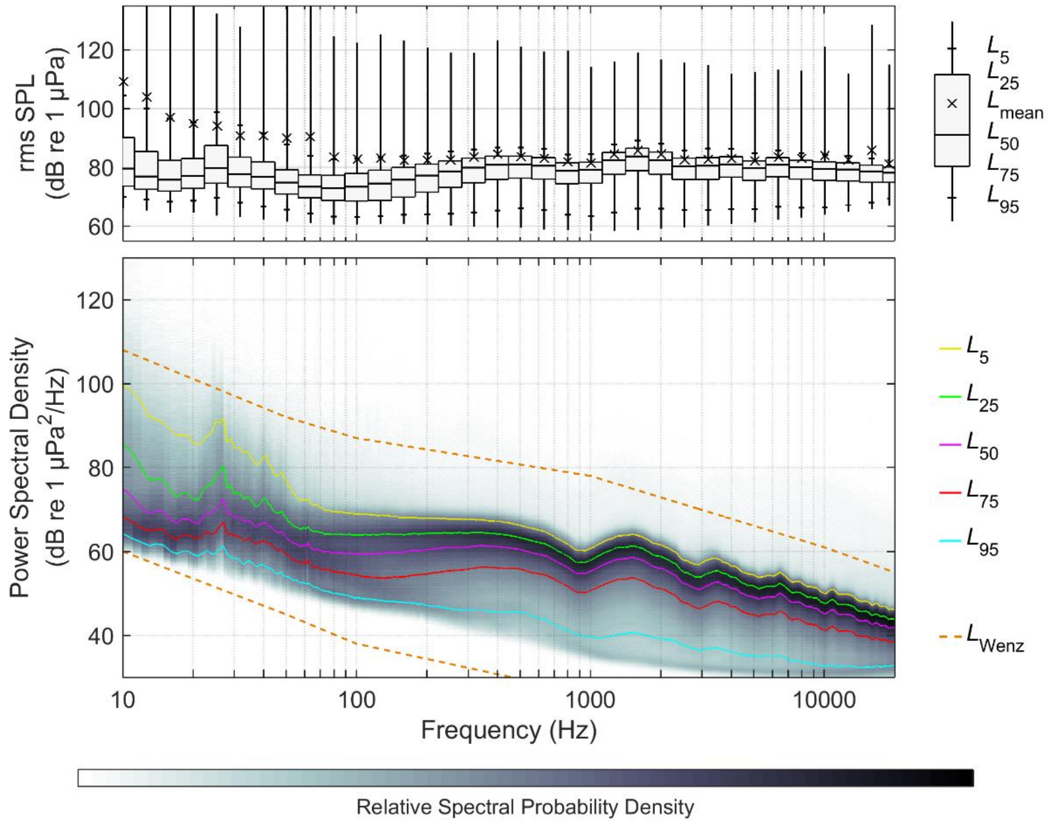


Figure 65. Deployment 2: Percentile power spectral density sound levels at Station J1 for 16 January to 16 July 2015.

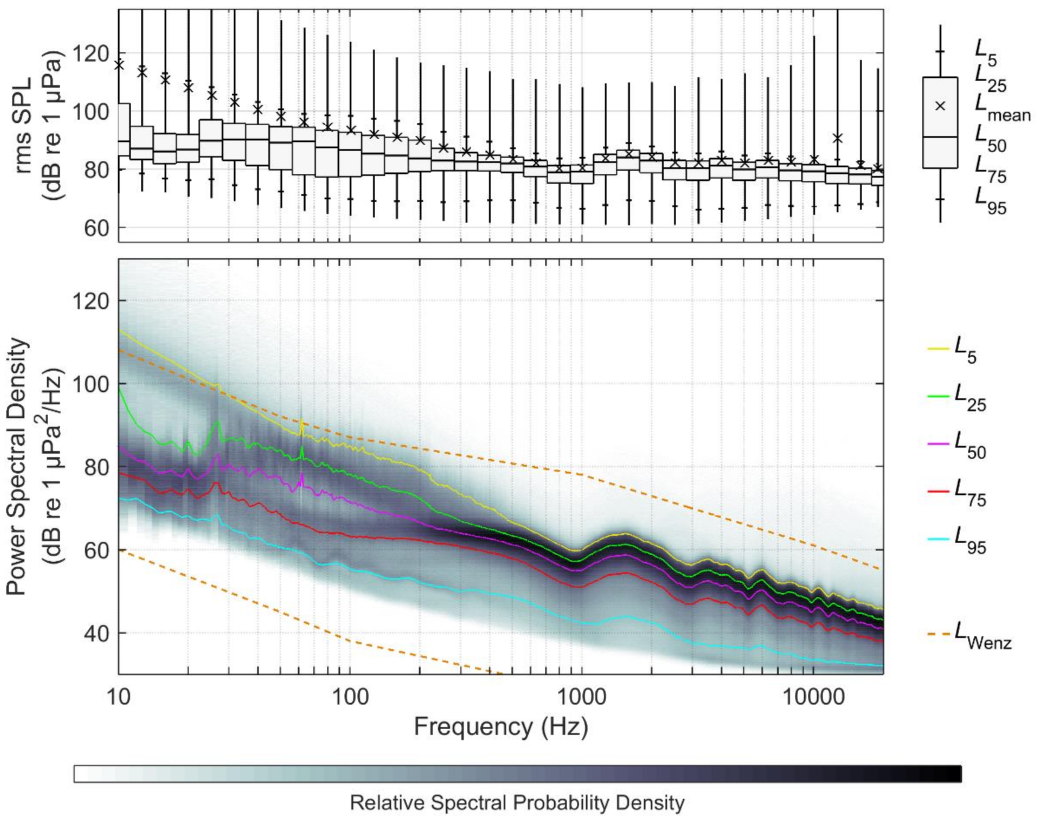


Figure 66. Deployment 2: Percentile power spectral density sound levels at Station J2 for 17 January to 15 July 2015.

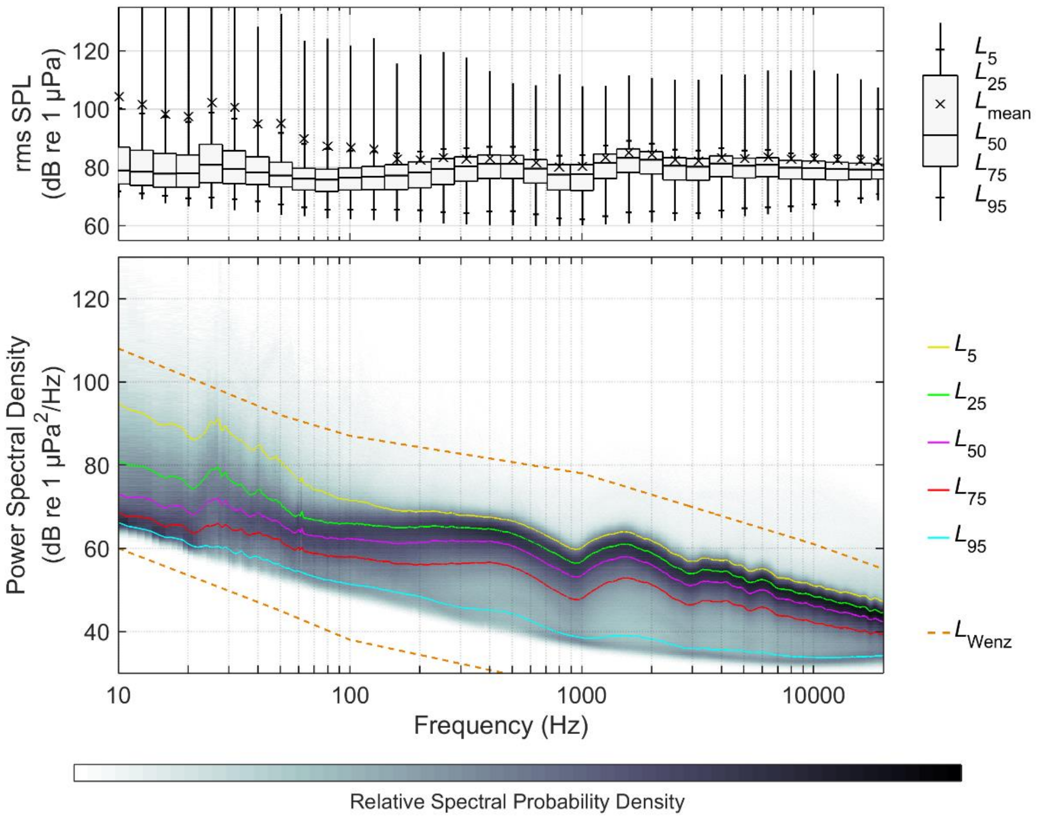


Figure 67. Deployment 2: Percentile power spectral density sound levels at Station J3 for 17 January to 15 July 2015.

The daily SEL values were extrapolated from the measured values and adjusted to account for the duty cycle of 840 s every 1800 s (Table 18). The median daily SEL for both stations was virtually identical during Deployment 1 at Stations J1 and J3 at 145.5 and 145.1 dB re 1 µPa²·s, respectively, and whilst 7 dB higher, only 1 dB different (151.9 as compared to 152.8 dB re 1 µPa²·s respectively) for Deployment 2. The median daily SEL at Station J2 was approximately 16 dB higher than the other stations during Deployment 1, but only approximately 1.5 dB higher during Deployment 2. A similar trend was observed for the mean daily SEL at all stations over both deployments. Across all stations for both deployments, the minimum daily SELs were within 9 dB of each other, whilst the maximums have a separation of 12.7 dB between the highest (Station J2, Deployment 1) and the smallest (Station J1, Deployment 1).

Table 18. Statistical analysis of sound levels for Stations J1, J2, and J3 SEL units: dB re 1 µPa²·s, Station J2 for the second deployment is only analysed until 10 June 2015.

Sound level statistic	Daily SEL		
	J1	J2	J3
Deployment 1 (10 Jul 2014 to 15 Jan 2015)			
Minimum	139.7	141.1	135.1
L_{95}	141.5	143.8	138.6
L_{75}	143.3	147.7	142.1
L_{50}	145.7	161.9	145.1
L_{25}	148.9	167.8	148.4
L_{5}	155.9	171.5	154.9
Maximum	166.8	178.5	168.1
Mean	150.6	166.1	150.1
Deployment 2 (16/17 Jan to 15/16 Jul 2015)			
Minimum	141.5	144	143.1
L_{95}	145.2	145.9	145.8
L_{75}	149	148.6	149.7
L_{50}	151.9	153.8	152.8
L_{25}	155	157.3	155.6
L_{5}	167.6	164.1	162.4
Maximum	175.1	165.8	173.2
Mean	160.6	157.4	158.2

3.4. Anthropogenic Sound

3.4.1. Vessel Detections

The daily SELs at each station, showing the overall daily SEL and the SEL attributed to detectable shipping are shown in Figure 68. During Deployment 1, the large number of vessel detections at Station J2 was due to either the MODU being detected as a vessel during periods of its activity, or the presence of its support vessels. During Deployment 2 there was more vessel activity, with the MODU presence at Station J2 again being a major contributor. There was a timing correlation between the drilling program detected at Stations J1 and J2 over Deployment 2, with many detections occurring at similar times. The seismic survey (Section 1.2.2) from July 2015 occurred at a similar time to a number of vessel detections. The seismic survey was detected at Station J1 and J3. The average number of vessels detected per day over Deployment 1 during the pattern analysis periods is listed in Table 19, while those for both deployments are listed in Table 20.

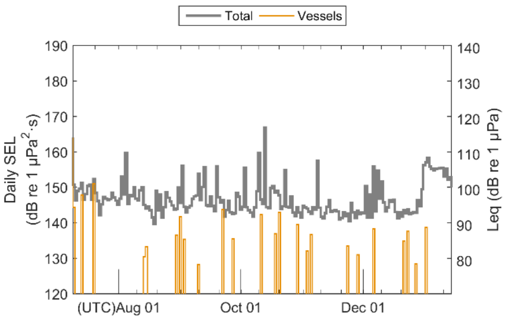
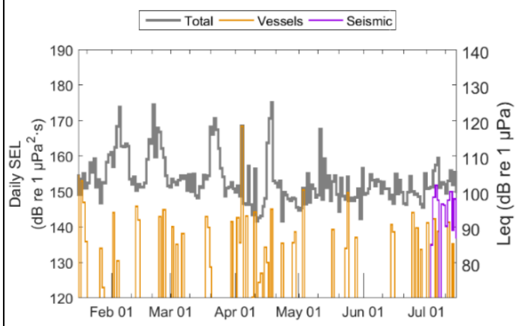
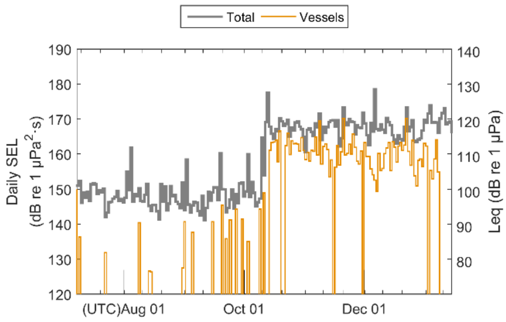
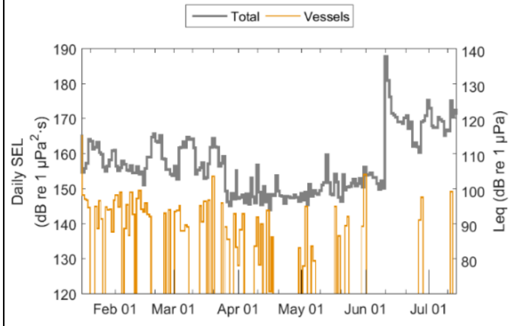
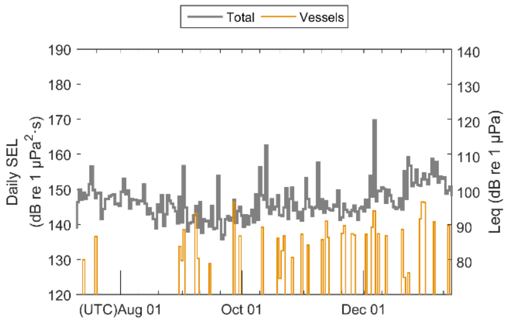
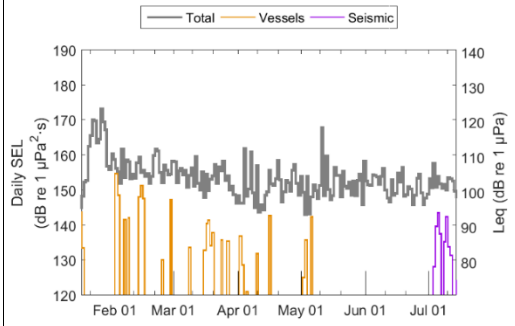
Station	Deployment 1 (10 July 2014 to 15 January 2015)	Deployment 2 (16/17 January to 15/16 July 2015)
J1		
J2		
J3		

Figure 68. Daily SELs at all stations, showing the overall daily SEL and the SEL attributed to detectable shipping and seismic activity (see Section 3.4.4). Note that a crustacean was present on Station J2 during Deployment 2 after 10 June 2015, however the daily SEL data is still shown to keep the figures axes consistent across stations.

Table 19. Deployment 1: Mean daily vessel detections at each station for four time periods, aligned with pattern analysis periods and normalised for effort.

Station	10 Jul–1 Sep 2014	1 Sep–10 Oct 2014	10 Oct–01 Jan 2015	01 Jan–15 Jan 2015
J1	0.1	0.1	0.2	0.1
J2	0.1	0.3	2.8	0.8
J3	0.2	0.3	0.3	0.1

Table 20. Mean daily vessel detections at each station for both deployments, normalised for effort.

Station	Deployment 1	Deployment 2
J1	0.1	0.4
J2	1.4	0.7
J3	0.3	0.3

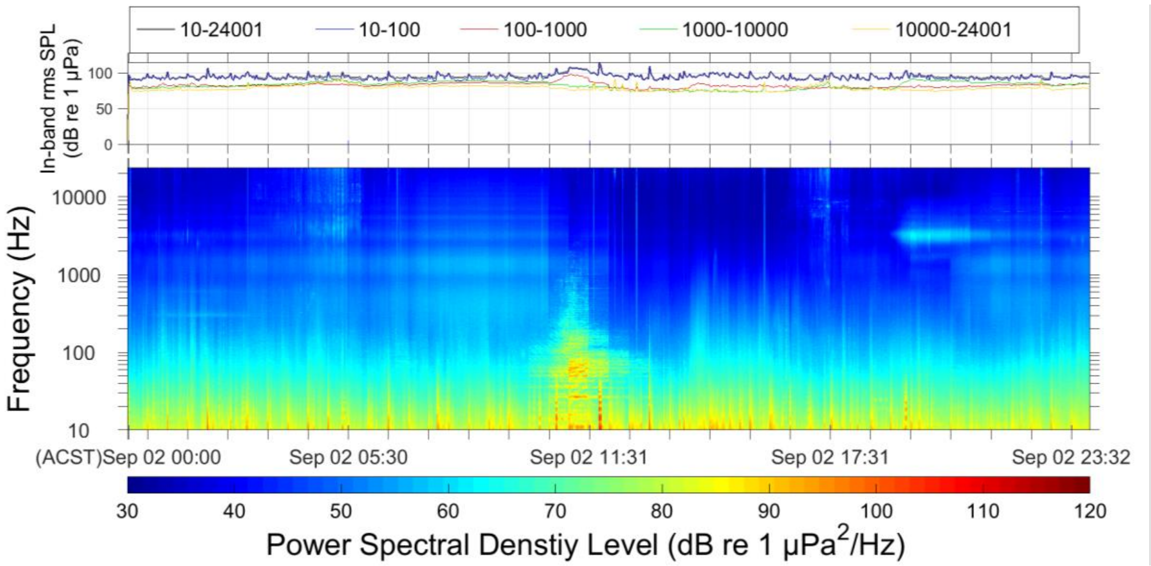


Figure 69. A passing vessel at long range from Station J1 at ~11:15 on 2 September 2014. The dusk fish chorus is also clearly visible at ~1800 hrs between 2-4 kHz.

3.4.2. MODU Operations

3.4.2.1. Deployment 1

MODU operations were a dominant contributor to the soundscape after it arrived on 12 October 2014. Figure 52 shows the influence of the MODU on a monthly timescale, while Figure 70 provides a daily spectrogram demonstrating the contribution. The majority of the contribution is below 200 Hz. This spectrogram also shows the pre-dawn fish chorus from 200–900 Hz and an individual vessel movement occurring around 20:30.

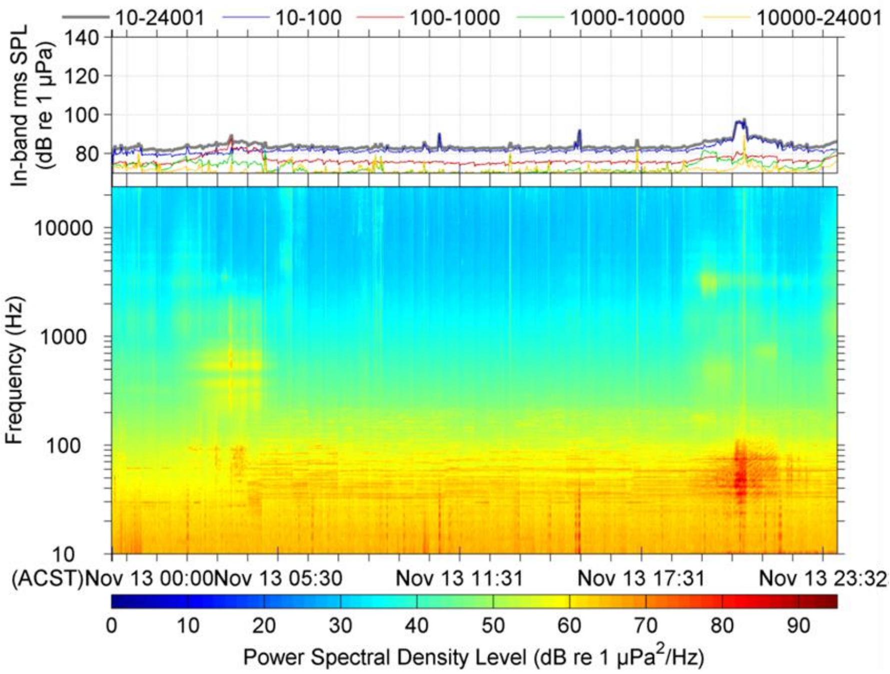


Figure 70. Example daily spectrogram of MODU operations, Station J2, 13 November 2014.

3.4.2.2. Deployment 2

For the first three months of Deployment 2, the MODU was again a dominant contributor to the soundscape at Station J2. The majority of the contribution was below 200 Hz, although it was still very influential up to approximately 600 Hz (Figure 71). During March, there was little fish chorusing activity at Station J2.

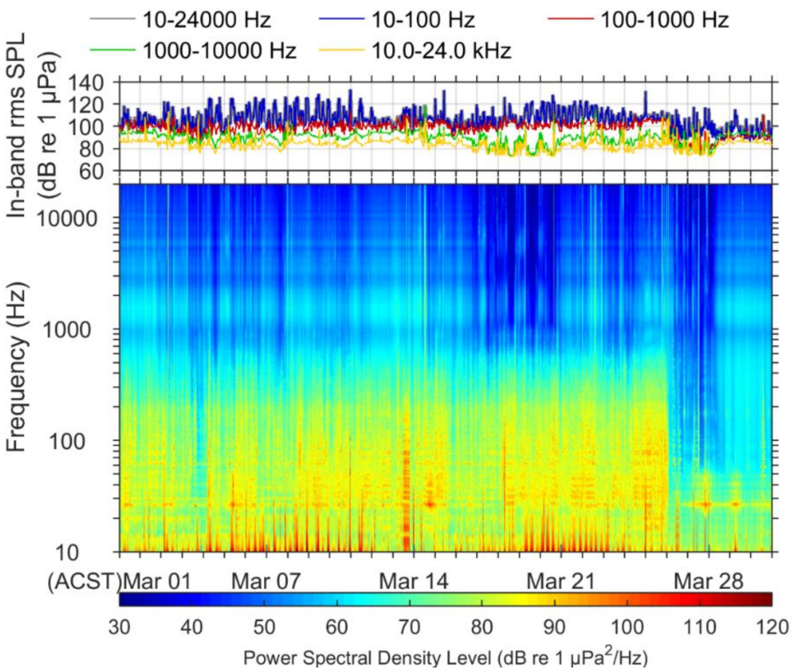


Figure 71. Example monthly spectrogram of MODU operations, Station J2, March 2015.

3.4.3. Airplane Overflight

Other anthropogenic sound sources were occasionally identified in the dataset. For example, a propeller airplane was detected at Station J2 on 7 September 2014 (Figure 72). The type of aircraft was determined by manual identification. Opportunistic detections such as these are not reported with the automatic anthropogenic analysis.

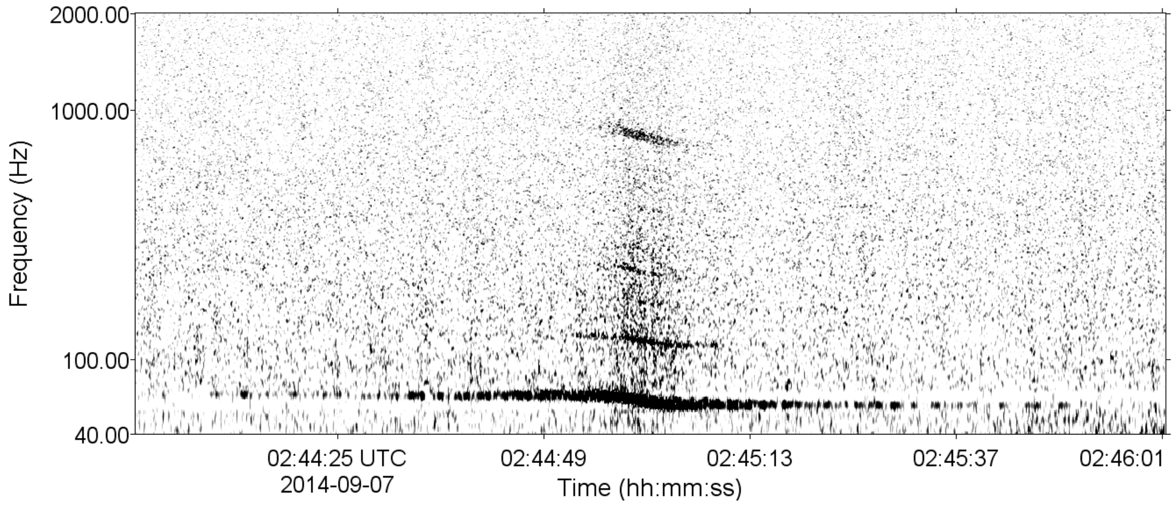


Figure 72. Doppler shift pattern of an airplane overflight at Station J2 on 07 September 2014.

3.4.4. Seismic Survey

A seismic survey, thought to be the CGG 2D BandaSeisV survey (Section 1.2.2), was detected at Stations J1 and J3 by the automated seismic detector, with the per pulse statistics shown in Table 21. At Station J1, the first shots were detected from 06:55 on 04 July 2015, and the last from 23:20 on 15 July 2015, while at Station J2, the first shots were detected from 09:49 on 04 July 2015, and the last from 23:20 on 14 July 2015. The average shot spacing at both stations was 10.5 seconds. The spectrogram for the period 1–17 July (Figure 73) shows the intermittent nature of the survey events, which can be seen as the periods below 100 Hz with levels greater than 90 dB. A fine timescale comparison of all three stations (Figure 74, left) confirms the lack of automated detections at Station J2. It also provides an example of the difference in the pulse time and frequency structure between the two stations (Figure 74, right), with the SPL of the first two seconds of a pulse at Station J1 being 119 dB, compared to 107 dB re 1 µPa at Station J3. While Figure 74 shows the time axis as synchronised, the stations have not been synchronised to the point of being able to do localisation, although the shot logs from the seismic survey would allow this to occur. July was also a period of extensive mysticete calling, which had similar amplitudes to the seismic source at J1 (Figure 75). The minor contribution of the seismic survey to the ambient statistics calculated over the entire second deployment is shown in Figures 76 and 77.

Table 21. Seismic survey per pulse statistics. SPL units: dB re 1 µPa, SEL units: dB re 1 µPa²·s.

Pulse statistics	Per Pulse Average SPL		Per Pulse Average SEL	
	Station J1	Station J3	Station J1	Station J3
Minimum	96.7	95.6	102.4	101.5
Maximum	125.0	118.6	126.0	119.3
Average	108.0	103.6	113.2	108.6
Median	107.1	102.6	112.5	108.1

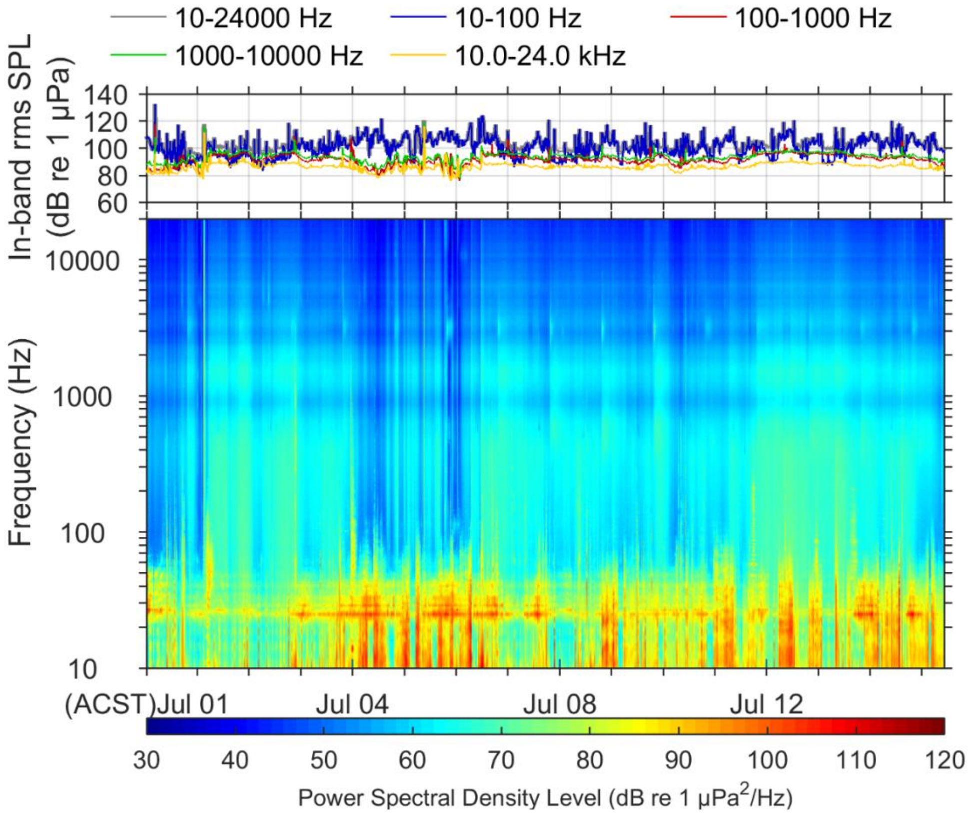


Figure 73. Spectrogram of Station J1, July 2015, showing seismic survey activity below 100 Hz. The 26–28 Hz tone from mysticete calls is visible even during the seismic activity.

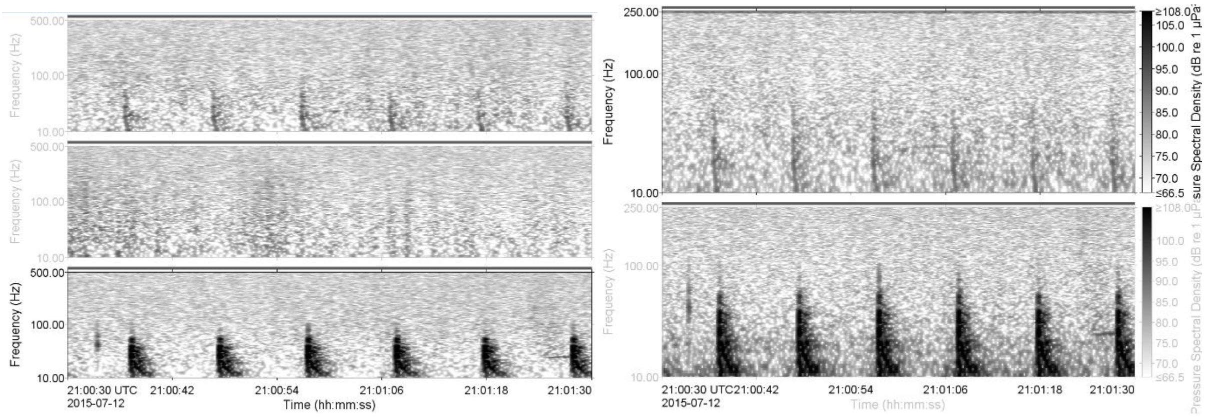


Figure 74. Left: Spectrogram of 12 July from 21:30 for Stations J1-J3 (bottom to top), and right: spectrogram of Stations J1 (bottom) and J3 (top) for the same period, showing PSD levels, (1 Hz frequency resolution, 1s time window, 0.1 s time step, and Hamming window).

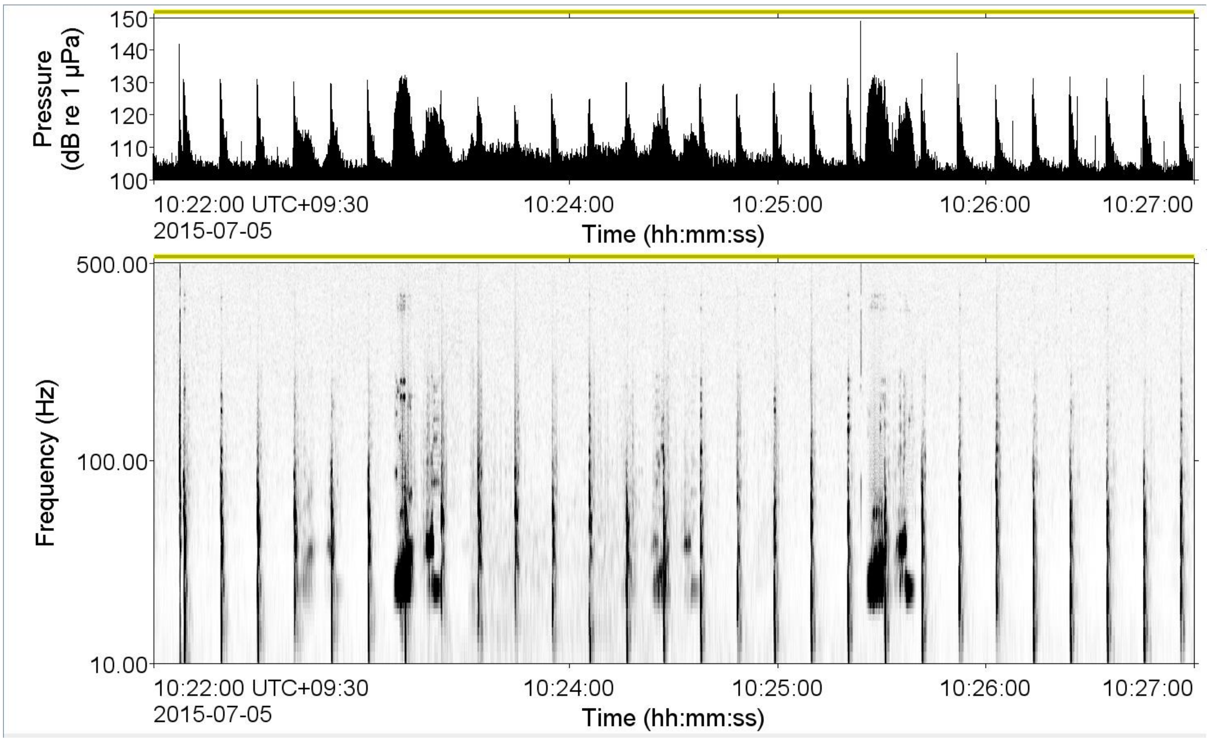


Figure 75. Five minutes of data from J1 on 5 July 2015 showing mysticete calls equal amplitude to the seismic pulses.

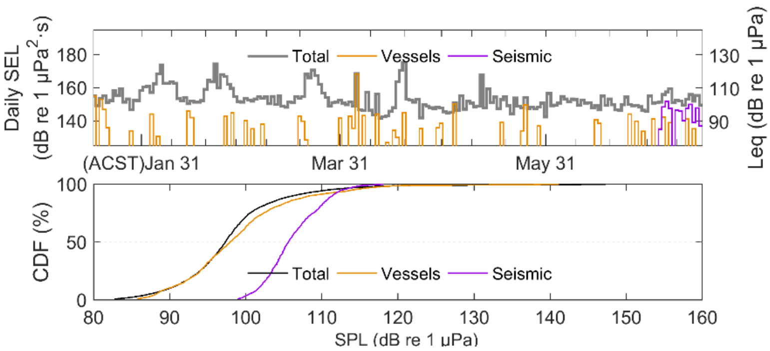


Figure 76. Station J1, Deployment 2, accumulated SEL and SPL cumulative distribution function

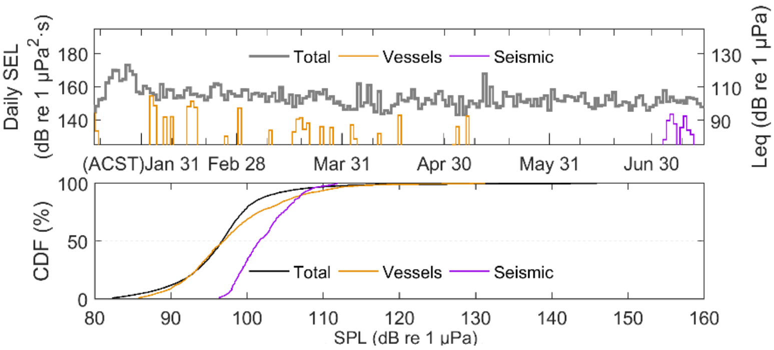


Figure 77. Station J3, Deployment 2, accumulated SEL and SPL cumulative distribution function

3.4.5. ROV Operation

A Remotely Operated Vehicle (ROV) was used to deploy a tertiary acoustic release at Station J1 on 4 April 2015 due to a malfunction of the releases on the mooring. The presence of the *MV Warrego* and the ROV on station was a dominant contributor to the soundscape from 10 Hz–24 kHz for the period it took to complete the operation (Figures 78 and 79).

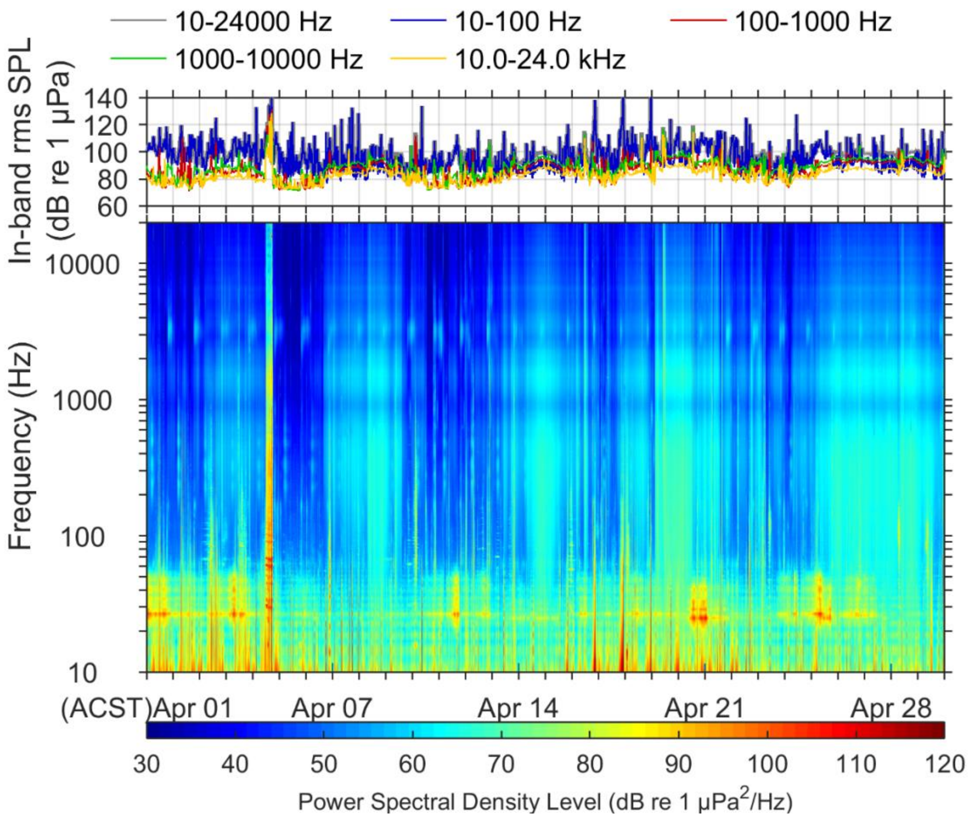


Figure 78. Monthly spectrogram for Station J1, April 2015. The ROV operations are the vertical red line on 5 April. The daily dawn chorus from 200-900 Hz and the evening chorus from 2-4 kHz can also be seen, as well as periods of mysticete calling at 26–28 Hz.

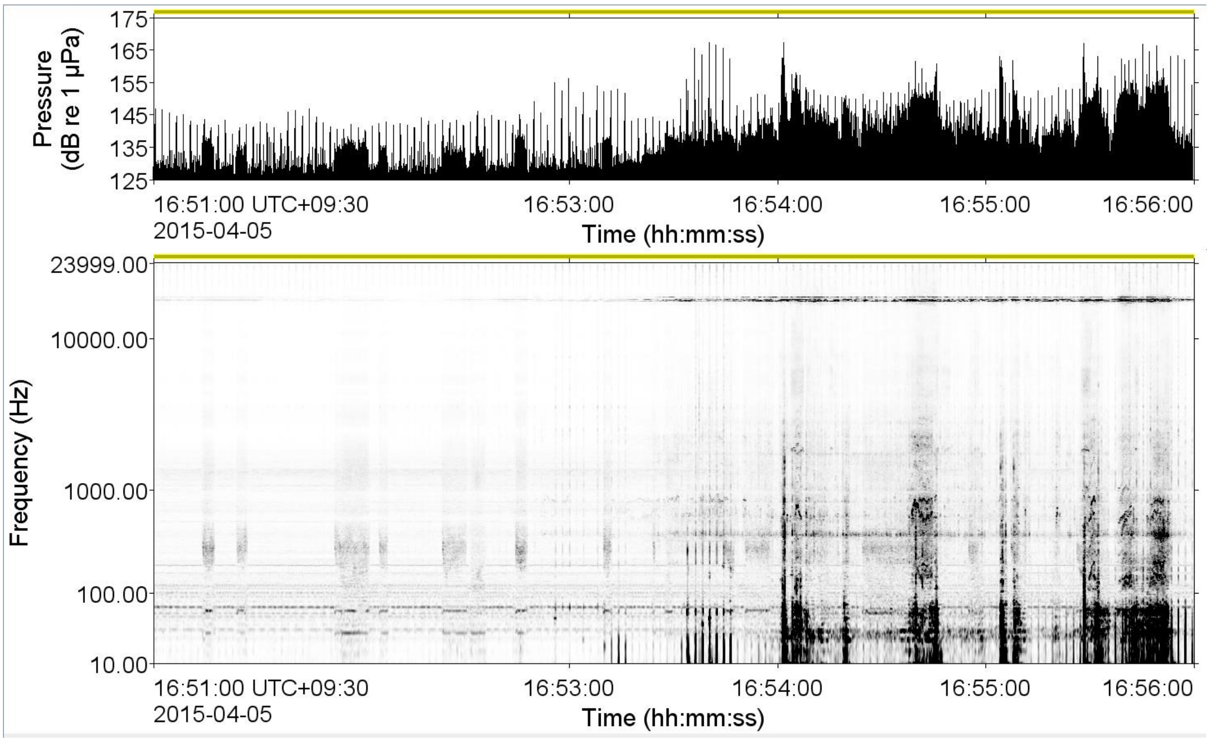


Figure 79. 5 minutes of data from 5 April 2015 during the ROV operations. The first two minute contain thruster manoeuvring as the ROV approached the J1 mooring. The last two minutes contains hydraulic sounds from the ROV manipulator arms. The spikes in the time series display are from acoustic locator beacons or from the M/V Warrego's echosounder.

3.5. Rhythmic Pattern Analysis

3.5.1. Deployment 1

The first deployment data were analysed over the entire period (Figure 80) and broken into three six-week periods (10 July to 1 September, 1 September to 10 October, and 10 October to 1 January) based upon different weather events and the presence of the MODU (Table 22). Patterns emerged from trends in the data over these periods in terms of biological contributors and the relative contributions of weather and the MODU-associated operations.

Analysis of the daily rhythms at Station J1 (Figure 81) shows that the low frequency decade (10-100 Hz) had approximately the same amplitude for all periods and all times of day at ~85 dB re 1 µPa. The 100-1000 Hz and 1000-10000 Hz decade bands were significantly above the 10-100 Hz band during the first period, but below the 10-100 Hz band during the other two periods. The two higher decades are often associated with wind and wave activity which was higher during the first period. The first and second periods appear to have increased wind and wave noise later in the day suggesting a deil heating increasing the winds in the afternoon.

The rhythms also confirmed the presence of the fish chorusing events, however only the evening chorus in the 1000–10000 Hz band is apparent during all periods, and the dawn chorus in the 100–1000 Hz is only apparent in the period 10 October–January 1. This aligns with the observations in Section 4.1.3. The weather events were less of a contributor in this period, thus the fish chorusing became detectable from the background in the total sound levels.

Analysis of the daily rhythms at Station J2 (Figure 82) show that the overall sound levels are generally consistent over a 24 h period, with only a slight difference between day and night. The 'bump' in the 100–1000 Hz band 1 September to 10 October at approximately 20:00 is also due to unknown causes. Weather raised the low frequency 10–100 Hz band sounds by 5–7 dB in the first period compared with the second period, whereas the MODU when present in the period 10 October–1 January raised the 10-100 Hz band sound levels by 20 dB compared to the 1 September–10 October period. A similar effect was observed in the 100–1000 Hz band, with weather raising the median SPL by 10 dB, while the MODU raised it by 10–15 dB. The presence of the MODU did not contribute to the 1000–10000 Hz band. In other periods weather increased the median SPL by approximately 10 dB during the first period compared to the second. Fish choruses were in the spectrograms (Section 3.2.4.2) although they are not apparent in the daily rhythms.

Analysis of the rhythms at Station J3 (Figure 83) shows a greater increase in the overall sound levels during the day relative to the night-time levels. The fish choruses are not apparent in the analysis for this station. The period with the highest influence from the weather, 10 July to 1 September, also had the highest overall levels. The 10–100 Hz band is the primary band in which the diurnal change is present, with an average 5 dB change occurring close to sunrise and sunset.

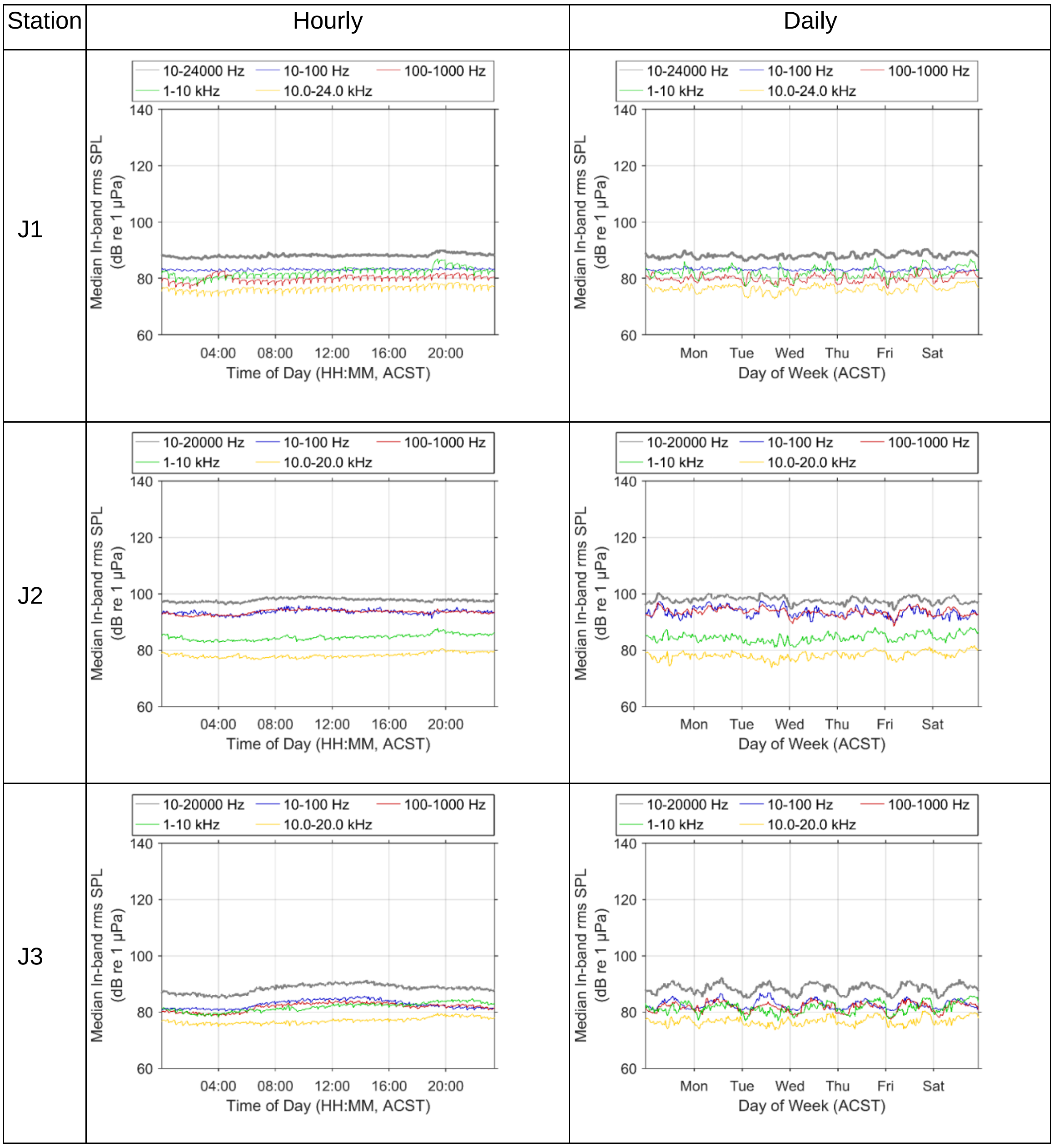


Figure 80. Deployment 1: Pattern analysis for the entire deployment for all stations, hourly (left) and daily (right)

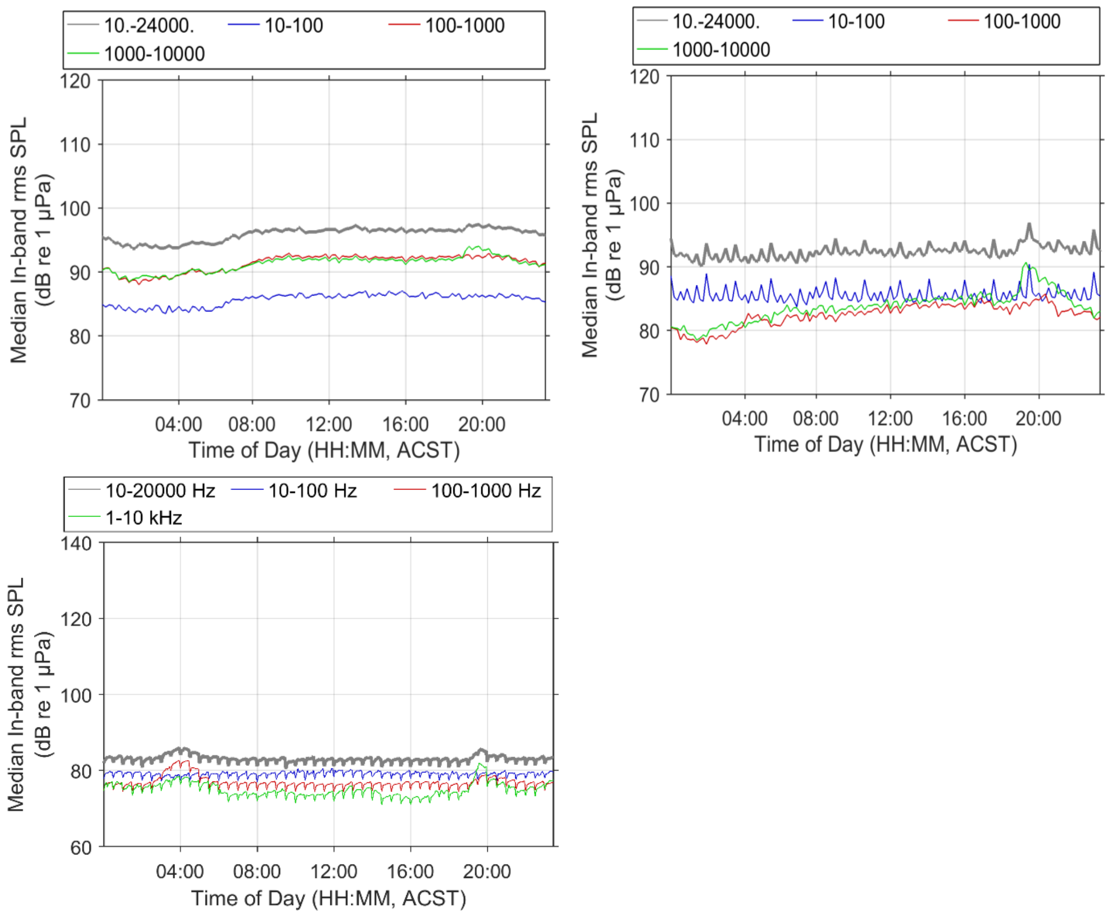


Figure 81. Deployment 1: Pattern analysis for Station J1, (top left) 10 July to 1 September 2014, (top right) 1 September to 10 October 2014, and (bottom left) 10 October 2014 to 1 January 2015.

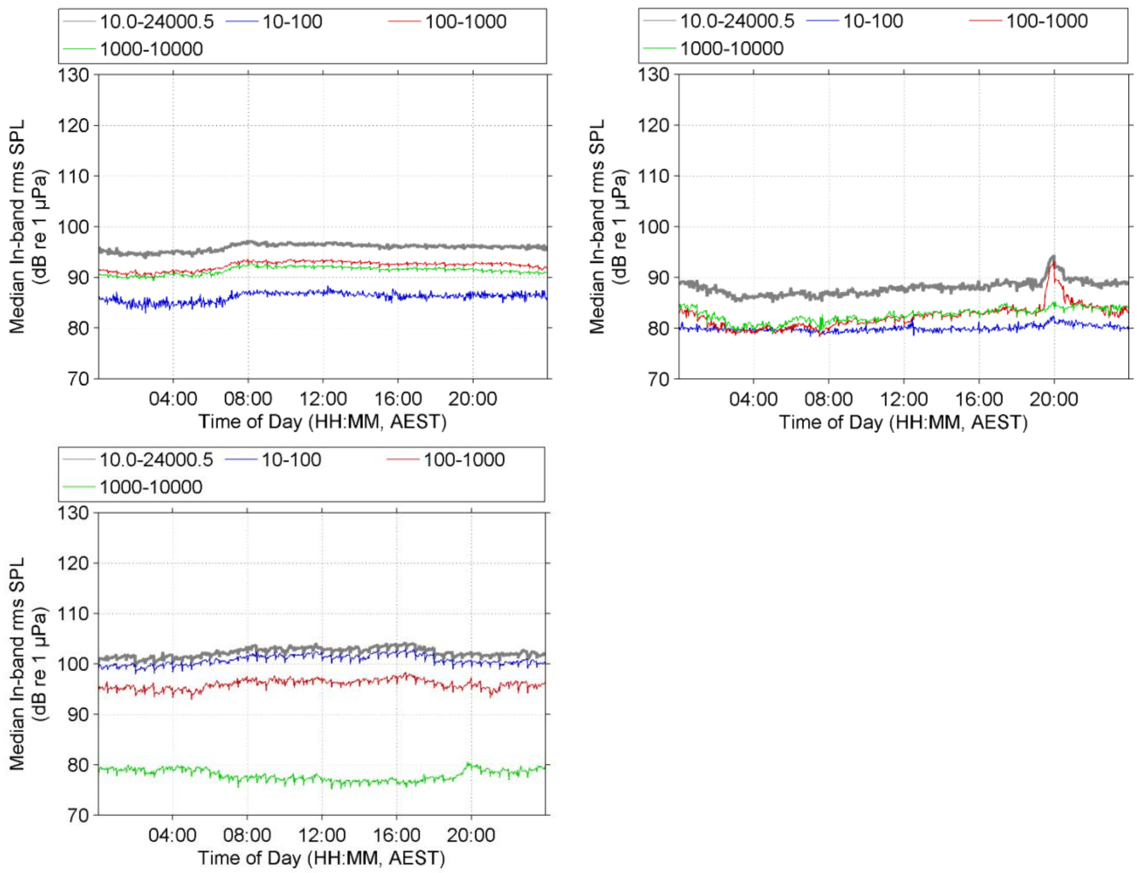


Figure 82. Deployment 1: Pattern analysis for Station J2 (top left), 10 July to 1 September 2014, (top right) 1 September to 10 October 2014, and (bottom left) 10 October 2014 to 1 January 2015.

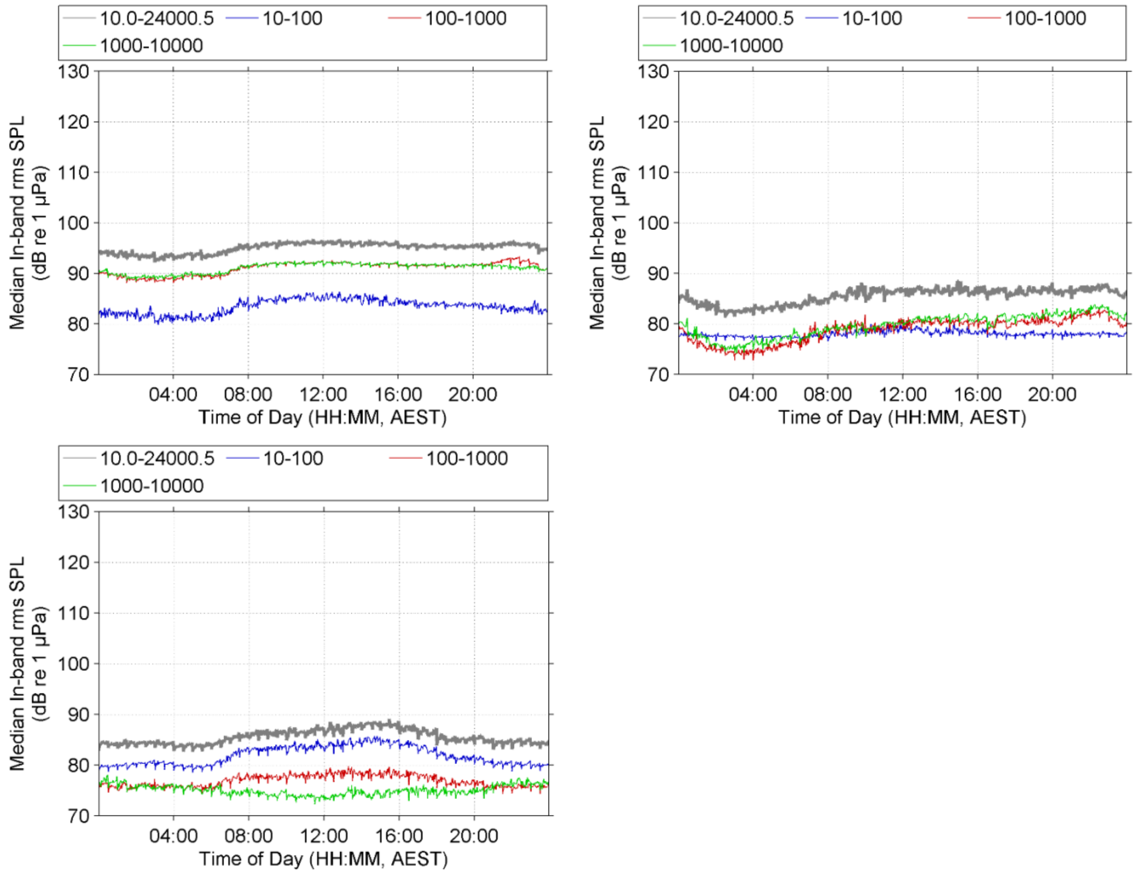


Figure 83. Deployment 1: Pattern analysis for Station J3, (top left) 10 July to 1 September 2014, (top right) 1 September to 10 October 2014, and (bottom left) 10 October 2014 to 1 January 2015.

3.5.2. Deployment 2

The second deployment data were analysed for patterns across the entire period (Figure 84). Similar to the first deployment, patterns emerged from trends in the data over these periods in terms of biological contributors and the relative contributions of weather and the MODU associated operations. The analysis was done on both a daily and weekly basis. Potentially due to the plots being analysed over the entire deployment, some of the minor patterns noted during the Deployment 1 analysis were not found, and it was not possible to determine weather contributions per period using the pattern analysis for this deployment.

Analysis of the rhythms at Station J1 did not show the fish chorusing as clearly as Deployment 1 and that the band levels were reasonably consistent through the entire deployment. The only pattern present was the slight increase in sound levels during the day relative to night-time levels. There was a slight rise in levels in the evening, centred at 20:00, which is possibly due to fish chorusing.

Station J2 sound levels were generally consistent over a 24 h period, with only a slight difference between day and night. The 'bump' present in the 100–1000 Hz band during 1 September–10 October at approximately 20:00 from Deployment 1 was also observed in this deployment, however was also present in the 1–10 kHz band; the cause is unknown, however likely due to biological contributors. The 10–100 Hz band is approximately 10 dB higher at this station, which is due to the presence of the MODU early in the deployment. Again, although they were apparent in the data and visible in the spectrograms, fish chorusing events are not apparent in the cyclic period analysis.

The patterns at Station J3 shows a greater increase in the overall sound levels during the day relative to the night time levels than the other stations, which is similar to Deployment 1. The fish choruses are not apparent in the cyclic period analysis for this station. The 10–100 Hz band is the again the primary band in which the diurnal change is present, with an average 5 dB change, similar in magnitude to Deployment 1, occurring close to sunrise and sunset.

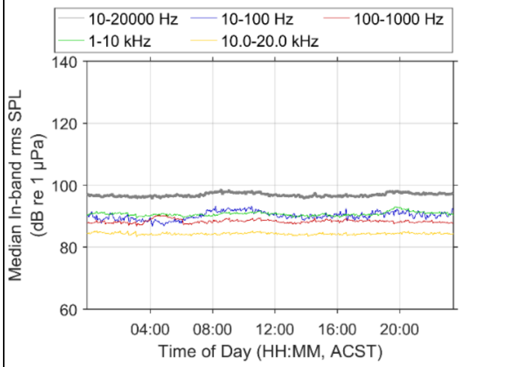
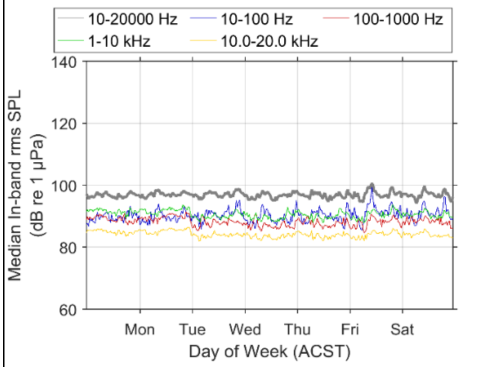
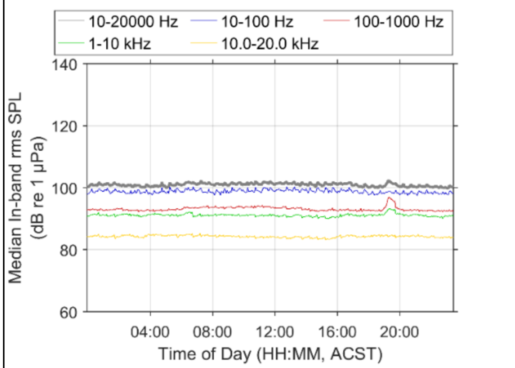
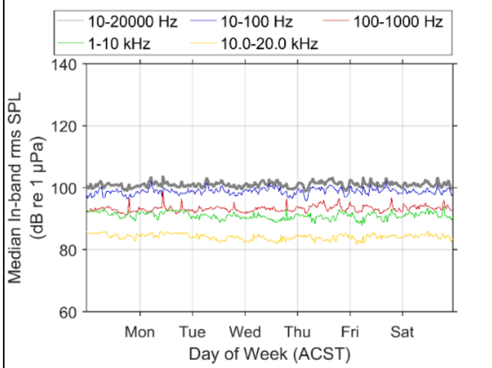
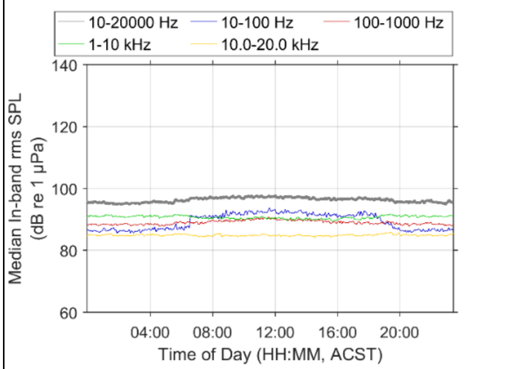
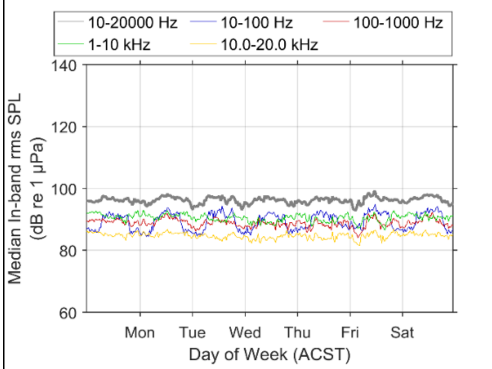
Station	Hourly	Daily
J1		
J2		
J3		

Figure 84. Deployment 2: Pattern analysis for the entire deployment for all stations, hourly (left) and daily (right)

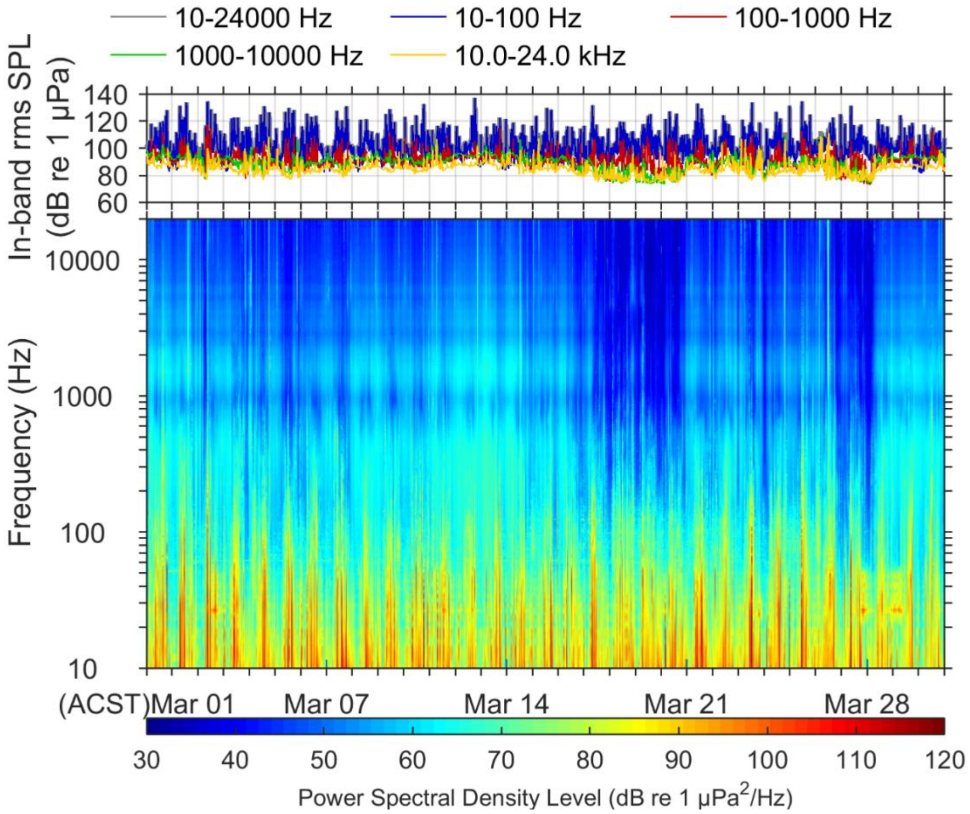


Figure 85. Station J3, difference between day/night

4. Discussion

4.1. Marine Fauna

4.1.1. Mysticetes

Mysticetes—Bryde's, minke, humpback, and pygmy blue whales—may occur in the Timor Sea and surrounding waters according to DoE (2015). In addition it is believed that the Omura's whale is also present.

The acoustic absence of minke and humpback whales in these data can be attributed to one or more of the following:

- They were not present in this part of the Timor Sea
- They were present, but not calling
- They were present and calling, but were masked by noises such as vessels
- The detectors did not adequately detect these species
- The manual analysis was too limited in scope to capture these species

Minke, and humpback whales migrate to Antarctic waters in the austral summer to feed (Chapman 1974, Kasamatsu et al. 1995, Branch et al. 2007), so they are not likely be present from October through January. However, minke whales might be present from July to September, although they were not detected. Minke whales produce stereotyped calls (Gedamke et al. 2001, Risch et al. 2014) that should make them reliable targets for automatic detectors. In addition, calling rates in this generally acoustically cryptic species increase in winter during the breeding season as in other rorqual whales. Therefore, one could reasonably expect to detect their calls, if present. The absence of detections is thus best explained by the absence of this species in the area.

Humpback whales, another acoustically active species particularly during migration (Dunlop et al. 2007, Smith et al. 2008), were not detected in the data and it is likely that they are absent from the area. Data from Jenner et al. (2001) indicates that between June and mid-November humpback whales use the Kimberley area as a calving ground. This species has been observed seasonally to complete their northern migration in the Camden Sound area of the West Kimberley (Jenner et al. 2001) after feeding in Antarctic waters during summer (Bannister and Hedley 2001). If they were to be present at all it would be most likely to be in the June–August period, but as they were absent from the data during this time, they are unlikely to be present during any time of year.

4.1.1.1. Pygmy Blue Whale

Pygmy blue whales were present in the data, which was unexpected because they typically migrate further west along the edge of the continental shelf (Double et al. 2014, McPherson et al. 2014). Because they are acoustically active when they migrate (McCauley et al. 2001, Gavrilov et al. 2011), it is likely they were only present during the limited detection period and otherwise truly absent from the area, and not missing for one of the above listed reasons.

The calls detected matched those from reports and literature (McCauley et al. 2001, Gavrilov et al. 2011, McPherson et al. 2014), with all three call types recorded. Calls regularly occurred in a consecutive manner from Station J1 to J2, with intermediary detections at Station J3, indicating movement through the region in a south-west to north-east direction in May and June which correlates with the timing and heading of movements by one tagged animal in this area (Double et al. 2014). Calls ranged from faint to loud, as would be expected of animals moving through an area. These movements occurred over limited periods of time suggesting either few individuals traverse the area or they travel in tight groups. The detections presented here are over 400 km further east than the northeast-bound migration corridor of pygmy blue whales described in Double et al. (2014). No detections were logged from the south-bound migration, suggesting a different migration path. Pygmy blue whale call rates were highest at Station J2 (Barossa field), which may reflect its greater depth and proximity to the trench.

The data analysis provides some insight into the usage of the region by the pygmy blue whales. For example, received pygmy blue whale calls at Station J2 (Barossa field) ranged in sound level from ~62-110 dB re 1 µPa with a median SPL of ~94 dB re 1 µPa. The whales, assumed to be calling from a depth of 30 m, were anywhere from approximately 5–80 km from Station J2 with a median distance of over 23 km (call source level of 179 dB re 1 µPa) or over 31 km from Station J2 (call source level of 183 dB re 1 µPa). Further analysis of data from all stations would provide more detailed information about this usage, and could also be used to confirm the published call source levels, along with determine the source levels of the other types of calls. However, the data analysis completed to inform this report is considered adequate to inform a baseline understanding of the species broad use of the area.

4.1.1.2. Omura's/Bryde's Whale

Variation in the spatial and temporal occurrence of double-barrel/monotonic and downsweeping calls indicates that the two call-types are likely not produced by the same species. Based on the year of recordings, double-barrel/monotonic calls occur in the region in all months of the year with the exception of the period between 1 November and 23 December. During periods of increased detection, the calls raised the percentile power spectral density levels near the peak frequency of their call (~26–28 Hz) by ~ 1-5 dB. In the summer whales producing double-barrel/monotonic calls seemed to enter the area in a south-west to north-east direction (calls occurred consecutively at J1 followed by J3 and finally J2). The calls occurred regularly through the autumn and winter, with the call rate greatest at the deepest station (J2). In the spring, double-barrel/monotonic calls became sparser and whales seemed to leave the area in a north-east to south-west direction (calls ended at J2 before J1 with J3 calls being more sporadic).

Downsweeping calls similarly occurred in the region from summer (January) to the following spring (October), but the manner in which they were detected across stations and where they were predominantly detected contrasts to that of the monotonic calls. In the summer through autumn whales producing downsweeping calls moved into the area in a south to north direction (occurring first at J3 followed by J1 then J2), not occurring in the deep most northerly station (J2) until mid-April. Through the late autumn and winter months, downsweeps were detected at all stations, though the calling rate was slightly higher at the shallower stations of J1 and J3. In the spring, rather than leaving the area closer to J1 as the whales producing double-barrel/monotonic calls did, the whales producing downsweeps were last heard at the shallowest most southerly J3 station. The contrasting trends observed in double-barrel/monotonic and downsweeping calls provide evidence that these call types are likely produced by two different mysticete species, Omura's and Bryde's whales.

The double-barrel/monotonic calls presented here have previously been ascribed to Bryde's whales by McCauley and Kent (2009) and JASCO during a previous acoustic monitoring program in the Browse Basin (McPherson et al. 2014) and the western Timor Sea (McPherson et al. 2012). McDonald (2006) describes a ~5 s, 22 Hz tonal call and paired 26 Hz calls with ~ 120 s spacing and tentatively (not conclusively) assigns it to Bryde's whale. However, there are no peer-reviewed publications from northern Australia attributing such calls to Bryde's whales. Therefore, there is still a considerable amount of uncertainty surrounding the taxonomy of the Bryde's whale clade. Small rorqual whales caught off Western Australia and maturing at a small size (11–12 m) were identified as "Bryde's whales" (Bannister 1964). They may have been a local form, possibly related to small forms of Bryde's whales found elsewhere, but they may also have been the Omura's whale (*B. omurai*). Oleson et al. (2003) described nine Bryde's call-types, none of which reached the duration observed in the double-barrel/monotonic calls observed here. Since the previously mentioned studies took place, new information on the range and calls of Omura's whales, a distant relative of the Bryde's, has come to light, providing a more likely candidate for the production of the double-barrel/monotonic calls.

Cerchio et al. (2015) studied the calls of the Omura's whale in Madagascar, and described them as occurring between 15–50 Hz, lasting for 8–9 s, and in a repeated sequence every 2–3 minutes. The authors suggest that these song-like calls may be mating displays and are potentially indicative of breeding habitat. These long calls are very similar to the monotonic calls detected during this study (Section 3.2.2.2, Figure 30), differing only in peak frequency, which may be the result of geographic variations in call attributes as noted between populations of several other rorqual species. The Madagascar population of Omura's has also been described as producing double-barrel calls similar to what has been observed here (Cerchio, personal communication).

Omura's whales were only described as a new species in 2003 (Wada et al. 2003) and remain poorly understood in terms of their spatio-temporal distribution as well as physical appearance and vocal behaviour, making misidentification during visual surveys common. Omura's whales are believed to be present in the Timor Sea, through the habitat and water temperature range described in Cerchio et al. (2015), the aforementioned paper, the distribution map on the IUCN Red List (Reilly et al. 2008b), sightings reported at Marinemammalscience.org, and carcasses washed ashore in Western Australia. While in the region they have been described opportunistically by tour groups as feeding over deep shoals and reefs with newborn calves present (Marinemammalscience.org). The available information strongly suggests that the double-barrel/monotonic calls observed here were produced by the little known Omura's whale.

The downsweeping calls described in Section 3.2.2.2.1 (Figure 32), have been observed in the western Timor Sea previously (McPherson et al. 2012). Omura's whales have not been reported to produce downsweeps, although the species' repertoire description is in its infancy. In contrast, downsweeps are known to be produced by Bryde's whales in several areas (Oleson et al. 2003, Širović et al. 2014). The presence of Bryde's whales would be expected based on findings by a number of studies that noted the species' occurrence in the area and the surrounding waters (Rudolph et al. 1997, Heaney et al. 1998, McDonald 2006, Reilly et al. 2008a, Dethmers et al. 2009). It is important to recognise that much of the previous literature describing Bryde's whales in the region took place before the Omura's whale was described, and after the fact it would be difficult to visually discern between the two species at a distance or in any reduced visibility. Therefore, it is possible that a portion of previously described Bryde's whale sightings were actually Omura's. Regardless, based on the available information, it is reasonable to conclude that the downsweeping calls described here were produced by Bryde's whales.

Unlike many mysticetes, Bryde's and Omura's whales are not known for long-distance, low-high latitude migrations, but some Bryde's populations have been observed to move toward the equator in the winter and away from it in the summer (Best 1977, Valdivia et al. 1981, Wiseman et al. 2011), similar to what has been observed here. The high Omura's calling rate at the deepest station suggests that, like the blue whales, they find some benefit in the deeper waters. The opposite trend was observed in Bryde's which showed slight preference for shallower areas. Similarly, Alves et al. (2010) found Bryde's to stay near shore and make predominantly shallow dives. However, the trend observed here was minimal and therefore may be unreliable due to a small sample size; alternatively, it may be evidence of variation between the species in feeding preferences. The findings in this report shed new light on the spatio-temporal distribution of the poorly understood Bryde's and Omura's whales in the Timor Sea.

4.1.2. Odontocetes

The clicks and whistles recorded across the three stations varied immensely in characteristics, suggesting the occurrence of a number of odontocete species. Such has been observed by Rudolph et al. (1997) and Dethmers et al. (2009) who found short-finned pilot whales, sperm whales, false killer whales, pygmy killer whales, melon-headed whales, Risso's dolphins, Fraser's dolphins, spotted dolphins, rough-toothed dolphins, and spinner dolphins to be present in the area. While it would be ideal to discriminate between species, success has been limited using automated detectors and the detailed manual analysis required to identify individual species (Steiner 1981, Rendell et al. 1999, Oswald et al. 2003, Baron et al. 2008) is beyond the scope of this report. From the data analysis undertaken, whistles similar to those of short-finned pilot whales were found on a number of occasions indicating the likely presence of the species in the more northern stations (Sayigh et al. 2013).

Due to the overlap in call types of many odontocetes, the presence of any of the aforementioned species with the exception of sperm whales cannot be conclusively ruled out. Sperm whale clicks are unique in nature and easily detected, therefore they were likely absent. Such is supported by (Dethmers et al. 2009) who only observed one sperm whale in a nearby area while small odontocetes were reported in the hundreds.

Vocalisations of beaked whales, species unknown, were positively identified during manual analysis, and a detector was created specifically for them. The data were re-processed using this detector, and they were found to be present on 3 days at Station J3 and one day at Station J2 (Section 3.2.3.1) over the entire monitoring program. One of the calls detected is similar to those defined as 'beaked whale

G' (BWG) (Baumann-Pickering et al. 2013), and as such does not match any of those currently attributed to a specific species. Baumann-Pickering et al. (2013) state that to date there has not been any indication that a single species might produce multiple types of frequency-modulated pulses, and while they agree that this cannot be ruled out, current evidence suggests that frequency-modulated pulse types are species-specific. Acoustic recordings in the presence of identified beaked whales do not exist for five known species, including the ginkgo-toothed beaked whale (*Mesoplodon ginkgodens*) which distribution range overlaps the Barossa area (Reilly et al. 2008c) and has little information known about it. The detected calls therefore could either belong to a species for which no vocalisation information exists, a yet undescribed species, or a known species may produce multiple signal types. The only beaked whale thought to be in the region, based on the DoE Protected Matters search (2015), is Cuvier's, the known vocalisations of which are quite different to those recorded.

The predominance of odontocete clicks and whistles during hours of darkness likely corresponds to foraging on prey species that follow the diel vertical migrations of zooplankton. Similar patterns have been observed in a number of whale species (Víkingsson 1997, Au et al. 2000, Wiggins et al. 2005, Baumgartner and Fratantoni 2008, Sayigh et al. 2013), and JASCO in other studies conducted northern Australian waters (McPherson et al. 2012, McPherson et al. 2014).

The high number of false click detections at Station J1 during Deployment 1 can be attributed to compounding physical and biological factors. An ROV found this station to be in a high-current, rocky-bottom area with gorgonian sea fans, sponges and soft corals (Figure 86). Such a habitat would be ideal for crustaceans such as snapping shrimp, which, combined with the noise from the water flow through the rocks and the sea fans, likely resulted in the noise causing false click detections.

Figure 86. Sea floor at Station J1, with mooring line.

4.1.3. Fish

Dawn and dusk fish chorusing activity was present throughout the entire deployment at all three stations. It varied in intensity across the deployment period, however was reasonably consistent in timing. Fish chorusing is not currently able to be analysed through automated detections, and the scope of work did not include a requirement for manual analysis of chorusing event levels.

The dawn chorus is quieter during winter, appearing to increase in level throughout the deployment, with the loudest chorusing events in December. In contrast, the dusk chorus was louder during winter (July) and appears to decrease in level throughout the deployment, with the quietest chorusing events occurring in December. During Deployment 2, chorusing events were more prevalent at Station J1 than either of the other stations, with Station J3 recording very little fish chorusing activity. The higher level of fish chorusing activity closer to Evans Shoal across the entire program suggests that this area has a higher fish abundance. Little is known about the vocalisations of specific fish species in the Barossa field region, although it is expected that nocturnal planktivorous fishes, believed to be of the families Holocentridae, Priacanthidae and Apogonidae are dominant contributors, particularly for chorusing events (McCauley 2012).

Individual calls were detected at all three stations, although the relative densities were not analysed, as a detector for the types of fish calls recorded had not been implemented. A number of the individual calls observed were similar to those made by lutjanids, which are best characterised by *Rhomboplites aurorubens* (Luna 2014). There is a lack of knowledge about vocalisations of the most common fish species present in the region. However it is possible that a large number of the observed vocalisations are attributable to members of the *Lutjaninae* family.

4.2. Anthropogenic contributors

Statistical analysis of sound levels for all stations over the monitoring program included examining the minimum, maximum and quartile percentiles for both PK and 1-min SPL, along with the percentage of exceedance of the 120 dB level (Table 16), the mean, median, minimum, maximum and daily SELs (Table 18), and the median 1 minute SPLs for the previously discussed pattern analysis periods for Deployment 1 (Table 17).

Generally, there was a low level of anthropogenic contribution across Deployment 1, with the exception of the presence of the MODU *Nan Hai VI* and associated support vessels. Table 22 summarises Tables 17–20 for the three stations for Deployment 1 to assist with comparison. The presence of vessels cannot be used to predict sound levels, as weather is also a contributor to the soundscape. When the mean daily vessel detection levels between the stations diverge, as occurs for the two periods after 10 October 2014, the median 1-min SPLs also diverge, being 25.15 and 16.45 dB higher for Station J2 than the combined average of both other stations, which are within 3.7 and 8.3 dB of each other respectively. The contribution of the MODU and associated support vessels to the soundscape is more noticeable than in other regions of Australia, for instance the North-West Shelf, due to the low volumes of shipping traffic. The highest mean daily detections over all stations and deployments is 1.4 at Station J2 during Deployment 2, likely associated with the MODU.

Although the MODU and associated support vessels were present for the first three months of Deployment 2, again close to Station J2, their impact over the entire deployment on the median daily SELs is minimal, causing a 1.45 dB relative increase as opposed to a 16.5 dB increase. Even though there is only one-month difference in the duration of presence, the additional distance between the MODU and the monitoring stations (23, 7.5 and 13 km extra respectively) has reduced the received levels.

At the two stations farthest from the MODU and the primary vessel activity in the region (i.e., Stations J1 and J3), anthropogenic activity typically does not determine either the median 1 min SPL sound levels or the average daily SEL, with natural and biological sources being dominant. Therefore, the MODU and rig tenders, while a dominant feature of the soundscape at close range, are less influential than the natural and biological sources typical of the region, and can be said to have a localised impact. When the MODU is 15.5 km away from Station J2 during Deployment 2, the mean daily SEL is less at Station J2 then at both other stations, indicating that at this range it doesn't define the soundscape when its contribution is considered over a six-month time period.

The seismic survey detected from 4–14 July 2015 was only a minor contributor to the soundscape, due to the low levels of the received pulses – the maximum per-pulse SEL was 126.0 dB re 1 µPa²·s, and the intermittent nature of the detections. The survey occurred to the north of the Barossa field, however received levels were consistently higher at Station J1 than Station J3 (the median per-pulse average SEL was 4.4 dB higher), and no pulses were detected at Station J2.

Table 22. Deployment 1, mean daily vessel detections, median 1 min SPLs sound levels and average daily SEL, Stations J1, J2, and J3. SPL units: dB re 1 µPa, SEL units: dB re 1 µPa²·s

Stn	10 Jul–1 Sep 2014			1 Sep–10 Oct 2014			10 Oct 2014–1 Jan 2015			1 Jan–15 Jul 2015		
	Mean daily vessel detect-ions	1-min SPL L_{50}	Mean SEL	Mean daily vessel detect-ions	1-min SPL L_{50}	Mean SEL	Mean daily vessel detect-ions	1-min SPL L_{50}	Mean SEL	Mean daily vessel detect-ions	1-min SPL L_{50}	Mean SEL
J1	0.1	97.3	146.9	0.1	93.7	146.3	0.2	93.6	145.3	0.1	106.4	154.6
J2	0.1	97.5	150	0.3	95.6	151.1	2.8	116.9	168.7	0.8	118.7	170.2
J3	0.2	96.6	147.8	0.3	88.1	144.8	0.3	89.9	151.9	0.1	98.1	151.7

Table 23. Mean daily vessel detections, median 1 min SPLs sound levels and average daily SEL, Stations J1, J2, and J3, both deployments SPL units: dB re 1 µPa, SEL units: dB re 1 µPa²·s

Stn	Deployment 1			Deployment 2		
	Mean daily vessel detect-ions	1-min SPL L_{50}	Mean SEL	Mean daily vessel detect-ions	1-min SPL L_{50}	Mean SEL
J1	0.1	95.2	150.6	0.4	97.7	160.6
J2	1.4	98.3	152.6	0.7	100.9	157.4
J3	0.3	89.8	147.7	0.3	98.2	158.2

5. Conclusion

The goals of this study were to characterise the contributions to the marine soundscape from natural sources, including sounds generated by tides and events, biological sources (including fish, whales (mysticetes and odontocetes) and crustaceans), and anthropogenic sources, including vessel traffic and the MODU's drilling operations.

Marine mammals were detected acoustically in the Barossa area during the entire deployment period. Pygmy blue, Omura's and Bryde's whales were detected, with detections commonly occurring during the months of May – August, while no detections occurred between 1 November and 23 December. The pygmy blue whale detections are over 400 km farther east than the currently estimated north-bound migration corridor of pygmy blue whales, and their detection is a significant regional scientific contribution.

Omura's whales were detected consistently from April to September inclusive, with a peak in June and July. Based on the year of recordings, the whales seemed to enter the region in a south-west to north-east direction, then maintain a higher presence within the Barossa field area (than compared to the Evans Shoal or Caldita field areas) for the autumn and winter months. They appeared to leave the region in a north-east to south-west direction, reversing their entry path, leaving the area by the start of November.

Pygmy blue whales were detected during their northward migration once in August 2014, over a few consecutive days in late May-early June 2015, on the 16 and 30 June, and 1 July 2015. No detections were logged from the south-bound migration, suggesting a different migration path. The highest calling rates of the three monitoring station occurred at the Barossa field.

Bryde's whales, distinguished from the Omura's whales through variations in the spatial and temporal occurrence of vocalisations, were present in the region from January to October. They appear to move into the area in a south to north direction during summer and autumn, then utilise the region with a preference for the shallower sections (Evans shoal and Caldita field areas) over the Barossa field region. They then leave the area in a north – south direction, with the last detections in early October.

Detections of odontocetes were abundant, equally distributed across the deployment period at Stations J2 and J3 and primarily occurred at night. The distribution of click detections at Station J1 during Deployment 1 and part of Deployment 2 was influenced by a large number of false positives due to the presence of crustaceans such as snapping shrimp. Based on manually verified click and whistle detections compared to automated detections of whistles, odontocetes at Station J1 were observed at a similar frequency to that at J2 and J3: i.e., present throughout the recording period and primarily at night. The presence of potentially unknown beaked whales is a significant scientific finding, however their rare presence, four days over the monitoring program, suggests they are not resident in the region. Unknown beaked whale species were detected on four days over the entire program at Stations J2 (Barossa field) and J3 (Caldita field).

Fish chorused at dawn and dusk over the entire deployment period at all three stations. Their chorusing varied in intensity over the deployment period, but was consistent in diel pattern.

The ambient sound levels indicate a region with low anthropogenic sound presence. A mean SPL of 95.7 dB re 1 µPa (s=2.6) was calculated from data collected at Stations J1 and J3 (at greater distance from the MODU operations), while a mean SPL of 103.55 dB re 1 µPa (s=2.65) was calculated from data collected at Station J2 closer to the operations. Weather was a significant contributor to the total received sound levels at all stations. Anthropogenic sound sources were only occasionally detected in the data, with the exception of sounds associated with the MODU. The ambient sound data identified minor diel variations in sound levels due to fish chorusing events. Diel variations in ambient sound data were primarily affected by weather events, which at times produced a noticeable diel variation in sound levels, with levels increasing during the day, and decreasing at night.

Based on the data collected, it is concluded that the typical soundscape in the Barossa area is dominated by (geophonic) naturally occurring sources such as wind and waves, with some contributions from biological sources (primarily fish and Omura's whales). There was a low presence of sound-producing anthropogenic activity, with the majority of it related to the exploration drilling program in the Barossa field. Given the short timeline of the activity, this increase in sound levels was also short term. The area appeared to be used consistently by Omura's and Bryde's whales from mid-autumn through mid-spring, and odontocetes throughout the year. The area is along the edge of the broader migration pathway for pygmy blue whales in winter, as they move through it as part of their broader northward migration. Fish chorusing activity changes with the seasons, and is most pronounced closer to Evans Shoal (Station J1), thereby suggesting that this area has a higher fish abundance.

Acknowledgements

The authors would like the acknowledge the assistance of the JASCO editors Katherine Williams and Karen Hiltz, the project manager and party chief Chris Teasdale from Jacobs, and the Gun Marine vessel crew. Reviews from Jacobs and ConocoPhillips were appreciated.

Glossary

µPa
micropascal, SI unit for f pressure and stress equal to 10^{-6} pascals

1/3-octave-band
Non-overlapping passbands that are one-third of an octave wide (where an octave is a doubling of frequency). Three adjacent 1/3-octave-bands make up one octave. One-third-octave-bands become wider with increasing frequency. See also octave.

90%-energy time window
The time interval over which the cumulative energy rises from 5% to 95% of the total pulse energy. This interval contains 90% of the total pulse energy. Symbol: T_{90}.

90% sound pressure level (SPL(T_{90}))
The root-mean-square sound pressure levels calculated over the 90%-energy time window of a pulse. Used only for pulsed sounds.

ambient noise
All-encompassing sound at a given place, usually a composite of sound from many sources near and far (ANSI S1.1-1994 R2004), e.g., shipping vessels, seismic activity, precipitation, sea ice movement, wave action, and biological activity.

background noise
Total of all sources of interference in a system used for the production, detection, measurement, or recording of a signal, independent of the presence of the signal (ANSI S1.1-1994 R2004). Ambient noise detected, measured, or recorded with a signal is part of the background noise.

cetacean
Any animal in the order Cetacea. These are aquatic, mostly marine mammals and include whales, dolphins, and porpoises.

continuous sound
A sound whose sound pressure level remains above ambient sound during the observation period (ANSI/ASA S1.13-2005 R2010). A sound that gradually varies in intensity with time, for example, sound from a marine vessel.

decibel (dB)
One-tenth of a bel. Unit of level when the base of the logarithm is the tenth root of ten, and the quantities concerned are proportional to power (ANSI S1.1-1994 R2004).

duty cycle
The time when sound is periodically recorded by an acoustic recording system.

F score
Metric used to measure the performance of an automated detector/classifier. The F score is computed as the harmonic mean of precision and recall.

false negatives (FN)
A signal of interest missed (i.e., not detected) by an automated detector/classifier.

false positives (FP)
A noise classified as a signal of interest by an automated detector/classifier (i.e., a false alarm).

FFT
Fast Fourier Transform.

FM
Frequency Modulated.

frequency
The rate of oscillation of a periodic function measured in cycles-per-unit-time. The reciprocal of the period. Unit: hertz (Hz). Symbol: *f*. 1 Hz is equal to 1 cycle per second.

ksps
kilosamples per second

hertz (Hz)
A unit of frequency defined as one cycle per second.

hydrophone
An underwater sound pressure transducer. A passive electronic device for recording or listening to underwater sound.

median
The 50th percentile of a statistical distribution.

mysticete
Mysticeti, a suborder of cetaceans, use their baleen plates, rather than teeth, to filter food from water. They are not known to echolocate, but use sound for communication. Members of this group include rorquals (Balaenopteridae), right whales (Balaenidae), and the gray whale (*Eschrichtius robustus*).

octave
The interval between a sound and another sound with double or half the frequency. For example, one octave above 200 Hz is 400 Hz, and one octave below 200 Hz is 100 Hz.

odontocete
The presence of teeth, rather than baleen, characterizes these whales. Members of the Odontoceti are a suborder of cetaceans, a group comprised of whales, dolphins, and porpoises. The toothed whales' skulls are mostly asymmetric, an adaptation for their echolocation. This group includes sperm whales, killer whales, belugas, narwhals, dolphins, and porpoises.

peak sound pressure level (PK)
The maximum instantaneous sound pressure level, in a stated frequency band, within a stated period. Also called zero-to-peak sound pressure level. Unit: decibel (dB).

peak-to-peak sound pressure level (peak-to-peak)
The difference between the maximum and minimum instantaneous sound pressure levels. Unit: decibel (dB).

percentile level, exceedance
The sound level exceeded *n*% of the time during a measurement.

point source
A source that radiates sound as if from a single point (ANSI S1.1-1994 R2004).

power spectrum density
The acoustic signal power per unit frequency as measured at a single frequency. Unit: $\mu Pa^2/Hz$, or $\mu Pa^2 \cdot s$.

power spectrum density level
The decibel level ($10\log_{10}$) of the power spectrum density, usually presented in 1 Hz bins. Unit: dB re 1 $\mu Pa^2/Hz$.

precision (P)
Metric used to measure the performance of a detector. The precision measures the exactness of an automated detector/classifier and is calculated based on the numbers of true positives (TP) and false positives (FP). Precision is usually used in conjunction with Recall (R).

pressure, acoustic
The deviation from the ambient hydrostatic pressure caused by a sound wave. Also called overpressure. Unit: pascal (Pa). Symbol: *p*.

recall (R)
Metric used to measure the performance of a detector. The recall measures the completeness of a detector and is calculated based on the number of true positives (TP), and false negatives (FN). Recall is usually used in conjunction with Precision (P).

received level
The sound level measured at a receiver.

rms
root-mean-square.

rms sound pressure level (SPL)
The root-mean-square average of the instantaneous sound pressure as measured over some specified time interval. For continuous sound, the time interval is one second. See also sound pressure level (SPL) and 90% SPL.

sound
A time-varying pressure disturbance generated by mechanical vibration waves travelling through a fluid medium such as air or water.

sound exposure
Time integral of squared, instantaneous frequency-weighted sound pressure over a stated time interval or event. Unit: pascal-squared second ($Pa^2 \cdot s$) (ANSI S1.1-1994 R2004).

sound exposure level (SEL)
A measure related to the sound energy in one or more pulses. Unit: dB re 1 $\mu Pa^2 \cdot s$.

sound intensity
Sound energy flowing through a unit area perpendicular to the direction of propagation per unit time.

sound pressure level (SPL)
The decibel ratio of the time-mean-square sound pressure, in a stated frequency band, to the square of the reference sound pressure (ANSI S1.1-1994 R2004).

For sound in water, the reference sound pressure is one micropascal (p_0 = 1 µPa) and the unit for SPL is dB re 1 µPa:

$$\text{SPL} = 10\log_{10}\left(p^2/p_0^2\right) = 20\log_{10}\left(p/p_0\right)$$

Unless otherwise stated, SPL refers to the root-mean-square sound pressure level (SPL).

sound speed profile
The speed of sound in the water column as a function of depth below the water surface.

source level (SL)
The sound pressure level measured 1 meter from a theoretical point source that radiates the same total sound power as the actual source. Unit: dB re 1 µPa @ 1 m.

spectrogram
A visual representation of acoustic amplitude versus time and frequency.

spectrum
An acoustic signal represented in terms of its power (or energy) distribution versus frequency.

true positives (TP)
A signal of interest correctly classified as such by an automated detector/classifier.

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Appendix F.

AIMS Regional Shoals and Shelf Assessment (Heyward et al. 2017)

Includes Addendum:
Regional Biodiversity Patterns and Connectivity Amongst the Submerged Shoals and Banks in Relation to the Area of Influence from a Hypothetical Uncontrolled Release

BARROSSA ENVIRONMENTAL BASELINE STUDY 2015
AIMS FINAL REPORT

Regional Shoals & Shelf Assessment 2015

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PRODUCED FOR
ConocoPhillips Australia Pty Ltd
Contract No. 251834.0-MSA-COMP-2.0

Australian Government | Australian Institute of Marine Science

PERTH
April 2017
Rev 1

BAROSSA ENVIRONMENTAL BASELINE STUDY 2015
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This report should be cited as: A Heyward *et al.* 2017; Barossa Environmental Baseline Study, Regional Shoals and Shelf Assessment 2015 Final Report. A report for ConocoPhillips Australia Exploration Pty Ltd by the Australian Institute of Marine Science, Perth 2017. 143pp

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Revision History
Issue Rev 1 Apr 2017
Issue Rev 0 Oct 2016
Draft Rev B Sept 2016
Draft Rev A June 2016

Acknowledgments: This survey relied on the professionalism and support of RV Solander's Master & crew. We gratefully acknowledge Anne Kennedy for exemplary use of the multibeam system and Shaun Hahn for maintenance of the towed video system. Olwyn Hunt provided administrative support for the field program and report production.

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Summary

This report presents final results from seabed biodiversity surveys of benthos and associated fish, by the Australian Institute of Marine Science (AIMS) in collaboration with ConocoPhillips, that were undertaken as part of the Barossa marine studies program. The surveys, conducted in October 2015, sampled five principle locations of regional interest, consisting of Evans, Tassie and Blackwood Shoals, the closest shoals to the Barossa Field, as well as two mid-shelf seabed locations adjacent to Goodrich Bank and Cape Helvetius, relevant to a potential gas export pipeline route.

The submerged shoals featured habitats consistent with other outer shelf shoals in the North and North-west marine regions, including the Margaret Harries Banks, the Sahul Banks and the Karmt Shoals. Analysis of the full benthic data set available from Evans, Tassie and Blackwood Shoals, including data from 9,961 high resolution still images of the seabed, provided a detailed, quantitative characterisation of the habitats encountered. The major elements of shoal plateau regions were light-dependent algal and coral assemblages, interspersed with sand and rubble areas which varied in extent between shoals. Average coral cover was similar between Evans and Tassie Shoals at around 9% of the total plateau area surveyed, but higher at Blackwood Shoal, where coral habitat was a consistent feature across the very small shoal plateau, with a mean of 25%. The three shoals closest to the Barossa Field support diverse tropical reef biota, with many species in common, but with each shoal somewhat different in character. All three appeared to be in healthy condition at the time of the survey.

The fish fauna on Evans and Tassie Shoals comprises a mix of shelf-based species normally found on Indo-Pacific reefs and some “oceanic” species. Economically important fishes, such as red emperor and gold-band snapper were encountered in deeper waters, but not in the large numbers we expected from such habitats remote from Australian ports. Shovelnose rays and hammerhead sharks, known to be prized in the shark-fin trade, were also relatively rare. In addition, the behaviour of large-bodied cods, snappers and emperors seemed shy in relation to approaching the bait, based on our experience in the North-West Shelf (NWS) and Great Barrier Reef. These observations are consistent with a fish community exposed to fishing pressure.

Species richness in the fish community was influenced most by the calcareous reef composition of the substratum, and the percentage cover of hard coral on this substratum type. Depths shallower than approximately 30 m had higher, steeply rising, richness, and bare seabeds had lower than average richness. Fish abundance was influenced most by the presence of any epibenthos on the seafloor (not just coral) and by calcareous reef composition of the substratum. Total fish abundance was above average for Stereo Baited Remote Underwater Videos (SBRUVS) where there was more than 20% of the seabed in the field of view covered by any category of epibenthos. Depth had a lesser influence, but fish abundance was below average in deeper waters and above average in shallows under 30 m.

It was clear that most of the “pattern” in diversity and abundance in the fish dataset was concentrated in the one-third of the SBRUVS set in shallow shoal waters where coral cover was highest. However, species accumulation curves for the five assemblages were far short of an

asymptote – implying that more SBRUVS sets in all habitats would produce more species. Where repeat surveys have been conducted on other shoals by AIMS, additional species have been observed, with total recorded fish species incrementing around 10% with each additional survey. Tassie Shoal is much smaller than Evans Shoal, yet they both supported only three distinct fish assemblages in the analysis. This is perhaps a function of the number of samples taken, with additional sampling possibly able to resolve finer scale differences in assemblages, but it supports further the notion that diversity increases sharply with coral cover and with decreasing depth. Tassie Shoal has outstanding fish diversity and abundance in comparison with shoals and reef bases at similar depths around Australia. It has the highest median species richness yet recorded by AIMS using the same sampling techniques. There were three new species records for Australia for fish known to occur in Indonesia.

The mid-shelf areas adjacent to Goodrich Bank and Cape Helvetius were turbid, typically had large areas of bare seabed, but supported patchy filter feeders habitats associated with limited areas of consolidated substrate. Sponges tended to be the dominant fauna, consistent with other studies in turbid shelf areas in this region, with gorgonian soft corals generally making lesser contributions to the mixed filter feeder communities. The sediment data collected during this project and a review of sediment data for the region suggest a complex spatial pattern of reworked old terrigenous sediments, likely related to the drowned coastal features across this region, and in situ production of carbonates, which may increase in importance in shallow waters as well as with distance from the coast.

Regional context

The shoals biodiversity and habitat data were assessed in the context of AIMS regional database covering 20 shoals located from west to east across the North and North-west marine regions.

The patterns of benthic habitat at Goodrich Bank and Cape Helvetius were consistent with the regional community analysis and regional spatial model where the majority of the area modelled consisted of predominantly bare areas, with insufficient biota to allow a discrete category to be modelled as a habitat class (Model Category "None" -69.24%), interspersed with areas where infauna, epibenthic fauna (Burrows/ Crinoids; 22.91%) and to a lesser extent filter feeding sessile organisms like sponges and seafans (6.44%) were the dominant contributors to benthic communities. Coral reef communities were associated with the shallower reefs, shoals and banks particularly as they moved away from the turbid coastal fringe. However these habitats made up a small proportion of the model spatial extent. Caution should be used interpreting the regional model beyond the extent of the surveyed data. There are large areas where there is no validation information available so estimates of model accuracy and error are not possible to calculate without additional field data. It should also be noted with caution that while over the entire regional model performed well for most habitat categories, the "None" category had the poorest performance most frequently under predicting filter feeder and Halimedia communities which by their nature can be discrete, stochastic and challenging to model.

The benthic habitats at all three shoals were consistent with other outer-shelf shoals. Both Evans and Tassie Shoals were similar in terms of coral cover and mid-ranking in a regional context, having similar coral community composition on their shallow plateaus but with Evans featuring a greater abundance of foliaceous hard coral below 30 m depths. In contrast, Blackwood Shoal, although the smallest of the three shoals studied, featured some of the highest levels of coral yet observed. Coral cover on Blackwood was on par with outer shelf shoals in the central area of the Oceanic Shoals bioregion, such as Kepah and Krill, situated 370 km west near the western lateral boundary of the Joint Petroleum Development Area (JPDA).

Cluster analysis of quantitative benthic data indicated similarities among shoals close together for some habitat attributes, but also found that some benthic community components, for example hard coral assemblages, could be shared by shoals at opposite ends of the bioregion. The quantitative measures of major habitat types and fine scale detail of coral abundance and diversity point to strong regional similarities among shoals. The available information indicates that each shoal has its own benthic community character, but that many coral species occur on shoals across the region. The abundance of particular coral species varied with depth and location. A dense band of foliaceous coral, approximately 300 m wide in places, was a notable feature in 40-60 m depths at Evans Shoal, but has also been observed elsewhere, including a small amount on Tassie Shoal at shallower depth and on reefs further west. The presence of an isolated very large colony of the coral *Pavona clavus* on Evans Shoal was unusual in terms of its size, but a smaller example was present on Tassie Shoal and another large example was previously observed by AIMS at Seringapatam Reef. The fish abundance and diversity at Evans and Tassie Shoals was most similar to shoals in the Margaret Harries Banks group, 100 km away, and other shoals >600 km to the southwest. Given the strong ocean currents throughout this bioregion, including the Indonesian Throughflow, connectivity between shoal features may be shaping the broad similarity in community composition. The status of the biota on each shoal may reflect varying connectivity, to some degree, but also varying disturbance event histories, such as cyclone or storm related damage and coral bleaching.

Conclusion

This report provides the final results from the October 2015 study and establishes baseline information relevant to the Barossa Field. It provides a general characterisation of habitat distributions and dominant biota on shoals and mid-shelf areas surveyed, within the context of similar studies throughout the region. The mid-shelf areas display limited amounts of macro-epibenthic life, restricted in distribution to locations with abrupt changes in bathymetry or the availability of suitable consolidated substrate to support the dominant filter feeders such as sponges and soft corals. This patchy distribution is consistent with other surveys in the region and is likely to be a widespread, repeated pattern linked to the underlying geology and complex bathymetry that are a legacy of the drowned coastal shelf area.

The submerged shoals closest to the Barossa Field were further offshore in much clearer water. While filter feeding communities exist there in the deeper zones on the sides of the shoals, their most striking attribute is a rich biodiversity more similar to coral reefs, driven by light in the upper regions and across the plateaux. This is also consistent with many other shoals in the same bioregion, although each individual shoal has its own character.

While the survey recorded the major habitat types and a large portion of the species present, it is clear that the biodiversity will continue to be further defined as part of additional regional survey efforts over time. Future repeats of this survey would likely produce a very similar broad characterisation of the seabed biodiversity, although change in abundance of dominant species and distribution of habitats is possible, with variability over time likely to be a natural attribute of these ecosystems. These systems, particularly the shallower habitats, may also be subject to larger scale changes from acute, but less predictable, natural disturbances such as a severe storms or elevated seawater temperature anomalies.

Background

ConocoPhillips Australia Exploration Pty Ltd (ConocoPhillips), as proponent on behalf of current and future joint venturers, are proposing to develop the gas and condensate reserves in the Barossa field and surrounds located approximately 300 kilometers (km) north of Darwin, Northern Territory (NT).

The retention lease permits NT/RL5 (Barossa) and NT/RL6 (Caldita) are located in the Bonaparte Basin, in Commonwealth waters offshore of the Northern Territory (NT). If results from the appraisal campaign support the business case for commercialisation of the Caldita-Barossa field, ConocoPhillips will evaluate a number of conceptual development options.

To facilitate the environmental approvals process for any development concept, a robust understanding of the existing state of the key environmental values of the Barossa field and surrounds will be necessary. This understanding will be gained from a series of studies and surveys to assess and monitor the baseline state of environmental factors such as water quality, sediment quality, underwater noise, metocean conditions and benthic habitats within the Barossa field and across a broader geographical area. Phased studies assessing these factors commenced in June 2014.

As part of that marine studies program, this study surveyed the seabed and associated biota at a number of submerged shoals near the edge of the continental shelf, with Evans Shoal 60 km to the west of the Barossa field, Tassie Shoal 70km to the southwest and at more distant, bathymetrically complex areas of the mid-continental shelf, through which a potential pipeline would pass.

Based on other shoals further west in the same bioregion, the shallow shelf-edge shoals closest to the Barossa field have the potential to support diverse tropical reef life, with significant benthic primary producer habitat, including reef building corals, macroalgae and seagrass. Following shoal assessments related to the Montara uncontrolled release the submerged shoals of this bioregion have been regarded as sensitive, key environment features (see Heyward et al. 2011). Shoreward from the shoals, the much more extensive seabed of the mid-continental shelf is structurally complex, with numerous ridges, shoals, valleys and plains. A number of studies conducted jointly in this more turbid region by Geoscience Australia and AIMS (e.g. Anderson et al, 2011; Nichol et al, 2013) have shown that the complex mid-shelf region supports patchily distributed filter feeders more than primary producer habitats seen on the clearer water shoal areas.

Submerged shoals assessments by AIMS began using a variety of data sources in the 1990s (Heyward et al, 1997). A more consistent methodology and quantitative analysis of the shoal benthic communities has been implemented by AIMS since 2009, beginning with survey of nine shoals at the western end of the bioregion following the Montara uncontrolled release (Heyward et al, 2012). Subsequently, additional shoals across the bioregion have been assessed using consistent methods, providing comparable information spanning the region.

1 Methods

The field survey methods are described in full in the December 2015 Interim Report (Heyward et al, 2015), with description of key aspects repeated below.

In support of the marine studies program, a research cruise was undertaken by AIMS during September-October, 2015. Areas identified for assessment included two mid-shelf regions and two submerged shoals. Multibeam and towed video were used at all locations to map the seabed and classify seabed habitats. Replicate sediment samples (collected using a Smith McIntyre Grab) and Conductivity Temperature Depth (CTD) casts were taken within each mid-shelf area to provide additional environmental data. At the shoals, sampling also included the fish communities, which was undertaken using stereo Baited Remote Underwater Video Stations (SBRUVS).

The mid-shelf locations were separate areas along a potential cross-shelf pipeline route from the Barossa field to the existing ConocoPhillips operated Bayu-Undan to Darwin pipeline. The southernmost of these was to the west of Cape Helvetius, at the southwest corner of Bathurst Island. The second area was midway to the shelf break, adjacent to and off the western side of Goodrich Bank. Evans and Tassie Shoals, lying further northwest on the outer shelf, were selected for investigation as larger submerged shoals, closest to the Barossa field. An initial towed video inspection was also undertaken at the much smaller Blackwood Shoal, lying a few kilometres to the west of Evans Shoal. In total the survey sampled in five principle locations, consisting of Evans, Tassie and Blackwood Shoals, open shelf adjacent to Goodrich Bank and open shelf adjacent to Cape Helvetius. The location of study areas and the vessel track for the voyage are shown in Figure 1.

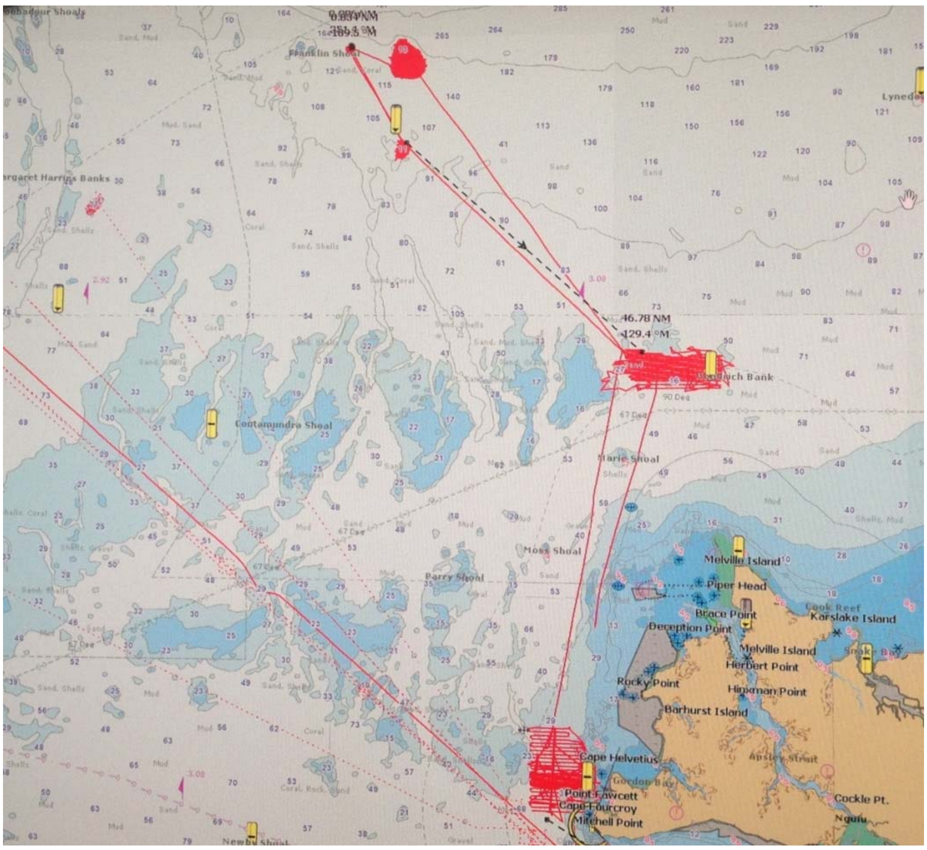


Figure 1: Location of shoal and shelf study sites. Track of the RV Solander during AIMS cruise 6251.

1.1 Field sampling – Benthic habitats

1.1.1 Sampling design

The location of seabed video transects was based on the textural analysis of existing LIDAR (Royal Australian Navy), single beam bathymetry (Geosciences Australia) and side-scan datasets (ConocoPhillips) using Generalized Random-Tessellation Stratified (GRTS) Survey Design (Stevens and Olsen 2004). This provided a habitat-stratified, spatially weighted sampling design covering the area of interest. Maps showing sampling completed on the three shoals are in Figures 15, 21 and 27. Maps showing sampling completed on the two mid-shelf areas are in Figures 7 and 9. Details of all sampling events are provided in Appendix 1.

1.1.2 Multibeam

The bathymetric and terrain surveys of the five study areas were conducted in September 2015 using a shipborn Reason 7125v2 multibeam with a POSMV-V5 motion reference unit. Setup of the multibeam echosounder, realtime field data and preparation of derived datasets are described in Heyward et al (2015).

For areas bisecting the planned pipeline route, multibeam was captured at 500m spacing and interpolated to a 50m pixel. For Tassie, Evans and Blackwood shoals, multibeam was captured allowing for a 20% overlap in beam, resulting in full coverage across the three shoals. The data was post processed in CARIS HIPS/SIPS to a two metre pixel size

1.1.3 Towed video

The AIMS towed video system comprises a towed camera platform sending a live camera feed to a vessel-based, realtime image classification system (see Heyward et al. 2011). The towed platform supports a forward-facing video camera with lights, together with a downward-facing high resolution still camera and strobe system programmed to take sequential still images at fixed time intervals of 10 seconds. The towed platform was deployed over the stern of the vessel, maintained within a metre of the seabed and towed at 1-2 knots (1.5 nominal) until a minimum distance of 1.5 km was covered in a continuous line transect. On the vessel, a computer-based towed video program managed collation of position, depth, and operator-derived habitat classification data, which was captured in real time as an operator interpreted the live video feed, and then archived for subsequent spatial analysis. At the completion of a transect, the tow platform was retrieved to the vessel deck, still camera images downloaded and the camera systems serviced as required while the vessel steamed to the next transect station.

1.1.4 Still photo analysis

The downward-looking still images were geo-referenced during post-processing then analysed using a point-intercept approach. The number of images collected and used in the analysis was proportional to the size of the shoal and total length of towed video transect conducted. After sorting and discarding poor quality photos, a total of 9,921 images from the three shoals were analysed for this report (Evans = 7,673; Tassie = 1,963; Blackwood = 285; Table 1). Still images from Cape Helvetius and Goodrich Bank towed video transects were not scored.

Information on benthic biota at each shoal was extracted from images using a point intercept approach with the AIMS Reefmon software (Jonker et al., 2008). All images were analysed using the Reefmon database system, with five overlaid points classified per photo and data logged against transect, depth and position. The benthos under each superimposed point was identified to the highest possible taxonomic classification and/or morphotype. Categories of benthos include: hard corals, soft corals, algae, seagrass, sponges, abiotic and other animals (Table 2). Hard corals were potentially identified to species but more typically to genus or genus morphotype, e.g. *Acropora* tabulate. Reefmon has added classification categories appropriate to the region or habitat, e.g. sponge morphotypes categories were expanded to include the common sponge morphologies encountered in deeper water tropical shoals i.e. hollow massive, simple massive, erect branching, simple erect, erect laminar and clathrate. Benthos was classified as seagrass only when the point fell on a seagrass leaf, rhizome or stalk. Crustose coralline algae (CCA) was regularly encountered during the classification process. When CCA was observed on rocks, consolidated pavement or reef-type substrate it was classified as CCA. However when CCA occurred on free rubble and small stones, with a nodule appearance, it was classified as Rhodoliths.

Table 1. Summary of the number of images used to quantify benthic community composition at Evans, Tassie and Blackwood Shoals across the three depth ranges.

Depth Range	Evans	Tassie	Blackwood	
<20m	1134	898	88	
20-40m	5105	330	166	
>40m	1434	735	31	
Totals	7673	1963	285	9921

Table 2. Benthic broad-scale and fine-scale image classification categories used for analysis of Evans, Tassie and Blackwood Shoals still images.

Broad-scale category	Fine-scale category	Benthic groups included
Algae	Macroalgae	Brown, green and red algae; any other algae described as macroalgae. Genera include: *Lobophora, Peyssonnelia, Dichotomaria, Caulerpa, Dictyota*
	Halimeda	Mostly *Halimeda* spp., small amounts of other unidentified articulated calcareous algae
	Rhodolith	Rhodoliths
	Padina	*Padina* spp.
Consolidated Reef		Consolidated substrate, reefal substrate, turf and crustose coralline algae (algal turf community), filamentous algae on consolidated substrate
Hard Coral	*Acropora* – branching, digitate, corymbose and table	Branching, digitate, corymbose and table forms of coral from the genera *Acropora*
	Branching	All non-*Acropora* branching scleractinian corals. Genera include: *Duncanopsammia* (Dendrophylliidae); *Hydnophora* (Merulinidae); *Seriatopora* (Pocilloporidae); *Porites* (Poritidae)
	Encrusting	Encrusting growth forms from all scleractinian corals. Genera include : *Montipora, Astreopora, Isopora* (Acroporidae); *Pavona* (Agariciidae); *Turbinaria* (Dendrophylliidae),

Broad-scale category	Fine-scale category	Benthic groups included
		Cyphastrea, Goniastrea, Echinopora, Favia, Platygyra, Favites (Faviidae); *Hydnophora, Merulina* (Merulinidae); *Galaxea* (Oculinidae); *Mycedium, Echinophyllia, Oxypora* (Pectiniidae); *Porites* (Poritidae)
	Foliose	Foliose growth forms from all scleractinian corals. Genera include: *Montipora* (Acroporidae); *Pachyseris, Leptoseris, Pavona* (Agaridiidae); *Turbinaria* (Dendrophylliidae); *Echinopora* (Faviidae); *Podabacia* (Fungiidae); *Merulina* (Merulinidae); *Echinophyllia, Mycedium, Oxypora, Pectinia* (Pectiniidae); *Porites* (Poritidae)
	Massive	Massive growth forms from all scleractinian corals. Genera include: *Astreopora* (Acroporidae); *Pavona* (Agariciidae); *Euphyllia, Physogyra, Plerogyra* (Euphyllidae); *Cyphastrea, Diploastrea, Favia, Favites, Goniastrea, Leptoria, Oulophyllia, Platygyra* (Faviidae); *Lobophyllia, Symphyllia (Mussidae);* *Alveopora, Goniopora, Porites* (Poritidae)
	Solitary/ free-living	All solitary and free-living corals including the genera: *Heteropsammia* (Dendrophylliidae); *Ctenactis, Diaseris, Fungia, Halomitra, Herpolitha, Polyphyllia, Sandalolitha, Zoopilus* (Fungiidae); *Cynarina* (Mussidae)
	Submassive/ columnar	Submassive and columnar growth forms from all scleractinian corals. Genera include: *Acropora, Isopora, Montipora* (Acroporidae); *Pavona* (Agariciidae); *Caulastrea, Favites* (Faviidae); *Hydnophora* (Merulinidae); *Galaxea* (Oculinidae); *Pocillopora, Stylophora* (Pocilloporidae); *Alveopora, Porites* (Poritidae); *Psammocora* (Siderastreidae)
Other	Ascidian	Ascidians
	Other organisms	All other non-ascidian animals, including: Anenomes, annelids, bryozoans, corallimorpharians, crinoids, gastropods, holothurians, hydroids, *Millepora* spp., seastars, *Tridacna* spp., urchins, zoanthids
Sand/silt		Sand and silt
Seagrass	Elliptical leaf	Seagrass with elliptical leaves from the genera *Halophila*

Broad-scale category	Fine-scale category	Benthic groups included
		(Hydrocharitaceae)
Soft Coral	Gorgonian	Members of the Gorgoniidae and Ellisellidae family including the genera *Rumphella* and *Junceella*
	Soft coral	All other non-gorgonian soft corals. Genera include: *Lobophytum, Sarcophyton, Sinlularia* (Alcyoniidae); *Erythropodium* (Anthothelidae); *Briareum* (Briareidae); *Clavularia* (Clavulariinae); *Heliopora* (Helioporidae); *Isis* (Isidae); *Capnella* (Nephtheidae); (Pennatulacea); *Plumarella* (Primnoidea); *Tubipora* (Tubiporidae); *Asterospicularia, Xenia* (Xeniidae)
Sponge	Sponge – encrusting	Encrusting growth forms
	Sponge – erect/ branching	Erect growth forms. Includes branching, fallacious, stalked, erect laminar and erect simple types
	Sponge – massive	All massive-like sponges, including both simple and hollow massive, barrel or ridge like, cup and vase shaped sponges
Unconsolidated substrate		Rubble, shells/skeletal rubble, turf algae on *Halimeda* spp., turf algae on sand

1.2 Fish Communities

Non-destructive, "video-fishing" techniques were used to survey fish communities at two shoals, Evans and Tassie.

Remotely operated, video-based monitoring techniques are emerging rapidly in the field of marine ecology. Video image quality has improved markedly whilst camera size and cost has reduced rapidly. Baited and unbaited video units are now widely used to identify, count and measure fish (see Cappo et al. 2007b, Mallet & Pelletier 2014 for reviews). A fleet of Baited Remote Underwater Video Stations (BRUVS™) was developed at AIMS to identify fish-habitat associations (eg Cappo et al. 2011, Fitzpatrick et al. 2012), measure the effects of marine protected areas (eg Denny et al. 2004, Cappo et al. 2012, Malcolm et al. 2007, McLean et al. 2010) and explore faunal boundaries at broad scales (eg Cappo et al. 2007a, Colton & Swearer 2012, Harvey et al. 2013). The BRUVS technique has proven useful to survey sharks (Espinoza et al. 2014) and sea snakes (Udyawer et al. 2013) as well as fish.

The Stereo Baited Remote Underwater Video Stations (SBRUVS) used in this study comprised a galvanised steel frame onto which two camera housings, an arm bearing a flashing diode and bait canister, ballast weights, ropes and floats were attached. A flexible bait arm held a plastic mesh bait bag containing 1 kg of crushed pilchards (*Sardinops sagax neopilchardus*) at a distance of approximately 1.5 m in front of the camera lens. SBRUVS frames were ballasted according to the prevailing sea-state and current conditions to ensure stability on the seabed. An 8mm diameter polypropylene rope with surface floats attached enabled the SBRUVS to be deployed and later retrieved from the surface with a pot-hauler (Figure 2). The scope of the rope length was selected to be approximately twice the water depth.

Each camera housing contained a Sony HDR-CX110E 'handicam' video camera fitted with a x0.6 wide conversion lens. The cameras were set to record at full high definition resolution (1920 x 1080 pixels), with focus set to infinity in manual focus mode. Camera footage was recorded onto a 16GB SD card, with recording initiated manually immediately prior to deployment. At the end of each deployment (60 minutes duration at the seabed) footage was downloaded from the cameras via Picture Motion Browser (Sony, 2010) software and stored on portable hard drives in .m2ts file format. The footage was converted to .avi format and is hitherto referred to as a "tape".

The allocation of deployment positions across each shoal was done using a "regular/random" design within the bounds of the 60 m depth contour whilst maintaining a minimum distance of 250 m between each SBRUVS unit. Once the positions were derived, the sequence of deployments, in sets of eight replicate units, was determined by proximity and prevailing sea conditions on the day. A total of 72 SBRUVS deployments were conducted at Evans Shoal, and 23 deployments at Tassie Shoal.

1.2.1 Video Analysis

The left-hand camera in each stereo pair was interrogated using custom software designed by AIMS ("BRUVS2.2.6.mdb) to capture and store the timing of events, reference images and counts of fish in the field of view. Records were made, for each species, of the time of first sighting, stage (adult or juvenile), time of first feeding at the bait, the maximum numbers seen together in progression of the whole tape (MaxN) and updated times at which each MaxN occurred. The use of MaxN has been reviewed by Schobernd et al. (2014) and Willis and Babcock (2000). It is the most widely accepted metric of relative abundance used in baited video studies.

Species identifications were made according to the Australian CAABCodes national standard (Yearsley et al. 1997). As some taxa were indistinguishable from each other on video footage, these were pooled either at the level of taxa, genus, family or order. These pooled taxa, hitherto referred to as species, were signified by the use of 'sp'. The MaxN data were then summed over adults and juveniles for each species. The term 'fish' hitherto refers to any marine vertebrate seen in the field of view, including sharks, rays and sea snakes.

A standardised classification scheme for the seabed in the SBRUVS field of view was developed for shoals of north-western Australia by AIMS for a previous study of the effects of the Montara uncontrolled release (Heyward et al. 2011). This same scheme was applied here by reviewing all images of the seafloor collected from all 95 SBRUVS deployments from Tassie and Evans shoals, and assigning habitats to one of eight qualitative categories of "bedform" (flat sand or gravel or silt, sand ripples, sand dunes, rubble field, Halimeda bank, low reef/outcrop, high reef/outcrop, or boulder field) with percentage cover (to the nearest 10%) estimated for six categories within these bedforms (mud, sand, gravel, rubble, bedrock and boulder, calcareous reef). In addition, the benthos in the SBRUVS images was assigned to one of six "habitat categories" (open sandy seabed, seagrass bed, macroalgal bed, low-relief rubble field, coral reef, gorgonian and seawhip gardens) with percentage cover (to the nearest 10%) estimated for 12 categories of epibenthos (gorgonian fans, sponges, sea whips, soft corals, hard corals, macroalgae, seagrass, Halimeda, bryozoans and encrusting animals, zoanthids, hydroids and "Bare").

Figure 2: Stereo-BRUVS units ready for deployment, during the process of retrieval, and in action capturing video on the seabed.

1.3 Statistical analysis

1.3.1 Benthic Spatial Models

Local scale

To infer spatial distributions of marine biota and abiotic substrate within each of the five study areas, we characterised environmental relationships in detail using a combination of forward facing towed video footage, downward facing digital stills and multibeam hydroacoustic surveys in conjunction with a statistical modelling approach. Towed video and digital images provide data on benthic diversity and cover on different scales. Secondary (textural) datasets correlated with seafloor properties were developed from the multibeam bathymetry (Table 3) to provide information on environmental characteristics, and give full coverage of the field area.

To model the relationship between physical and biological parameters, we implemented the most recent development in boosted regression methods "xgboost". This method provides very comparable accuracy to boosted regression trees and its computationally efficient making it suitable for spatial prediction of large multibeam datasets. A detailed description of the application of boosted regression method with ecological data is outlined in De'ath at al. (2007) and Elith et al. (2006, 2009, 2011). Boosted regression methods are very commonly used in ecological analysis as they provide accurate and robust predictions with complex data containing non-linear responses and interactions. A detailed description of xgboost method is outlined in Chen and He (2015) and was implemented using the r package xgboost 0.3. (http://xgboost.readthedocs.io/ en/latest/ python/index.html). Model accuracy is based on testing the models against a 20% blind validation dataset (checked and adjusted for spatial autocorrelation with the testing dataset).

Regional model

To infer a regional scale distribution of course benthic categories a habitat model was produced covering both the study area and the broader Bonaparte Basin. The regional habitat model was developed based on the Oceanic Shoals Commonwealth Marine Reserve benthic habitat model produced as part of the Australian National Environmental Science Programme (http://northwestatlas.org/node/1710). Both the Oceanic Shoals Commonwealth Marine Reserve benthic habitat model and the regional habitat model were developed as part of the National Environmental Research Project D1 (as descripted here http://maps.northwestatlas.org/files/montara/html_popups_oceanic_shoals/Spatial_benthic_habitat_model_for_the_Oceanic_Shoals_CMR_6dec16.pdf). The extension of the model included additional benthic habitat data help by AIMS and collected as part of this report which extending beyond the Oceanic Shoals Commonwealth Marine Reserve in some areas see outlined below.

The regional model was at a much coarser resolution than the local scale model and based on Geosciences Australia 250 m bathymetry grid (http://www.ga.gov.au/metadata-gateway/metadata/record/gcat_67703) combined with a regional database of AIMS towed video real time classification (http://www.aims.gov.au/docs/research/monitoring/seabed/video-monitoring.html). As with the local scale models, secondary textural datasets were developed (Table 3) providing environmental characteristics information over the whole of the regional model domain.

Multivariate models expressing the relationship between physical and biological parameters were developed using randomForest classification trees (Breiman et al. 1984, Breiman 2001, Cutler et al.

2007). This method has the same general advantages of boosted regression trees and is also commonly used in ecological analysis. randomForest classification has efficiency advantages for modelling large datasets and can model multiple classes simultaneously (producing a map of maximum likelihood for habitat found in each pixel). The randomForest classification was performed using the Python programing language (Python library scikit-learn 0.18.1 with Python version 3.5 http://scikit-learn.org/stable/). Model accuracy and Kappa statistics were calculated by testing the models against a 33% blind validation dataset (checked and adjusted for spatial autocorrelation with the testing dataset).

Table 3. Datasets derived from multibeam bathymetry that were used as environmental surrogate variables for modelling biota, substrate and fish abundance/richness.

Dataset prefixes	Predictor datasets	Definition
depth	Bathymetry	Elevation relative to the Australian Height Datum (AHD)
asp	Aspect	Azimuthal direction of the steepest slope, calculated on a 3 x 3 pixel area
slp	Slope	First derivative of elevation: Average change in elevation / distance calculated on a 3 x 3 pixel area
prof	Profile curvature	Second derivative of elevation: concavity/convexity parallel to the slope, calculated on a 3 x 3 pixel area
plan	Plan curvature	Second derivative of elevation: concavity/convexity perpendicular to the slope, calculated on a 3 x 3 pixel area
curv	Curvature	Combined index of profile and plan curvature
mean	mean depth[a]	Mean depth local neighbourhood
rng	Local relief (Range) [a,b]	Maximum minus the minimum elevation in a local neighbourhood
std	Std Dev [a,b]	Standard deviation of elevation

[a] Local scale models neighbourhood analysis: run on circles of kernel pixel radius 5, 10, 25, 50 original cell size is 2.5 m
[b] Local neighbourhood analysis: run on circles of kernel pixel radius 3 and 5 with original cell size is 250 m

1.3.2 Benthic composition within and between shoals

All benthic codes from the scored images from Tassie, Evans and Blackwood Shoals were aggregated to broad- and fine-scale taxonomic groupings that were considered robust to observer variation and included pooling of some rare categories to avoid issues with zero inflation.

Data were analysed at the image level and compared among the three shoals, as well as across three depth bands within each shoal (<20 m, 20-40 m, >40 m, Table 2). Bar and pie charts were constructed to examine differences in community composition, and represented the proportion of scored points for each category for a given shoal and tow combination, or shoal and depth combination.

1.3.3 Fish community composition within and between shoals

Fish communities were analysed using techniques identical to those applied for the same types of exploration of the Great Barrier Reef Marine Park (Cappo et al. 2007a), James Price Point (Cappo et al. 2011), and the Montara shoals (Heyward et al 2011).

They are based on boosted regression introduced to the ecological literature relatively recently by De'ath (2002; 2007). This approach derives from both classification and regression trees starting with a data model (De'ath & Fabricius 2000) and from 'machine learning' where no data model is specified and algorithms are used to learn the relationship between a predictor and its response (Breiman 2001). Boosted regression trees are therefore an 'ensemble' method, whereby models are improved by first fitting many simple models and then combining them for prediction, using an algorithm from classification and a 'boosting' algorithm, which combines a collection of models (Elith et al. 2008).

Boosted regression trees are complex, but can be summarised in ways that give powerful ecological insight by representing complex information in a visual way that is easily interpretable. They are robust and flexible, because explanatory (predictor) variables can be numeric, categorical, binary, or of any other type, and model outcomes are unaffected by transformations and different scales of measurement of the predictors. They are not sensitive to outliers, and handle missing data in predictors by applying best surrogates with little loss of information. Trees are hierarchical structures, and input variables at the tree leaves are dependent on input variables at higher nodes. This allows simple modelling of complex, non-linear interactions that simply cannot be handled by other approaches (see examples in De'ath 2007).

A mixture of 32 explanatory covariates (Table 4) were used to predict univariate responses using aggregated boosted regression trees (abt; De'ath 2007, Ridgeway 2007). The responses were:

1. species richness (raw total number of species on 95 SBRUVS drops),
2. total fish abundance (∑MaxN ; 4th root transformed)

The models were run for interaction depths of 1, 3 and 5 m, and the results show the relative influence of all covariates explaining and predicting the response. They are best portrayed as partial dependency plots, which show the effect of one particular covariate with the effects of all others held constant. Interactions are viewed using partial interaction plots.

To explore similarities and differences in the fish community composition between four nominal depth categories (<=23m, 23-42m, 42-60m and >60m), we used clustering and ordination of the fish genera without any constraints by environmental covariates. Relative fish abundance data (MaxN) was transformed by 4th root to down weigh the influence of rarely occurring but abundant fish such as schooling fusiliers and trevallies, and raise the influence of common species that occur in low numbers.

We avoided rare species and singletons by aggregating fish counts at the level of 98 fish genera in this preliminary clustering and ordination. The transformed abundance (4th root MaxN) data for these genera was converted to a matrix of Bray-Curtis dissimilarities and we computed agglomerative hierarchical clustering of the matrix. The distance between two clusters was the average of the dissimilarities between the points in one cluster and the points in the other cluster. We then conducted an unconstrained principal coordinates analysis (PCoA) on the matrix of Bray-Curtis dissimilarities. The site scores were plotted to reveal trends by depth, and the longest vectors were also plotted to show high correlations between principal coordinates and the abundance of genera.

To define fish assemblages in terms of depth, shoal location, seabed composition and epibenthic cover we used multivariate prediction and regression trees (mvpart). This approach uses the abundances of a large number of species at each SBRUVS site as a multivariate response (see De'ath 2002). We selected 179 species that occurred on at least three individual SBRUVS (~3% of samples) for this analysis and 32 explanatory covariates. As some of the %cover and % composition categories of substratum or epibenthos were absent, or poorly represented, in the dataset, these were pooled with other, larger categories to derive the list of covariates in Table 4. Abiotic covariates were derived using seafloor maps produced from multibeam acoustics (Table 4). From this analysis, links between environmental characters and fish assemblages can be visualised in a tree structure. Each split in the tree minimises the "distance" of sites from the centroids of nodes to which they belong.

This is equivalent to maximising the distance between node centroids. Each terminal node of the tree (leaf) can be defined by the multivariate mean of its sites, the predictors that define it, the number of sites that were grouped there, and by Dufrêne-Legendre species indicators (DLI). Nodes represent fish assemblages.

Indicator values (DLI; Dufrêne and Legendre 1997) were calculated for each species for each upper (branch) and terminal (leaf) node of the tree. For a given species and a given group of sites, the DLI is defined as the product of the mean species abundance occurring in the group divided by the sum of the mean abundances in all other groups (specificity), times the proportion of sites within the group where the species occurs (fidelity), multiplied by 100. Each species can be associated with the tree node (assemblage) where its maximum DLI value occurred. The index distinguishes between ubiquitous species that dominate many groups in absolute abundance, and species that occur consistently within single groups but have low abundance (Dufrêne and Legendre 1997). The DLI for species at the root node are simply the prevalence of those species in the entire dataset. Species with high DLI can be used as characteristic representatives of each fish assemblage, and the spatial extent of the assemblages was mapped onto diagrams of each shoal.

Species accumulation curves were derived for each assemblage to identify how much latent biodiversity remained after the completion of the single visit to Tassie and Evans shoals. The location of sites within each assemblage were mapped for each shoal.

All analyses used the open-source "R" statistical package (R.Development.Core.Team 2006). We used the public libraries mvpart, vegan, and abt (Ridgeway 2007). The use of common and scientific names follows those reported in Allen & Swainston (1988).

Table 4 Definition of the 32 explanatory covariates used in univariate and multivariate models to examine the relative effect of "habitat" on the univariate and multivariate responses for the fish sighted on SBRUVS at Tassie and Evans shoals. Covariate types included those estimated in the SBRUVS field of view (substratum, epibenthos) and those derived using multibeam acoustic maps. Brief definitions of each covariate are given in the right hand column.

Covariate abbreviation	**Covariate type**	**Covariate Definition**
name	spatial	Shoal name
depth	spatial	Depth (m) measured under the hull when the SBRUVS were deployed
latitude	spatial	SBRUVS GPS position
longitude	spatial	SBRUVS GPS position
BRUVS field-of-view		
% composition of seafloor by 6 pooled categories of substratum		
bdrck	substratum	% substratum classified as "bedrock"
calc.rf	substratum	% substratum classified as "calcareous reef"
grvl	substratum	% substratum classified as "gravel"
rbbl	substratum	% substratum classified as "rubble"
snd	substratum	% substratum classified as "sand"
mud	substratum	% substratum classified as "mud"

% coverage of 7 pooled categories of epibenthos			
bare		epibenthos	% coverage of seafloor with no epibenthos
encr		epibenthos	% coverage of the seafloor by "encrusting organisms"
fltrs		epibenthos	% coverage of the seafloor by "fans", "sponges", "sea whips", "zoanthids"
hlmda		epibenthos	% coverage of the seafloor by "*Halimeda*"
alg		epibenthos	% coverage of the seafloor by "algae
crl		epibenthos	% coverage of seafloor by "massive corals" and "solitary corals"
sft.crl		epibenthos	% coverage of seafloor by "soft corals"
Multibeam acoustic derivatives			
asp.dir		spatial	Azimuthal direction of the steepest slope, calculated on a 3 x 3 pixel area
curv		spatial	Combined index of profile and plan curvature {concavity/convexity parallel to and perpendicular to the slope), calculated on a 3 x 3 pixel area
hyp5		topography	Hypsometric index - Indicator of whether a cell is a high or low point within the local neighbourhood (kernel pixel radius of 5) original cell size 4m
hyp10		topography	Hypsometric index (kernel pixel radius of 10)
hyp25		topography	Hypsometric index (kernel pixel radius of 25)
hyp50		topography	Hypsometric index (kernel pixel radius of 50)
rng5		topography	Maximum minus the minimum elevation in a local neighbourhood (5 pixels)
rng10		topography	Maximum minus the minimum elevation in a local neighbourhood (10 pixels)
rng25		topography	Maximum minus the minimum elevation in a local neighbourhood (25 pixels)
rng50		topography	Maximum minus the minimum elevation in a local neighbourhood (50 pixels)
std5		topography	Standard deviation of elevation (5 pixels)
std10		topography	Standard deviation of elevation (10 pixels)
std25		topography	Standard deviation of elevation (25 pixels)
std50		topography	Standard deviation of elevation (50 pixels)
slp		topography	First derivative of elevation: Average change in elevation / distance calculated on a 3 x 3 pixel area

1.3.4 Analysis of regional patterns in benthic and fish communities.

To provide a regional context for the data collected during this survey, an analysis based on coarse-scale habitat data for major benthic groups (greater than 3% total cover) was conducted using data from 28 sites covering the Sahul shelf and Timor Sea. The analysis was done based on percentage total of each benthos group at each site and was conducted using a "distance average" paired hierarchical cluster analysis and heat-map plot (see R library vegan and gplots). The results from the hierarchical analysis dissimilarity measure was use to delimit seven groups of similar sites and these groups were subsequently mapped in order to examine geographical trends.

In addition, the benthic community of Evans, Tassie and Blackwood Shoals was compared with 17 other shoals from the NW Shelf based on the data derived from point-intercept analysis of still images. Bar plots of percentage cover for broad–scale benthic categories and hard coral categories were summarised for each shoal. The bar plots aggregate the data as "All data <60 m", which was then split into two depth bands, <=30 m and >30-60 m. Multivariate differences in community types based on point intercept data were also examined using a "distance average" paired hierarchical cluster analysis and heatmap plot (see R library vegan and gplots).

A regional comparison of fish species richness and abundance (as transformed 4th root) was undertaken to compare fish communities at Tassie and Evans Shoals with reefs and shoals of the

Great Barrier Reef, as well as six reefs and shoals on the NW Shelf. Sites included in the comparison were selected to have similar depths and habitats as the BRUVS imagery analysed from Evans and Tassie Shoals.

1.4 Data management

All data was collated and archived on the AIMS server, under the control of the Perth AIMS Data Manager (m.case@aims.gov.au). The resulting derived files were added to the ConocoPhillips archive.

2. Results

2.1 Spatial coverage of sampling

Work was completed as planned, using all methods, with the exception of a small number of towed video stations in the mid-shelf areas that were unable to be surveyed due to strong tidal currents. Additional benthic transects were completed with the towed video system across Blackwood Shoal. CTD casts, sampling the water column for conductivity, temperature, depth and light, were made twice a day throughout the voyage. A small number of sediment grabs were collected at the shelf locations adjacent to Cape Helvetius and Goodrich Bank. A summary of all sampling locations is included as Appendix 1. The spatial coverage of all sampling is summarised in Figures 7, 9, 15, 21 & 27.

2.2 Shelf area characteristics

Benthic communities at the two survey locations on the continental shelf were strikingly different from those observed on the shoals. Our general observations revealed the shelf areas contained complex bathymetry which to a large degree is likely a legacy of past sea level stands. The resulting plateaus and channels provide various depths and aspects, likely to influence the presence/absence of different benthic biota, with strong tidally driven currents bringing at times highly turbid water over the ridges and valleys. Both shelf locations were much more turbid than the shoals, resulting in greatly reduced amount of light reaching the seabed and an associated shift from primary producer dominated habitats to those featuring sessile filter feeders. Initial review of a subset of water column light profiles indicated progressive drops in water clarity from the outer shelf shoals shorewards, with surface light (corrected PAR) attenuated to <5% at around 45 m depths on the shoals, 30 m at Goodrich Bank and 10m near Cape Helvetius. From the real-time towed-video classifications, it was apparent that phototrophic species such as hard corals were rare and only encountered on the shallowest survey transects to depths of less than 30 m (Figure 3) near Goodrich Bank. Macroscopic biota was generally sparse, but low-medium density filter feeder habitats were encountered in both the Goodrich Bank and Cape Helvetius areas (Figures 5 & 6). Sponges tended to dominate the filter feeder habitats, with various small to medium sized soft corals contributing less biomass. In all cases these communities were associated with small scale patches of consolidated substrate, either sandy pavement or minor rocky outcrops.

Figure 3: Goodrich Bank area examples – limited partial hard coral habitat at 25 m depth (left image) was rare and only encountered at the shallowest sites, while coarse sandy substrate and sparse filter feeders (right image) were more typical.

Figure 4: Goodrich Bank area examples - medium density mixed filter feeder community associated with patches of low relief outcropping rock.

2.2.1 Shelf Area Modelling results

Goodrich Bank and Cape Helvetius were modelled separately from Blackwood, Evans and Tassie shoal because multibeam variables were collected, interpolated and derived at different spatial scales). Accuracy estimates for major benthic modelling results based onoblique forward-facing real time towed video modelled against interpolated multibeam transects (50 m pixel) are shown in Table 7. Model accuracy is based on testing the models against a 20% blind validation dataset (checked and adjusted for spatial autocorrelation with the testing dataset). Real time towed benthic video model test indicated very high accuracy results with AUC values all greater than 0.95.

Spatial representations of probabilistic models for real time video modelled with interpolated multibeam are shown for Goodrich Bank in Figure 6 and Cape Helvetius in Figure 8. A heat map with Euclidian distance based cluster analysis was used to summarise the relative variable importance (scaled model accuracy "Gain" index) for the prediction of biotic groups from multibeam (Figure 9) and more detailed information on model accuracy (AUC plot), variable importance (plot of gain index for all multibeam variables) and the partial responses of each biotic group to the most important six variables are detailed in Appendix 3 (Figures A3.15-A3.19).

For habitat models based on real time towed video, analysis of the relationships between multibeam variables and each biotic group identified two major clusters (based on the first break in the dendogram y-axis, Figure 9). The first cluster contains the "Dense filter feeders" and "Burrowers" communities, where the most important predictor variable is broad scale depth (mean50). Both communities in this cluster show distinctive broad depth responses (probability declining with depth to 50m in Burrowers, and probability increasing with depth to 85 m in dense filter feeders; Appendix 3 Figures A3.15 and A3.16). Both profiles show non-linear responses in mean50 which also indicates that landscape scale topography may influence distribution (for example sloping areas)(Appendix 3 Figures A3.15 and A3.16). The second major cluster contains "medium" and "sparse filter feeder communities" as well as habitats with no benthos (Figure 9). Membership of this second clusteris most highly correlated with the slope and rugosity measure rng50, and depth. As for dense filter feeders, the occurrence of medium and sparse filter feeder communities increases where there is change in topology (indicated by rng50 a measure of change in depth) and where water depth increases (Appendix 3 Figures A3.17 and A3.18

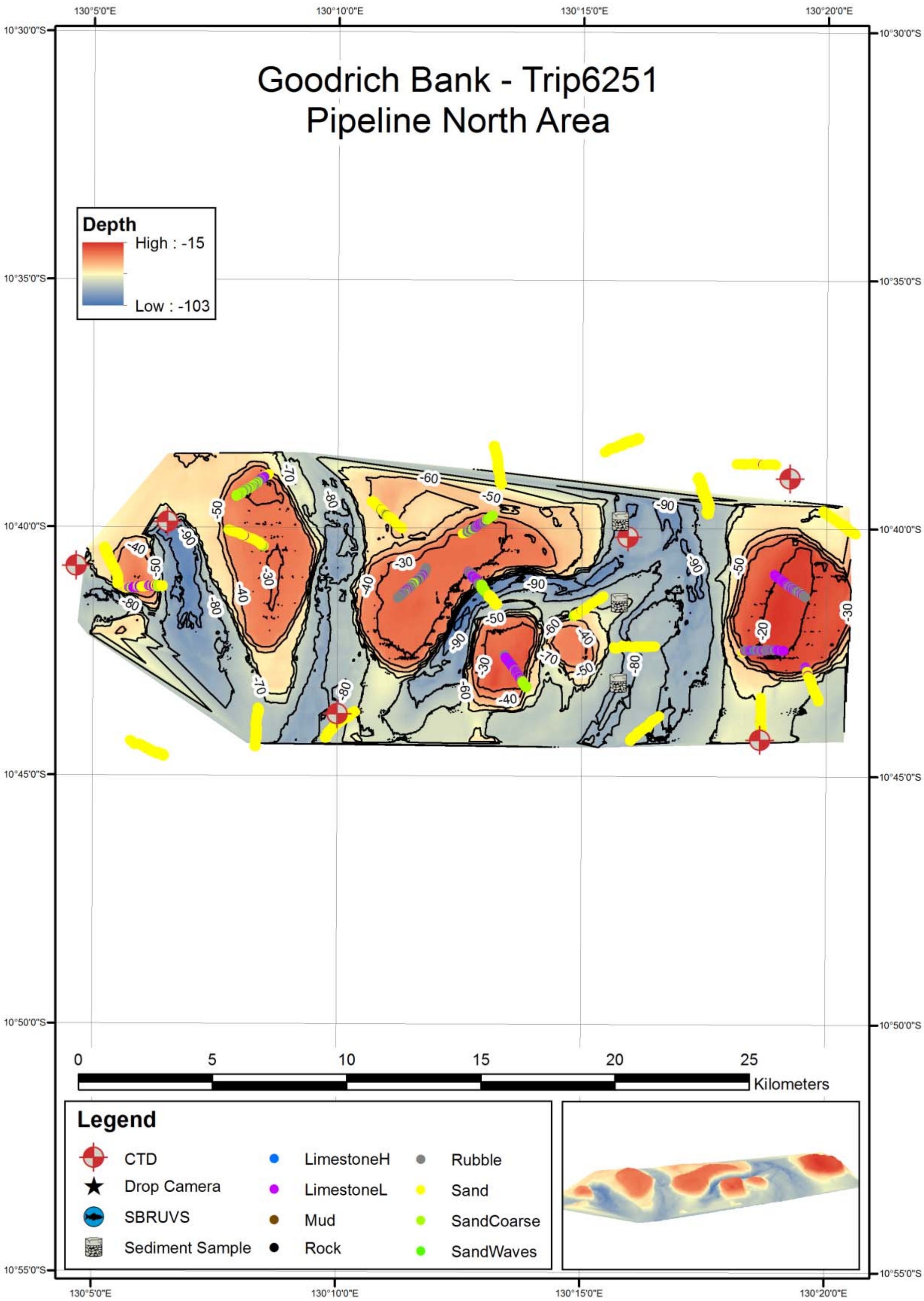


Figure 5: Towed video sampling completed adjacent to Goodrich Bank. The bathymetric representation of the shoal was produced from the expedition's multibeam data. A 3D representation of the shoal is shown in the lower right box. Warmer colours associated with shallower depths. The multi-coloured "worms" summarise the benthos as observed from the real-time towed video.

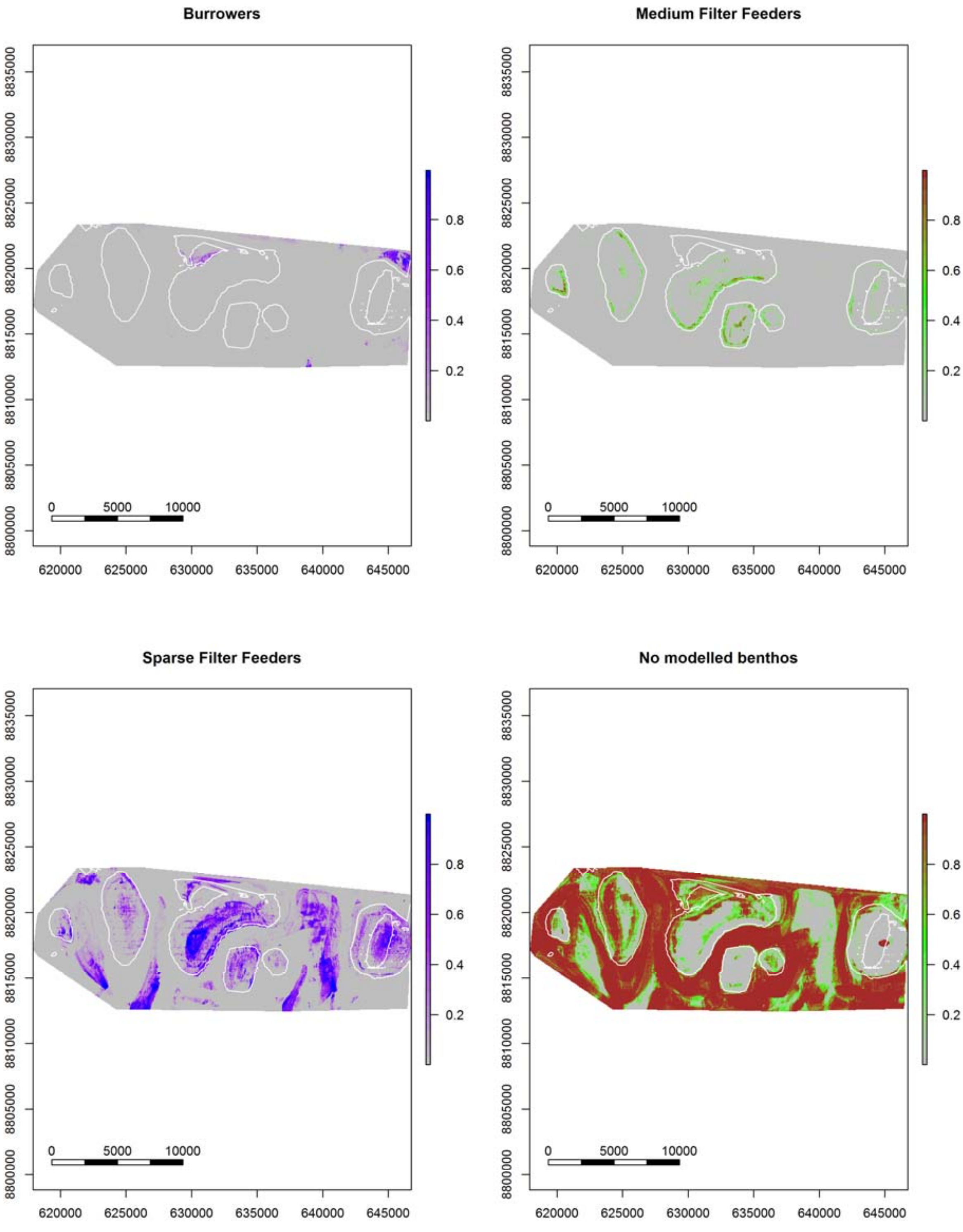


Figure 6: Goodrich bank survey area - modelled spatial distributions describing the presence/absence probabilities for major benthic habitat classes generated using oblique forward facing real-time scored towed video. The 30 and 50m depth contours are shown in white.

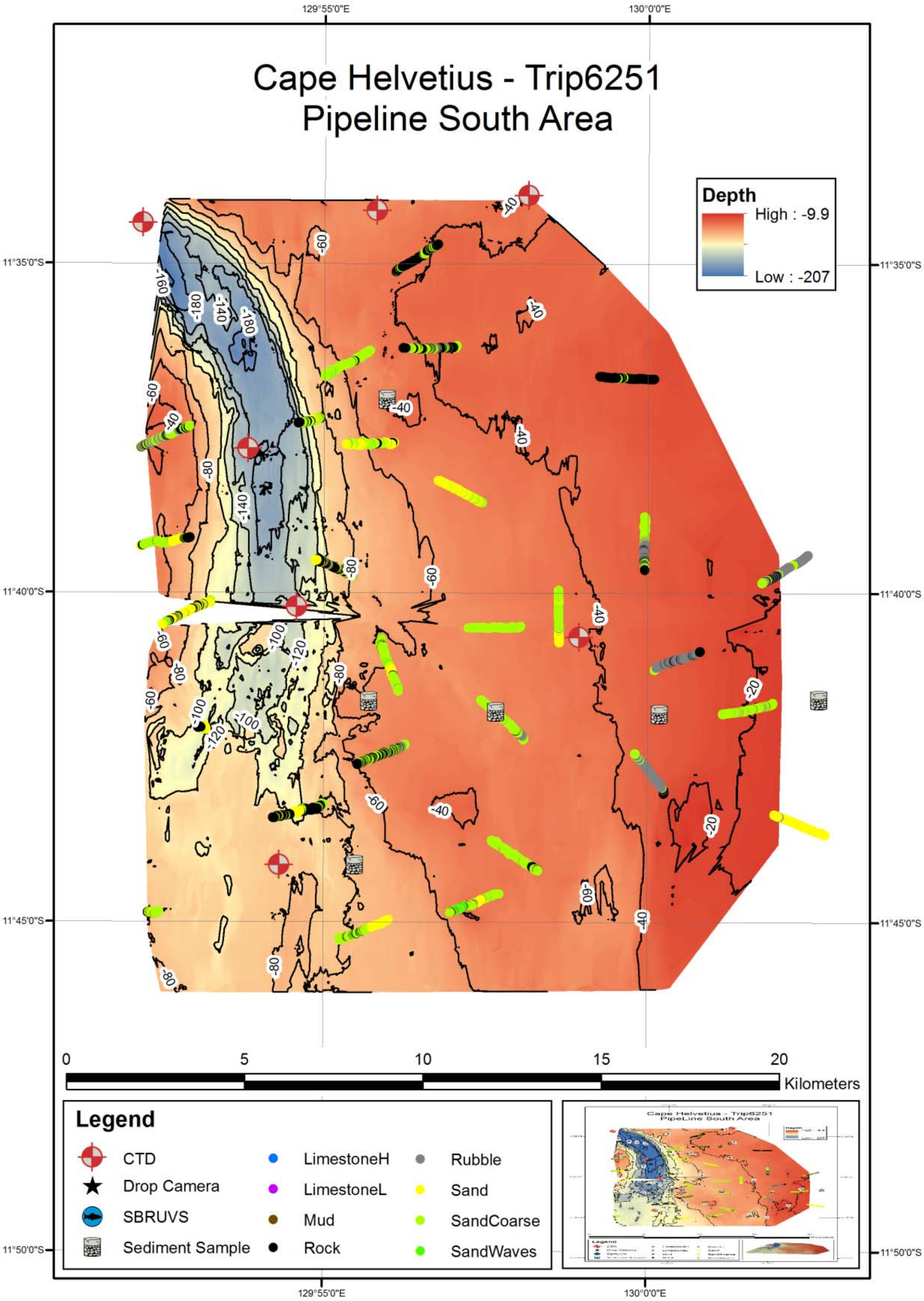


Figure 7: Towed video sampling completed adjacent to Cape Helvetius. The bathymetric representation of the shoal was produced from the expedition's multibeam data. A 3D representation of the shoal is shown in the lower right box. Warmer colours associated with shallower depths. The multi-coloured "worms" summarise the benthos as observed from the real-time towed video.

Modelling of habitat distributions in both shelf areas (Figures 6 & 8) confirms the limited and patchy distribution of the filter feeding habitats and points to associations of filter feeders with high spots and regions of steep bathymetry. In both cases this likely reflects the availability of exposed consolidated substrates for recruitment and subsequent growth.

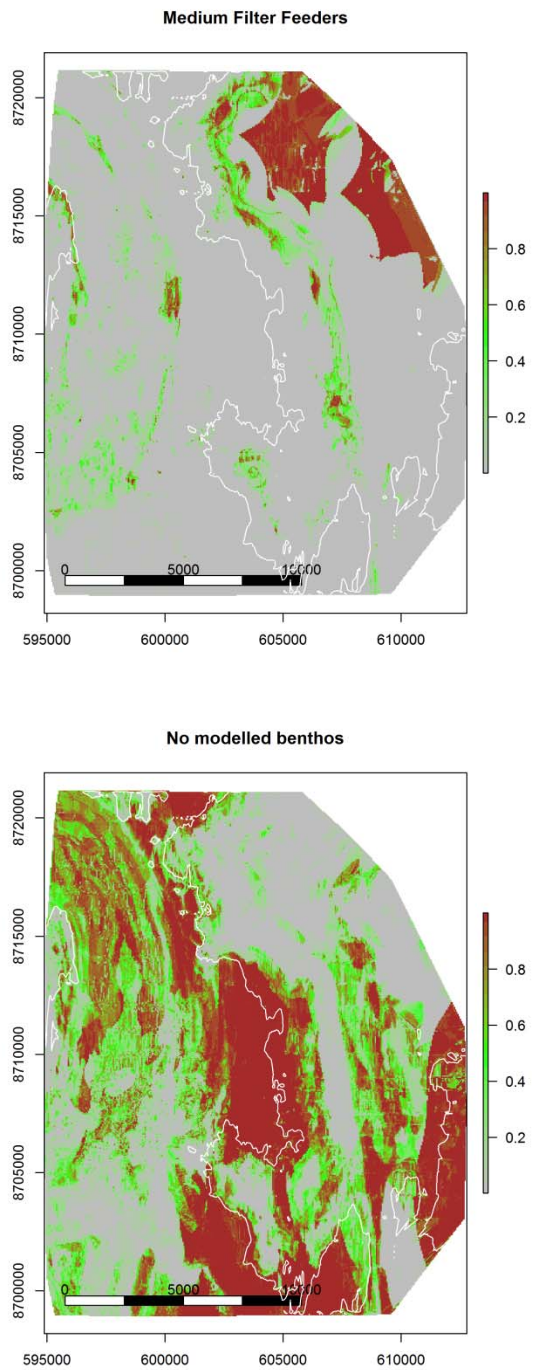


Figure 8: Cape Helvetius survey area modelled spatial distributions describing the presence/absence probabilities for major benthic habitat classes generated using oblique forward facing real-time scored towed video. The 50 m depth contour is shown in white.

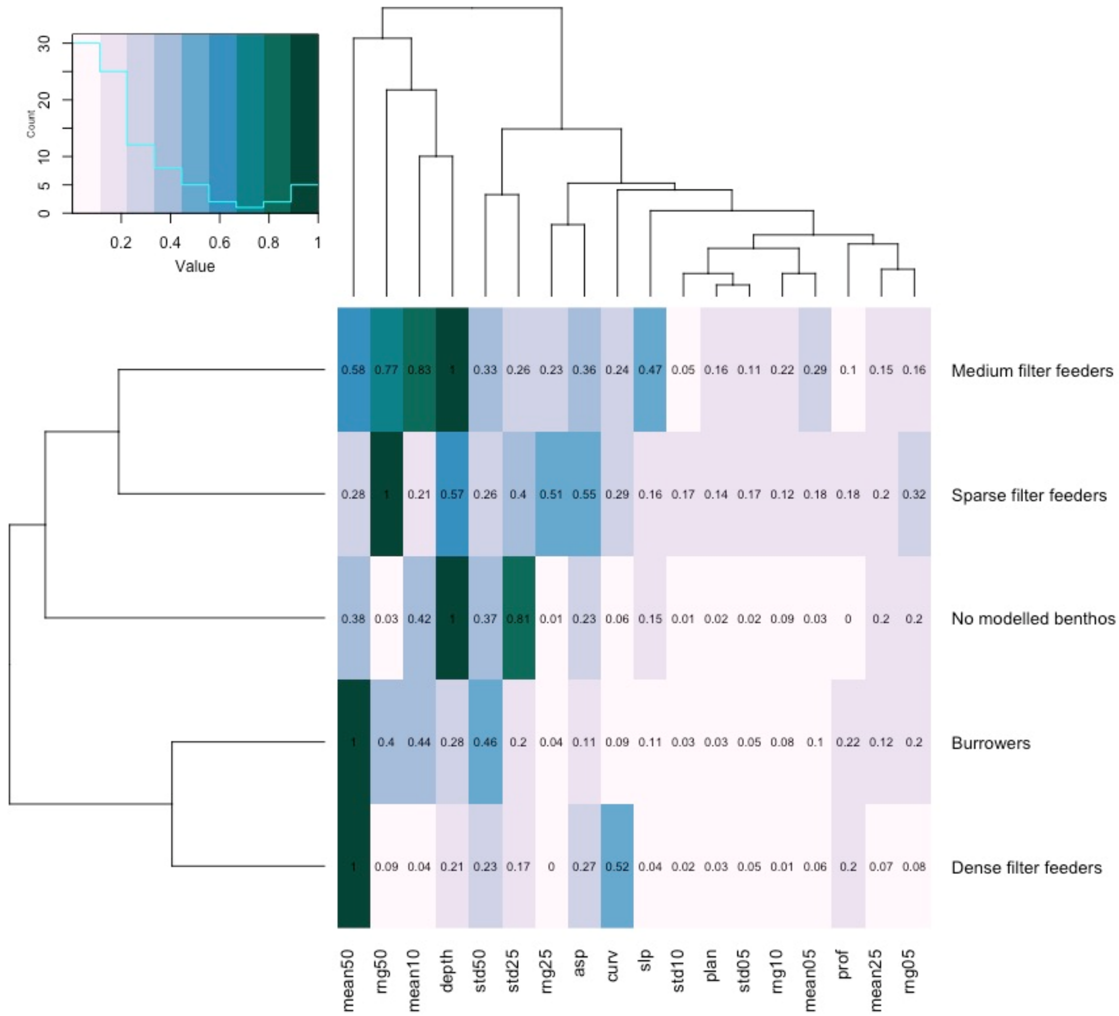


Figure 9: Heatmap with Euclidean distance cluster analysis showing the relative importance of predictor variables (0-1 from least to most important) for towed video real-time classification based on benthic habitat for Cape Helvetius and Goodrich Bank areas. Benthic groups are on the y-axis and 50m interpolated multibeam depth and derivatives are on the x-axis (see Table 3 for variable descriptions).

2.3 Shelf Sediments

Analysis of a limited number (n= 9) of sediment samples, collected with Smith-McIntyregrab within the sampling region near Goodrich Bank and Cape Helvetius (Figures 5, 7, Appendix 1), found that carbonate estimates averaged 48.2% near Goodrich Bank and 39.6% near Cape Helvetius, based on sample weight differences between initial weight and that after hydrochloric acid treatment (Table 5). This is consistent with increasing carbonate contribution to the sediment at locations further offshore. Whilst most of the samples were made up of coarse sand (>2mm), sand (2mm-63 μm) or silty sand (<63μm) (Table 6), some of the samples collected near Cape Helvetius also contained small pebble-sized (5-10mm) mudstone-like pieces, plus some shells.

Table 5 Carbonate fraction, based on the change in sample weights after 10% HCl treatment, for grab samples collected near Goodrich Bank and Cape Helvetius. Sample locations are listed in Appendix 1.

Sample location	% Carbonate	
	2mm-63µm	< 63µm
01 Goodrich Bank	61.59718534	36.23739118
02 Goodrich Bank	56.92279367	40.21009241
03 Goodrich Bank	56.16877229	38.08362577
04 Cape Helvetius	41.23585938	38.73897419
05 Cape Helvetius	38.65095729	39.21727944
06 Cape Helvetius	54.20339849	36.47874184
07 Cape Helvetius	25.83954667	39.68263963
08 Cape Helvetius	55.53110234	37.71587041
09 Cape Helvetius	44.91093347	23.4668703

Table 6 Grain size distribution for grain samples collected near Goodrich Bank and Cape Helvetius. Sample locations are listed in Appendix 1.

Sample location	Grainsize - Percent of total sample		
	>2mm	2mm-63µm	<63µm
01 Goodrich Bank	4.908129877	40.24666499	54.84520513
02 Goodrich Bank	22.26778392	51.72044928	26.0117668
03 Goodrich Bank	33.3007335	29.76365118	36.93561532
04 Cape Helvetius	31.85715964	51.00434629	17.13849407
05 Cape Helvetius	33.10485516	53.08853529	13.80660955
06 Cape Helvetius	26.53565938	60.71118241	12.75315821
07 Cape Helvetius	21.70781893	66.96673525	11.32544582
08 Cape Helvetius	35.34838766	45.83077058	18.82084175
09 Cape Helvetius	54.91081906	30.04576391	15.04341704

2.3.1 Regional comparisons - sediment

At the regional scale, using the Geosciences Australia MARS sediment characteristic database, co-cluster analysis and heatmap results (Figure 10) show the majority of on-shelf locations have a high degree of heterogeneity with respect to broad sediment characteristics, although sand particles (63 µm to 2mm) make up the majority of sediment samples (75% or greater) by weight. The remaining proportion of the sample is made up either of silts (> 63µm) or gravels (> 2mm). The exceptions are a) Eugune McDermott which is located on the shelf edge, surrounded by deeper water, were bottom sediments are subject to less hydrodynamic disturbance and turbulence which corresponds to a sediment sample where 87% is silt and the rest is gravel; b) Heywood, Echuca and Goeree shelf edge shoals where sediment samples are dominated by gravel (>77% by weight). These gravels may be a result of scouring of past land and present biogenic reef present on these shoals.

Overall the grain size data shows no consistent trends with distance from shore, longitude or latitude (Figure 11). Local hydrodynamic factors will have a large influence on the grain sizes reported, but with present knowledge it would seem difficult to predict the grain size composition form one location to another. The more predictable gradient may be an increasing carbonate component of the sediments with distance from shore, but the presence of underlying ancient coastal features in many locations means there is likely to be widespread terrigenous component in many locations throughout the region.

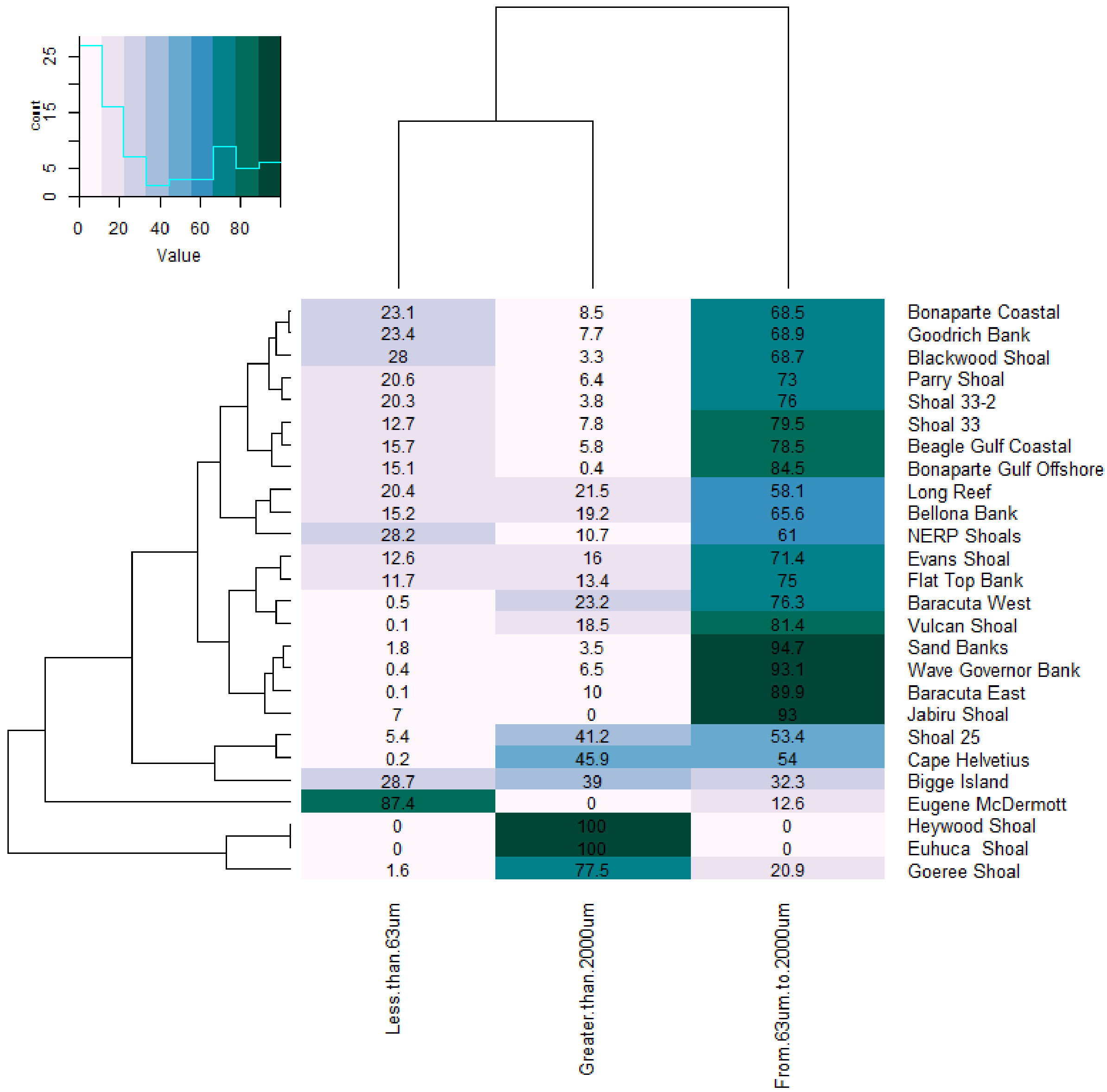


Figure 10: A heat map and co-cluster comparative analysis of the proportion of the three sediment classes represented at sites across the NW Shelf. This was completed using Euclidean distance based hierarchical co-cluster analysis of locations and sediment classes (Mardia et al. 1979, Becker et al., 1988). The sites are on the y-axis and sediment classes on the x-axis. The heat map cell values show the percent by weight of sediment in each class.

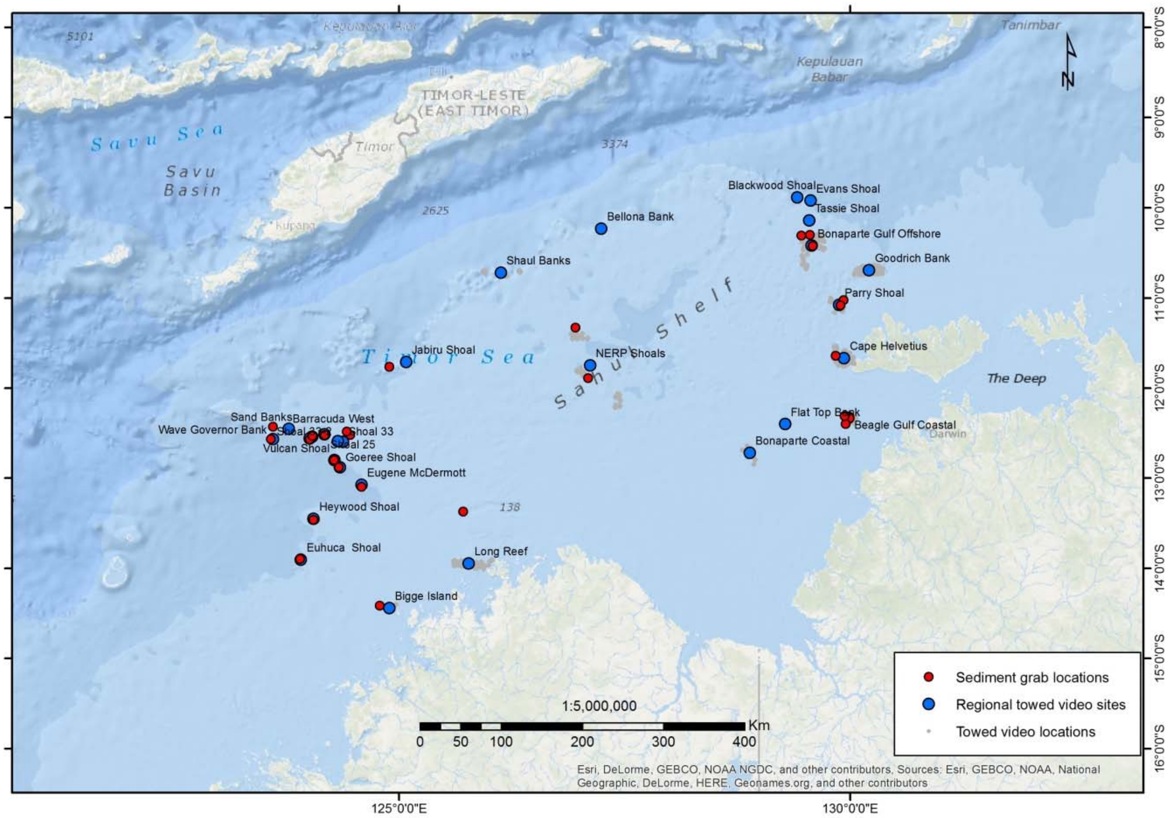


Figure 11: Regional sediment grain size analysis: location of regional comparison centroid locations, general habitat classifications from towed video data and the nearest corresponding location of sediment grabs extracted from the Geosciences Australia MARS sediment database.

2.4 Shoal characteristics

2.4.1 Benthic habitats

2.4.1.1 Broadscale Shoal features

The three submerged shoals surveyed all supported light-dependent benthic communities across the shallower regions of the shoal plateaus down to depths of around 60 m.

Evans Shoal had by far the largest plateau area, much of which had low vertical relief and extensive sand and rubble. The central plateau did support a variety of biota including varying densities of erect *Halimeda* and a few extensive fields with the solitary coral *Heteropsammia*, but was dominated by sandy bare substrates or various forms of low relief algae. Rugosity increased with a greater frequency of small isolated bommies and outcropping reef, along the outer margins of the plateau. Multibeam data suggest a crescent-shaped distribution of more fine-scale rugosity from north to south and along the eastern side of the plateau. These areas of hard substrate supported corals, often mixed with algae, red crustose coralline or green erect calcareous algae such as the widespread *Halimeda*. In localised areas these coral and algal communities included moderate densities of mixed filter feeding organisms, such as sponges and soft corals. Hard coral density was sparse or absent across large areas of Evans Shoal plateau but increased noticeably towards the outer edges of the horizontal section of the plateau. At the northern and southern ends of the shoal coral cover was variable as the seabed slope and depth started to increase, but at 40 m a band of dense foliaceous coral was encountered on multiple transects. Where it did occur, the foliaceous coral habitat extended down the slope until it transitioned to mostly sparse filter feeder areas, generally occurring on coarse sandy substrates with occasional, isolated small rocky outcrops. This habitat is notable and accounts for dense coral in a narrow depth band at the northern and southern ends of the shoal. It did not occur all the way around the shoal, being noticeably absent from the western margin, where a sandy slope, possibly associated with sediment transported off the plateau, had accumulated. To a lesser extent this was also observed in similar depths at Tassie Shoal and similar mesophotic coral communities have been observed elsewhere in the North and North-west marine regions at around 40-50 m, including at Barton Shoal and in the deeper lagoon at South Scott Reef.

Tassie Shoal plateau covers 5.3km^2 in depths down to 30 m, much smaller than the 43 km^2 on Evans Shoal. Across the shallower region on the top of the plateau Tassie Shoal had a more complex arrangement of low relief ridges and small bommies, interspersed with patches of sand and rubble, but lacking the extensive, low cover sand and rubble dominated fields seen on Evans Shoal. The benthic communities of the two shoals appeared to be very similar in composition, but coral cover on Tassie Shoal was more commonly medium density rather than sparse. Overall, the density of benthic biota was higher on Tassie than Evans Shoal and it was common to encounter mixed coral-algae-filter feeder communities. Slightly more fine scale vertical relief in the reef habitat was seen on Tassie Shoal across the plateau, supporting medium to high coral cover in general and often clearly associated with bommies or ledges. It should be noted however, that although both Evans and Tassie Shoals had very similar coral cover of around 9%, the shoal plateau of Evans is almost nine times bigger. The seabed at Tassie Shoal typically had gentle transition over plateau rim and down slope. This was particularly noticeable along the western margin, where the edge and slope of the shoal were very sandy (see Figure 34) with the sandy slope areas appearing to include fine sand, coarse sand and gravel. These plateau margins often supported very low epibenthic cover at greater depths (60-100 m), though occasional patches of medium density and larger sized filter feeders, including medium sized sponges and gorgonian fans, were encountered.

An unusual feature on both Evans and Tassie Shoals was the presence of single large bommies of the coral *Pavona clavus* on the southwestern quadrant of each plateau. The *Pavona* bommie on Evans Shoal was by far the largest of the two and may be the largest example yet recorded worldwide (Figure 12).

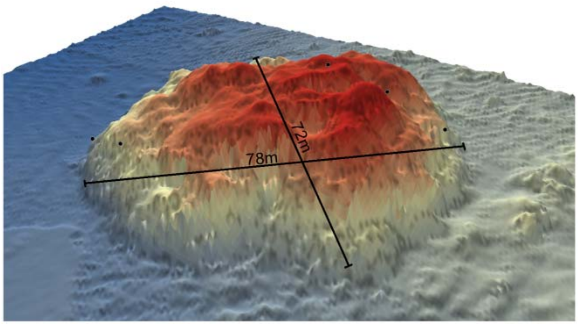


Figure 12: Very large <u>Pavona clavus</u> bommie on Evans Shoal. Left image is multibeam rendering, showing the bommie diameter of approximately 75 m. Right is a drop camera image showing a close up of the bommie and associated fish aggregation

Blackwood Shoal is further from the Barossa field than Evans or Tassie Shoals. It was the smallest and shallowest shoal plateau investigated, with only 0.7km^2 of the central plateau lying within the 30 m depth contour. Two towed video transects oriented perpendicular to each other across the top of the plateau revealed medium to high density of coral habitat throughout. Low relief reef supported mostly high coral cover, especially of the genus *Acropora*, represented by branching, tabulate and corymbose forms. Beyond the plateau rim the slope increased and supported mixed *Halimeda* and corals. The multibeam revealed a slight step down from the shallow plateau to a deeper sloping apron surrounding it, before the slope increased and dropped away (Figure 27). On one tow over the slightly deeper apron a narrow band of foliaceous coral habitat, similar to that seen at Evans and Tassie Shoals, was observed at 45-50 m depth, which then transitioned, as observed on the other shoals, into sand/rubble with greater depth.

The most distinguishing feature of the shoals was the presence of hard corals, which occurred at varying densities but with percentage cover in the most dense coral habitat patches not dissimilar to that found on healthy, emergent coral reefs. Evans and Tassie Shoals at a qualitative level show similar, though not identical assemblages, featuring sparse to medium density coral, sparse filter feeders and a comparable percentage of bare substrate. Blackwood Shoal differs in the dominance of the medium to high density coral habitat, along with other mixed habitats including coral and the algae *Halimeda*.

The shoal locations were noticeably less turbid than the mid-shelf, with sand sediments featuring on extensive bare areas across the shoal plateaus. Bare sand was observed on Evans Shoal to continue over the plateau edges and down the shoal slopes, along a NE-SW axis, suggestive of sediment transport off the plateau regions. The orientation may relate to prevailing patterns of wave energy and tidal currents. In contrast the northern and southern slope regions on Evan Shoal supported dense patches of foliose coral.

2.4.1.2 Fine scale image analysis of Evans, Tassie and Blackwood Shoals

Quantitative analysis of the high resolution images along each towed video transect allowed for fine scale discrimination of the abundance and distribution of benthic components at each shoal. Evans Shoal features large areas of sand, with turf and macroalgae covered consolidated reef representing the most abundant organisms (Figure 14). Coral abundance is highly variable with location and the average cover of 9% is in the mid-range for coral cover observed on other shoals. The relative proportions of the major benthic categories varies with depth, for example hard corals are most abundant in the shallow areas (<20 m depth) and also beyond 40 m (Figure 15). This deep coral communitiy is dominated by dense foliaceous species packed in a narrow band between 40-60 m. Figures 16, 17 & 19 provide additional detail on the composition of algal, hard coral and other invertebrates and variation between depth zones.

Mean coral cover on Tassie Shoal (8.6%) was similar to Evans Shoal (Figure 20), but no hard coral was observed below 40 m depth, and areas below 40 m at Tassie Shoal were predominantley sand (Figure 21). The shallow plateau area of Tassie Shoal had a similar mix of coral species to Evans Shoal (Figures 17 & 23), but there was more reefy substrate and small bommies with encrusting coral and algae were common. Figures 21-24 summarise the relative abundance of the major biotic groups and changes in their relative contribution to the benthos with depth.

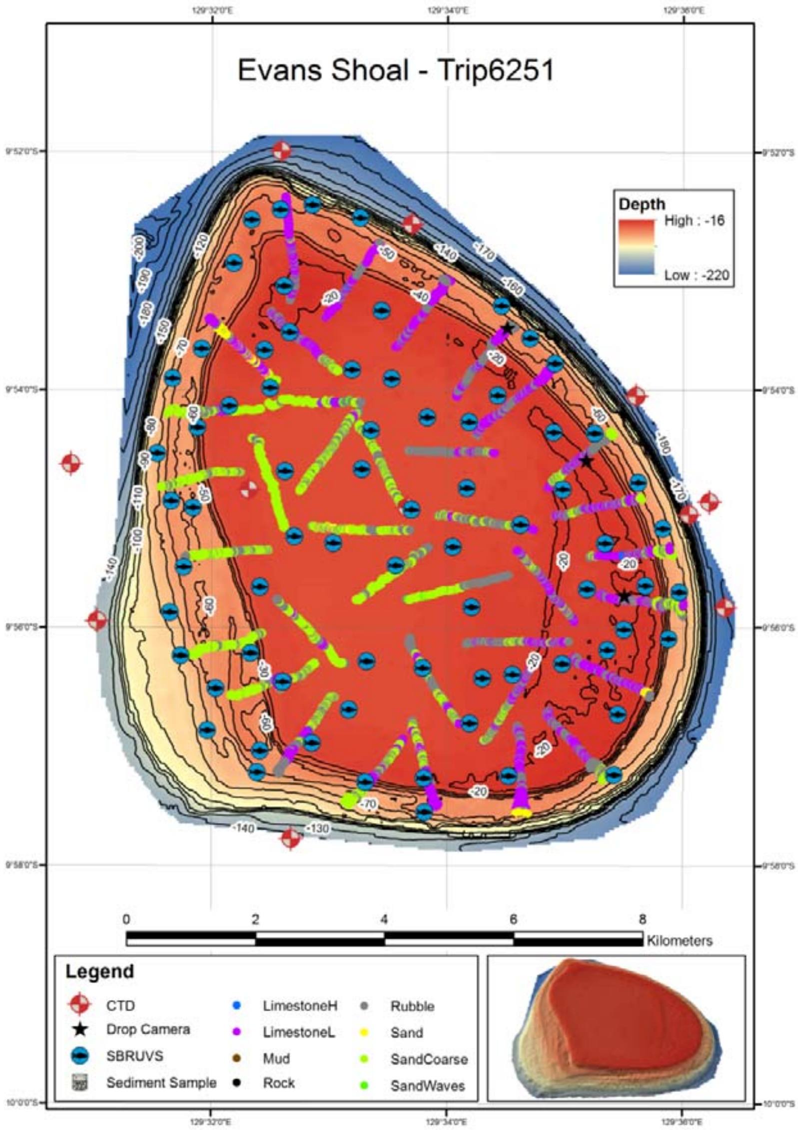


Figure 13: Sampling completed at Evans Shoal. Towed video and SBRUVS stations are overlaid on bathymetry of the shoal produced from the expedition's multibeam data. A 3D representation of the shoal is shown in the lower right box. Warmer colours associated with shallower depths. The multi-coloured "worms" summarise the benthos as observed from the real-time towed video.

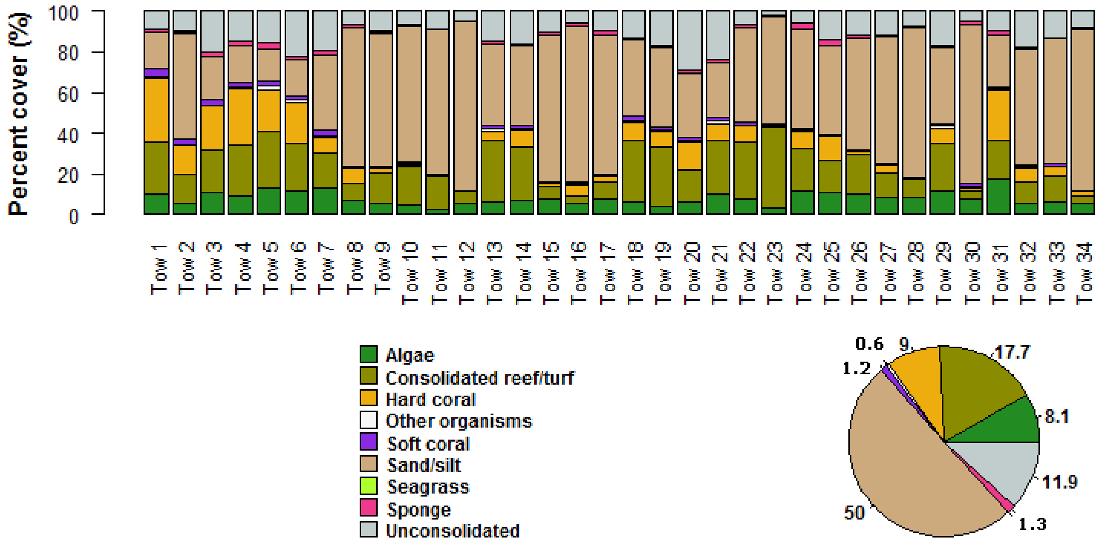


Figure 14:. Summary of the abundance (% cover) of the broad-scale categories of benthos at Evans Shoal, derived from image analysis of high resolution still photos taken using the AIMS towvideo system. Data for individual transects are shown in the bar plots and overall image level percentages for the shoal in the pie diagram.

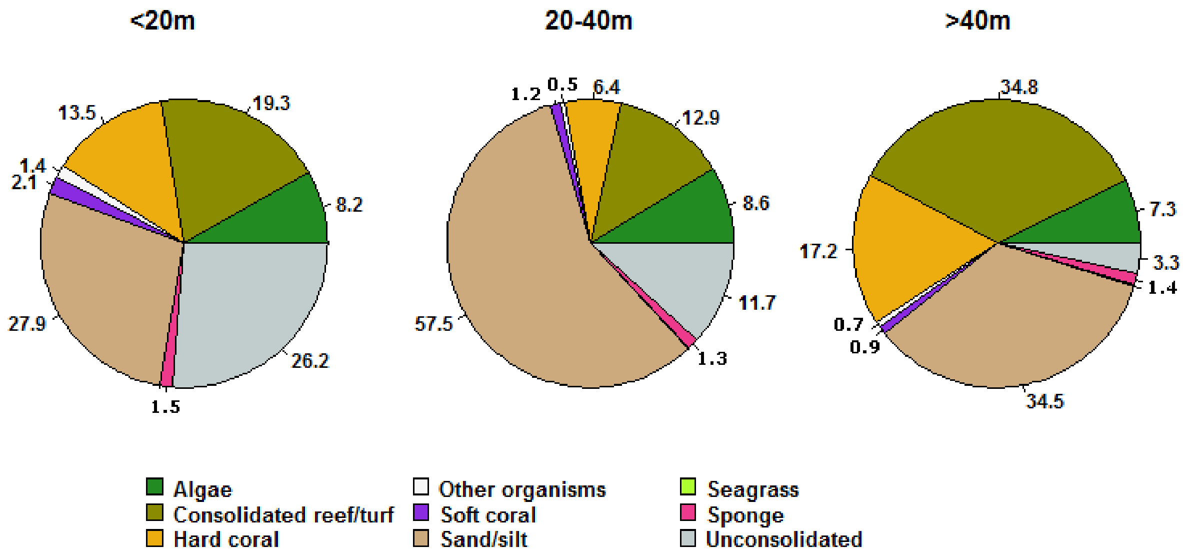


Figure 15: Summary of the relative proportion of each of the broad-scale categories of benthos across depths at Evans Shoal.

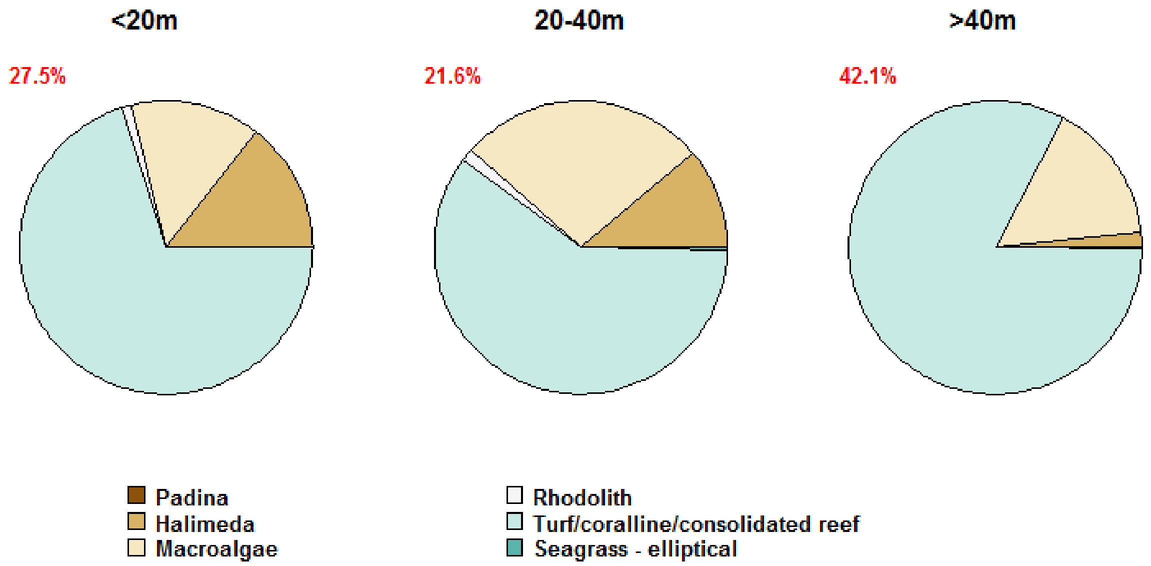


Figure 16: Summary of the proportion of each of the fine-scale categories of algae and seagrass occurring across Evans Shoal grouped by depth. The proportion of all benthos within each grouping that was represented by alage and seagrass is denoted alongside each pie diagram.

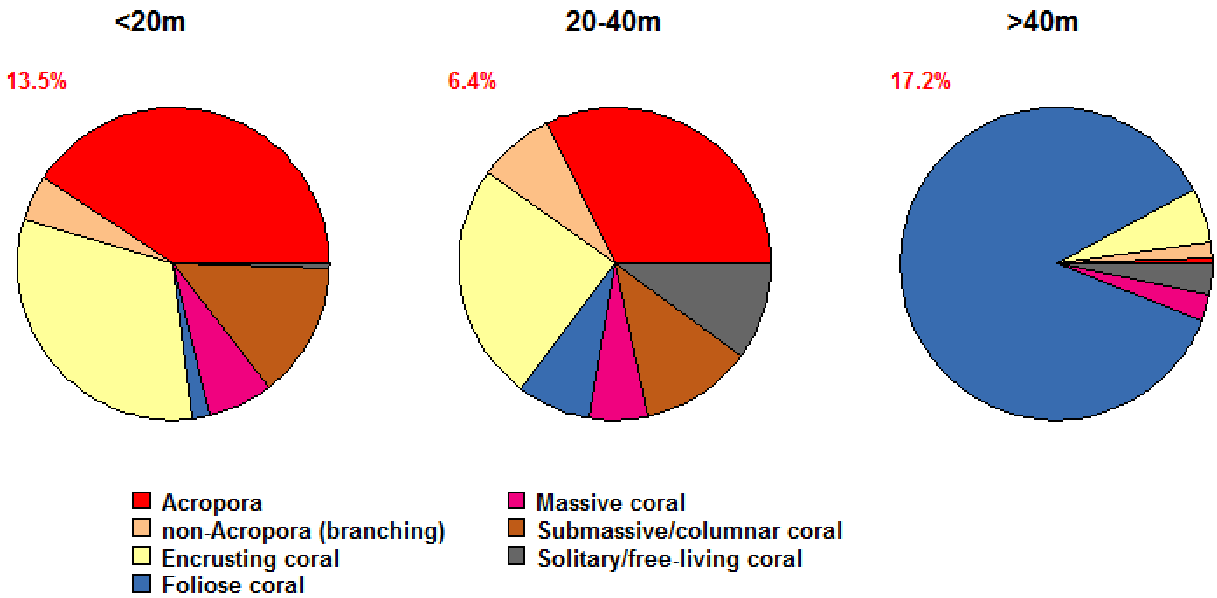


Figure 17: Summary of the proportion of each of the fine-scale categories of hard coral occurring across Evans Shoal grouped by depth. The proportion of all benthos within each grouping that was represented by hard coral is denoted alongside each pie diagram.

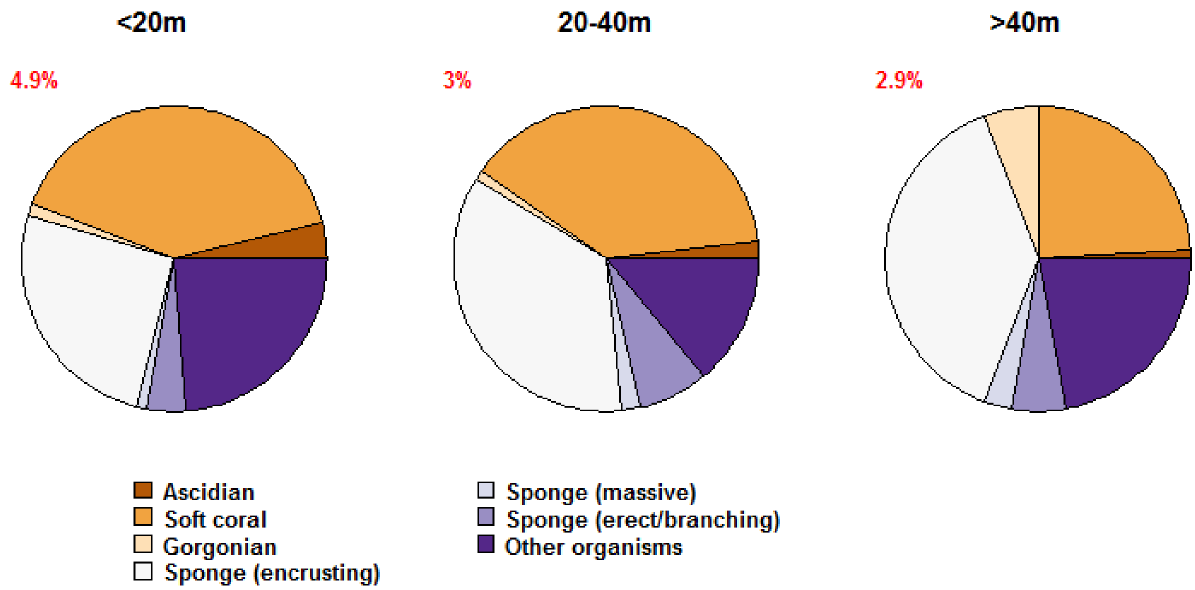


Figure 18: Summary of the proportion of each of the fine-scale categories of other organisms occurring across Evans Shoal grouped by depth. The proportion of all benthos within each grouping that was represented by other organisms is denoted alongside each pie diagram.

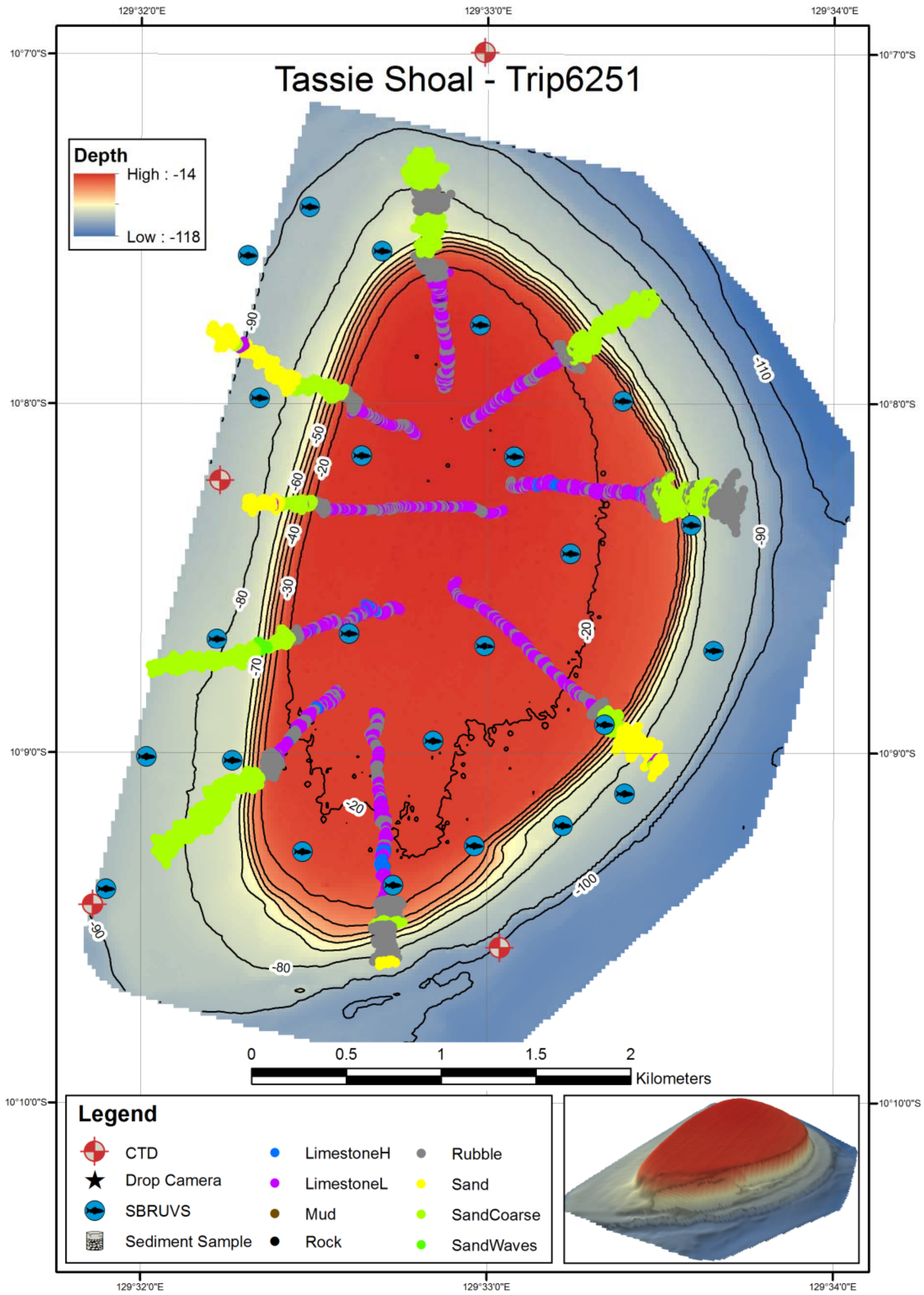


Figure 19: Sampling completed at Tassie Shoal. Towed video and SBRUVS stations are overlaid on bathymetry of the shoal produced from the expedition's multibeam data. A 3D representation of the shoal is shown in the lower right box. Warmer colours associated with shallower depths. The multi-coloured "worms" summarise the benthos as observed from the real-time towed video.

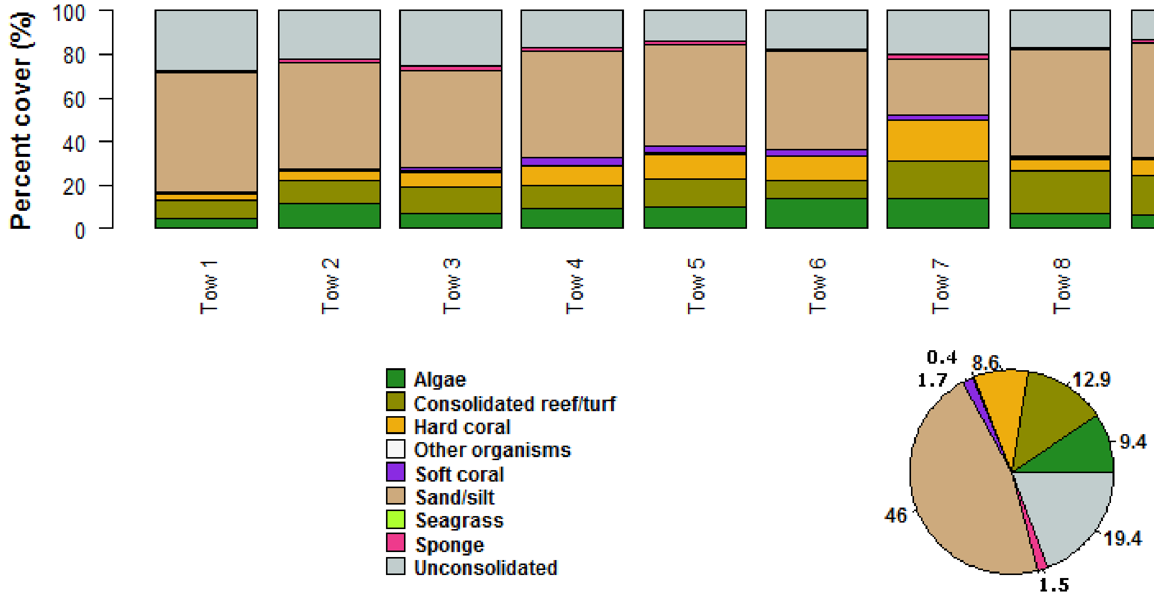


Figure 20: Summary of the abundance (% cover) of the broad-scale categories of benthos at Tassie Shoal, derived from image analysis of high resolution still photos taken using the AIMS towvideo system. Data for individual transects are shown in the bar plots and overall image level percentages for the shoal in the pie diagram.

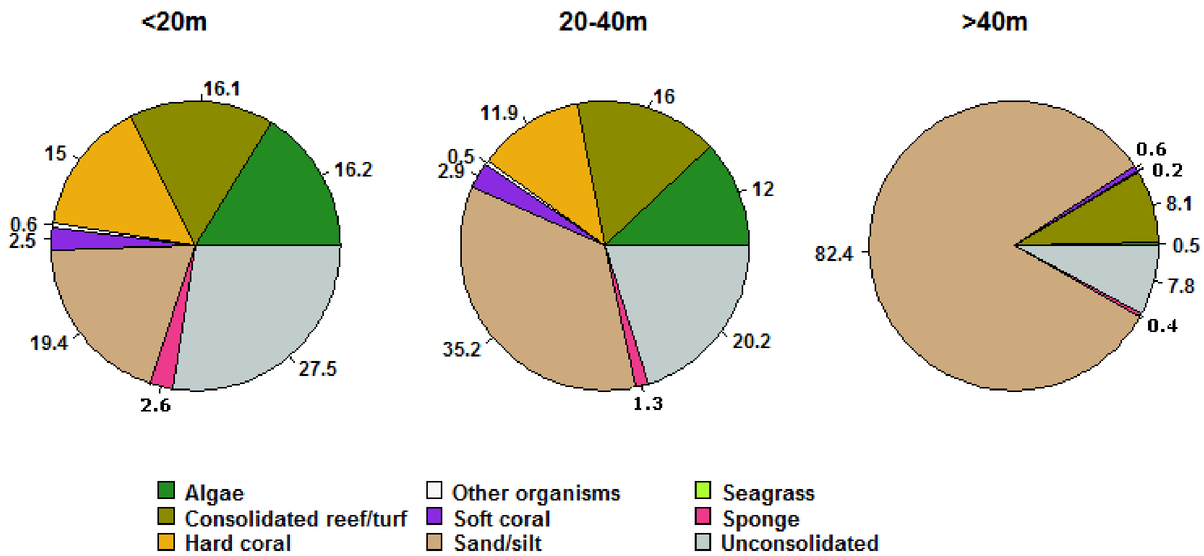


Figure 21: Summary of the relative proportion of each of the broad-scale categories of benthos across depths at Tassie Shoal.

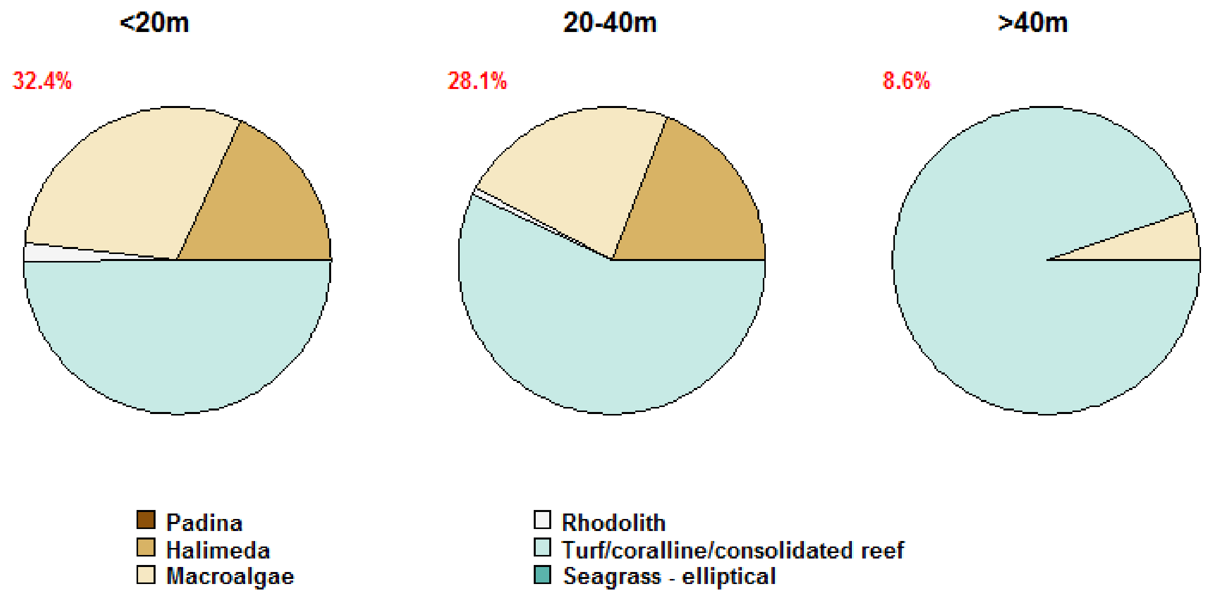


Figure 22: Summary of the proportion of each of the fine-scale categories of algae and seagrass occurring across Tassie Shoal grouped by depth. The proportion of all benthos within each grouping that was represented by alage and seagrass is denoted alongside each pie diagram.

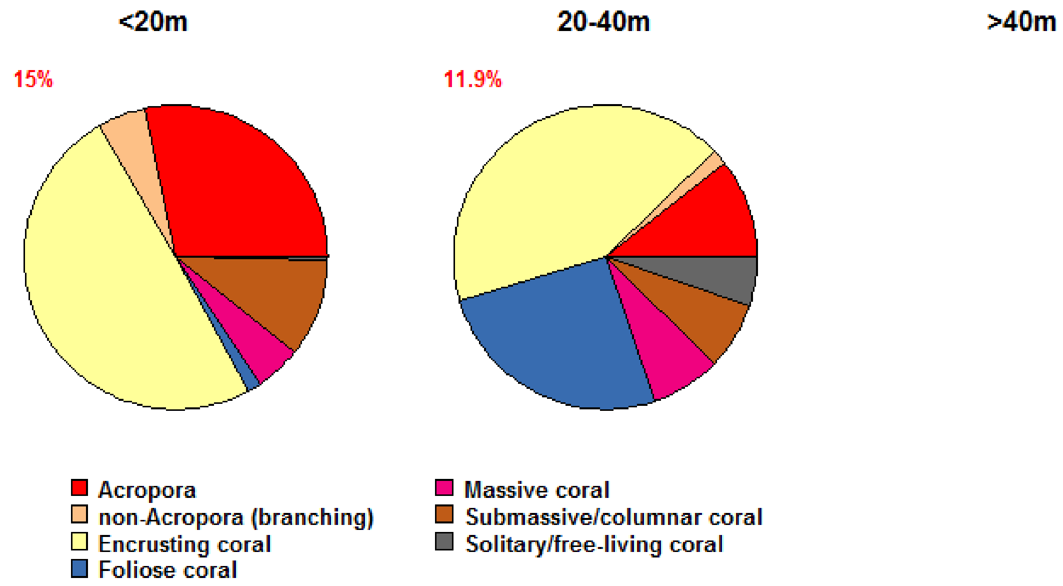


Figure 23: Summary of the proportion of each of the fine-scale categories of hard coral occurring across Tassie Shoal grouped by depth. The proportion of all benthos within each grouping that was represented by hard coral is denoted alongside each pie diagram.

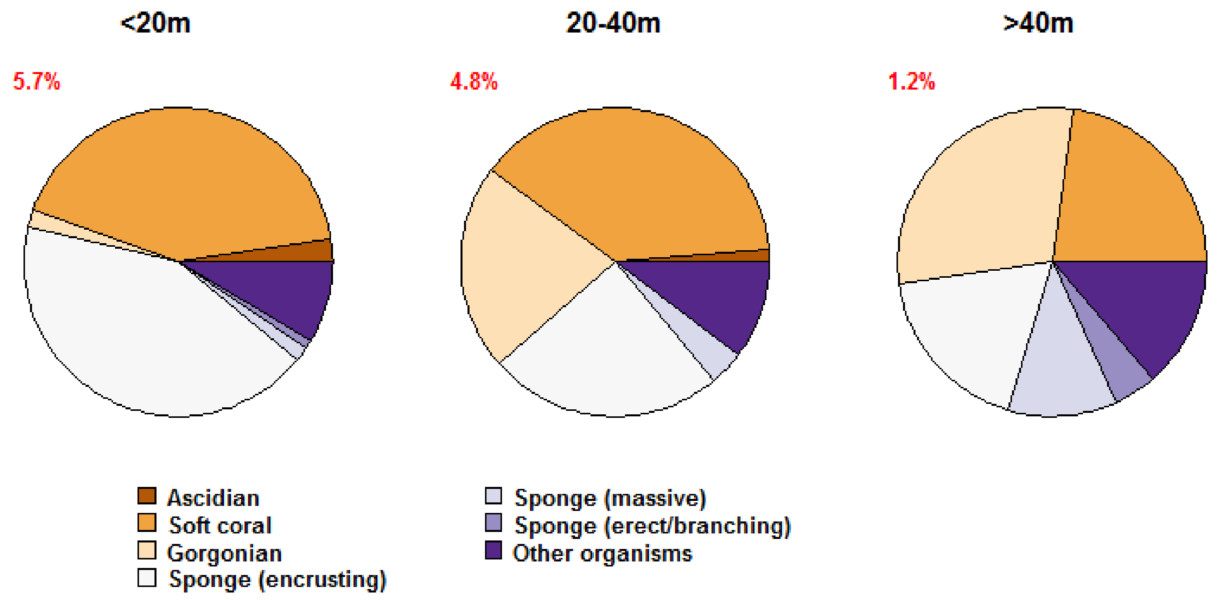


Figure 24: Summary of the proportion of each of the fine-scale categories of other organisms occurring across Tassie Shoal grouped by depth. The proportion of all benthos within each grouping that was represented by other organisms is denoted alongside each pie diagram.

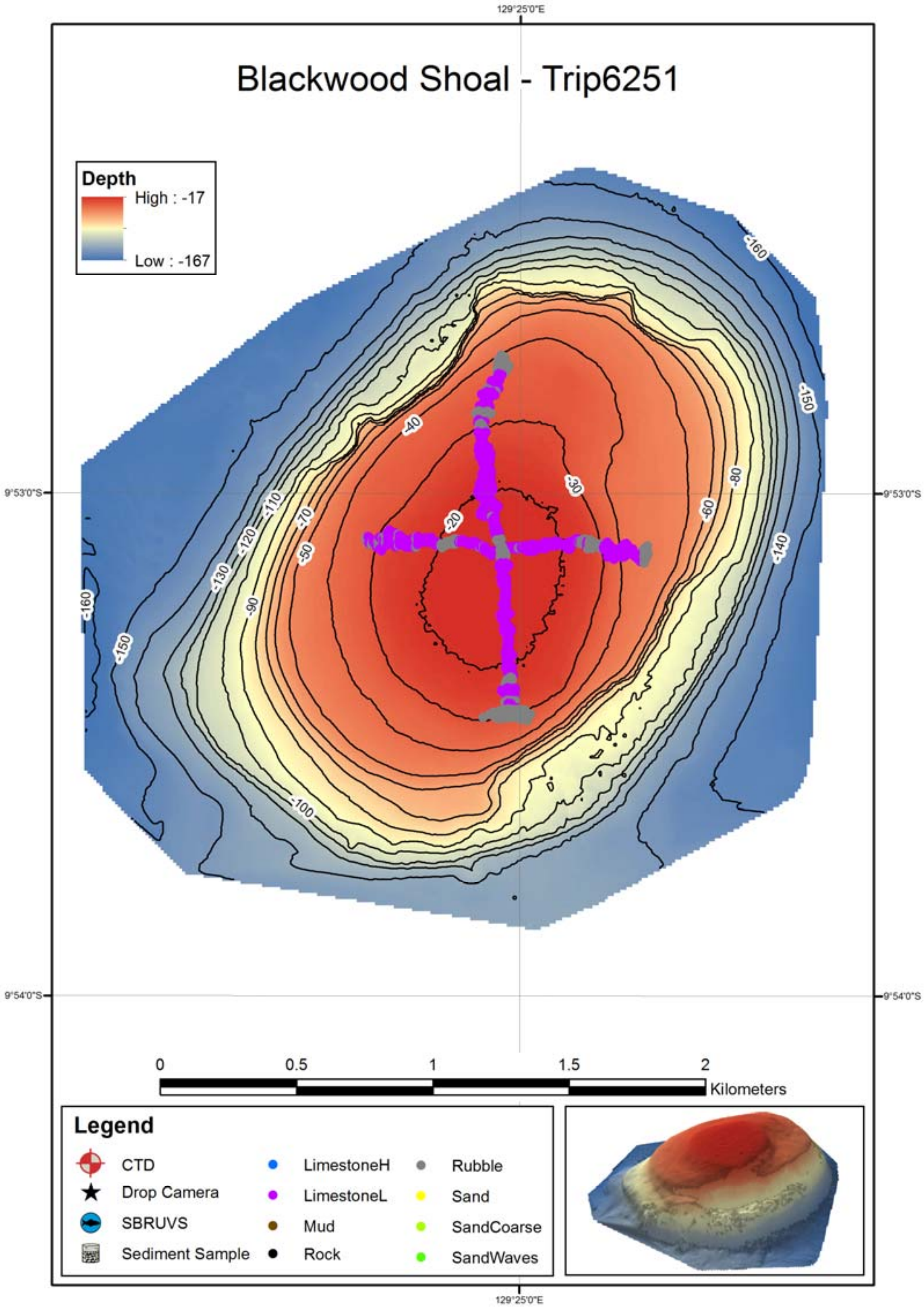


Figure 25: Sampling completed at Blackwood Shoal, which consisted of multibeam mapping and two towed video transects across central plateau region. The bathymetric representation of the shoal was produced from the expedition's multibeam data. A 3D representation of the shoal is shown in the lower right box. Warmer colours associated with shallower depths. The multi-coloured "worms" summarise the benthos as observed from the real-time towed video.

Blackwood Shoal was the smallest and shallowest shoal visited, with only two towed video transects captured representing the broad north-south and east-west axes of the plateau. It was a coral dominated shoal plateau (Figure 26), particularly accross the shallowest area, where coral cover reached 40% in depths <20 m (Figure 27). Coral cover declined to 20% beyond 20 m depth and contributed 17% beyond 40 m depth, where the shallow Acroporid species gave way to a foliaceous dominated assemblage (Figure 29). In contrast the contribution of plants, particularly Halimeda and macroalgae was highest below 20 m depth (Figure 28). Changes with depth in other invertabrate contributions to the benthic ocmmunity, such as soft corals, was also recorded (Figure 30).

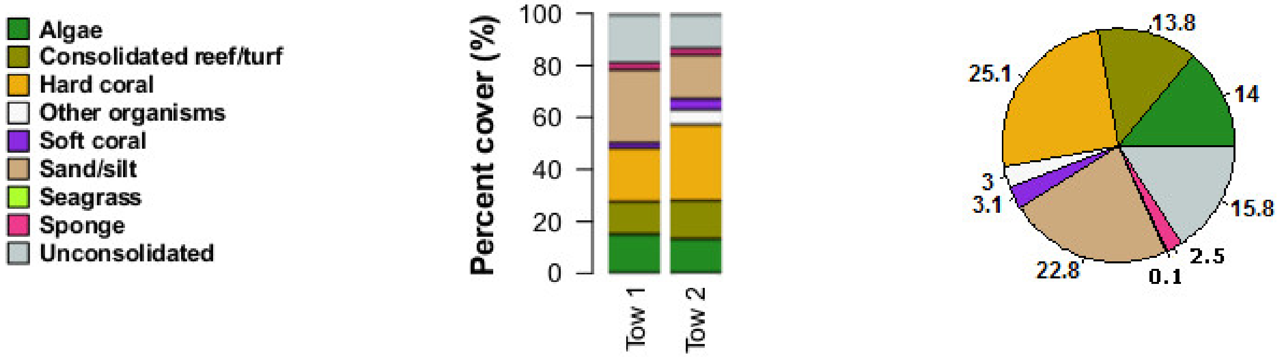


Figure 26: Summary of the abundance (% cover) of the broad-scale categories of benthos at Blackwood Shoal, derived from image analysis of high resolution still photos taken using the AIMS towvideo system. Data for individual transects are shown in the bar plots and overall image level percentages for the shoal in the pie diagram.

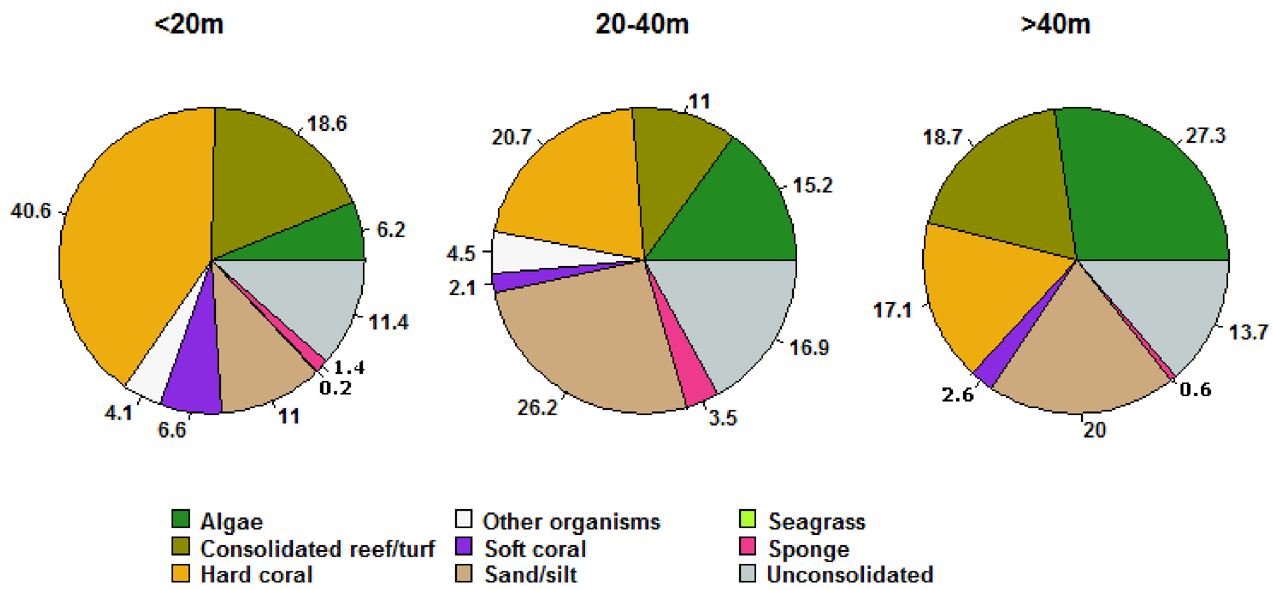


Figure 27: Summary of the relative proportion of each of the broad-scale categories of benthos across depths at Blackwood Shoal.

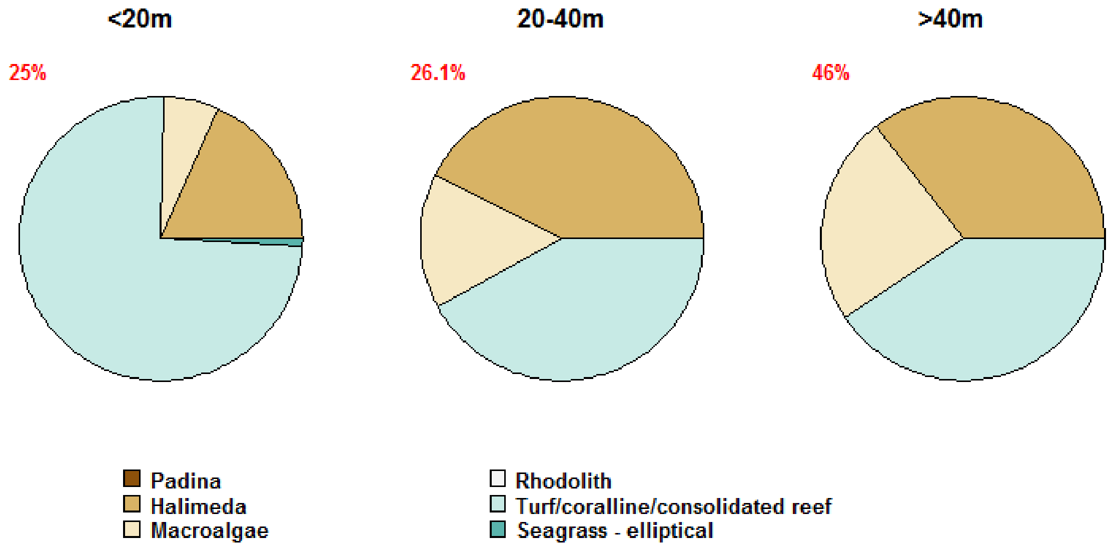


Figure 28: Summary of the proportion of each of the fine-scale categories of algae and seagrass occurring across Blackwood Shoal grouped by depth. The proportion of all benthos within each grouping that was represented by alage and seagrass is denoted alongside each pie diagram.

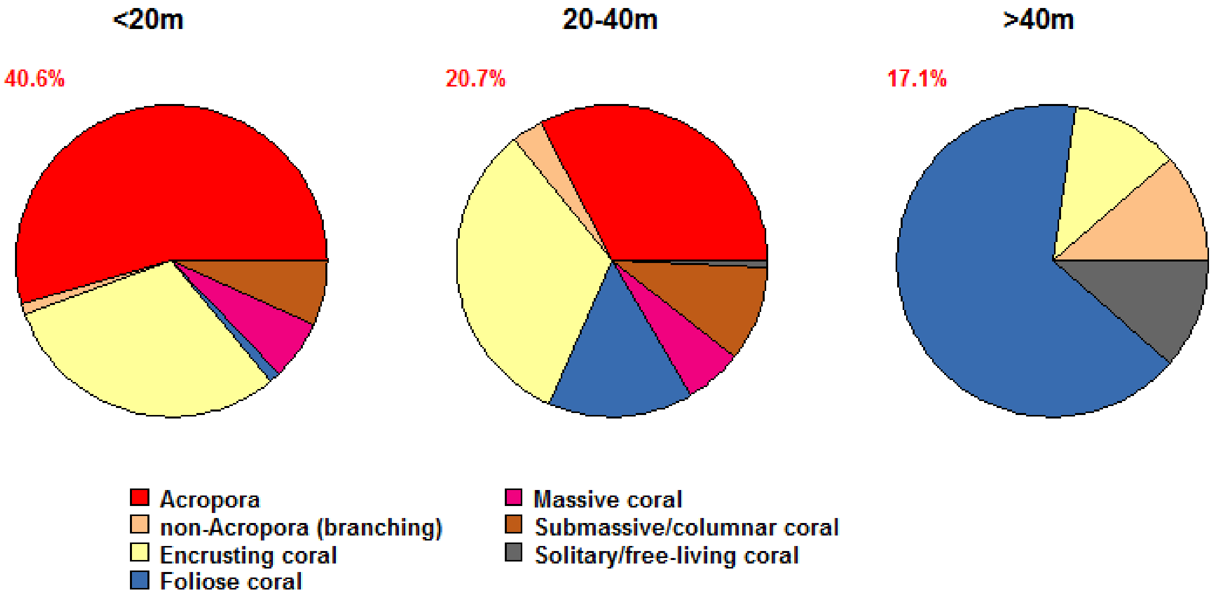


Figure 29: Summary of the proportion of each of the fine-scale categories of hard coral occurring across Blackwood Shoal grouped by depth. The proportion of all benthos within each grouping that was represented by hard coral is denoted alongside each pie diagram.

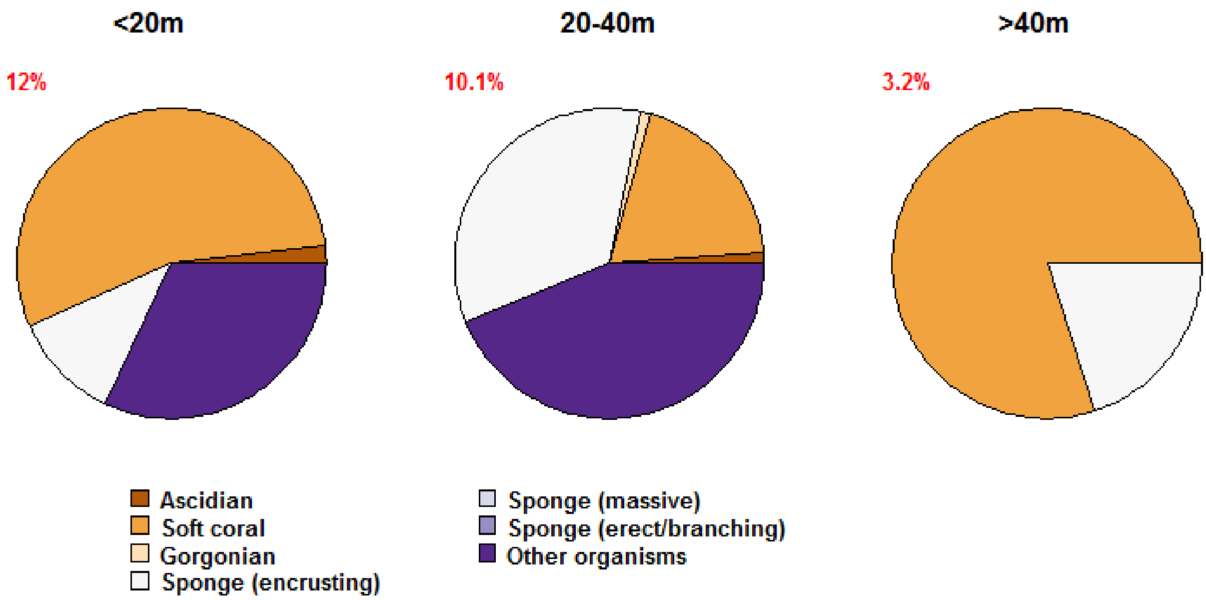


Figure 30: Summary of the proportion of each of the fine-scale categories of other organisms occurring across Blackwood Shoal grouped by depth. The proportion of all benthos within each grouping that was represented by other organisms is denoted alongside each pie diagram.

2.4.1.3 Shoal Benthic Habitat Modelling results

Accuracy estimates for benthic modelling based on downward facing still images and forward facing real time towed video showed each approach performed quite differently. The real time towed video benthic model test indicated very high accuracy results with AUC values all greater than 0.95 (Table 7). Digital still image model performance was much poorer than the real time towed video, with only two of the seven models tested having AUC values over 0.6 (Table 7).

The discrepancy in model accuracy comparing the two image methods is most likely due to biases in the way the biotic habitats are sampled (both based on spatial scale and canopy verses fragmented understory communities). Forward facing towed video provides a broad-scale landscape measure of habitat, well matched to the spatial scale of the multibeam depth and derived habitat metrics (scale 10s-100s of metres, Table 3). Thus the model based on real-time video is sensitive to large three dimensional habitat forming communities such as mature corals, algae and sponges; however understory communities and areas of bare substrate are typically under-represented. In contrast, the downward facing camera picks up fine scale patterns (sub metre) in understory communities, and larger mature three dimensionally complex habitats are under underrepresented. In the model based on digital still data encrusting and juvenile benthic groups are better represented and areas of bare substrate with no-biota (rubble/sand) can make up a very large representation of the points sampled. The combination of broad scale (forward facing real time towed video) and fine scale (downward facing digital stills) provide a holistic and less biased view of community composition. To aid this interpretation a couple of measures could be used to increase the model accuracy of the towed video digital stills; for example for each image, thresholding the five points per image to classify each image into one habitat type based on a majority rule. The second method would be to aggregate habitat classifications based on a range of neighbouring images. The appropriate size of the neighbourhood can be determined based on a spatial autocorrelation metric such as a variogram and may vary based on the spatial pattern and patchiness of different biotic groups (see Holmes et al 2007 for methods and interpretation).

Spatial representations of probabilistic models from real time video and digital stills are shown for Evans Shoal in Figure 32 and 33, for Tassie Shoal in Figures 35 and 36 and for Blackwood Shoal in Figures 38 and 39. A heat map with Euclidian distance based cluster analysis was used to summarise relative variable importance (scaled model accuracy "Gain" index) for model prediction of biotic groups from multibeam is shown in Figure 40 for digital stills and Figure 41 for real time towed video. More detailed information on model accuracy (AUC plot), variable importance (plot of gain index for all multibeam variables) and the partial response of each biotic group to the most important six variables are detailed in Appendix 3 (Figures A3.1-A3.6 for digital stills and Figures A3.7-A3.12 for real time towed video).

For habitat models based on digital stills (Figures 32, 35 and 38), some caution must be used when interpreting the relationships between the habitat variables and biotic groups as poor model performance effects the accuracy of these relationships compared to the real time towed video. As a result, the relationship between multibeam variables and each biotic group is quite variable and the cluster analysis (Figure 40) identified four main groups in the dendogram. Firstly there is the "Macroalage and Sponge group" where two variables "plan" and "rng50" dominate. These variables are both measures of rugosity and for this group, identify a correlation with areas that are flatter with low rugosity. The second cluster "Tabulate acropora" is highly correlated with the variable mean50, which is a broad scale indicator of depth dependence with probability of occurrence increasing with depths up to 50 m (Figure A3.3). The third cluster contains "Branching acropora" and "All hard corals", and are most highly correlated to mean50, asp and rng50. This cluster shows a broad-scale depth relationship (mean 50) found between 20-60 meters, in areas of higher rigosity (rng50) and more commonly on the east and west edges of the shoals (asp) (Figures A3.1 and A3.4). The final cluster contains "Turf and coralline algae", "Soft corals" and "other corals" (such as free living species). This group is typified by its relationship with rng50 and rng25 plus asp showing correlation with slopes (indicated by rng values) particularly a north facing aspect (Figures A3.2, A3.6 and A3.7).

For habitat models based on real time towed video (Figures 33, 36 and 39) the relationships between multibeam variables and each biotic group identified two distinct clusters (Figure 41). The first cluster contains the main coral groups (dense, medium and sparse) where the most important predictor variables are mean50 and rng50. The patterns here show an increase in coral probability over certain depth distributions (less than 50 m and greater than 50 m to 75 m; Figures A3.10, A3.12 and A3.13) which are likely to be indicative of two different types of coral communities and may also reflect the different depth profiles at each shoal. The probability of coral occurrence increases with broad scale rugosity indicative of three dimensionally complex areas and slopes. The second cluster contains the "medium" and "sparse filter feeder" communities as well as the "Medium hard coral and Halimeda community". This cluster is also characterised by the importance of mean50 and rng50 with an increase in probability of occurrence with a decrease in depth from 50 m but this is contrasted in most cases (the exception being Medium hard coral and Halimeda community) in areas of lower rugosity (rng50) typified by flatter lagoon and rubble zone areas (Figures A3.8, A3.9 and A3.11).

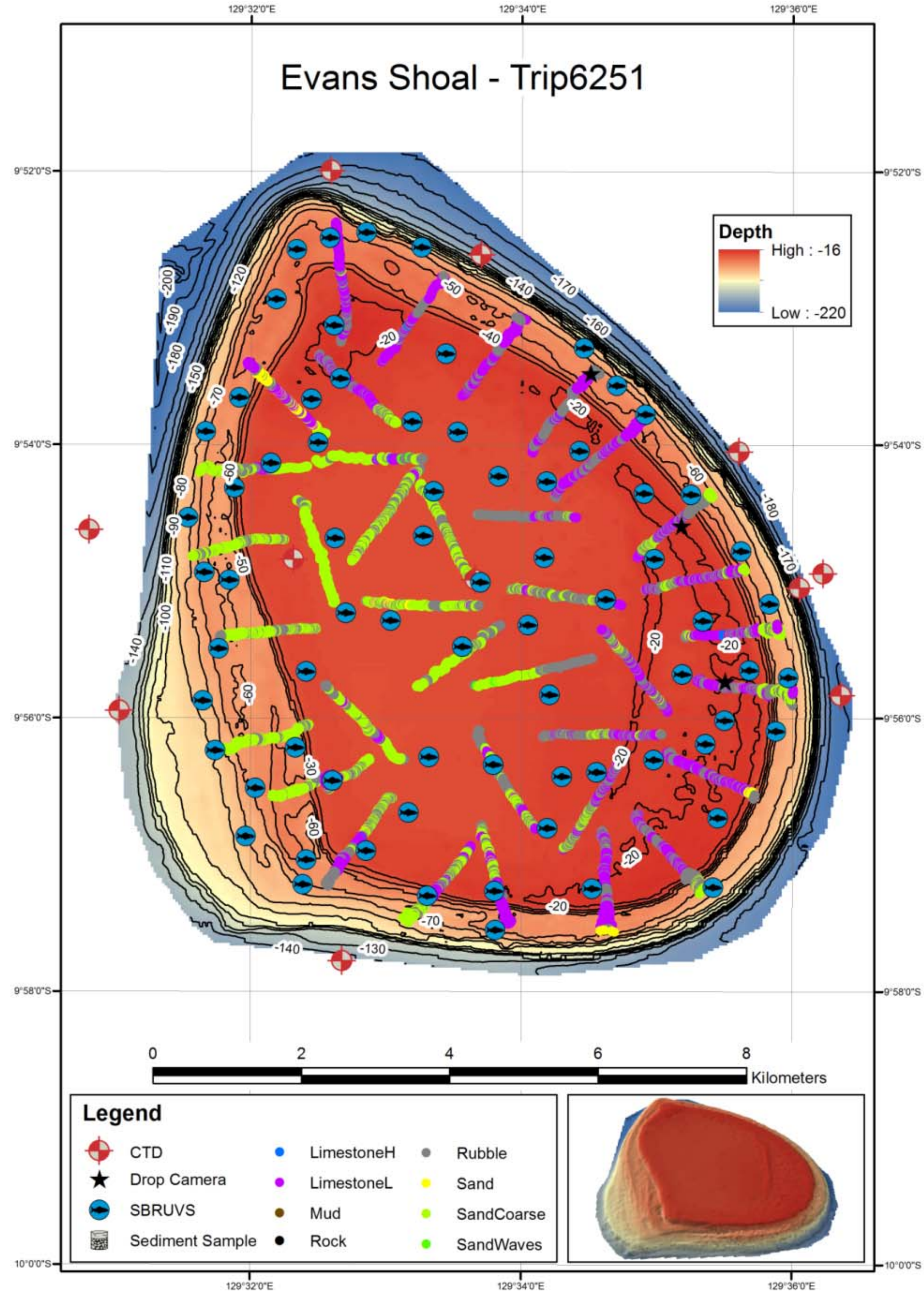


Figure 31: Sampling completed at Evans Shoal. Towed video and SBRUVS stations are overlaid on bathymetry of the shoal produced from the expedition's multibeam data. A 3D representation of the shoal is shown in the lower right box. Warmer colours associated with shallower depths.

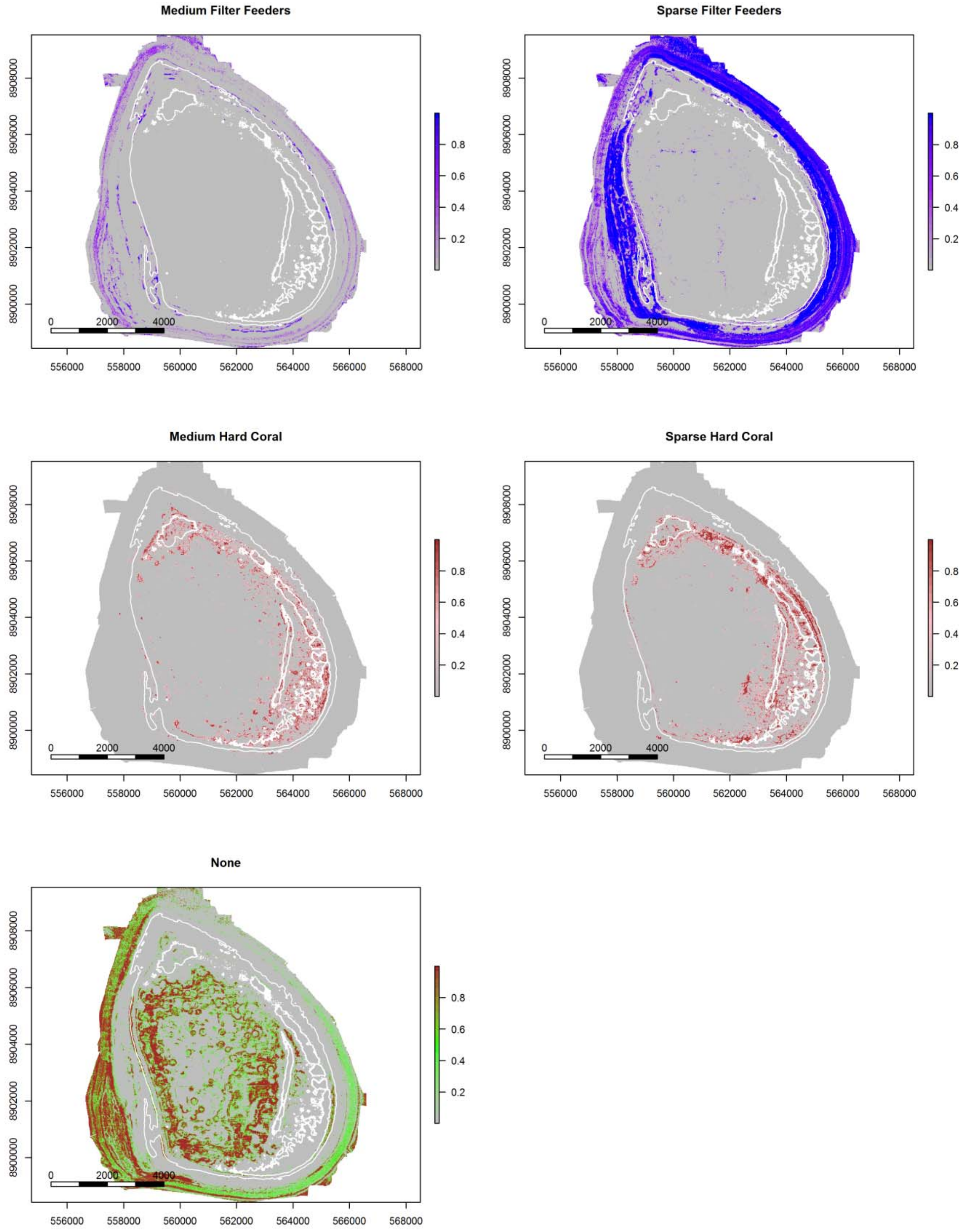


Figure 32: Evans Shoal - modelled spatial distributions describing the presence/absence probabilities for major benthic habitat classes generated using oblique forward facing real-time scored towed video. The 20 m & 50 m depth contours shown in white.

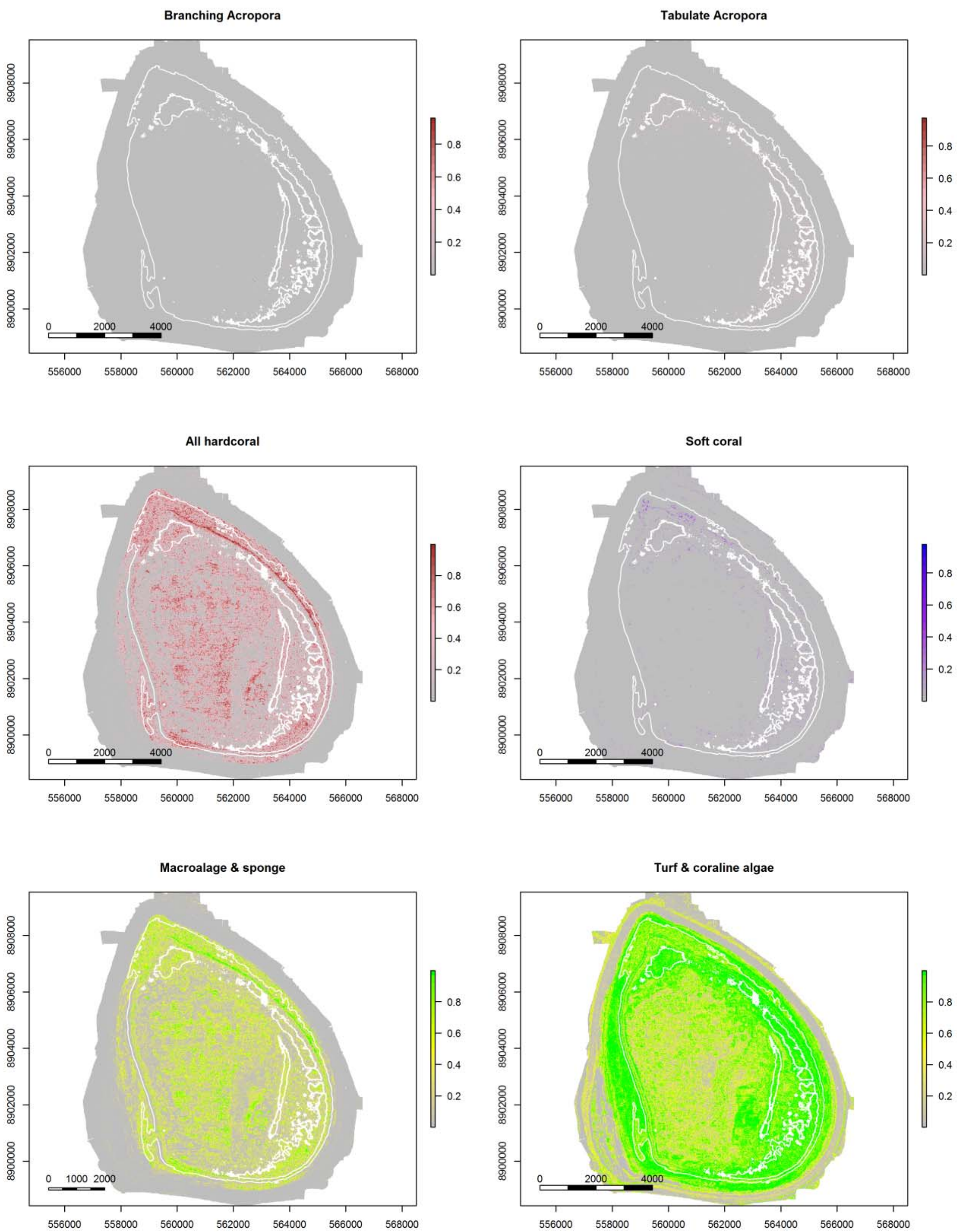


Figure 33: Evans Shoal - modelled spatial distributions describing the presence/absence probabilities for major benthic habitat classes generated using post processed downward facing digital stills. The 20 m & 50 m depth contours shown in white

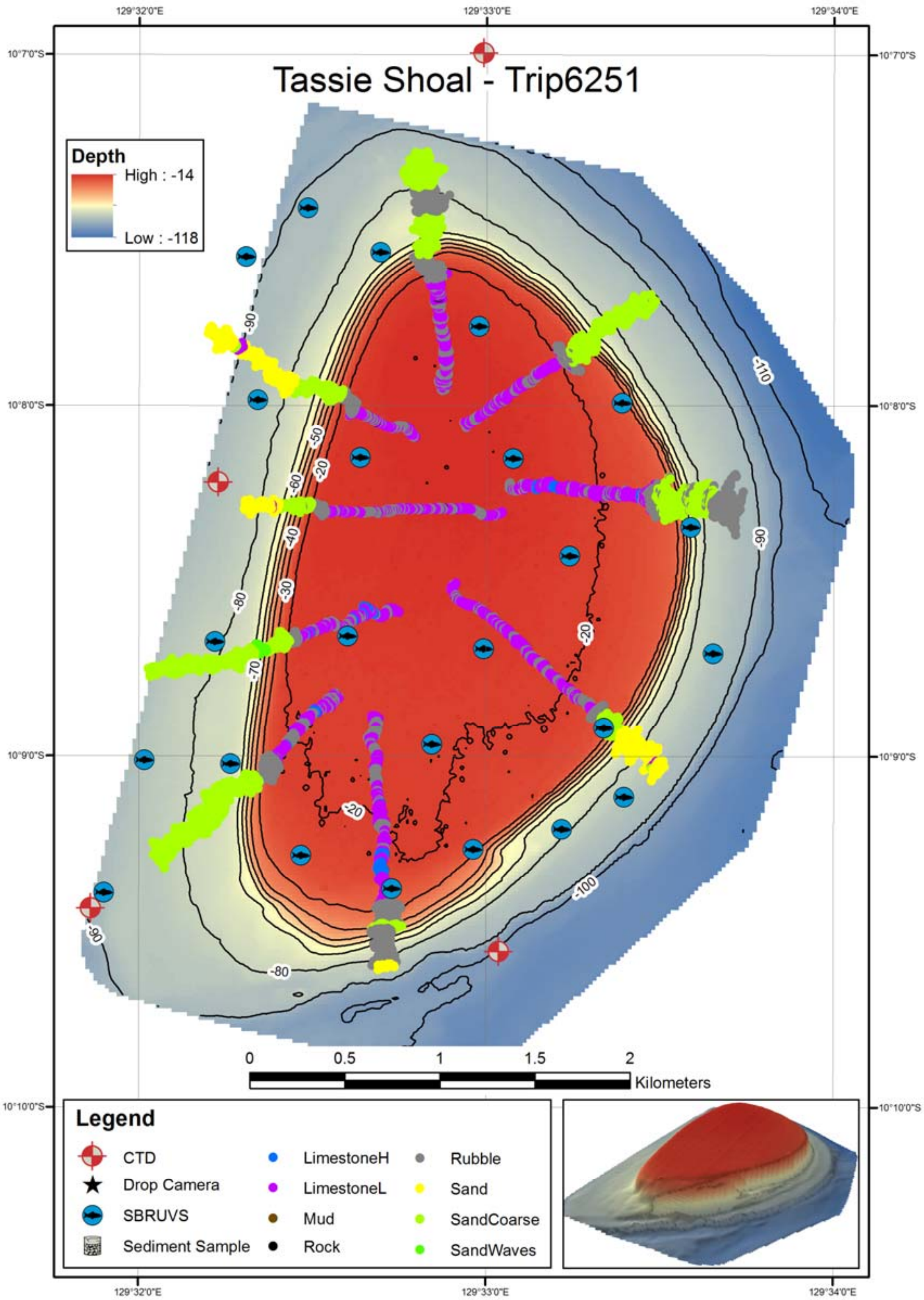


Figure 34: Sampling completed at Tassie Shoal. Towed video and SBRUVS stations are overlaid on bathymetry of the shoal produced from the expedition's multibeam data. A 3D representation of the shoal is shown in the lower right box. Warmer colours associated with shallower depths.

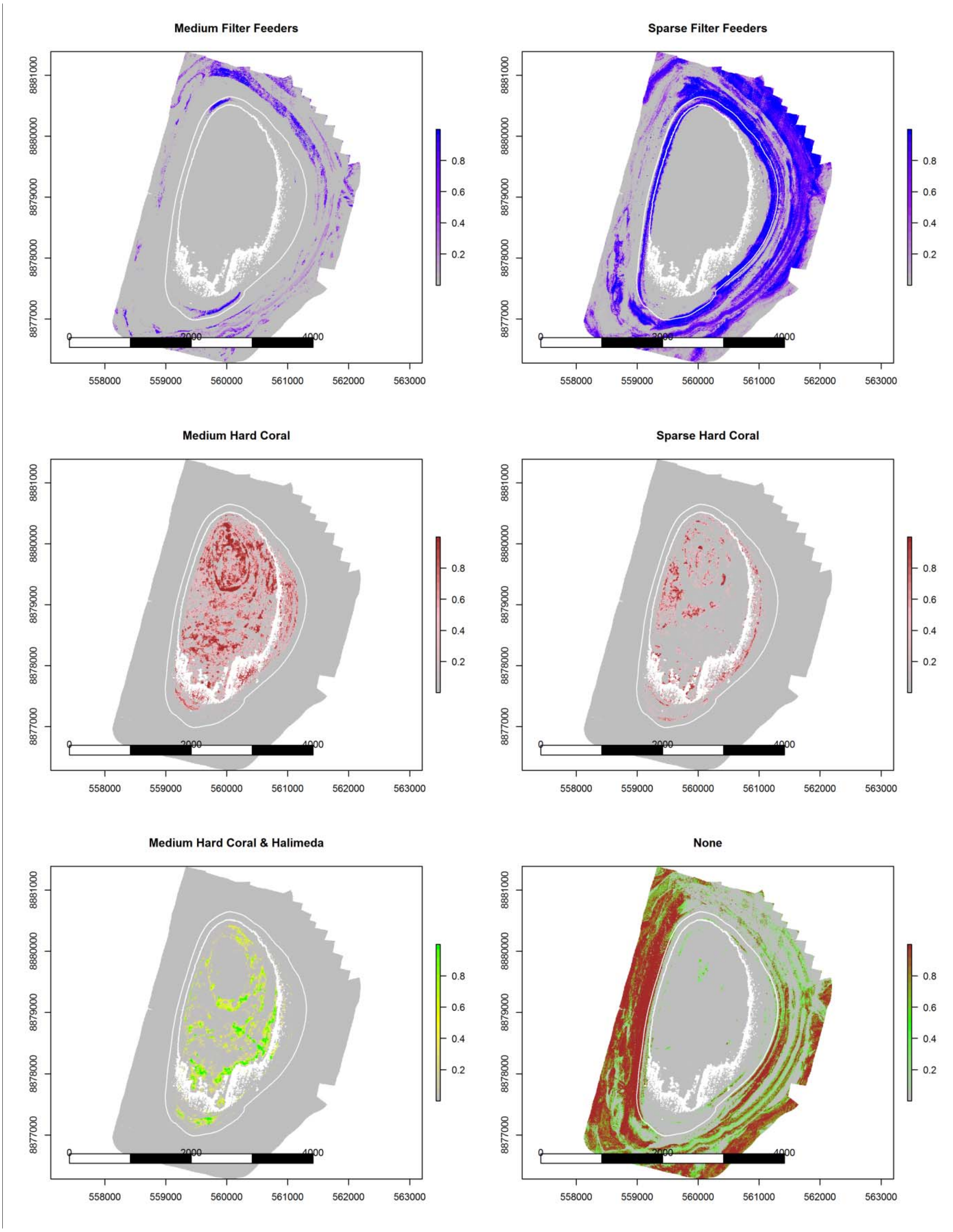


Figure 35: Tassie Shoal - modelled spatial distributions describing the presence/absence probabilities for major benthic habitat classes generated using oblique forward facing real-time scored towed video. The 20 m & 50 m depth contours shown in white.

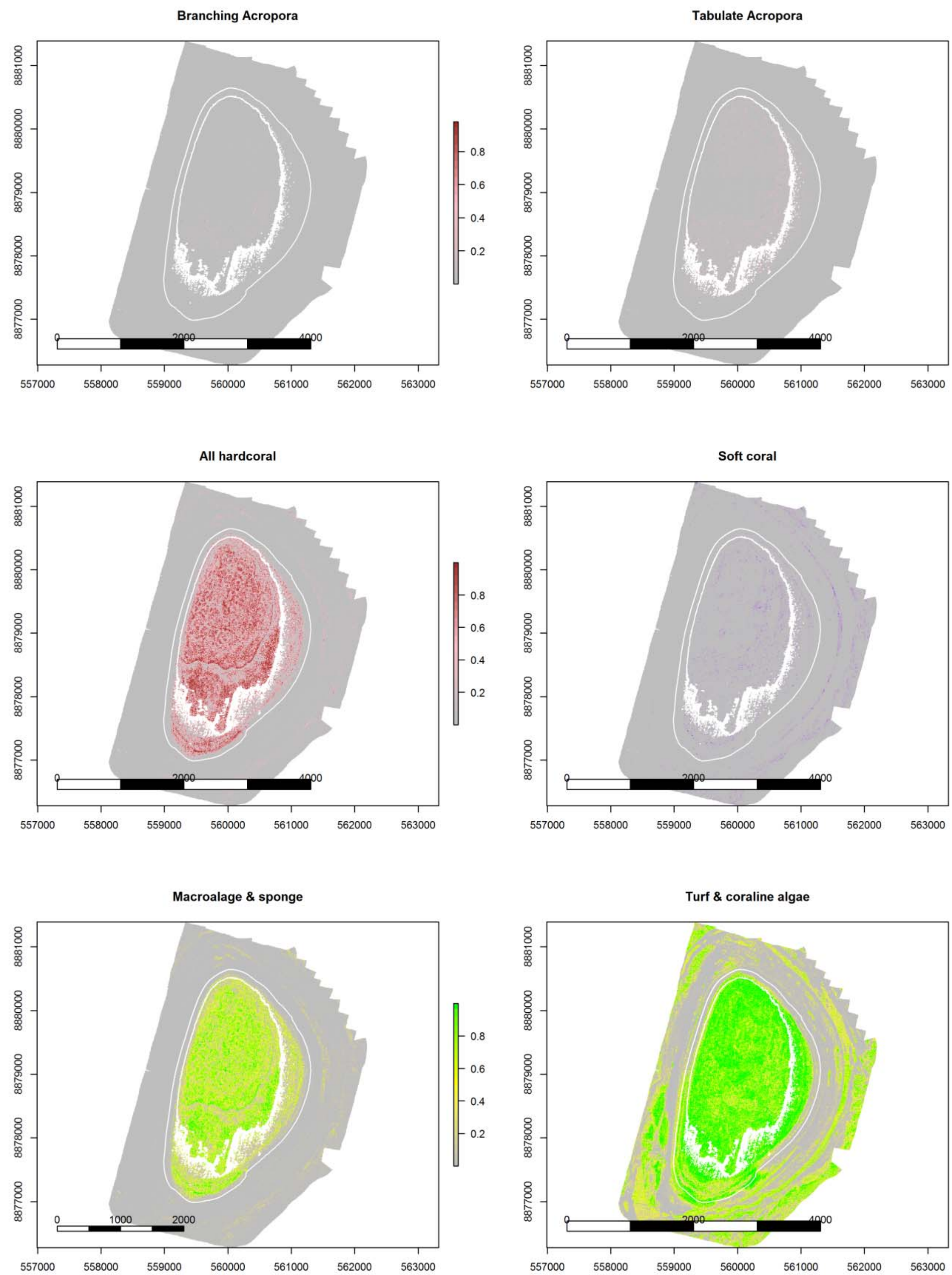


Figure 36: Tassie Shoal - modelled spatial distributions describing the presence/absence probabilities for major benthic habitat classes generated using post processed downward facing digital stills. The 20 m & 50 m depth contours shown in white.

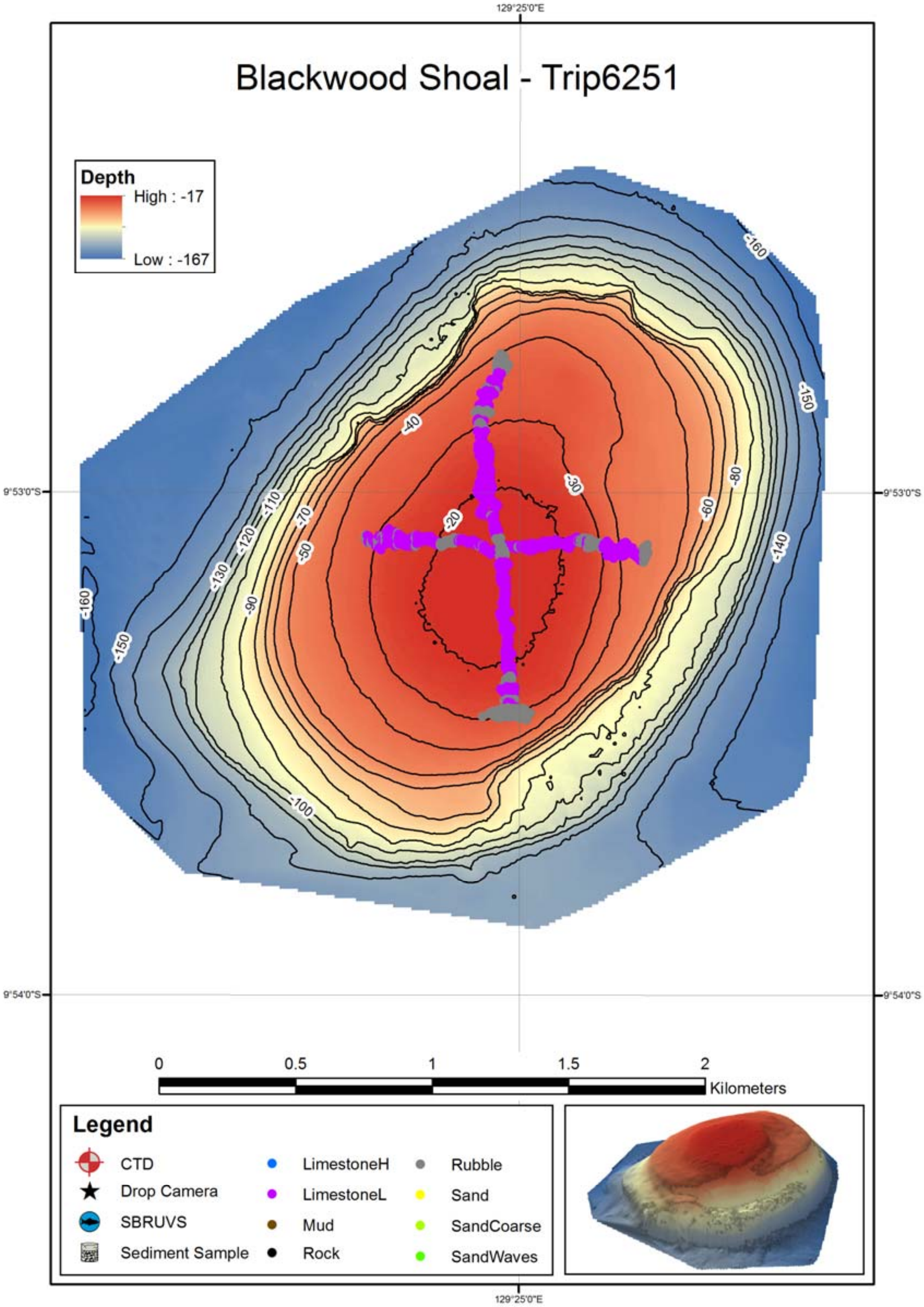


Figure 37: Sampling completed at Blackwood Shoal, which consisted of multibeam mapping and two towed video transects across central plateau region. The bathymetric representation of the shoal was produced from the expedition's multibeam data. A 3D representation of the shoal is shown in the lower right box. Warmer colours associated with shallower depths.

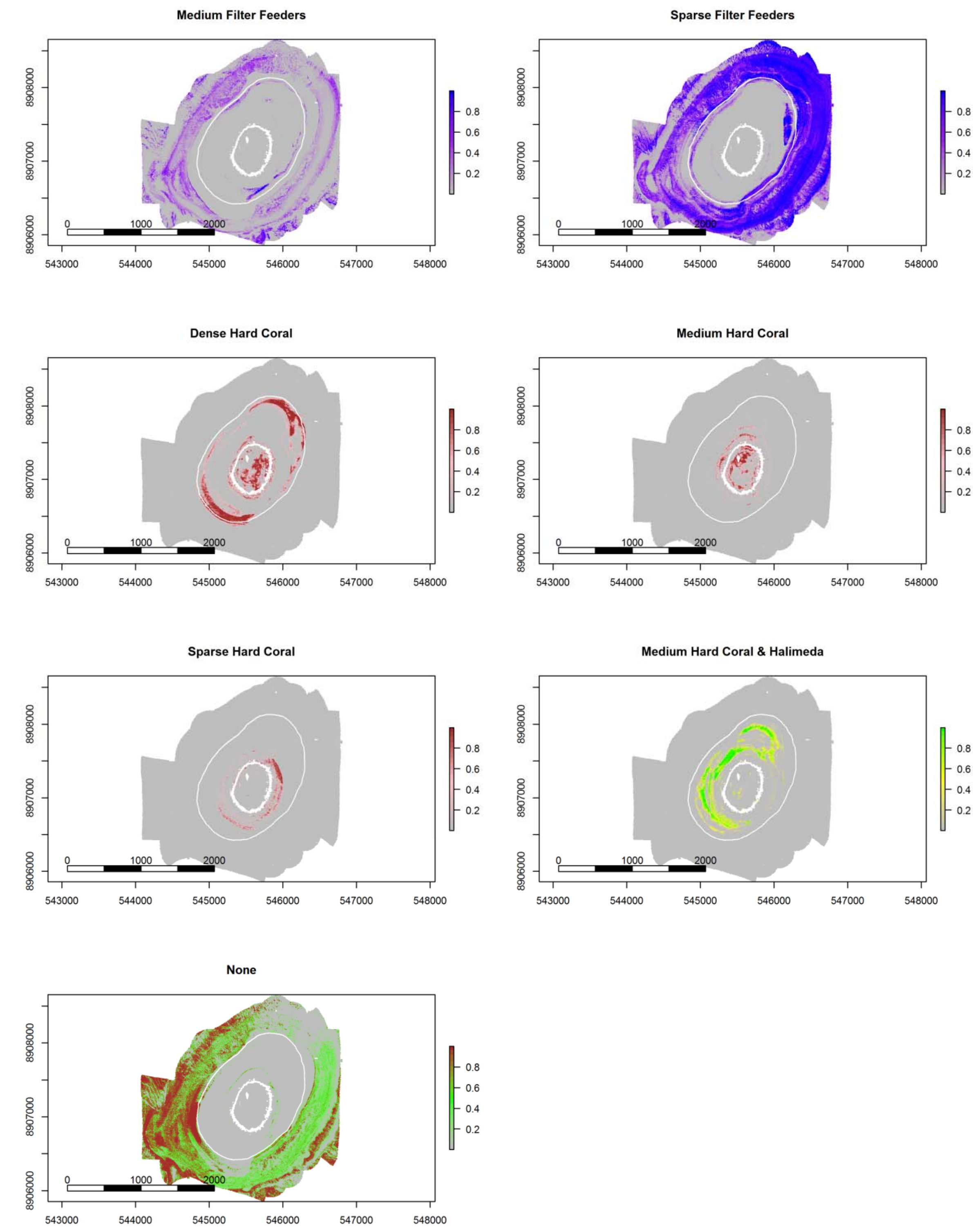


Figure 38: Blackwood Shoal - modelled spatial distributions describing the presence/absence probabilities for major benthic habitat classes generated using oblique forward facing real-time scored towed video. The 20 m & 50 m depth contours shown in white.

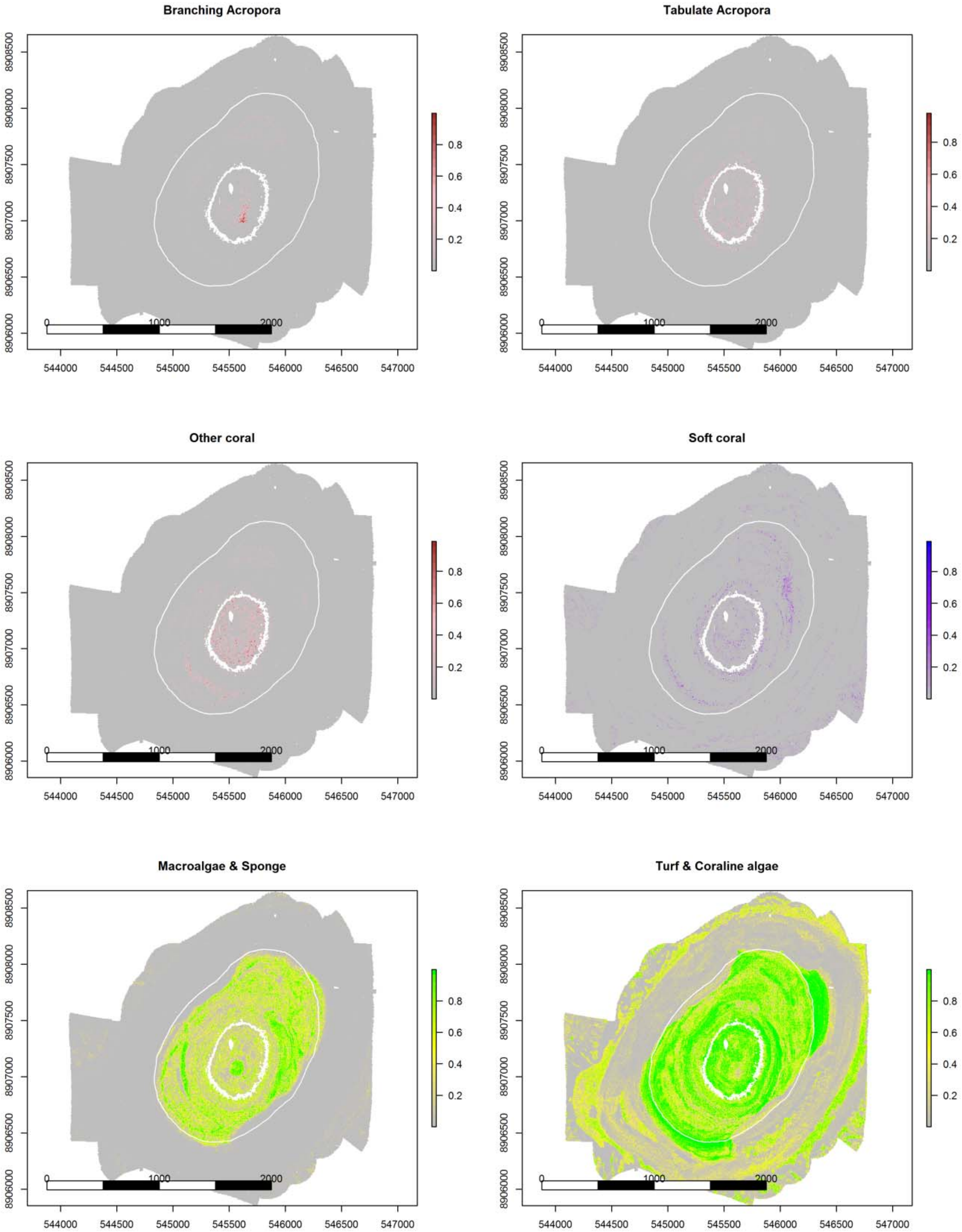


Figure 39: Blackwood Shoal - modelled spatial distributions describing the presence/absence probabilities for major benthic habitat classes generated using post processed downward facing digital stills. The 20 m & 50 m depth contours shown in white.

Table 7. Boosted model (xgboost) model accuracy estimates (AUC and Kappa) comparing towed video and digital stills biota measurement with full resolution multibeam depth and derivatives (2 m pixel at Blackwood, Evans and Tassie shoal) and interpolated multibeam depth and derivatives (50 m pixel at Cape Helveticus and Goodrich Bank).

Method	Sites	Biotic Group	Threshold	% correct	sensitivity	specificity	Kappa	AUC
Digital Stills 2 m bin multibeam	Blackwood, Evans & Tassie	All hard corals	0.50	0.50	0.56	0.49	0.03	0.50
Digital Stills 2 m bin multibeam	Blackwood, Evans & Tassie	Soft corals	0.50	0.95	0.00	1.00	0.00	0.50
Digital Stills 2 m bin multibeam	Blackwood, Evans & Tassie	Tabulate acropora	0.50	0.95	0.00	1.00	0.00	0.64
Digital Stills 2 m bin multibeam	Blackwood, Evans & Tassie	Branching Acropora	0.50	0.98	0.00	1.00	0.00	0.66
Digital Stills 2 m bin multibeam	Blackwood, Evans & Tassie	Macroalgae and sponge	0.50	0.76	0.01	0.98	0.20	0.51
Digital Stills 2 m bin multibeam	Blackwood, Evans & Tassie	Other corals	0.50	0.97	0.00	1.00	0.00	0.55
Digital Stills 2 m bin multibeam	Blackwood, Evans & Tassie	Turf and coralline algae	0.50	0.47	1.00	0.00	0.00	0.50
Real-time towed video 2 m bin multibeam	Blackwood, Evans & Tassie	Medium Filter feeders	0.50	0.99	0.60	1.00	0.69	0.99
Real-time towed video 2 m bin multibeam	Blackwood, Evans & Tassie	Sparse filter feeders	0.50	0.97	0.85	0.98	0.84	0.99
Real-time towed video 2 m bin multibeam	Blackwood, Evans & Tassie	Dense Hard Coral	0.50	0.98	0.77	1.00	0.83	0.99
Real-time towed video 2 m bin multibeam	Blackwood, Evans & Tassie	Medium Hard Coral & Halimeda	0.50	0.98	0.73	1.00	0.80	0.99
Real-time towed video 2 m bin multibeam	Blackwood, Evans & Tassie	Medium Hard Coral	0.50	0.95	0.76	0.98	0.78	0.97
Real-time towed video 2 m bin multibeam	Blackwood, Evans & Tassie	Sparce Hard Coral	0.50	0.95	0.75	0.98	0.78	0.97
Real-time towed video 2 m bin multibeam	Blackwood, Evans & Tassie	None	0.50	0.96	0.89	0.98	0.87	0.99
Real-time towed video 50 m bin multibeam	Cape Helveticus & Goodrich Bank	Burrowers	0.50	0.99	0.46	1.00	0.55	0.99
Real-time towed video 50 m bin multibeam	Cape Helveticus & Goodrich Bank	Dense filter feeders	0.50	1.00	0.38	1.00	0.34	0.85
Real-time towed video 50 m bin multibeam	Cape Helveticus & Goodrich	Medium filter feeders	0.50	0.95	0.74	0.98	0.77	0.98

	Bank							
Real-time towed video 50 m bin multibeam	Cape Helveticus & Goodrich Bank	Sparse filter feeders	0.50	0.90	0.79	0.94	0.74	0.96
Real-time towed video 50 m bin multibeam	Cape Helveticus & Goodrich Bank	No modelled benthos	0.50	0.93	0.95	0.91	0.86	0.98

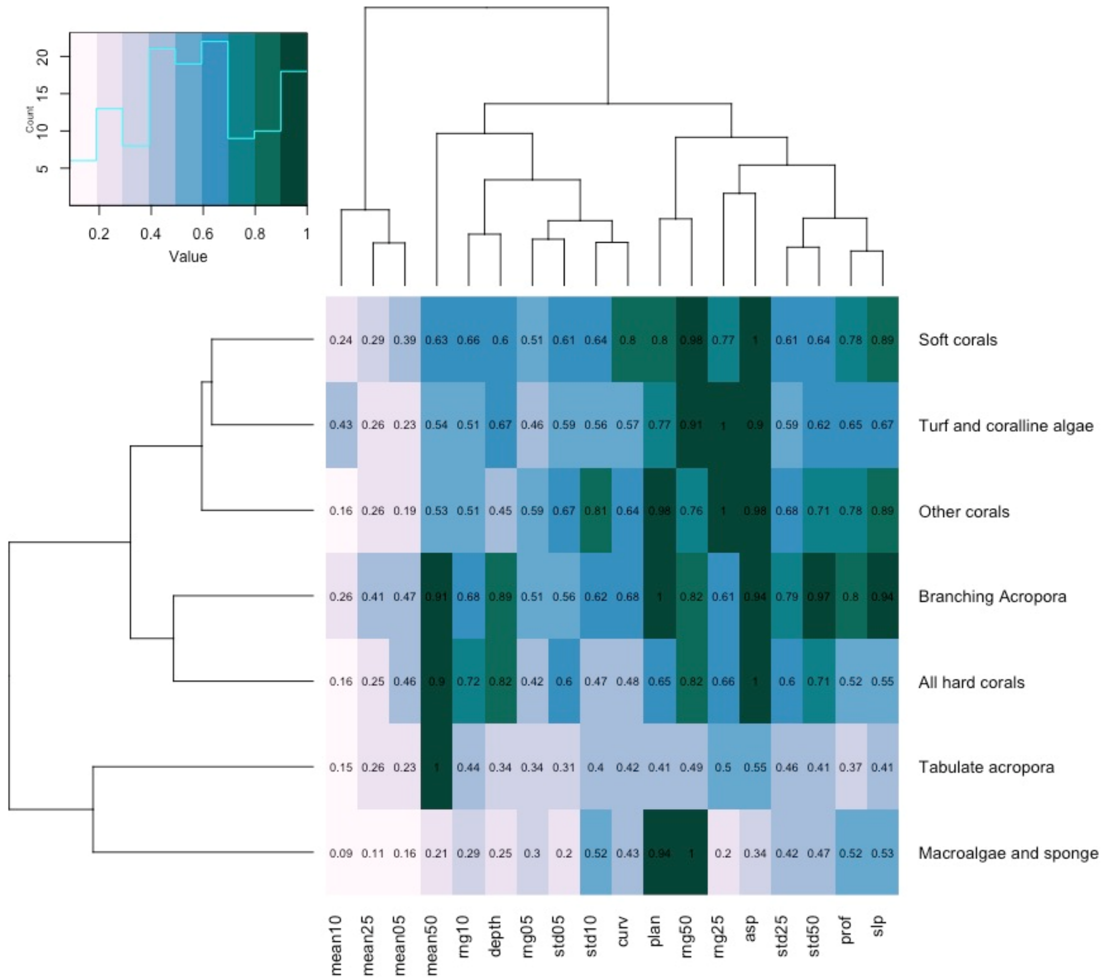


Figure 40: Heatmap with Euclidean distance cluster analysis showing the relative importance for predictor variables (0-1 from least to most important) for towed digital still based benthic habitat models of Blackwood, Evans and Tassie shoal. Benthic groups are on the y-axis and 2 m multibeam depth and derivatives (see Table 3 for descriptions) are on the x-axis.

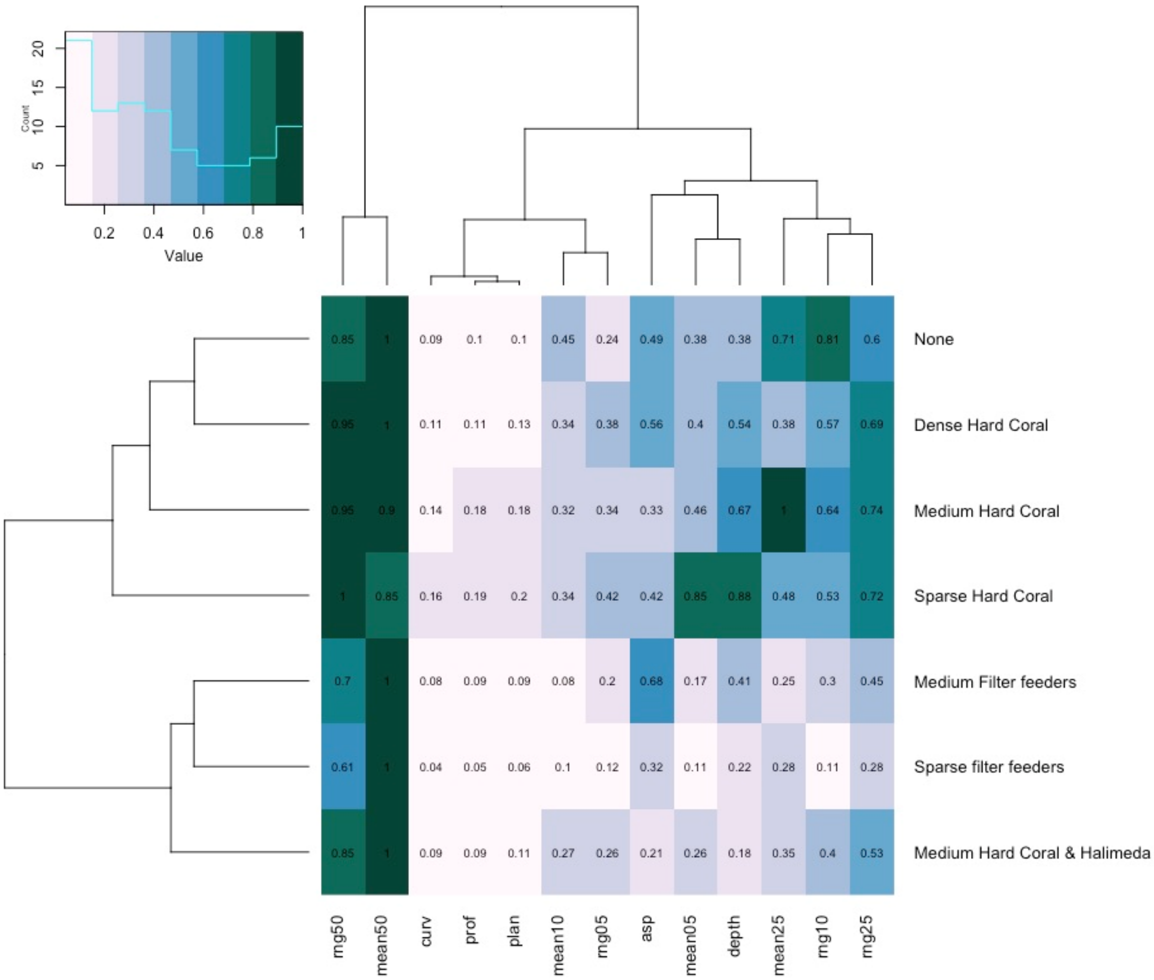
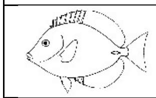
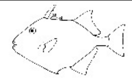
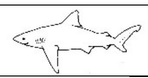
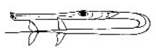
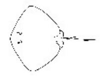
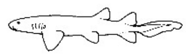
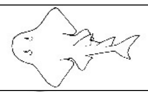


Figure 41: Heatmap with Euclidean distance cluster analysis showing the relative importance for predictor variables (0-1 from least to most important) for towed video real-time classification based benthic habitat models of Blackwood, Evans and Tassie shoal. Benthic groups are on the y-axis and 2 m multibeam depth and derivatives (see Table 3 for descriptions) are on the x-axis.

2.4.1.4. Fish communities

A total of 7282 fish from 304 species were recorded in interrogation of 95 SBRUVS videos (72 from Evans shoal and 23 from Tassie shoal). These included a diverse range of demersal and semi-pelagic fishes, sharks, rays and sea snakes (see Appendix I for full list). The bony fishes were most numerous (Actinopterygii; 7175 individuals) followed by the sharks and rays (Chondrichthyes; 81 individuals) and sea snakes (Reptilia; 26 individuals) (Table 8).

Table 8 Summary of each taxonomic Order recorded on 95 SBRUVS samples from Evans Shoal and Tassie Shoal, in decreasing order of diversity.

	Order	Common Name	*n* families	*n* genera	*n* species	*n* individuals
	Perciformes	Perch-like fishes	30	102	261	6565
	Tetraodontiformes	Puffers and triggerfish	3	13	21	396
	Carcharhiniformes	Sharks	2	5	6	62
	Anguilliformes	Moray eels	1	3	5	8
	Beryciformes	Squirrelfish	1	1	1	3
	Clupeiformes	Herrings	1	1	1	200
	Gasterosteiformes	Flutemouths	1	1	1	3
	Myliobatiformes	Rays	1	2	2	10
	Orectolobiformes	Wobbegong sharks	1	1	1	8
	Rajiformes	Shovelnose rays	1	1	1	1
	Squamata	Sea snakes	1	4	4	26

Models of richness and abundance as a function of "habitat"

The most parsimonious models of richness and transformed abundance were additive (including only main effects, not any interactions). The final models included only 10 environmental predictors each, but only the first few of these had relatively high influence on the univariate responses.

Species richness was influenced most by the calcareous reef composition of the substratum, and the percentage cover of hard coral on this substratum (Figure 42). The mean species richness in the entire dataset was 21.38 species, with a variance of 258.8 species. The model explained about 62% of this variation in species richness. Species richness was above average for SBRUVS where %calcareous substrata was about 40%, and where %coral cover was about 20%. The partial effects plots show the single influence of one predictor with all other predictors held to their mean value. These influences were about eight extra species above average (~21) once seabed composition exceeded 60% calcareous reef, and about five extra species once %coral cover exceeded 40% (Figure 44). Depths shallower than ~30 m had higher, steeply rising, richness, and bare seabeds had lower than average richness.

Transformed fish abundance was influenced most by the presence of any epibenthos on the seafloor (%bare) and by calcareous reef composition of the substratum. Low values of %bare indicated that the field of view of the SBRUVS was largely covered by epipenthos of any category (e.g. macroalgae, filter feeders) – not just coral. High values of %bare were open seafloors of sand, gravel, or rubble with little or no epibenthic cover. The model explained about half (50.7%) of the variation in transformed fish abundance. Abundance was above average for SBRUVS where there was more than 20% of the seabed in the field of view covered by any category of epibenthos. At this coverage, transformed fish abundance rose above the average transformed abundance by about 0.4 units, or 15%. Back-transformation of the slopes in Figure 45 showed that samples where %bare~20% had ~60-70 fish (about 20-40%) more than the mean (~50 fish). The seabed classifications where %calcareous substrata exceeded 40% also had above average fish abundance (Figure 43). Depth had a lesser influence, but fish abundance was below average in deeper waters and above average in shallows under 30 m.

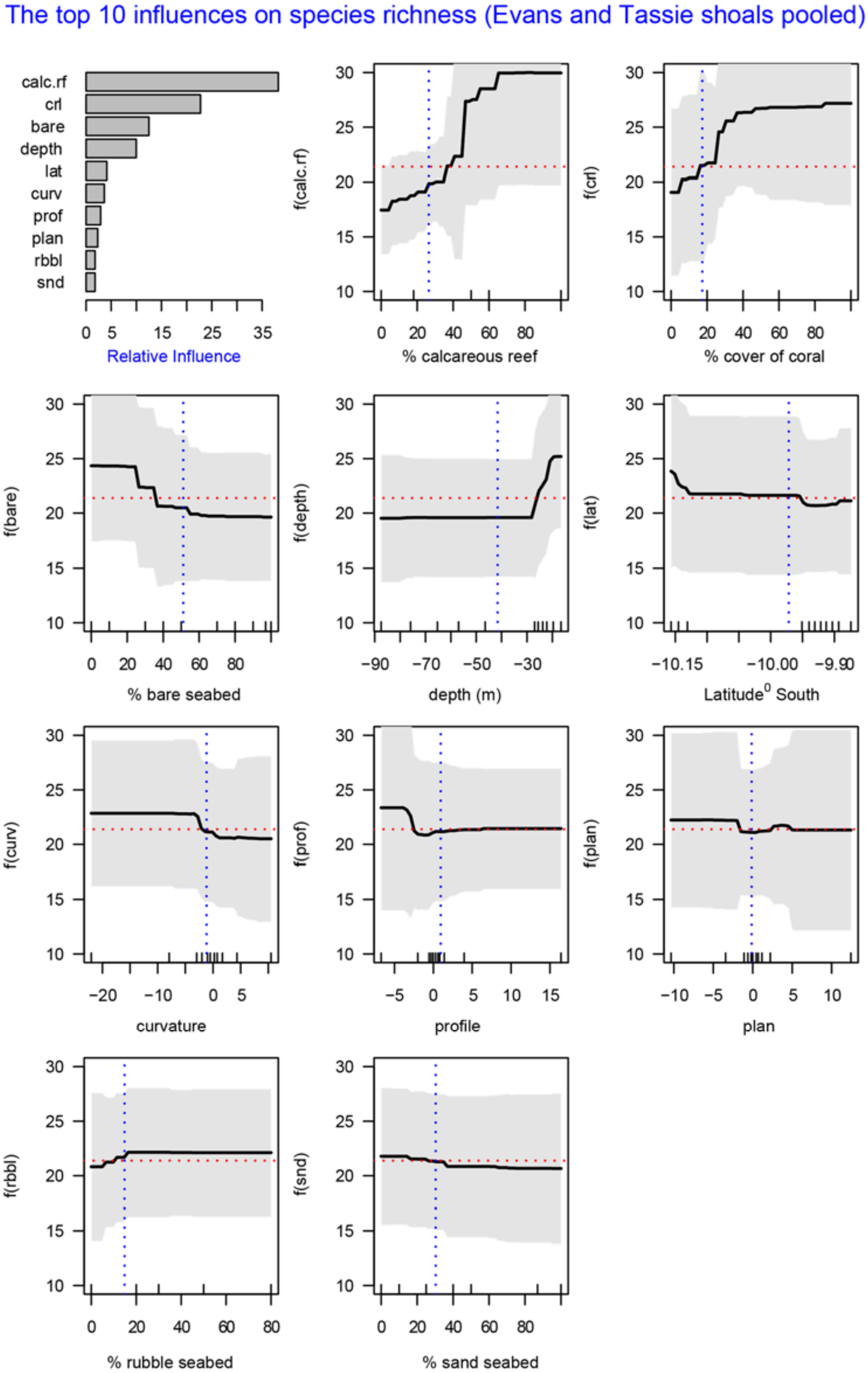


Figure 42: Partial dependency plots of the 10 major influences on species richness. The reduced model of 10 covariates was applied. Horizontal dotted lines (red) show the mean richness across all SBRUVS drops. Vertical dotted lines (blue) show the mean value for each predictor. The response lines shown the relationship of richness as a function of each predictor, with the influence of all other predictors held to a constant (ie accounted for). Shading around the response lines are 2 standard errors. Calcareous composition of the seabed, and percentage cover of coral, were the major drivers of species richness.

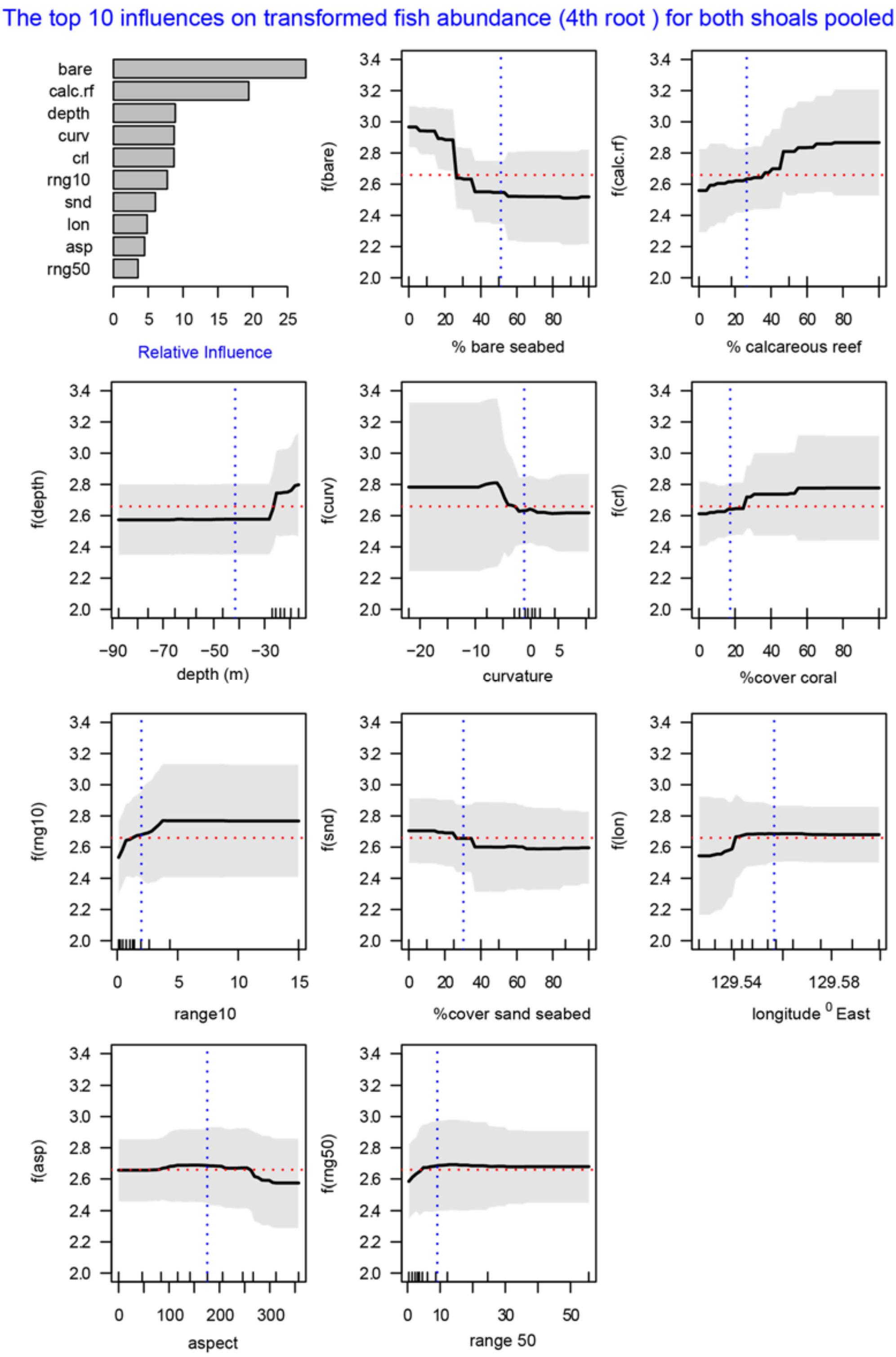


Figure 43: Partial dependency plots of the 10 major influences on total abundance (MaxN 4th root transformed). All conventions follow Figure 42. The y-scale is in the transformed units of abundance. SBRUVS with low %bare seabed (ie higher cover of any type of epibenthos), and those with higher % calcareous composition of the substratum in the field of view, had higher fish abundances.

Community assemblage structure as a function of "habitat"

Clustering of the Bray-Curtis dissimilarity matrix of transformed abundance of 98 fish genera by 95 SBRUVS sites revealed 14 significant clusters of data (Figure 44 A). Assigning these samples to four depth categories showed higher diversity of clusters in the shallower categories (nine clusters in waters less than 23 m deep, and eight in 23-42 m) (Figure 44 B). An unconstrained ordination of the same matrix explained about 31% of the distance variation in the dissimilarity matrix. The first two principal components (axes) in Figure 45 explained ~35% of this total. The site scores showed that the highest species richness occurred in the shallowest sites along the first axis, whereas the deeper sites were separated mainly along both axes (Figure 47).

The species scores in Figure 46 showed there was a high correlation between the first axis and the abundance of many "reef associated" fish genera, such as *Plectropomus* (coral trouts), *Pomacentrus* and *Dascyllus* (damselfishes), *Scarus* (parrot fish), *Chaetodon* (butterflyfish) and *Cirrhilabrus* (wrasses). In contrast, "sand associated" genera were highly correlated with the second axis. These were larger-bodied fish in the genera *Lethrinus* and *Gymnocranius* (emperors), *Abalistes* (trigger fish) and *Symphorus* (a snapper). The biplot in Figure 47 shows the clustering in multidimensional space of shallow sites highly correlated with "reef associated" genera.

These three representations of the unconstrained clustering and ordination show that "reef associated" genera were highly correlated with shallow sites with richest species diversity. However, there are numerous other dimensions accounting for the other 65% of the "structure" in the dissimilarity matrix that cannot be visualised or interpreted this way.

This multivariate variation is best explored with multivariate prediction and regression trees where we modelled the transformed abundance of 179 species as a response to shoal name, site depth, the seven categories of epibenthic cover, and the six categories of substratum (see Table 4). The first split in the tree distinguished sites with %coral cover (in the field of view) less than or greater than 35% (Figure 48). Two thirds of the sites (n=63) grouped together, irrespective of shoal name, in one terminal node we termed "Barer seabed". The other third of the data was split into Tassie and Evans Shoal sites based on depth, where shoal tops and shoal bases separated. Just three of the shallowest Tassie Shoal sites (<17.9m) formed a distinct assemblage where species were both numerous and abundant. The shallowest shoal tops with >35% coral cover had the highest species richness and abundance at both shoals in the histograms at the bottom of Figure 48.

Inspection of the DLI species values shows groups of species ubiquitous amongst assemblages (such as some large mobile carangid trevallies), at the root node (Figure 48), and assemblages of "reef associated" species characteristic of the shallow sites where coral cover was 35% or more. The full list of indicator species is detailed in Table 9. It is important to note that some of the species characterising "Barer seabed" are also found on coral reefs sometimes (e.g. silvertip whaler sharks *Carcharhinus albimarginatus*), but all other "reefy" nodes are distinguished by high DLI values for species that are only found on Indo-Pacific coral reefs (not inter-reefal shelf plains) (Figure 48 and Table 9). These include species such as corallivorous butteflyfishes (*Chaetodon lunula, C. ornatissimus*), coral-scraping parrotfish (*Scarus forsteni*), reef planktivores (*Pterocaesio marri*), reef herbivores (*Kyphosus cinerascens*) and cleaner fish (*Labroides bicolor*).

The "Barer seabed" node had an average richness of ~12 species and average abundance of ~37 fish, but these parameters doubled, tripled or quadrupled for the "reefy" nodes as the depth decreased (Table 10). It was clear that most of the "pattern" in diversity and abundance in the dataset was concentrated in the one-third of the SBRUVS set in shallow shoal waters where coral cover was highest.

Species accumulation curves for the five assemblages showed that all were still rising toward an asymptote of much higher diversity (Figure 49 A). More SBRUVS sets in all habitats would produce more species. The maps in Figure 49 (Inset B) show that only the "Barer seabed" assemblage is shared between shoals. Tassie Shoal is much smaller than Evans Shoal, yet they both supported only three distinct assemblages in the analysis. This may be because of the under-sampling of latent fish diversity evident from the species accumulation curves. It is also important to note that many sites on the top of Evans Shoal were classified by the analysis in the "Barer seabed" node with coral cover <35%. The tree analysis and the assemblage maps support further the notion that diversity increases sharply with coral cover and with decreasing depth.

The model had high error predicting the node membership of sites (only 7% success rate), and explained only 25% of the multivariate variation, but the best fit recognised five fish assemblages amongst the two shoals, based on depth, shoal name, and the percentage composition of calcareous reefal substrata in the field of view. Histograms on the "leaves" show abundance of each species, and the number of sites (*n*) are given with node names and node numbers. The species indicators (DLI) characterising each branch and each terminal node (leaf) are an index of fidelity and specificity of a species to a tree node. The hierarchical nature of the tree allows examination of which species are ubiquitous amongst Tassie and Evans Shoals with DLI at the "stump", and which species characterise the terminal assemblages. Only the top 10 DLI are shown for each node. The full list is given in Table 9.

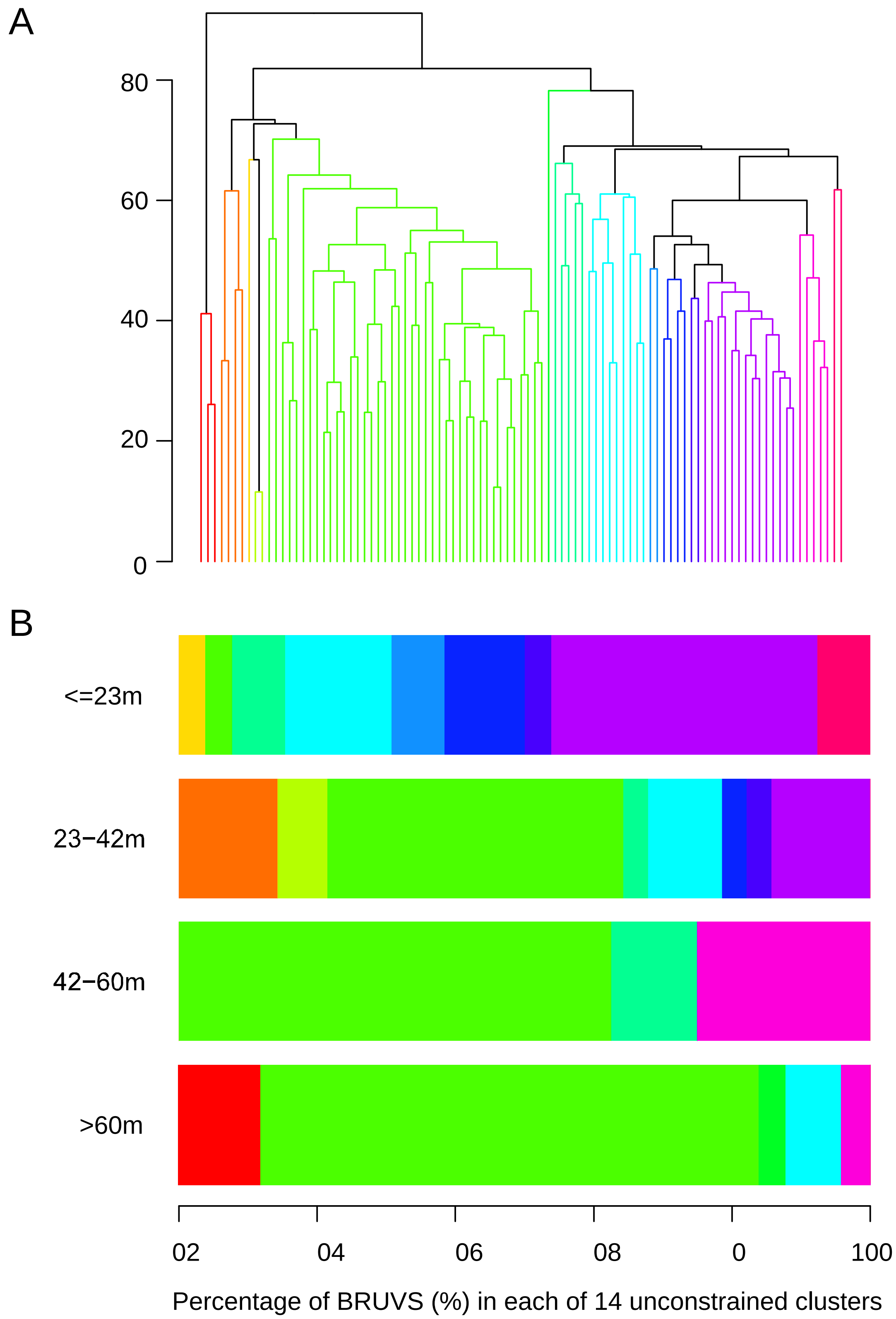


Figure 44: Unconstrained cluster analysis of transformed abundance (4th root MaxN) of 98 fish genera from 95 SBRUVS surveyed on Tassie and Evans Shoals (A), including a visual representation of the proportion of the 14 significant clusters that occurred in each of four nominal depth strata (B). Shallow SBRUVS sites had most clusters of fish genera.

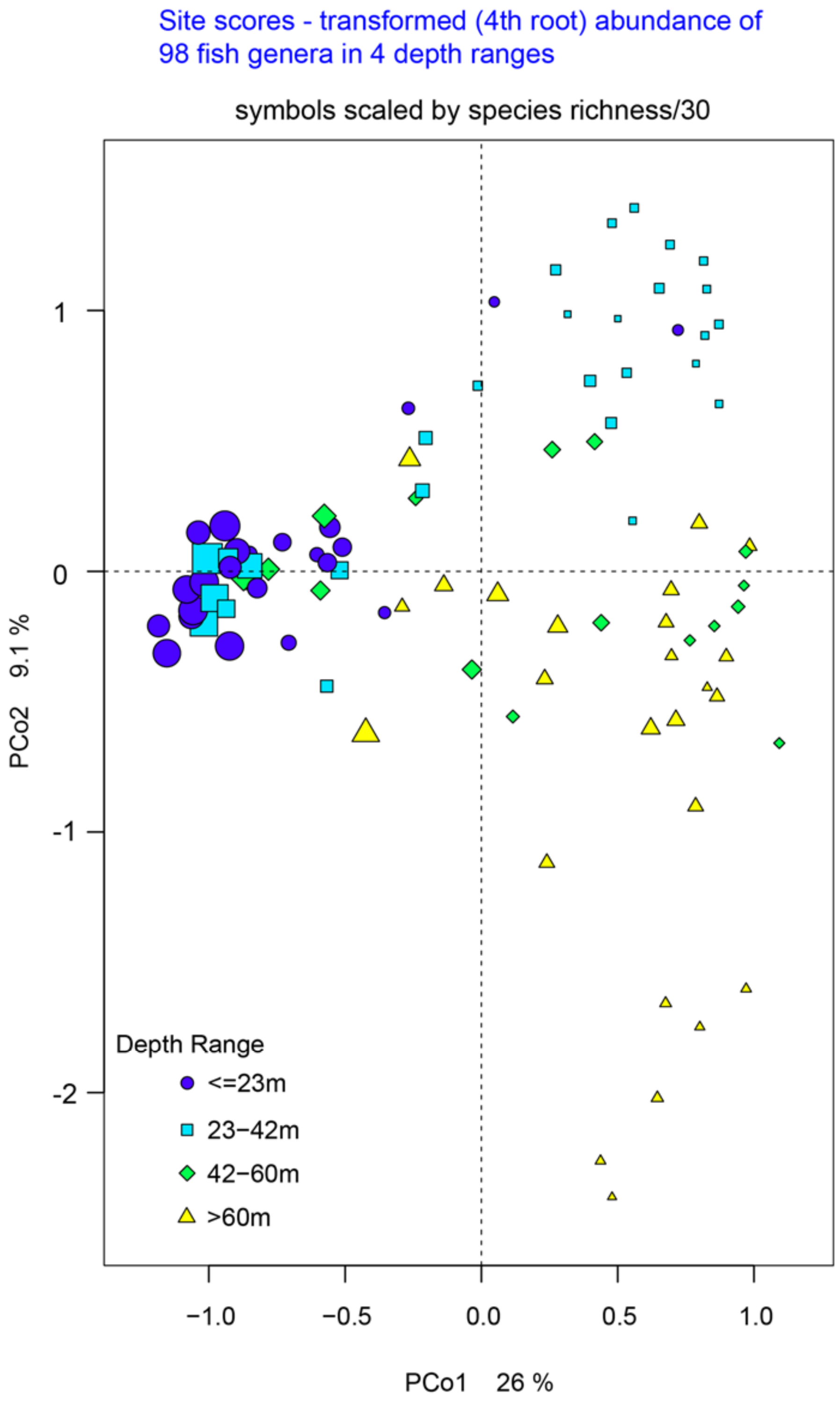


Figure 45: Unconstrained ordination of the Bray-Curtis dissimilarity matrix produced for all 95 SBRUVS sets using the transformed abundance (4th root MaxN) of 98 fish genera. The first 2 principal components accounted for 35% of the total variation explained (31%) in the abundance of these genera. The separation of BRUVS sets in 4 nominal depth categories is most evident in the scores along the first axis. Site symbols are scaled by species richness/30. Shallow sites had more species.

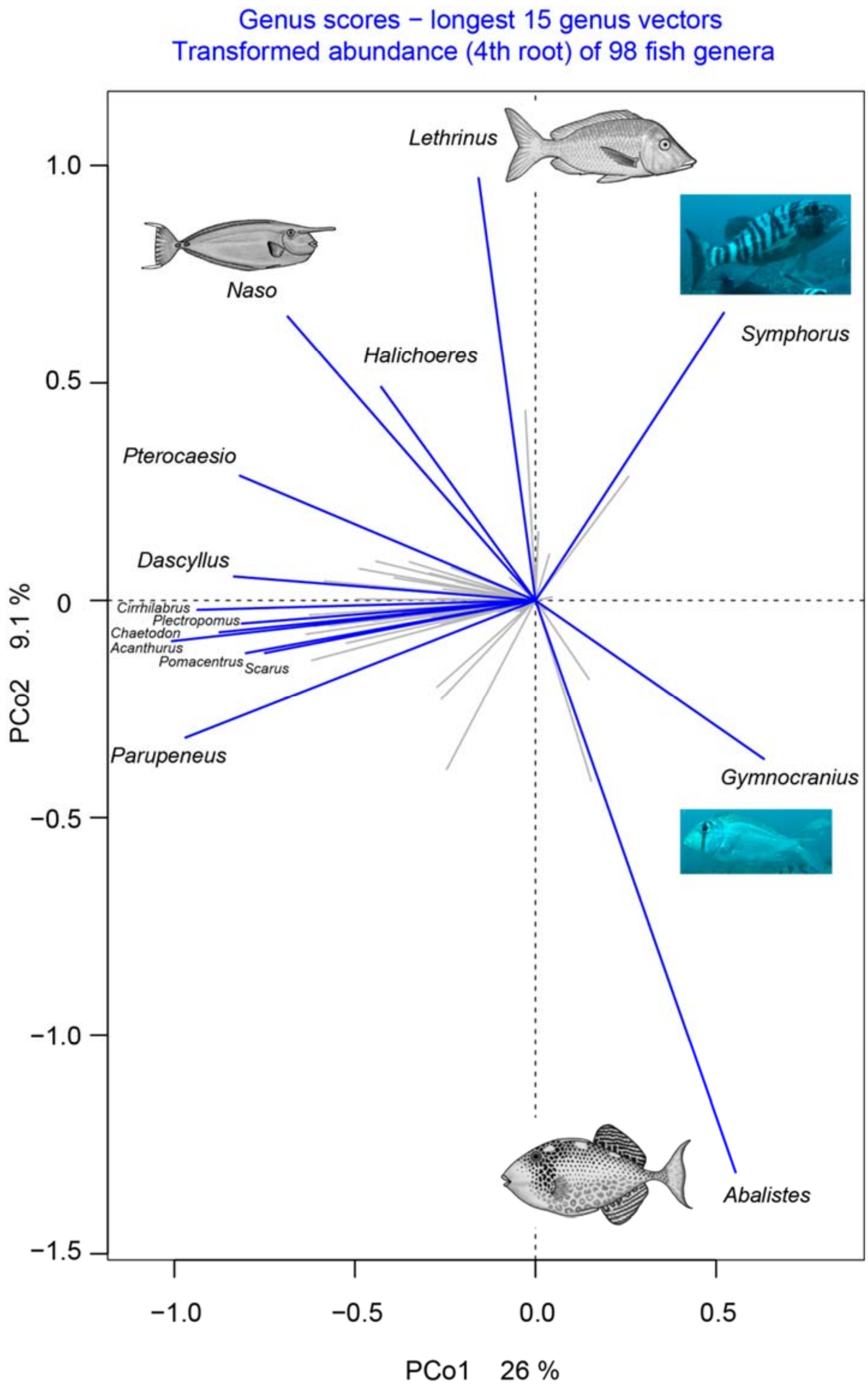


Figure 46: Unconstrained ordination of the Bray-Curtis dissimilarity matrix produced for all 95 SBRUVS sets using the transformed abundance (4th root MaxN) of 98 fish genera. The top 15 genera correlated with these 2 principal components are shown by blue vectors. Grey vectors represent the remainder in these first 2 dimensions. "Reef-associated" genera were correlated with the first axis, and fewer, "sand-associated", genera were correlated with the second axis.

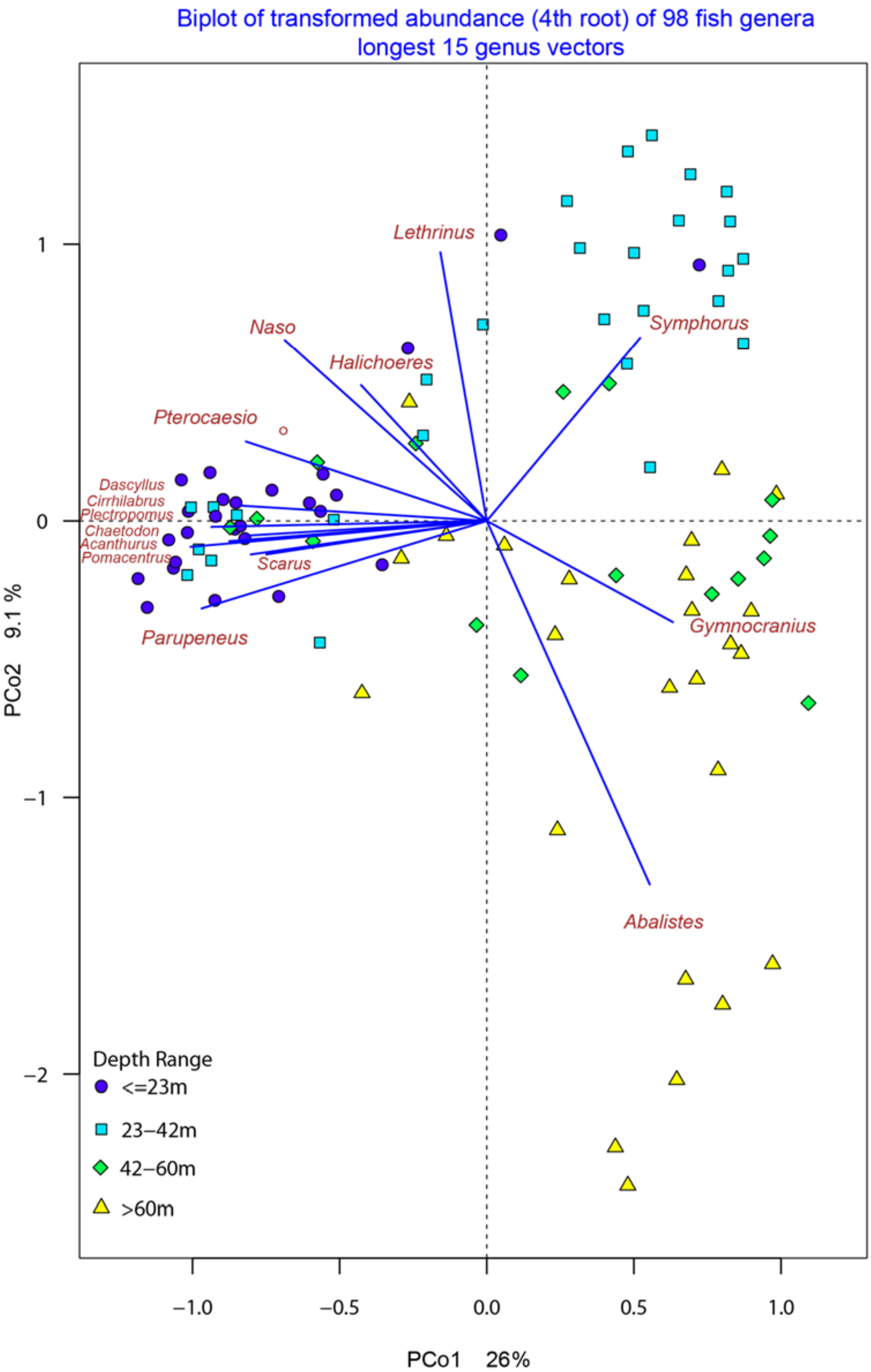


Figure 47: Biplot of an unconstrained ordination of the Bray-Curtis dissimilarity matrix produced for all 95 SBRUVS sets using the transformed abundance (4th root MaxN) of 98 fish genera. The top 15 genera correlated with these 2 principal components are shown by blue vectors. "Reef-associated" genera were correlated with shallow sites on the first axis, and fewer, "sand-associated", genera were correlated along the second axis with deeper sites.

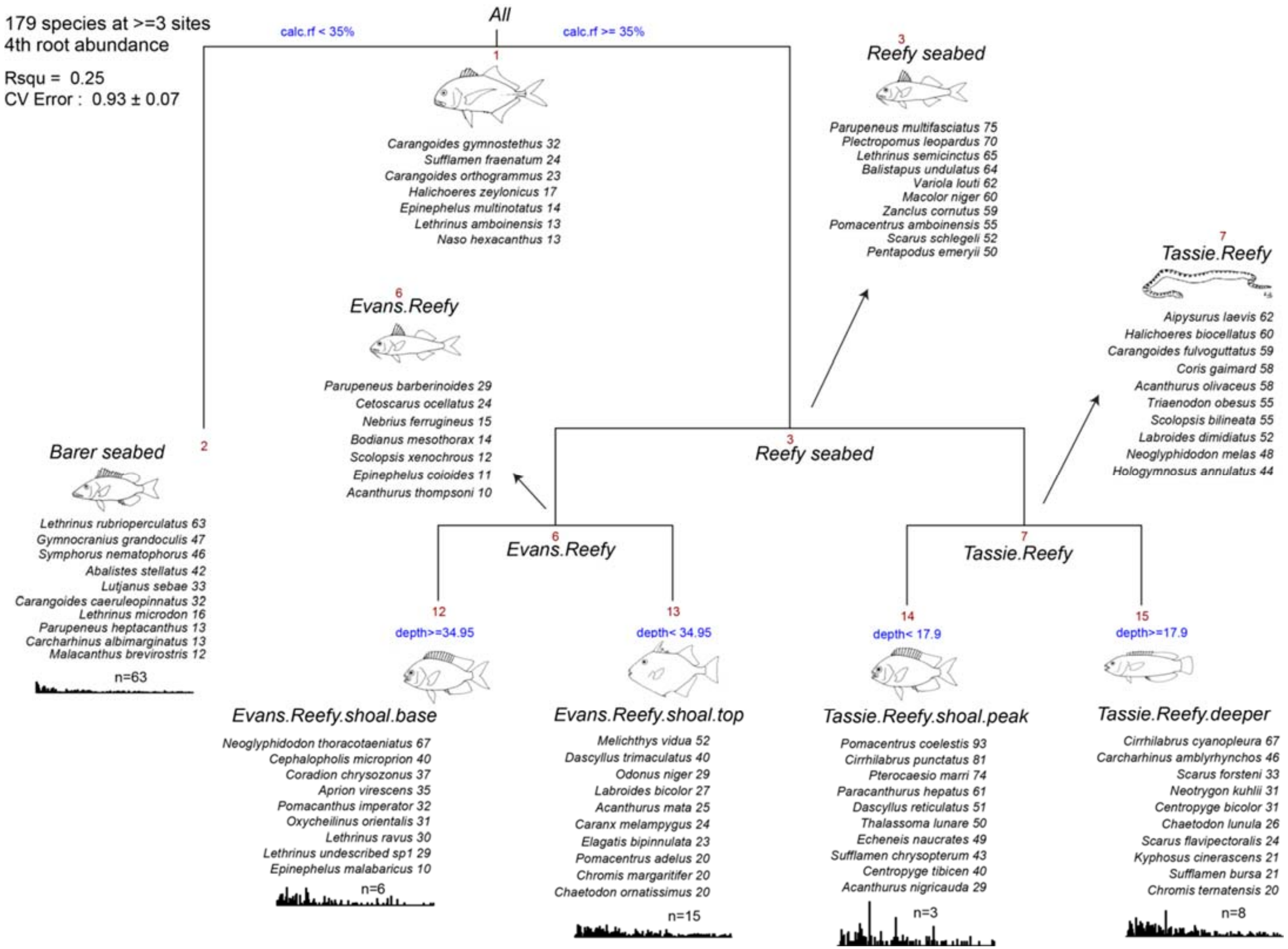


Figure 48: The best tree structure from a multivariate analysis of the transformed abundance (4th root MaxN) of 179 species predicted by the biotic explanatory covariates.This subset of 179 fish species were present on at least 3 SBRUVS.

Table 9. The Dufrene-Legendre indices (DLI) for each of the 179 species analysed as the multivariate response in Figure 50. The DLI species, and their values, are shown for each node of the tree. These nodes include the hierarchical branches, and the terminal nodes comprising the 5 fish assemblages (in bold italics).

Nodename	node	DLI values
All	1	*Carangoides gymnostethus(32), Sufflamen fraenatum(24), Carangoides orthogrammus(23), Halichoeres zeylonicus(17), Epinephelus multinotatus(14), Lethrinus amboinensis(13), Naso hexacanthus(13), Lutjanus lemniscatus(4), Pseudobalistes fuscus(4)*
Barer_seabed	2	*Lethrinus rubrioperculatus(63), Gymnocranius grandoculis(47), Symphorus nematophorus(46), Abalistes stellatus(42), Lutjanus sebae(33), Carangoides caeruleopinnatus(32), Lethrinus microdon(16), Parupeneus heptacanthus(13), Carcharhinus albimarginatus(13), Malacanthus brevirostris(12), Parupeneus barberinus(10), Aluterus monoceros(10), Pristipomoides filamentosus(10), Naso mcdadei(10), Lagocephalus sceleratus(10), Oxycheilinus bimaculatus(8), Carangoides ferdau(8), Carangoides chrysophrys(8), Lethrinus nebulosus(8), Naso fageni(7), Lethrinus lentjan(6), Decapterus sp(6), Epinephelus areolatus(5), Parupeneus cyclostomus(5), Pristipomoides typus(5), Xyrichtys melanopus(5), Pseudojuloides severnsi(5), Cirrhilabrus sp(5), Naso tonganus(5)*
Reefy_seabed	3	*Parupeneus multifasciatus(75), Plectropomus leopardus(70), Lethrinus semicinctus(65), Balistapus undulatus(64), Variola louti(62), Macolor niger(60), Zanclus cornutus(59), Pomacentrus amboinensis(55), Scarus schlegeli(52), Pentapodus emeryii(50), Naso lituratus(47), Apolemichthys trimaculatus(46), Aethaloperca rogaa(45), Lutjanus bohar(43), Parupeneus pleurostigma(42), Lethrinus erythracanthus(41), Chaetodon kleinii(40), Oxycheilinus celebicus(38), Ctenochaetus striatus(38), Naso vlamingii(28), Cephalopholis miniata(27), Chlorurus bleekeri(25), Pygoplites diacanthus(25), Monotaxis grandoculis(25), Chaetodon lunulatus(25), Naso brevirostris(24), Chromis weberi(22), Amblyglyphidodon leucogaster(22), Forcipiger longirostris(22), Chaetodon trifascialis(19), Acanthurus grammoptilus(17), Lutjanus rivulatus(12), Chaetodon adiergastos(12), Choerodon jordani(11), Heniochus singularius(9), Naso caesius(9)*
Evans_Reefy	6	*Parupeneus barberinoides(29), Cetoscarus ocellatus(24), Nebrius ferrugineus(15), Bodianus mesothorax(14), Scolopsis xenochrous(12), Epinephelus coioides(11), Acanthurus thompsoni(10)*
Tassie_Reefy	7	*Aipysurus laevis(62), Halichoeres biocellatus(60), Carangoides fulvoguttatus(59), Coris gaimard(58), Acanthurus olivaceus(58), Triaenodon obesus(55), Scolopsis bilineata(55), Labroides dimidiatus(52), Neoglyphidodon melas(48), Hologymnosus annulatus(44), Acanthurus pyroferus(43), Hologymnosus doliatus(43), Coris batuensis(36), Balistoides viridescens(35), Chaetodon auriga(34), Genicanthus lamarck(32), Halichoeres chrysus(31), Carangoides plagiotaenia(29), Parapercis xanthozona(28), Cirrhilabrus exquisitus(24)*
Evans_Reefy shoal_base	*12*	*Neoglyphidodon thoracotaeniatus(67), Cephalopholis microprion(40), Coradion chrysozonus(37), Aprion virescens(35), Pomacanthus imperator(32), Oxycheilinus orientalis(31), Lethrinus ravus(30), Lethrinus undescribedsp1(29), Epinephelus malabaricus(10), Lethrinus olivaceus(9)*
Evans_Reefy shoal_top	*13*	*Melichthys vidua(52), Dascyllus trimaculatus(40), Odonus niger(29), Labroides bicolor(27), Acanthurus mata(25), Caranx melampygus(24), Elagatis bipinnulata(23), Pomacentrus adelus(20), Chromis margaritifer(20), Chaetodon ornatissimus(20), Acanthurus nigros(20), Acanthurus nigricans(19), Plectorhinchus vittatus(19), Lutjanus gibbus(18), Acanthurus blochii(16), Zebrasoma scopas(13), Oxycheilinus digrammus(13), Coris pictoides(5), Heniochus acuminatus(5), Naso unicornis(4)*
Tassie_Reefy shoal_peak	*14*	*Pomacentrus coelestis(93), Cirrhilabrus punctatus(81), Pterocaesio marri(74), Paracanthurus hepatus(61), Dascyllus reticulatus(51), Thalassoma lunare(50), Echeneis naucrates(49), Sufflamen chrysopterum(43), Centropyge tibicen(40), Acanthurus nigricauda(29), Acanthurus dussumieri(28), Siganus punctatus(25), Thalassoma amblycephalum(25), Naso brachycentron(24), Caranx ignobilis(23), Chaetodon baronessa(23), Cantherhines dumerilii(22), Melichthys niger(22), Caesio teres(21), Plectroglyphidodon johnstonianus(21), Cephalopholis urodeta(20), Leptojulis cyanopleura(20), Chromis xanthura(19), Plectropomus laevis(19), Hydrophis sp(18), Acanthurus leucocheilus(18), Aluterus scriptus(17), Cirrhilabrus temminckii(14)*
Tassie_Reefy deeper	*15*	*Cirrhilabrus cyanopleura(67), Carcharhinus amblyrhynchos(46), Scarus forsteni(33), Neotrygon kuhlii(31), Centropyge bicolor(31), Chaetodon lunula(26), Scarus flavipectoralis(24), Kyphosus cinerascens(21), Sufflamen bursa(21), Chromis ternatensis(20), Chaetodon lineolatus(19), Acanthurus nigrofuscus(19), Pomacentrus philippinus(18), Balistoides conspicillum(18), Hemitaurichthys polylepis(17), Epinephelus maculatus(15), Arothron stellatus(10), Novaculichthys taeniourus(8), Scarus ghobban(7), Siganus argenteus(7)*

Table 10 Summaries of the overall abundance and species richness in the 5 fish assemblages identified in the multivariate tree (Figure 48). Each SBRUVS station was assigned to an assemblage. The range in species richness (S) and abundance (∑MaxN) for each of the n BRUVS sites within an assemblage was then tallied as S and ∑∑MaxN. The node number and assemblage name, from Figure 48, is accompanied by the total number of DLI species (nDLI) from Table 9.

nodes	*n* sites	Node name	Richness *S*	∑∑ *MaxN*	*n* DLI	*S* range	*S* mean	∑*MaxN* range	∑*MaxN* mean
2	63	Barer seabed	180	2368	29	(1 - 34)	(12.2 ± 7.2)	(3 - 318)	(37.6 ± 46.2)
12	6	Evans.Reefy shoal.base	86	502	10	(13 - 36)	(25.3 ± 8.1)	(49 - 112)	(83.7 ± 22.5)
13	15	Evans.Reefy shoal.top	216	2181	20	(15 - 59)	(40.5 ± 14.5)	(37 - 343)	(145.4 ± 90.2)
14	3	Tassie.Reefy shoal.peak	82	989	28	(38 - 45)	(40.3 ± 4)	(123 - 626)	(329.7 ± 263.2)
15	8	Tassie.Reefy deeper	135	1242	20	(32 - 66)	(45.8 ± 12.6)	(68 - 257)	(155.2 ± 74)

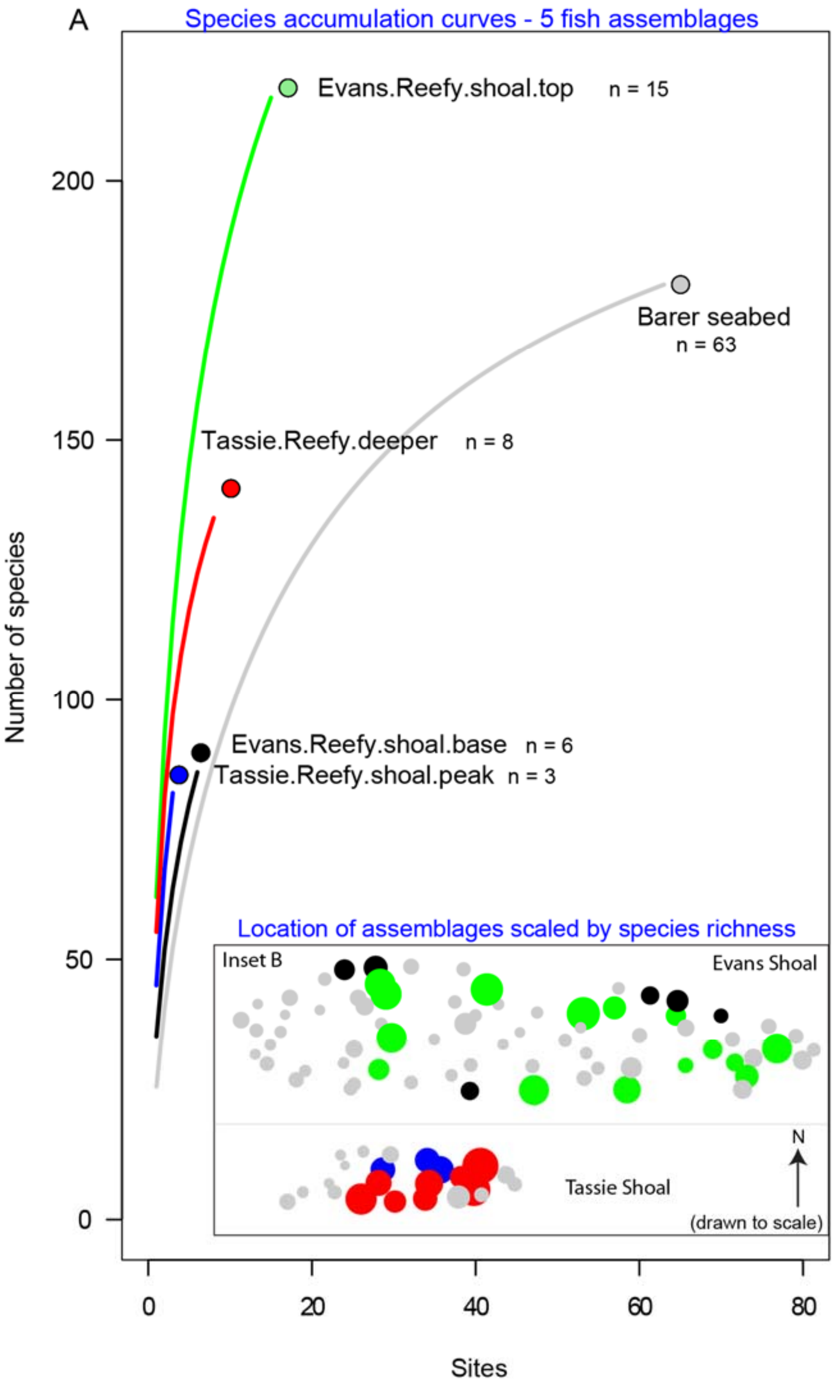


Figure 49: Species accumulation curves (A) derived for the 5 assemblages identified in Figure 50. The numbers and node names are shown. In general the curves were still ascending toward an asymptote, indicating that there remained much latent fish diversity in the assemblages. The colour-coded location of sites in each assemblage are shown on maps of the shoals as an inset (B). Shoals are drawn to scale with each other, but the latitudinal scale has been broken to place the maps next to each other. Symbols are scaled by species richness/40. Tassie Shoal top was the most diverse and comprised two fish assemblages based on depth.

2.5. Regional comparisons

2.5.1 Benthos

A cluster analysis using the coarse scale habitat data from real-time towed video data collected during this survey and the AIMS dataset from similar surveys across the Timor Sea and Bonaparte Gulf region showed similarities in benthic community composition among shelf edge shoals, such as Evans, Tassie and Blackwood, the Sahul Shoals and Eugene McDermott Shoal far to the west (Figure 50) but also differences between some close neighbouring sites, for example between Vulcan and Goeree Shoals. There is also a clear differentiation across the shelf, with the current study sites at Goodrich Bank and Cape Helvetius grouping with more coastal locations, likely influenced by the presence of bare soft substrate and a greater contribution from filter feeders and burrowing infauna (Figure 50). Notably, this analysis grouped Evans, Tassie and Blackwood Shoals together, along with other shoals in the central and western ends of the bioregion, based on the relative contribution of sparse to medium density hard coral habitats on all three shoals and similarities in the amount of bare substrate observed between Evans and Tassie Shoals (Figure 51).

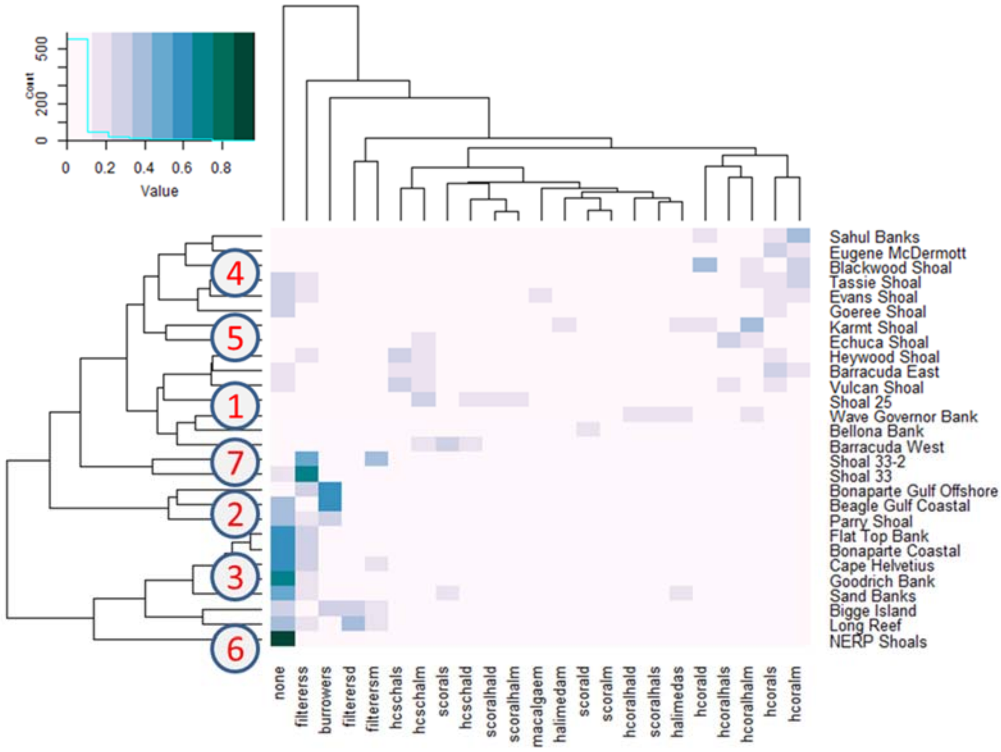


Figure 50: Cluster analysis from real time towed-video data showing the contribution of major habitat classifications to seabed communities surveyed on shoals and shelf areas throughout the region.

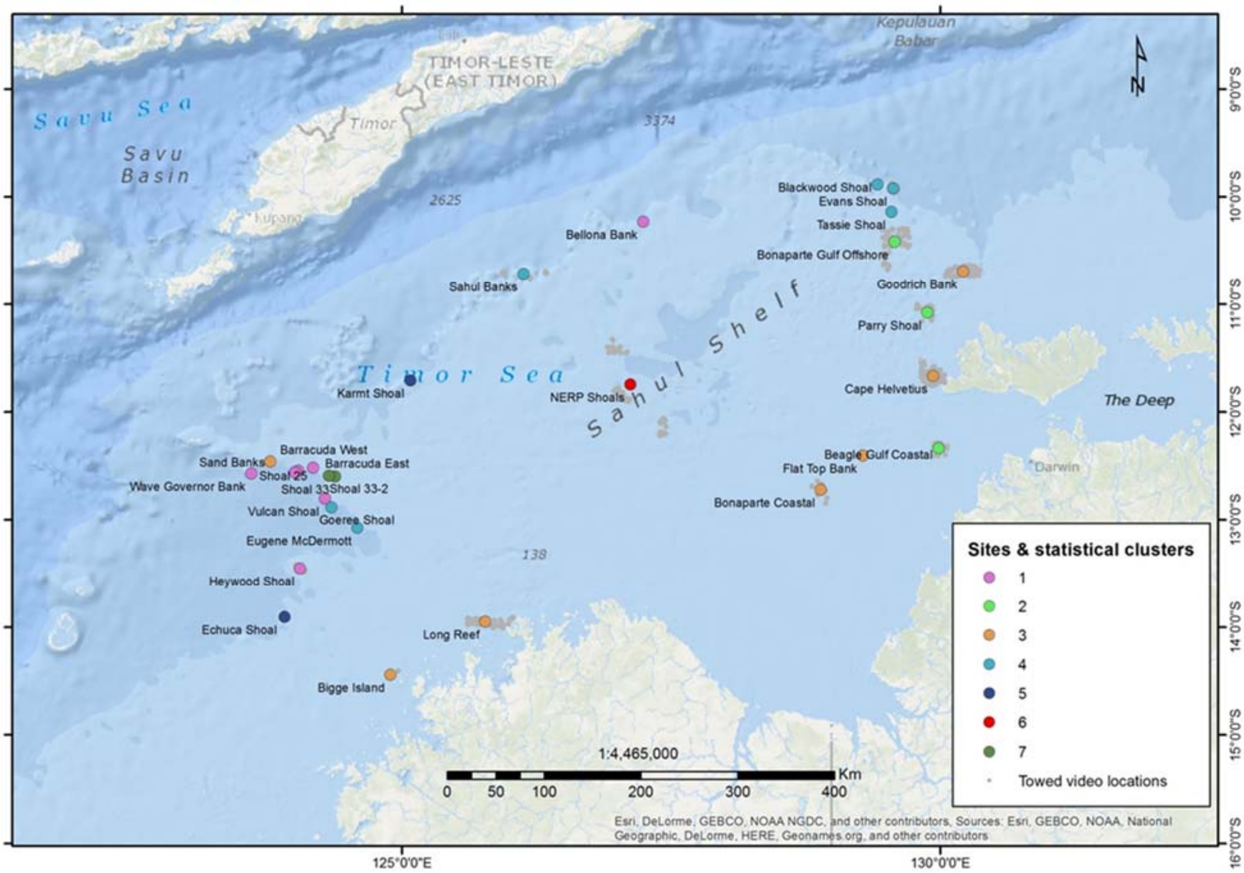


Figure 51: Colour coded regional similarities and differences in shelf and shoal locations based on initial analysis of coarse level benthic habitat classes, produced by realtime classification of video during towvid transects.

The realtime classification data has a limited range of categories into which to place particular habitats as they are viewed during a towed video transect. Corals, for example, may be classed as high medium or low density habitats, which can limit the ability to resolve more subtle differences. The use of still photo derived data removes these limitations. Hence a second cluster analysis based on fine-scale point intercept classification of all still images collected at Evans, Tassie and Blackwood Shoals with other AIMS data was performed. This provided a more stringent analysis of regional similarities and differences among 20 shoals across the NW Shelf. The relative proportion of each of the categories of benthos across depths (Figure 52), confirms the presence of the same major benthic categories, but some variability in the relative importance of these, on each shoal. These data represent submerged shoals distributed across more than 600 km of the North and North-west marine regions and a variety of shelf positions. Bare sand and consolidated reef, often supporting turfing algae, are major features of all shoals. Hard corals and macroalgae are ubiquitous but variable in abundance, with soft corals and sponges often important components of the benthos. Evans and Tassie Shoals are in the middle of the range for categories such as hard corals. Evans Shoal is notable for the large areas of sand, and similar to one of the three Margaret Harries Banks, though with more hard coral overall and notably with one of the higher abundances of deep coral between 30-60 m on the shoal slopes. The deep coral community at Evans Shoal consists of foliaceous corals, such as *Montipora* spp. and *Pachyseris* spp. which were encountered in a discrete depth band between approximately 40-60 m deep at the northern and southern ends of the shoal. By comparison Tassie Shoal had slightly less hard coral, but also a more even contribution from all the benthic biota, which relates to the presence of a greater proportion of consolidated substrate across the plateau, often in the form of small patch reefs and outcrops. The foliaceous community observed at Evans Shoal was also found on Tassie Shoal but was more limted in extent and shallower in depth distribution. No hard coral was found on Tassie Shoal below 30 m, which is unusual for these shoals.

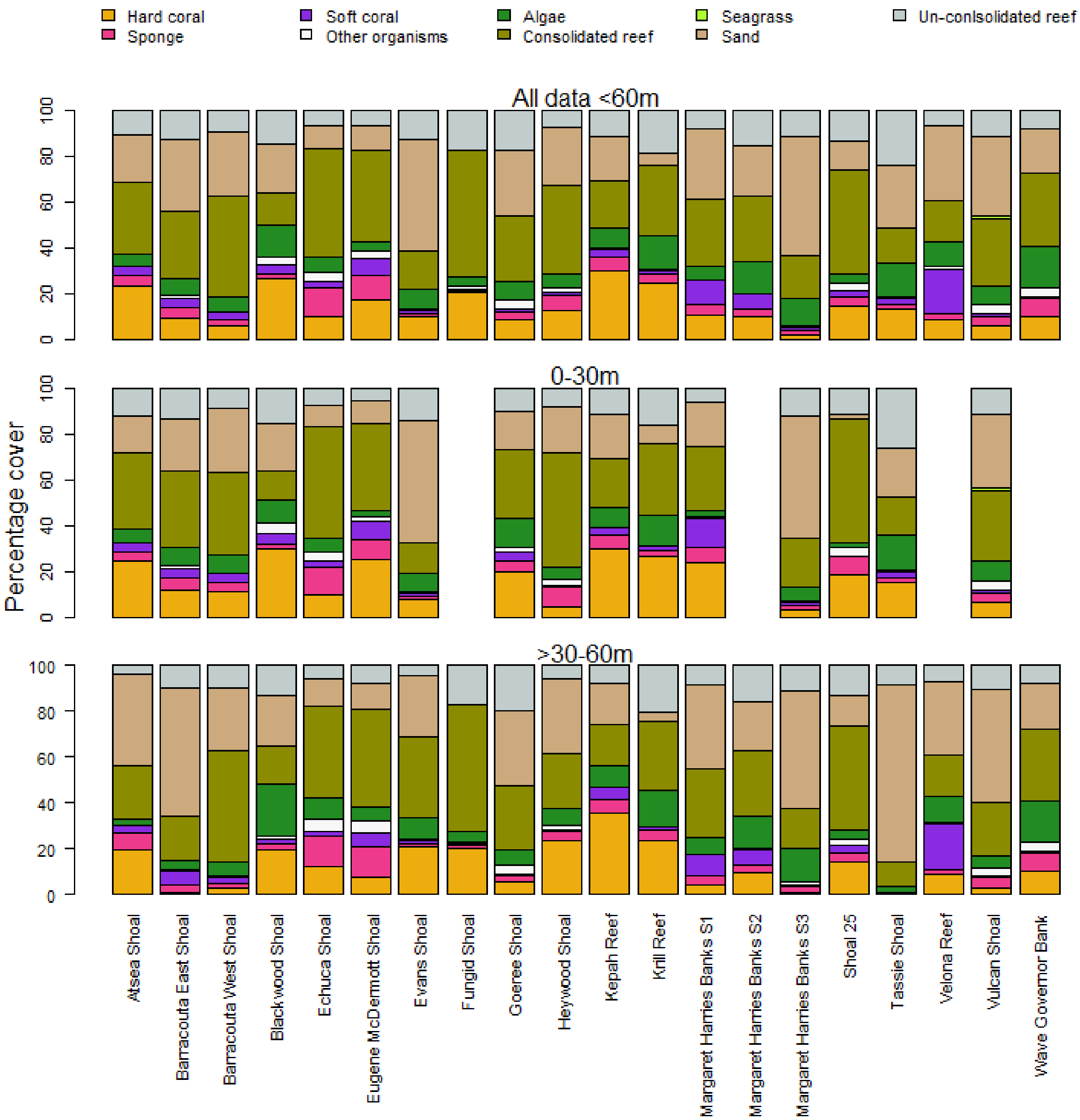


Figure 52: Summary of quantitative data derived from point intercept photo analysis: 20 shoals across the region showing the relative proportion of each of the broad-scale categories of benthos across depths.

The high level habitat comparisons (Figure 52) do not, however, reveal some of the fine scale complexities in the composition of broad scale habitats found within and between shoals. For example, the abundance of coral is similar at Fungid Shoal and Evans Shoal, but the composition of the two shoal coral communities is quite different. Evans Shoal corals are diverse and various branching and massive species in the Families Acroporidae, Poitidae and Favidae make major contributions to coral habitats across the shallower regions of the plateau. However there is also a substantial presence of hard coral on the deeper edges of the plateau, in the 30-60 m depth range, consisting mainly of foliaceous species in the Families Acroporidae and Agaricidae. In contrast Fungid Shoal in the middle of the bioregion, while having a similar abundance of hard coral, is dominated by the Fungidae and Agaricidae between 30-60 m.

The regional comparison of shoals, using the quantitative data derived from high resolution still image interpretation, confirms the similarity of benthic communities at Tassie Shoal and Blackwood Shoal, in particular with regard to the abundance of sand and unconsolidated reef areas and some similarity in coral cover. However, Evans Shoal groups most strongly with one of the Margaret Harries Banks, which lies approximately 100 km to the south west, rather than with the nearby Tassie and Blackwood Shoals (Figures 53 & 54).

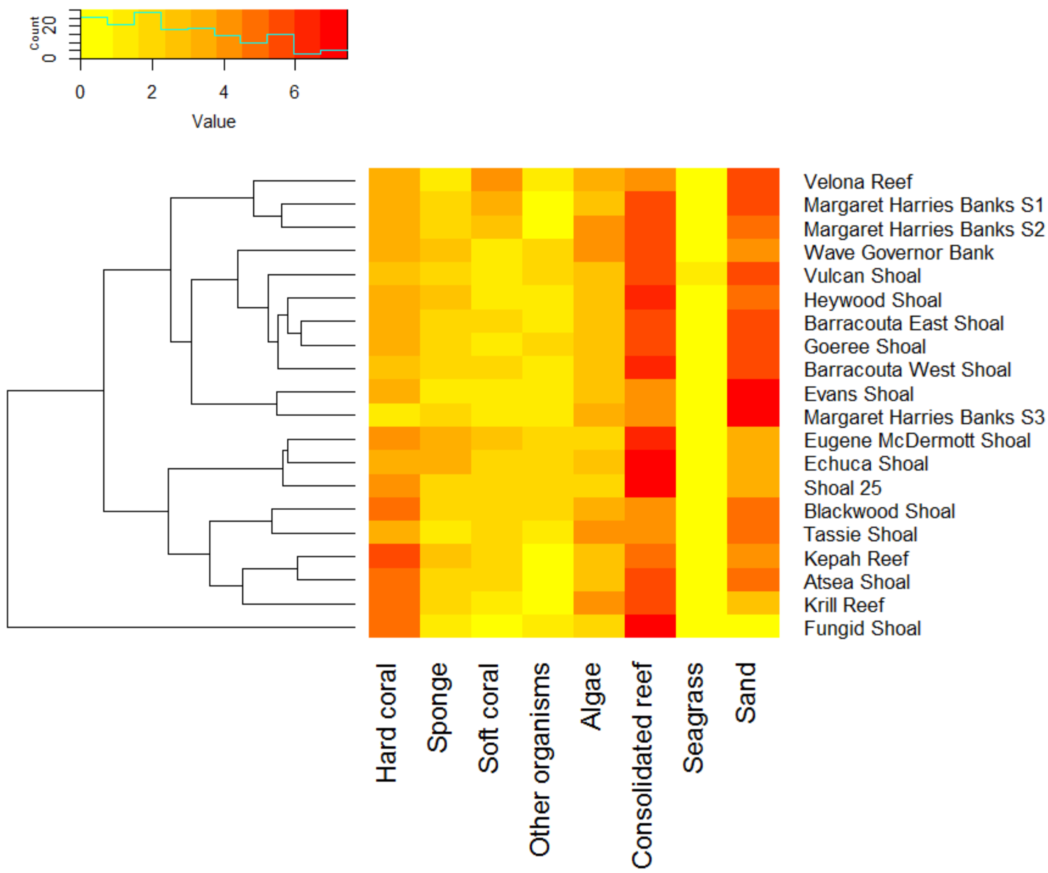


Figure 53: Cluster analysis, based on the quantitative data derived from high resolution imagery analysis, showing the contribution of major habitat classifications to seabed communities surveyed on shoals throughout the region.

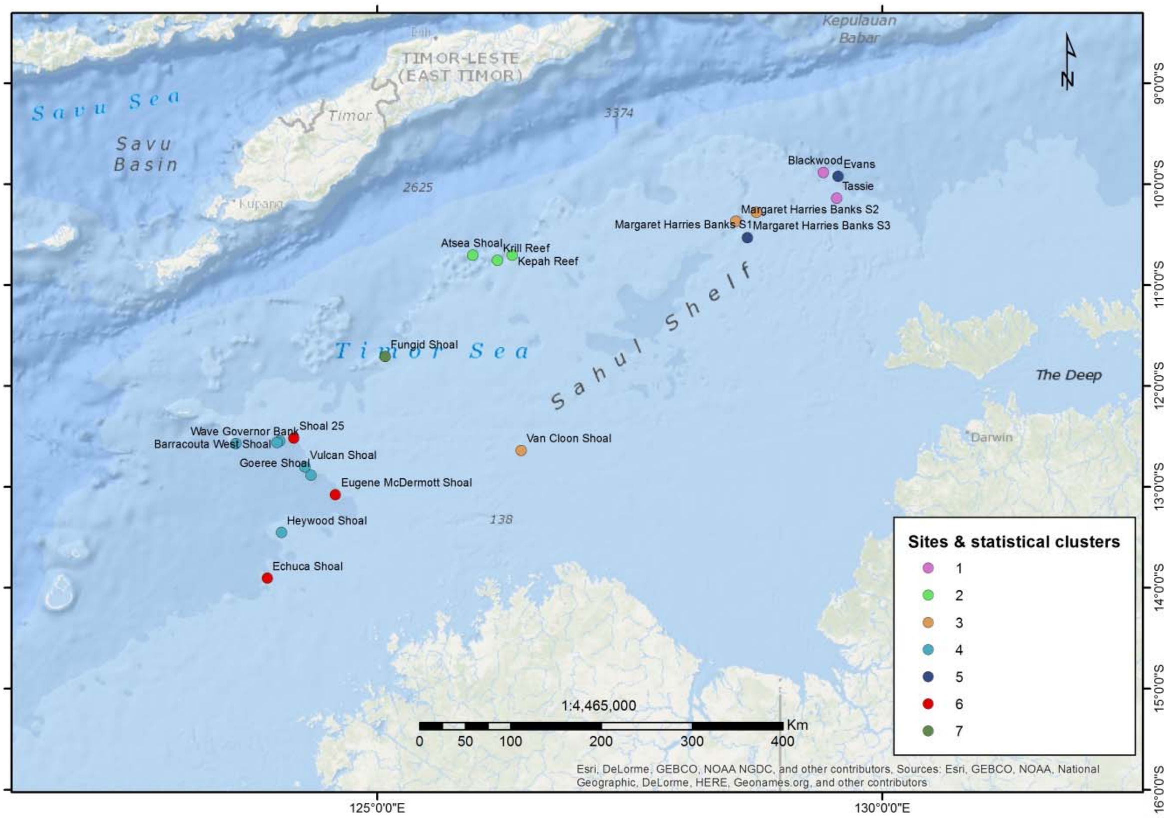


Figure 54: Colour coded regional similarities and differences shoal locations based on cluster analysis of fine scale benthic habitat classes, produced by point intercept analysis of high resolution benthic still imagery.

The coral composition found on shoals across the region (Figure 55) varies among shoals, sometimes substantially, but many general attributes are shared. Acroporid corals in a mix of branching, corymbose and tabulate growth forms are widespread throughout the region. Together with other branching and encrusting species they contribute a major proportion of the hard corals found on the shallowest areas of the shoals, particularly in depths less than 30 m. While these groups do extend into greater depths, the shoal regions between 30-60 m also support sometimes dense patches of foliose coral and/or solitary corals in the family Fungiidae. Unlike the majority of reef building coral species found on the shoal plateaus, these free living corals have the ability to colonise areas of unconsolidated substrate and also appear to thrive across a range of depths, including areas below 30 m.

While overall habitat composition suggests Evans Shoal is most similar to one of the Margaret Harries Banks (Figure 54), comparison of just coral assemblages across the region (Figure 56), indicates Evans Shoal to be most similar to Echuca, Goree and Barracouta West Shoals, while Tassie Shoal is most similar to Eugene McDermott Shoal. All of these shoals are situated at the western end of the bioregion, and the Blackwood Shoal coral community is most similar to two shoals, Atsea and Kepah, in the central area of the bioregion.

Overall these results suggest that while many attributes and species are shared throughout the region, individual shoals have their own character and the status of their benthic communities may reflect different disturbance and recruitment histories, as well as potentially different ecosystem trajectories.

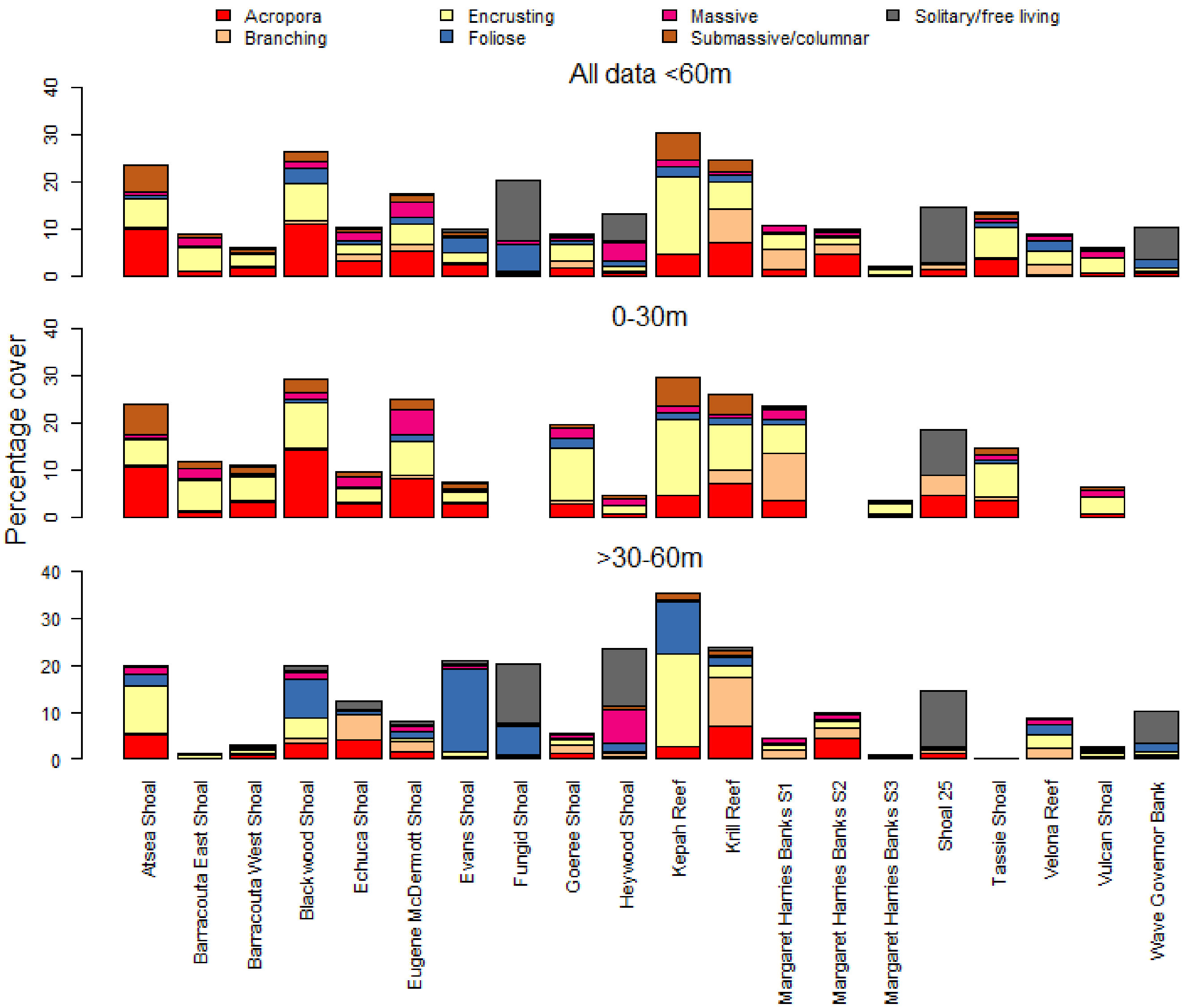


Figure 55: Relative proportion of each of the hard coral categories across depths; summary from 20 shoals distributed across 750 km of the submerged shoals region (see Figure 54 for locations).

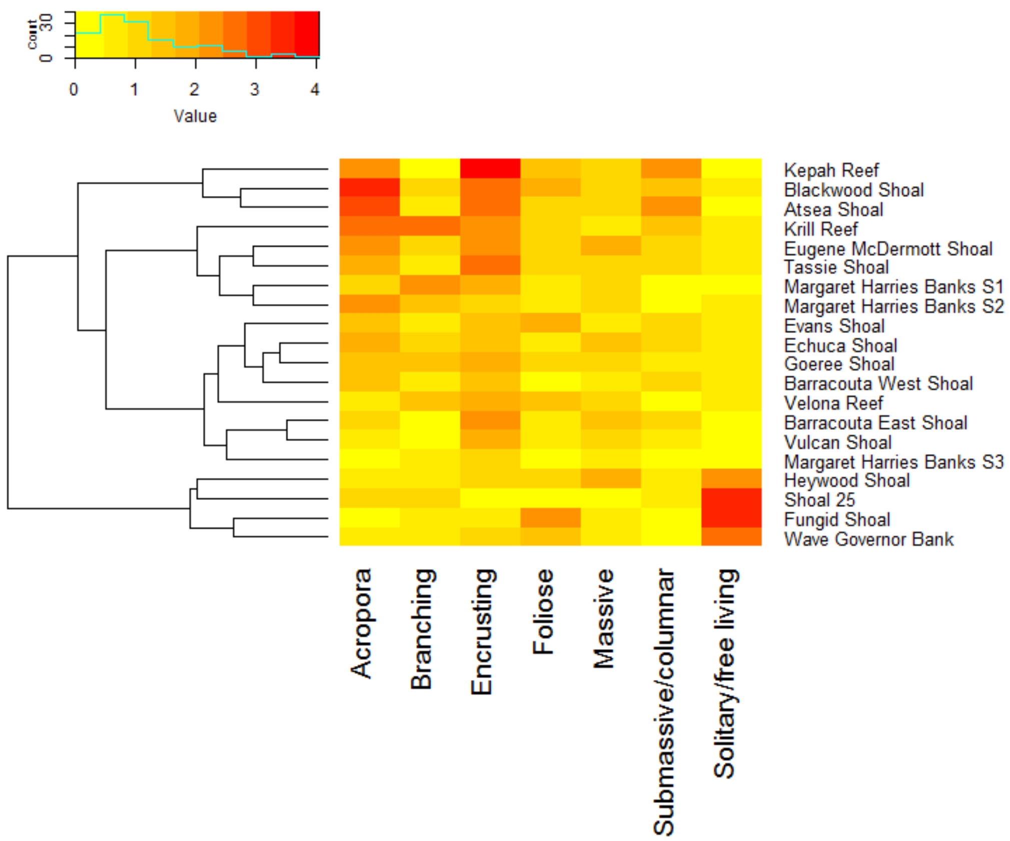


Figure 56: Cluster analysis of the contribution of hard coral categories to towed video benthic surveys at 20 shoals in the region.

2.5.2 Regional scale habitat model

The regional scale habitat model (Figure 57) results cover ~46,810 sq km and show a mosaic of habitats throughout the model domain. These habitats are dominated by Burrower/Crinoid soft sediment communities (Table 5, making up ~23% of the total area) interspersed with no modelled biota present (category "None" making up ~ 69% of the total areas). There was also a lesser but significant amount of filter feeder communities (~6%) most commonly found in the east of the model domain within the bounds of the Oceanic Shoals Commonwealth Marine Reserve (OSCMR). Hard corals (including free living forms), soft corals, macroalgae and gorgonians all make up less than one percent of regional scale model by area. Their distribution is largely associated with the shoals, banks and emergent reefs in the northern extent of the study domain. However, hard coral also extends into areas of the OSCMR, with towed video analysis suggesting that this is most likely associated with isolates and free leaving coral forms. Alycon, seagrass, whips and *Halimeda* are marginal environments through the model domain with less than or equal to 0.1% by area.

Overall model accuracy was assessed using Kappa (Table 6) with the outcome showing a good level of accuracy (Kappa >= 0.7, Hosmer and Lemeshow 2000). The confusion matrix showed that the majority of habitats are accurately classified (~80%) with the exception of "None" which is the weakest class with only ~50% accuracy. While all reasonable efforts are made to make model results as representative and accurate as possible, interpreting the regional habitat model results should be done with caution particularly at fine scales. It is also important to note that large areas of the model outside the sites detailed in Figure 57 have no validation data and model accuracy cannot be assessed in these regions. A detailed ecological interpretation of drivers of each modelled benthic group in the regional scale model is beyond the scope of this report. It should also be noted with caution that while over the entire regional model performed well for most habitat categories, the "None" category had the poorest performance most frequently under predicting filter feeder (including whips) and Halimedia communities which by their nature can be discrete, stochastic and challenging to model.

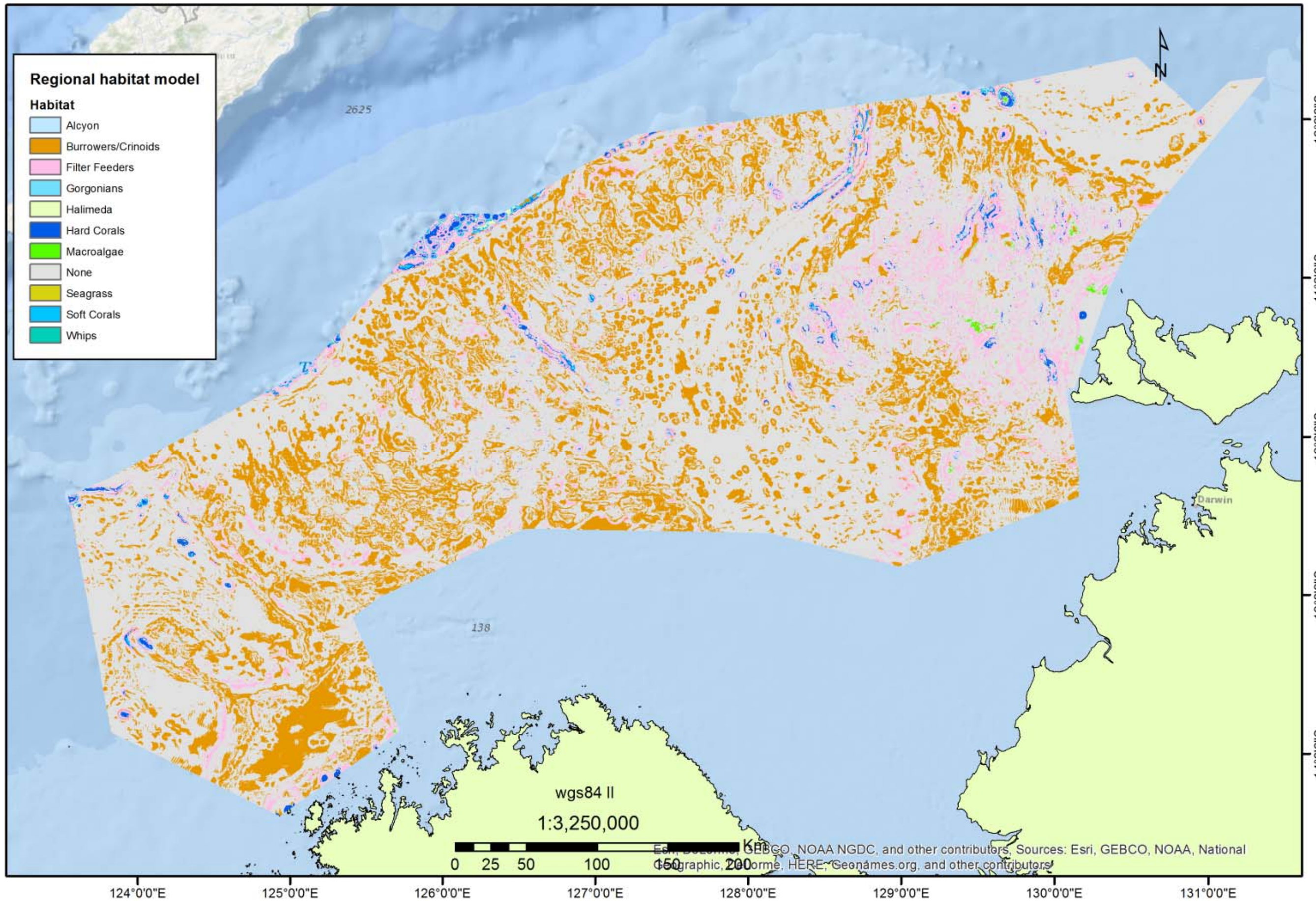


Figure 57. Regional habitat model (v 5) based on Geosciences Australia National 250 m bathymetry and derived variables modelled with coarse level benthic habitat classes, produced by realtime classification of video during towvid transects, as shown in Figure 14.

Table 5. Proportion broad scale benthic habitat class model area by type for regional model.

Habitat	Percent
Alcyon	0.10%
Burrowers/Crinoids	22.91%
Filter Feeders	6.44%
Gorgonians	0.18%
Halimeda	0.10%
Hard Corals	0.65%
Macroalgae	0.09%
Soft Corals	0.28%
Seagrass	0.00%
Whips	0.00%
None	69.24%

Table 6. Accuracy confusion matrix and statistics for regional habitat model (based on 33% blind validation n 113822)

		Predicted											
		None	Alcyon	Burrowers/Crinoids	Filter Feeders	Gorgonians	Halimeda	Hard Corals	Macroalgae	Soft Corals	Seagrass	Sponges	Whips
Observed	None	1040	1	96	225	0	185	22	35	3	7	433	51
	Alcyon	0	4942	174	0	0	0	0	0	1	0	390	2
	Burrowers/Crinoids	1	119	13042	0	8	1461	48	162	0	0	1708	7
	Filter Feeders	183	0	31	1268	0	37	1	6	0	22	371	101
	Gorgonians	0	0	42	0	383	410	4	36	0	0	314	0
	Halimeda	203	0	747	1	73	42194	66	633	47	0	1468	0
	Hard Corals	8	0	61	0	0	21	1419	0	0	0	184	0
	Macroalgae	9	0	145	0	75	1081	22	2341	0	0	241	0
	Soft Corals	0	0	0	0	0	607	0	0	169	0	24	0
	Seagrass	66	0	3	132	0	63	0	0	0	54	71	15
	Sponges	188	182	1522	357	12	2906	252	302	5	29	27085	19
	Whips	241	22	161	206	0	0	0	0	0	0	212	506
	Total Accuracy	82.97%											
	Kappa	0.76											

2.5.3 *Fish community comparisons*

Tassie Shoal has notably higher fish diversity in comparison with shoals and reefs at similar depths around Australia, and relatively high levels of fish abundance (Figure 57). Tassie shoal has the highest median species richness yet recorded by AIMS at any location using BRUVS techniques. The geographically closest shoals for comparison are the Margaret Harries Banks, which also have higher fish species richness and abundance compared with the global mean. In contrast, Evans Shoal has fish species richness and abundance much closer to the global mean.

The highly diverse fish communities at Tassie Shoal include three new species records for Australia in the data. These were an undescribed emperor (*Lethrinus* sp1), not yet classified in the scientific literature, and two parrotfish known to occur in Indonesia – *Scarus hypselopterus* and *Scarus* *fuscodocaudalis* (see Appendix 2). There were a number of other species recorded for the first time in AIMS sampling of the north-western bioregions, such as the Pinjalo snapper (*Pinjalo lewisi*).

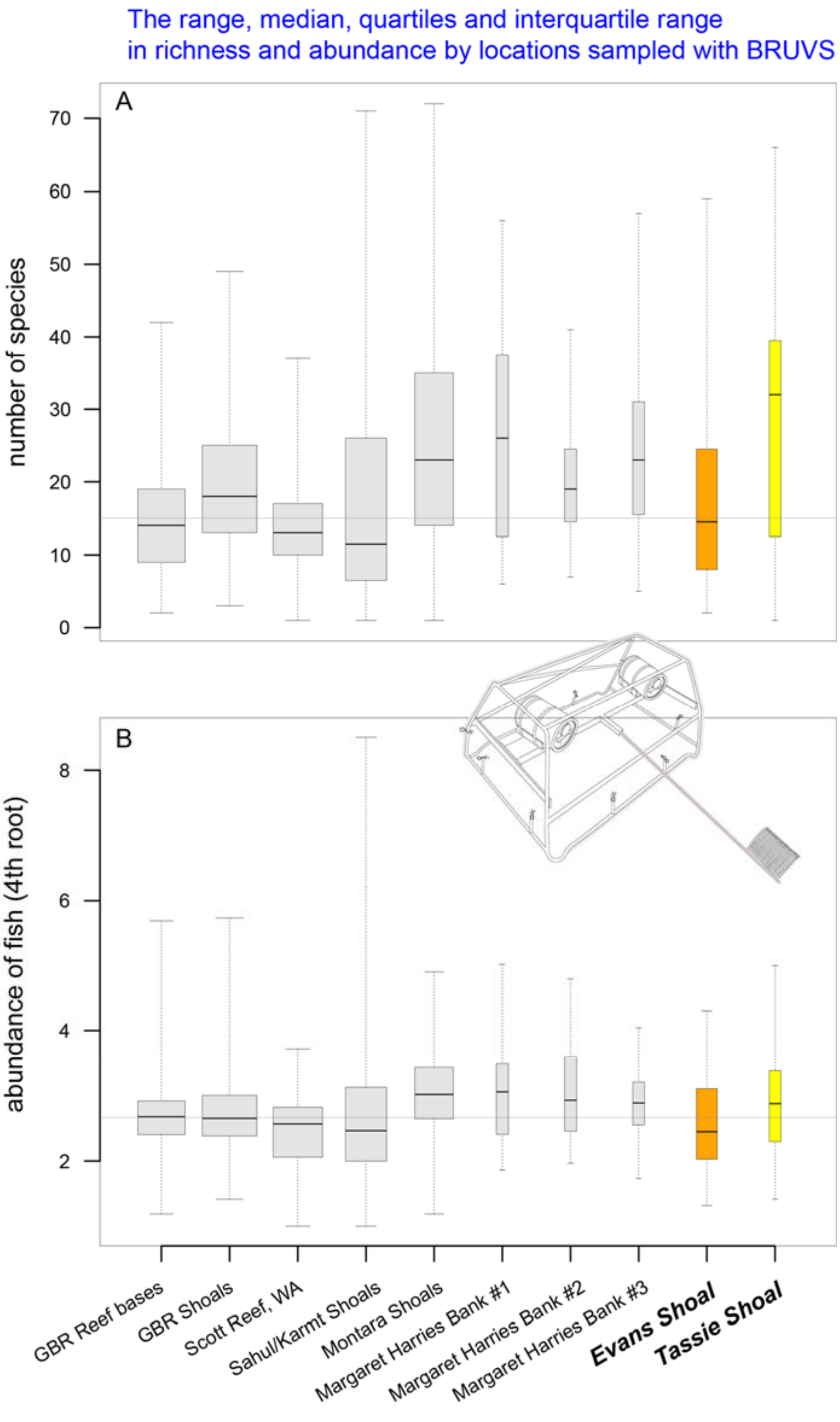


Figure 57: Comparison of species richness and transformed abundance (4th root) of fishes, sharks, rays and sea snakes pooled among baited videos (BRUVS) set in different regions. The samples from each region were selected to have similar depths and habitats as the BRUVS imagery analysed from Evans and Tassie Shoals. The box and whisker plots show the ranges, medians, and interquartile ranges in data. The box widths are proportional to the square root of the sample size

(number of SBRUVS drops). Horizontal lines show the global medians in richness and transformed abundance across the 10 regions compared. Tassie shoal has the highest diversity and abundance of any region sampled by AIMS.

3 Discussion

On both Tassie and Evans Shoals, the presence of extensive carbonate sand fields down a proportion of the shoal slope is suggestive of sediments being moved from the plateau regions and accumulating on the slopes. This feature was particularly noticeable on the western margins, but could be found on both eastern and western sides of the shoals, though less extensive or absent at northern and southern ends. This distribution of unconsolidated sand may reflect an approximate east-west sediment transport environment associated with prevailing currents and wave regimes. Clearer water along the outer shelf allowed light dependent organisms to dominate the upper regions of all shoals in the region. Coral cover was more consistent and increased its contribution to the shallow plateau habitats as shoal depth and plateau size decreased. However, the mechanism responsible for this possible trend is not clear and it may merely reflect the level of consolidated substrate available to support coral recruitment and growth. Similarly, it is unclear why some, but not all parts of the upper plateau rim and slopes, supported dense areas of foliaceous coral. The biota observed on all three shoals appeared to be in healthy condition. It is notable that only two giant clams were observed in total on the transects surveyed at the three shoals. Although the detectability of clams using towed video is not known, clams of the sizes represented by those confiscated from illegal fishing boats in the area in recent years should be clearly visible and the lack of clams may reflect a general loss of these larger specimens from the shallower and more accessible areas. Other than the lack of clams, there was little or no mortality seen amongst the coral species and on all shoals the presence of large table corals greater than a metre in diameter suggests no recent major disturbances from storms.

The three shoals shared similar habitats and species, but the relative contribution of key biota and associated habitat complexity varied on each. The benthic community on Tassie Shoal was more similar to Blackwood, although with less hard coral overall, while Evans Shoal was most comparable for benthic community structure with one of the Margaret Harries Banks shoals. In terms of hard corals, overall coral cover was similar at Tassie and Evans Shoal, at approximately 9% cover, while Blackwood was significantly higher at a mean cover of 25%. This relates to Blackwood Shoal having coral dominated habitat more consistently spread across much of its small plateau, while on Tassie and Evans Shoals a variety of other habitat types are more common. An analysis of coral cover on individual transects revealed that maximum coral cover within coral dominated habitats was more similar between these three shoals, typically ranging between 21-32%. This level of coral cover is typical of coral dominated habitats on healthy coral reefs. An AIMS analysis of individual transects featuring moderate to high coral cover over distances of 250-900 m, found that maximum coral cover at Evans, Tassie and Blackwood Shoals, within a single transect, was in the middle ranking of the twenty shoals for which AIMS has comparable data. The one exception to this mid-ranking level of coral abundance was in the deeper foliaceous coral habitats found at Evans Shoal, where corals appeared to be closely packed and coral cover reached a maximum of 63% over approximately 300 m on one transect during its transit across that coral community. This type of coral community is not unique to Evans Shoal, however, having also been observed, but much more limited extent on Tassie Shoal, as well as during 2004 AIMS surveys at Barton Shoal to the west and in the deeper lagoon habitat at south Scott Reef (Heyward, pers.obs.).

The larger Evans Shoal had very extensive areas of sand and rubble across large proportions of it plateau, with corals patchy and variable in abundance and diversity. Some areas of medium to high coral density were noted, including the presence in selected areas between 40-60 m, of foliaceous coral habitat very similar to that observed further west in the Sahul Shoals and within the deeper lagoon at Scott Reef. The steepening slopes at the shoal edges saw an increase in the presence of coarse sand, likely being transported off the plateaus, with filter feeding biota becoming more prevalent on any rocky outcrops beyond around 60 m.

The benthic habitats at all three shoals were consistent with other outer-shelf shoals observed by AIMS across the North and North-west bioregions. The quantitative measures of major habitat types and fine scale detail of coral abundance and diversity point to strong regional similarities between shoals. The available information indicates that each shoal has its own characteristic benthic community but that there are many species that are in common among shoals. The fish communities encountered at Evans and Tassie Shoals were similarly comparable to other shoals in the region in terms of abundance and diversity, sharing many species, although the Tassie Shoal data was notably more diverse than several others and features three species not recorded elsewhere by AIMS. It is a feature of all BRUVS sampling conducted on shoals by AIMS in this region that the fish data from a single survey captures a majority of species present, but species accumulation curves fall well short of reaching an asymptote. The 300 species of finfish, sharks and rays encountered in this study is typical of the diversity seen during initial survey of shoals in this region. Where repeat surveys have been conducted on other shoals by AIMS, additional species have been observed, with total recorded fish species incrementing around 10% with each additional survey. Records of fish diversity would increase if further BRUVS deployments were made at Evans and Tassie Shoals, particularly in the reefy habitat areas.

Levels of ecological connectivity among the shoals remain to be demonstrated, but the strong surface currents tracked using satellite drifters throughout this bioregion (AIMS, unpublished data), indicate transport rates of 20km/day under light to moderate wind conditions and much higher during storms or seasonal tradewind periods. Consequently connectivity, at least on evolutionary timescales, between shoal features is expected. The status of the biota on each shoal may reflect varying connectivity, to some degree, but also disturbance events such as cyclone and storm damage and coral bleaching.

The two mid-shelf areas investigated were much more turbid than the shelf-edge shoals and did not support notable benthic primary producer habitat, other than the occasional coral on the very shallowest transects <30 m. Sparse to moderate density filter feeders, dominated by small sponges, were observed on areas of bare rock or sand covered pavement, with larger organisms observed on outcropping low relief reef or rocks where the seabed slope changed around the edge of deeper channels. In general, epibenthic biota was sparse and initial observations suggest the dominant species present are consistent with what has been seen during other surveys of similarly turbid waters in the region, e.g. Kelly & Prezlawski (2012). Most of these areas were found to have a seabed covered in unconsolidated sediments such as coarse sand and mud, but occasionally gravels, with epibenthic fauna present at low densities attached to areas of consolidated pavement covered in fine sediment, or on low relief rock outcropping, most commonly present around ridges and sharp drop offs. These patterns were also consistent with the regional community analysis and regional spatial model (Figure 57) where large areas were sparsely populated with epibenthic fauna (Burrows/Crinoids; 22.91%) and to a lesser extent filter feeder communities (6.44%). Coral reef communities were associated with the shallower reefs, shoals and banks particularly as they moved away from the turbid coastal fringe. No benthic habitat was predicted for a substantial portion of the area (69.24%). These areas will contain various organisms, but in general insufficient biota to allow a discrete category to be modelled as a habitat class. However caution should be used interpreting the extrapolations in the regional model beyond the extent of the surveyed data. The "none" habitat category is most likely to represent areas with little or no habitat forming biota, but is less well predicted by the model that the other categories. Caution should be used interpreting the regional model beyond the extent of the surveyed data. There are large areas where there is no validation information available so estimates of model accuracy and error are not possible to calculate without additional field data. It should also be noted with caution that while over the entire regional model performed well for most habitat categories, the "None" category had the poorest performance most frequently under predicting filter feeder (including whips) and Halimedia communities which by their nature can be discrete, stochastic and challenging to model.

The complex seabed bathymetry gives rise to turbulence associated with tidal flows and resuspension of fine sediments, which is a feature of these mid- and inner shelf areas. Spring tides with associated high turbidity and strong tidal currents were encountered during the field survey, particularly when surveying across some of the submerged channel features adjacent to Cape Helvetius. The limited sediment data collected during this project and the review of sediment data for the region suggest a complex spatial pattern of reworked old terrigenous sediments and *in situ* production of carbonates, which may increase in importance in shallow waters and in particular with distance from the coast.

In summary, this report represents the final results from the October 2015 study and establishes baseline information relevant to the Barossa Field and surrounds. It provides a general characterisation of habitat distributions and dominant biota on shoals and mid-shelf areas surveyed. Both the mid-shelf areas and the shoals displayed biological communities consistent with other similar areas in the broader region. The patchy distribution of filter feeder communities on the mid-shelf suggests a pattern linked to the underlying geology and complex bathymetry that are a legacy of the drowned coastal shelf area. The outer shelf shoals support filter feeding communities, but their most striking feature is a rich biodiversity more similar to coral reefs, driven by light in the upper regions and across the plateaux.

While the survey recorded the major habitat types and a large portion of the species present, it is clear that the biodiversity will continue to be further defined as part of additional regional survey efforts over time. Future repeats of this survey would likely produce a very similar broad characterisation of the seabed biodiversity, although change in abundance of dominant species and distribution of habitats is possible, with variability over time likely to be a natural attribute of these ecosystems. These systems, particularly the shallower habitats, may also be subject to larger scale changes from acute, but less predictable natural disturbances, such as a severe storms or elevated seawater temperature anomalies.

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Appendix 1

Date	Technique	Site	Name	Data	Latitude	Longitude	Depth
14-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow19	Real Time Benthic Classification, Video, HD Images	-10.6803	130.1968	27.3
14-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow15	Real Time Benthic Classification, Video, HD Images	-10.6816	130.2113	28.3
14-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow13	Real Time Benthic Classification, Video, HD Images	-10.7094	130.2238	26.4
14-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow14	Real Time Benthic Classification, Video, HD Images	-10.6960	130.2476	52.1
14-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow11	Real Time Benthic Classification, Video, HD Images	-10.7066	130.2615	77.2
14-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow8	Real Time Benthic Classification, Video, HD Images	-10.7379	130.2664	77.6
14-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow4	Real Time Benthic Classification, Video, HD Images	-10.7081	130.3045	42.1
14-Sep-15	CTD	Goodrich Bank	Trip6251_CTD1	CTD	-10.7377	130.3110	66.7
14-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow7	Real Time Benthic Classification, Video, HD Images	-10.7371	130.3111	66.1
15-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow28	Real Time Benthic Classification, Video, HD Images	-10.6972	130.0634	103.8
15-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow27	Real Time Benthic Classification, Video, HD Images	-10.7219	130.0527	29
15-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow26	Real Time Benthic Classification, Video, HD Images	-10.7301	130.0583	28.8
15-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow25	Real Time Benthic Classification, Video, HD Images	-10.7385	130.0963	52.3
15-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow21	Real Time Benthic Classification, Video, HD Images	-10.7277	130.1395	73.9
15-Sep-15	CTD	Goodrich Bank	Trip6251_CTD2	CTD	-10.7293	130.1669	77
15-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow20	Real Time Benthic Classification, Video, HD Images	-10.7369	130.1633	75.8
15-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow29	Real Time Benthic Classification, Video, HD Images	-10.6855	130.0917	42.7
15-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow22	Real Time Benthic Classification, Video, HD Images	-10.6872	130.0949	34

15-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow24	Real Time Benthic Classification, Video, HD Images	-10.6730	130.1415	30.6
15-Sep-15	CTD	Goodrich Bank	Trip6251_CTD3	CTD	-10.6797	130.0777	74.8
16-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow5	Real Time Benthic Classification, Video, HD Images	-10.7132	130.3262	20.6
16-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow3	Real Time Benthic Classification, Video, HD Images	-10.6817	130.3153	19.3
16-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow9	Real Time Benthic Classification, Video, HD Images	-10.6808	130.3572	64.9
16-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow2	Real Time Benthic Classification, Video, HD Images	-10.6681	130.3429	56.7
16-Sep-15	CTD	Goodrich Bank	Trip6251_CTD4	CTD	-10.6498	130.3209	53.7
16-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow1	Real Time Benthic Classification, Video, HD Images	-10.6451	130.3038	71
16-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow12	Real Time Benthic Classification, Video, HD Images	-10.6407	130.2588	80.4
16-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow10	Real Time Benthic Classification, Video, HD Images	-10.6610	130.2928	78.9
16-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow17	Real Time Benthic Classification, Video, HD Images	-10.6509	130.2222	52.5
16-Sep-15	CTD	Goodrich Bank	Trip6251_CTD5	CTD	-10.6696	130.2658	84.7
17-Sep-15	Smith McIntryre Grab	Goodrich Bank	Goodrich Bank_Stn01Gr01	Sediment Samples	-10.7187	130.2625	80.8
17-Sep-15	Smith McIntryre Grab	Goodrich Bank	Goodrich Bank_Stn02Gr02	Sediment Samples	-10.6918	130.2629	67.6
17-Sep-15	Smith McIntryre Grab	Goodrich Bank	Goodrich Bank_Stn03Gr03	Sediment Samples	-10.6643	130.2631	83.5
17-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow16	Real Time Benthic Classification, Video, HD Images	-10.6686	130.2092	28.2
17-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow18	Real Time Benthic Classification, Video, HD Images	-10.6580	130.1789	49.4
17-Sep-15	Towed Video	Goodrich Bank	Goodrich Bank_Tow23	Real Time Benthic Classification, Video, HD Images	-10.6493	130.1436	34.3
17-Sep-15	CTD	Evans Shoal	Trip6251_CTD6	CTD	-9.9305	129.6060	179.3
18-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow31	Real Time Benthic Classification, Video, HD Images	-9.9476	129.5767	
18-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow21	Real Time Benthic Classification, Video, HD Images	-9.9455	129.5811	19.7

18-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow20	Real Time Benthic Classification, Video, HD Images	-9.9377	129.5846	19.3
18-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow19	Real Time Benthic Classification, Video, HD Images	-9.9289	129.5887	18.7
18-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow18	Real Time Benthic Classification, Video, HD Images	-9.9234	129.5873	22.1
18-Sep-15	CTD	Evans Shoal	Trip6251_CTD7	CTD	-9.9156	129.6038	190
18-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow14	Real Time Benthic Classification, Video, HD Images	-9.9176	129.5823	18.9
18-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow13	Real Time Benthic Classification, Video, HD Images	-9.9134	129.5811	18
18-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow6	Real Time Benthic Classification, Video, HD Images	-9.9058	129.5711	25.5
18-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow5	Real Time Benthic Classification, Video, HD Images	-9.9005	129.5682	26.2
18-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow4	Real Time Benthic Classification, Video, HD Images	-9.8936	129.5596	22.7
18-Sep-15	CTD	Evans Shoal	Trip6251_CTD8	CTD	-9.8665	129.5432	169.9
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM1RIG1	Stereo Video	-9.8882	129.5743	68
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM2RIG2	Stereo Video	-9.8927	129.5783	56.6
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM3RIG3	Stereo Video	-9.8963	129.5819	56.2
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM4RIG4	Stereo Video	-9.9060	129.5875	49.7
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM5RIG5	Stereo Video	-9.9129	129.5937	60.9
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM6RIG6	Stereo Video	-9.9194	129.5971	64.9
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM7RIG7	Stereo Video	-9.9283	129.5995	68.1
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM8RIG9	Stereo Video	-9.9349	129.5980	60.8
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM9RIG9	Stereo Video	-9.8889	129.5573	19.6
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM10RIG7	Stereo Video	-9.9008	129.5738	20.7
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM11RIG6	Stereo Video	-9.9059	129.5817	18
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM12RIG5	Stereo Video	-9.9139	129.5830	21.1
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM13RIG4	Stereo Video	-9.9214	129.5890	19.6
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM14RIG3	Stereo Video	-9.9275	129.5947	18.3
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM15RIG2	Stereo Video	-9.9336	129.5917	19.1
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM16RIG1	Stereo Video	-9.9455	129.5908	17.5
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM17RIG1	Stereo Video	-9.8972	129.5532	24.5
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM18RIG2	Stereo Video	-9.8984	129.5588	25.9

19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM19RIG3	Stereo Video	-9.9038	129.5638	26.3
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM20RIG4	Stereo Video	-9.9045	129.5698	25
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM21RIG5	Stereo Video	-9.9137	129.5694	25.6
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM22RIG6	Stereo Video	-9.9189	129.5770	24.5
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM23RIG7	Stereo Video	-9.9280	129.5864	22.2
19-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM24RIG9	Stereo Video	-9.9365	129.5893	20.9
19-Sep-15	Panda	Evans Shoal	EvansShoal_Drop1	Oblique Images	-9.9288	129.5917	19.6
19-Sep-15	Panda	Evans Shoal	EvansShoal_Drop2	Oblique Images	-9.8913	129.5751	53.3
19-Sep-15	Panda	Evans Shoal	EvansShoal_Drop3	Oblique Images	-9.9099	129.5863	19.9
19-Sep-15	CTD	Evans Shoal	Trip6251_CTD9	CTD	-9.9008	129.5934	181.4
20-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow36	Real Time Benthic Classification, Video, HD Images	-9.9471	129.5619	26.8
20-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow22	Real Time Benthic Classification, Video, HD Images	-9.9491	129.5604	24.7
20-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow24	Real Time Benthic Classification, Video, HD Images	-9.9433	129.5504	26.8
20-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow33	Real Time Benthic Classification, Video, HD Images	-9.9387	129.5476	26.7
20-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow23	Real Time Benthic Classification, Video, HD Images	-9.9346	129.5395	41.5
20-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow11	Real Time Benthic Classification, Video, HD Images	-9.9224	129.5410	24.5
20-Sep-15	CTD	Evans Shoal	Trip6251_CTD10	CTD	-9.9103	129.5135	168.2
20-Sep-15	CTD	Evans Shoal	Trip6251_CTD11	CTD	-9.9139	129.5386	24.7
20-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow10	Real Time Benthic Classification, Video, HD Images	-9.9117	129.5375	24.1
20-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow9	Real Time Benthic Classification, Video, HD Images	-9.9027	129.5400	25.1
20-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow2	Real Time Benthic Classification, Video, HD Images	-9.8985	129.5422	23.9
20-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow3	Real Time Benthic Classification, Video, HD Images	-9.8871	129.5445	18.3
20-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow1	Real Time Benthic Classification, Video, HD Images	-9.8897	129.5496	22.9
20-Sep-15	CTD	Evans Shoal	Trip6251_CTD12	CTD	-9.8768	129.5617	151.2
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM25RIG1	Stereo Video	-9.8759	129.5543	75.4
21-Sep-15	SBRUVS	Evans	EvansShoal_CAM26RIG2	Stereo Video	-9.8741	129.5475	56.9

		Shoal					
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM27RIG3	Stereo Video	-9.8747	129.5430	47.2
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM28RIG4	Stereo Video	-9.8762	129.5390	43.8
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM29RIG5	Stereo Video	-9.8822	129.5364	44.7
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM30RIG6	Stereo Video	-9.8942	129.5319	56.4
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM31RIG7	Stereo Video	-9.8984	129.5278	66.6
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM32RIG9	Stereo Video	-9.9052	129.5313	39.9
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM33RIG9	Stereo Video	-9.9089	129.5256	71.6
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM34RIG7	Stereo Video	-9.9155	129.5277	57.1
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM35RIG6	Stereo Video	-9.9249	129.5294	56.4
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM36RIG5	Stereo Video	-9.9312	129.5275	75.1
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM37RIG4	Stereo Video	-9.9373	129.5290	79.4
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM38RIG3	Stereo Video	-9.9419	129.5339	56.9
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM39RIG2	Stereo Video	-9.9478	129.5328	73.4
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM40RIG1	Stereo Video	-9.9536	129.5398	62.4
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM41RIG1	Stereo Video	-9.9276	129.5402	23.8
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM42RIG2	Stereo Video	-9.9369	129.5389	54.5
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM43RIG3	Stereo Video	-9.9506	129.5402	52.3
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM44RIG4	Stereo Video	-9.9495	129.5476	22.5
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM45RIG5	Stereo Video	-9.9550	129.5551	46.8
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM46RIG6	Stereo Video	-9.9592	129.5635	58.1
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM47RIG7	Stereo Video	-9.9541	129.5754	18.2
21-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM48RIG9	Stereo Video	-9.9539	129.5903	65.8
21-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow32	Real Time Benthic Classification, Video, HD Images	-9.9489	129.5722	23.6
21-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow29	Real Time Benthic Classification, Video, HD Images	-9.9356	129.5696	23.2
21-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow25	Real Time Benthic Classification, Video, HD Images	-9.9327	129.5847	21.5
21-Sep-15	CTD	Evans Shoal	Trip6251_CTD13	CTD	-9.9174	129.6009	161.9
22-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow7	Real Time Benthic Classification, Video, HD Images	-9.8893	129.5420	18.7
22-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow8	Real Time Benthic Classification, Video, HD Images	-9.9019	129.5417	26.3

22-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow15	Real Time Benthic Classification, Video, HD Images	-9.9031	129.5539	27.4
22-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow12	Real Time Benthic Classification, Video, HD Images	-9.9067	129.5393	25.2
22-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow16	Real Time Benthic Classification, Video, HD Images	-9.9192	129.5483	27.1
22-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow17	Real Time Benthic Classification, Video, HD Images	-9.9049	129.5543	26.8
22-Sep-15	CTD	Evans Shoal	Trip6251_CTD14	CTD	-9.9164	129.5610	26.3
22-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow26	Real Time Benthic Classification, Video, HD Images	-9.9085	129.5618	26.2
22-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow27	Real Time Benthic Classification, Video, HD Images	-9.9178	129.5655	25.1
22-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow30	Real Time Benthic Classification, Video, HD Images	-9.9223	129.5636	25.4
22-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow28	Real Time Benthic Classification, Video, HD Images	-9.9293	129.5614	25.6
22-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow35	Real Time Benthic Classification, Video, HD Images	-9.9353	129.5615	25.9
22-Sep-15	Towed Video	Evans Shoal	EvansShoal_Tow34	Real Time Benthic Classification, Video, HD Images	-9.9382	129.5517	27.1
22-Sep-15	CTD	Evans Shoal	Trip6251_CTD15	CTD	-9.9324	129.5172	138.2
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM49RIG1	Stereo Video	-9.8854	129.5436	18.5
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM50RIG2	Stereo Video	-9.8919	129.5443	21.3
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM51RIG3	Stereo Video	-9.8944	129.5408	23.4
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM52RIG4	Stereo Video	-9.8997	129.5416	24.8
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM53RIG5	Stereo Video	-9.9022	129.5358	23.3
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM54RIG6	Stereo Video	-9.9114	129.5437	27.4
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM55RIG7	Stereo Video	-9.9111	129.5546	26.8
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM56RIG9	Stereo Video	-9.9056	129.5558	27.9
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM57RIG9	Stereo Video	-9.9165	129.5307	59
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM58RIG7	Stereo Video	-9.9205	129.5450	26.1
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM59RIG6	Stereo Video	-9.9214	129.5505	27.6
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM60RIG5	Stereo Video	-9.9246	129.5594	26.3
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM61RIG4	Stereo Video	-9.9168	129.5616	26.8
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM62RIG3	Stereo Video	-9.9220	129.5674	25.2

23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM63RIG2	Stereo Video	-9.9305	129.5701	23.9
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM64RIG1	Stereo Video	-9.9390	129.5632	25.7
23-Sep-15	Panda	Evans Shoal	EvansShoal_Drop4	Oblique Images	-9.9407	129.5434	18.5
23-Sep-15	Panda	Evans Shoal	EvansShoal_Drop5	Oblique Images	-9.9408	129.5435	18.5
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM65_RIG1	Stereo Video	-9.9410	129.5434	18.6
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM66_RIG2	Stereo Video	-9.9448	129.5528	26.4
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM67_RIG3	Stereo Video	-9.9381	129.5553	27
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM68_RIG4	Stereo Video	-9.9544	129.5634	19.8
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM69_RIG5	Stereo Video	-9.9467	129.5699	23.5
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM70_RIG6	Stereo Video	-9.9404	129.5716	21.7
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM71_RIG7	Stereo Video	-9.9399	129.5759	21.4
23-Sep-15	SBRUVS	Evans Shoal	EvansShoal_CAM72_RIG9	Stereo Video	-9.9384	129.5829	21.3
23-Sep-15	Towed Video	Evans Shoal	EvansShoal_Pavona1	Real Time Benthic Classification, Video, HD Images	-9.9406	129.5417	26.6
23-Sep-15	Towed Video	Evans Shoal	EvansShoal_Pavona2	Real Time Benthic Classification, Video, HD Images	-9.9415	129.5430	24.8
23-Sep-15	CTD	Evans Shoal	Trip6251_CTD16	CTD	-9.9629	129.5447	135.8
24-Sep-15	Towed Video	Blackwood Shoal	BlackwoodShoal_Tow1	Real Time Benthic Classification, Video, HD Images	-9.8849	129.4120	28.6
24-Sep-15	Towed Video	Blackwood Shoal	BlackwoodShoal_Tow2	Real Time Benthic Classification, Video, HD Images	-9.8789	129.4159	38.9
24-Sep-15	CTD	Tassie Shoal	Trip6251_CTD17	CTD	-10.1166	129.5499	113.7
24-Sep-15	Towed Video	Tassie Shoal	TassieShoal_Tow4	Real Time Benthic Classification, Video, HD Images	-10.1341	129.5493	15.3
24-Sep-15	Towed Video	Tassie Shoal	TassieShoal_Tow3	Real Time Benthic Classification, Video, HD Images	-10.1324	129.5480	14.7
24-Sep-15	Towed Video	Tassie Shoal	TassieShoal_Tow5	Real Time Benthic Classification, Video, HD Images	-10.1363	129.5501	14.9
24-Sep-15	Towed Video	Tassie Shoal	TassieShoal_Tow5a	Real Time Benthic Classification, Video, HD Images	-10.1373	129.5512	14.3
24-Sep-15	Towed Video	Tassie Shoal	TassieShoal_Tow9	Real Time Benthic Classification, Video, HD Images	-10.1472	129.5429	18.3
24-Sep-15	CTD	Tassie Shoal	Trip6251_CTD18	CTD	-10.1572	129.5310	89.4
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM1_RIG9	Stereo Video	-10.1239	129.5414	88.2
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM2_RIG7	Stereo Video	-10.1263	129.5385	95.9
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM3_RIG6	Stereo Video	-10.1331	129.5390	84.9

25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM4_RIG5	Stereo Video	-10.1358	129.5439	16.3
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM5_RIG4	Stereo Video	-10.1443	129.5434	18.8
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM6_RIG3	Stereo Video	-10.1446	129.5370	81.1
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM7_RIG2	Stereo Video	-10.1502	129.5336	85
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM8_RIG1	Stereo Video	-10.1565	129.5317	88.5
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM9_RIG1	Stereo Video	-10.1261	129.5449	77.2
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM10_RIG2	Stereo Video	-10.1296	129.5496	17
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM11_RIG3	Stereo Video	-10.1359	129.5513	16.1
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM12_RIG4	Stereo Video	-10.1405	129.5540	19.1
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM13_RIG5	Stereo Video	-10.1449	129.5499	18.8
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM14_RIG6	Stereo Video	-10.1494	129.5474	19.6
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM15_RIG7	Stereo Video	-10.1547	129.5411	22.3
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM16_RIG9	Stereo Video	-10.1504	129.5377	77.6
25-Sep-15	CTD	Tassie Shoal	Trip6251_CTD19	CTD	-10.1593	129.5506	101.3
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM17_RIG9	Stereo Video	-10.1332	129.5565	24.1
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM18_RIG7	Stereo Video	-10.1391	129.5598	61.3
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM19_RIG6	Stereo Video	-10.1451	129.5609	85.6
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM20_RIG5	Stereo Video	-10.1486	129.5556	23.3
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM21_RIG4	Stereo Video	-10.1519	129.5566	85.1
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM22_RIG3	Stereo Video	-10.1535	129.5536	74.3
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM23_RIG2	Stereo Video	-10.1544	129.5494	26
25-Sep-15	SBRUVS	Tassie Shoal	TassieShoal_CAM24_RIG1	Stereo Video	-10.1563	129.5455	25.3
25-Sep-15	Towed Video	Tassie Shoal	TassieShoal_TowBommie	Real Time Benthic Classification, Video, HD Images	-10.1547	129.5418	20.3
25-Sep-15	Towed Video	Tassie Shoal	TassieShoal_Tow7	Real Time Benthic Classification, Video, HD Images	-10.1485	129.5446	18.3
25-Sep-15	Towed Video	Tassie Shoal	TassieShoal_Tow8	Real Time Benthic Classification, Video, HD Images	-10.1432	129.5454	16.7
25-Sep-15	CTD	Tassie Shoal	Trip6251_CTD20	CTD	-10.1370	129.5371	96.7
26-Sep-15	Towed Video	Tassie Shoal	TassieShoal_Tow1	Real Time Benthic Classification, Video, HD Images	-10.1346	129.5462	15.1
26-Sep-15	Towed Video	Tassie Shoal	TassieShoal_Tow2	Real Time Benthic Classification, Video, HD Images	-10.1384	129.5504	16.5
26-Sep-15	Towed Video	Tassie Shoal	TassieShoal_Tow6	Real Time Benthic Classification, Video, HD Images	-10.1421	129.5486	

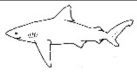
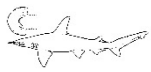
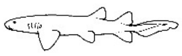
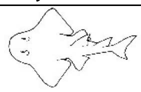
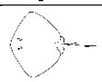
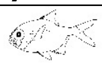
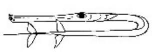
26-Sep-15	Towed Video	Tassie Shoal	TassieShoal_Panda1		-10.1575	129.5447	29.6
26-Sep-15	Towed Video	Tassie Shoal	TassieShoal_Kanga2	Real Time Benthic Classification, Video, HD Images	-10.1572	129.5442	28.2
26-Sep-15	Towed Video	Tassie Shoal	TassieShoal_Kanga3	Real Time Benthic Classification, Video, HD Images	-10.1577	129.5450	33.1
26-Sep-15	Towed Video	Tassie Shoal	TassieShoal_Kanga4	Real Time Benthic Classification, Video, HD Images	-10.1362	129.5485	15.8
26-Sep-15	Towed Video	Tassie Shoal	TassieShoal_Kanga5	Real Time Benthic Classification, Video, HD Images	-10.1364	129.5500	16.4
26-Sep-15	Towed Video	Tassie Shoal	TassieShoal_Kanga6	Real Time Benthic Classification, Video, HD Images	-10.1351	129.5577	28
27-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow32	Real Time Benthic Classification, Video, HD Images	-11.5852	129.9353	41.7
27-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow14	Real Time Benthic Classification, Video, HD Images	-11.6045	129.9506	38.7
27-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow24	Real Time Benthic Classification, Video, HD Images	-11.6054	129.9285	52.7
27-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow27	Real Time Benthic Classification, Video, HD Images	-11.6224	129.9159	81.7
27-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow29	Real Time Benthic Classification, Video, HD Images	-11.6300	129.8694	34.7
27-Sep-15	CTD	Cape Helvetius	Trip6251_CTD23	CTD	-11.6301	129.8972	162.5
27-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow25	Real Time Benthic Classification, Video, HD Images	-11.6288	129.9353	44.2
27-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow11	Real Time Benthic Classification, Video, HD Images	-11.6441	129.9576	48.9
27-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow20	Real Time Benthic Classification, Video, HD Images	-11.6790	129.9772	45.3
27-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow5	Real Time Benthic Classification, Video, HD Images	-11.6567	130.0414	19
27-Sep-15	CTD	Cape Helvetius	Trip6251_CTD22	CTD	-10.6648	130.1088	93.9
27-Sep-15	CTD	Cape Helvetius	Trip6251_CTD24	CTD	-11.5659	129.9693	
27-Sep-15	CTD	Cape Helvetius	Trip6251_CTD25	CTD	-11.5729	129.8700	180.5
27-Sep-15	CTD & 2 DRIFTERS	Cape Helvetius	Trip6251_CTD21	CTD, GPS Locations	-9.4817	129.4184	131
28-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow7	Real Time Benthic Classification, Video, HD Images	-11.6123	130.0016	26.6
28-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow6	Real Time Benthic Classification, Video, HD Images	-11.6470	129.9995	31.4

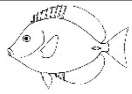
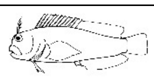
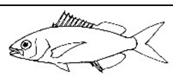
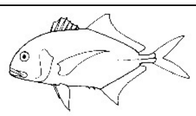
28-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow8	Real Time Benthic Classification, Video, HD Images	-11.6751	129.9678	45
28-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow22	Real Time Benthic Classification, Video, HD Images	-11.6787	129.9315	55.3
28-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow12	Real Time Benthic Classification, Video, HD Images	-11.6625	129.9239	76.8
28-Sep-15	CTD	Cape Helvetius	Trip6251_CTD26	CTD	-11.6701	129.9098	136
28-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow3	Real Time Benthic Classification, Video, HD Images	-11.7172	130.0045	31.2
28-Sep-15	CTD	Cape Helvetius	Trip6251_CTD27	CTD	-11.6778	129.9825	77.8
29-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow10	Real Time Benthic Classification, Video, HD Images	-11.7296	129.9603	46.1
29-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow2	Real Time Benthic Classification, Video, HD Images	-11.7279	130.0460	11.5
29-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow1	Real Time Benthic Classification, Video, HD Images	-11.6944	130.0324	17
29-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow19	Real Time Benthic Classification, Video, HD Images	-11.7054	129.9379	45.8
29-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow18	Real Time Benthic Classification, Video, HD Images	-11.7204	129.9169	75.8
29-Sep-15	CTD	Cape Helvetius	Trip6251_CTD28	CTD	-11.7354	129.9054	82.3
29-Sep-15	Smith McIntrye Grab	Cape Helvetius	Cape Helvetius_Stn04Gr04	Sediment Samples	-11.7356	129.9248	76
29-Sep-15	Smith McIntrye Grab	Cape Helvetius	Cape Helvetius_Stn05Gr05	Sediment Samples	-11.6942	129.9283	57.1
29-Sep-15	Smith McIntrye Grab	Cape Helvetius	Cape Helvetius_Stn06Gr06	Sediment Samples	-11.6178	129.9329	42
29-Sep-15	Smith McIntrye Grab	Cape Helvetius	Cape Helvetius_Stn07Gr07	Sediment Samples	-11.6968	129.9610	55.6
29-Sep-15	Smith McIntrye Grab	Cape Helvetius	Cape Helvetius_Stn08Gr08	Sediment Samples	-11.6974	130.0032	33.2
29-Sep-15	Smith McIntrye Grab	Cape Helvetius	Cape Helvetius_Stn09Gr09	Sediment Samples	-11.6937	130.0442	16
29-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow4	Real Time Benthic Classification, Video, HD Images	-11.6863	130.0018	33.2
29-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow23	Real Time Benthic Classification, Video, HD Images	-11.6550	129.8695	51.5
29-Sep-15	CTD	Cape Helvetius	Trip6251_CTD29	CTD	-11.5698	129.9303	58.5
30-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow9	Real Time Benthic Classification, Video, HD Images	-11.7428	129.9621	50.1

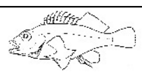
30-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow15	Real Time Benthic Classification, Video, HD Images	-11.7543	129.9213	81
30-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow16	Real Time Benthic Classification, Video, HD Images	-11.7476	129.8712	75.4
30-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow28	Real Time Benthic Classification, Video, HD Images	-11.6691	129.8875	105.1
30-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow28a	Real Time Benthic Classification, Video, HD Images	-11.6689	129.8875	105.6
30-Sep-15	Towed Video	Cape Helvetius	CapeHelvetius_Tow13	Real Time Benthic Classification, Video, HD Images	-11.7013	129.8865	115.6

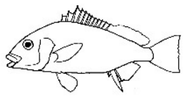
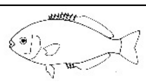
Appendix 2

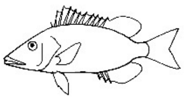
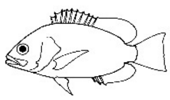
Total counts (sum *MaxN*) of each fish taxa recorded on 95 video files from Evans Shoal (n=72) and Tassie Shoal (n=23), in phylogenetic order. Families, genera and species are listed in alphabetical order within phylogenetic orders. Species marked with an asterisk are new records for Australia.

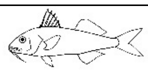
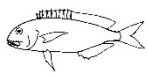
Order/Family	Common name	Scientific name	Evans	Tassie
Carcharhiniformes				
 Carcharhinidae	Silvertip whaler shark	*Carcharhinus albimarginatus*	5	5
	Grey reef shark	*Carcharhinus amblyrhynchos*	12	10
	White tip reef shark	*Triaenodon obesus*	13	13
	Slit-eye shark	*Loxodon macrorhinus*	0	1
	Lemon shark	*Negaprion acutidens*	1	0
 Sphyrnidae	Great Hammerhead	*Sphyrna mokarran*	2	0
Orectolobiformes				
 Ginglymostomatidae	Tawny nurse shark	*Nebrius ferrugineus*	8	0
Rajiformes				
 Rhynchobatidae	Shovelnose ray	*Rhynchobatus australiae*	1	0
Myliobatiformes				
 Dasyatidae	Blue-spotted stingray	*Neotrygon kuhlii*	5	4
	Blotched fantail ray	*Taeniurops meyeni*	1	0
Anguilliformes				
 Muraenidae	Grayface moray eel	*Siderea thrysoidea*	2	1
		Echidna nebulosa	1	0
		Gymnothorax javanicus	0	1
		Gymnothorax sp	2	0
		Gymnothorax zonipectis	1	0
Clupeiformes				
 Clupeidae	Blue sprat	*Spratelloides delicatulus*	200	0
Beryciformes				
 Holocentridae	Squirrelfish	*Sargocentron caudimaculatum*	3	0
Gasterosteiformes				
 Fistulariidae	Flutemouth	*Fistularia petimba*	3	0

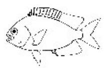
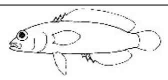
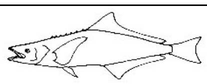
Order/Family	Common name	Scientific name	Evans	Tassie
Perciformes				
 Acanthuridae	Ringtail surgeonfish	*Acanthurus blochii*	9	3
	Eyestripe surgeonfish	*Acanthurus dussumieri*	2	1
	Finelined Surgeonfish	*Acanthurus grammoptilus*	11	7
	Surgeonfish	*Acanthurus leucocheilus*	4	5
	Elongate Surgeonfish	*Acanthurus mata*	142	11
		Acanthurus nigricans	9	0
	Blackstreak Surgeonfish	*Acanthurus nigricauda*	3	3
	Brown Surgeonfish	*Acanthurus nigrofuscus*	3	8
	Bluelined Surgeonfish	*Acanthurus nigros*	8	0
	Orange band Surgeonfish	*Acanthurus olivaceus*	13	11
	Mimic Surgeonfish	*Acanthurus pyroferus*	14	14
		Acanthurus sp	0	1
		Acanthurus thompsoni	26	0
	Yellowfin Surgeonfish	*Acanthurus xanthopterus*	6	0
	Bristletooth Surgeonfish	*Ctenochaetus sp*	1	0
	Bristletooth surgeonfish	*Ctenochaetus striatus*	11	8
	Whitemargin unicornfish	*Naso annulatus*	1	0
	Humpback unicornfish	*Naso brachycentron*	14	1
	Spotted unicornfish	*Naso brevirostris*	10	2
	Thorpe's unicornfish	*Naso caesius*	6	1
	Fagen's unicornfish	*Naso fageni*	16	0
	Sleek unicornfish	*Naso hexacanthus*	130	0
	Orangespine unicornfish	*Naso lituratus*	12	10
		Naso lopezi	7	0
	McDade's unicornfish	*Naso mcdadei*	33	0
	Slender unicornfish	*Naso minor*	3	0
		Naso tonganus	3	0
	Bluespine unicornfish	*Naso unicornis*	4	0
	Vlaming's unicornfish	*Naso vlamingii*	14	3
	Palette surgeonfish	*Paracanthurus hepatus*	5	3
	Brushtail tang	*Zebrasoma scopas*	5	1
 Blenniidae		*Meiacanthus lineatus*	1	1
	Bluestriped fangblenny	*Plagiotremus rhinorhynchos*	3	0
		Plagiotremus tapeinosoma	1	1
 Caesionidae	Blue and gold fusilier	*Caesio teres*	67	21
		Caesio lunaris	4	0
	Black-tipped fusilier	*Pterocaesio marri*	481	680
		Pterocaesio trilineata	80	0
		*Atule mate*	12	0

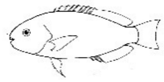
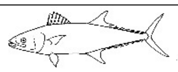
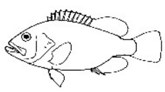
Order/Family	Common name	Scientific name	Evans	Tassie
Carangidae				
	Onion trevally	*Carangoides coeruleopinnatus*	40	18
	Longnose trevally	*Carangoides chrysophrys*	0	31
		Carangoides dinema	0	2
	Blue trevally	*Carangoides ferdau*	8	0
	Goldspot trevally	*Carangoides fulvoguttatus*	2	8
	Bludger trevally	*Carangoides gymnostethus*	55	46
	Coachwhip trevally	*Carangoides orthogrammus*	31	2
	Trevally	*Carangoides plagiotaenia*	5	6
		Carangoides sp	6	0
	Blue-spotted trevally	*Caranx bucculentus*	1	0
	Giant trevally	*Caranx ignobilis*	3	1
	Bluefin trevally	*Caranx melampygus*	25	1
	Scad	*Decapterus sp*	317	0
	Rainbow runner	*Elagatis bipinnulata*	46	0
	Queenfish	*Scomberoides lysan*	0	7
	Queenfish	*Scomberoides tol*	7	0
	Highfin amberjack	*Seriola rivoliana*	0	1
 Chaetodontidae	Butterflyfish	*Chaetodon adiergastos*	5	1
	Threadfin butterflyfish	*Chaetodon auriga*	8	10
	Triangular butterflyfish	*Chaetodon baronessa*	4	1
		Chaetodon ephippium	2	0
	Klein's butterflyfish	*Chaetodon kleinii*	16	9
		Chaetodon leucopleura	3	0
	Lined butterflyfish	*Chaetodon lineolatus*	4	3
	Raccoon butterflyfish	*Chaetodon lunula*	6	3
	Redfin butterflyfish	*Chaetodon lunulatus*	9	6
		Chaetodon meyeri	1	2
	Ornate butterflyfish	*Chaetodon ornatissimus*	4	0
		Chaetodon speculum	1	0
	Chevroned butterflyfish	*Chaetodon trifascialis*	4	4
		Chaetodon trifasciatus	1	0
	Double-saddled butterflyfish	*Chaetodon ulietensis*	0	1
	Teardrop butterflyfish	*Chaetodon unimaculatus*	2	2
		Chaetodon vagabundus	1	0
	Orange-banded coralfish	*Coradion chrysozonus*	5	1
		Forcipiger flavissimus	2	0
	Longnose butterflyfish	*Forcipiger longirostris*	7	2
	Pyramid butterflyfish	*Hemitaurichthys polylepis*	6	2
		Heniochus acuminatus	2	2
	Singular bannerfish	*Heniochus singularius*	4	1
		Heniochus varius	2	0
 Cirrhitidae	Blackside hawkfish	*Paracirrhites forsteri*	2	0

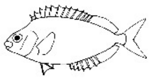
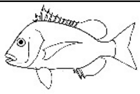
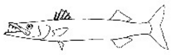
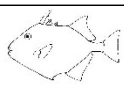
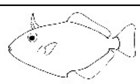
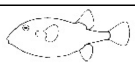
Order/Family	Common name	Scientific name	Evans	Tassie
 Echeneidae	Suckerfish	*Echeneis naucrates*	18	10
 Gobiidae		*Amblygobius phalaena*	2	0
 Ephippidae	Orbicular batfish	*Platax orbicularis*	1	0
 Haemulidae	Painted sweetlips	*Diagramma pictum*	3	0
		Plectorhinchus vittatus	3	1
 Kyphosidae	Topsail drummer	*Kyphosus cinerascens*	1	3
 Labridae		*Anampses meleagrides*	1	0
		Anampses neoguinaicus	1	0
		Anampses twistii	2	0
		Biochoeres biocellatus	2	0
		Bodianus anthioides	0	1
		Bodianus mesothorax	3	0
	Redbreasted maori wrasse	*Cheilinus fasciatus*	1	0
		Choerodon cephalotes	1	0
	Gomon's wrasse	*Choerodon gomoni*	1	0
	Jordan's wrasse	*Choerodon jordani*	12	1
	Zamboanga tuskfish	*Choerodon zamboangae*	3	1
	Blueside wrasse	*Cirrhilabrus cyanopleura*	26	386
	Exquisite wrasse	*Cirrhilabrus exquisitus*	1	11
	Morrison's wrasse	*Cirrhilabrus morrisoni*	60	0
	Dotted wrasse	*Cirrhilabrus punctatus*	54	101
	Wrasse	*Cirrhilabrus sp*	16	0
	Temminck's wrasse	*Cirrhilabrus temminckii*	61	10
	Goldline coris	*Coris aurilineata*	3	0
	Schroeder's coris	*Coris batuensis*	9	8
		Coris dorsomacula	1	0
	Yellowtail coris	*Coris gaimard*	4	8
	Black-striped wrasse	*Coris pictoides*	6	0
		Gomphosus varius	2	0
	Red-lined wrasse	*Halichoeres biocellatus*	1	14
	Golden wrasse	*Halichoeres chrysus*	5	13
		Halichoeres hortulanus	2	0
		Halichoeres margaritaceus	1	0
	Nebulous wrasse	*Halichoeres nebulosus*	1	1
	Twotone wrasse	*Halichoeres prosopeion*	2	0
	Goldstripe wrasse	*Halichoeres zeylonicus*	56	0

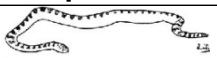
Order/Family	Common name	Scientific name	Evans	Tassie
		Hemigymnus fasciatus	2	0
	Ringwrasse	*Hologymnosus annulatus*	2	7
	Pastel ringwrasse	*Hologymnosus doliatus*	4	8
	Bicolour cleaner wrasse	*Labroides bicolor*	4	0
	Cleaner wrasse	*Labroides dimidiatus*	21	14
	Shoulderspot wrasse	*Leptojulis cyanopleura*	10	2
		Labropsis xanthonota	1	0
	Rockmover wrasse	*Novaculichthys taeniourus*	3	2
		Oxycheilinus arenatus	1	0
	Twospot maori wrasse	*Oxycheilinus bimaculatus*	13	0
	Celebes maori wrasse	*Oxycheilinus celebicus*	32	3
	Cheeklined maori wrasse	*Oxycheilinus digrammus*	4	1
		Oxycheilinus orientalis	15	0
	wrasse	*Pseudojuloides severnsi*	5	0
	Gunther's wrasse	*Pseudolabrus guentheri*	2	0
	Bluntheaded wrasse	*Thalassoma amblycephalum*	9	5
	Jansen's wrasse	*Thalassoma jansenii*	4	0
	Moon wrasse	*Thalassoma lunare*	30	29
		Xyrichtys melanopus	6	0
	Pavo razorfish	*Xyrichtys pavo*	2	0
 Lethrinidae	Robinson's seabream	*Gymnocranius grandoculis*	75	33
	Ambon emperor	*Lethrinus amboinensis*	27	3
	Yellow-tailed emperor	*Lethrinus atkinsoni*	0	1
	Yellow-spotted emperor	*Lethrinus erythracanthus*	7	6
	Pink-eared emperor	*Lethrinus lentjan*	0	10
	Smalltooth emperor	*Lethrinus microdon*	12	3
	Spangled emperor	*Lethrinus nebulosus*	4	1
	Orange-striped emperor	*Lethrinus obsoletus*	2	0
	Long-nose emperor	*Lethrinus olivaceus*	7	0
	Drab emperor	*Lethrinus ravus*	52	41
	Spotcheek emperor	*Lethrinus rubrioperculatus*	119	3
	Emperor	*Lethrinus semicinctus*	151	49
	Unidentified emperor	*Lethrinus sp*	8	0
*	Undescribed emperor	*Lethrinus undescribed sp1**	10	5
	Bigeye bream	*Monotaxis grandoculis*	11	3
 Lutjanidae		*Aphareus furca*	1	0
	Ironjaw jobfish	*Aphareus rutilans*	7	0
	Green jobfish	*Aprion virescens*	31	0
	Red bass	*Lutjanus bohar*	79	8
	Crimson seaperch	*Lutjanus erythropterus*	3	0
	Paddle-tail	*Lutjanus gibbus*	7	0
		Lutjanus kasmira	100	0

Order/Family	Common name	Scientific name	Evans	Tassie
	Dark-tailed seaperch	*Lutjanus lemniscatus*	3	3
	Saddletail seaperch	*Lutjanus malabaricus*	1	0
	Onespot snapper	*Lutjanus monostigma*	0	1
	Maori seaperch	*Lutjanus rivulatus*	3	1
		Lutjanus rufolineatus	1	2
	Red emperor	*Lutjanus sebae*	26	11
	Brown-stripe snapper	*Lutjanus vitta*	0	3
	Midnight seaperch	*Macolor macularis*	0	1
	Midnight seaperch	*Macolor niger*	22	24
		Pinjalo lewisi	0	8
	Rosy jobfish	*Pristipomoides filamentosus*	3	6
	Goldband snapper	*Pristipomoides multidens*	0	3
		Pristipomoides typus	0	10
	Chinaman fish	*Symphorus nematophorus*	41	11
 Malacanthidae	Dusky tilefish	*Hoplolatilus cuniculus*	3	0
	Quakerfish	*Malacanthus brevirostris*	18	0
 Microdesmidae	Flagtail dartfish	*Ptereleotris uroditaenia*	2	0
 Mullidae		*Mulloidichthys flavolineatus*	3	0
	Swarthy-headed goatfish	*Parupeneus barberinoides*	28	1
	Dash-and-dot goatfish	*Parupeneus barberinus*	9	0
	Gold-saddled goatfish	*Parupeneus cyclostomus*	6	0
	Spotted golden goatfish	*Parupeneus heptacanthus*	25	13
	Manybar goatfish	*Parupeneus multifasciatus*	55	30
	Sidespot goatfish	*Parupeneus pleurostigma*	36	7
 Nemipteridae	Purple threadfin bream	*Pentapodus emeryii*	61	22
	Western butterfish	*Pentapodus vitta*	2	0
		Scolopsis affinis	3	0
	Bridled monocle bream	*Scolopsis bilineata*	13	11
		Scolopsis margaritifer	1	0
	Monocle bream	*Scolopsis monogramma*	1	1
	Pearl-streaked monocle bream	*Scolopsis xenochrous*	38	0
 Pinguipedidae	Spothead grubfish	*Parapercis clathrata*	0	3
		Parapercis nebulosa	0	1
		Parapercis sp	2	0
		Parapercis tetracantha	2	0
	Yellowbar sandperch	*Parapercis xanthozona*	7	4
 Pomacanthidae	Three-spot angelfish	*Apolemichthys trimaculatus*	18	11
	Bicolor angelfish	*Centropyge bicolor*	11	6

Order/Family	Common name	Scientific name	Evans	Tassie
	Keyhole angelfish	*Centropyge tibicen*	3	9
	Pearlscale angelfish	*Centropyge vroliki*	0	2
	Lamarck's angelfish	*Genicanthus lamarck*	6	14
		Genicanthus melanospilos	2	0
	Emperor angelfish	*Pomacanthus imperator*	21	6
	Regal angelfish	*Pygoplites diacanthus*	8	4
 Pomacentridae	Spiny chromis	*Acanthochromis polyacanthus*	1	0
	Golden damselfish	*Amblyglyphidodon aureus*	5	0
	Staghorn damselfish	*Amblyglyphidodon curacao*	3	1
	Yellowbelly damselfish	*Amblyglyphidodon leucogaster*	15	3
	Black-banded demoiselle	*Amblypomacentrus breviceps*	2	0
	Anemone fish	*Amphiprion clarkii*	2	0
	Bicolor chromis	*Chromis margaritifer*	6	0
	Ternate chromis	*Chromis ternatensis*	6	5
	Weber's chromis	*Chromis weberi*	47	102
	Paletail chromis	*Chromis xanthura*	6	2
		Chrysiptera caeruleolineata	5	0
	Reticulate dascyllus	*Dascyllus reticulatus*	54	109
	Threespot dascyllus	*Dascyllus trimaculatus*	17	0
	Black damselfish	*Neoglyphidodon melas*	5	7
	Barhead damsel	*Neoglyphidodon thoracotaeniatus*	6	0
	Johnston Island damsel	*Plectroglyphidodon johnstonianus*	3	4
		Plectroglyphidodon lacrymatus	2	0
		Pomacentrus adelus	8	0
	Ambon damsel	*Pomacentrus amboinensis*	23	27
	Goldbelly damsel	*Pomacentrus auriventris*	3	0
	Charcoal damsel	*Pomacentrus brachialis*	3	0
	Neon damsel	*Pomacentrus coelestis*	4	25
		Pomacentrus lepidogenys	6	0
	Miller's damselfish	*Pomacentrus milleri*	1	0
		Pomacentrus nagasakiensis	1	1
		Pomacentrus nigromanus	0	3
	Philippine damsel	*Pomacentrus philippinus*	7	6
	Ocellate damselfish	*Pomacentrus vaiuli*	0	1
 Pseudochromidae	Firetail Dottyback	*Labracinus cyclophthalmus*	1	0
		Labracinus japonicus	2	0
		Pseudochromis fuscus	2	0
		Pseudochromis perspicillatus	1	0
 Rachycentridae	Cobia	*Rachycentron canadum*	2	2

Order/Family	Common name	Scientific name	Evans	Tassie
 Scaridae	Red-speckled parrotfish	*Cetoscarus ocellatus*	5	0
	Bleeker's parrotfish	*Chlorurus bleekeri*	6	5
		Chlorurus capistratoides	3	0
	Blunt-head parrotfish	*Chlorurus microrhinos*	0	1
	Bullethead parrotfish	*Chlorurus sordidus*	1	1
	Yellowfin parrotfish	*Scarus flavipectoralis*	1	5
	Forsten's parrotfish	*Scarus forsteni*	2	3
		Scarus frenatus	2	0
*	Darktail parrotfish	*Scarus fuscocaudalis**	6	0
		Scarus ghobban	3	4
		Scarus globiceps	1	1
*	Yellowtail parrotfish	*Scarus hypselopterus**	0	1
	Dark-capped parrotfish	*Scarus oviceps*	0	2
		Scarus psittacus	1	0
	Schlegel's parrotfish	*Scarus schlegeli*	50	20
	Unidentified parrotfish	*Scarus sp*	0	2
		Scarus xanthopleura	0	1
 Scombridae	Shark mackerel	*Grammatorcynus bilineatus*	9	0
	Dogtooth tuna	*Gymnosarda unicolor*	1	0
	Spanish mackerel	*Scomberomorus commerson*	2	0
	School mackerel	*Scomberomorus queenslandicus*	1	0
	Unidentified mackerel	*Scomberomorus sp*	2	0
 Serranidae	Redflushed rockcod	*Aethaloperca rogaa*	13	7
		Anyperodon leucogrammicus	2	0
	Bluelined rockcod	*Cephalopholis formosa*	0	1
		Cephalopholis leopardus	2	0
	Freckled rockcod	*Cephalopholis microprion*	4	1
	Coral cod	*Cephalopholis miniata*	11	7
	Tomato cod	*Cephalopholis sonnerati*	4	0
	Strawberry grouper	*Cephalopholis spiloparaea*	3	0
	Flagtailed rockcod	*Cephalopholis urodeta*	4	4
	Yellow-spotted rockcod	*Epinephelus areolatus*	2	9
		Epinephelus bleekeri	1	0
	Goldspot cod	*Epinephelus coioides*	6	0
	Flowery cod	*Epinephelus fuscoguttatus*	1	0
	Trout cod	*Epinephelus maculatus*	4	7
	Blackspot cod	*Epinephelus malabaricus*	2	3
	Rankin cod	*Epinephelus multinotatus*	17	4
	Maori cod	*Epinephelus undulatostriatus*	0	3
	Bluespot coral trout	*Plectropomus laevis*	6	1
	Common coral trout	*Plectropomus leopardus*	35	19
	Undientified fairy basslet	*Pseudanthias sp*	4	0

Order/Family	Common name	Scientific name	Evans	Tassie
	Lyretail trout	*Variola albimarginata*	4	0
	Coronation trout	*Variola louti*	26	14
	Unidentified coronation trout	*Variola sp*	1	0
 Siganidae	Spinefoot	*Siganus argenteus*	19	2
	Masked spinefoot	*Siganus puellus*	0	2
	Goldspotted spinefoot	*Siganus punctatus*	5	2
		Siganus vulpinus	2	0
 Sparidae	Frying-pan snapper	*Argyrops spinifer*	0	5
 Sphyraenidae	Great barracuda	*Sphyraena barracuda*	1	1
 Zanclidae	Moorish idol	*Zanclus cornutus*	31	13
Tetraodontiformes				
 Balistidae	Starry triggerfish	*Abalistes stellatus*	20	39
	Red-lined triggerfish	*Balistapus undulatus*	20	16
	Clown triggerfish	*Balistoides conspicillum*	2	2
	Titan triggerfish	*Balistoides viridescens*	1	4
	Spotted oceanic triggerfish	*Canthidermis maculatus*	1	0
		Melichthys niger	7	1
	Pinktail triggerfish	*Melichthys vidua*	16	0
	Redtooth triggerfish	*Odonus niger*	155	6
		Pseudobalistes flavimarginatus	1	0
	Dusky triggerfish	*Pseudobalistes fuscus*	4	0
	Pallid triggerfish	*Sufflamen bursa*	1	2
	Black triggerfish	*Sufflamen chrysopterum*	10	4
	Brown triggerfish	*Sufflamen fraenatum*	21	9
		Sufflamen sp	1	0
		Xanthichthys auromarginatus	1	0
 Monacanthidae		*Aluterus monoceros*	17	1
	Scribbled leatherjacket	*Aluterus scriptus*	7	2
	Yelloweye leatherjacket	*Cantherhines dumerilii*	2	3
 Tetraodontidae		*Arothron firmamentum*	1	0
	Stars and stripes puffer	*Arothron hispidus*	0	1
		Arothron nigropunctatus	2	0
	Starry pufferfish	*Arothron stellatus*	1	2

Order/Family	Common name	Scientific name	Evans	Tassie
	Silver toadfish	*Lagocephalus sceleratus*	7	6
Squamata				
 Hydrophiidae	Olive sea snake	*Aipysurus laevis*	0	9
	Turtle-headed sea snake	*Emydocephalus annulatus*	2	0
	Unidentified sea snake	*Hydrophis sp*	7	5
	Unidentified sea snake	*Seasnake sp*	0	1
	Unidentified sea snake	*seasnake sp_banded*	0	2

Appendix 3

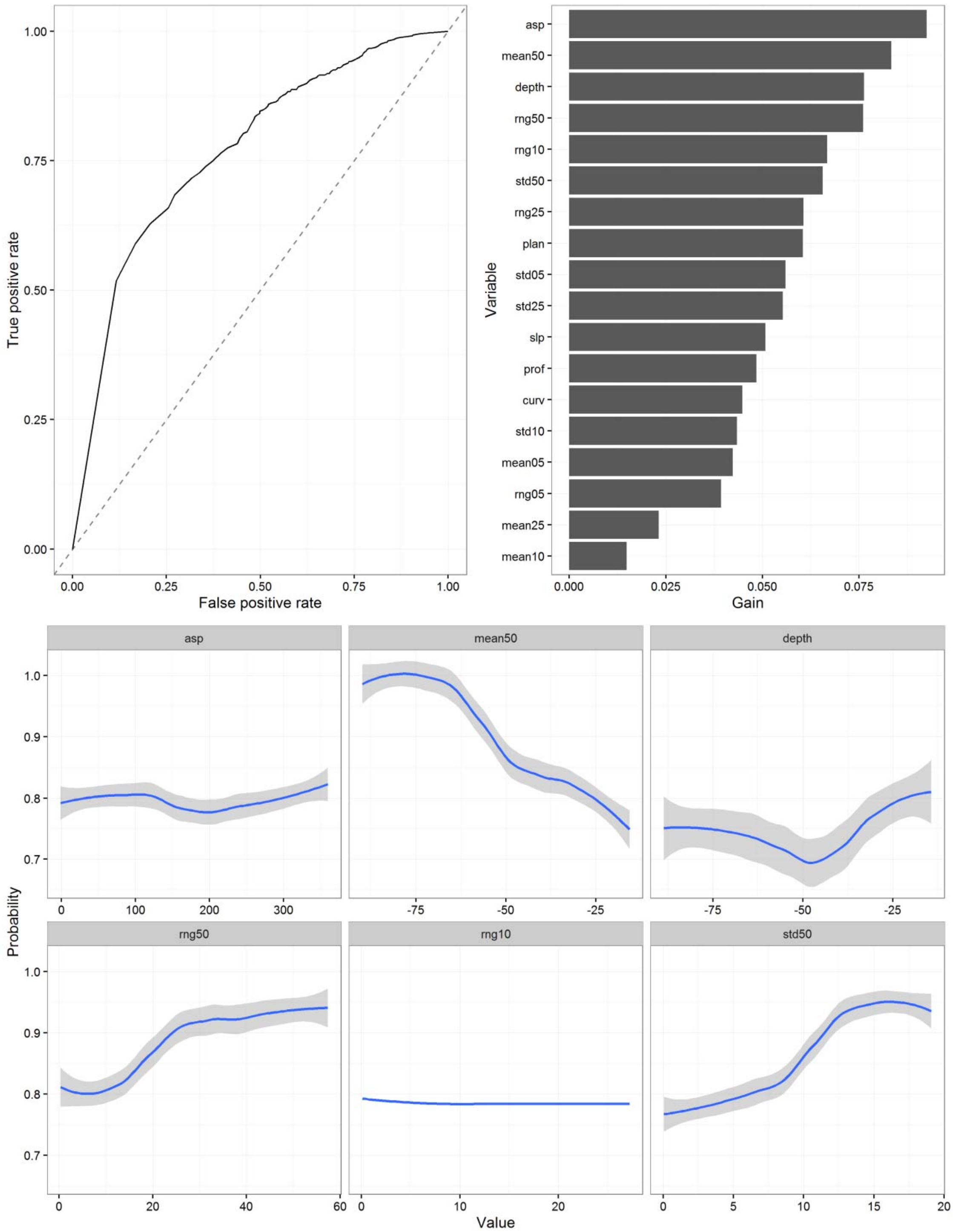


Figure A3.1: All hard coral - Towed digital still image model AUC performance plot (top left), relative measure of variable influence ("Gain") for improvement on model performance (top right) and partial response plots for the top 6 most influential model variables (bottom panel). For variable descriptions see Table 3 in the main report).

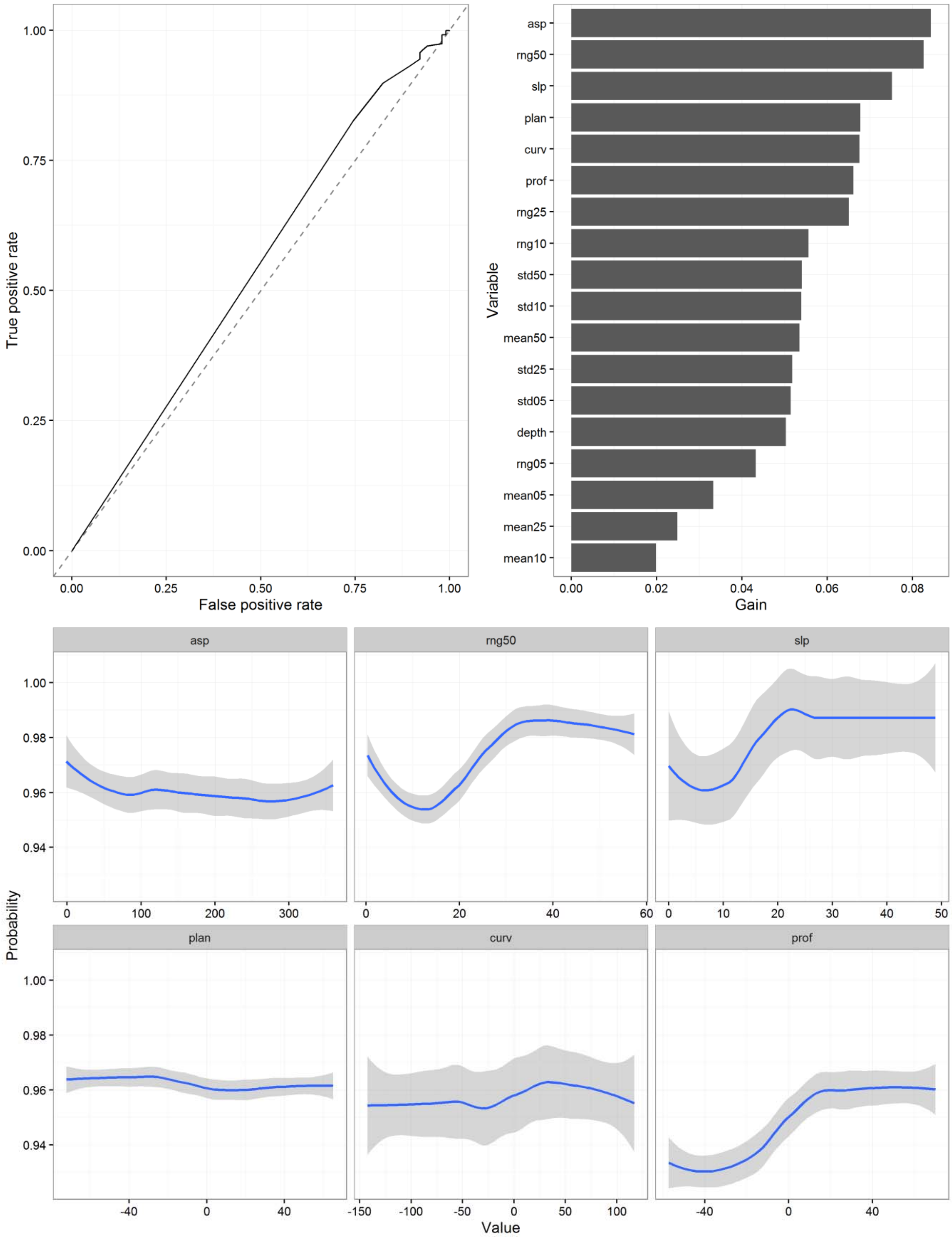


Figure A3.2: Soft corals - Towed digital still image model AUC performance plot (top left), relative measure of variable influence ("Gain") for improvement on model performance (top right) and partial response plots for the top 6 most influential model variables (bottom panel). For variable descriptions see Table 3 in the main report).

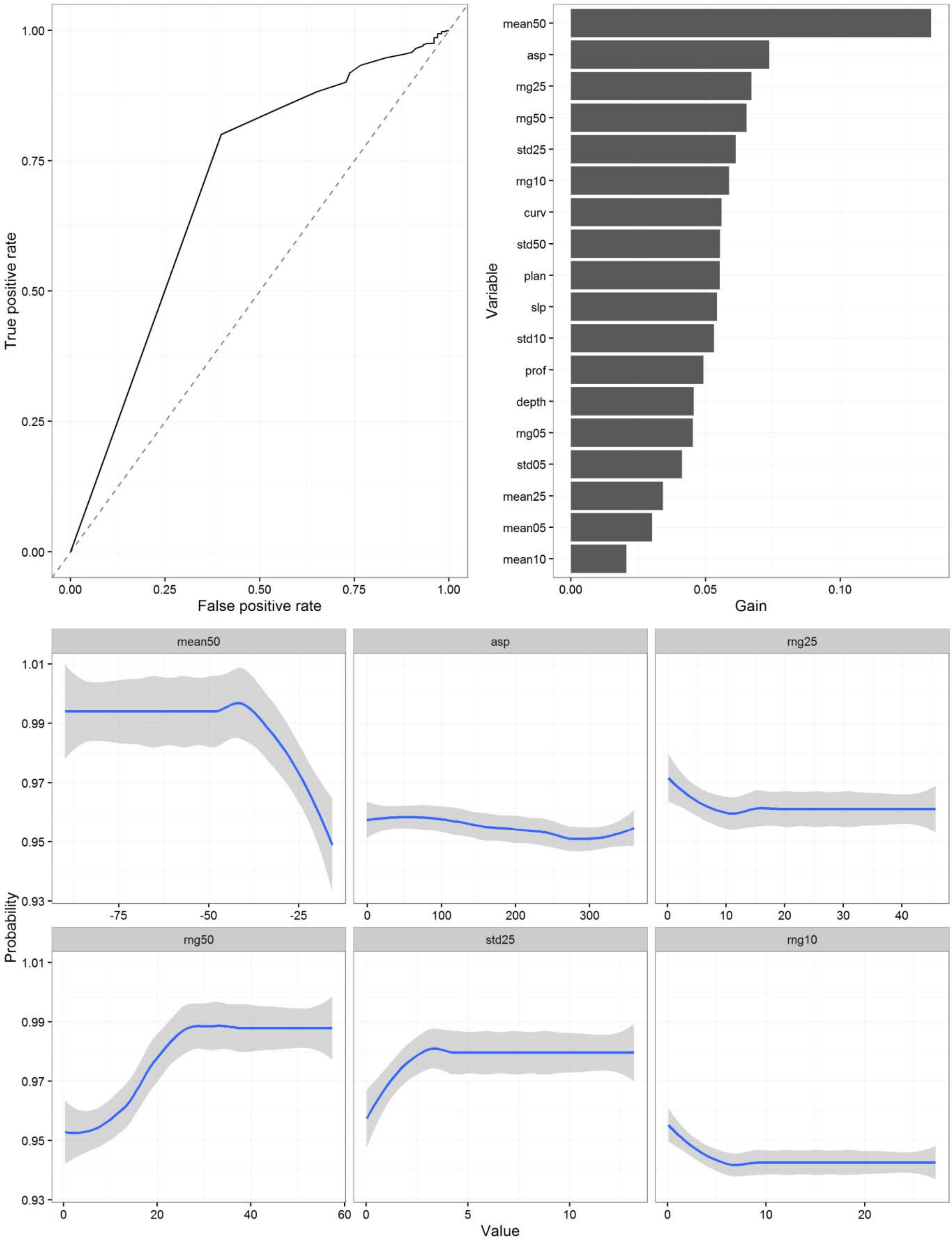


Figure A3.3 Tabulate Acropora - Towed digital still image model AUC performance plot (top left), relative measure of variable influence ("Gain") for improvement on model performance (top right) and partial response plots for the top 6 most influential model variables (bottom panel). For variable descriptions see Table 3 in the main report).

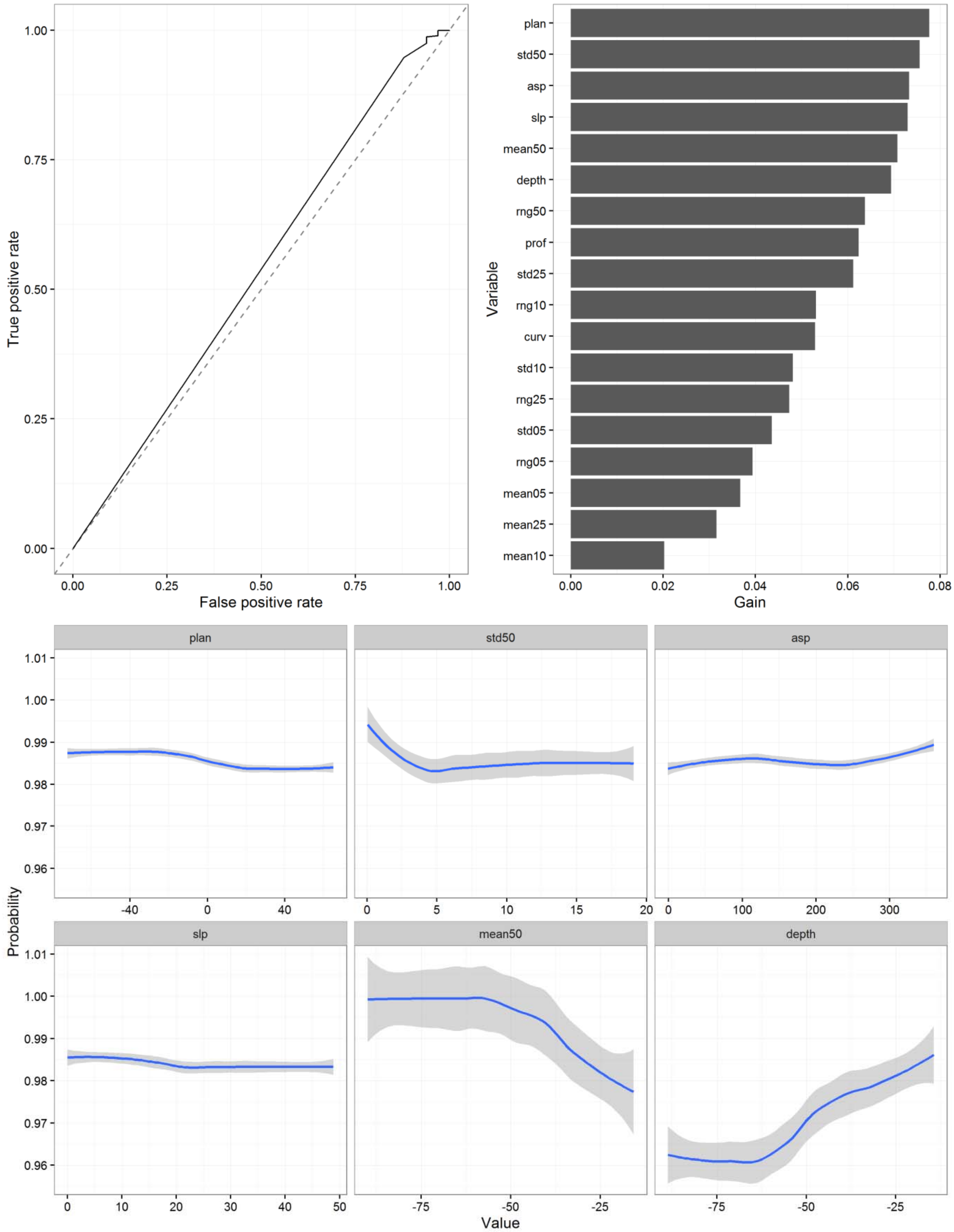


Figure A3.4: Branching Acropora - Towed digital still image model AUC performance plot (top left), relative measure of variable influence ("Gain") for improvement on model performance (top right) and partial response plots for the top 6 most influential model variables (bottom panel). For variable descriptions see Table 3 in the main report).

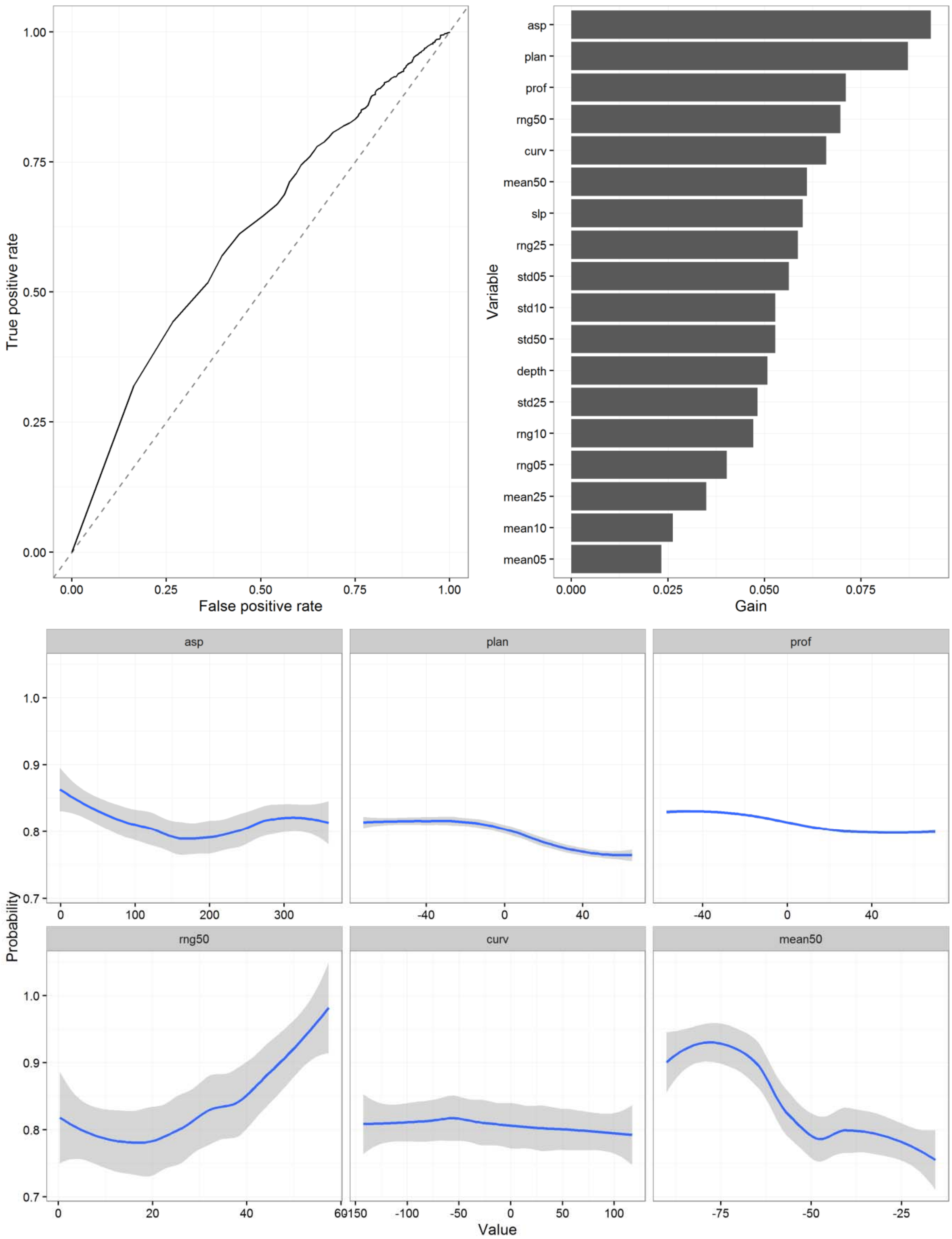


Figure A3.5: Macroalgae and sponge - Towed digital still image model AUC performance plot (top left), relative measure of variable influence ("Gain") for improvement on model performance (top right) and partial response plots for the top 6 most influential model variables (bottom panel). For variable descriptions see Table 3 in the main report).

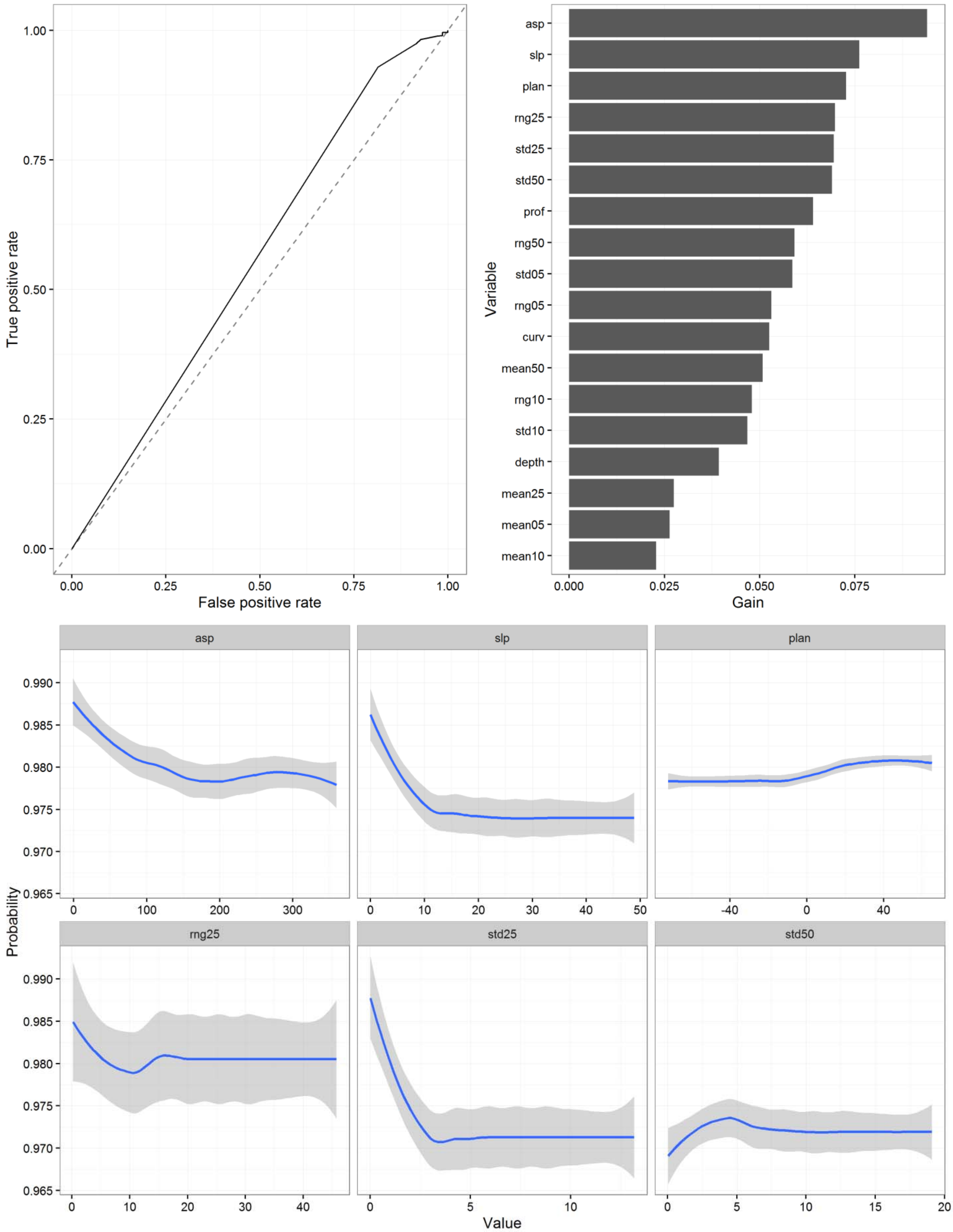


Figure A3.6: Other corals - Towed digital still image model AUC performance plot (top left), relative measure of variable influence ("Gain") for improvement on model performance (top right) and partial response plots for the top 6 most influential model variables (bottom panel). For variable descriptions see Table 3 in the main report).

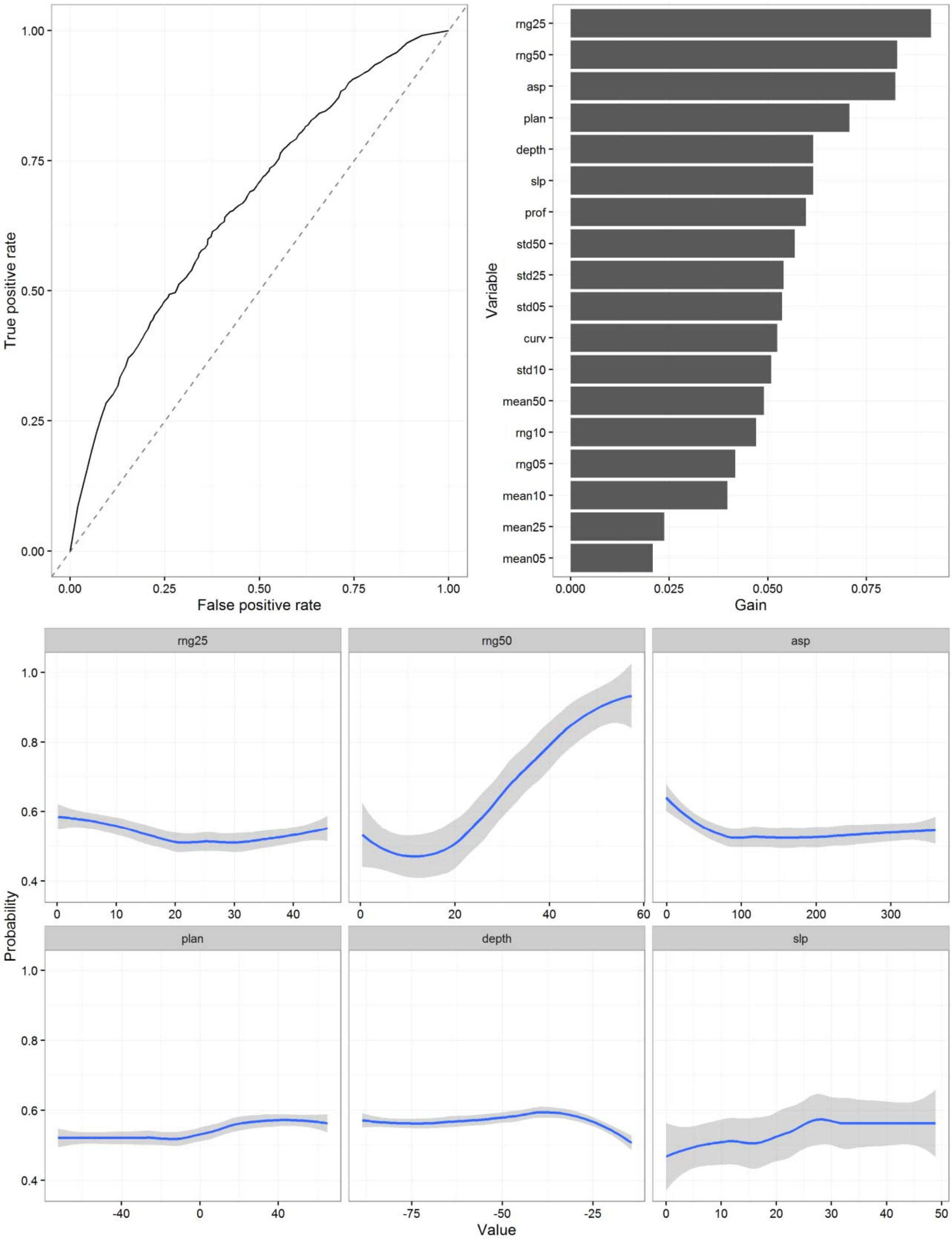


Figure A3.7: Turf and coralline algae - Towed digital still image model AUC performance plot (top left), relative measure of variable influence ("Gain") for improvement on model performance (top right) and partial response plots for the top 6 most influential model variables (bottom panel). For variable descriptions see Table 3 in the main report).

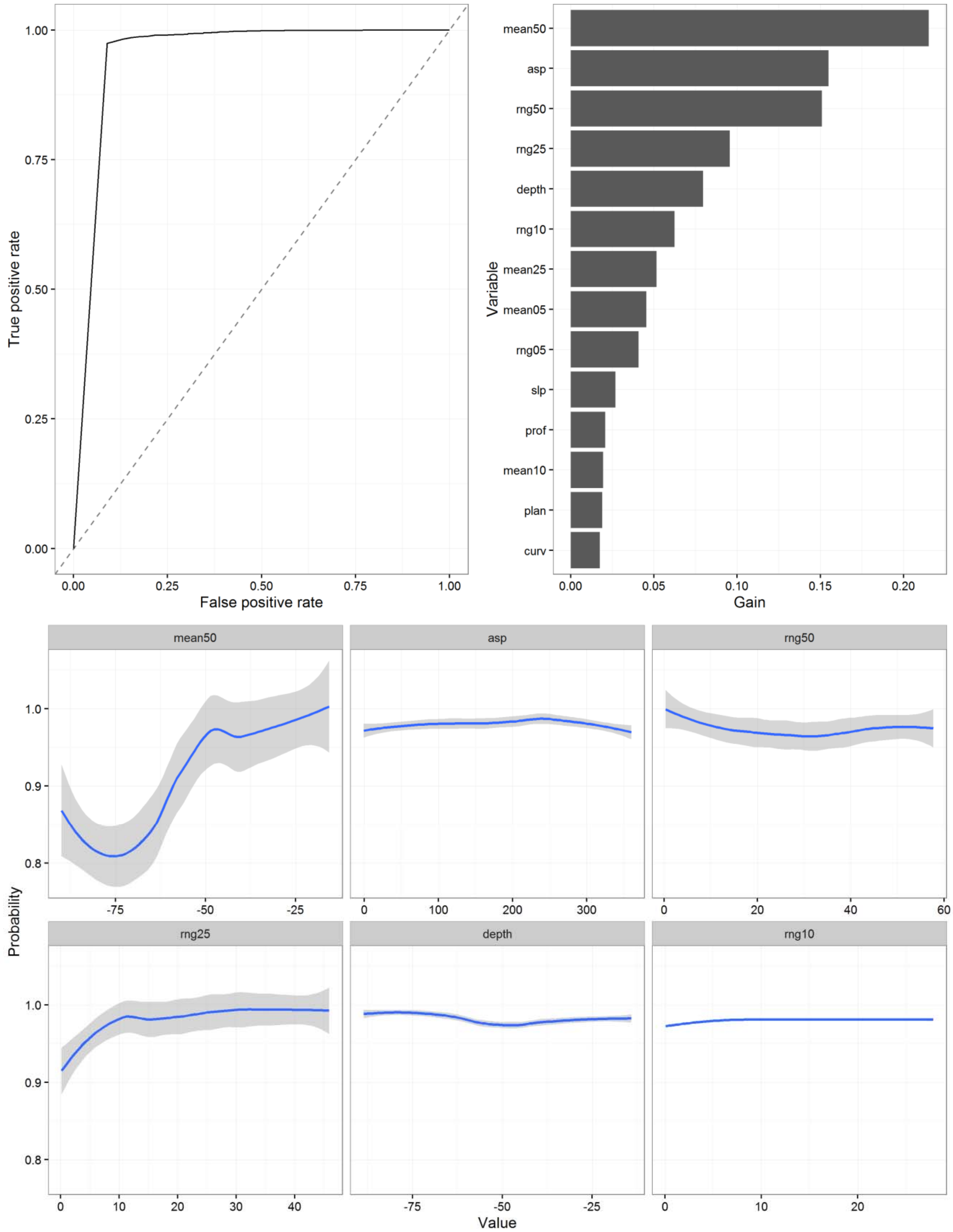


Figure A3.8 Medium filter feeders - Towed real-time video model (with 2m binned multibeam and covariates) AUC performance plot (top left), relative measure of variable influence ("Gain") for improvement on model performance (top right) and partial response plots for the top 6 most influential model variables (bottom panel). For variable descriptions see Table 3 in the main report).

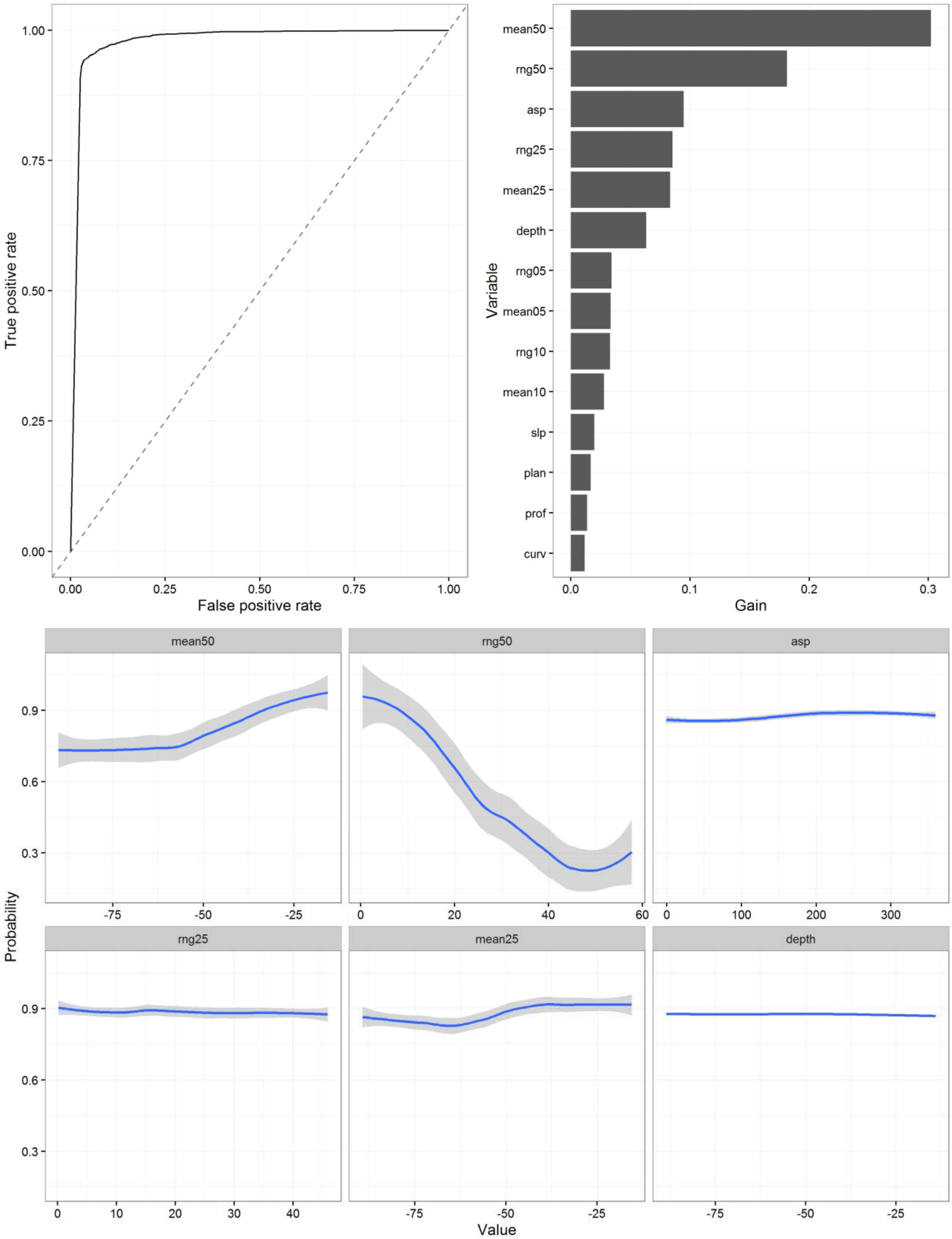


Figure A3.9: Sparse filter feeders - Towed real-time video model (with 2m binned multibeam and covariates) AUC performance plot (top left), relative measure of variable influence ("Gain") for improvement on model performance (top right) and partial response plots for the top 6 most influential model variables (bottom panel). For variable descriptions see Table 3 in the main report).

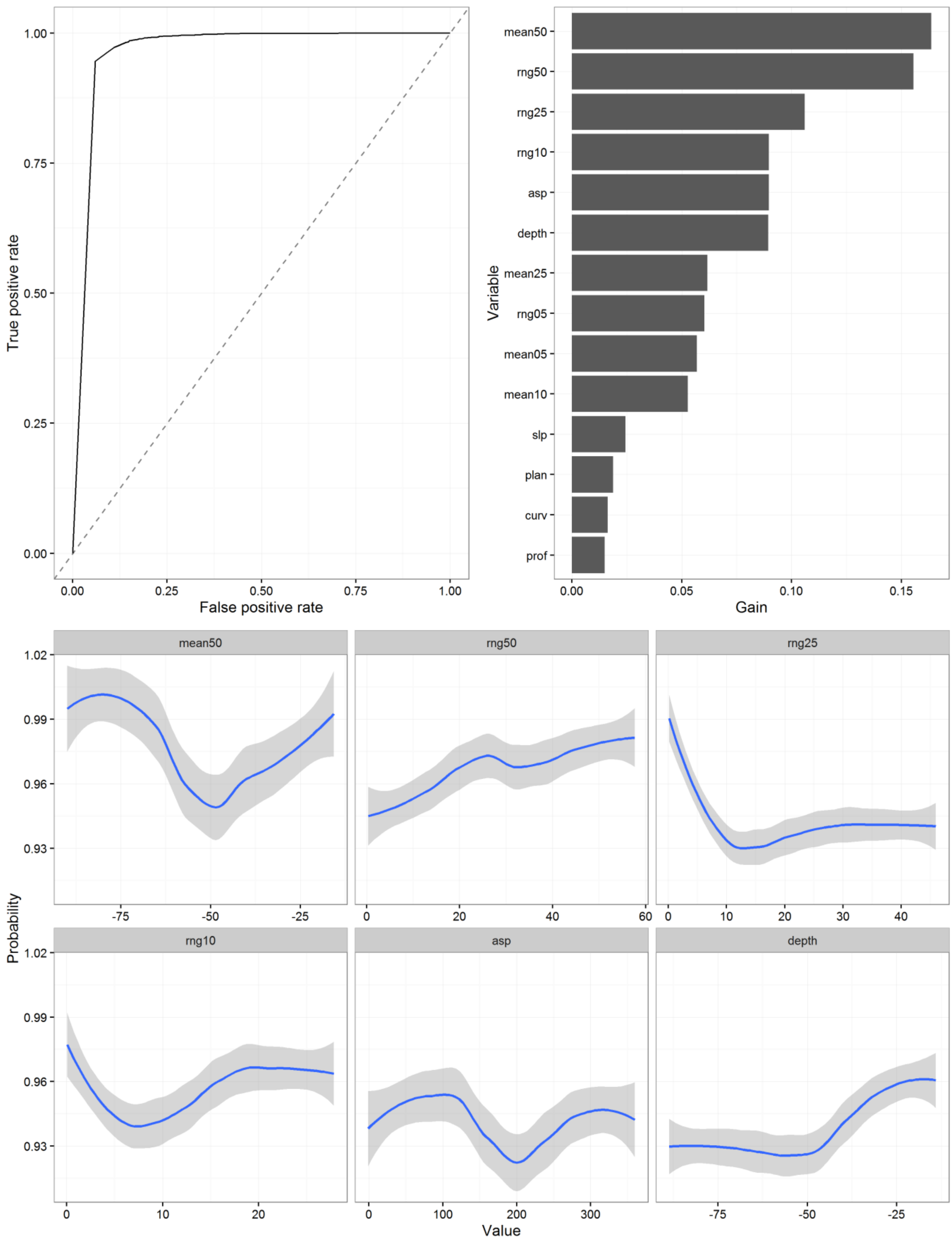


Figure A3.10: Dense hard coral - Towed real-time video model for shoals (with 2m binned multibeam and covariates) AUC performance plot (top left), relative measure of variable influence ("Gain") for improvement on model performance (top right) and partial response plots for the top 6

most influential model variables (bottom panel). For variable descriptions see Table 3 in the main report).

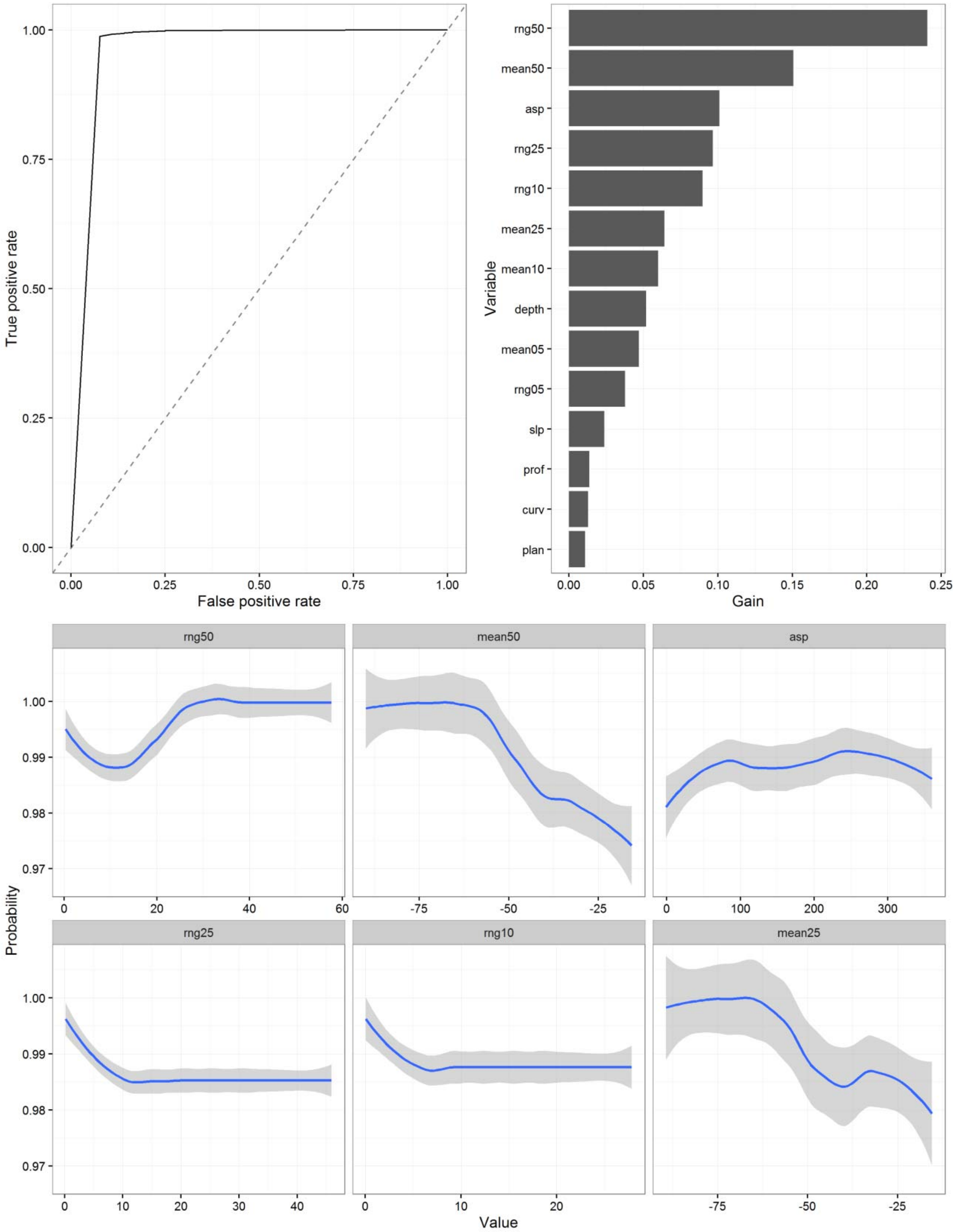


Figure A3.11 Medium hard coral and Halimeda - Towed real-time video model for shoals (with 2m binned multibeam and covariates) AUC performance plot (top left), relative measure of variable influence ("Gain") for improvement on model performance (top right) and partial response plots for the top 6 most influential model variables (bottom panel). For variable descriptions see Table 3 in the main report).

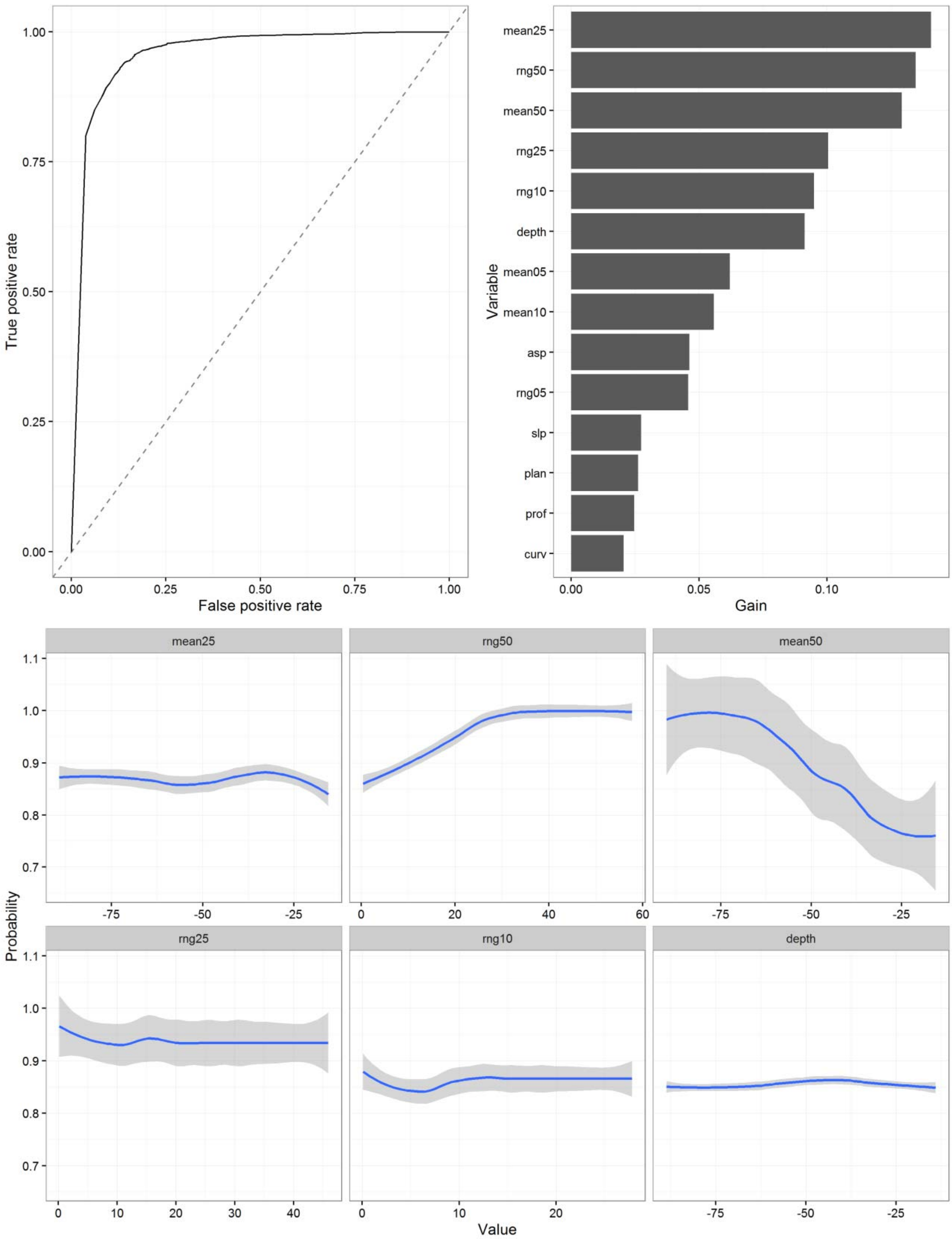


Figure A3.12: Medium hard coral - Towed real-time video model for shoals (with 2m binned multibeam and covariates) AUC performance plot (top left), relative measure of variable influence ("Gain") for improvement on model performance (top right) and partial response plots for the top 6 most influential model variables (bottom panel). For variable descriptions see Table 3 in the main report).

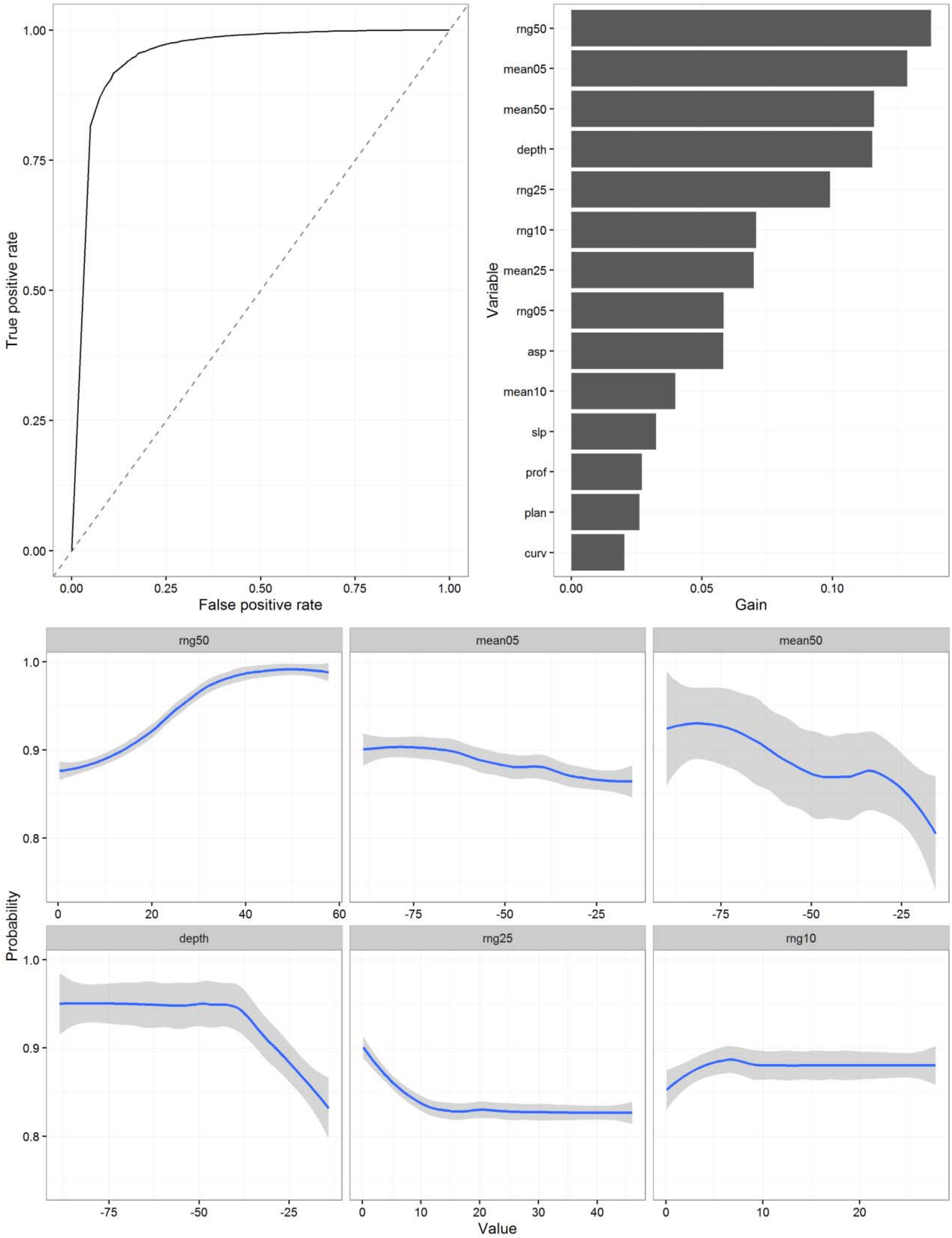


Figure A3.13: Sparse hard coral - Towed real-time video model for shoals (with 2m binned multibeam and covariates) AUC performance plot (top left), relative measure of variable influence ("Gain") for improvement on model performance (top right) and partial response plots for the top 6 most influential model variables (bottom panel). For variable descriptions see Table 3 in the main report).

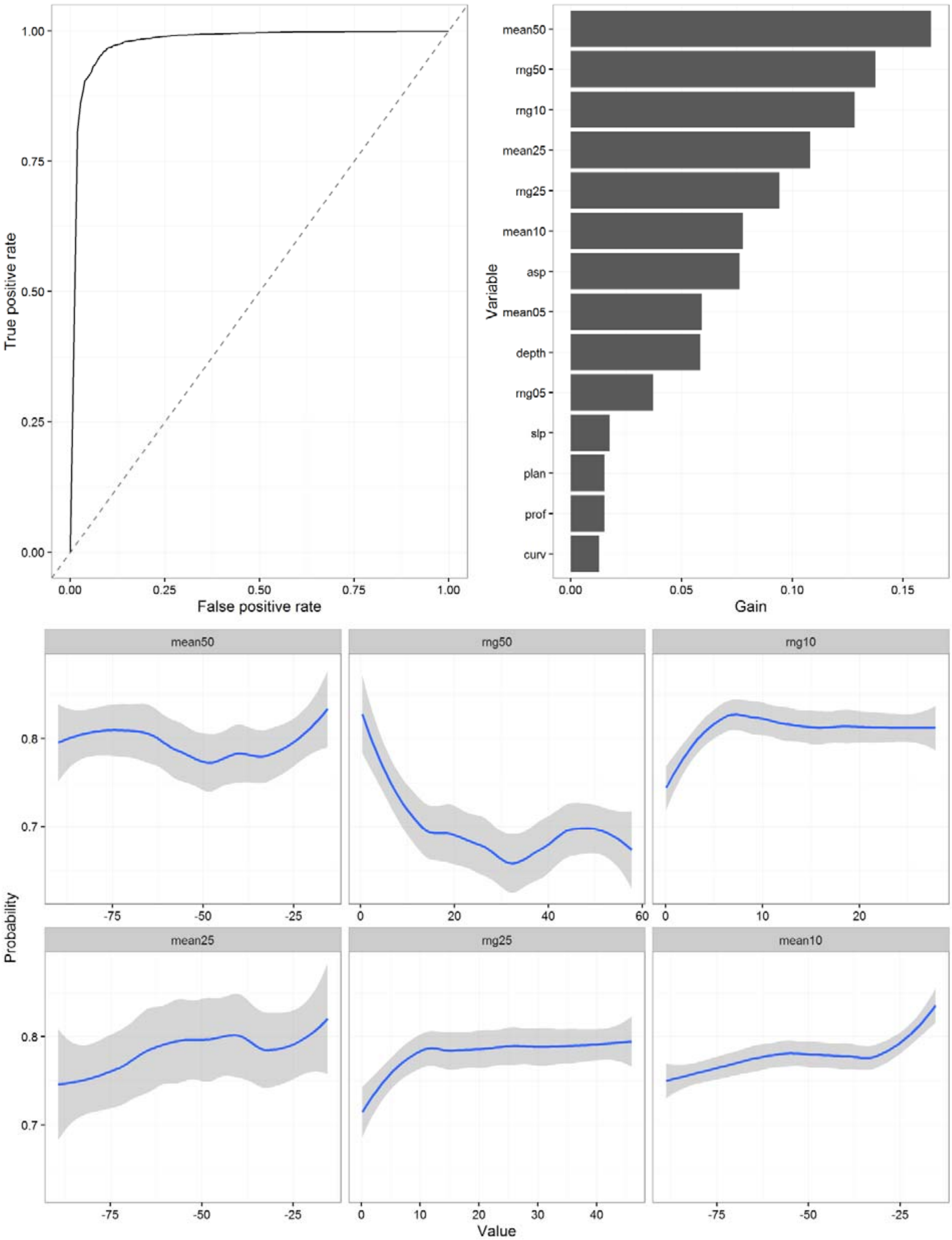


Figure A3.14: None (no modelled benthos) - Towed real-time video model for shoals (with 2m binned multibeam and covariates) AUC performance plot (top left), relative measure of variable influence ("Gain") for improvement on model performance (top right) and partial response plots for the top 6 most influential model variables (bottom panel). For variable descriptions see Table 3 in the main report).

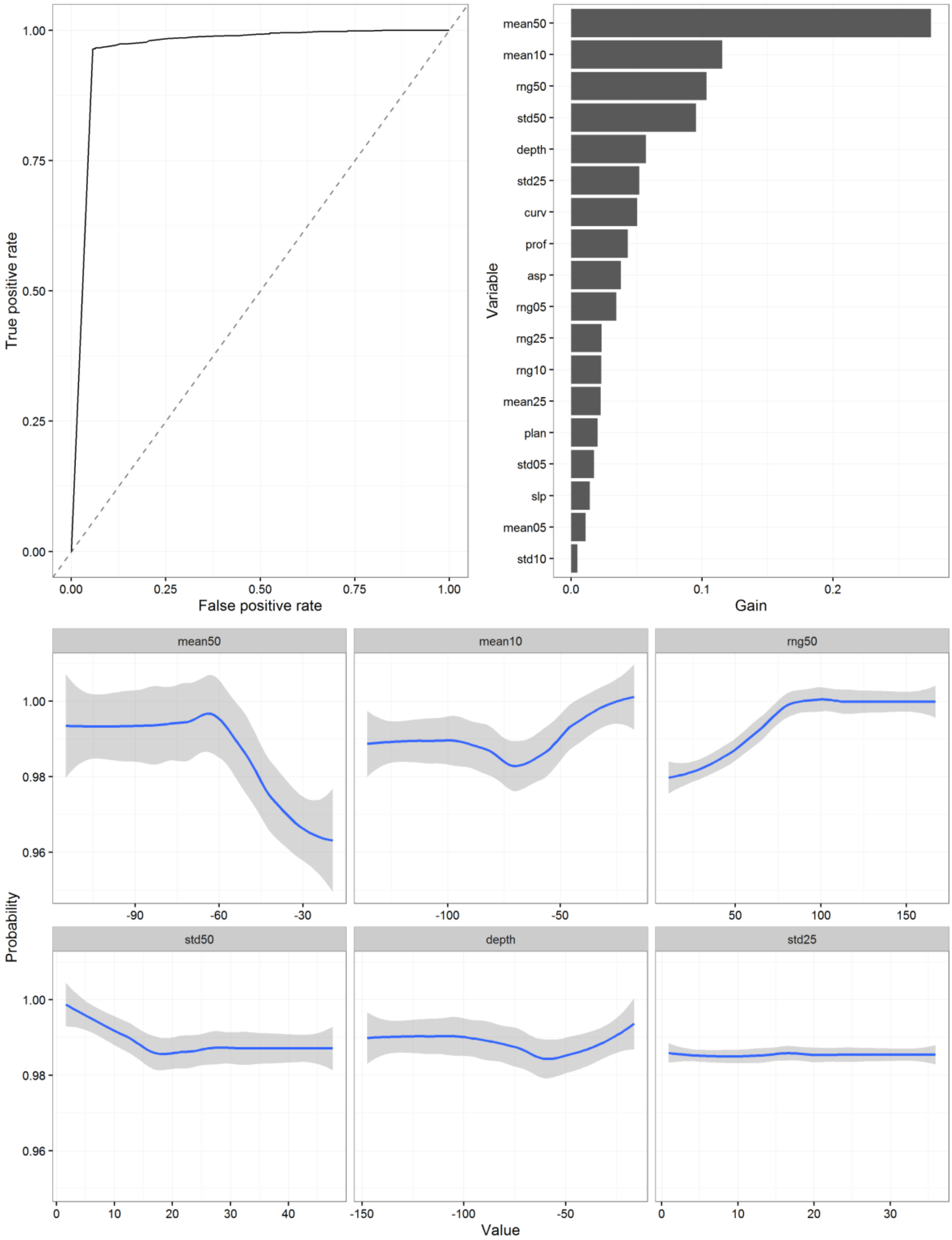


Figure A3.15: Burrows - Towed real-time video model for shelf regions (with 50 m binned multibeam and covariates) AUC performance plot (top left), relative measure of variable influence ("Gain") for improvement on model performance (top right) and partial response plots for the top 6 most influential model variables (bottom panel). For variable descriptions see Table 3 in the main report).

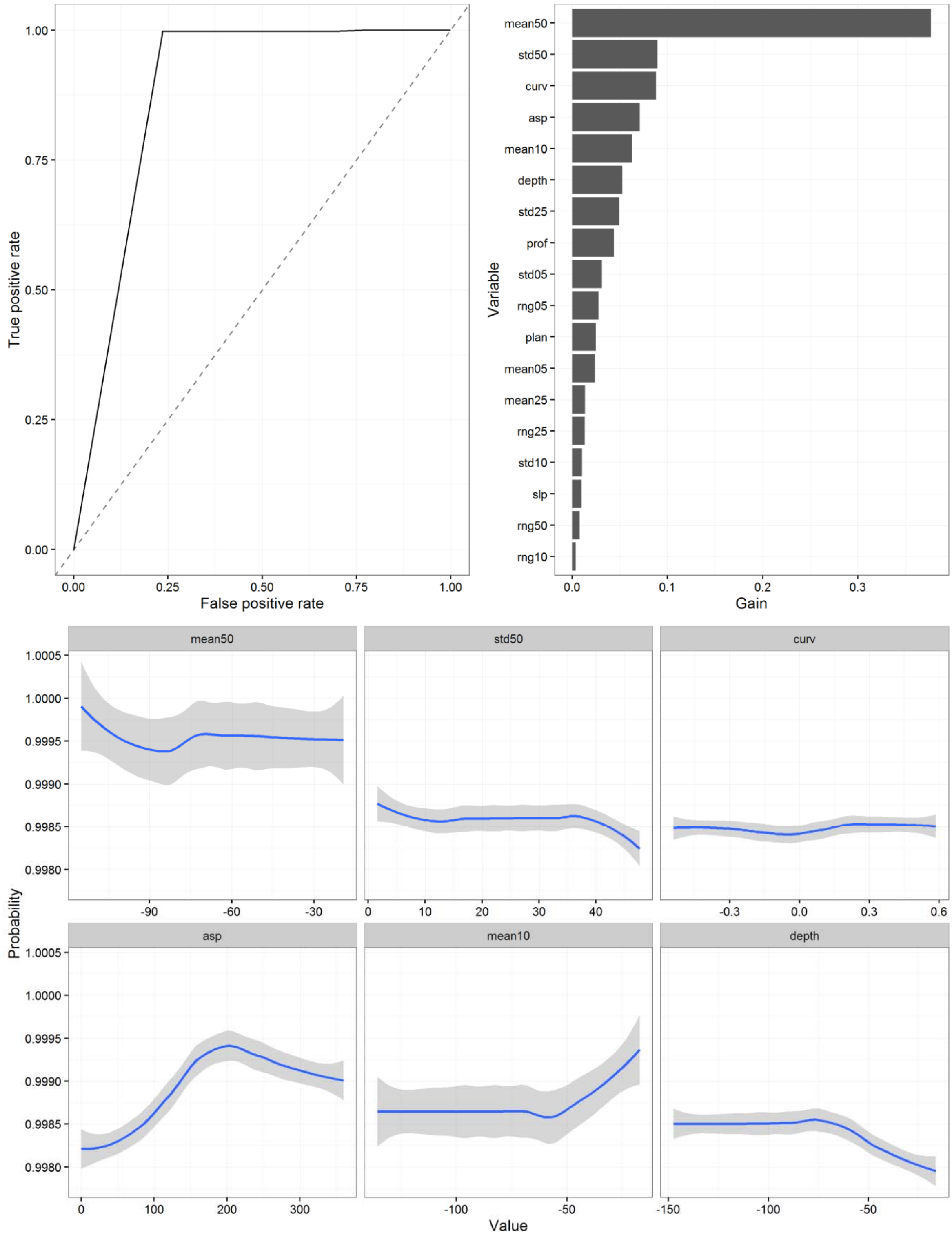


Figure A3.16: Dense filter feeders - Towed real-time video model for shelf regions (with 50m binned multibeam and covariates) AUC performance plot (top left), relative measure of variable influence ("Gain") for improvement on model performance (top right) and partial response plots for the top 6 most influential model variables (bottom panel). For variable descriptions see Table 3 in the main report).

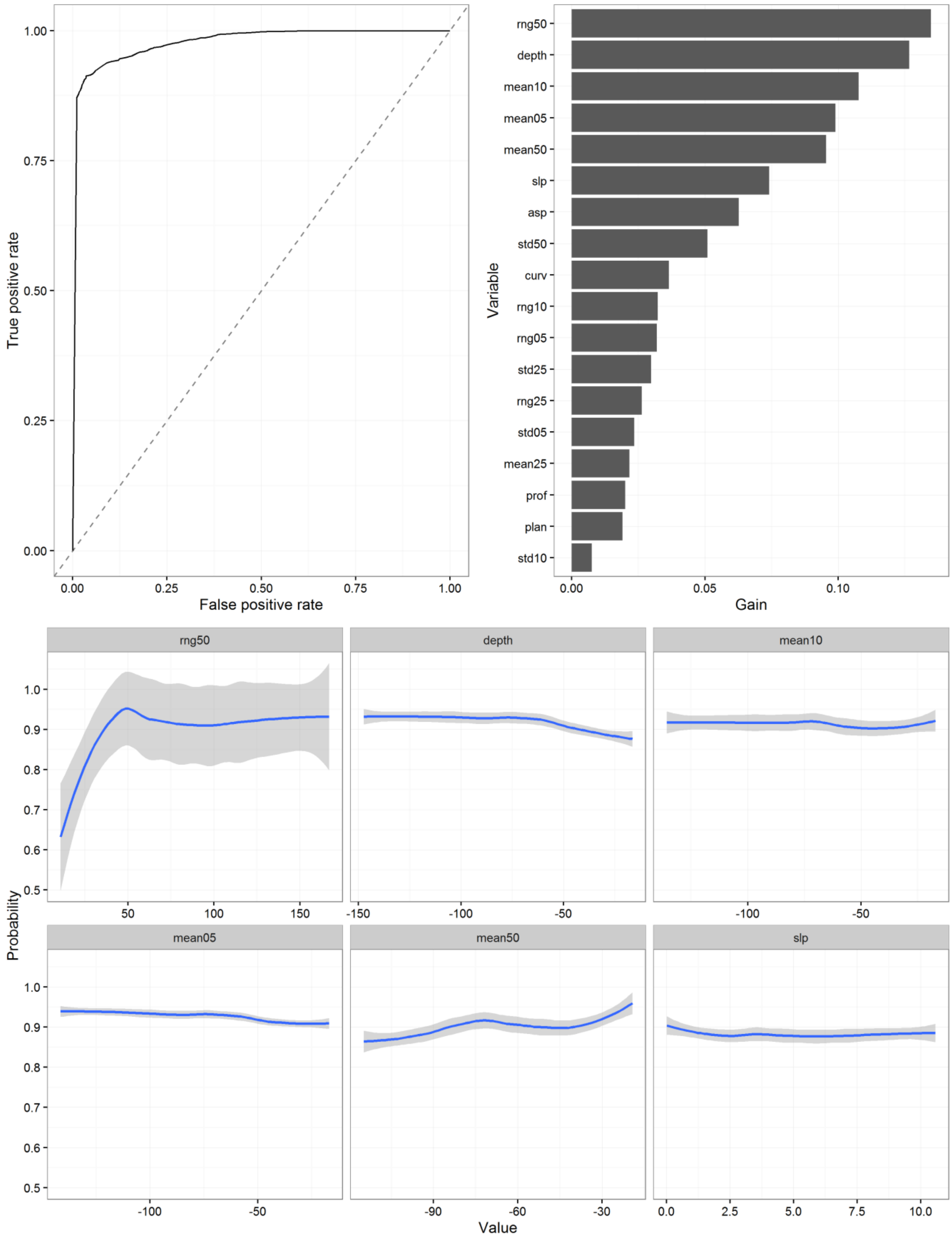


Figure A3.17: Medium filter feeders - Towed real-time video model for shelf regions (with 50m binned multibeam and covariates) AUC performance plot (top left), relative measure of variable influence ("Gain") for improvement on model performance (top right) and partial response plots for the top 6 most influential model variables (bottom panel). For variable descriptions see Table 3 in the main report).

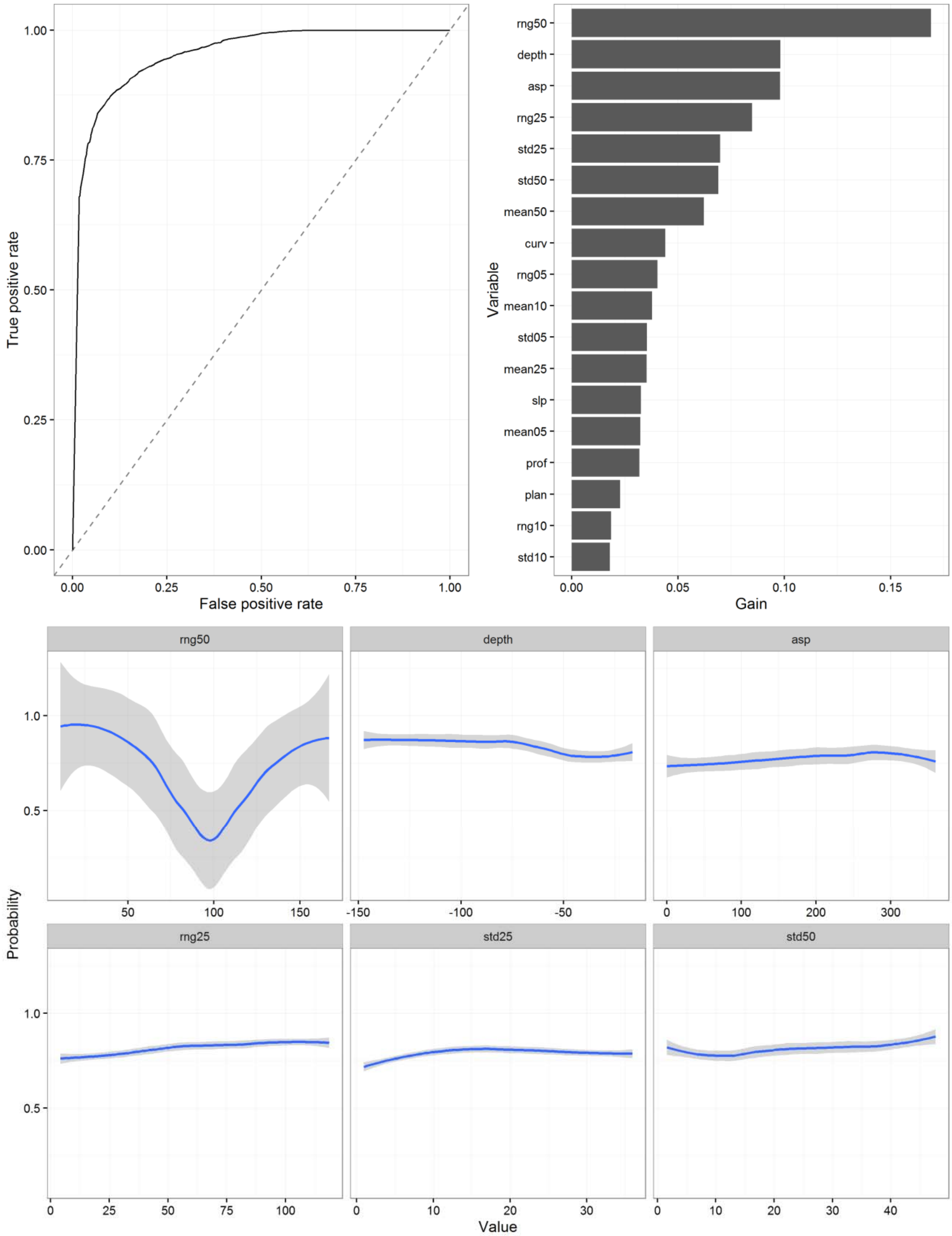


Figure A3.18: Sparse filter feeders - Towed real-time video model for shelf regions (with 50m binned multibeam and covariates) AUC performance plot (top left), relative measure of variable influence ("Gain") for improvement on model performance (top right) and partial response plots for the top 6 most influential model variables (bottom panel). For variable descriptions see Table 3 in the main report).

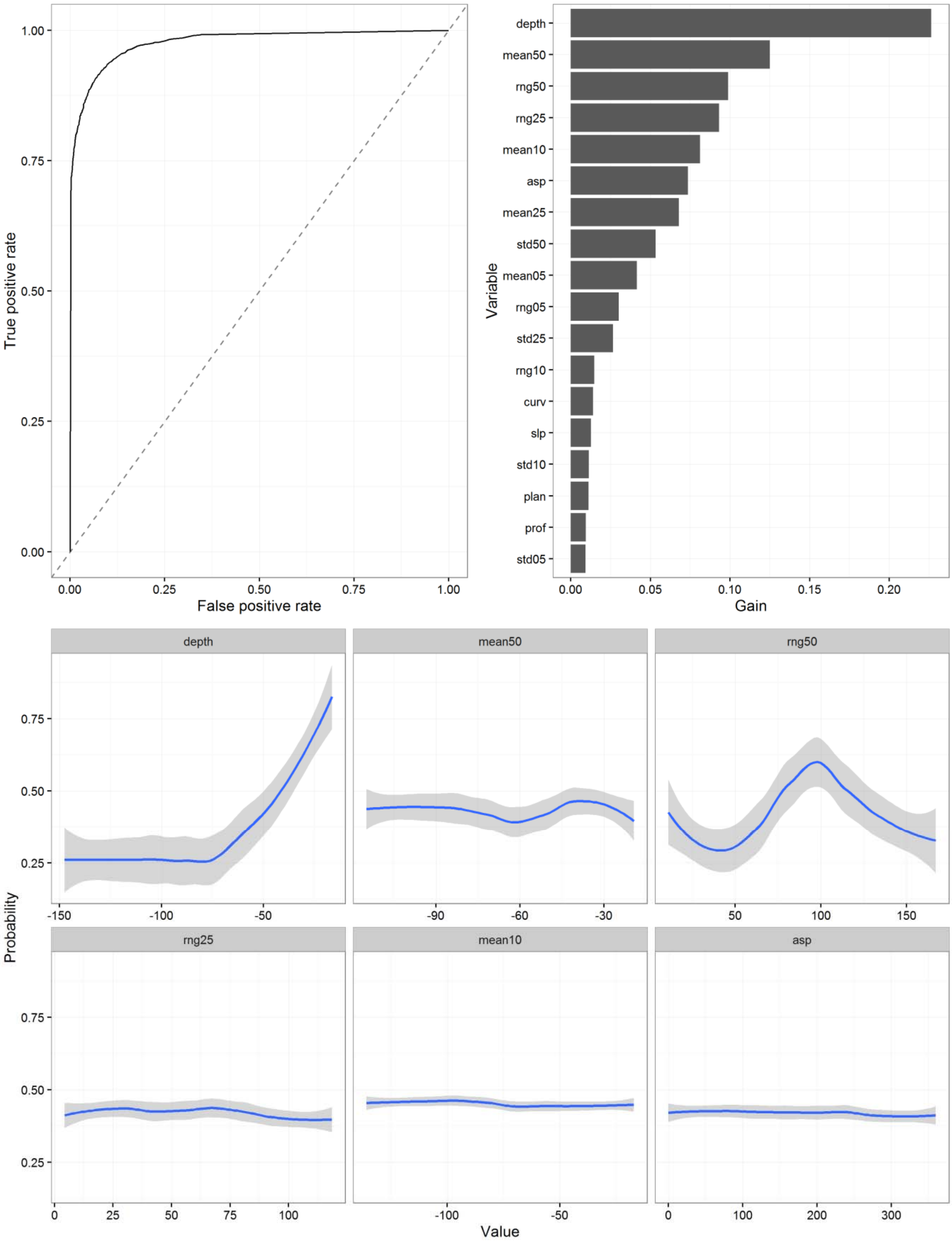


Figure A3.19: No modelled benthos - Towed real-time video model for shelf regions (with 50m binned multibeam and covariates) AUC performance plot (top left), relative measure of variable influence ("Gain") for improvement on model performance (top right) and partial response plots for the top 6 most influential model variables (bottom panel). For variable descriptions see Table 3 in the main report).

Addendum to the AIMS Barossa Environmental Baseline Study, Regional Shoals and Shelf Assessment Report[1]: regional biodiversity patterns and connectivity amongst the submerged shoals and banks in relation to the area of influence from a hypothetical uncontrolled release.

Connectivity

The shoals/banks in the Timor Sea and broader region share a tropical marine biota consistent with that found on emergent reef systems of the Indo West Pacific. Based on larval development rates, current speeds and the distance between various shoals, banks and reefs, a high level of interconnectivity is likely (1).

While larvae of many species are likely to actively influence their dispersal to some extent, usually in the direction of greater local retention, passive larval dispersal in surface currents is often used in the analysis of prevailing larval transport routes (1,2). Surface currents at the eastern and western end of the Sahul Shelf ,measured by AIMS using satellite tracked drifters (Heyward, unpublished data), demonstrate common speeds of 20-30 km/day during mild weather in the monsoonal periods, with much faster speeds measured during winter or modelled under cyclone modified conditions (1). Given the peak reproductive season for corals and many fish occurs over warmer months and noting that larvae may easily be competent for days to weeks (2,3), a planktonic dispersal range of 50-100 km is very plausible for many species in this region. The distribution of >150 shoal features across the Sahul Shelf, with individual shoals often separated by 5-20 km, suggests an extensive series of stepping stone habitats are available to recruit larvae from the plankton and connect these ecosystems at ecological time scales.

The bank and shoal features in Australian water within the modelled 'area of influence' from a large scale hydrocarbon release (Figure 1) are present at highest density west of the Barossa offshore development area along the outer portion of the continental shelf. These shoals and banks are likely to be highly interconnected by surface currents carrying species that produce pelagic larvae. Sources of larvae supply to the east would include a number of seabed features in Australian waters such as Lynedoch Bank, but importantly this region sits within the strong Indonesian Throughflow, providing a source of larvae from tropical benthic habitats from the Coral Triangle region (5).

Shoal and bank attributes - Ubiquity and Uniqueness

The submerged shoals and banks of the Sahul Shelf surveyed by AIMS to date (2, 6, Figure 1) have all supported a range of tropical biota typical throughout the region (6). A hierarchical cluster analysis of benthic communities in the Barossa Environmental Baseline Study 2015 Final Report showed that neighbouring shoals and banks (i.e. within 100s of km's) frequently share approximately 80% of benthic community composition whereas cross shelf (>200 km) there is less similarity (approximately 60%) between turbidity inshore areas and clearer water offshore shoals (Figure 1, 2 a and b). This pattern is driven by variation in the dominance of key habitats and species. The shallower depths, where sufficient light reaches the seabed, support benthic primary producers. These include various algae, corals and occasionally seagrass. Beyond those depths, usually at the margins on the steeper slopes of shoals and banks, filter feeders and detritivores become more prominent. In the clearer oceanic waters of the outer continental shelf, consolidated substrate can support hard coral habitat in 10-60 m depths, with filter feeding fauna like sponges and seafans becoming dominant on rocky substrates below these depths. In mid-shelf locations where water clarity is reduced, the transition between primary producers and heterotrophic habitats is often observed at shallower depths due to reduced light reaching the seabed. The most influential determinants of the biota observed to date appear to be depth associated light intensity, substrate consolidation and substrate three dimensional complexity. Each of the shoals is likely to have the potential to support similar types of benthic habitats, dependent on extent of these underlying variables and the influence of the ecology of particular species and the local history of recruitment events and natural disturbances. Each shoal and bank has its own character in terms of species abundance and the relative contribution key taxa may make to the benthic community, but the same suite of habitats have been observed on multiple shoals and banks. Consequently the shoals and banks across the region represent a mosaic of benthic habitats, with variations in the abundance and distribution of both substrates and key species, but sharing many species in common.

While temporal datasets for the region's shoals are limited, changes from year to year on individual shoals have been observed (6). Available observations are consistent with the composition of the benthic assemblages being dynamic, in much the same way the bioregion's emergent coral reefs are (7) in response to natural disturbances such thermal stress events, storms and cyclones.

Cycles of natural disturbances and subsequent founder effects, particularly involving species that can propagate locally via asexual reproduction, may explain some of the variability between shoals. For example, monospecific stands of soft corals, seagrass or hard corals seen in some shoals but markedly lower levels of abundance of the same species have been observed on neighbouring shoals.

At the regional scale, therefore, the shoals and banks all support high levels of seabed biodiversity, but vary in the abundance and diversity of dominant benthic species, with subsets of species featuring more prominently on some than others. Similarly the associated fish fauna is highly diverse but variable between shoals (8), being influenced by depth, substrate and exposure to prevailing weather, though with all shoals sharing many species.

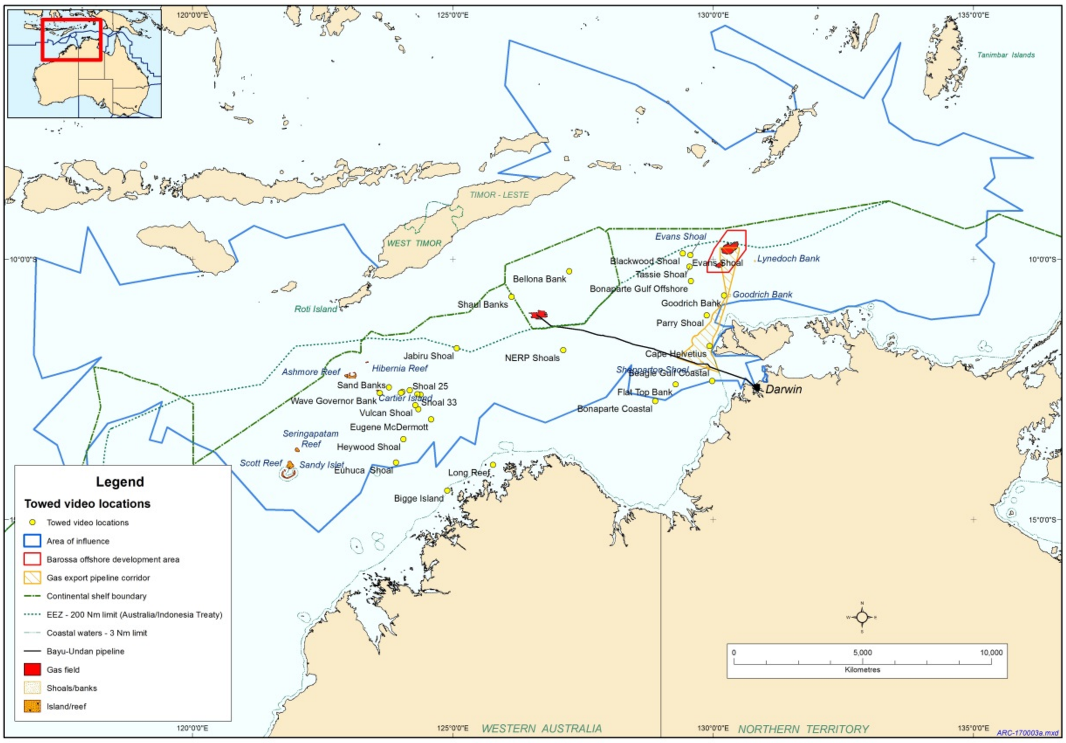


Figure 1: Regional towed video sites across the Sahul Shelf and adjacent coastal sites used in the "Barossa Environmental Baseline Study 2015 Final Report".

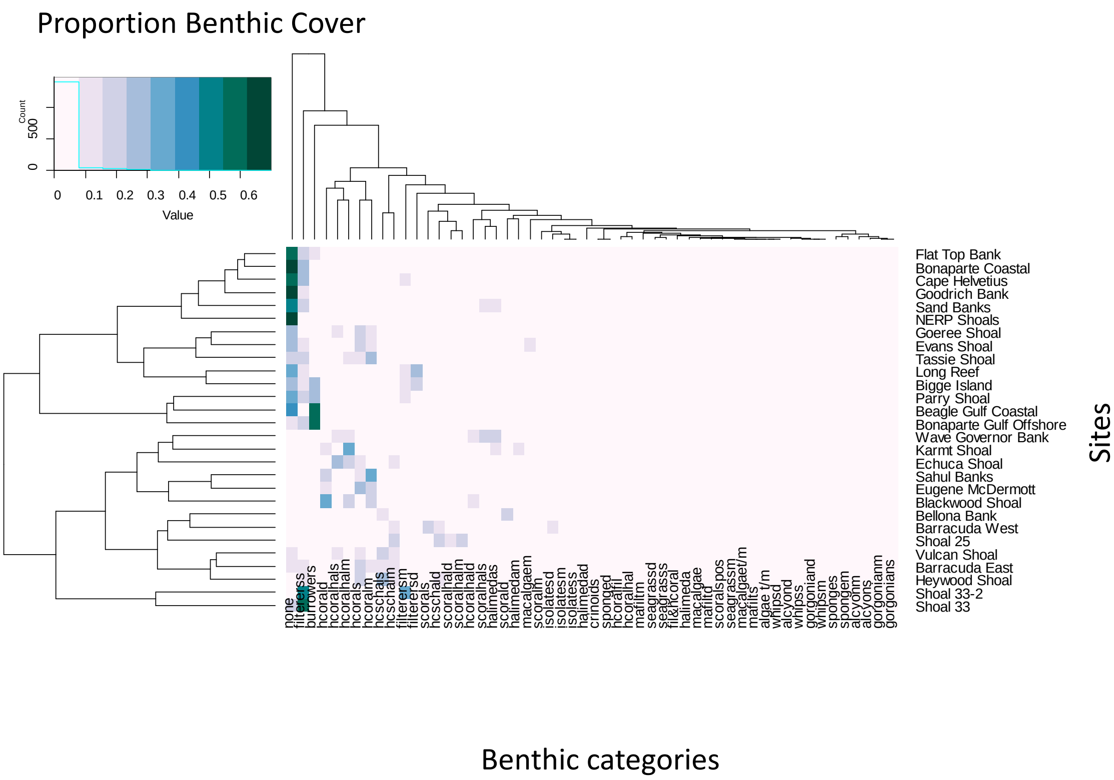


Figure 2 a) Euclidian distance based hierarchical cluster analysis of benthic categories and cover type from 20 towed video site surveys spanning ~900 km the Sahul Shelf and adjacent coastal sites.

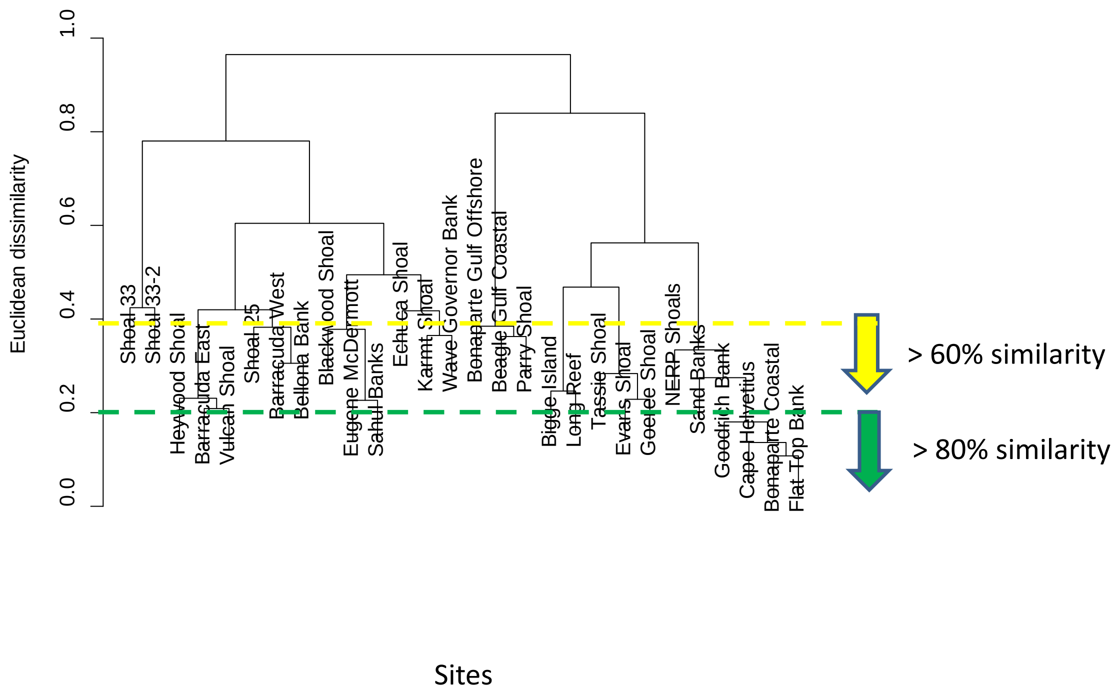


Figure 2 b) Annotation of cluster analysis in Figure a) clustering Sahul Shelf and adjacent coastal sites of sites based on 80% similarity and 60% similarity.

Connectivity has high potential between shoals and banks across the bioregion, with nearest neighbour shoals or banks likely to act as source reefs for shoals downstream. The coral triangle region to the north of the Barossa offshore development area, beyond the Australian Exclusive Economic Zone, is also a probable upstream source of tropical larvae for the region. With steady recruitment of marine larvae onto the region's shoals and banks, the key factors influencing the biodiversity and assemblage structures observed at any point in time on a particular shoal will include the depth, substrate type and complexity, hydrodynamic environment and position on the continental shelf. Some shoals or banks may be notable for the abundance of particular biota, but that status can be dynamic and available data points to many species being shared in common across the region. In terms of biodiversity all shoals and banks should be regarded as sensitive receptors.

Therefore, in the event of a large-scale hydrocarbon release, the spill response measures implemented to protect shoals would the same for all of these features, as the direct impact pathway is the same (i.e. contact with in-water hydrocarbons and/or dispersants), with the predominant factor determining the scale of potential impact being water depth. As was the case in the Montara uncontrolled release (6), an entrained pollutant potentially intersecting with the shoal and bank habitats would be a reasonable trigger for assessment and monitoring.

The Barossa Environmental Baseline Study 2015 findings and links to the CMR Benthic Habitat Model.

To infer a regional scale distribution of coarse benthic categories a habitat model was produced covering both the study area and the broader Bonaparte Basin. The regional habitat model was developed based on the Oceanic Shoals Commonwealth Marine Reserve benthic habitat model produced as part of the Australian National Environmental Science Programme (http://northwestatlas.org/node/1710). Both the Oceanic Shoals Commonwealth Marine Reserve benthic habitat model and the regional habitat model were developed as part of the National Environmental Research Project D1 (as descripted here http://maps.northwestatlas.org/files/montara/ html_popups_oceanic_shoals/ Spatial_benthic_habitat_model_for_the_Oceanic_Shoals_CMR_6dec16.pdf). This contains comprehensive habitat assessments at 18 field sites spanning 800 km of the oceanic shoals of the Sahul Shelf. The extension of the model included additional benthic habitat data held by AIMS and data collected as part of Barossa Environmental Baseline Study 2015 Final Report [2] and extends the model beyond the Oceanic Shoals Commonwealth Marine Reserve.

The regional scale habitat model results cover approximately 46,810 sq km and show a mosaic of habitats throughout the model domain. These habitats are dominated by Burrower/Crinoid soft sediment communities (making up ~23% of the total area) interspersed with no modelled biota present (category "None" making up ~ 69% of the total areas). There was also a lesser but significant amount of filter feeder communities (~6%) most commonly found in the east of the model domain within the bounds of the Oceanic Shoals Commonwealth Marine Reserve (OSCMR). Hard corals (including free living forms), soft corals, macroalgae and gorgonians all make up less than one percent of regional scale model by area. Their distribution is largely associated with the shoals, banks and emergent reefs in the northern extent of the study domain. However, hard coral also extends into areas of the OSCMR, with towed video analysis suggesting that this is most likely associated with isolates and free living coral forms. Alycon, seagrass, whips and Halimeda are marginal environments through the model domain with less than or equal to 0.1% by area.

A description of the how the model was developed and assessment of the model accuracy is provided in the Barossa Environmental Baseline Study 2015 Final Report (2). While all reasonable efforts are made to make model results as representative and accurate as possible, it's important to understand the assumptions and limitations when interpreting the regional habitat model results. For example a caution approach should be applied when interpreting results at fine scales (< 300 m), where validation information is not available and where the model performs poorly (Kappa values < 0.7). Model interpretation guidelines and limitations are detailed in Environmental Baseline Study 2015 Final Report (2).

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Appendix G.

Drill cuttings and fluids dispersion modelling study (APASA 2012)

DRILL CUTTINGS AND MUDS DISCHARGE MODELLING STUDY, FOR APPRAISAL DRILLING CAMPAIGN IN PERMIT NT/P69, BONAPARTE BASIN

REV 1 - 13/12/2012

Prepared for:

ConocoPhillips Australia Pty Ltd

Document control form:

Revision	*Originated*	*Edit & review*	*Authorised*	*Date*
Rev A - Issued for internal review	*Alan Newnham* *Dr Sasha Zigic*	*Dr Sasha Zigic* *Dr Ryan Dunn*		
Rev 0 – Draft issued for client review		*Dr Sasha Zigic*	*Dr Sasha Zigic*	*25/06/2012*
Rev 1 - Issued for client review		*Dr Sasha Zigic* *Dr Ryan Dunn*	*Dr Sasha Zigic*	*13/12/2012*

Document name: COPA_Barossa-NTP69_Cuttings Modelling_Report_Rev1

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EXECUTIVE SUMMARY

<u>*Background*</u>

ConocoPhillips Australia Exploration Pty Ltd (ConocoPhillips) intends to drill, evaluate and flow test up to three hydrocarbon appraisal wells (appraisal wells) in petroleum exploration permit NT/P69. This permit is located in the Bonaparte Basin, in Commonwealth waters offshore the Northern Territory (NT). The appraisal wells comprise the Bonaparte Basin Barossa Appraisal Drilling Campaign (the drilling campaign). The drilling campaign will seek to determine whether potentially commercial hydrocarbon resources exist within the Barossa gas field which was discovered in 2006.

Each well is to be drilled as four separate intervals (conductor, surface, intermediate and production hole), with the diameter of each section decreasing with increasing depth. The conductor and surface holes will be drilled as an open system (riserless) with the extracted drill cuttings and fluids returned directly to the seafloor from the wellhead over 10.9 days. The cuttings and used fluids from the intermediate and production holes will be brought up to the surface through a riser for treatment through solids control equipment and discharged overboard near the sea surface over 28.4 days (approximately). In total approximately 39.3 days of active drilling is anticipated to complete each well.

Prior to commencing the drilling campaign, a dispersion modelling study was conducted to estimate the spatial distribution of the discharged cuttings and fluid solids deposited on the seabed. The discharges were simulated for one release location. As a conservative approach the closest location in the drilling area to the shoals was selected as the proposed release site for the modelling study. Point "F" is located approximately 60 km from Evans Shoal and 70 km from Tassie Shoal.

The main objective of this study was to report the <u>total</u> predicted sediment deposition (g/m^2), resulting from the discharge of drill cuttings and fluid solids over 10.9 days (near seabed discharge – total model duration of 15 days) and 28.4 days (surface discharge – total model duration of 32 days), under varying current conditions for the start of each calendar month (January to December).

The modelling applied a minimum threshold of 10 g/m^2 <u>total (non-temporal, total load)</u>, over the entire modelling period (i.e. total period of discharge); equating to an average sedimentation rate of 0.2 g/m^2/day.

Methodology

The modelling study was carried out in several stages. Firstly, the tidal currents for the region were generated using ASA's ocean/coastal model, HYDROMAP. Secondly, the large scale ocean currents were obtained from the CSIRO Bluelink ReANalysis (BRAN) ocean model for the same region over a one year period (2004) and combined with tidal currents. The year-long dataset describes the complex vertical (through the water column with respect to depth) and horizontal (across the water column with respect to distance) current patterns. Finally, the current data and discharge characteristics were used as input into the far-field sediment model, MUDMAP, to predict the movement and initial settlement of discharged drill cuttings and fluids for the start of each month.

The 2004 ocean current data was selected as it was shown to include periods where strong ocean currents were directed towards the nearby shoals providing a conservative approach to the modelling in regard to potential sediment deposition.

In addition, sediment re-suspension was not included as part of the study as in an oceanic, open water environment such as the drilling area, it would ultimately have a dilution effect (i.e. reduce the total deposition loading at any location) and that sediments would, over time, demonstrate a net migration away from the high energy shallow water environment of the reefs into the surrounding deeper, depositional areas. Consequently, the original sedimentation footprint as reported herein would likely represent a worst-case in terms of total deposition on the shoals environment, rather than an underestimation.

Results: Near-seabed discharges

During drilling of the initial well sections (conductor and surface intervals) where drill cuttings and fluids will be discharged to the seabed, modelling indicated that the larger sediments (diameter greater than 0.15 mm) would settle within 60 m south from the release site. The modelling also showed that sediments smaller than 0.15 mm diameter will be carried further away from the release site (up to 3-4 km), due to slower settling velocities, in varying directions as a very thin layer of sediments. Within 100 m from the release site, the average and maximum bottom thickness was 4.5 mm and 11 mm, respectively.

No sediments were predicted to make contact with Evans Shoal or Tassie Shoal at a measureable level (above a value of 0.0026 mm or 10 g/m^2). The minimum distance from Evans Shoal and Tassie Shoal to the 10 g/m^2 contour was 53.1 km and 62.0 km, respectively.

Results: Sea surface discharges

With the sea surface releases occuring approximately 220 m above the seabed, the sediment was exposed to the force of the current for a longer period of time, thus transporting the material further away from the release site and causing it to settle over a larger area as a thinner pile. The seabed accumulation was much less compared to the seabed discharges. Within 100 m from the release site, the average and maximum bottom thickness was 0.05 mm and 0.14 mm, respectively.

No sediments were predicted to make contact with Evans Shoal or Tassie Shoal at a measureable level (above a value of 0.0026mm or 10 g/m^2). The minimum distance from Evans Shoal and Tassie Shoal to the 10 g/m^2 contour was 60.2 km and 67.9 km, respectively,

1 INTRODUCTION

1.1 Project Background

ConocoPhillips Australia Exploration Pty Ltd (ConocoPhillips) intends to conduct an appraisal drilling campaign in permit NT/P69. This permit is located in the Bonaparte Basin, in Commonwealth waters offshore the Northern Territory (NT) (see Figure 1).

Each well is to be drilled as four separate intervals (conductor, surface, intermediate and production hole), with the diameter of each section decreasing with increasing depth. The conductor and surface holes will be drilled as an open system (riserless) with the extracted drill cuttings and fluids returned directly to the seafloor from the wellhead. The cuttings and used fluids from the intermediate and production holes will be brought up to the surface through a riser for treatment through solids control equipment and discharged overboard near the sea surface. Approximately, 39.3 days will be required to complete the active drilling of each well, with the discharge of drill cuttings and fluids near the seabed conducted over 10.9 days and the sea surface discharges over a 28.4 day period (approximately).

Prior to commencing the drilling campaign, a dispersion modelling study was conducted to estimate the spatial distribution of the discharged cuttings and fluids deposited on the seabed. The study examined the near seabed and surface discharges under varying current conditions for the start of each calendar month (January to December) from one release location.

A conservative approach has been used to estimate the likely probability of exposure to sedimentation to the submergent shoals and distant shorelines in the region. Point “F” in Figure 1, the closest location in the drilling area to the shoals was selected as the proposed release site for the modelling study. Point “F” is located approximately 60 km from Evans Shoal and 70 km from Tassie Shoal, in a water depth of approximately 220 m. Figure 1 and Table 1 provides a summary of the modelled release location and water depth.

The main objective of this study was to report the total predicted sediment deposition (g/m^2), resulting from the discharge of drill cuttings and fluids over 10.9 days (near seabed discharge – modelled for 10.9 days) and 28.4 days (surface discharge – modelled for 28.4 days), under varying current conditions for the start of each calendar month (January to December).

Table 1: Release location used as part of the drill cuttings and fluids dispersion modelling study.

Latitude	**Longitude**	**Water depth (m)**
9º 54’ 55.1” S	130º 10’ 4.4” E	~220

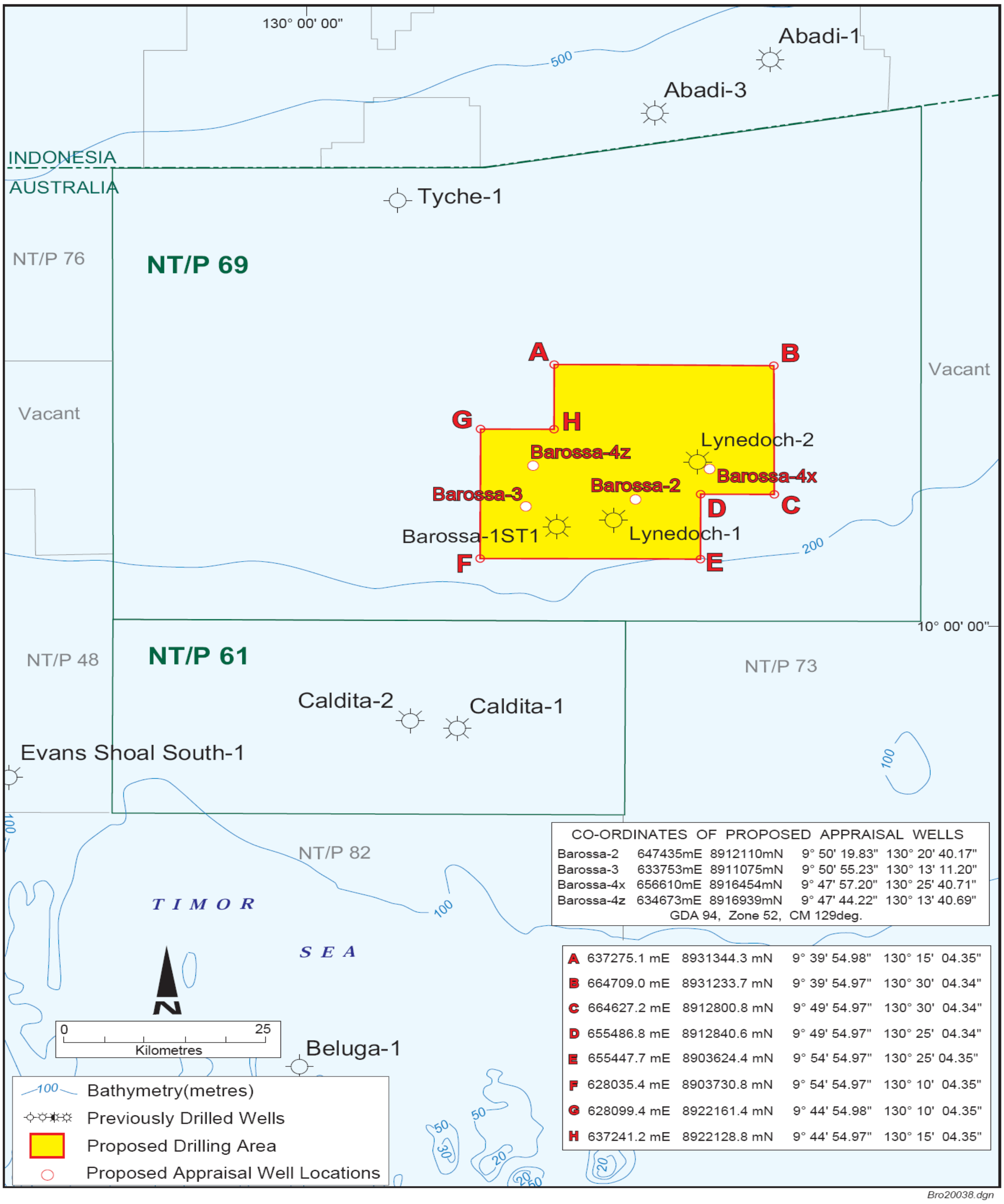

Figure 1: Map showing the location of the appraisal wells and release location in the drilling area, used as part of the drill cuttings and fluids dispersion modelling study. (source: ConocoPhillips Australia Exploration Pty Ltd July 2012).

1.2 Scope of Work

The scope of work included the following components:

1. Generate tidal current patterns of the receiving waters using a validated ocean/coastal model, HYDROMAP;
2. Create a year-long (2004) dataset describing the large scale flow of ocean waters from the CSIRO Bluelink ReANalysis (BRAN) ocean model and combine with HYDROMAP predicted tidal currents. This combined dataset was used to describe the total water current within the region;
3. Use current data and discharge characteristics as input into the far-field sediment model, MUDMAP, to predict the movement and initial settlement of discharged drill cuttings and fluids for the start of each month;
4. Report the predicted sediment deposition, area of coverage and distance from adjacent reefs, from the seabed discharge from the start of each month;
5. Report the predicted sediment deposition, area of coverage and distance from shoals and coastlines, from the surface discharge from the start of each month; and
6. Report the total predicted sediment deposition, area of coverage and distance from shoals and coastlines, from the combined seabed and sea surface discharge from the start of each month

2 REGIONAL CURRENTS

The drilling area is located within the influence of the Indonesian throughflow, a large scale current system characterised as a series of migrating gyres and connecting jets that are steered by the continental shelf. This results in sporadic events of deep ocean surface currents exceeding 1.5 m/s (~ 3 knots).

While the mass flow is generally towards the southwest, year-round, the internal gyres generate local currents in any direction. As these gyres migrate through the area, large spatial variations in the speed and direction of currents will occur at a given location over time.

While, the tidal currents are generally weak in the deeper waters, its influence is greatest along the inshore and coastal passage regions, and in and around, the many reef systems on the continental shelf. Hence, the net current forcing can be variably affected by the tidal and deep ocean currents. Therefore it was critical to include the influence of both types of currents to rigorously understand the likely drift patterns of hydrocarbon spills within in the region.

2.1 Ocean Currents

To account for the prevailing ocean currents, data was obtained from the BRAN (Bluelink ReAnalysis – Oke et al., 2008, 2009; Schiller et al., 2008) model developed by CSIRO's Marine and Atmospheric Research group. It is a very comprehensive ocean current dataset, which includes data between October 1992 to December 2006. The model uses an assimilative technique for remotely sensed measurements and runs with a horizontal cell size resolution of approximately 10 km and 47 vertical layers.

For the study a five year data set was obtained (2001 to 2005 (inclusive)). Figure 2 shows the surface current roses for each individual year. Note the convention for defining current direction is the direction the current flows to, which is used to reference current direction throughout this report. Each branch of the rose represents the currents flowing to that direction, with north to the top of the diagram. Sixteen directions are used. The branches are divided into segments of different colours, which represent the current speed interval for each direction. Speed intervals of 0.1 m/s are used in these current roses. The length of each coloured segment is relative to the proportion of currents flowing within the corresponding speed and direction.

Figure 3 shows the seasonal surface current roses for 2004 as an example at the modelled release site. The data shows that the ocean current speeds and directions varied between seasons. During the winter (April to August) and transitional (March and September to November) periods, currents flowed predominantly to the west-southwest. For the summer months (December to February) surface currents flowed in both a westerly and easterly direction. The current speeds were weaker during summer in comparison to the winter and transitional seasons.

Figure 4 shows a screenshot of the predicted ocean currents at the surface during summer and winter conditions. The colouration of the individual vectors indicates current speed (m/s).

As the model neglects tidal forcing, tidal currents were independently generated and added to describe the net water movement (see Section 2.2 Tid).

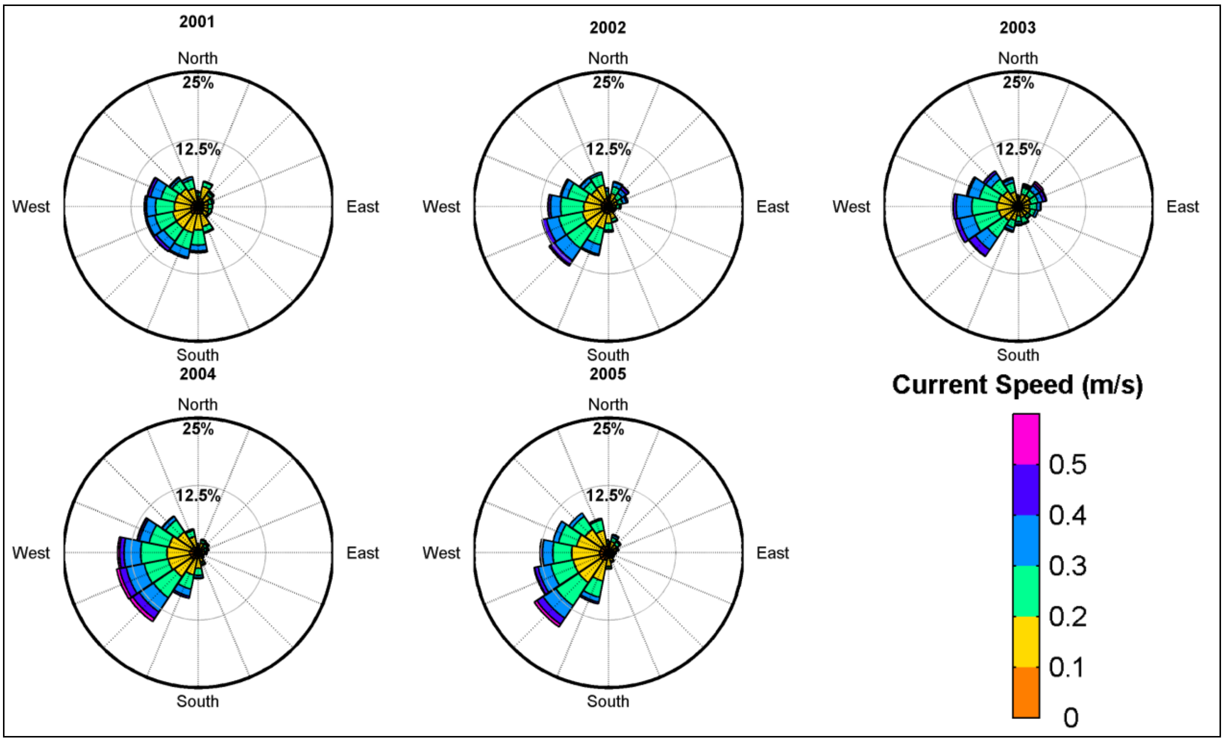

Figure 2: Annual surface ocean current rose plots at the modelled release location. Data from 2001 to 2005 was obtained from the BLUElink ReANalysis deep ocean model.

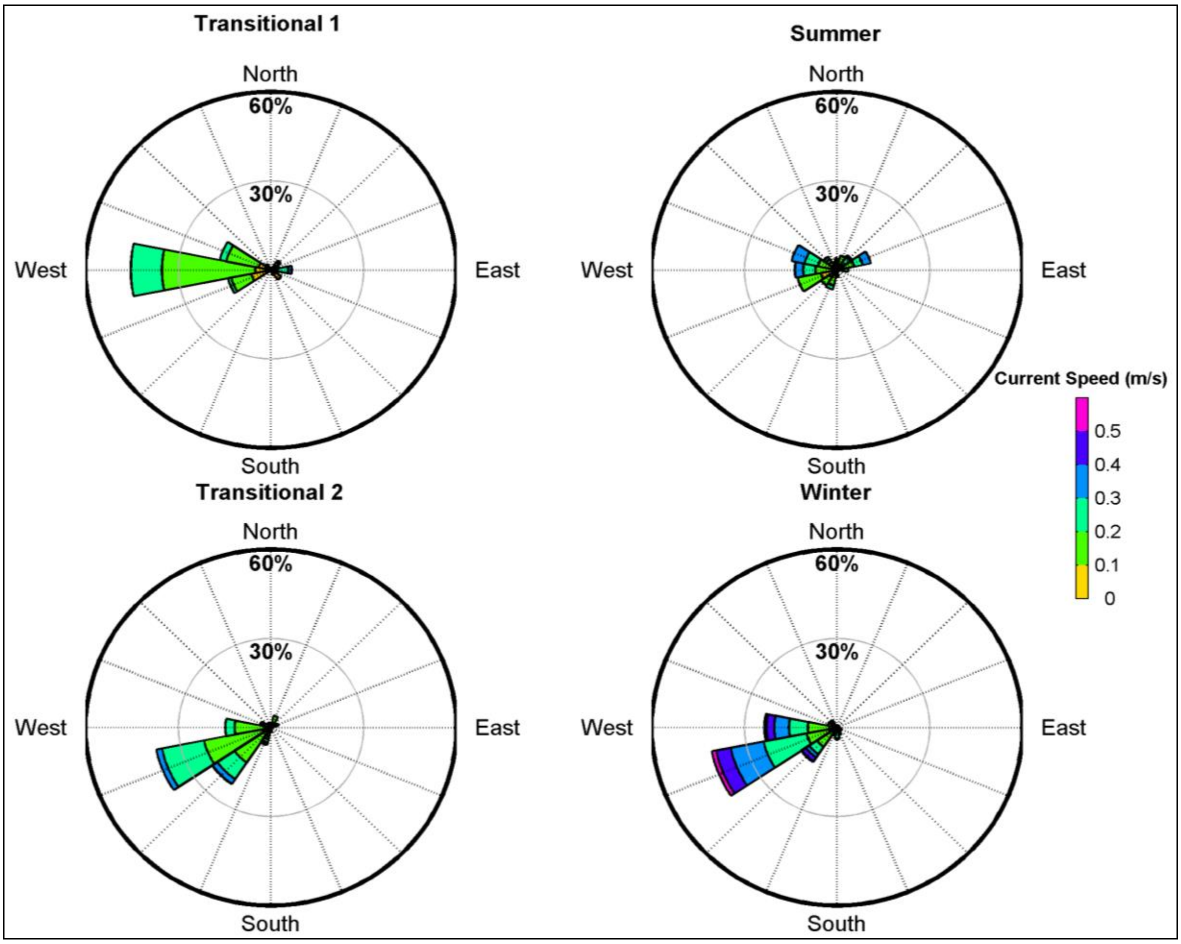

Figure 3: Seasonal current rose distributions for 2004 at the modelled release site.

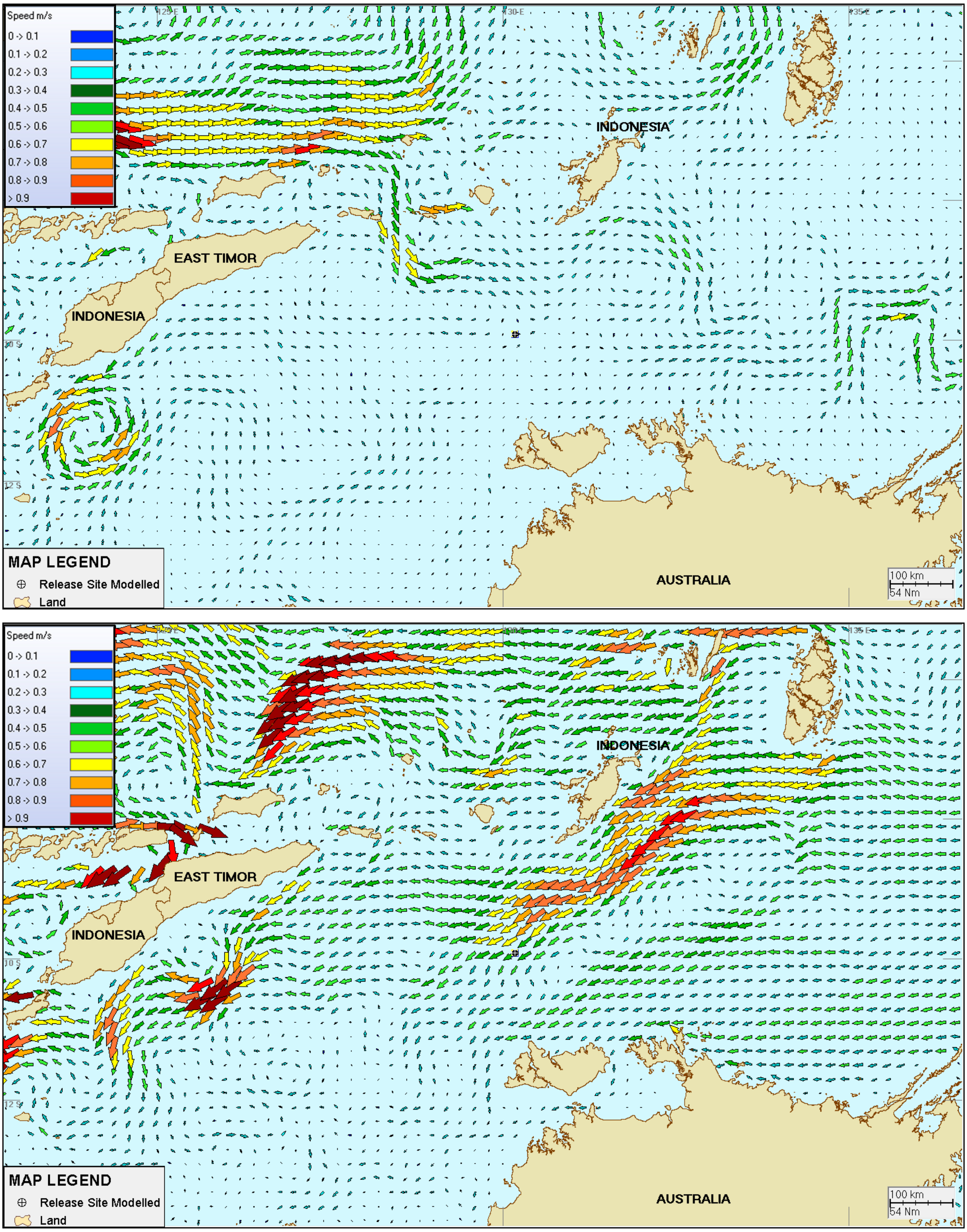

Figure 4: Screenshot of the predicted surface ocean current vectors during a single time-point during the summer (upper image) and winter seasons (lower image). The colours of the vectors indicate current speed in m/s. The release location is depicted by the black crosshair icon.

2.2 Tidal Currents

The tidal current data was generated using ASA's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world over the past 25 years (Isaji and Spaulding, 1984; Isaji et al., 2001; Zigic et al., 2003). In fact, HYDROMAP tidal current data have been previously used as input to forecast (in the future) and hindcast (in the past) oil spills in Australian waters and forms part of the Australian National Oil Spill Emergency Response System operated by AMSA (Australian Maritime Safety Authority).

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 nested-gridding strategy, supporting up to six levels of spatial resolution. This allows for a higher resolution of currents within areas of greater bathymetric and coastline complexity, or of particular interest to a study. To simulate the ocean-circulation over any area of interest, the model must be provided with the following data:

(1) Measured bathymetry for the area, which defined the shape of the seafloor;

(2) The amplitude and phase of tidal constituents, which were used to calculate sea heights over time at the open boundaries of the model domain. Changes in sea heights were used, in turn, to calculate the propagation of tidal currents through the model region; and

(3) Wind data to define the wind shear at the sea surface.

The numerical solution methodology 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 and Spaulding (1984).

1.1.1 Grid Set Up

HYDROMAP was set-up over a domain that extended 1,525 km (east–west) by 1,240 km (north–south). The domain was subdivided horizontally into a grid with 5 levels of resolution. The resolution of the primary level was set at 14 km. The resolution of the second, third, fourth and fifth levels were 7 km, 3.5 km, 1.75 km and 876 m, respectively. The finer grids were allocated in a step-wise fashion to more accurately resolve flows along the coastline, around islands and over more complex bathymetry.

1.1.2 Tidal Data

The detailed tidal data was in the form of amplitude and phase records along the open boundaries of the model grid, which was extracted from the Topex/Poseidon global tidal database (TPX07.1; National Oceanographic and Atmospheric Administration). The database is derived from long-term satellite measurements. Using the tidal data, surface heights were firstly calculated along the open boundaries, at each time step in the model, using the eight largest and most significant tidal constituents for the area (M_2, S_2, K_1, O_1, N_2, P_1, K_2, and Q_1).

For the purposes of verifying the tidal data, results from a 29-day simulation were compared against the National Tidal Facility (NTF) observed tides at six tide stations (Table 2). As can be seen in Figure 5 and Figure 6, the HYDROMAP predictions compare very well to the timing and height of the observed tidal data. This demonstrates that the model and input data is accurately predicting the propagation of tidal currents.

Table 2: Location of observation tide stations

Station	Latitude and Longitude	Distance to NT/P69 (km)
Newby Shoal	11º 52' S; 129 º 11' E	230
Two Hills Bay	11º 31' S; 132 º 4' E	240
Jensen Bay	11º 11' S; 136 º 41' E	690
Sir Charles Hardy Island	11º 55' S; 143 º 28' E	1,330
Archer River	13º 20' S; 141 º 39' E	1,270
Port Moresby (Papua New Guinea)	9º 29' S; 147 º 6' E	1,820

Figure 7 shows a screen shot of the predicted tidal current vectors surrounding the drilling area. Note, only every 3rd tidal vector is shown to ensure clarity. The colouration of the individual vectors in Figure 7 indicates current speed.

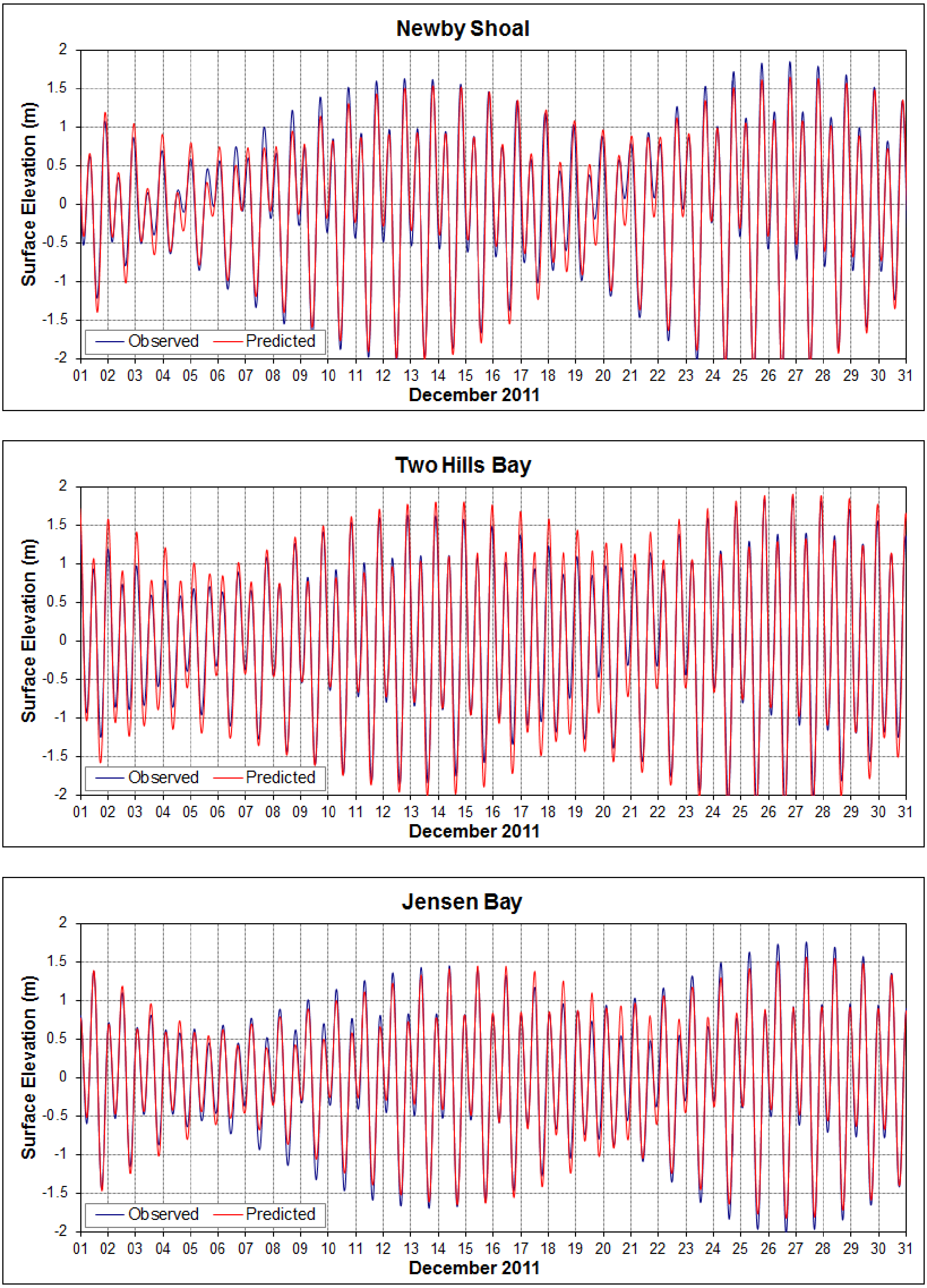

Figure 5: Comparison between predicted (red line) and observed (blue line) surface elevations at Newby Shoal (top), Two Hills Bay (middle) and Jensen Bay (bottom), 1st - 31st December 2011.

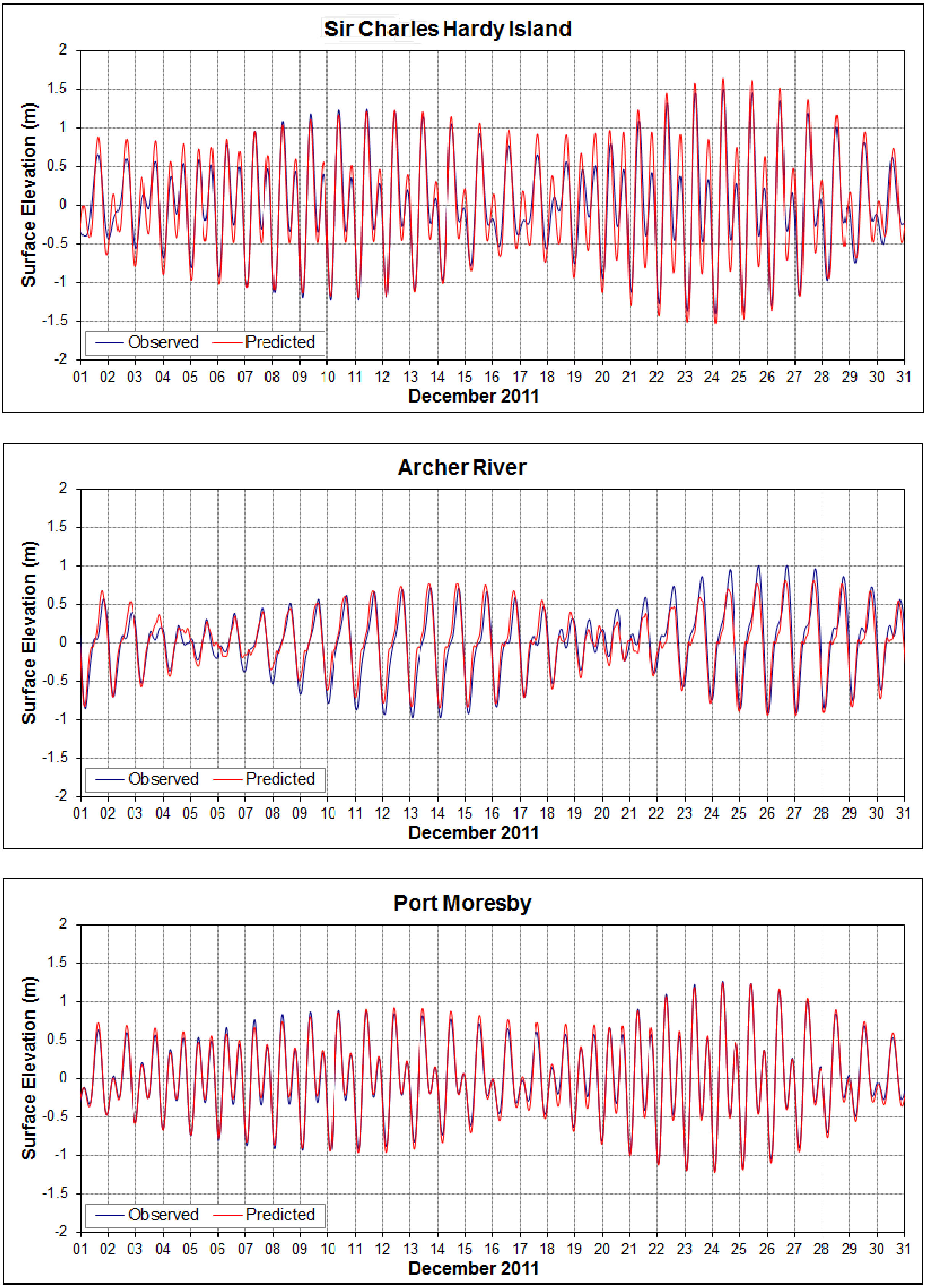

Figure 6: Comparison between predicted (red line) and observed (blue line) surface elevations at Sir Charles Hardy Island (top), Archer River (middle) and Port Moresby (bottom), 1st - 31st December 2011.

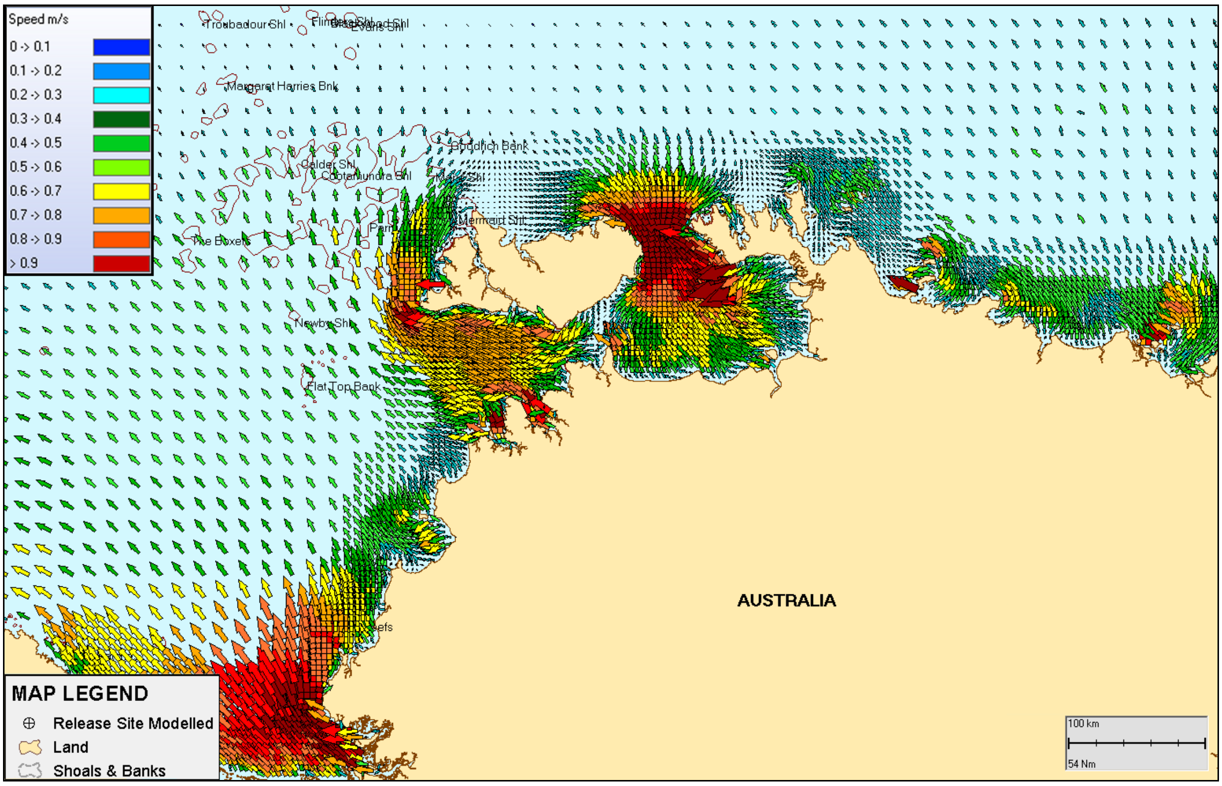

Figure 7: Screenshot of the predicted tidal current vectors. Note the density of the tidal vectors vary with the grid resolution, particularly along the coastline and around the islands. Colourations of individual vectors indicate current speed in m/s.

2.3 Net Water Current

Figure 8 show the monthly and annualised surface and near bottom current roses at the release location for 2004. Note the convention for defining current direction is the direction the current flows to, which is used to reference current direction throughout this report. Each branch of the rose represents the currents flowing to that direction, with north to the top of the diagram. Eight directions are used. The branches are divided into segments of different thicknesses, which represent current speed ranges for each direction. Speed intervals of 0.1 m/s are used in these current roses. The width of each segment within a branch is proportional to the frequency of currents flowing within the corresponding range of speeds for that direction (e.g. thick segments of the branches represent a higher frequency of currents of that speed flowing in that direction compared to segments which are thinner).

As the current roses illustrate, the speeds and directions vary as a function of depth. The average and maximum surface currents were 0.2 m/s and 0.71 m/s, respectively, which are significantly stronger than the near bottom currents (an average and maximum of 0.1 m/s and 0.4 m/s, respectively).

Directionality of the surface currents were also shown to vary between each month, predominately due to the prevailing seasonal wind conditions. During the summer months (December to the following February) the winds were from the west which is in opposite direction of the main current flow. While during the winter months (April to August), winds blew from the east, which in line with the direction of the currents.

Figure 9 shows the hourly predicted net surface current speeds and directions and Figure 10 shows the hourly predicted net bottom current speeds and directions for 2004 at the modelled release site.

As shown in Figure 9, compared to Figure 10, the surface current speeds were consistently higher for an extended period of time, due to the influence of winds.

Figure 11 is a screenshot of the predicted net surface and bottom current vectors surrounding the modelled release site, at 12 am 1st April 2004. The image again demonstrates the higher current speeds at the surface compared to the bottom waters. Note the difference in directionality between surface and bottom currents at the selected point in time.

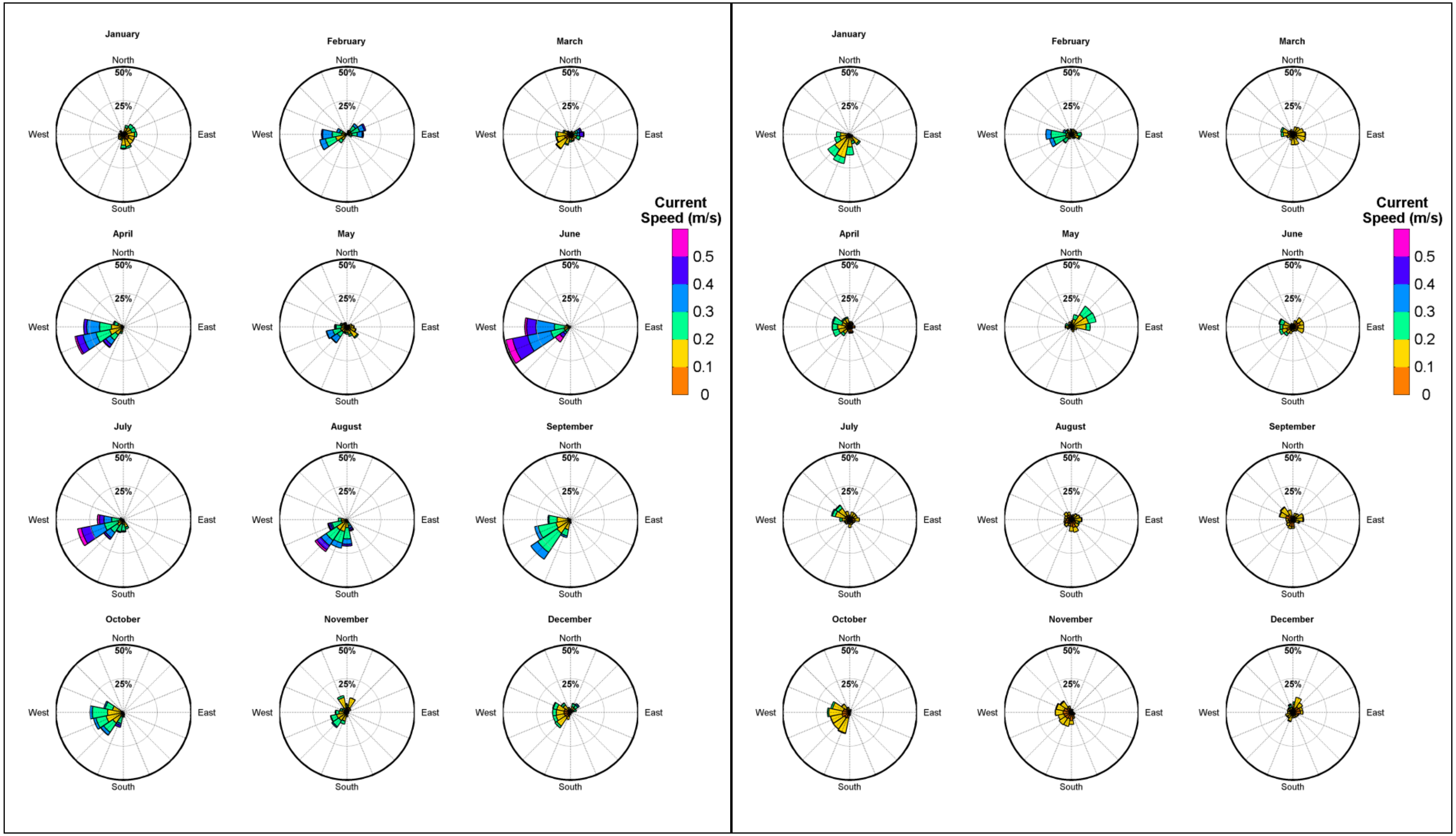

Figure 8: Monthly net surface (left image) and bottom (right image) current roses at the modelled release site for 2004. Current roses depict the net movement of currents (combined ocean and tidal currents).

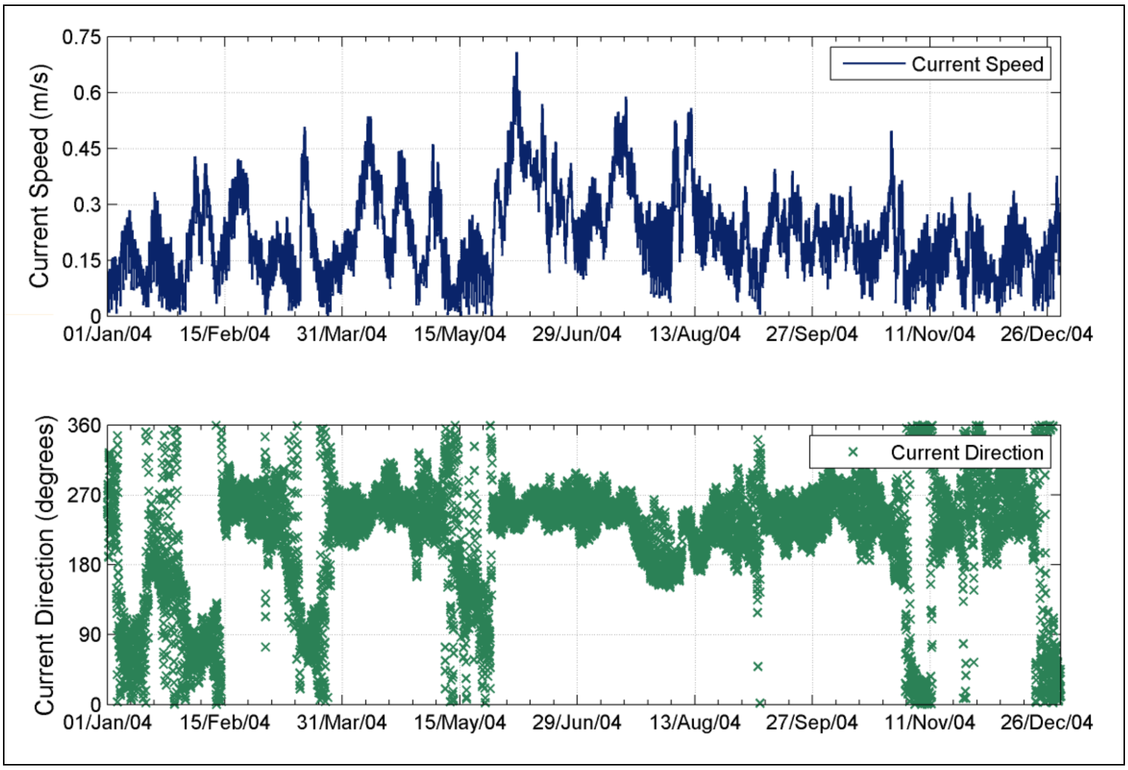

Figure 9: Predicted hourly net surface current speeds and directions at the modelled release site for 2004. Currents depict the net movement of currents (combined ocean and tidal currents).

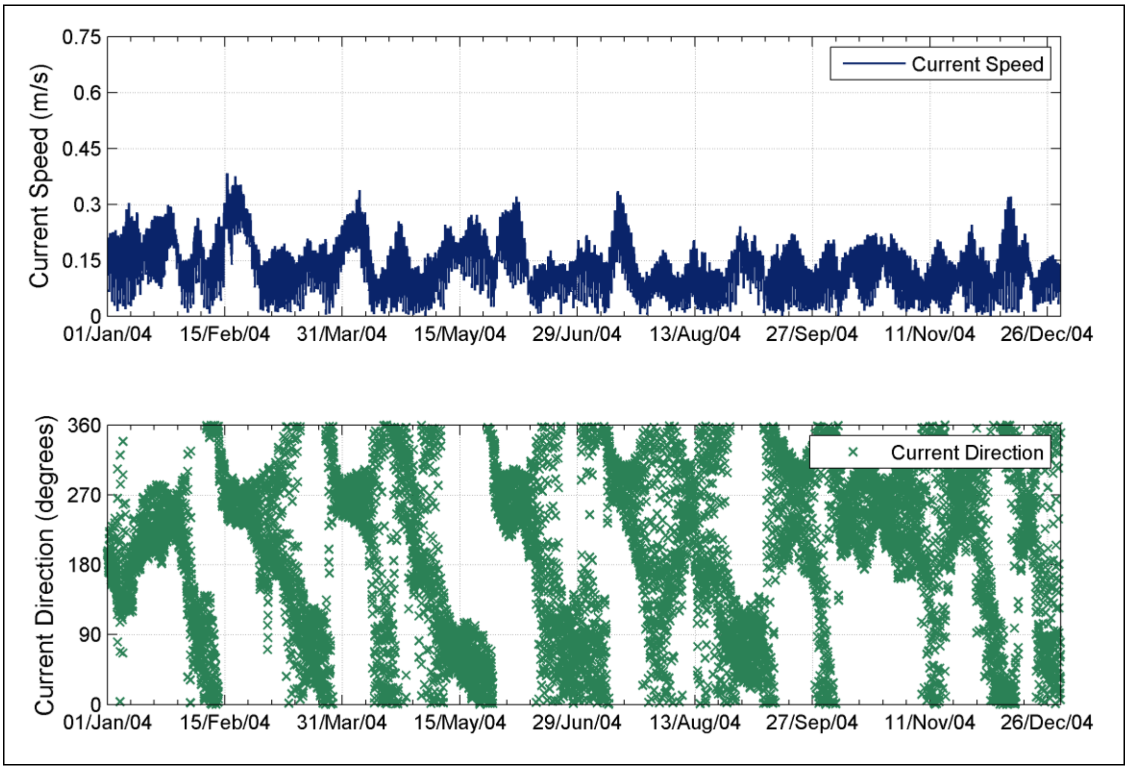

Figure 10: Predicted hourly net bottom current speeds and directions at the modelled release site for 2004. Currents depict the net movement of currents (combined ocean and tidal currents).

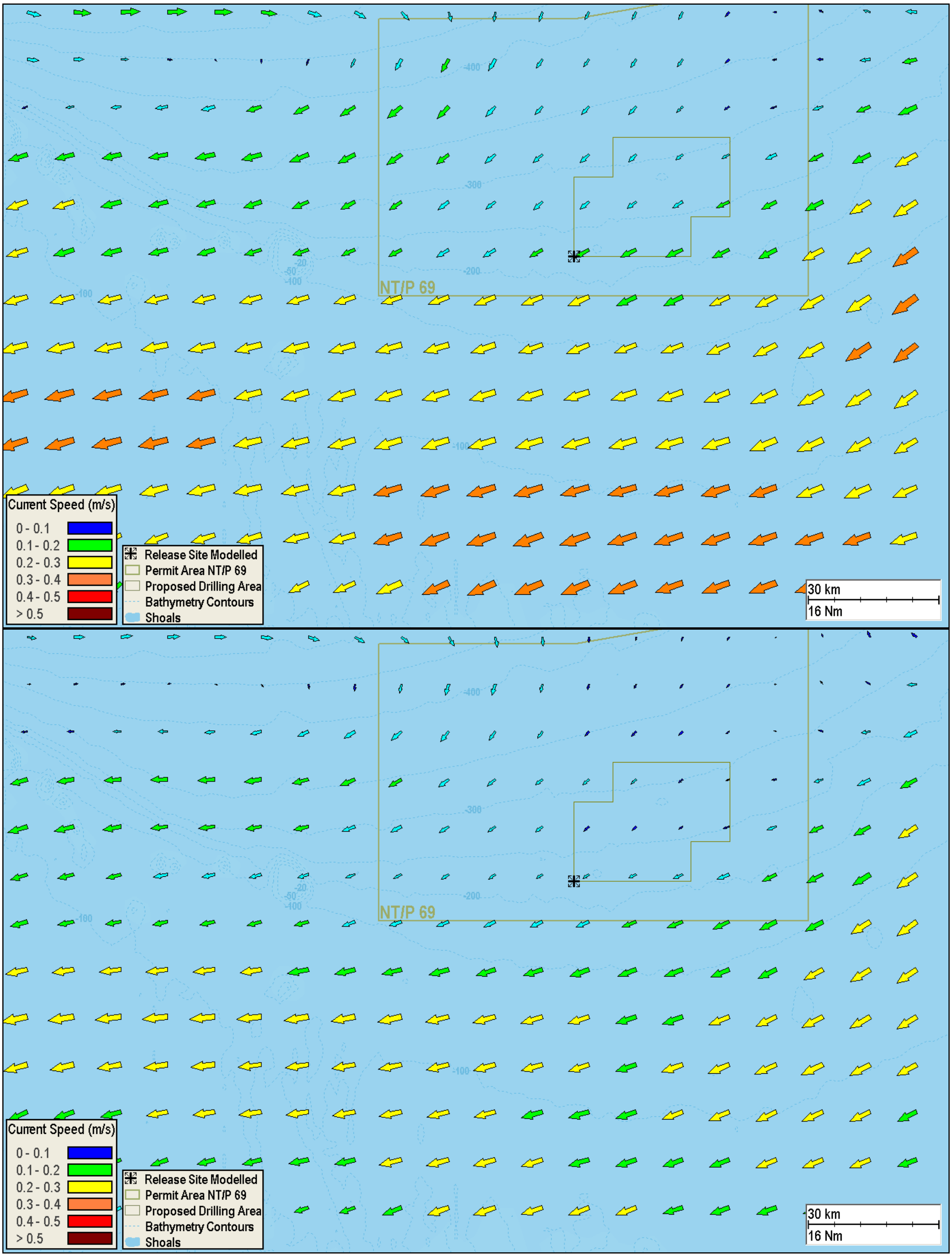

Figure 11: Screenshot of the surface (top image) and bottom (lower image) net (combined ocean and tidal) currents at 12 am 1st April 2004.

3 Water Temperature and Salinity Profile

The influence of temperature and salinity variations on sediment plumes in the far-field is negligible, these parameters were included as input into the model for completeness (see Table 3). Temperature and salinity data was obtained from the National Oceanographic Data Centre – World Ocean Atlas 2005 (http://www.nodc.noaa.gov/OC5/indprod.html).

Table 3: Temperature and salinity data as a function of water depth near the modelled release site.

Depth (m)	***Temperature (ºC)***	***Salinity (ppt)***
0	28.4	34.4
50	27.4	34.4
100	23.2	34.7
200	15.3	35.5
300	11.2	35.6

4 DISPERSION MODELLING METHODOLOGY

4.1 Sediment Dispersion Model Description - MUDMAP

MUDMAP is a highly advanced three-dimensional plume model used by industry and regulators to aid in assessing the potential environmental effects from operational discharges such as drill cuttings, drilling fluids and produced water. Since its inception in 1994, the model has been applied to hundreds of assessments in over 35 countries, including Australia (since 1996).

The model itself is an enhancement of the Offshore Operators Committee (OOC (Brandsma and Sauer, 1983)) model and calculates the fates of discharges through three distinct stages, as defined by laboratory and field studies (Koh and Chang, 1973; Khondaker, 1999):

Stage 1: **Convective decent –** free fall of the combined mass of fluids and cuttings;

Stage 2: **Dynamic collapse stage –** the collapse of the combined mass as it loses the initial jet related momentum and turbulence; and

Stage 3: **Dispersion stage –** model predicts the transport and dispersion of the discharged fluids and cuttings by the local currents. Dispersion of the discharged material will be enhanced with increased current speeds and water depth and with greater variation in current direction over time and depth.

Each stage plays an integral role at different times and distance scales. The governing equations and solutions were built on the formulas originally developed by Koh and Chang (1973) and are extended by the work of Brandsma and Sauer (1983), known as the OOC model, for Stages 1 and 2 of plume motion.

The far-field calculation (passive dispersion stage), however, employs a particle-based, random walk procedure. The model predicts the dynamics of the discharge material and resulting seabed concentrations and bottom thicknesses over the near field (i.e. the immediate area of the discharge) and the far-field (the wider region). Figure 12 shows a conceptual diagram of the dispersion and fates of drill cuttings and fluids discharge to the ocean and the idealized representation of the three discharge phases.

Along with the advanced analyses tools, MUDMAP can simulate six classes (or 36 subcategories), each with its own density and particle size distribution. This means that the fluids, cuttings, water and chemicals can be included in the near-field and far-field computations. The discharged material is represented by a large sample of Lagrangian particles (32,000). During the dispersion stage, the particles are transported in three-dimensions according to the current data and horizontal and vertical mixing coefficients at each time step according to the governing equations.

MUDMAP has been extensively validated and applied for discharge operations in Australian coastal waters (e.g. Burns et. al., 1999; King and McAllister, 1997, 1998; Spaulding, 1994). A document titled “A review of models in support of oil and gas exploration off the North Coast of British Columbia”, prepared by the Institute of Ocean Sciences Fisheries and Oceans Canada (Foreman et al., 2005) stated that “for a drilling mud model, we feel that MUDMAP seems to be the best choice.”

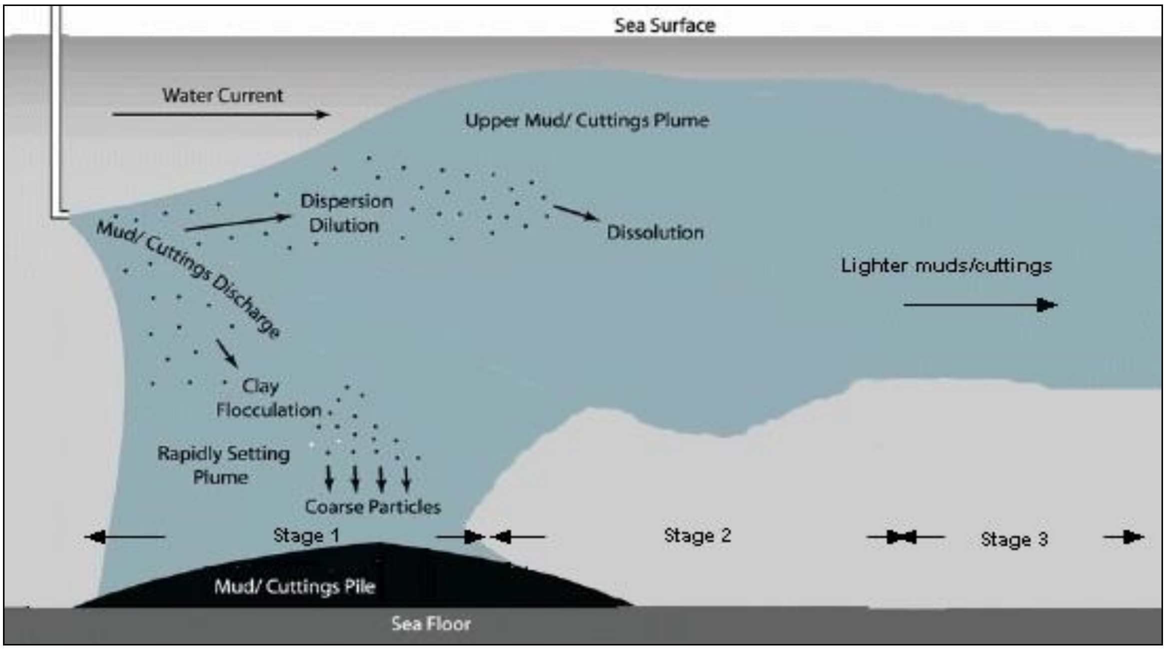

Figure 12: Conceptual diagram showing the general behaviour of cuttings and fluids (muds) following the discharge to the ocean (Neff, 2005) and the idealised representation of the three discharge phases.

4.2 Well Construction and Drilling Discharge

The first interval in the well will be the conductor section. A 36” conductor hole will be drilled riserless using seawater and high viscosity sweeps with all cuttings and drilling mud returned to the sea floor. The second interval in the well will be the surface section. A 17.5" surface hole will be drilled riserless using seawater and high viscosity sweeps. All drill fluids and drill cuttings will be returned to the seabed during the drilling of this section.

A 12.25" hole section will be drilled with synthetic based drilling fluid. Additionally, the 8.5" section will also be drilled using a synthetic based drilling fluid. The drill cuttings and fluids will be returned to the sea surface.

Approximately, 39.3 days of active drilling will be required to drill each well. Table 4 summarises the drilling fluid types and estimated volume of drill cuttings for each well interval.

Table 4: Drilling fluid types and estimated generated volumes of drill cuttings per well section.

Well interval	***Hole diameter (inches)***	***Cuttings***	***Drilling fluid type***		***Point of discharge***	***Active drilling (days)***
		Approximate volume (m^3) (Note 1)	***Type***	***Approximate volume (m^3)***		
Conductor hole	36	39	Seawater with high viscosity sweeps	100	*Seabed*	0.1
Surface hole	17.5	302	Seawater with high viscosity sweeps	1,542	*Seabed*	10.8
Intermediate hole	12.25	131	SBM	36*	*Sea surface**	9.9
Production hole	8.5	12	SBM	4*	*Sea surface**	18.5
	Total	**484**	**Total**	**1,642**	**Total**	**39.3**

Note 1: Volumes provided are best available estimates, calculated based on data acquitted from previous drilling activity undertaken by ConocoPhillips in the Bonaparte Basin.

** Best available estimates, calculated based on 10% oil on cuttings*

The input data into the dispersion model included:

- Volume and discharge duration of the cuttings and unrecoverable fluid solids;
- Sediment grain size distributions and associated settling velocities;
- Bulk density of the released material;
- Temperature and salinity profiles of the receiving waters;
- The size and orientation of the discharge pipe;
- The height of the point of discharge relative to mean sea level; and
- Current data to represent local physical forcing.

Table 5 shows a summary of the discharge configuration and model parameters used as input into the discharge model. All cuttings generated by riserless drilling of the 36” conductor hole and 17.5" surface hole will be returned to the seabed where they will accumulate in the vicinity of the wellhead. The drilling of conductor and surface hole sections typically takes approximately 10.9 days with the rate of discharge was assumed constant throughout the 10.9 day release. The model was run for a 15 day period to allow finer sediment to settle out of suspension.

The lower hole sections of each well, comprising the 12.25" and 8.5" sections, will be drilled using a recirculating drilling fluid system. Drilling time of the two lower sections is estimated at approximately 28.4 days, during which time the rate of discharge was assumed constant. The model was run for a total duration of 32 days to allow finer sediment to settle out of suspension. A marine riser run between the blowout preventer (BOP) and the mobile offshore drilling unit (MODU) will provide a conduit for the return of drilling fluid and cuttings back to the MODU. On the MODU the drilled cuttings and drilling fluid will be separated and cleaned using solids control equipment. After recovery of drill fluids, the drill cuttings will be discharged from the MODU at the well site to the sea surface.

The density of the cuttings and drilling fluids were assumed at 2,550 kg/m^3 and 4,200 kg/m^3, respectively (Nedweed, 2004). Based on the volumes of cuttings and fluids released, the bulk density for the seabed and sea surface discharges was approximately 3,916 kg/m^3 and 2,911 kg/m^3, respectively. It is important to note that grain size (in turn settling velocity) has a greater influence on the rate of settling than density (Neff, 2005).

Table 5: Input data used for the drill cuttings and muds dispersion modelling.

Parameter/description	*Detail*
Volume of cuttings discharged at the seabed	341 m^3
Volume of drilling fluid discharged at the seabed	1,642 m^3
Volume of cuttings discharged at the sea surface	143 m^3
Total volume of cuttings discharged	484 m^3
Total volume of drilling fluid discharged	1,642 m^3
Density of drill cuttings	2,550 kg/m^3
Density of drilling fluid	4,200 kg/m^3
Seabed discharge duration [model duration]	10.9 days [15 days]
Sea surface discharge duration [model duration]	28.4 days [32 days]
Depth of seabed discharge	2 m above seabed
Depth of sea surface discharge	Near the sea surface
Sea surface discharge pipe orientation	Vertically downward
Ocean current (see note 1)	- BLUElink ReANalysis model (BRAN) - Hourly dataset for 2004 - High resolution dataset spanning entire grid domain
Tidal currents (see note 1)	- Currents generated using ASA advanced ocean/coastal model (HYDROMAP) - Hourly dataset for 2004 - Validated currents against six observation tide stations
Water temperature and salinity (see note 2)	Regional specific seasonal sea surface temperature and salinity values

Note 1: CSIRO BLUElink ReANalysis deep ocean model and APASA Ocean/Coastal model, HYDROMAP

Note 2: National Oceanographic Data Centre, 2005 World Ocean Atlas

Table 6 shows the sediment grain sizes, settling velocities and distributions according to the fluid type and fluid to solids ratio for each well interval, as confirmed by the ConocoPhillips geoscience team.

The conductor and surface well intervals are to be drilled with seawater and high viscosity sweeps and the grain sizes are expected to range from 0.016 mm to 6 mm. The intermediate and production holes are to be drilled with synthetic based drilling fluid and the grain sizes are expected to range between 0.026 mm to 6 mm.

The settling velocity for each sediment grain size was obtained from empirical data provided by Dyer (1986). As can be seen in Table 6, settling velocities vary significantly between the smallest and largest grain sizes.

Table 6: Sediment grain size, settling velocities and distribution for each well interval according to fluid type and fluid to solids ratio.

Class	Sediment grain size (mm)	Settling velocity (cm/s)	Conductor and surface holes (%)	Intermediate and production holes (%)
Large cuttings	6	53.62	2.1	9.4
	5	49.46	2.1	9.4
	2	28.55	2.1	9.4
	1	12.73	1.4	6.3
	0.5	7.5	1.4	6.3
	0.45	6.6	0.7	3.1
Medium cuttings	0.4	6	0.7	3.1
	0.35	5	0.7	3.1
	0.3	4	0.7	3.1
	0.25	3.1	0.7	3.1
	0.2	2.3	0.7	3.1
	0.15	1.6	0.7	3.1
Small cuttings	0.1	0.8	0.7	3.1
	0.05	0.22	0.7	3.1
	0.04	0.15	0.7	3.1
	0.03	0.08	0.7	6.2
	0.02	0.04	0.7	0.0
Drilling fluid solids	0.063	0.34	1.2	0.0
	0.05	0.22	4.5	1.2
	0.035	0.11	10.7	2.9
	0.026	0.06	17.4	17.8
	0.02	0.038	21.6	0.0
	0.016	0.026	27.4	0.0

4.3 Grid Configuration

To calculate the concentrations from the seabed discharges, each horizontal grid cell size was 20 m x 20 m, covering a 20 km (longitude, x-direction) x 20 km (latitude, y-direction) extent around the release location. For the sea surface discharges, each horizontal grid cell was 10 m x 10 m grid covering a 10 km x 10 km extent around the release location.

4.4 Bathymetry

A combination of datasets was used to describe the shape of the sea bed and resolve the nearby shoals. Data from Geoscience Australia national bathymetric dataset, which has a nominal resolution of approximately 250 m, were interpolated spatially with spot and contour depths from recent electronic nautical charts to form a seamless, highly accurate representation of the seabed (Geoscience Australia, 2009).

4.5 Mixing Parameters

For discharges at the sea surface, a horizontal coefficient value of 0.25 m^2/s was used as model input to account for the turbulence of the sediment as it is transported from the release site. A vertical coefficient value of 0.1 m^2/s was used as model input to account for the influence of turbulence within the water column, as well as wave induced turbulence. Values are based on previous studies by Copeland (1996).

For the discharge of cuttings and drilling fluids near the seabed, the horizontal dispersion coefficient used was 0.25 m^2/s; however, a very low vertical parameter was set (0.0001 m^2/sec), as vertical turbulence is negligible at 2 m above the seabed.

5 RESULTS

5.1 Presentation of Model Results

The predicted total sediment deposition from the near seabed and surface discharges from the release site are presented in Sections 5.2 and 5.3, respectively.

As the MUDMAP model is able to track sediment to thicknesses that are lower than biologically significant levels, it was necessary to specify a minimum threshold for the results which would record the "coverage" on the seafloor above the natural sedimentation.

The natural sedimentation threshold was determined from a digital database compiled by the National Geophysical Data Center (NGDC) within the United States. The database indicates that the annual natural sedimentation rate for the study region is approximately 60 g/m^2, which is typical of Australian ocean environments. This equated to an approximate minimum threshold of 10 g/m^2 total (non-temporal, total load) over the entire modelling period and a conservative thickness of 0.0026 mm.

To aid in the interpretation of model results, bottom deposition is presented as both mass per area (g/m^2) as well as thickness (mm).

5.2 Seabed Discharges

No contact was predicted (above a bottom deposition threshold of 10 g/m^2) for Evans Shoal and Tassie Shoal from the seabed discharges at the release location for any of the 12 modelling commencement months. The predicted minimum distance from Evans Shoal and Tassie Shoal to the 10 g/m^2 contour was 53.1 km and 62.0 km, respectively.

Figure 13 to Figure 24 show the predicted area covered (greater than 10 g/m^2) from discharges at the seabed, under varying current conditions for the start of each calendar month (January to December).

Table 7 shows the predicted maximum seabed deposition and area of coverage (above 10 g/m^2) for each seabed discharge simulation. The highest predicted sediment thickness (between 361 mm to 432 mm) was predicted to occur immediately adjacent to the release site within a 20 m x 20 m area. Within 100 m from the release site, the average and maximum bottom thickness decreased to 4.5 mm and 11 mm, respectively.

The modelling results showed that due to the height of the model release (modelled at 2 m above the seabed) the currents had little influence on the larger sediment (>150 mm diameter) which readily settled within 60 m south from the release site. The currents did have an effect on the transport of the smaller sediment (<0.15 mm diameter), which were predicted to will be carried further away from the release site (up to 3-4 km), due to slower settling velocities, in varying directions as a very thin layer of sediments.

Table 7: Summary of the maximum predicted bottom thicknesses and area of coverage for the seabed discharge simulations, initiated on the first day of each month. Also shown is the minimum distance from sensitive receptors to the 10 g/m² contour.

Commencement month	**Maximum bottom deposition (mm)**	**Total area of coverage above the natural sedimentation threshold of 10 g/m² or 0.0026 mm (km²)**	**Minimum distance from the sensitive receptor to the 10 g/m² contour (km)**	
			Evans Shoal	**Tassie Shoal**
January	398	1.45	60.6	68.1
February	361	10.78	61.2	68.7
March	428	3.99	58.5	66.4
April	390	12.05	53.1	62.0
May	376	13.52	59.8	67.8
June	399	11.29	53.2	62.1
July	391	18.82	55.6	65.4
August	427	6.66	56.8	65.4
September	375	14.59	59.0	67.3
October	415	12.99	54.9	65.2
November	432	6.14	58.0	66.0
December	395	10.43	58.5	67.5
Minimum	**361**	**1.45**	**53.1**	**62.0**
Maximum	**432**	**18.82**	**61.2**	**68.7**

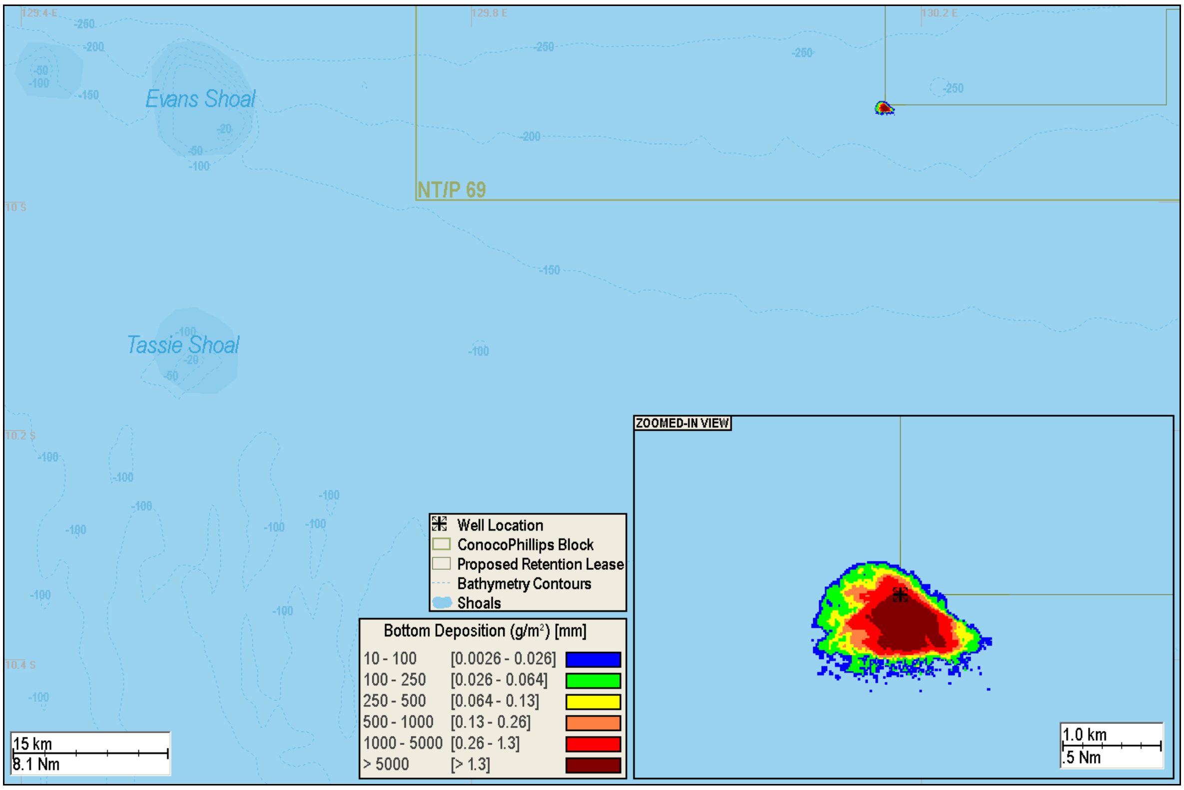

Figure 13: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings and fluids at the seabed, commencing in January. The inset shows a zoomed in view.

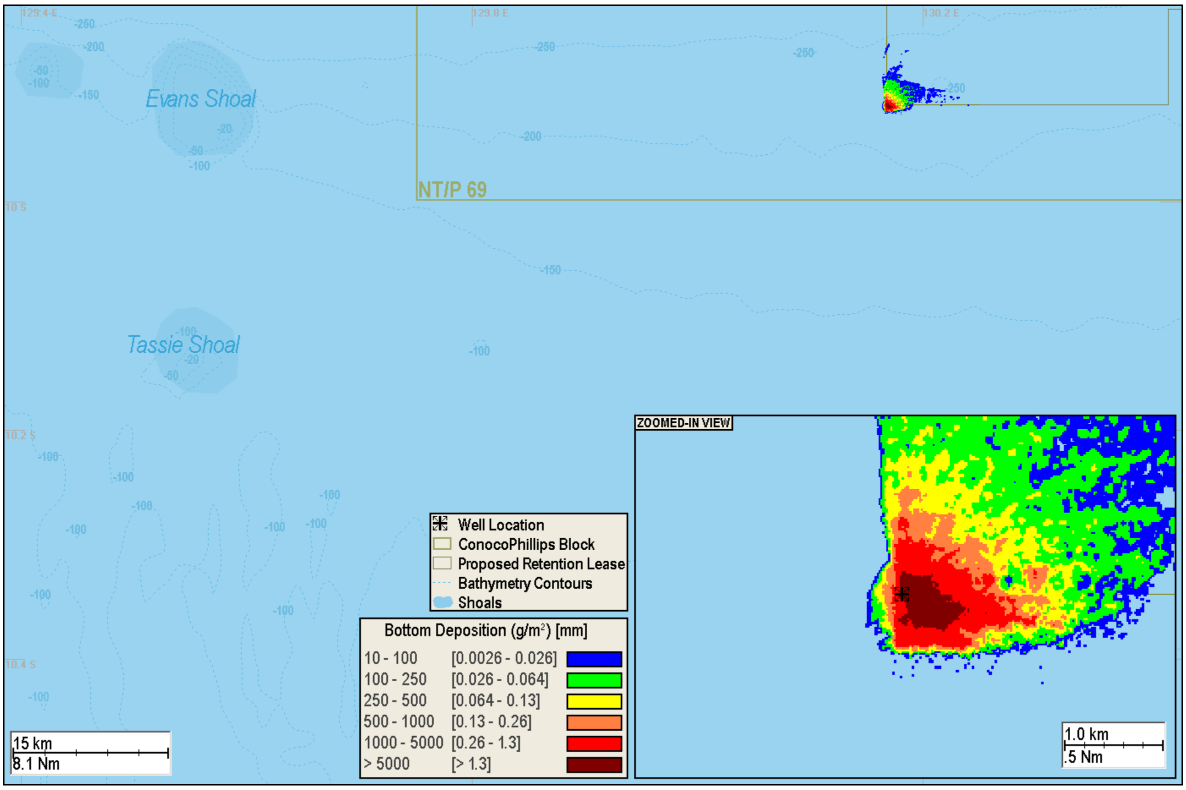

Figure 14: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings and fluids at the seabed, commencing in February. The inset shows a zoomed in view.

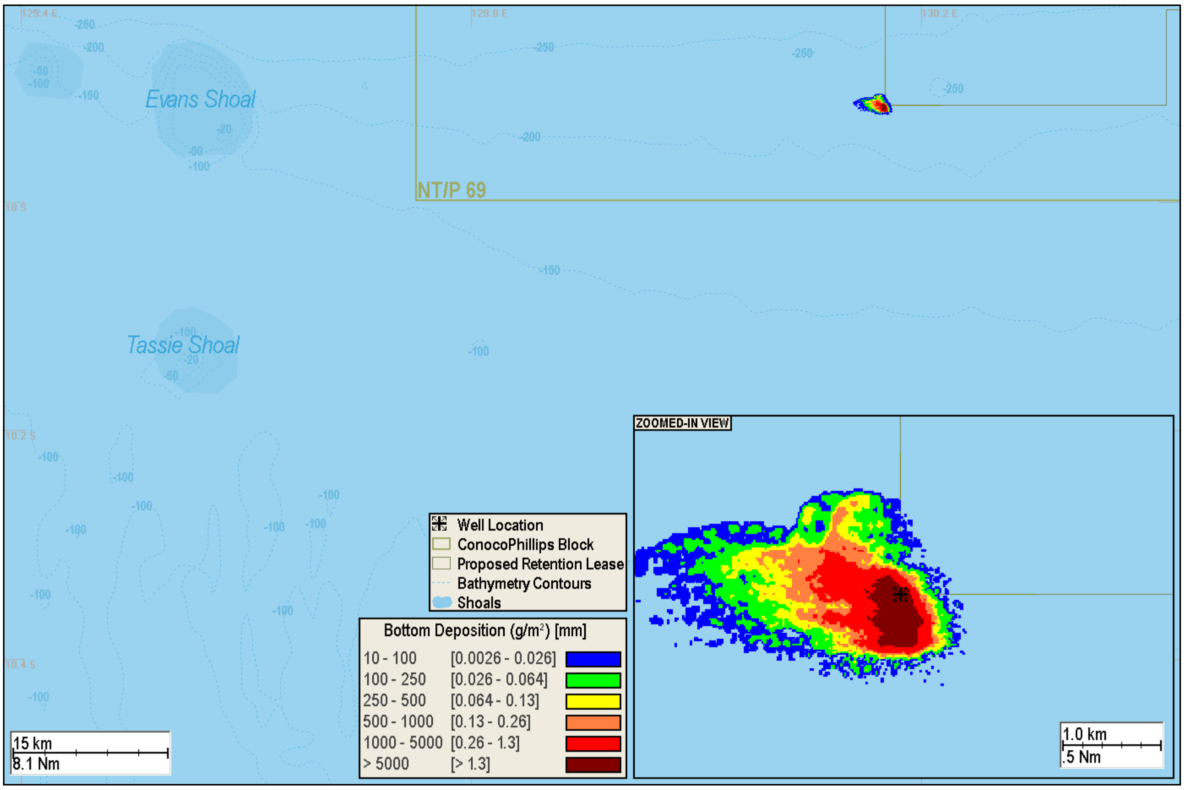

Figure 15: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings and fluids at the seabed, commencing in March. The inset shows a zoomed in view.

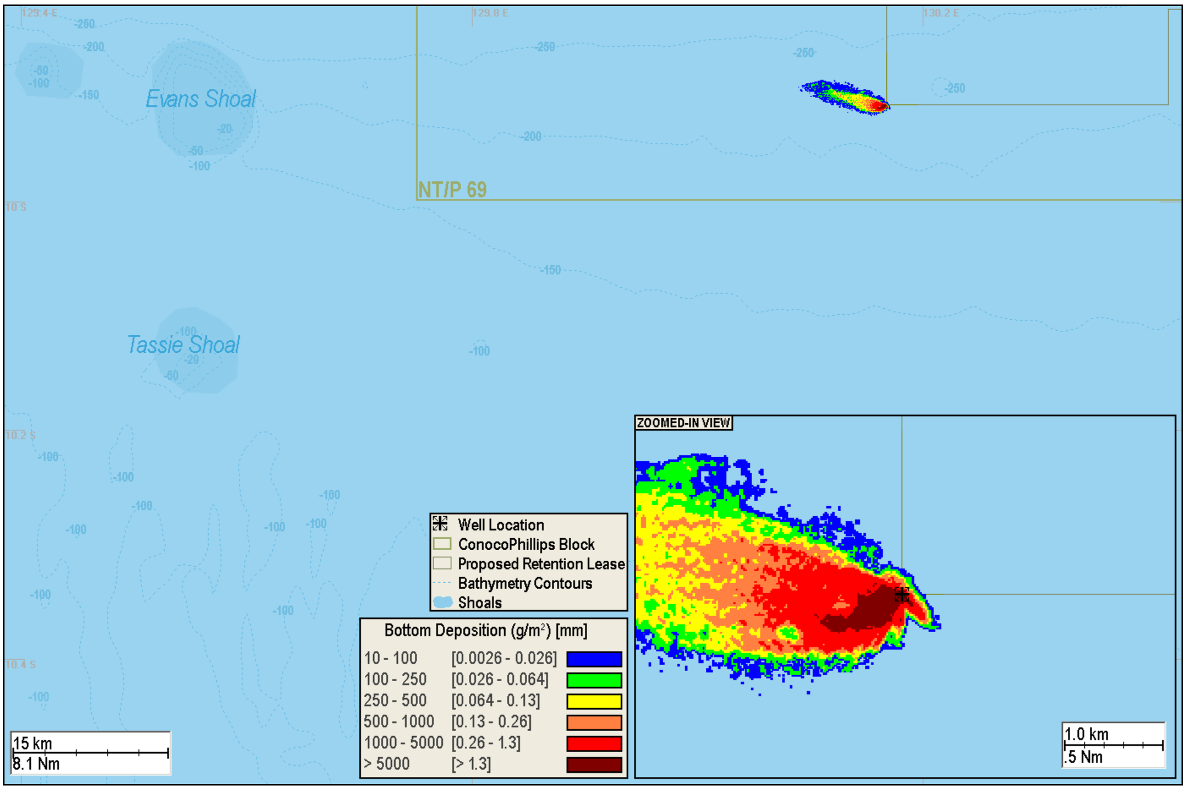

Figure 16: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings and fluids at the seabed, commencing in April. The inset shows a zoomed in view.

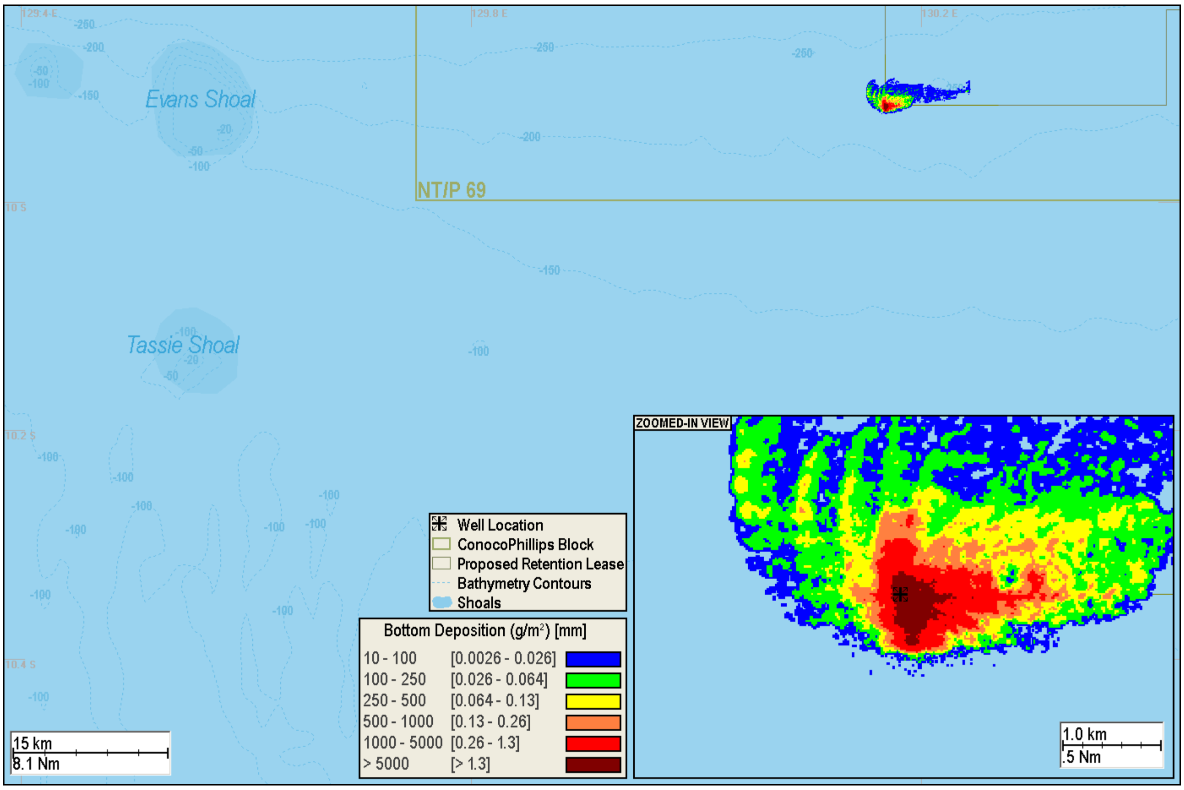

Figure 17: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings and fluids at the seabed, commencing in May. The inset shows a zoomed in view.

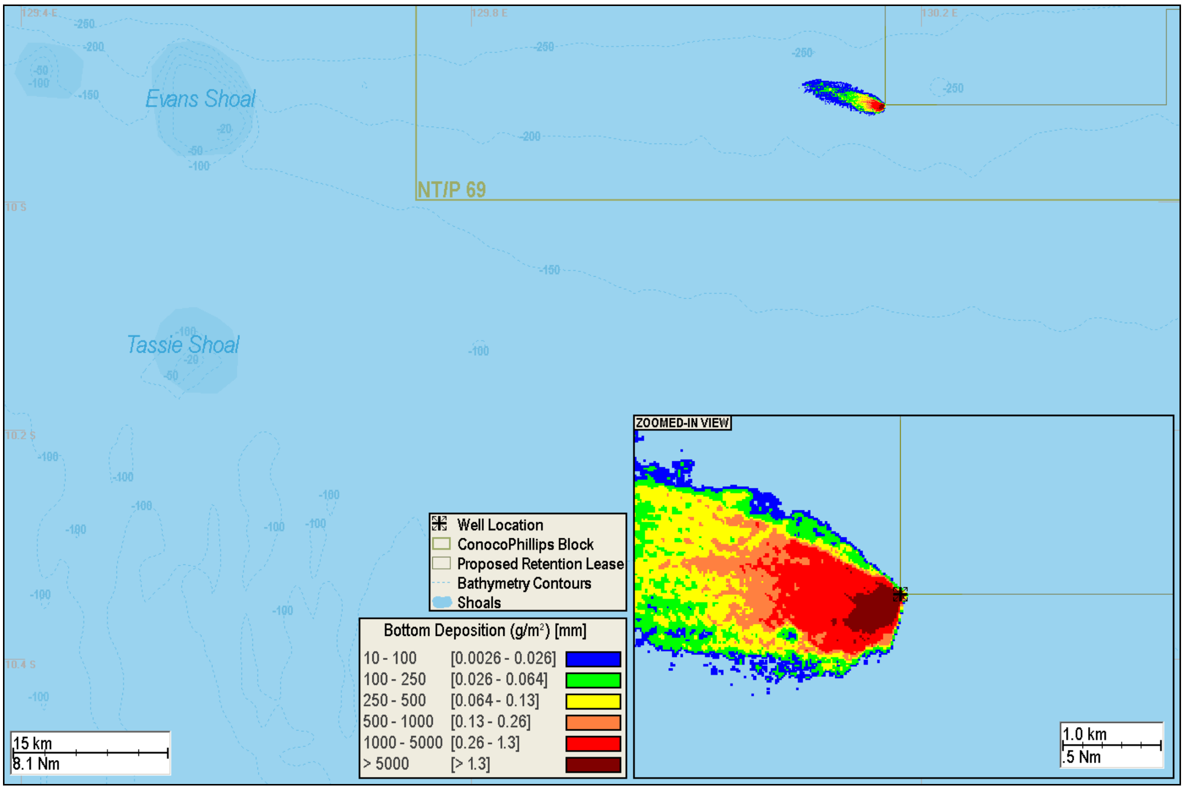

Figure 18: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings and fluids at the seabed, commencing in June. The inset shows a zoomed in view.

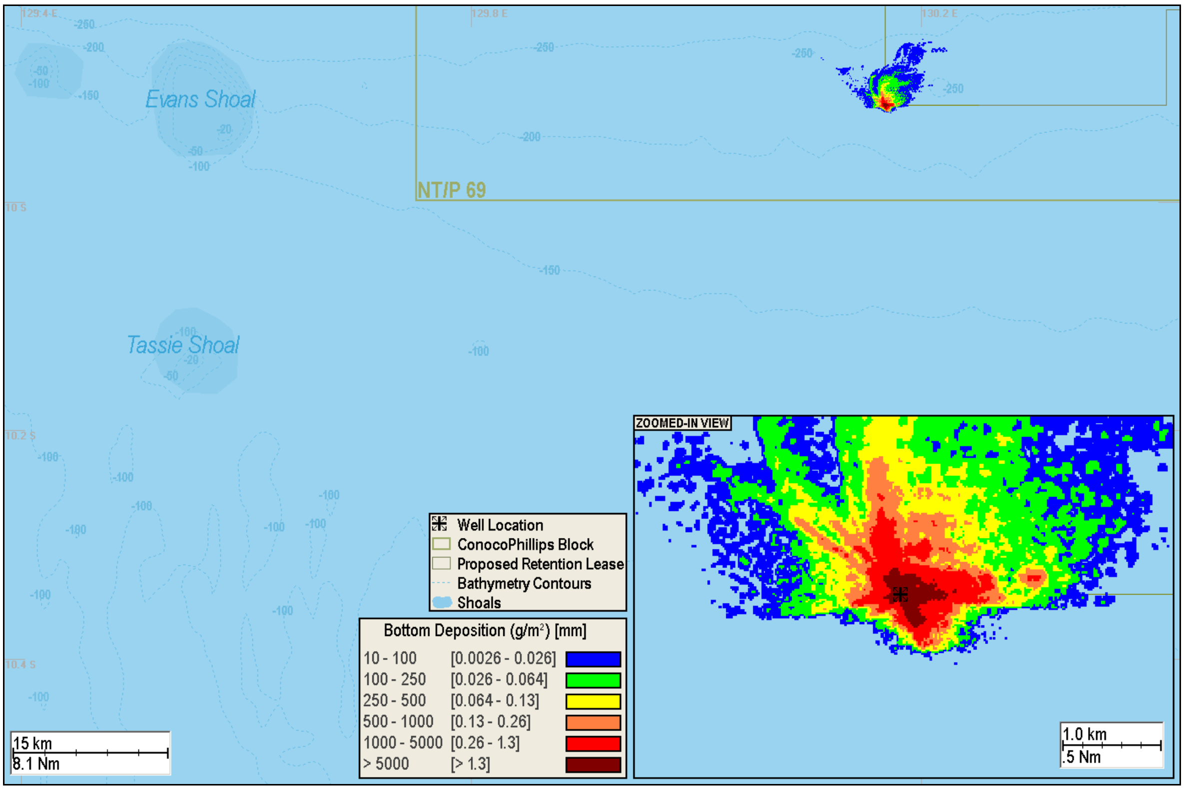

Figure 19: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings and fluids at the seabed, commencing in July. The inset shows a zoomed in view.

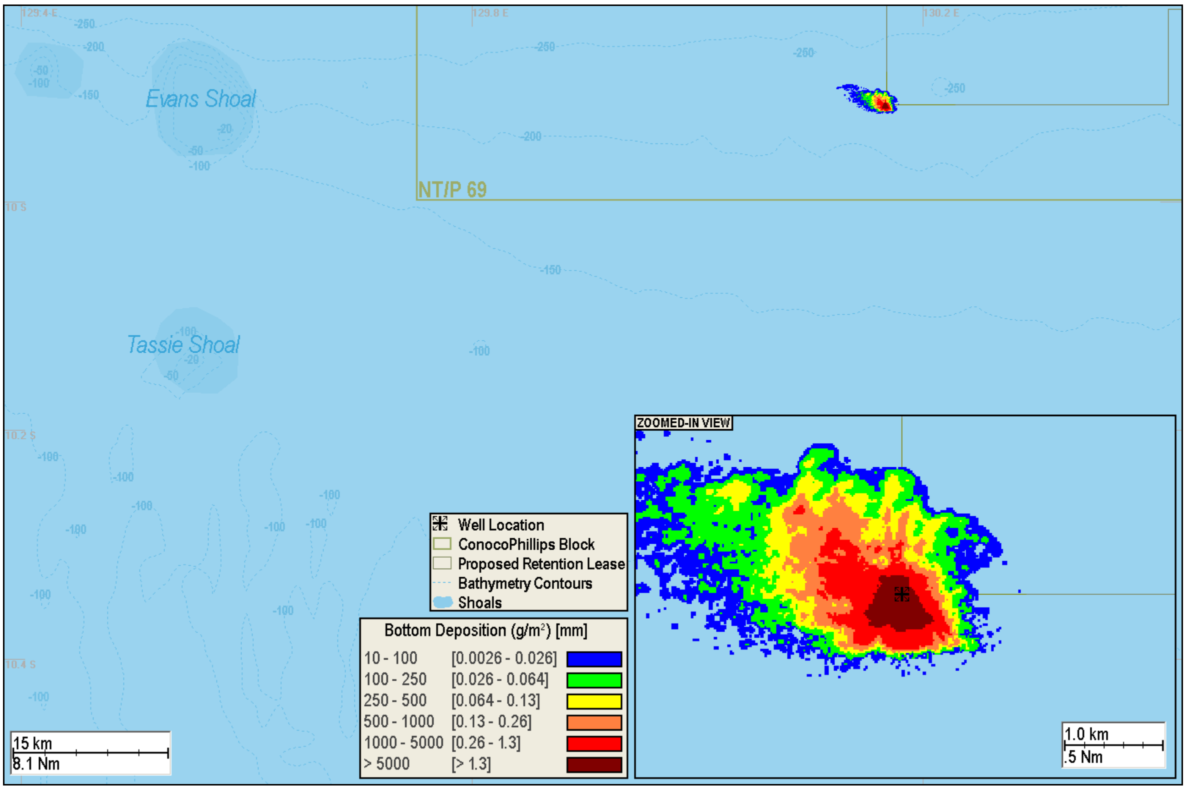

Figure 20: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings and fluids at the seabed, commencing in August. The inset shows a zoomed in view.

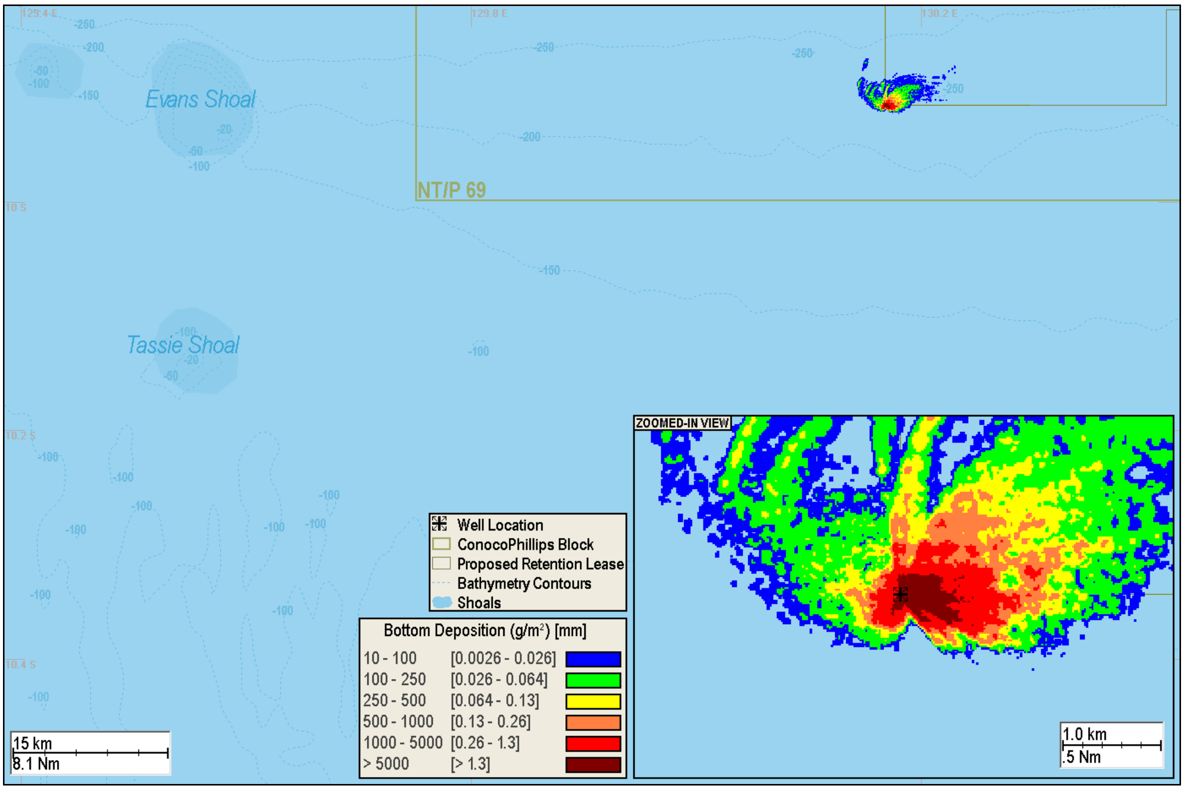

Figure 21: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings and fluids at the seabed, commencing in September. The inset shows a zoomed in view.

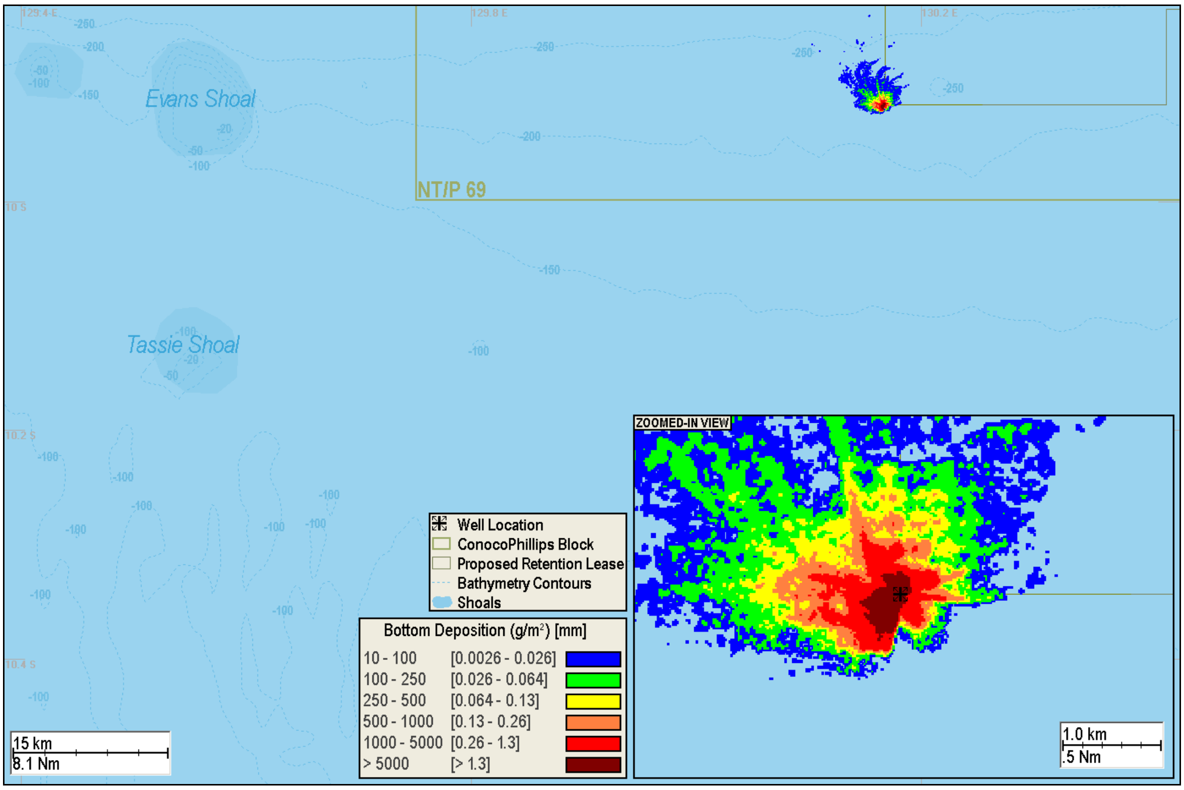

Figure 22: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings and fluids at the seabed, commencing in October. The inset shows a zoomed in view.

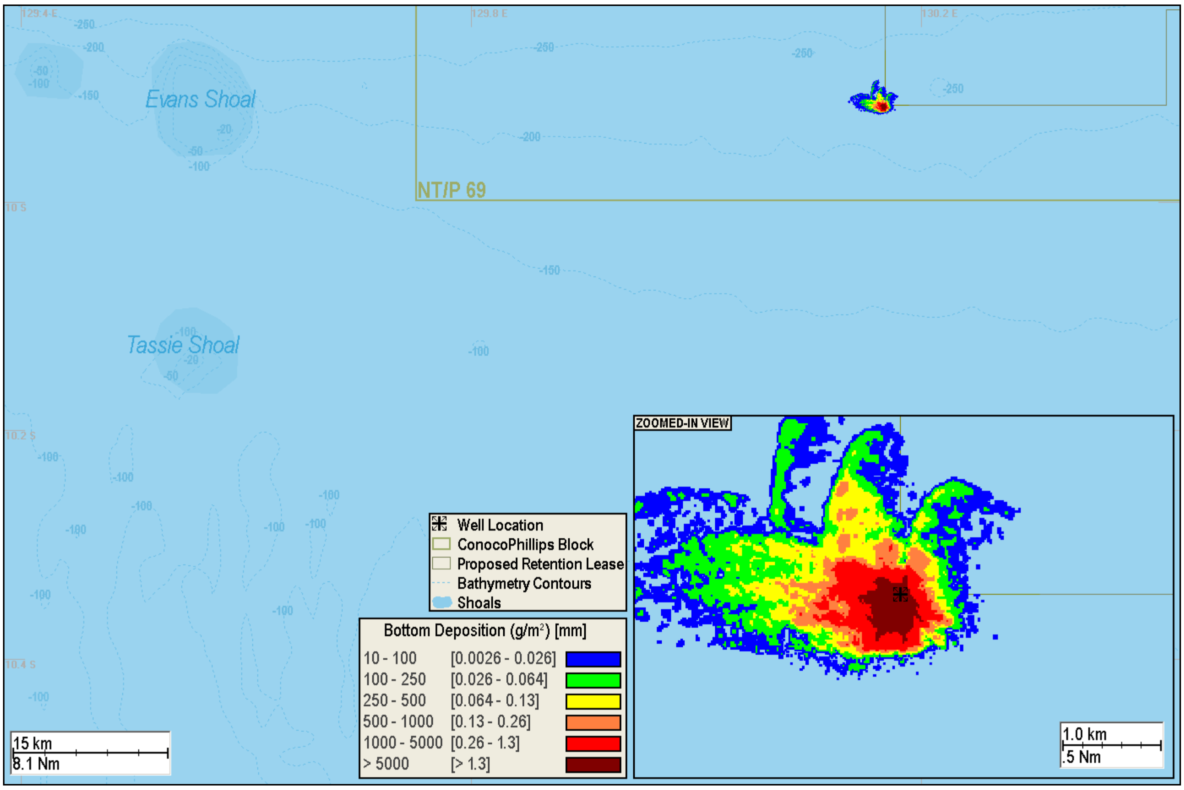

Figure 23: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings and fluids at the seabed, commencing in November. The inset shows a zoomed in view.

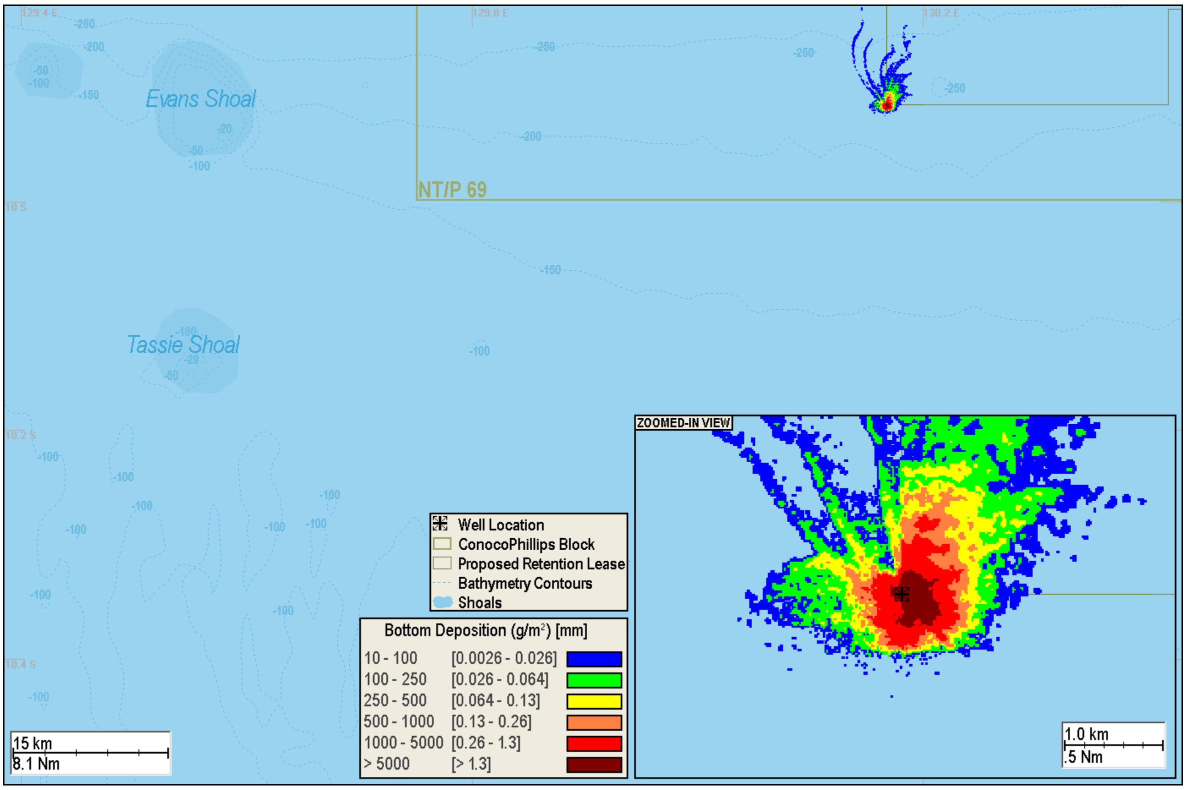

Figure 24: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings and fluids at the seabed, commencing in December. The inset shows a zoomed in view.

5.3 Sea Surface Discharges

No contact was predicted (above a bottom deposition threshold of 10 g/m^2) for Evans Shoal and Tassie Shoal from the sea surface discharges at the release location for any of the 12 modelling commencement months. The predicted minimum distance from Evans Shoal and Tassie Shoal to the 10 g/m^2 contour was 60.2 km and 67.9 km, respectively.

Figure 25 to Figure 36 show the predicted area covered (greater than 10 g/m^2) from discharges at the sea surface, under varying current conditions for the start of each calendar month (January to December).

Table 8 shows the predicted maximum seabed deposition and area of coverage (above 10 g/m^2) for each seabed discharge simulation. The seabed accumulation resulting from the sea surface discharges was much less compared to the seabed discharges and ranged from a maximum of 2 to 7 mm. Within 100 m from the release site, the predicted average and maximum bottom thickness was 0.5 mm and 2.4 mm, respectively. The modelling showed that with the sea surface releases occuring approximately 220 m above the seabed, the sediment was exposed to the force of the current for a longer period of time. Thus, transporting the material further away from the release site and causing it to settle over a larger area as a thinner pile.

Table 8: Summary of the maximum predicted bottom thicknesses and area of coverage for the sea surface discharge simulations, initiated on the first day of each month. Also shown is the minimum distance from sensitive receptors to the 10 g/m² contour.

Commencement month	Maximum bottom deposition (mm)	Total area of coverage above the natural sedimentation threshold of 10 g/m² or 0.0034 mm (km²)	Minimum distance from the sensitive receptor to the 10 g/m² contour (km)	
			Evans Shoal	Tassie Shoal
January	6	1.11	61.0	68.6
February	2	0.78	60.2	67.9
March	3	1.23	60.5	68.3
April	6	1.05	60.7	68.4
May	4	1.27	60.5	68.2
June	2	0.63	60.9	68.6
July	3	1.21	60.5	68.3
August	5	1.10	61.0	68.7
September	6	0.99	60.5	68.3
October	4	1.20	60.5	68.3
November	7	1.04	60.8	68.5
December	5	1.18	60.7	68.4
Minimum	**2**	**0.63**	**60.2**	**67.9**
Maximum	**7**	**1.27**	**61.0**	**68.7**

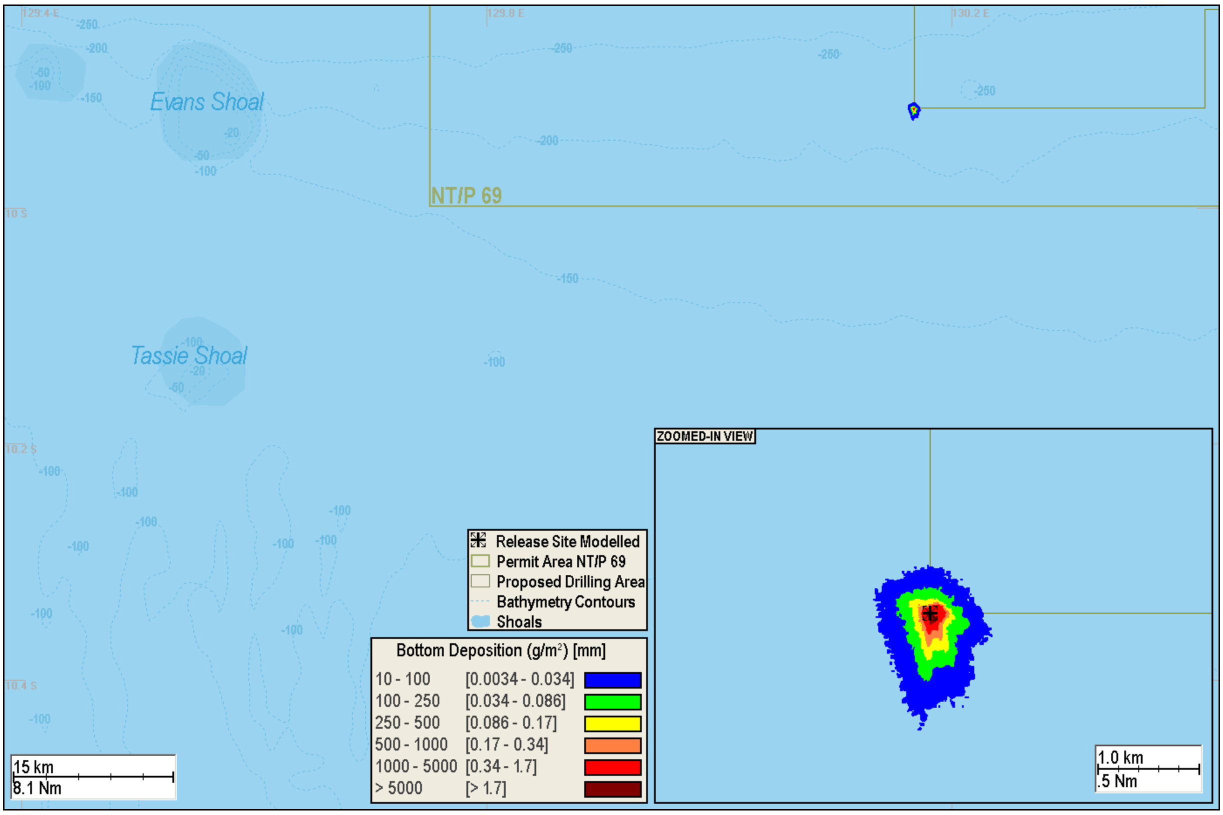

Figure 25: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings at the sea surface, commencing in January. The inset shows a zoomed in view.

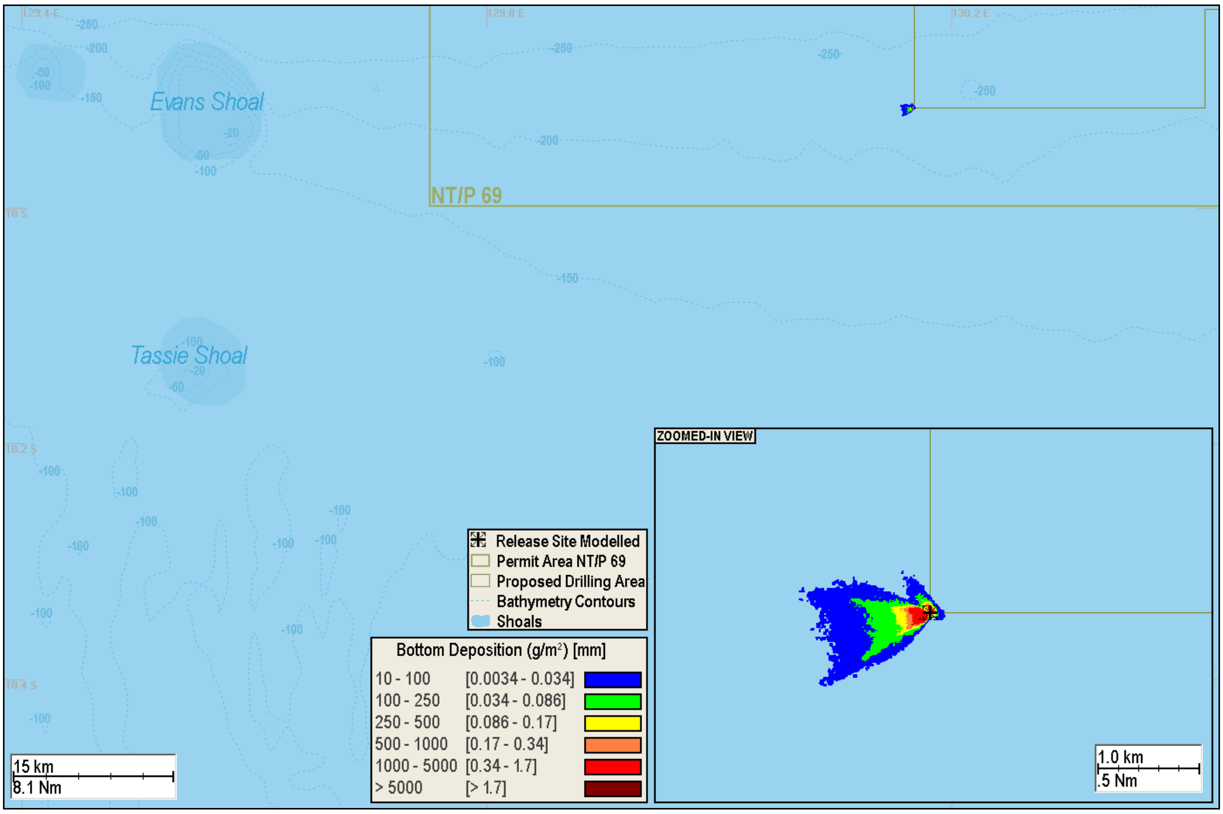

Figure 26: Predicted bottom deposition and seafloor coverage due to a 28.4 day discharge of drill cuttings at the sea surface, commencing in February. The inset shows a zoomed in view.

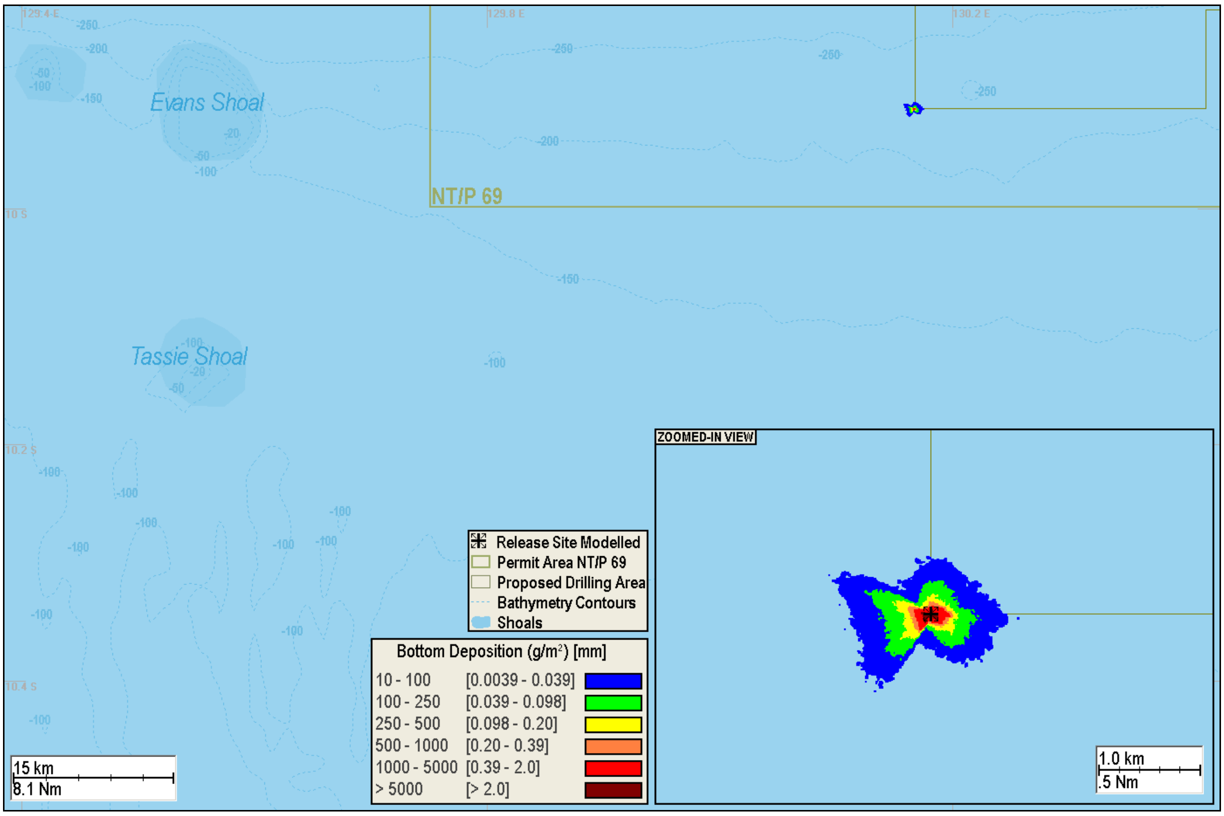

Figure 27: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings at the sea surface, commencing in March. The inset shows a zoomed in view.

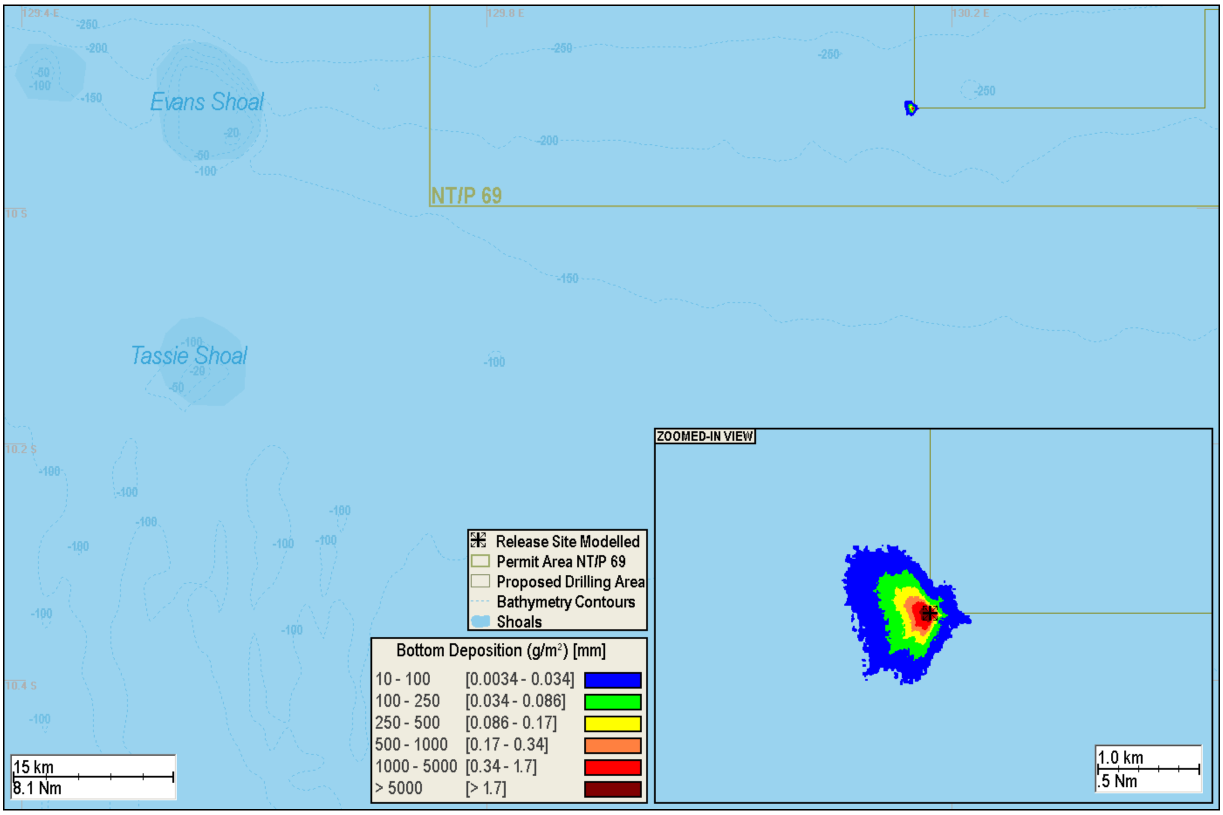

Figure 28: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings at the sea surface, commencing in April. The inset shows a zoomed in view.

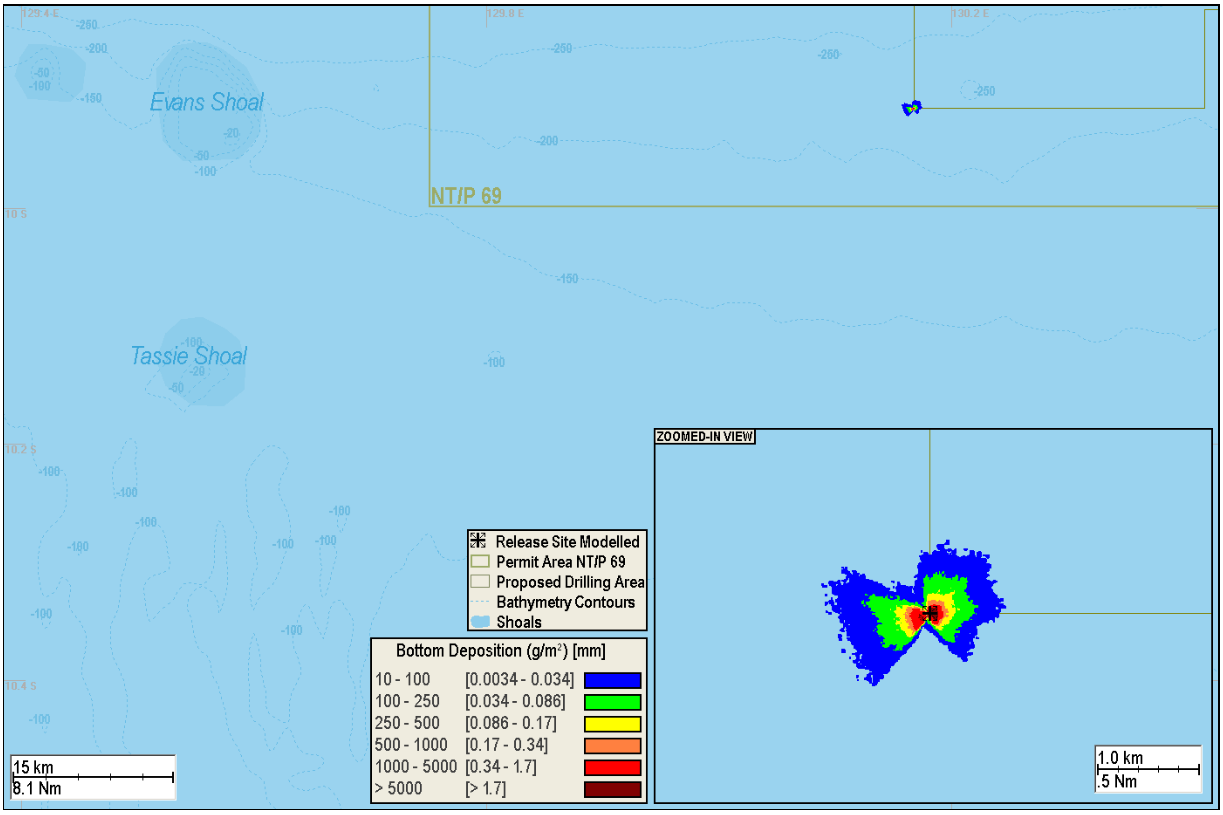

Figure 29: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings at the sea surface, commencing in May. The inset shows a zoomed in view.

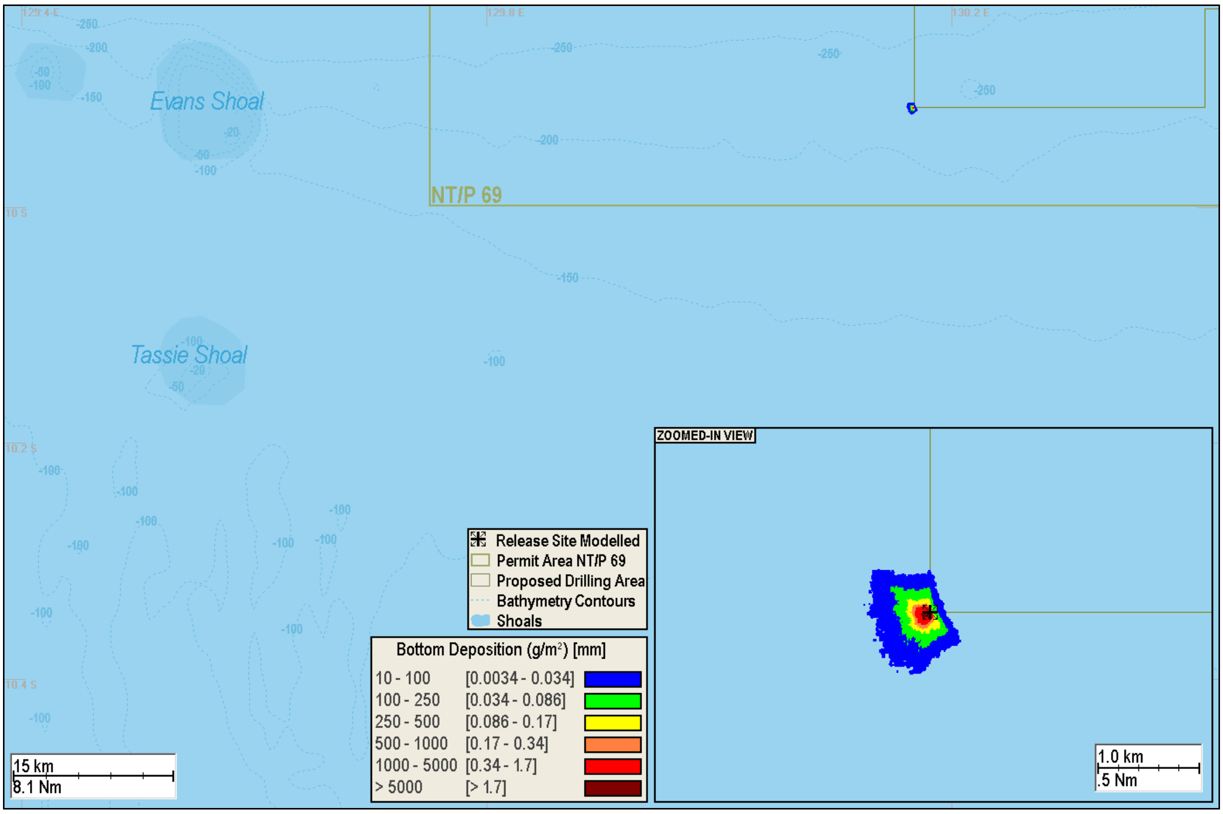

Figure 30: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings at the sea surface, commencing in June. The inset shows a zoomed in view.

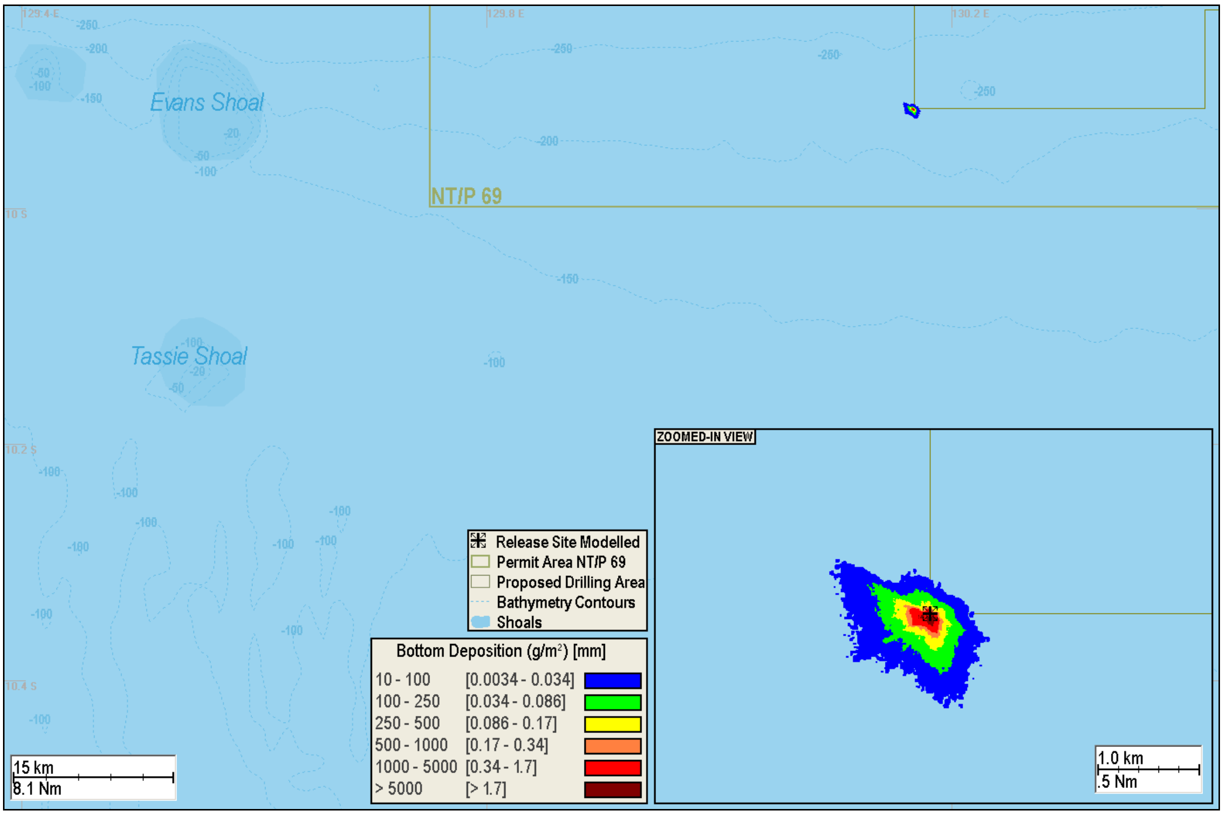

Figure 31: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings at the sea surface, commencing in July. The inset shows a zoomed in view.

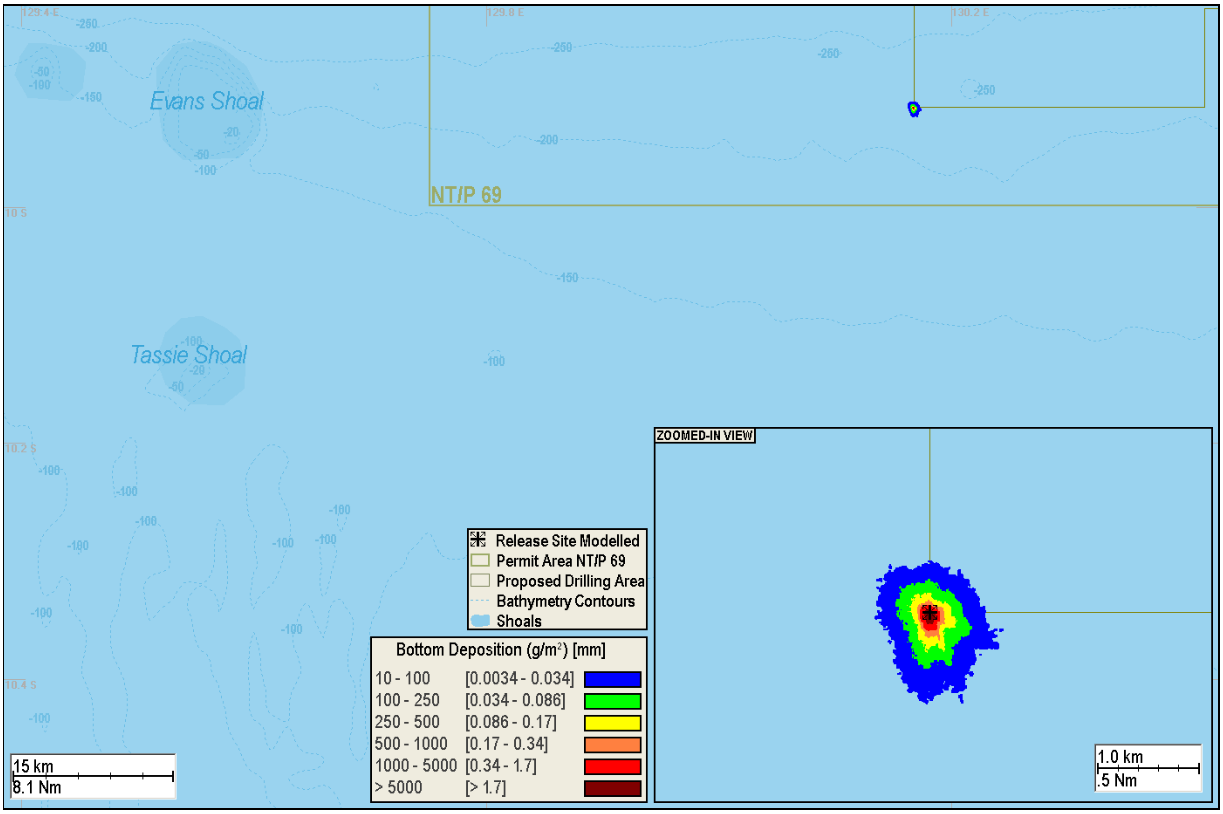

Figure 32: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings at the sea surface, commencing in August. The inset shows a zoomed in view.

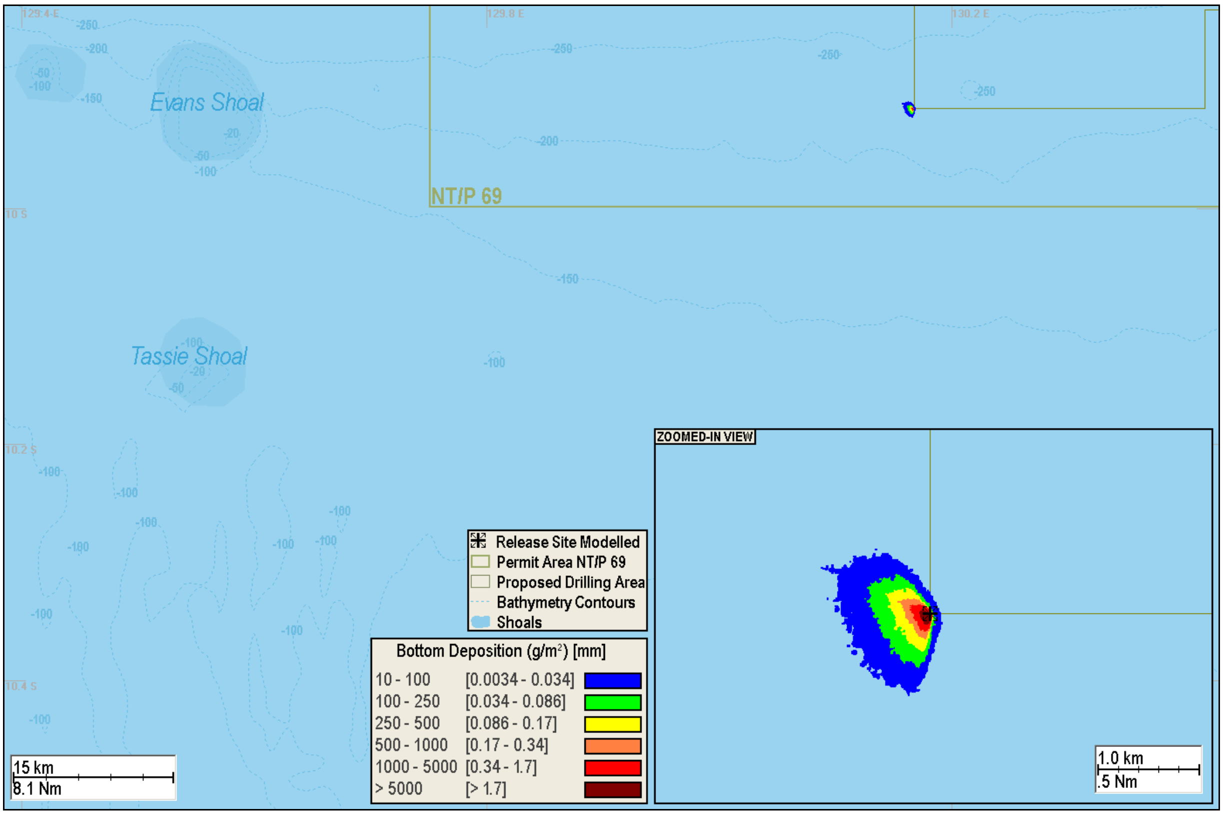

Figure 33: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings at the sea surface, commencing in September. The inset shows a zoomed in view.

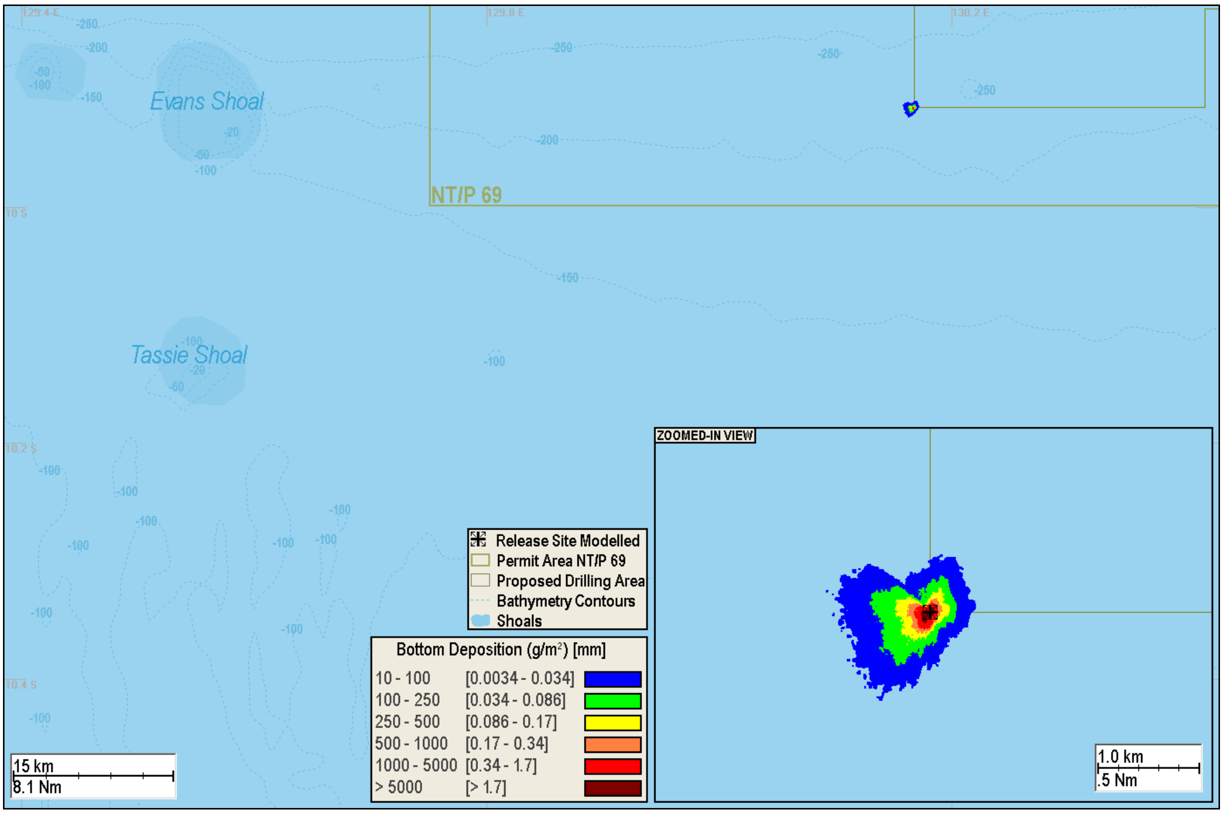

Figure 34: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings at the sea surface, commencing in October. The inset shows a zoomed in view.

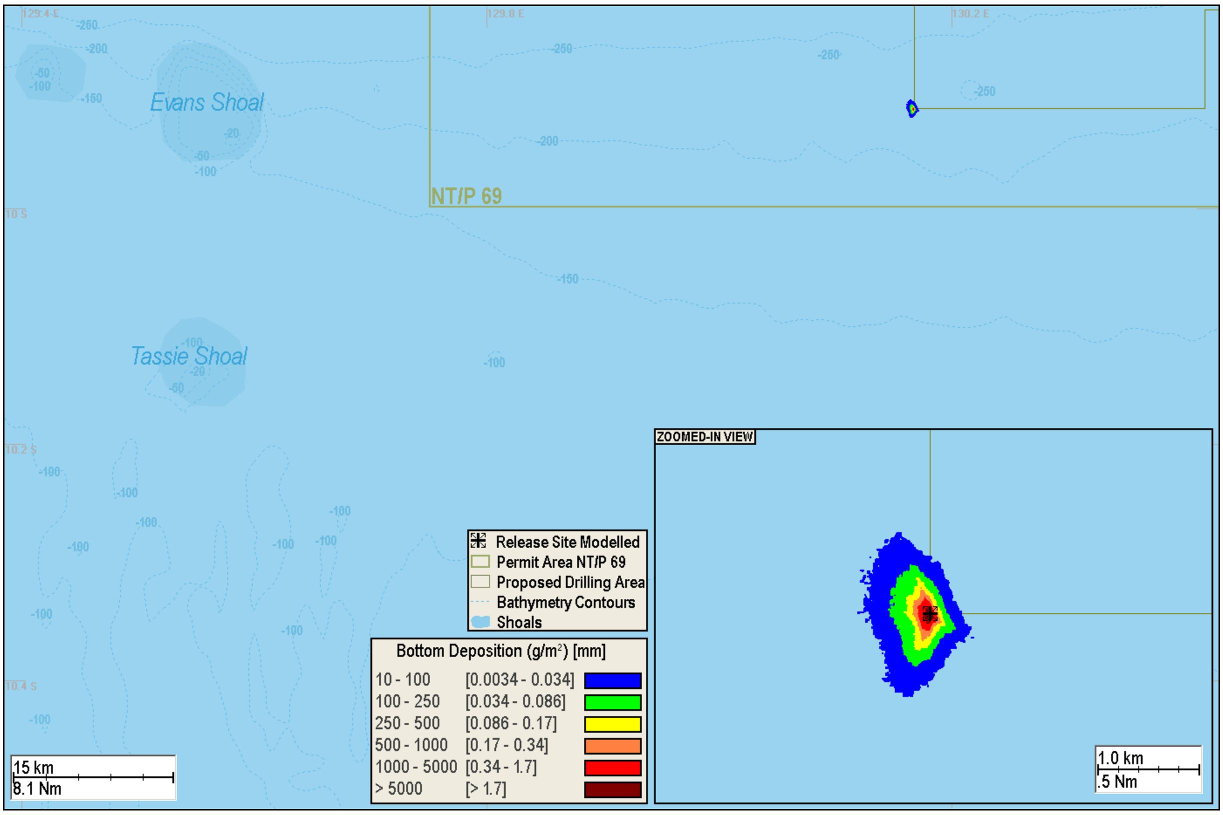

Figure 35: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings at the sea surface, commencing in November. The inset shows a zoomed in view.

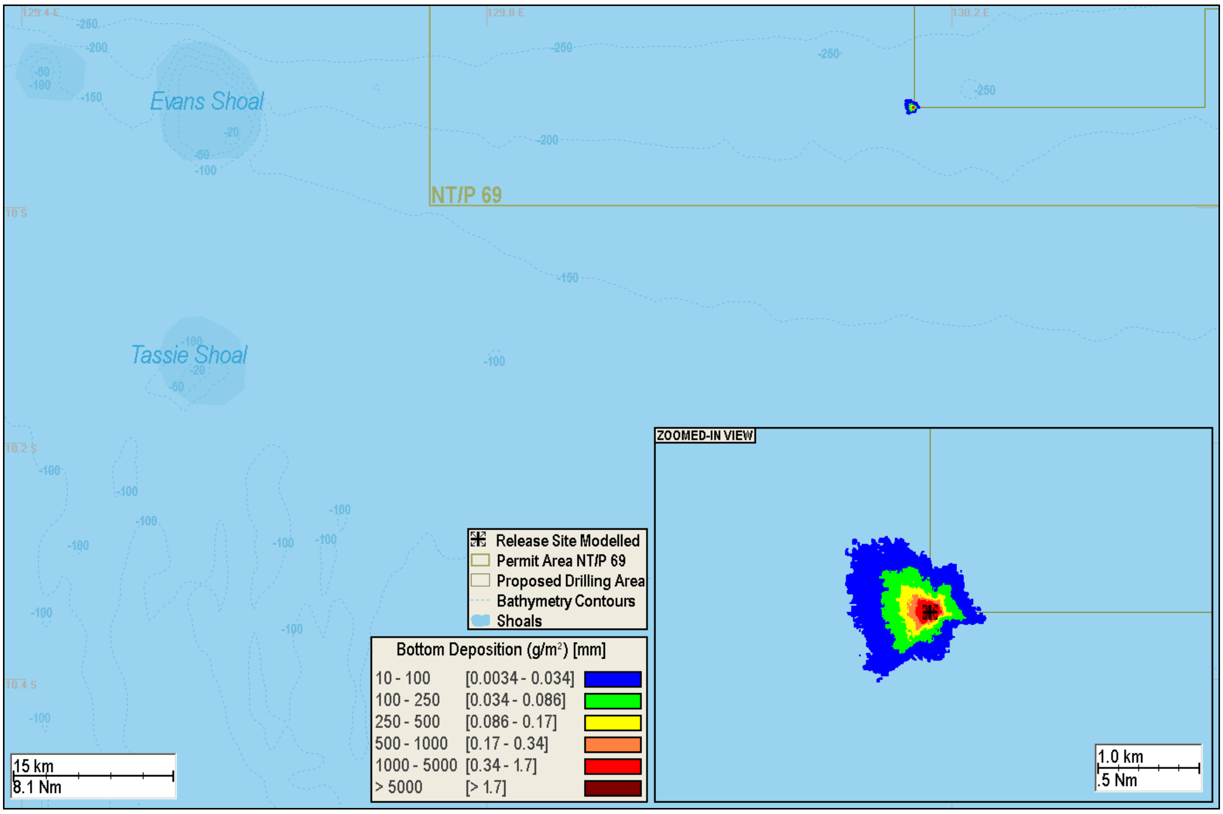

Figure 36: Predicted bottom deposition and seafloor coverage from the discharge of drill cuttings at the sea surface, commencing in December. The inset shows a zoomed in view.

5.4 Total Accumulated Thickness (Combined Discharges)

No contact was predicted (above a bottom deposition threshold of 10 g/m^2) for Evans Shoal and Tassie Shoal based on the combined seabed and surface discharge simulations at the release location for any of the 12 modelling commencement months. The predicted minimum distance from Evans Shoal and Tassie Shoal to the 10 g/m^2 contour was 53.1 km and 62.0 km, respectively.

Figure 37 to Figure 48 show the predicted bottom deposition (above 10 g/m^2) from the combined seabed and surface discharge simulations initiated at the start of each month (January to December).

Table 9 shows the predicted maximum seabed deposition and area of coverage (above 10 g/m^2) for the combined releases at the commencement of each month.

Figure 49 shows a cross section of the predicted thickness along the north-south and east-west axes by commencing discharges in November (based on the maximum predicted bottom thickness). The figure highlights the mounding adjacent to the discharge site and the exponential decline of the bottom thickness further away. Note the vertical axis is greatly exaggerated.

Table 9: Summary of the maximum predicted bottom thicknesses and area of coverage for the combined seabed and surface discharge simulations initiated on the first day of each month. Also shown is the minimum distance from sensitive receptors to the 10 g/m² contour.

Commencement month	**Maximum bottom deposition (mm)**	**Total area of coverage above the natural sedimentation threshold of 10 g/m² or 0.0026 mm (km²)**	**Minimum distance from the sensitive receptor to the 10 g/m² contour (km)**	
			Evans Shoal	**Tassie Shoal**
January	400	1.66	60.6	68.1
February	362	11.43	60.4	68.0
March	429	4.28	58.5	66.4
April	391	12.41	53.1	62.0
May	377	13.85	59.8	67.8
June	401	11.83	53.2	62.1
July	392	19.12	55.6	65.4
August	431	6.88	56.8	65.4
September	375	14.87	59.0	67.2
October	416	13.29	54.9	65.2
November	437	6.44	58.0	66.0
December	397	10.84	58.5	67.5
Minimum	**362**	**1.66**	**53.1**	**62.0**
Maximum	**437**	**19.12**	**60.6**	**68.1**

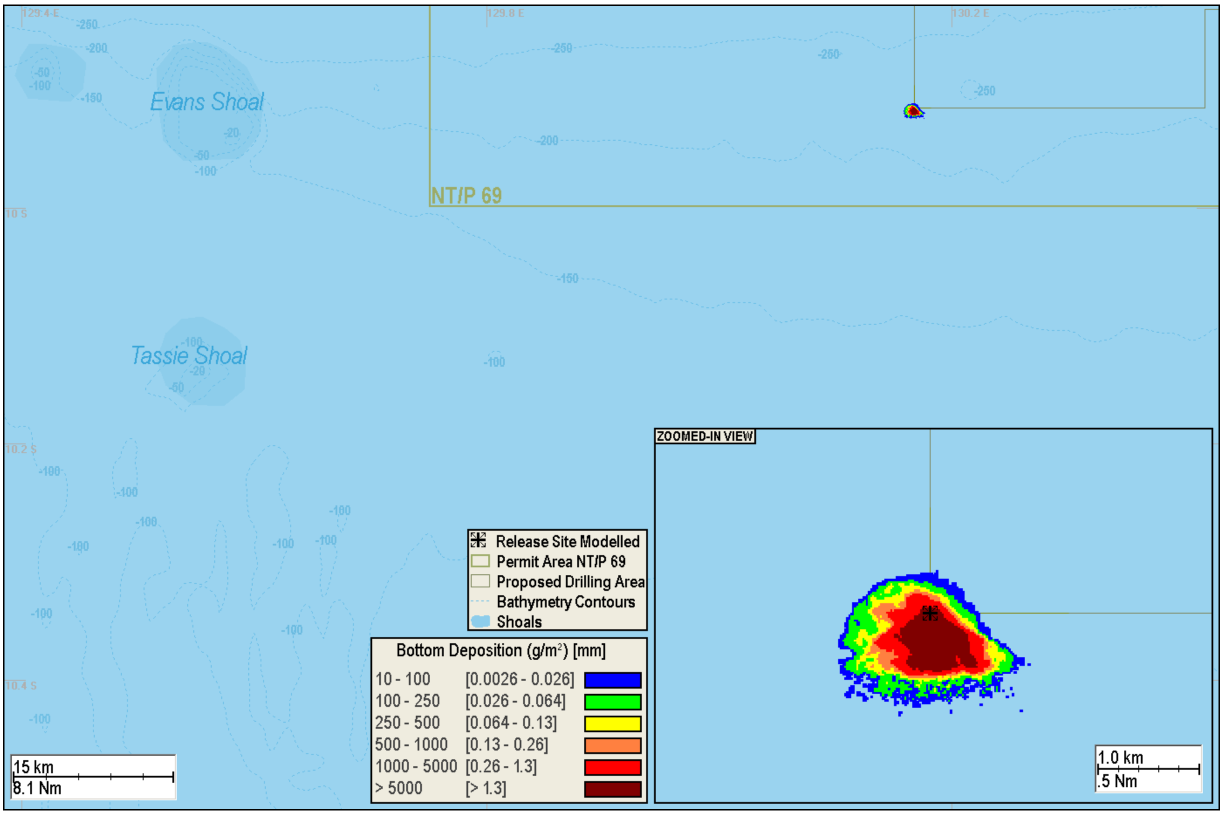

Figure 37: Predicted bottom deposition and seafloor coverage from the combined near-seabed and sea surface discharge simulations, commencing in January. The inset shows a zoomed in view.

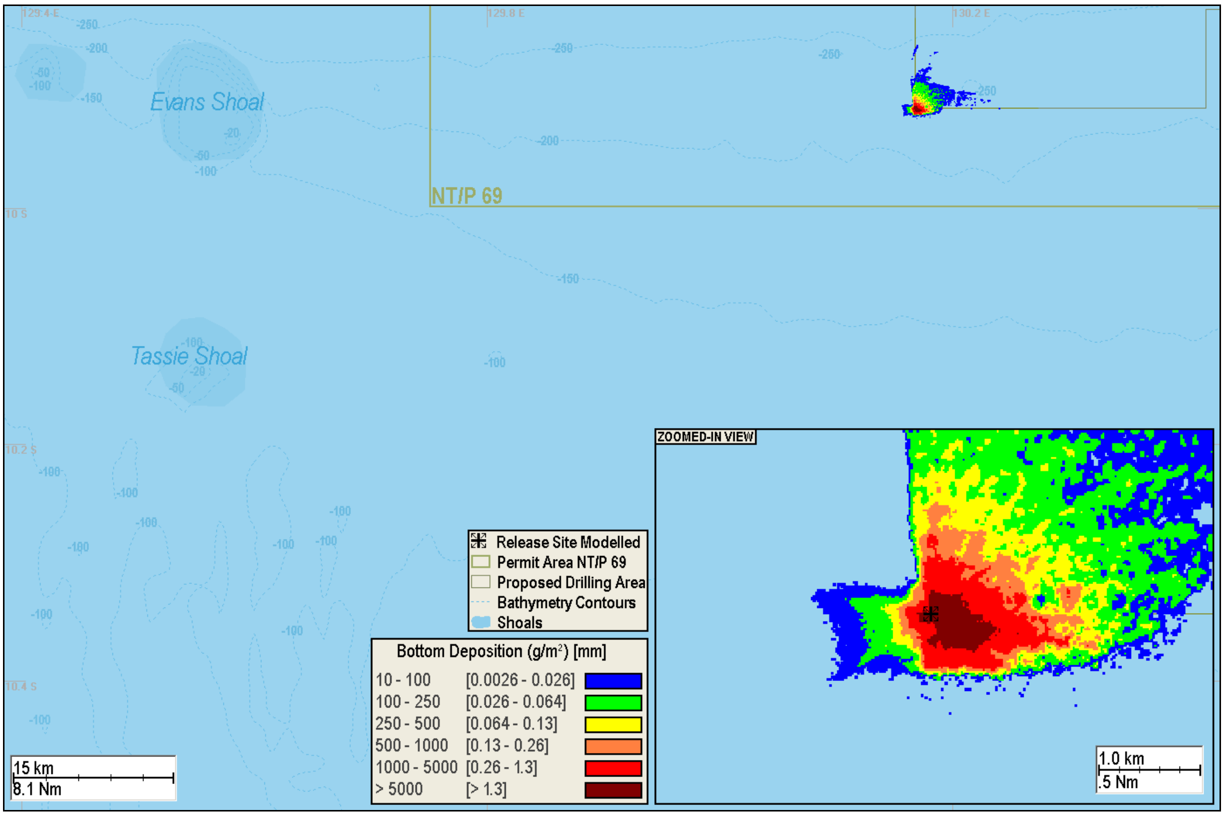

Figure 38: Predicted bottom deposition and seafloor coverage from the combined seabed and sea surface discharge simulations, commencing in February. The inset shows a zoomed in view.

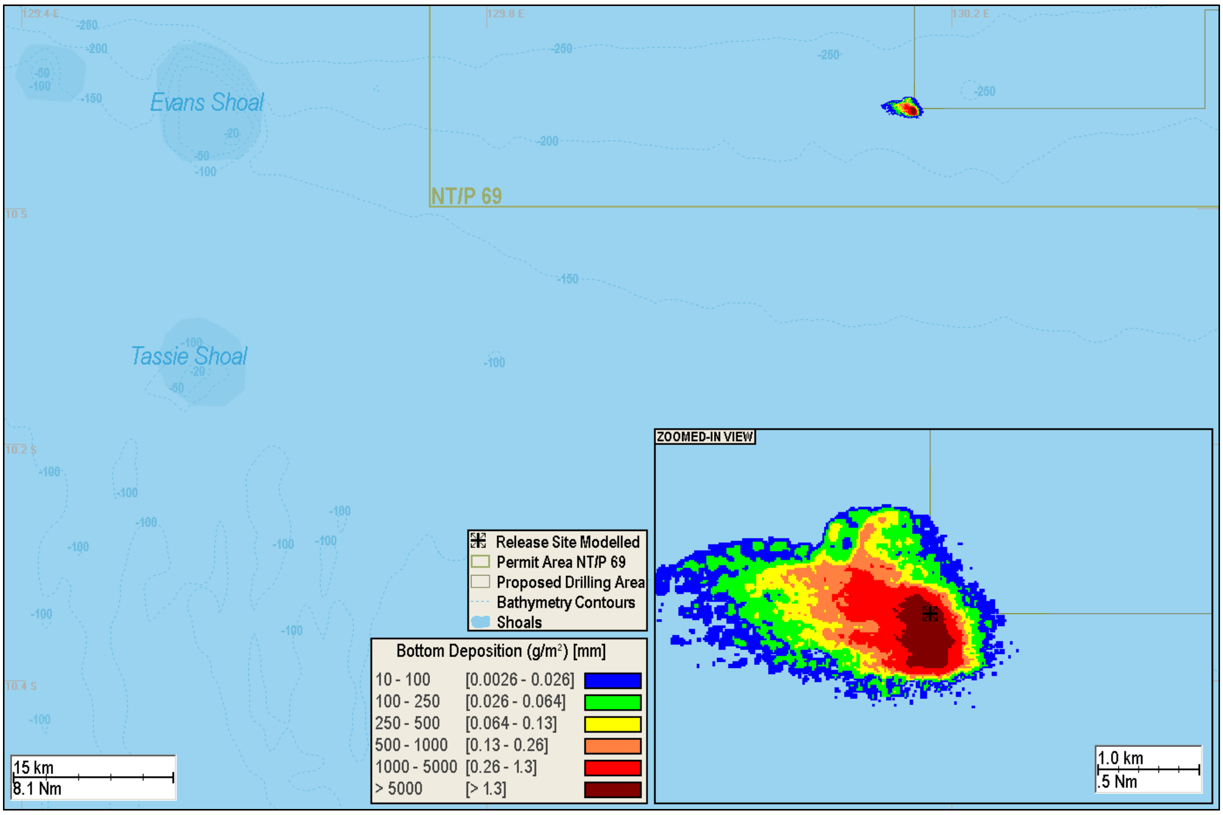

Figure 39: Predicted bottom deposition and seafloor coverage from the combined seabed and sea surface discharge simulations, commencing in March. The inset shows a zoomed in view.

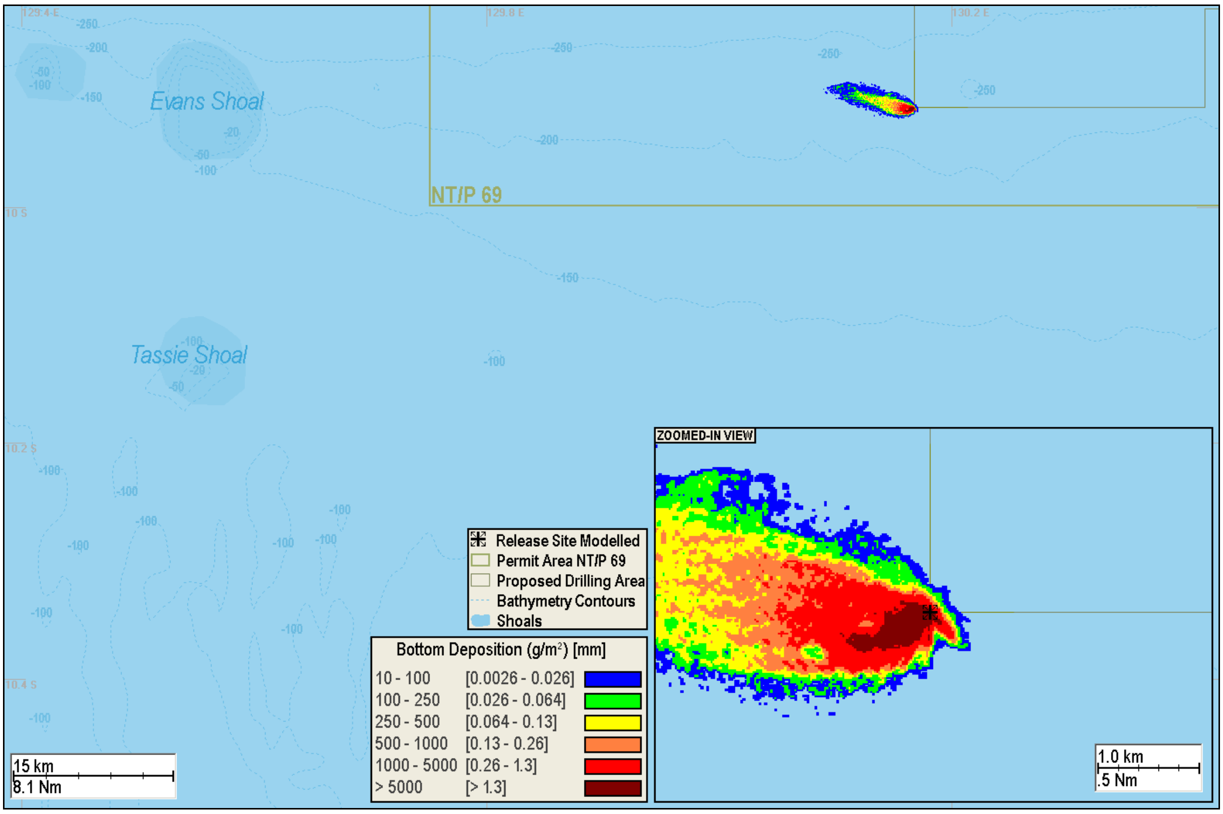

Figure 40: Predicted bottom deposition and seafloor coverage from the combined seabed and sea surface discharge simulations, commencing in April. The inset shows a zoomed in view.

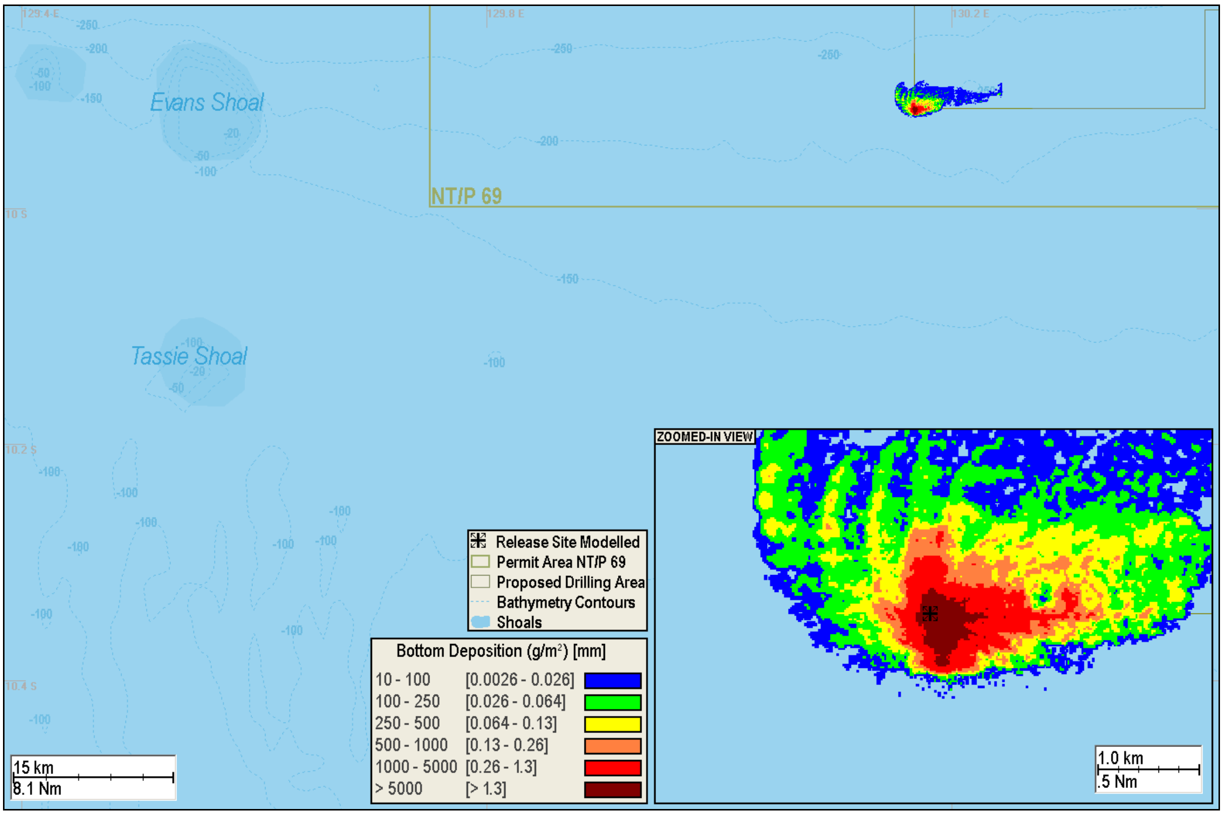

Figure 41: Predicted bottom deposition and seafloor coverage from the combined seabed and sea surface discharge simulations, commencing in May. The inset shows a zoomed in view.

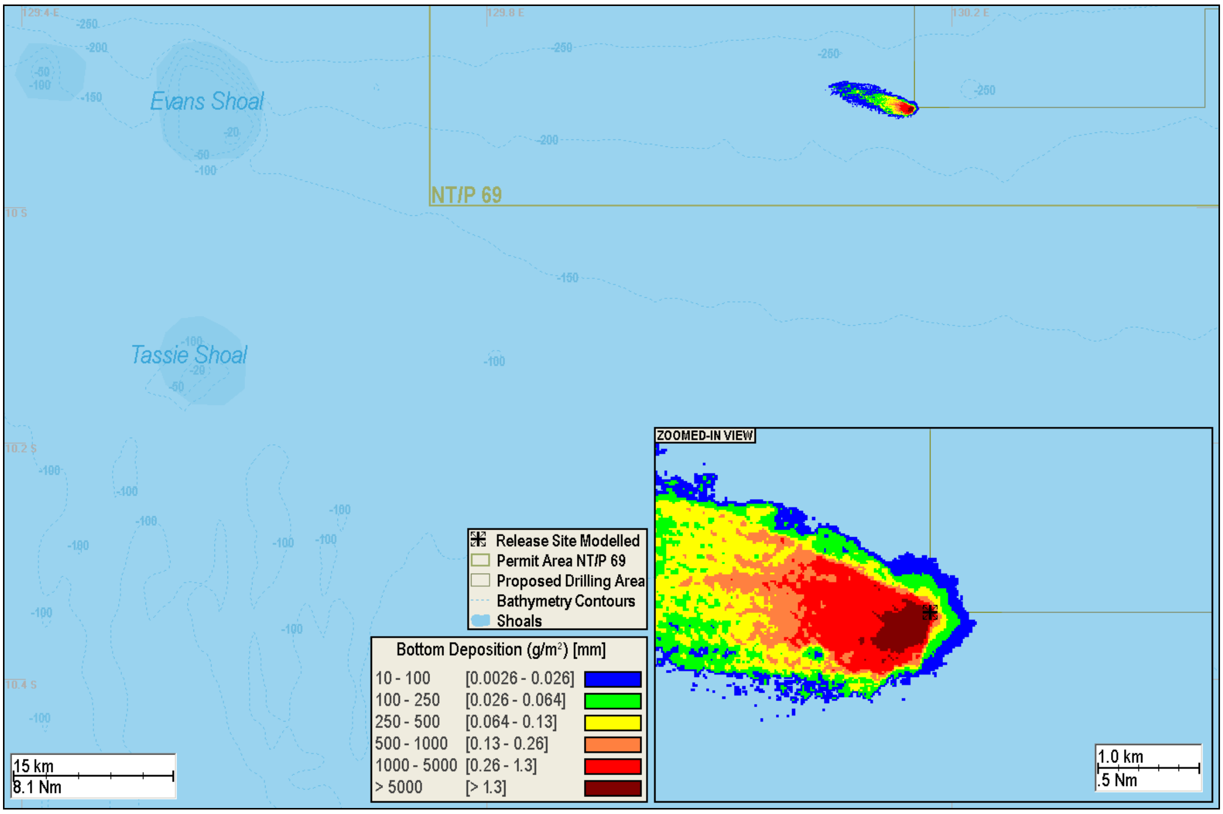

Figure 42: Predicted bottom deposition and seafloor coverage from the combined seabed and sea surface discharge simulations, commencing in June. The inset shows a zoomed in view.

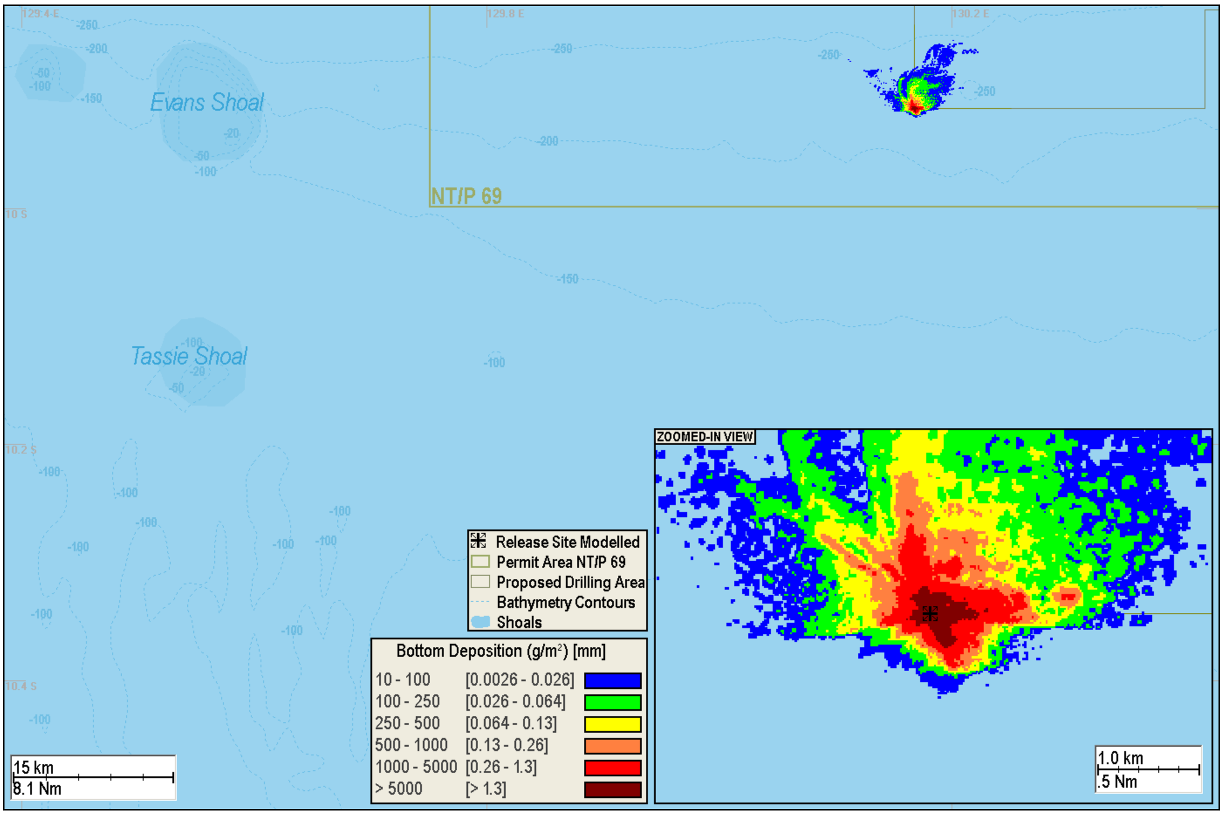

Figure 43: Predicted bottom deposition and seafloor coverage from the combined seabed and sea surface discharge simulations, commencing in July. The inset shows a zoomed in view.

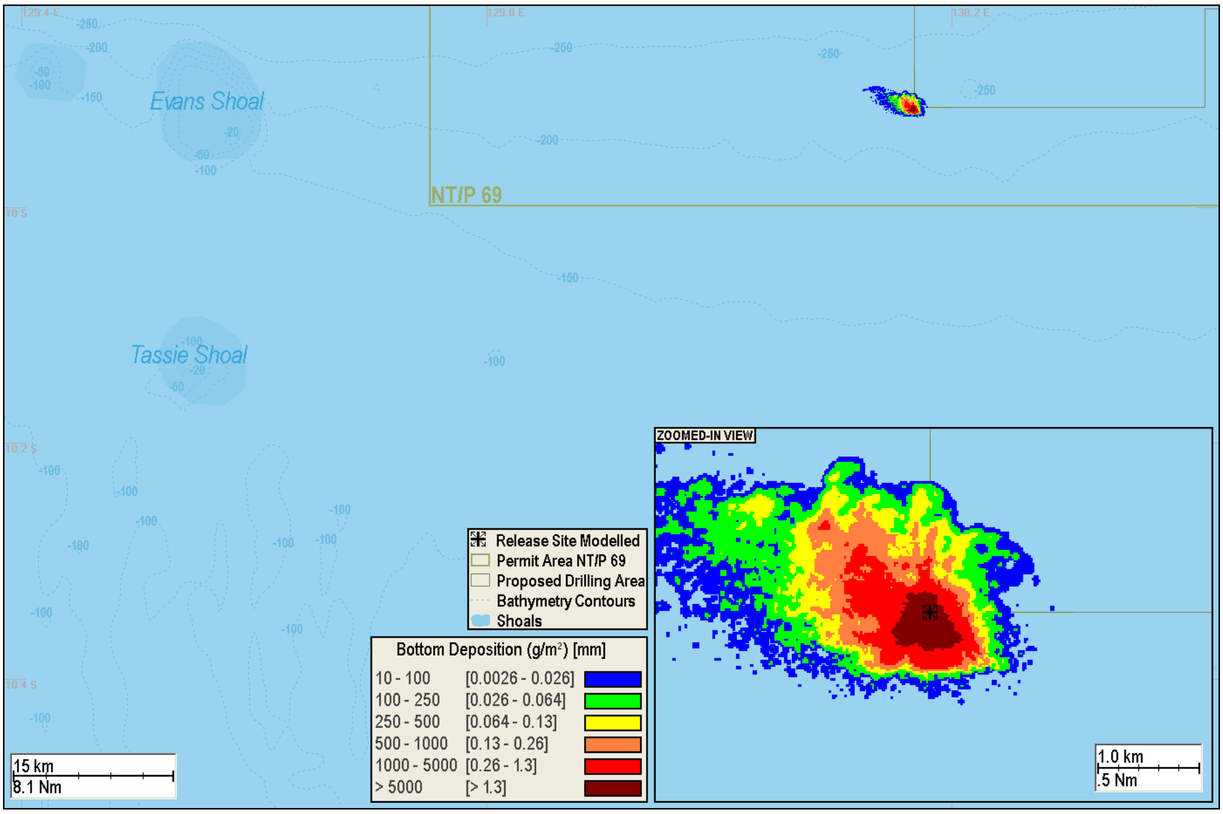

Figure 44: Predicted bottom deposition and seafloor coverage from the combined seabed and sea surface discharge simulations, commencing in August. The inset shows a zoomed in view.

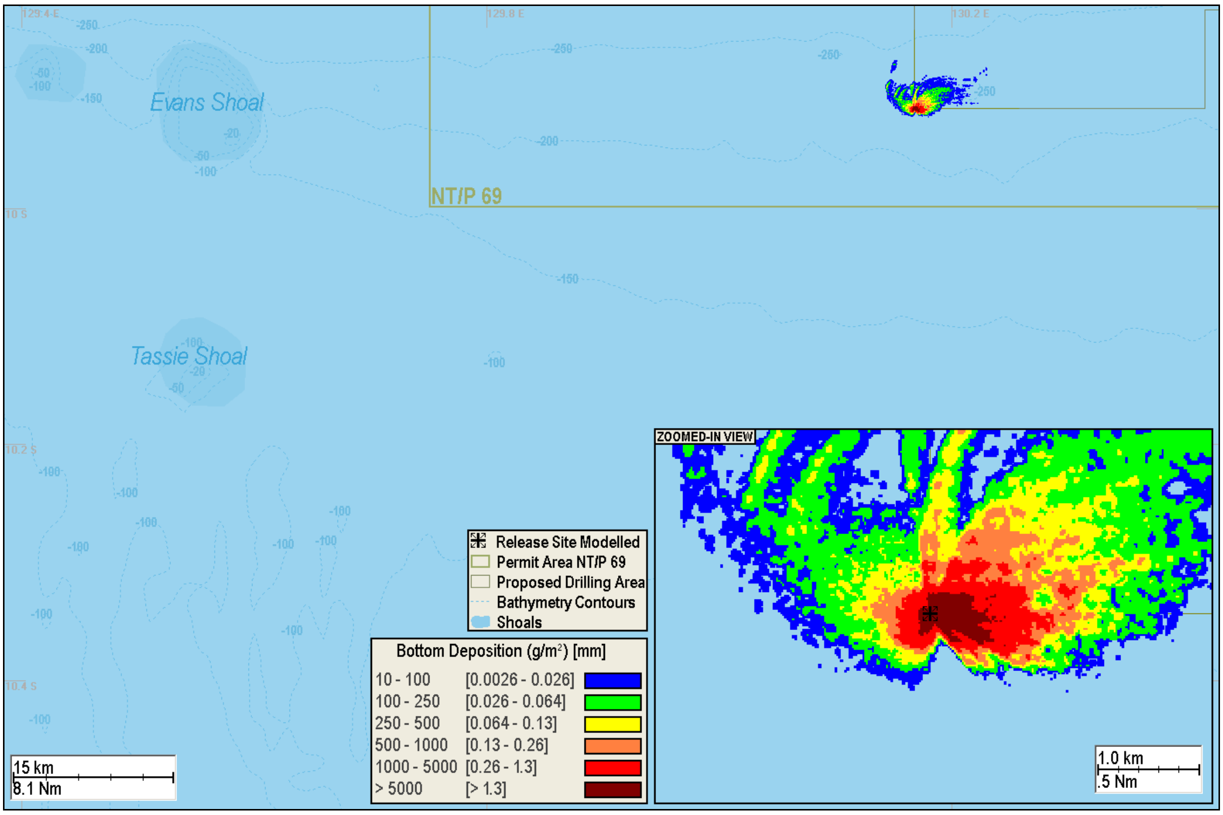

Figure 45: Predicted bottom deposition and seafloor coverage from the combined seabed and sea surface discharge simulations, commencing in September. The inset shows a zoomed in view.

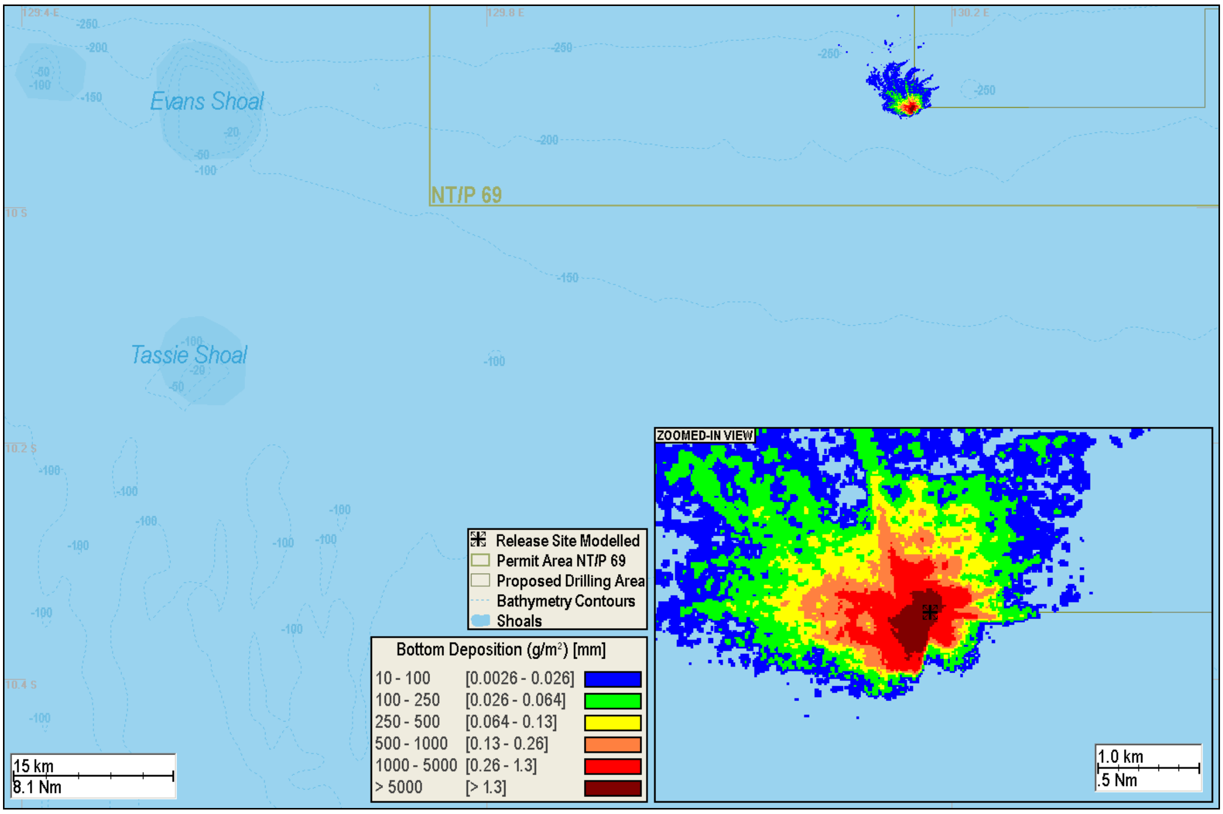

Figure 46: Predicted bottom deposition and seafloor coverage from the combined seabed and sea surface discharge simulations, commencing in October. The inset shows a zoomed in view.

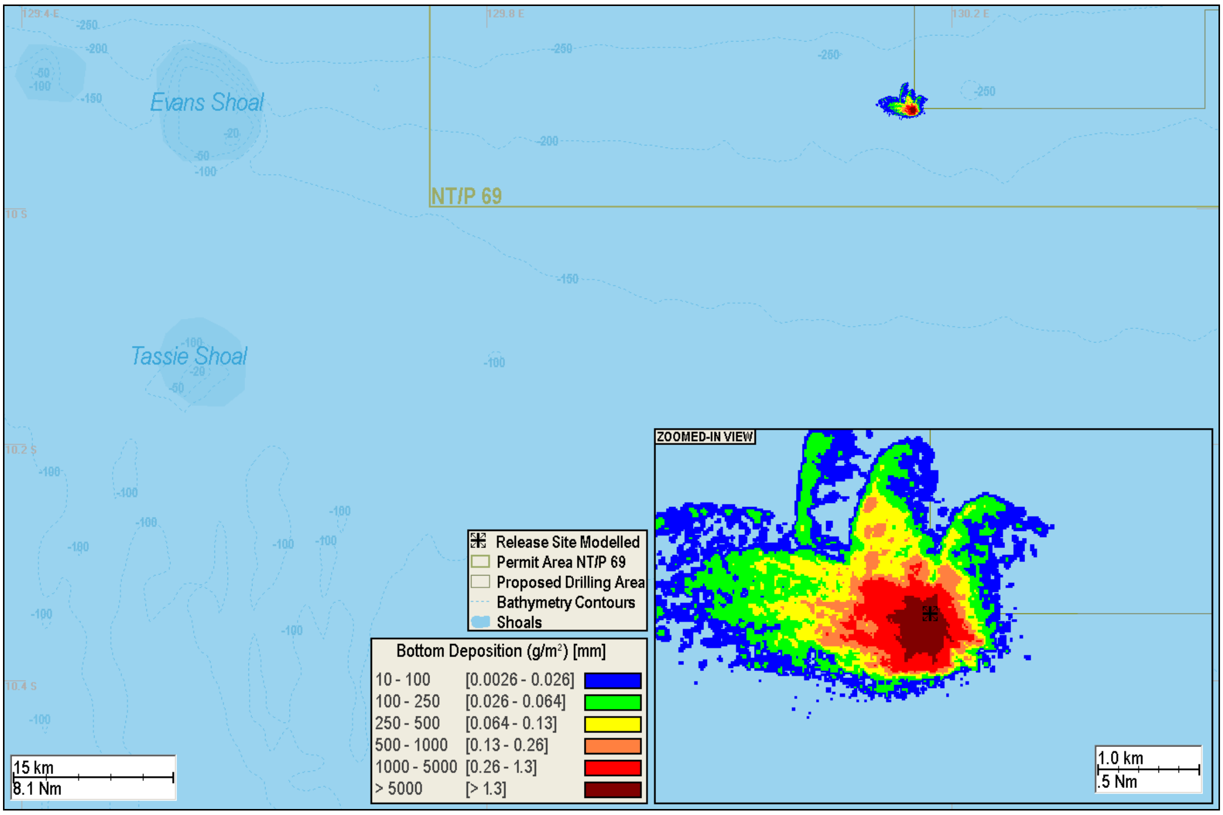

Figure 47: Predicted bottom deposition and seafloor coverage from the combined seabed and sea surface discharge simulations, commencing in November. The inset shows a zoomed in view.

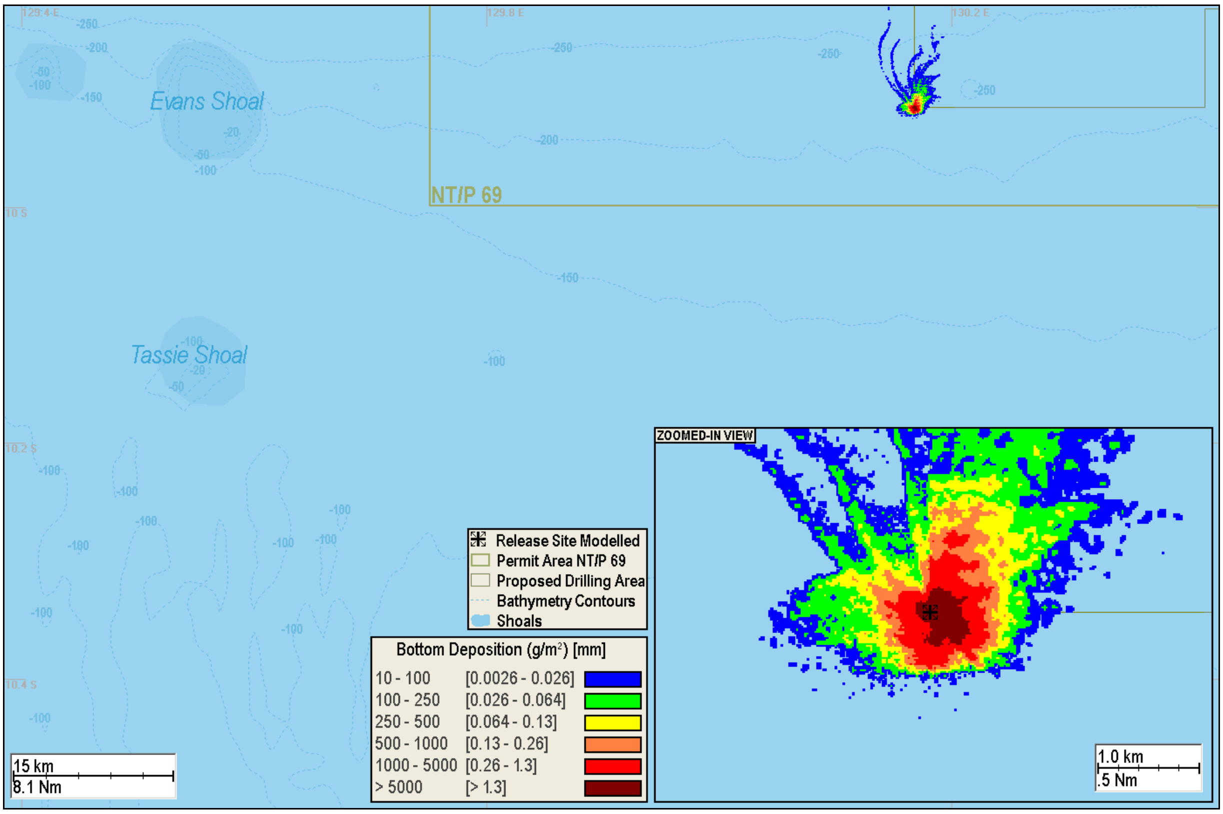

Figure 48: Predicted bottom deposition and seafloor coverage from the combined seabed and sea surface discharge simulations, commencing in December. The inset shows a zoomed in view.

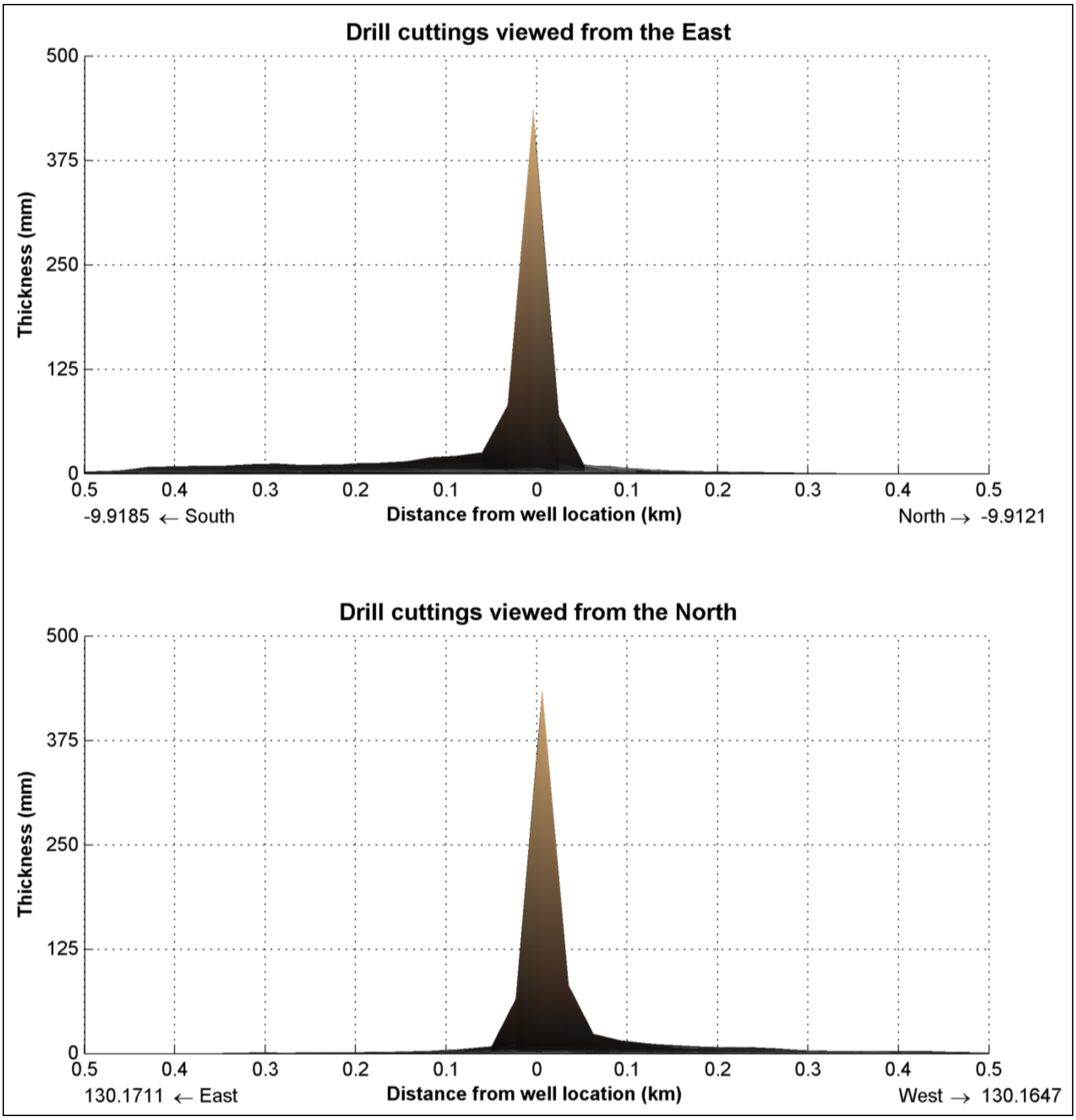

Figure 49: Cross sectional view of the predicted bottom thickness on the seafloor along the north-south axis (upper image) and east-west axis (lower image) from the combined seabed and sea surface discharge simulations. The images illustrate predicted bottom thicknesses corresponding to distances from the well in each cardinal direction. Results are based on the 39.3 day discharge of drill cuttings and muds commencing in November. Note the vertical scale is exaggerated.

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Appendix H.

PFW dispersion modelling study (RPS 2017a)

ConocoPhillips Barossa Project

Produced Formation Water Dispersion Modelling

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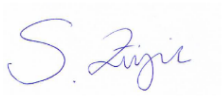
Document Status

Version	Purpose of Document	Original	Review	Review Date
DraftA	*Issued for client review*	Dr Ryan Dunn	Dr Sasha Zigic	28/2/2017
Rev 0	*Issued for client review*	Dr Ryan Dunn	Dr Sasha Zigic	28/2/2017
Rev 1	Issued to client		Dr Sasha Zigic	14/3/2017

Approval for Issue

Name	Signature	Date
Dr Sasha Zigic		14/3/2017

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1.0 Introduction

1.1 Project background

ConocoPhillips Australia Exploration Proprietary (Pty) Limited (Ltd.) (ConocoPhillips), as proponent on behalf of the current and future co-venturers, is proposing to develop natural gas resources in the Timor Sea into high quality products in a safe, reliable and environmentally responsible manner. The Barossa Area Development (herein referred to as the “project”) is located in Commonwealth waters within the Bonaparte Basin, offshore northern Australia, and is approximately 300 kilometres (km) north of Darwin, Northern Territory (NT).

The development concept of the gas resource includes a floating production storage and offloading (FPSO) facility and a gas export pipeline that are located in Commonwealth jurisdictional waters. The FPSO facility will be the central processing facility to stabilise, store and offload condensate, and to treat, condition and export gas. The extracted lean dry gas will be exported through a new gas export pipeline that will tie into the existing Bayu-Undan to Darwin gas export pipeline. The lean dry gas will then be liquefied for export at the existing ConocoPhillips operated Darwin Liquefied Natural Gas facility at Wickham Point, NT.

Produced formation water (PFW) will be generated during the project and will be discharged into the open ocean. The PFW stream is generally characterised as having a naturally high temperature due to exposure to geothermal heat in the reservoir and may contain a mixture of constituents including dissolved and dispersed hydrocarbons at levels exceeding the receiving marine waters.

The volumes of PFW generated from the hydrocarbon reservoirs will vary over the life of the field. The volumes of PFW tend to be lowest at the start of production and peak towards to end of each field’s lifecycle.

To assess the change in temperature and rate of mixing of the residual condensate in the PFW stream from the FPSO facility, ConocoPhillips commissioned RPS to undertake a dispersion modelling study for the two flow rates (minimum of 1,590 m^3/d and maximum of 3,260 m^3/d). The coordinate of the indicative release location is presented in Table 1 and graphically in Figure 1. The purpose of the modelling was to assist in understanding the potential area that may be influenced by the routine discharge of PFW based on the engineering information available in the early stage of the project design phase.

The potential area that may be influenced by the PFW discharge stream was assessed for three distinct seasons; (i) summer (December to the following February), (ii) the transitional periods (March and September to November) and (iii) winter (April to August). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

The closest environmental values and sensitivities to the modelled release location are submerged shoals and banks including Lynedoch Bank (70 km to the south-east), Evans Shoal (64 km to the west) and Tassie Shoal (74 km to the south-west).

Table 1 Barossa offshore development area PFW dispersion modelling study release location

Release location	Latitude	Longitude	Water depth (mLAT)
Barossa offshore development area release location	9° 52’ 35.8” S	130° 11’ 8.4” E	~230

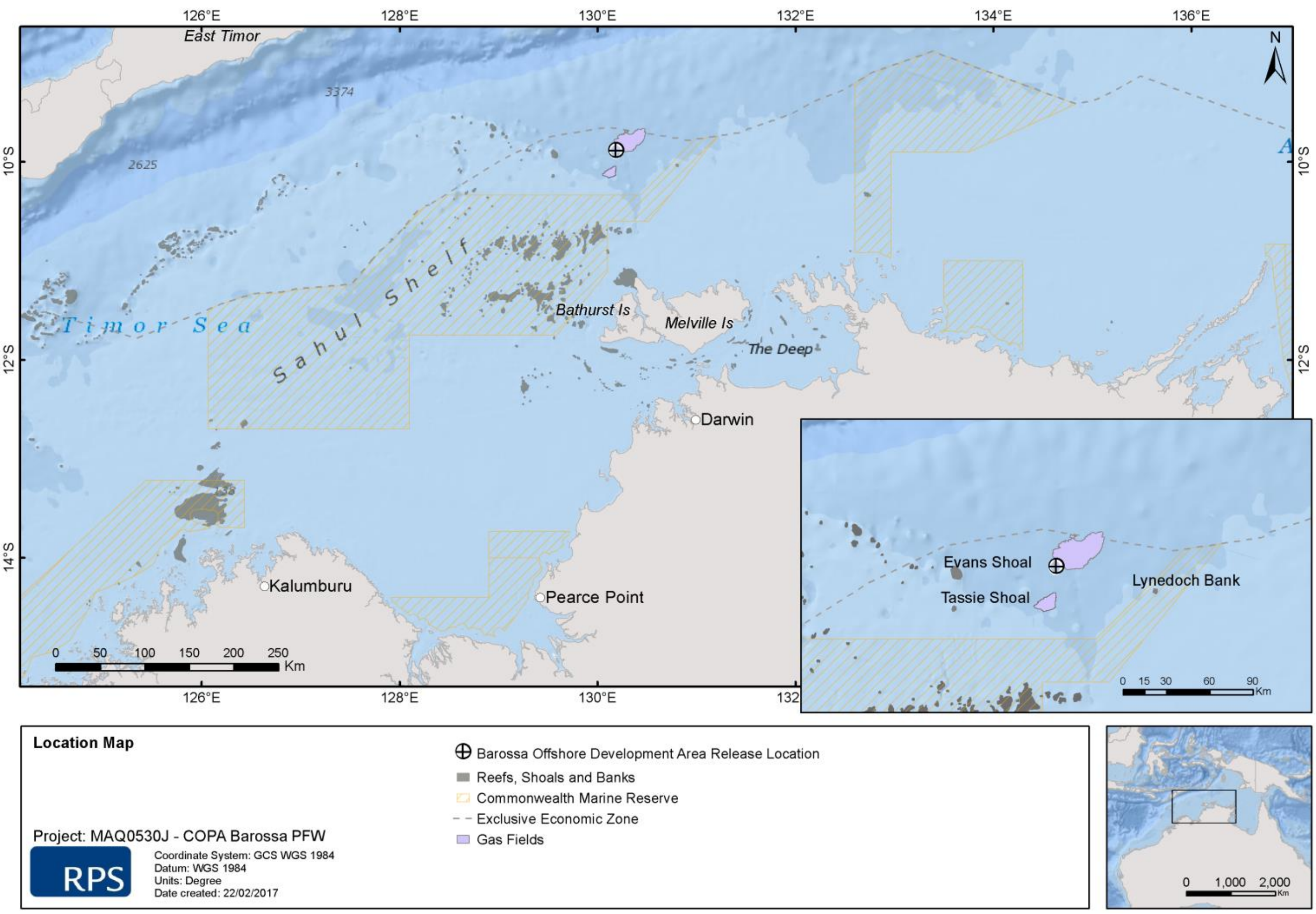


Figure 1 Map of the Barossa offshore development area PFW modelling study release location.

2.0 Dispersion modelling

The physical mixing of the PFW stream can be separated into two distinct zones; near-field and far-field.

The near-field zone is defined by the region where the levels of mixing and dilution are controlled by the plume's initial jet momentum and the buoyancy flux, resulting from the density difference. When the plume encounters a boundary such as the water surface, seabed or density stratification layer, the near-field mixing is complete and the far-field mixing begins. During the far-field phase, the plume is transported and mixed by the ambient currents.

Therefore, to accurately determine the dilution and the mixing zone of the PFW water stream, the effect of near-field mixing needs to be considered first, followed by an investigation of the far-field mixing. Section 2.1 and Section 2.2 describe the near-field and far-field dispersion model. The physical mixing of the PFW water stream can be separated into two distinct zones; near-field and far-field.

2.1 Near-field model

2.1.1 Description

The near-field mixing of the PFW water discharge stream was predicted using the fully three-dimensional flow model, Updated Merge (UM3). The UM3 model is used for simulating single and multi-port submerged discharges and is part of the Visual Plumes suite of models maintained by the United States Environmental Protection Agency (Frick et al. 2003).

The UM3 model has been extensively tested for various discharges and found to predict the observed dilutions more accurately (Roberts and Tian 2004) than other near-field models (e.g. RSB or CORMIX).

In this Lagrangian 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 growth of each element, UM3 uses the shear (or Taylor) entrainment hypothesis and the projected-area-entrainment hypothesis. The flows begin as round buoyant jets issuing from one side of the diffuser and can merge to a plane buoyant jet (Carvalho et al. 2002). Model output consists of plume characteristics, including centerline dilution, rise-rate, width, centreline height and diameter of the plume. Dilution is reported as the “effective dilution”, which is the ratio of the initial concentration to the concentration of the plume at a given point, following Baumgartner et al. (1994).

2.1.2 Model setup

The PFW discharge characteristics are summarised in Table 2. The PFW discharge was modelled 10 m below the water surface through a single outlet, and was anticipated to have a salinity, temperature and initial oil in water (OIW) concentration of 15 parts per thousand (ppt), 60°C and 30 milligrams per litre (mg/L), respectively.

The volumes of PFW generated from the project will vary over the life of the field. In general, PFW volumes are lowest at the start of production and peak towards to end of each field’s lifecycle. Based on the engineering definition available at the time of commissioning the dispersion modelling study, the minimum and maximum (peak) volumes are estimated at 1,590 m^3/d and 3,260 m^3/d, respectively.

Additional input data used to setup the near-field model included range of current speeds, water temperature and salinity as a function of depth. Defining the water temperature and salinity is important to correctly replicate the buoyancy of the plume. The buoyancy dynamics in this case will be dominated by the temperature and salinity differences between the PFW plume and receiving waters. Table 3 presents the measured water temperature and salinity data collected by Fugro (2015) as part of the Barossa marine studies program. The minimum water temperature at 30 m below mean sea level (BMSL) was used as it represents the most conservative conditions considering water temperature varies with depth and would be warmer at the surface in comparison to temperatures at 30 m.

Table 4 presents the 5th, 50th and 95th percentiles of current speeds, which reflect contrasting dilution and advection cases:

- 5th percentile current speed: weak currents, low dilution and slow advection
- 50th percentile (median): medium current speed, moderate dilution and advection
- 95th percentile current speed: strong currents, high dilution and rapid advection to nearby areas.

The 5th percentile, 50th percentile (median) and 95th percentile values are referenced as weak, medium and strong current speeds, respectively.

Table 2 PFW discharge and pipe configuration characteristics summary

Parameter	Value/design
Flow rate (m^3/d)	Minimum flow rate: 1,590 Maximum flow rate: 3,260
Outlet pipe internal diameter (m)	0.310

Parameter	Value/design
Pipe orientation	Vertically downward
Depth of pipe below sea surface (m)	10
Discharge salinity (ppt)	15
Discharge water temperature (ºC)	60
Initial OIW concentration (mg/L; ppm)	30

Table 3 Water temperature and salinity model inputs

Parameter	Season		
	Summer	Transitional	Winter
Ambient minimum water temperature (ºC) (30 m BMSL)	25.4	24.7	26.3
Ambient mean salinity (Practical Salinity Units (PSU)) (30 m BMSL)	34.1	33.6	33.6

Table 4 Seasonal ambient percentile current speeds, strength and predominant direction as a function of water depth at the release location

Depth below the water surface (m)	Parameter	Reporting current strength	Season					
			Summer		Transitional		Winter	
			Speed (m/s)	Predominant direction	Speed (m/s)	Predominant direction	Speed (m/s)	Predominant direction
0	5th percentile	Weak	0.04	East	0.05	West-south-west	0.03	South-west
	50th percentile	Medium	0.11		0.14		0.11	
	95th percentile	Strong	0.27		0.29		0.27	
10	5th percentile	Weak	0.03	East	0.03	South-west	0.04	South-west
	50th percentile	Medium	0.09		0.12		0.12	
	95th percentile	Strong	0.23		0.26		0.25	
20	5th percentile	Weak	0.03	East-south-east	0.03	South-west	0.03	South-west
	50th percentile	Medium	0.08		0.11		0.12	
	95th percentile	Strong	0.20		0.24		0.24	

2.2 Far-field model

2.2.1 Description

The far-field modelling expands on the near-field model predictions as it also takes into account the time-varying nature of currents, together with the potential for recirculation of the plume back to the release location. In the latter case near-field concentrations can be increased due to the discharge plume mixing with the remnant plume from an earlier time.

The three-dimensional plume behaviour model, MUDMAP, was used to simulate the far-field mixing and dispersion of the OIW within the PFW plume. MUDMAP is an industry standard computerised modelling system, which has been applied throughout the world to predict the dispersion of sediment (cuttings and muds) and liquid (produced water) discharges since 1994 (Spaulding 1994). The model is a development of the Offshore Operators Committee (OOC) model and like the OOC model calculates the fates of discharges through three known distinct integrated stages (Koh and Chang 1973; Khondaker 2000; Brandsma and Sauer Jr 1983a, 1983b).

The PFW release is represented by placing a fixed number of “particles” at the release location on each time-step. These particles are moved on each subsequent time-step according to the horizontal and vertical components from the hydrodynamic model. The plume spread is dependent on the horizontal and vertical mixing coefficients.

The MUDMAP system is based on a conservative tracer (no reaction or decay), constituting a “worst case” scenario, to examine the mixing and dilution of effluent plumes. The concentration distribution of the constituent in water is estimated using a counting grid. The number of particles in a grid square over a depth interval from the water surface down to a specified depth is counted, giving the mass of the constituent in a known volume, and therefore concentration.

The system has been extensively validated and applied for discharge operations in Australian waters (e.g. Burns et. al. 1999; King and McAllister 1997, 1998).

2.2.2 Model setup

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 3.1.

The two PFW flow rates were modelled as a constant discharge for each month during 2010, 2012 and 2014. Once the results were complete, they were reported on a combined seasonal basis: (i) summer (December to the following February); (ii) the transitional (March, April, September to November) and (iii) winter (May to August).

MUDMAP uses a three-dimensional grid to represent the water depth and bathymetric profiles of the study area. Due to the rapid mixing and small-scale influences of the discharge, it was necessary to use a very fine grid with a resolution of 10 m x 10 m to track the movement and fate of the plume. The extent of the grid region measured 10 km (longitude or x-axis) x 10 km (latitude or y-axis). It is important to note, that the 10 m grid cell sizes were selected following extensive sensitivity testing in order to achieve similar dilution rates at the end of the near-field mixing.

Table 5 presents a summary of the far-field model parameters used to simulate the PFW discharges during the three seasons and two flow rates.

Spatially constant, conservative horizontal and vertical dispersion coefficients were used to control the exchange of the PFW in the horizontal and vertical directions respectively. The coefficients were selected following extensive sensitivity testing in order to recreate similar plume characteristics and dilutions at the end of the near-field mixing.

Table 5 Summary of the far-field PFW model inputs

Parameter	Value/design
Years simulated	• 2010 (La Niña conditions) • 2012 (neutral/mixed) • 2014 (El Niño conditions)
Seasons (months simulated and reported)	• Summer (December, January, February) • Transitional periods (March, April, September to November) • Winter (May to August)
Total months modelled and analysed per flow rate	36
Flow rate (m^3/d)	Minimum flow rate: 1,590 Maximum flow rate: 3,260
Discharge type	Continuous
Period of discharge (days)	Entire month
PFW discharge temperature (ºC)	60
PFW discharge salinity (ppt)	15
Initial OIW concentration (mg/L; ppm)	30

2.3 Interannual variability

The region is strongly affected by the strength of the Indonesian Throughflow, which fluctuates from one year to the next due to the exchange between the Pacific and Indian Oceans. Therefore, in order to examine the potential range of variability, the Southern Oscillation Index (SOI) data sourced from the Australian Bureau of Meteorology was used to identify interannual trends for the last 10 years (2005–2014). The SOI broadly defines neutral, El Niño (sustained negative values of the SOI below −8 often indicate El Niño episodes) and La Niña (sustained positive values of the SOI above +8 are typical of La Niña episodes) conditions based on differences in the surface air-pressure between Tahiti on the eastern side of the Pacific Ocean and Darwin (Australia), on the western side (Rasmusson and Wallace 1983, Philander 1990). El Niño episodes are usually accompanied by sustained warming of the central and eastern tropical Pacific Ocean and a decrease in the strength of the Pacific trade winds. La Niña episodes are usually associated with converse trends (i.e. increase in strength of the Pacific trade winds).

Figure 2 shows the SOI monthly values and Figure 3 shows the surface ocean current roses for the period 2004–2013 at the proposed release location. Each current rose diagram provides an understanding of the speed, frequency and direction of currents, over the given year:

- Current speed – speed is divided into segments of different colour, ranging from 0 to greater than 1 m/s. Speed intervals of 0.2 m/s are used. The length of each coloured segment is relative to the proportion of currents flowing within the corresponding speed and direction;
- Frequency – each of the rings on the diagram corresponds to a percentage (proportion) of time that currents were flowing in a certain direction at a given speed;
- Direction – each diagram shows currents flowing towards particular directions, with north at the top of the diagram.

Based on the combination of the SOI assessment and surface ocean currents, 2010 was selected as a representative La Niña year, 2012 was selected as a representative neutral year, and 2014 was selected as an El Niño year.

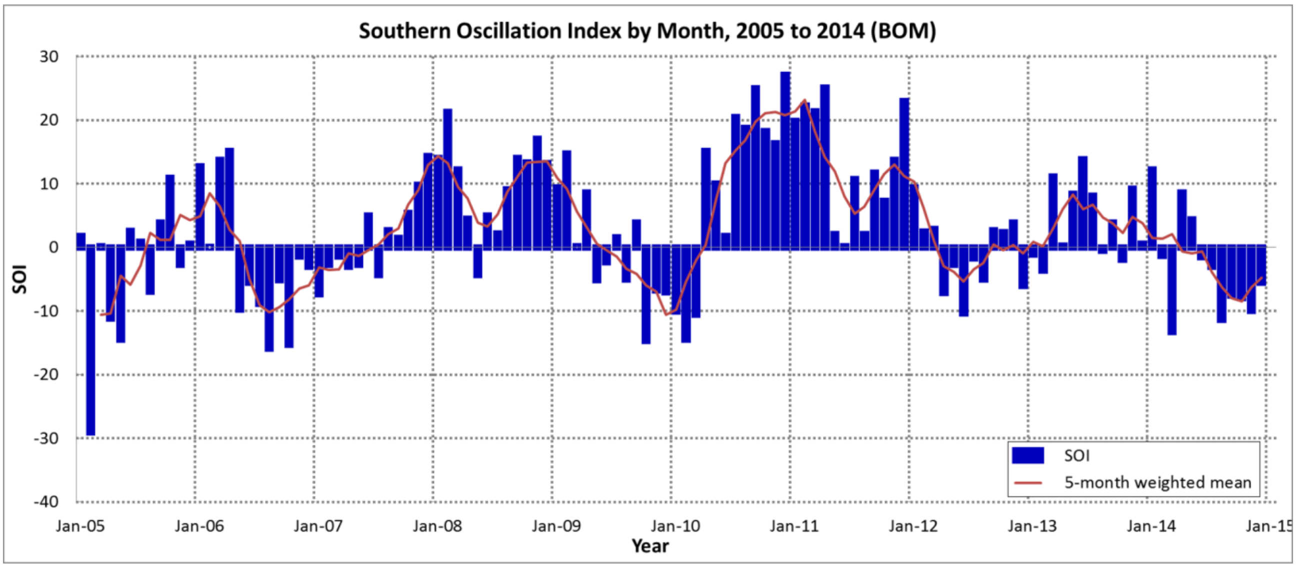


Figure 2 Monthly values of the SOI 2005-2014. Sustained positive values indicate La Niña conditions, while sustained negative values indicate El Niño conditions (Data sourced from Australian Bureau of Meteorology 2015).

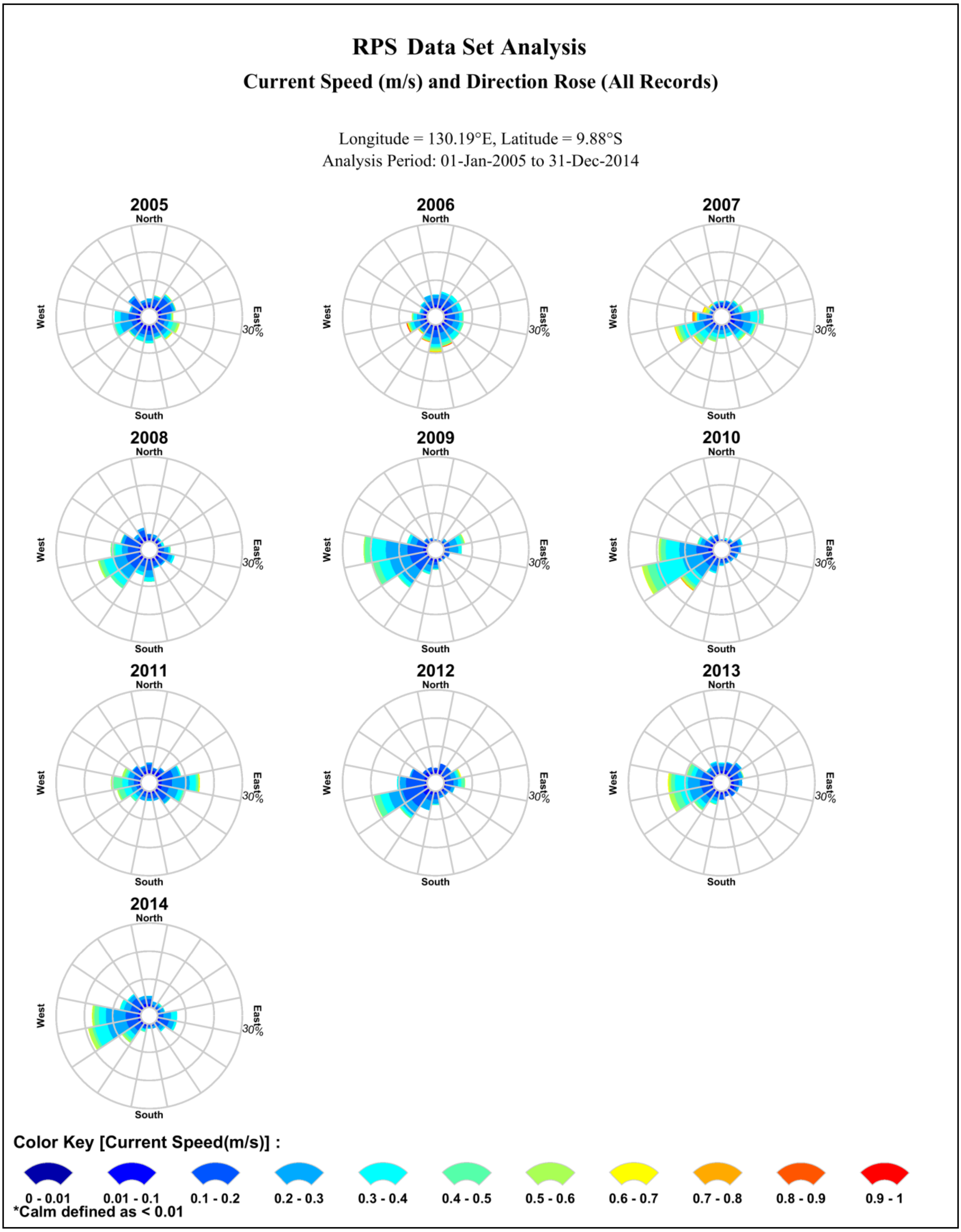


Figure 3 Annual surface ocean current rose plots within the Barossa offshore development area. Derived from analysis of HYCOM ocean data for the years 2005–2014. The colour key shows the current speed (m/s), the compass shows the direction and the length of the wedge gives the percentage of the record for a particular speed and direction combination.

2.4 Development of regional current data

The project is located within the influence of the Indonesian Throughflow, a large scale current system characterised as a series of migrating gyres and connecting jets that are steered by the continental shelf. This results in sporadic deep ocean events causing surface currents to exceed 1.5 m/s (approximately 3 knots).

While the ocean currents generally flow toward the southwest, year-round, the internal gyres generate local currents in any direction. As these gyres migrate through the area, large spatial variations in the speed and direction of currents will occur at a given location over time.

The influence of tidal currents is generally weaker in the deeper waters and greatest surrounding regional reefs and islands. Therefore, it was critical to include the influence of both types of currents (ocean and tides) to rigorously understand the likely discharge characteristics in the project's area of influence.

A detailed description of the tidal and ocean current data inputted into the model is provided below.

2.4.1 Tidal currents

The tidal circulation was generated using RPS's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world over the past 26 years (Isaji and Spaulding 1984; Isaji et al. 2001; Zigic et al. 2003). In addition, HYDROMAP tidal current data has been used as input to forecast (in the future) and hindcast (in the past) condensate spills in Australian waters and forms part of the Australian National Oil Spill Emergency Response System operated by the Australian Maritime Safety Authority (AMSA).

HYDROMAP employs a sophisticated sub-gridding strategy, which supports up to six levels of spatial resolution, halving the grid cell size as each level of resolution is employed. The sub-gridding allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, and/or of particular interest to a study.

The numerical solution methodology 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 and Spaulding (1984), Isaji et al. (2001) and Owen (1980).

1.1.1.1 Tidal grid setup

The HYDROMAP tidal grid was established over a domain that extended approximately 2,400 km (east–west) by 1,575 km (north–south) (Figure 4). Computational cells were square, with sizes varying from 8 km in the open waters down to 1 km in some areas, to more accurately resolve flows along the coastline, around islands and reefs, and over more complex bathymetry (Figure 5).

Bathymetry used in the model was obtained from multiple sources (Figure 6). This included bathymetry data sourced from the Geoscience Australia database and commercially available digitised navigation charts.

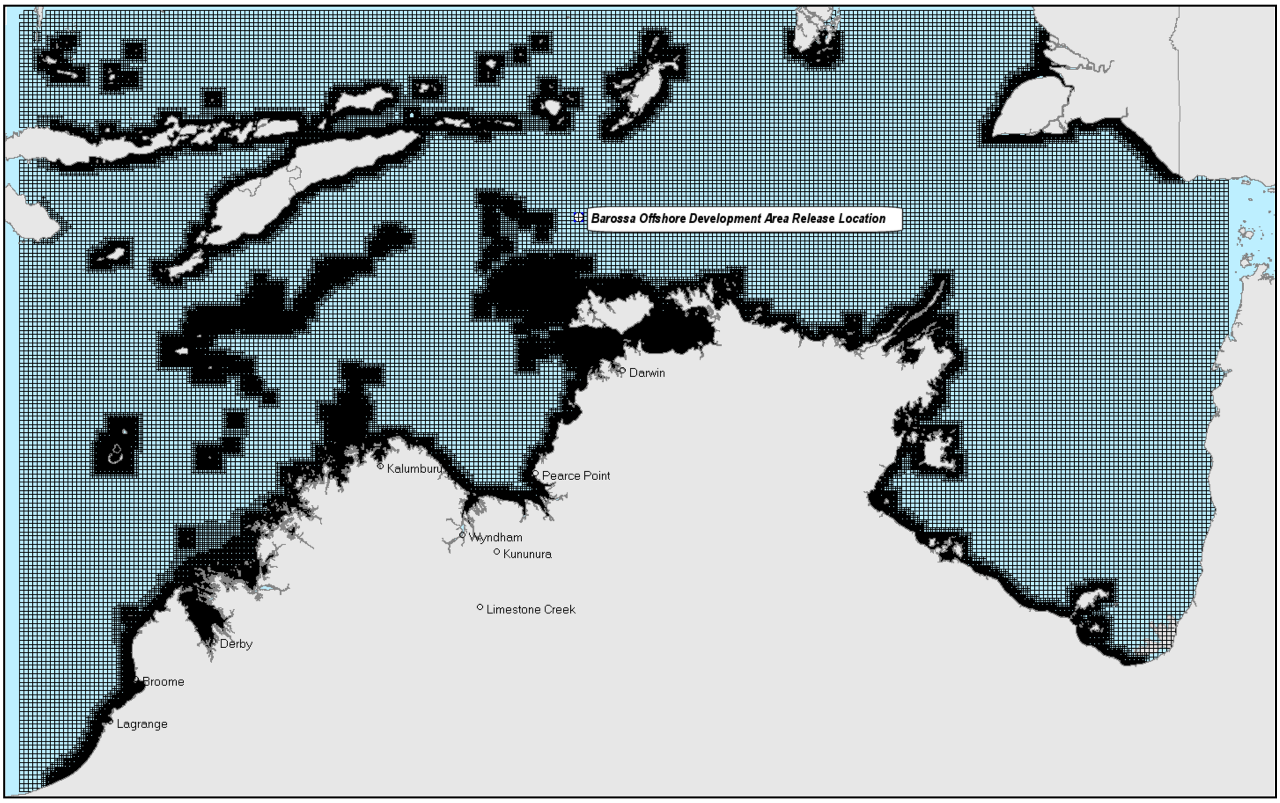


Figure 4 Map showing the extent of the tidal model grid. Note, darker regions indicate higher grid resolution.

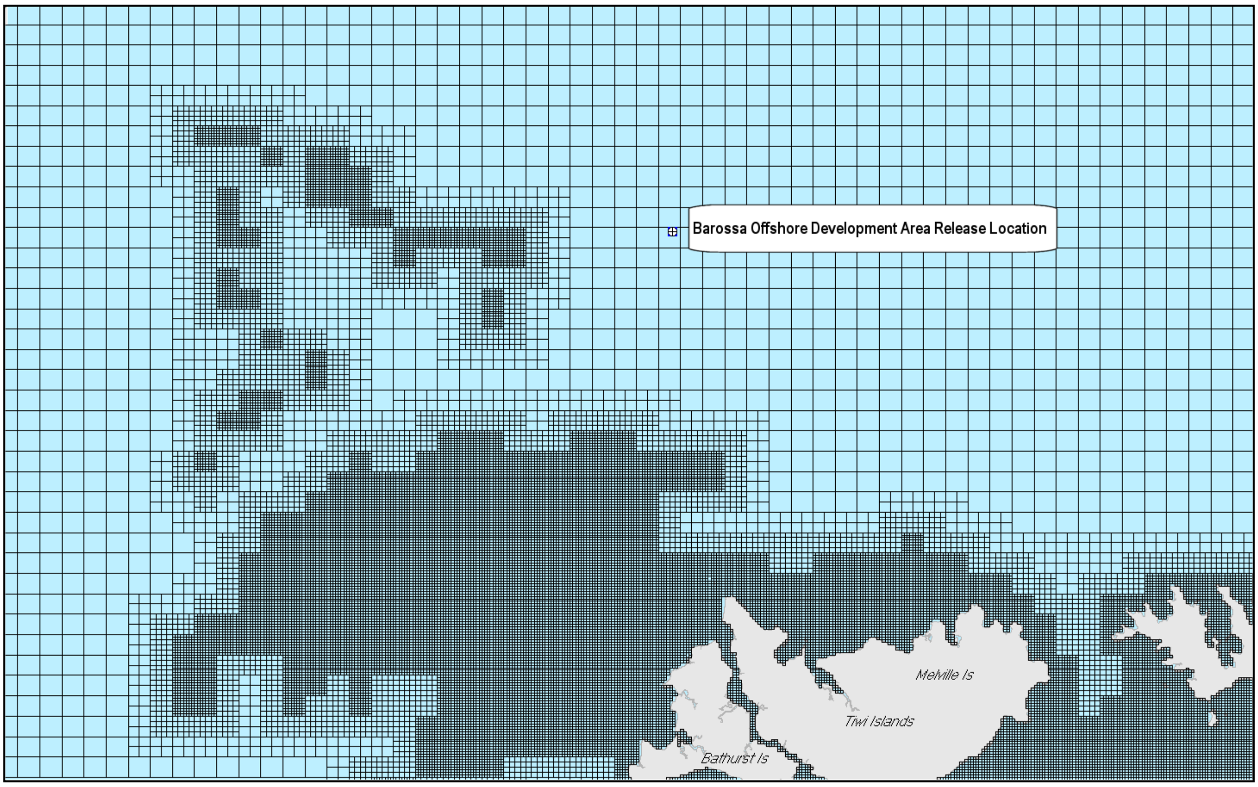


Figure 5 Zoomed in map showing the tidal model grid), illustrating the resolution sub-gridding in complex areas (e.g. islands, banks, shoals or reefs)

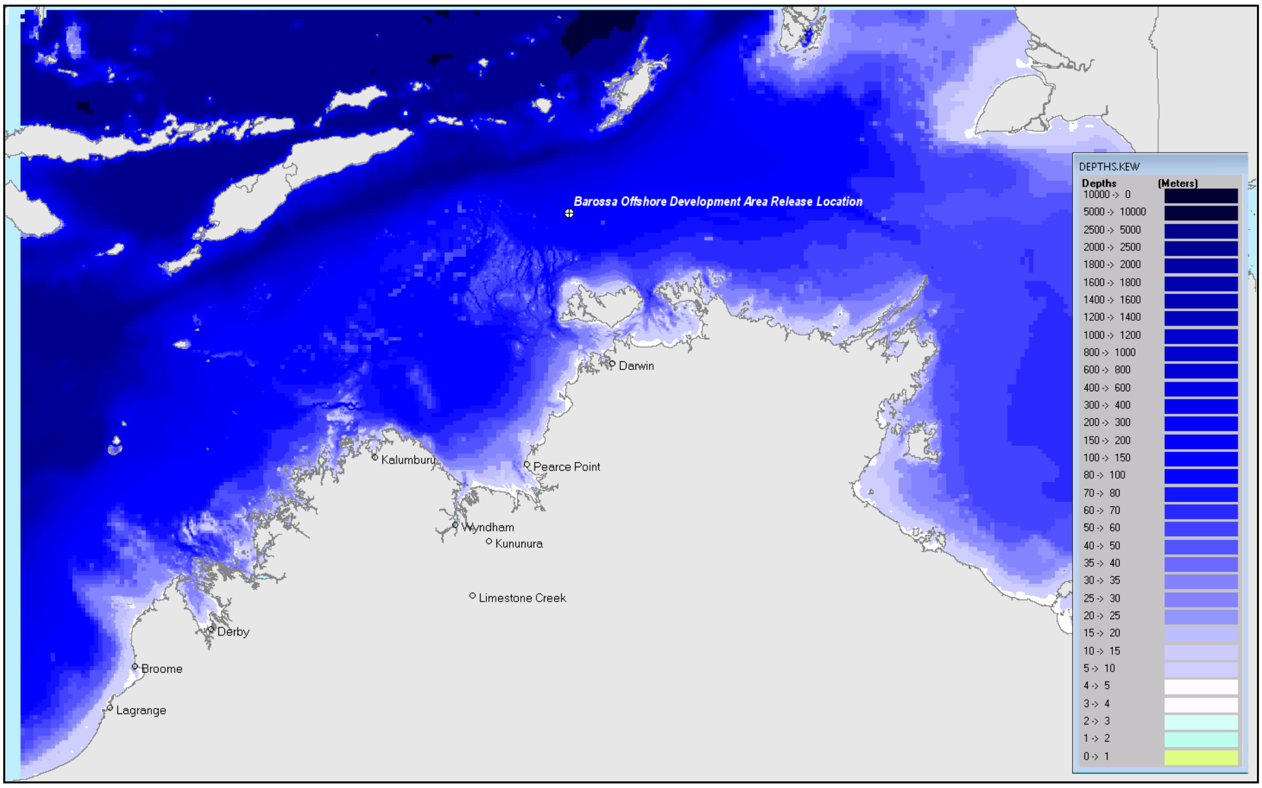


Figure 6 Map showing the bathymetry of the tidal model grid

1.1.1.2 Tidal data

The ocean boundary data for the regional model was obtained from satellite measured altimetry data (TOPEX/Poseidon 7.2) which provided estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. Using the tidal data, surface heights were 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 National Aeronautics and Space Administration (NASA). The satellites, equipped with two highly accurate altimeters that are capable of taking sea level measurements to an accuracy of less than 5 cm, measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005; see Fu et al., 1994; NASA/Jet Propulsion Laboratory 2013a; 2013b). In total these satellites carried out 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 and Tangdong 2004, Qiu and Chen 2010). As such the Topex/Poseidon tidal data is considered accurate for this study.

2.4.2 Ocean currents

Data describing the flow of ocean currents was obtained from the Hybrid Coordinate Ocean Model (HYCOM) (see Chassignet et al. 2007, 2009), which is operated by the HYCOM Consortium, sponsored by the Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a data-assimilative, three-dimensional ocean model that is run as a hindcast, assimilating time-varying observations of sea surface height, sea surface temperature and in-situ temperature and salinity measurements (Chassignet et al. 2009). The HYCOM predictions for drift currents are produced at a horizontal spatial resolution of approximately 8.25 km (1/12th of a degree) over the region, at a frequency of once per day. 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 zlevel coordinates in the mixed layer and/or unstratified seas.

For this modelling study, the HYCOM hindcast currents were obtained for the years 2010 to 2014 (inclusive). Figure 7 shows the seasonal surface current roses distributions adjacent to the release location by combining 2010, 2012 and 2014. The data shows that the surface current speeds and directions varied between seasons. In general, during transitional conditions (March, April and September to November) currents were shown to have the strongest average speed (average speed of 0.15 m/s with a maximum of 0.39 m/s) and tended to flow to the west-southwest. During summer (December to February) and winter (May to August) conditions the current flow was more variable though mostly toward the east and west, respectively. The average and maximum speeds during summer was 0.11 m/s and 0.41 m/s, respectively. During winter the average was 0.13 m/s and 0.47 m/s as the maximum.

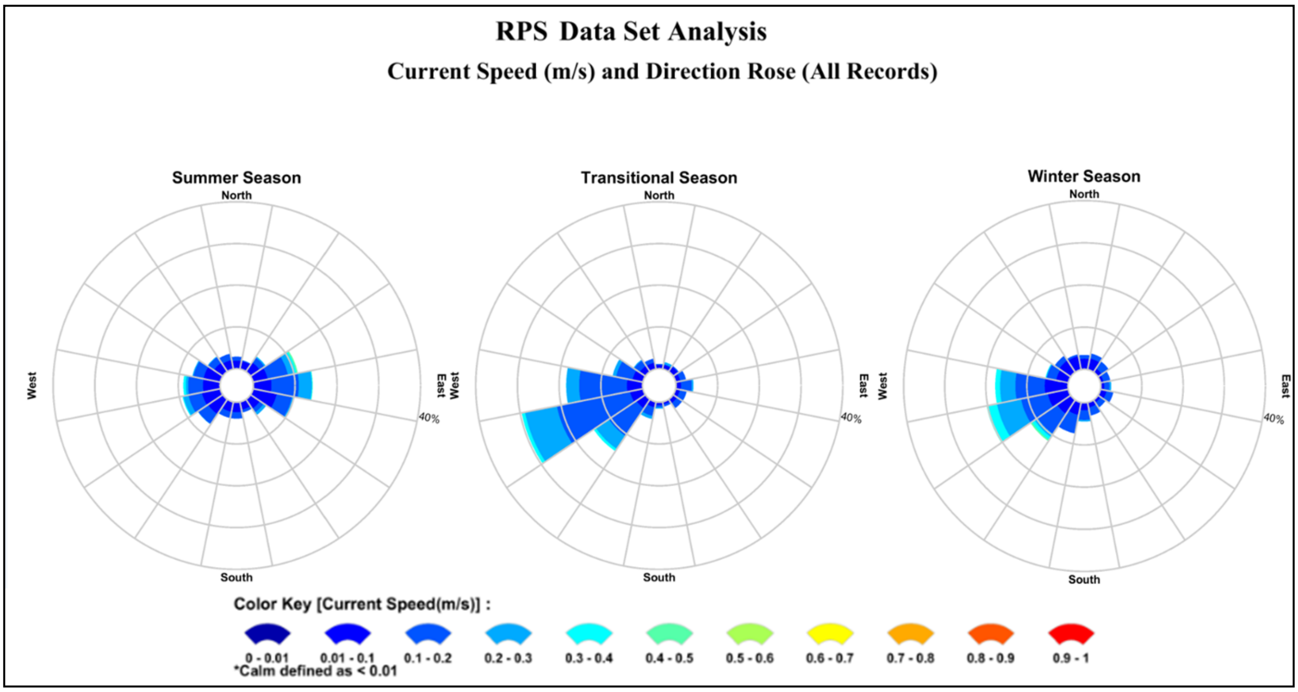


Figure 7 Seasonal surface current rose plots adjacent to the release location. Data was derived from the HYCOM ocean currents for years, 2010, 2012 and 2014. The colour key shows the current magnitude (m/s), the compass direction provides the current direction flowing TOWARDS and the length of the wedge gives the percentage of the record for a particular speed and direction combination.

Figure 8 shows example screenshots of the predicted HYCOM ocean currents during summer and winter conditions. The colours of the arrows indicate current speed (m/s).

In addition, Figure 9 to Figure 11 show the monthly surface current rose plots adjacent to the release location for 2010, 2012 and 2014, respectively. The data is derived by combining the ocean currents and tidal currents.

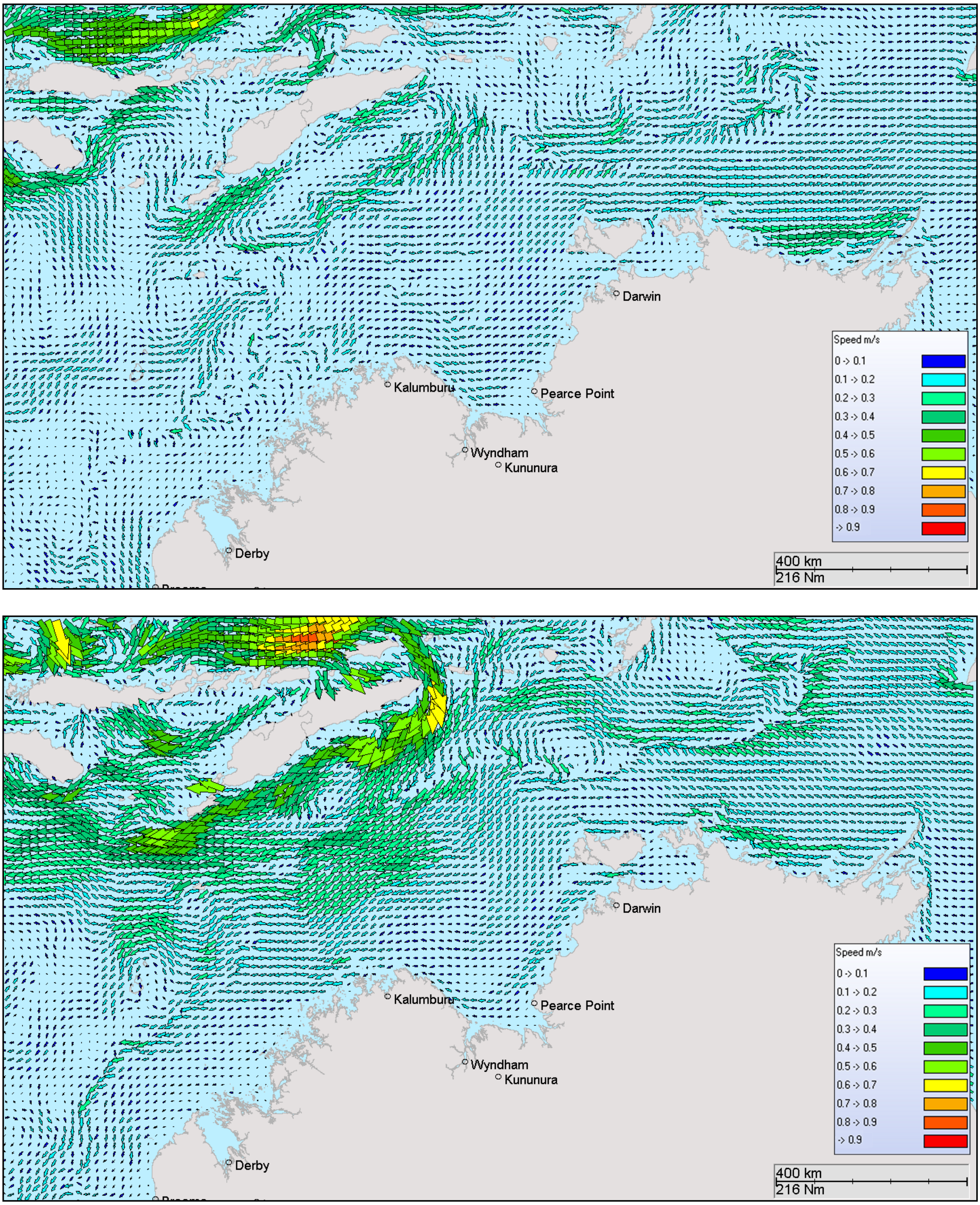


Figure 8 Modelled HYCOM surface ocean currents on the 6th February 2012, summer conditions (upper image) and 11th May 2012, winter conditions (lower image). Derived from the HYCOM ocean hindcast model (Note: for image clarity only every 2nd vector is displayed).

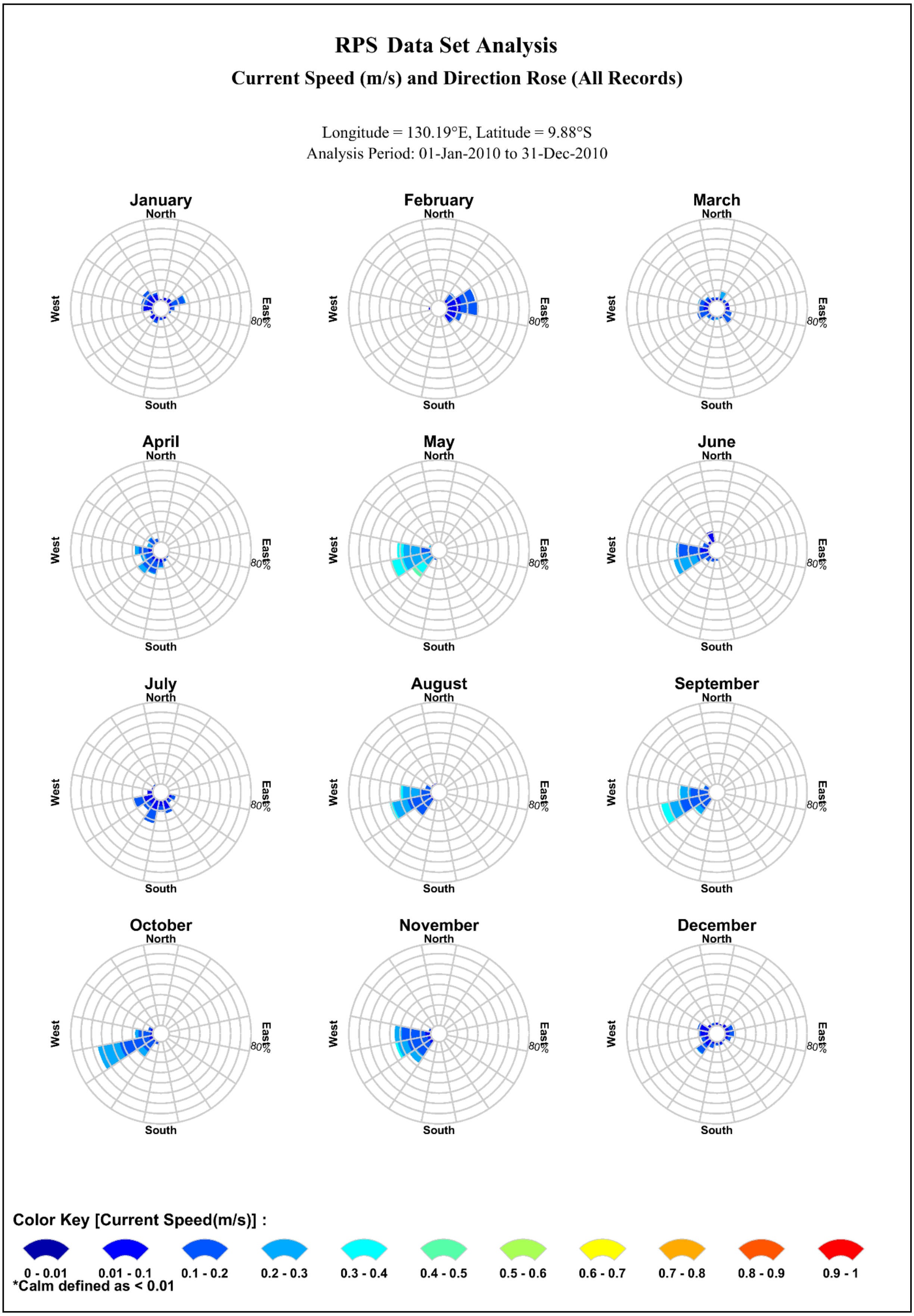


Figure 9 Monthly surface current rose plots adjacent to the model release location. Derived from analysis of HYCOM ocean data and tidal data for 2010 (La Niña year). The colour key shows the current speed (m/s), the compass shows the direction and the length of the wedge gives the percentage of the record for a particular speed and direction combination.

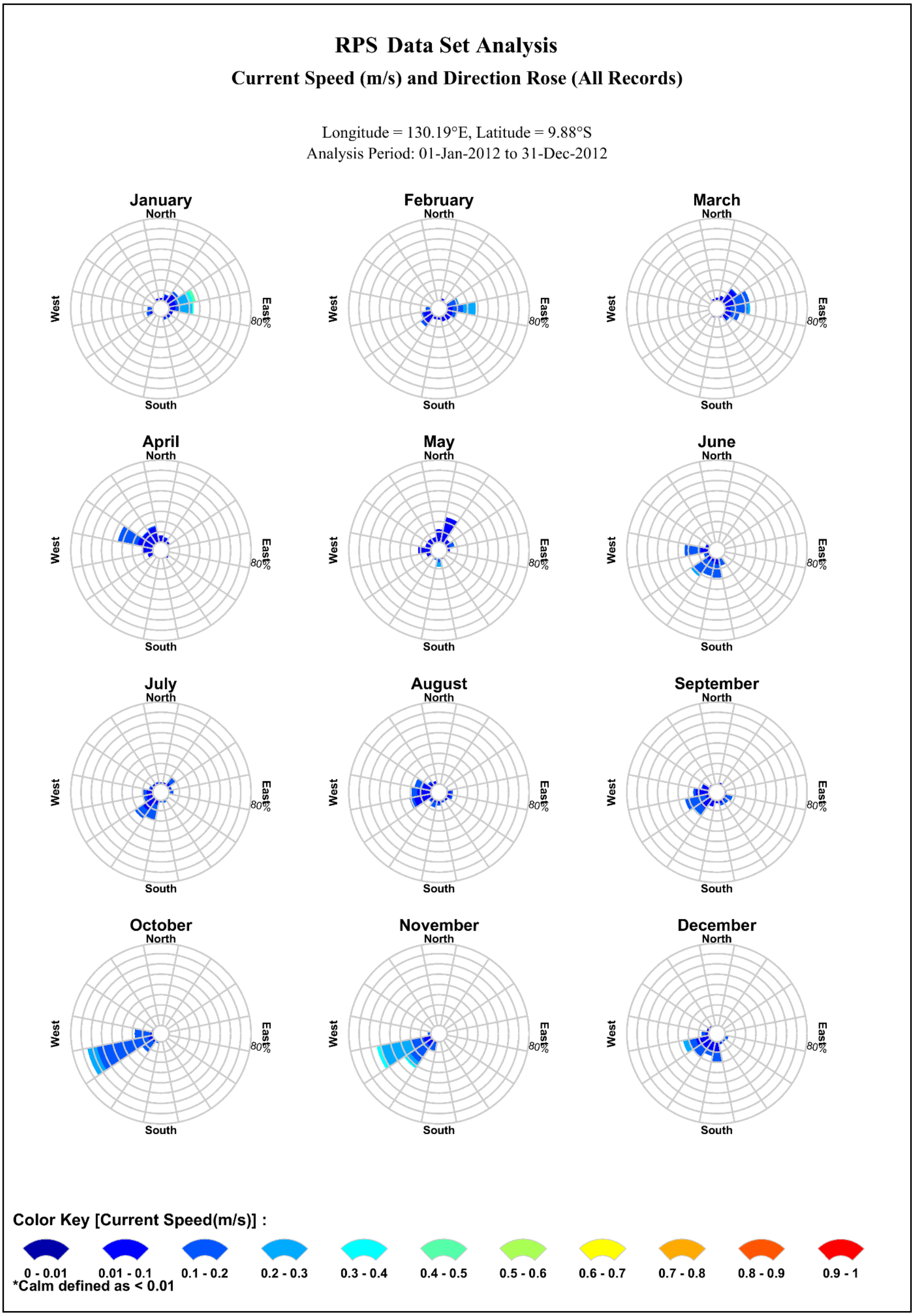


Figure 10 Monthly surface current rose plots adjacent to the model release location. Derived from analysis of HYCOM ocean data and tidal data for 2012 (neutral year). The colour key shows the current speed (m/s), the compass shows the direction and the length of the wedge gives the percentage of the record for a particular speed and direction combination.

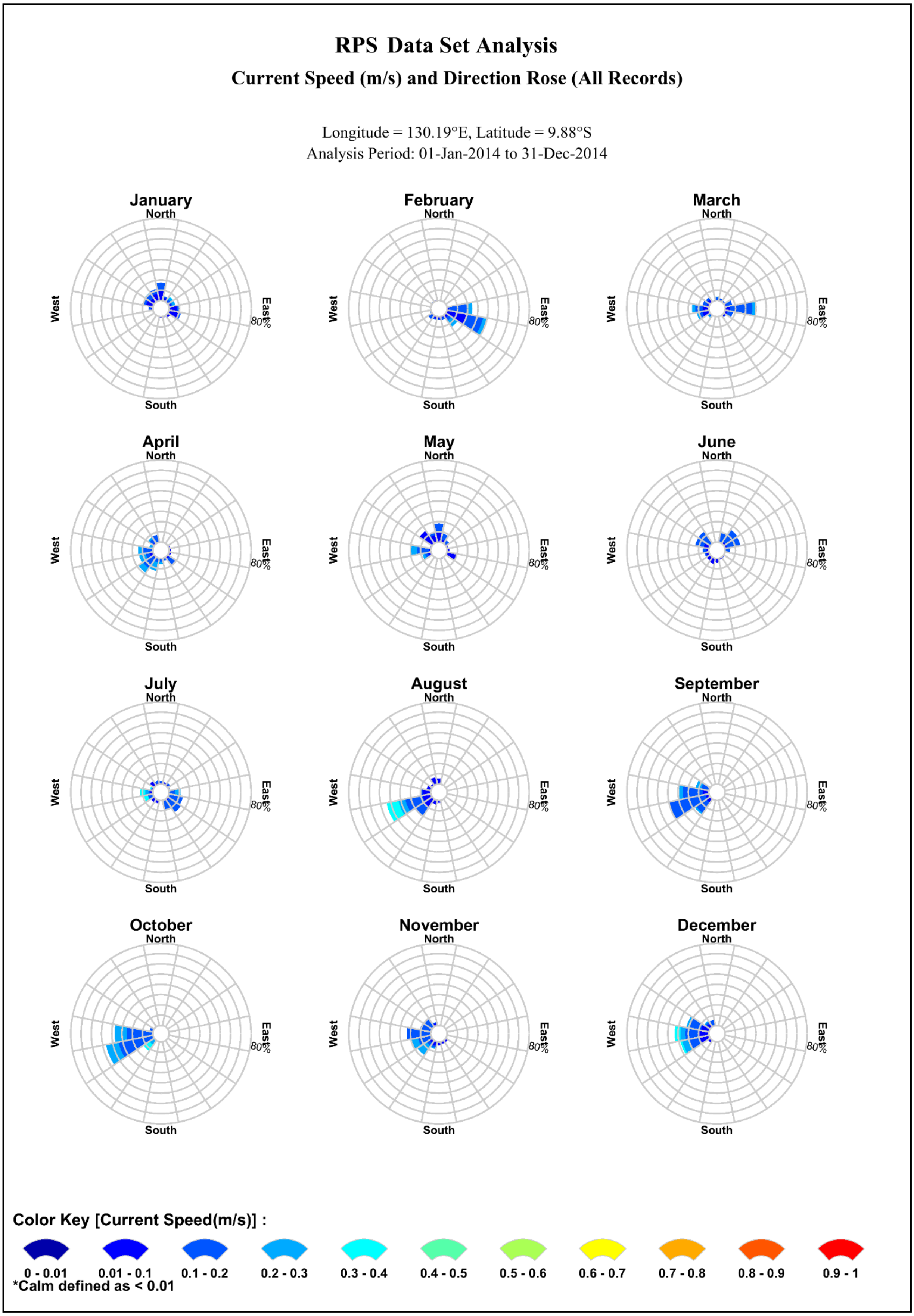


Figure 11 Monthly surface current rose plots adjacent to the model release location. Derived from analysis of HYCOM ocean data and tidal data for 2014 (El Niño year). The colour key shows the current speed (m/s), the compass shows the direction and the length of the wedge gives the percentage of the record for a particular speed and direction combination.

2.4.3 Tidal and current model validation

Fugro measured water levels and currents (speed and directions) at three locations within the Barossa offshore development area as part of the Barossa marine studies program (Figure 12, Fugro 2015). The measured data from the survey was made available to validate the predicted currents, which corresponds to the three identified seasons of the region (i.e. summer (December to February), transitional (March and September to November) and winter (April to August)).

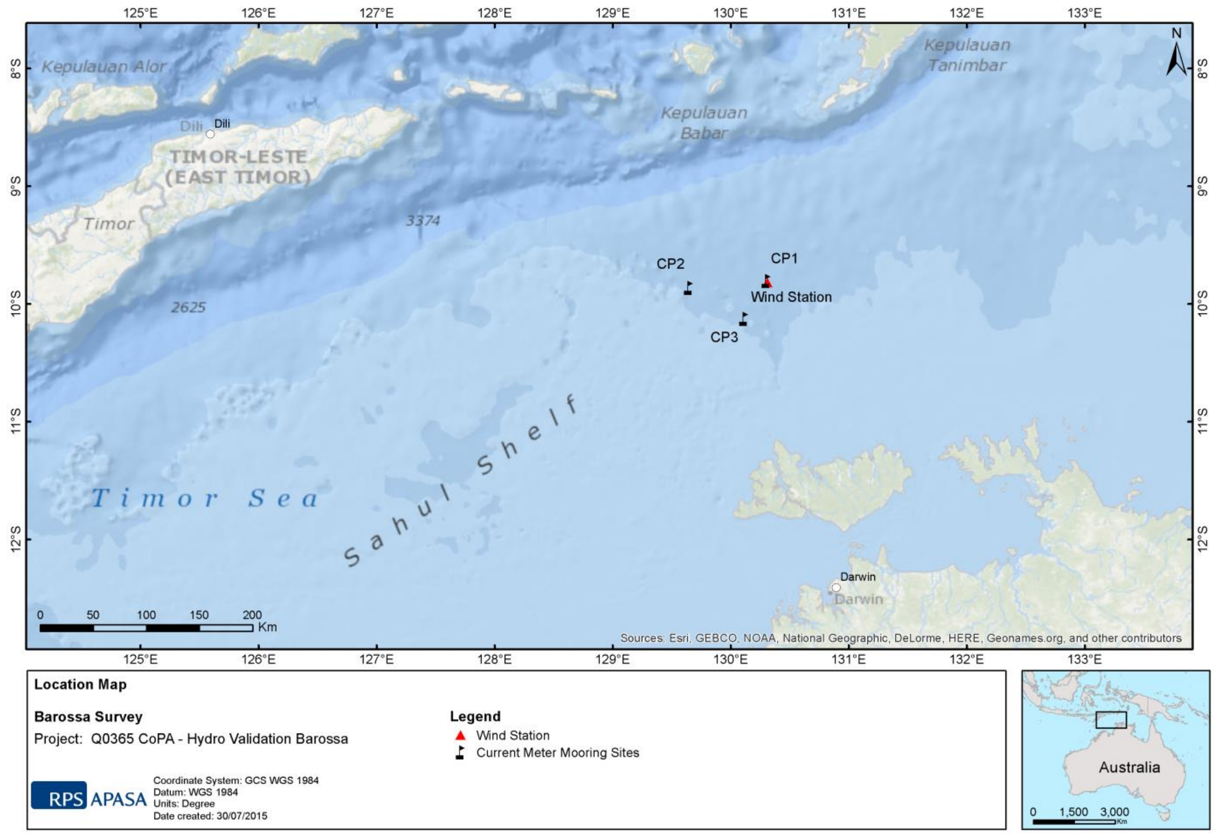


Figure 12 Locations of the CP1, CP2 and CP3 current meter moorings and the wind station

As an example, Figure 13 shows a comparison between the measured and predicted water levels at CP1 from 28 October 2014 to 14 March 2015. The figure shows a strong agreement in tidal amplitude and phasing throughout the entire deployment duration at the CP1 location.

To provide a statistical quantification of the model accuracy, comparisons were performed by determining the deviations between the predicted and measured data. As such, the root-mean square error (RMSE), root-mean square percentage (RMS %) and relative mean absolute error (RMAE) were calculated. Qualification of the RMAE ranges are reported in accordance with Walstra et al. (2001).

Table 6 shows the model performance when compared with measured water levels at CP1 from 28 October to 14 March 2015. According to the statistical measure, the HYDROMAP tidal model predictions were in very good agreement with the measured water levels at CP1.

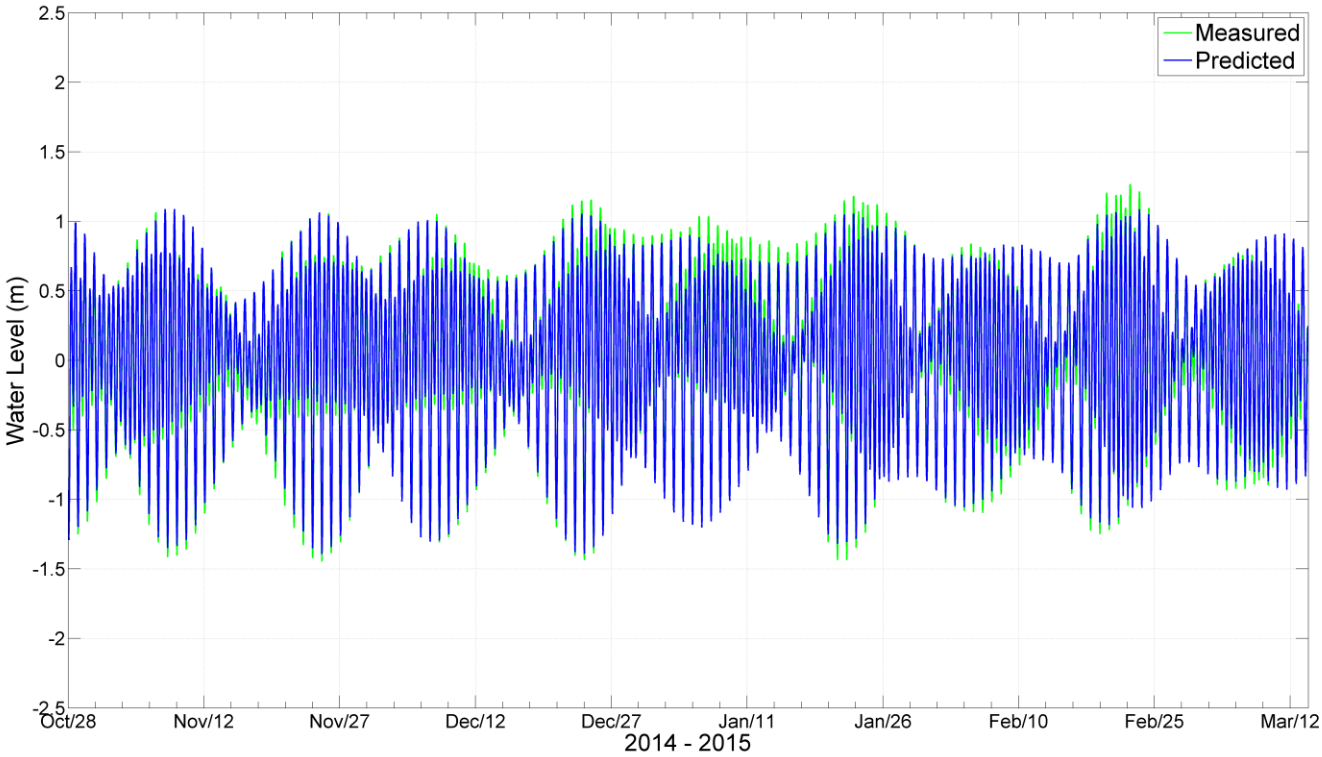


Figure 13 Comparison of measured and modelled water levels at CP1

Table 6 Statistical evaluation between measured water levels and HYDROMAP predicted water levels at CP1

Site	RMSE (m)	RMS (%)	RMAE	RMAE qualification
Mooring CP1	0.061	0.03	0.05	Very good

In addition, the HYCOM ocean currents combined with HYDROMAP tidal currents were compared to the measured current speed and directions from the CP1, CP2 and CP3 moorings. Figure 14 to Figure 16 show current comparison plots of the measured and predicted currents at each location for a range of depths (10 m, 50 m and 125 m BMSL) to highlight the differences between the wind-influenced surface layers and the mid water column.

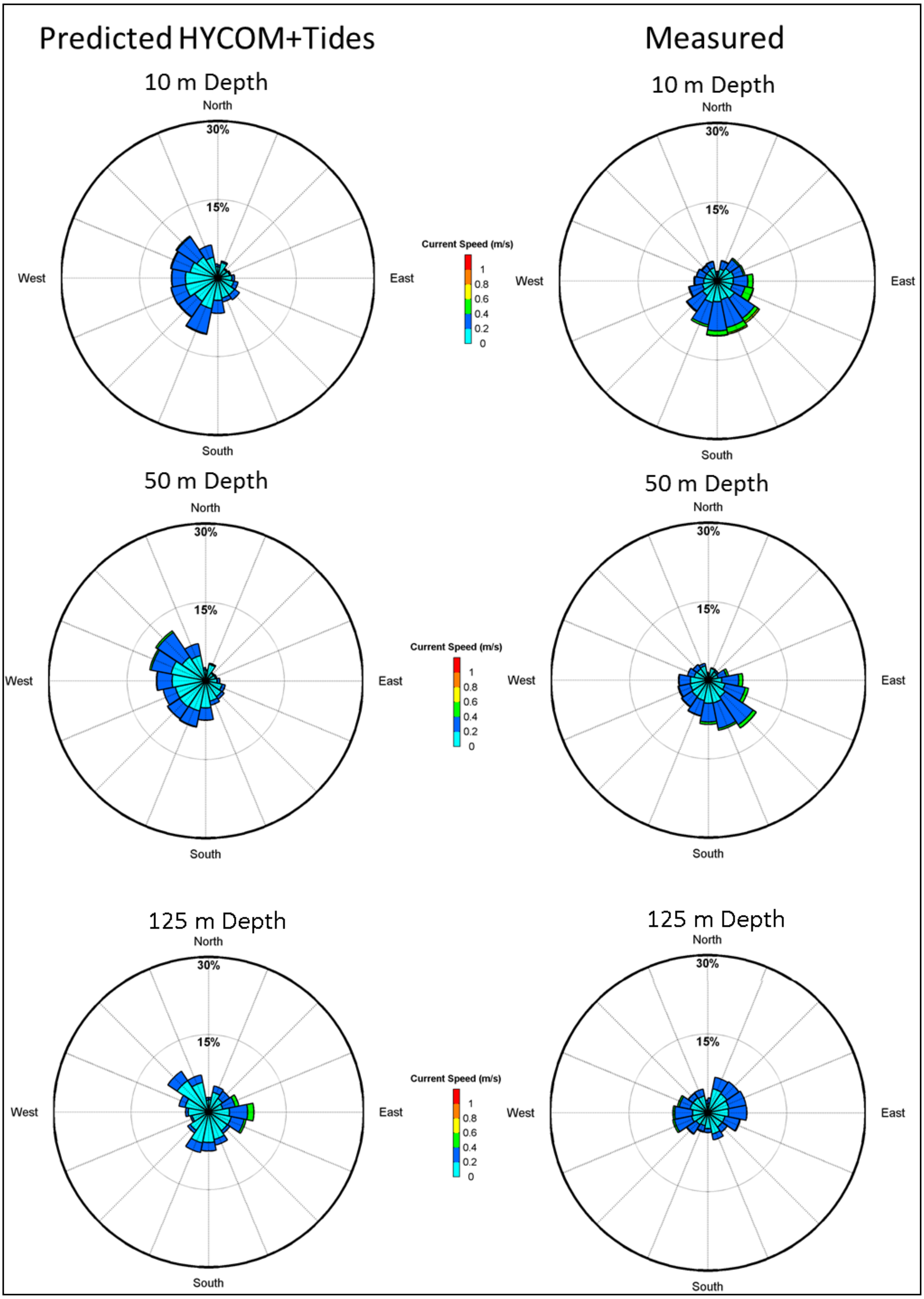


Figure 14 Comparison of predicted and measured current roses at CP1 from 9th July 2014 to 21st March 2015

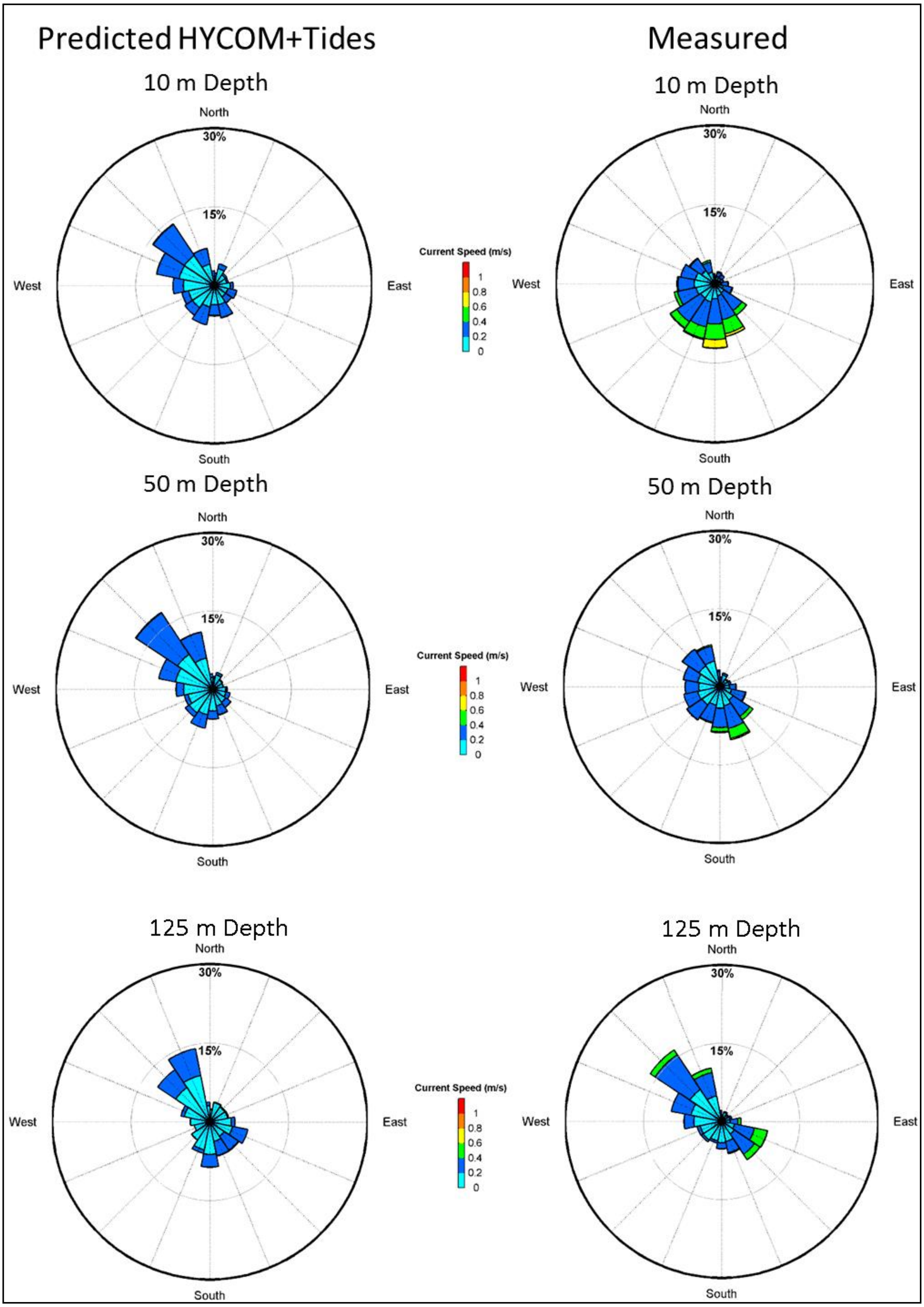


Figure 15 Comparison of predicted and measured current roses at CP2 from 10th July 2014 to 20st March 2015

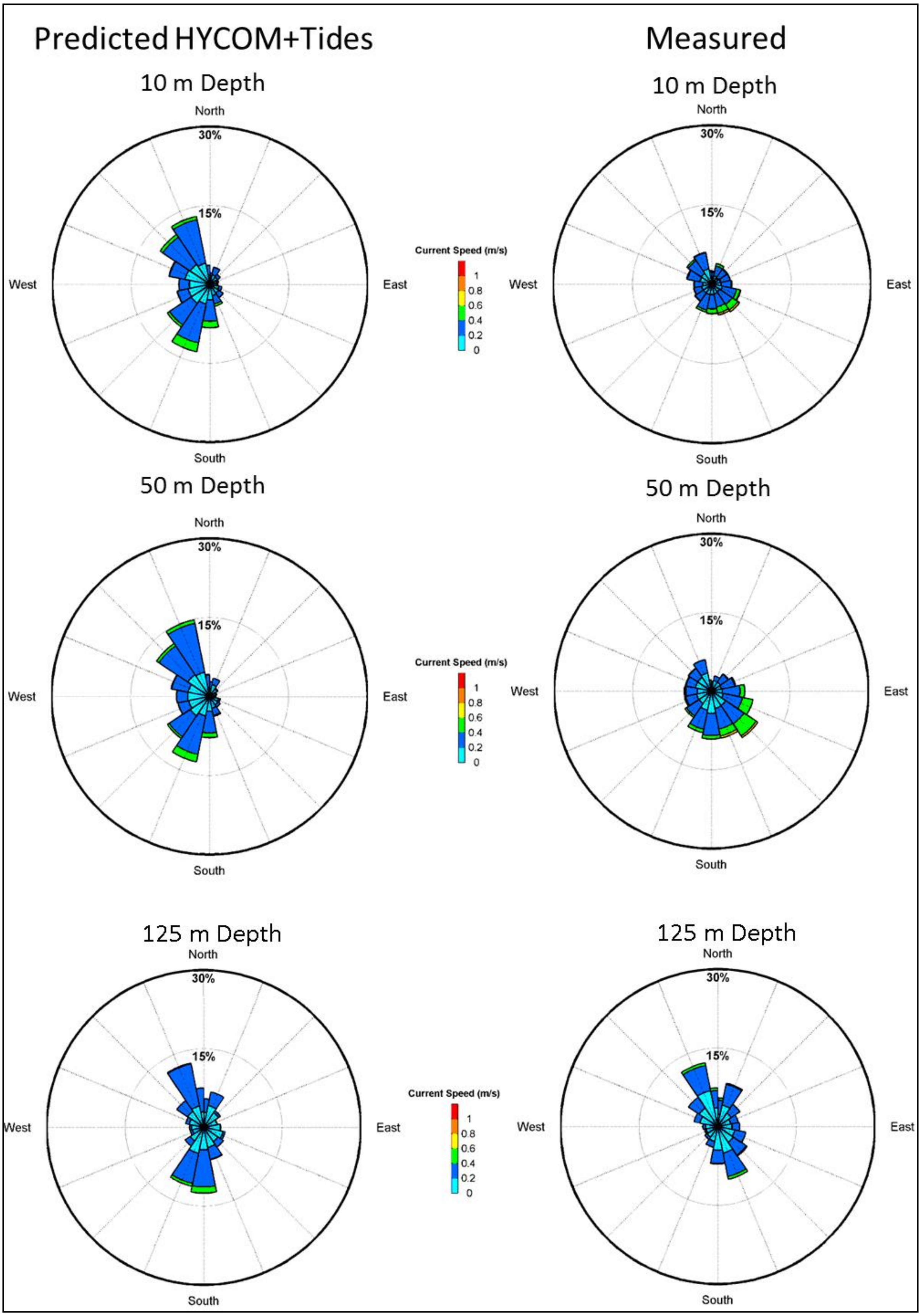


Figure 16 Comparison of predicted and measured current roses at CP3 from 9th July 2014 to 21st March 2015.

Overall, there was a good agreement between the predicted and measured currents at each site and depth. The model predictions were also able to recreate the two-layer flow which can be seen in the measured data and the reduction in current speeds as function of depth. From 10 m down to approximately 100 m below mean sea level (BMSL) the currents generally flowed south-east, with little variation due to tidal changes. The model predictions replicated this behaviour. Below 100 m, the influence of the tides became more pronounced, rotating between a south-eastward flow and a north-westward flow with the turning of the tide. Both tidal-scale and large-scale fluctuations in currents were typically reproduced at a similar magnitude and timing.

There was some divergence between the predicted and measured currents, mostly between data from July to October inclusive, due to the occurrence of solitons (or high frequency internal waves that can produce unusually high currents) which was highlighted by Fugro (2015). Despite these variations, the statistical comparisons between the measured and predicted current speeds indicate a reasonable to very good agreement (Table 7). Therefore, it can be concluded it is a good comparison and that the predicted current data reliably reproduced the complex conditions within the Barossa offshore development area and surrounding region. The RPS APASA (2015) model validation report provides a more detail regarding the tide and current comparison.

In summary, the Fugro (2015) data provides information specifically for the Barossa offshore development area and is considered the best available and most accurate data for this particular region. This data has been provided and reviewed by RPS to confirm predicted currents applied are accurate. As a result, the current data used herein is considered best available and highly representative of the characteristics influencing the marine environment in the Barossa offshore development area.

Table 7 Statistical evaluation between averaged measured currents and HYCOM ocean current and HYDROMAP tidal current at CP1, CP2 and CP3 at varying water depths (July 2014 to March 2015)

Site	Depth (m BMSL)	RMSE (m/s)	Measured peak value (m/s)	RMSE (%)	RMAE qualification
Mooring CP1	10	0.14	0.71	20	Good
	50	0.14	0.63	22	Very good
	125	0.13	0.61	22	Very good
Mooring CP2	10	0.16	0.82	19	Reasonable
	50	0.14	0.81	17	Good
	125	0.16	0.72	22	Reasonable
Mooring CP3	10	0.15	0.88	18	Very good
	50	0.14	0.78	18	Very good
	125	0.13	0.60	21	Very good

2.5 Environmental reporting criteria

The following environmental criteria were used for the modelling study.

Temperature

The criterion of assessing that temperature is within 3˚C within 100 m from the release location was applied for the PFW dispersion modelling study. This criterion represents a commonly adopted industry standard as part of the International Finance Corporation (IFC) Industry Environmental, Health and Safety Guideline for Offshore Oil and Gas Development (IFC 2015) for cooling water discharges, and is therefore not directly applicable to PFW. However, it has been used as a guide in the absence of any formally recognised criterion for PFW discharges.

Maximum extent of the plume

As the field is not yet producing, it is not possible to undertake ecotoxicological tests on the PFW. Therefore, the far-field modelling results are presented as dilution contour maps at intervals of 1:50, 1:75, 1:100, 1:150, 1:200, 1:300 and 1:500. Given an initial OIW concentration of 30 mg/L, the dilutions correspond to 0.6, 0.4, 0.3, 0.2, 0.15, 0.1 and 0.06 mg/L. This approach allows a direct comparison of the minimum dilutions for various chemicals (or whole stream) once ecotoxicological testing on actual Barossa operational discharges can be undertaken.

As a guide, the dissolved hydrocarbon thresholds from the Woodside Browse Floating LNG PFW were calculated to be 0.09 mg/L (or 0.09 ppm) based on Torosa condensate. This is equivalent to a dilution of 1:333 based on an initial OIW concentration 30 mg/L limit (Woodside Energy Ltd. 2011). It is understood that this threshold provides protection among the most sensitive of species (algae and copepods) and that the vast majority of species have higher tolerance compared to this threshold.

Based on RPS's experience and knowledge, ecotoxicological results from PFW discharges on the North West Shelf and in the Timor Sea shows that a dilution of 1:300 (or 0.1 mg/L concentration) is a conservative threshold for species protection for no effect concentration.

Additionally, the far-field modelling was used to calculate the distance to achieve an OIW concentration of ≤ 7 µg/L, representing a 99% species protection level based on ANZECC/ARMCANZ (2000) guidelines. This is equivalent to a dilution of 1:4,285 based on an initial OIW concentration of 30 mg/L limit.

3.0 Modelling results

3.1 Near-field modelling

Figure 17 to Figure 22 (note the differing x- and y-axis aspect ratios) show the change in minimum temperature and dilution of the PFW plume under the varying flow rates (minimum and maximum), seasonal conditions (summer, transitional and winter) and current speeds (weak, medium and strong). The figures show the predicted distances travelled by the plume along the horizontal before contacting the sea surface.

The results showed that due to the momentum of the PFW discharge, a turbulent mixing zone was created approximately 1 m below the discharge pipe which is 10 m below the water surface. The increased flow rate only marginally changed (<0.2 m) the depth of the predicted mixing zone. While the increased ambient current strengths were shown to slightly reduce the plunge depth, the stronger currents did considerably force the plume further horizontally from the discharge pipe.

Following the initial plunge, the plume remained buoyant enough to rise to the surface for both flow rates (1,590 m^3/d and 3,260 m^3/d) and all current strengths. As the plume rose through the water column, it continued to mix with ambient waters, however as the plume approached the sea surface the rate of mixing slowed.

Table 8 to Table 9 show the predicted plume characteristics varying flow rates, seasonal conditions and current speeds. The strong currents were capable of pushing the buoyant plume horizontally up to a maximum distance of 36.3 m during the 1,590 m^3/d flow rate and 26.3 m during the 3,260 m^3/d flow rate, allowing for additional mixing prior to reaching the surface. The plume for the lower discharge rate had travelled further before reaching the water surface. The diameter of the PFW plume at the sea surface ranged from 3.0 m to 10.6 m during weak and strong currents under 1,590 m^3/d flow rate and 2.9 m to 10.0 m during weak and strong currents under 3,260 m^3/d flow rate conditions.

In all cases, the temperature of the PFW plume was predicted to be within 3°C of the ambient (background) temperature within 100 m from the release location. Appendix A and Appendix B provide graphs of the predicted difference in temperature between the PFW plume and ambient temperature versus distance from release location for the 1,590 m^3/d and 3,260 m^3/d flow rates, respectively. The temperature of the PFW plume generally returned to within 3°C of ambient water temperature within 2 m horizontally from the release location.

For all seasons and flow rates modelled, the primary factor influencing dilution of the PFW, was the strength of the ambient current. Weak currents had little effect on the plume during the rise process and therefore, it reached the sea surface quickly, slowing the rate of dilution (see Table 8 to Table 9 and Figure 17 to Figure 22). The average dilutions of the PFW plume upon encountering the sea surface under medium and strong constant currents were predicted to be >1:190 during the 1,590 m^3/d flow rate and >1:89 during 3,260 m^3/d flow rate, respectively. Additionally, the minimum dilutions of the PFW plume (i.e. dilution of plume centreline) upon encountering the sea surface under medium and strong constant currents were predicted to be >1:66 during the 1,590 m^3/d flow rate and >1:37 during 3,260 m^3/d flow rate, respectively. Note that these predictions rely on the persistence of current speed and direction over time and does not account for the build-up of the plume.

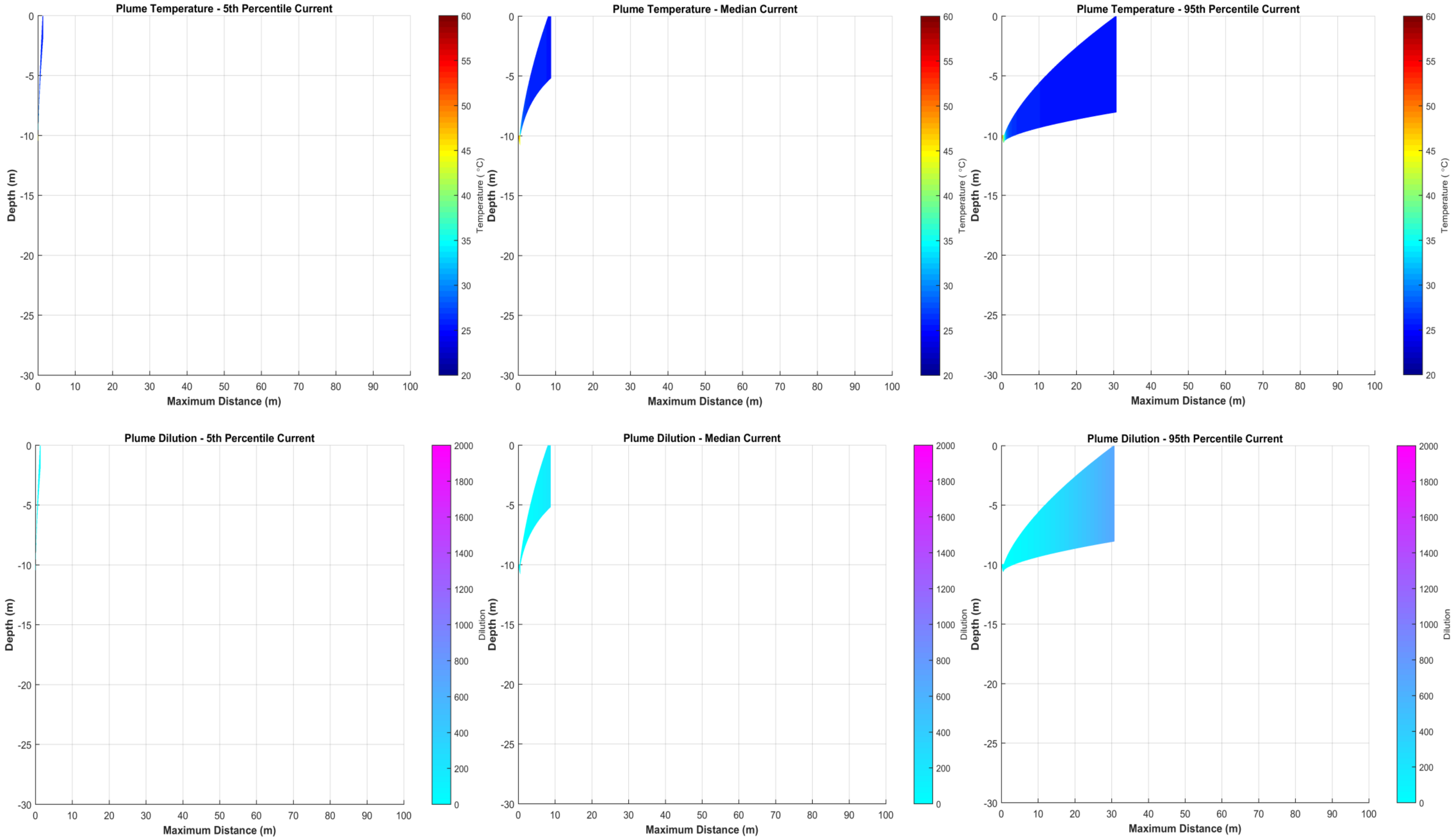


Figure 17 Near-field average temperature and dilution results for constant weak, medium and strong summer currents (1,590 m³/d flow rate).

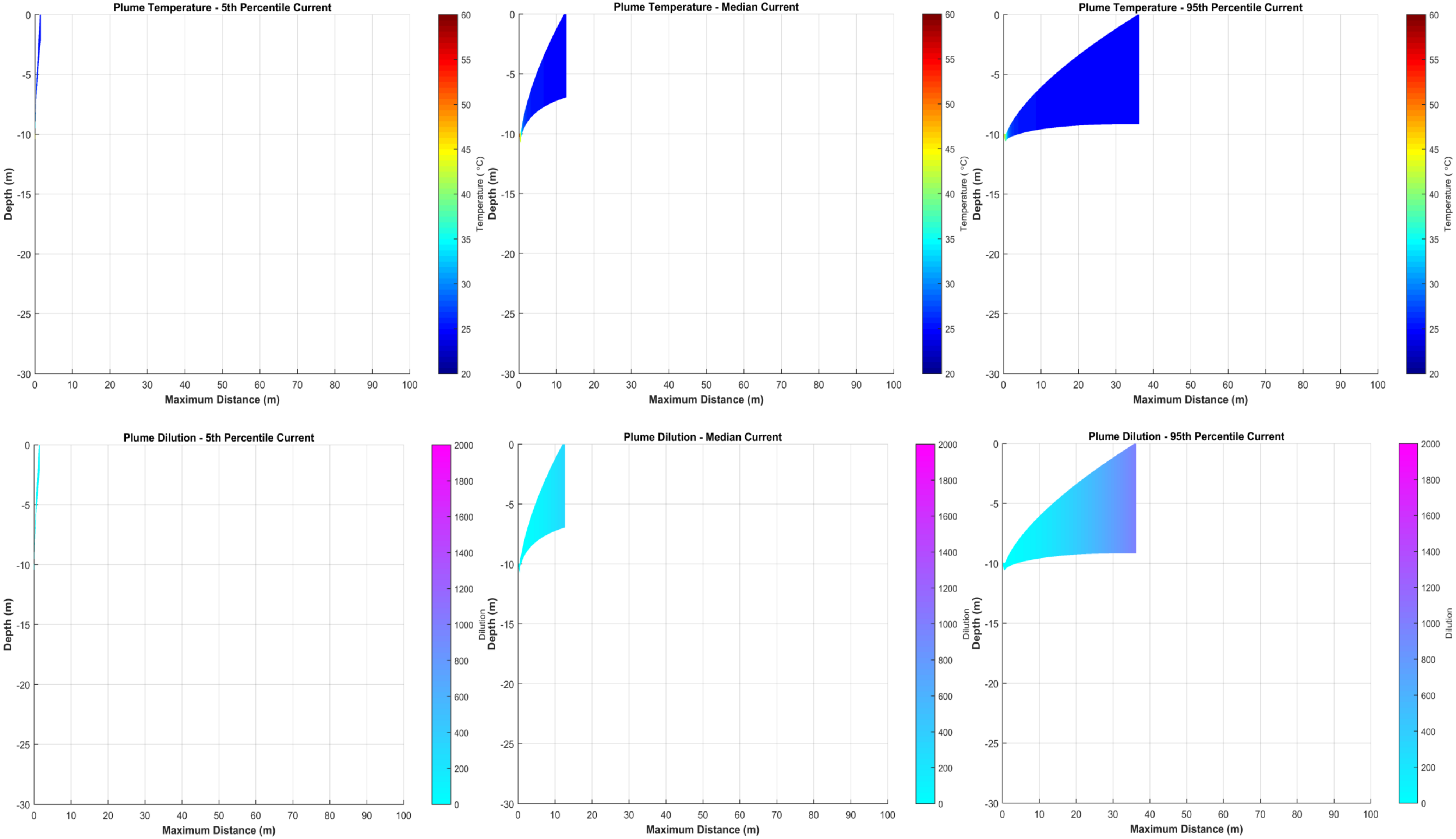


Figure 18 Near-field average temperature and dilution results for constant weak, medium and strong transitional currents (1,590 m^3/d flow rate).

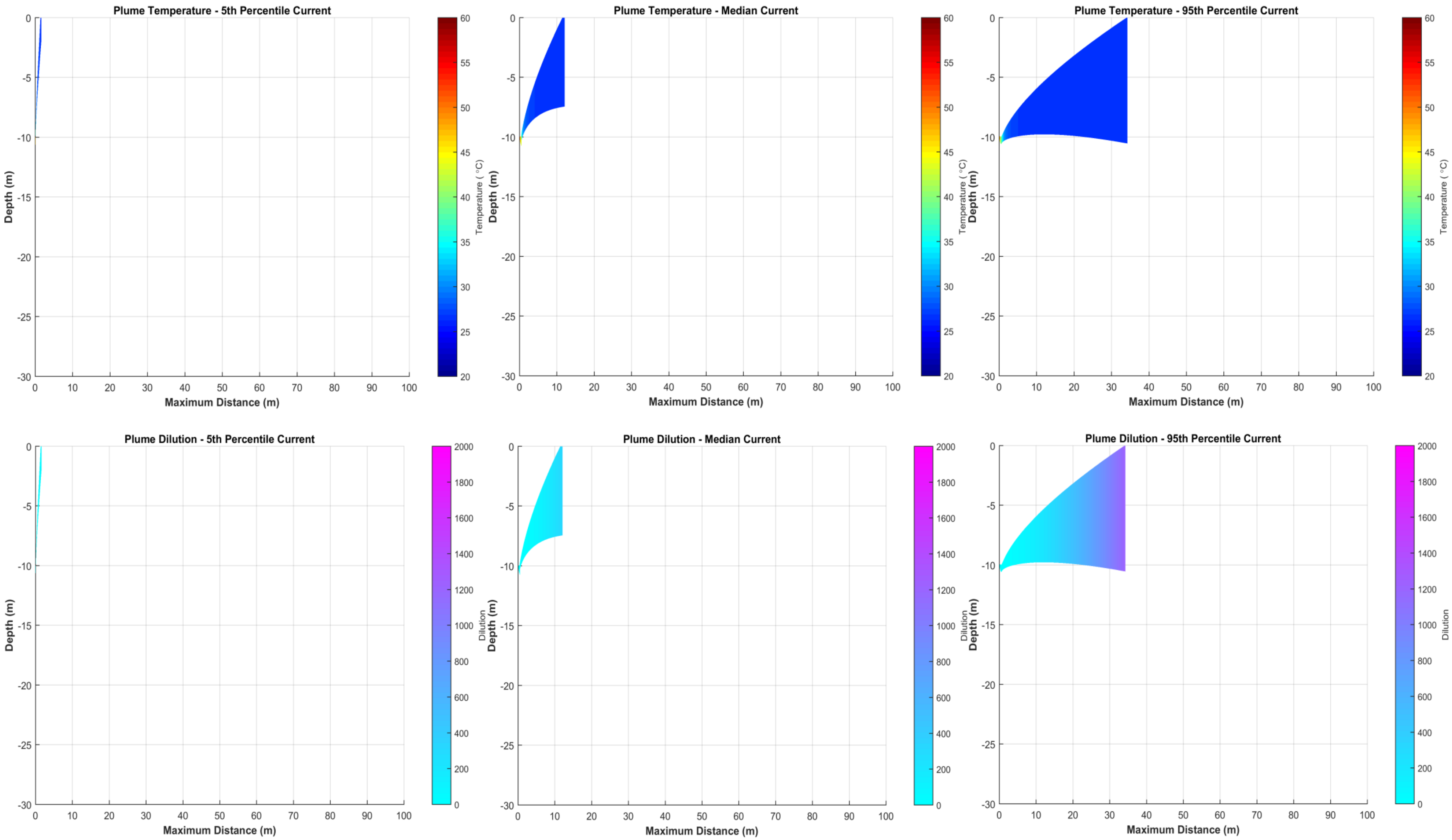


Figure 19 Near-field average temperature and dilution results for constant weak, medium and strong winter currents (1,590 m^3/d flow rate).

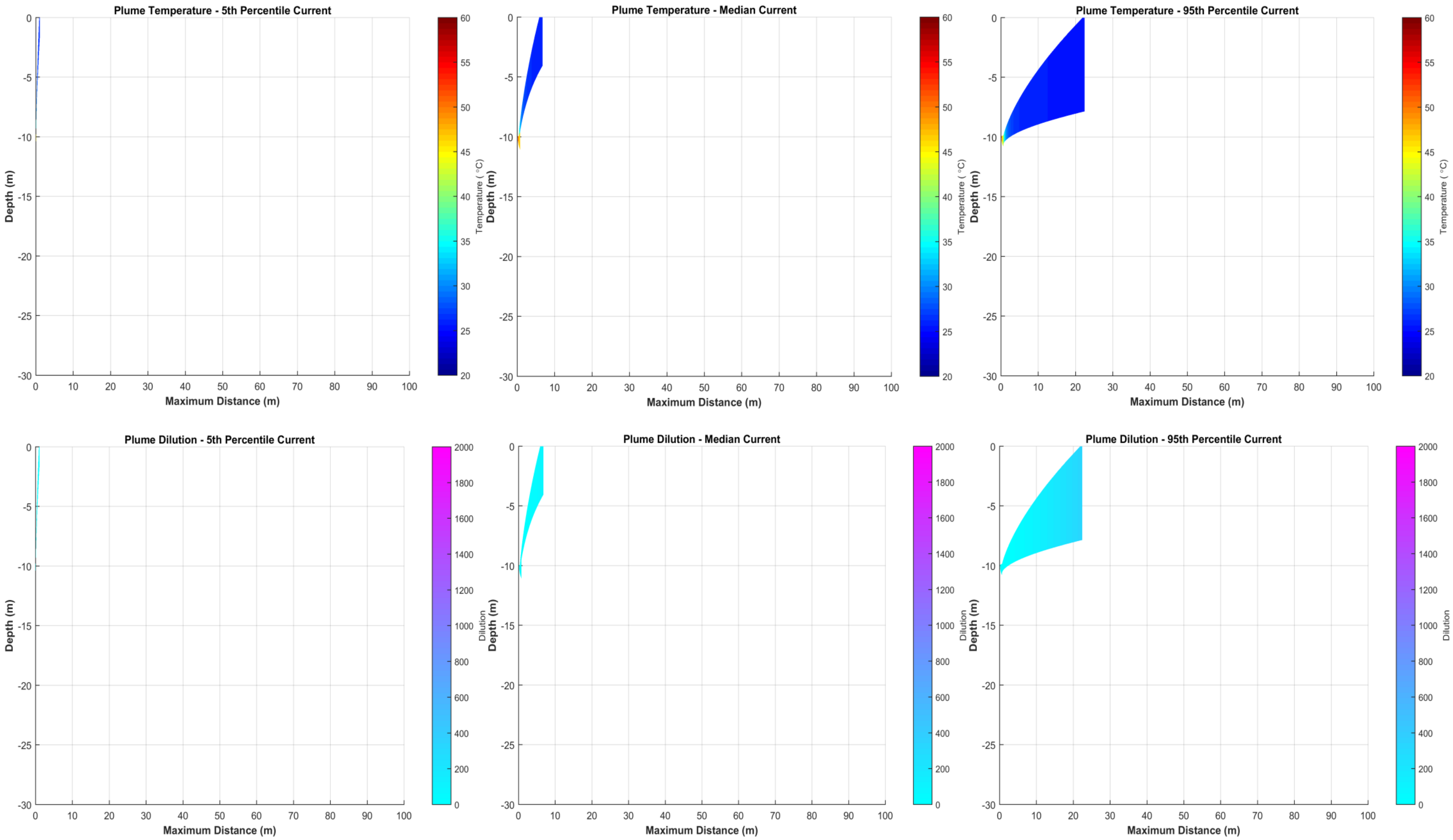


Figure 20 Near-field average temperature and dilution results for constant weak, medium and strong summer currents (3,260 m^3/d flow rate).

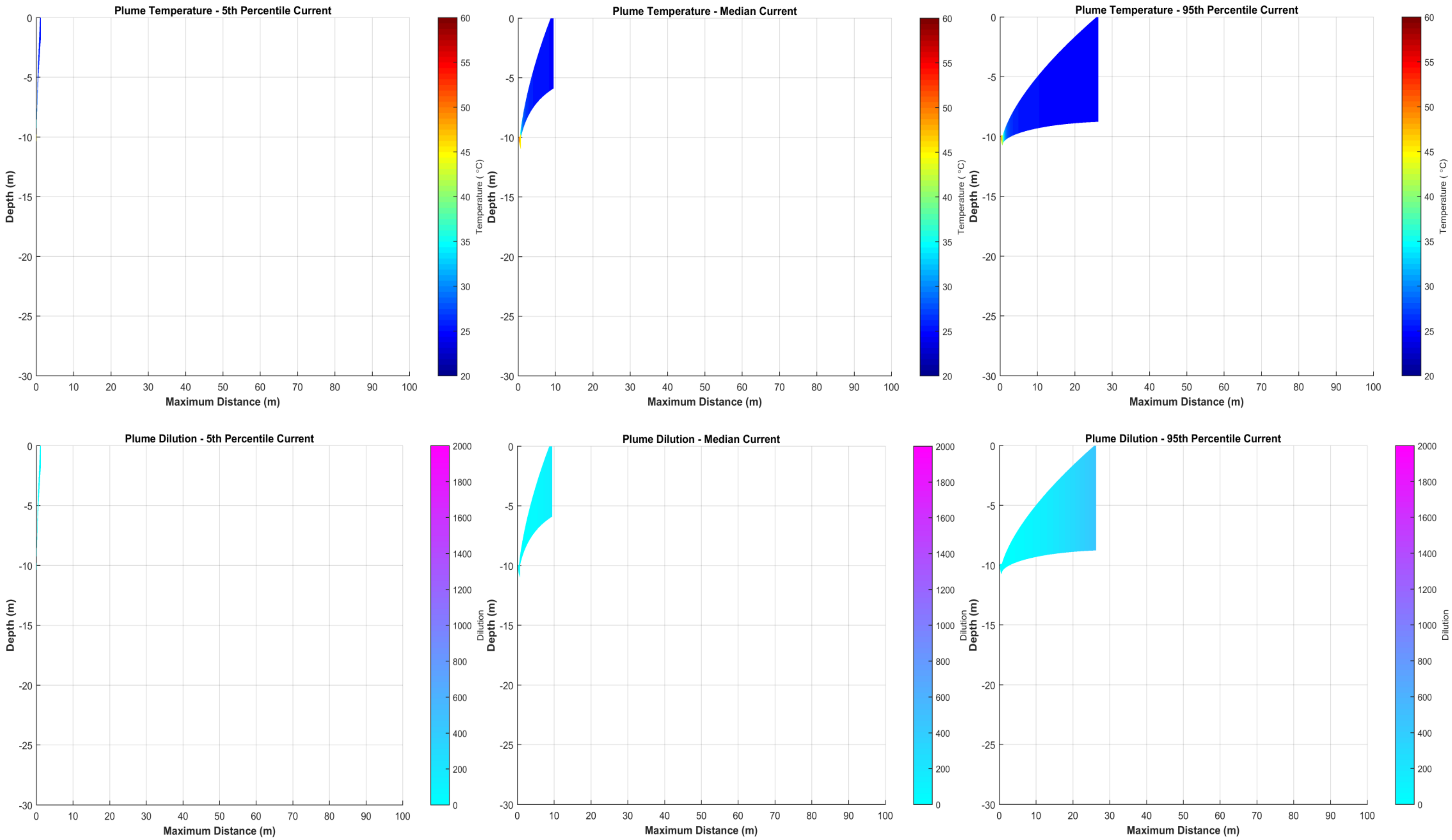


Figure 21 Near-field average temperature and dilution results for constant weak, medium and strong transitional currents (3,260 m^3/d flow rate).

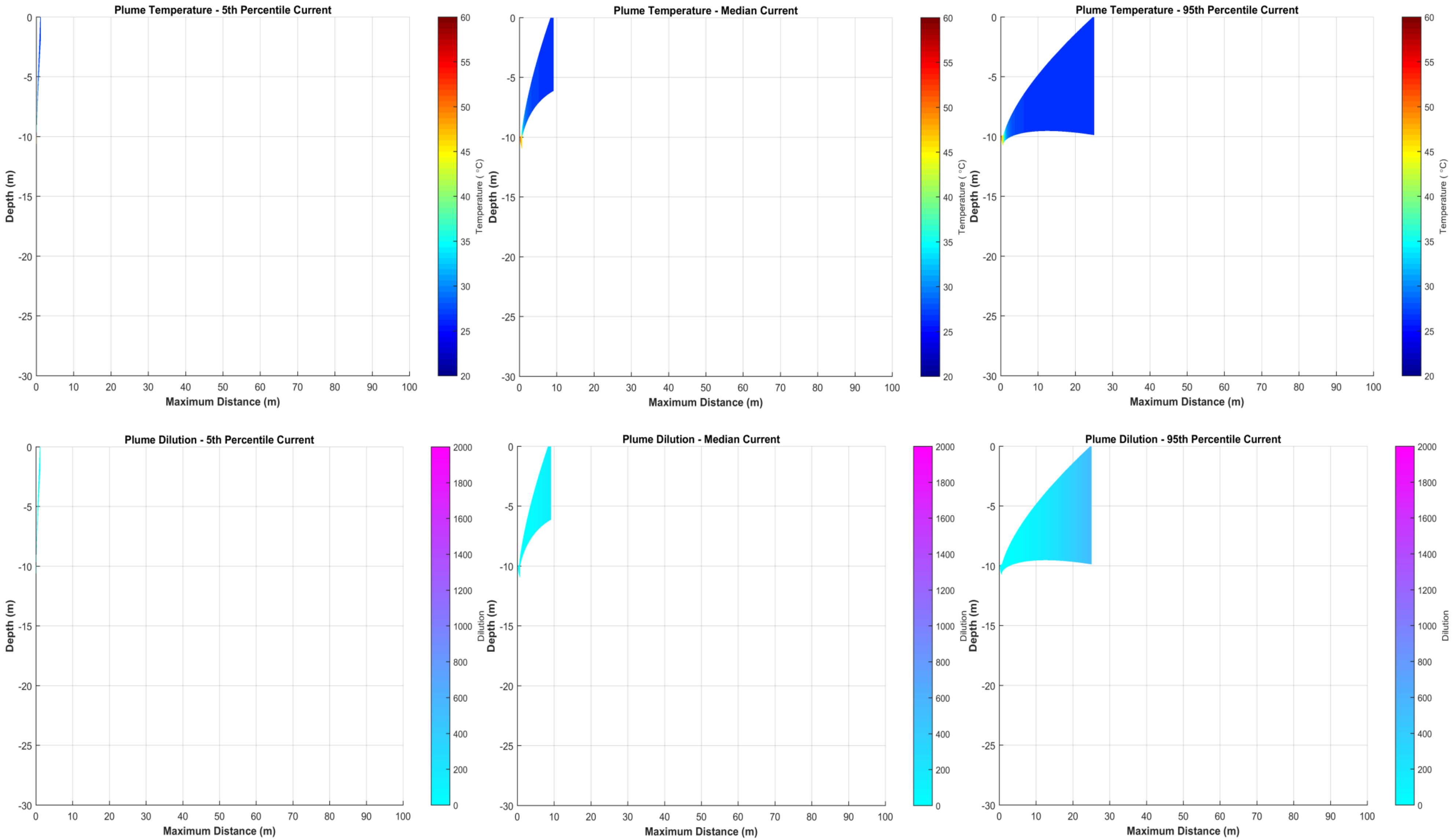


Figure 22 Near-field average temperature and dilution results for constant weak, medium and strong winter currents (3,260 m^3/d flow rate).

Table 8 Predicted plume characteristics upon encountering the sea surface (end of near-field mixing) for the minimum flow rate (1,590 m^3/d flow) for each season and current speed.

Season	Surface current speed (m/s)	Plume diameter at the sea surface (m)	Plume temperature (ºC)	Difference between plume and ambient temperature (ºC)	Dilution of the plume (1:x)		Maximum horizontal distance (m)
					Minimum	Average	
Summer	Weak (0.04)	3.0	25.9	0.5	34	67	1.4
	Medium (0.11)	5.9	25.6	0.2	66	190	8.8
	Strong (0.27)	8.1	25.5	0.1	177	698	30.8
Transitional	Weak (0.05)	3.4	25.2	0.5	38	76	1.6
	Medium (0.14)	7.3	24.8	0.1	92	318	12.7
	Strong (0.29)	9.2	24.7	0.0	253	992	36.3
Winter	Weak (0.03)	3.3	26.7	0.4	39	76	1.6
	Medium (0.11)	7.8	26.4	0.1	102	329	12.1
	Strong (0.27)	10.6	26.3	0.0	314	1,224	26.3

Table 9 Predicted plume characteristics upon encountering the sea surface (end of near-field mixing) for the maximum flow rate (3,260 m^3/d flow) for each season and current speed.

Season	Surface current speed (m/s)	Plume diameter at the sea surface (m)	Plume temperature (ºC)	Difference between plume and ambient temperature (ºC)	Dilution of the plume (1:x)		Maximum horizontal distance (m)
					Minimum	Average	
Summer	Weak (0.04)	2.9	26.3	0.9	20	40	1.1
	Medium (0.11)	5.1	25.8	0.4	37	89	6.8
	Strong (0.27)	8.0	25.5	0.1	87	336	22.5
Transitional	Weak (0.05)	3.1	25.5	0.8	22	44	1.2
	Medium (0.14)	6.5	25.0	0.3	47	140	9.5
	Strong (0.29)	8.9	24.8	0.1	116	451	26.3
Winter	Weak (0.03)	3.2	27.0	0.7	23	45	1.2
	Medium (0.11)	6.9	26.5	0.2	51	141	9.2
	Strong (0.27)	10.0	26.4	0.1	139	534	25.1

3.2 Far-field modelling

3.2.1 General observations

Figure 23 to Figure 24 show screenshots of predicted dilutions (equivalent concentrations) for the OIW every 2 hours from 12 pm to 10 pm on the 10^{th} December 2010. The results are based on the maximum flow rate of 3,260 m^3/d.

The images have been included to illustrate that the concentrations (and in turn dilutions) became more variable over time as a result of the change in current directions and speeds. Higher dilutions (lower concentrations) were predicted during periods of increased current speeds, whereas patches of lower dilutions (higher concentrations) tended to accumulate during the turn of the tide and/or during prolonged periods of decreased current speeds. During these periods of decreased current speed, the plume had a more continuous appearance, with the higher concentration patches moving as a unified group. These findings are in agreement with the research of King and McAllister (1997, 1998) who also noted that concentrations of oil within PFW plumes generated by the Harriet Alpha platform (located on the North West Shelf of Western Australia) were patchy and peak around the turn of the tides. Furthermore, the far-field modelling results demonstrated that due to the buoyant nature of the plume, the plume predominantly remained in the 0 m–10 m surface waters.

Figure 25 shows time series graphs of the OIW dilutions at 4 compass points (north, east, west and south) 100 m from the release location during December 2010 conditions (3,260 m^3/d flow rate). As the graph shows, high dilutions of 1:3,000 were achieved daily within 100 m of the release location, over the 31 day period in all four directions.

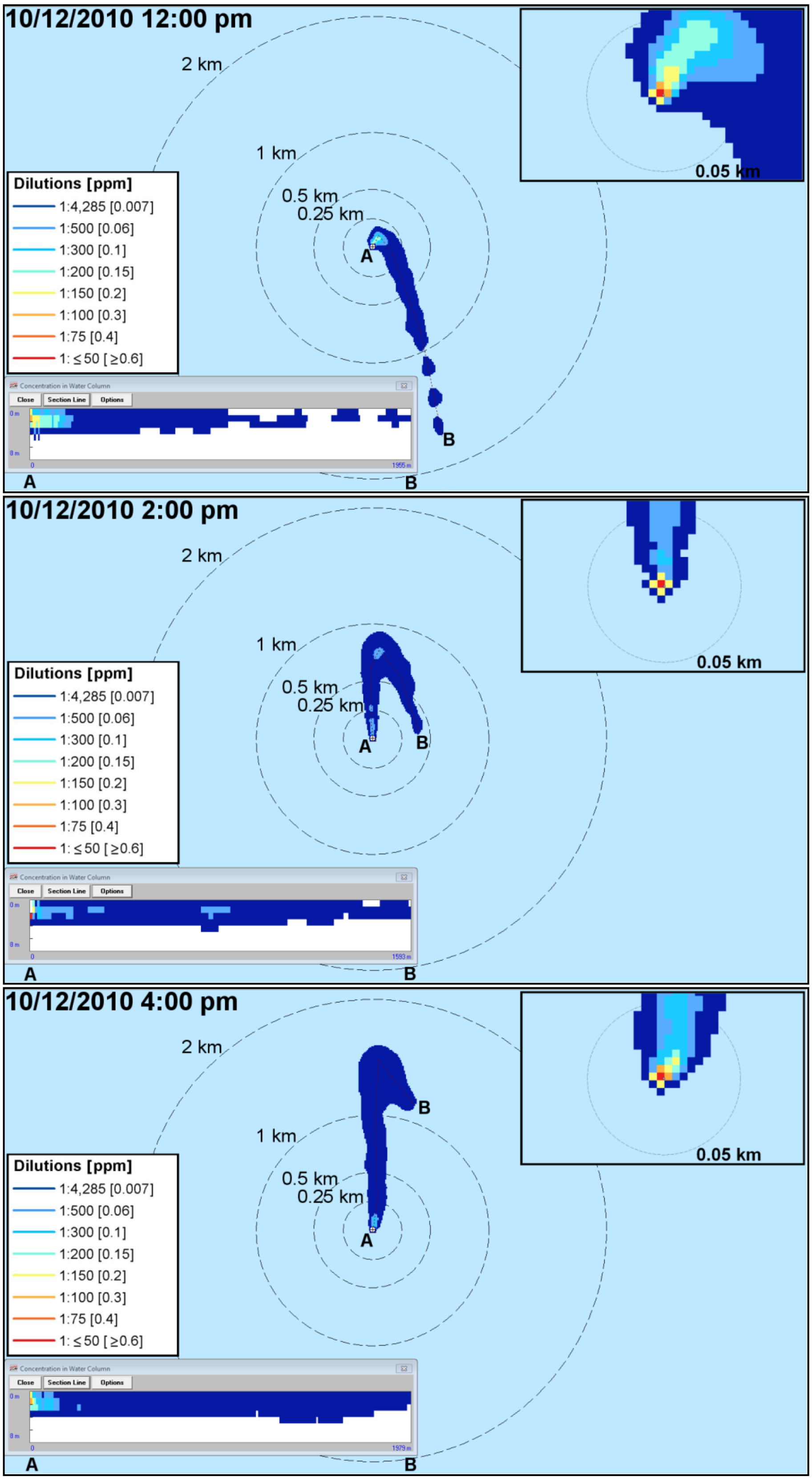


Figure 23 Screenshots every 2 hours of the predicted OIW dilutions (and equivalent concentration, mg/L) from 12 pm to 4 pm 10th December 2010. Results are based on the surface waters (0-1 m depth) for the maximum discharge rate scenario (3,260 m^3/d flow with 30 mg/L initial OIW concentration). Figure insets illustrate zoomed-in view of predicted plume dilutions.

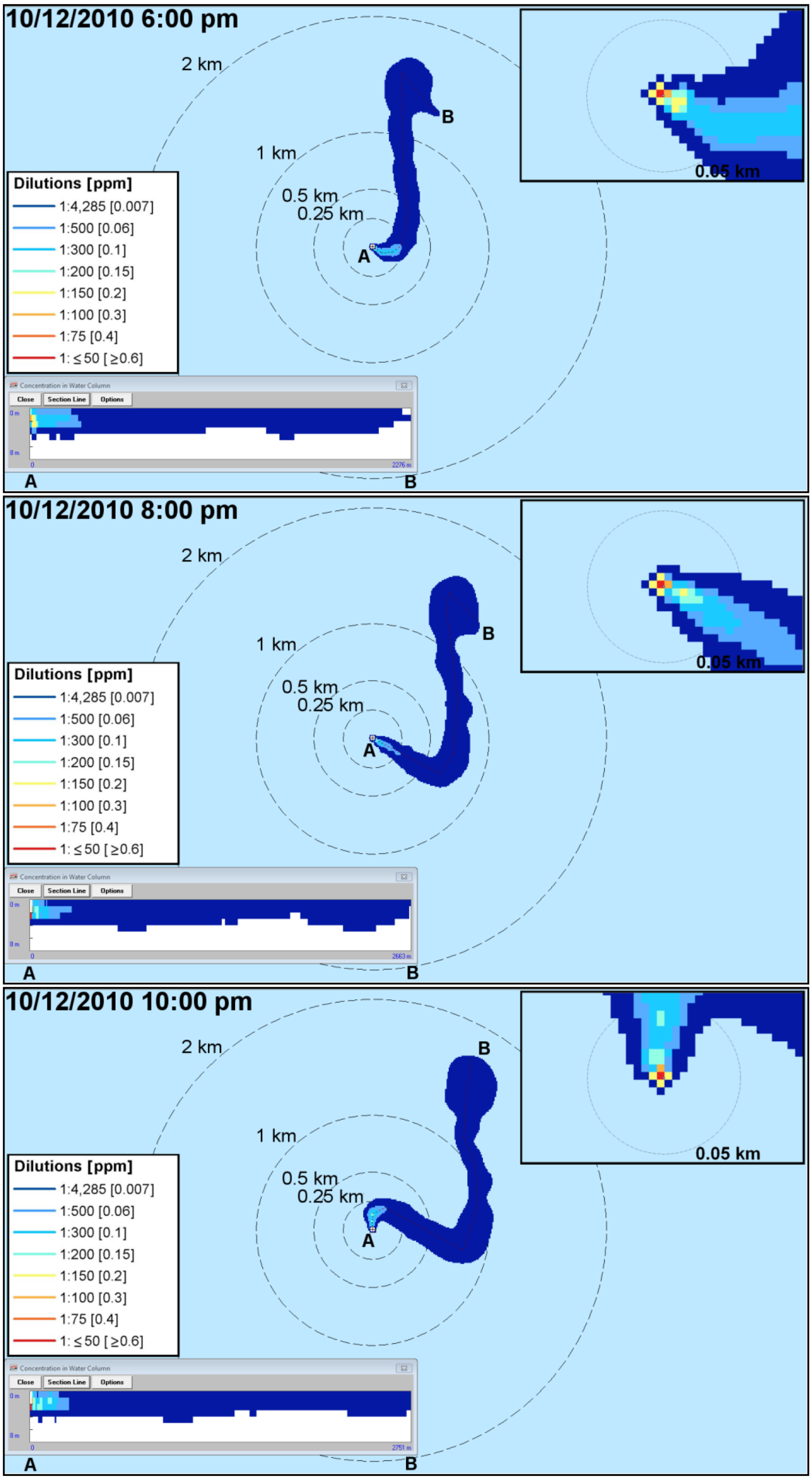


Figure 24 Screenshots every 2 hours of the predicted OIW dilutions (and equivalent concentration, mg/L) from 6 pm to 10 pm 10th December 2010. Results are based on the surface waters (0-1 m depth) for the maximum discharge rate scenario (3,260 m^3/d flow with 30 mg/L initial OIW concentration). Figure insets illustrate zoomed-in view of predicted plume dilutions.

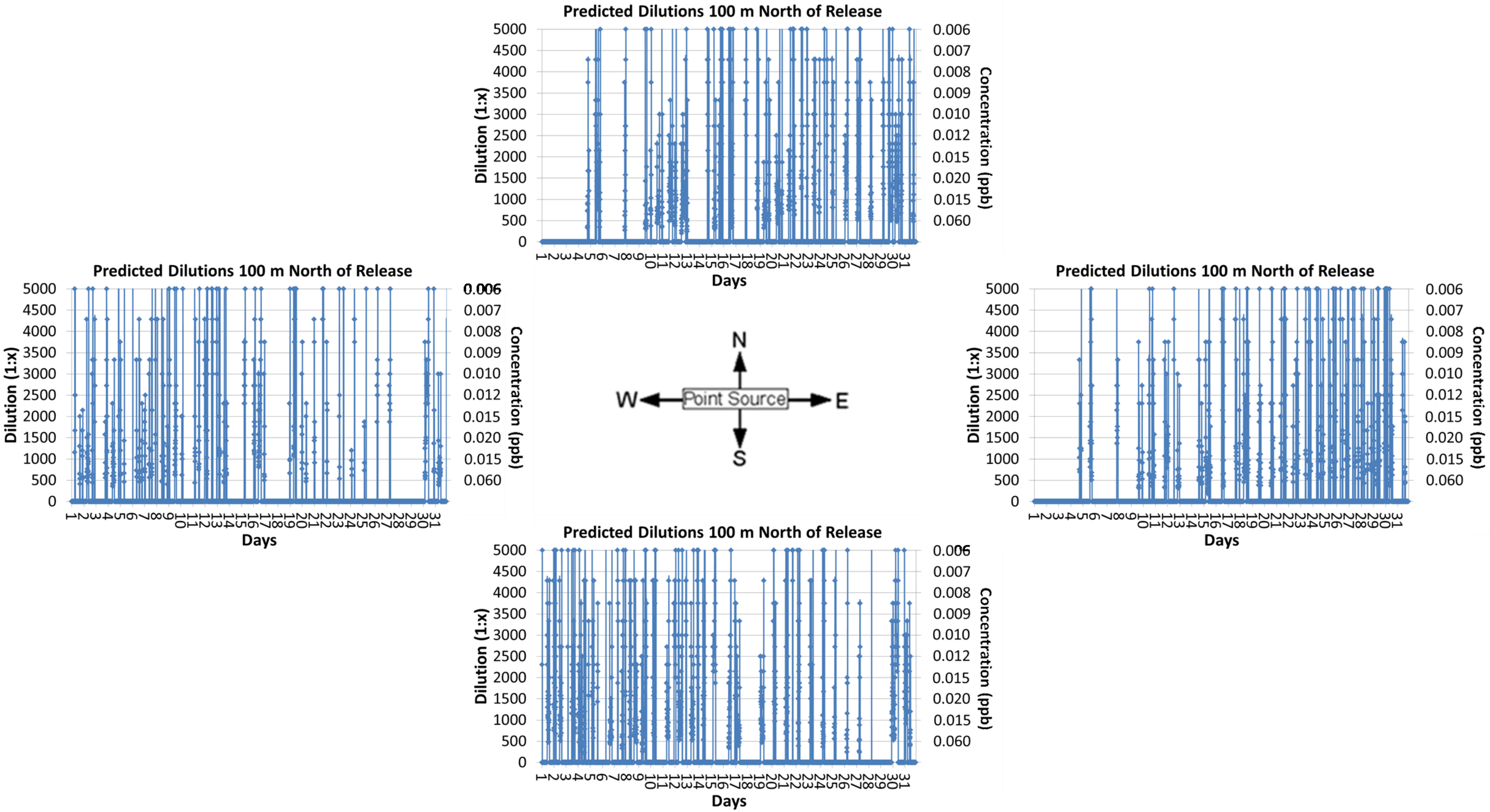


Figure 25 Predicted OIW dilutions at four compass points (north, east, west and south), 100 m from the release location during December 2010 conditions and maximum flow rate (3,260 m^3/d)

3.2.2 Seasonal analysis

The 10 minute model outputs for each month from each of the three years (2010, 2012 and 2014) were combined and analysed according to the respective season (i.e. summer – December, January, February; transitional periods – March, April and September to November; and winter – May to August). This approach assists with identifying the potential for exposure on a seasonal basis, to the nearest shoals/banks to the Barossa offshore development area (i.e. Evans Shoal, Tassie Shoal and Lynedoch Bank) whilst taking into account the interannual variability.

Table 10 shows the minimum dilution achieved at specific distances from the release location for each flow rate and season.

Table 11 provides a summary of the maximum distances from the release location to achieve a given dilution for each flow rate and season. Dilutions of 1:4,285 (equivalent to approximately 7 µg/L, which represents a 99% species protection level based on ANZECC/ARMCANZ (2000) guidelines) were predicted to occur between 3.45 km to 4.57 km from the release location for the 1,590 m^3/d flow rate and 5.53 km to 6.07 km for the 3,260 m^3/d flow rate. Based on the maximum distance from the 1:4,285 dilution contour to the nearest shoal/bank being Evans Shoal (minimum distance of approximately 59.4 km and 57.9 km, respectively) no exposure is expected to non-transient species. However, pelagic species may come into contact with the plume and may be exposed intermittently.

Table 12 presents the total area of coverage for a given dilution for each flow rate and season. Based on the 1,590 m^3/d flow rate and 1:4,285 dilution, the area of exposure was largest during the summer conditions (6.31 km^2) and smallest during the transitional months (4.29 km^2). The extent was found to be influenced by the rate of discharge. For example, by increasing the flow rate to 3,260 m^3/d and maintaining the initial OIW concentration of 30 mg/L, the 1:4,285 dilution area increased by approximately 96% for the summer conditions (from 6.31 km^2 to 12.39 km^2).

Figure 26 to Figure 31 show the extent of the minimum dilutions (under 2010, 2012 and 2014 conditions) for each flow rate and season assuming an initial OIW concentration of 30 mg/L. Note that the images represent the lowest predicted dilution (highest concentration) at any given time-step through the water column and do not take into account frequency or duration.

Table 10 Minimum dilution achieved at specific distances from the PFW discharge release location for each flow rate and season.

Flow rate (m^3/d)	Season	Minimum achieved dilution at specific distances from the release location						
		0.1 km radius	0.5 km radius	1 km radius	2 km radius	3 km radius	5 km radius	> 5 km radius
1,590	Summer	1:300	1:500	1:4,285	1:4,285	1:4,285	>1:4,285	>1:4,285
	Transitional	1:200	1:4,285	1:4,285	1:4,285	1:4,285	>1:4,285	>1:4,285
	Winter	1:200	1:500	1:500	1:4,285	1:4,285	>1:4,285	>1:4,285
3,260	Summer	1:100	1:300	1:500	1:500	1:4,285	1:4,285	1:4,285
	Transitional	1:100	1:200	1:500	1:4,285	1:4,285	1:4,285	1:4,285
	Winter	1:100	1:300	1:500	1:500	1:4,285	1:4,285	1:4,285

Table 11 Maximum distance from the PFW discharge release location to achieve a given dilution for each flow rate and season.

Flow rate (m^3/d)	Season	Maximum distance (km) from release location to achieve given dilution							
		1:50 dilution	1:75 dilution	1:100 dilution	1:150 dilution	1:200 dilution	1:300 dilution	1:500 dilution	1:4,285 dilution
1,590	Summer	<0.01	0.01	0.02	0.02	0.07	0.16	0.48	3.45
	Transitional	<0.01	0.01	0.02	0.02	0.06	0.15	0.41	3.88
	Winter	<0.01	0.01	0.02	0.02	0.07	0.18	0.49	4.57
3,260	Summer	0.02	0.04	0.07	0.11	0.30	0.68	2.26	5.91
	Transitional	0.02	0.03	0.06	0.10	0.29	0.71	1.90	5.53
	Winter	0.02	0.04	0.07	0.11	0.35	0.76	2.88	6.07

Table 12 Total area of coverage for a given dilution for each flow rate and season.

Flow rate (m3/d)	Season	Total area (km^2) of coverage for a given dilution							
		1:50 dilution	1:75 dilution	1:100 dilution	1:150 dilution	1:200 dilution	1:300 dilution	1:500 dilution	1:4,285 dilution
1,590	Summer	<0.001	<0.001	<0.001	<0.001	0.005	0.024	0.15	6.31
	Transitional	<0.001	<0.001	<0.001	<0.001	0.003	0.018	0.11	4.29
	Winter	<0.001	<0.001	<0.001	<0.001	0.005	0.024	0.16	6.18
3,260	Summer	<0.001	<0.001	0.003	0.004	0.049	0.178	1.10	12.40
	Transitional	<0.001	<0.001	0.003	0.003	0.041	0.158	0.91	8.93
	Winter	<0.001	<0.001	0.004	0.004	0.049	0.178	1.11	11.97

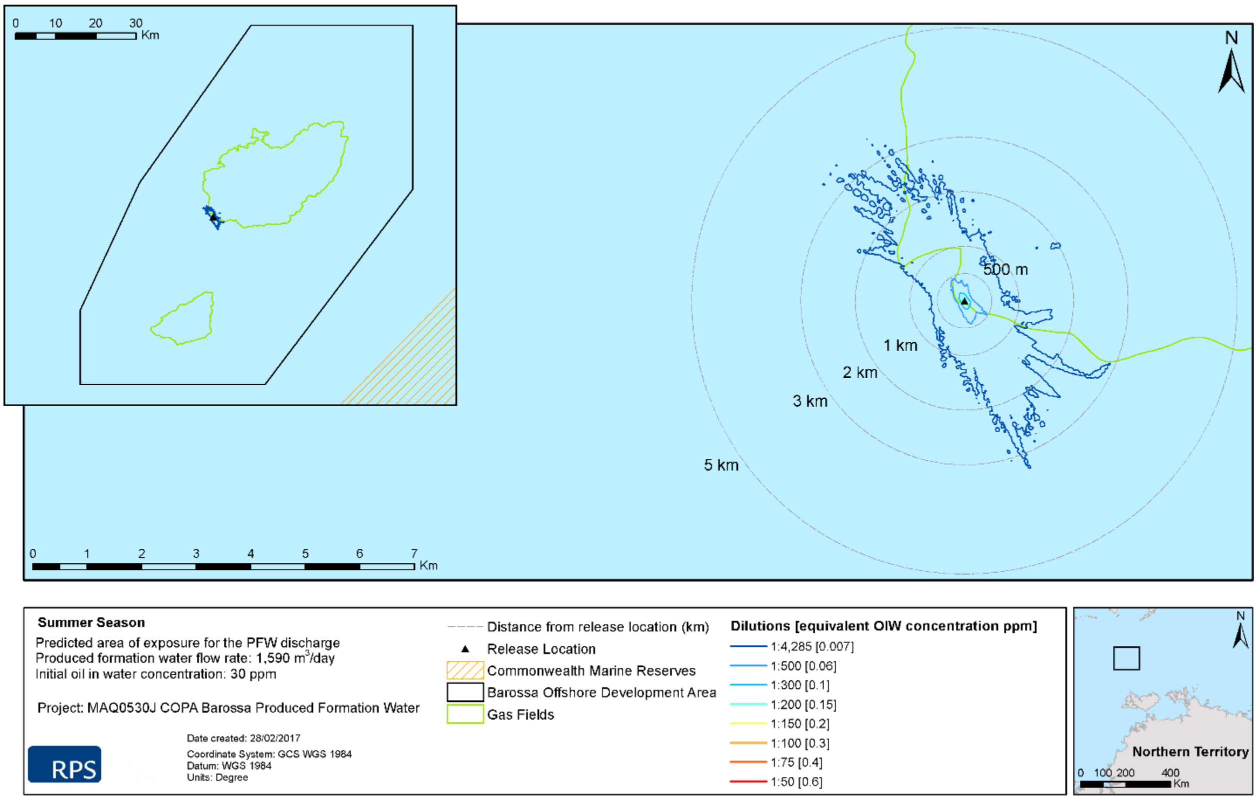


Figure 26 Predicted OIW dilutions under summer conditions for the minimum PFW flow rate (1,590 m^3/d).

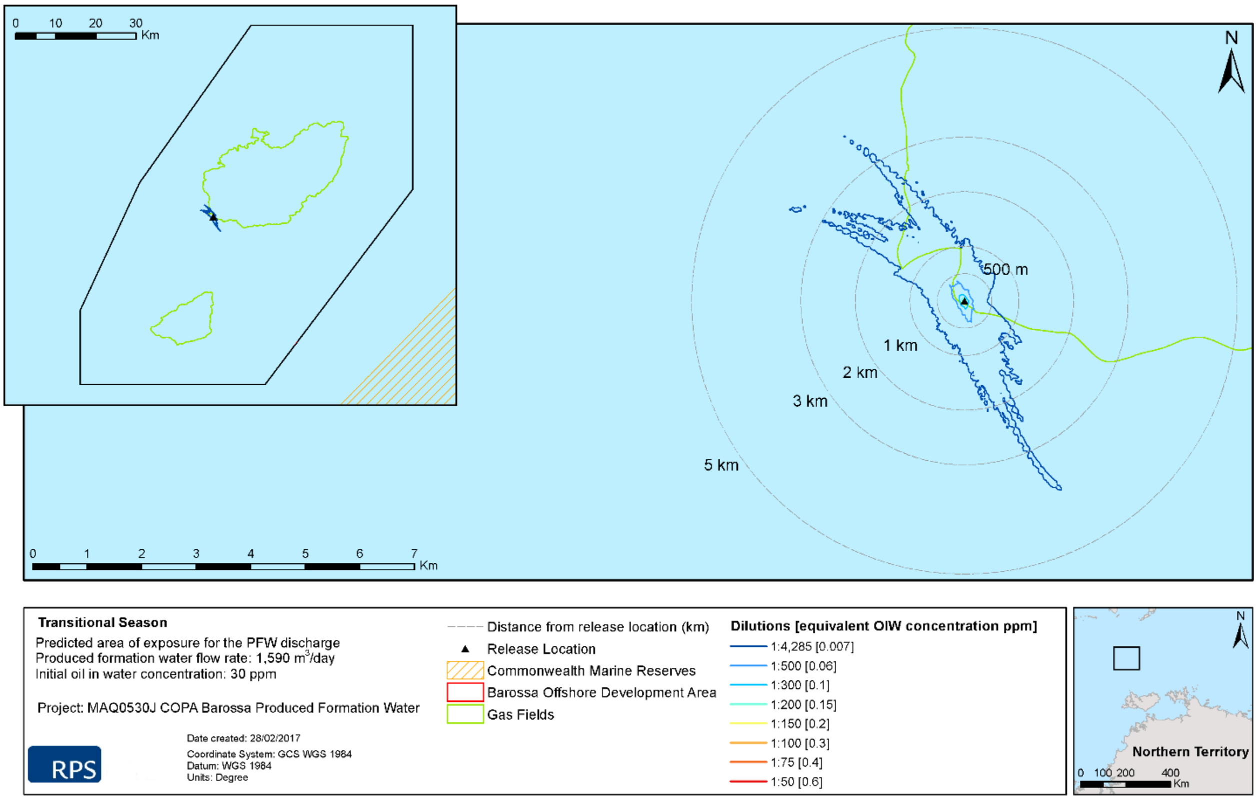


Figure 27 Predicted OIW dilutions under transitional conditions for the minimum PFW flow rate (1,590 m^3/d)

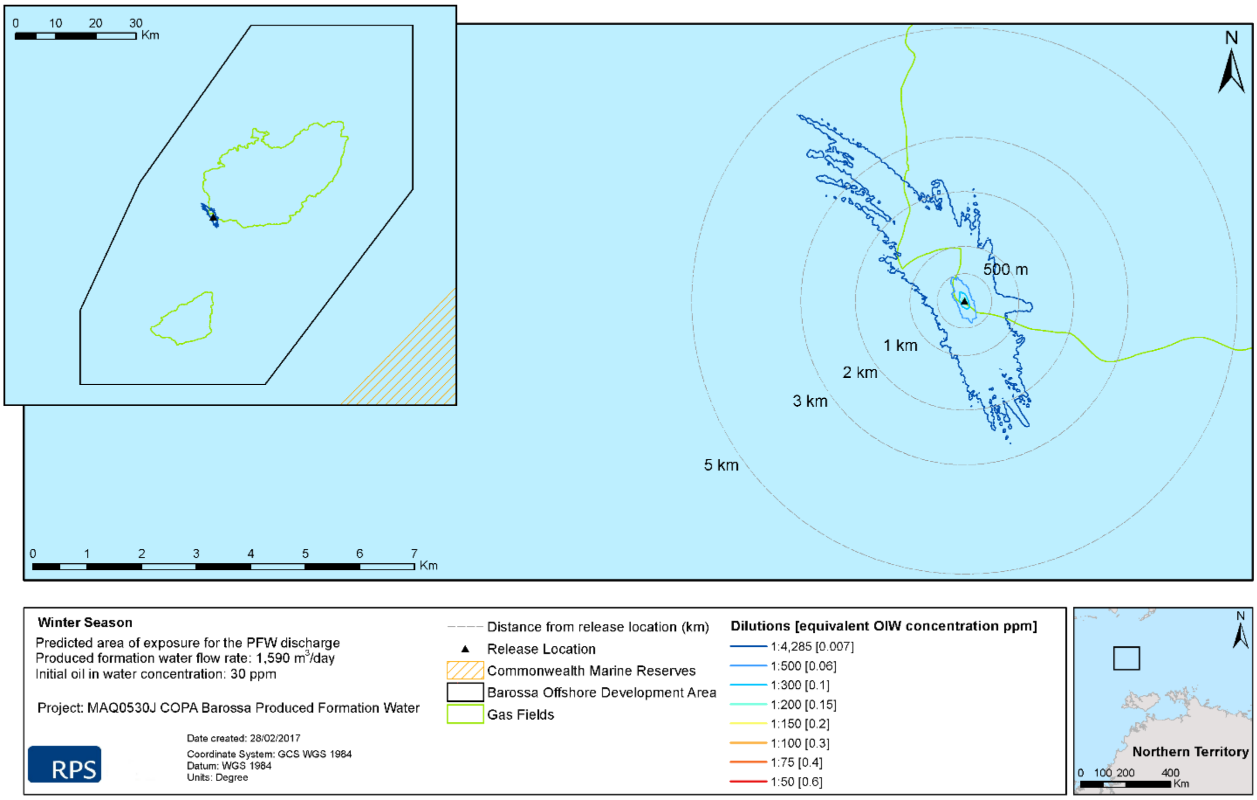


Figure 28 Predicted OIW dilutions under winter conditions for the minimum PFW flow rate (1,590 m^3/d).

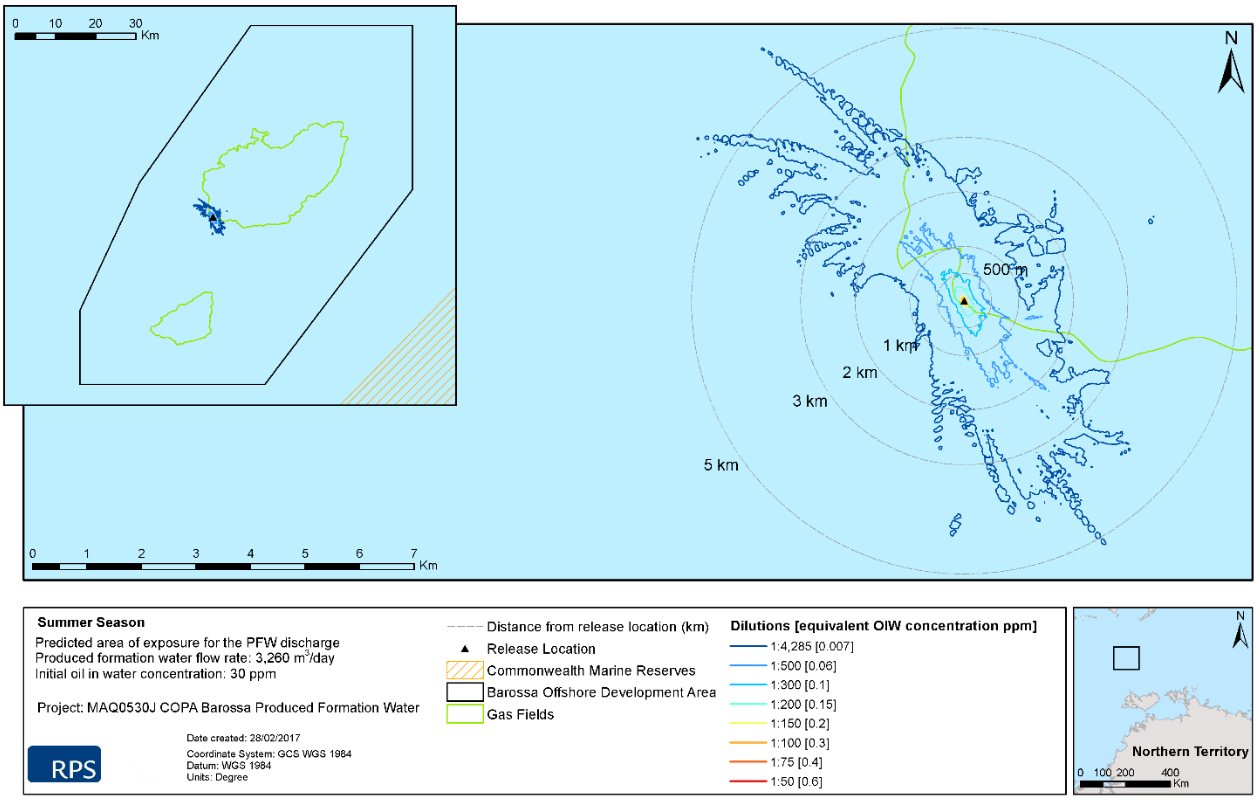


Figure 29 Predicted OIW dilutions under summer conditions for the maximum PFW flow rate (3,260 m^3/d).

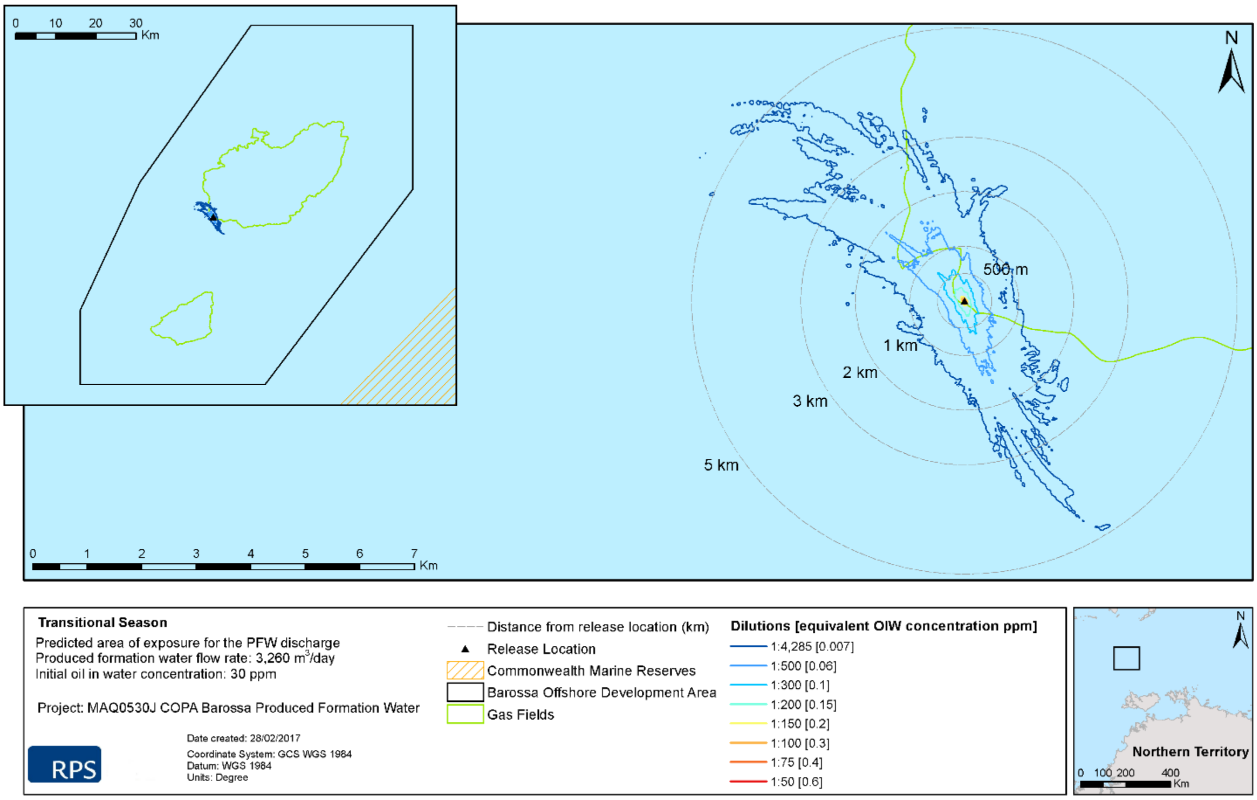


Figure 30 Predicted OIW dilutions under transitional conditions for the maximum PFW flow rate (3,260 m^3/d).

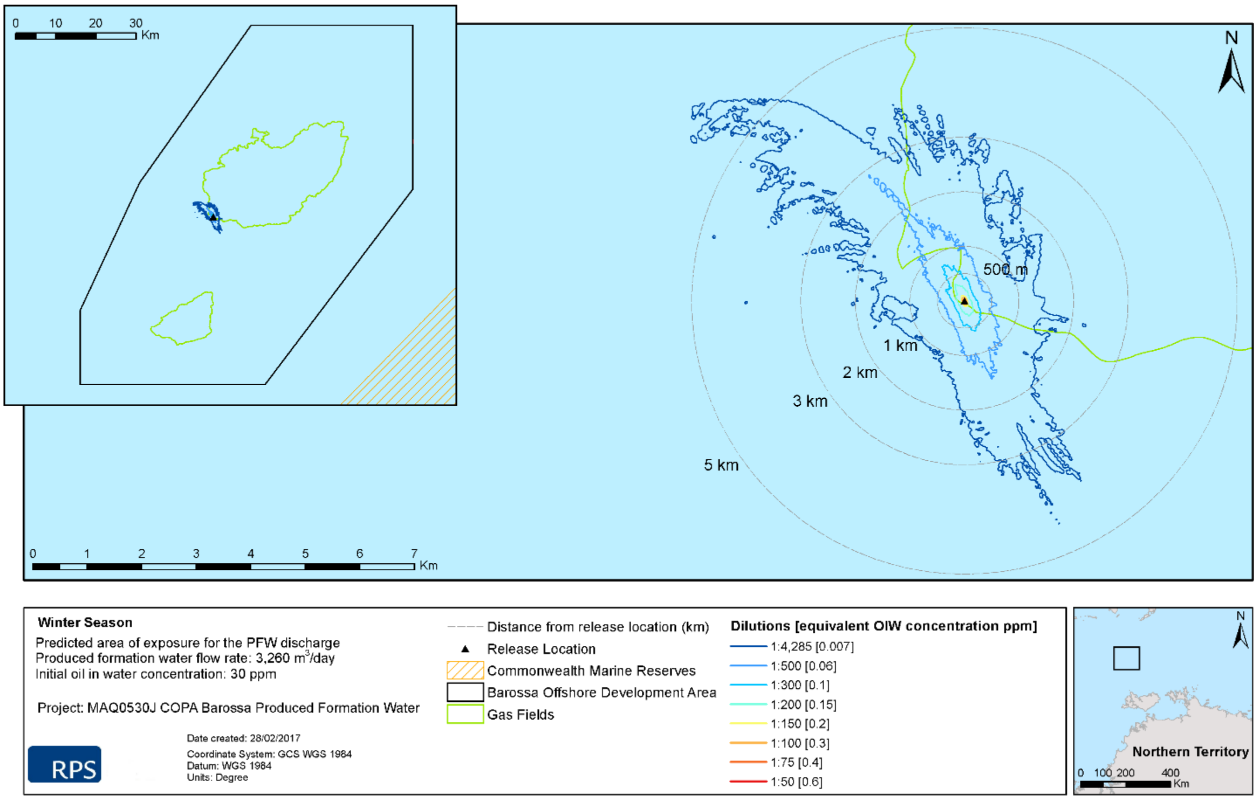


Figure 31 Predicted OIW dilutions under winter conditions for the maximum PFW flow rate (3,260 m^3/d).

3.2.3 Combined analysis

Table 13 shows the maximum distance from release location to achieve a given dilution for each flow rate. The dilutions of 1:4,285 (equivalent to approximately 7 µg/L, which represents a 99% species protection level based on ANZECC/ARMCANZ (2000) guidelines) were predicted to be 4.57 km from the release location for the 1,590 m³/d flow rate and 6.07 km for the 3,260 m³/d flow rate. Based on distance from the 1:4,285 dilution contours to the nearest shoal/bank being Evans Shoal, no exposure is expected to non-transient species. However, pelagic species may come into contact with the plume and maybe exposed intermittently.

Table 14 shows the total area of coverage for a given dilution for each flow rate. Based on the 3,260 m³/d flow rate and 1:4,285 dilution, the area of exposure was 12.39 km², which was approximately 53% larger than the mixing zone generated by the 1,590 m³/d flow rate (8.11 km²).

Figure 32 to Figure 33 present the predicted OIW dilutions based on combined results for 2010, 2012 and 2014 conditions for the minimum and maximum PFW flow rates, respectively.

Table 13 Maximum distance from PFW discharge release location to achieve a given dilution for each flow rate.

Flow rate (m³/d)	Maximum distance (km) from release location to achieve given dilution							
	1:50 dilution	1:75 dilution	1:100 dilution	1:150 dilution	1:200 dilution	1:300 dilution	1:500 dilution	1:4,285 dilution
1,590	<0.01	0.01	0.02	0.02	0.07	0.18	0.49	4.57
3,260	0.02	0.04	0.07	0.11	0.35	0.76	2.88	6.07

Table 14 Total area of coverage for a given dilution for each flow rate.

Flow rate (m³/d)	Total area (km²) of coverage for a given dilution							
	1:50 dilution	1:75 dilution	1:100 dilution	1:150 dilution	1:200 dilution	1:300 dilution	1:500 dilution	1:4,285 dilution
1,590	<0.001	<0.001	<0.001	<0.001	0.005	0.028	1.46	8.11
3,260	<0.001	<0.001	0.004	0.004	0.049	0.178	1.102	12.39

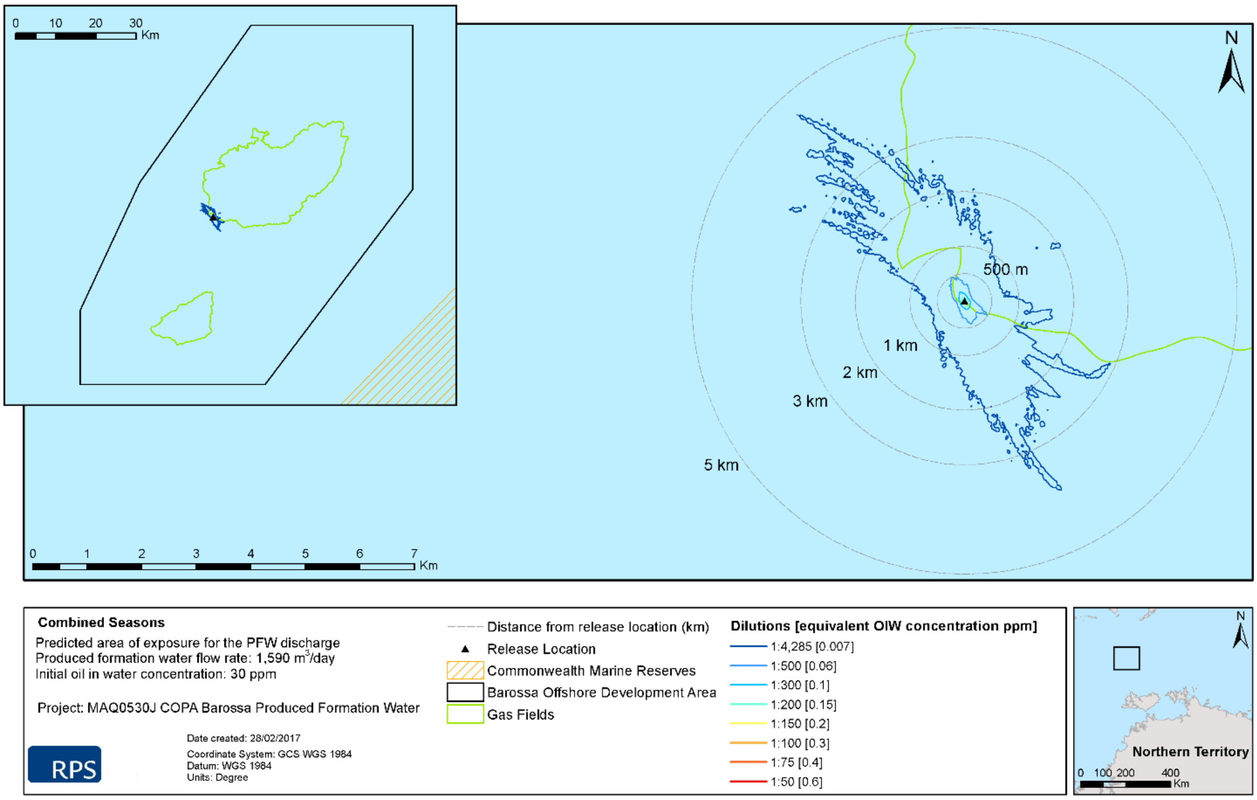
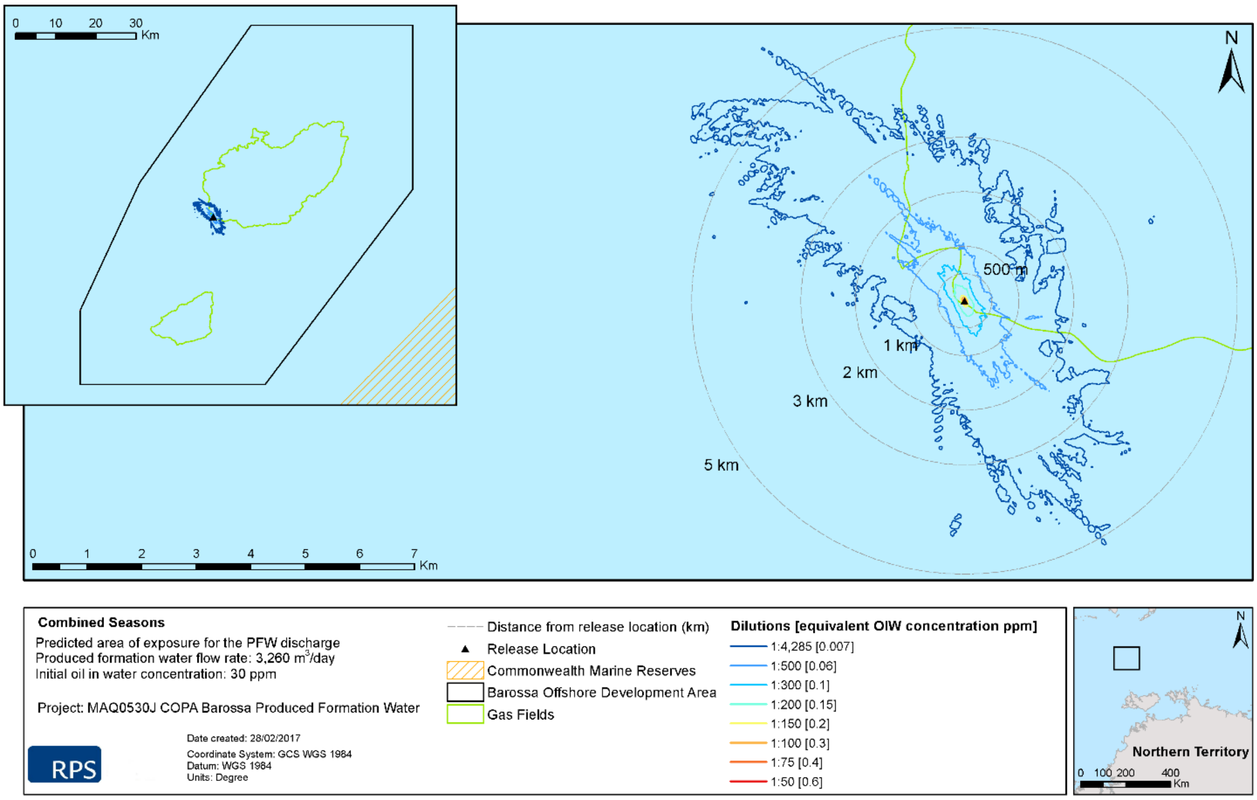


Figure 32 Predicted dilutions for the minimum PFW flow rate (1,590 m^3/d).



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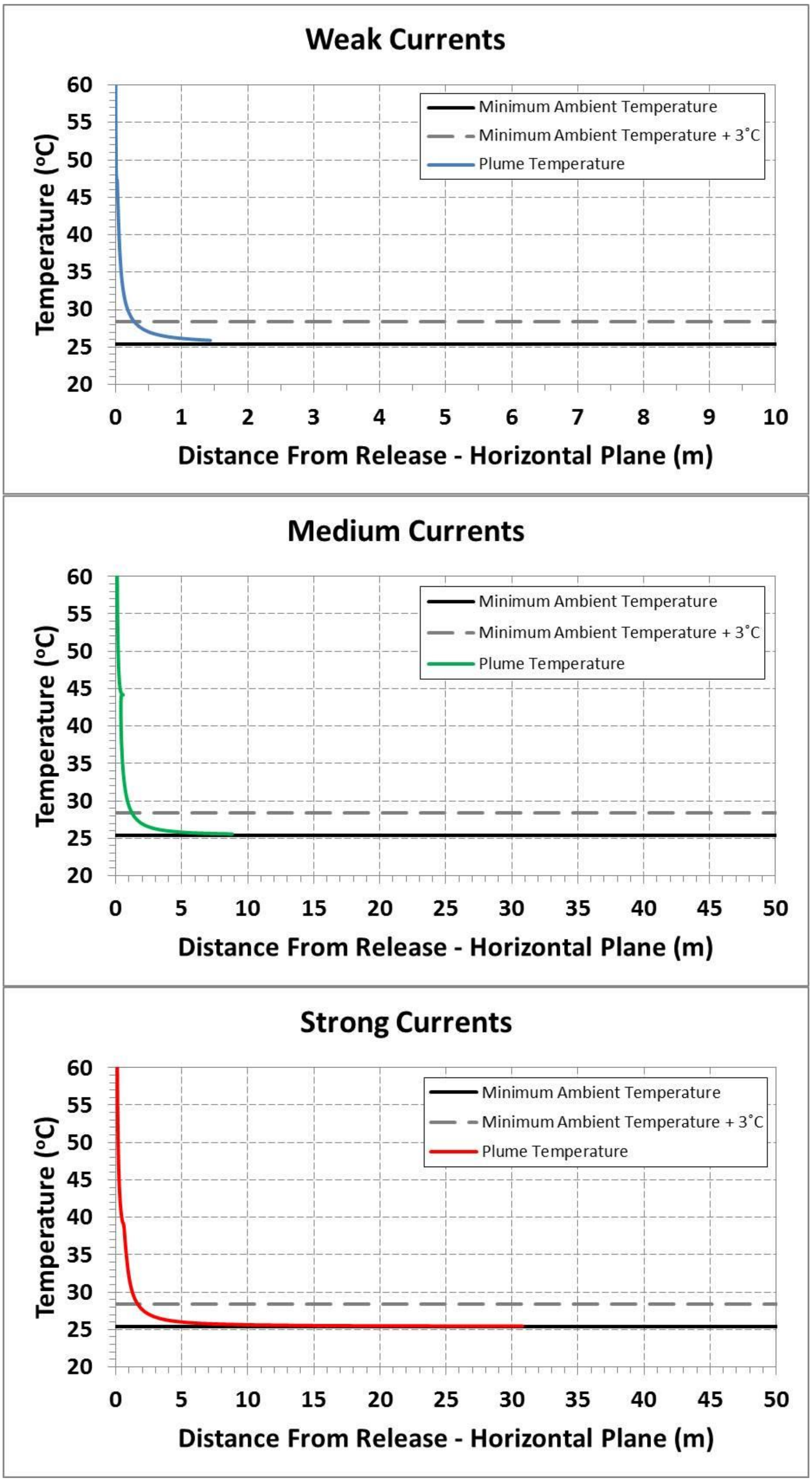

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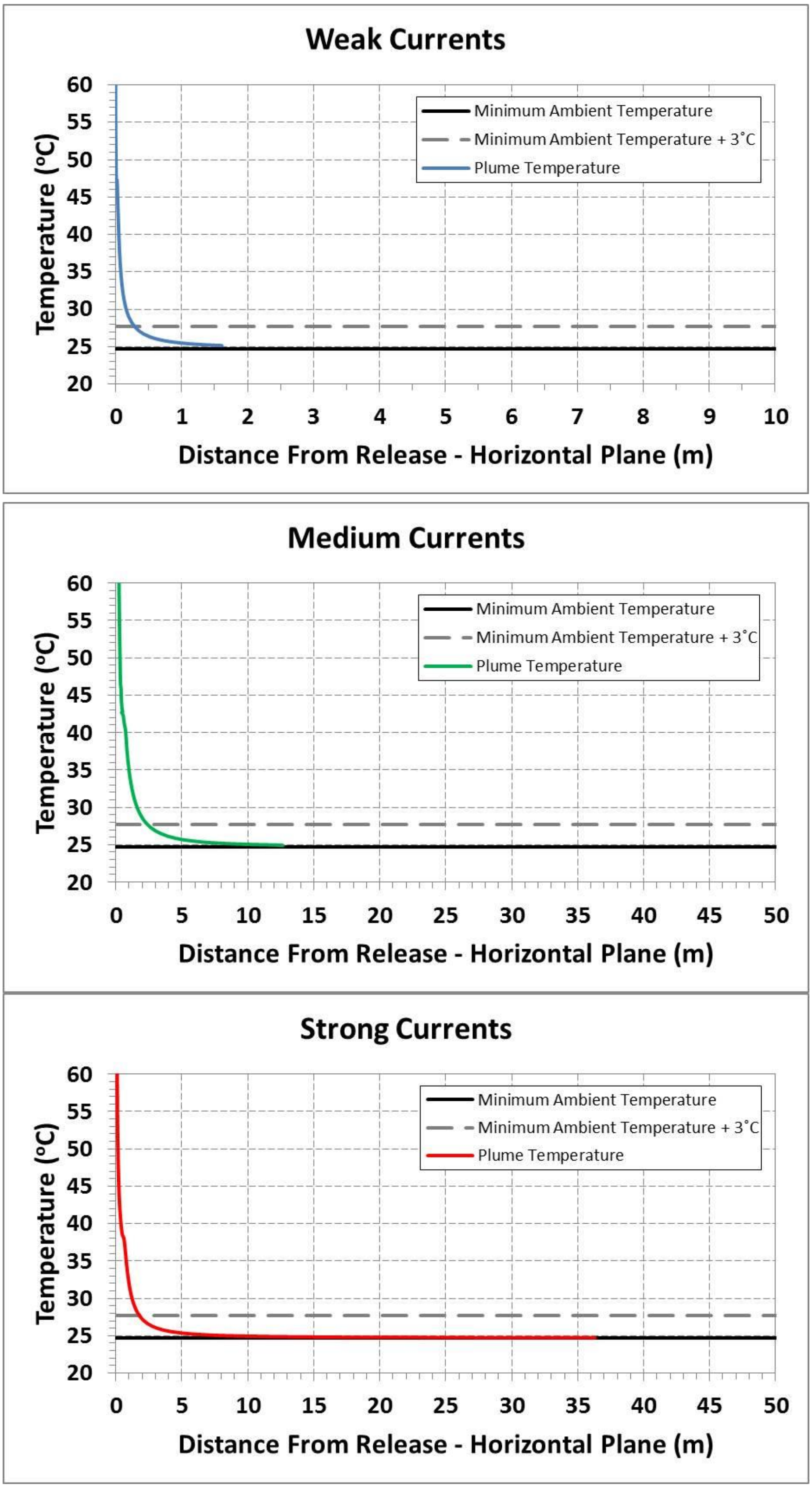
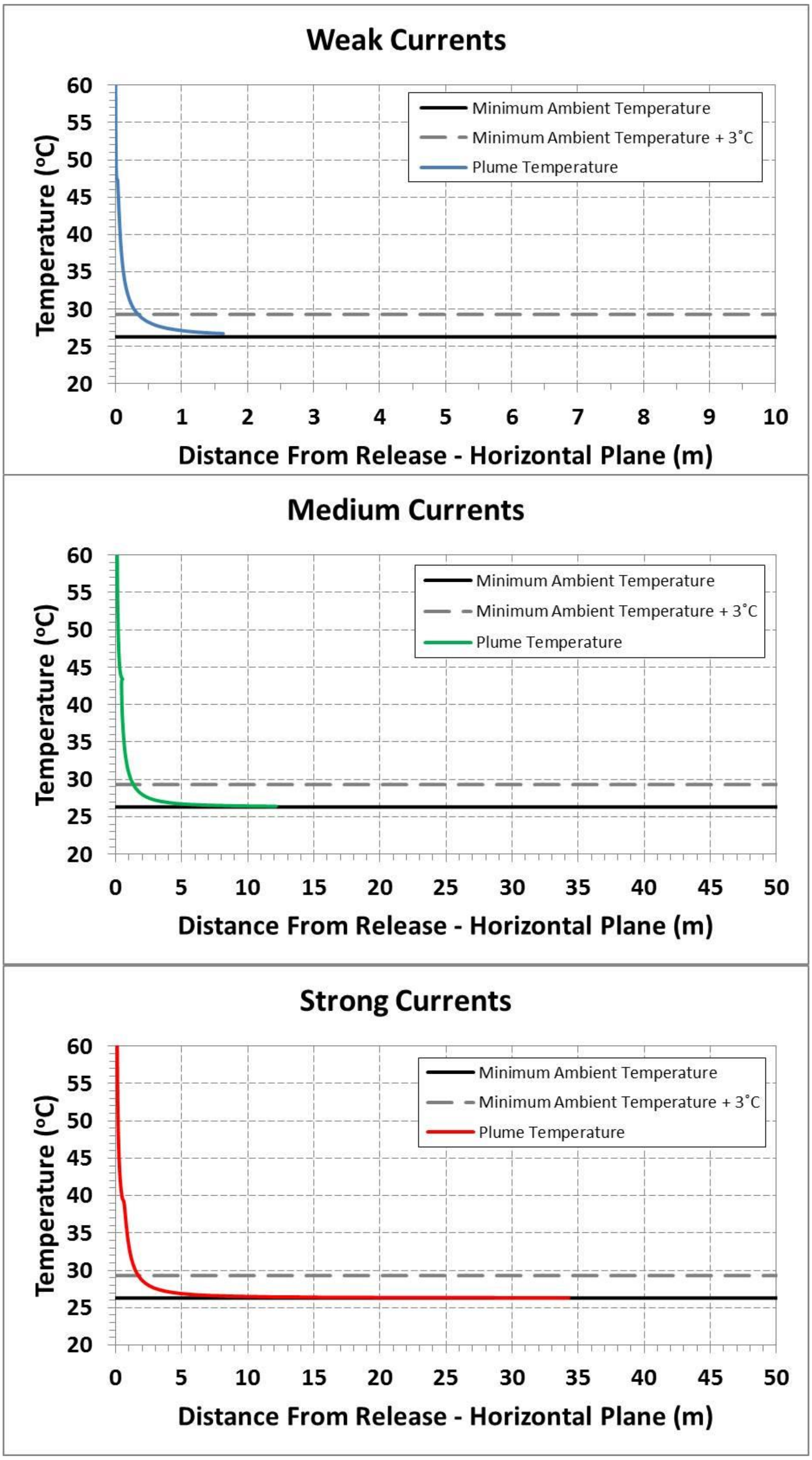


Figure 35 Predicted change in PFW plume temperature as a function of distance from release location under weak, medium and strong current strengths during transitional conditions (1,590 m^3/d)



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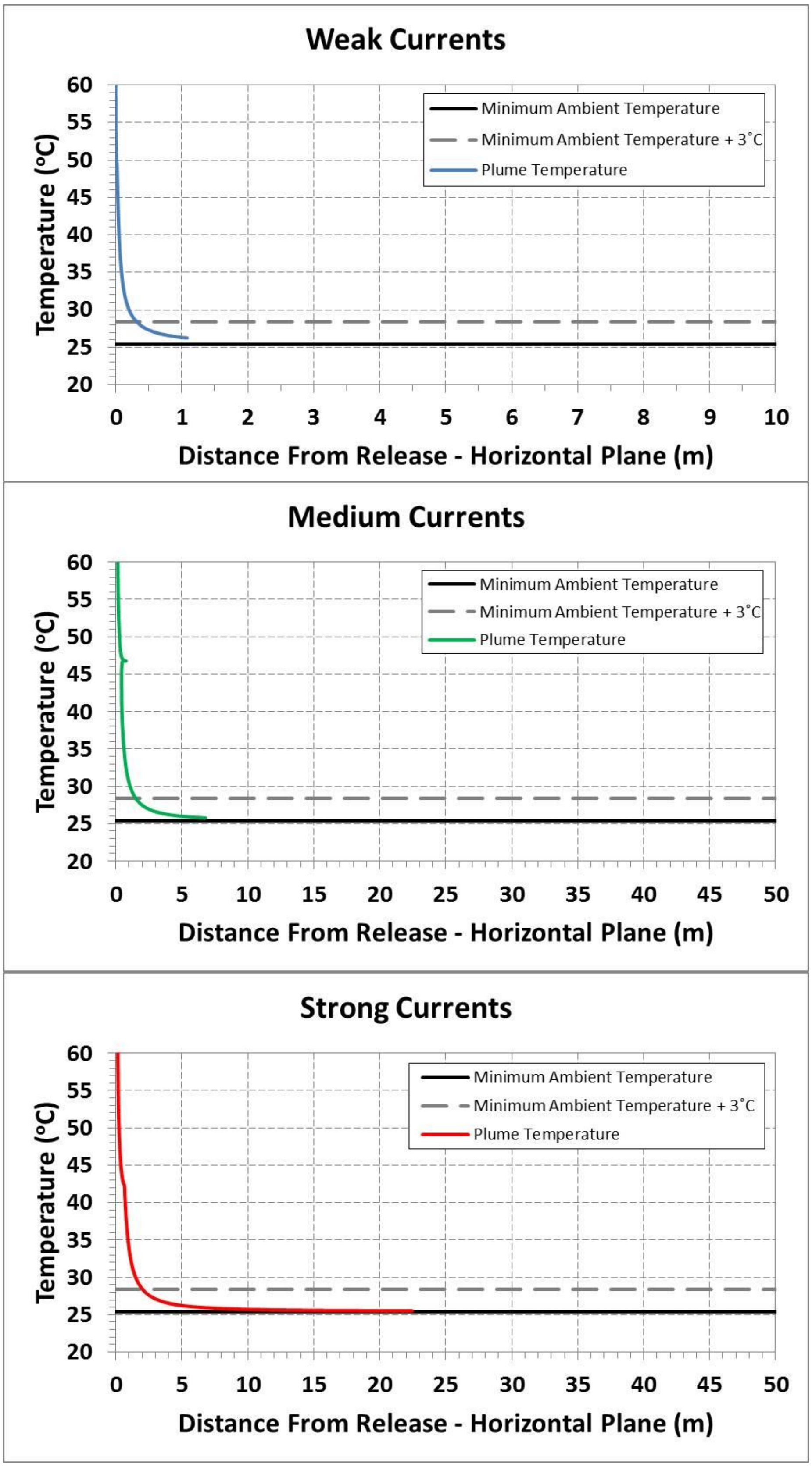


Figure 37 Predicted change in PFW plume temperature as a function of distance from release location under weak, medium and strong current strengths during summer conditions (3,260 m^3/d)

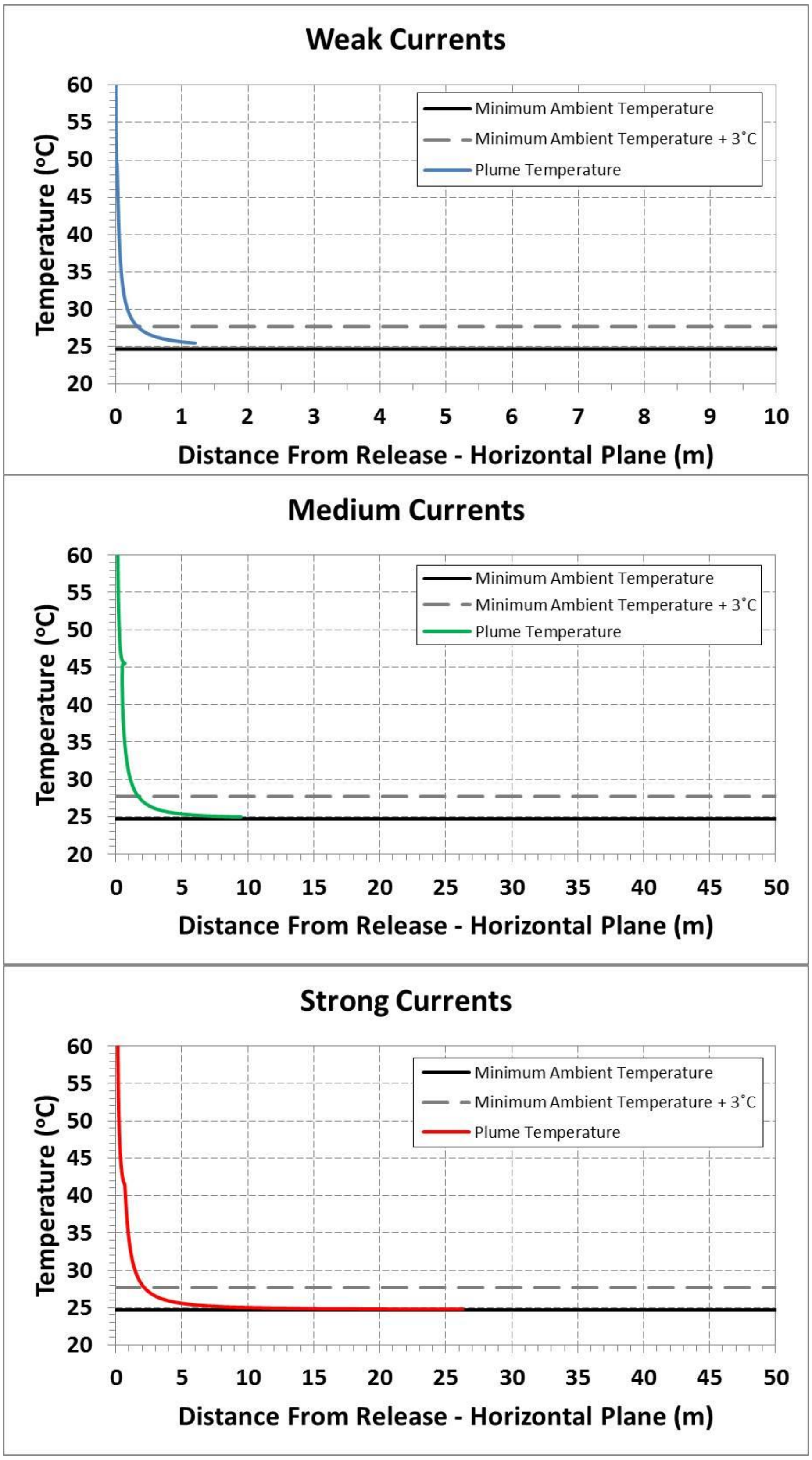
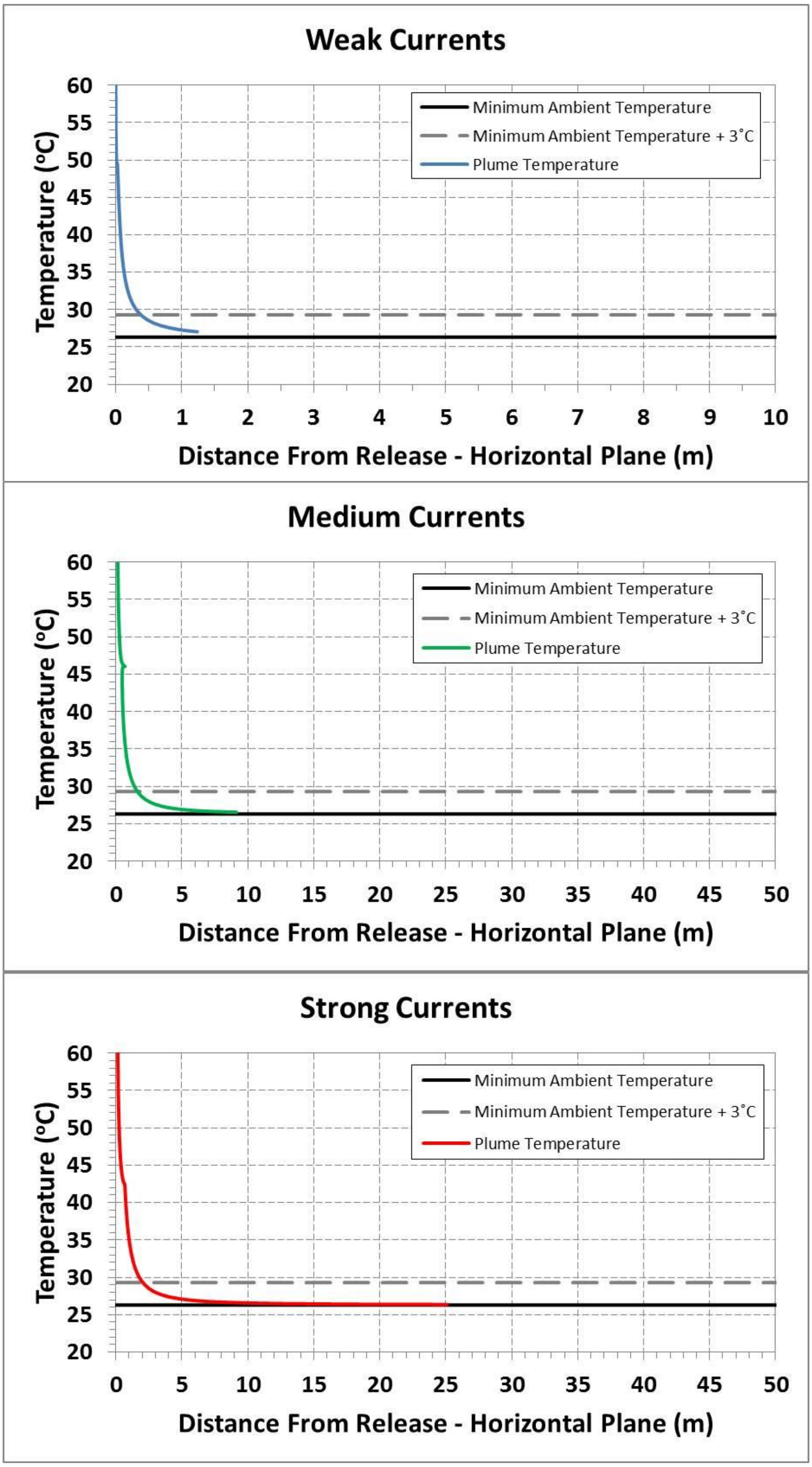


Figure 38 Predicted change in PFW plume temperature as a function of distance from release location under weak, medium and strong current strengths during transitional conditions (3,260 m^3/d)



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Appendix I.

Cooling water dispersion modelling study (RPS 2017b)

ConocoPhillips Barossa Project

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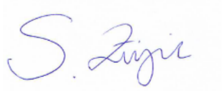
Document Status

Version	Purpose of Document	Original	Review	Review Date
DraftA	*Issued for client review*	Dr Ryan Dunn	Dr Sasha Zigic	28/2/2017
Rev 0	*Issued for client review*	Dr Ryan Dunn	Dr Sasha Zigic	28/2/2017
Rev 1	Issued to client		Dr Sasha Zigic	14/3/2017
Rev 2	Issued to client – assessment for 3 ppm free chlorine		Dr Sasha Zigic	7/4/2017

Approval for Issue

Name	Signature	Date
Dr Sasha Zigic		7/4/2017

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1.0 Introduction

1.1 Project background

ConocoPhillips Australia Exploration Proprietary (Pty) Limited (Ltd.) (ConocoPhillips), as proponent on behalf of the current and future co-venturers, is proposing to develop natural gas resources in the Timor Sea into high quality products in a safe, reliable and environmentally responsible manner. The Barossa Area Development (herein referred to as the “project”) is located in Commonwealth waters within the Bonaparte Basin, offshore northern Australia, and is approximately 300 kilometres (km) north of Darwin, Northern Territory (NT).

The development concept of the gas resource includes a floating production storage and offloading (FPSO) facility and a gas export pipeline that are located in Commonwealth jurisdictional waters. The FPSO facility will be the central processing facility to stabilise, store and offload condensate, and to treat, condition and export gas. The extracted lean dry gas will be exported through a new gas export pipeline that will tie into the existing Bayu-Undan to Darwin gas export pipeline. The lean dry gas will then be liquefied for export at the existing ConocoPhillips operated Darwin Liquefied Natural Gas facility at Wickham Point, NT.

The FPSO facility includes cooling water flows as part of the process. The cooling water will be used to regulate the temperature in the system, and generally involves a once-through circuit, where ambient seawater is drawn in from deep seawater intakes, passed through the system and discharged as a thermal waste stream below the sea surface. To avoid bio-fouling of the pipe work and heat exchangers, dosing with chlorine is undertaken, leaving a residual concentration in the discharged water. In summary, cooling water is generally characterised by elevated temperatures and some residual concentrations of antifoulant, generally sodium hypochlorite.

To assess the change in temperature and the residual chlorine concentrations in the cooling water stream, ConocoPhillips commissioned RPS to undertake a dispersion modelling study. The coordinate of the indicative release location is presented in Table 1 and graphically in Figure 1. The purpose of the modelling was to assist in understanding the potential area that may be influenced by the routine discharge of cooling water based on the engineering information available in the early stage of the project design phase.

The potential area that may be influenced by the cooling water discharge stream was assessed for three distinct seasons; (i) summer (December to the following February), (ii) the transitional periods (March and September to November) and (iii) winter (April to August). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

The closest environmental values and sensitivities to the modelled release location are submerged shoals and banks including Lynedoch Bank (70 km to the south-east), Evans Shoal (64 km to the west) and Tassie Shoal (74 km to the south-west).

Table 1 Barossa offshore development area cooling water dispersion modelling study release location

Release location	Latitude	Longitude	Water depth (mLAT)
Barossa offshore development area release location	9° 52’ 35.8” S	130° 11’ 8.4” E	~230

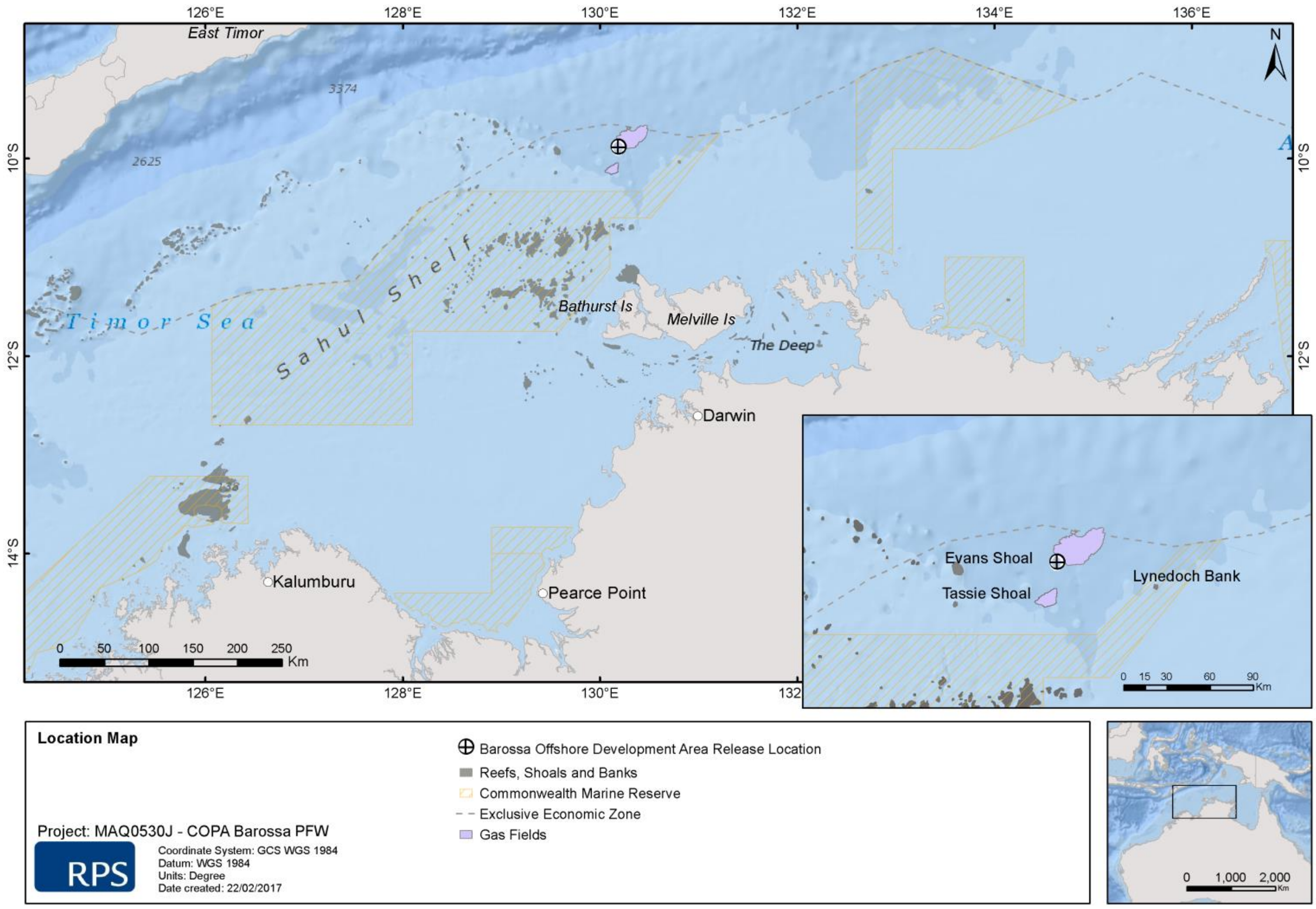

Figure 1 Map of the Barossa offshore development area cooling water modelling study release location

2.0 Dispersion modelling

The physical mixing of the cooling water stream can be separated into two distinct zones; near-field and far-field.

The near-field zone is defined by the region where the levels of mixing and dilution are controlled by the plume's initial jet momentum and the buoyancy flux, resulting from the density difference. When the plume encounters a boundary such as the water surface, seabed or density stratification layer, the near-field mixing is complete and the far-field mixing begins. During the far-field phase, the plume is transported and mixed by the ambient currents.

Therefore, to accurately determine the dilution and the mixing zone of the cooling water stream, the effect of near-field mixing needs to be considered first, followed by an investigation of the far-field mixing. Section 2.1 and Section 2.2 describe the near-field and far-field dispersion model. The physical mixing of the cooling water stream can be separated into two distinct zones; near-field and far-field.

2.1 Near-field model

2.1.1 Description

The near-field mixing of the cooling water discharge stream was predicted using the fully three-dimensional flow model, Updated Merge (UM3). The UM3 model is used for simulating single and multi-port submerged discharges and is part of the Visual Plumes suite of models maintained by the United States Environmental Protection Agency (Frick et al. 2003).

The UM3 model has been extensively tested for various discharges and found to predict the observed dilutions more accurately (Roberts and Tian 2004) than other near-field models (e.g. RSB or CORMIX).

In this Lagrangian 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 growth of each element, UM3 uses the shear (or Taylor) entrainment hypothesis and the projected-area-entrainment hypothesis. The flows begin as round buoyant jets issuing from one side of the diffuser and can merge to a plane buoyant jet (Carvalho et al. 2002). Model output consists of plume characteristics, including centerline dilution, rise-rate, width, centreline height and diameter of the plume. Dilution is reported as the "effective dilution", which is the ratio of the initial concentration to the concentration of the plume at a given point, following Baumgartner et al. (1994).

2.1.2 Model setup

The cooling water discharge characteristics are summarised in Table 20. The cooling water discharge was modelled 10 m below the water surface through a single outlet, and was anticipated to have a temperature of 45°C and initial chlorine concentration 3,000 parts per billion (ppb).

Additional input data used to setup the near-field model included range of current speeds, water temperature and salinity as a function of depth. Defining the water temperature and salinity is important to correctly replicate the buoyancy of the plume. The buoyancy dynamics in this case will be dominated by the temperature and salinity differences between the cooling water plume and receiving waters. Table 3 presents the measured water temperature and salinity data collected by Fugro Survey Pty Ltd (Fugro) (2015) as part of the Barossa marine studies program. The minimum water temperature at 30 m below mean sea level (BMSL) was used as it represents the most conservative conditions considering water temperature varies with depth and would be warmer at the surface in comparison to temperatures at 30 m.

Table 4 presents the 5th, 50th and 95th percentiles of current speeds, which reflect contrasting dilution and advection cases:

- 5th percentile current speed: weak currents, low dilution and slow advection
- 50th percentile (median): medium current speed, moderate dilution and advection
- 95th percentile current speed: strong currents, high dilution and rapid advection to nearby areas.

The 5th percentile, 50th percentile (median) and 95th percentile values are referenced as weak, medium and strong current speeds, respectively.

Table 2 Cooling water discharge and pipe configuration characteristics summary

Parameter	Value/design
Flow rate (m^3/day)	Minimum flow rate: 288,000 Maximum flow rate: 360,576
Outlet pipe internal diameter (m)	1
Pipe orientation	Vertically downward
Depth of pipe below sea surface (m)	10
Discharge salinity (practical salinity units (PSU))	33.6–34.1 (variation based on ambient mean seasonal conditions)
Discharge water temperature (ºC)	45
Initial chlorine concentration (ppb)	3,000

Table 3 Water temperature and salinity model inputs

Parameter	Season		
	Summer	Transitional	Winter
Ambient minimum water temperature (ºC) (30 m BMSL)	25.4	24.7	26.3
Ambient mean salinity (Practical Salinity Units (PSU)) (30 m BMSL)	34.1	33.6	33.6

Table 4 Seasonal ambient percentile current speeds, strength and predominant direction as a function of water depth at the release location

Depth below the water surface (m)	Parameter	Reporting current strength	Season					
			Summer		Transitional		Winter	
			Speed (m/s)	Predominant direction	Speed (m/s)	Predominant direction	Speed (m/s)	Predominant direction
0	5th percentile	Weak	0.04	East	0.05	West-south-west	0.03	South-west
	50th percentile	Medium	0.11		0.14		0.11	
	95th percentile	Strong	0.27		0.29		0.27	
10	5th percentile	Weak	0.03	East	0.03	South-west	0.04	South-west
	50th percentile	Medium	0.09		0.12		0.12	
	95th percentile	Strong	0.23		0.26		0.25	
20	5th percentile	Weak	0.03	East-south-east	0.03	South-west	0.03	South-west
	50th percentile	Medium	0.08		0.11		0.12	
	95th percentile	Strong	0.20		0.24		0.24	

2.2 Far-field model

2.2.1 Description

The far-field modelling expands on the near-field model predictions as it also takes into account the time-varying nature of currents, together with the potential for recirculation of the plume back to the discharge location. In the latter case, near-field concentrations can be increased due to the discharge plume mixing with the remnant plume from an earlier time.

CHEMMAP is an advanced three-dimensional discharge and plume behaviour model that calculates the fate of discharges in the far-field (wider region). Detailed presentations of the model can be found in French McCay and Isaji (2004) and French McCay et al. (2006).

CHEMMAP predicts the trajectory and fate of a wide variety of chemical products, including floating, sinking, soluble and insoluble chemicals and product mixtures. The chemical fates model estimates the distribution of the chemical (as mass and concentrations) on the water surface, on shorelines, in the water column and in the sediments. The three-dimensional model separately tracks surface slicks, entrained droplets or particles of pure chemical, chemical adsorbed to suspended particulates, and dissolved chemical. Processes that are simulated include spreading, transport, dispersion, evaporation-volatilisation, entrainment, dissolution, partitioning, sedimentation, and degradation.

CHEMMAP is a Lagrangian model that uses a set of particles to represent the discharge. Each particle represents a portion of the discharge, by mass, and the particles are released at a given rate to represent the rate of the discharge (mass per unit time). These particles are moved in three-dimensions over each subsequent time-step according to the governing equations within each of the model stages. Particles are transported in three dimensions as defined by currents and horizontal and vertical mixing processes. Concentration of the constituent is predicted over time by counting the number of particles that fall within a given depth level within a given grid cell and converting this value to mass per unit volume.

2.3 Model setup

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 3.1.

The two cooling water flow rates were modelled as a constant discharge for each month during 2010, 2012 and 2014. Once the results were complete, they were reported on a combined seasonal basis: (i) summer (December to the following February); (ii) the transitional (March, April, September to November) and (iii) winter (May to August).

CHEMMAP uses a three-dimensional grid to represent the water depth and bathymetric profiles of the area. Due to the rapid mixing and small-scale influences of the discharge, it was necessary to use a fine grid with a resolution of 50 m x 50 m to track the movement and fate of the plume. The extent of the grid region measured approximately 80 km (longitude or x-axis) x 80 km (latitude or y-axis). Sensitivity testing for the 50 m grid cell size was performed in order to achieve similar dilution rates as calculated by the near-field modelling.

The model used sodium hypochlorite as a surrogate for the free chlorine to enable the results to be compared to guideline values. Therefore, the chemical and physical properties were directly accounted for in the model (e.g. Shams El Din et al. 2000; Zeng et al. 2009).

Table 5 presents a summary of the far-field model parameters used to simulate the cooling water discharge during the three seasons and two flow rates.

Spatially constant, conservative horizontal and vertical dispersion coefficients were used to control the exchange of the chlorien in the horizontal and vertical directions respectively. The coefficients were selected following extensive sensitivity testing in order to recreate similar plume characteristics and dilutions at the end of the near-field mixing.

Table 5 Summary of the far-field cooling water model inputs

Parameter	Value/design
Years simulated	• 2010 (La Niña conditions) • 2012 (neutral/mixed) • 2014 (El Niño conditions)
Seasons (months simulated and reported)	• Summer (December, January, February) • Transitional periods (March, April, September to November) • Winter (May to August)
Total months modelled and analysed per flow rate	36
Flow rate (m^3/day)	Minimum flow rate: 288,000 Maximum flow rate: 360,576
Discharge type	Continuous
Period of discharge (days)	Entire month
Initial chlorine concentration (ppb)	3,000
Cooling water discharge salinity (PSU)	33.6–34.1 (variation based on ambient mean seasonal conditions)
Cooling water discharge temperature (°C)	45

2.4 Interannual variability

The region is strongly affected by the strength of the Indonesian Throughflow, which fluctuates from one year to the next due to the exchange between the Pacific and Indian Oceans. Therefore, in order to examine the potential range of variability, the Southern Oscillation Index (SOI) data sourced from the Australian Bureau of Meteorology was used to identify interannual trends for the last 10 years (2005–2014). The SOI broadly defines neutral, El Niño (sustained negative values of the SOI below −8 often indicate El Niño episodes) and La Niña (sustained positive values of the SOI above +8 are typical of La Niña episodes) conditions based on differences in the surface air-pressure between Tahiti on the eastern side of the Pacific Ocean and Darwin (Australia), on the western side (Rasmusson and Wallace 1983, Philander 1990). El Niño episodes are usually accompanied by sustained warming of the central and eastern tropical Pacific Ocean and a decrease in the strength of the Pacific trade winds. La Niña episodes are usually associated with converse trends (i.e. increase in strength of the Pacific trade winds).

Figure 2 shows the SOI monthly values and Figure 3 shows the surface ocean current roses for the period 2004–2013 at the proposed release location. Each current rose diagram provides an understanding of the speed, frequency and direction of currents, over the given year:

- Current speed – speed is divided into segments of different colour, ranging from 0 to greater than 1 m/s. Speed intervals of 0.2 m/s are used. The length of each coloured segment is relative to the proportion of currents flowing within the corresponding speed and direction;
- Frequency – each of the rings on the diagram corresponds to a percentage (proportion) of time that currents were flowing in a certain direction at a given speed;
- Direction – each diagram shows currents flowing towards particular directions, with north at the top of the diagram.

Based on the combination of the SOI assessment and surface ocean currents, 2010 was selected as a representative La Niña year, 2012 was selected as a representative neutral year, and 2014 was selected as an El Niño year.

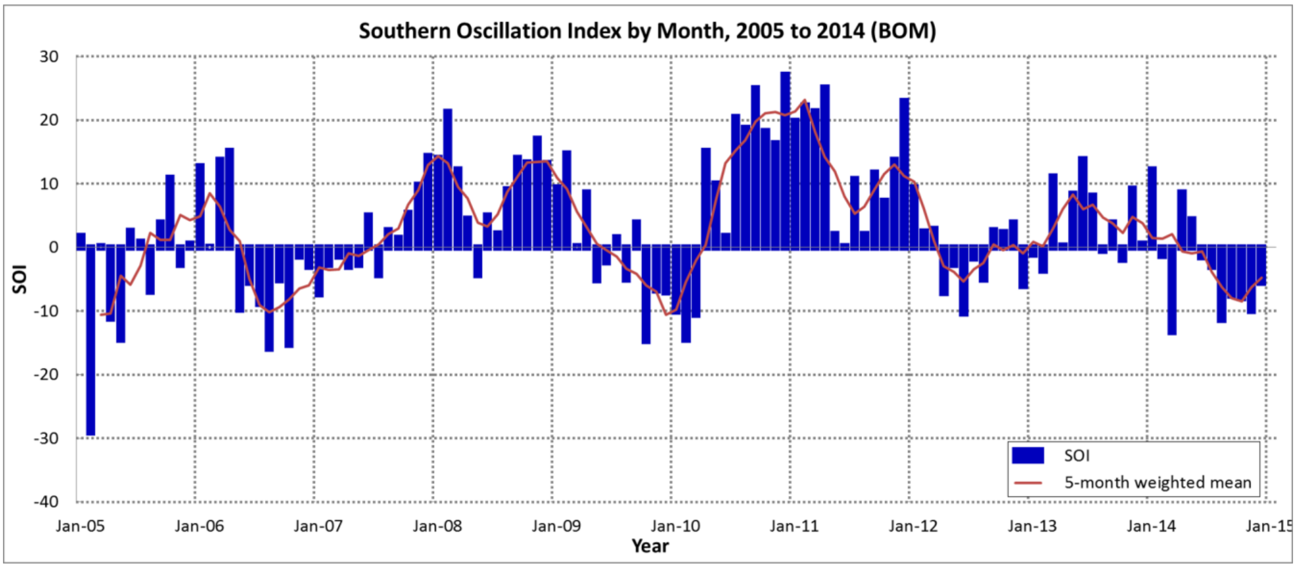

Figure 2 Monthly values of the SOI 2005-2014. Sustained positive values indicate La Niña conditions, while sustained negative values indicate El Niño conditions (Data sourced from Australian Bureau of Meteorology 2015).

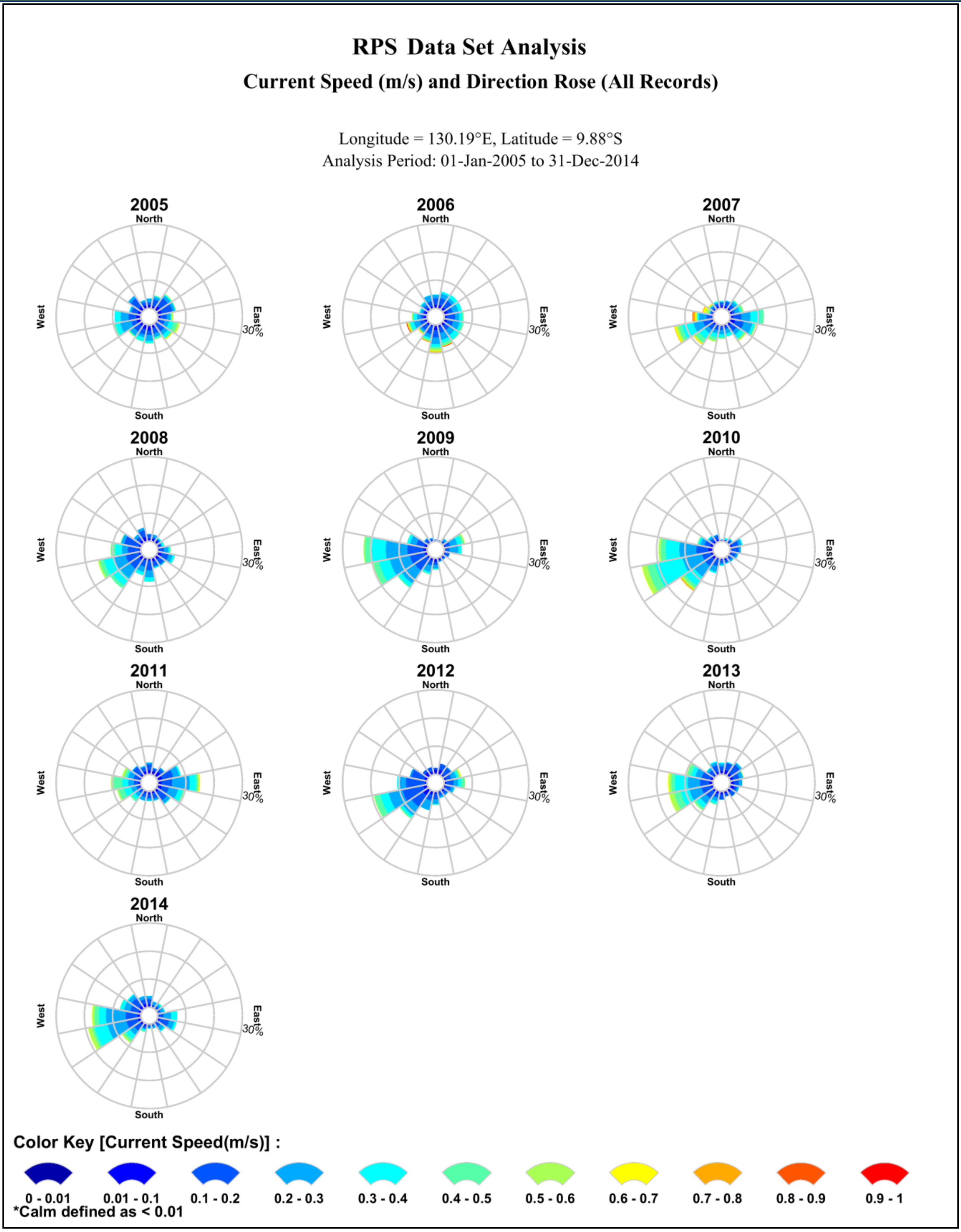

Figure 3 Annual surface ocean current rose plots within the Barossa Offshore Development Area. Derived from analysis of HYCOM ocean data for the years 2005–2014. The colour key shows the current speed (m/s), the compass shows the direction and the length of the wedge gives the percentage of the record for a particular speed and direction combination.

2.5 Development of regional current data

The project is located within the influence of the Indonesian Throughflow, a large scale current system characterised as a series of migrating gyres and connecting jets that are steered by the continental shelf. This results in sporadic deep ocean events causing surface currents to exceed 1.5 m/s (approximately 3 knots).

While the ocean currents generally flow toward the southwest, year-round, the internal gyres generate local currents in any direction. As these gyres migrate through the area, large spatial variations in the speed and direction of currents will occur at a given location over time.

The influence of tidal currents is generally weaker in the deeper waters and greatest surrounding regional reefs and islands. Therefore, it was critical to include the influence of both types of currents (ocean and tides) to rigorously understand the likely discharge characteristics in the project's area of influence.

A detailed description of the tidal and ocean current data inputted into the model is provided below.

2.5.1 Tidal currents

The tidal circulation was generated using RPS's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world over the past 26 years (Isaji and Spaulding 1984; Isaji et al. 2001; Zigic et al. 2003). In addition, HYDROMAP tidal current data has been used as input to forecast (in the future) and hindcast (in the past) condensate spills in Australian waters and forms part of the Australian National Oil Spill Emergency Response System operated by the Australian Maritime Safety Authority (AMSA).

HYDROMAP employs a sophisticated sub-gridding strategy, which supports up to six levels of spatial resolution, halving the grid cell size as each level of resolution is employed. The sub-gridding allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, and/or of particular interest to a study.

The numerical solution methodology 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 and Spaulding (1984), Isaji et al. (2001) and Owen (1980).

1.1.1.1 Tidal grid setup

The HYDROMAP tidal grid was established over a domain that extended approximately 2,400 km (east–west) by 1,575 km (north–south) (Figure 4). Computational cells were square, with sizes varying from 8 km in the open waters down to 1 km in some areas, to more accurately resolve flows along the coastline, around islands and reefs, and over more complex bathymetry (Figure 5).

Bathymetry used in the model was obtained from multiple sources (Figure 6). This included bathymetry data sourced from the Geoscience Australia database and commercially available digitised navigation charts.

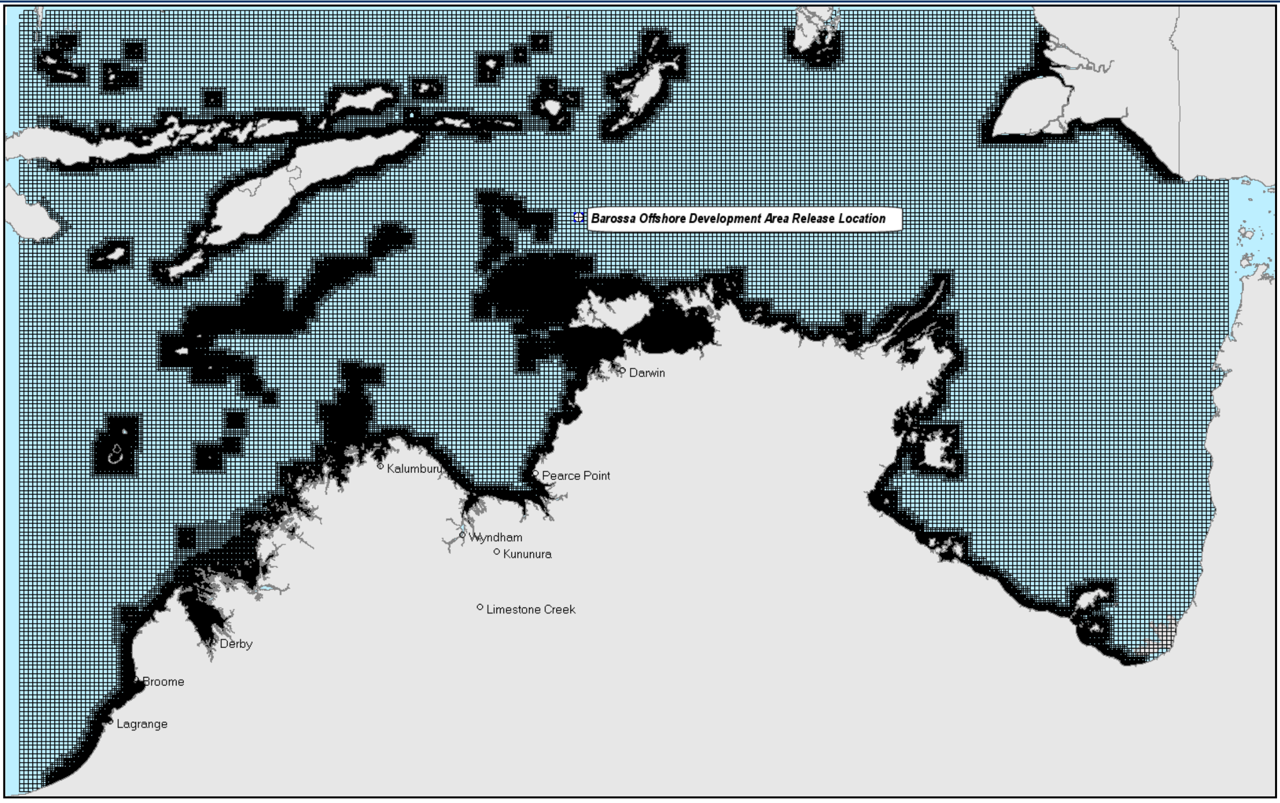

Figure 4 Map showing the extent of the tidal model grid. Note, darker regions indicate higher grid resolution.

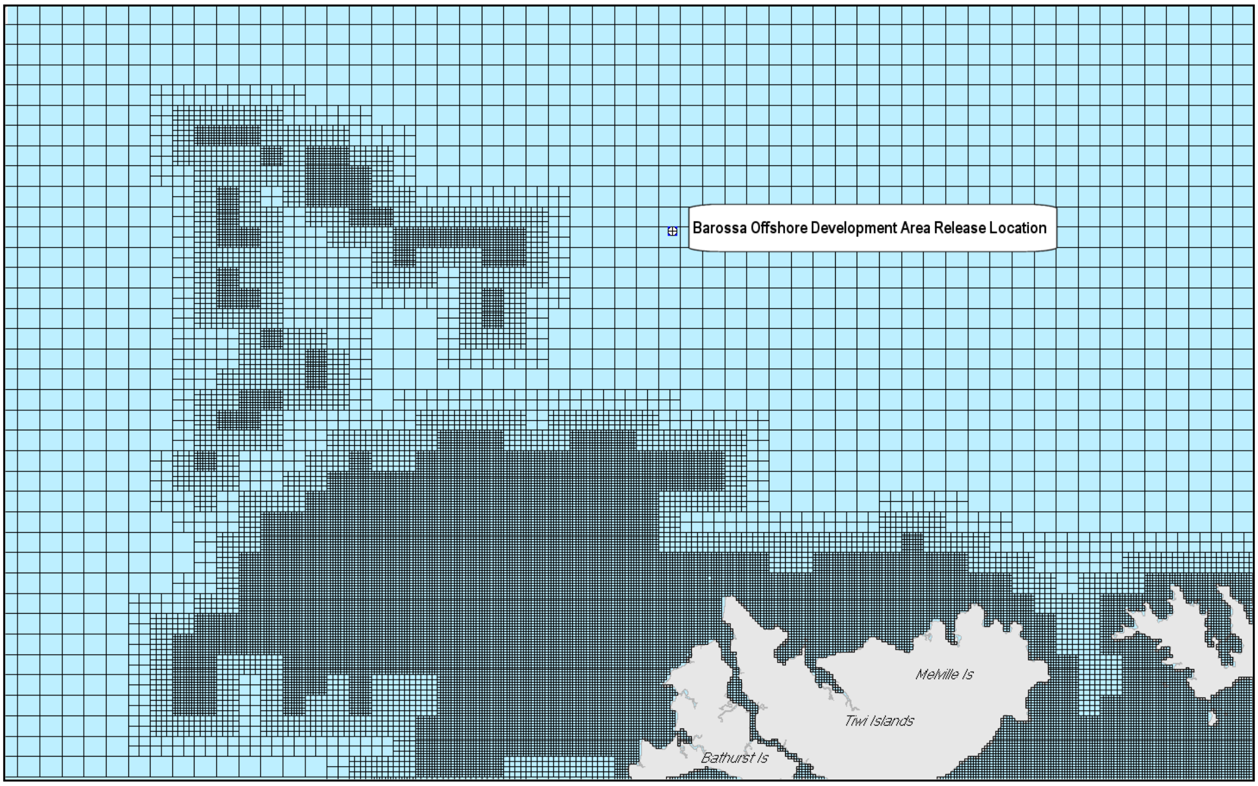

Figure 5 Zoomed in map showing the tidal model grid), illustrating the resolution sub-gridding in complex areas (e.g. islands, banks, shoals or reefs)

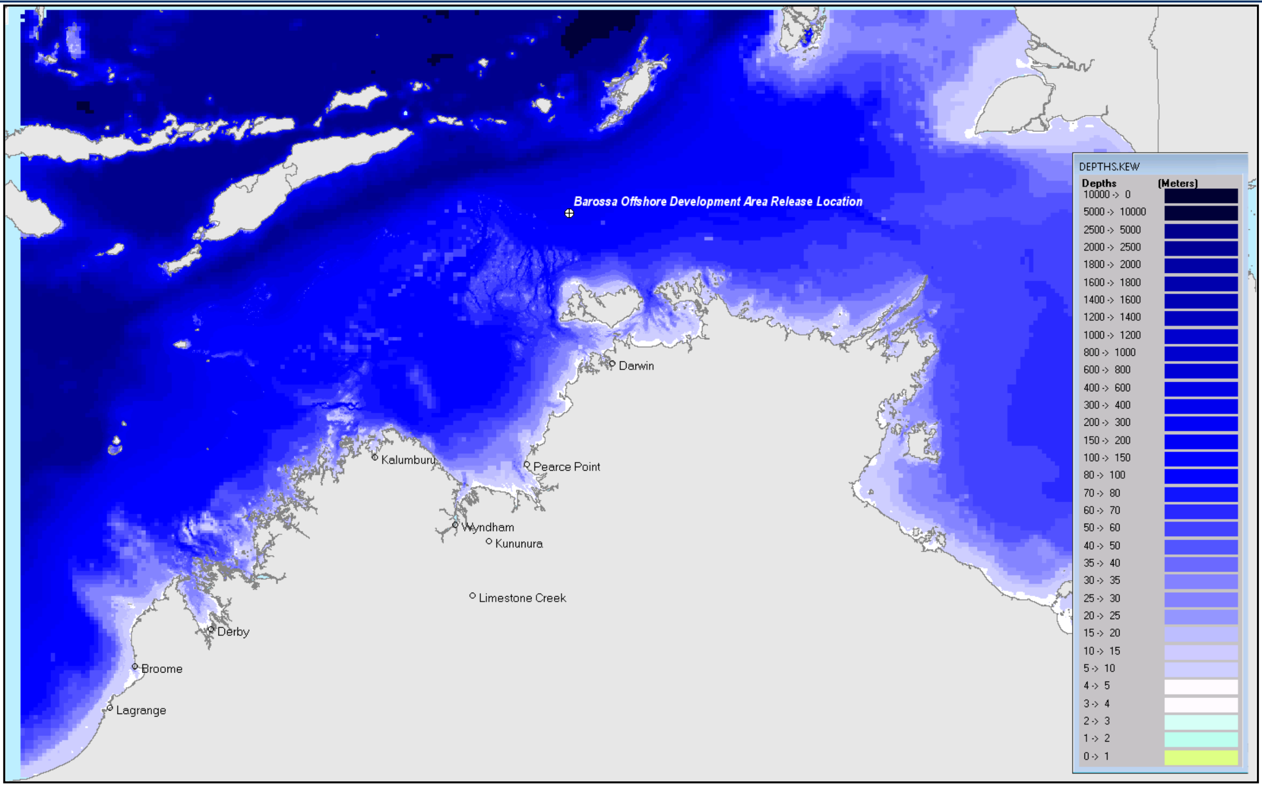

Figure 6 Map showing the bathymetry of the tidal model grid

1.1.1.2 Tidal data

The ocean boundary data for the regional model was obtained from satellite measured altimetry data (TOPEX/Poseidon 7.2) which provided estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. Using the tidal data, surface heights were 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 National Aeronautics and Space Administration (NASA). The satellites, equipped with two highly accurate altimeters that are capable of taking sea level measurements to an accuracy of less than 5 cm, measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005; see Fu et al., 1994; NASA/Jet Propulsion Laboratory 2013a; 2013b). In total these satellites carried out 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 and Tangdong 2004, Qiu and Chen 2010). As such the Topex/Poseidon tidal data is considered accurate for this study.

2.5.2 Ocean currents

Data describing the flow of ocean currents was obtained from the Hybrid Coordinate Ocean Model (HYCOM) (see Chassignet et al. 2007, 2009), which is operated by the HYCOM Consortium, sponsored by the Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a data-assimilative, three-dimensional ocean model that is run as a hindcast, assimilating time-varying observations of sea surface height, sea surface temperature and in-situ temperature and salinity measurements (Chassignet et al. 2009). The HYCOM predictions for drift currents are produced at a horizontal spatial resolution of approximately 8.25 km (1/12th of a degree) over the region, at a frequency of once per day. 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.

For this modelling study, the HYCOM hindcast currents were obtained for the years 2010 to 2014 (inclusive). Figure 7 shows the seasonal surface current roses distributions adjacent to the release location by combining 2010, 2012 and 2014. The data shows that the surface current speeds and directions varied between seasons. In general, during transitional conditions (March, April and September to November) currents were shown to have the strongest average speed (average speed of 0.15 m/s with a maximum of 0.39 m/s) and tended to flow to the west-southwest. During summer (December to February) and winter (May to August) conditions the current flow was more variable though mostly toward the east and west, respectively. The average and maximum speeds during summer was 0.11 m/s and 0.41 m/s, respectively. During winter the average was 0.13 m/s and 0.47 m/s as the maximum.

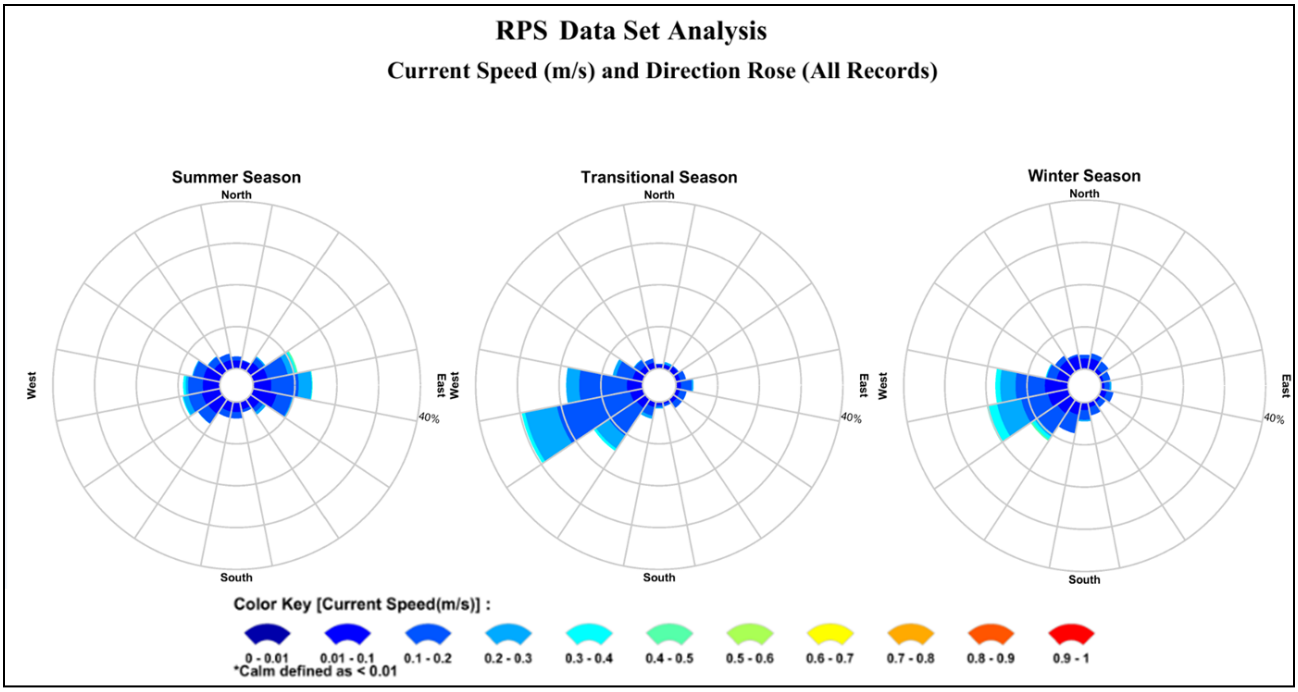

Figure 7 Seasonal surface current rose plots adjacent to the release location. Data was derived from the HYCOM ocean currents for years, 2010, 2012 and 2014. The colour key shows the current magnitude (m/s), the compass direction provides the current direction flowing TOWARDS and the length of the wedge gives the percentage of the record for a particular speed and direction combination.

Figure 8 shows example screenshots of the predicted HYCOM ocean currents during summer and winter conditions. The colours of the arrows indicate current speed (m/s).

In addition, Figure 9 to Figure 11 show the monthly surface current rose plots adjacent to the release location for 2010, 2012 and 2014, respectively. The data is derived by combining the ocean currents and tidal currents.

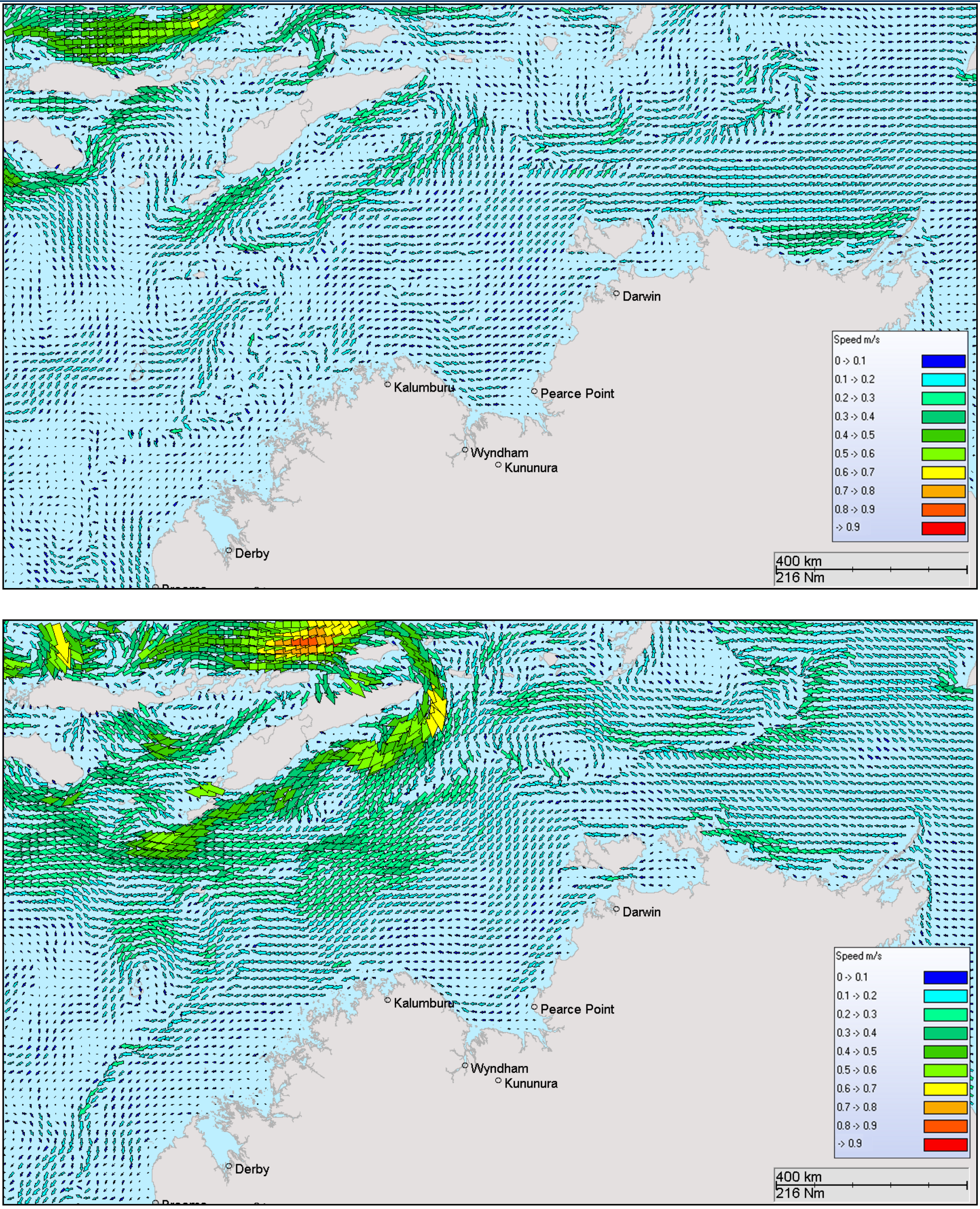

Figure 8 Modelled HYCOM surface ocean currents on the 6th February 2012, summer conditions (upper image) and 11th May 2012, winter conditions (lower image). Derived from the HYCOM ocean hindcast model (Note: for image clarity only every 2nd vector is displayed).

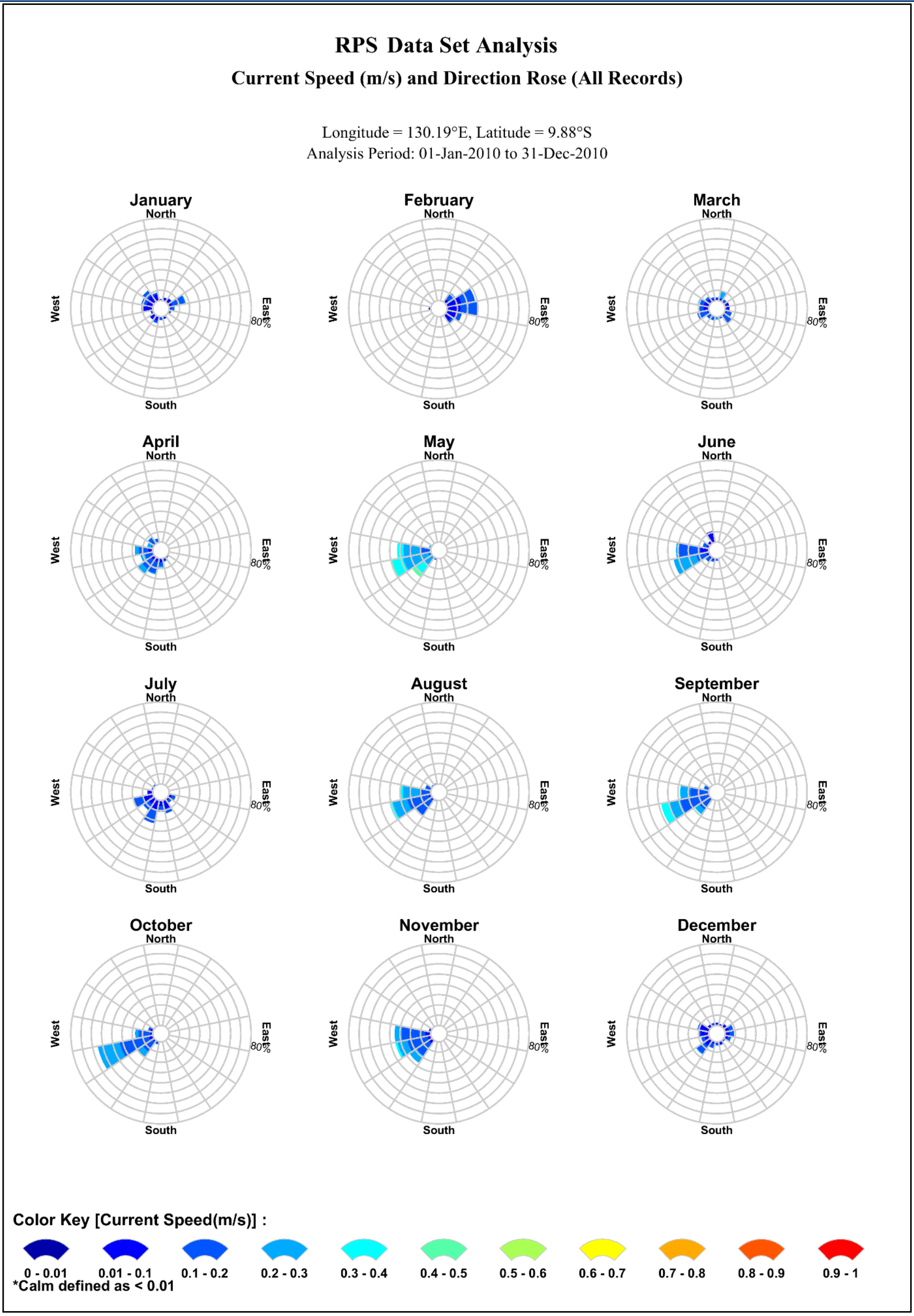

Figure 9 Monthly surface current rose plots adjacent to the model release location. Derived from analysis of HYCOM ocean data and tidal data for 2010 (La Niña year). The colour key shows the current speed (m/s), the compass shows the direction and the length of the wedge gives the percentage of the record for a particular speed and direction combination.

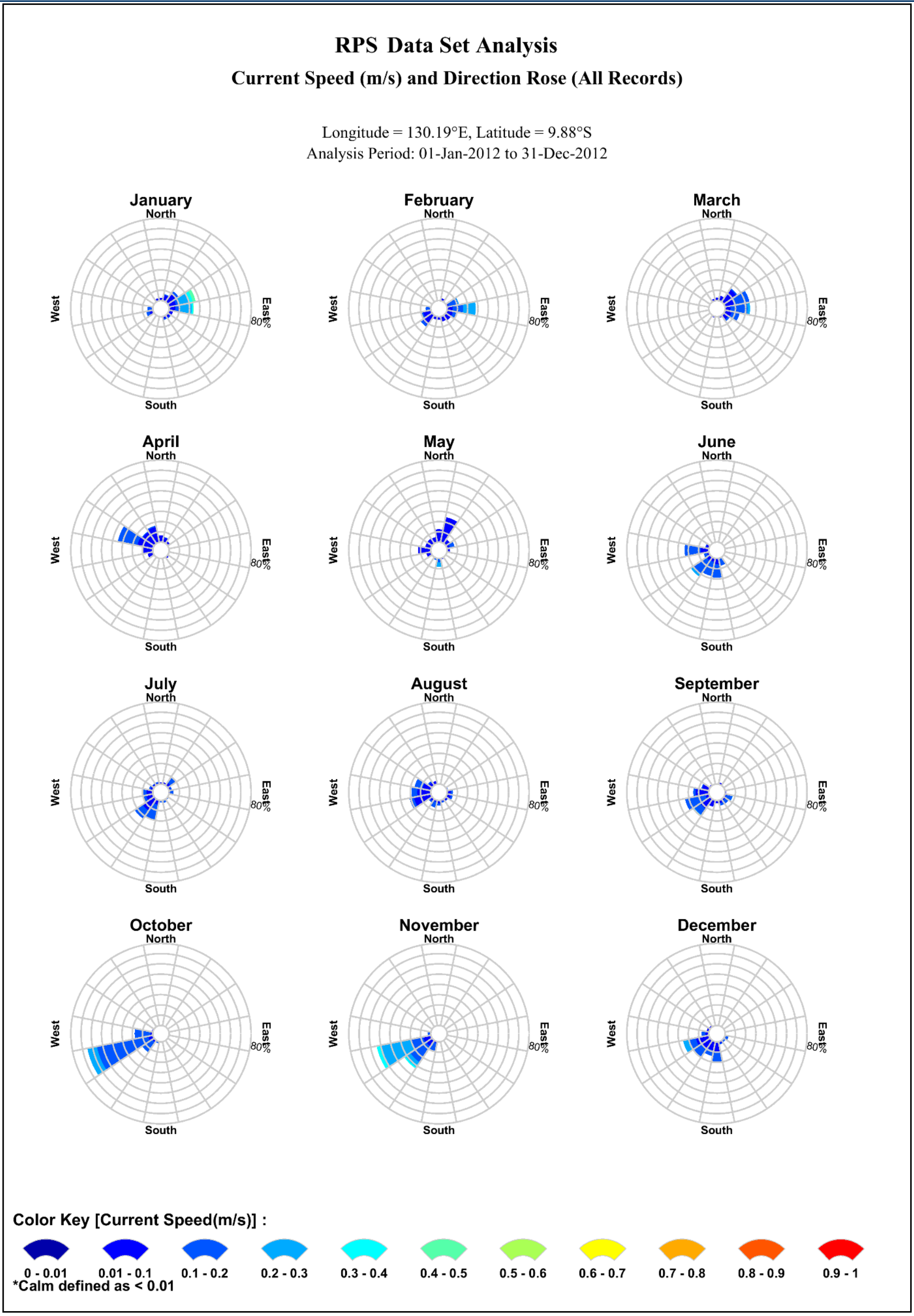

Figure 10 Monthly surface current rose plots adjacent to the model release location. Derived from analysis of HYCOM ocean data and tidal data for 2012 (neutral year). The colour key shows the current speed (m/s), the compass shows the direction and the length of the wedge gives the percentage of the record for a particular speed and direction combination.

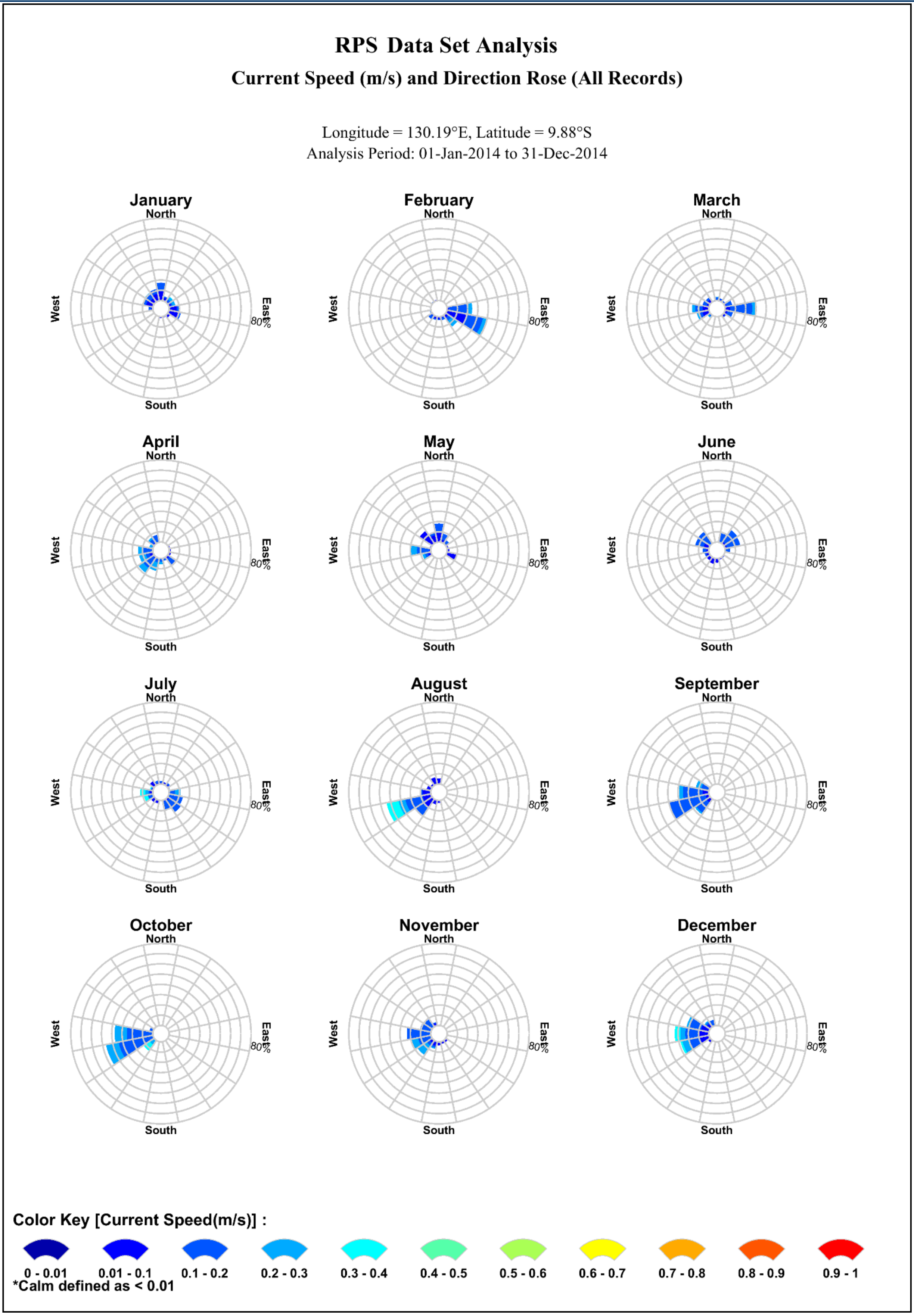

Figure 11 Monthly surface current rose plots adjacent to the model release location. Derived from analysis of HYCOM ocean data and tidal data for 2014 (El Niño year). The colour key shows the current speed (m/s), the compass shows the direction and the length of the wedge gives the percentage of the record for a particular speed and direction combination.

2.5.3 Tidal and current model validation

Fugro measured water levels and currents (speed and directions) at three locations within the Barossa offshore development area as part of the Barossa marine studies program (Figure 12**,** Fugro 2015). The measured data from the survey was made available to validate the predicted currents, which corresponds to the three identified seasons of the region (i.e. summer (December to February), transitional (March and September to November) and winter (April to August)).

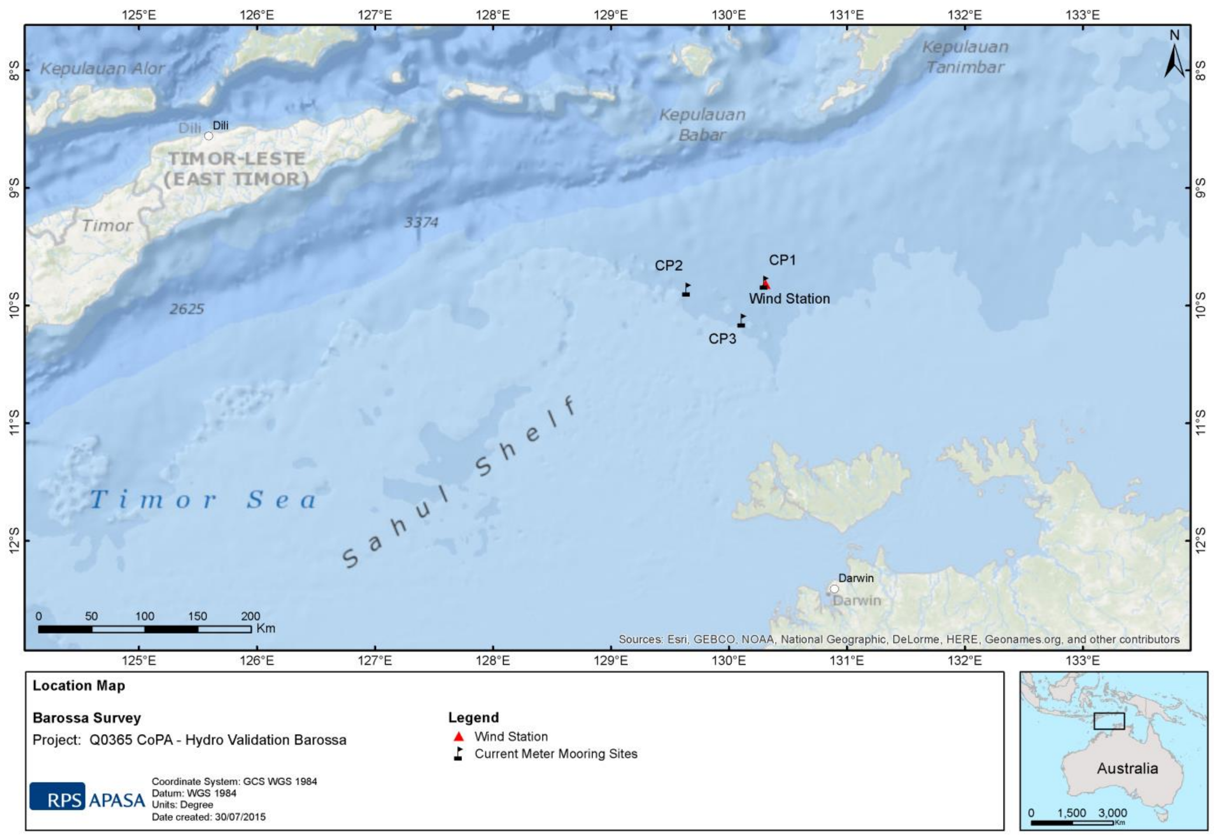

Figure 12 Locations of the CP1, CP2 and CP3 current meter moorings and the wind station

As an example, Figure 13 shows a comparison between the measured and predicted water levels at CP1 from 28 October 2014 to 14 March 2015. The figure shows a strong agreement in tidal amplitude and phasing throughout the entire deployment duration at the CP1 location.

To provide a statistical quantification of the model accuracy, comparisons were performed by determining the deviations between the predicted and measured data. As such, the root-mean square error (RMSE), root-mean square percentage (RMS %) and relative mean absolute error (RMAE) were calculated. Qualification of the RMAE ranges are reported in accordance with Walstra et al. (2001).

Table 6 shows the model performance when compared with measured water levels at CP1 from 28 October to 14 March 2015. According to the statistical measure, the HYDROMAP tidal model predictions were in very good agreement with the measured water levels at CP1.

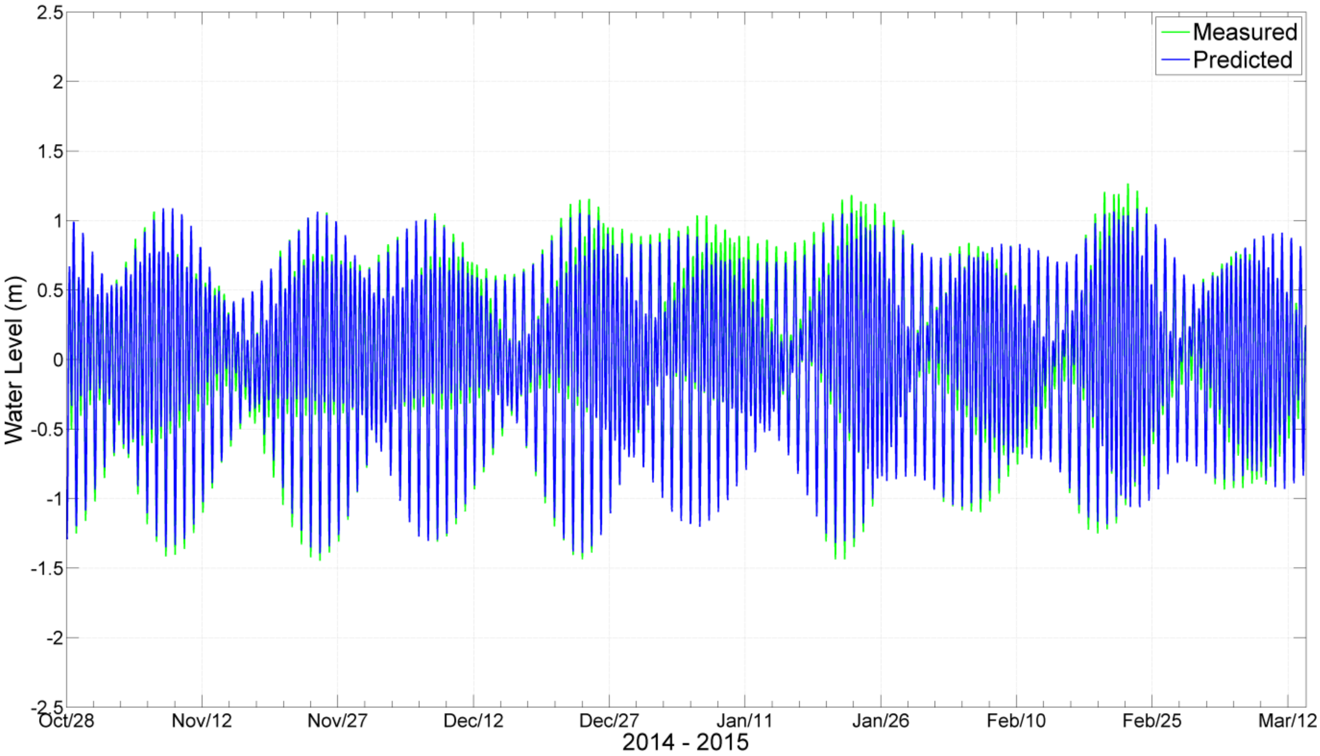

Figure 13 Comparison of measured and modelled water levels at CP1

Table 6 Statistical evaluation between measured water levels and HYDROMAP predicted water levels at CP1

Site	RMSE (m)	RMS (%)	RMAE	RMAE qualification
Mooring CP1	0.061	0.03	0.05	Very good

In addition, the HYCOM ocean currents combined with HYDROMAP tidal currents were compared to the measured current speed and directions from the CP1, CP2 and CP3 moorings. Figure 14 to Figure 16 show current comparison plots of the measured and predicted currents at each location for a range of depths (10 m, 50 m and 125 m BMSL) to highlight the differences between the wind-influenced surface layers and the mid water column.

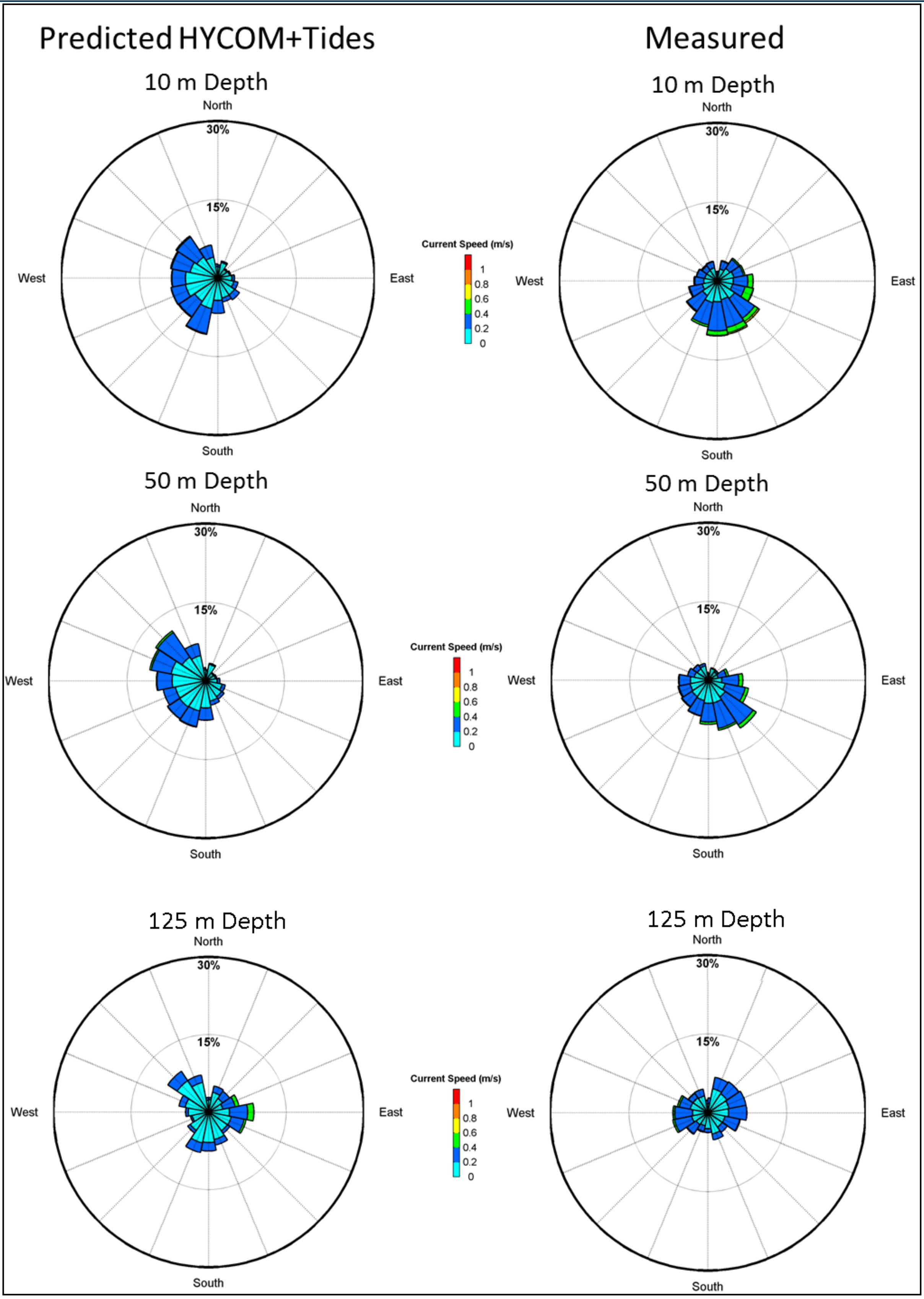

Figure 14 Comparison of predicted and measured current roses at CP1 from 9th July 2014 to 21st March 2015

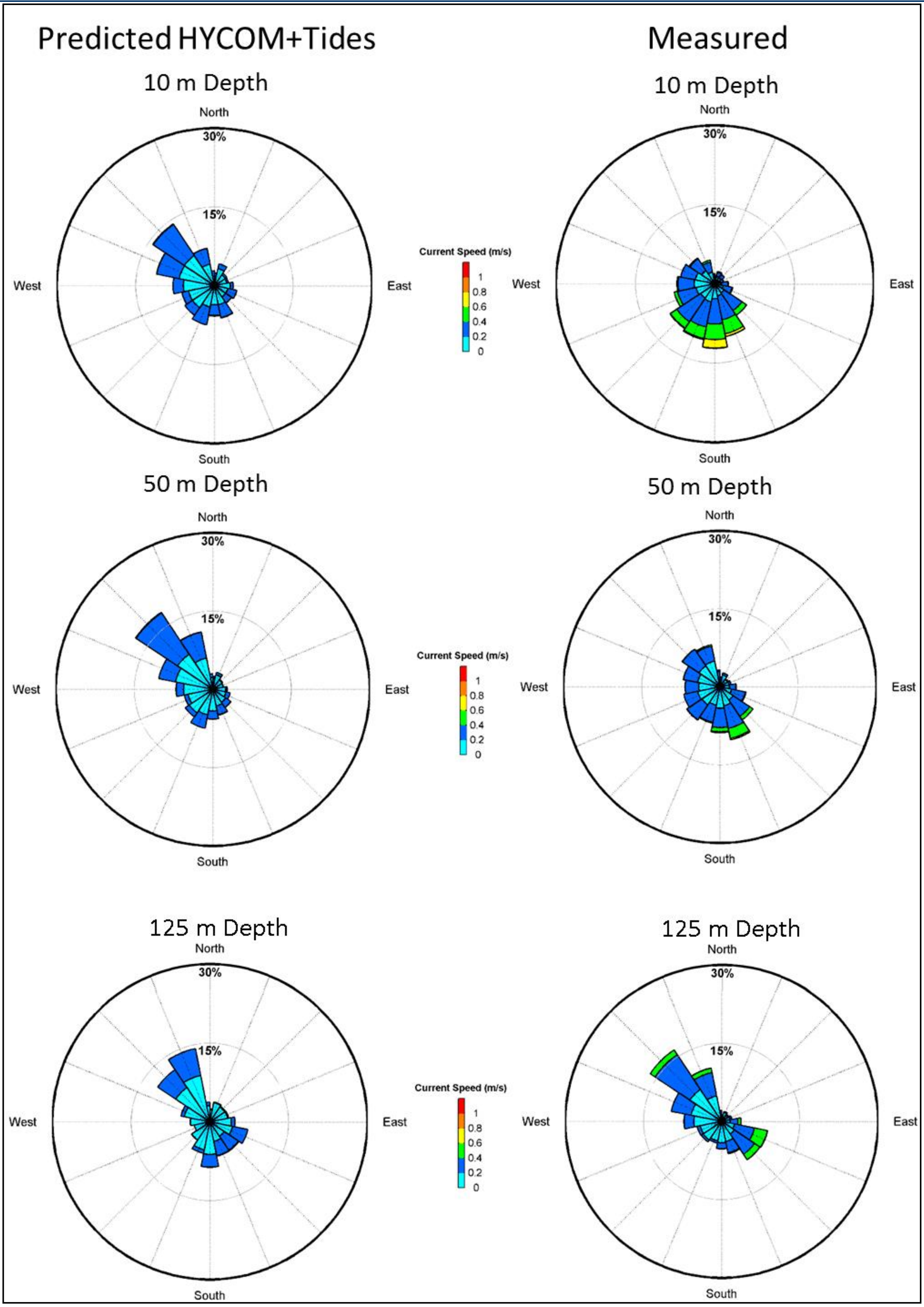

Figure 15 Comparison of predicted and measured current roses at CP2 from 10th July 2014 to 21st March 2015

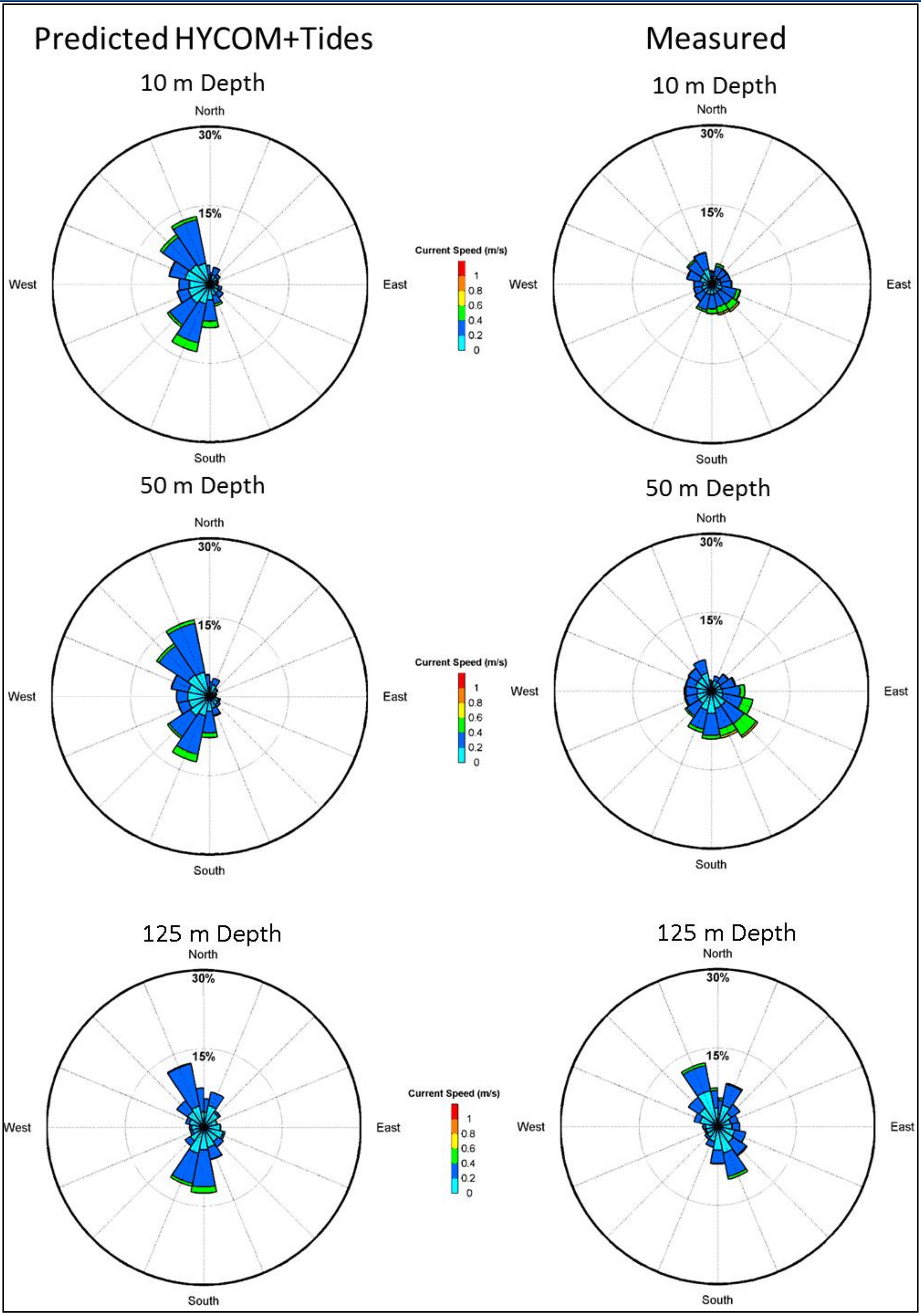

Figure 16 Comparison of predicted and measured current roses at CP3 from 9th July 2014 to 21st March 2015.

Overall, there was a good agreement between the predicted and measured currents at each site and depth. The model predictions were also able to recreate the two-layer flow which can be seen in the measured data and the reduction in current speeds as function of depth. From 10 m down to approximately 100 m below mean sea level (BMSL) the currents generally flowed south-east, with little variation due to tidal changes. The model predictions replicated this behaviour. Below 100 m, the influence of the tides became more pronounced, rotating between a south-eastward flow and a north-westward flow with the turning of the tide. Both tidal-scale and large-scale fluctuations in currents were typically reproduced at a similar magnitude and timing.

There was some divergence between the predicted and measured currents, mostly between data from July to October inclusive, due to the occurrence of solitons (or high frequency internal waves that can produce unusually high currents) which was highlighted by Fugro (2015). Despite these variations, the statistical comparisons between the measured and predicted current speeds indicate a reasonable to very good agreement (Table 7). Therefore, it can be concluded it is a good comparison and that the predicted current data reliably reproduced the complex conditions within the Barossa offshore development area and surrounding region. The RPS APASA (2015) model validation report provides a more detail regarding the tide and current comparison.

In summary, the Fugro (2015) data provides information specifically for the Barossa offshore development area and is considered the best available and most accurate data for this particular region. This data has been provided and reviewed by RPS to confirm predicted currents applied are accurate. As a result, the current data used herein is considered best available and highly representative of the characteristics influencing the marine environment in the Barossa offshore development area.

Table 7 Statistical evaluation between averaged measured currents and HYCOM ocean current and HYDROMAP tidal current at CP1, CP2 and CP3 at varying water depths (July 2014 to March 2015)

Site	Depth (m BMSL)	RMSE (m/s)	Measured peak value (m/s)	RMSE (%)	RMAE qualification
Mooring CP1	10	0.14	0.71	20	Good
	50	0.14	0.63	22	Very good
	125	0.13	0.61	22	Very good
Mooring CP2	10	0.16	0.82	19	Reasonable
	50	0.14	0.81	17	Good
	125	0.16	0.72	22	Reasonable
Mooring CP3	10	0.15	0.88	18	Very good
	50	0.14	0.78	18	Very good
	125	0.13	0.60	21	Very good

2.6 Environmental reporting criteria

The following environmental criteria were used for the modelling study.

Temperature

The criterion of assessing that temperature is within 3˚C within 100 m from the release location was applied for the cooling water dispersion modelling study. This criterion is defined in the International Finance Corporation (IFC) Industry Environmental, Health and Safety Guideline for Offshore Oil and Gas Development (IFC 2015) and represents a commonly adopted industry standard.

Maximum extent of the chlorine

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) scientific literature review on the toxicity of chlorine, for the Browse Floating LNG Development referral (Woodside Energy Ltd 2011), had found that 13 ppb corresponds to the predicted no effect concentration for acute exposure. Whereas 2 ppb as the predicted no effect concentration in the event of chronic exposure to chlorine at the 99% species protection level (Chariton and Stauber 2008). The literature review had made note that the vast majority of species will have higher tolerance compared to the 2 ppb threshold, and that only be the most sensitive species have a toxic response.

Therefore, the far-field modelling results are presented as contour maps which include concentrations of 2, 3, 4, 8, 13 and 20 ppb and corresponding dilution intervals of: 1:1,500, 1:1,000; 1:750, 1:375, 1:231, and 1:150 on the keys. The dilution intervals are based on an initial chlorine concentration of 3,000 ppb.

3.0 Modelling results

3.1 Near-field modelling

Figure 17 to Figure 22 (note the differing x- and y-axis aspect ratios) show the predicted change in temperature and dilution, under the varying flow rates (minimum and maximum), as a function of horizontal distance before reaching the sea surface, for each current speed (weak, medium and strong) and season (summer, transitional and winter). The results can also be found summarised in tabulated form in Table 8 and Table 9.

The results showed that due to plume momentum, the cooling water plume initially plunges downward creating a turbulent mixing zone ranging between approximately 40 m to 63 m for the minimum flow rate (288,000 m^3/d) and approximately 48 m to 70 m for the maximum flow rate (360,576 m^3/d) below the water surface. The cooling water plunged deeper under weak current conditions for both minimum and maximum flow rates. Once the plume lost its momentum it began to rise to the surface due to the temperature difference with ambient waters. As the plume rose through the water column, it continued to mix with ambient waters, though at a slower rate. During both flow rates, the plume was sufficiently buoyant to rise to the sea surface during all current speeds at distances less than 100 m from the release location.

Upon encountering the sea surface (i.e. end of near-field mixing), the diameter of the cooling water plume at the sea surface ranged from approximately 18 m to 37 m for the minimum flow rate and approximately 22 m to 43 m for the maximum flow rate (Table 8 and Table 9).

In all cases, the temperature of the cooling water plume was predicted to be within 3°C of the ambient (background) temperature within 100 m from the release location. **Appendix A** and **Appendix B** provide graphs of the predicted difference in temperature between the cooling water plume and ambient temperature versus distance from release location for the minimum and maximum flow rates, respectively. The temperature of the cooling water plume generally returned to within 3°C of ambient water temperature within approximately 5 m to 6 m of the discharge location, with the greatest distance of 12 m recorded in medium currents during the transitional season (minimum flow rate).

For all seasons and flow rates modelled, the primary factor influencing the dilution of the discharged cooling water plume was the speed of the current. Weak currents had little effect on the plume during the rise process and therefore it reached the surface quickly (i.e. within 5 m from the release location for the minimum flow rate and approximately 8 m for the maximum flow rate) and slowing the rate of dilution. The medium and strong currents were capable of pushing the buoyant plume horizontally up to a maximum distance of approximately 37 m and 67 m for the minimum flow rate (see Table 8), respectively, and approximately 45 m and 81 m during the maximum flow rate (see Table 9), respectively, allowing for additional mixing prior to reaching the surface. Average dilutions of the cooling water plume upon reaching the sea surface for the minimum and maximum flow rates ranged between 1:24 to 1:69 and 1:30 to 1:80, respectively.

Additionally, the minimum dilutions of the cooling water plume (i.e. dilution of plume centreline) upon the plume boundary encountering the sea surface under medium and strong constant currents were predicted to range between be 1:13 to 1:31 during the minimum flow rate and 1:15 to 1:43 during the maximum flow rate, respectively.

Note that these predictions rely on the persistence of current speed and direction over time and does not account for the build-up of the plume.

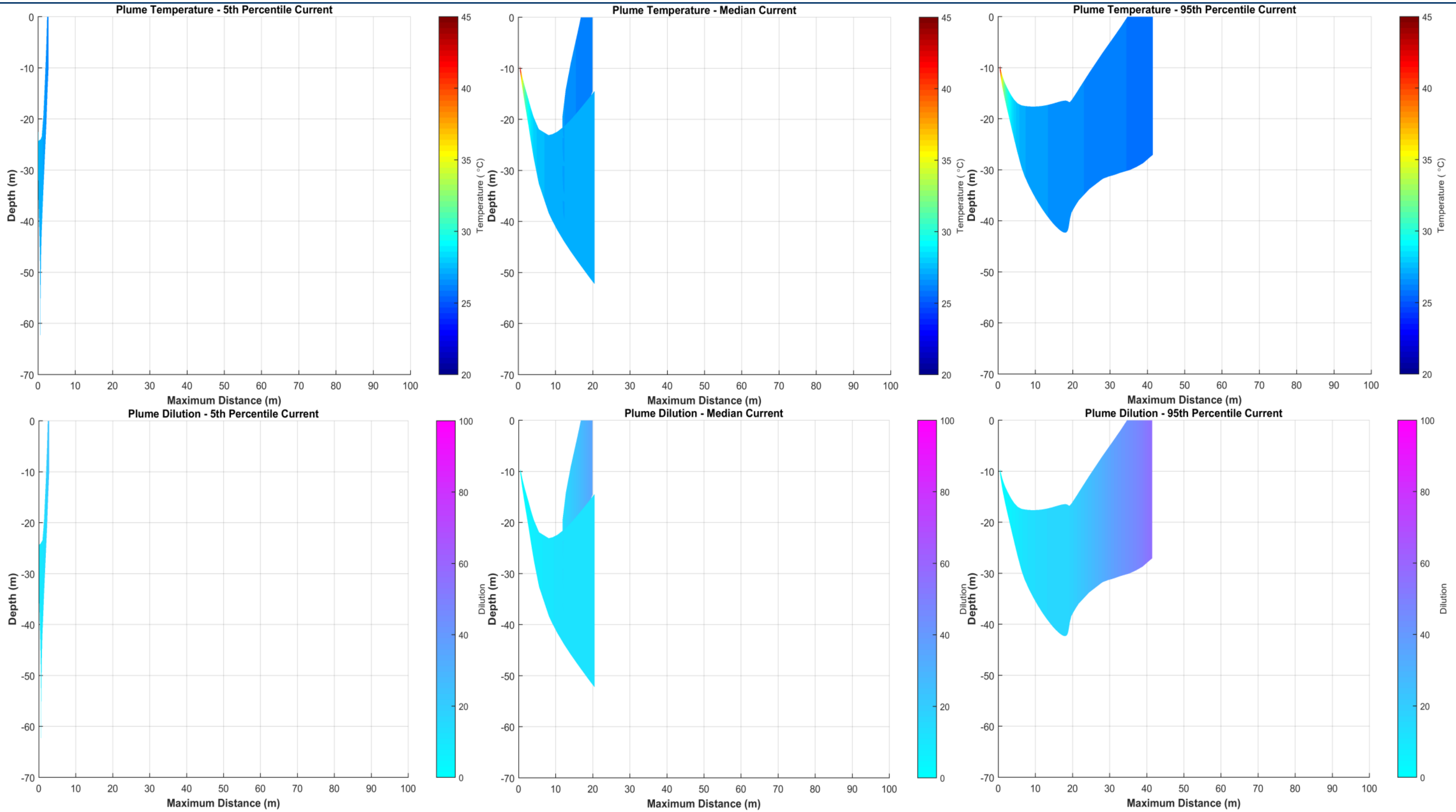

Figure 17 Near-field average temperature and dilution results for constant weak, medium and strong summer currents for the minimum flow rate (288,000 m³/d)

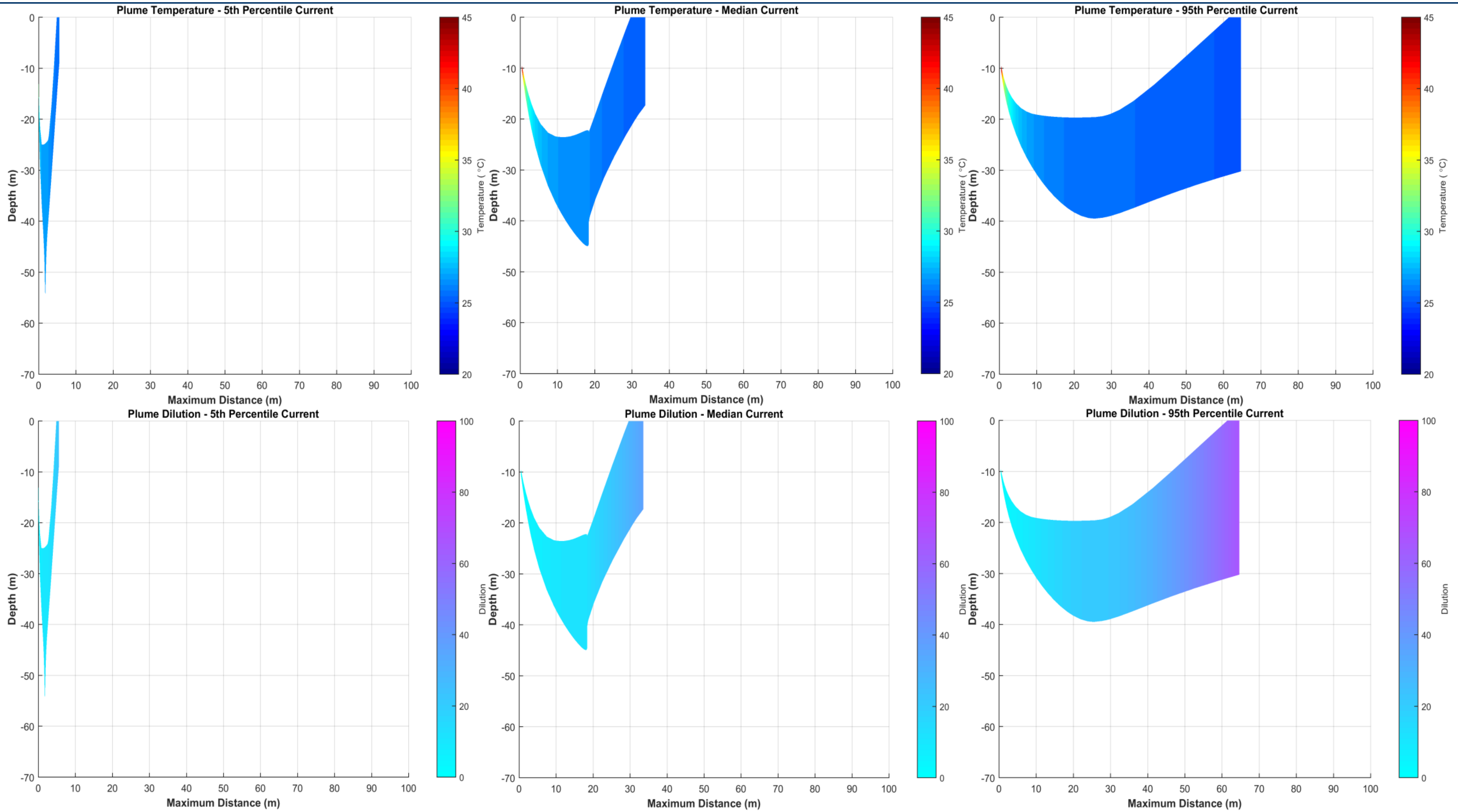

Figure 18 Near-field average temperature and dilution results for constant weak, medium and strong transitional currents for the minimum flow rate (288,000 m^3/d)

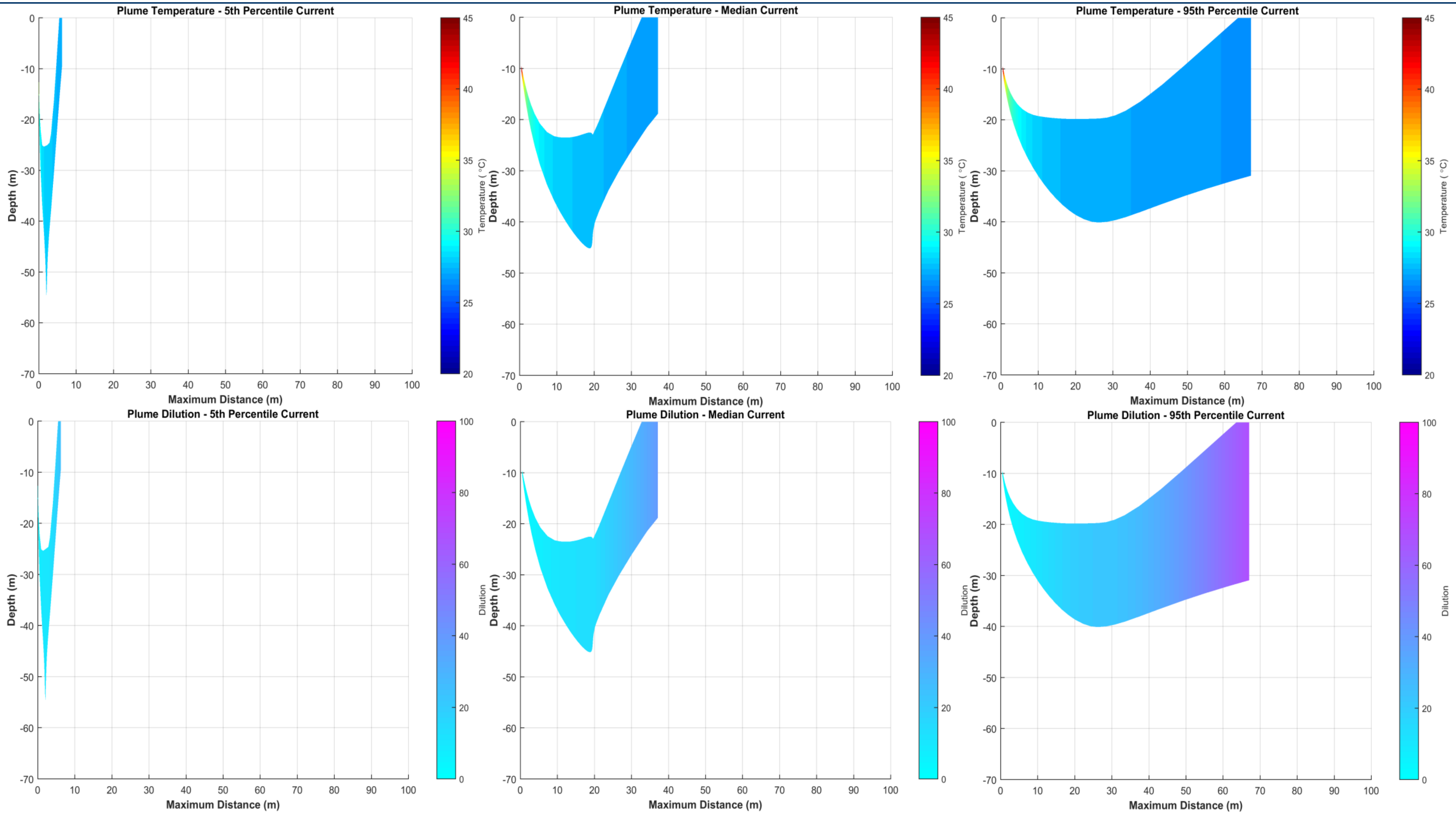

Figure 19 Near-field average temperature and dilution results for constant weak, medium and strong winter currents for the minimum flow rate (288,000 m^3/d)

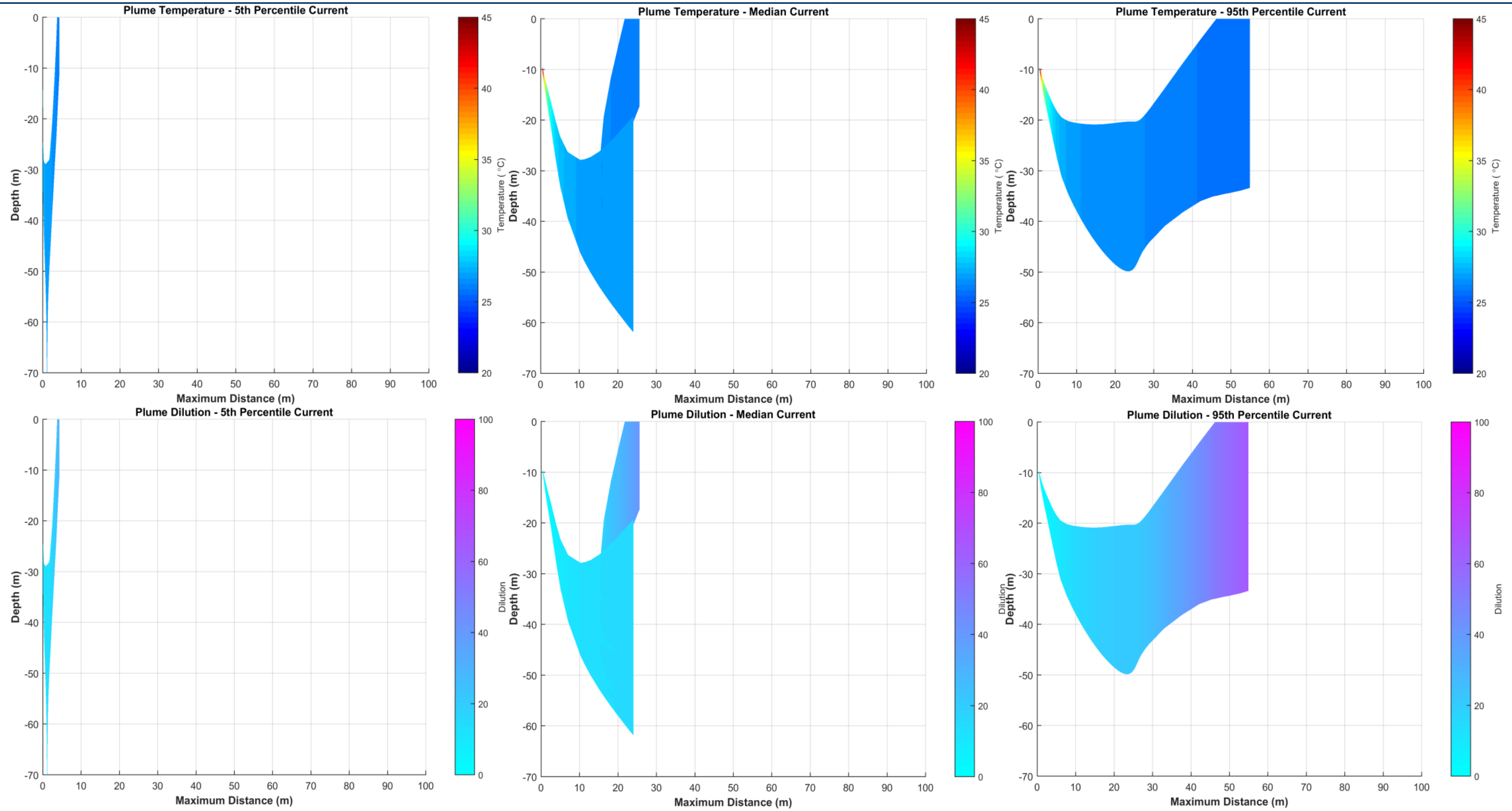

Figure 20 Near-field average temperature and dilution results for constant weak, medium and strong summer currents for the maximum flow rate (360,576 m^3/d)

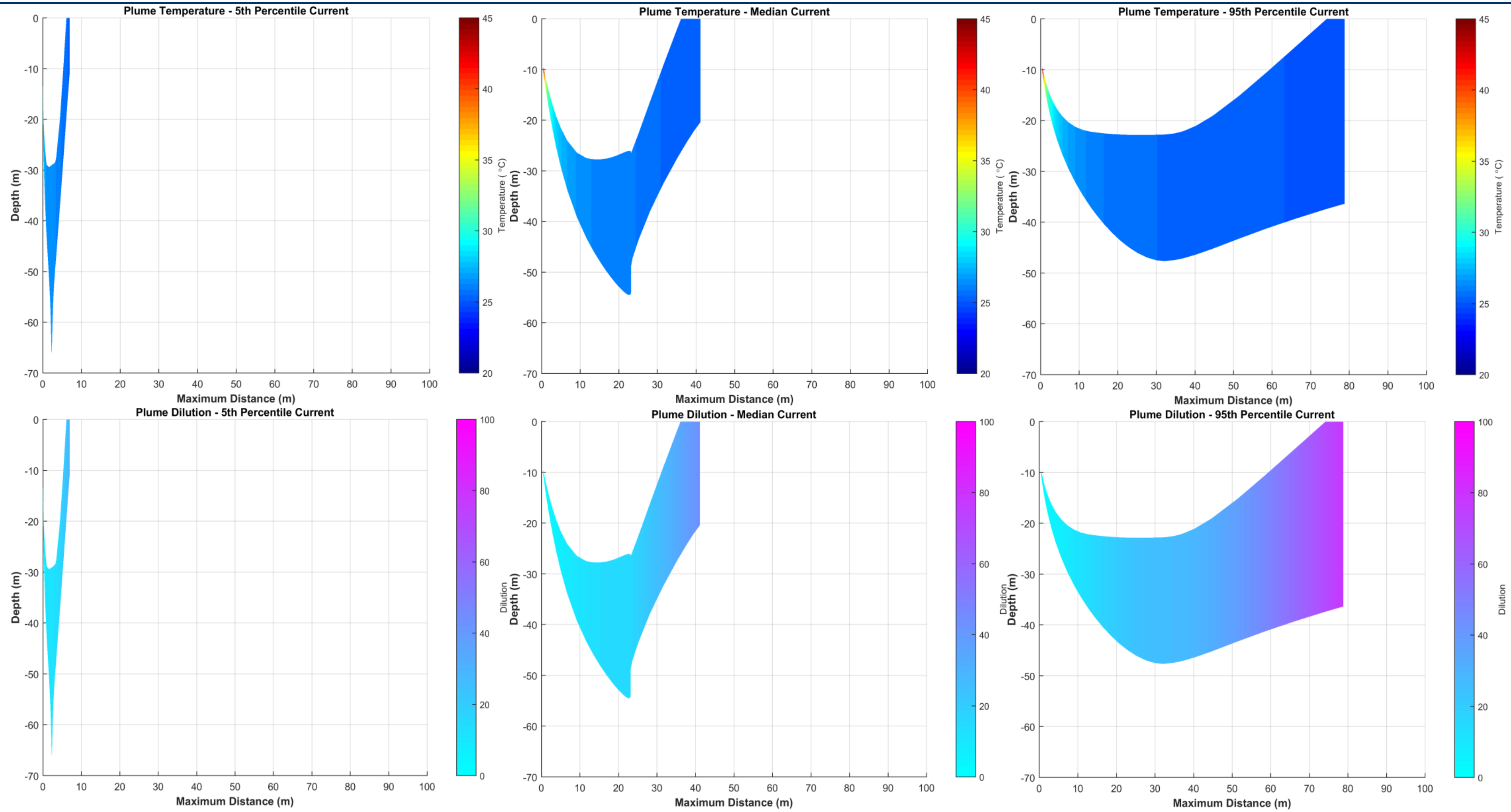

Figure 21 Near-field average temperature and dilution results for constant weak, medium and strong transitional currents for the maximum flow rate (360,576 m^3/d)

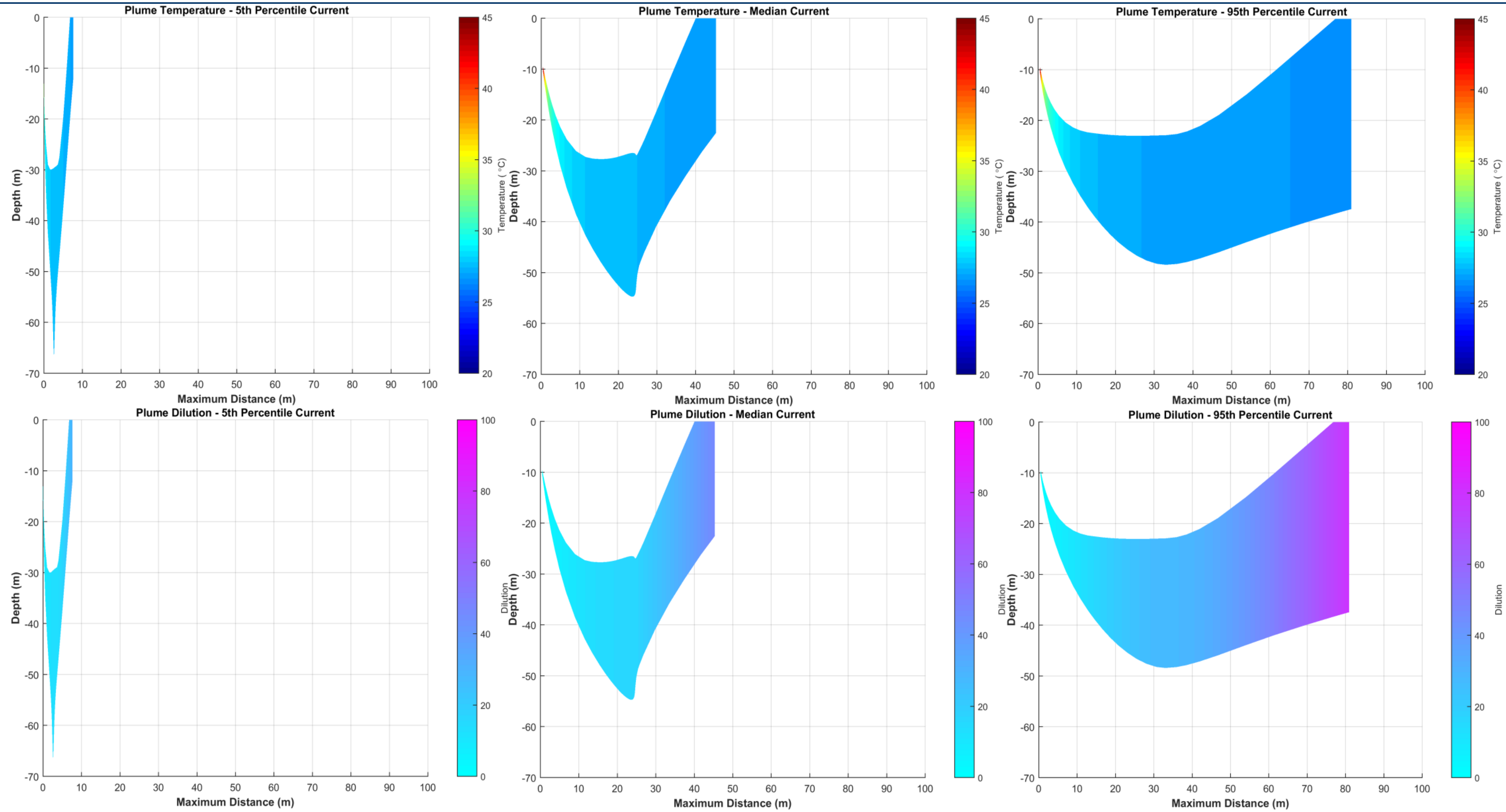

Figure 22 Near-field average temperature and dilution results for constant weak, medium and strong winter currents for the maximum flow rate (360,576 m^3/d)

Table 8 Predicted plume characteristics upon encountering the sea surface (end of near-field mixing) for the minimum flow rate (288,000 m^3/d flow) for each season and current speed.

Season	Surface current speed (m/s)	Plume diameter at the sea surface (m)	Plume temperature (ºC)	Difference between plume and ambient temperature (ºC)	Dilution of the plume (1:x)		Maximum horizontal distance (m)
					Minimum	Average	
Summer	Weak (0.04)	18.6	26.2	0.8	13	26	2.8
	Medium (0.11)	24.8	25.9	0.5	18	36	20.0
	Strong (0.27)	36.5	25.7	0.3	31	57	41.5
Transitional	Weak (0.05)	17.6	25.5	0.8	13	24	5.6
	Medium (0.14)	24.5	25.2	0.5	17	37	33.6
	Strong (0.29)	32.3	25.0	0.3	20	66	64.7
Winter	Weak (0.03)	18.2	27.0	0.7	13	25	6.2
	Medium (0.11)	26.0	26.8	0.5	19	40	37.2
	Strong (0.27)	33.1	26.6	0.3	21	69	67.1

Table 9 Predicted plume characteristics upon encountering the sea surface (end of near-field mixing) for the maximum flow rate (360,576 m^3/d) for each season and current speed.

Season	Surface current speed (m/s)	Plume diameter at the sea surface (m)	Plume temperature (ºC)	Difference between plume and ambient temperature (ºC)	Dilution of the plume (1:x)		Maximum horizontal distance (m)
					Minimum	Average	
Summer	Weak (0.04)	22.8	26.3	0.6	16	31	4.3
	Medium (0.11)	29.3	25.9	0.5	21	41	25.7
	Strong (0.27)	43.0	25.7	0.3	43	65	55.0
Transitional	Weak (0.05)	21.6	25.4	0.7	15	30	7.0
	Medium (0.14)	29.8	25.2	0.5	20	44	41.2
	Strong (0.29)	39.4	25.0	0.3	24	78	78.8
Winter	Weak (0.03)	22.2	26.9	0.6	16	30	7.7
	Medium (0.11)	31.44	26.7	0.4	22	47	45.4
	Strong (0.27)	40.1	26.5	0.2	25	80	81.0

3.2 Far-field modelling

3.2.1 General observations

Figure 23 and Figure 24 show screenshots of predicted concentrations (and equivalent dilutions) for the chlorine every 2 hours from 4 am to 2 pm 1st September 2012. The results are based on the minimum flow rate of 288,000 m^3/d.

The images have been included to illustrate that the concentrations (and in turn dilutions) became more variable over time as a result of the change in current directions and speeds. Lower concentrations (higher dilution rates) occurred during stronger currents, whereas patches of higher concentrations (lower dilution rates) tended to build up at the turn of the tide or during weaker current events. Additionally, during these periods of decreased current speeds the predicted plume typically demonstrated a more continuous appearance, with the higher concentration patches moving as a unified group.

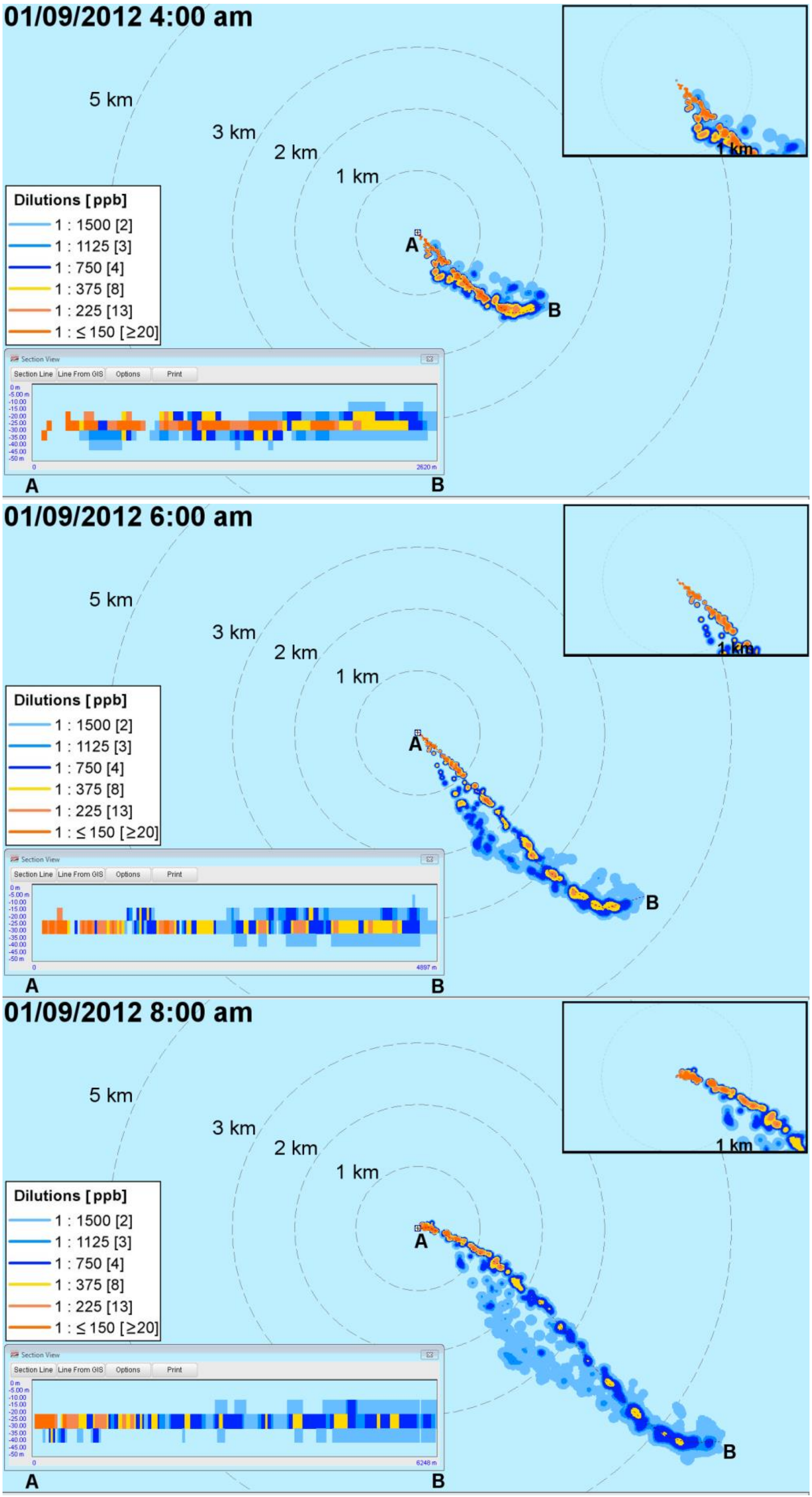

Figure 23 Screenshot every 2 hours of the predicted chlorine concentration (and equivalent dilution) from 4 am to 8 am 1st September 2012. Results are based on the maximum water column concentration for the maximum flow rate scenario (288,000 m^3/d). Figure insets illustrate zoomed-in view of predicted plume concentrations.

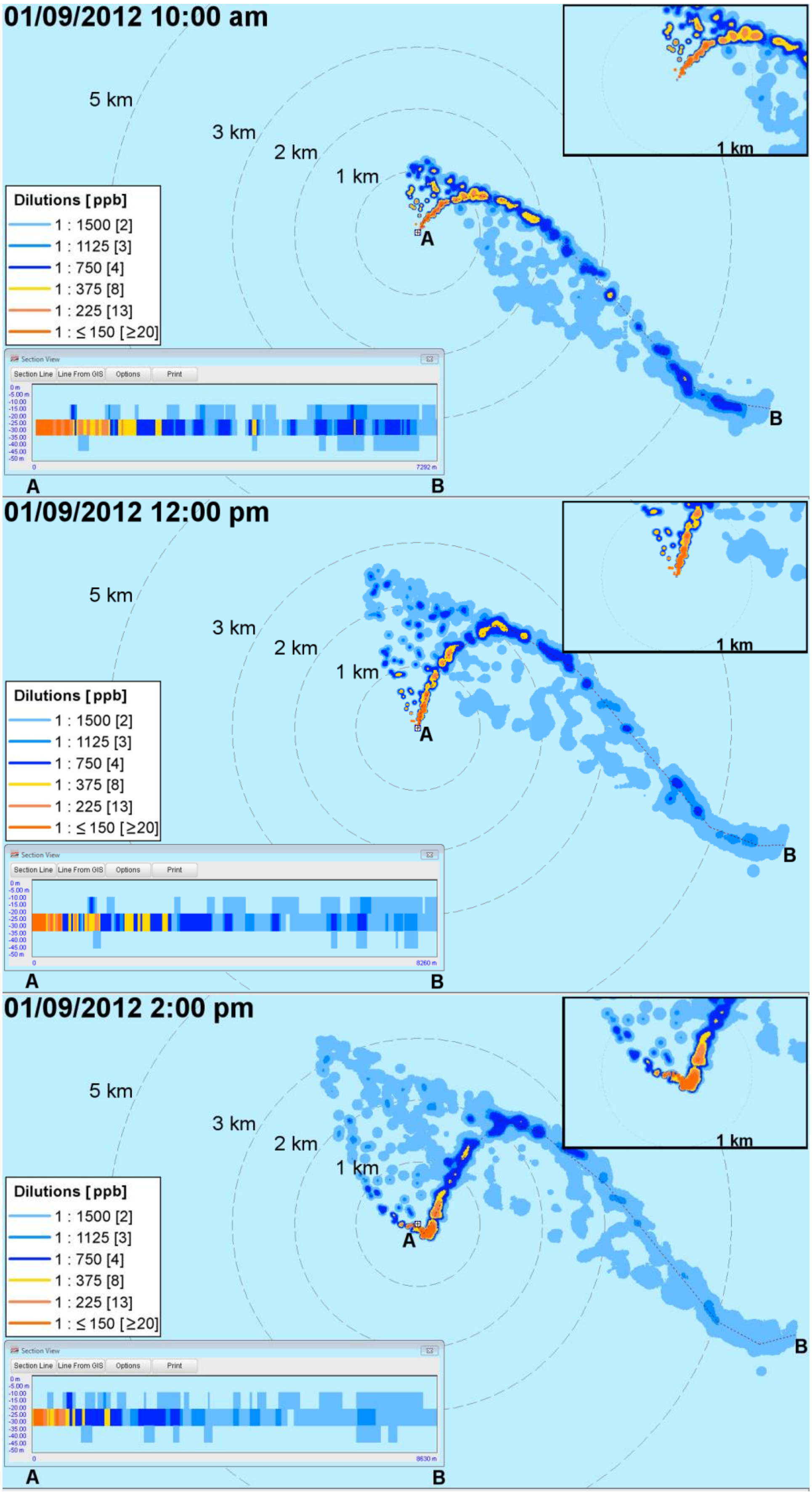

Figure 24 Screenshot every 2 hours of the predicted chlorine concentration (and equivalent dilution) from 10 am to 2 pm 1st September 2012. Results are based on the maximum water column concentration for the maximum flow rate scenario (288,000 m^3/d). Figure insets illustrate zoomed-in view of predicted plume concentrations.

3.2.2 Seasonal analysis

The 15 minute model outputs for each month from each of the three years (2010, 2012 and 2014) were combined and analysed according to the respective season (i.e. summer – December, January, February; transitional periods – March, April and September to November; and winter – May to August). This approach assists with identifying the potential for exposure on a seasonal basis, to the nearest shoals/banks (i.e. Evans Shoal, Tassie Shoal and Lynedoch Bank) whilst taking into account the interannual variability.

Table 10 shows the chlorine concentrations achieved at specific distances from the release location for each flow rate and season.

Table 11 is a summary of the maximum distances from release site to achieve a given concentration for each flow rate and season. For both flow rates and all three seasons, 13 ppb (which represents the predicted no effect concentration for acute exposure based on Chariton and Stauber (2008)) was achieved within 4.6 km from the release location. The maximum distance to achieve 2 ppb (which represents the predicted no effect concentration in the event of chronic exposure to chlorine at the 99% species protection level, as reported by CSIRO (Chariton and Stauber 2008)) was 20.51 km from the release location. Based on the distance from the 13 ppb and 2 ppb chlorine concentration contours to the closest shoal/bank being Evans Shoal (minimum distance of approximately 62.49 km and 53.37 km, respectively) no exposure is expected for non-transient species and receptors.

Table 12 presents the total area of coverage for a given chlorine concentration for each flow rate and season. Based on the minimum flow rate (288,000 m^3/d) and ≥13 ppb concentration, the total area of coverage was largest during the transitional months (19.50 km^2) and smallest during the summer months (18.92 km^2). The extent was found to be influenced by the rate of discharge. For example, by increasing the flow rate to 360,576 m^3/d and maintaining the initial chlorine concentration of 3,000 ppb, the ≥13 ppb area of coverage increased by 60% for the summer conditions (from 18.92 km^2 to 30.43 km^2). The maximum extent of the ≥ 13 ppb area was 30.43 km^2. For ≥ 2 ppb and minimum flow rate, the area of coverage was largest during the summer conditions (313.06 km^2). When assessing the maximum flow rate, the ≥ 2 ppb area of coverage increased by approximately 22% for the summer conditions (366.42 km^2).

The predicted extents of the chlorine concentrations (and minimum dilutions) for each season and flow rate (288,000 m^3/d and 360,576 m^3/d), assuming an initial chlorine concentration of 1,000 ppb, are shown in Figure 25 to Figure 30. Note that the images represent the highest chlorine concentration at any given time-step through the water column and does not take into account frequency or duration.

Table 10 Chlorine concentrations achieved at specific distances from the cooling water discharge release location for each flow rate and season

Flow rate (m^3/d)	Season	Maximum chlorine concentrations (ppb) achieved at specific distances from the release location						
		0.1 km radius	0.5 km radius	1 km radius	2 km radius	3 km radius	5 km radius	> 5 km radius
288,000	Summer	≥ 20	≥ 20	≥ 20	13	13	4	2
	Transitional	≥ 20	≥ 20	≥ 20	13	13	2	2
	Winter	≥ 20	≥ 20	≥ 20	13	13	2	2
360,576	Summer	≥ 20	≥ 20	≥ 20	13	13	8	2
	Transitional	≥ 20	≥ 20	≥ 20	13	13	2	2
	Winter	≥ 20	≥ 20	≥ 20	13	13	4	2

Table 11 Maximum distance from the release location to achieve a given chlorine concentration for each flow rate and season

Flow rate (m^3/d)	Season	Maximum distance (km) from release location to achieve chlorine concentrations (ppb)					
		≥ 20	13	8	4	3	2
288,000	Summer	2.36	3.55	5.27	9.76	11.87	18.99
	Transitional	2.74	3.51	4.84	10.17	12.89	19.30
	Winter	2.49	3.58	5.15	9.67	11.97	19.22
360,576	Summer	3.32	4.55	5.70	10.23	12.90	19.94
	Transitional	3.00	3.97	6.37	11.57	18.61	20.51
	Winter	3.11	4.60	5.79	10.41	16.29	20.03

Table 12 Total area of coverage for a given chlorine concentration for each flow rate and season

Flow rate (m^3/d)	Season	Total area (km^2) of coverage for assigned chlorine concentrations (ppb)					
		≥ 20	≥ 13	≥ 8	≥ 4	≥ 3	≥ 2
288,000	Summer	4.63	18.92	47.52	119.17	177.52	313.06
	Transitional	6.69	19.50	41.94	125.43	187.80	300.45
	Winter	5.54	17.66	40.77	118.67	190.41	310.39
360,576	Summer	11.87	30.43	60.30	158.01	249.05	343.03
	Transitional	12.82	29.01	60.90	166.51	254.33	366.42
	Winter	11.47	27.83	56.88	166.72	263.04	331.70

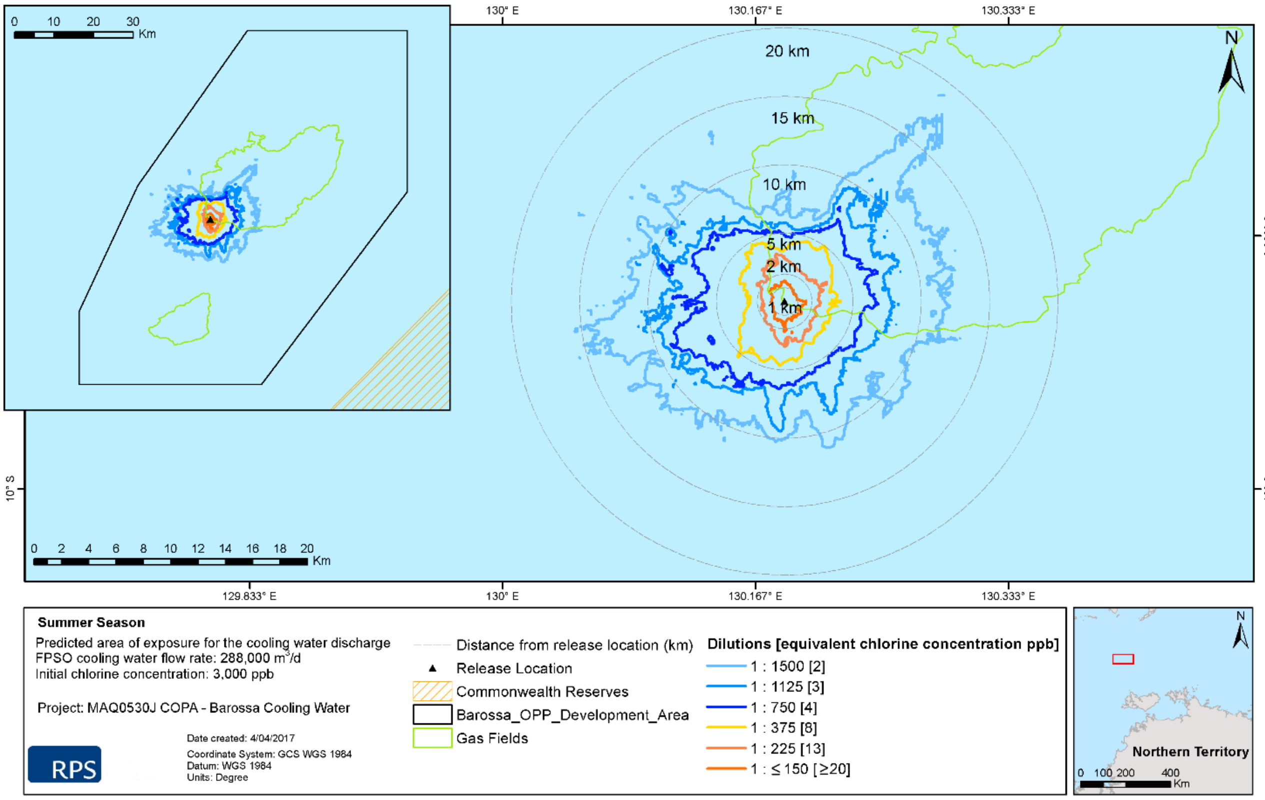

Figure 25 Predicted area of exposure by chlorine under summer conditions for the minimum cooling water flow rate (288,000 m^3/d)

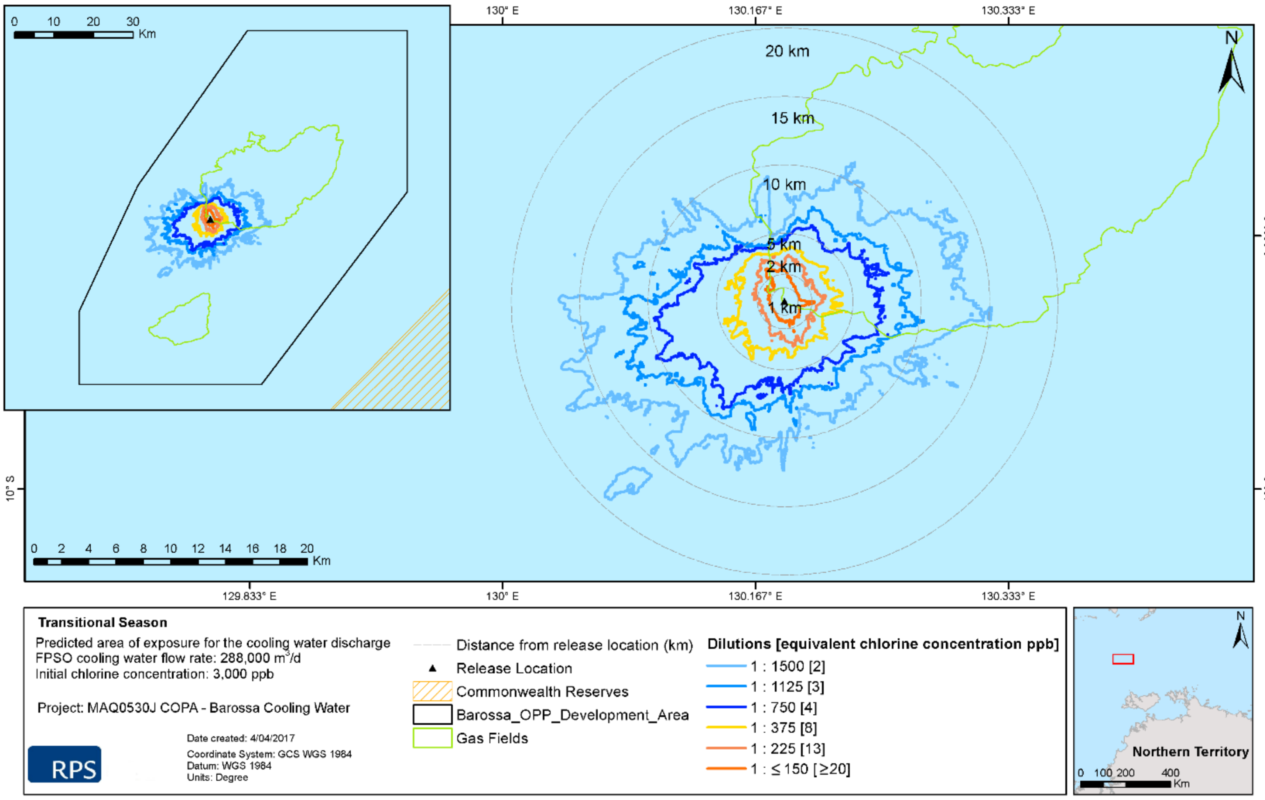

Figure 26 Predicted area of exposure by chlorine under transitional conditions for the minimum cooling water flow rate (288,000 m^3/d)

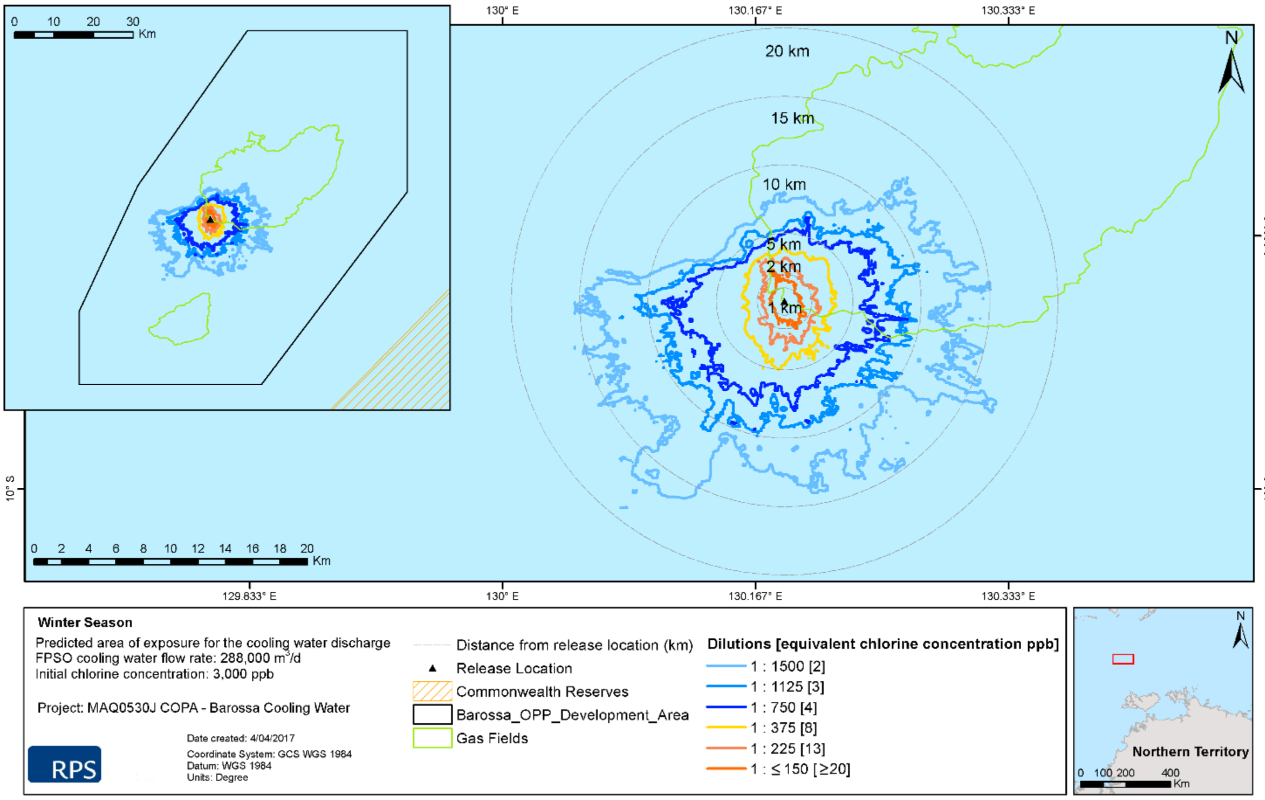

Figure 27 Predicted area of exposure by chlorine under winter conditions for the minimum cooling water flow rate (288,000 m^3/d)

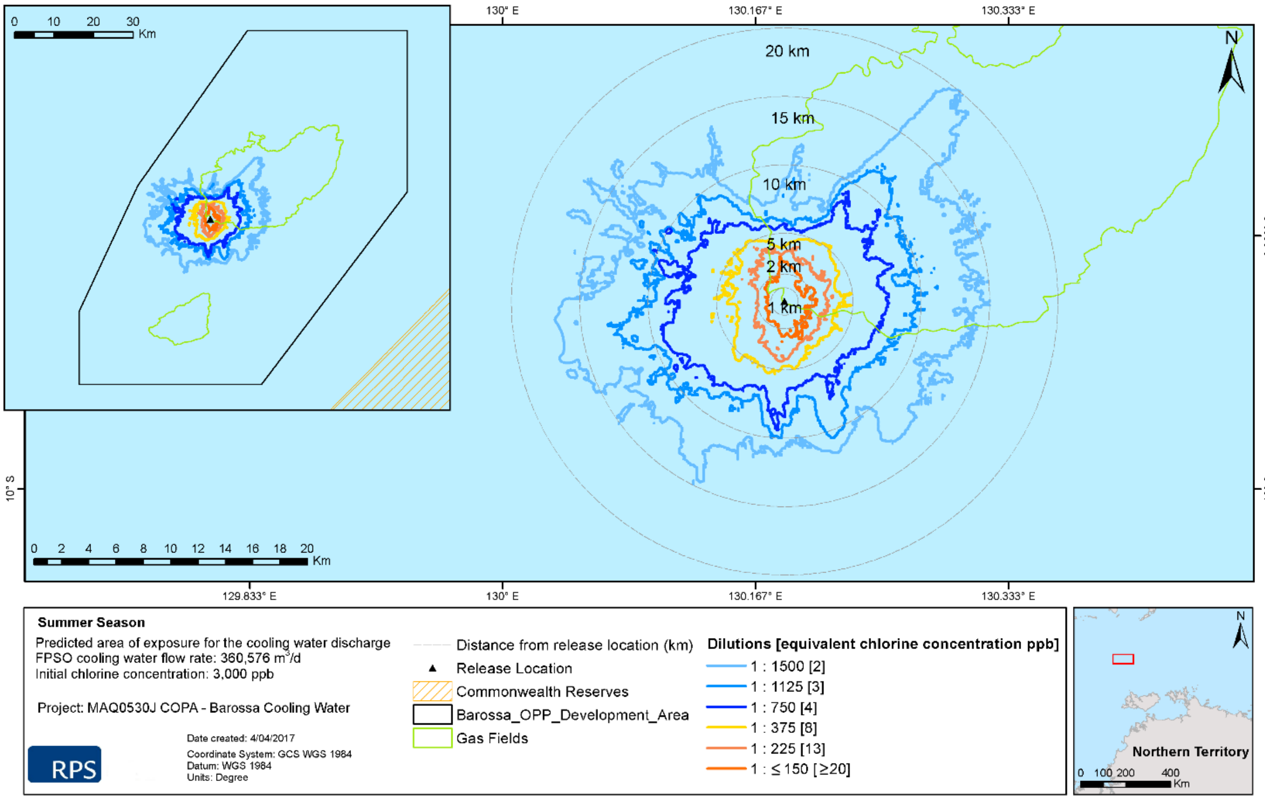

Figure 28 Predicted area of exposure by chlorine under summer conditions for the maximum cooling water flow rate (360,576 m^3/d)

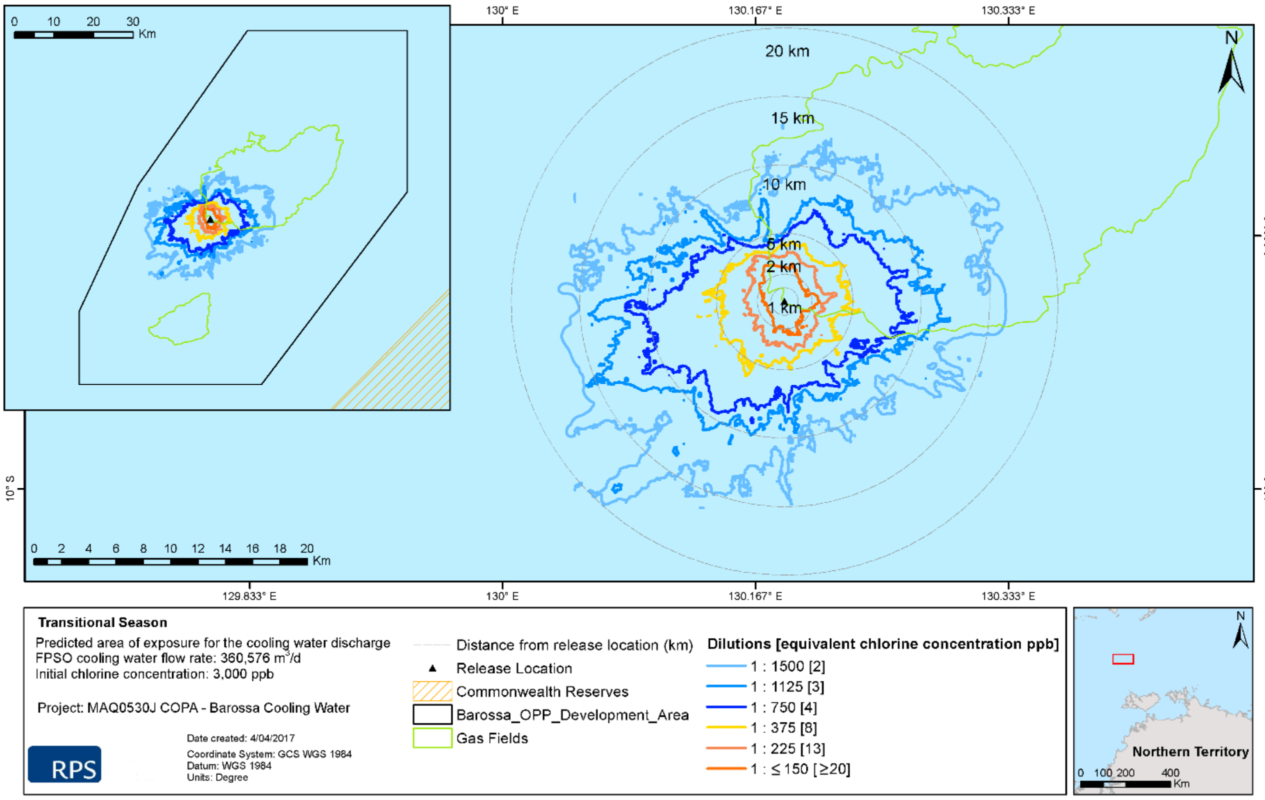

Figure 29 Predicted area of exposure by chlorine under transitional conditions for the maximum cooling water flow rate (360,576 m^3/d)

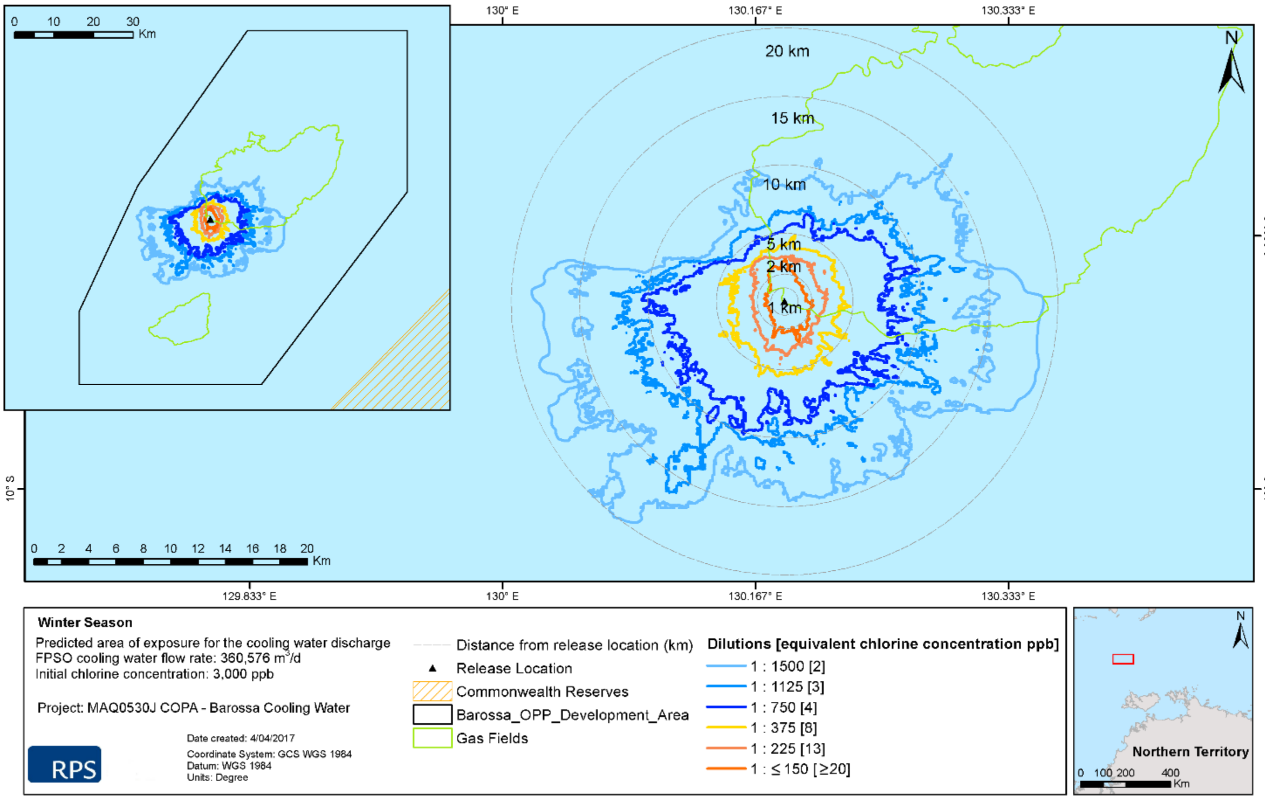

Figure 30 Predicted area of exposure by chlorine under winter conditions for the maximum cooling water flow rate (360,576 m^3/d)

3.2.3 Combined analysis

Table 13 shows the maximum distance from the release location to achieve chlorine concentrations for each flow rate. The 13 ppb contour was predicted to be 3.58 km and 4.60 km from the release location for the minimum and maximum flow rate, respectively. Whereas, the 2 ppb zone was predicted to extend up to 19.33 km and 20.51 km from the release location for the minimum and maximum flow rate, respectively.

Table 14 shows the total area of coverage for a given chlorine concentration for each flow rate. Based on the maximum flow rate and ≥ 2 ppb , the area of coverage was 420.18 km^2, which was approximately 12% larger, compared to the results for the minimum flow rate (376.16 km^2).

Figure 31 and Figure 32 present the predicted residual chlorine concentrations (and minimum dilutions) based on combined results for 2010, 2012 and 2014 conditions for the minimum and maximum cooling water flow rates, respectively.

Table 13 Maximum distance from cooling water discharge release location to achieve chlorine concentrations for each flow rate

Flow rate (m^3/d)	Maximum distance (km) from release location to achieve chlorine concentrations (ppb)					
	≥ 20	≥ 13	≥ 8	≥ 4	≥ 3	≥ 2
288,000	2.74	3.58	5.27	10.17	12.89	19.30
360,576	3.32	4.60	6.37	11.57	18.61	20.51

Table 14 Total area of coverage for given chlorine concentrations for each flow rate

Flow rate (m^3/d)	Total area (km^2) of coverage for assigned chlorine concentrations (ppb)					
	≥ 20	≥ 13	≥ 8	≥ 4	≥ 3	≥ 2
288,000	7.63	22.26	52.37	148.30	232.77	376.21
360,576	15.37	33.99	72.60	204.85	327.35	420.18

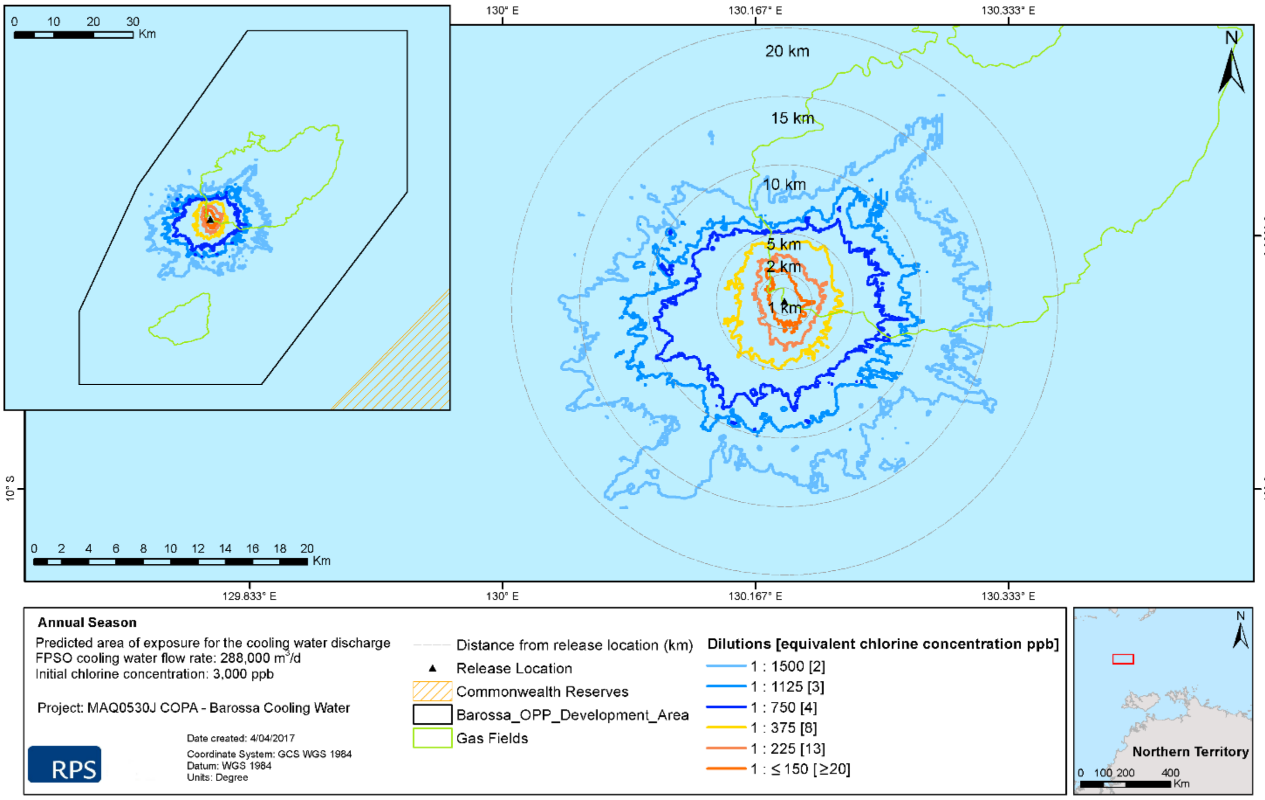

Figure 31 Predicted area of exposure by chlorine based on the minimum cooling water flow rate (288,000 m^3/d)

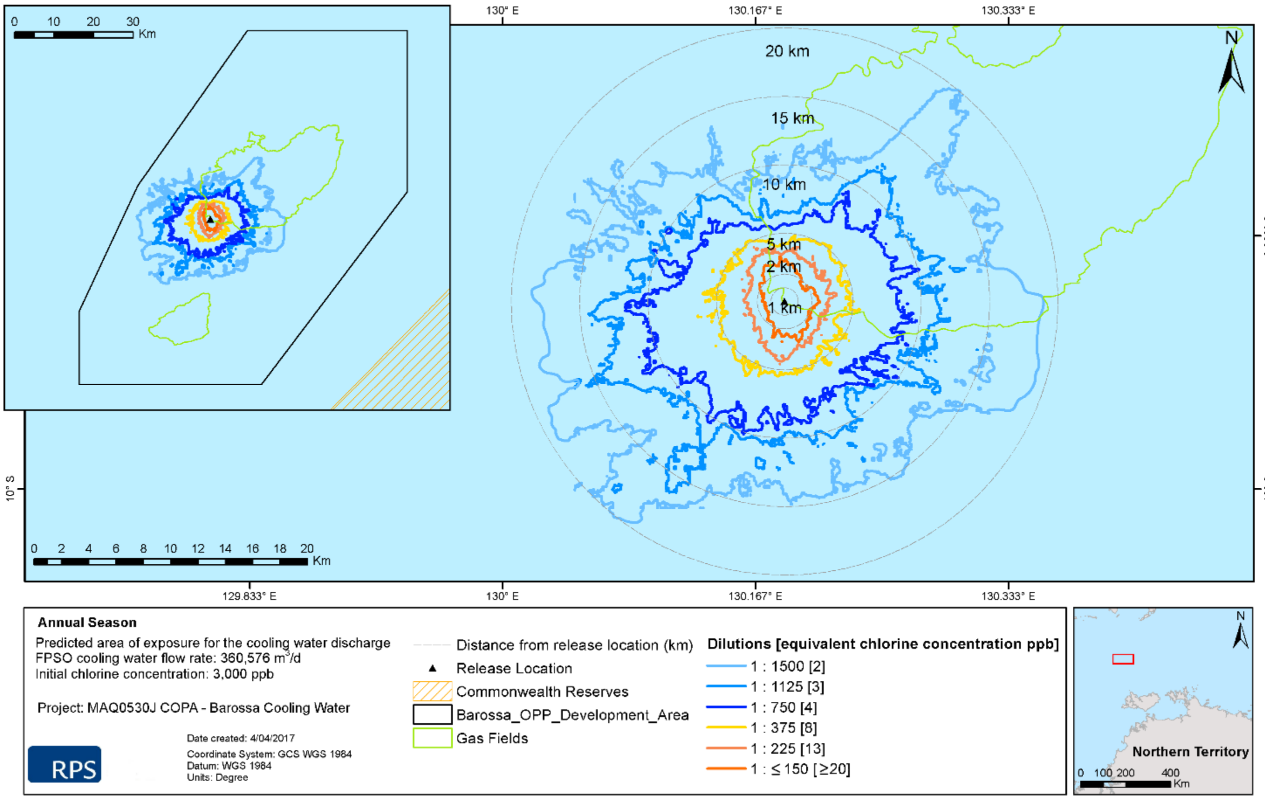

Figure 32 Predicted area of exposure by chlorine based on the maximum cooling water flow rate (360,576 m^3/d)

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5.0 Appendices

Appendix A. Predicted plume temperature and distance plots for 288,000 m^3/d flow rate

Figure 33 to Figure 35 illustrate the predicted difference in plume and ambient sea surface temperature versus distance from the release location for the minimum flow rate (288,000 m^3/d) under weak, medium and strong current strengths and seasonal conditions.

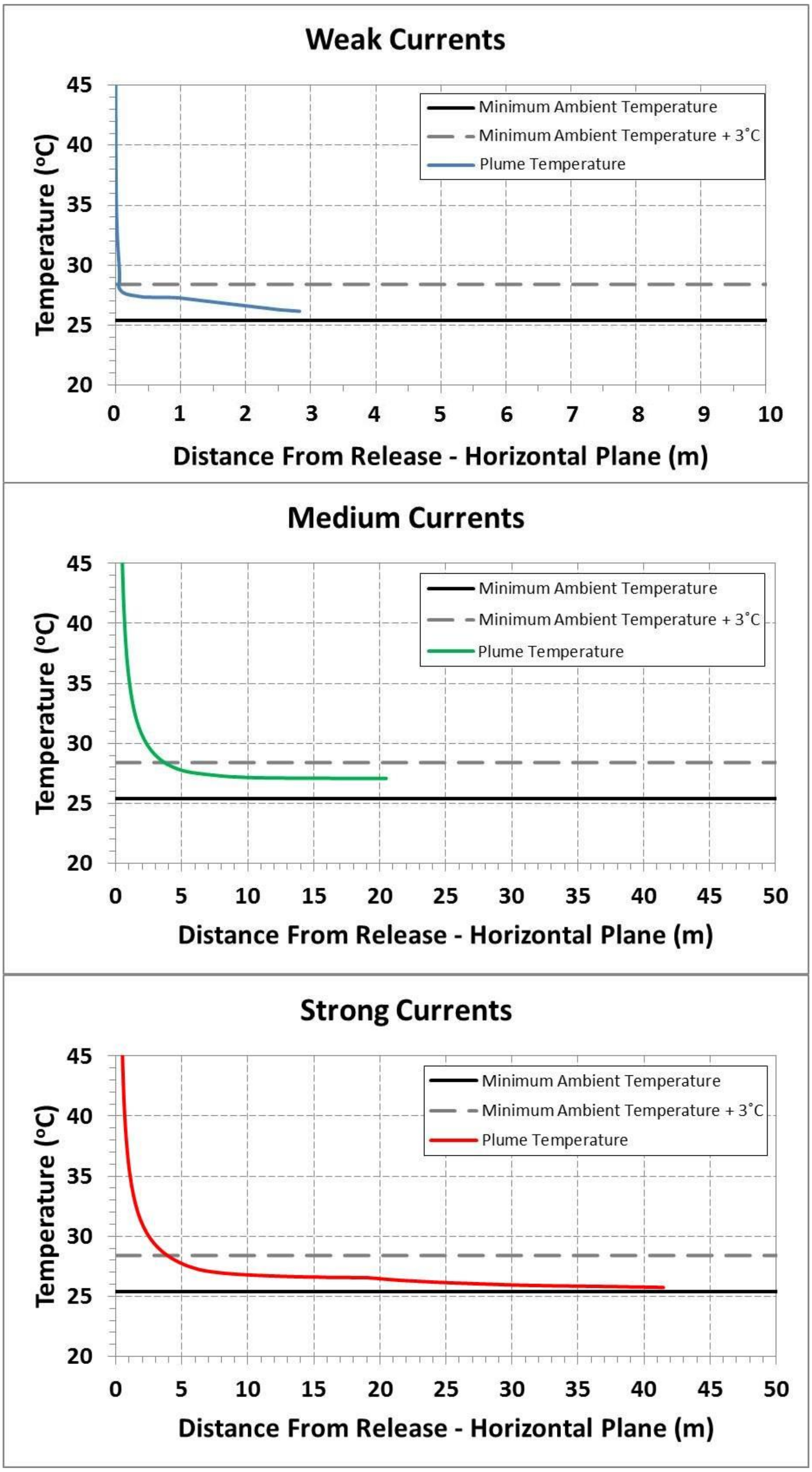
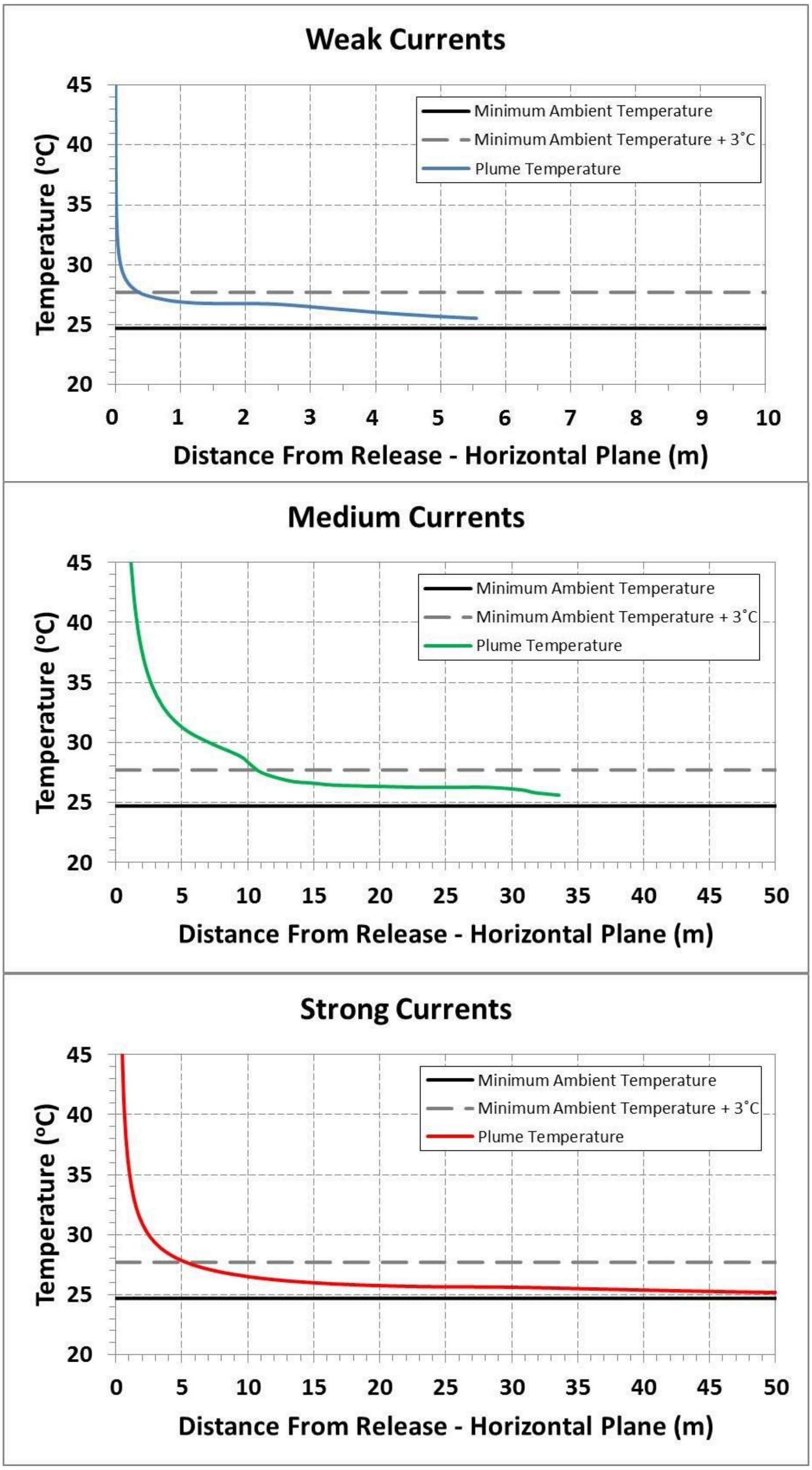


Figure 33 Predicted change in cooling water plume temperature as a function of distance from release location under weak, medium and strong current strengths during summer conditions (288,000 m^3/d)



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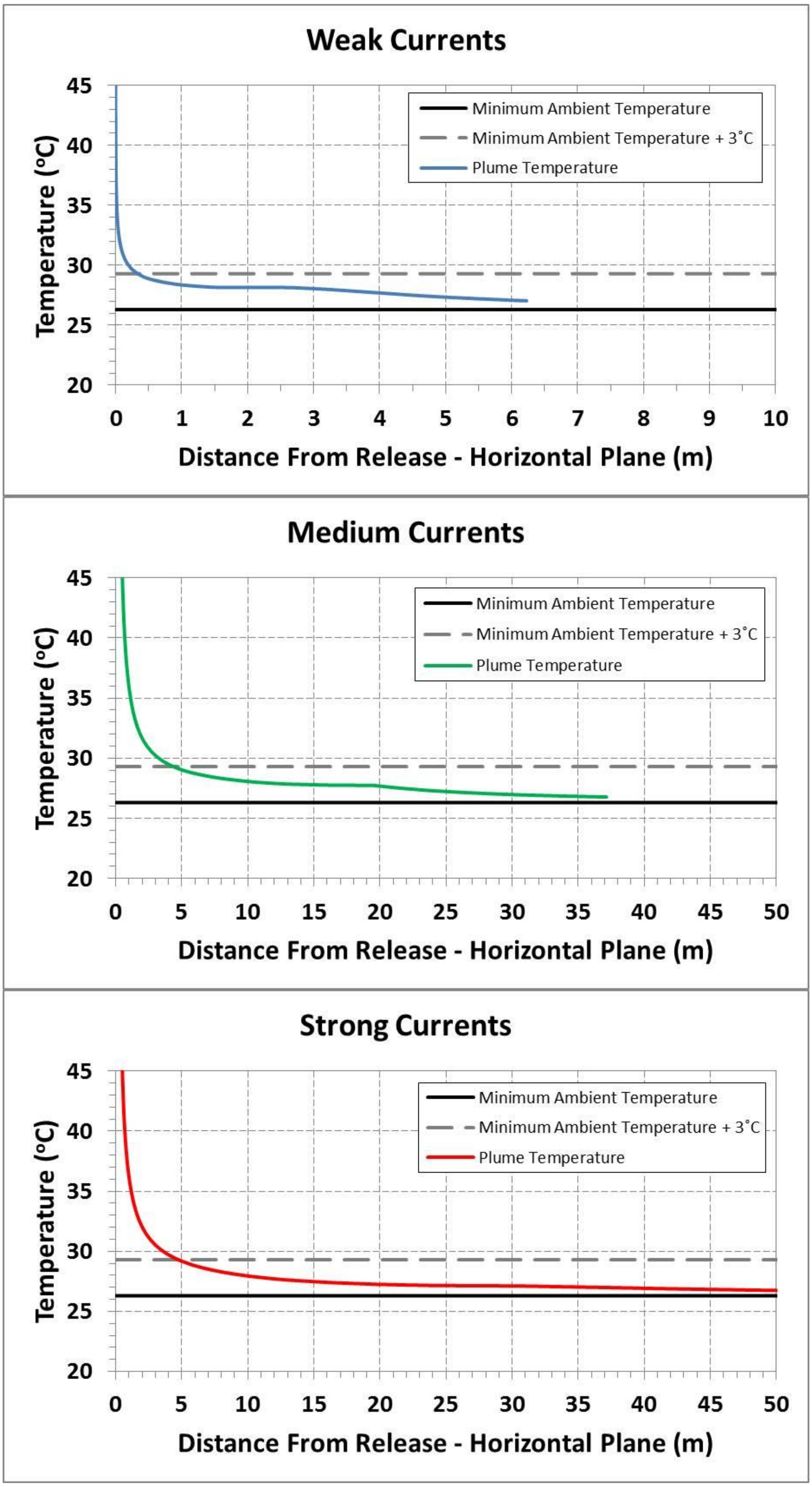


Figure 35 Predicted change in cooling water plume temperature as a function of distance from release location under weak, medium and strong current strengths during winter conditions (288,000 m^3/d)

Appendix B. Predicted plume temperature and distance plots for 360,576 m^3/d flow rate

Figure 36 to Figure 38 illustrate the predicted difference in plume and ambient sea surface temperature versus distance from release location for the maximum flow rate (360,576 m^3/d) weak, medium and strong current strengths and seasonal conditions.

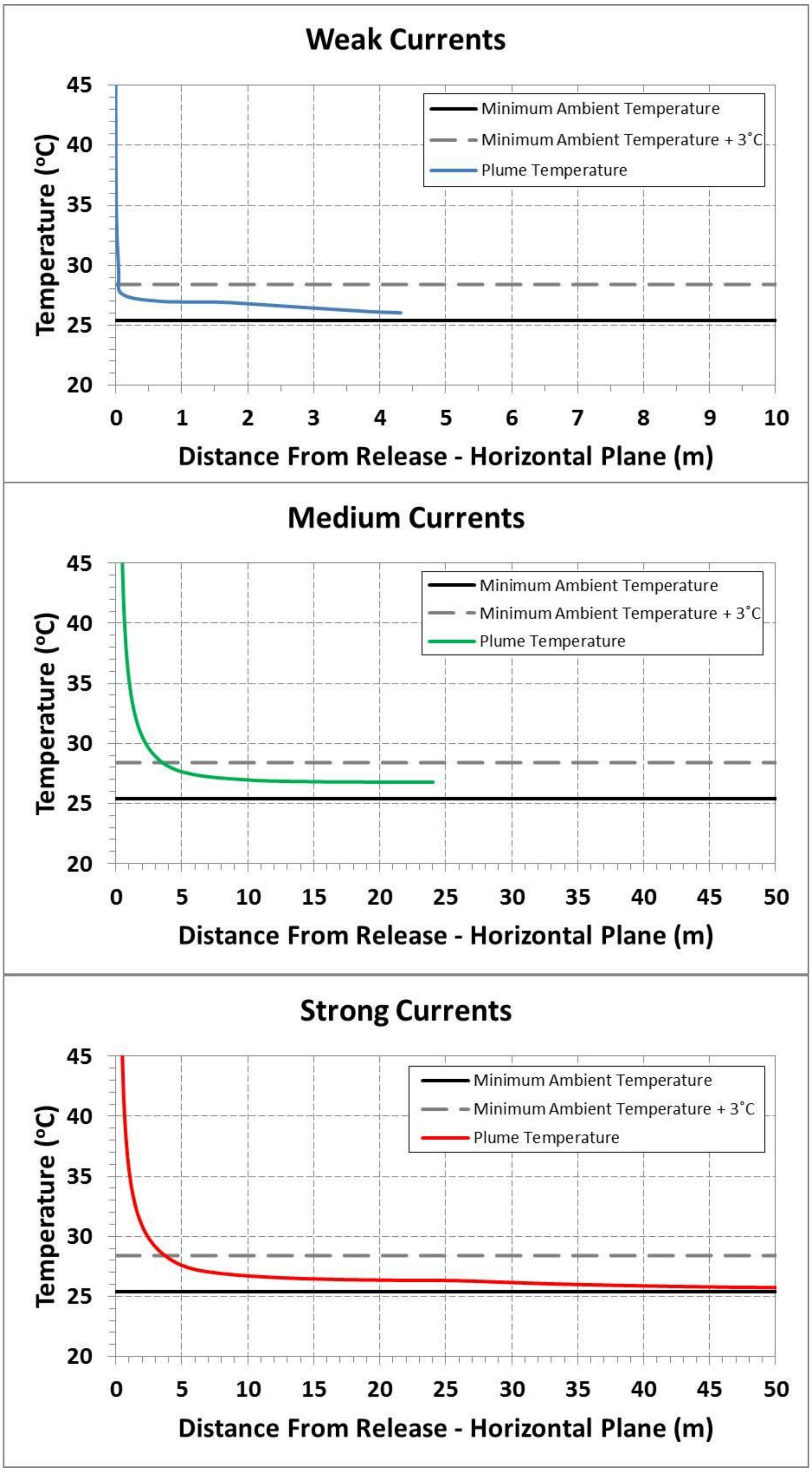
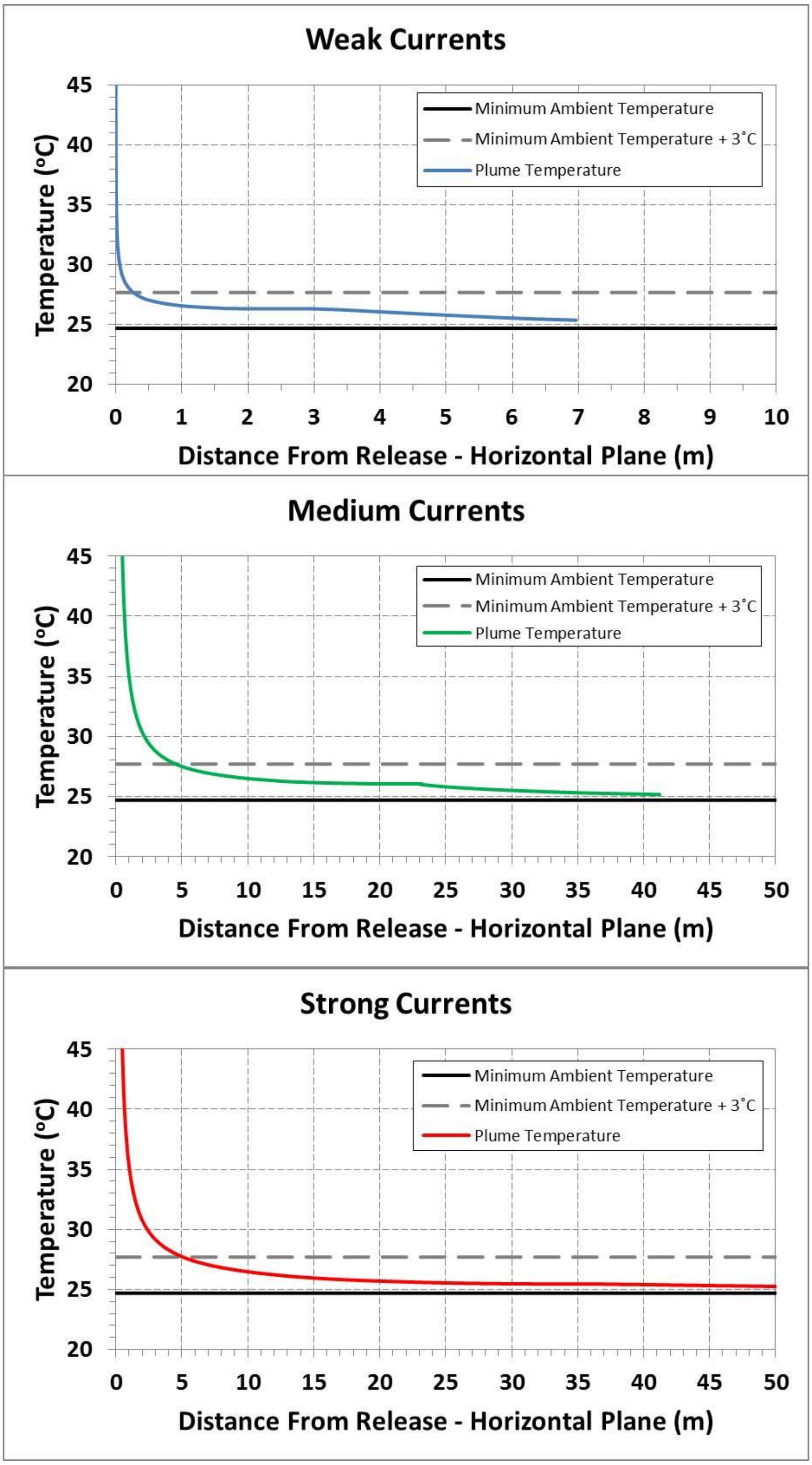


Figure 36 Predicted change in cooling water plume temperature as a function of distance from release location under weak, medium and strong current strengths during summer conditions (360,576 m^3/d)



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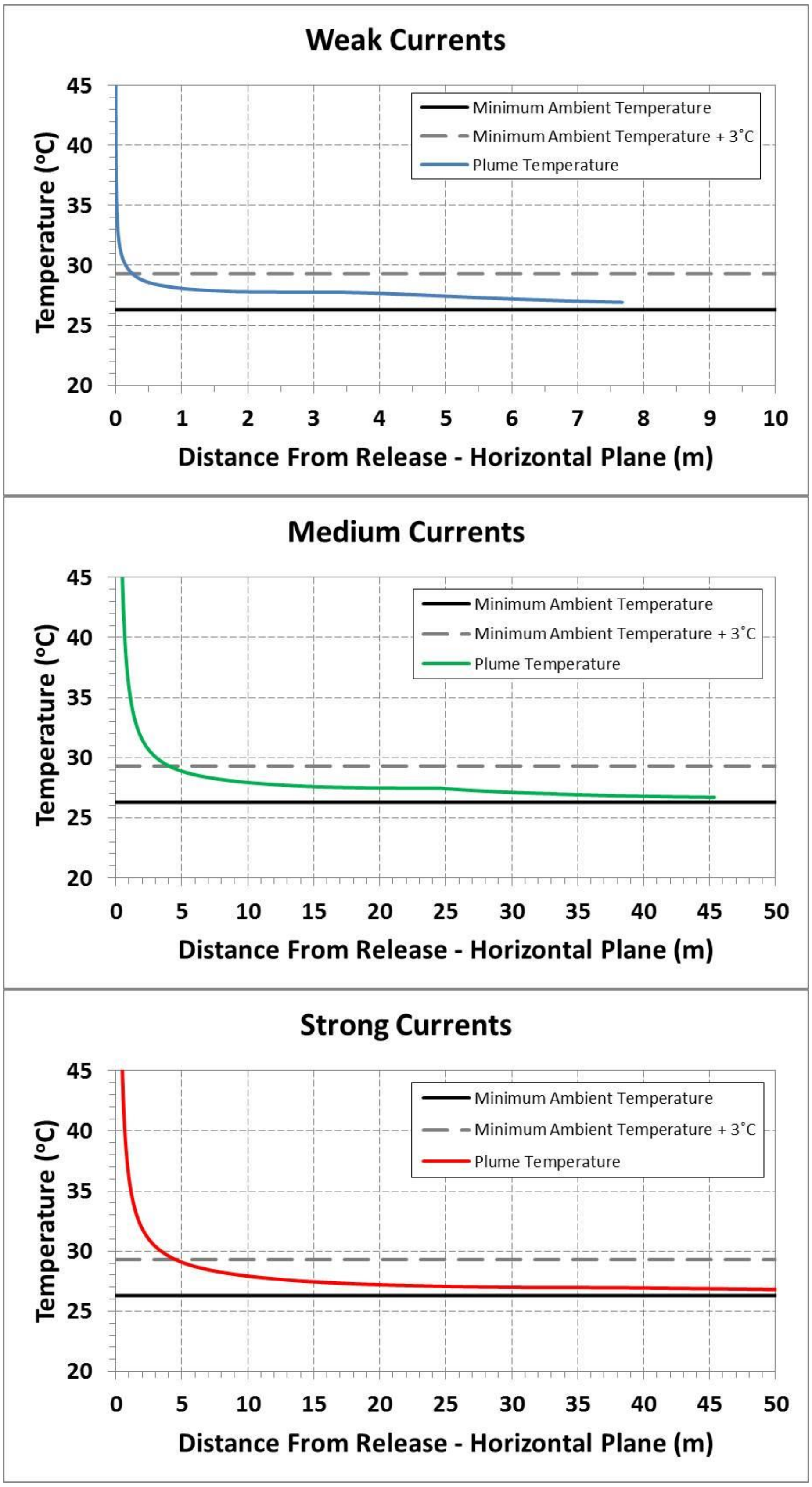

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Appendix J.

Wastewater dispersion modelling study (RPS 2017c)

ConocoPhillips Barossa Project

Wastewater Dispersion Modelling

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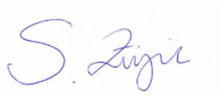
Document Status

Version	Purpose of Document	Original	Review	Review Date
Draft A	*Issued for client review*	Dr Ryan Dunn	Dr Sasha Zigic	28/2/2017
Rev 0	*Issued for client review*	Dr Ryan Dunn	Dr Sasha Zigic	28/2/2017
Rev 1	Issued to client		Dr Sasha Zigic	14/3/2017

Approval for Issue

Name	Signature	Date
Dr Sasha Zigic		14/3/2017

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1.0 Introduction

1.1 Project background

ConocoPhillips Australia Exploration Proprietary (Pty) Limited (Ltd.) (ConocoPhillips), as proponent on behalf of the current and future co-venturers, is proposing to develop natural gas resources in the Timor Sea into high quality products in a safe, reliable and environmentally responsible manner. The Barossa Area Development (herein referred to as the "project") is located in Commonwealth waters within the Bonaparte Basin, offshore northern Australia, and is approximately 300 kilometres (km) north of Darwin, Northern Territory (NT).

The development concept of the gas resource includes a floating production storage and offloading (FPSO) facility and a gas export pipeline that are located in Commonwealth jurisdictional waters. The FPSO facility will be the central processing facility to stabilise, store and offload condensate, and to treat, condition and export gas. The extracted lean dry gas will be exported through a new gas export pipeline that will tie into the existing Bayu-Undan to Darwin gas export pipeline. The lean dry gas will then be liquefied for export at the existing ConocoPhillips operated Darwin Liquefied Natural Gas facility at Wickham Point, NT.

The FPSO facility will be required to discharge wastewater (includes treated sewage, greywater and deck drainage waters) to the marine environment. The wastewater contains constituents such as oil/grease, suspended solids and coliform bacteria, into the receiving environment.

As the wastewater will contain constituents exceeding levels those of the ambient marine waters, ConocoPhillips commissioned RPS to conduct a dispersion modelling study. The main objective of the study was to assess the near-field mixing and dilution zones for the wastewater discharge during the two stages under static weak, medium and strong current strengths. The coordinate of the indicative release location is presented in Table 1 and graphically in Figure 1. The purpose of the modelling was to assist in understanding the potential area that may be influenced by the routine discharge of wastewater based on the engineering information available in the early stage of the project design phase.

The potential area that may be influenced by the wastewater discharge stream was assessed for three distinct seasons; (i) summer (December to the following February), (ii) the transitional periods (March and September to November) and (iii) winter (April to August). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

The closest environmental values and sensitivities to the modelled release location are submerged shoals and banks including Lynedoch Bank (70 km to the south-east), Evans Shoal (64 km to the west) and Tassie Shoal (74 km to the south-west).

Table 1 Barossa offshore development area wastewater dispersion modelling study release location

Release location	Latitude	Longitude	Water depth (mLAT)
Barossa offshore development area release location	9° 52' 35.8" S	130° 11' 8.4" E	~230

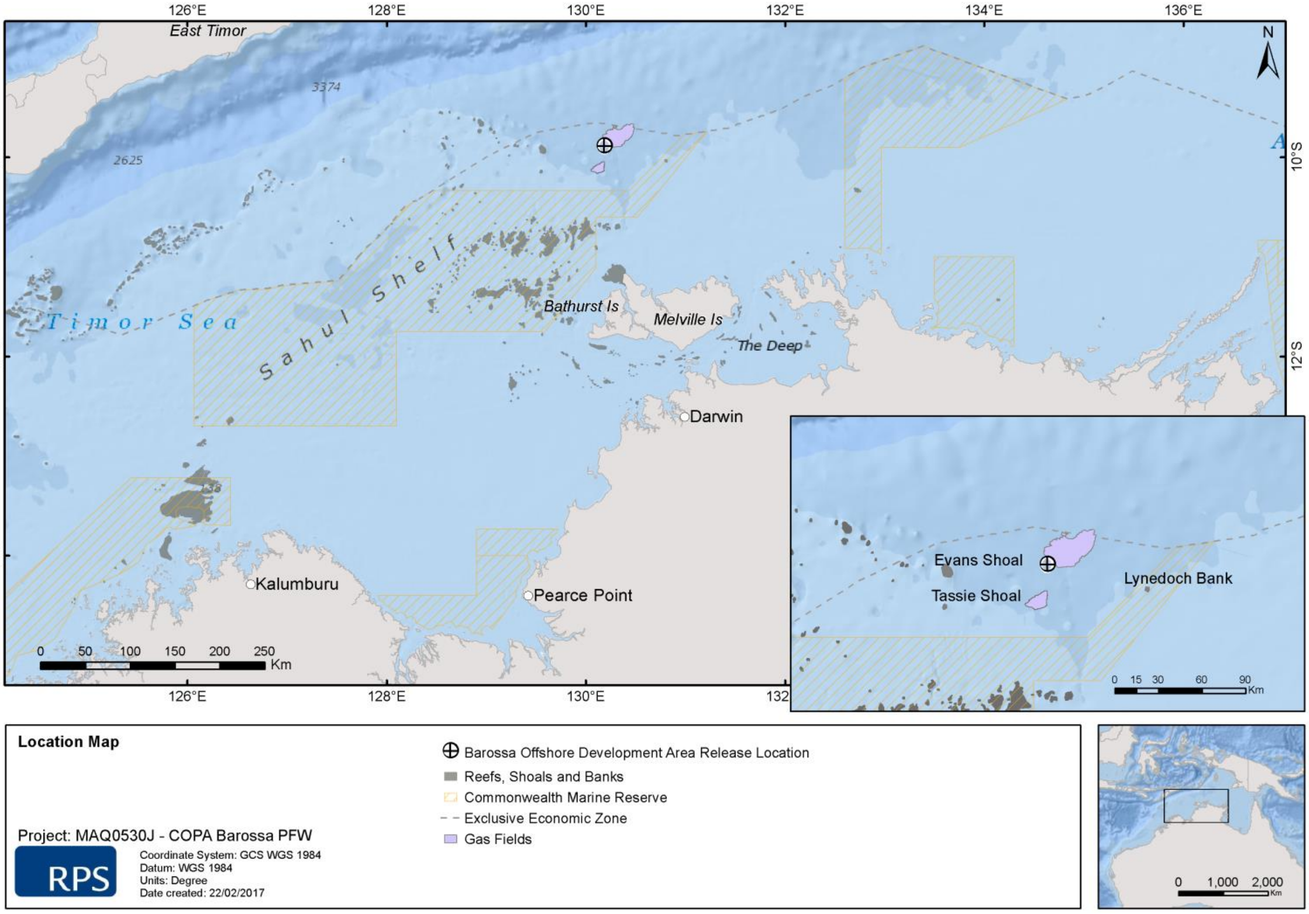


Figure 1 Map of the Barossa offshore development area wastewater modelling study release location.

2.0 Dispersion modelling

Due to the low flow rate and characteristics of the wastewater near-field modelling was only required to assess the very localised zone of influence.

The near-field zone is defined by the region where the levels of mixing and dilution are controlled by the plume's initial jet momentum and the buoyancy flux, resulting from the density difference. When the plume encounters a boundary such as the water surface, seabed or density stratification layer, the near-field mixing is complete and the far-field mixing begins.

2.1 Near-field model

2.1.1 Description

The near-field mixing of the wastewater discharge stream was predicted using the fully three-dimensional flow model, Updated Merge (UM3). The UM3 model is used for simulating single and multi-port submerged discharges and is part of the Visual Plumes suite of models maintained by the United States Environmental Protection Agency (Frick et al. 2003).

The UM3 model has been extensively tested for various discharges and found to predict the observed dilutions more accurately (Roberts and Tian 2004) than other near-field models (e.g. RSB or CORMIX).

In this Lagrangian 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 growth of each element, UM3 uses the shear (or Taylor) entrainment hypothesis and the projected-area-entrainment hypothesis. The flows begin as round buoyant jets issuing from one side of the diffuser and can merge to a plane buoyant jet (Carvalho et al. 2002). Model output consists of plume characteristics, including centerline dilution, rise-rate, width, centreline height and diameter of the plume. Dilution is reported as the "effective dilution", which is the ratio of the initial concentration to the concentration of the plume at a given point, following Baumgartner et al. (1994).

2.1.2 Model setup

The discharge characteristics for the wastewater during the commissioning and operational stages are summarised in Table 20. The wastewater was modelled as a discharge 10 m below the water surface through a single outlet, and was anticipated to have a salinity and temperature of 1 part per thousand (ppt) and 25°C, respectively, during commissioning and operational stages. The modelled initial oil/grease concentration was 30 mg/L, the initial total suspended solids concentration was 50 milligrams per litre (mg/L) and the initial coliform bacteria concentration was 250 col/100 mL, for both stages. As detailed engineering design of the FPSO was yet to be undertaken at the time the modelling was commissioned, the concentrations of the wastewater constituents were based on those publically available in Shell's Prelude Floating LNG Environmental Impact Statement (Shell 2009).

Additional input data used to setup the near-field model included range of current speeds, water temperature and salinity as a function of depth. Defining the water temperature and salinity is important to correctly replicate the buoyancy of the diluting plume. The buoyancy dynamics in this case will be dominated by the salinity differences between the wastewater plume and receiving waters.

Table 3 presents the measured water temperature and salinity data collected by Fugro Survey Pty Ltd (Fugro) (2015) as part of the Barossa marine studies program. The minimum water temperature at 30 m below mean sea level (BMSL) was used as it represents the most conservative conditions considering water temperature varies with depth and would be warmer at the surface in comparison to temperatures at 30 m.

Table 4 presents the 5th, 50th and 95th percentiles of current speeds, which reflect contrasting dilution and advection cases:

- 5th percentile current speed: weak currents, low dilution and slow advection
- 50th percentile (median): medium current speed, moderate dilution and advection
- 95th percentile current speed: strong currents, high dilution and rapid advection to nearby areas.

The 5th percentile, 50th percentile (median) and 95th percentile values are referenced as weak, medium and strong current speeds, respectively.

Table 2 Wastewater discharge and pipe configuration characteristics summary

Parameter	Value/design
Flow rate (m^3/day)	Commissioning flow rate: 96.1 Operational flow rate: 45.0
Outlet pipe internal diameter (m)	0.03
Pipe orientation	Vertically downward
Depth of pipe below sea surface (m)	10
Discharge salinity (ppt)	1
Discharge temperature (°C)	25
Discharge oil-in-water concentration (mg/L)	30

Table 3 Water temperature and salinity model inputs

Parameter	Season		
	Summer	Transitional	Winter
Ambient minimum water temperature (°C) (30 m BMSL)	25.4	24.7	26.3
Ambient mean salinity (Practical Salinity Units (PSU)) (30 m BMSL)	34.1	33.6	33.6

Table 4 Seasonal ambient percentile current speeds, strength and predominant direction as a function of water depth at the release location

Depth below the water surface (m)	Parameter	Reporting current strength	Season					
			Summer		Transitional		Winter	
			Speed (m/s)	Predominant direction	Speed (m/s)	Predominant direction	Speed (m/s)	Predominant direction
0	5th percentile	Weak	0.04	East	0.05	West-south-west	0.03	South-west
	50th percentile	Medium	0.11		0.14		0.11	
	95th percentile	Strong	0.27		0.29		0.27	
10	5th percentile	Weak	0.03	East	0.03	South-west	0.04	South-west
	50th percentile	Medium	0.09		0.12		0.12	
	95th percentile	Strong	0.23		0.26		0.25	
20	5th percentile	Weak	0.03	East-south-east	0.03	South-west	0.03	South-west
	50th percentile	Medium	0.08		0.11		0.12	
	95th percentile	Strong	0.20		0.24		0.24	

2.2 Interannual variability

The region is strongly affected by the strength of the Indonesian Throughflow, which fluctuates from one year to the next due to the exchange between the Pacific and Indian Oceans. Therefore, in order to examine the potential range of variability, the Southern Oscillation Index (SOI) data sourced from the Australian Bureau of Meteorology was used to identify interannual trends for the last 10 years (2005–2014). The SOI broadly defines neutral, El Niño (sustained negative values of the SOI below −8 often indicate El Niño episodes) and La Niña (sustained positive values of the SOI above +8 are typical of La Niña episodes) conditions based on differences in the surface air-pressure between Tahiti on the eastern side of the Pacific Ocean and Darwin (Australia), on the western side (Rasmusson and Wallace 1983, Philander 1990). El Niño episodes are usually accompanied by sustained warming of the central and eastern tropical Pacific Ocean and a decrease in the strength of the Pacific trade winds. La Niña episodes are usually associated with converse trends (i.e. increase in strength of the Pacific trade winds).

Figure 2 shows the SOI monthly values and Figure 3 shows the surface ocean current roses for the period 2004–2013 at the proposed release location. Each current rose diagram provides an understanding of the speed, frequency and direction of currents, over the given year:

- Current speed – speed is divided into segments of different colour, ranging from 0 to greater than 1 m/s. Speed intervals of 0.2 m/s are used. The length of each coloured segment is relative to the proportion of currents flowing within the corresponding speed and direction;
- Frequency – each of the rings on the diagram corresponds to a percentage (proportion) of time that currents were flowing in a certain direction at a given speed;
- Direction – each diagram shows currents flowing towards particular directions, with north at the top of the diagram.

Based on the combination of the SOI assessment and surface ocean currents, 2010 was selected as a representative La Niña year, 2012 was selected as a representative neutral year, and 2014 was selected as an El Niño year.

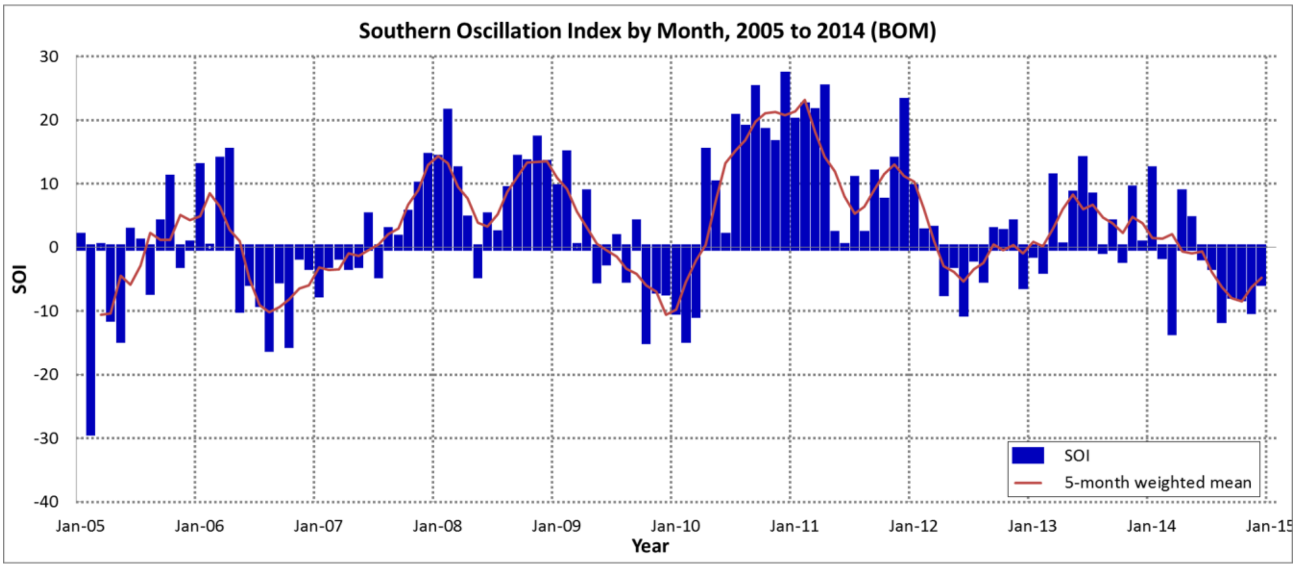


Figure 2 Monthly values of the SOI 2005-2014. Sustained positive values indicate La Niña conditions, while sustained negative values indicate El Niño conditions (Data sourced from Australian Bureau of Meteorology 2015).

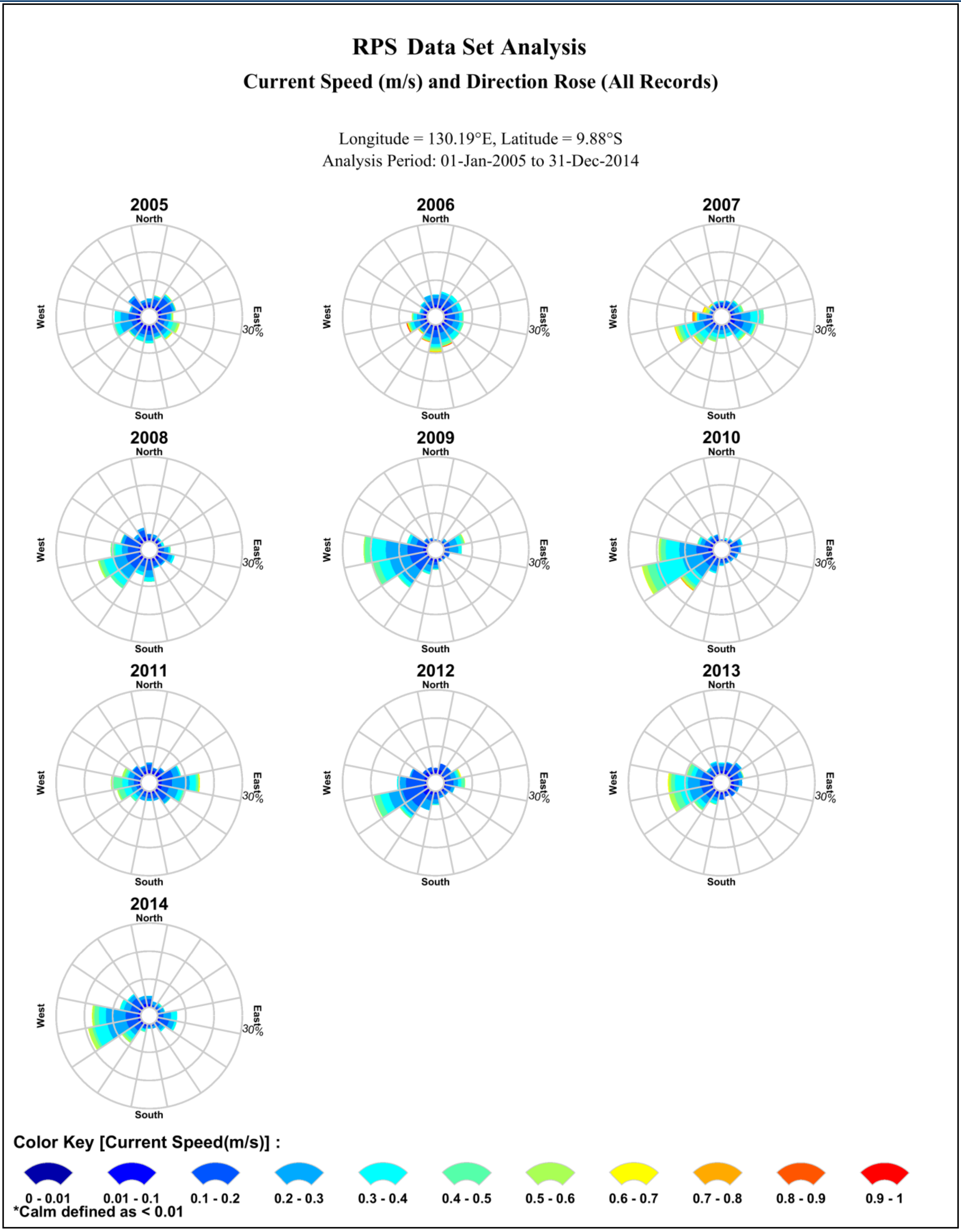


Figure 3 Annual surface ocean current rose plots within the Barossa offshore development area. Derived from analysis of HYCOM ocean data for the years 2005–2014. The colour key shows the current speed (m/s), the compass shows the direction and the length of the wedge gives the percentage of the record for a particular speed and direction combination.

2.3 Development of regional current data

The project is located within the influence of the Indonesian Throughflow, a large scale current system characterised as a series of migrating gyres and connecting jets that are steered by the continental shelf. This results in sporadic deep ocean events causing surface currents to exceed 1.5 m/s (approximately 3 knots).

While the ocean currents generally flow toward the southwest, year-round, the internal gyres generate local currents in any direction. As these gyres migrate through the area, large spatial variations in the speed and direction of currents will occur at a given location over time.

The influence of tidal currents is generally weaker in the deeper waters and greatest surrounding regional reefs and islands. Therefore, it was critical to include the influence of both types of currents (ocean and tides) to rigorously understand the likely discharge characteristics in the project's area of influence.

A detailed description of the tidal and ocean current data inputted into the model is provided below.

2.3.1 Tidal currents

The tidal circulation was generated using RPS's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world over the past 26 years (Isaji and Spaulding 1984; Isaji et al. 2001; Zigic et al. 2003). In addition, HYDROMAP tidal current data has been used as input to forecast (in the future) and hindcast (in the past) condensate spills in Australian waters and forms part of the Australian National Oil Spill Emergency Response System operated by the Australian Maritime Safety Authority (AMSA).

HYDROMAP employs a sophisticated sub-gridding strategy, which supports up to six levels of spatial resolution, halving the grid cell size as each level of resolution is employed. The sub-gridding allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, and/or of particular interest to a study.

The numerical solution methodology 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 and Spaulding (1984), Isaji et al. (2001) and Owen (1980).

1.1.1.1 Tidal grid setup

The HYDROMAP tidal grid was established over a domain that extended approximately 2,400 km (east–west) by 1,575 km (north–south) (Figure 4). Computational cells were square, with sizes varying from 8 km in the open waters down to 1 km in some areas, to more accurately resolve flows along the coastline, around islands and reefs, and over more complex bathymetry (Figure 5).

Bathymetry used in the model was obtained from multiple sources (Figure 6). This included bathymetry data sourced from the Geoscience Australia database and commercially available digitised navigation charts.

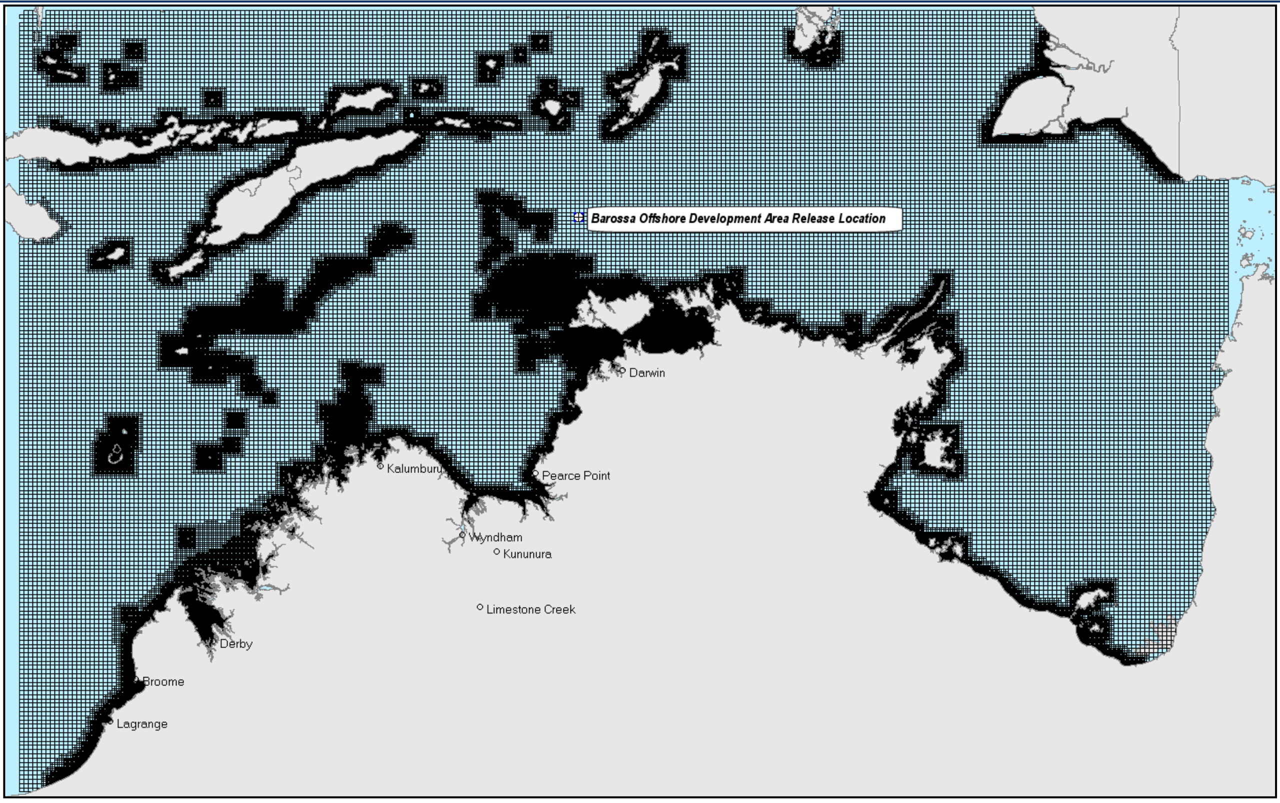


Figure 4 Map showing the extent of the tidal model grid. Note, darker regions indicate higher grid resolution.

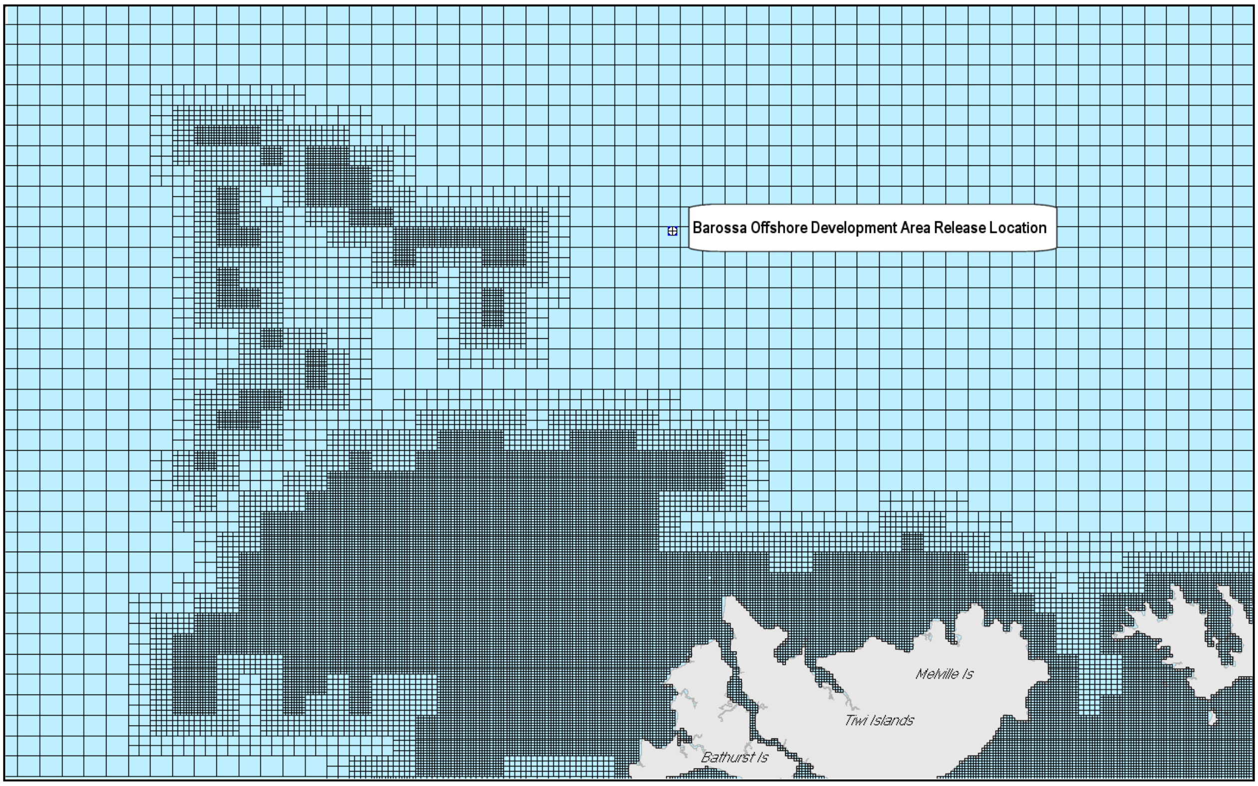


Figure 5 Zoomed in map showing the tidal model grid), illustrating the resolution sub-gridding in complex areas (e.g. islands, banks, shoals or reefs)

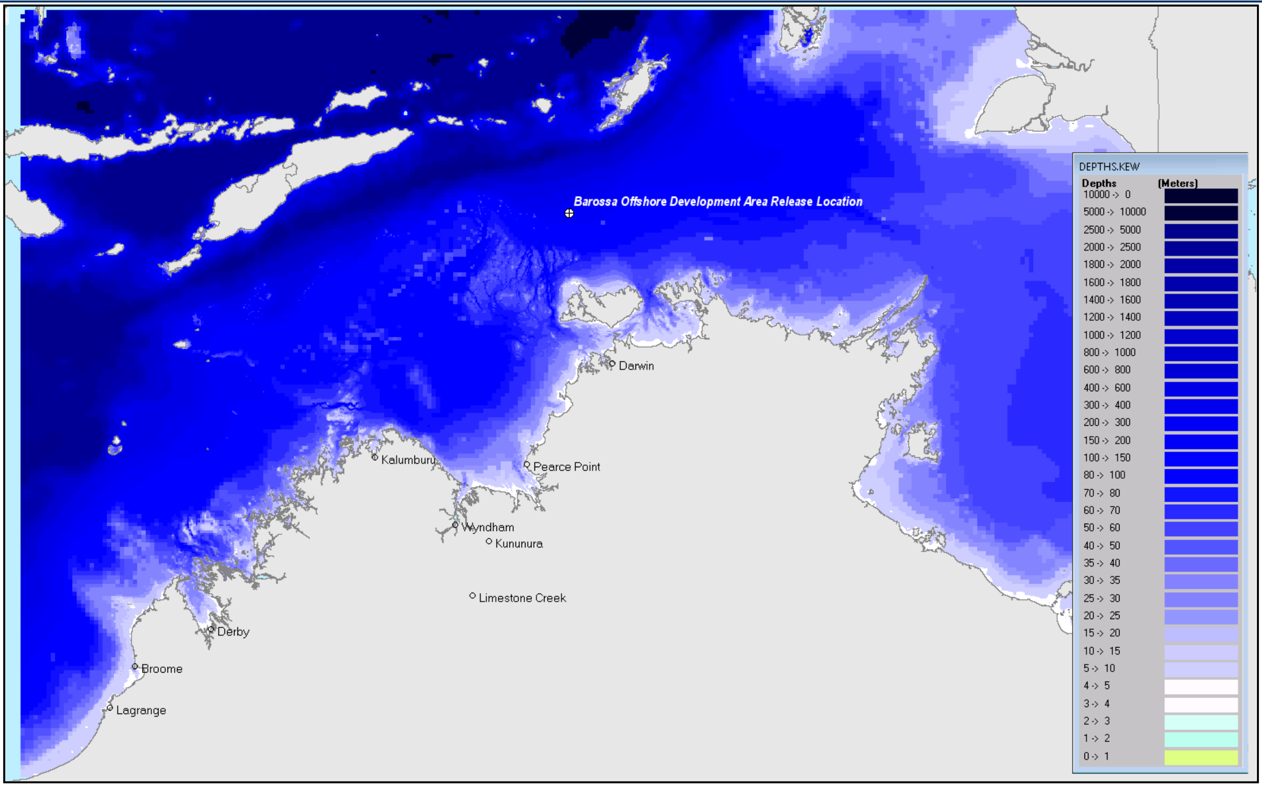


Figure 6 Map showing the bathymetry of the tidal model grid

1.1.1.2 Tidal data

The ocean boundary data for the regional model was obtained from satellite measured altimetry data (TOPEX/Poseidon 7.2) which provided estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. Using the tidal data, surface heights were 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 National Aeronautics and Space Administration (NASA). The satellites, equipped with two highly accurate altimeters that are capable of taking sea level measurements to an accuracy of less than 5 cm, measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005; see Fu et al., 1994; NASA/Jet Propulsion Laboratory 2013a; 2013b). In total these satellites carried out 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 and Tangdong 2004, Qiu and Chen 2010). As such the Topex/Poseidon tidal data is considered accurate for this study.

2.3.2 Ocean currents

Data describing the flow of ocean currents was obtained from the Hybrid Coordinate Ocean Model (HYCOM) (see Chassignet et al. 2007, 2009), which is operated by the HYCOM Consortium, sponsored by the Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a data-assimilative, three-dimensional ocean model that is run as a hindcast, assimilating time-varying observations of sea surface height, sea surface temperature and in-situ temperature and salinity measurements (Chassignet et al. 2009). The HYCOM predictions for drift currents are produced at a horizontal spatial resolution of approximately 8.25 km (1/12th of a degree) over the region, at a frequency of once per day. 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 zlevel coordinates in the mixed layer and/or unstratified seas.

For this modelling study, the HYCOM hindcast currents were obtained for the years 2010 to 2014 (inclusive). Figure 7 shows the seasonal surface current roses distributions adjacent to the release location by combining 2010, 2012 and 2014. The data shows that the surface current speeds and directions varied between seasons. In general, during transitional conditions (March, April and September to November) currents were shown to have the strongest average speed (average speed of 0.15 m/s with a maximum of 0.39 m/s) and tended to flow to the west-southwest. During summer (December to February) and winter (May to August) conditions the current flow was more variable though mostly toward the east and west, respectively. The average and maximum speeds during summer was 0.11 m/s and 0.41 m/s, respectively. During winter the average was 0.13 m/s and 0.47 m/s as the maximum.

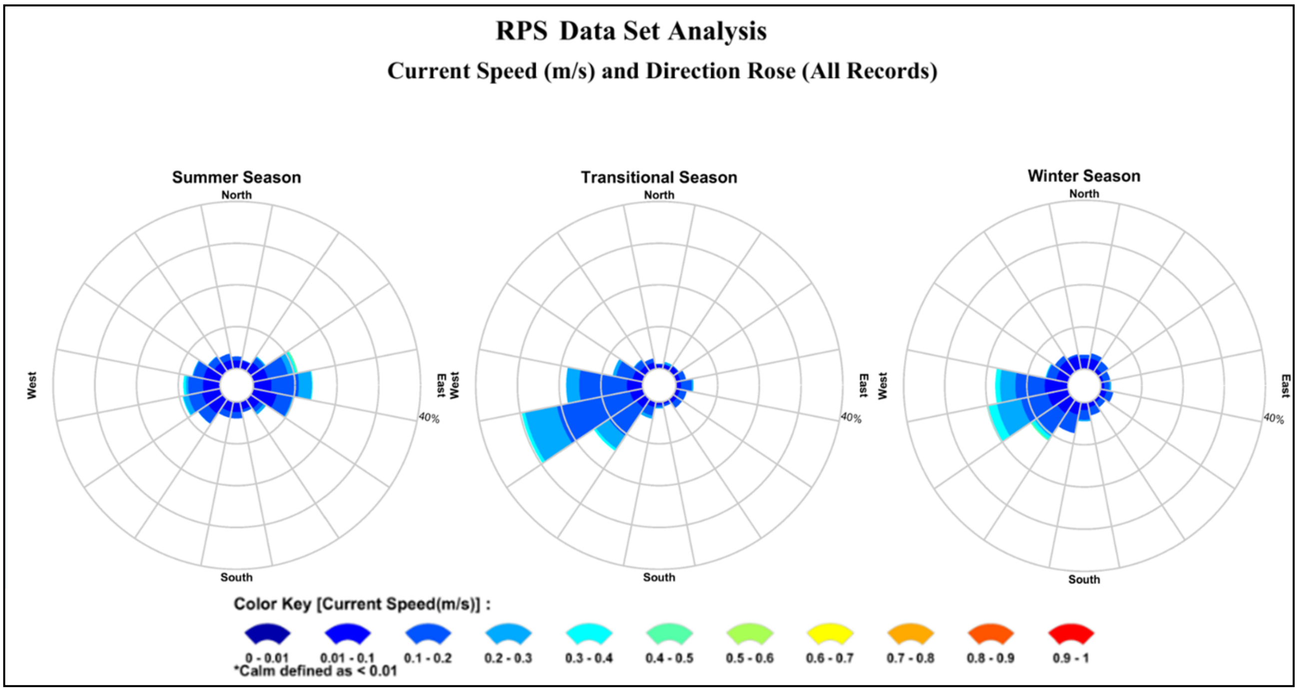
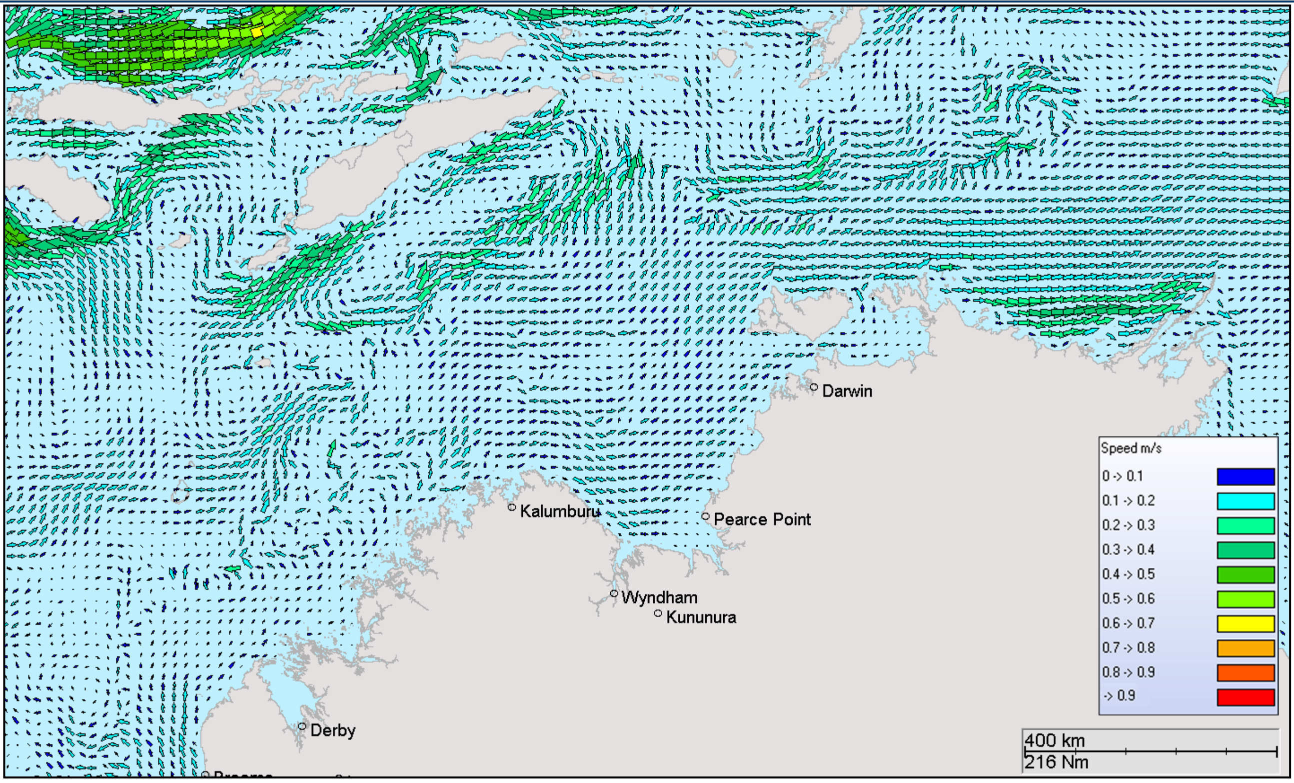


Figure 7 Seasonal surface current rose plots adjacent to the release location. Data was derived from the HYCOM ocean currents for years, 2010, 2012 and 2014. The colour key shows the current magnitude (m/s), the compass direction provides the current direction flowing TOWARDS and the length of the wedge gives the percentage of the record for a particular speed and direction combination.

Figure 8 shows example screenshots of the predicted HYCOM ocean currents during summer and winter conditions. The colours of the arrows indicate current speed (m/s).

In addition, Figure 9 to Figure 11 show the monthly surface current rose plots adjacent to the release location for 2010, 2012 and 2014, respectively. The data is derived by combining the ocean currents and tidal currents.



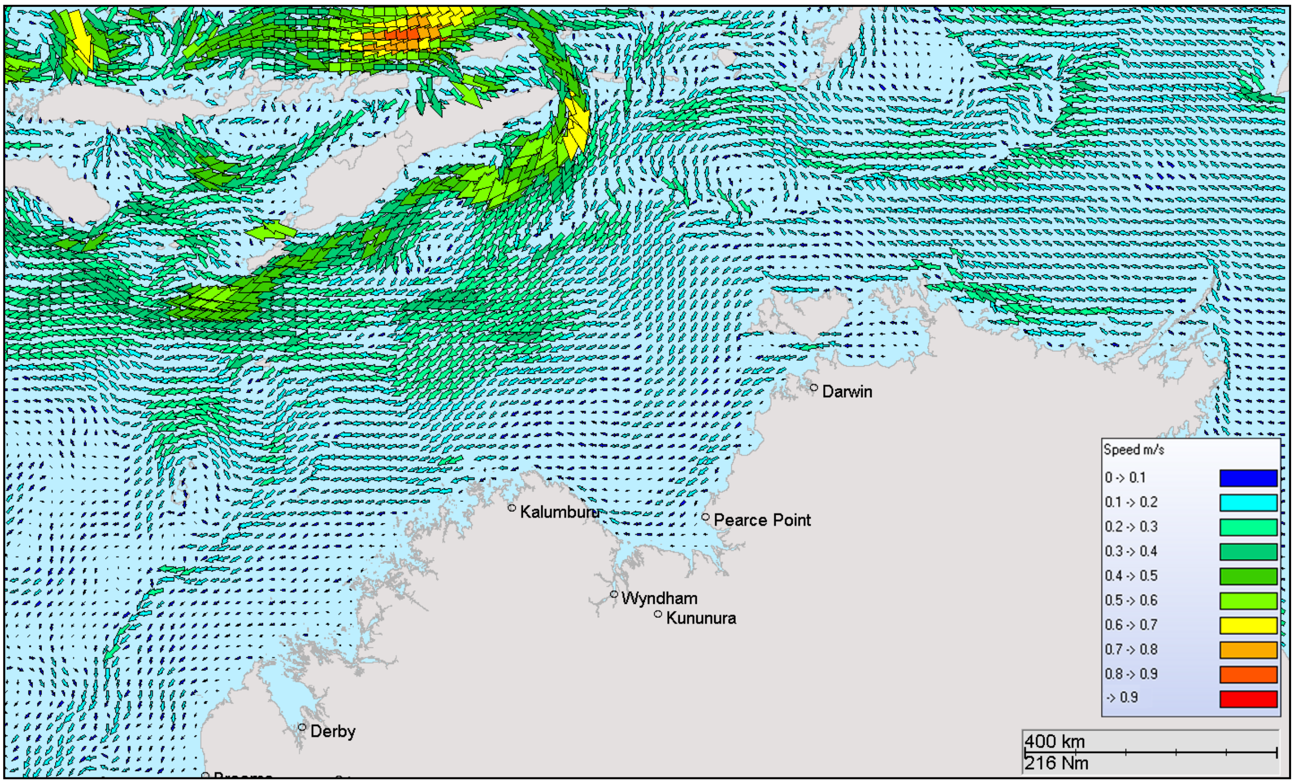


Figure 8 Modelled HYCOM surface ocean currents on the 6th February 2012, summer conditions (upper image) and 11th May 2012, winter conditions (lower image). Derived from the HYCOM ocean hindcast model (Note: for image clarity only every 2nd vector is displayed).

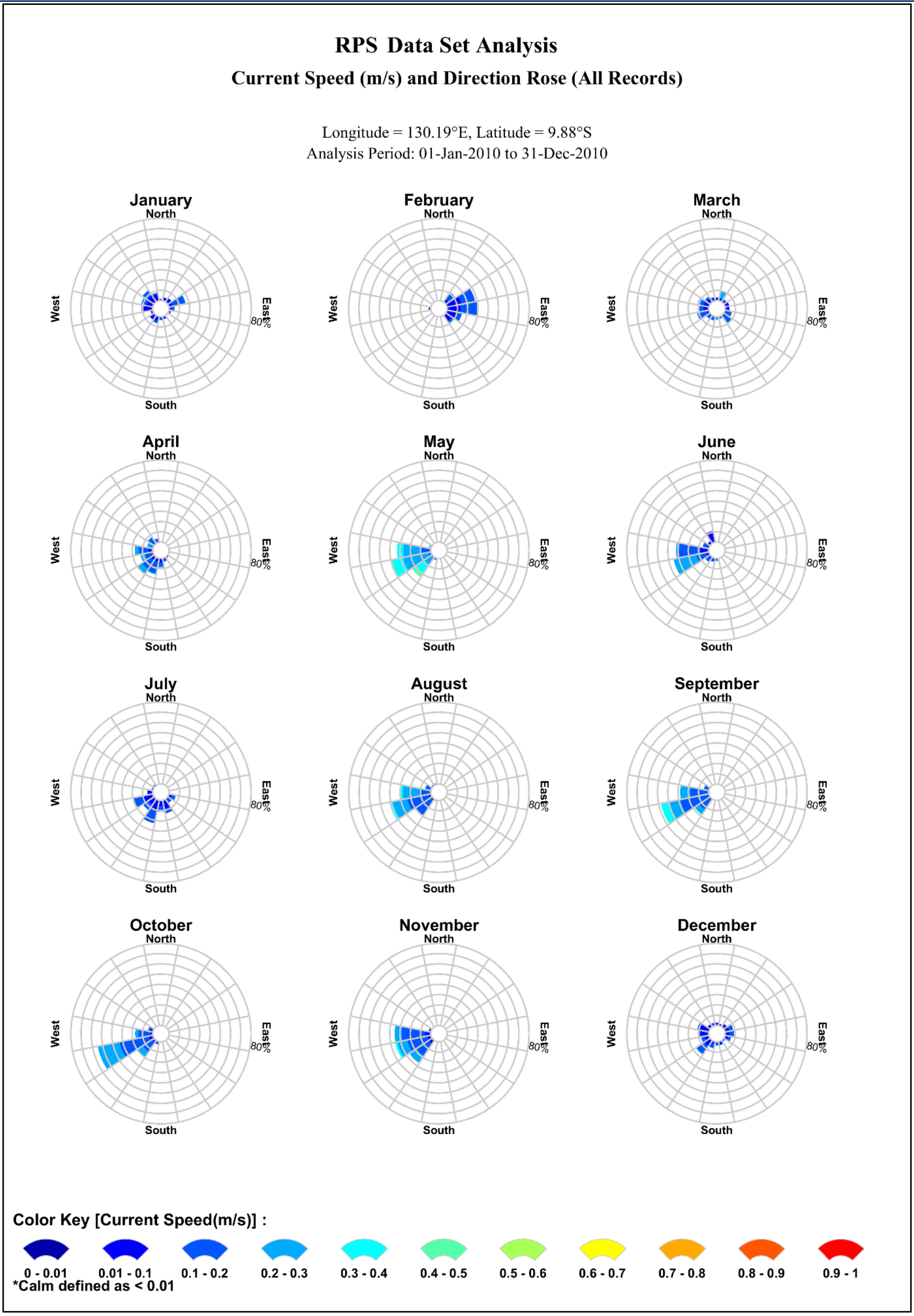


Figure 9 Monthly surface current rose plots adjacent to the model release location. Derived from analysis of HYCOM ocean data and tidal data for 2010 (La Niña year). The colour key shows the current speed (m/s), the compass shows the direction and the length of the wedge gives the percentage of the record for a particular speed and direction combination.

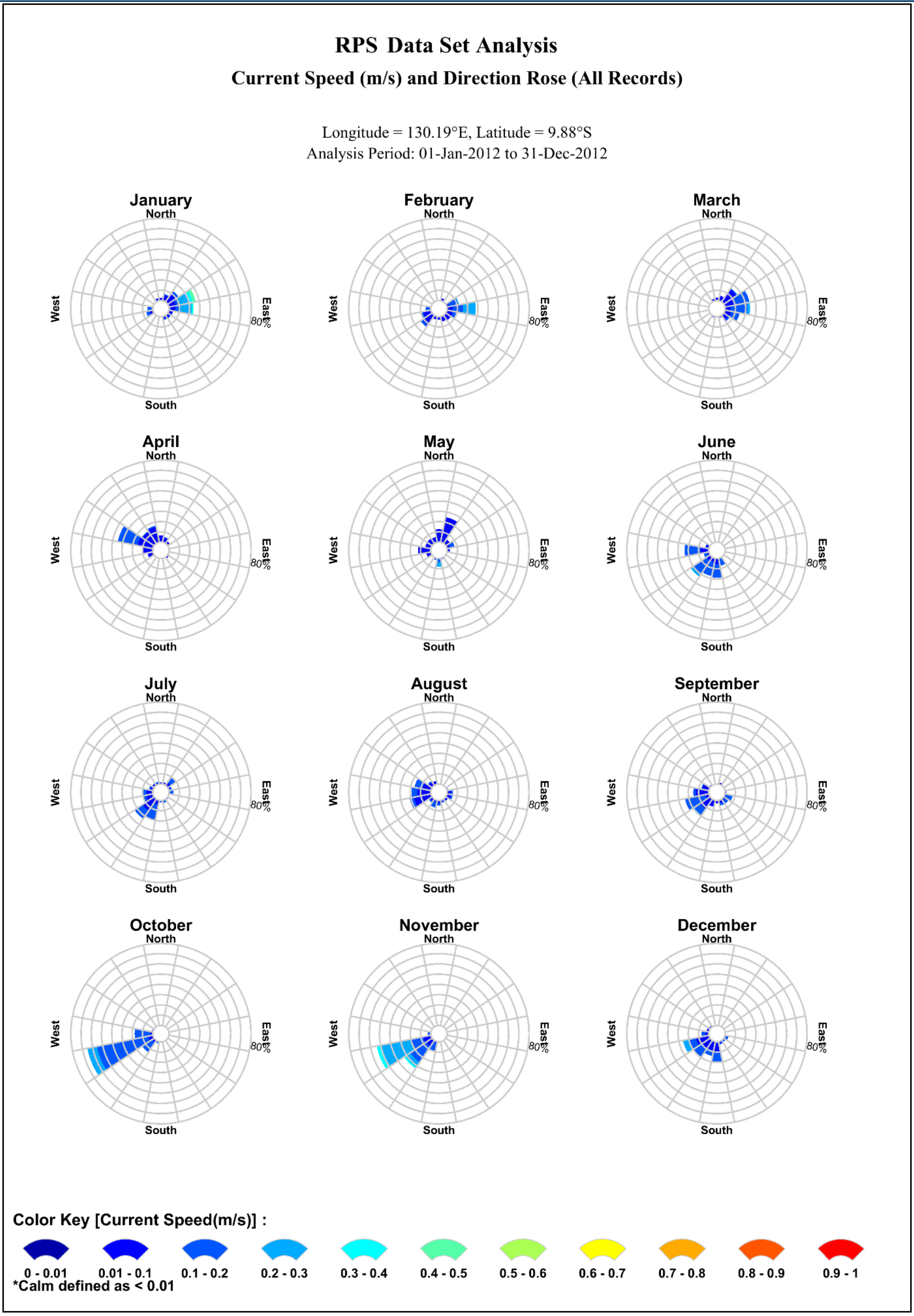


Figure 10 Monthly surface current rose plots adjacent to the model release location. Derived from analysis of HYCOM ocean data and tidal data for 2012 (neutral year). The colour key shows the current speed (m/s), the compass shows the direction and the length of the wedge gives the percentage of the record for a particular speed and direction combination.

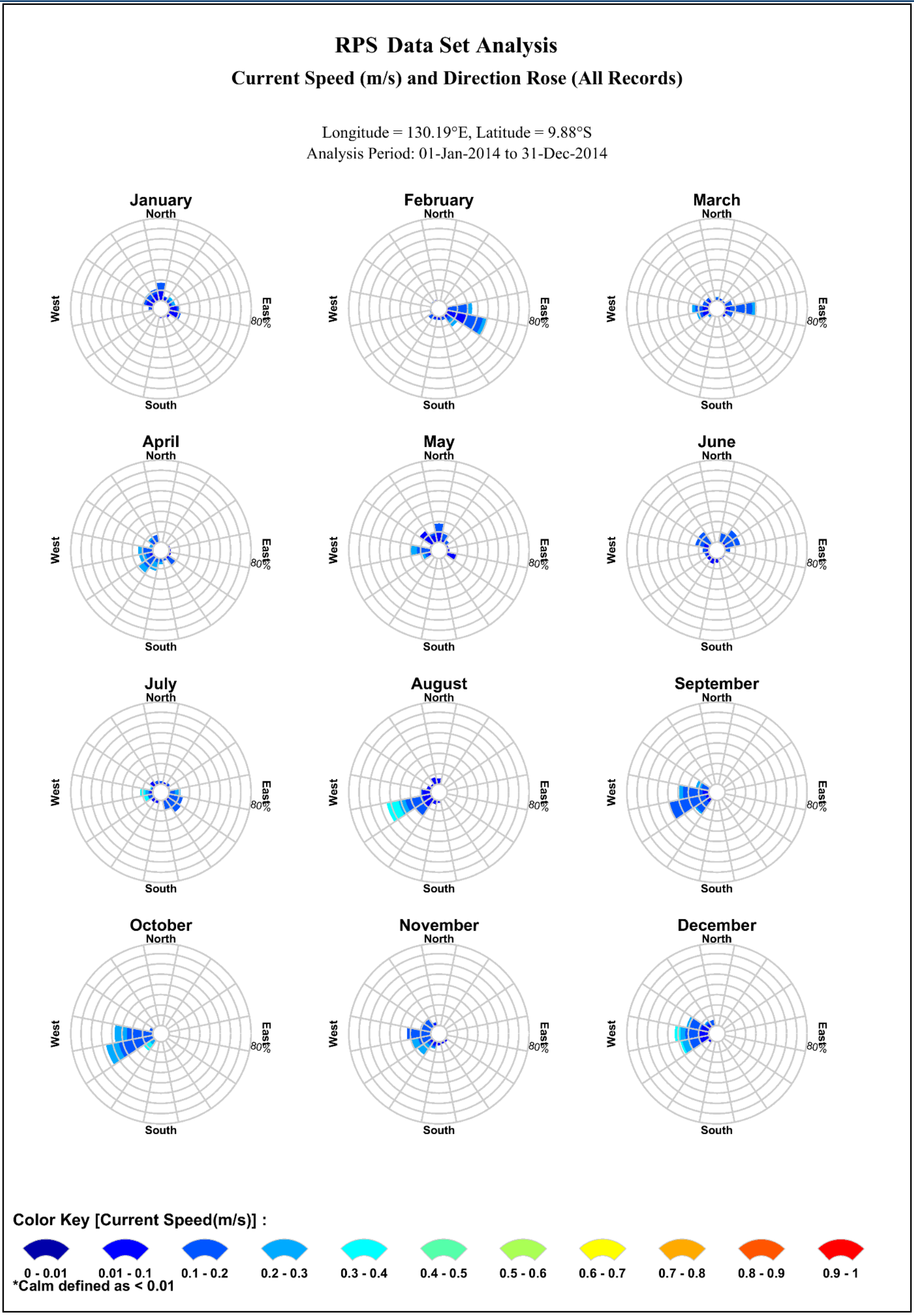


Figure 11 Monthly surface current rose plots adjacent to the model release location. Derived from analysis of HYCOM ocean data and tidal data for 2014 (El Niño year). The colour key shows the current speed (m/s), the compass shows the direction and the length of the wedge gives the percentage of the record for a particular speed and direction combination.

2.3.3 Tidal and current model validation

Fugro measured water levels and currents (speed and directions) at three locations within the Barossa offshore development area as part of the Barossa marine studies program (Figure 12**,** Fugro 2015). The measured data from the survey was made available to validate the predicted currents, which corresponds to the three identified seasons of the region (i.e. summer (December to February), transitional (March and September to November) and winter (April to August)).

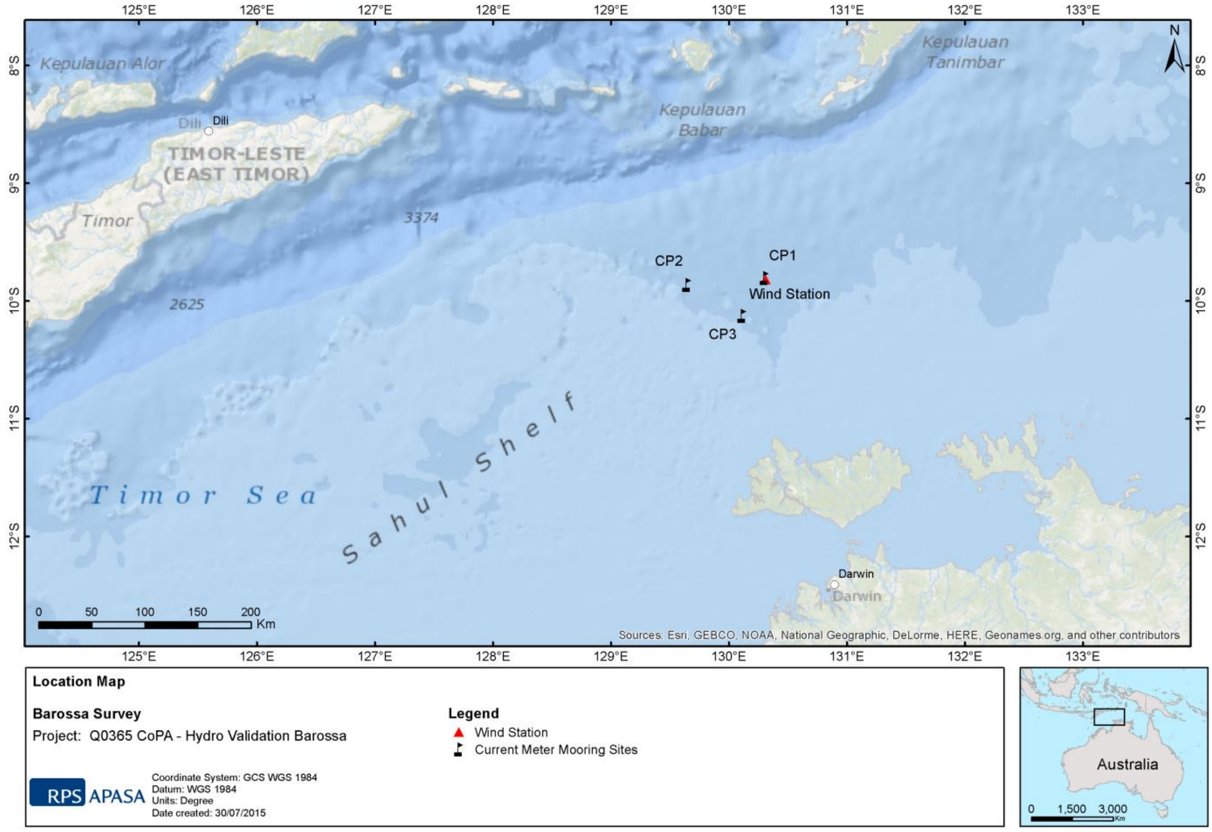


Figure 12 Locations of the CP1, CP2 and CP3 current meter moorings and the wind station

As an example, Figure 13 shows a comparison between the measured and predicted water levels at CP1 from 28 October 2014 to 14 March 2015. The figure shows a strong agreement in tidal amplitude and phasing throughout the entire deployment duration at the CP1 location.

To provide a statistical quantification of the model accuracy, comparisons were performed by determining the deviations between the predicted and measured data. As such, the root-mean square error (RMSE), root-mean square percentage (RMS %) and relative mean absolute error (RMAE) were calculated. Qualification of the RMAE ranges are reported in accordance with Walstra et al. (2001).

Table 5 shows the model performance when compared with measured water levels at CP1 from 28 October to 14 March 2015. According to the statistical measure, the HYDROMAP tidal model predictions were in very good agreement with the measured water levels at CP1.

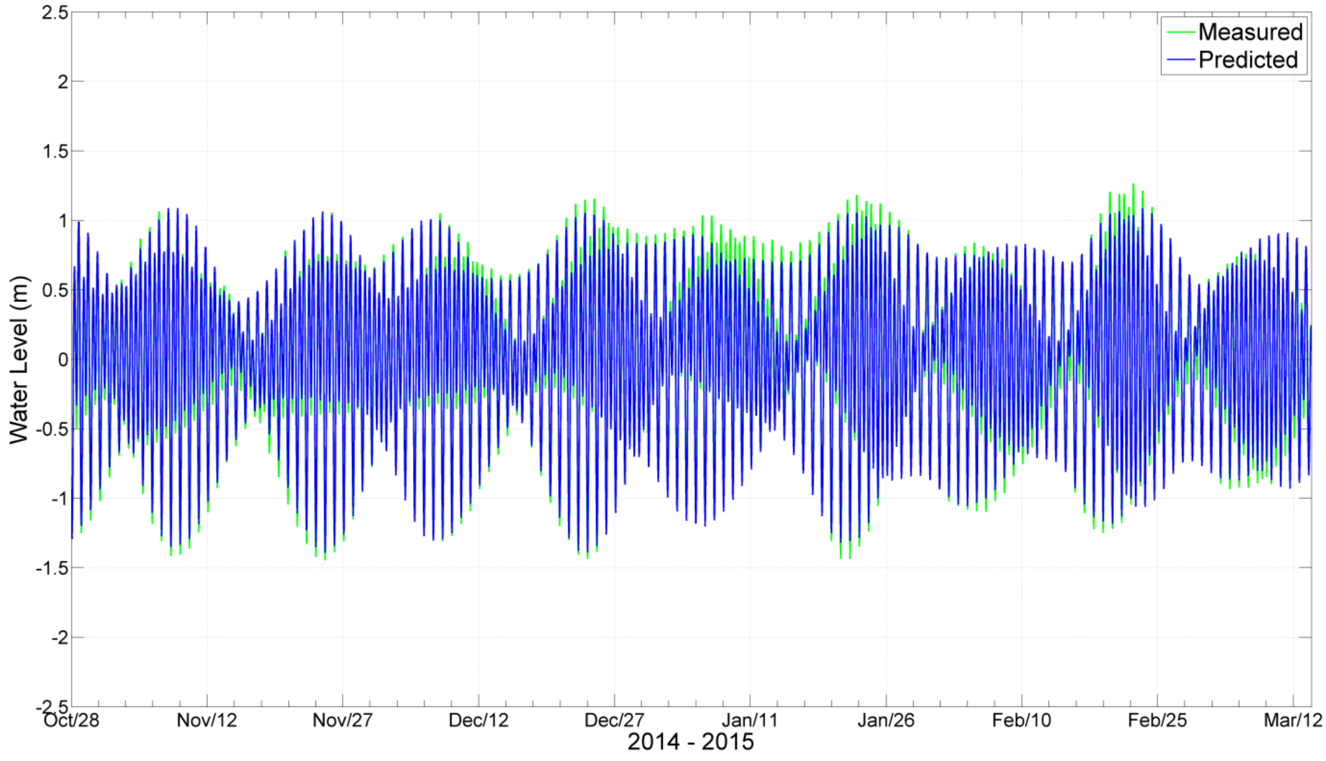


Figure 13 Comparison of measured and modelled water levels at CP1

Table 5 Statistical evaluation between measured water levels and HYDROMAP predicted water levels at CP1

Site	RMSE (m)	RMS (%)	RMAE	RMAE qualification
Mooring CP1	0.061	0.03	0.05	Very good

In addition, the HYCOM ocean currents combined with HYDROMAP tidal currents were compared to the measured current speed and directions from the CP1, CP2 and CP3 moorings. Figure 14 to Figure 16 show current comparison plots of the measured and predicted currents at each location for a range of depths (10 m, 50 m and 125 m BMSL) to highlight the differences between the wind-influenced surface layers and the mid water column.

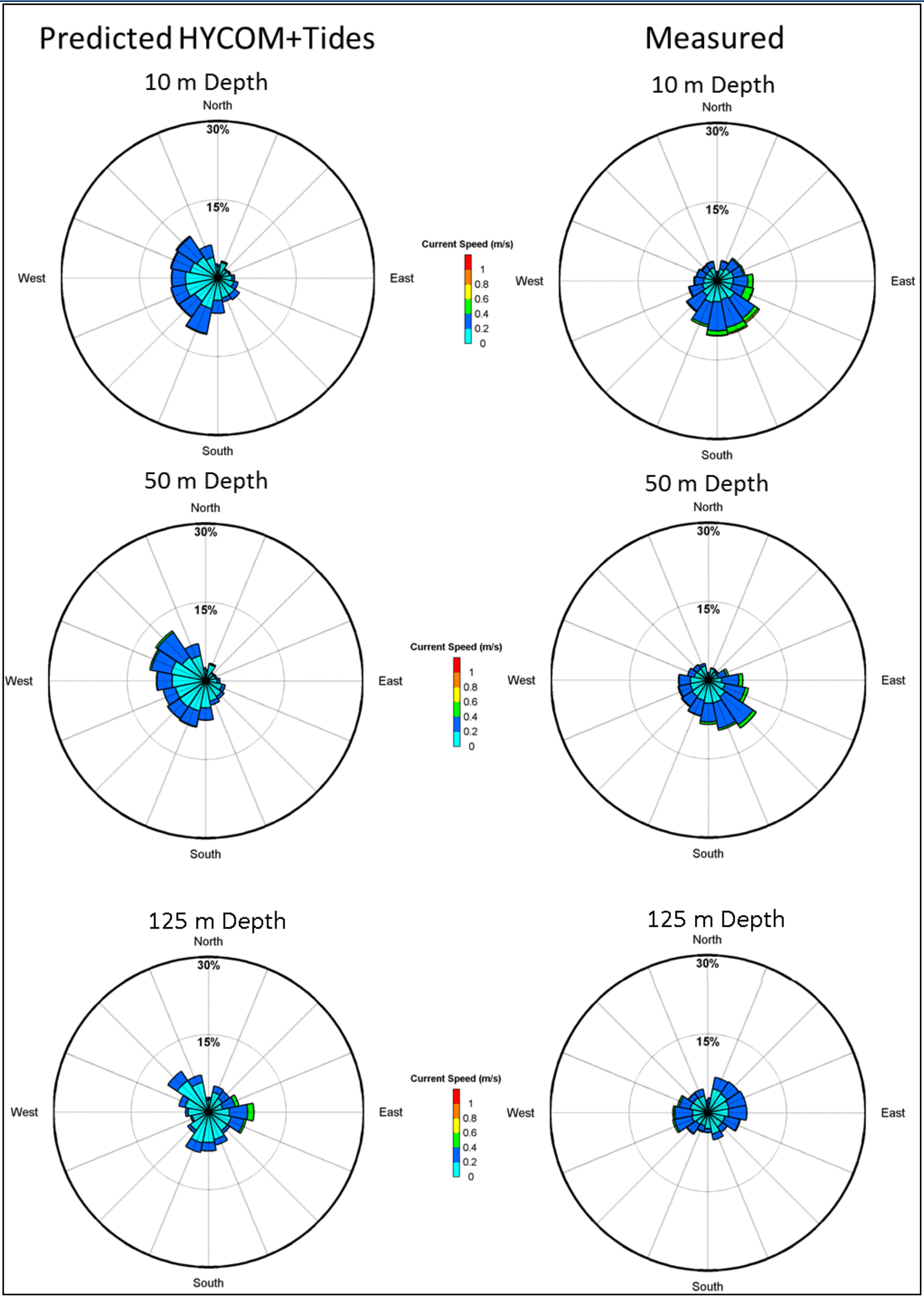


Figure 14 Comparison of predicted and measured current roses at CP1 from 9th July 2014 to 21st March 2015

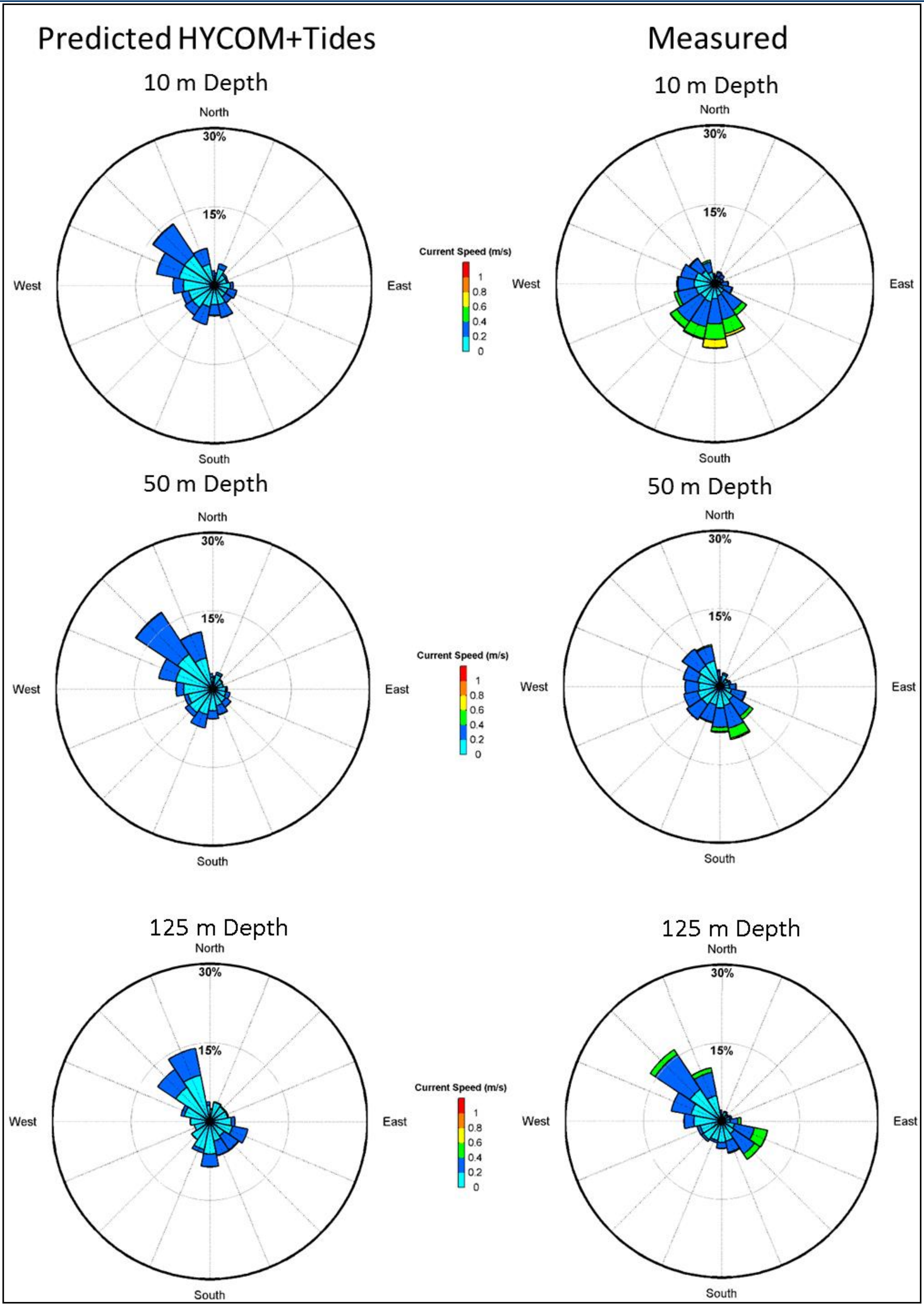


Figure 15 Comparison of predicted and measured current roses at CP2 from 10th July 2014 to 20st March 2015

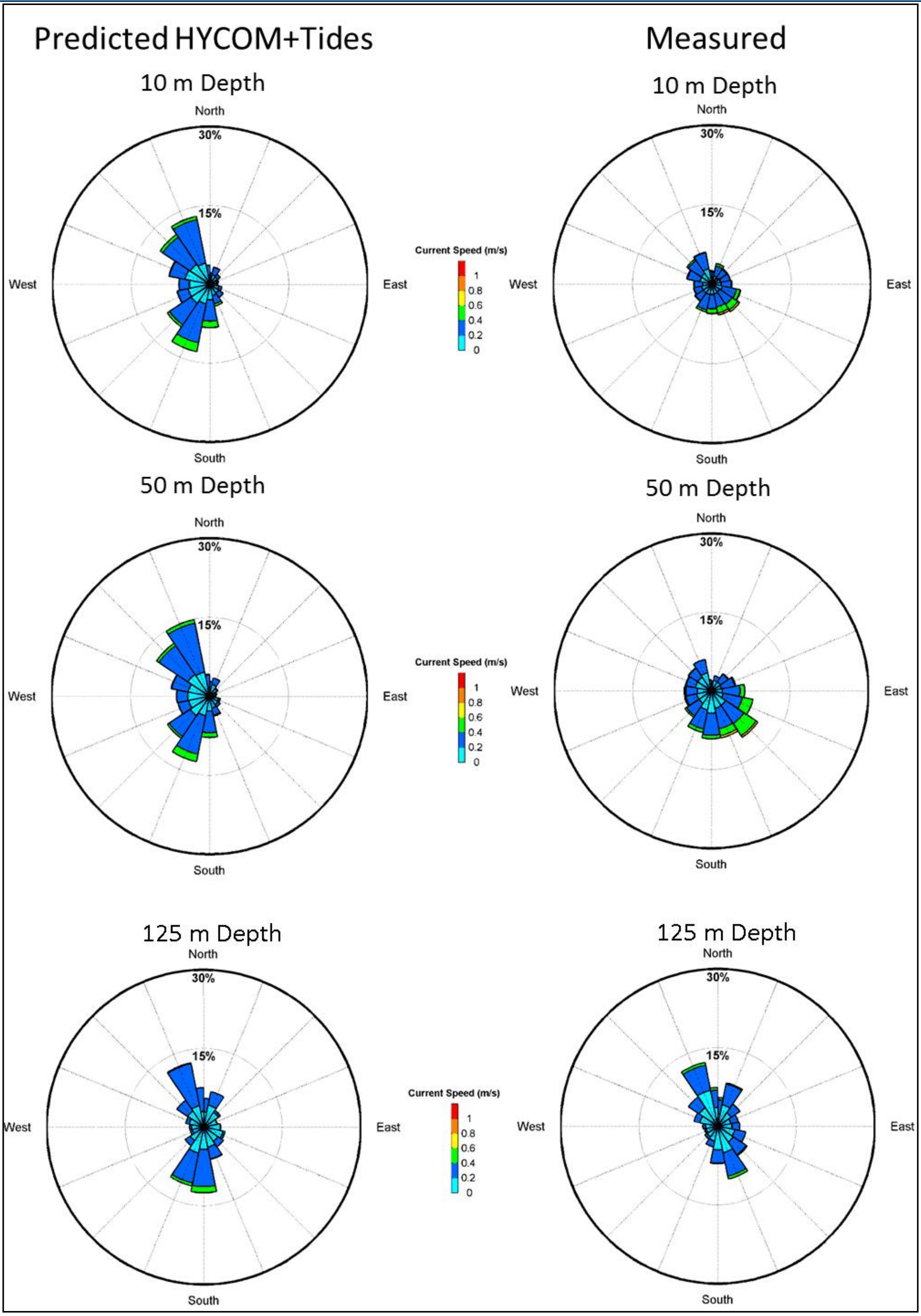


Figure 16 Comparison of predicted and measured current roses at CP3 from 9th July 2014 to 21st March 2015.

Overall, there was a good agreement between the predicted and measured currents at each site and depth. The model predictions were also able to recreate the two-layer flow which can be seen in the measured data and the reduction in current speeds as function of depth. From 10 m down to approximately 100 m below mean sea level (BMSL) the currents generally flowed south-east, with little variation due to tidal changes. The model predictions replicated this behaviour. Below 100 m, the influence of the tides became more pronounced, rotating between a south-eastward flow and a north-westward flow with the turning of the tide. Both tidal-scale and large-scale fluctuations in currents were typically reproduced at a similar magnitude and timing.

There was some divergence between the predicted and measured currents, mostly between data from July to October inclusive, due to the occurrence of solitons (or high frequency internal waves that can produce unusually high currents) which was highlighted by Fugro (2015). Despite these variations, the statistical comparisons between the measured and predicted current speeds indicate a reasonable to very good agreement (Table 6). Therefore, it can be concluded it is a good comparison and that the predicted current data reliably reproduced the complex conditions within the Barossa offshore development area and surrounding region. The RPS APASA (2015) model validation report provides a more detail regarding the tide and current comparison.

In summary, the Fugro (2015) data provides information specifically for the Barossa offshore development area and is considered the best available and most accurate data for this particular region. This data has been provided and reviewed by RPS to confirm predicted currents applied are accurate. As a result, the current data used herein is considered best available and highly representative of the characteristics influencing the marine environment in the Barossa offshore development area.

Table 6 Statistical evaluation between averaged measured currents and HYCOM ocean current and HYDROMAP tidal current at CP1, CP2 and CP3 at varying water depths (July 2014 to March 2015)

Site	Depth (m BMSL)	RMSE (m/s)	Measured peak value (m/s)	RMSE (%)	RMAE qualification
Mooring CP1	10	0.14	0.71	20	Good
	50	0.14	0.63	22	Very good
	125	0.13	0.61	22	Very good
Mooring CP2	10	0.16	0.82	19	Reasonable
	50	0.14	0.81	17	Good
	125	0.16	0.72	22	Reasonable
Mooring CP3	10	0.15	0.88	18	Very good
	50	0.14	0.78	18	Very good
	125	0.13	0.60	21	Very good

2.4 Environmental reporting criteria

The following environmental criteria were used for the modelling study.

Dilution contours

The near-field modelling results are presented as dilutions levels to enable direct comparison of the minimum dilutions for various wastewater constituents, including those that have yet to be confirmed or determined. Dilution intervals of 1:10, 1:50, 1:100, 1:500, 1:1,000, 1:2,000, 1:3,333 and 1:5,000 were reported and are considered very conservative in terms of the dilutions.

3.0 Modelling results

The results were carefully assessed to better understand the change in temperature and dilution of the wastewater plume. Due to the low wastewater flow rates during both the commissioning (96.1 m^3/day) and operation (45.0 m^3/day) stages, the wastewater plume was predicted to plunge less than 0.8 m below the discharge pipe under all current conditions (weak, medium and strong). Following the discharge and initial dilution, the wastewater plume was pushed horizontally from the discharge pipe while rising through the water column due to density differences with the receiving waters.

Table 7 presents the predicted maximum distance from the release location to achieve a given average dilution for each flow rate (commissioning and operation) and season (summer, transitional and winter). In summary, dilution rates of 1:100 and 1:5,000 were achieved within 5.0 m and 53.3 m, respectively, from the release location due to the low flow rates and buoyancy of the wastewater discharge stream. **Appendix A** provides a summary of the maximum distance from the release location to achieve a given minimum dilution (i.e. dilution of plume centreline) for each flow rate and season.

During commissioning (96.1 m^3/day), a 1:100 dilution was achieved within 2.1 m, 3.0 m and 5.0 m from the release location during the constant weak, medium and strong current conditions, respectively. Additionally, the 1:100 dilution extended a maximum distance of 3.6 m, 5.0 m and 5.0 m from the release location under summer, transitional and winter conditions, respectively (Table 7).

For the operational stage (45.0 m^3/day), a 1:100 dilution was predicted to be achieved within 1.4 m, 2.2 m and 3.6 m from the release location during the constant weak, medium and strong current conditions, respectively. Additionally, during the operational stage, the 1:100 dilution extended a maximum distance of 3.1 m, 3.6 m and 3.5 m from the release location under summer, transitional and winter conditions, respectively (Table 7).

Table 8 and Table 9 present the plume characteristics upon either reaching the sea surface or achieving 1:5,000 average dilution for the two stages. There were no differences observed between final plume temperature and ambient water temperature for both stages and all current speeds.

Based on the commissioning flow rate, the maximum horizontal distance to achieve the 1:5,000 average dilution by the plume was 34.4 m and 53.3 m under constant medium and strong current conditions, respectively (Table 8). The corresponding minimum dilution was 1:1,267 and 1:1,236 under constant medium and strong current conditions, respectively. During constant weak currents, the plume reached the sea surface and the average dilution achieved was < 1:1,637, up to 10.7 m from the release location. The plume diameter at the sea surface was < 7.3 m, <8.7 m and <5.4 m under constant weak, medium and strong current conditions, respectively (Table 8).

Results for the operational flow rate, showed the maximum horizontal distance to achieve a 1:5,000 average dilution travelled by the plume was 28.9 m and 46.2 m under constant medium and strong current conditions, respectively (Table 9). The corresponding minimum dilution was 1:1,328 and 1:1,183 under constant medium and strong current conditions, respectively. During constant weak currents, the plume reached the sea surface and the average dilution achieved was < 1:3,523, 12.8 m from the release location. The plume diameter at the sea surface was < 7.8 m, <5.6 m and <3.8 m under constant weak, medium and strong current conditions, respectively (Table 9).

Figure 17 to Figure 22 (note the differing x- and y-axis aspect ratios) shows the predicted plume orientation and dimensionality with regard to temperature and achieved average dilutions (up to 1:5,000) according to distance from the release location. The primary factor influencing the dilution of the wastewater plume was the speed of the ambient current.

Table 7 Maximum distance from wastewater discharge release location to achieve defined average dilution levels for each flow rate, season and current strength

Flow rate (m^3/d)	Season	Surface current speed (m/s)	Maximum (m) distance to a: 1:10 dilution	1:50 dilution	1:100 dilution	1:500 dilution	1:1,000 dilution	1:2,000 dilution	1:3,333 dilution	1:5,000 dilution
Commissioning stage (96.1 m^3/d)	Summer	Weak (0.04)	0.3	1.1	1.8	4.9	8.1	-	-	-
		Medium (0.11)	0.3	1.5	2.5	6.3	10.9	16.6	25.4	33.8
		Strong (0.27)	0.2	1.6	3.6	8.8	15.1	24.2	39.0	53.3
	Transitional	Weak (0.05)	0.3	1.2	1.7	4.6	7.5	-	-	-
		Medium (0.14)	0.2	2.0	2.9	7.6	12.6	18.4	26.8	34.4
		Strong (0.29)	0.2	2.7	5.0	13.4	19.2	31.3	39.9	50.7
	Winter	Weak (0.03)	0.3	1.3	2.1	5.4	8.6	-	-	-
		Medium (0.11)	0.2	2.1	3.0	7.6	11.8	17.1	24.0	30.1
		Strong (0.27)	0.2	2.7	5.0	12.5	17.4	26.9	33.4	41.4
Operation stage (45.0 m^3/d)	Summer	Weak (0.04)	0.3	0.8	1.4	3.9	5.7	9.4	-	-
		Medium (0.11)	0.3	1.2	1.9	5.4	8.2	14.4	19.1	25.4
		Strong (0.27)	0.2	1.9	3.1	9.2	14.3	25.7	34.5	46.2
	Transitional	Weak (0.05)	0.3	0.8	1.3	3.7	5.4	8.8	-	-
		Medium (0.14)	0.2	1.5	2.2	6.0	10.2	15.1	22.4	28.9
		Strong (0.29)	0.2	2.1	3.6	9.9	16.6	24.4	35.7	45.7
	Winter	Weak (0.03)	0.4	1.0	1.4	3.8	6.1	8.7	12.4	-
		Medium (0.11)	0.2	1.4	2.2	5.9	9.7	14.0	20.1	25.4
		Strong (0.27)	0.2	2.1	3.5	9.2	14.9	21.1	30.0	37.4

Table 8 Predicted wastewater plume characteristics upon either reaching the sea surface or achieving 1:5,000 average dilution for the commissioning stage (96.1 m³/day)

Season	Surface current speed (m/s)	Plume diameter at the sea surface (m)	Plume temperature (ºC)	Difference between plume and ambient temperature (ºC)	Dilution of the plume (1:x)		Maximum horizontal distance (m)
					Minimum	Average	
Summer	Weak (0.04)	5.4	25.4	0	429	1,151	8.4
	Medium (0.11)	8.7	25.4	0	1,313	5,000	33.8
	Strong (0.27)	5.4	25.4	0	1,236	5,000	53.3
Transitional	Weak (0.05)	6.3	24.7	0	444	1,370	9.0
	Medium (0.14)	7.5	24.7	0	1,267	5,000	34.4
	Strong (0.29)	5.0	24.7	0	1,184	5,000	50.7
Winter	Weak (0.03)	7.3	26.3	0	601	1,637	10.7
	Medium (0.11)	7.8	26.3	0	1,341	5,000	30.1
	Strong (0.27)	5.1	26.3	0	1,188	5,000	41.4

Table 9 Predicted wastewater plume characteristics upon either reaching the sea surface or achieving 1:5,000 average dilution for the operation stage (45.0 m³/day)

Season	Surface current speed (m/s)	Plume diameter at the sea surface (m)	Plume temperature (ºC)	Difference between plume and ambient temperature (ºC)	Dilution of the plume (1:x)		Maximum horizontal distance (m)
					Minimum	Average	
Summer	Weak (0.04)	6.0	25.4	0	713	2,255	9.9
	Medium (0.11)	5.6	25.4	0	1,165	5,000	25.4
	Strong (0.27)	3.6	25.4	0	1,183	5,000	46.2
Transitional	Weak (0.05)	6.6	24.7	0	800	2,866	11.0
	Medium (0.14)	5.3	24.7	0	1,328	5,000	28.9
	Strong (0.29)	3.7	24.7	0	1,356	5,000	45.7
Winter	Weak (0.03)	7.8	26.3	0	1,113	3,523	12.8
	Medium (0.11)	5.5	26.3	0	1,393	5,000	25.4
	Strong (0.27)	3.8	26.3	0	1,376	5,000	37.4

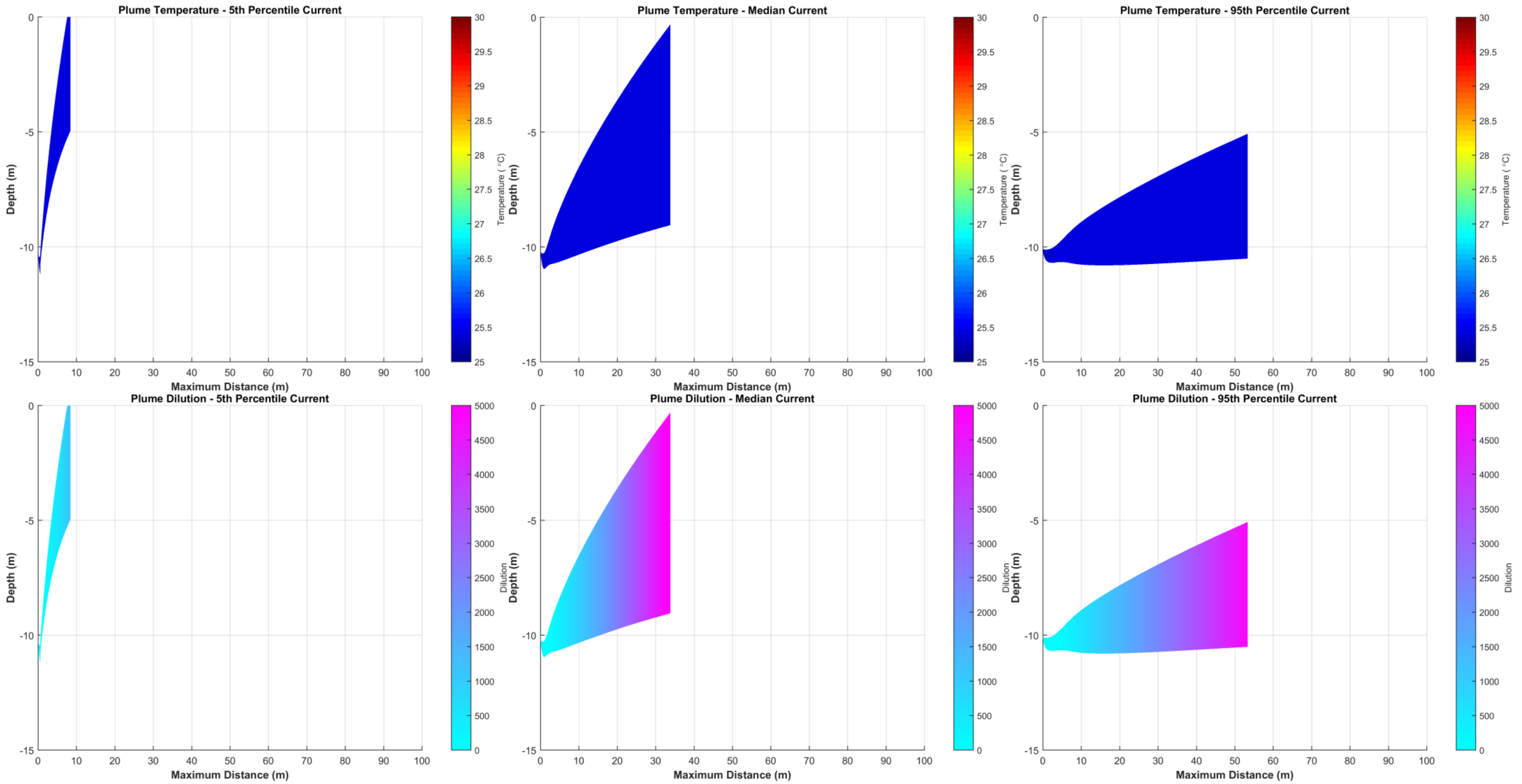


Figure 17 Near-field average temperature and dilution results for constant weak, medium and strong summer currents (96.1 m^3/d flow rate)

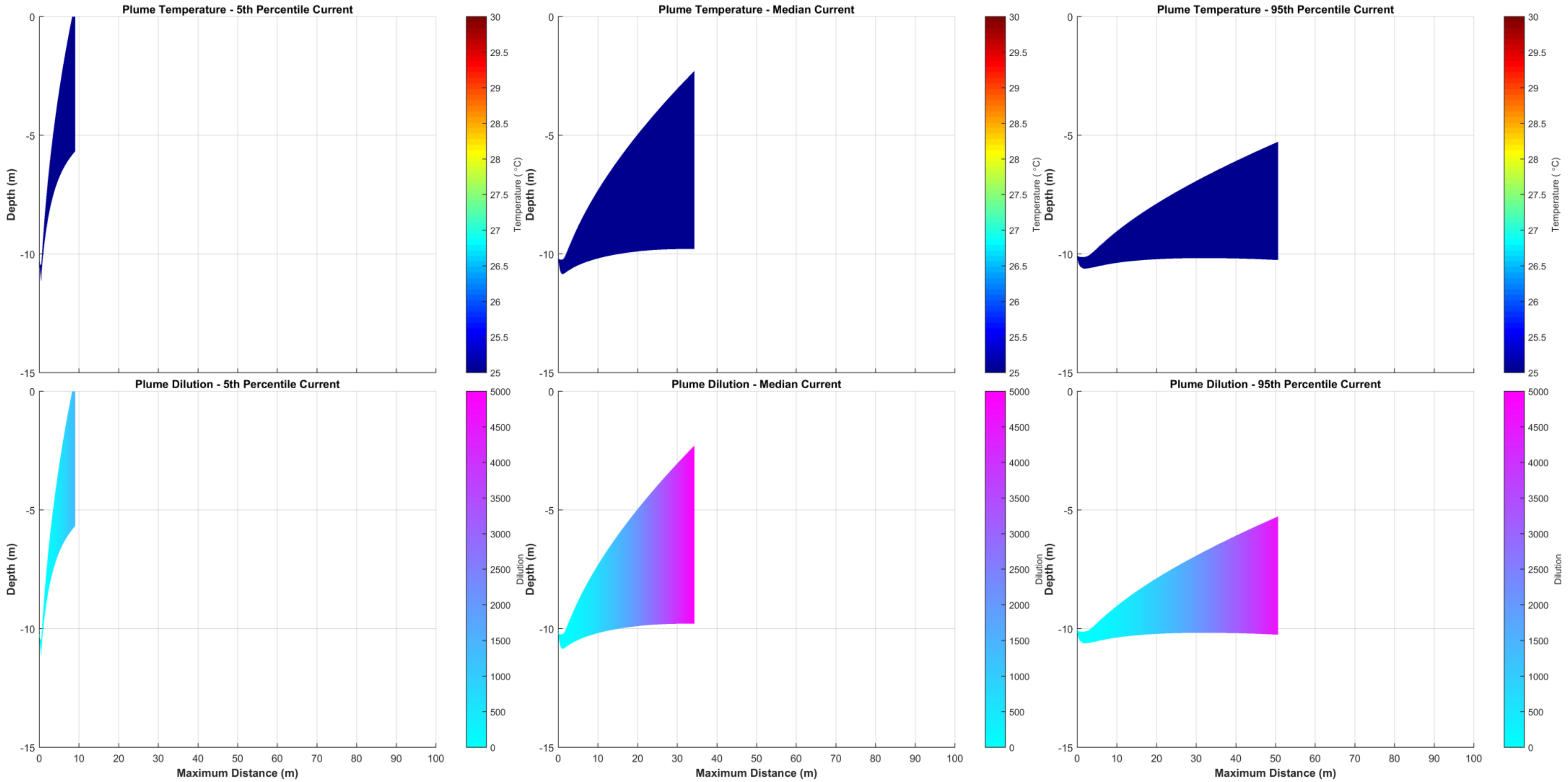


Figure 18 Near-field average temperature and dilution results for constant weak, medium and strong transitional currents (96.1 m^3/d flow rate)

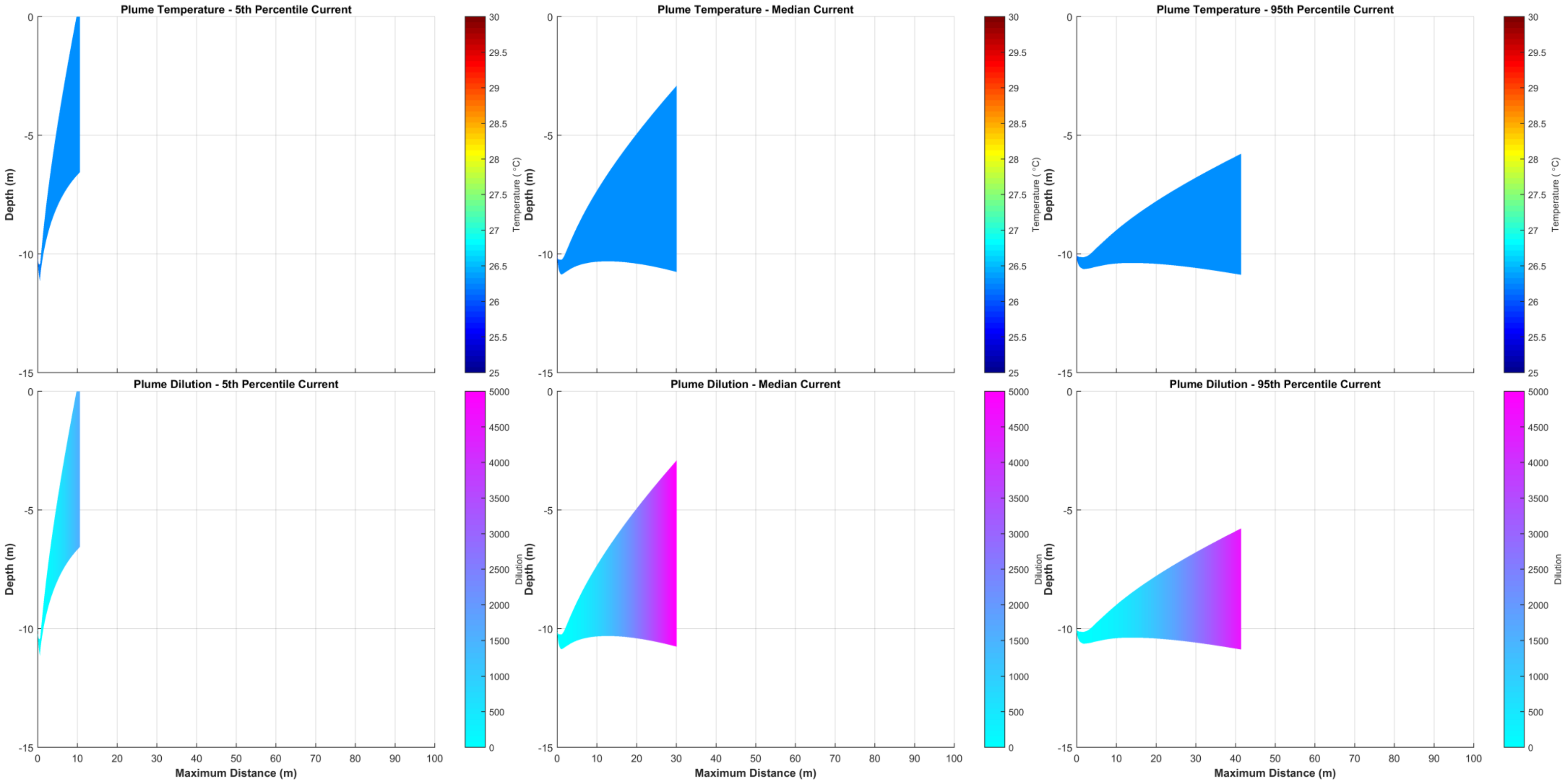


Figure 19 Near-field average temperature and dilution results for constant weak, medium and strong winter currents (96.1 m^3/d flow rate)

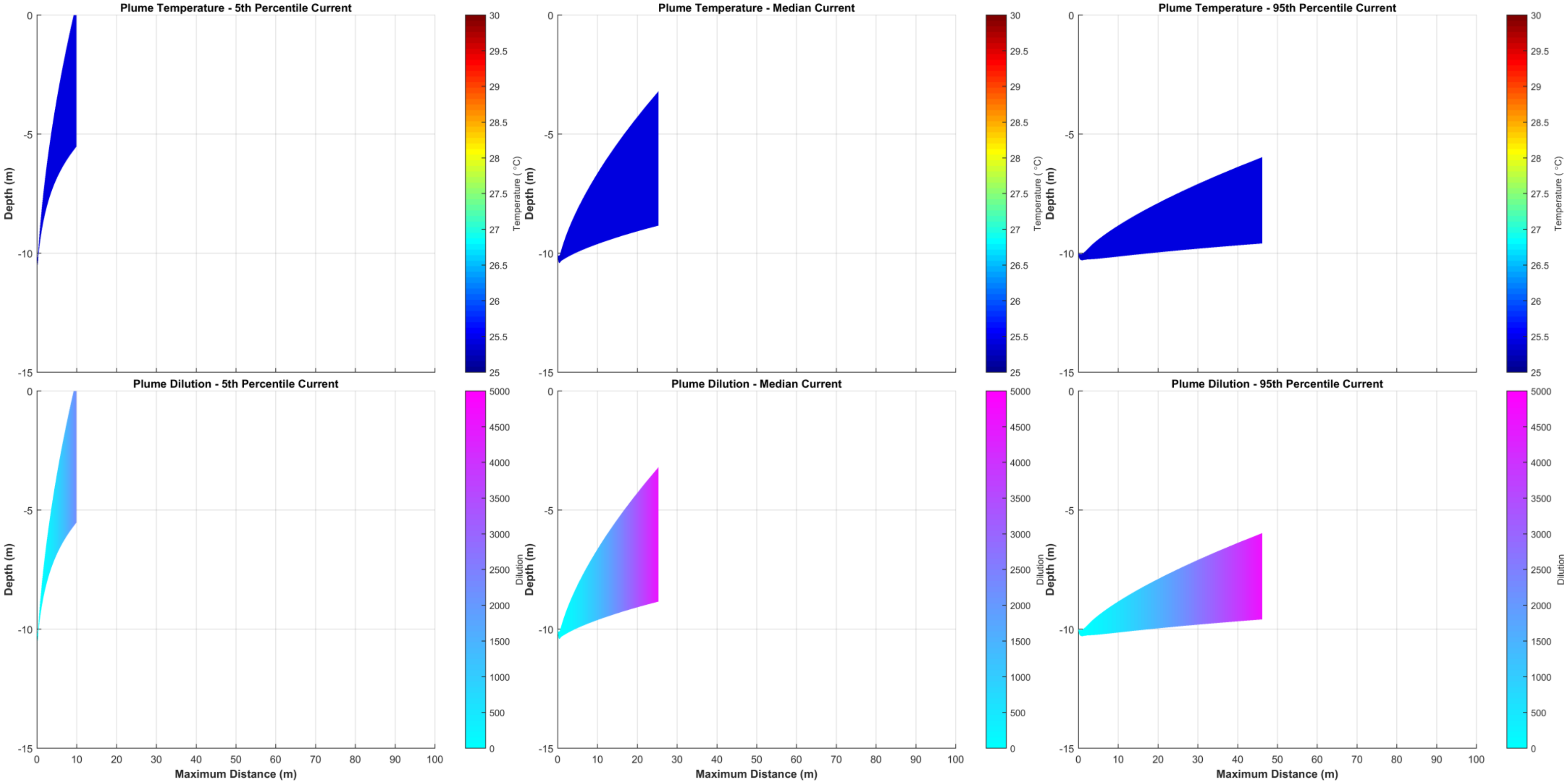


Figure 20 Near-field average temperature and dilution results for constant weak, medium and strong summer currents (45.0 m^3/d flow rate)

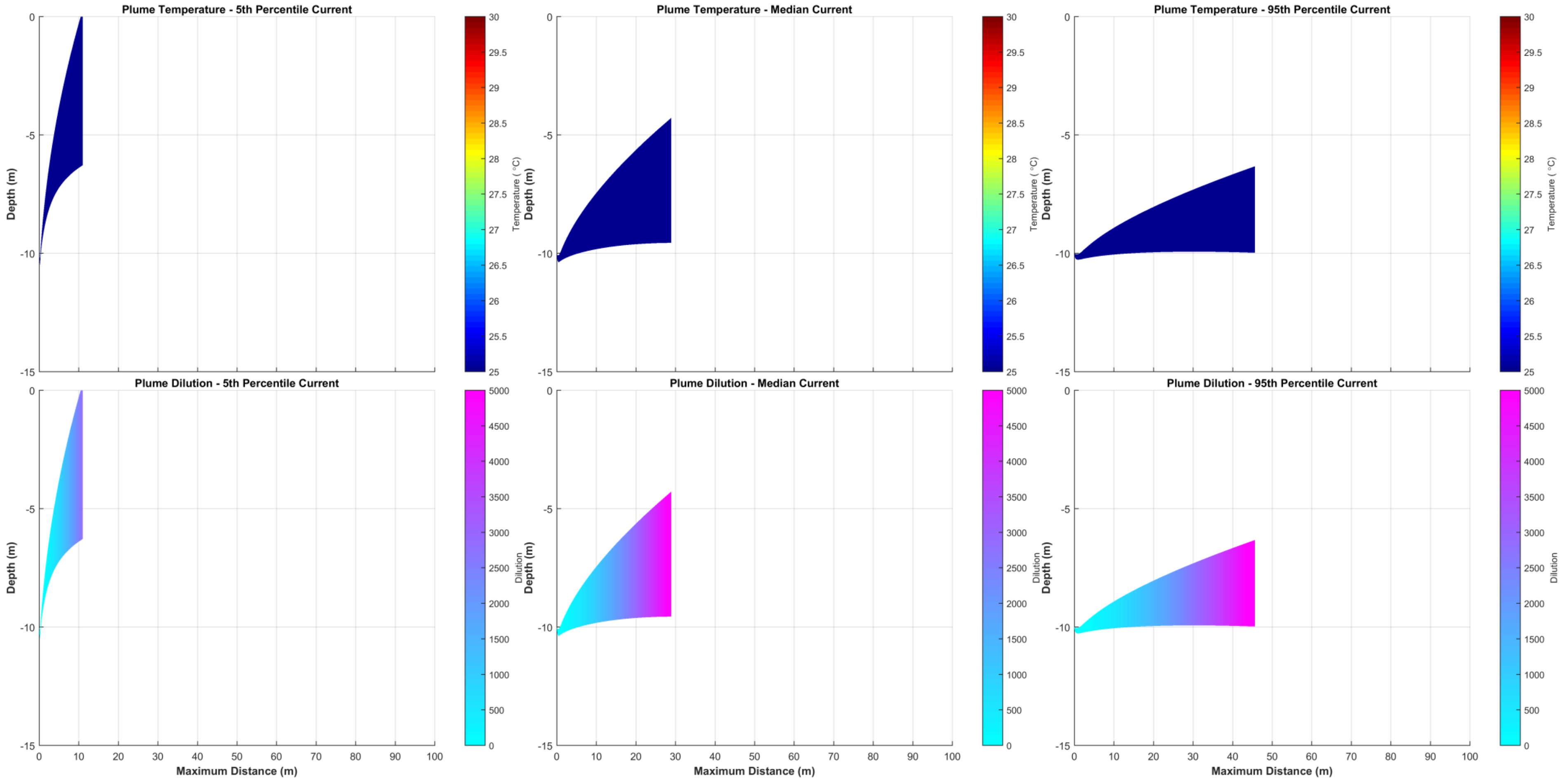


Figure 21 Near-field average temperature and dilution results for constant weak, medium and strong transitional currents (45.0 m^3/d flow rate)

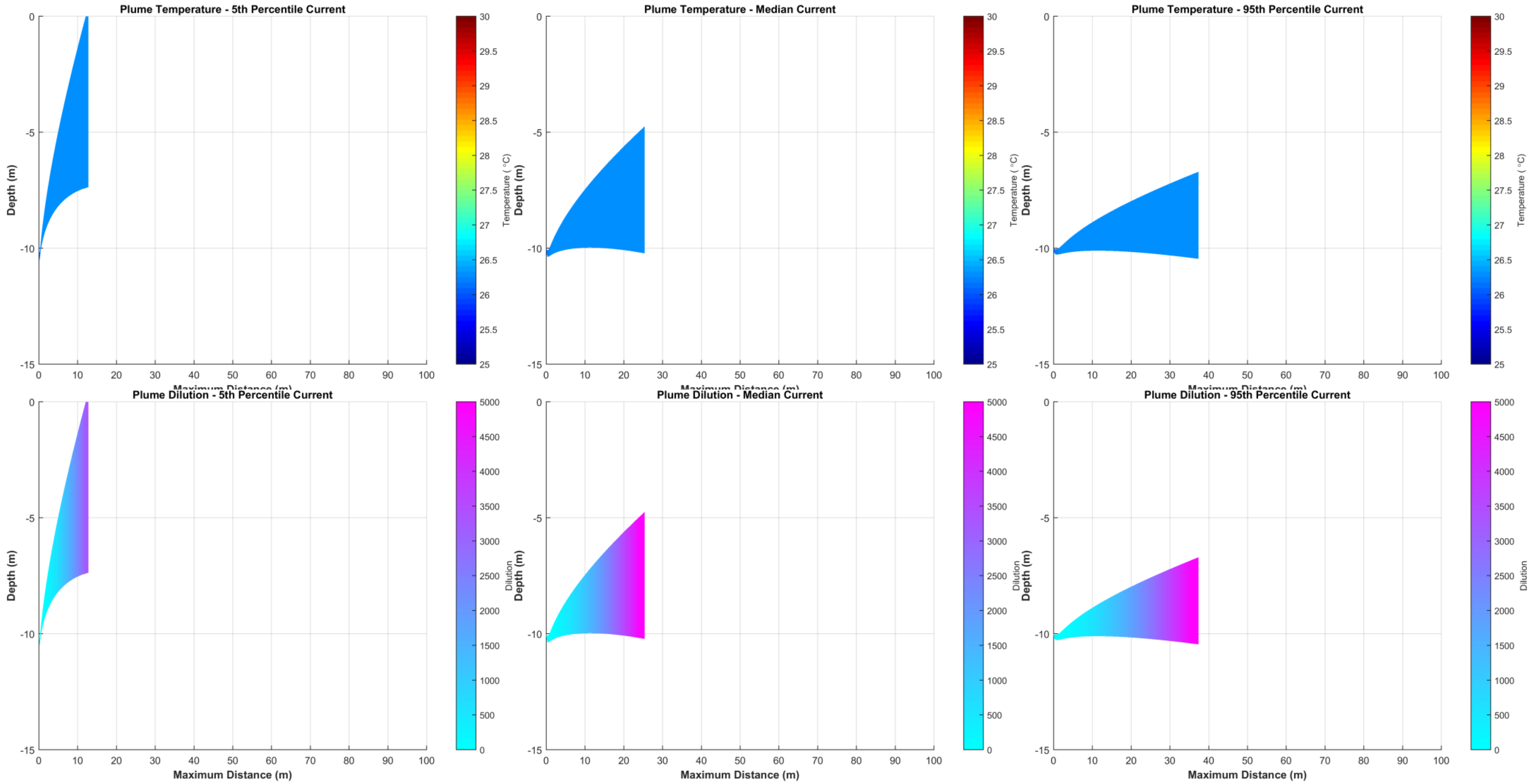


Figure 22 Near-field average temperature and dilution results for constant weak, medium and strong winter currents (45.0 m^3/d flow rate)

4.0 KEY FINDINGS

Near-field dispersion modelling was conducted for the commissioning and operational flow rates (96.1 m^3/d and 45.0 m^3/d, respectively) under varying constant current speeds. Below is a summary of the key findings:

- Due to the low flow rates and buoyancy of the stream, dilution rates of 1:10 and 1:5,000 were achieved within 5 m and 54 m from the release location
- Based on the high level of mixing achieved in the near-field modelling, it was deemed not necessary to undertake far-field modelling for the resulting oil and grease, coliforms and TSS concentrations
- The results of the modelling demonstrate that the zone of influence from wastewater discharges during both commissioning and operations is very localised.

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6.0 Appendices

6.1 Appendix A. Predicted minimum plume dilution

Table 10 presents a summary of the maximum distance from release site to achieve a given minimum dilution (i.e. dilution of plume centreline) for each flow rate and season.

Table 10 Maximum distance from wastewater discharge release location to achieve defined minimum dilution levels for each flow rate, season and current strength

Flow rate (m^3/d)	Season	Surface current speed (m/s)	Maximum (m) distance to a:							
			1:10 dilution	1:50 dilution	1:100 dilution	1:500 dilution	1:1,000 dilution	1:2,000 dilution	1:3,333 dilution	1:5,000 dilution
Commissioning stage (96.1 m^3/d)	Summer	Weak (0.04)	0.7	1.8	2.9	-	-	-	-	-
		Medium (0.11)	1.3	3.4	5.5	16.6	29.4	-	-	-
		Strong (0.27)	1.1	5.9	7.9	24.2	45.6	-	-	-
	Transitional	Weak (0.05)	0.7	1.9	2.8	-	-	-	-	-
		Medium (0.14)	1.4	4.2	6.7	18.4	30.4	-	-	-
		Strong (0.29)	1.6	7.3	10.8	31.3	45.0	-	-	-
	Winter	Weak (0.03)	0.8	2.1	3.4	9.7	-	-	-	-
		Medium (0.11)	1.5	4.3	6.8	17.1	24.0	-	-	-
		Strong (0.27)	1.6	7.2	10.9	26.9	37.2	-	-	-
Operation stage (45.0 m^3/d)	Summer	Weak (0.04)	0.5	1.4	2.3	7.3	-	-	-	-
		Medium (0.11)	0.9	2.8	4.2	14.4	22.0	-	-	-
		Strong (0.27)	1.7	4.5	6.9	25.7	40.0	-	-	-
	Transitional	Weak (0.05)	0.5	1.3	2.2	7.8	-	-	-	-
		Medium (0.14)	1.2	3.2	5.3	15.1	25.5	-	-	-
		Strong (0.29)	1.8	5.2	8.7	24.4	35.7	-	-	-
	Winter	Weak (0.03)	0.5	1.6	2.6	7.7	12.4	-	-	-
		Medium (0.11)	1.2	3.2	5.2	14.0	20.1	-	-	-
		Strong (0.27)	1.8	5.0	8.2	21.1	29.9	-	-	-

Appendix K.

Hydrocarbon spill modelling study (RPS 2017d)

ConocoPhillips Barossa Project

Hydrocarbon Spill Modelling

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Document Status

Version	Purpose of Document	Original	Review	Review Date
Draft A	*Issued for client review*	Dr Ryan Dunn	Dr Sasha Zigic	28/2/2017
Rev 0	*Issued for client review*	Dr Ryan Dunn	Dr Sasha Zigic	28/2/2017
Rev 1	Issued to client		Dr Sasha Zigic	04/4/2017

Approval for Issue

Name	Signature	Date
Dr Sasha Zigic		30/3/2017

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TERMS AND ABBREVIATIONS

ADCP - Acoustic Doppler Current Profiler

AMSA – Australian Maritime Safety Authority

ANZECC – Australian and New Zealand Environment and Conservation Council

API – American Petroleum Institute gravity. A measure of how heavy or light petroleum liquid is compared to water

ARMCANZ – Agriculture and Resources Management Council of Australia and New Zealand

ASA – Applied Science Associates

ASTM – American Society for Testing and Materials

BMSL – Below mean sea level

Bonn Agreement Oil Appearance Code – An agreement for cooperation in dealing with pollution of the North Sea by oil and other harmful substances, 1983, includes: Governments of the Kingdom of Belgium, the Kingdom of Denmark, the French Republic, the Federal Republic of Germany, the Republic of Ireland, the Kingdom of the Netherlands, the Kingdom of Norway, the Kingdom of Sweden, the United Kingdom of Great Britain and Northern Ireland and the European Union.

CFSR – Climate Forecast System Reanalysis

CMR – Commonwealth Marine Reserve

Condensate – The part of the hydrocarbon stream which is in a vapour formation and condenses to a liquid when cooled. Generally, the condensates are composed of C5 to C8 and have an API gravity >40.

cP – centipoise

CTD – Conductivity, temperature and depth profiler

Decay – The process where oil components are changed either chemically or biologically (biodegradation) to another compound. It includes breakdown to simpler organic carbon compounds by bacteria and other organisms, photo-oxidation by solar energy, and other chemical reactions.

Dissolved aromatic hydrocarbons – dissolved aromatic hydrocarbons within the water column with alternating double and single bonds between carbon atoms forming rings, containing at least one 6-membered benzene ring.

Entrained hydrocarbons – Droplets or globules of oil that are physically mixed (but not dissolved) throughout the water column. Physical entrainment can occur either during pressurised release from a sub-surface location, or through the action of breaking waves (>12 knots).

Evaporation – The process whereby components of the hydrocarbon mixture are transferred from the sea surface to the atmosphere

GODAE – Global Ocean Data Assimilation Experiment

HFO – Heavy Fuel Oil

HYCOM – Hybrid Coordinate Ocean Model

HYDROMAP – Three-dimensional advanced ocean/coastal computational model

IFO-180 – Intermediate fuel oil used as a propulsion fuel for ships. Has a maximum viscosity of 180 Cst.

ITOPF –International Tanker Owners Pollution Federation

Isopycnal layers – Water column layers with corresponding water densities

KEF – Key ecological feature

LC_{50} – Median lethal dose. The dose required for mortality of 50% of a tested population after a specified test duration.

NASA – National Aeronautics and Space Administration

NCEP – National Centre for Environmental Prediction

NOAA – National Oceanic and Atmospheric Administration

Marine diesel oil (MDO) – is a blend of gas oil and heavy fuel oil utilised in maritime-based diesel-fuelled engine applications.

MSL – mean sea level

ppb – parts per billion

RMAE – relative mean absolute error

RMS % – root-mean square percentage

RMSE – root-mean square error

RPS APASA – RPS APASA Pty Ltd

SIMAP – Spill Impact Mapping Analysis Program

USCG – US Coast Guard

USEPA – US Environmental Protection Authority

1. Introduction

1.1 Project background

ConocoPhillips Australia Exploration Proprietary (Pty) Limited (Ltd.) (ConocoPhillips), as proponent on behalf of the current and future co-venturers, is proposing to develop natural gas resources in the Timor Sea into high quality products in a safe, reliable and environmentally responsible manner. The Barossa Area Development (herein referred to as the “project”) is located in Commonwealth waters within the Bonaparte Basin, offshore northern Australia, and is approximately 300 kilometres (km) north of Darwin, Northern Territory (NT).

The development concept of the gas resource includes a floating production storage and offloading (FPSO) facility and a gas export pipeline that are located in Commonwealth jurisdictional waters. The FPSO facility will be the central processing facility to stabilise, store and offload condensate, and to treat, condition and export gas. The extracted lean dry gas will be exported through a new gas export pipeline that will tie into the existing Bayu-Undan to Darwin gas export pipeline. The lean dry gas will then be liquefied for export at the existing ConocoPhillips operated Darwin Liquefied Natural Gas (LNG) facility at Wickham Point, NT.

The key objective of the modelling study was to provide an assessment of the probabilities of hydrocarbon contact (at defined concentrations) and quantification of the effects on both the surface waters and within the water column (i.e. entrained and dissolved aromatic hydrocarbons) at depth levels relevant to the environmental values and sensitivities (e.g. shoals/banks, offshore reefs and islands, Commonwealth marine reserves etc.).

The assessment considers a number of spill scenarios involving different sources, spill durations and hydrocarbon types. The scenarios modelled were identified by ConocoPhillips to represent maximum credible scenarios that may be associated with the project.

The six hydrocarbon spill scenarios modelled were:

- Scenario 1 – 10 m^3 instantaneous surface release of marine diesel oil (MDO) to represent a refuelling incident in the Barossa offshore development area;
- Scenario 2 – 2,975 m^3 surface release of MDO over 6 hours to represent a single fuel tank rupture in the Barossa offshore development area;
- Scenario 3 – 19,400 m^3 surface release of Barossa condensate over 6 hours to represent a loss of contents from a storage tank following a vessel collision in the Barossa offshore development area;
- Scenario 4 – 16,833 m^3 subsea release of Barossa condensate over 80 days (approximately 210 m^3/day) to represent a long term subsea well blowout in the Barossa offshore development area;
- Scenario 5 – 650 m^3 surface release of heavy fuel oil (HFO) over 6 hours to represent a vessel collision leading to loss of an export tanker fuel tank; and
- Scenario 6 – 500 m^3 surface release of intermediate fuel oil (IFO)-180 over 6 hours to represent a ship collision and rupture of a single fuel tank from a pipelay vessel along the proposed gas export pipeline corridor.

The modelling provides an understanding of a conservative ‘outer envelope’ of the potential area that may be affected in the unlikely event of a large-scale hydrocarbon release. The modelling does not take into consideration any of the spill prevention, mitigation and response capabilities that would be implemented in response to the spill. Therefore, the modelling results represent the maximum extent that the released hydrocarbon may influence.

The coordinates of the release locations are presented in Table 1 and graphically in Figure 1. For Scenario 6, a point along the gas export pipeline corridor that represents a notional location close to a shoreline (i.e. Bathurst Island) was selected as the release location.

The closest environmental values and sensitivities to the Barossa offshore development area (FPSO facility) are submerged shoals and banks, including Lynedoch Bank (70 km to the south-east), Evans Shoal (64 km to the south-west) and Tassie Shoal (74 km to the south-west). The nearest emergent receptors to the gas export pipeline corridor are Bathurst Island and Melville Island. The closest submerged receptors to the gas export pipeline corridor are Goodrich Bank, Marie Shoal (both directly adjacent to the pipeline corridor), Shepparton Shoal (within the pipeline corridor) as well as Moss Shoal (3 km to the west).

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for three distinct seasons; (i) summer (December to the following February), (ii) the transitional periods (March and September to November) and (iii) winter (April to August). This approach assists with identifying the environmental values and sensitivities that would be at risk of exposure on a seasonal basis.

The spill modelling was performed using an advanced three-dimensional trajectory and fates model; Spill Impact Mapping Analysis Program (SIMAP). The SIMAP model calculates the transport, spreading, entrainment and evaporation of spilled hydrocarbons over time, based on the prevailing wind and current conditions and the physical and chemical properties.

The hydrocarbon spill model, the method and analysis applied herein uses modelling algorithms which have been anonymously peer reviewed and published in international journals. Further, RPS warrants that this work meets and exceeds the American Society for Testing and Materials (ASTM) Standard F2067-13 "*Standard Practice for Development and Use of Oil Spill Models*".

Table 1 Barossa offshore development area and gas export pipeline corridor hydrocarbon spill modelling release locations

Release location	Scenario	Latitude	Longitude	Water depth (mLAT)
Barossa offshore development area release location	1 to 5	9° 52' 35.77" S	130° 11' 8.36" E	~230
Gas export pipeline corridor release location	6	11° 46' 8.4" S	129° 55' 22.8 E	~67

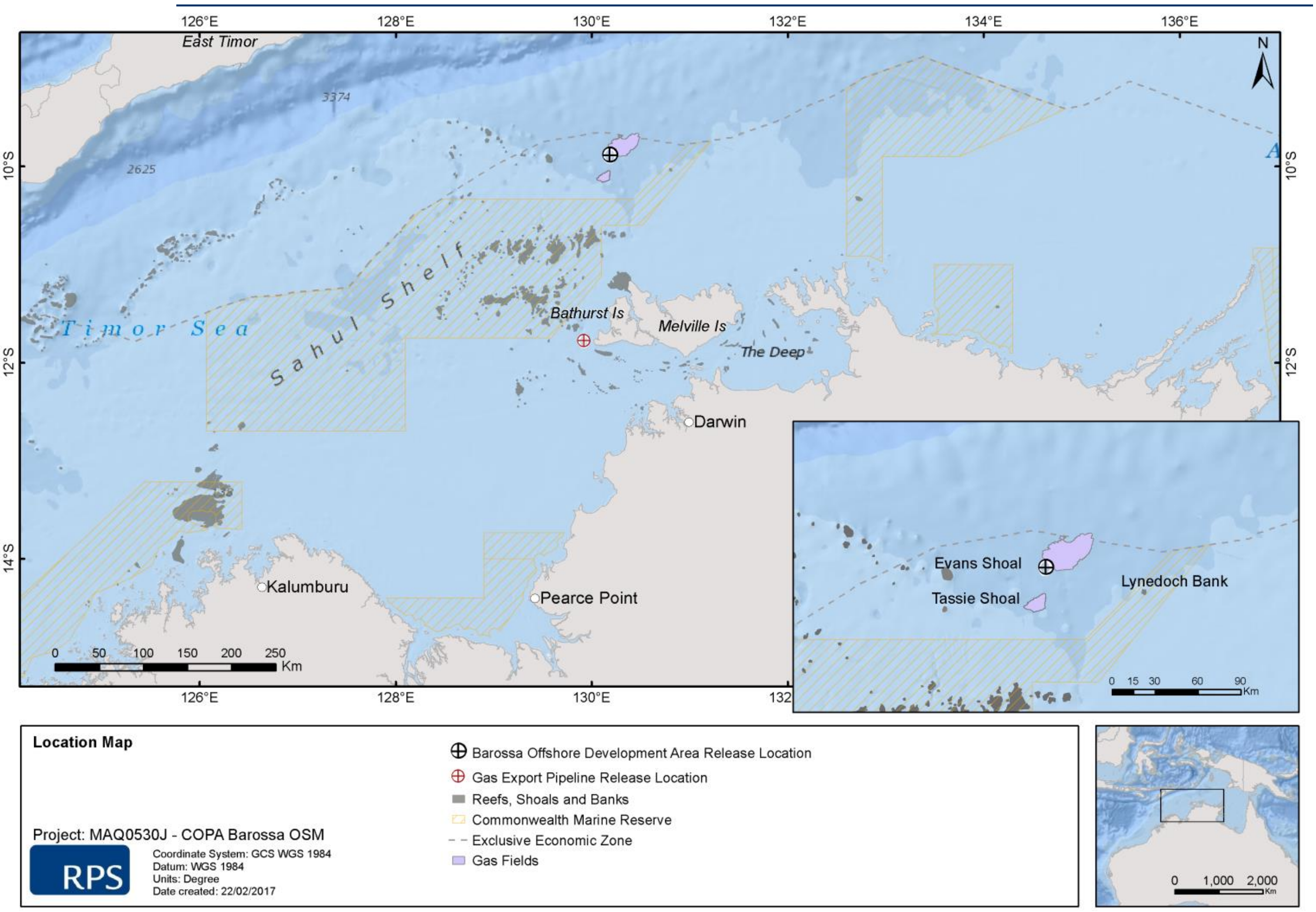


Figure 1 Map of the Barossa offshore development area and gas export pipeline hydrocarbon spill modelling release locations.

2. HYDROCARBON SPILL MODEL

The spill modelling was performed using an advanced three-dimensional trajectory and fates model; Spill Impact Mapping Analysis Program (SIMAP). SIMAP is designed to simulate the fates and effects of spilled hydrocarbons for either surface or subsea releases (Spaulding et al. 1994, French 1998, French, Schuttenberg and Isaji 1999, French-McCay 2003, French-McCay 2004).

The SIMAP model calculates two components: (i) the transport, spreading, entrainment, evaporation and decay of surface hydrocarbons and, (ii) the entrained and dissolved hydrocarbons released from the surface hydrocarbons into the water column. Input specifications for hydrocarbon-types include the density, viscosity, pour point, distillation curve (volume lost versus temperature) and the aromatic/aliphatic component ratios within given boiling point ranges.

The SIMAP trajectory model separately calculates the movement of the material that is on the water surface or in the water column (as either entrained whole hydrocarbon droplets or dissolved hydrocarbons). The model calculates the transport of surface hydrocarbons from the combined forces exerted by surface currents and wind acting on the hydrocarbon. Transport of entrained and dissolved hydrocarbons (that is below the water surface) is calculated using the currents only.

The current and wind data input into the SIMAP model are discussed in Sections 2.1 and 2.2, respectively.

2.1 Development of regional current data

The project is located within the influence of the Indonesian Throughflow, a large scale current system characterised as a series of migrating gyres and connecting jets that are steered by the continental shelf. This results in sporadic deep ocean events causing surface currents to exceed 1.5 m/s (approximately 3 knots).

While the ocean currents generally flow toward the southwest, year-round, the internal gyres generate local currents in any direction. As these gyres migrate through the area, large spatial variations in the speed and direction of currents will occur at a given location over time.

Whereas, the tidal currents are generally weaker in the deeper waters, with the influence of the tidal currents greatest surrounding regional reefs and islands. Therefore, it was critical to include the influence of both types of currents (ocean and tides) to rigorously understand the likely discharge characteristics in the project's area of influence.

A detailed description of the current (tidal and ocean) and wind data inputted into the model is provided below.

2.1.1 Tidal currents

The tidal circulation was generated using RPS's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world over the past 26 years (Isaji and Spaulding 1984; Isaji et al. 2001; Zigic et al. 2003). In addition, HYDROMAP tidal current data has been used as input to forecast (in the future) and hindcast (in the past) condensate spills in Australian waters and forms part of the Australian National Oil Spill Emergency Response System operated by the Australian Maritime Safety Authority (AMSA).

HYDROMAP employs a sophisticated sub-gridding strategy, which supports up to six levels of spatial resolution, halving the grid cell size as each level of resolution is employed. The sub-gridding allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, and/or of particular interest to a study.

The numerical solution methodology 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 and Spaulding (1984), Isaji et al. (2001) and Owen (1980).

2.1.1.1 Tidal grid setup

The HYDROMAP tidal grid was established over a domain that extended approximately 2,400 km (east–west) by 1,575 km (north–south) (Figure 2). Computational cells were square, with sizes varying from 8 km in the open waters down to 1 km in some areas, to more accurately resolve flows along the coastline, around islands and reefs, and over more complex bathymetry (Figure 3).

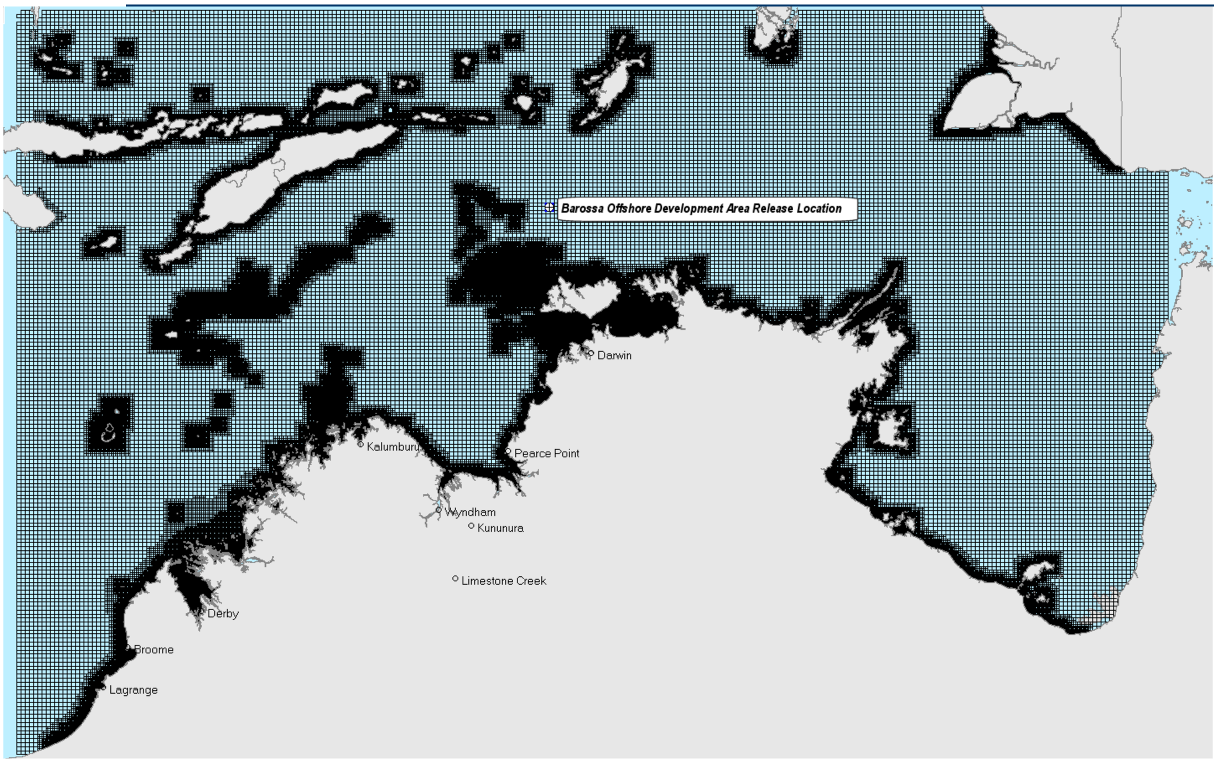


Figure 2 Map showing the extent of the tidal model grid. Note, darker regions indicate higher resolution.

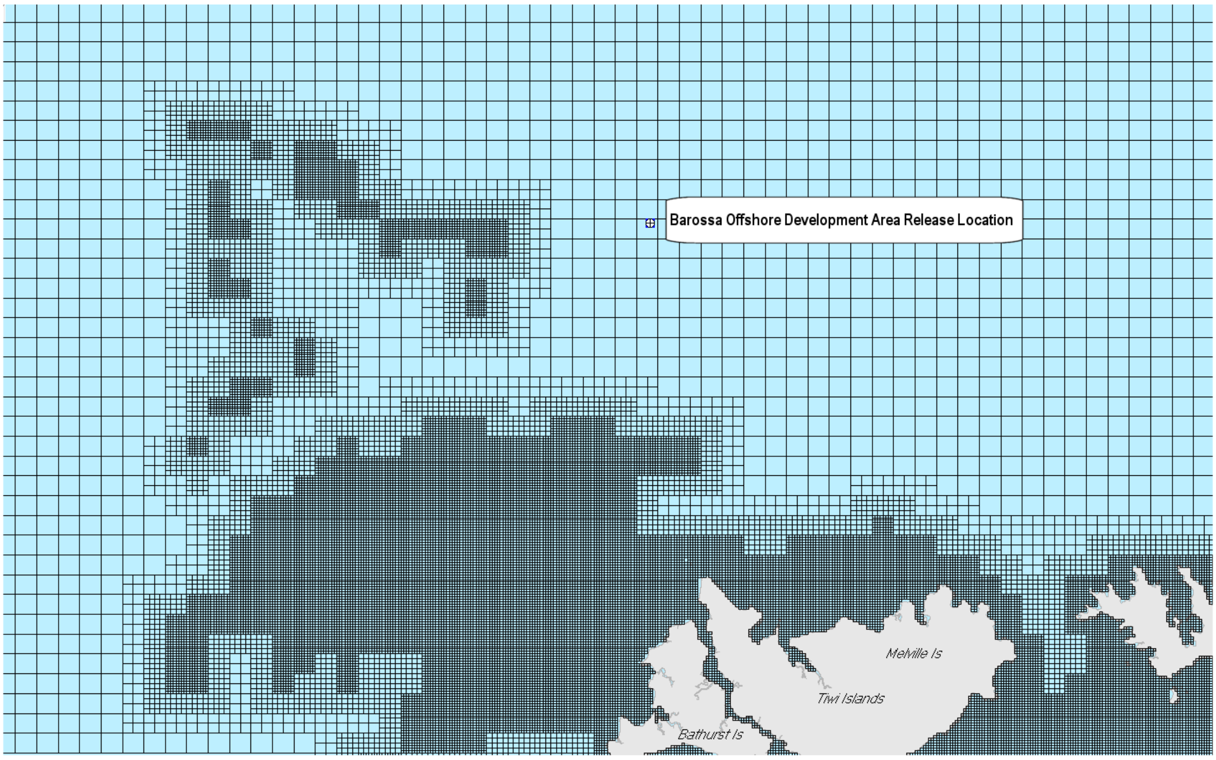


Figure 3 Zoomed in map showing the tidal model grid), illustrating the resolution sub-gridding in complex areas (e.g. islands, banks, shoals or reefs).

Bathymetry used in the model was obtained from multiple sources (Figure 4). This included bathymetry data sourced from the Geoscience Australia database and commercially available digitised navigation charts.

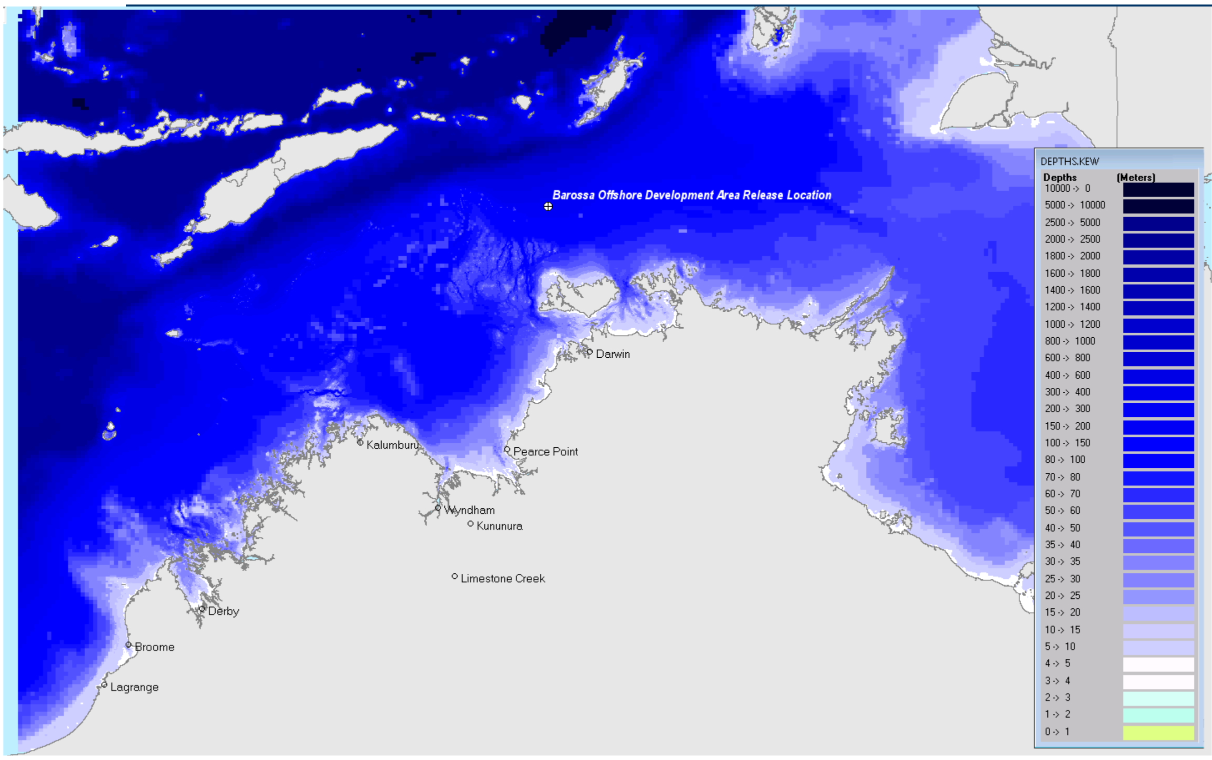


Figure 4 Map showing the bathymetry of the tidal model grid

2.1.2 Tidal conditions

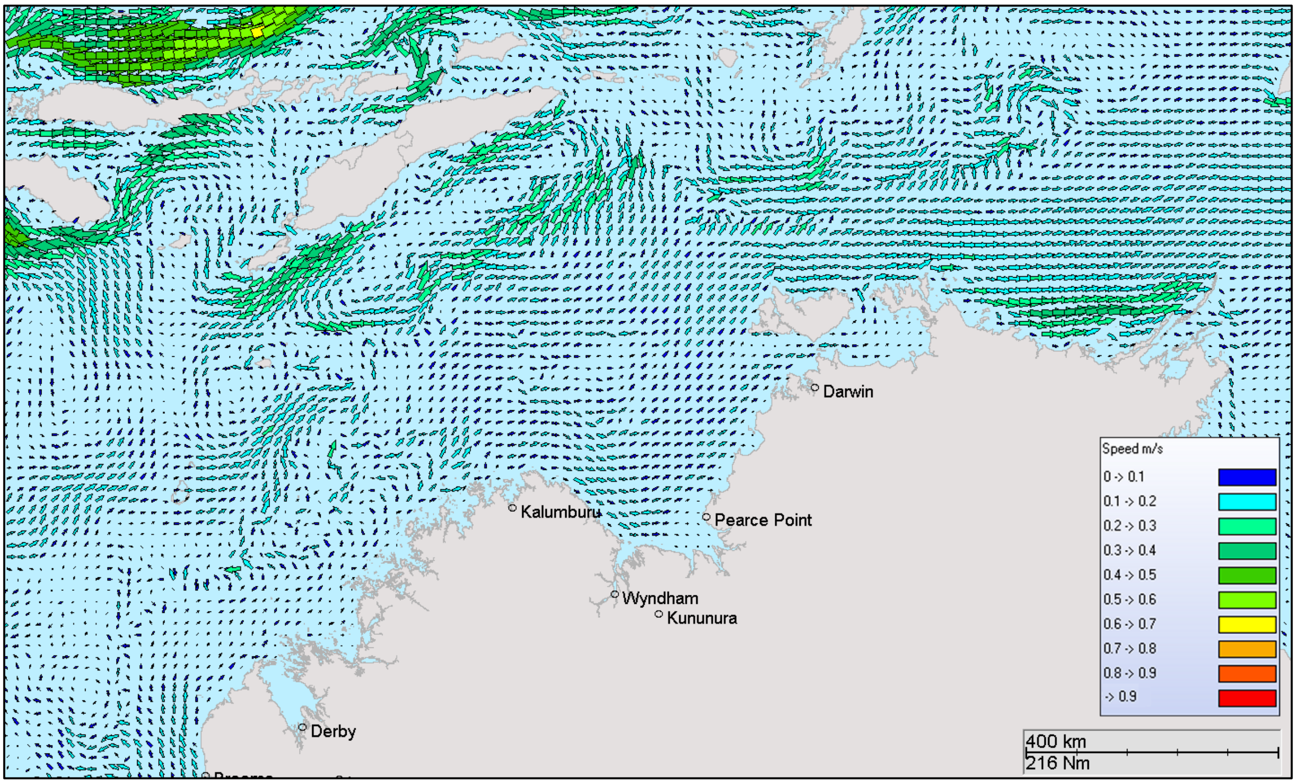
The ocean boundary data for the regional model was obtained from satellite measured altimetry data (TOPEX/Poseidon 7.2) which provided estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. Using the tidal data, surface heights were firstly calculated along the open boundaries, at each time step in the model.

The Topex-Poseidon satellite data is produced and quality controlled by the National Aeronautics and Space Administration (NASA). The satellites, equipped with two highly accurate altimeters that are capable of taking sea level measurements to an accuracy of less than 5 cm, measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005; see Fu et al., 1994; NASA/Jet Propulsion Laboratory 2013a; 2013b). In total these satellites carried out 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 and Tangdong 2004, Qiu and Chen 2010). As such the Topex/Poseidon tidal data is considered accurate for this study.

2.1.3 Ocean currents

Data describing the flow of ocean currents was obtained from the Hybrid Coordinate Ocean Model (HYCOM) (see Chassignet et al. 2007, 2009), which is operated by the HYCOM Consortium, sponsored by the Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a data-assimilative, three-dimensional ocean model that is run as a hindcast, assimilating time-varying observations of sea surface height, sea surface temperature and in-situ temperature and salinity measurements (Chassignet et al. 2009). The HYCOM predictions for drift currents are produced at a horizontal spatial resolution of approximately 8.25 km (1/12th of a degree) over the region, at a frequency of once per day. 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.

For this modelling study, the HYCOM hindcast currents were obtained for the years 2010 to 2014 (inclusive). Figure 5 shows example screenshots of the predicted HYCOM ocean currents during summer and winter conditions. The colours of the arrows indicate current speed (m/s).



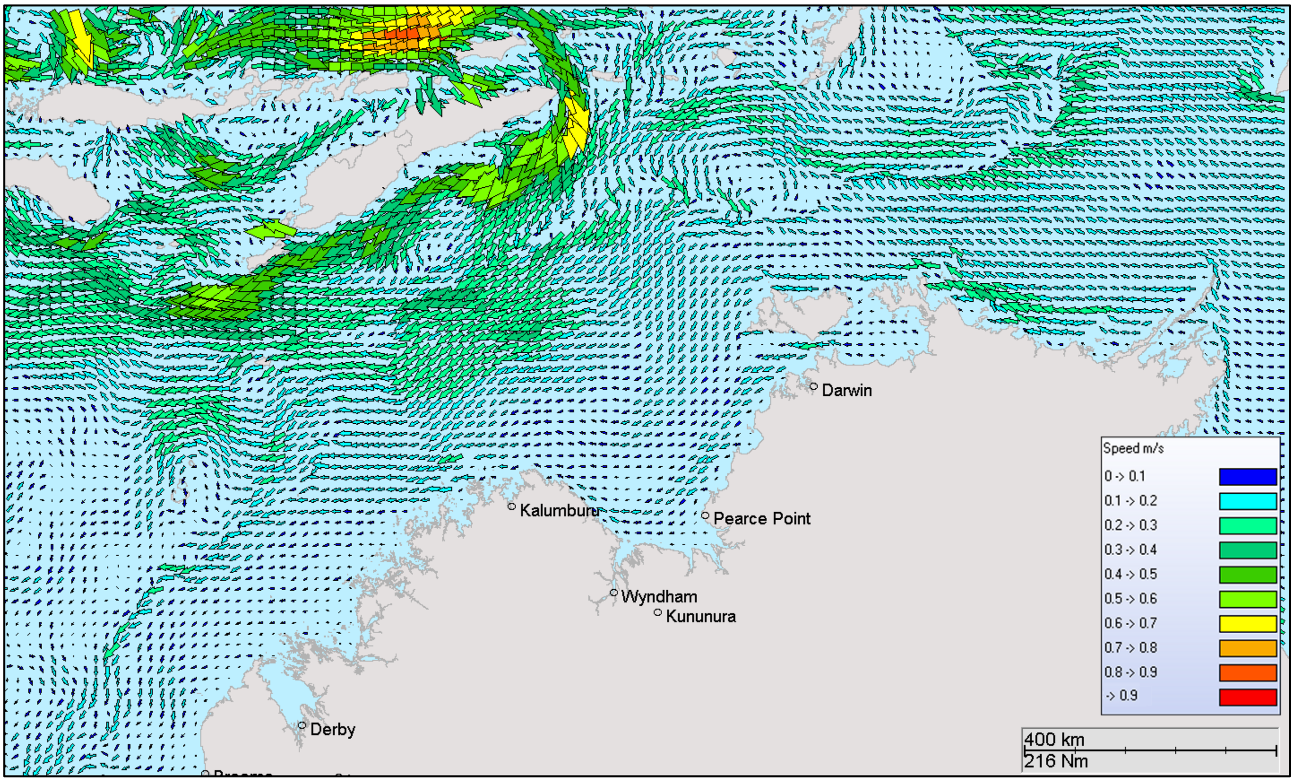


Figure 5 Modelled HYCOM surface ocean currents on the 6th February 2012, summer conditions (upper image) and 11th May 2012, winter conditions (lower image). Derived from the HYCOM ocean hindcast model (Note: for image clarity only every 2nd vector is displayed).

2.1.4 Surface currents in the Barossa offshore development area

Table 2 displays the average and maximum current speeds adjacent to the Barossa offshore development area release location. Data was derived by combining the HYCOM ocean data and HYDROMAP tidal data from 2010-2014 (inclusive). The average monthly current speeds in the Barossa offshore development area ranged between 0.11 m/s and 0.19 m/s. Under summer conditions the predominant current direction was toward the east and southwest. During winter months the currents were mostly to the west and southwest. Similarly, the currents during the transitional months generally flowed southwest. Seasonal average current speeds ranged between 0.12 m/s (summer), 0.13 m/s (winter) and 0.15 m/s (transitional).

Figure 6 and Figure 7 show monthly and seasonal surface current roses adjacent to the Barossa offshore development area release location. Note the convention for defining current direction is the direction the current flows towards, which is used to reference current direction throughout this report. Each branch of the rose represents the currents flowing to that direction, with north to the top of the diagram. The rose branches are each divided into segments of different colour according to speed intervals of 0.1 m/s, which represent current speeds within the monthly or seasonal datasets, respectively. The length of each coloured segment (indicative of speeds) is relative to the proportion of time the currents flow to the corresponding direction.

Table 2 Predicted average and maximum surface current speeds adjacent to the Barossa offshore development area release location. Data derived by combining the HYCOM ocean data and HYDROMAP tidal data from 2010-2014 (inclusive).

Season	Month	Average current speed (m/s)	Maximum current speed (m/s)	General direction (towards)
Summer	January	0.13	0.43	East
	February	0.11	0.32	East
Transitional	March	0.11	0.28	East (variable)
Winter	April	0.12	0.30	West-northwest
	May	0.14	0.47	West and northward
	June	0.13	0.33	West (variable)
	July	0.12	0.40	Southwest (variable)
	August	0.13	0.38	Southwest
Transitional	September	0.14	0.40	Southwest
	October	0.17	0.32	Southwest
	November	0.19	0.36	Southwest
Summer	December	0.11	0.33	Southwest
	Minimum	**0.11**	**0.28**	
	Maximum	**0.19**	**0.47**	

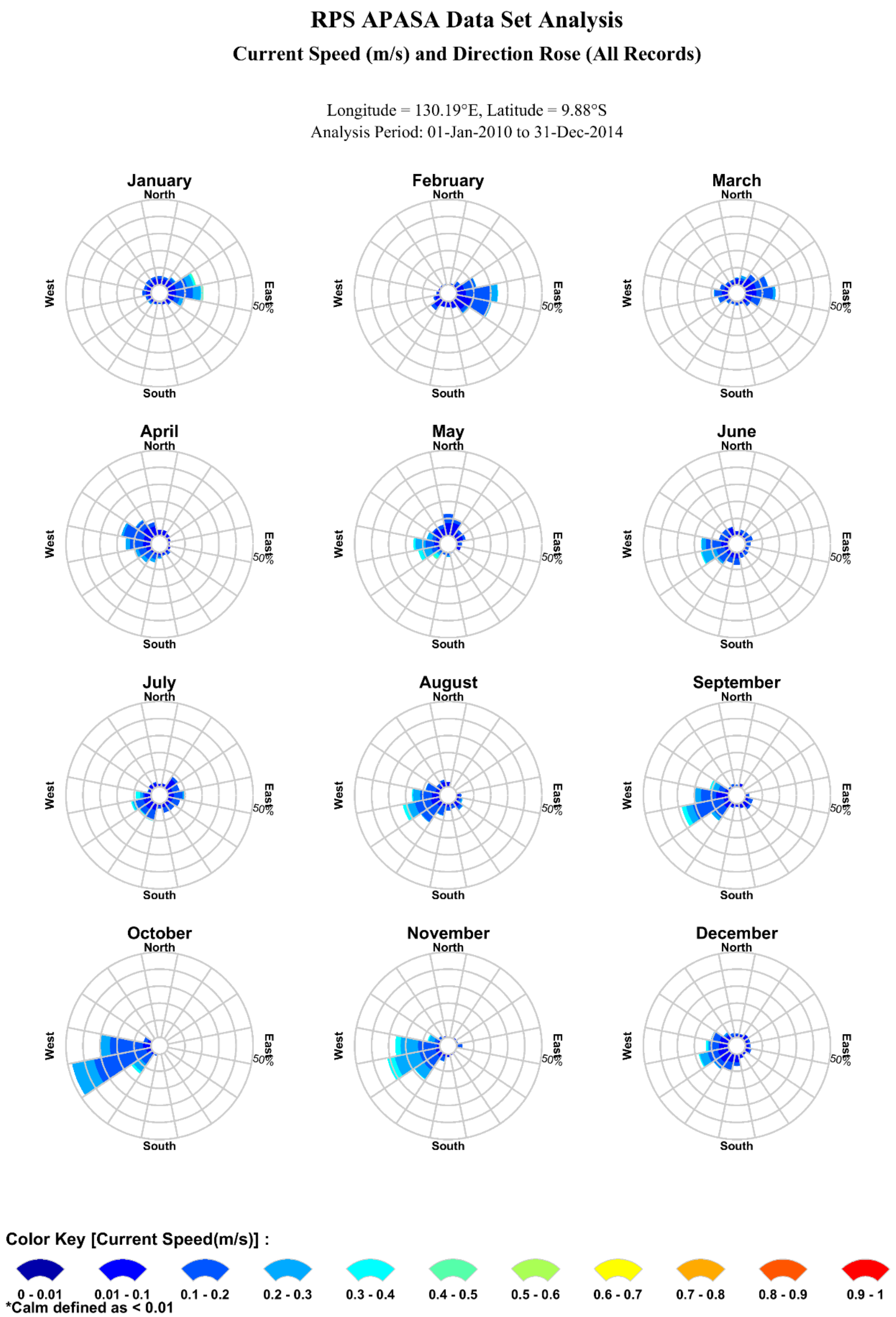


Figure 6 Predicted monthly surface current rose plots adjacent to the Barossa offshore development area release location. Data was derived by combining the HYCOM ocean currents and HYDROMAP tidal currents for 2010–2014 inclusive. The colour key shows the current speed (m/s), the compass direction provides the current direction (flowing towards), and the length of the rose branch indicates the proportion of time the currents flow for particular speed and direction combinations.

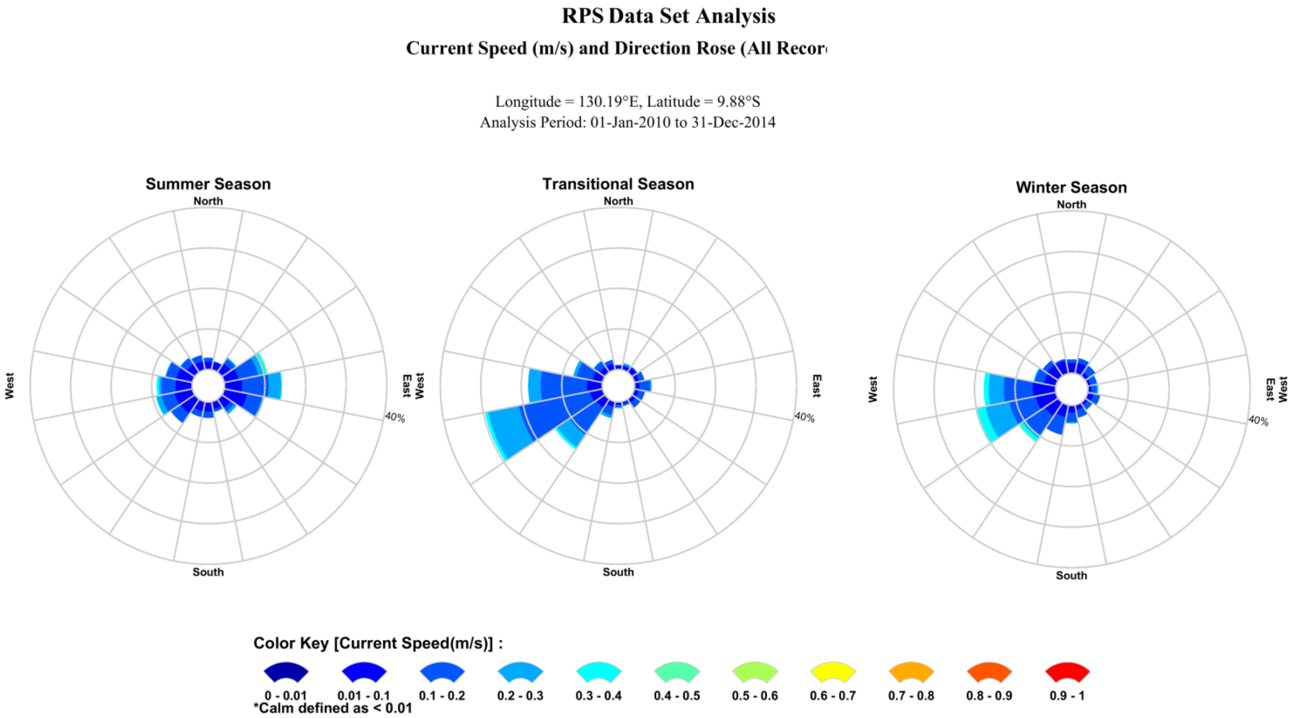


Figure 7 Seasonal surface current rose plots adjacent to the Barossa offshore development area release location. Data was derived by combining the HYCOM ocean currents and HYDROMAP tidal currents for 2010-2014 inclusive. The colour key shows the current speed (m/s), the compass direction provides the current direction (flowing towards), and the length of the rose branch indicates the proportion of time the currents flow for particular speed and direction combinations.

2.1.5 Tidal and current model validation

Fugro Survey Pty Ltd (Fugro) measured water levels and currents (speed and directions) at three locations within the Barossa offshore development area as part of the Barossa marine studies program (Figure 8; Fugro 2015). The measured data from the survey was made available to validate the predicted currents, which corresponds to the three identified seasons of the region (i.e. summer (December to February), transitional (March and September to November) and winter (April to August)).

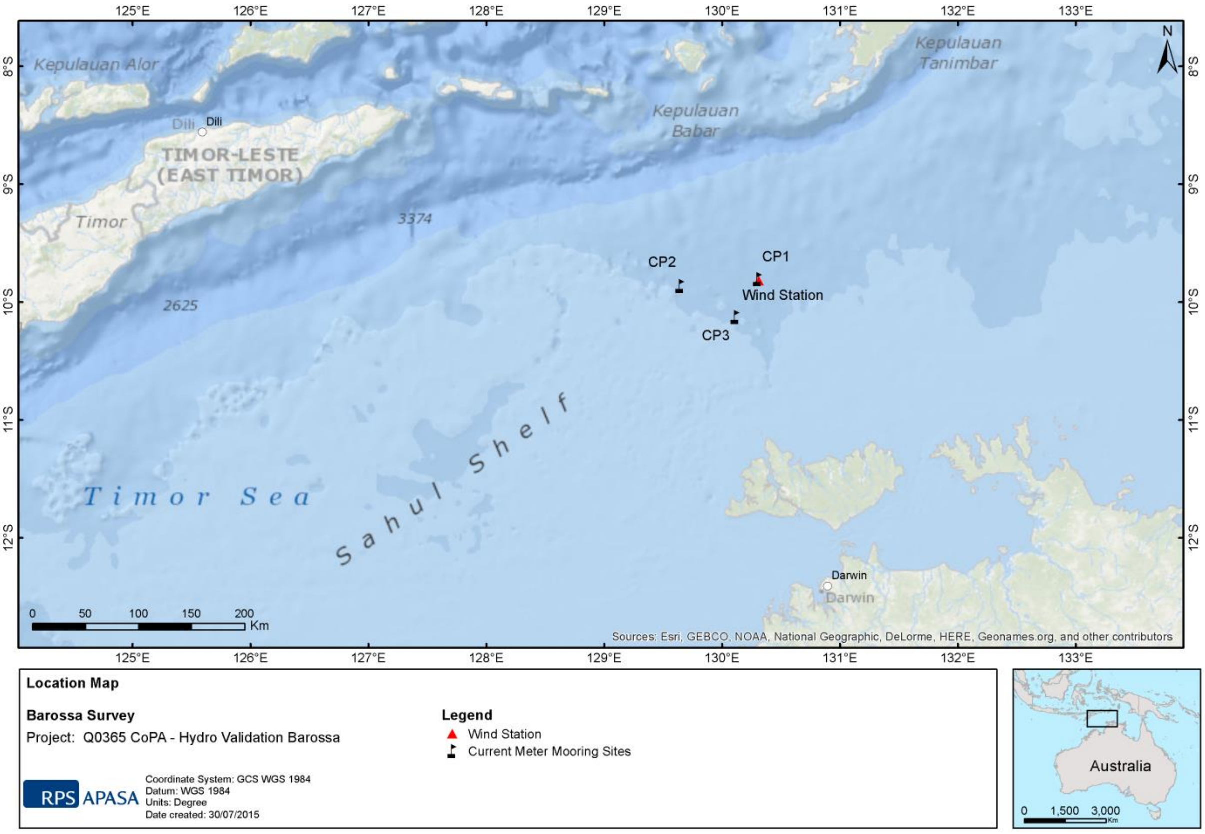


Figure 8 Locations of the CP1, CP2 and CP3 current meter moorings and the wind station

As an example, Figure 9 shows a comparison between the measured and predicted water levels at CP1 from 28 October 2014 to 14 March 2015. The figure shows a strong agreement in tidal amplitude and phasing throughout the entire deployment duration at the CP1 location.

To provide a statistical quantification of the model accuracy, comparisons were performed by determining the deviations between the predicted and measured data. As such, the root-mean square error (RMSE), root-mean square percentage (RMS %) and relative mean absolute error (RMAE) were calculated. Qualification of the RMAE ranges are reported in accordance with Walstra et al. (2001).

Table 3 shows the model performance when compared with measured water levels at CP1 from 28 October to 14 March 2015. According to the statistical measure, the HYDROMAP tidal model predictions were in very good agreement with the measured water levels at CP1.

Table 3 Statistical evaluation between measured water levels and HYDROMAP predicted water levels at CP1

Site	RMSE (m)	RMS (%)	RMAE	RMAE qualification
Mooring CP1	0.061	0.03	0.05	Very good

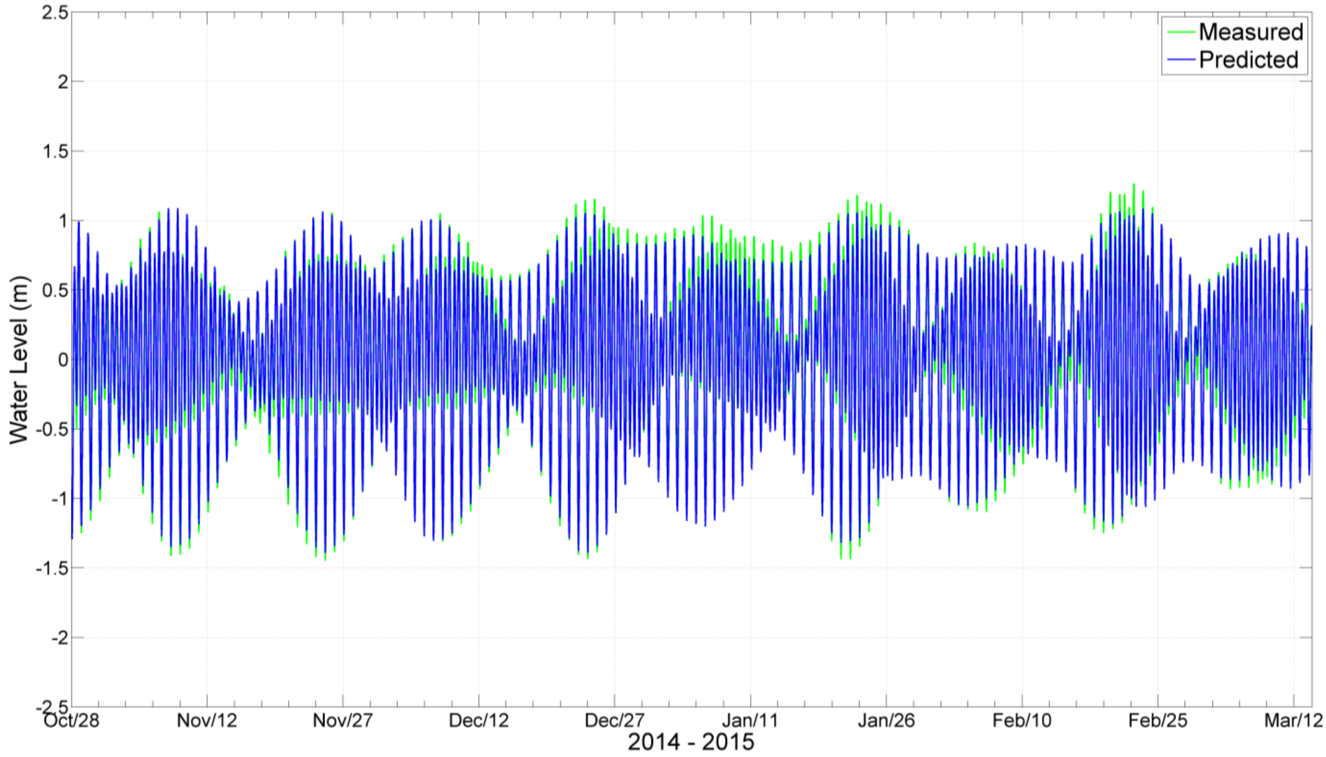


Figure 9 Comparison of measured and modelled water levels at CP1

In addition, the HYCOM ocean currents combined with HYDROMAP tidal currents were compared to the measured current speed and directions from the CP1, CP2 and CP3 moorings. Figure 10 to Figure 12 show current comparison plots of the measured and predicted currents at each location for a range of depths (10 m, 50 m and 125 m BMSL) to highlight the differences between the wind-influenced surface layers and the mid water column.

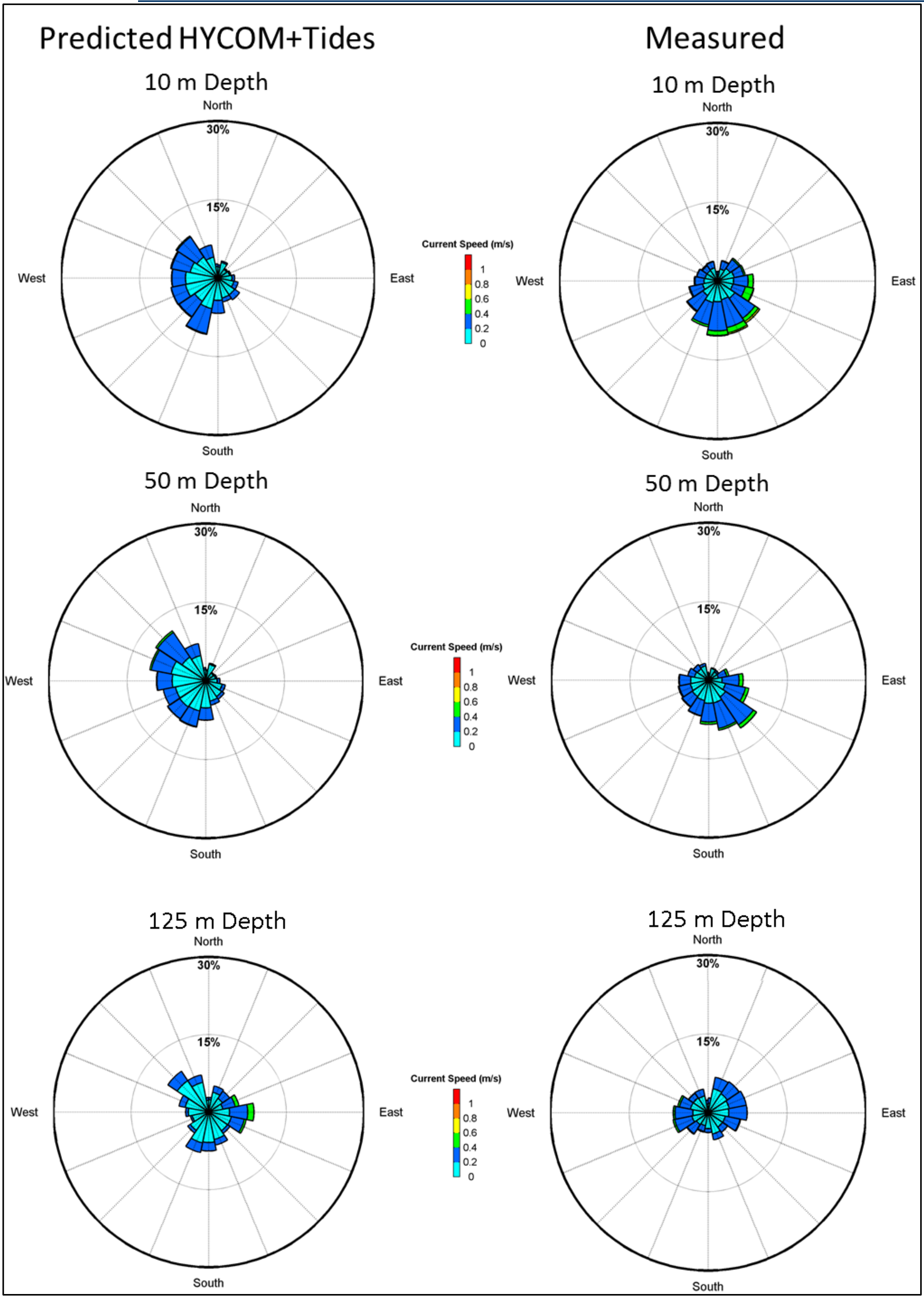


Figure 10 Comparison of predicted and measured current roses at CP1 from 9th July 2014 to 21st March 2015

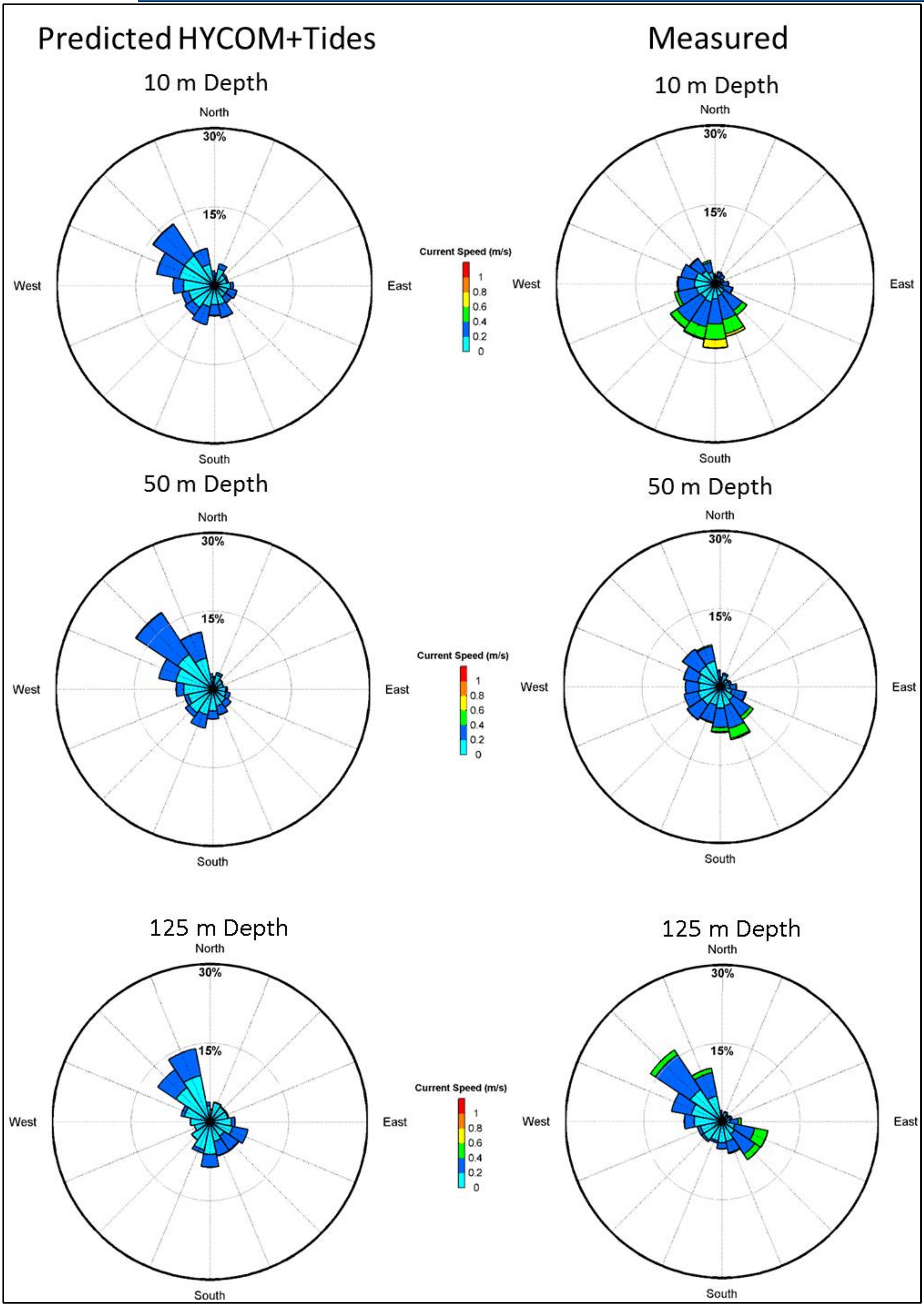


Figure 11 Comparison of predicted and measured current roses at CP2 from 10th July 2014 to 21st March 2015

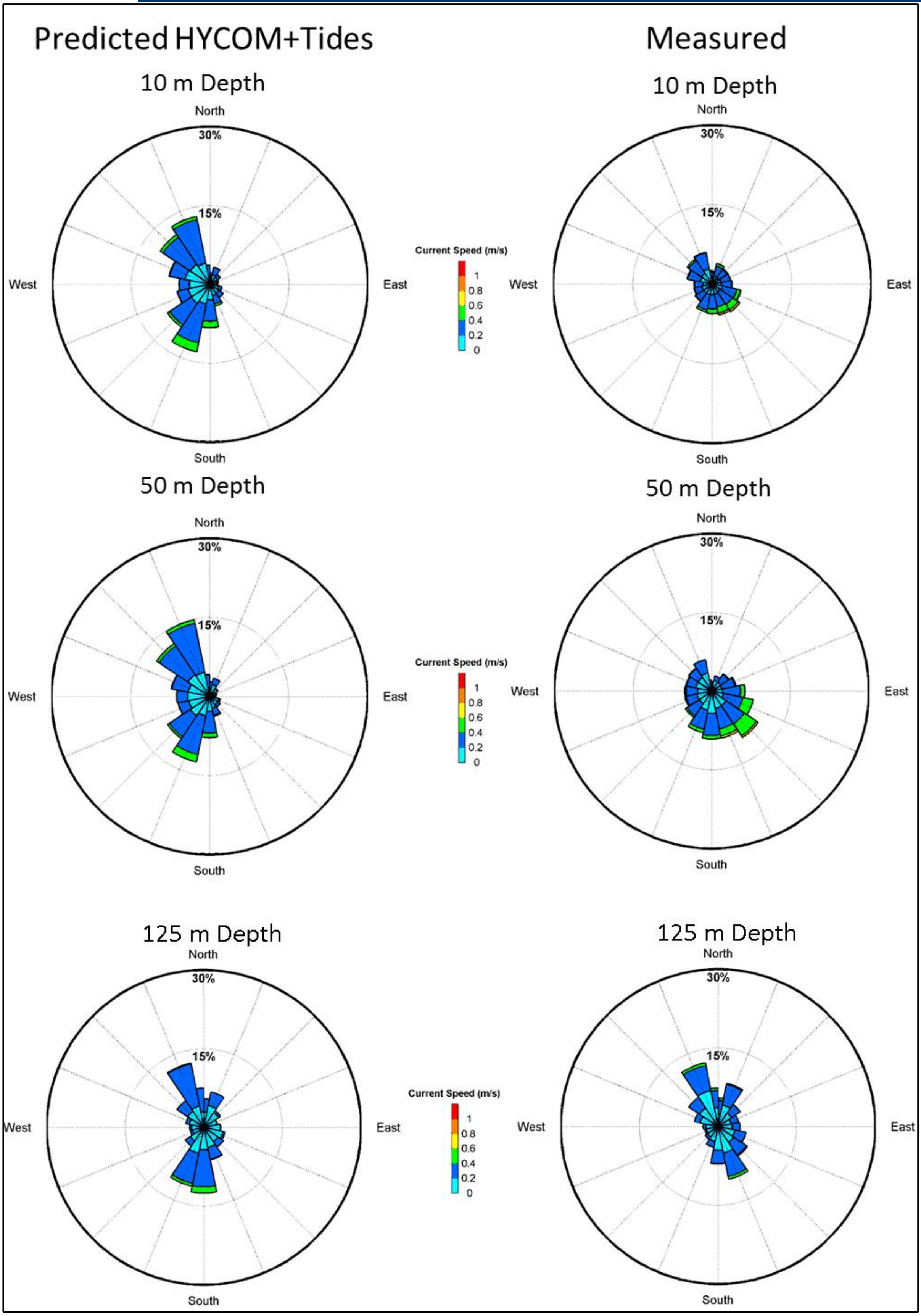


Figure 12 Comparison of predicted and measured current roses at CP3 from 9th July 2014 to 21st March 2015

Overall, there was a good agreement between the predicted and measured currents at each site and depth. The model predictions were also able to recreate the two-layer flow which can be seen in the measured data and the reduction in current speeds as function of depth. From 10 m down to approximately 100 m below mean sea level (BMSL) the currents generally flowed south-east, with little variation due to tidal changes. The model predictions replicated this behaviour. Below 100 m, the influence of the tides became more pronounced, rotating between a south-eastward flow and a north-westward flow with the turning of the tide. Both tidal-scale and large-scale fluctuations in currents were typically reproduced at a similar magnitude and timing.

There was some divergence between the predicted and measured currents, mostly between data from July to October inclusive, due to the occurrence of solitons (or high frequency internal waves that can produce unusually high currents) which was highlighted by Fugro (Fugro 2015). Despite these variations, the statistical comparisons between the measured and predicted current speeds indicate a reasonable to very good agreement (Table 4). Therefore, it can be concluded it is a good comparison and that the predicted current data reliably reproduced the complex conditions within the Barossa offshore development area and surrounding region. The RPS APASA (2015) model validation report provides a more detail regarding the tide and current comparison.

In summary, the Fugro (2015) data provides information specifically for the Barossa offshore development area and is considered the best available and most accurate data for this particular region. This data has been provided and reviewed by RPS APASA to confirm predicted currents applied are accurate. As a result, the current data used herein is considered best available and highly representative of the characteristics influencing the marine environment in the Barossa offshore development area.

Table 4 Statistical evaluation between averaged measured currents and HYCOM ocean current and HYDROMAP tidal current at CP1, CP2 and CP3 at varying water depths (July 2014 to March 2015)

Site	Depth (m BMSL)	RMSE (m/s)	Measured peak value (m/s)	RMSE (%)	RMAE qualification
Mooring CP1	10	0.14	0.71	20	Good
	50	0.14	0.63	22	Very good
	125	0.13	0.61	22	Very good
Mooring CP2	10	0.16	0.82	19	Reasonable
	50	0.14	0.81	17	Good
	125	0.16	0.72	22	Reasonable
Mooring CP3	10	0.15	0.88	18	Very good
	50	0.14	0.78	18	Very good
	125	0.13	0.60	21	Very good

2.2 Wind data

Wind data from 2010 to 2014 (inclusive) was sourced from the National Centre for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) (Saha et al. 2010). The CFSR wind model includes observations from many data sources; surface observations, upper-atmosphere air balloon observations, aircraft observations and satellite observations. The model is capable of accurately representing the interaction between the earth's oceans, land and atmosphere. As shown in Figure 13 the wind nodes are spaced 33 km apart and contain datasets based on hourly intervals. Figure 13 also shows the location of the wind node used to generate a summary of the wind conditions nearby the Barossa offshore development area release location.

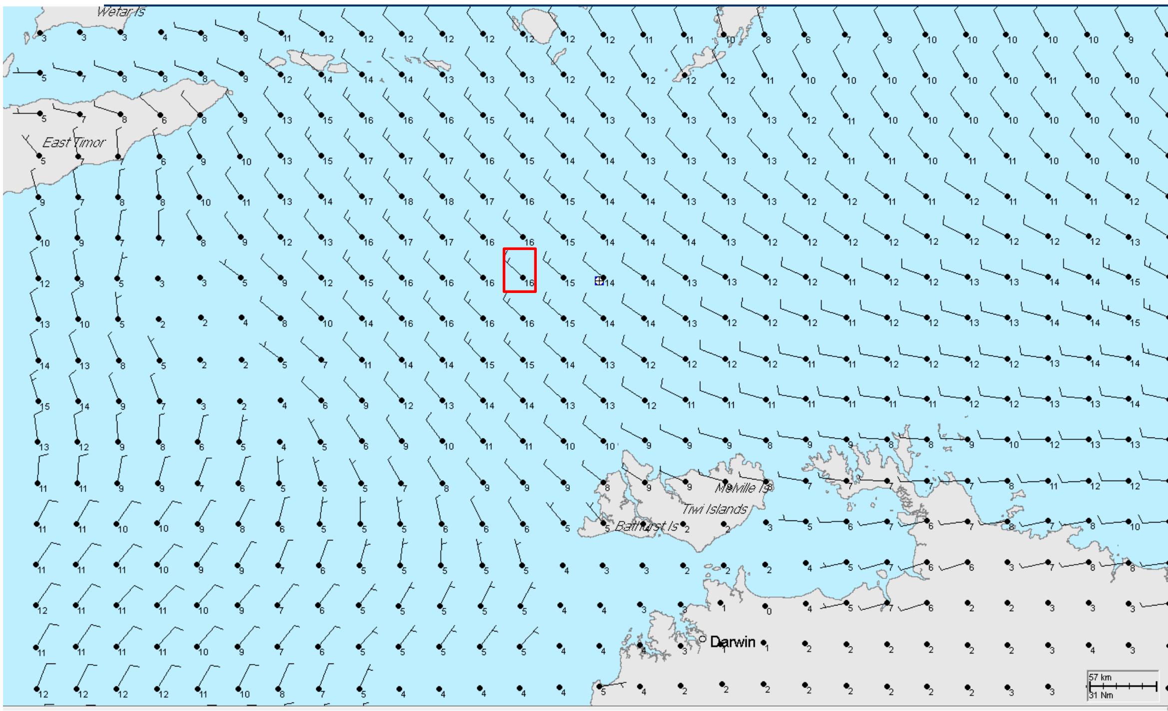


Figure 13 Image of the surrounding wind nodes used as input into the hydrocarbon spill model. Note the values describe the wind speed (knots) at that particular time-step. The red box indicates location of the wind node used to generate wind rose plots.

Table 5 displays the monthly average and maximum wind speeds and general directions derived from the CFSR wind node adjacent to the Barossa offshore development area release location. Figure 14 and Figure 15 show the corresponding monthly and seasonal wind rose plots.

The monthly average wind speeds ranged between 6.0 knots (November) and 15.9 knots (July) and were found to vary seasonally. During the summer season (December to February) winds were predominantly from the west with an average speed of 10.1 knots. During the winter season (April to August) winds were predominantly from the east-southeast with an average speed of 13.3 knots. The transitional period observed greater variations in wind direction and weaker wind speeds with an average of 8.0 knots.

Table 5 Predicted average and maximum winds for the closest station to the Barossa offshore development area

Season	Month	Average wind (knots)	Maximum wind (knots)	General direction (from)
Summer	January	12.6	37.1	West
	February	10.7	31.1	West
Transitional	March	8.9	29.6	West-north-west (variable)
Winter	April	8.7	23.8	East-south-east
	May	13.7	25.1	East-south-east
	June	15.4	25.5	East-south-east
	July	15.9	25.9	East-south-east
	August	13.0	26.8	East-south-east
Transitional	September	9.4	23.9	East-south-east
	October	7.5	17.8	East-south-east
	November	6.0	21.4	East (variable)
Summer	December	7.0	26.5	West (variable)
	Minimum	**6.0**	**17.8**	
	Maximum	**15.9**	**37.1**	

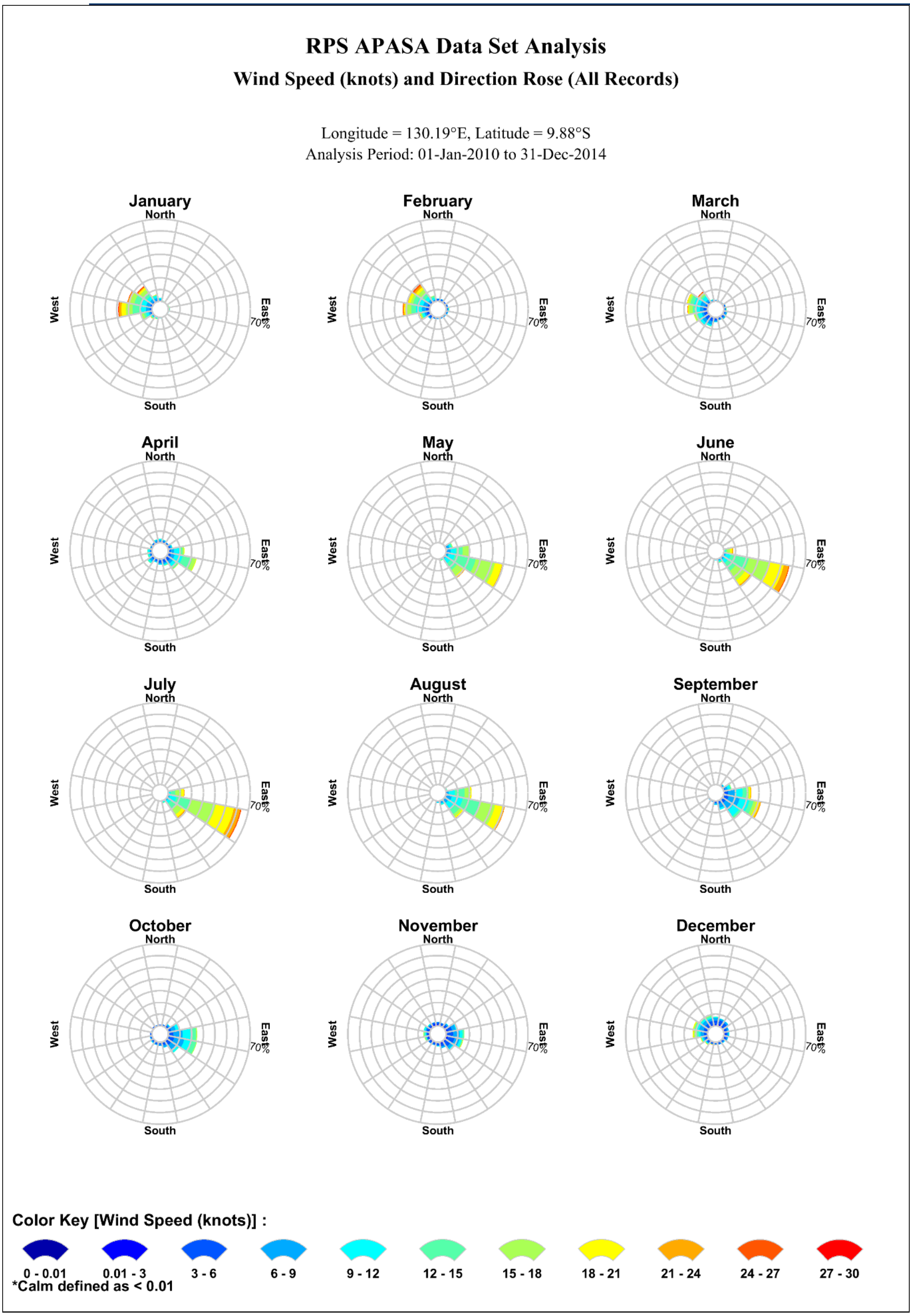


Figure 14 Monthly wind rose plots derived from CFSR data from 2010-2014 (inclusive), for an adjacent wind node to the Barossa offshore development area release location. The colour key shows the wind speed (knots), the compass direction provides the direction (from), and the length of the rose branch indicates the proportion of time the winds originate from for particular speed and direction combinations.

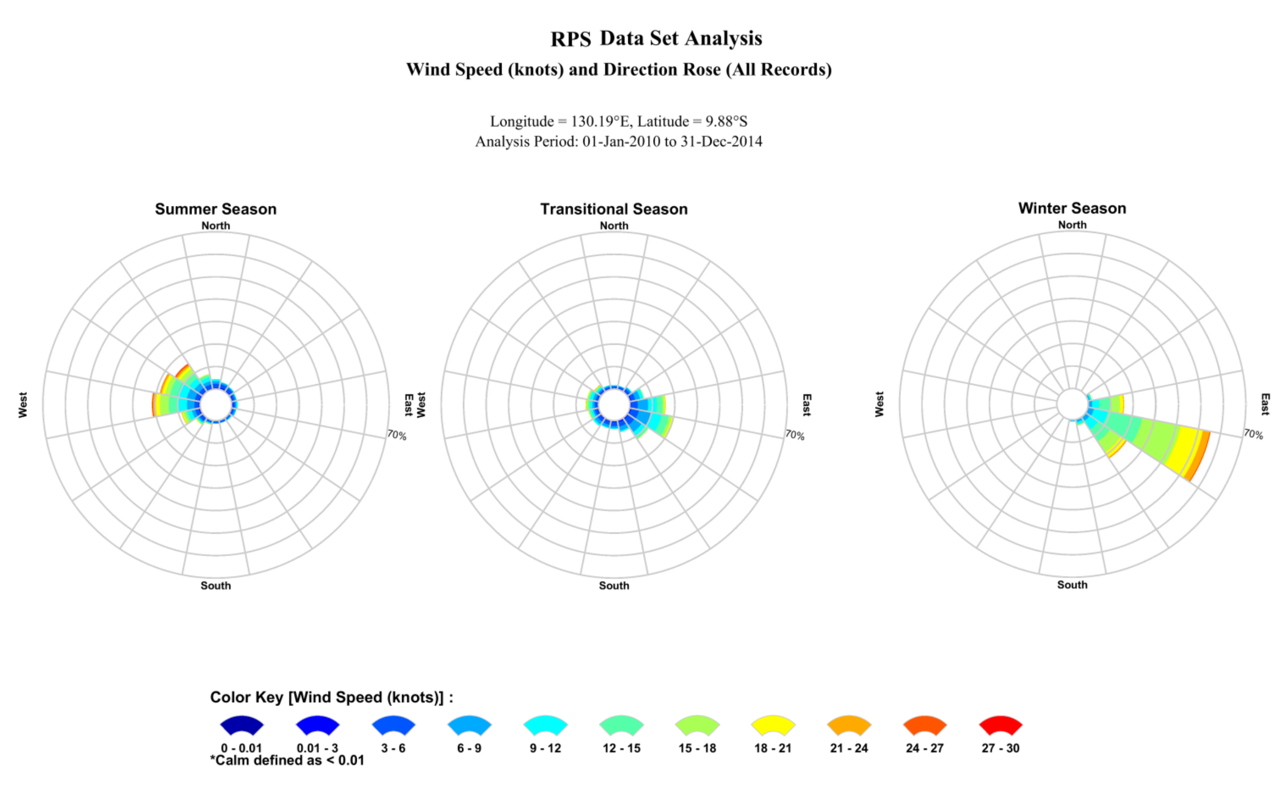


Figure 15 Seasonal wind rose plots derived from CFSR data from 2010-2014 (inclusive), for an adjacent wind node to the Barossa offshore development area release location. The colour key shows the wind speed (knots), the compass direction provides the direction (from), and the length of the rose branch indicates the proportion of time the winds originate from for particular speed and direction combinations.

2.2.1 Wind data validation

Fugro measured wind speed and direction, air temperature, air pressure and humidity (4 m above mean sea level (MSL)) as part of the Barossa marine studies program. As an example, Table 6 shows the measured average and maximum wind speeds between 8 July 2014 and 27 March 2015. During this period, winds were predominantly from the east, reaching a maximum speed of 29.9 knots in January (2015) and maximum average speed of 17.1 knots in January (2015).

Table 6 Measured average and maximum wind speeds in the Barossa offshore development area

Month	Average speed (knots)	Maximum speed (knots)
July 2014	15.4	24.7
August 2014	14.7	22.8
September 2014	9.0	16.6
October 2014	9.3	19.9
November 2014	7.6	19.8
December 2014	7.1	27.2
January 2015	17.1	29.9
February 2015	10.5	22.5
March 2015	10.8	19.6

As shown in Figure 16, there was a very good agreement between the measured and modelled winds of the general trends and although the model is not necessarily capturing the extremes, it does capture the shift in speed and direction over time. The good agreement is further confirmed in the rose plots shown in Figure 17 for the entire period.

Based on the qualitative assessment, the modelled data indicates a very good fit to the measured winds (Table 7). These statistics provide further confidence in the accuracy of the predicted wind data to be used for the spill and discharge modelling studies.

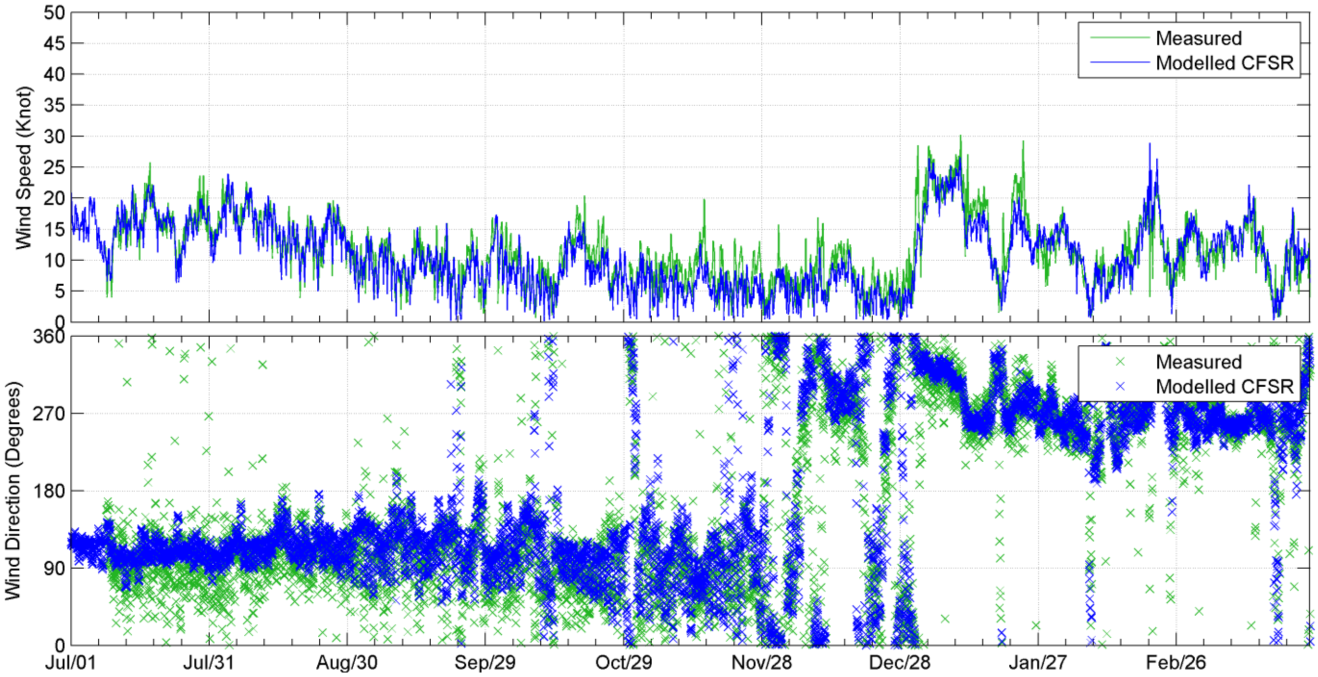


Figure 16 Comparison of the hourly measured and predicted wind speeds (upper image) and directions (lower image) (July 2014 to March 2015)

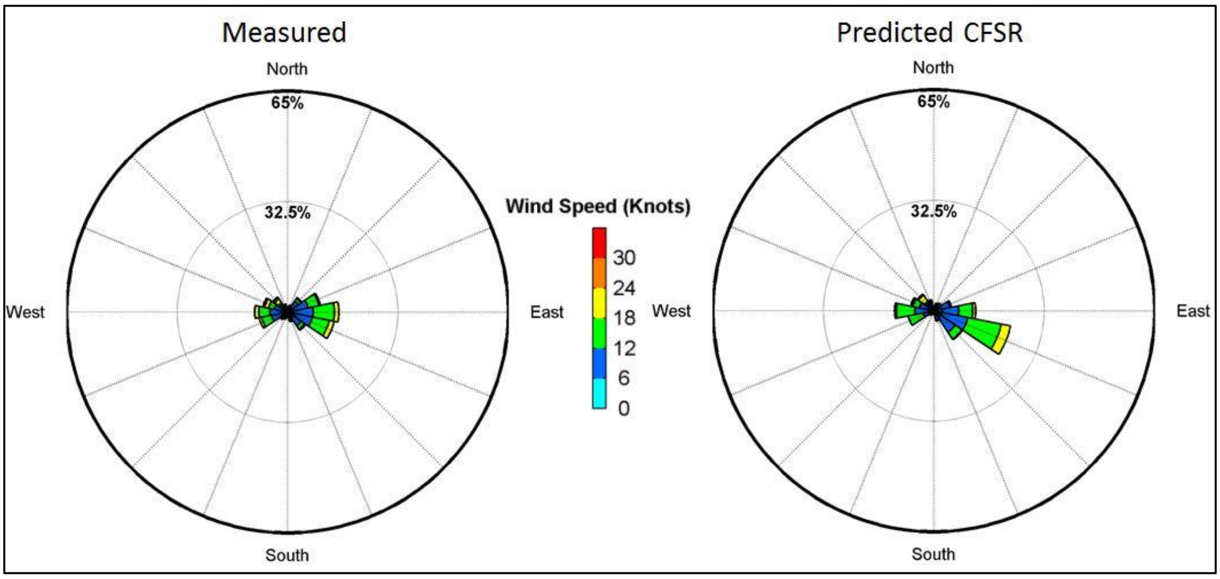


Figure 17 Combined comparison of wind rose plots between measured and predicted CFSR datasets for 8th July 2014 and 27th March 2015.

Table 7 Statistical evaluation between the measured and predicted winds

RMSE (knots)	RMS (%)	RMAE	RMAE qualification
2.8	10.5	<0.01	Very good

2.3 Drifter Buoy Deployment

Eighteen Pathfinder surface current drifter buoys were deployed on three separate field surveys (July 2014, January 2015 and April 2015) within the Barossa offshore development area to better understand the complex seasonal surface-water circulation. The July, January and April field surveys were selected to represent winter, summer and transitional conditions, respectively, within the study region. Figure 18 is a photograph of a deployed Pathfinder drifter buoy at sea and its dimensions.

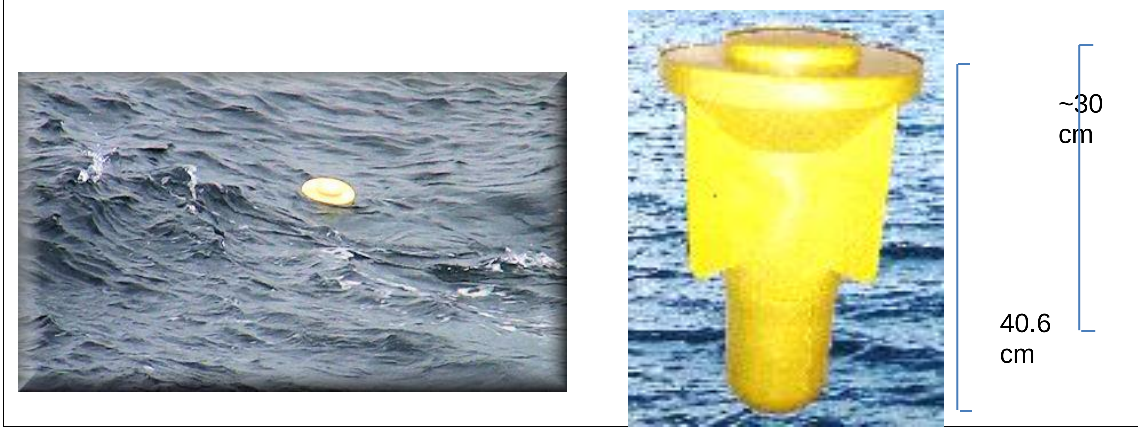


Figure 18 (left) Photograph of a deployed Pathfinder drifter buoy out at sea; and (right) the dimensions.

During the July 2014 field survey, the drifters provided positional updates for deployment periods ranging between 5–93 days. Whilst updates of the drifter positions during the January 2015 and April 2015 field surveys were provided during deployment periods ranging between 3–92 days and 6–51 days, respectively.

There was a clear distinction in directionality of the Pathfinder drifter buoys according to the seasonal metocean conditions. For example, all 12 drifters deployed under the winter conditions (July 2014) and transitional conditions (April 2015) drifted west from the release location. The six drifters deployed under summer metocean conditions (January 2015) drifted east from the release location.

2.3.1 Model comparisons and validation

Sixteen measured drifter tracks were selected from the field surveys to verify the ability of the hydrocarbon spill model to recreate their movements field surveys; five tracks during July - August (winter conditions), five tracks for January (summer conditions) and six during April (transitional conditions). The duration of the drifter tracks ranged from 6 days to 55 days and over distances between 32 km to 986 km. The measured drifter tracks were selected on the basis that they represented varying seasonal drift directions and starting positions, to principally show the accuracy of the model along sections of the track at any given time after the initial deployment. For the purposes of this report, only 6 of the drifter track comparisons are shown herein, two per season (see Table 8).

The modelled wind data and current data described in the sections above were used as input into the hydrocarbon spill software to recreate the modelled tracks. The model also included allowances for sub-grid scale turbulence and diffusion, specified as a horizontal diffusion coefficient value of 5 m^2/s.

Figure 19 to Figure 24 show the comparison plots of the six measured and predicted drifter tracks. Figure 19 and Figure 20 shows that the measured drifter tracks headed principally west under winter conditions (July to September 2014 deployments) and that the model predictions also drifted west. The drifter tracks during winter conditions were compared with the model predictions over durations ranging between 20 to 25 days and over vast distances ranging from 452 km to 636 km.

Figure 21 and Figure 22 shows that under summer conditions (January to March 2015 deployments) the measured drifters travelled either east or northeast from the comparison start point. The model also demonstrated the capability of accurately recreating the movement of the drifter buoys. The distances associated with the drifter track model comparisons ranged between 971 km and 986 km over 55 days.

During the transitional months (April to May 2015) the model was shown capable of correctly predicting the drifter movements which were mostly west (Figure 23 and Figure 24). However, on a number of occasions in the transitional months the drifters remained near the around the release location and in turn did not travel as far (31 km to 147 km) when compared to the winter and summer tracks.

Overall, the tracks demonstrated a good agreement between the measured and predicted drifts both in terms of distances and directions. Therefore, the results provide confidence in the hydrocarbon spill model to replicate spills in any direction based on the wind and current data used, even up to a travelled distance of 985 km.

Table 8 Drifter buoy identification number (ID), comparison duration and distance travelled buoy used as part of the drifter track model comparisons during winter, summer and transitional deployments.

Duration and distances used as part of the drifter track model comparisons								
Winter			Summer			Transitional		
Buoy ID	Duration (days)	Distance (km)	Buoy ID	Duration (days)	Distance (km)	Buoy ID	Duration (days)	Distance (km)
7579	25	452	7599	55	986	7578	20	32
7588	20	636	7601	55	971	7584	6	117

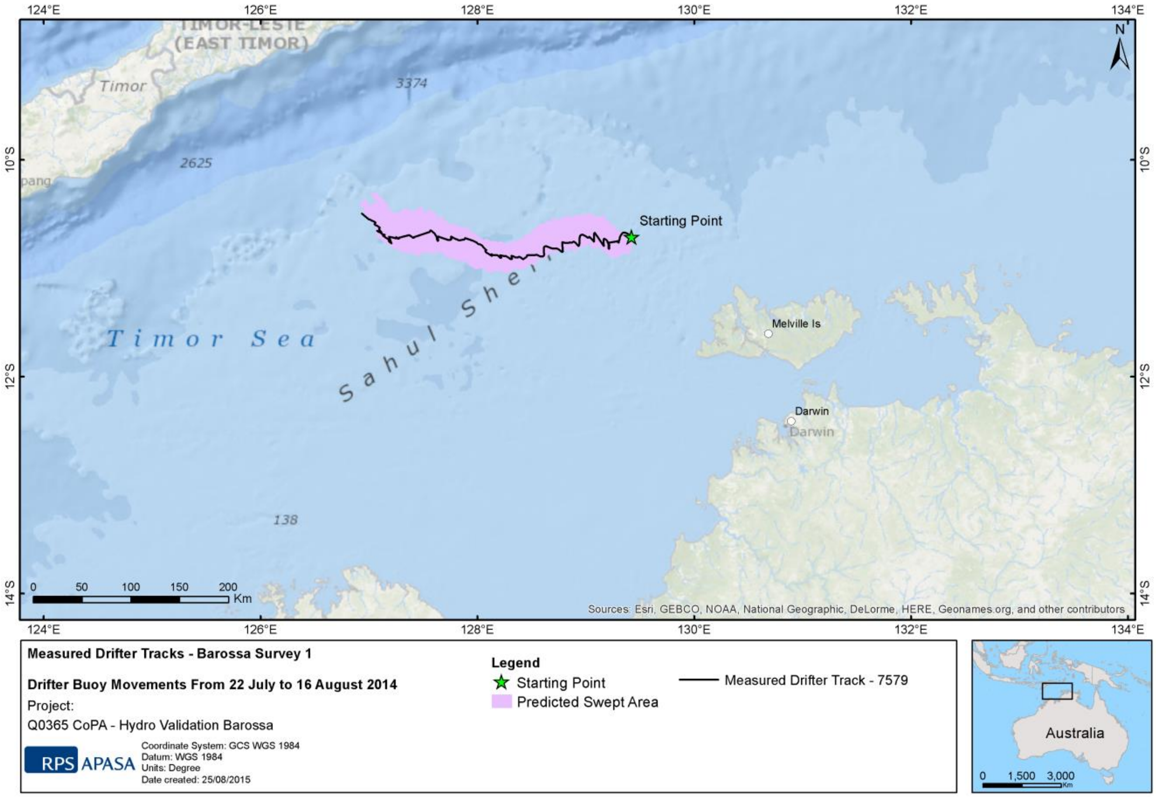


Figure 19 Comparison between the measured and predicted drifter track (buoy 7579) over a 25-day period between 22nd July and 16th August 2014 (winter conditions).

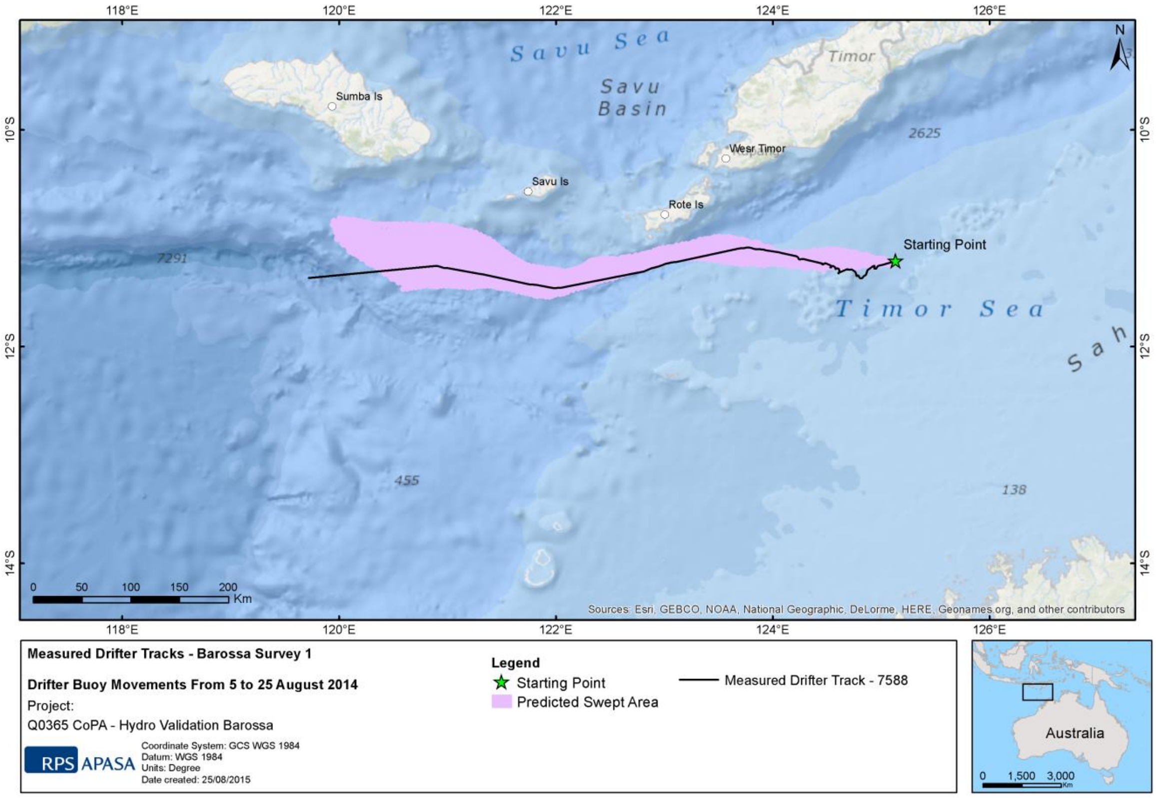


Figure 20 Comparison between the measured and predicted drifter track (buoy 7588) for a 20-day period in August 2014 (winter conditions)

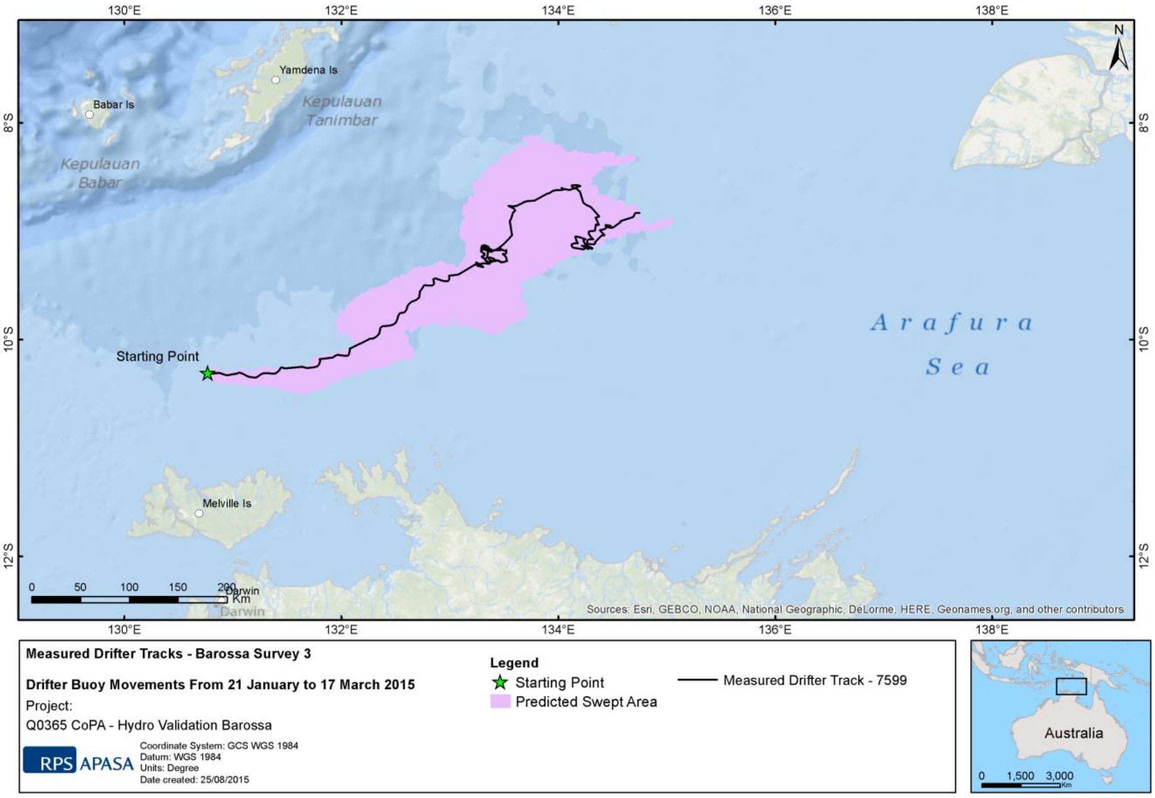


Figure 21 Comparison between the measured and predicted drifter track (buoy 7599) for a 55-day period between January and March 2015 (summer conditions)

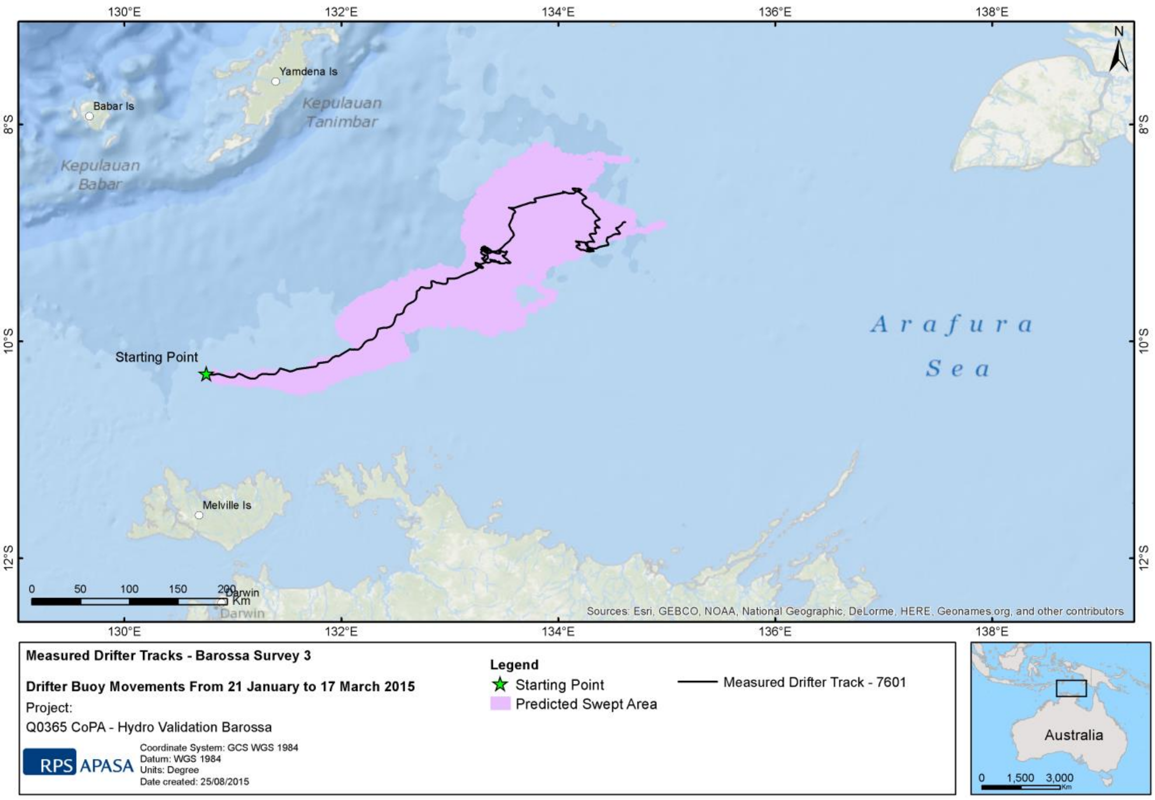


Figure 22 Comparison between the measured and predicted drifter track (buoy 7601) for a 55-day period between 21st January and 17th March 2015 (summer conditions)

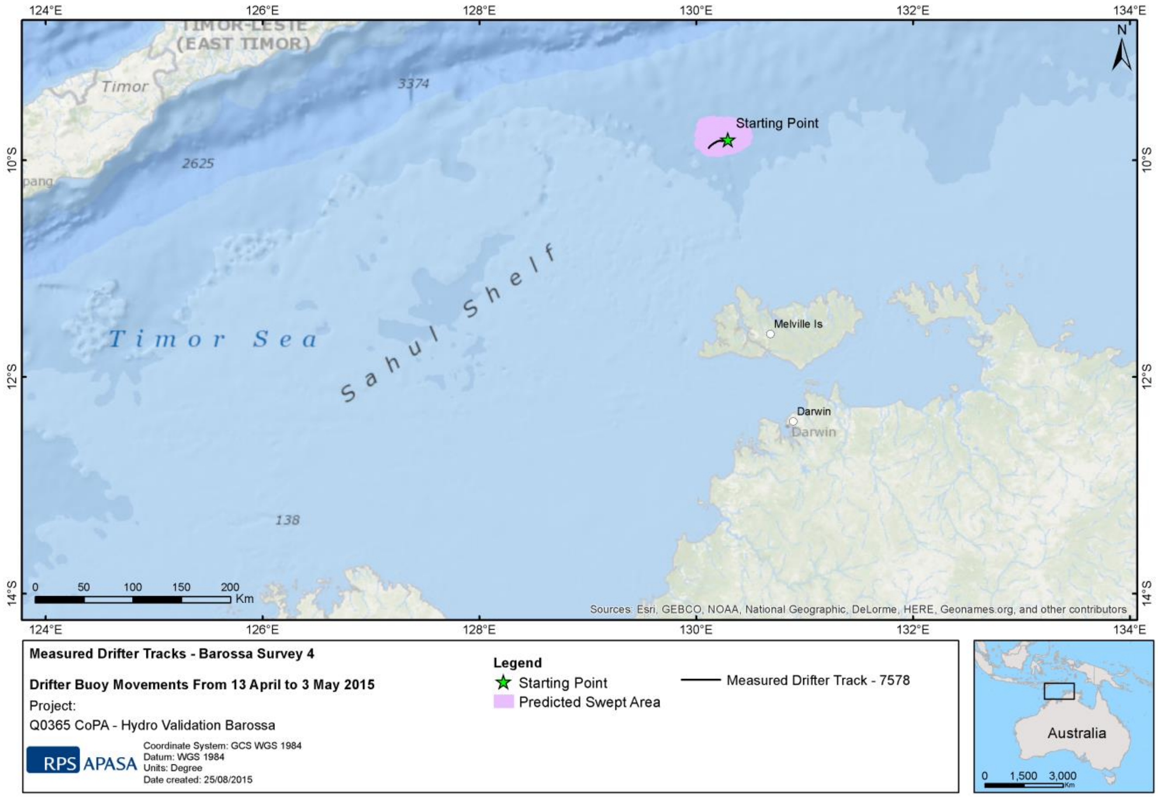


Figure 23 Comparison between the measured and predicted drifter track for a 20-day period between April and May 2015 (transitional conditions)

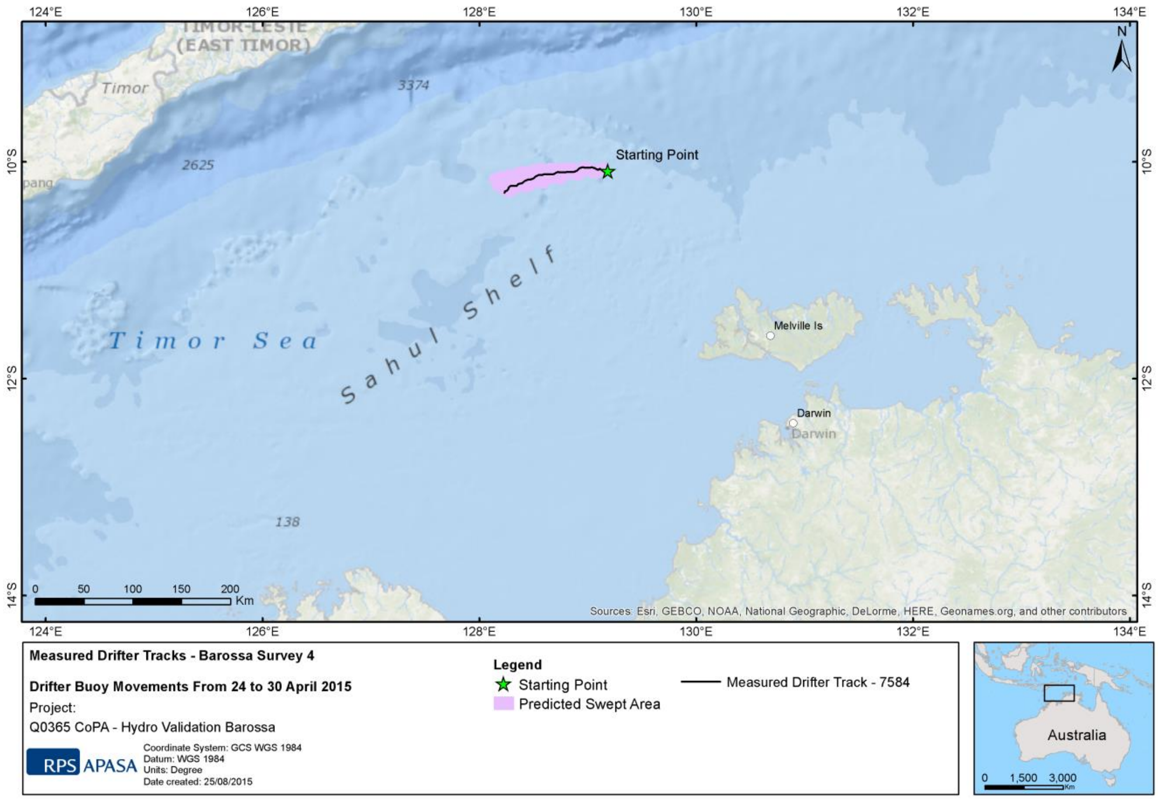


Figure 24 Comparison between the measured and predicted drifter track (buoy 7584) for a 6-day period between 24th April and 30th April 2015 (transitional conditions)

2.4 Ocean temperature and salinity

To accurately represent the water column temperature and salinity within the region, the monthly temperature and salinity for 25 depth layers was obtained from the World Ocean Atlas 2013 database produced by the National Oceanographic Data Centre (National Oceanic and Atmospheric Administration) and its co-located World Data Center for Oceanography (Levitus et al. 2013).

The World Ocean Atlas 2013 is a set of objectively analysed (1° grid) fields of in situ parameters (e.g. temperature, salinity and dissolved oxygen) at standard depth levels for annual, seasonal, and monthly periods for the global oceans. The dataset represents the largest collection of restriction-free ocean profile data available internationally. Locarnini et al. (2013) and Zweng et al. (2013) provide discussion regarding the temperature and salinity data as part of the World Ocean Atlas 2013 database.

Table 9 show the monthly mean sea surface temperature and salinity values derived from the World Ocean Atlas 2013 database.

The water temperature and salinity values from the World Ocean Atlas 2013 database compared well to collected data by Fugro as part of the Barossa marine studies program (Fugro 2015).

Table 9 Seasonal sea surface temperature and salinity per month at the Barossa offshore development area

Season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (˚C)	29.5	28.5	28.8	29.4	28.8	27.1	26.8	26.9	27.1	28.1	29.7	30.4
Salinity (ppt)	34.4	34.3	34.1	34.1	34.1	34.1	33.6	33.5	34.4	34.4	34.5	34.6

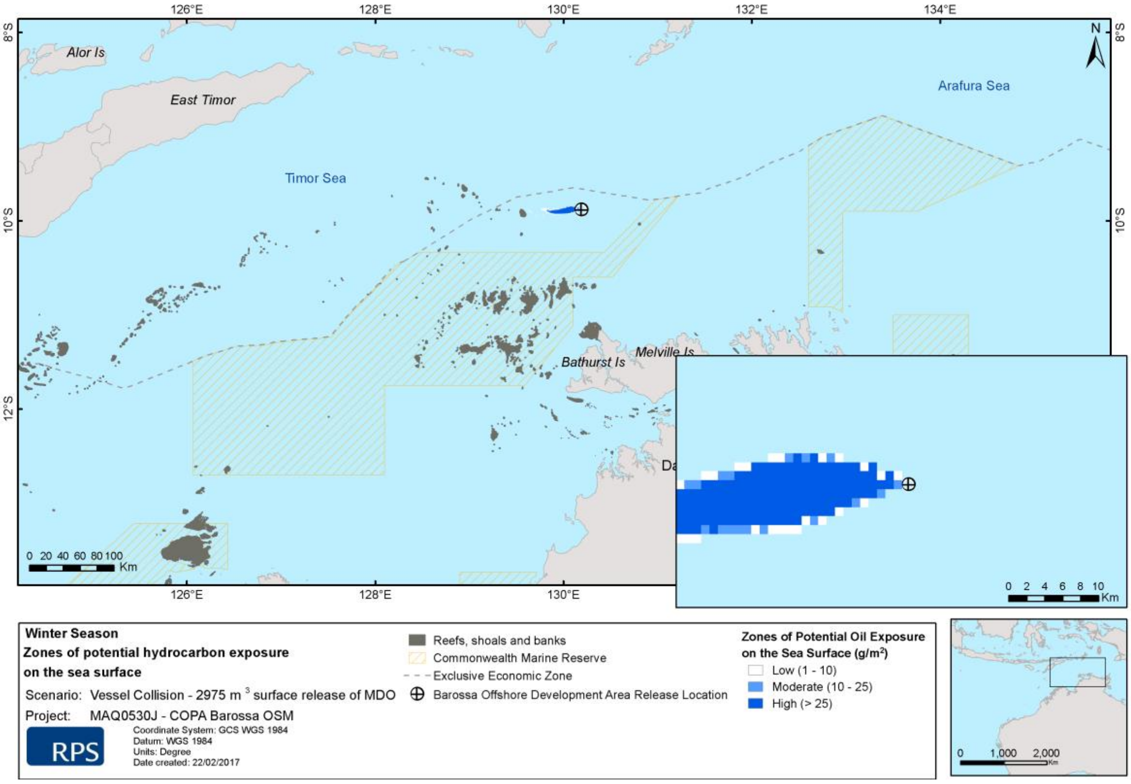
2.5 Stochastic modelling

As hydrocarbon spills can occur during any set of wind and current conditions, a stochastic modelling process was applied to all scenarios. This involved SIMAP being applied to repeatedly simulate the defined spill scenarios using the same spill information (e.g. release location, spill volume, duration and hydrocarbon type) but with varied start dates and times. This ensured that each spill was exposed to different wind and current conditions. A hundred single spill trajectories were simulated per season per scenario. During each simulation, the model records the grid cells exposed by the spill trajectory, as well as the time elapsed.

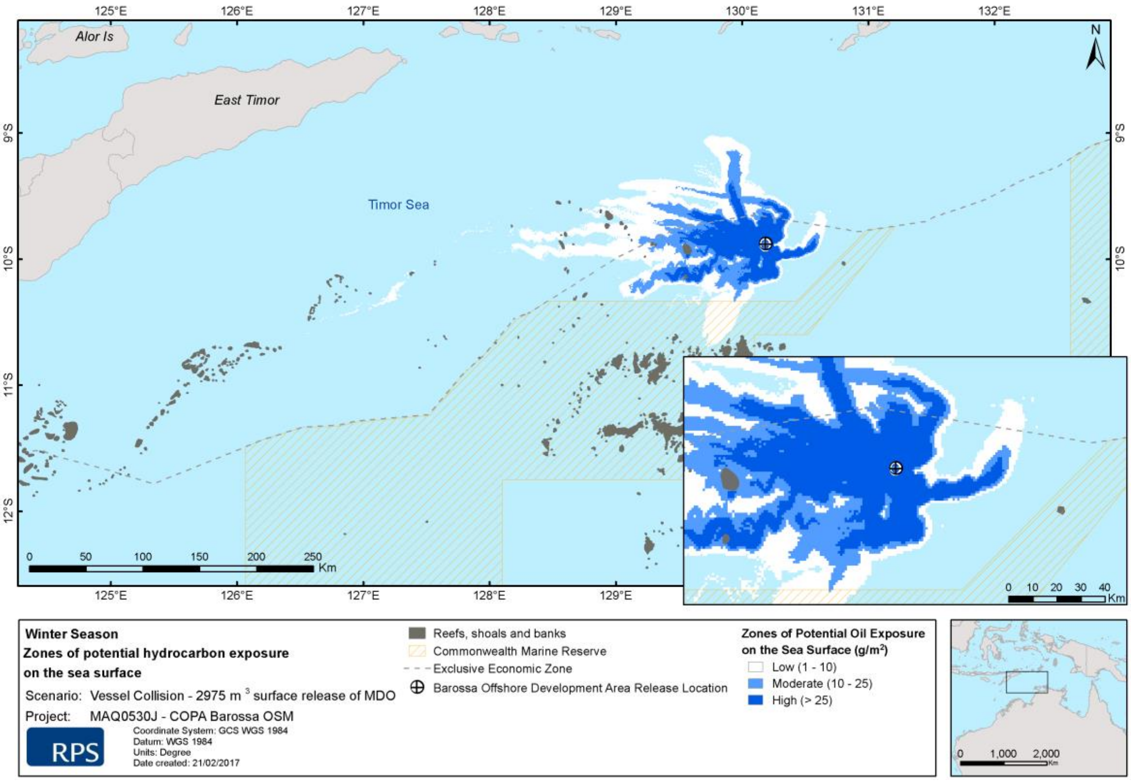
Results of the repeated simulations were then statistically analysed and mapped to define contours around the release location. The stochastic model output provides a summary, based on the collective assessment of the behaviour of all 100 individual trajectories, for each scenario and each season. This equates to 1,800 spill trajectories for the entire assessment (i.e. all scenarios and seasons).

It is important to note that in interpreting the stochastic modelling, the results are calculated independently for each grid cell from many simulations (i.e. 100 single spill trajectories per season). Therefore, the stochastic modelling plots do not show the extent of exposure that would be expected from any single release; rather the likelihood or probability of exposure to a grid cell above a specified threshold. For example, a cell with a probability of 25%, indicates that of the 100 individual spill trajectories, 25 passed over that particular model grid cell equal to or greater than the specific threshold.

As the stochastic model provides a summary of all trajectories run for each scenario and each season, the potential extent and duration of exposure from an individual spill would be significantly smaller, shorter and unlikely to extend simultaneously over vast areas (with the exception of a long-term well blowout). An example of the difference in results between a single spill trajectory (i.e. deterministic modelling) and stochastic modelling outputs for the same scenario (2,975 m^3 surface release of marine diesel over six hours during winter conditions; Scenario 2) is shown in Figure 25.



a) Deterministic modelling outputs – potential areas of sea-surface exposure (at varying thresholds) from a single spill trajectory



b) Stochastic modelling outputs – potential areas of sea-surface exposure (at varying thresholds) calculated from 100 spill trajectories

Figure 25 Comparison of deterministic and stochastic spill modelling results

2.6 Hydrocarbon properties

Four different hydrocarbons were used as part of the modelling study; MDO, Barossa condensate, HFO and IFO-180. The different hydrocarbons have varying physical and chemical properties which determine the way it will behave in the marine environment.

Table 10 and Table 11 show the physical characteristics and boiling point ranges for each hydrocarbon, respectively. The classification of hydrocarbon property category and hydrocarbon persistence classification were derived from Australian Maritime Safety Authority (AMSA 2012) guidelines. The classification is based on a hydrocarbons specific gravity in combination with relevant boiling point ranges.

Table 10 Physical properties for the hydrocarbons modelled

Properties	MDO	Barossa condensate	HFO	IFO-180
Density (kg/m^3)	829 (at 25 ºC)	796.6	974.9 (@ 25°C)	947.0 (at 5°C)
API	37.6	51.6	12.3	17.9
Dynamic viscosity (cP)	4 (at 25 ºC)	0.766 (at 25°C)	3,180 (@ 25°C)	2,324 (at 15°C)
Pour point (ºC)	-14	-40	7	24
Hydrocarbon property category	Group III	Group I	Group IV	Group IV
Hydrocarbon property classification	Persistent (medium)	Non-persistent	Persistent (heavy)	Persistent (heavy)

Table 11 Boiling point ranges for the hydrocarbons modelled

Characteristic/ Hydrocarbon type	Volatiles (%)	Semi-volatiles (%)	Low volatiles (%)	Residual (%)
Boiling point (°C)	<180	180–265	265–380	>380
	Non-persistent			Persistent
MDO	6	35	54	5
Barossa condensate	57	22	14	7
HFO	1.0	4.9	11.3	82.8
IFO-180	1.0	14.4	20.8	63.8

MDO

MDO is a mixture of volatile and persistent hydrocarbons with low viscosity. When released to the marine environment it will spread quickly and thin out to low thickness levels, thereby increasing the rate of evaporation. Due to its chemical composition, up to 60% will generally evaporate over the first two days depending upon the prevailing conditions and spill volume. Approximately 5% is considered “persistent hydrocarbons”, which are unlikely to evaporate and will decay over time.

The MDO also has a strong tendency to entrain into the upper water column (0 m–20 m) (and consequently reduce evaporative loss) in the presence of moderate winds (> 10 knots) and breaking waves. However, diesel re-surfaces when the conditions calm.

Figure 26 illustrates the predicted weathering and fates of a 10 m^3 surface release of MDO (Scenario 1) under three constant wind speeds (5, 10 and 15 knots). Figure 27 illustrates the predicted fates and weathering graph of a 2,975 m^3 surface release of MDO (Scenario 2) under the same three constant wind speeds.

For each spill volume (Scenarios 1 and 2), the fates and weathering graphs showed the MDO displayed similar behaviour. The MDO has a strong tendency to entrain into the upper water column (typically the top 0 m–20 m layer) in the presence of winds above 10 knots. Once the MDO enters the water column (i.e. penetrates the sub-surface) it can remain there for long periods of time under persistent winds, which in turn delays evaporation.

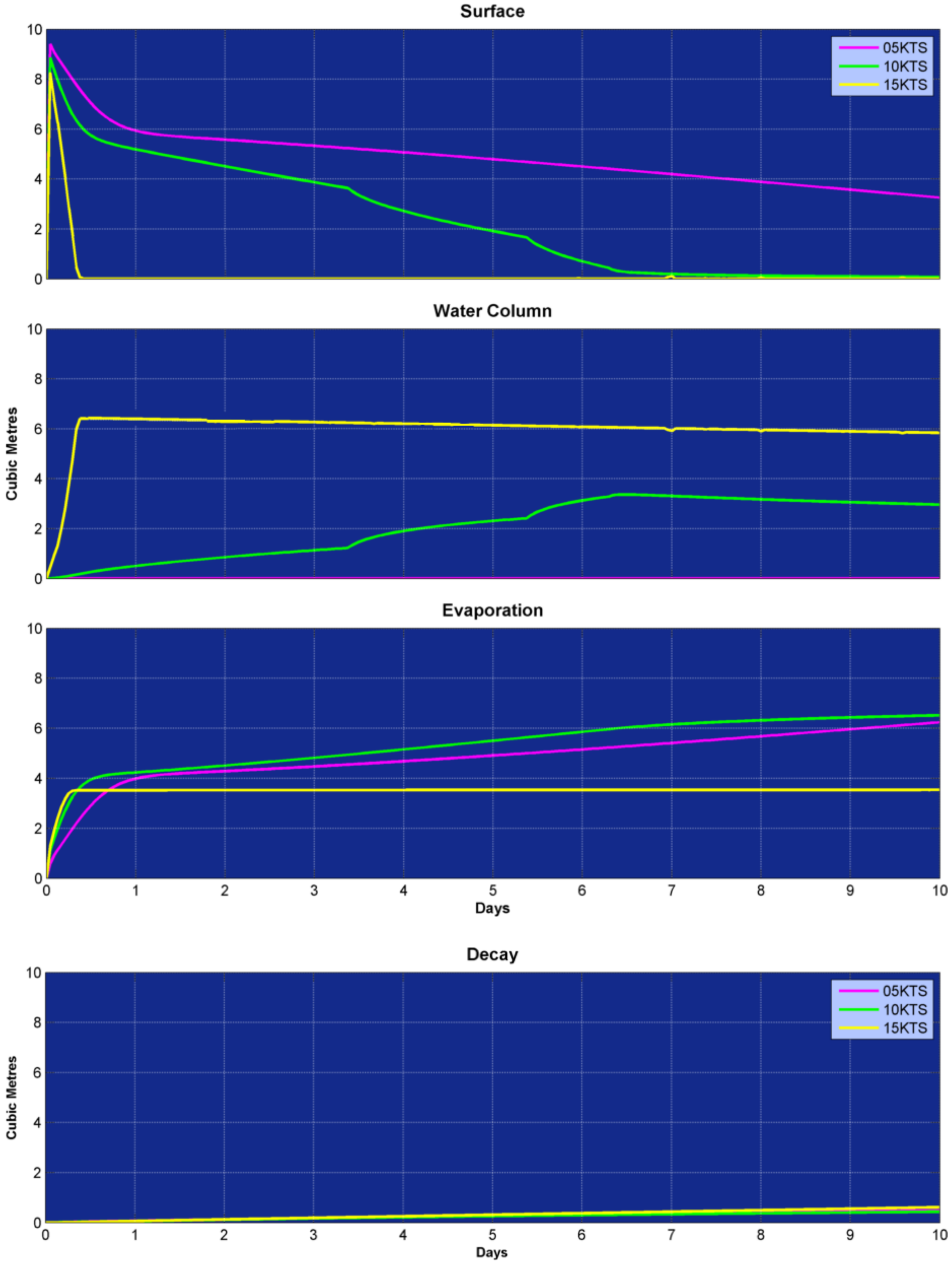


Figure 26 Weathering and fates graph, as a function of volume, for an instantaneous 10 m³ surface release of MDO tracked over 10 days, under 5, 10 and 15 knots constant wind speeds.

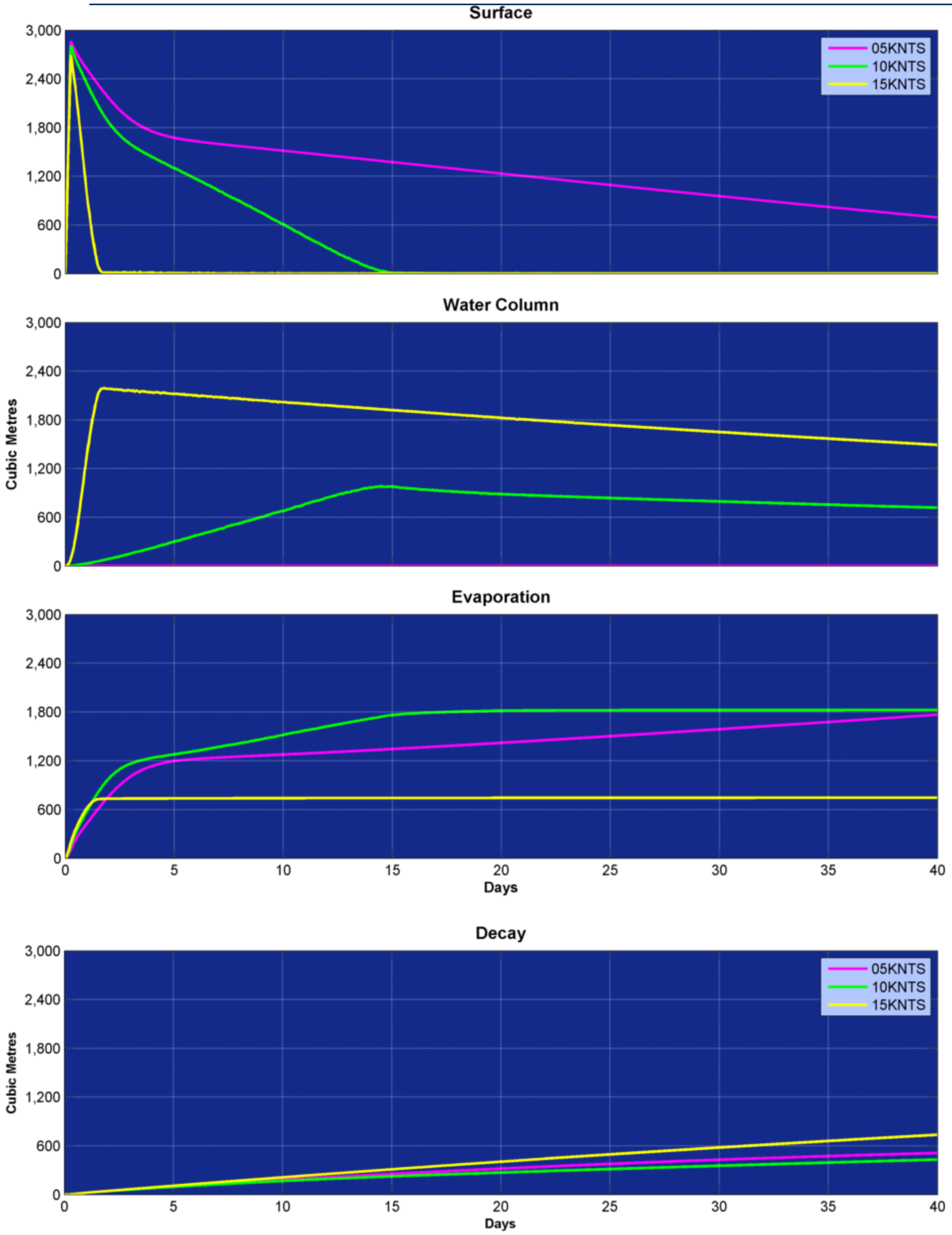


Figure 27 Weathering and fates graph, as a function of volume, for a 2,975 m^3 surface release of MDO over 6 hours tracked over 40 days, under 5, 10 and 15 knots constant wind speeds.

Barossa condensate

The physical-chemical properties of Barossa condensate were based on an assay obtained during the 2013/2014 Barossa appraisal drilling campaign. The assay is considered to be representative of the reservoir characteristics of the Barossa field (i.e. unprocessed, 'volatile enriched' condensate) and the composition used to determine the weathering characteristics of the Barossa condensate.

The condensate is characterised by a low viscosity and is considered a Group I oil (non-persistent), as per the grouping classification presented by AMSA (2015). If spilt on the sea surface, the condensate would rapidly spread and thin out resulting in a large surface area of hydrocarbon available for evaporation. The volatile component of Group I oils (non-persistent) tend to dissipate through evaporation within a few hours (ITOPF 2015). Based upon the Barossa condensate assay (boiling point range, Table 11), up to 57% of the hydrocarbon would evaporate over the first few hours or day, with up to 79% evaporated after a few days when on the sea surface. Only 7% of the condensate is considered persistent, which would eventually breakdown due to the decay. Barossa condensate released to the sea surface may also become entrained into the water column in the presence of moderate winds (above 10 knots) and in turn breaking waves, however, it would re-surface under calm conditions (less than 10 knots).

Figure 28 displays the predicted weathering and fates of the 19,400 m^3 surface release of Barossa condensate, under three constant wind speeds. When released on the surface, the condensate is observed to entrain under wind speeds greater than 10 knots. Condensate on the sea surface is shown to evaporate quicker during winds of 10 knots or less and is not expected to persist on the sea surface for extended amounts of time.

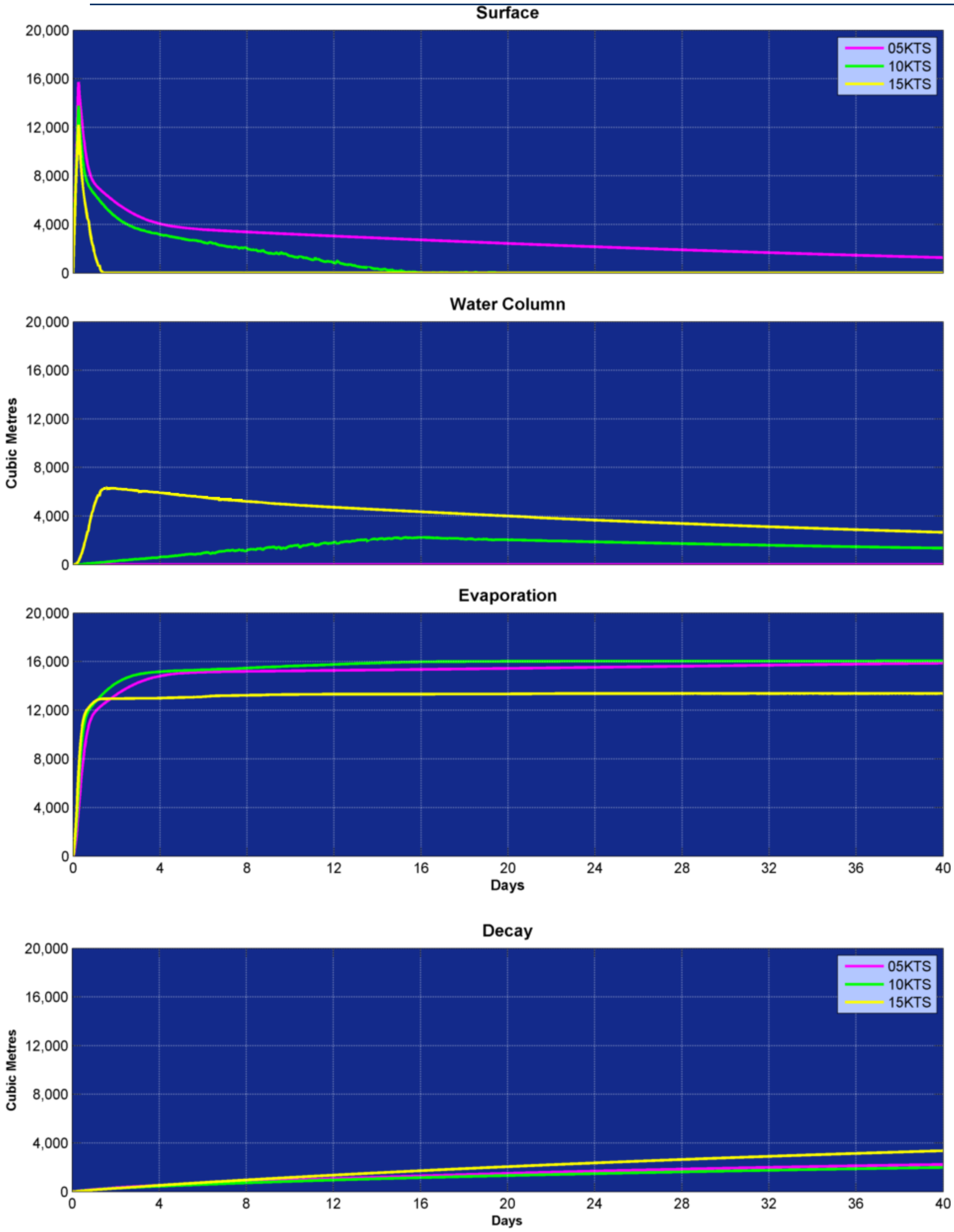


Figure 28 Weathering and fates graph, as a function of volume, for a 19,400 m^3 surface release of Barossa condensate over 6 hours tracked over 40 days, under 5, 10 and 15 knots constant wind speeds.

During a well blowout, the gas and condensate is typically released at the seabed into the water column as a hot plume under high pressure. It will initially behave like a jet, which dissipates in the water column over a short distance (<5 m). Following this phase, the buoyancy of the gas and condensate mixture relative to the surrounding waters controls the plume rise until it penetrates the surface waters or loses its momentum. At this point, the far-field model SIMAP is used to simulate the rise of the individual condensate droplets due to their own buoyant nature.

Modelling for the well blowout scenario (scenario 4) showed that the condensate would be expected to separate into droplets of variable sizes between 18.4 µm and 92.1 µm. The minimum time for the condensate droplets to reach the surface at concentrations above the minimum sea surface threshold (1 g/m^2) was approximately one-hour post release. However, due to varying wind and current conditions, smaller condensate droplets can remain in the water column for days or weeks before reaching the sea surface. Therefore, evaporation rates would initially be expected to be rapid during the early phase of the release scenario, where larger droplets surface, and then decline over time.

On release from the seabed, the plume is predicted to rise through the water column (average velocity of approximately 3 m per second) and rupture at the sea surface (Table 12). Therefore, the concentration of entrained hydrocarbons is predicted to be greatest in the surface layer and lowest at the seabed. The maximum core diameter of the plume was predicted to be approximately 31 m.

Table 12 Predicted near-field plume dynamics for Scenario 4 (long-term well blow out)

Variable	Scenario 4 - Well Blowout
Average plume rise velocity (m/s)	3.0
Maximum plume rise velocity (m/s)	5.7
Plume rise time in seconds (until plume collapse)	81
Maximum plume core diameter (m)	31
Plume trapping depth below the sea surface (m)	Surface

Figure 29 illustrates predicted weathering and fates of the 210 m^3 subsea release of Barossa condensate, under three constant wind speeds. The graph shows that as wind speed increased, a larger volume of hydrocarbon remained entrained in the water column, and consequently less evaporation occurred. Wind speed was observed to have a minimal effect on the volume of condensate floating on the sea surface because the condensate rapidly evaporates when exposed to the atmosphere.

On weathering, the Barossa condensate would undergo a series of changes to appearance, colour and phase state. Within 24 hours of release, the remaining condensate would be expected to be almost semi-solid at average sea surface temperature. As weathering continues, the weathered residues of the Barossa condensate would be mostly in the form of paraffins, which would remain afloat as the hydrocarbon spreads out and thins. As the residues become solid, they would form thin, clear sheets with patches of white crystalline ‘pancakes’ which would then begin to break up into small, white waxy flakes due to the action of the waves and wind over time.

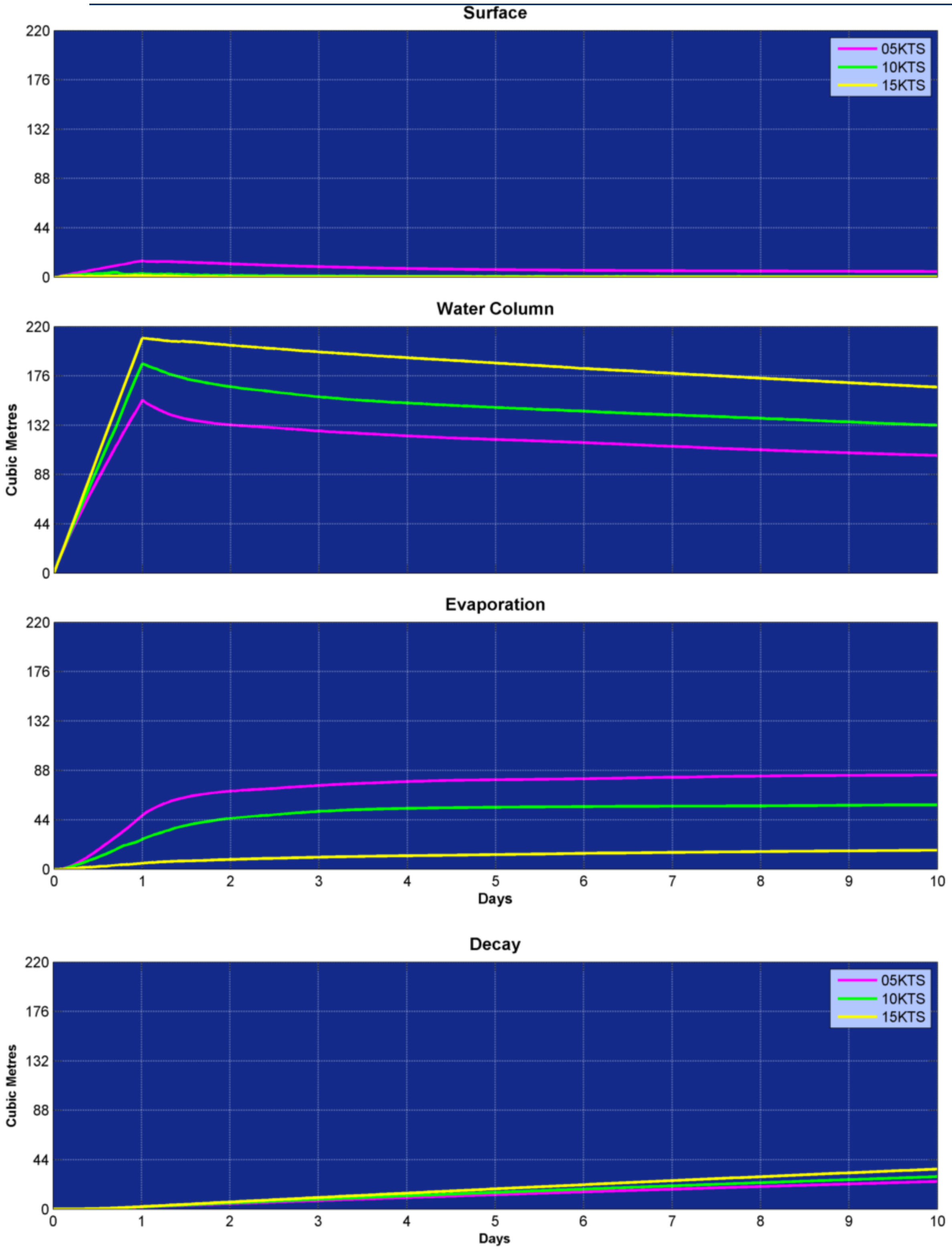


Figure 29 Weathering and fates graph, as a function of volume, for a 210 m^3 subsea release of Barossa condensate over 24 hours tracked over 10 days, under 5, 10 and 15 knots constant wind speeds.

Hydrocarbons that cause most of the "aquatic toxicity" are generally the smaller aromatic and soluble components of hydrocarbon (one ring and two ring aromatics) or the polyaromatic hydrocarbons (PAHs). The low volatility fraction of the Barossa condensate contains very low levels of aromatics in the three ring and above PAHs according to the assay. Therefore, the weathered residues of the condensate are not considered to present an ecotoxological threat in the water column.

A comparative analysis of the physical characteristics and boiling point ranges of the Barossa and Caldita condensates were undertaken to assess if the properties, and therefore modelling results, were comparable. The analysis of the two condensates is presented in Table 13 and Table 14 shows that the key physical-chemical properties are very similar and, consequently, the behaviour, fate, weathering and toxicity of the condensates are highly comparable. As part of the analysis, the results of the Jacobs (2017) Barossa condensate ecotoxicity assessment were reviewed to assess the comparability of the potential toxicity impacts from unweathered and weathered Barossa or Caldita condensate. Given the similarity of the condensates, especially the benzene, toluene, ethylbenzene, and xylene (BTEX) compounds which are known to contribute to toxicity (Barossa condensate – approximately 6.9% weight and Caldita condensate – approximately 5.3% weight), the review concluded that the Barossa ecotoxicity study is representative of Caldita condensate. Therefore, the modelling results for the Barossa condensate scenarios are considered to be representative of potential modelling scenarios involving Caldita condensate.

Table 13 Physical properties for Barossa and Caldita condensates

Properties	Barossa condensate	Caldita condensate
Density (kg/m^3)	796.6	754.2
API	51.6	48-50.5
Dynamic viscosity (cP)	0.766 (at 25°C)	-
Pour point (ºC)	-40	-
Hydrocarbon property category	Group I	Group 1
Hydrocarbon property classification	Non-persistent	Non-persistent

Table 14 Boiling point ranges for Barossa and Caldita condensates

Characteristic/ Hydrocarbon type	Volatiles (%)	Semi-volatiles (%)	Low volatiles (%)	Residual (%)
Boiling point (°C)	<180	180–265	265–380	>380
	Non-persistent			Persistent
Barossa condensate	57	22	14	7
Caldita condensate	45	30	13	12

HFO

HFO is characterised by a very high density at 974.9 (API Gravity of 12.3) and a high dynamic viscosity (3,180 cP (@ 25ºC). It is comprised of a high percentage of persistent components (82.8%), which will not evaporate. When spilt at sea the HFO will initially remain as a liquid as sea surface temperatures are above its pour point during all seasons. The volatile components (1%) are immediately lost via evaporation and the physical properties will change quickly as the lighter more fluid components evaporate and disperse by the action of wind and waves. The residual component (approximately 83%) is expected to become semi-solid to solid at ambient temperatures and is susceptible to decay overtime. Previous weathering tests with HFO used as bunker fuels have shown that both the pour point and the viscosity of the oil increased with time (by an average of two orders of magnitude within 96 hours of weathering). Once the pour point of oil exceeded the seawater temperature (within 9-12 hours during all seasons) the oil weathered to a point where mostly solid non-spreading oil remained (up to 70% of bunker fuel remained as a solid residue even after the most extreme weathering tests).

Laboratory tests with Bunker C Crude oil (Fingas et al. 2002, Fingas and Fieldhouse 2004) which has similar physical properties to the HFO modelled in this study have shown that HFO does not form stable emulsions. Rather, when HFO is spilt at sea it takes up water very rapidly over a short energy range and the stability of the water-oil mixture remains the same in that it does not stabilise with increasing energy. This behaviour is consistent with entrained water in oil, where spilt oil will first appear as a black viscous liquid with large water droplets and within one week will become separated into oil and water as water energies abate.

The toxic potential of weathered HFO is low in comparison to other crudes, MDO and condensates as weathered oil is insoluble and the bioavailable portion of the oil is soon lost through evaporation. Solid residues can persist in the marine environment for extended periods and its longevity is dependent on its unique physio-chemical properties. The heaviest fractions (>C20) often break into discrete patches and may float or sink depending on density relationships and become incorporated into soils or sediments (American Petroleum Institute 2012). Selective biodegradation can also deplete hydrocarbons on sediments and on the sea surface overtime (Lee et al. 2003). Direct consumption of the residual tar patties or contaminated sediment poses the greatest risk to macrofauna and would present a greater threat for shallow coastal embayments with concentrated populations and coastal vegetation.

Figure 30 illustrates predicted weathering and fates of the surface release of HFO, under three constant wind speeds. As the graph demonstrates, the wind speed has very little influence on the weathering of the HFO and decay is the major source of removal of hydrocarbon from the sea surface.

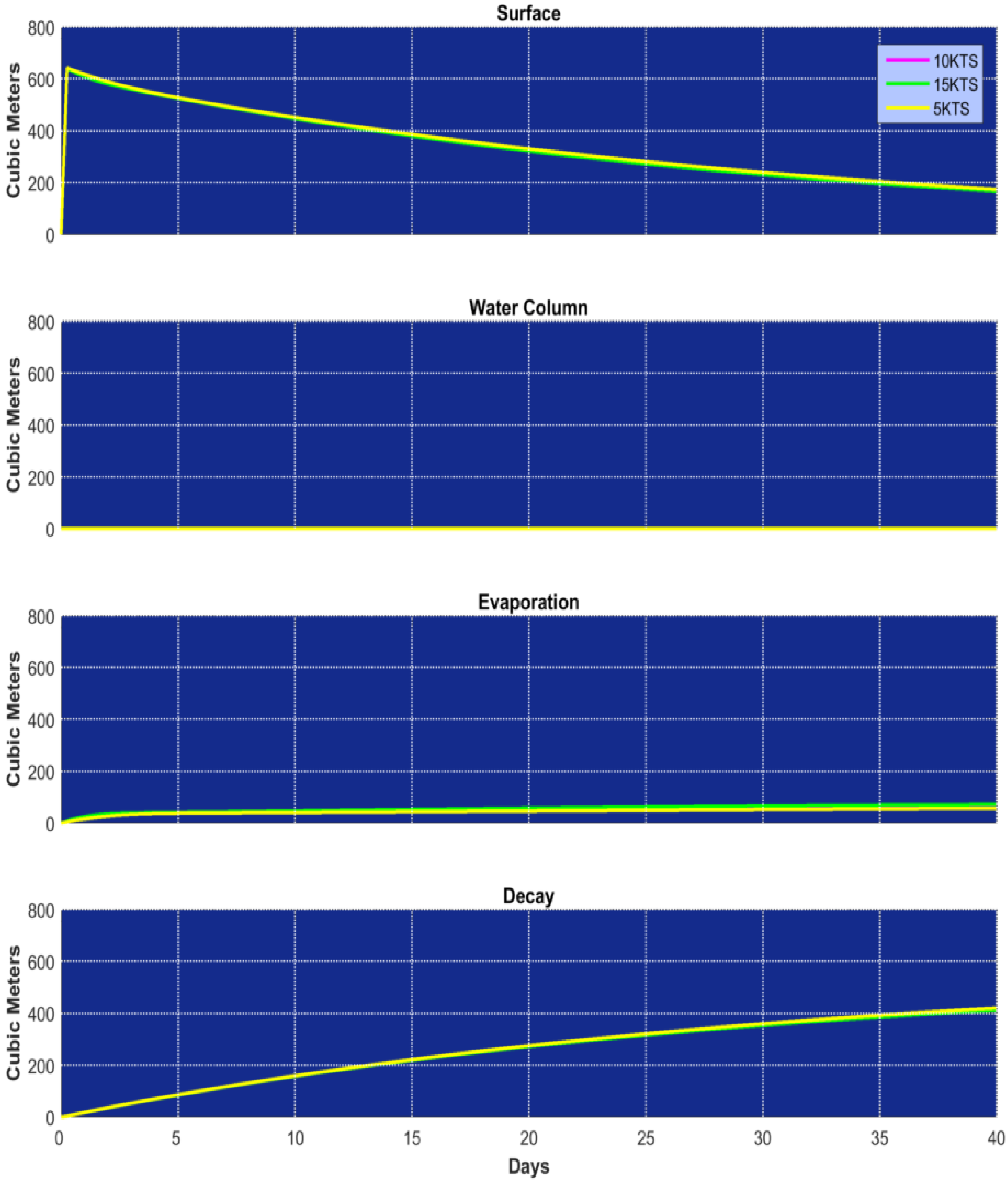


Figure 30 Weathering and fates graph, as a function of volume, for a 650 m^3 surface release of HFO over 6 hours tracked over 40 days, under 5, 10 and 15 knots constant wind speeds.

IFO-180

The IFO-180 has a high density (947 kg/m^3 and API of 17.9) and a high viscosity (2,324 cP). It consists mainly of low volatile (20.8%) and persistent hydrocarbons (63.8%). If released to the marine environment the light volatiles (1%) are rapidly lost via evaporation while the residual component (approximately 64%) is expected to become semi-solid to solid at ambient temperatures. IFO-180 does not tend to entrain in the upper water column based on the hydrocarbon characteristics.

IFO can form stable or meso-stable water-in-oil emulsions in which seawater droplets become suspended into the oil matrix (Fingas and Fieldhouse 2004). This process requires physical mixing (i.e. wave action) with the stability of the emulsion influenced by the properties of the hydrocarbon product, including viscosities and asphaltene and resin content. Stable emulsions generally have an average water content of approximately 80% after 24 hours and have been shown to remain stable for up to four weeks under laboratory and test tank conditions (Fingas and Fieldhouse 2004). Meso-stable water-in-oil emulsions have an average water content of around 70% after 24 hours which decreases to approximately 30% after one week (Fingas and Fieldhouse 2004). Meso-stable emulsions generally become unstable within three days, as shown under laboratory conditions. Emulsification of IFO-180 will affect the spreading and weathering of the oil and increase the volume of oily material. If not within an emulsion state, the decay of IFO-180 is more rapid in comparison to condensates and marine diesel as microbial decay is generally faster for hydrocarbons with higher viscosity.

The toxic potential of IFO-180 is largely dependent on the properties it has been blended with but generally contains <10% distillate with the remaining 90% composed of HFOs. The volatile and soluble components include those that are responsible for producing most of the aquatic toxicity due to its bioavailability to marine organisms. Thus Barossa condensate and MDO are considered to have a higher aquatic toxicity potential in comparison to IFO-180. However non-persistent components are short-lived and susceptible to evaporation and degradation. The weathered portion of IFO would behave similar to HFO. The residual components would eventually become insoluble in seawater and end up adhered to sediment or biota reducing the risk of acute toxicity.

Figure 31 illustrates predicted weathering and fates of the IFO-180, under three constant wind speeds. Under all three wind speeds tested, the evaporative loss was very similar. The graph demonstrates the highly persistent and viscous nature of the oil, with entrainment only occurring during 15 knot wind conditions. Decay of IFO-180 is more rapid in comparison to condensates and MDO as microbial decay is generally faster for hydrocarbons with higher viscosity.

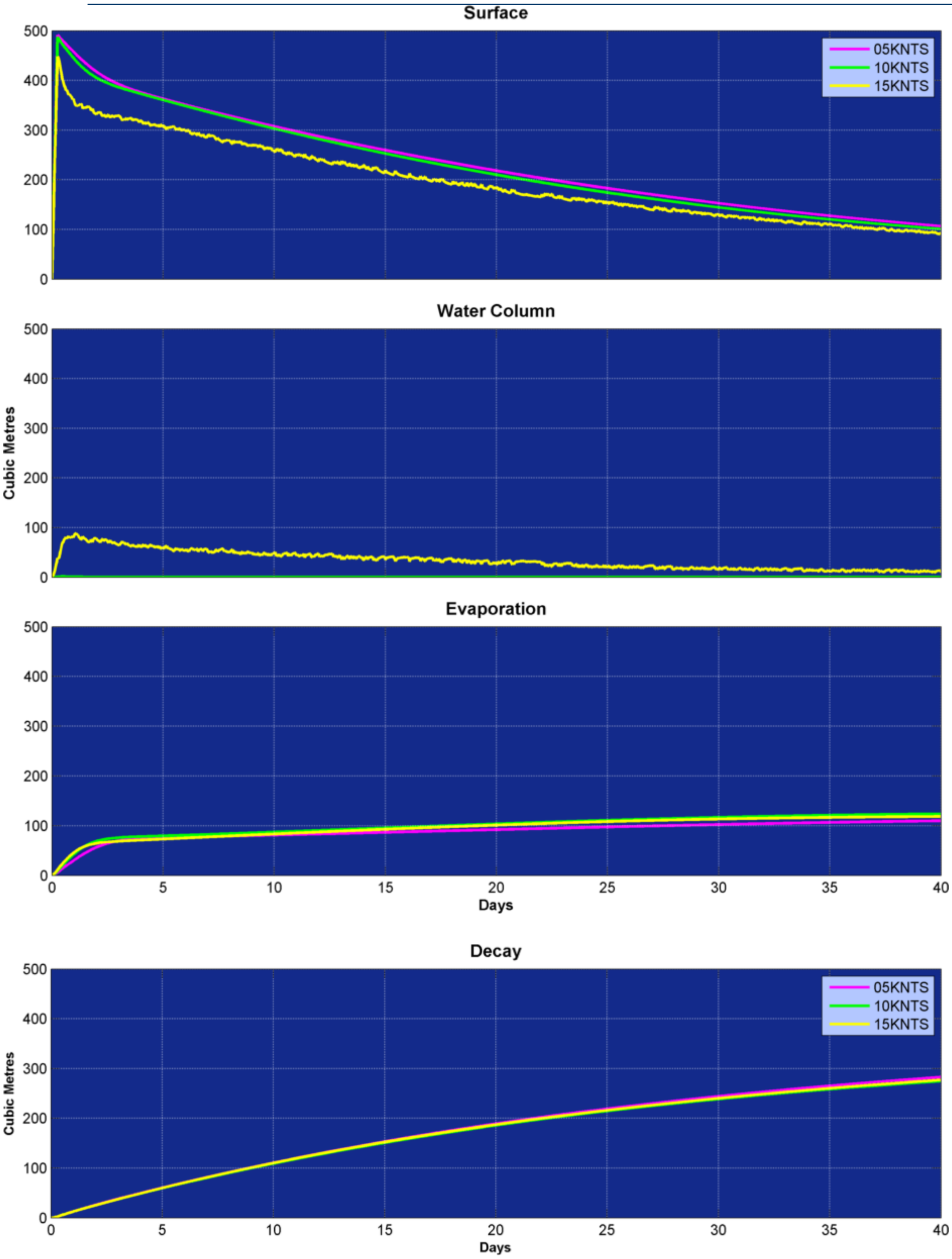


Figure 31 Weathering and fates graph, as a function of volume, for a 500 m^3 surface release of IFO-180 tracked over 40 days, under 5, 10 and 15 knots constant wind speeds.

2.7 Model settings and assumptions

Table 15 provides a summary of the hydrocarbon spill model settings and assumptions. The simulation lengths were carefully selected for each scenario based on extensive sensitivity testing. During the sensitivity testing process, sample spill trajectories are run for longer than intended durations for each scenario. Upon completion of the spill trajectories, the results are carefully assessed to examine the persistence of the hydrocarbon (i.e. whether the maximum evaporative loss has been achieved for the period of time modelled; and whether a substantial volume of hydrocarbons remain in the water column (if any)) in conjunction with the extent of sea surface exposure based on reporting thresholds. The persistence of the hydrocarbons on the sea surface and entrained within the water column is based on several factors including the nature of release (duration, volume and type (subsea or surface)), residual properties of the hydrocarbon type and weathering. Once there is agreement between the two factors (i.e. the final fate of hydrocarbon is accounted for and the full exposure area is identified) the simulation length is deemed appropriate.

Table 15 Summary of the hydrocarbon spill model settings

Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Scenario description	Refuelling incident	Ship collision and support vessel fuel tank rupture	Ship collision and FPSO storage tank rupture	Long term subsea well blowout	Ship collision and export tanker fuel tank rupture	Ship collision and single tank rupture from pipelay vessel
Location	Barossa offshore development area					Gas export pipeline corridor
Number of randomly selected spill start times per season	100	100	100	100	100	100
Hydrocarbon type	MDO	MDO	Barossa condensate	Barossa condensate	HFO	IFO-180
Spill volume (m^3)	10	2,975	19,400	16,833	650	500
Release type	Surface	Surface	Surface	Subsea	Surface	Surface
Release duration	Instantaneous	6 hours	6 hours	80 days	6 hours	6 hours
Simulation length	10 days	40 days	40 days	90 days	40 days	40 days
Seasons assessed	Summer season (December to February) Transitional period (March and September to November) Winter season (April to August)					
Reporting surface hydrocarbon exposure thresholds	1 g/m^2 (low exposure), 10 g/m^2 (moderate exposure) and 25 g/m^2 (high exposure)					
Reporting entrained hydrocarbon thresholds	10 ppb (low exposure), 100 ppb (moderate exposure) and 500 ppb (high exposure)					
Reporting dissolved aromatic thresholds	6 ppb (low exposure), 50 ppb (moderate exposure) and 400 ppb (high exposure)					

2.8 Sea surface and sub-surface thresholds

The SIMAP model is able to track hydrocarbons to levels lower than biologically significant or visible to the naked eye. Therefore, reporting thresholds have been specified (based on the scientific literature) to account for "exposure" on the sea surface and "contact" to environmental receptors at meaningful levels.

The thresholds for the surface and sub-surface hydrocarbons, and their correlation with the zones of exposure, are presented in Table 16. Table 16 also provides supporting justification of the thresholds applied and additional context relating to the area of influence, as assessed in the Barossa OPP.

Table 16 Sea surface and sub-surface thresholds and zones of exposure

Exposure zone	Threshold	Justification
Sea surface film threshold		
Exposure zone Low exposure (1 g/m^2–10 g/m^2)	1 g/m^2	The 1 g/m^2 threshold represents the practical limit of observing hydrocarbon sheens in the marine environment and therefore has been used to define the outer boundary of the low exposure zone. This threshold is considered below levels which would cause environmental harm and is more indicative of the areas perceived to be affected due to its visibility on the sea-surface. This exposure zone is not considered to be of significant biological impact and is therefore outside the adverse exposure zone. This exposure zone represents the area contacted by the spill.
Adverse exposure zone Moderate exposure (10 g/m^2–25 g/m^2)	10 g/m^2	Ecological impact has been estimated to occur at 10 g/m^2 as this level of oiling has been observed to mortally impact birds and other wildlife associated with the water surface (French et al. 1996; French-McCay 2009). The 10 g/m^2 threshold has been selected to define the moderate exposure zone and outer boundary for the adverse exposure zone. Contact within this exposure zone may result in impacts to the marine environment and is therefore considered to be within the area of influence from a hydrocarbon spill.
Adverse exposure zone High exposure (> 25 g/m^2)	25 g/m^2	The 25 g/m^2 threshold is above the minimum threshold observed to cause ecological impact. Studies have indicated that a concentration of surface oil 25 g/m^2 or greater would be harmful for the majority of birds that contact the hydrocarbon at this concentration (Scholten et al. 1996; Koops et al. 2004). Exposure above this threshold is used to define the high exposure zone and is within the adverse exposure zone. This area is also within the area of influence.
Entrained hydrocarbon threshold		
Exposure zone Low exposure (10 ppb–100 ppb)	10 ppb	The 10 ppb threshold represents the lowest concentration and corresponds generally with the lowest trigger levels for chronic exposure for entrained hydrocarbons in the Australian and New Zealand Environment and Conservation Council and Agricultural and Resource Management Council of Australia and New Zealand (2000) water quality guidelines. Due to the requirement for relatively long exposure times (> 24 hours) for these concentrations to be significant, they are likely to be more meaningful for juvenile fish, larvae and planktonic organisms that might be entrained (or otherwise moving) within the entrained plumes, or when entrained hydrocarbons adhere to organisms or is trapped against a shoreline for periods of several days or more. This exposure zone is not considered to be of significant biological impact and is therefore outside the adverse exposure zone. This exposure zone represents the area contacted by the spill. This area does not define the area of influence as it is considered that the environment will not be affected by the hydrocarbon spill.
Adverse exposure zone Moderate exposure (100 ppb–500 ppb)	100 ppb	The 100 ppb threshold is considered conservative in terms of potential for toxic effects leading to mortality for sensitive mature individuals and early life stages of species. This threshold has been defined to indicate a potential zone of acute exposure, which is more meaningful over shorter exposure durations.

Exposure zone	Threshold	Justification
		The 100 ppb threshold has been selected to define the moderate exposure zone and outer boundary for the adverse exposure zone. Contact within this exposure zone may result in impacts to the marine environment and is therefore considered to be within the area of influence from a hydrocarbon spill.
Adverse exposure zone High exposure (> 500 ppb)	500 ppb	The 500 ppb threshold is considered conservative high exposure level in terms of potential for toxic effects leading to mortality for more tolerant species or habitats. As discussed above, this threshold has been defined to indicate a potential zone of acute exposure, which is more meaningful over shorter exposure durations (RPS APASA 2016d). The 500 ppb threshold has been selected to define the high exposure zone and is within the adverse exposure zone. This area is also within the area of influence.
Dissolved aromatic hydrocarbon threshold		
Exposure zone Low exposure (6 ppb–50 ppb)	6 ppb	The threshold value for species toxicity in the water column is based on global data from French et al. (1999) and French-McCay (2002, 2003), which showed that species sensitivity (fish and invertebrates) to dissolved aromatics exposure > 4 days (96-hour LC_{50}) under different environmental conditions varied from 6 ppb–400 ppb, with an average of 50 ppb. This range covered 95% of aquatic organisms tested, which included species during sensitive life stages (eggs and larvae). Based on scientific literature, a minimum threshold of 6 ppb used to define the low exposure zones (Engelhardt 1983; Clark 1984; Geraci and St. Aubin 1988; Jenssen 1994; Tsvetneko 1998). This exposure zone is not considered to be of significant biological impact and is therefore outside the adverse exposure zone. This exposure zone represents the area contacted by the spill. This area does not define the area of influence as it is considered that the environment will not be affected by the hydrocarbon spill.
Adverse exposure zone Moderate exposure (50 ppb–400 ppb)	50 ppb	A conservative threshold of 50 ppb was chosen as it is more likely to be indicative of potentially harmful exposure to fixed habitats over short exposure durations (French 2002). French-McCay (2002) indicates that an average 96-hour LC_{50} of 50 ppb could serve as an acute lethal threshold to 5% of biota. The 50 ppb threshold has been selected to define the moderate exposure zone and outer boundary for the adverse exposure zone. Contact within this exposure zone may result in impacts to the marine environment and is therefore considered to be within the area of influence from a hydrocarbon spill.
Adverse exposure zone High exposure (> 400 ppb)	400 ppb	A conservative threshold of 400 ppb was chosen as it is more likely to be indicative of potentially harmful exposure to fixed habitats over short exposure durations (French-McCay 2002). French-McCay (2002) indicates that an average 96-hour LC_{50} of 400 ppb could serve as an acute lethal threshold to 50% of biota. The 400 ppb threshold has been selected to define the high exposure zone and is within the adverse exposure zone. This area is also within the area of influence.

LC_{50}: Median lethal dose required for mortality of 50% of a tested population after a specified test duration.

2.9 Receptors assessed

Figure 32 shows the emergent receptors assessed for surface and subsea exposure from hydrocarbons. Figure 33 to Figure 36 display islands, reefs, shoals and banks (submerged receptors) while Figure 37 displays the Commonwealth Marine Reserves (CMRs) and commercial fisheries (i.e. Timor Reef Fishery) assessed for sea surface and subsea exposure. Figure 38 displays the key ecological features (KEF) used to assess surface and subsea exposure.

When reporting subsea exposure for the Timor Reef Fishery and KEFs, the maximum depth modelled within that scenario was used. This is because the Timor Reef Fishery is associated with deep water fishing at 80 m–120 m and the KEFs are marine regions based on different benthic habitats. As such the results at the greatest depth are most relevant to these receptors.

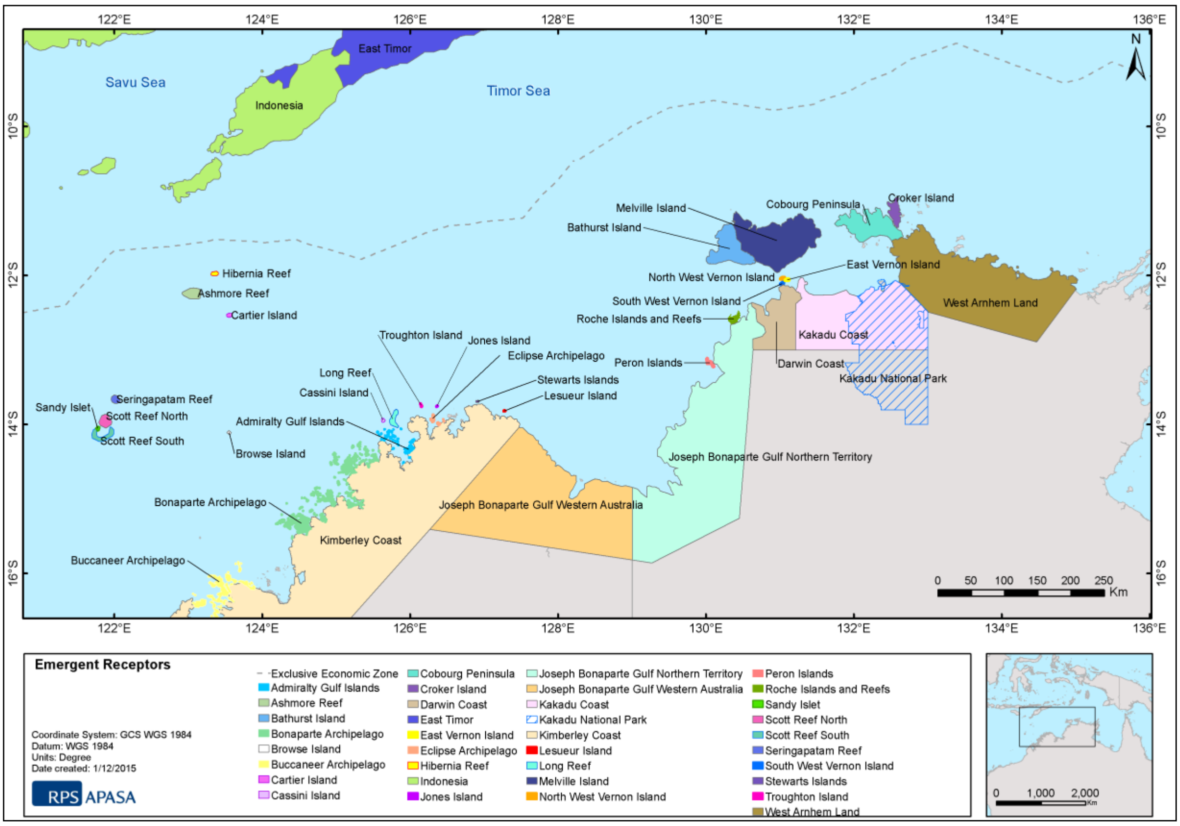


Figure 32 Coastlines (emergent receptors) assessed for surface and subsea exposure from hydrocarbons

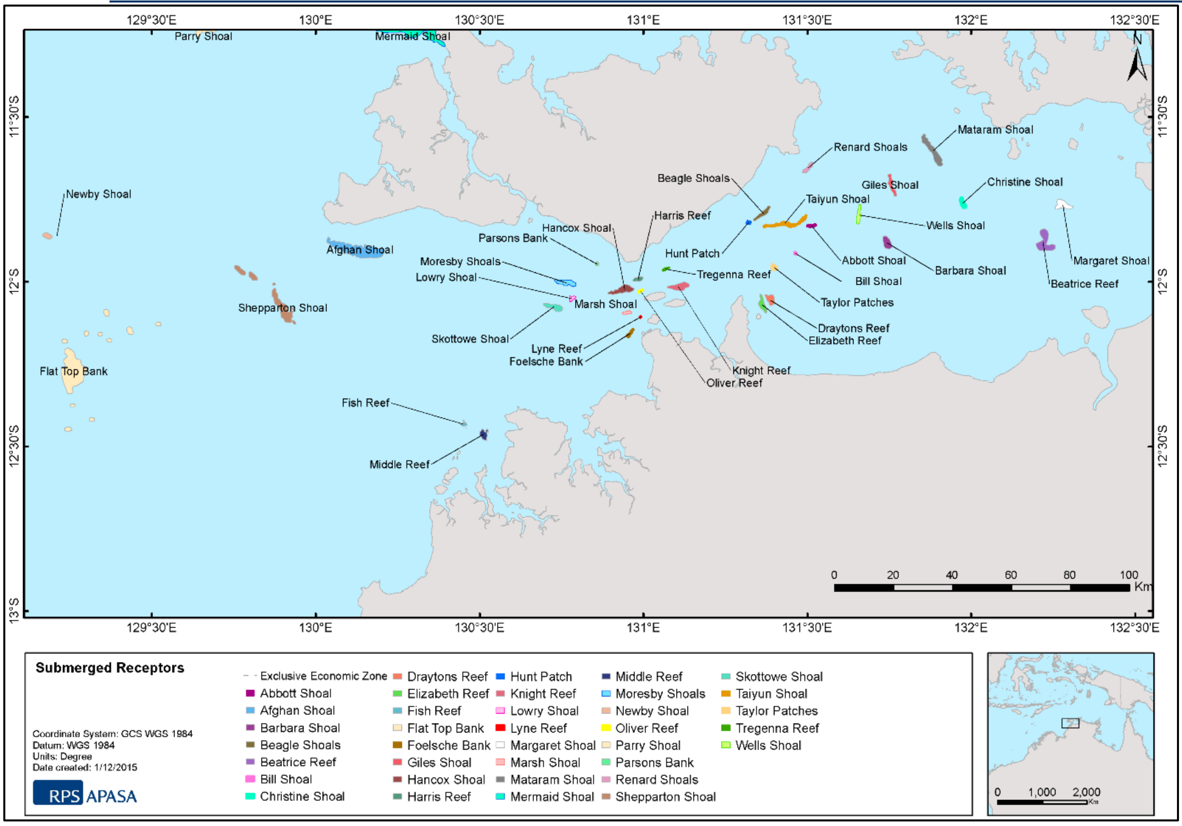


Figure 33 Van Diemen Gulf reefs, islands and shoals/banks (submerged receptors) assessed for sea surface and subsea exposure from hydrocarbons

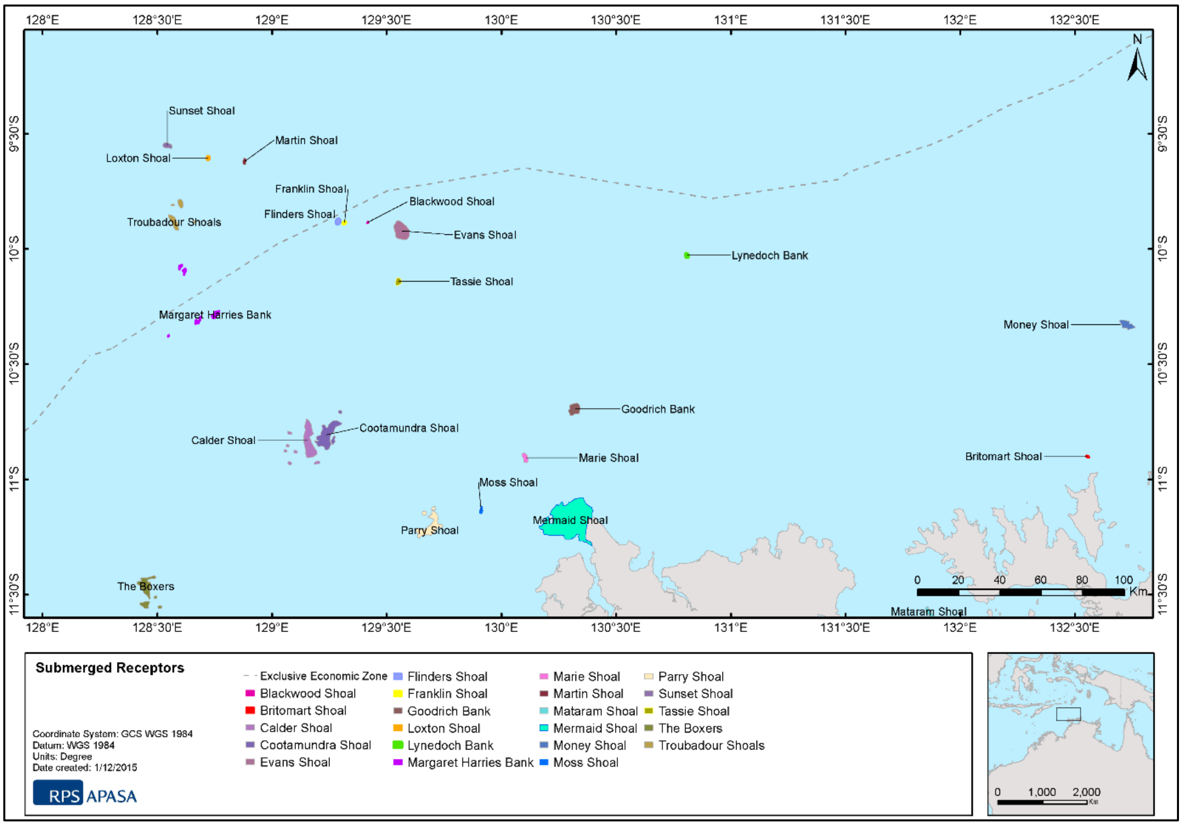


Figure 34 Northern reefs, islands and shoals/banks (submerged receptors) assessed for sea surface and subsea exposure from hydrocarbons

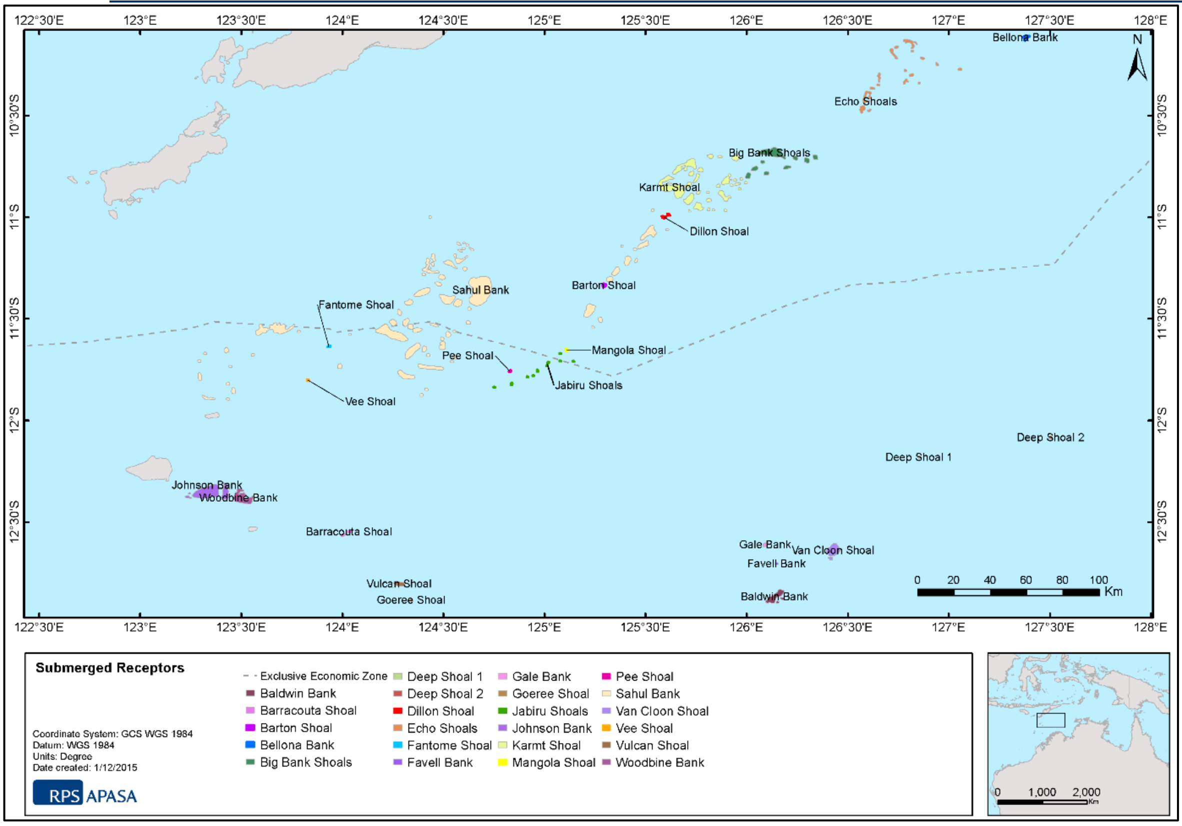


Figure 35 North-west reefs, islands and shoals/banks (submerged receptors) assessed for sea surface and subsea exposure from hydrocarbons

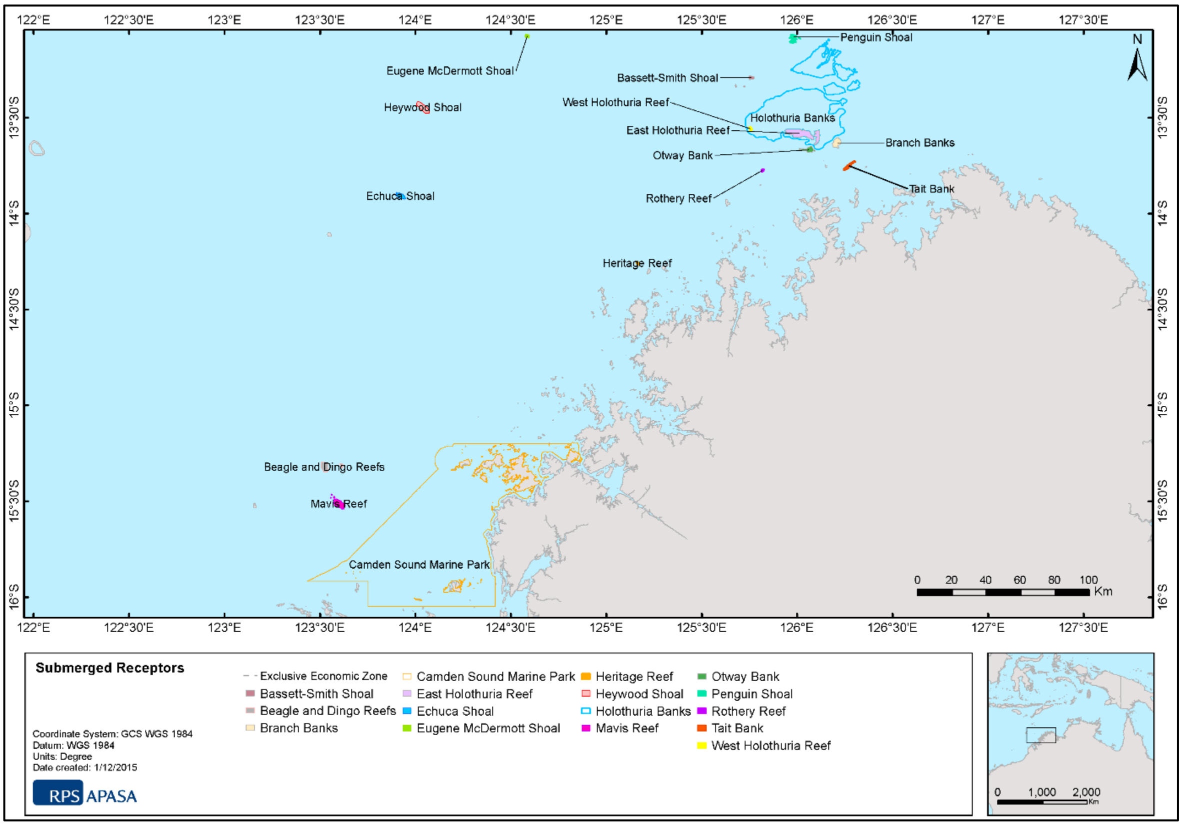


Figure 36 South-west reefs, islands and shoals/banks (submerged receptors) assessed for sea surface and subsea exposure from hydrocarbons

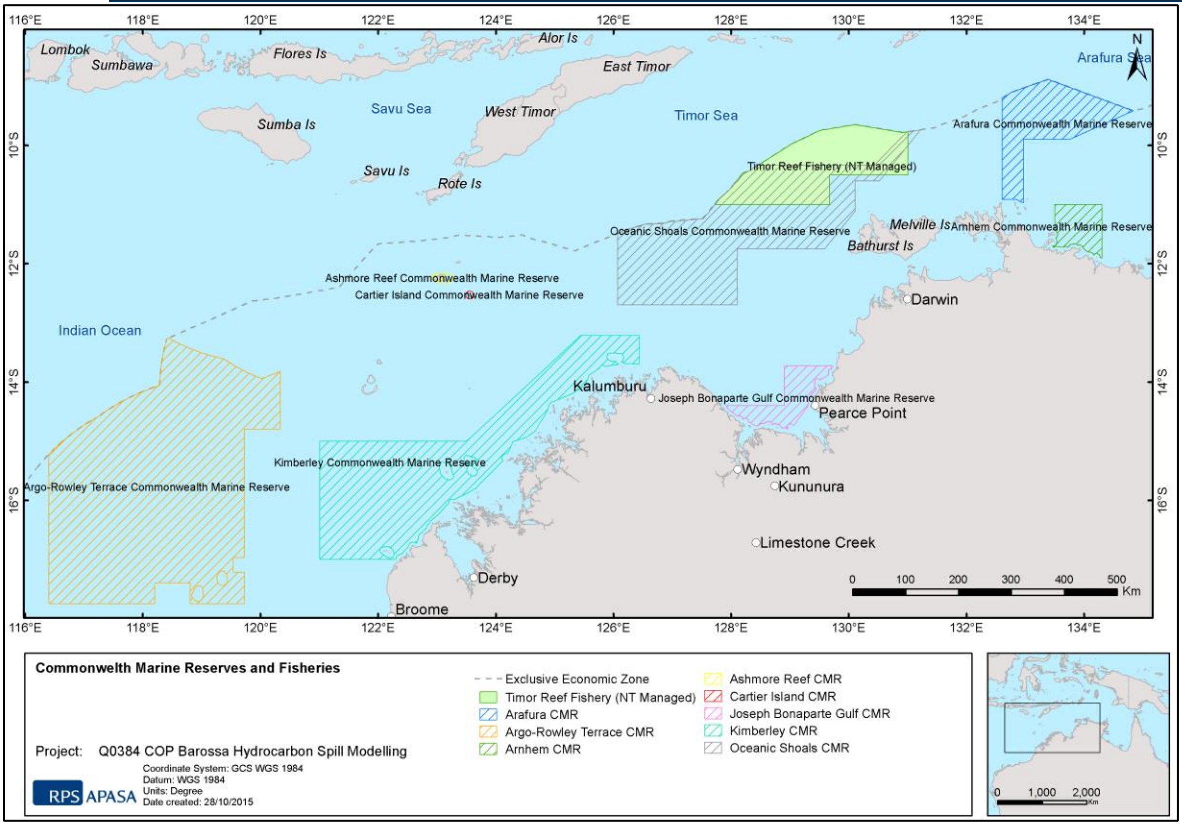


Figure 37 CMRs and Timor Reef Fishery assessed for sea surface and subsea exposure from hydrocarbons

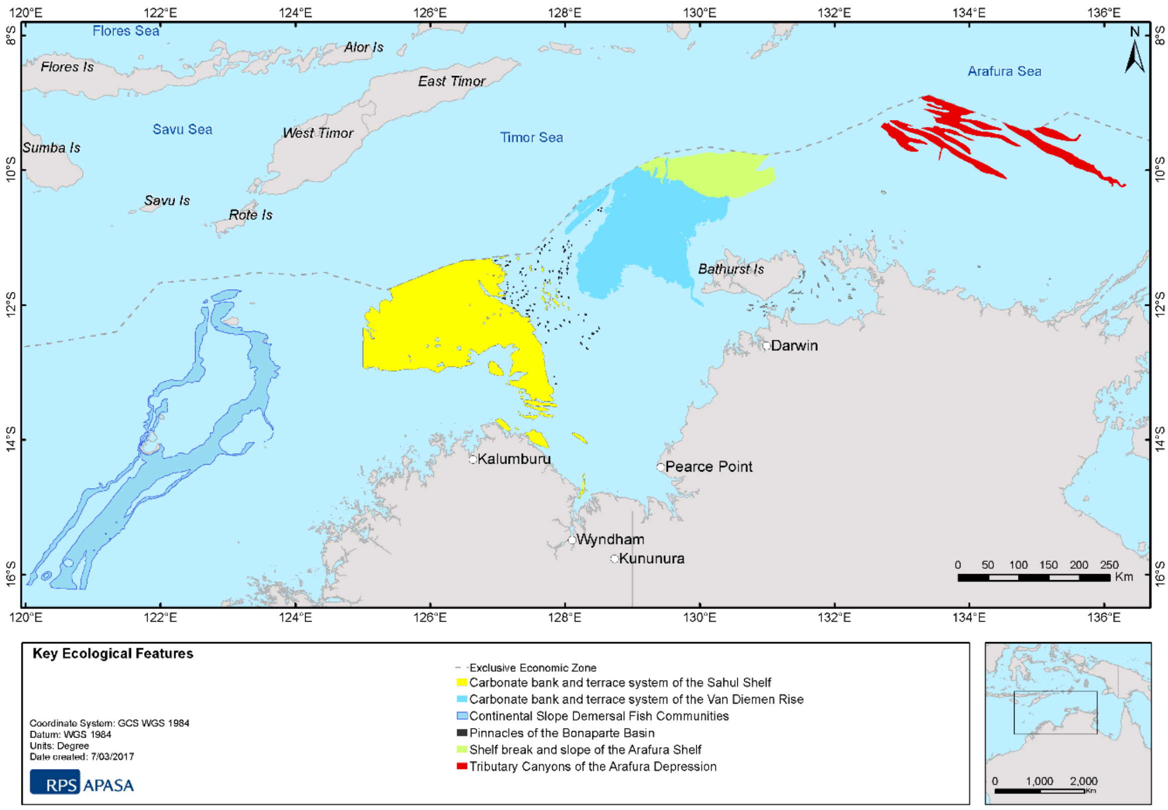


Figure 38 KEFs assessed for sea surface and subsea exposure from hydrocarbons

3. MODELLING RESULTS

A summary of the key modelling outputs for each of the maximum credible scenarios is presented in the following sections. For each scenario, results are presented in both tabular summaries and figures for sea surface, entrained and dissolved aromatic hydrocarbons for all thresholds and exposure zones (i.e. low, moderate and high). However, the up-front summary of the stochastic modelling results focusses on the moderate sea-surface, entrained and dissolved aromatic thresholds as these are considered to define the outer boundary of the adverse exposure zone, and therefore, the area that may be impacted by the spill scenario (i.e. area of influence).

The results are calculated as follows:

- probability of hydrocarbon exposure on the sea surface – is calculated by dividing the number of spill trajectories passing over a given model grid cell (above a defined threshold) by the total number of spill trajectories
- probability of exposure to environmental receptors – is determined by ranking the maximum predicted probabilities of exposure for any grid cell within the boundaries of any receptor for each of the 100 trajectories, with the greatest probability from the 100 trajectories being reported for each receptor
- minimum time before hydrocarbon exposure on the sea surface – is determined by ranking the elapsed time before sea surface exposure to a given location/grid cell (above a defined threshold) for each of the 100 spill trajectories, with the minimum time from all spill trajectories being presented
- potential sea surface exposure zones – are calculated for each grid cell and the highest predicted threshold of exposure (i.e. low exposure: 1–10 g/m^2; moderate exposure: 10–25 g/m^2 and high exposure: >25 g/m^2) for any given grid cell based on the assessment of all 100 single spill trajectories
- potential entrained hydrocarbon exposure zones – are calculated for any given grid cell by applying the thresholds of 10 ppb, 100 ppb and 500 ppb
- potential dissolved aromatics exposure zones – calculated for any given grid cell by applying the thresholds of 6 ppb, 50 ppb and 400 ppb
- probability of entrained hydrocarbon or dissolved aromatic exposure – are calculated by dividing the number of spill trajectories passing over that given cell by the total number of spill trajectories above the specified threshold value.

The modelling presents the probability of contact with entrained and dissolved hydrocarbons at depth specific intervals applicable for each of the receptors. For offshore reefs, shoals and banks, the model used the minimum depth of the feature while the surface water layer (0 m–10 m) was used for the Commonwealth marine reserves. The KEFs and commercial fisheries were assessed at different depths as relevant to the maximum depth layer modelled for the scenario. Potential impacts to the KEFs and commercial fisheries were assessed at depths of 40 m–50 m for Scenarios 2, 5 and 6 (vessel collision releasing MDO, HFO and IFO-180), while the 90 m–100 m depth layer was assessed for Scenario 3 (vessel collision releasing Barossa condensate) and Scenario 4 (long-term well blowout).

3.1 Scenario 1: Refuelling incident (10 m³ MDO)

3.1.1 Single trajectory

A spill trajectory during the summer season has been selected to illustrate the change in direction from the general trend (east or north-east). The spill starting at 7 pm 5th December 2010 is presented as an example only. Figure 39 shows the potential sea surface hydrocarbon exposure zones over the 10 day model simulation.

The spill initially drifted north-west of the release location, before travelling south-west. The sea surface adverse exposure zone (moderate and high exposure thresholds) was limited to within 1 km of the release location. There was no entrained or dissolved aromatic hydrocarbon exposure predicted at any threshold; consequently, no subsea images are presented for this scenario.

Figure 40 illustrates the fates and weathering graph for the example spill trajectory. The graph demonstrates that the MDO readily evaporated within the first 24 hours following release and by the end of day 2, approximately 41% (4.1 m^3) had undergone evaporation. At the end of the simulation (day 10) approximately 53% (5.3 m^3) had evaporated, 42% (4.2 m^3) remained on the surface and 5% (0.5 m^3) had decayed.

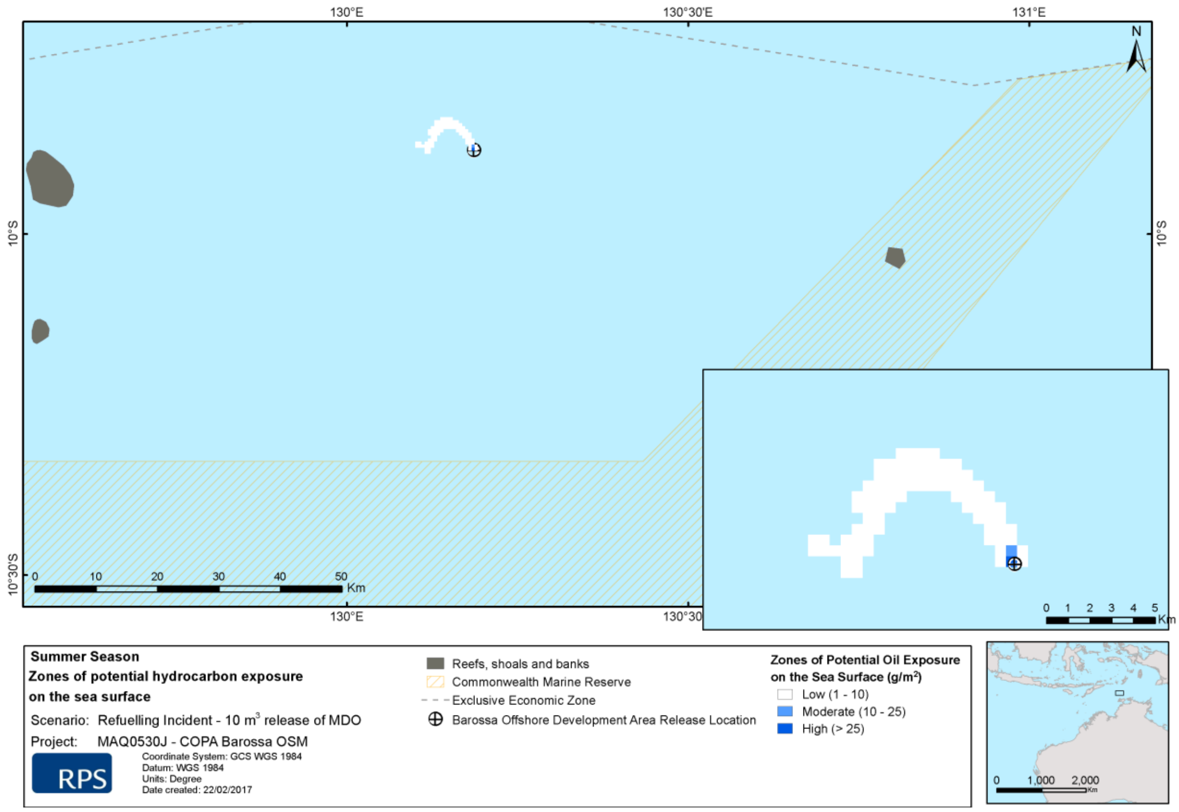


Figure 39 Single spill trajectory outputs showing the potential sea surface exposure zones (10 m³ MDO)

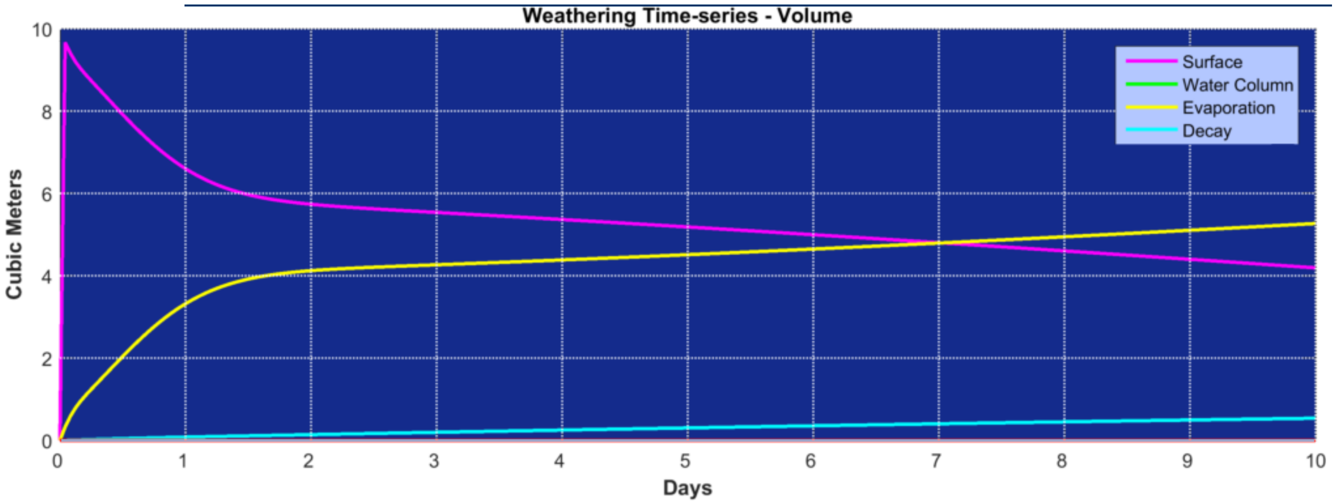


Figure 40 Predicted weathering and fates graph for the example spill trajectory from an instantaneous 10 m^3 surface release of MDO from a refuelling incident (tracked for 10 days)

3.1.2 Stochastic modelling

In summary, the stochastic modelling results showed:

- during summer, modelling showed low sea surface exposures towards the east and northeast. Modelling results for the transitional season revealed that spill trajectories travelled west and southwest from the release location. In winter, the spill trajectories were predicted to travel west.
- the maximum distance for the sea surface adverse exposure zone is predicted to vary between seasons extending to within 1.4 km, 2.7 km and 3.0 km during summer, transitional and winter conditions, respectively (Table 17).
- contact was predicted by the sea surface adverse exposure zone with the open waters above the KEF of the shelf break and slope of the Arafura Shelf (a unique seafloor feature) and the Timor Reef Fishery in all seasons as the Barossa offshore development area is located within the bounds of this KEF and Fishery (Table 18).
- no contact was predicted with the sea surface films at shores, reefs or open waters of the CMRs for any threshold in any season. Figure 41 to Figure 43 show the potential exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 44 shows the potential sea surface adverse exposure zone for all seasons.
- no entrained or dissolved aromatic hydrocarbon exposure is predicted at any threshold in any season and therefore, no contact with submerged or in-water receptors is expected.

Table 17 Maximum distances (and direction) from the release location to zones of potential sea surface exposure for each season (10 m^3 MDO)

Season	Distance and direction	Sea surface exposure thresholds		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Summer	Maximum distance travelled (km) by a spill trajectory	26.6	1.4	0.2
	Direction	East-northeast	East-southeast	West-northwest
Transitional	Maximum distance travelled (km) by a spill trajectory	27.5	2.7	0.2
	Direction	West-southwest	West	West-northwest
Winter	Maximum distance travelled (km) by a spill trajectory	26.3	3.0	0.2
	Direction	West	Northwest	West-northwest

Table 18 Probability and minimum time before hydrocarbon exposure on the sea surface for receptors assessed (10 m³ MDO)

Summer conditions (December to February)							
Receptor		Probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)	Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)
KEF	Shelf break slope of the Arafura Shelf	100	100	100	0.04	0.04	0.04
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.04	0.04	0.04
Transitional conditions (March and September to November)							
Receptor		Probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)	Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)
KEF	Shelf break slope of the Arafura Shelf	100	100	100	0.04	0.04	0.04
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.04	0.04	0.04
Winter conditions (April to August)							
Receptor		Probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)	Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)
KEF	Shelf break slope of the Arafura Shelf	100	100	100	0.04	0.04	0.04
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.04	0.04	0.04

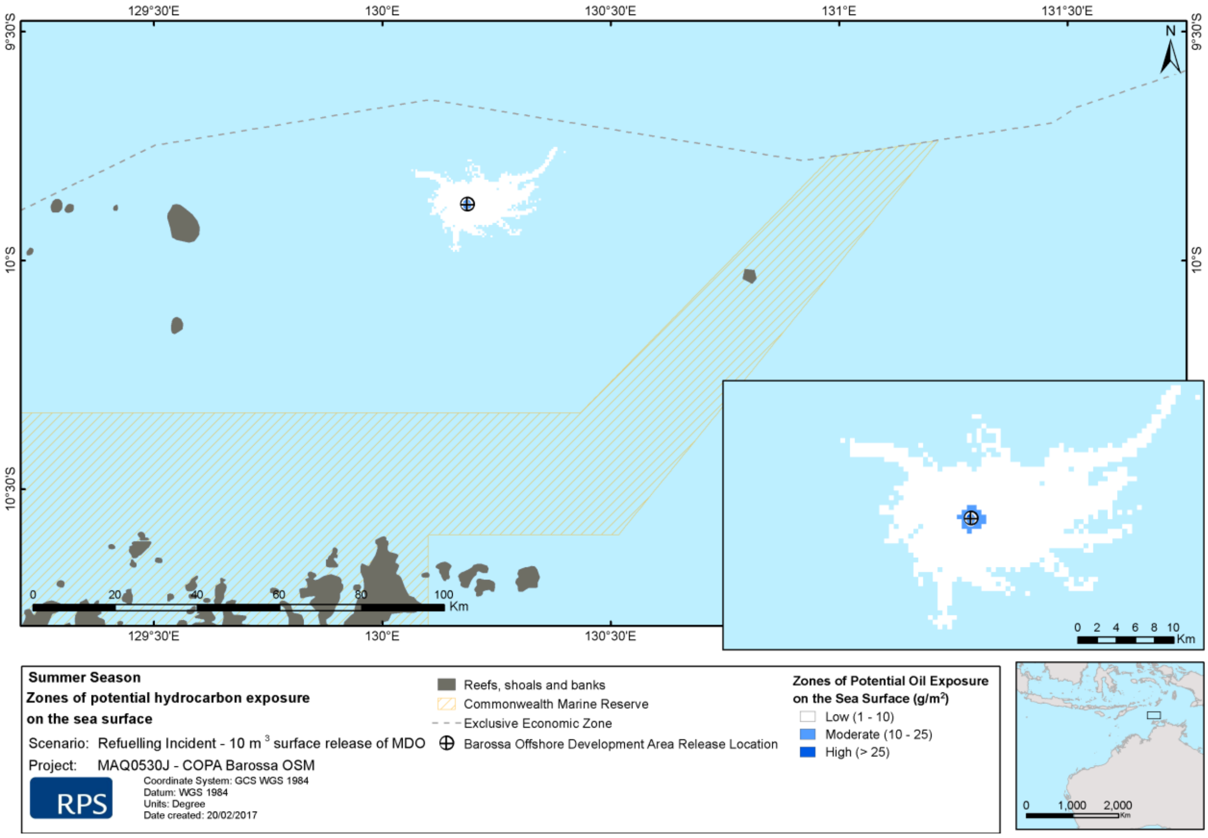


Figure 41 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during summer conditions (10 m^3 MDO)

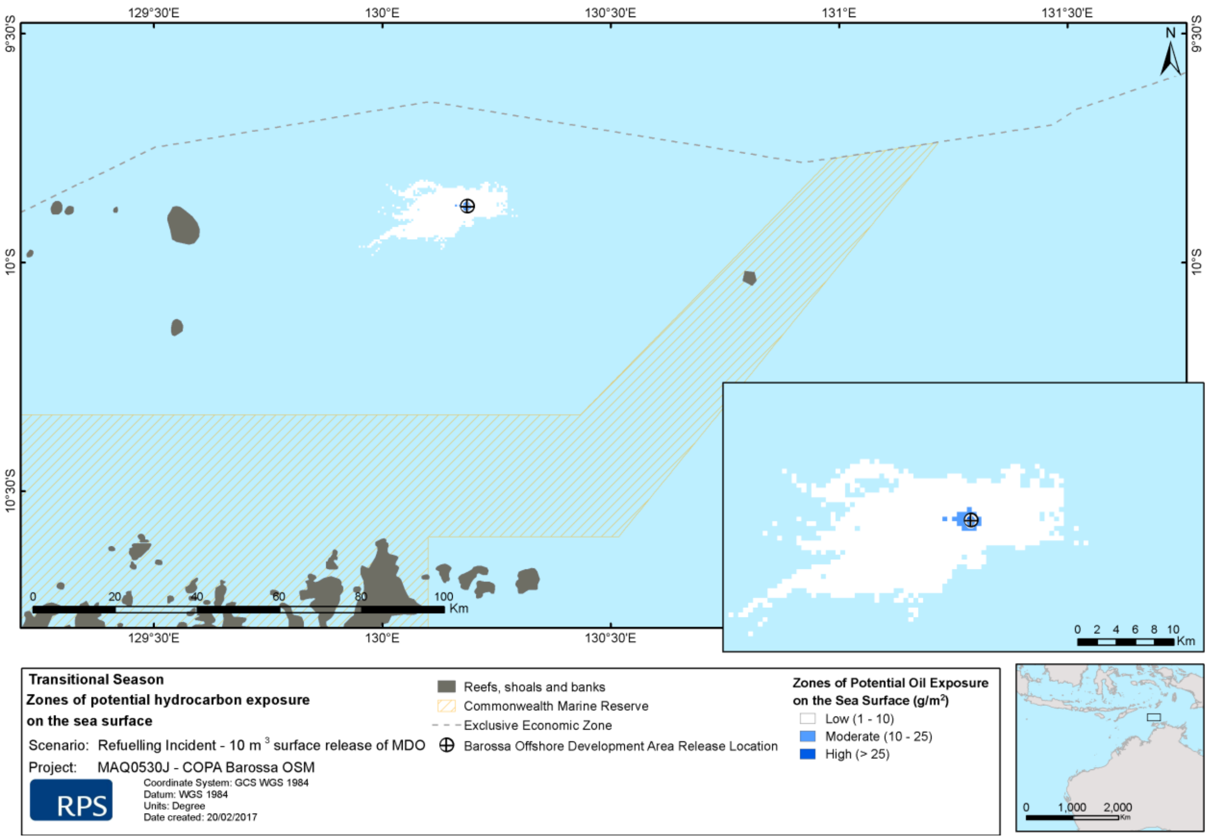


Figure 42 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during transitional conditions (10 m^3 MDO)

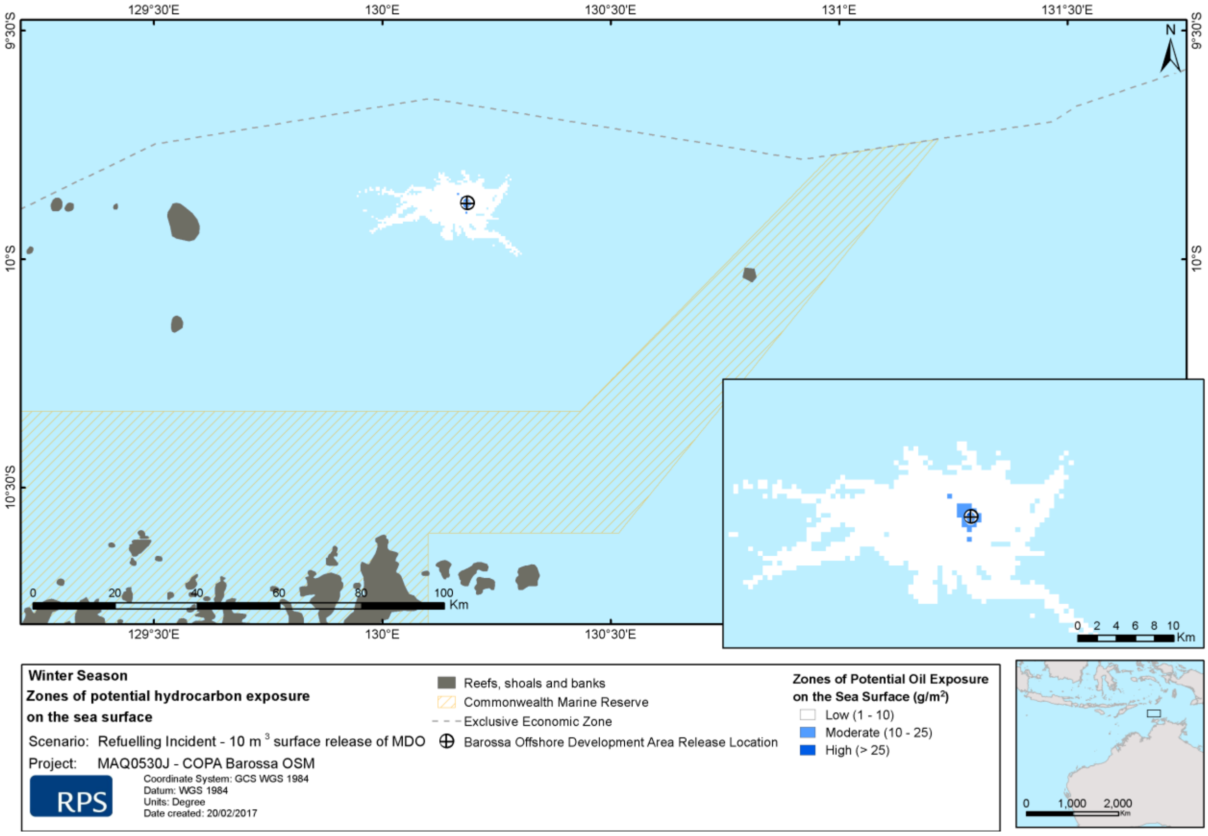


Figure 43 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during winter conditions (10 m^3 MDO)

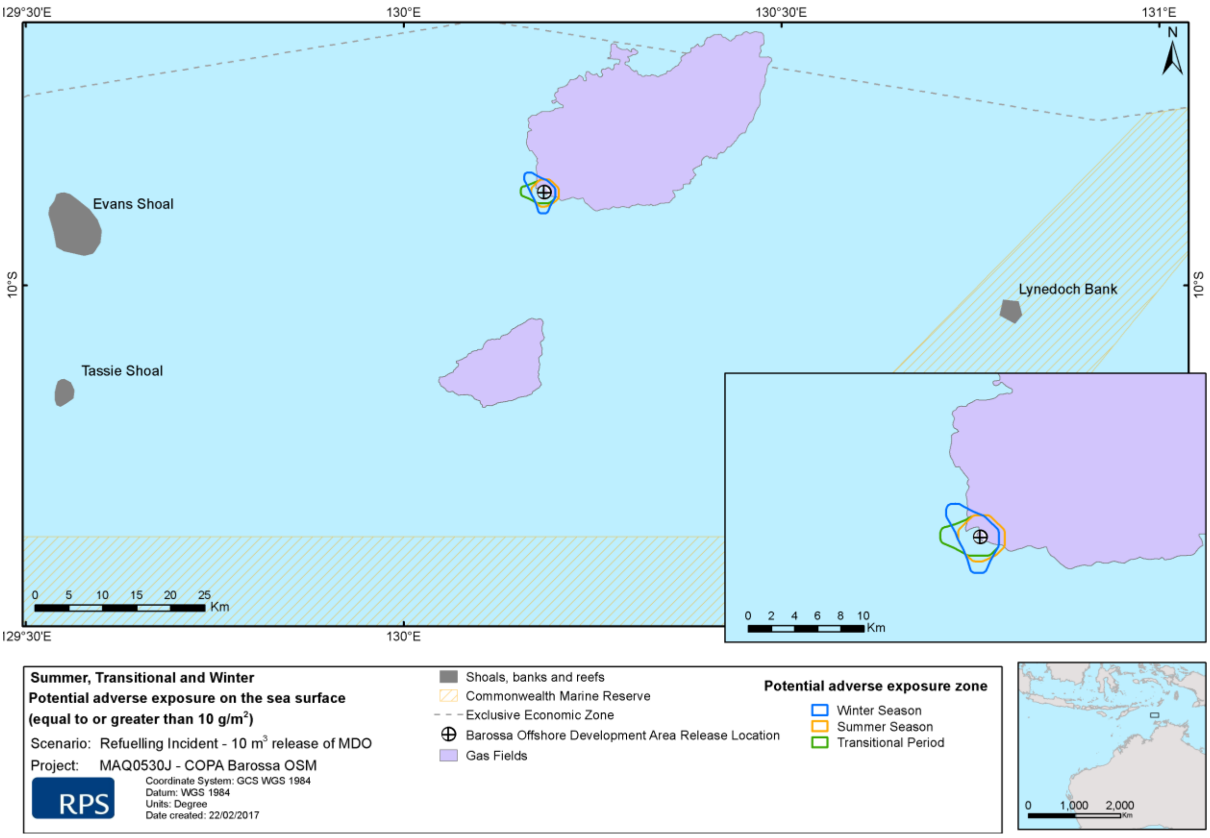


Figure 44 Stochastic modelling outputs showing the potential adverse exposure zone on the sea surface from a refuelling incident releasing MDO (10 m^3)

3.2 Scenario 2: Vessel collision leading to loss of a single FPSO facility (2,975 m^3 MDO)

3.2.1 Single trajectory

Figure 45 shows the predicted sea surface hydrocarbon exposure zones over the entire 40 day model simulation. From the 100 simulations completed, the spill starting at 2 am 8th August 2014 was used as an example trajectory to illustrate the potential exposure toward the south-west by entrained hydrocarbons to adjacent shoals/banks during the winter season. Figure 46 and Figure 47 display the entrained and dissolved aromatic hydrocarbon exposure zones.

The spill generally travelled west from the release location for the entire simulation period. The sea surface adverse exposure zone was observed up to 40 km and 36 km from the release location (moderate and high, respectively). Low, moderate and high entrained hydrocarbon exposure was recorded up to 636 km, 459 km and 172 km, respectively, from the release location. Dissolved aromatic hydrocarbon exposure was predicted up to 106 km from the release location at the low threshold while the adverse exposure zone was limited to within 82 km from the release location.

Figure 48 illustrates the fates and weathering graph for the corresponding winter spill trajectory. The graph demonstrates that the MDO readily entrained in the water column due to strong winds early in the simulation with approximately 77% (2,278 m^3) of the total spill volume entrained by day 2. The hydrocarbon was observed to remain entrained, undergoing gradual microbial decay, until the end of the simulation. At the end of the simulation (day 40) approximately 23% (972 m^3) had evaporated, 51% (1,540 m^3) remained entrained and 25% (761 m^3) had decayed.

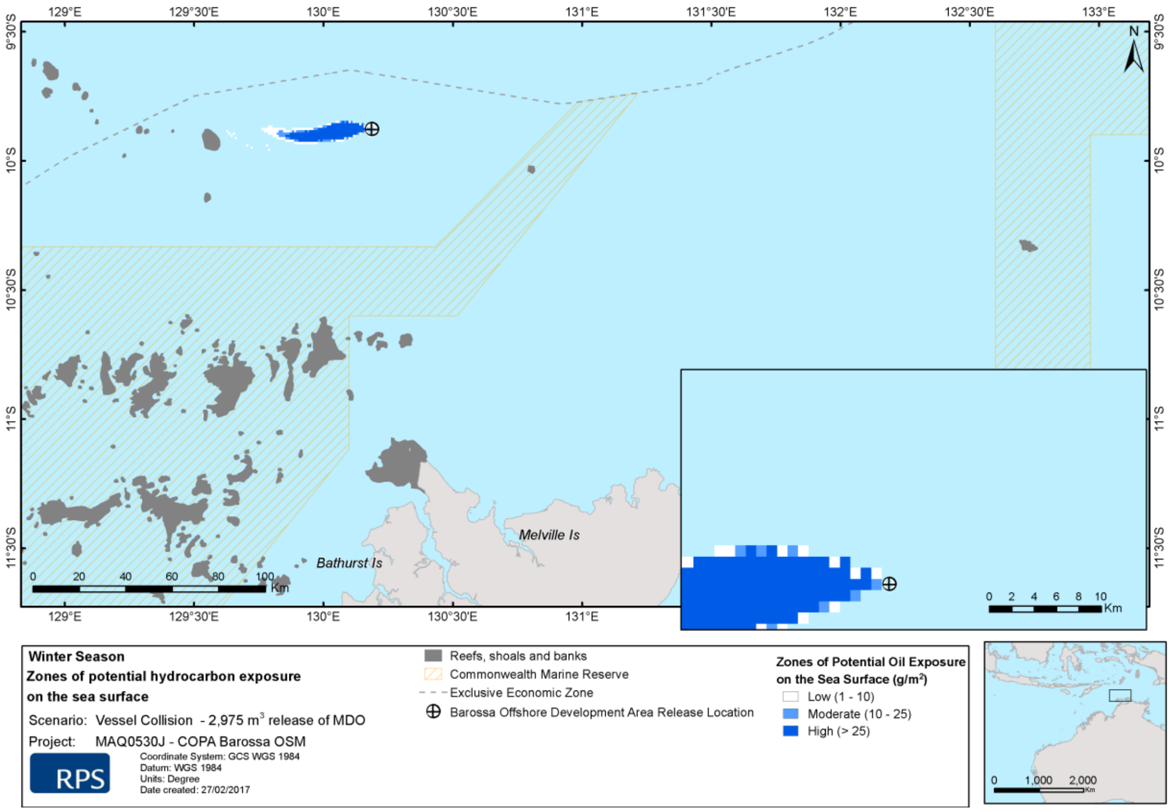


Figure 45 Single spill trajectory outputs showing the potential sea surface exposure zones (2,975 m^3 MDO)

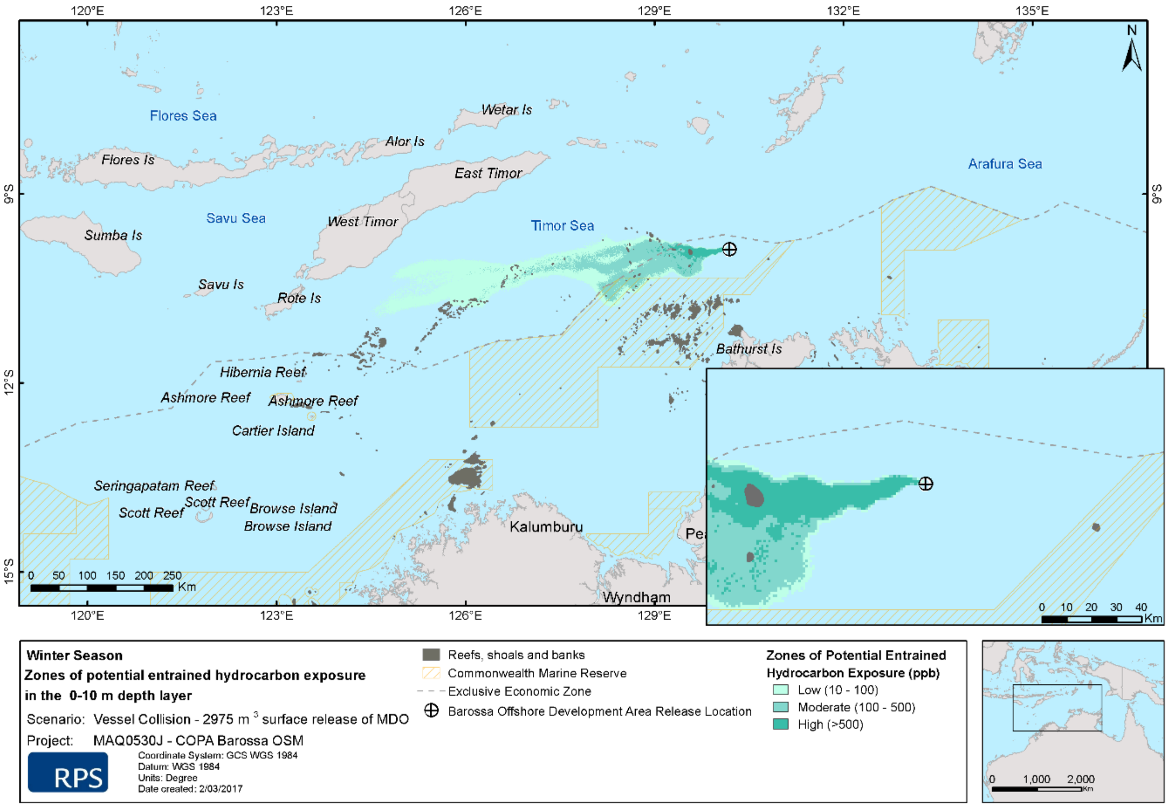


Figure 46 Single spill trajectory outputs showing the potential entrained exposure zones (2,975 m^3 MDO)

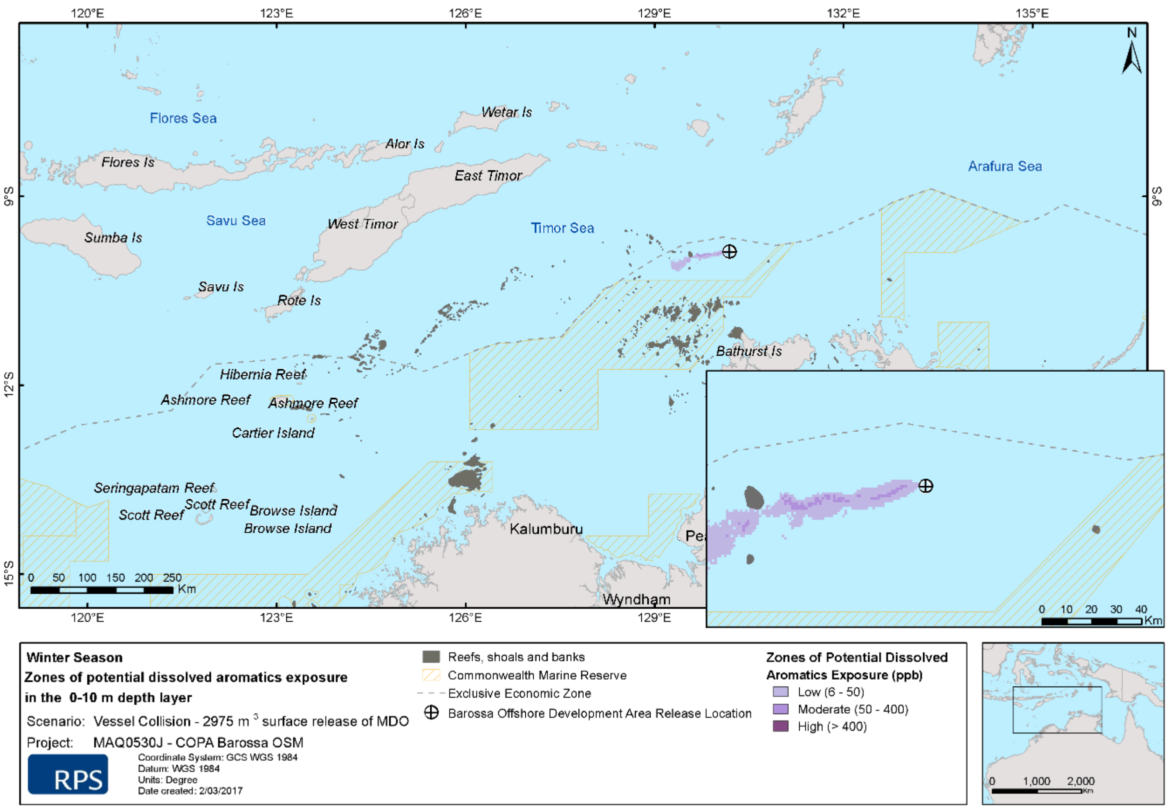


Figure 47 Single spill trajectory outputs showing the potential dissolved aromatic exposure zones (2,975 m^3 MDO)

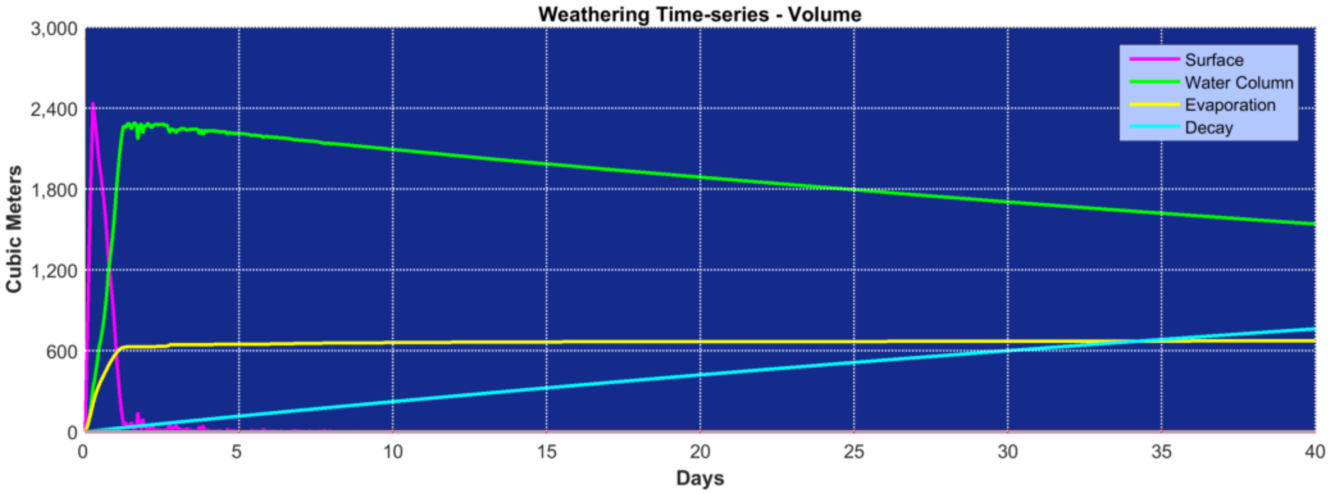


Figure 48 Predicted weathering and fates graph for the example spill trajectory selected from a 2,975 m^3 surface release of MDO from a ship collision and fuel tank rupture (tracked for 40 days)

3.2.2 Stochastic modelling

In summary, the stochastic modelling results showed:

- during transitional and winter conditions the MDO initially travelled west of the release location. During the transitional season the MDO was observed to travel greater distances on the sea surface comparative to winter, due to calm to moderate wind speeds which allowed the hydrocarbon on the sea surface to be carried great distances without entraining. During summer the MDO was initially predicted to move east of the release location, but overall movement of sea surface trajectories was variable.
- the maximum distance for the sea surface adverse exposure zone is predicted to vary between seasons with approximately 319 km, 392 km and 124 km of the sea surface exposed during summer, transitional and winter conditions, respectively (Table 19).
- some contact was predicted (1–14% probability) by sea surface films within the adverse exposure zone with the surface waters above a number of submerged shoals/banks (total of 13) KEFs of the carbonate bank and terrace system of Van Diemen Rise and Pinnacles of the Bonaparte Basin, and the open waters of the Oceanic Shoals CMR, depending on the season (Table 20). Figure 49 to Figure 51 show the potential sea surface hydrocarbon exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 58 shows the potential sea surface adverse exposure zone for all seasons.
- during summer conditions, the surface waters above Tassie Shoal recorded the highest probability of contact with the sea surface adverse exposure zone of all shoals/banks (2%) while during transitional conditions the waters above Evans Shoal was predicted to have the highest probability of contact with the sea surface adverse exposure zone (14%). During winter conditions, the waters above Evans Shoal, Tassie Shoal, Flinders Shoal and Franklin Shoal were contacted by the sea surface adverse exposure zone (1–2%).
- contact by the sea surface adverse exposure zone with the waters above the KEF of the shelf break and slope of the Arafura Shelf (a unique seafloor feature) and open waters of the Timor Reef Fishery was predicted in all seasons as the Barossa offshore development area is located within the bounds of these features (Table 20).
- no residual hydrocarbons were predicted to accumulate on any shoreline in any season to levels that may affect sensitive receptors onshore.
- contact was predicted (1–37% probability) by entrained hydrocarbons within the adverse exposure zone for various submerged shoals/banks (total of 25), open waters of the Oceanic Shoals, Arafura, Ashmore Reef and Cartier Island CMRs, waters above the KEFs of the shelf break and slope of the Arafura Shelf, carbonate bank and terrace system of Van Diemen Rise, pinnacles of the Bonaparte Basin, carbonate bank and terrace system of Sahul Shelf and tributary canyons of the Arafura Depression, and waters of the Timor

Reef Fishery, depending on the season (Table 21). Figure 52 to Figure 54 shows the potential entrained hydrocarbon exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 59 shows the potential entrained hydrocarbon adverse exposure zone for all seasons.

- during summer conditions, Lynedoch Bank recorded the highest probability of contact for submerged shoals with the entrained adverse exposure zone (6%) while during transitional and winter conditions Flinders Shoal was predicted to have the highest probability of contact with entrained the adverse exposure zone (19% and 37% respectively). The open waters of the Oceanic Shoals CMR recorded the highest probability (30%) of contact during summer conditions overall.
- some contact predicted at low probability (1% probability) by entrained hydrocarbons within the adverse exposure zone at Hibernia and Ashmore Reef during transitional conditions only (Table 21)
- some contact predicted at low probability (1–2% probability) by dissolved aromatic hydrocarbons within the adverse exposure zone for 10 submerged shoals/banks, open waters of the Oceanic Shoals CMR, waters above the KEFs of the shelf break and slope of the Arafura Shelf and carbonate bank and terrace system of Van Diemen Rise, and waters of the Timor Reef Fishery, depending on the season (Table 22). Figure 55 to Figure 57 shows the potential dissolved aromatic hydrocarbon exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 60 shows the potential dissolved aromatic hydrocarbon adverse exposure zone for all seasons.
- no contact with the adverse exposure zone for sea surface or sub-surface hydrocarbons was predicted with the NT/WA coastline or adjacent islands (Table 20 to Table 22).

Table 19 Maximum distances (and direction) from the release location to zones of potential sea surface exposure for each season (2,975 m^3 MDO)

Season	Distance and direction	Sea surface exposure thresholds		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Summer	Maximum distance travelled (km) by a spill trajectory	366.9	318.5	153.2
	Direction	West	West	West-southwest
Transitional	Maximum distance travelled (km) by a spill trajectory	679.9	391.7	367.1
	Direction	West-southwest	West-southwest	West
Winter	Maximum distance travelled (km) by a spill trajectory	590.9	124.2	91.1
	Direction	West	West-southwest	West-southwest

Table 20 Probability and minimum time before hydrocarbon exposure on the sea surface for receptors assessed (2,975 m^3 MDO)

Summer conditions (December to February)								
Receptor		Probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)	Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Submerged receptor	Sunset Shoal	-	-	-	-	-	-
	Loxton Shoal	1	-	-	17.5	-	-
	Martin Shoal	1	1	-	10.4	12.4	-
	Sunrise Bank	1	-	-	16.4	-	-
	Troubadour Shoals	1	-	-	9.3	-	-
	Flinders Shoal	-	-	-	-	-	-
	Evans Shoal	6	1	-	3.4	19.0	-
	Tassie Shoal	7	2	-	6.2	6.2	-
	Franklin Shoal	1	-	-	10.9	-	-
	Blackwood Shoal	2	-	-	10.8	-	-
	Lynedoch Bank	4	-	-	4.0	-	-
	Margaret Harries Bank	3	1	-	9.5	19.8	-
	Bellona Bank	1	-	-	34.0	-	-
	Echo Shoals	1	-	-	34.3	-	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
	Cootamundra Shoal	2	1	-	12.6	14.2	-
	Sahul Bank	-	-	-	-	-	-
Emergent	Indonesia	-	-	-	-	-	-
CMR	Oceanic Shoals CMR	30	12	8	2.8	4.5	6.4
KEF	Shelf break and slope of the Arafura Shelf	100	100	100	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	18	16	9	3.0	3.4	3.5
	Pinnacles of the Bonaparte Basin	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.04	0.04	0.04

Transitional conditions (March and September to November)								
Receptor		Probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)	Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)
Submerged receptor	Sunset Shoal	16	4	1	5.7	6.2	10.5
	Loxton Shoal	15	4	-	5.4	5.8	-
	Martin Shoal	9	2	-	4.9	5.1	-
	Sunrise Bank	9	3	-	11.5	22.9	-
	Troubadour Shoals	16	6	-	7.6	7.9	-
	Flinders Shoal	18	9	3	3.9	4.1	4.3
	Evans Shoal	28	14	6	2.3	2.4	2.5
	Tassie Shoal	6	2	-	4.2	7.5	-
	Franklin Shoal	16	9	3	3.8	3.9	4.3
	Blackwood Shoal	14	8	1	3.4	3.4	5.5
	Lynedoch Bank	-	-	-	-	-	-
	Margaret Harries Bank	13	3	-	7.4	10.3	-
	Bellona Bank	5	1	1	18.2	18.4	18.8
	Echo Shoals	8	-	-	18.4	-	-
	Big Bank Shoals	1	-	-	21.3	-	-
	Karmt Shoal	1	-	-	22.0	-	-
	Cootamundra Shoal	-	-	-	-	-	-
	Sahul Bank	1	-	-	33.7	-	-
Emergent	Indonesia	-	-	-	-	-	-
CMR	Oceanic Shoals CMR	9	5	3	3.0	3.2	5.6
KEF	Shelf break and slope of the Arafura Shelf	100	100	100	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	27	15	6	2.7	2.8	2.8
	Pinnacles of the Bonaparte Basin	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.04	0.04	0.04

Winter conditions (April to August)							
Receptor		Probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)	Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)
Submerged receptor	Sunset Shoal	-	-	-	-	-	-
	Loxton Shoal	-	-	-	-	-	-
	Martin Shoal	1	-	-	3.75	-	-
	Sunrise Bank	-	-	-	-	-	
	Troubadour Shoals	2	-	-	3.08	-	-
	Flinders Shoal	2	1	-	1.67	1.7	-
	Evans Shoal	5	2	-	3.79	3.8	
	Tassie Shoal	3	2	-	3.02	3.1	
	Franklin Shoal	2	1	-	2.46	2.5	-
	Blackwood Shoal	3	-	-	8	15.0	-
	Lynedoch Bank	1	-	-	8.3	-	-
	Margaret Harries Bank	2	1	-	12.6	15.1	-
	Bellona Bank	1	-	-	13.33	-	-
	Echo Shoals	-	-	-	-	-	-
	Big Bank Shoals	1	-	-	4.81	-	-
	Karmt Shoal	1	-	-	15.75	-	-
	Cootamundra Shoal	1	-	-	17.25	-	-
	Sahul Bank	1	-	-	19.22	-	-
Emergent	Indonesia	1	-	-	20.63	-	-
CMR	Oceanic Shoals CMR	2	1	-	21.06	22.0	-
KEF	Shelf break and slope of the Arafura Shelf	100	100	100	22.04	26.0	35.33
	Carbonate bank and terrace system of Van Diemen Rise	16	8	4	28.31	31.0	34.8
	Pinnacles of the Bonaparte Basin	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	33.67	-	-

Table 21 Probability and minimum time before entrained hydrocarbon exposure for receptors assessed (2,975 m^3 MDO)

Summer conditions (December to February)							
Receptor		Probability of exposure to entrained concentrations at specific receptor depth (%)			Minimum time to entrained concentration at any depth [days]		
		10 ppb	100 ppb	500 ppb	10 ppb	100 ppb	500 ppb
Submerged receptor	Sunset Shoal	3	1	-	10.4	36.7	-
	Loxton Shoal	3	1	-	9.5	12.1	-
	Martin Shoal	2	2	-	9.8	18.8	-
	Sunrise Bank	-	-	-	-	-	-
	Flinders Shoal	7	1	-	10.8	35.7	-
	Evans Shoal	10	1	-	12.5	19.0	-
	Tassie Shoal	12	5	-	9.4	12.7	-
	Franklin Shoal	4	1	-	10.8	35.7	-
	Blackwood Shoal	7	1	-	10.7	19.1	-
	Lynedoch Bank	23	6	1	2.7	2.9	3.0
	Margaret Harries Bank	5	1	-	18.0	19.8	-
	Bellona Bank	1	-	-	35.3	-	-
	Echo Shoals	1	-	-	35.2	-	-
	Money Shoal	13	3	-	20.6	22.4	-
	Troubadour Shoals	1	1	-	29.5	31.5	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
	Cootamundra Shoal	7	1	-	14.1	15.2	-
	Calder Shoal	6	1	-	14.0	18.5	-
	Sahul Bank	-	-	-	-	-	-
	Dillon Shoal	-	-	-	-	-	-
	Barton Shoal	-	-	-	-	-	-
	Fantome Shoal	-	-	-	-	-	-
	Mangola Shoal	-	-	-	-	-	-
	Jabiru Shoals	-	-	-	-	-	-
	Pee Shoal	-	-	-	-	-	-
	Vee Shoal	-	-	-	-	-	-

	Johnson Bank	-	-	-	-	-	-
	Woodbine Bank	-	-	-	-	-	-
	Barracouta Shoal	-	-	-	-	-	-
Emergent receptor	Indonesia	2	1	-	29.1	31.4	-
	East Timor	1	-	-	37.0	-	-
	Hibernia Reef	-	-	-	-	-	-
	Ashmore Reef	-	-	-	-	-	-
	Cartier Island	-	-	-	-	-	-
CMR	Arafura CMR	33	13	2	15.1	18.1	21.7
	Oceanic Shoals CMR	47	30	11	2.1	2.2	2.5
	Ashmore Reef CMR	-	-	-	-	-	-
	Cartier Island CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	19	4	1	16.9	19.1	25.6
	Shelf break and slope of the Arafura Shelf	22	12	2	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	12	2	1	4.7	10.8	12.7
	Pinnacles of the Bonaparte Basin	1	-	-	20.6	-	-
	Carbonate bank and terrace system of Sahul Shelf	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	25	12	2	0.04	0.04	0.04

Transitional conditions (March and September to November)							
Receptor		**Probability of exposure to entrained concentrations at specific receptor depth (%)**			**Minimum time to entrained concentration at any depth [days]**		
		10 ppb	**100 ppb**	**500 ppb**	**10 ppb**	**100 ppb**	**500 ppb**
Submerged receptor	Sunset Shoal	21	6	-	7.8	8.0	-
	Loxton Shoal	25	5	-	5.8	7.2	
	Martin Shoal	20	2	-	5.8	6.9	
	Sunrise Bank	17	-	-	8.4	-	
	Flinders Shoal	36	19	-	3.2	3.9	
	Evans Shoal	30	9	-	1.6	1.8	
	Tassie Shoal	17	3	-	2.2	2.3	
	Franklin Shoal	28	3	-	3.2	4.4	

	Blackwood Shoal	27	1	-	2.8	3.3	-
	Lynedoch Bank	8	4	1	3.4	4.3	6.7
	Margaret Harries Bank	21	3	-	7.5	8.0	
	Bellona Bank	20	-	-	13.2	16.4	
	Echo Shoals	25	-	-	16.3	18.0	
	Money Shoal	-	-	-	-	-	-
	Troubadour Shoals	28	5	-	7.0	7.8	-
	Big Bank Shoals	16	-	-	19.7	-	-
	Karmt Shoal	18	-	-	19.8	-	-
	Cootamundra Shoal	1	1	-	24.9	27.8	-
	Calder Shoal	1	1	-	31.9	35.7	-
	Sahul Bank	21	-	-	20.8	-	-
	Dillon Shoal	14	1	-	20.5	24.5	-
	Barton Shoal	7	-	-	22.8	-	-
	Fantome Shoal	5	1	-	32.9	34.9	-
	Mangola Shoal	3	1	-	24.9	28.9	-
	Jabiru Shoals	4	-	-	25.0	-	-
	Pee Shoal	3	-	-	27.3	-	-
	Vee Shoal	2	-	-	33.9		-
	Johnson Bank	5	-	-	35.5	-	-
	Woodbine Bank	3	-	-	37.2	-	-
	Barracouta Shoal	-	-	-	-	-	-
Emergent receptor	Indonesia	5	2	1	17.1	17.4	21.3
	East Timor	8	1	-	26.9	35.0	-
	Hibernia Reef	8	1	-	33.7	33.9	-
	Ashmore Reef	5	1	-	35.2	36.7	-
	Cartier Island	1	-	-	37.9	-	-
CMR	Arafura CMR	-	-	-	-	-	-
	Oceanic Shoals CMR	19	9	4	2.9	3.1	5.7
	Ashmore Reef CMR	6	-	-	35.0	-	-
	Cartier Island CMR	3	-	-	37.8	-	-

KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	14	4	2	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	18	6	1	1.8	1.9	2.0
	Pinnacles of the Bonaparte Basin	9	2	-	13.3	14.1	
	Carbonate bank and terrace system of Sahul Shelf	3	-	-	24.9	-	-
Fishery	Timor Reef Fishery (NT Managed)	18	3	2	0.04	3.0	0.04
Winter conditions (April to August)							
Receptor		**Probability of exposure to entrained concentrations at specific receptor depth (%)**			**Minimum time to entrained concentration at any depth [days]**		
		10 ppb	**100 ppb**	**500 ppb**	**10 ppb**	**100 ppb**	**500 ppb**
Submerged receptor	Sunset Shoal	41	11	1	4.7	4.8	7.1
	Loxton Shoal	42	14	-	4.3	4.4	
	Martin Shoal	39	11	2	3.8	3.8	3.8
	Sunrise Bank	27	4	-	7.3	7.9	
	Flinders Shoal	63	37	13	3.1	3.2	3.2
	Evans Shoal	59	31	5	1.7	1.7	2.1
	Tassie Shoal	35	9	-	3.8	3.8	
	Franklin Shoal	52	28	-	3.0	3.1	
	Blackwood Shoal	54	23	1	2.5	2.5	2.6
	Lynedoch Bank	11	1	-	8.0	15.0	
	Margaret Harries Bank	24	8	3	8.3	9.3	11.3
	Bellona Bank	23	4	-	12.6	15.1	
	Echo Shoals	26	7	1	13.3	15.9	19.9
	Money Shoal	-	-	-	-	-	-
	Troubadour Shoals	44	17	2	4.8	5.3	7.5
	Big Bank Shoals	27	8	1	15.8	16.0	19.9
	Karmt Shoal	29	7	1	17.3	19.8	24.5
	Cootamundra Shoal	1	1	-	19.2	20.4	-
	Calder Shoal	1	1	-	20.6	21.5	-
	Sahul Bank	28	11	1	21.1	22.0	36.0
	Dillon Shoal	23	5	1	22.0	26.0	35.3

	Barton Shoal	10	3	-	28.3	31.0	
	Fantome Shoal	2	-	-	35.4	-	-
	Mangola Shoal	5	1	-	33.7	35.6	-
	Jabiru Shoals	6	1	-	31.0	37.7	-
	Pee Shoal	7	1	-	31.1	37.6	-
	Vee Shoal	3	-	-	36.1	-	-
	Johnson Bank	-	-	-	-	-	-
	Woodbine Bank	-	-	-	-	-	-
	Barracouta Shoal	-	-	-	-	-	-
Emergent receptor	Indonesia	9	4	1	19.4	27.3	38.2
	East Timor	3	1	-	21.9	24.1	-
	Hibernia Reef	1	-	-	38.0	-	-
	Ashmore Reef	-	-	-	-	-	-
	Cartier Island	-	-	-	-	-	-
CMR	Arafura CMR	-	-	-	-	-	-
	Oceanic Shoals CMR	23	13	6	4.8	4.8	5.7
	Ashmore Reef CMR	-	-	-	-	-	-
	Cartier Island CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	23	6	2	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	22	5	2	1.7	1.8	2.0
	Pinnacles of the Bonaparte Basin	8	1	-	13.6	14.3	
	Carbonate bank and terrace system of Sahul Shelf	3	1	-	26.3	28.6	
Fishery	Timor Reef Fishery (NT Managed)	24	3	2	0.04	0.04	0.04

Table 22 Probability and minimum time before dissolved aromatic hydrocarbon exposure for receptors assessed (2,975 m³ MDO)

Summer conditions (December to February)							
Receptor		Probability of exposure to dissolved aromatic concentrations at specific receptor depth (%)			Minimum time to dissolved aromatic concentration at any depth (days)		
		6 ppb	50 ppb	400 ppb	6 ppb	50 ppb	400 ppb
Submerged receptor	Sunset Shoal	-	-	-	-	-	-
	Loxton Shoal	-	-	-	-	-	-
	Martin Shoal	-	-	-	-	-	-
	Sunrise Bank	-	-	-	-	-	-
	Flinders Shoal	-	-	-	-	-	-
	Evans Shoal	-	-	-		-	-
	Tassie Shoal	-	-	-	-	-	-
	Franklin Shoal	-	-	-	-	-	-
	Blackwood Shoal	-	-	-	-	-	-
	Lynedoch Bank	1	-	-	15.5	-	-
	Margaret Harries Bank	1	-	-	29.8	-	-
	Bellona Bank	-	-	-	-	-	-
	Echo Shoals	-	-	-	-	-	-
	Money Shoal	-	-	-	-	-	-
	Troubadour Shoals	1	-	-	32.2	-	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
	Cootamundra Shoal	-	-	-	-	-	-
	Calder Shoal	-	-	-	-	-	-
	Sahul Bank	-	-	-	-	-	-
	Dillon Shoal	-	-	-	-	-	-
	Barton Shoal	-	-	-	-	-	-
	Fantome Shoal	-	-	-	-	-	-
	Mangola Shoal	-	-	-	-	-	-
	Jabiru Shoals	-	-	-	-	-	-
	Pee Shoal	-	-	-	-	-	-
	Vee Shoal	-	-	-	-	-	-

	Johnson Bank	-	-	-	-	-	-
	Woodbine Bank	-	-	-	-	-	-
	Barracouta Shoal	-	-	-	-	-	-
Emergent receptor	Indonesia	-	-	-		-	-
	East Timor	-	-	-	-	-	-
	Hibernia Reef	-	-	-	-	-	-
	Ashmore Reef	-	-	-	-	-	-
	Cartier Island	-	-	-	-	-	-
CMR	Arafura CMR	2	-	-	18.2	-	-
	Oceanic Shoals CMR	7	1	-	3.2	3.7	-
	Ashmore Reef CMR	-	-	-	-	-	-
	Cartier Island CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	3	-	-	30.0	-	-
	Shelf break and slope of the Arafura Shelf	14	2	-	0.04	0.09	-
	Carbonate bank and terrace system of Van Diemen Rise	1	-	-	9.0	-	-
	Pinnacles of the Bonaparte Basin	-	-	-	-	-	-
	Carbonate bank and terrace system of Sahul Shelf	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	14	2	-	0.04	0.09	-

Transitional conditions (March and September to November)							
Receptor		Probability of exposure to dissolved aromatic concentrations at specific receptor depth (%)			Minimum time to dissolved aromatic concentration at any depth (days)		
		6 ppb	50 ppb	400 ppb	6 ppb	50 ppb	400 ppb
Submerged receptor	Sunset Shoal	2	-	-	18.2	-	-
	Loxton Shoal	3	-	-	7.8	-	-
	Martin Shoal	-	-	-		-	-
	Sunrise Bank	1	-	-	21.1	-	-
	Flinders Shoal	2	-	-	4.3	-	-
	Evans Shoal	4	1	-	2.8	3.0	-
	Tassie Shoal	5	1	-	2.3	4.8	-
	Franklin Shoal	2	-	-	4.4	-	-
	Blackwood Shoal	1	-	-	10.3	-	-

	Lynedoch Bank	2	-	-	7.1	-	-
	Margaret Harries Bank	1	-	-	10.2	-	-
	Bellona Bank	-	-	-		-	-
	Echo Shoals	-	-	-		-	-
	Money Shoal	-	-	-	-	-	-
	Troubadour Shoals	4	1	-	9.3	12.3	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
	Cootamundra Shoal	-	-	-	-	-	-
	Calder Shoal	-	-	-	-	-	-
	Sahul Bank	-	-	-	-	-	-
	Dillon Shoal	-	-	-	-	-	-
	Barton Shoal	-	-	-	-	-	-
	Fantome Shoal	-	-	-	-	-	-
	Mangola Shoal	-	-	-	-	-	-
	Jabiru Shoals	-	-	-	-	-	-
	Pee Shoal	-	-	-	-	-	-
	Vee Shoal	-	-	-	-	-	-
	Johnson Bank	-	-	-	-	-	-
	Woodbine Bank	-	-	-	-	-	-
	Barracouta Shoal	-	-	-	-	-	-
Emergent receptor	Indonesia	1	-	-	21.3	-	-
	East Timor	-	-	-	-	-	-
	Hibernia Reef	-	-	-	-	-	-
	Ashmore Reef	-	-	-	-	-	-
	Cartier Island	-	-	-	-	-	-
CMR	Arafura CMR	-	-	-	-	-	-
	Oceanic Shoals CMR	3	1	-	6.2	7.0	-
	Ashmore Reef CMR	-	-	-	-	-	-
	Cartier Island CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-

	Shelf break and slope of the Arafura Shelf	11	2	-	0.04	0.06	-
	Carbonate bank and terrace system of Van Diemen Rise	7	-	-	2.3	-	-
	Pinnacles of the Bonaparte Basin	3	-	-	14.3	-	-
	Carbonate bank and terrace system of Sahul Shelf	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	11	2	-	0.04	0.06	-
Winter conditions (April to August)							
Receptor		**Probability of exposure to dissolved aromatic concentrations at specific receptor depth (%)**			**Minimum time to dissolved aromatic concentration at any depth (days)**		
		6 ppb	**50 ppb**	**400 ppb**	**6 ppb**	**50 ppb**	**400 ppb**
Submerged receptor	Sunset Shoal	7	1	-	5.0	6.3	-
	Loxton Shoal	7	1	-	4.5	7.3	-
	Martin Shoal	5	1	-	4.1	4.2	-
	Sunrise Bank	2	-	-	9.5	-	-
	Flinders Shoal	10	1	-	3.4	4.8	-
	Evans Shoal	18	2	-	2.5	2.6	-
	Tassie Shoal	5	1	-	5.6	7.9	-
	Franklin Shoal	14	1	-	3.4	3.8	-
	Blackwood Shoal	15	1	-	3.3	5.6	-
	Lynedoch Bank	-	-	-	-	-	-
	Margaret Harries Bank	2	1	-	11.4	12.4	-
	Bellona Bank	2	-	-	23.6	-	-
	Echo Shoals	3	-	-	16.7	-	-
	Money Shoal	-	-	-	-	-	-
	Troubadour Shoals	8	-	-	7.2	-	-
	Big Bank Shoals	1	-	-	22.7	-	-
	Karmt Shoal	3	-	-	21.0	-	-
	Cootamundra Shoal	-	-	-	-	-	-
	Calder Shoal	-	-	-	-	-	-
	Sahul Bank	2	-	-	24.9	-	-
	Dillon Shoal	1	-	-	31.0	-	-
	Barton Shoal	-	-	-	-	-	-

	Fantome Shoal	-	-	-	-	-	-
	Mangola Shoal	-	-	-	-	-	-
	Jabiru Shoals	-	-	-	-	-	-
	Pee Shoal	-	-	-	-	-	-
	Vee Shoal	-	-	-	-	-	-
	Johnson Bank	-	-	-	-	-	-
	Woodbine Bank	-	-	-	-	-	-
	Barracouta Shoal	-	-	-	-	-	-
Emergent receptor	Indonesia	1	-	-	30.9	-	-
	East Timor	-	-	-	-	-	-
	Hibernia Reef	-	-	-	-	-	-
	Ashmore Reef	-	-	-	-	-	-
	Cartier Island	-	-	-	-	-	-
CMR	Arafura CMR	-	-	-	-	-	-
	Oceanic Shoals CMR	3	1	-	6.6	8.7	-
	Ashmore Reef CMR	-	-	-	-	-	-
	Cartier Island CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	18	4	-	0.04	0.04	-
	Carbonate bank and terrace system of Van Diemen Rise	8	1	-	2.2	2.2	-
	Pinnacles of the Bonaparte Basin	2	-	-	21.7	-	-
	Carbonate bank and terrace system of Sahul Shelf	2	-	-	28.3	-	-
Fishery	Timor Reef Fishery (NT Managed)	18	4	-	0.04	0.04	-

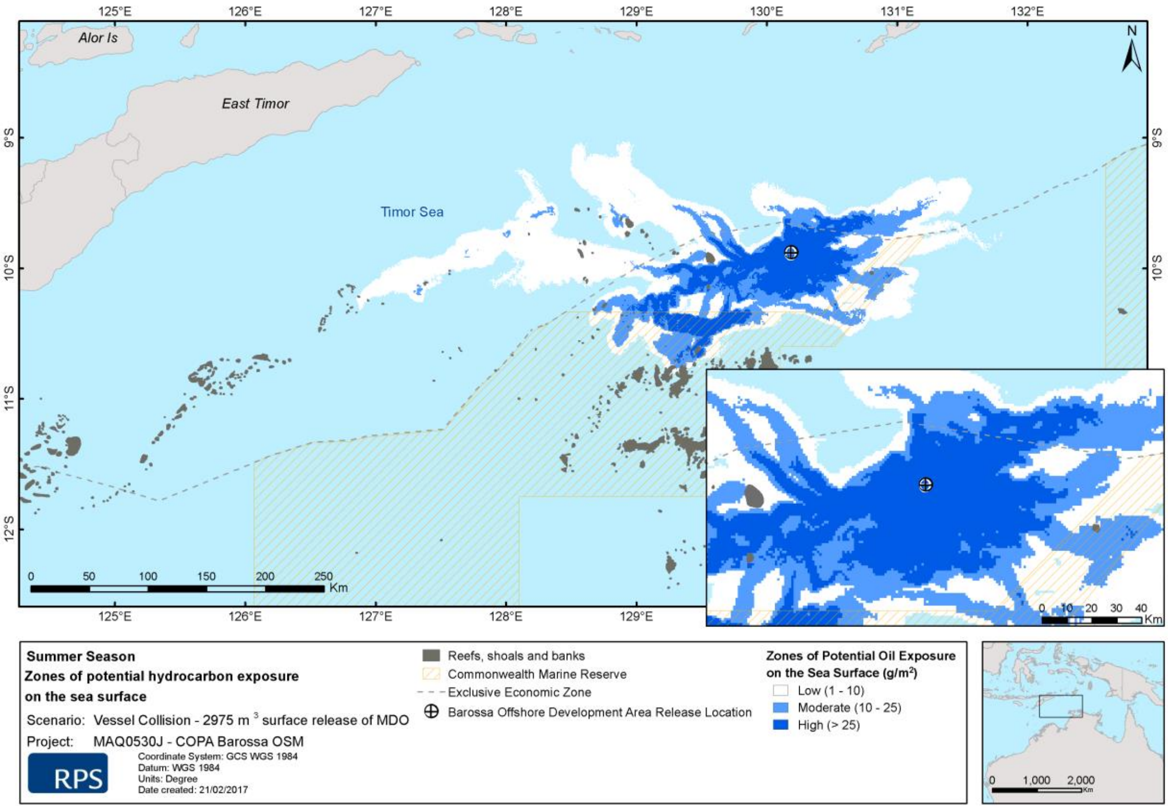


Figure 49 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during summer conditions (2,975 m^3 MDO)

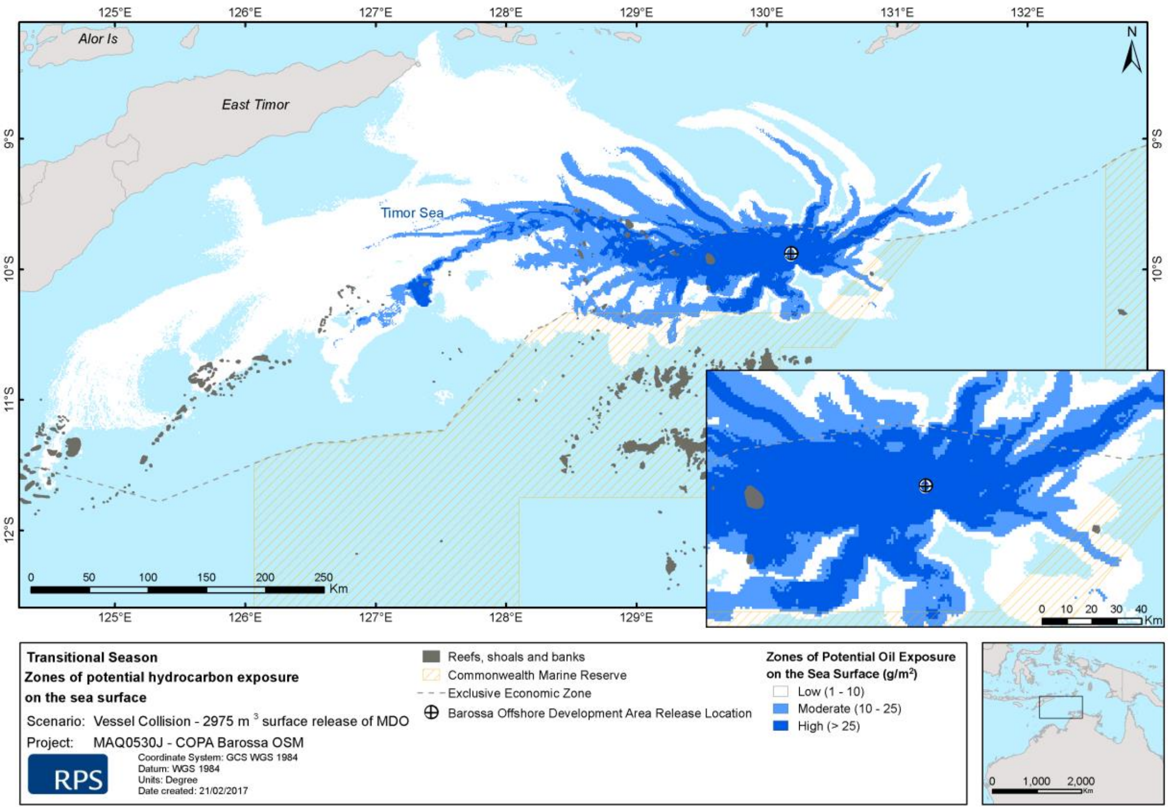


Figure 50 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during transitional conditions (2,975 m^3 MDO)

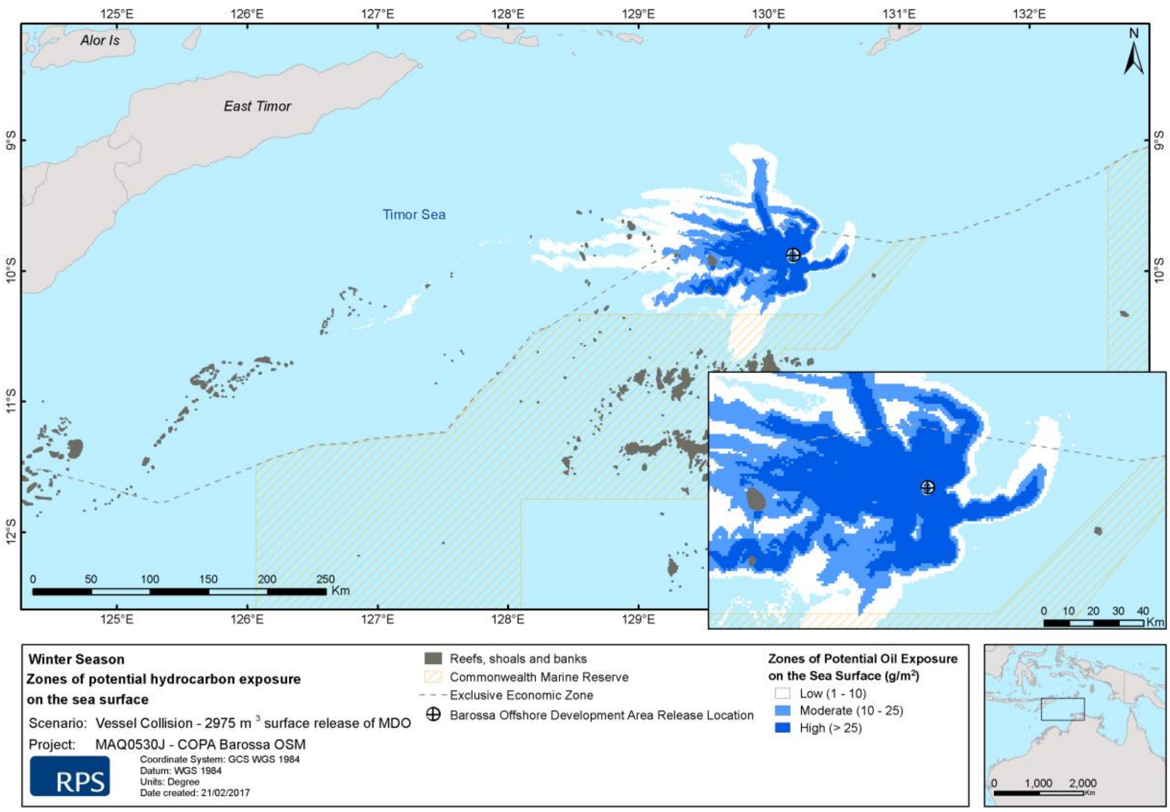


Figure 51 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during winter conditions (2,975 m³ MDO)

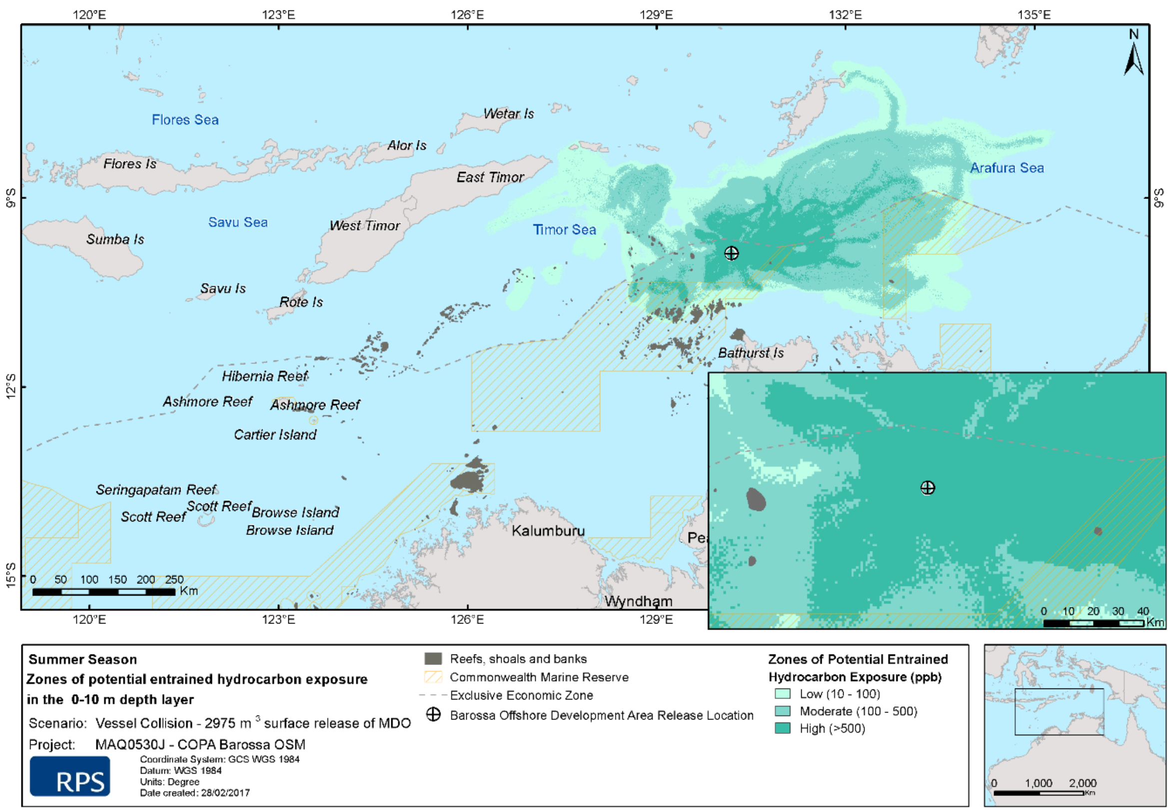


Figure 52 Stochastic modelling outputs showing the potential entrained hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during summer conditions (2,975 m³ MDO)

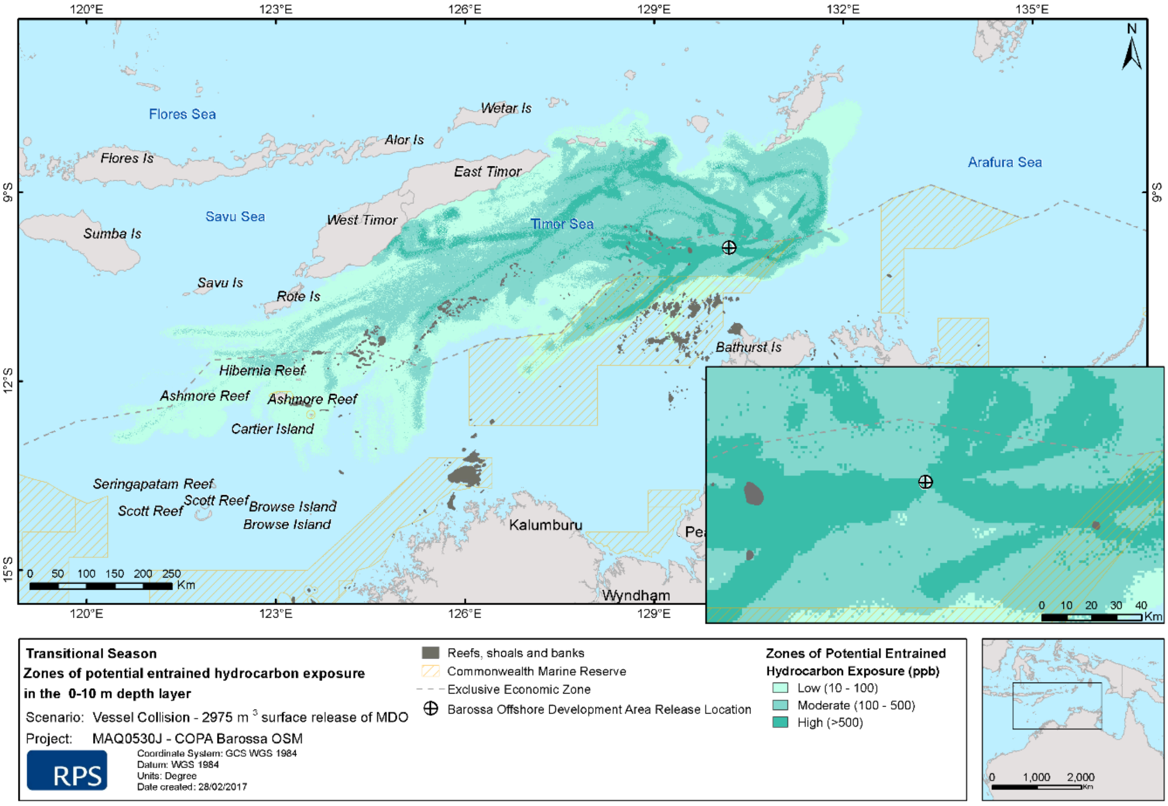


Figure 53 Stochastic modelling outputs showing the potential entrained hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during transitional conditions (2,975 m^3 MDO)

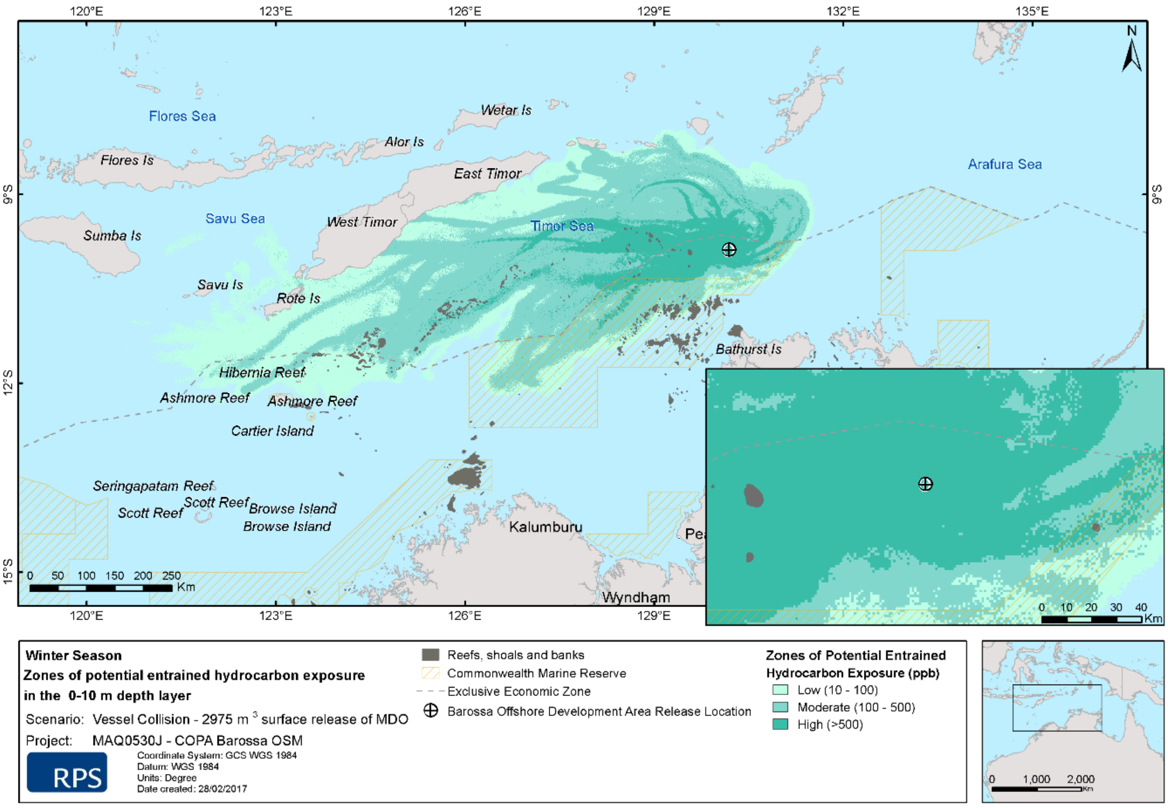


Figure 54 Stochastic modelling outputs showing the potential entrained hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during winter conditions (2,975 m^3 MDO)

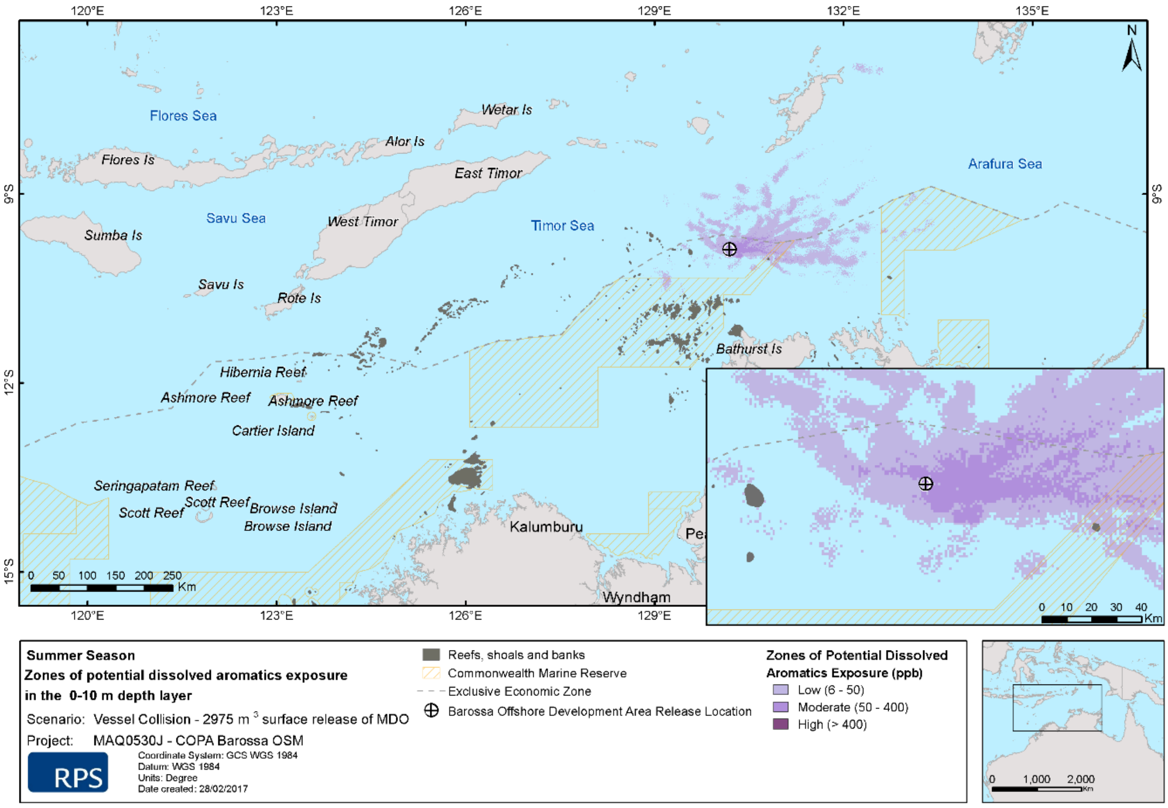


Figure 55 Stochastic modelling outputs showing the potential dissolved aromatic hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during summer conditions (2,975 m^3 MDO)

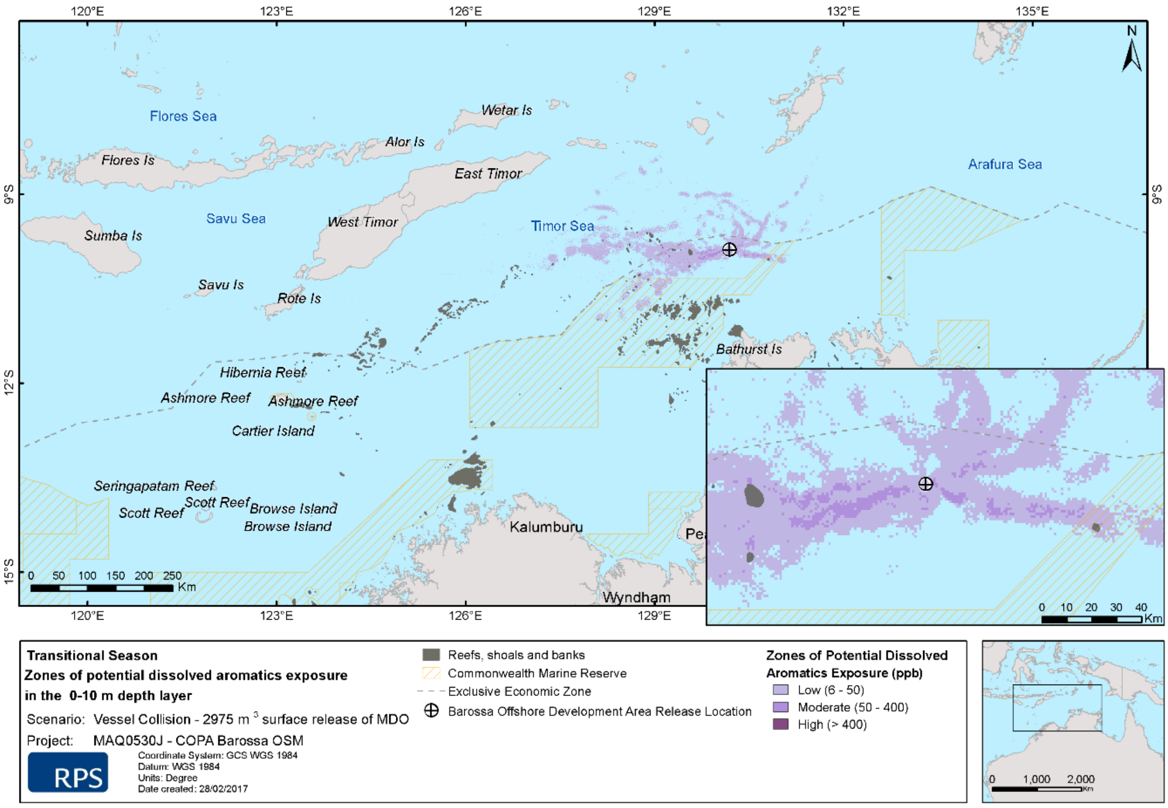


Figure 56 Stochastic modelling outputs showing the potential dissolved aromatic hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during transitional conditions (2,975 m^3 MDO)

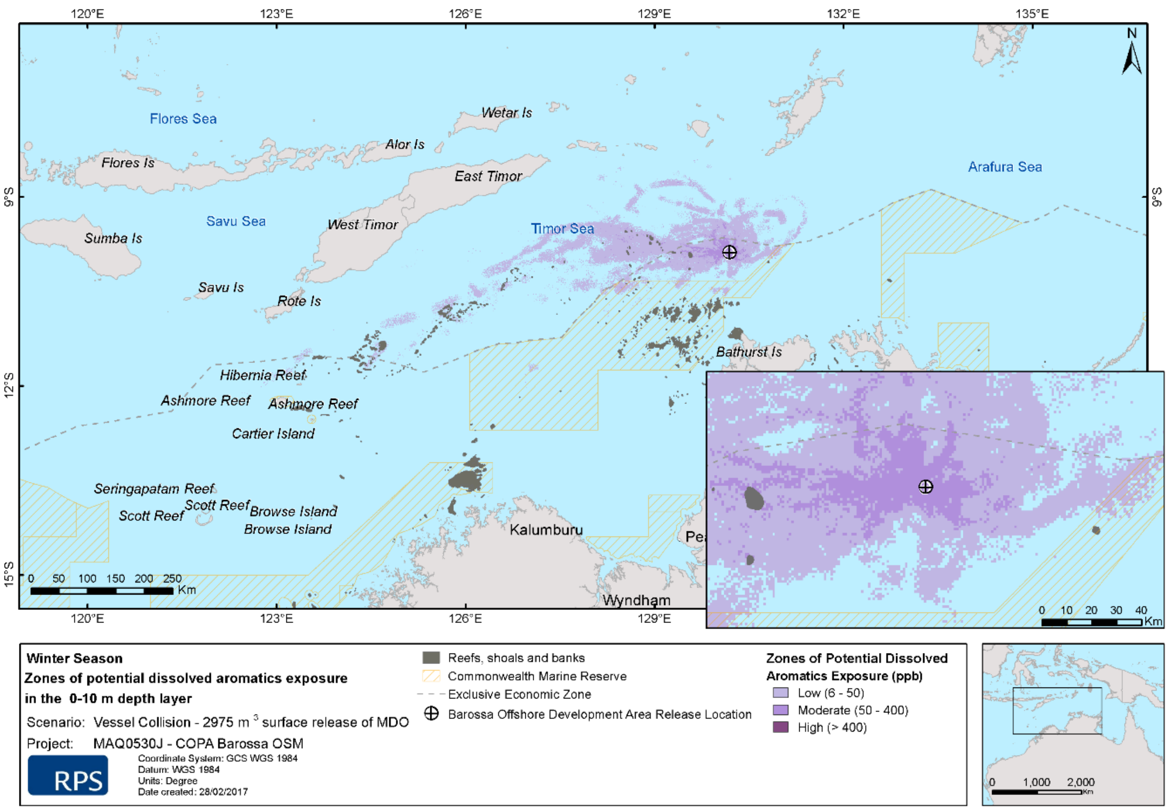


Figure 57 Stochastic modelling outputs showing the potential dissolved aromatic hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during summer conditions (2,975 m^3 MDO)

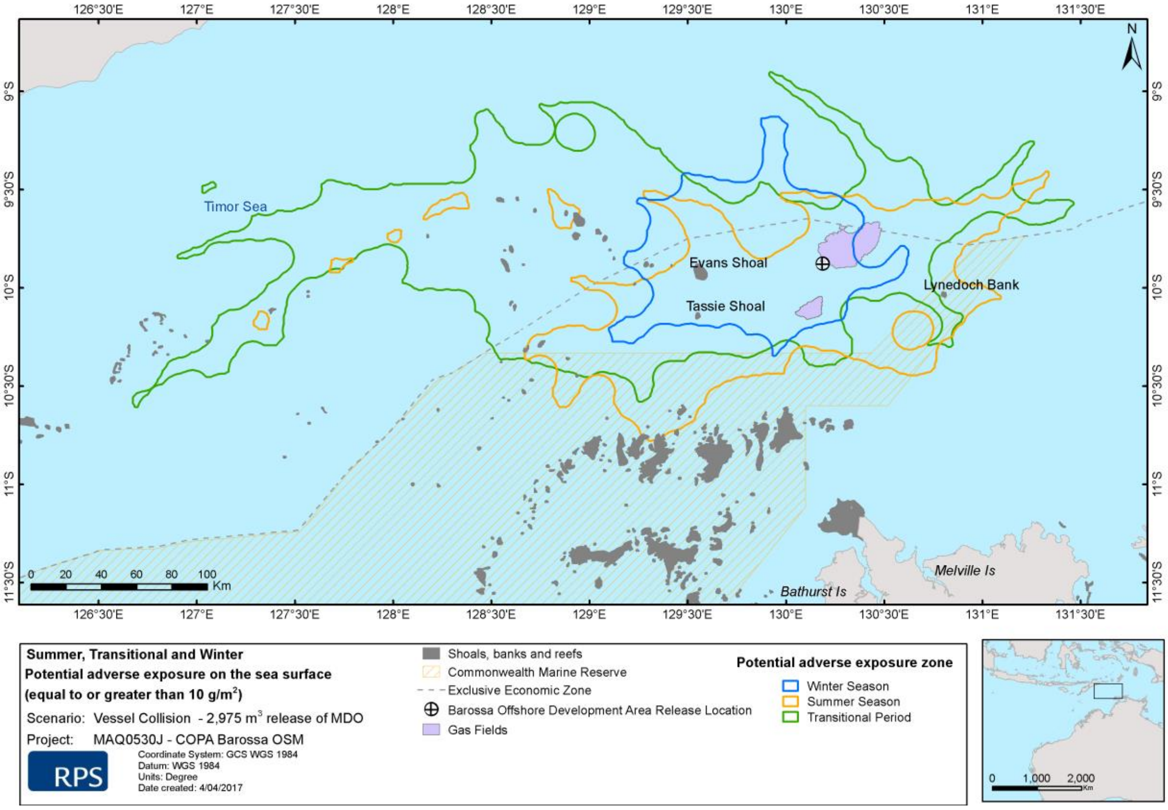


Figure 58 Stochastic modelling outputs showing the potential adverse exposure zone on the sea surface from a vessel collision releasing MDO (2,975 m^3)

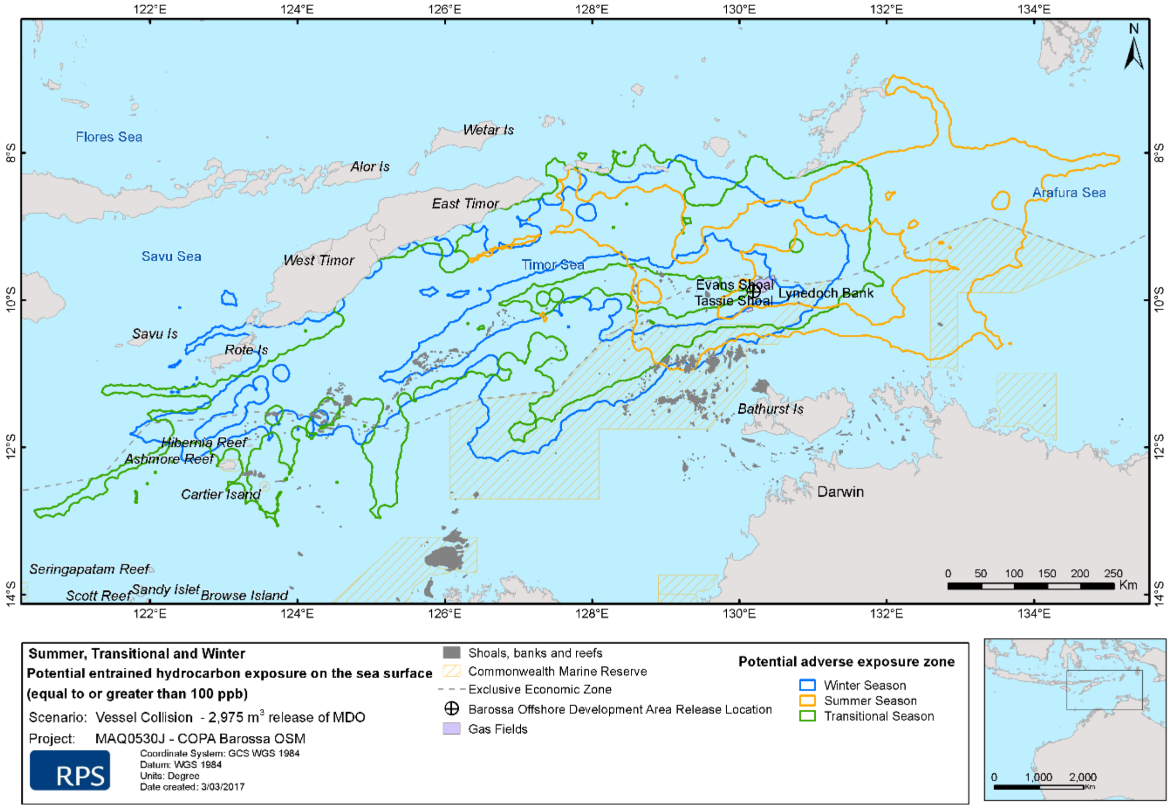


Figure 59 Stochastic modelling outputs showing the potential adverse exposure zone (0-10 m depth layer) for entrained hydrocarbons from a vessel collision releasing MDO (2,975 m^3)

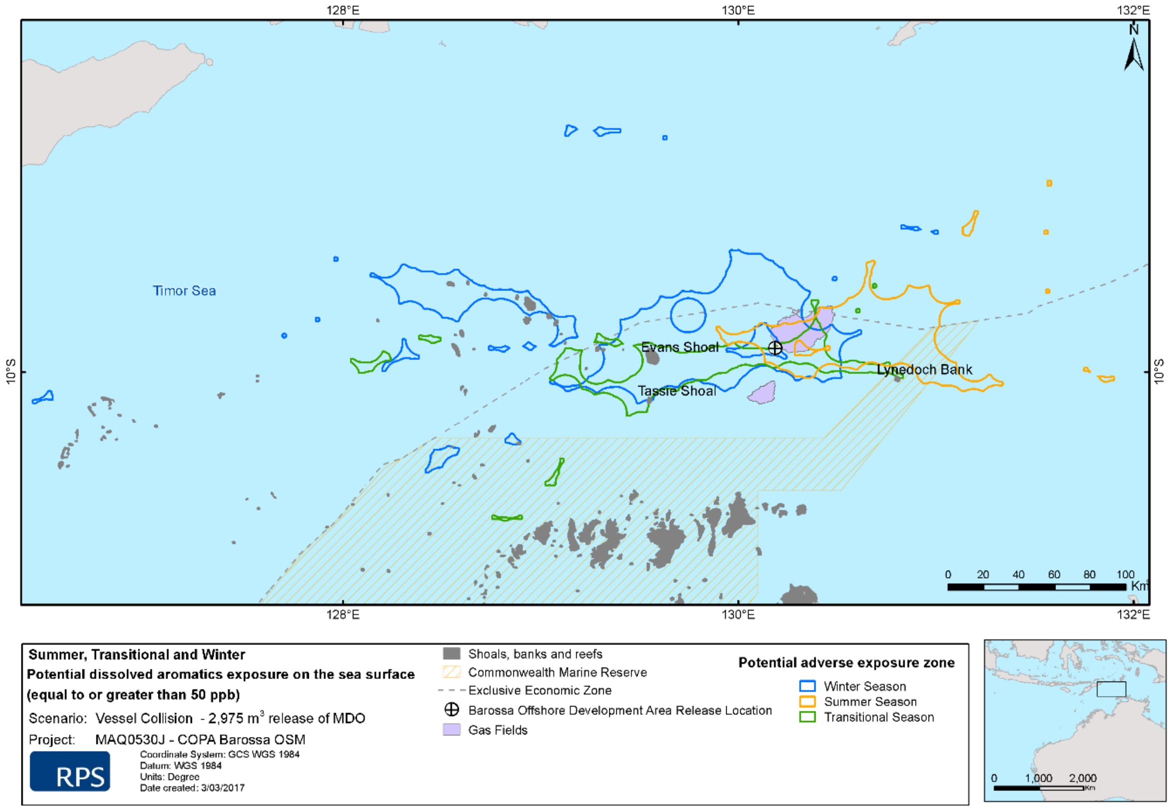


Figure 60 Stochastic modelling outputs showing the potential adverse exposure zone (0-10 m depth layer) for dissolved aromatic hydrocarbons from a vessel collision releasing MDO (2,975 m^3)

3.3 Scenario 3: Vessel collision leading to loss of a single FPSO facility condensate storage tank (19,400 m^3 Barossa condensate)

3.3.1 Single trajectory

Figure 61 shows the potential sea surface hydrocarbon exposure zones over the entire 40 day model simulation. The spill starting at 8 pm 25th June 2014 was used an example trajectory to illustrate the potential exposure by entrained and dissolved aromatic hydrocarbons to nearby shoals/banks during the winter season.

Figure 62 and Figure 63 display the potential dissolved aromatic and entrained hydrocarbon exposure zones, respectively.

Condensate on the sea surface was predicted to drift west of the release location, with low condensate exposure diverting northwest for a brief period before falling below the minimum reporting threshold. Low condensate sea surface exposure was predicted up to 264 km away, whereas moderate exposure was observed a maximum of 49 km from the release location. The entrained and dissolved aromatic hydrocarbons were shown to travel in more variable directions, as they moved with ocean currents. Low, moderate and high entrained hydrocarbons were recorded up to 707 km, 441 km and 60 km, respectively, from the release location. Low, moderate and high dissolved aromatics were observed up to 274 km, 250 km and 30 km, respectively, from the release location.

Figure 64 illustrates the fates and weathering graph for the corresponding winter spill trajectory. The graph demonstrates that the condensate rapidly evaporates and by day 5 approximately 83% of the total spill volume (16,199 m^3) had evaporated. At the end of the simulation (day 40) approximately 88% (17,005 m^3) had evaporated, 4% (818 m^3) remained entrained in the water column and 8% (1,511 m^3) had decayed.

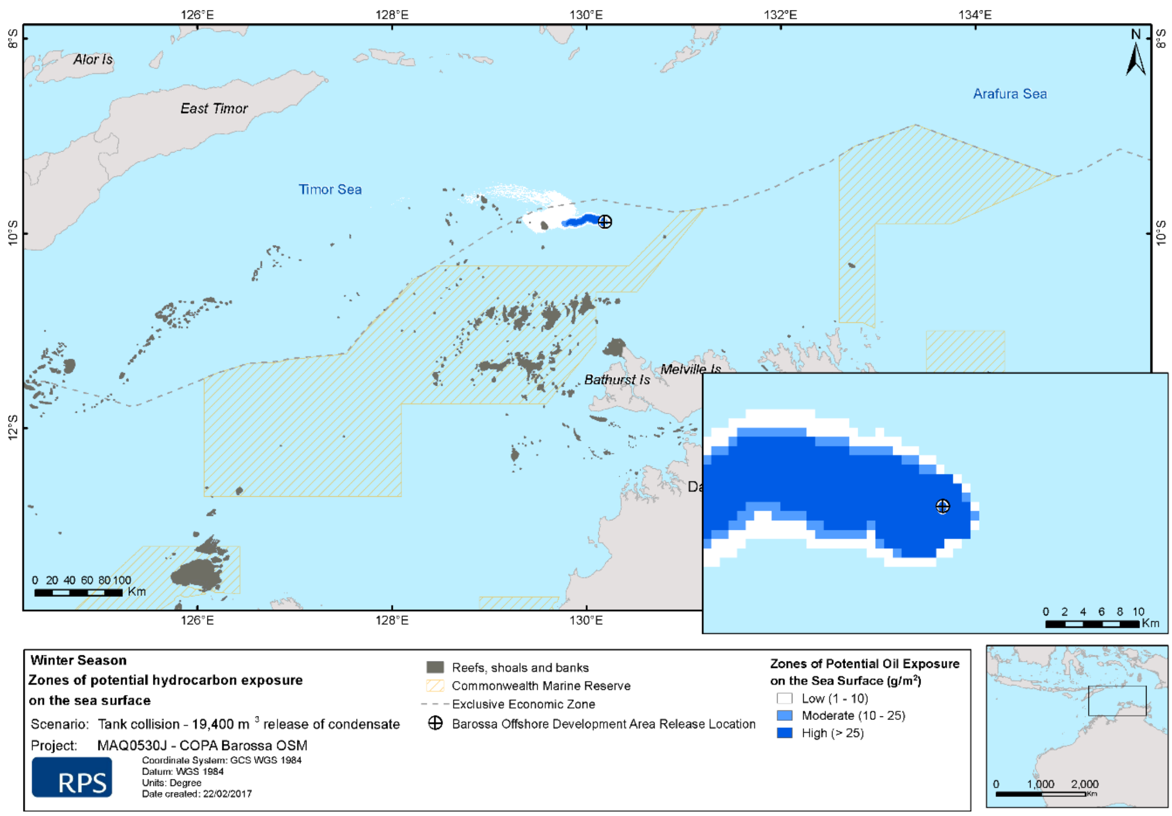


Figure 61 Single spill trajectory outputs showing the potential sea surface exposure zones (19,400 m^3 Barossa condensate)

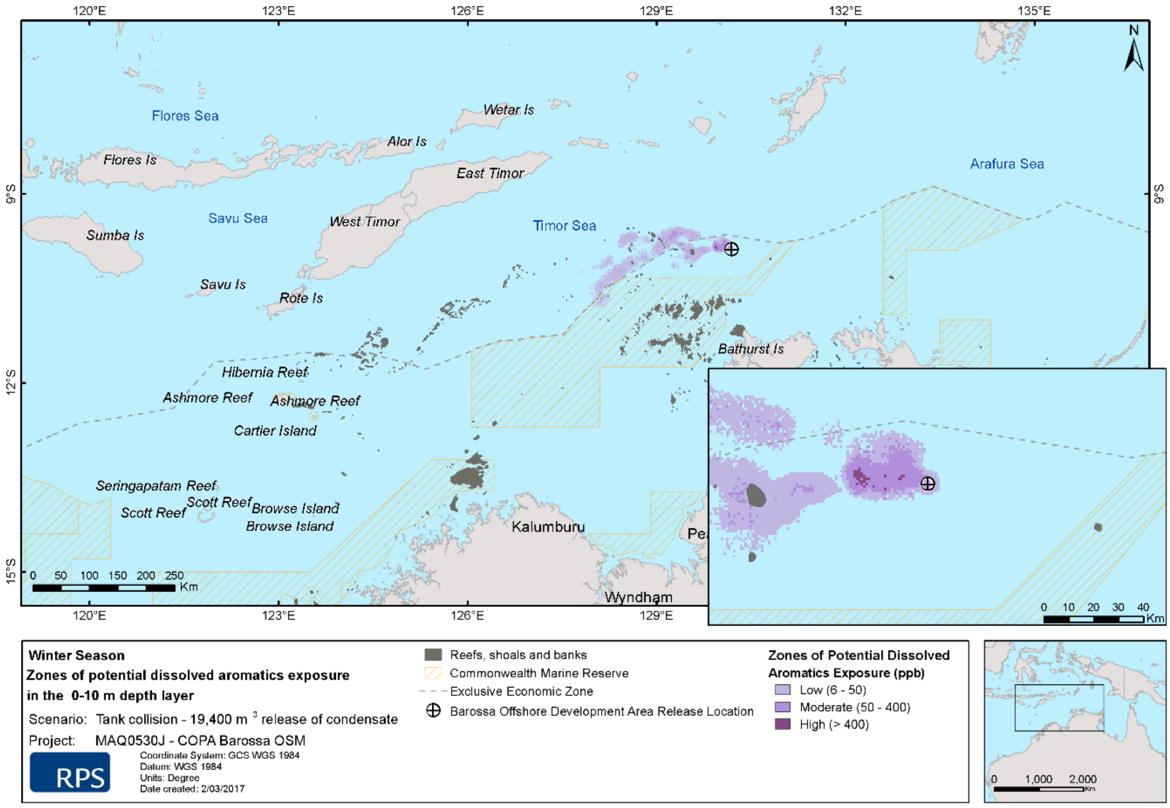


Figure 62 Single spill trajectory outputs showing the potential entrained exposure zones (19,400 m^3 Barossa condensate)

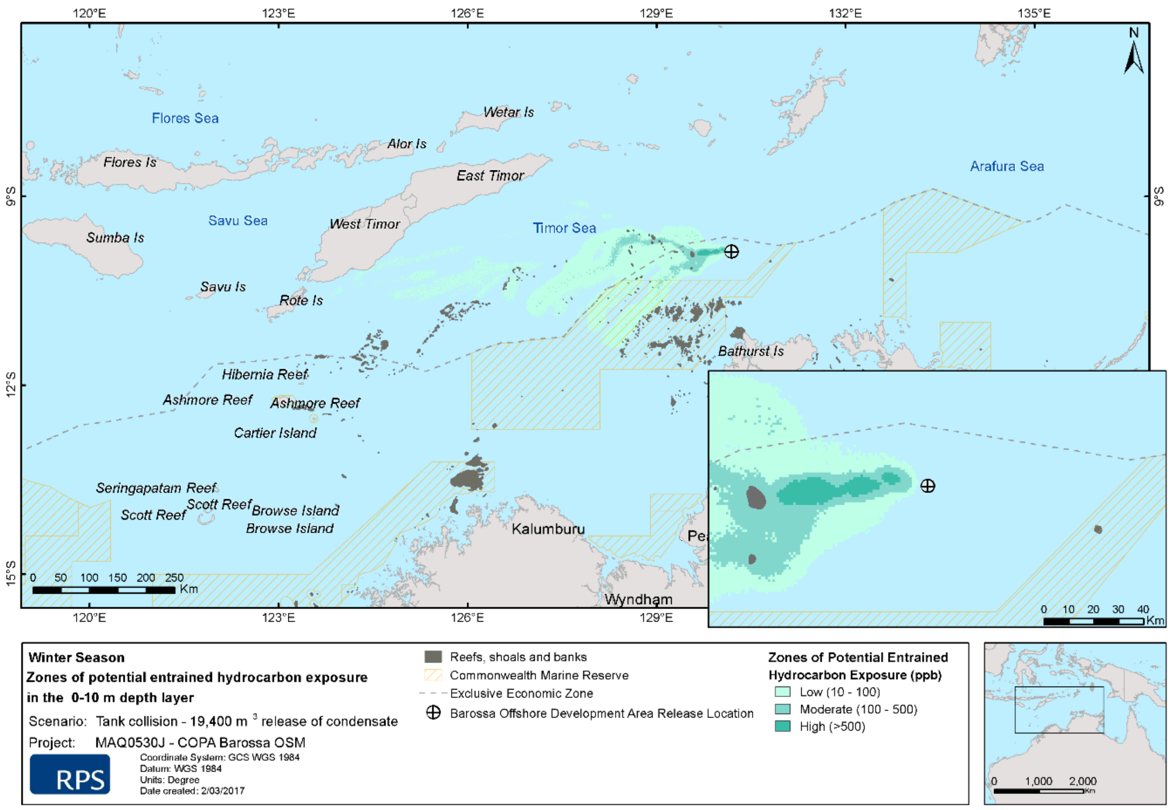


Figure 63 Single spill trajectory outputs showing the potential dissolved aromatic exposure zones (19,400 m^3 Barossa condensate)

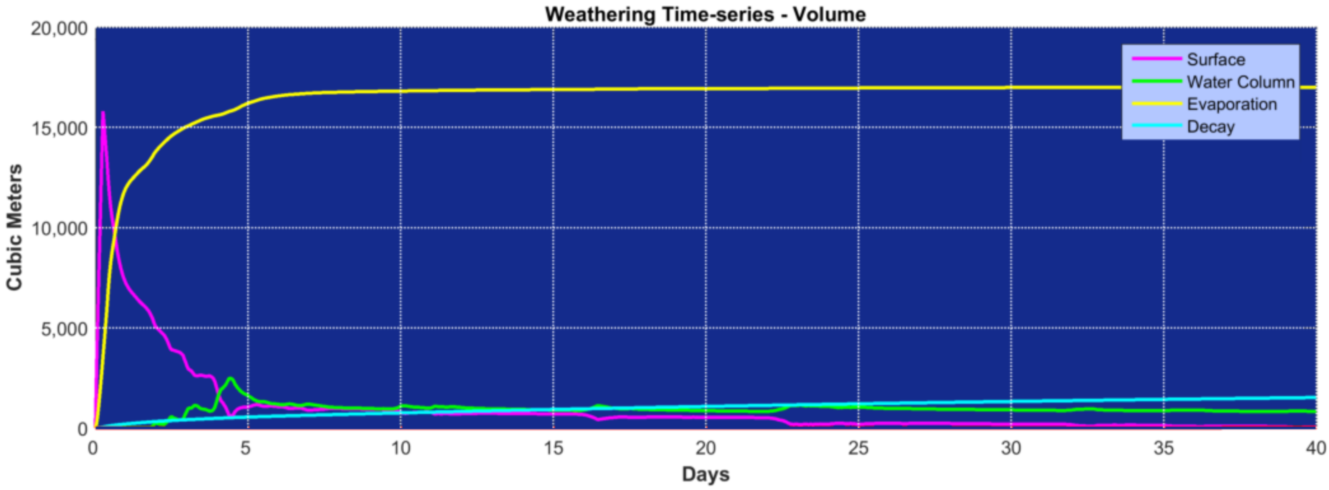


Figure 64 Predicted weathering and fates graph for the example spill trajectory from a 19,400 m^3 surface release of Barossa condensate from a storage tank rupture (tracked for 40 days)

3.3.2 Stochastic modelling

In summary, the stochastic modelling results showed:

- during summer, the released hydrocarbons tended to initially travel east of the release location before travelling in variable directions, whereas during the transitional and winter seasons hydrocarbons were directed more towards the west. Weaker wind speeds during the transitional season resulted in less entrainment, consequently spills during this season travelled greater distances on the sea surface.
- the maximum distance for the sea surface adverse exposure zone is predicted to vary between seasons with approximately 320 km, 560 km and 303 km during summer, transitional and winter conditions, respectively (Table 23)
- contact was predicted (1–13% probability) by sea surface films within the adverse exposure zone with the surface waters above a number of submerged shoals/banks (total of 14), KEFs of the carbonate bank and terrace system of Van Diemen Rise and pinnacles of the Bonaparte Basin, and the open waters of the Oceanic Shoals CMR, depending on the season (Table 24).
- Figure 65 to Figure 67 shows the potential sea surface exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 74 shows the potential sea surface adverse exposure zone for all seasons.
- during summer conditions, the surface waters above Tassie Shoal recorded the highest probability of contact for submerged receptors with the sea surface adverse exposure zone (7%) while during transitional and winter conditions the waters above Evans Shoal was predicted to have the highest probability of contact with the sea surface adverse exposure zone (13% and 4% respectively). The Oceanic Shoals CMR and carbonate bank and terrace system of Van Diemen Rise had contact probabilities of 5-6% and 2-6%, respectively, dependant on season.
- contact by the sea surface adverse exposure zone with the waters above the KEF of the shelf break and slope of the Arafura Shelf (a unique seafloor feature) and open waters of the Timor Reef Fishery was predicted in all seasons as the Barossa offshore development area is located within the bounds of these features (Table 24).
- no residual hydrocarbons were predicted to accumulate on any shoreline in any season to levels that may affect sensitive receptors onshore.
- contact was predicted (1–7% probability) by entrained hydrocarbons within the adverse exposure zone for various submerged shoals/banks (total of 24), Cartier Island, open waters of the Arafura, Ashmore Reef, Oceanic Shoals and Cartier Island CMRs, waters above the KEFs of the shelf break and slope of the Arafura

Shelf and tributary canyons of the Arafura Depression and waters of the Timor Reef Fishery, depending on the season (Table 25). Figure 52 to Figure 54 shows the potential entrained hydrocarbon exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 59 shows the potential sea surface adverse exposure zone for all seasons.

- during transitional and winter conditions, Evans Shoal recorded the highest probability of contact for submerged receptors with the entrained adverse exposure zone (14% and 27% respectively). During summer conditions probabilities did not extend beyond 1% for submerged receptors.
- contact was predicted (1–36% probability) by dissolved aromatic hydrocarbons within the adverse exposure zone for various submerged shoals/banks (total of 23), open waters of the Arafura and Ocean Shoals CMRs, waters above the KEFs of the shelf break and slope of the Arafura Shelf, and carbonate bank and terrace system of Van Diemen Rise, and waters of the Timor Reef Fishery, depending on the season (Table 26 and Figure 76). Figure 71 to Figure 73 show the potential dissolved aromatic hydrocarbon exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 76 shows the potential sea surface adverse exposure zone for all seasons.
- during summer, transitional and winter conditions, Evans Shoal recorded the highest probability of contact with the dissolved aromatics adverse exposure zone for submerged receptors (8%, 18% and 36% respectively).
- no contact with the adverse exposure zone for sea surface or sub-surface hydrocarbons was predicted with the NT/WA coastline or adjacent islands (Table 24 to Table 26).

Table 23 Maximum distances (and direction) from the release location to zones of potential sea surface exposure for each season (19,400 m^3 Barossa condensate)

Season	Distance and direction	Sea surface exposure thresholds		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Summer	Maximum distance travelled (km) by a spill trajectory	393.6	319.6	317.7
	Direction	West-southwest	West	West
Transitional	Maximum distance travelled (km) by a spill trajectory	857.6	559.8	402.5
	Direction	West	West	West
Winter	Maximum distance travelled (km) by a spill trajectory	813.8	302.5	300.8
	Direction	West	West-southwest	West-southwest

Table 24 Probability and minimum time before hydrocarbon exposure on the sea surface for receptors assessed (19,400 m³ Barossa condensate)

Summer conditions (December to February)							
Receptor		Maximum probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)	Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)
Submerged receptor	Sunset Shoal	-	-	-	-	-	-
	Loxton Shoal	2	-	-	17.2	-	-
	Martin Shoal	2	2	-	10.1	11.3	-
	Sunrise Bank	1	1	-	11.8	12.9	-
	Troubadour Shoals	1	1	1	7.9	8.1	8.6
	Flinders Shoal	1	-	-	10.4	-	-
	Evans Shoal	10	4	2	2.5	2.5	2.6
	Tassie Shoal	10	7	6	6.3	6.5	6.5
	Franklin Shoal	1	1	-	10.4	10.5	-
	Blackwood Shoal	3	1	-	1.0	10.4	-
	Lynedoch Bank	12	3	-	3.0	7.0	-
	Margaret Harries Bank	2	2	-	28.2	28.3	-
	Bellona Bank	1	1	-	31.0	35.3	-
	Echo Shoals	1	-	-	35.4	-	-
	Money Shoal	-	-	-	-	-	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
	Cootamundra Shoal	6	-	-	13.0	-	-
	Calder Shoal	4	-	-	14.7	-	-
	Sahul Bank	-	-	-	-	-	-
	Dillon Shoal	-	-	-	-	-	-
Emergent receptor	Indonesia	-	-	-	-	-	-
	East Timor	-	-	-	-	-	-
	Ashmore Reef	-	-	-	-	-	-
CMR	Arafura CMR	1	-	-	23.5	-	-
	Oceanic Shoals CMR	18	6	4	2.2	3.8	4.0

	Ashmore Reef CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	100	100	100	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	13	4	4	2.4	2.5	2.5
	Pinnacles of the Bonaparte Basin	2	-	-	30.0	-	-
	Continental slope demersal fish communities	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.04	0.04	0.04

Transitional conditions (March and September to November)							
Receptor		Maximum probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)	Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Submerged receptor	Sunset Shoal	12	5	-	6.3	6.4	-
	Loxton Shoal	11	1	-	5.7	5.8	-
	Martin Shoal	10	3	-	5.4	7.4	-
	Sunrise Bank	7	3	-	10.0	27.3	-
	Troubadour Shoals	11	6	-	6.0	6.3	-
	Flinders Shoal	18	6	-	3.0	3.1	-
	Evans Shoal	28	13	5	1.6	1.8	2.3
	Tassie Shoal	7	4	-	3.4	3.4	-
	Franklin Shoal	19	8	-	3.0	3.1	-
	Blackwood Shoal	14	5	-	2.9	3.7	-
	Lynedoch Bank	2	-	-	5.7	-	-
	Margaret Harries Bank	11	3	-	7.7	8.7	-
	Bellona Bank	11	1	-	15.7	28.1	-
	Echo Shoals	9	5	-	14.8	16.8	-
	Money Shoal	-	-	-	-	-	-
	Big Bank Shoals	3	-	-	17.5	-	-
	Karmt Shoal	4	-	-	16.9	-	-
	Cootamundra Shoal	1	-	-	30.8	-	-
	Calder Shoal	1	-	-	32.8	-	-

	Sahul Bank	3	-	-	19.5	-	-
	Dillon Shoal	2	-	-	26.0	-	-
Emergent receptor	Indonesia	1	-	-	20.1	-	-
	East Timor	1	-	-	22.3	-	-
	Ashmore Reef	1	-	-	32.0	-	-
CMR	Arafura CMR	-	-	-	-	-	-
	Oceanic Shoals CMR	13	5	2	3.8	4.1	4.8
	Ashmore Reef CMR	2	-	-	32.0	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	100	100	100	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	9	2	1	2.0	2.2	2.4
	Pinnacles of the Bonaparte Basin	6	1	-	10.0	13.8	-
	Continental slope demersal fish communities	2	-	-	30.3	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.04	0.04	0.04
Winter conditions (April to August)							
Receptor		**Maximum probability of hydrocarbon exposure on the sea surface (%)**			**Minimum time before receptor exposed to hydrocarbons on the sea surface (days)**		
		Low (1–10 g/m²)	**Moderate (10–25 g/m²)**	**High (>25 g/m²)**	**Low (1–10 g/m²)**	**Moderate (10–25 g/m²)**	**High (>25 g/m²)**
Submerged receptor	Sunset Shoal	2	-	-	7.0	-	-
	Loxton Shoal	3	-	-	6.3	-	-
	Martin Shoal	3	-	-	6.2	-	-
	Sunrise Bank	2	-	-	9.0	-	-
	Troubadour Shoals	5	-	-	7.1	-	-
	Flinders Shoal	5	1	-	3.8	8.2	-
	Evans Shoal	10	4	2	2.3	2.5	4.3
	Tassie Shoal	5	2	1	2.5	2.5	4.3
	Franklin Shoal	5	1	-	3.8	8.3	-
	Blackwood Shoal	5	0	-	3.2	-	-
	Lynedoch Bank	1	1	-	5.0	5.3	-
	Margaret Harries Bank	4	-	-	9.0	-	-

	Bellona Bank	-	-	-	-	-	-
	Echo Shoals	1	-	-	24.2	-	-
	Money Shoal	-	-	-	-	-	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
	Cootamundra Shoal	-	-	-	-	-	-
	Calder Shoal	-	-	-	-	-	-
	Sahul Bank	-	-	-	-	-	-
	Dillon Shoal	-	-	-	-	-	-
Emergent receptor	Indonesia	1	-	-	24.3	-	-
	East Timor	1	-	-	35.3	-	-
	Ashmore Reef	-	-	-	-	-	-
CMR	Arafura CMR	-	-	-	-	-	-
	Oceanic Shoals CMR	8	5	3	3.7	3.7	3.7
	Ashmore Reef CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	100	100	100	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	9	6	5	1.8	1.8	2.1
	Pinnacles of the Bonaparte Basin	2	1	1	10.8	11.2	-
	Continental slope demersal fish communities	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.04	0.04	0.04

Table 25 Probability and minimum time before entrained hydrocarbon exposure for receptors assessed (19,400 m^3 Barossa condensate)

Summer conditions (December to February)							
Receptor		Probability of exposure to entrained concentrations at specific receptor depth (%)			Minimum time to entrained concentration at any depth [days]		
		10 ppb	100 ppb	500 ppb	10 ppb	100 ppb	500 ppb
Submerged receptor	Sunset Shoal	-	-	-	-	-	-
	Loxton Shoal	1	1	-	13.9	17.6	-
	Martin Shoal	2	1	-	13.0	17.2	-
	Sunrise Bank	-	-	-	-	-	-
	Flinders Shoal	2	1	-	10.3	24.2	-
	Evans Shoal	3	-	-	18.8	-	-
	Tassie Shoal	5	-	-	4.2	-	-
	Franklin Shoal	1	-	-	10.3	-	-
	Blackwood Shoal	2	1	-	10.2	15.2	-
	Lynedoch Bank	35	-	-	2.9	-	-
	Margaret Harries Bank	3	1	-	25.2	29.6	-
	Bellona Bank	-	-	-	-	-	-
	Echo Shoals	-	-	-	-	-	-
	Money Shoal	8	1	-	18.6	19.7	-
	Troubadour Shoals	1	1	-	27.6	31.6	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
	Cootamundra Shoal	1	1	-	15.8	22.1	-
	Calder Shoal	-	-	-	-	-	-
	Britomart Shoal	-	-	-	-	-	-
	Sahul Bank	-	-	-	-	-	-
	Dillon Shoal	-	-	-	-	-	-
	Barton Shoal	-	-	-	-	-	-
	The Boxers	-	-	-	-	-	-
	Fantome Shoal	-	-	-	-	-	-
	Mangola Shoal	-	-	-	-	-	-
	Jabiru Shoals	-	-	-	-	-	-

	Pee Shoal	-	-	-	-	-	-
	Vee Shoal	-	-	-	-	-	-
	Johnson Bank	-	-	-	-	-	-
	Woodbine Bank	-	-	-	-	-	-
Emergent receptor	Indonesia	-	-	-	-	-	-
	East Timor	-	-	-	-	-	-
	Hibernia Reef	-	-	-	-	-	-
	Ashmore Reef	-	-	-	-	-	-
	Cartier Island	1	1	-	13.2	14.5	-
CMR	Arafura CMR	41	15	1	10.3	11.7	17.2
	Oceanic Shoals CMR	49	31	13	1.2	1.4	1.5
	Arnhem CMR	-	-	-	-	-	-
	Ashmore Reef CMR	2	1	-	15.7	16.7	-
	Cartier Island CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	3	-	-	11.7	-	-
	Shelf break and slope of the Arafura Shelf	2	-	-	0.04	-	-
	Carbonate bank and terrace system of Van Diemen Rise	-	-	-	-	-	-
	Continental slope demersal fish communities	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	3	1	-	0.04	0.04	-

Transitional conditions (March and September to November)							
Receptor		Probability of exposure to entrained concentrations at specific receptor depth (%)			Minimum time to entrained concentration at any depth [days]		
		10 ppb	100 ppb	500 ppb	10 ppb	100 ppb	500 ppb
Submerged receptor	Sunset Shoal	16	1	-	9.0	12.3	-
	Loxton Shoal	17	-	-	8.8	-	-
	Martin Shoal	13	-	-	7.7	-	-
	Sunrise Bank	5	1	-	11.5	12.1	-
	Flinders Shoal	37	4	3	2.9	4.1	5.1
	Evans Shoal	38	14	1	1.6	2.0	3.7
	Tassie Shoal	9	1	-	3.3	4.8	-
	Franklin Shoal	27	1	-	2.9	3.4	-

	Blackwood Shoal	27	1	-	2.8	3.3	-
	Lynedoch Bank	11	-	-	4.4	-	-
	Margaret Harries Bank	25	4	-	7.6	8.9	-
	Bellona Bank	15	1	-	17.1	20.2	-
	Echo Shoals	22	2	-	17.5	18.7	-
	Money Shoal	-	-	-	-	-	-
	Troubadour Shoals	31	7	-	6.1	7.4	-
	Big Bank Shoals	9	1	-	21.4	23.4	-
	Karmt Shoal	8	1	-	20.2	21.6	-
	Cootamundra Shoal	-	-	-	-	-	-
	Calder Shoal	-	-	-	-	-	-
	Britomart Shoal	3	-	-	29.1	-	-
	Sahul Bank	5	1	-	32.5	36.5	-
	Dillon Shoal	4	-	-	33.5	-	-
	Barton Shoal	-	-	-	-	-	-
	The Boxers	-	-	-	-	-	-
	Fantome Shoal	-	-	-	-	-	-
	Mangola Shoal	-	-	-	-	-	-
	Jabiru Shoals	-	-	-	-	-	-
	Pee Shoal	-	-	-	-	-	-
	Vee Shoal	-	-	-	-	-	-
	Johnson Bank	-	-	-	-	-	-
	Woodbine Bank	1	1	-	21.5	25.1	-
Emergent receptor	Indonesia	2	1	-	31.1	35.4	-
	East Timor	1	1	-	35.4	37.8	-
	Hibernia Reef	1	-	-	38.2	-	-
	Ashmore Reef	-	-	-	-	-	-
	Cartier Island	3	-	-	20.8	-	-
CMR	Arafura CMR	11	2	-	3.6	4.0	-
	Oceanic Shoals CMR	26	11	2	2.1	2.4	3.5
	Arnhem CMR	-	-	-	-	-	-

	Ashmore Reef CMR	-	-	-	-	-	-
	Cartier Island CMR	11	1	-	21.0	23;8	-
KEF	Tributary Canyons of the Arafura Depression	8	2	-	2.1	2.3	-
	Shelf break and slope of the Arafura Shelf	3	1	-	10.2	17.9	-
	Carbonate bank and terrace system of Van Diemen Rise	2	-	-	24.9	-	-
	Continental slope demersal fish communities	1	-	-	36.1	-	-
Fishery	Timor Reef Fishery (NT Managed)	4	2	-	0.04	0.04	-
Winter conditions (April to August)							
Receptor		**Probability of exposure to entrained concentrations at specific receptor depth (%)**			**Minimum time to entrained concentration at any depth [days]**		
		10 ppb	**100 ppb**	**500 ppb**	**10 ppb**	**100 ppb**	**500 ppb**
Submerged receptor	Sunset Shoal	39	12	1	6.9	7.1	7.8
	Loxton Shoal	37	14	1	6.5	7.4	7.8
	Martin Shoal	37	8	1	5.8	6.2	6.5
	Sunrise Bank	24	1	-	9.5	9.7	-
	Flinders Shoal	47	30	7	3.3	3.9	4.2
	Evans Shoal	55	27	9	1.9	2.2	2.8
	Tassie Shoal	36	15	8	2.4	2.5	4.1
	Franklin Shoal	51	19	7	3.1	3.8	4.2
	Blackwood Shoal	51	22	6	2.8	3.1	3.7
	Lynedoch Bank	5	1	-	13.1	14.2	-
	Margaret Harries Bank	19	4	1	7.1	9.4	11.8
	Bellona Bank	19	6	1	14.3	15.3	17.3
	Echo Shoals	36	8	1	14.2	14.8	16.7
	Money Shoal	-	-	-	-	-	-
	Troubadour Shoals	45	14	1	6.1	6.8	7.2
	Big Bank Shoals	18	4	-	18.7	33.9	-
	Karmt Shoal	19	3	-	19.1	19.6	-
	Cootamundra Shoal	1	1	-	30.1	31.6	-
	Calder Shoal	1	1	-	9.4	13.2	-

	Britomart Shoal	-	-	-	-	-	-
	Sahul Bank	22	4	-	23.3	27.5	-
	Dillon Shoal	11	7	-	25.1	26.3	-
	Barton Shoal	9	1	-	34.7	36.8	-
	The Boxers	1	-	-	30.8	-	-
	Fantome Shoal	5	-	-	30.9	-	-
	Mangola Shoal	6	-	-	23.2	-	-
	Jabiru Shoals	6	1	-	24.3	26.8	-
	Pee Shoal	5	-	-	25.3	-	-
	Vee Shoal	1	-	-	33.5	-	-
	Johnson Bank	3	-	-	34.8	-	-
	Woodbine Bank	1	-	-	15.9	-	-
Emergent receptor	Indonesia	12	8	1	14.7	15.2	16.3
	East Timor	8	3	-	23.2	28.5	-
	Hibernia Reef	2	-	-	34.3	-	-
	Ashmore Reef	1	-	-	35.6	-	-
	Cartier Island	1	-	-	37.8	-	-
CMR	Arafura CMR	-	-	-	-	-	-
	Oceanic Shoals CMR	22	14	5	3.5	3.5	3.6
	Arnhem CMR	-	-	-	-	-	-
	Ashmore Reef CMR	1	-	-	35.4	-	-
	Cartier Island CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	4	1	-	0.04	0.04	-
	Carbonate bank and terrace system of Van Diemen Rise	2	-	-	2.4	-	-
	Continental slope demersal fish communities	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	7	2	-	0.04	0.04	-

Table 26 Probability and minimum time before dissolved aromatic hydrocarbon exposure for receptors (19,400 m³ Barossa condensate)

Summer conditions (December to February)							
Receptor		Probability of exposure to dissolved aromatic concentrations at specific receptor depth (%)			Minimum time to dissolved aromatic concentration at any depth (days)		
		6 ppb	50 ppb	400 ppb	6 ppb	50 ppb	400 ppb
Submerged receptor	Sunset Shoal	5	1	-	10.2	18.2	-
	Loxton Shoal	2	1	-	9.1	15.3	-
	Martin Shoal	3	1	-	8.1	8.2	-
	Sunrise Bank	1	-	-	34.4	-	-
	Flinders Shoal	5	2	-	10.1	10.5	-
	Evans Shoal	12	8	-	2.8	8.3	-
	Tassie Shoal	10	4	-	7.0	8.8	-
	Franklin Shoal	4	1	-	10.1	14.1	-
	Blackwood Shoal	5	-	-	9.7	-	-
	Lynedoch Bank	19	4	-	3.2	3.4	-
	Margaret Harries Bank	7	2	-	23.1	24.3	-
	Bellona Bank	1	-	-	36.5	-	-
	Echo Shoals	-	-	-	-	-	-
	Money Shoal	5	1	-	20.4	23.6	-
	Troubadour Shoals	5	1	-	8.6	30.3	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
	Cootamundra Shoal	2	-	-	15.8	-	-
	Calder Shoal	1	-	-	17.0	-	-
	Britomart Shoal	-	-	-	-	-	-
	Sahul Bank	-	-	-	-	-	-
	Dillon Shoal	-	-	-	-	-	-
	Barton Shoal	-	-	-	-	-	-
	The Boxers	-	-	-	-	-	-
	Fantome Shoal	-	-	-	-	-	-
	Mangola Shoal	-	-	-	-	-	-
	Jabiru Shoals	-	-	-	-	-	-

	Pee Shoal	-	-	-	-	-	-
	Vee Shoal	-	-	-	-	-	-
	Johnson Bank	-	-	-	-	-	-
	Woodbine Bank	1	-	-	30.1	-	-
Emergent receptor	Indonesia	-	-	-	-	-	-
	East Timor	-	-	-	-	-	-
	Hibernia Reef	-	-	-	-	-	-
	Ashmore Reef	-	-	-	-	-	-
	Cartier Island	-	-	-	-	-	-
CMR	Arafura CMR	12	3	1	15.9	18.8	25.3
	Oceanic Shoals CMR	32	19	5	1.5	1.5	1.9
	Arnhem CMR	-	-	-	-	-	-
	Ashmore Reef CMR	-	-	-	-	-	-
	Cartier Island CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	8	-	-	15.7	-	-
	Shelf break and slope of the Arafura Shelf	9	4	3	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	2	1	1	3.0	3.4	3.9
	Continental slope demersal fish communities	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	5	1	1	0.04	0.04	0.04
Transitional conditions (March and September to November)							
Receptor		**Probability of exposure to dissolved aromatic concentrations at specific receptor depth (%)**			**Minimum time to dissolved aromatic concentration at any depth (days)**		
		6 ppb	**50 ppb**	**400 ppb**	**6 ppb**	**50 ppb**	**400 ppb**
Submerged receptor	Sunset Shoal	9	2	-	9.1	13.4	-
	Loxton Shoal	16	4	-	6.3	9.8	-
	Martin Shoal	14	6	1	5.8	9.1	24.7
	Sunrise Bank	14	5	-	11.1	12.6	-
	Flinders Shoal	29	9	1	3.0	3.8	3.9
	Evans Shoal	40	18	3	1.7	2.1	2.8
	Tassie Shoal	4	3	1	3.3	3.3	3.4
	Franklin Shoal	29	11	-	2.9	3.8	-

	Blackwood Shoal	26	9	1	3.4	3.4	3.4
	Lynedoch Bank	5	1	-	5.8	6.4	-
	Margaret Harries Bank	17	6	1	7.8	8.9	13.5
	Bellona Bank	12	3	-	16.3	21.4	-
	Echo Shoals	16	3	-	17.7	20.4	-
	Money Shoal	-	-	-	-	-	-
	Troubadour Shoals	23	10	3	6.0	6.9	7.0
	Big Bank Shoals	5	2	-	19.7	24.2	-
	Karmt Shoal	11	5	-	20.4	24.2	-
	Cootamundra Shoal	3	1	-	24.9	27.0	-
	Calder Shoal	2	1	-	25.9	28.1	-
	Britomart Shoal	6	2	-	25.7	26.0	-
	Sahul Bank	9	2	-	25.8	28.0	-
	Dillon Shoal	3	2	-	28.8	29.5	-
	Barton Shoal	-	-	-	-	-	-
	The Boxers	-	-	-	-	-	-
	Fantome Shoal	1	-	-	31.2	-	-
	Mangola Shoal	1	-	-	32.2	-	-
	Jabiru Shoals	-	-	-	-	-	-
	Pee Shoal	1	-	-	32.8	-	-
	Vee Shoal	-	-	-	-	-	-
	Johnson Bank	-	-	-	-	-	-
	Woodbine Bank	2	1	-	24.1	34.4	-
Emergent receptor	Indonesia	2	1	-	23.5	38.8	-
	East Timor	1	-	-	30.9	-	-
	Hibernia Reef	1	-	-	31.2	-	-
	Ashmore Reef	-	-	-	-	-	-
	Cartier Island	2	-	-	20.7	-	-
CMR	Arafura CMR	6	2	1	3.8	4.9	5.0
	Oceanic Shoals CMR	18	6	1	2.8	3.6	4.5
	Arnhem CMR	1	-	-	33.7	-	-

	Ashmore Reef CMR	-	-	-	-	-	-
	Cartier Island CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	8	7	1	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	3	1	-	25.3	37.4	-
	Continental slope demersal fish communities	1	-	-	29.9	-	-
Fishery	Timor Reef Fishery (NT Managed)	9	4	2	0.04	0.04	0.04
Winter conditions (April to August)							
Receptor		**Probability of exposure to dissolved aromatic concentrations at specific receptor depth (%)**			**Minimum time to dissolved aromatic concentration at any depth (days)**		
		6 ppb	**50 ppb**	**400 ppb**	**6 ppb**	**50 ppb**	**400 ppb**
Submerged receptor	Sunset Shoal	18	7	2	7.2	9.4	9.6
	Loxton Shoal	25	9	2	6.7	7.6	8.9
	Martin Shoal	21	11	2	5.9	6.5	9.1
	Sunrise Bank	25	9	2	9.6	10.5	15.9
	Flinders Shoal	42	23	4	3.5	3.7	3.8
	Evans Shoal	58	36	11	2.1	2.3	2.8
	Tassie Shoal	28	15	6	3.1	3.1	3.1
	Franklin Shoal	44	21	8	3.4	3.8	4.0
	Blackwood Shoal	45	22	5	2.9	3.1	3.4
	Lynedoch Bank	3	2	-	12.6	14.0	-
	Margaret Harries Bank	16	6	1	7.1	8.4	9.3
	Bellona Bank	16	5	-	15.0	16.4	27.4
	Echo Shoals	16	7	1	16.8	18.6	27.9
	Money Shoal	-	-	-	-	-	-
	Troubadour Shoals	38	19	4	6.2	6.8	7.1
	Big Bank Shoals	11	2	-	20.7	22.3	-
	Karmt Shoal	11	5	1	21.3	22.3	23.0
	Cootamundra Shoal	1	1	-	30.2	32.2	-
	Calder Shoal	4	1	-	8.4	9.5	-

	Britomart Shoal	7	2	-	23.5	24.5	-
	Sahul Bank	8	1	-	23.8	33.2	-
	Dillon Shoal	2	-	-	35.1	-	-
	Barton Shoal	-	-	-	-	-	-
	The Boxers	-	-	-	-	-	-
	Fantome Shoal	-	-	-	-	-	-
	Mangola Shoal	-	-	-	-	-	-
	Jabiru Shoals	-	-	-	-	-	-
	Pee Shoal	-	-	-	-	-	-
	Vee Shoal	-	-	-	-	-	-
	Johnson Bank	-	-	-	-	-	-
	Woodbine Bank	4	2	-	15.4	16.2	-
Emergent receptor	Indonesia	2	2	1	28.0	28.0	28.3
	East Timor	-	-	-	-	-	-
	Hibernia Reef	-	-	-	-	-	-
	Ashmore Reef	-	-	-	-	-	-
	Cartier Island	-	-	-	-	-	-
CMR	Arafura CMR	3	2	-	3.5	3.5	-
	Oceanic Shoals CMR	10	4	1	3.5	3.8	4.2
	Arnhem CMR	-	-	-	-	-	-
	Ashmore Reef CMR	-	-	-	-	-	-
	Cartier Island CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	9	5	1	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	3	2	-	2.6	2.6	2.6
	Continental slope demersal fish communities	1	-	-	38.3	-	-
Fishery	Timor Reef Fishery (NT Managed)	9	6	3	0.04	0.04	0.04

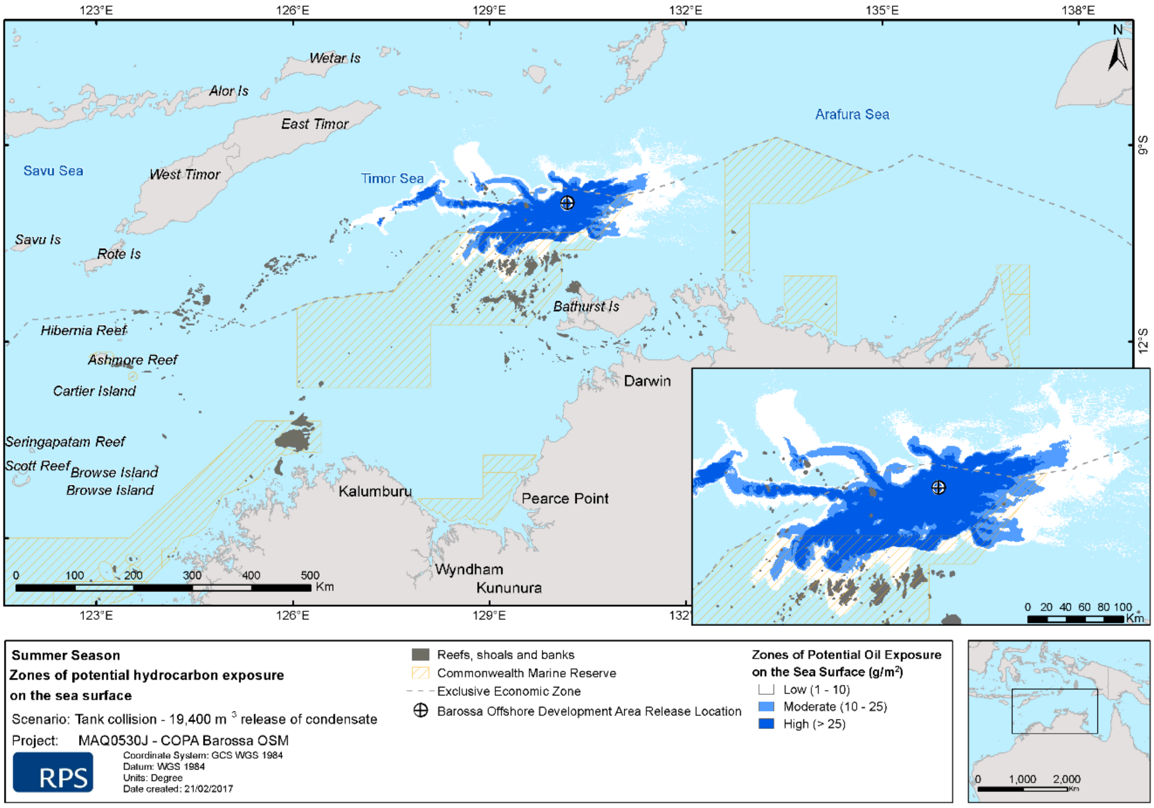


Figure 65 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during summer conditions (19,400 m³ Barossa condensate)

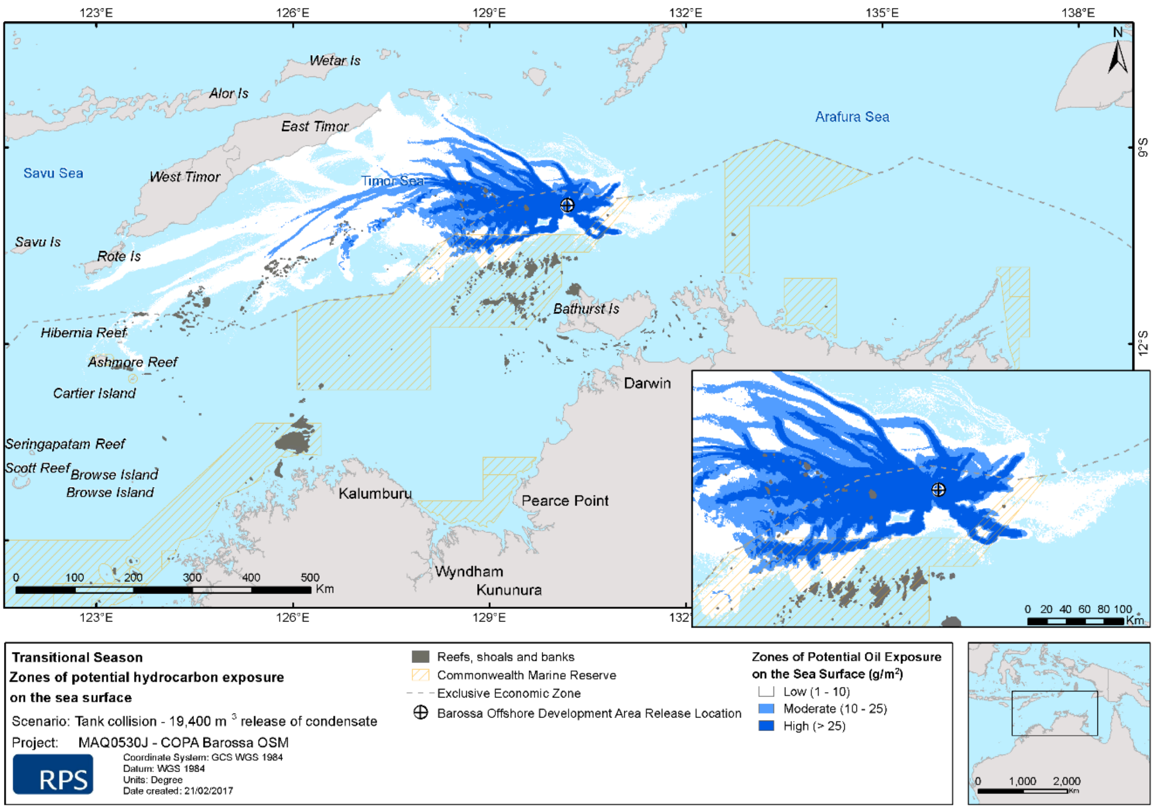


Figure 66 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during transitional conditions (19,400 m³ Barossa condensate)

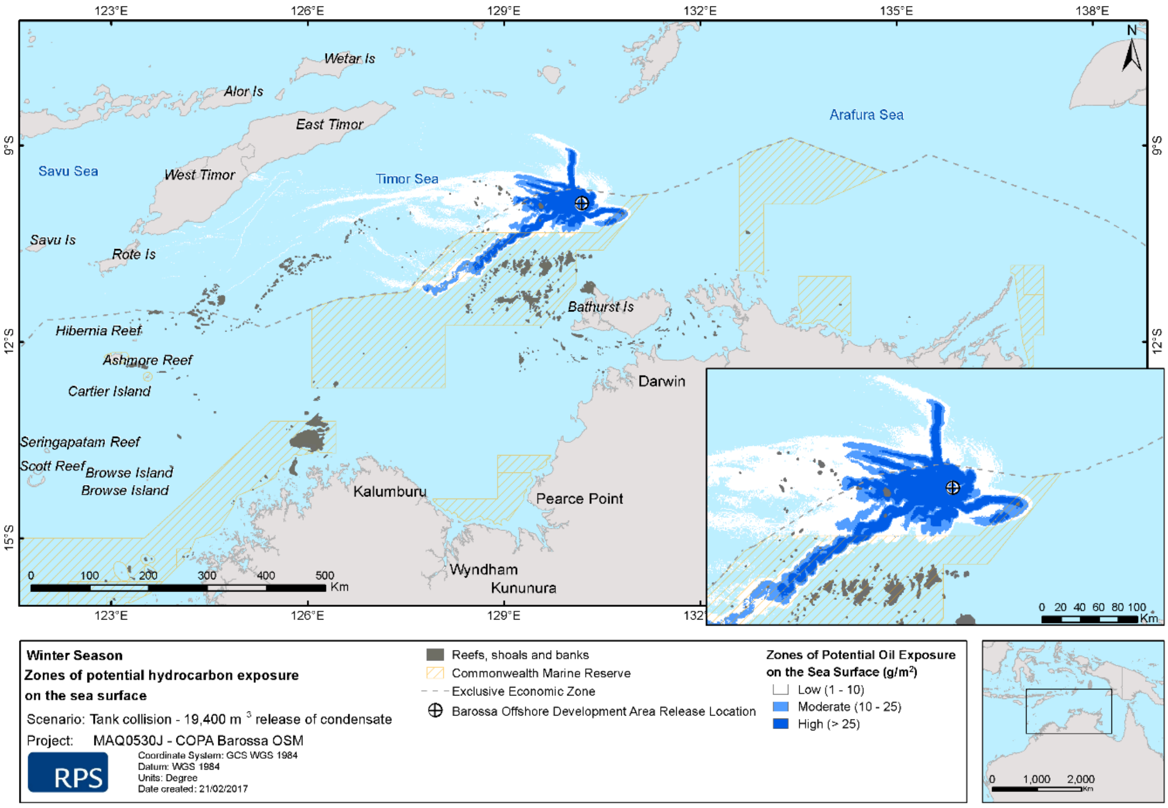


Figure 67 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during winter conditions (19,400 m^3 Barossa condensate)

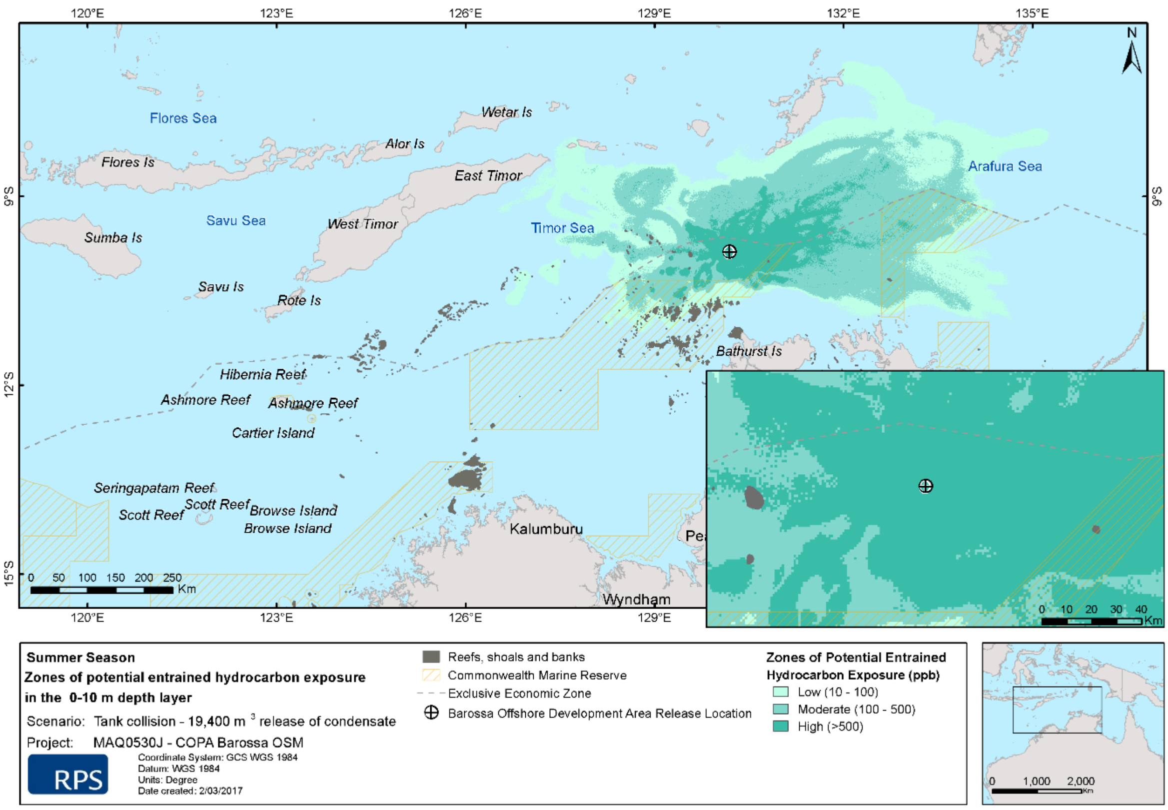


Figure 68 Stochastic modelling outputs showing the potential entrained hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during summer conditions (19,400 m^3 Barossa condensate)

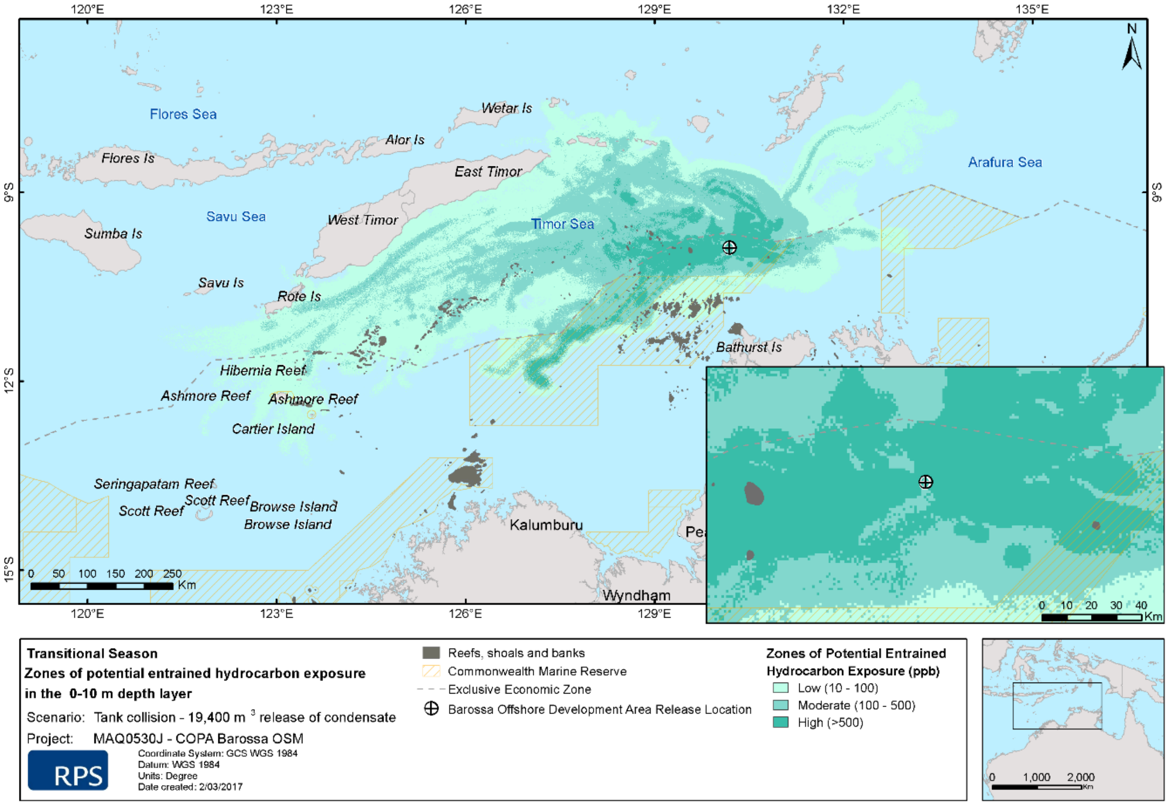


Figure 69 Stochastic modelling outputs showing the potential entrained hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during transitional conditions (19,400 m^3 Barossa condensate)

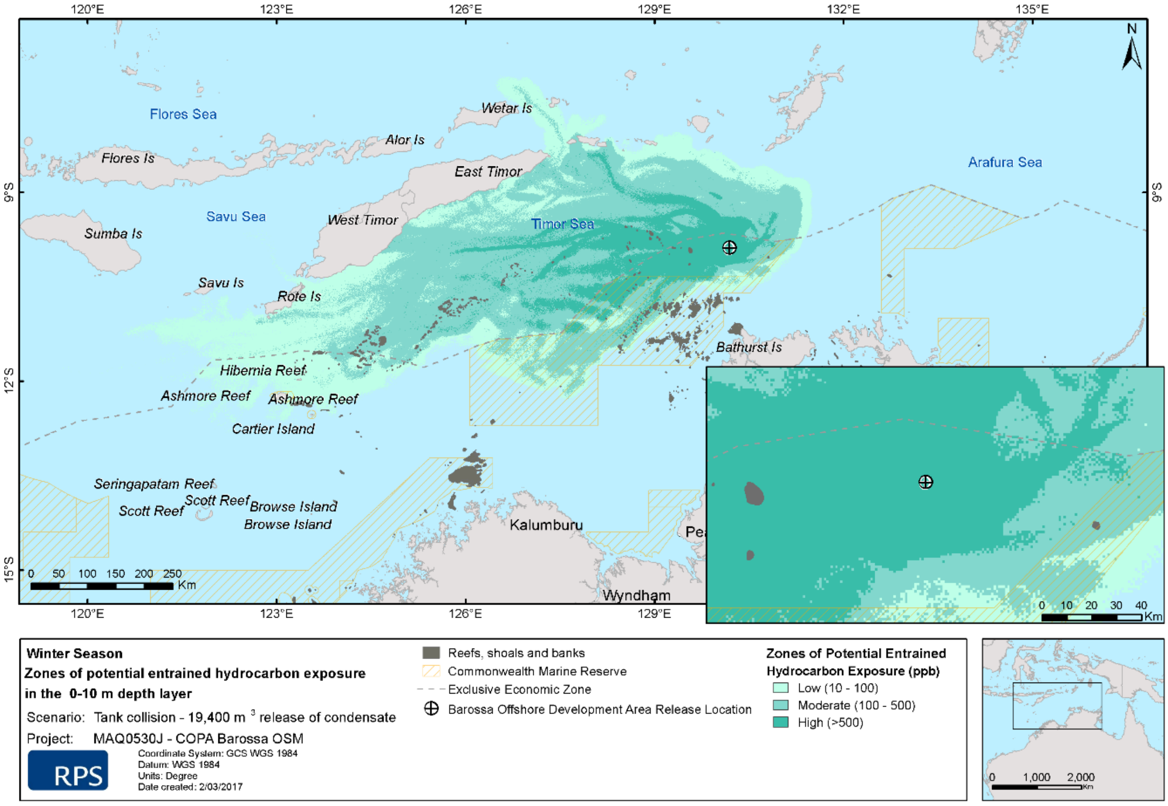


Figure 70 Stochastic modelling outputs showing the potential entrained hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during winter conditions (19,400 m^3 Barossa condensate)

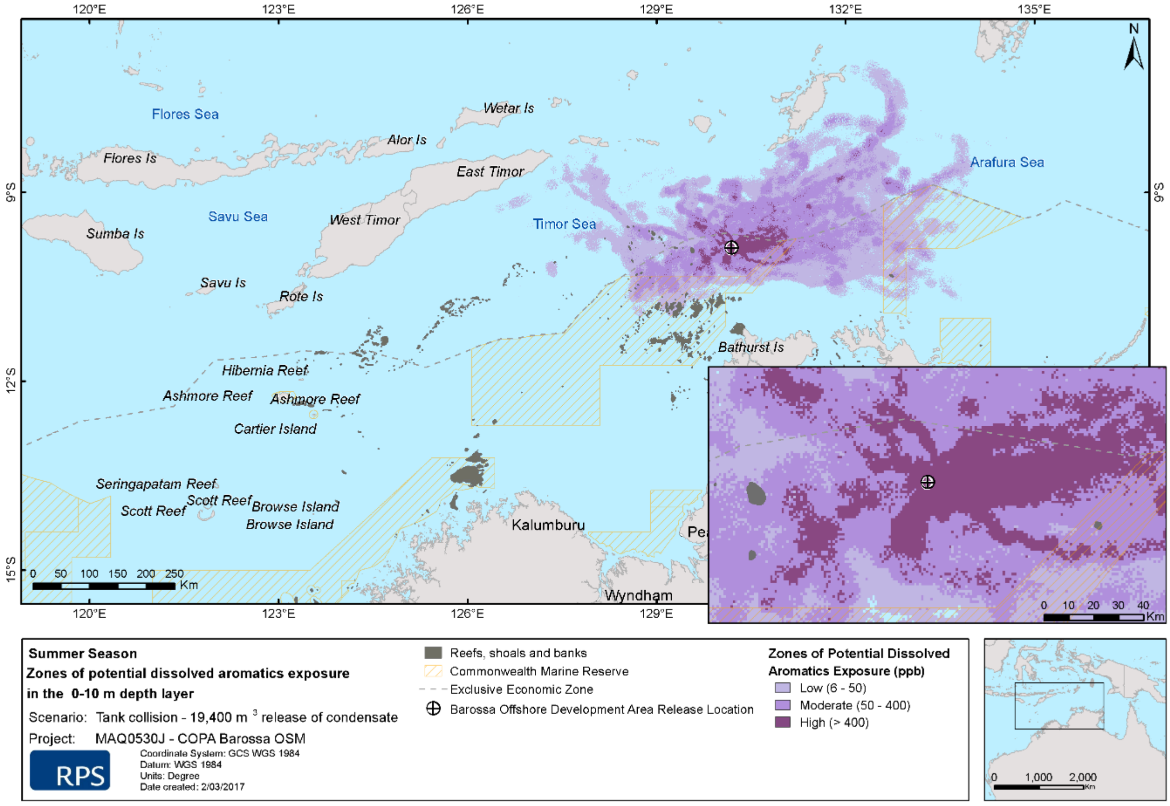


Figure 71 Stochastic modelling outputs showing the potential dissolved aromatic hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during summer conditions (19,400 m^3 Barossa condensate)

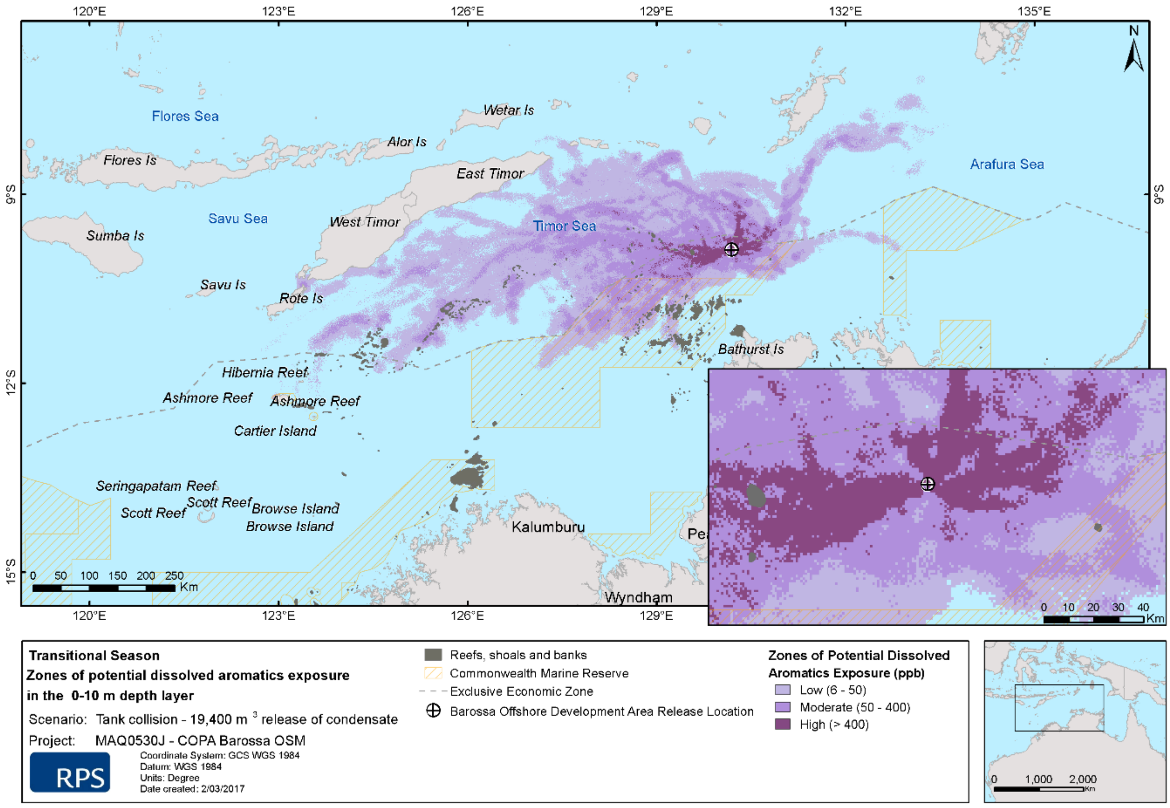


Figure 72 Stochastic modelling outputs showing the potential dissolved aromatic hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during transitional conditions (19,400 m^3 Barossa condensate)

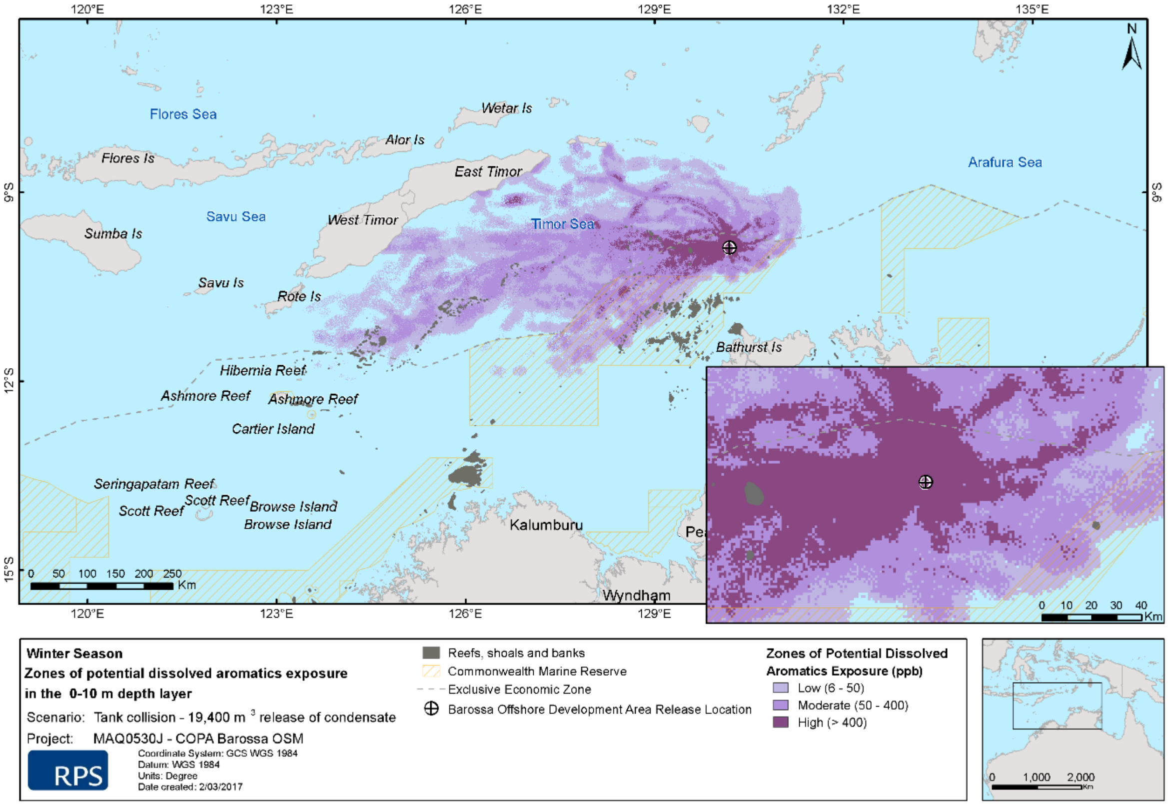


Figure 73 Stochastic modelling outputs showing the potential dissolved aromatic hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during winter conditions (19,400 m^3 Barossa condensate)

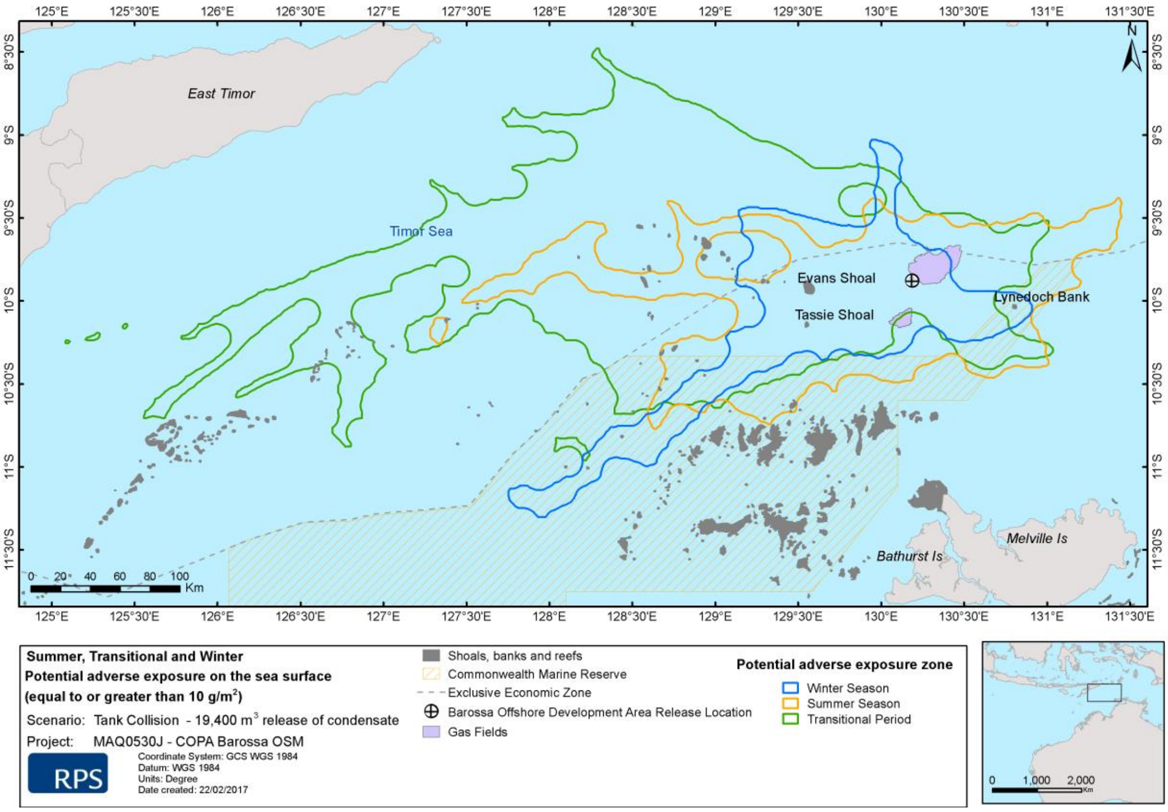


Figure 74 Stochastic modelling outputs showing the potential adverse exposure zone on the sea surface from a vessel collision releasing Barossa condensate (19,400 m^3)

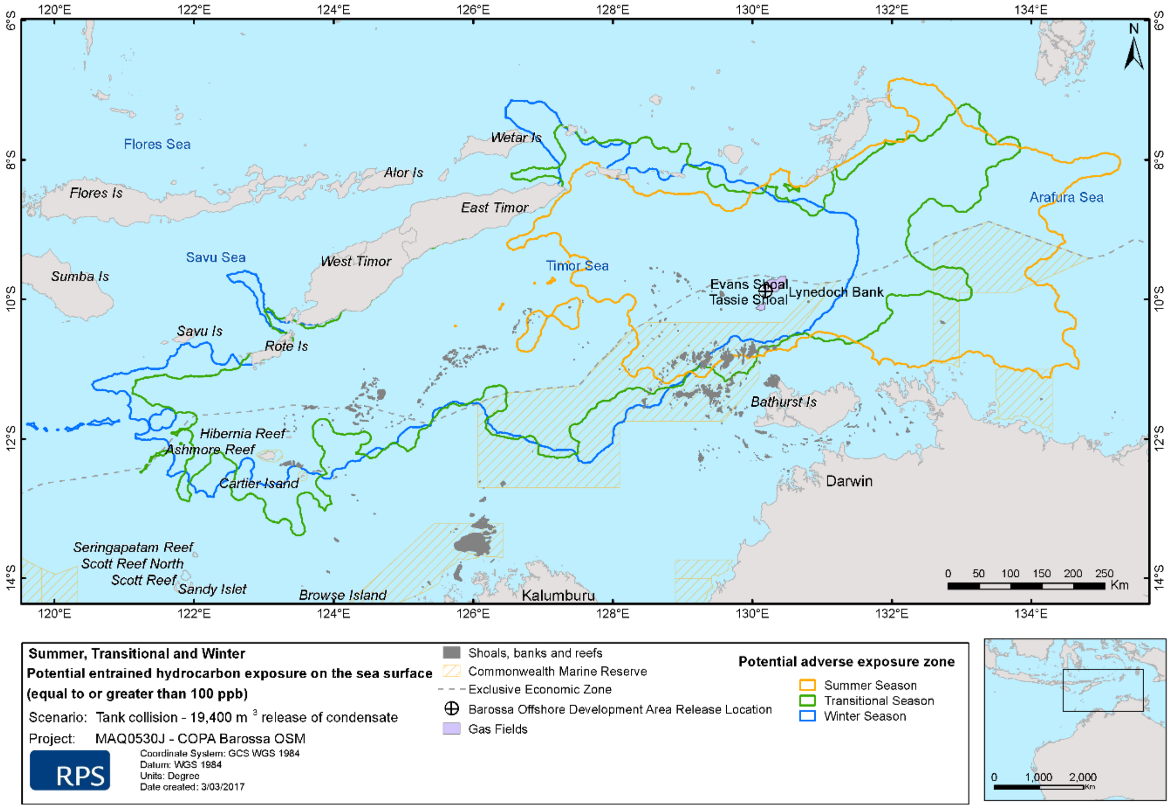


Figure 75 Stochastic modelling outputs showing the potential adverse exposure zone (0-10 m depth layer) for entrained hydrocarbons from a vessel collision releasing Barossa condensate (19,400 m³)

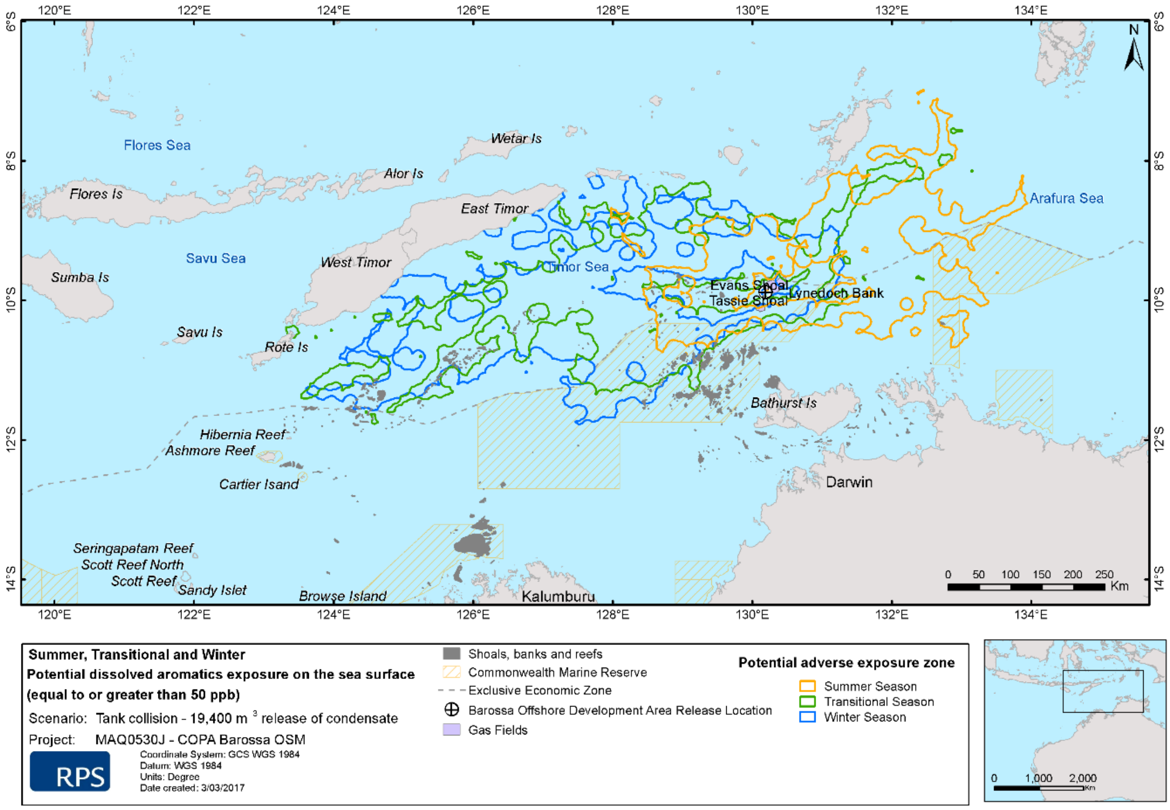


Figure 76 Stochastic modelling outputs showing the potential adverse exposure zone (0-10 m depth layer) for dissolved aromatic hydrocarbons from a vessel collision releasing Barossa condensate (19,400 m³)

3.4 Scenario 4: Long-term well blowout (16,833 m^3 Barossa condensate)

3.4.1 Single trajectory

Figure 77 shows the potential sea surface hydrocarbon exposure over the entire 90 day model simulation. The spill starting at 8 pm 25th June 2014 was chosen as an example trajectory to illustrate the potential exposure by entrained and dissolved aromatic hydrocarbons to nearby shoals/banks.

Figure 78 and Figure 79 display the potential entrained and dissolved aromatic hydrocarbon exposure zones.

As condensate rose to the sea surface from the subsea well blowout, the spill travelled west and northwest of the release location. Low condensate exposure on the sea surface was predicted up to 381 km away, whereas moderate exposure was limited to within 2 km. The in-water entrained hydrocarbons and dissolved aromatics were shown to move west and from the release location. Low, moderate and high entrained hydrocarbon was recorded up to 1,105 km, 580 km and 215 km, respectively, from the release location. Low, moderate and high dissolved aromatics were observed up to 707 km, 75 km and 5 km, respectively, from the release location.

Figure 80 illustrates the fates and weathering graph for the corresponding winter spill trajectory. The graph demonstrates that the condensate remains entrained in the water column, whereby gradual and persistent decay occurs. At the end of the simulation (day 90) approximately 28% (4,706 m^3) remained entrained in the water column and 46% (7,789 m^3) had decayed.

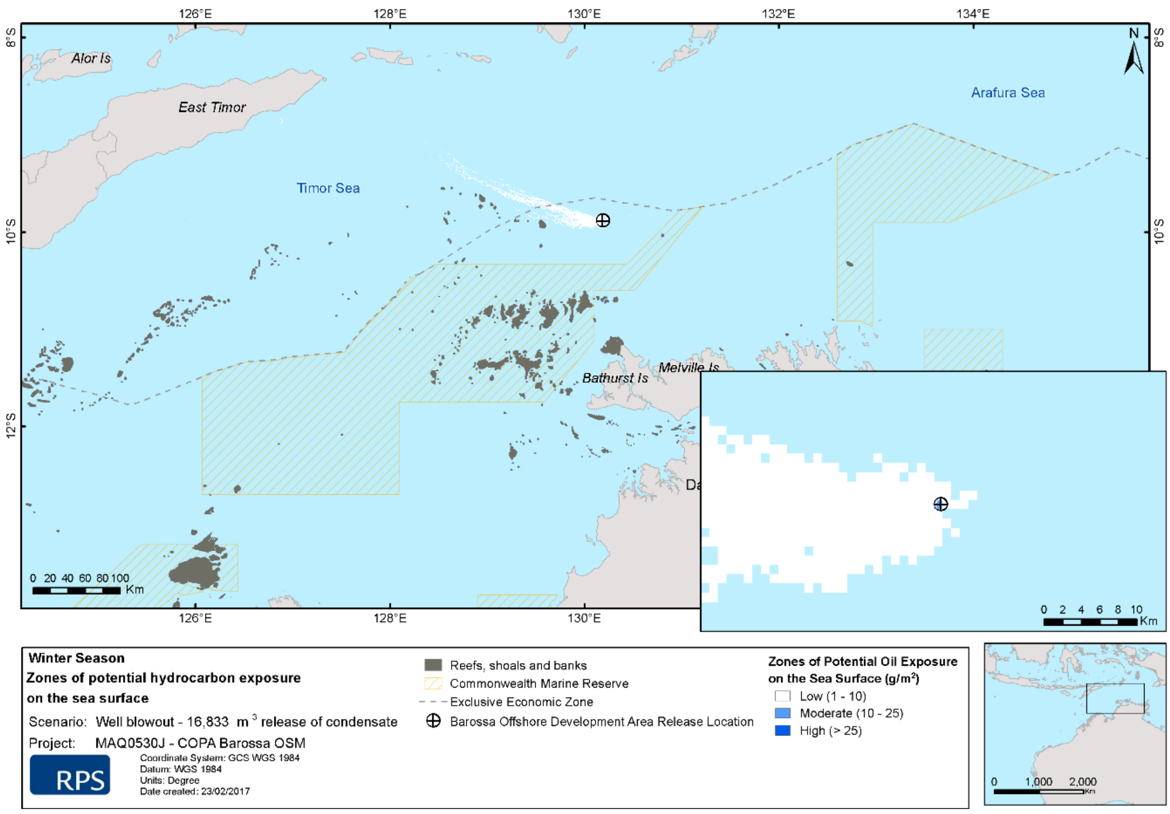


Figure 77 Single spill trajectory outputs showing the potential sea surface exposure zones (16,833 m^3 Barossa condensate)

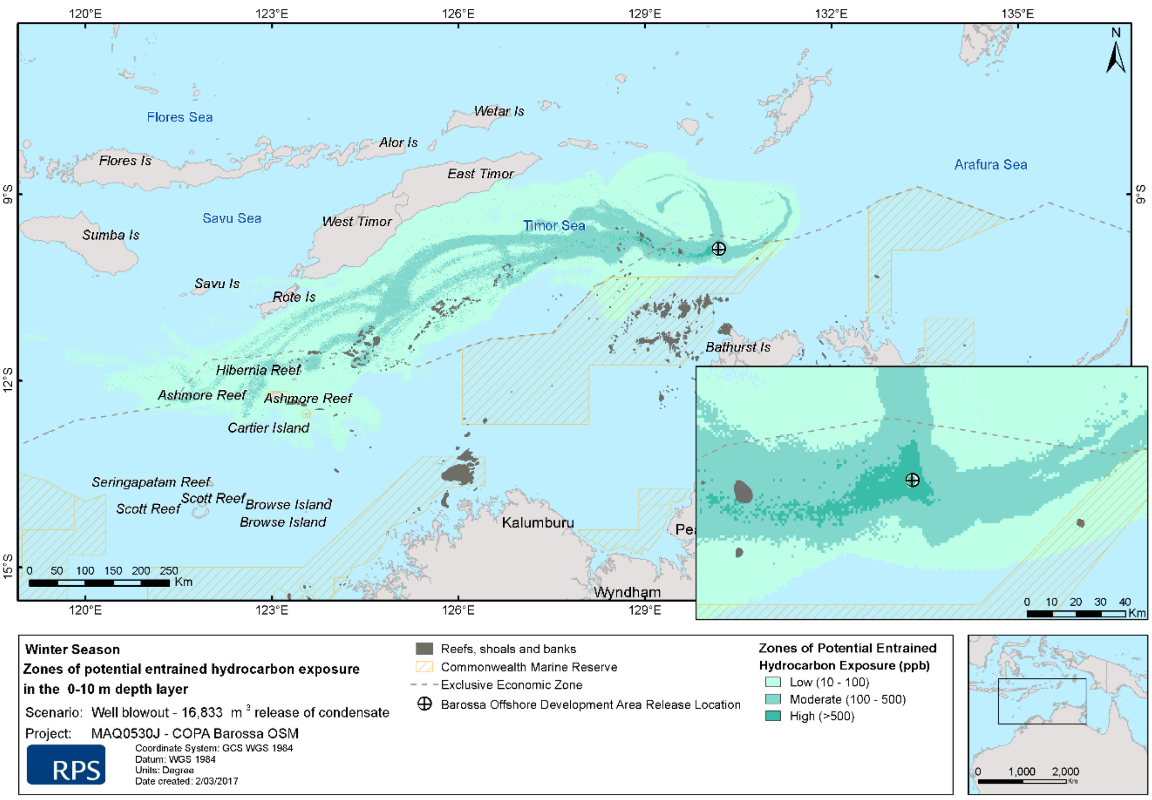


Figure 78 Single spill trajectory outputs showing the potential entrained exposure zones (16,833 m^3 Barossa condensate)

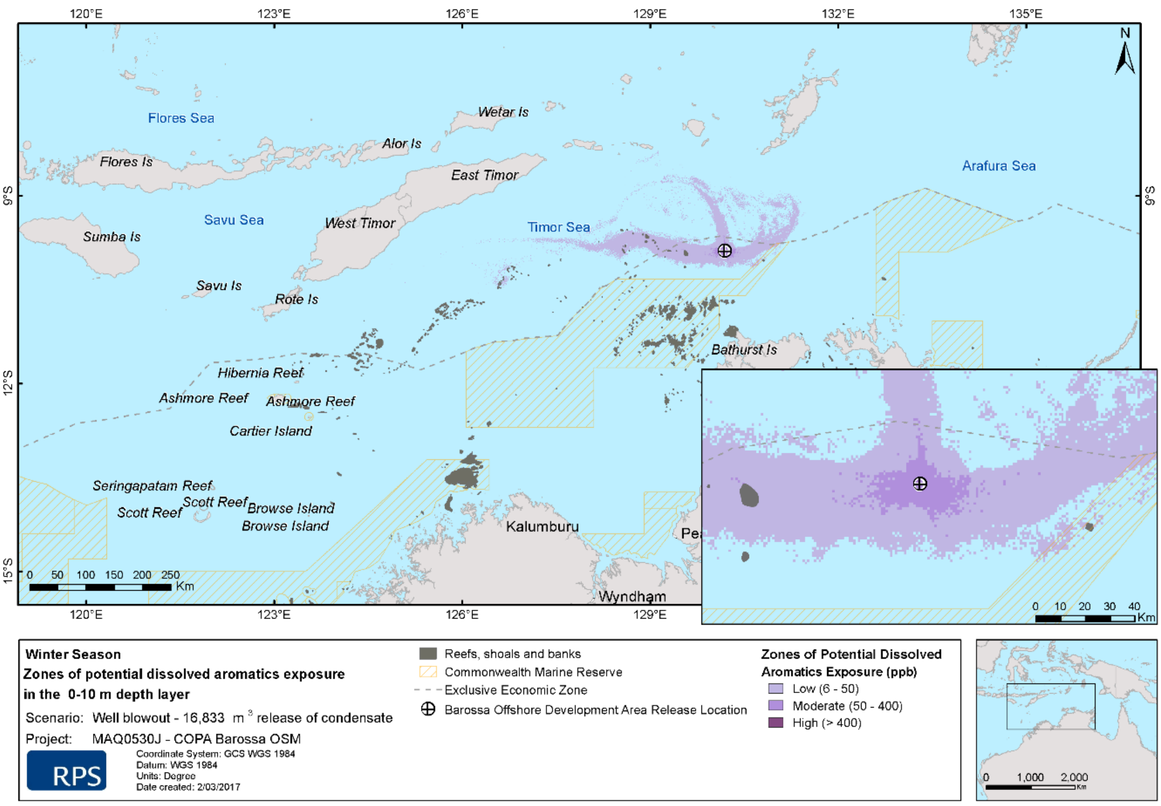


Figure 79 Single spill trajectory outputs showing the potential dissolved aromatic exposure zones (16,833 m^3 Barossa condensate)

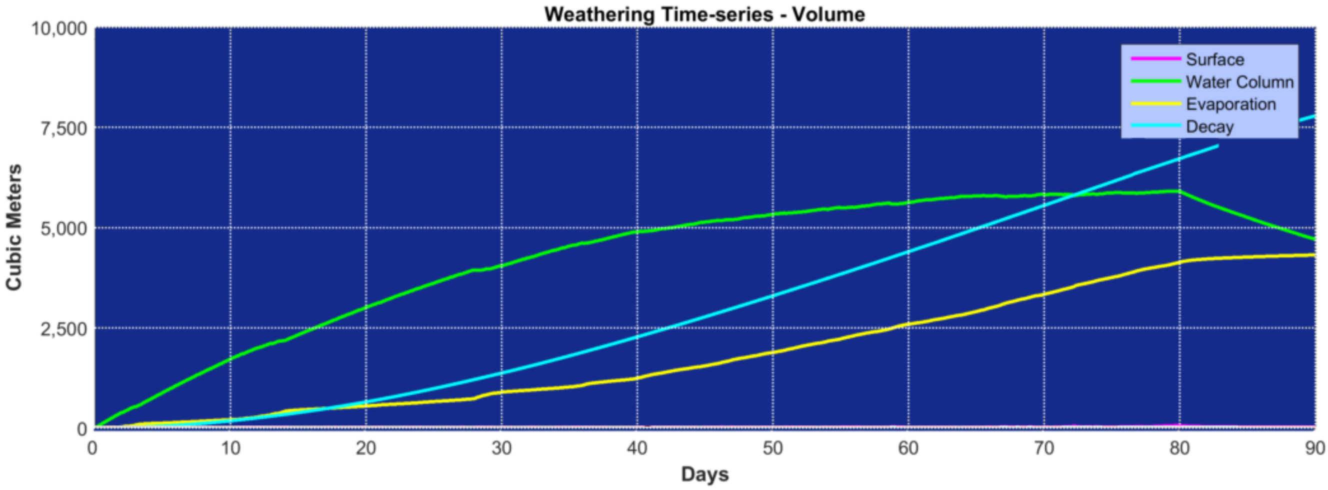


Figure 80 Predicted weathering and fates graph for the example spill trajectory selected from a 16,833 m^3 subsea release of Barossa condensate from a long-term well blowout (tracked for 90 days)

3.4.2 Stochastic modelling

In summary, the stochastic modelling results showed:

- during summer, the condensate tended to oscillate around the release location and drift east and west. While under the transitional and winter seasons it was directed to drift west.
- the maximum distance for the sea surface adverse exposure zone is predicted to vary between seasons with approximately 34 km (south-southwest), 227 km (west) and 17 km (east-northeast) during summer, transitional and winter conditions, respectively (Table 27).
- low probability of contact predicted (3%) by sea surface films within the adverse exposure zone with the surface waters above the KEF of the carbonate bank and terrace system of Van Diemen Rise during summer and transitional conditions only (Table 28). Figure 81 to Figure 83 shows the potential sea surface exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 90 shows the potential sea surface adverse exposure zone for all seasons.
- no contact with waters above the various submerged banks/shoals for the sea surface adverse exposure zone was predicted during any seasonal conditions.
- contact by the sea surface adverse exposure zone with the waters above the KEF of the shelf break and slope of the Arafura Shelf (a unique seafloor feature) and open waters of the Timor Reef Fishery was predicted in all seasons as the Barossa offshore development area is located within the bounds of these features (Table 28).
- no residual hydrocarbons were predicted to accumulate on any shoreline in any season to levels that may affect sensitive receptors onshore.
- contact was predicted (1–90% probability) by entrained hydrocarbons within the adverse exposure zone for various submerged shoals/banks (total of 35), Ashmore Reef, Cartier Island, Hibernia Reef, North and South Scott Reef, open waters of the Oceanic Shoals, Arafura, Ashmore Reef, Arnhem, Cartier Island and Kimberley CMRs, KEFs of the shelf break and slope of the Arafura Shelf, carbonate bank and terrace system of Van Diemen Rise, carbonate bank and terrace system of Sahul Shelf, pinnacles of the Bonaparte Basin and continental slope demersal fish communities, and waters of the Timor Reef Fishery, depending on the season (Table 29). Figure 84 to Figure 86 shows the potential entrained hydrocarbon exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 91 shows the potential sea surface adverse exposure zone for all seasons.
- during all seasons, Flinders Shoal recorded the highest probability of contact by entrained hydrocarbons at the adverse exposure zone (51% during summer conditions, 86% during transitional and 90% during winter conditions).

- contact was predicted (1–74% probability) by dissolved aromatic hydrocarbons within the adverse exposure zone for various submerged shoals/banks (total of 31), Ashmore Reef, Hibernia Reef, open waters of the Oceanic Shoals, Arafura, Kimberley and Ashmore Reef CMRs, waters above the KEFs of the shelf break and slope of the Arafura Shelf, carbonate bank and terrace systems of Van Diemen Rise, carbonate bank and terrace system of and Sahul Shelf, tributary canyons of the Arafura Depression, pinnacles of the Bonaparte Basin and continental slope demersal fish communities and waters of the Timor Reef Fishery, depending on the season (Table 30). Figure 87 to Figure 89 shows the potential dissolved aromatic hydrocarbon exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 92 shows the potential sea surface adverse exposure zone for all seasons.
- during transitional and winter conditions, Evans Shoal recorded the highest probability of contact with the dissolved aromatics adverse exposure zone (63 % during transitional and winter conditions 74%). Blackwood Shoal recorded the highest probability of contact with the dissolved aromatics adverse exposure zone during summer conditions (26%).
- no contact with the adverse exposure zone for sea surface or sub-surface hydrocarbons was predicted with the NT/WA coastline or adjacent islands (Table 28 to Table 30).

Table 27 Maximum distances (and direction) from the release location to zones of potential sea surface exposure for each season (16,833 m^3 Barossa condensate)

Season	Distance and direction	Sea surface exposure thresholds		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Summer	Maximum distance travelled (km) by a spill trajectory	584.2	33.7	3.6
	Direction	East	South-southwest	Northwest
Transitional	Maximum distance travelled (km) by a spill trajectory	933.2	227.3	1.0
	Direction	West-southwest	West	North-northwest
Winter	Maximum distance travelled (km) by a spill trajectory	1,142.9	16.6	1.3
	Direction	West-southwest	East-northeast	South-southeast

Table 28 Probability and minimum time before hydrocarbon exposure on the sea surface for receptors assessed (16,833 m³ Barossa condensate)

Summer conditions (December to February)								
Receptor		Maximum probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)			
		Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)	Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)
Submerged receptor	Sunset Shoal	2	-	-	43.2	-	-
	Loxton Shoal	2	-	-	39.3	-	-
	Martin Shoal	2	-	-	44.4	-	-
	Sunrise Bank	-	-	-	-	-	-
	Troubadour Shoals	3	-	-	41.5	-	-
	Flinders Shoal	4	-	-	38.5	-	-
	Evans Shoal	7	-	-	10.1	-	-
	Tassie Shoal	9	-	-	8.4	-	-
	Franklin Shoal	1	-	-	71.2	-	-
	Blackwood Shoal	-	-	-	-	-	-
	Lynedoch Bank	5	-	-	48.8	-	-
	Margaret Harries Bank	3	-	-	28.6	-	-
	Bellona Bank	-	-	-	-	-	-
	Echo Shoals	-	-	-	-	-	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
Emergent receptor	Indonesia	-	-	-	-	-	-
	East Timor	-	-	-	-	-	-
CMR	Oceanic Shoals CMR	15	-	-	5.5	-	-
KEF	Tributary Canyons of the Arafura Depression	1	-	-	82.2	-	-
	Shelf break and slope of the Arafura Shelf	100	100	100	0.1	0.1	0.2
	Carbonate bank and terrace system of Van Diemen Rise	24	3	-	4.3	14.7	-
	Carbonate bank and terrace system of Sahul Shelf	-	-	-	-	-	-
	Continental slope demersal fish communities	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.08	0.08	0.08

Transitional conditions (March and September to November)							
Receptor		Maximum probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)	Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)
Submerged receptor	Sunset Shoal	11	-	-	33.4	-	-
	Loxton Shoal	9	-	-	37.5	-	-
	Martin Shoal	5	-	-	16.1	-	-
	Sunrise Bank	2	-	-	84.8	-	-
	Troubadour Shoals	7	-	-	34.0	-	-
	Flinders Shoal	15	-	-	4.5	-	-
	Evans Shoal	19	-	-	2.6	-	-
	Tassie Shoal	15	-	-	5.2	-	-
	Franklin Shoal	10	-	-	6.6	-	-
	Blackwood Shoal	12	-	-	25.6	-	-
	Lynedoch Bank	-	-	-	-	-	-
	Margaret Harries Bank	7	-	-	35.9	-	-
	Bellona Bank	7	-	-	48.3	-	-
	Echo Shoals	2	-	-	69.6	-	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	3	-	-	58.2	-	-
Emergent receptor	Indonesia	2	-	-	62	-	-
	East Timor	2	-	-	49.2	-	-
CMR	Oceanic Shoals CMR	24	1	-	9.4	79.1	-
KEF	Tributary Canyons of the Arafura Depression	1	-	-	76.6	-	-
	Shelf break and slope of the Arafura Shelf	100	100	100	0.1	0.1	0.1
	Carbonate bank and terrace system of Van Diemen Rise	25	3	-	2.8	69.4	-
	Carbonate bank and terrace system of Sahul Shelf	1	-	-	78.6	-	-
	Continental slope demersal fish communities	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.1	0.1	0.1

Winter conditions (April to August)							
Receptor		Maximum probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)	Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)
Submerged receptor	Sunset Shoal	2	-	-	71.1	-	-
	Loxton Shoal	3	-	-	59.9	-	-
	Martin Shoal	3	-	-	46.8	-	-
	Sunrise Bank	1	-	-	38.4	-	-
	Troubadour Shoals	3	-	-	58.2	-	-
	Flinders Shoal	7	-	-	61.5	-	-
	Evans Shoal	11	-	-	29.8	-	-
	Tassie Shoal	4	-	-	59.8	-	-
	Franklin Shoal	4	-	-	61.5	-	-
	Blackwood Shoal	2	-	-	41.9	-	-
	Lynedoch Bank	-	-	-	-	-	-
	Margaret Harries Bank	2	-	-	60.8	-	-
	Bellona Bank	-	-	-	-	-	-
	Echo Shoals	1	-	-	63.3	-	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	2	-	-	65.6	-	-
Emergent receptor	Indonesia	-	-	-	-	-	-
	East Timor	-	-	-	-	-	-
CMR	Oceanic Shoals CMR	6	-	-	6	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	100	100	100	0.1	0.1	0.1
	Carbonate bank and terrace system of Van Diemen Rise	12	-	-	2.9	-	-
	Carbonate bank and terrace system of Sahul Shelf	1	-	-	81.1	-	-
	Continental slope demersal fish communities	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.1	0.1	0.1

Table 29 Probability and minimum time before entrained hydrocarbon exposure for receptors assessed (16,833 m^3 Barossa condensate)

Summer conditions (December to February)							
Receptor		Probability of exposure to entrained concentrations at specific receptor depth (%)			Minimum time to entrained concentration at any depth [days]		
		10 ppb	100 ppb	500 ppb	10 ppb	100 ppb	500 ppb
Submerged receptor	Sunset Shoal	50	7	-	5.0	8.5	-
	Loxton Shoal	48	3	-	4.5	4.5	-
	Martin Shoal	43	4	-	4.1	4.2	-
	Sunrise Bank	22	1	-	6.9	7.3	-
	Flinders Shoal	73	51	3	2.4	2.7	2.7
	Evans Shoal	84	44	3	0.9	0.9	2.2
	Tassie Shoal	82	42	3	2.9	3.2	4.3
	Franklin Shoal	72	22	-	2.3	2.6	-
	Blackwood Shoal	81	26	-	2.0	2.5	-
	Lynedoch Bank	81	21	-	2.4	2.6	-
	Margaret Harries Bank	58	10	1	6.8	7.2	10.4
	Bellona Bank	19	7	-	10.8	12.3	-
	Echo Shoals	22	5	-	14.0	14.1	-
	Money Shoal	17	1	-	19.3	33.4	-
	Troubadour Shoals	51	15	1	4.8	4.9	5.7
	Big Bank Shoals	19	7	-	16.4	18.2	-
	Goodrich Bank	-	-	-	-	-	-
	Karmt Shoal	21	9	-	18.2	19.4	-
	Cootamundra Shoal	28	2	-	11.9	13.2	-
	Calder Shoal	17	2	-	8.3	14.4	-
	Marie Shoal	-	-	-	-	-	-
	Sahul Bank	20	10	1	19.9	20.3	33.8
	Dillon Shoal	19	2	-	19.5	20.8	-
	Mermaid Shoal	-	-	-	-	-	-
	Parry Shoal	-	-	-	-	-	-
	Moss Shoal	-	-	-	-	-	-
	Barton Shoal	16	3	-	21.5	23.0	-

	The Boxers	-	-	-	-	-	-
	Fantome Shoal	13	1	-	26.6	53.3	-
	Mangola Shoal	12	2	-	24.5	30.7	-
	Jabiru Shoals	16	5	1	24.4	27.7	50.3
	Pee Shoal	13	5	-	28.1	38.2	-
	Vee Shoal	10	2	-	27.3	35.6	-
	Newby Shoal	-	-	-	-	-	-
	Shepparton Shoal	-	-	-	-	-	-
	Deep Shoal 2	-	-	-	-	-	-
	Flat Top Bank	-	-	-	-	-	-
	Deep Shoal 1	-	-	-	-	-	-
	Johnson Bank	8	5	-	39.0	41.9	-
	Woodbine Bank	7	3	-	38.3	42.0	-
	Barracouta Shoal	4	1	-	41.9	44.6	-
	Gale Bank	-	-	-	-	-	-
	Van Cloon Shoal	-	-	-	-	-	-
	Favell Bank	-	-	-	-	-	-
	Vulcan Shoal	3	1	-	51.4	55.4	-
	Baldwin Bank	-	-	-	-	-	-
	Goeree Shoal	2	1	-	54.4	55.7	-
	Penguin Shoal	-	-	-	-	-	-
	Eugene McDermott Shoal	-	-	-	-	-	-
	Holothuria Banks	-	-	-	-	-	-
	Bassett-Smith Shoal	-	-	-	-	-	-
	Heywood Shoal	2	-	-	70.0	-	-
	West Holothuria Reef	-	-	-	-	-	-
	East Holothuria Reef	-	-	-	-	-	-
	Branch Banks	-	-	-	-	-	-
	Otway Bank	-	-	-	-	-	-
	Tait Bank	-	-	-	-	-	-
	Rothery Reef	-	-	-	-	-	-

	Echuca Shoal	1	-	-	83.7	-	-
	Heritage Reef	-	-	-	-	-	-
	Beagle and Dingo Reefs	-	-	-	-	-	-
	Mavis Reef	-	-	-	-	-	-
Emergent receptor	Indonesia	48	14	1	15.0	16.7	19.9
	East Timor	25	7	-	21.3	24.1	-
	Melville Island	-	-	-	-	-	-
	Bathurst Island	-	-	-	-	-	-
	Hibernia Reef	11	3	-	29.8	37.2	-
	Ashmore Reef	10	5	-	34.4	39.2	-
	Cartier Island	5	1	-	41.2	46.5	-
	Seringapatam Reef	4	-	-	58.8	-	-
	Stewarts Islands	-	-	-	-	-	-
	Troughton Island	-	-	-	-	-	-
	Kimberley Coast	-	-	-	-	-	-
	Jones Island	-	-	-	-	-	-
	Long Reef	-	-	-	-	-	-
	Lesueur Island	-	-	-	-	-	-
	Eclipse Archipelago	-	-	-	-	-	-
	Scott Reef North	3	-	-	62.7	-	-
	Cassini Island	-	-	-	-	-	-
	Sandy Islet	2	-	-	74.5	-	-
	Scott Reef South	2	-	-	69.6	-	-
	Joseph Bonaparte Gulf Western Australia	-	-	-	-	-	-
	Admiralty Gulf Islands	-	-	-	-	-	-
	Browse Island	-	-	-	-	-	-
	Bonaparte Archipelago	-	-	-	-	-	-
	Buccaneer Archipelago	-	-	-	-	-	-
CMR	Arafura CMR	65	29	6	10.9	11.7	13.5
	Oceanic Shoals CMR	100	68	11	1.3	1.3	2.2
	Arnhem CMR	11	1	-	23.3	27.6	-

	Ashmore Reef CMR	10	5	1	33.2	38.7	43.4
	Cartier Island CMR	6	2	-	41.2	46.5	-
	Kimberley CMR	1	-	-	72.5	-	-
	Joseph Bonaparte Gulf CMR	-	-	-	-	-	-
	Argo-Rowley Terrace CMR	3	-	-	57.6	-	-
KEF	Tributary Canyons of the Arafura Depression	1	-	-	12.5	-	-
	Shelf break and slope of the Arafura Shelf	4	-	-	0.04	-	-
	Carbonate bank and terrace system of Van Diemen Rise	1	-	-	0.9	-	-
	Pinnacles of the Bonaparte Basin	-	-	-	-	-	-
	Carbonate bank and terrace system of Sahul Shelf	-	-	-	-	-	-
	Continental slope demersal fish communities	7	2	1	30.2	38.7	51.7
Fishery	Timor Reef Fishery (NT Managed)	5	-	-	0.04	0.04	0.04
Transitional conditions (March and September to November)							
Receptor		**Probability of exposure to entrained concentrations at specific receptor depth (%)**			**Minimum time to entrained concentration at any depth [days]**		
		10 ppb	**100 ppb**	**500 ppb**	**10 ppb**	**100 ppb**	**500 ppb**
Submerged receptor	Sunset Shoal	86	24	-	5.1	6.3	-
	Loxton Shoal	81	16	1	4.5	4.8	14.7
	Martin Shoal	85	17	-	4.1	4.3	-
	Sunrise Bank	65	9	-	6.7	7.0	-
	Flinders Shoal	99	86	11	2.5	2.7	3.4
	Evans Shoal	100	63	4	0.4	1.0	2.1
	Tassie Shoal	97	41	2	2.5	2.7	4.7
	Franklin Shoal	99	60	3	2.4	2.7	3.5
	Blackwood Shoal	100	51	-	2.4	2.4	-
	Lynedoch Bank	37	18	-	2.6	2.9	-
	Margaret Harries Bank	85	30	3	6.4	7.3	9.7
	Bellona Bank	56	4	-	10.6	12.3	-
	Echo Shoals	58	10	1	12.1	13.7	14.0
	Money Shoal	6	3	-	23.0	26.9	-

	Troubadour Shoals	91	41	1	4.6	5.3	6.2
	Big Bank Shoals	46	10	-	17.4	17.5	-
	Goodrich Bank	-	-	-	-	-	-
	Karmt Shoal	46	6	1	15.3	18.5	19.5
	Cootamundra Shoal	16	4	-	8.0	9.6	-
	Calder Shoal	16	2	-	7.6	8.3	-
	Marie Shoal	-	-	-	-	-	-
	Sahul Bank	49	12	5	18.1	19.9	20.7
	Dillon Shoal	43	3	-	18.6	19.8	-
	Mermaid Shoal	-	-	-	-	-	-
	Parry Shoal	-	-	-	-	-	-
	Moss Shoal	-	-	-	-	-	-
	Barton Shoal	38	7	-	21.7	23.3	-
	The Boxers	6	-	-	9.9	-	-
	Fantome Shoal	39	2	-	28.0	38.8	-
	Mangola Shoal	33	2	-	25.4	25.4	-
	Jabiru Shoals	42	5	-	26.0	26.2	-
	Pee Shoal	34	3	-	27.5	27.5	-
	Vee Shoal	20	1	-	29.2	35.1	-
	Newby Shoal	2	1	-	42.3	48.1	-
	Shepparton Shoal	-	-	-	-	-	-
	Deep Shoal 2	2	-	-	27.1	-	-
	Flat Top Bank	2	2	-	45.1	46.7	-
	Deep Shoal 1	1	-	-	28.9	-	-
	Johnson Bank	19	4	-	28.2	33.2	-
	Woodbine Bank	13	2	-	32.2	36.2	-
	Barracouta Shoal	8	1	-	41.5	47.8	-
	Gale Bank	1	-	-	37.1	-	-
	Van Cloon Shoal	2	1	-	37.0	41.3	-
	Favell Bank	1	-	-	40.1	-	-
	Vulcan Shoal	9	-	-	47.7	-	-

	Baldwin Bank	1	-	-	40.6	-	-
	Goeree Shoal	5	-	-	49.8	-	-
	Penguin Shoal	2	-	-	46.3	-	-
	Eugene McDermott Shoal	1	-	-	51.3	-	-
	Holothuria Banks	1	-	-	78.0	-	-
	Bassett-Smith Shoal	-	-	-	-	-	-
	Heywood Shoal	6	-	-	41.2	-	-
	West Holothuria Reef	-	-	-	-	-	-
	East Holothuria Reef	-	-	-	-	-	-
	Branch Banks	-	-	-	-	-	-
	Otway Bank	-	-	-	-	-	-
	Tait Bank	-	-	-	-	-	-
	Rothery Reef	-	-	-	-	-	-
	Echuca Shoal	4	-	-	43.7	-	-
	Heritage Reef	-	-	-	-	-	-
	Beagle and Dingo Reefs	-	-	-	-	-	-
	Mavis Reef	-	-	-	-	-	-
Emergent receptor	Indonesia	53	17	6	11.4	11.8	15.0
	East Timor	64	18	3	18.2	18.7	19.4
	Melville Island	-	-	-	-	-	-
	Bathurst Island	-	-	-	-	-	-
	Hibernia Reef	25	2	-	29.7	31.5	-
	Ashmore Reef	26	3	-	31.0	39.9	-
	Cartier Island	12	2	-	31.0	47.6	-
	Seringapatam Reef	8	-	-	48.7	-	-
	Stewarts Islands	-	-	-	-	-	-
	Troughton Island	-	-	-	-	-	-
	Kimberley Coast	-	-	-	-	-	-
	Jones Island	-	-	-	-	-	-
	Long Reef	-	-	-	-	-	-
	Lesueur Island	-	-	-	-	-	-

	Eclipse Archipelago	-	-	-	-	-	-
	Scott Reef North	7	1	-	49.8	68.7	-
	Cassini Island	-	-	-	-	-	-
	Sandy Islet	5	-	-	49.7	-	-
	Scott Reef South	6	1	-	48.6	72.2	-
	Joseph Bonaparte Gulf Western Australia	-	-	-	-	-	-
	Admiralty Gulf Islands	-	-	-	-	-	-
	Browse Island	6	-	-	46.2	-	-
	Bonaparte Archipelago	-	-	-	-	-	-
	Buccaneer Archipelago	-	-	-	-	-	-
CMR	Arafura CMR	17	12	9	11.8	13.6	17.2
	Oceanic Shoals CMR	90	71	24	1.5	1.7	2.0
	Arnhem CMR	-	-	-	-	-	-
	Ashmore Reef CMR	27	3	-	30.2	34.5	-
	Cartier Island CMR	14	3	-	31.0	34.1	-
	Kimberley CMR	3	-	-	48.3	-	-
	Joseph Bonaparte CMR	-	-	-	-	-	-
	Argo-Rowley Terrace CMR	7	-	-	53.1	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	2	2	-	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	1	1	-	1.1	1.1	-
	Pinnacles of the Bonaparte Basin	-	-	-	-	-	-
	Carbonate bank and terrace system of Sahul Shelf	-	-	-	-	-	-
	Continental slope demersal fish communities	6	1	1	28.4	31.0	43.5
Fishery	Timor Reef Fishery (NT Managed)	3	-	-	0.04	-	-
Winter conditions (April to August)							
Receptor		**Probability of exposure to entrained concentrations at specific receptor depth (%)**			**Minimum time to entrained concentration at any depth [days]**		
		10 ppb	**100 ppb**	**500 ppb**	**10 ppb**	**100 ppb**	**500 ppb**
Submerged	Sunset Shoal	95	33	1	4.4	4.4	5.6

receptor	Loxton Shoal	97	36	1	3.9	4.2	6.1
	Martin Shoal	96	31	1	3.5	3.6	4.3
	Sunrise Bank	79	6	1	7.0	7.4	11.4
	Flinders Shoal	100	90	12	2.3	2.3	2.8
	Evans Shoal	100	72	3	1.1	1.5	1.9
	Tassie Shoal	98	42	1	1.6	1.6	2.9
	Franklin Shoal	100	60	1	2.4	2.4	3.4
	Blackwood Shoal	100	66	2	2.0	2.1	2.3
	Lynedoch Bank	34	3	1	5.9	7.6	17.1
	Margaret Harries Bank	97	29	1	5.0	5.0	8.5
	Bellona Bank	86	6	1	9.5	10.8	41.9
	Echo Shoals	99	23	1	9.9	12.3	13.9
	Money Shoal	-	-	-	-	-	-
	Troubadour Shoals	100	38	1	4.8	5.5	6.3
	Big Bank Shoals	88	18	2	13.2	13.7	14.9
	Goodrich Bank	-	-	-	-	-	-
	Karmt Shoal	87	21	1	12.7	13.8	16.2
	Cootamundra Shoal	8	5	1	19.4	21.3	22.8
	Calder Shoal	16	3	1	7.9	23.7	28.5
	Marie Shoal	-	-	-	-	-	-
	Sahul Bank	90	30	3	14.5	16.7	18.4
	Dillon Shoal	82	12	1	14.7	17.5	17.5
	Mermaid Shoal	-	-	-	-	-	-
	Parry Shoal	-	-	-	-	-	-
	Moss Shoal	-	-	-	-	-	-
	Barton Shoal	65	8	-	16.1	19.8	21.6
	The Boxers	6	-	-	19.2	19.8	-
	Fantome Shoal	63	13	-	20.0	25.7	-
	Mangola Shoal	41	3	-	21.5	25.9	-
	Jabiru Shoals	54	4	-	22.0	32.4	-
	Pee Shoal	46	6	-	22.0	28.4	-

	Vee Shoal	48	-	-	23.2	29.5	-
	Newby Shoal	5	-	-	42.1	45.7	-
	Shepparton Shoal	-	-	-	-	-	-
	Deep Shoal 2	4	1	-	36.4	55.3	-
	Flat Top Bank	3	3	-	44.3	47.6	-
	Deep Shoal 1	5	1	-	40.4	49.0	-
	Johnson Bank	38	2	-	25.8	31.2	-
	Woodbine Bank	28	1	-	29.6	44.3	-
	Barracouta Shoal	8	-	-	36.3	-	-
	Gale Bank	1	-	-	65.2	-	-
	Van Cloon Shoal	3	-	-	57.8	-	-
	Favell Bank	-	-	-	69.2	-	-
	Vulcan Shoal	6	-	-	52.4	-	-
	Baldwin Bank	-	-	-	-	-	-
	Goeree Shoal	2	-	-	59.8	-	-
	Penguin Shoal	-	-	-	-	-	-
	Eugene McDermott Shoal	2	1	-	60.4	67.6	-
	Holothuria Banks	-	-	-	-	-	-
	Bassett-Smith Shoal	-	-	-	-	-	-
	Heywood Shoal	3	-	-	38.1	-	-
	West Holothuria Reef	-	-	-	-	-	-
	East Holothuria Reef	-	-	-	-	-	-
	Branch Banks	-	-	-	-	-	-
	Otway Bank	-	-	-	-	-	-
	Tait Bank	-	-	-	-	-	-
	Rothery Reef	-	-	-	-	-	-
	Echuca Shoal	1	-	-	54.8	-	-
	Heritage Reef	-	-	-	-	-	-
	Beagle and Dingo Reefs	-	-	-	-	-	-
	Mavis Reef	-	-	-	-	-	-
Emergent	Indonesia	65	15	-	14.9	15.2	-

receptor	East Timor	51	13	1	12.4	14.6	43.4
	Melville Island	-	-	-	-	-	-
	Bathurst Island	-	-	-	-	-	-
	Hibernia Reef	56	2	-	25.1	27.2	-
	Ashmore Reef	41	3	-	29.2	30.6	-
	Cartier Island	32	1	-	32.2	32.5	-
	Seringapatam Reef	7	-	-	48.0	-	-
	Stewarts Islands	-	-	-	-	-	-
	Troughton Island	-	-	-	-	-	-
	Kimberley Coast	-	-	-	-	-	-
	Jones Island	-	-	-	-	-	-
	Long Reef	-	-	-	-	-	-
	Lesueur Island	-	-	-	-	-	-
	Eclipse Archipelago	-	-	-	-	-	-
	Scott Reef North	1	-	-	55.7	-	-
	Cassini Island	-	-	-	-	-	-
	Sandy Islet	1	-	-	82.7	-	-
	Scott Reef South	4	-	-	60.3	-	-
	Joseph Bonaparte Gulf Western Australia	-	-	-	-	-	-
	Admiralty Gulf Islands	-	-	-	-	-	-
	Browse Island	1	-	-	47.6	-	-
	Bonaparte Archipelago	-	-	-	-	-	-
	Buccaneer Archipelago	-	-	-	-	-	-
CMR	Arafura CMR	-	-	-	-	-	-
	Oceanic Shoals CMR	88	54	5	1.1	2.2	4.2
	Arnhem CMR	-	-	-	-	-	-
	Ashmore Reef CMR	44	3	-	26.3	30.3	-
	Cartier Island CMR	35	1	-	31.9	38.6	-
	Kimberley CMR	2	1	-	70.1	84.2	-
	Joseph Bonaparte Gulf CoCMR	-	-	-	-	-	-
	Argo-Rowley Terrace CMR	4	-	-	40.7	-	-

KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	100	38	5	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	99	19	2	0.4	1.3	2.1
	Pinnacles of the Bonaparte Basin	61	7	1	8.5	8.5	10.6
	Carbonate bank and terrace system of Sahul Shelf	15	4	-	21.3	23.5	28.9
Fishery	Timor Reef Fishery (NT Managed)	100	38	5	0.04	0.04	0.04

Table 30 Probability and minimum time before dissolved aromatic hydrocarbon exposure for receptors (16,833 m^3 Barossa condensate)

Summer conditions (December to February)							
Receptor		Probability of exposure to dissolved aromatic concentrations at specific receptor depth (%)			Minimum time to dissolved aromatic concentration at any depth (days)		
		6 ppb	50 ppb	400 ppb	6 ppb	50 ppb	400 ppb
Submerged receptor	Sunset Shoal	25	7	-	8.9	10.4	-
	Loxton Shoal	23	9	-	4.8	5.0	-
	Martin Shoal	21	4	-	4.2	4.3	-
	Sunrise Bank	11	1	-	8.0	9.9	-
	Flinders Shoal	48	18	1	2.8	2.8	3.4
	Evans Shoal	72	25	3	1.1	1.1	1.2
	Tassie Shoal	10	18	1	2.4	2.6	4.0
	Franklin Shoal	49	19	1	2.7	2.8	3.4
	Blackwood Shoal	56	26	1	2.4	2.4	10.4
	Lynedoch Bank	48	23	-	1.6	2.5	-
	Margaret Harries Bank	20	6	-	7.3	8.7	-
	Bellona Bank	9	2	-	12.8	12.9	-
	Echo Shoals	7	1	-	17.5	18.5	-
	Money Shoal	5	-	-	34.1	-	-
	Troubadour Shoals	29	8	-	5.5	5.5	-
	Big Bank Shoals	8	1	-	19.4	19.6	-
	Goodrich Bank	-	-	-	-	-	-
	Karmt Shoal	12	2	-	19.8	20.6	-
	Cootamundra Shoal	13	3	-	12.5	15.8	-
	Calder Shoal	5	2	-	7.4	7.4	-
	Marie Shoal	-	-	-	-	-	-
	Sahul Bank	5	1	-	21.0	21.6	-
	Dillon Shoal	7	1	-	20.9	29.0	-
	Mermaid Shoal	-	-	-	-	-	-
	Parry Shoal	-	-	-	-	-	-
	Moss Shoal	-	-	-	-	-	-
	Barton Shoal	4	1	-	24.3	24.4	-

	The Boxers	-	-	-	-	-	-
	Fantome Shoal	2	1	-	35.1	39.5	-
	Mangola Shoal	2	-	-	37.7	-	-
	Jabiru Shoals	2	1	-	26.8	28.5	-
	Pee Shoal	1	1	-	30.6	33.2	-
	Vee Shoal	2	1	-	29.3	35.8	-
	Newby Shoal	-	-	-	-	-	-
	Shepparton Shoal	-	-	-	-	-	-
	Deep Shoal 2	-	-	-	-	-	-
	Flat Top Bank	-	-	-	-	-	-
	Deep Shoal 1	-	-	-	-	-	-
	Johnson Bank	2	1	-	39.3	40.4	-
	Woodbine Bank	3	-	-	56.0	-	-
	Barracouta Shoal	1	-	-	43.9	-	-
	Gale Bank	-	-	-	-	-	-
	Van Cloon Shoal	-	-	-	-	-	-
	Favell Bank	-	-	-	-	-	-
	Vulcan Shoal	1	1	-	50.8	51.9	-
	Baldwin Bank	-	-	-	-	-	-
	Goeree Shoal	-	-	-	-	-	-
	Penguin Shoal	-	-	-	-	-	-
	Eugene McDermott Shoal	-	-	-	-	-	-
	Holothuria Banks	-	-	-	-	-	-
	Bassett-Smith Shoal	-	-	-	-	-	-
	Heywood Shoal	-	-	-	-	-	-
	West Holothuria Reef	-	-	-	-	-	-
	East Holothuria Reef	-	-	-	-	-	-
	Branch Banks	-	-	-	-	-	-
	Otway Bank	-	-	-	-	-	-
	Tait Bank	-	-	-	-	-	-
	Rothery Reef	-	-	-	-	-	-

	Echuca Shoal	-	-	-	-	-	-
	Heritage Reef	-	-	-	-	-	-
	Camden Sound Marine Park	-	-	-	-	-	-
	Beagle and Dingo Reefs	-	-	-	-	-	-
	Mavis Reef	-	-	-	-	-	-
Emergent receptor	Indonesia	11	2	-	18.5	20.9	-
	East Timor	12	3	-	22.7	22.9	-
	Melville Island	-	-	-	-	-	-
	Bathurst Island	1	-	-	32.7	-	-
	Hibernia Reef	1	-	-	39.2	39.5	-
	Ashmore Reef	-	-	-	-	-	-
	Cartier Island	-	-	-	-	-	-
	Seringapatam Reef	-	-	-	-	-	-
	Stewarts Islands	-	-	-	-	-	-
	Troughton Island	-	-	-	-	-	-
	Kimberley Coast	-	-	-	-	-	-
	Jones Island	-	-	-	-	-	-
	Long Reef	-	-	-	-	-	-
	Lesueur Island	-	-	-	-	-	-
	Eclipse Archipelago	-	-	-	-	-	-
	Scott Reef North	-	-	-	-	-	-
	Cassini Island	-	-	-	-	-	-
	Sandy Islet	-	-	-	-	-	-
	Scott Reef South	-	-	-	-	-	-
	Joseph Bonaparte Gulf Western Australia	-	-	-	-	-	-
	Admiralty Gulf Islands	-	-	-	-	-	-
	Browse Island	-	-	-	-	-	-
	Bonaparte Archipelago	-	-	-	-	-	-
	Buccaneer Archipelago	-	-	-	-	-	-
CMR	Arafura CMR	27	13	3	0.8	0.8	1.1
	Oceanic CMR	76	28	3	0.3	0.3	1.4

	Arnhem Commonwealth Marine Reserve	-	-	-	-	-	-
	Ashmore Reef CMR	1	-	-	62.5	-	-
	Cartier Island CMR	-	-	-	-	-	-
	Kimberley CMR	-	-	-	-	-	-
	Joseph Bonaparte Gulf CCMR	-	-	-	-	-	-
	Argo-Rowley Terrace CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	22	9	-	15.3	20.8	-
	Shelf break and slope of the Arafura Shelf	65	29	8	0.1	0.1	0.1
	Carbonate bank and terrace system of Van Diemen Rise	31	7	1	1.4	1.4	1.5
	Pinnacles of the Bonaparte Basin	1	-	-	14.6		-
	Carbonate bank and terrace system of Sahul Shelf	-	-	-	-	-	-
	Continental slope demersal fish communities	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	68	38	14	0.04	0.04	0.04
Transitional conditions (March and September to November)							
Receptor		**Probability of exposure to dissolved aromatic concentrations at specific receptor depth (%)**			**Minimum time to dissolved aromatic concentration at any depth (days)**		
		6 ppb	**50 ppb**	**400 ppb**	**6 ppb**	**50 ppb**	**400 ppb**
Submerged receptor	Sunset Shoal	55	14	-	5.7	6.6	-
	Loxton Shoal	56	16	-	4.4	4.8	-
	Martin Shoal	67	19	1	3.5	3.9	7.7
	Sunrise Bank	53	14	-	8.1	8.7	-
	Flinders Shoal	87	48	4	1.0	1.5	1.6
	Evans Shoal	97	63	12	0.1	0.1	0.3
	Tassie Shoal	89	46	7	0.1	0.1	0.8
	Franklin Shoal	91	59	6	0.6	0.6	1.3
	Blackwood Shoal	90	52	2	0.4	0.4	1.8
	Lynedoch Bank	19	8	-	1.4	2.0	-
	Margaret Harries Bank	75	29	2	2.5	2.9	8.3
	Bellona Bank	44	12	-	13.1	13.2	-
	Echo Shoals	28	6	-	14.8	14.9	-
	Money Shoal	3	1	-	33.0	33.8	-

	Troubadour Shoals	79	39	3	5.3	5.4	5.5
	Big Bank Shoals	23	5	-	19.4	19.7	-
	Goodrich Bank	-	-	-	-	-	-
	Karmt Shoal	23	4	-	17.3	21.5	-
	Cootamundra Shoal	11	3	-	8.7	8.8	-
	Calder Shoal	12	4	-	7.4	8.2	-
	Marie Shoal	-	-	-	-	-	-
	Sahul Bank	15	2	-	23.6	27.3	-
	Dillon Shoal	18	3	-	21.7	26.7	-
	Mermaid Shoal	-	-	-	-	-	-
	Parry Shoal	-	-	-	-	-	-
	Moss Shoal	-	-	-	-	-	-
	Barton Shoal	10	1	-	30.7	34.7	-
	The Boxers	2	2	-	16.6	16.6	-
	Fantome Shoal	2	-	-	41.9	-	-
	Mangola Shoal	3	-	-	34.2	-	-
	Jabiru Shoals	2	1	-	31.3	36.2	-
	Pee Shoal	2	1	-	31.4	36.7	-
	Vee Shoal	1	1	-	35.6	38.2	-
	Newby Shoal	-	-	-	-	-	-
	Shepparton Shoal	-	-	-	-	-	-
	Deep Shoal 2	1	-	-	30.5	-	-
	Flat Top Bank	-	-	-	-	-	-
	Deep Shoal 1	-	-	-	-	-	-
	Johnson Bank	2	-	-	39.8	-	-
	Woodbine Bank	3	-	-	37.4	-	-
	Barracouta Shoal	1	-	-	41.5	-	-
	Gale Bank	-	-	-	-	-	-
	Van Cloon Shoal	-	-	-	67.5	-	-
	Favell Bank	-	-	-	-	-	-
	Vulcan Shoal	2	-	-	46.8	-	-

	Baldwin Bank	1	-	-	71.8	-	-
	Goeree Shoal	2	-	-	50.7	-	-
	Penguin Shoal	-	-	-	-	-	-
	Eugene McDermott Shoal	-	-	-	-	-	-
	Holothuria Banks	-	-	-	-	-	-
	Bassett-Smith Shoal	-	-	-	-	-	-
	Heywood Shoal	1	-	-	54.5	-	-
	West Holothuria Reef	-	-	-	-	-	-
	East Holothuria Reef	-	-	-	-	-	-
	Branch Banks	-	-	-	-	-	-
	Otway Bank	-	-	-	-	-	-
	Tait Bank	-	-	-	-	-	-
	Rothery Reef	-	-	-	-	-	-
	Echuca Shoal	1	-	-	71.9	-	-
	Heritage Reef	-	-	-	-	-	-
	Beagle and Dingo Reefs	-	-	-	-	-	-
	Mavis Reef	-	-	-	-	-	-
Emergent receptor	Indonesia	12	3	-	16.9	17.0	-
	East Timor	11	3	-	18.8	18.8	-
	Melville Island	-	-	-	-	-	-
	Bathurst Island	2	-	-	35.3	-	-
	Hibernia Reef	3	1	-	33.3	38.8	-
	Ashmore Reef	3	1	-	48.3	51.1	-
	Cartier Island	-	-	-	-	-	-
	Seringapatam Reef	-	-	-	-	-	-
	Stewarts Islands	-	-	-	-	-	-
	Troughton Island	-	-	-	-	-	-
	Kimberley Coast	-	-	-	-	-	-
	Jones Island	-	-	-	-	-	-
	Long Reef	-	-	-	-	-	-
	Lesueur Island	-	-	-	-	-	-

	Eclipse Archipelago	-	-	-	-	-	-
	Scott Reef North	-	-	-	-	-	-
	Cassini Island	-	-	-	-	-	-
	Sandy Islet	-	-	-	-	-	-
	Scott Reef South	-	-	-	-	-	-
	Joseph Bonaparte Gulf Western Australia	-	-	-	-	-	-
	Admiralty Gulf Islands	-	-	-	-	-	-
	Browse Island	-	-	-	-	-	-
	Bonaparte Archipelago	-	-	-	-	-	-
	Buccaneer Archipelago	-	-	-	-	-	-
CMR	Arafura CMR	8	3	-	18.5	19.8	-
	Oceanic Shoals CMR	67	26	3	0.6	0.6	0.8
	Arnhem CMR	-	-	-	-	-	-
	Ashmore Reef CMR	3	-	-	33.2	-	-
	Cartier Island CMR	3	-	-	45.6	-	-
	Kimberley CMR	1	1	-	56.2	56.8	-
	Joseph Bonaparte Gulf CMR	-	-	-	-	-	-
	Argo-Rowley Terrace CMR	1	-	-	51.3	-	-
KEF	Tributary Canyons of the Arafura Depression	10	8	-	19.8	23.1	
	Shelf break and slope of the Arafura Shelf	41	18	9	0.1	0.1	0.1
	Carbonate bank and terrace system of Van Diemen Rise	39	7	1	0.1	0.1	0.2
	Pinnacles of the Bonaparte Basin	6	2	-	11.8	12.6	-
	Carbonate bank and terrace system of Sahul Shelf	8	2	-	24.3	24.6	-
	Continental slope demersal fish communities	1	-	-	30.0	-	-
Fishery	Timor Reef Fishery (NT Managed)	55	14	-	0.1	0.1	0.1
Winter conditions (April to August)							
Receptor		**Probability of exposure to dissolved aromatic concentrations at specific receptor depth (%)**			**Minimum time to dissolved aromatic concentration at any depth (days)**		
		6 ppb	**50 ppb**	**400 ppb**	**6 ppb**	**50 ppb**	**400 ppb**
Submerged receptor	Sunset Shoal	77	20	1	4.4	5.0	8.6
	Loxton Shoal	82	22	1	3.9	4.0	7.7

	Martin Shoal	86	36	1	2.8	3.7	6.3
	Sunrise Bank	61	11	-	9.1	9.2	-
	Flinders Shoal	95	52	5	1.2	1.2	1.4
	Evans Shoal	99	74	10	0.1	0.9	0.9
	Tassie Shoal	92	43	2	0.9	0.9	1.0
	Franklin Shoal	97	60	4	1.2	1.2	3.2
	Blackwood Shoal	99	56	1	1.2	1.2	2.6
	Lynedoch Bank	17	2	-	7.5	8.9	-
	Margaret Harries Bank	71	24	1	5.6	6.2	7.4
	Bellona Bank	59	9	-	10.4	13.6	-
	Echo Shoals	56	7	-	12.3	13.5	-
	Money Shoal	-	-	-	-	-	-
	Troubadour Shoals	91	37	1	5.1	5.5	9.3
	Big Bank Shoals	37	4	-	15.2	15.5	-
	Goodrich Bank	-	-	-	-	-	-
	Karmt Shoal	46	8	1	14.5	17.2	22.9
	Cootamundra Shoal	7	4	-	18.7	19.5	-
	Calder Shoal	9	1	-	7.8	8.7	-
	Marie Shoal	-	-	-	-	-	-
	Sahul Bank	32	4	1	16.3	21.1	26.7
	Dillon Shoal	37	3	-	16.9	21.0	-
	Mermaid Shoal	-	-	-	-	-	-
	Parry Shoal	-	-	-	-	-	-
	Moss Shoal	-	-	-	-	-	-
	Barton Shoal	16	2	-	20.1	25.8	-
	The Boxers	5	1	-	19.9	23.3	-
	Fantome Shoal	6	-	-	28.3	-	-
	Mangola Shoal	4	1	-	35.4	40.3	-
	Jabiru Shoals	4	1	-	33.7	44.6	-
	Pee Shoal	4	1	-	27.7	39.9	-
	Vee Shoal	3	1	-	37.0	47.4	-

	Newby Shoal	1	-	-	45.2	-	-
	Shepparton Shoal	-	-	-	-	-	-
	Deep Shoal 2	2	-	-	40.3	-	-
	Flat Top Bank	2	-	-	45.9	-	-
	Deep Shoal 1	4	1	-	42.8	55.5	-
	Johnson Bank	1	-	-	48.3	-	-
	Woodbine Bank	1	-	-	48.8	-	-
	Barracouta Shoal	-	-	-	-	-	-
	Gale Bank	-	-	-	-	-	-
	Van Cloon Shoal	-	-	-	61.3	-	-
	Favell Bank	-	-	-	-	-	-
	Vulcan Shoal	-	-	-	-	-	-
	Baldwin Bank	-	-	-	-	-	-
	Goeree Shoal	-	-	-	-	-	-
	Penguin Shoal	-	-	-	-	-	-
	Eugene McDermott Shoal	1	-	-	73.0	-	-
	Holothuria Banks	-	-	-	-	-	-
	Bassett-Smith Shoal	-	-	-	-	-	-
	Heywood Shoal	-	-	-	-	-	-
	West Holothuria Reef	-	-	-	-	-	-
	East Holothuria Reef	-	-	-	-	-	-
	Branch Banks	-	-	-	-	-	-
	Otway Bank	-	-	-	-	-	-
	Tait Bank	-	-	-	-	-	-
	Rothery Reef	-	-	-	-	-	-
	Echuca Shoal	-	-	-	-	-	-
	Heritage Reef	-	-	-	-	-	-
	Beagle and Dingo Reefs	-	-	-	-	-	-
	Mavis Reef	-	-	-	-	-	-
Emergent receptor	Indonesia	8	2	-	15.3	24.4	-
	East Timor	10	1	-	18.6	27.8	-

Emergent receptor	Melville Island	-	-	-	-	-	-
	Bathurst Island	-	-	-	-	-	-
	Hibernia Reef	1	-	-	42.0	-	-
	Ashmore Reef	2	-	-	41.0	51.5	-
	Cartier Island	1	-	-	54.9	-	-
	Seringapatam Reef	-	-	-	-	-	-
	Stewarts Islands	-	-	-	-	-	-
	Troughton Island	-	-	-	-	-	-
	Kimberley Coast	-	-	-	-	-	-
	Jones Island	-	-	-	-	-	-
	Long Reef	-	-	-	-	-	-
	Lesueur Island	-	-	-	-	-	-
	Eclipse Archipelago	-	-	-	-	-	-
	Scott Reef North	-	-	-	-	-	-
	Cassini Island	-	-	-	-	-	-
	Sandy Islet	-	-	-	-	-	-
	Scott Reef South	-	-	-	-	-	-
	Joseph Bonaparte Gulf Western Australia	-	-	-	-	-	-
	Admiralty Gulf Islands	-	-	-	-	-	-
	Browse Island	-	-	-	-	-	-
	Bonaparte Archipelago	-	-	-	-	-	-
	Buccaneer Archipelago	-	-	-	-	-	-
CMR	Arafura CMR	-	-	-	-	-	-
	Oceanic Shoals CMR	52	21	2	1.7	1.7	3.4
	Arnhem CMR	-	-	-	-	-	-
	Ashmore Reef CMR	2	1	-	38.1	51.5	-
	Cartier Island CMR	1	-	-	53.9	-	-
	Kimberley CMR	-	-	-	-	-	-
	Joseph Bonaparte Gulf CMR	-	-	-	-	-	-
	Argo-Rowley Terrace CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-

	Shelf break and slope of the Arafura Shelf	42	15	9	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	32	12	1	0.2	0.2	0.2
	Pinnacles of the Bonaparte Basin	50	18	1	8.4	8.4	9.7
	Carbonate bank and terrace system of Sahul Shelf	7	2	1	23.3	24.1	34.1
	Continental slope demersal fish communities	7	1	-	31.0	40.4	-
Fishery	Timor Reef Fishery (NT Managed)	41	12	6	0.04	0.04	0.04

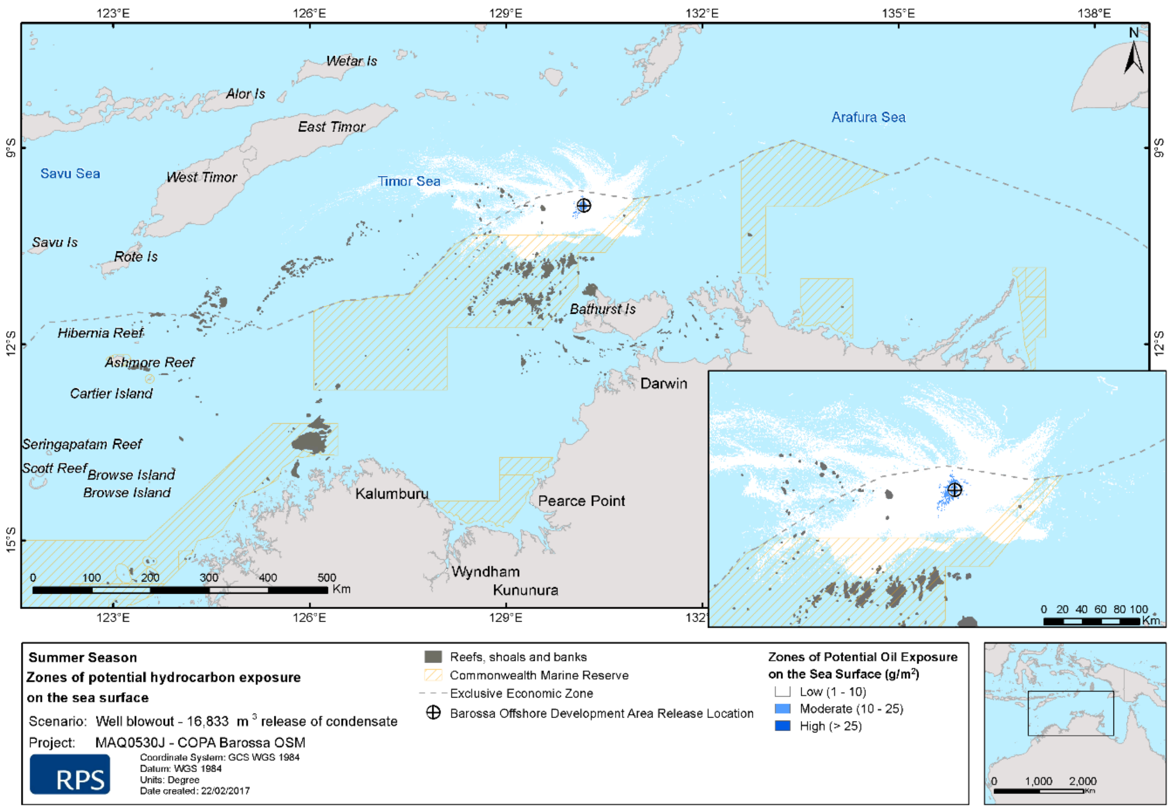


Figure 81 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during summer conditions (16,833 m^3 Barossa condensate)

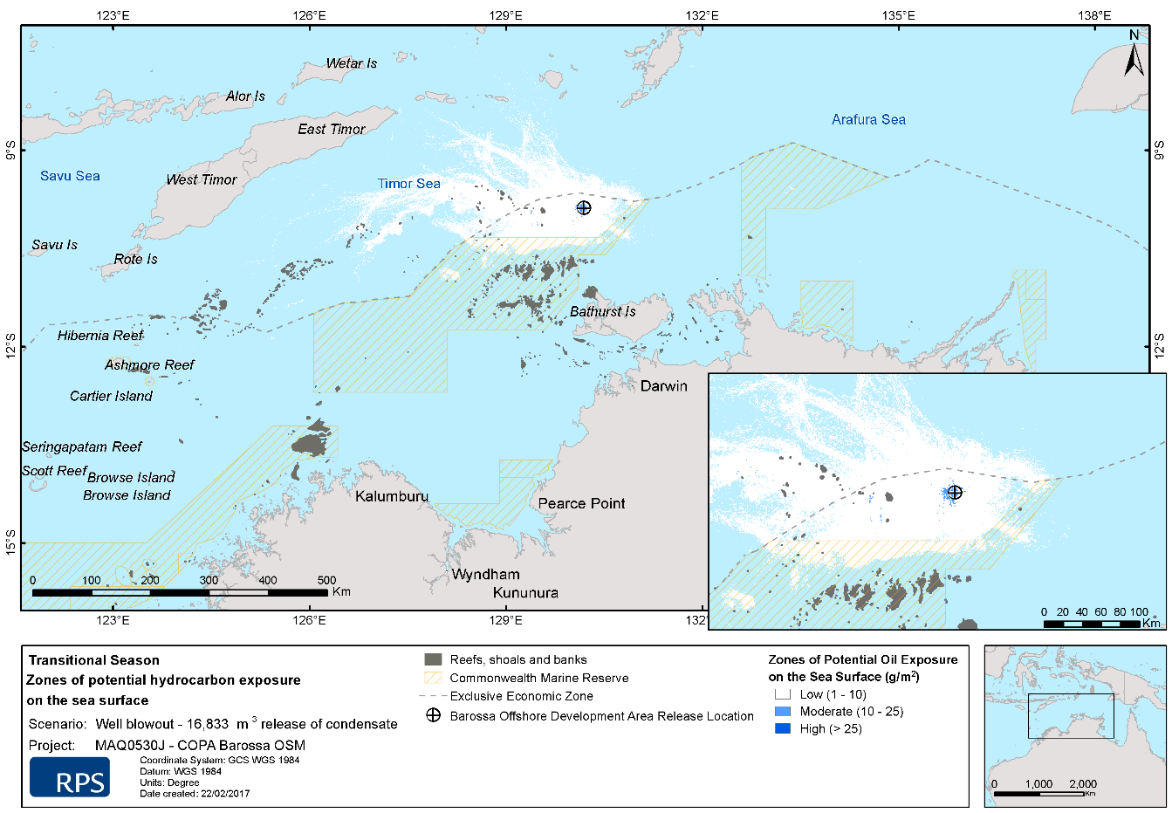


Figure 82 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during transitional conditions (16,833 m^3 Barossa condensate)

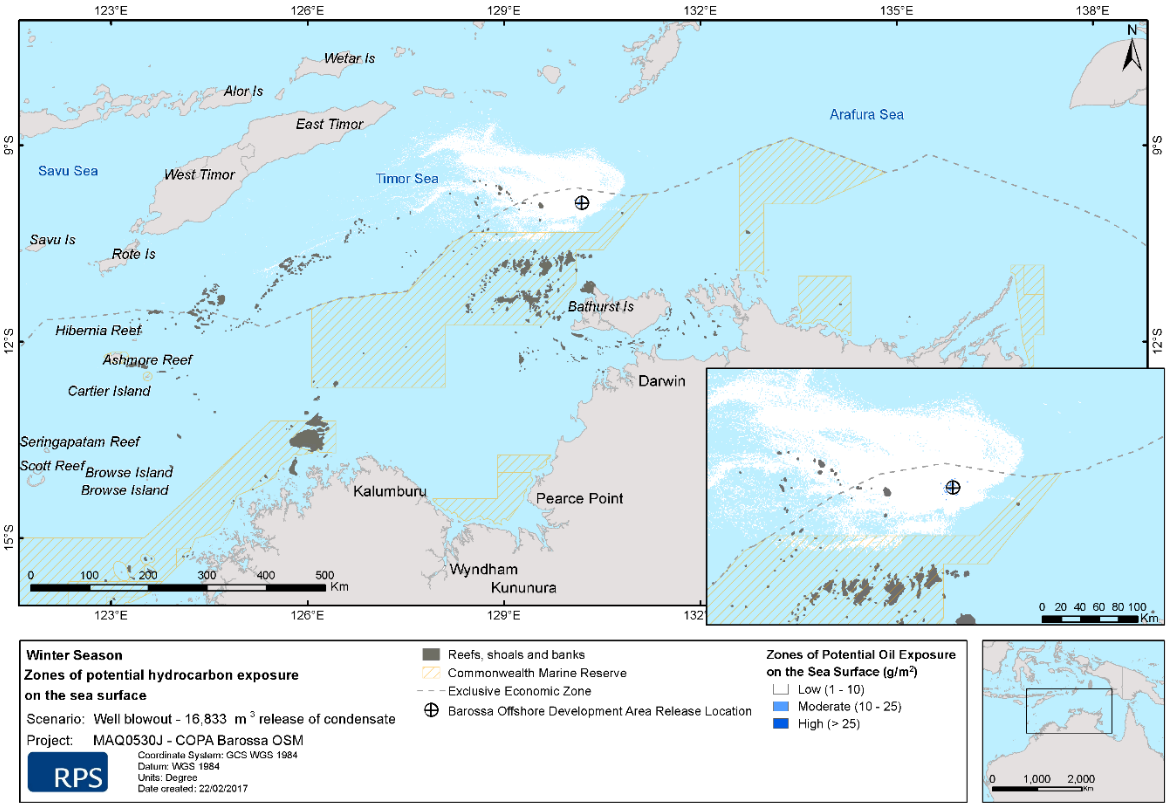


Figure 83 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during winter conditions (16,833 m^3 Barossa condensate)

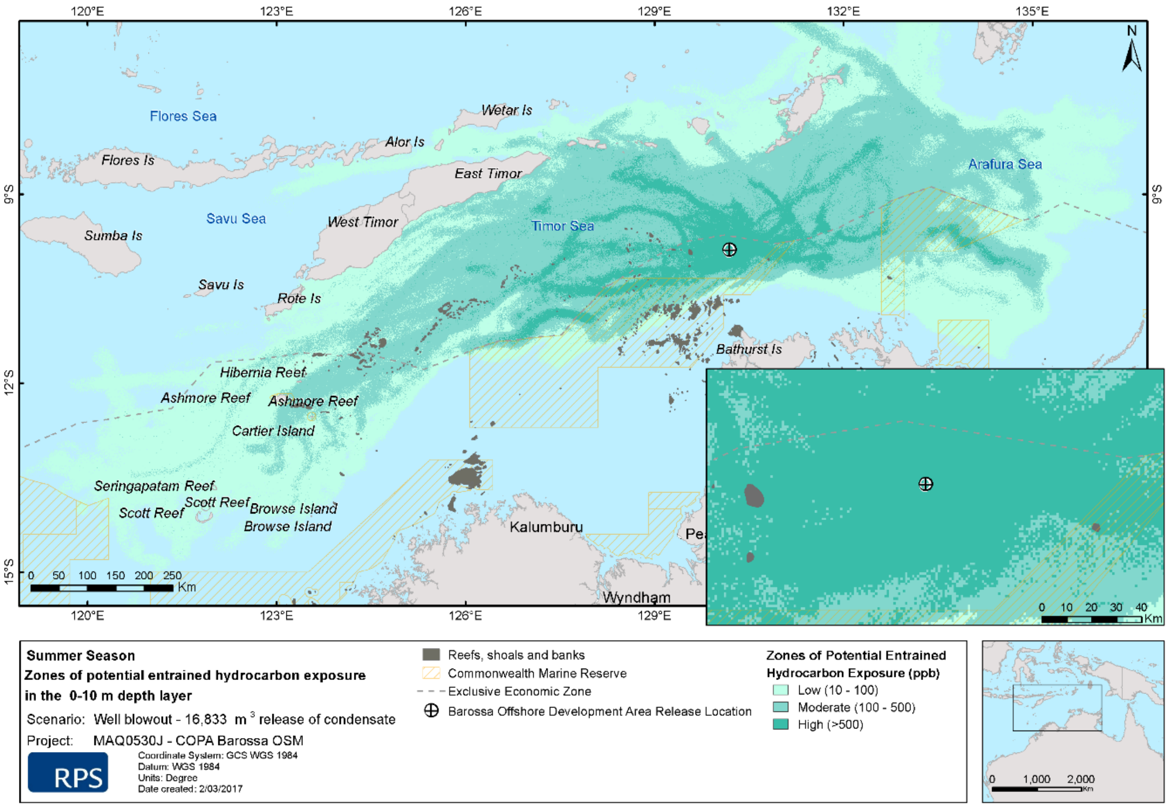


Figure 84 Stochastic modelling outputs showing the potential entrained hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during summer conditions (16,833 m^3 Barossa condensate)

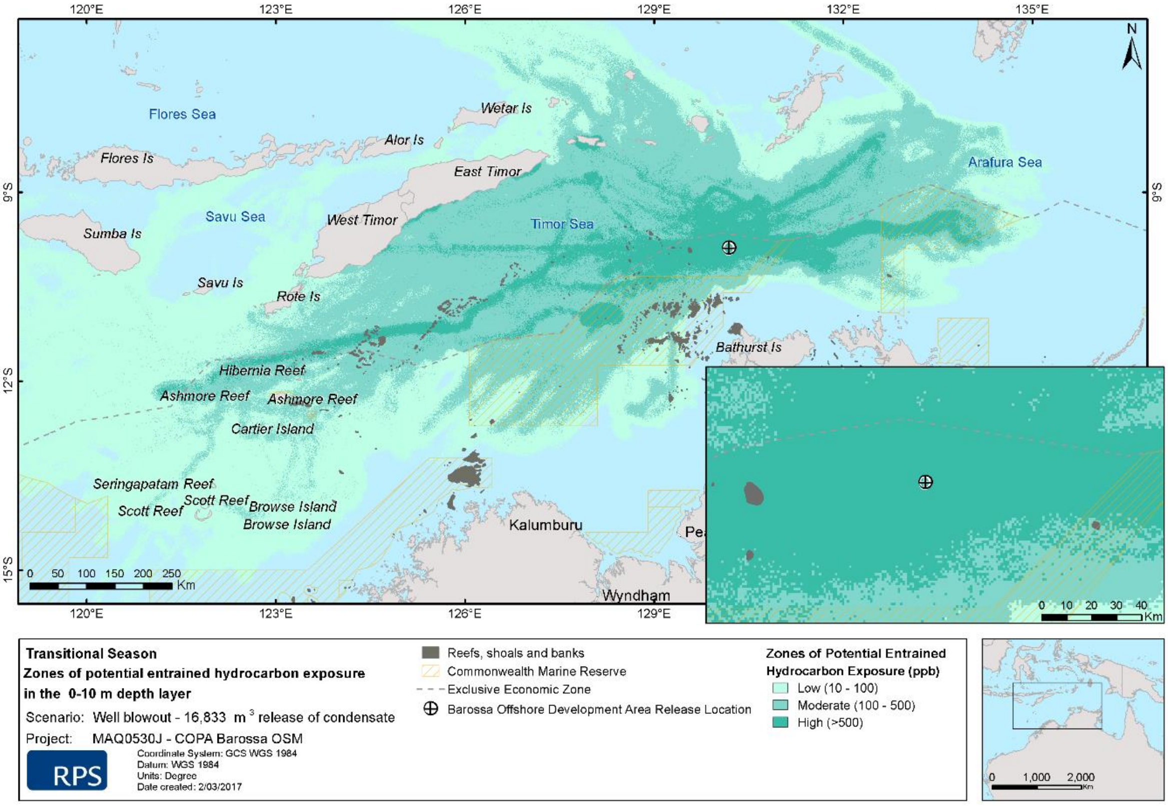


Figure 85 Stochastic modelling outputs showing the potential entrained hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during transitional conditions (16,833 m^3 Barossa condensate)

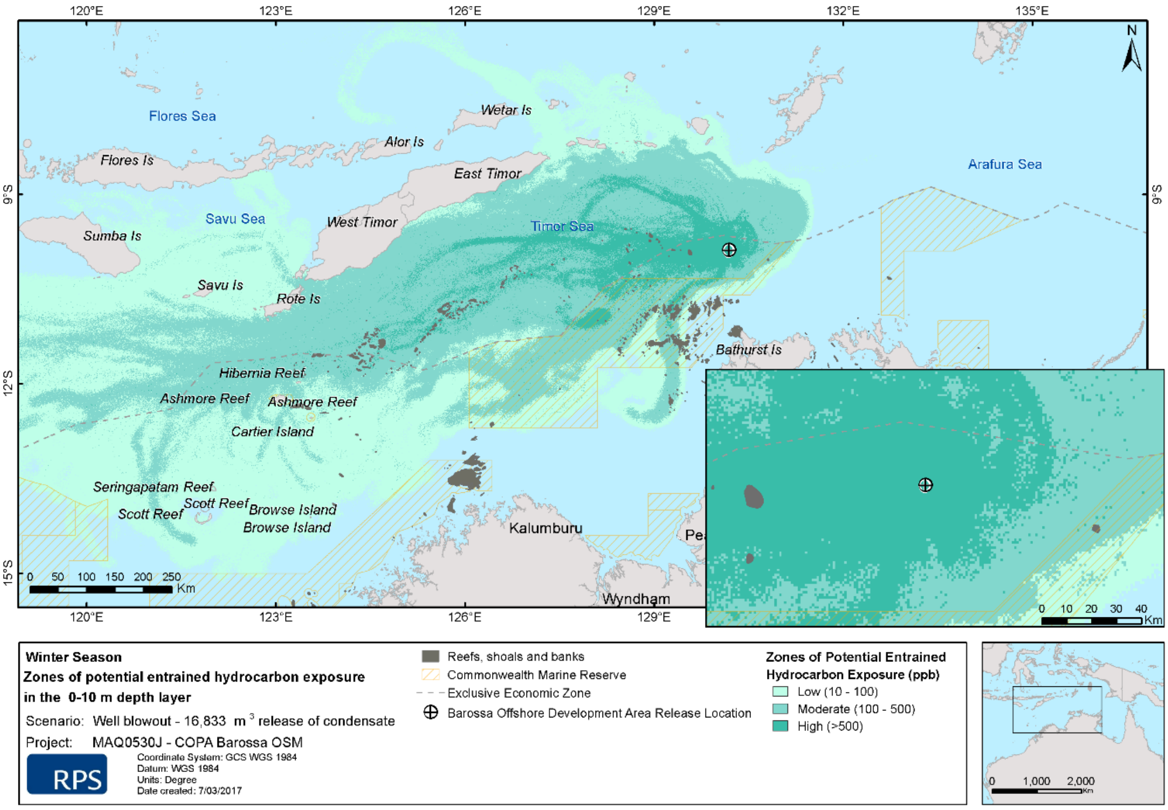


Figure 86 Stochastic modelling outputs showing the potential entrained hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during winter conditions (16,833 m^3 Barossa condensate)

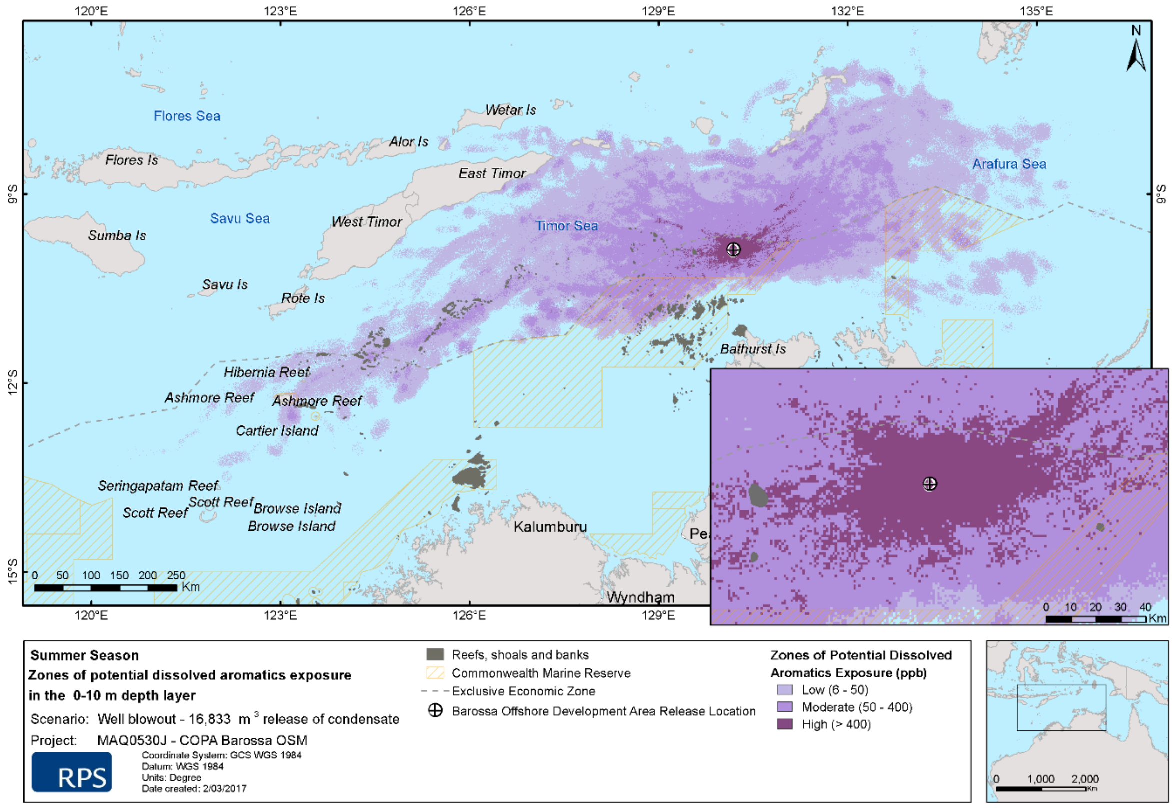


Figure 87 Stochastic modelling outputs showing the potential dissolved aromatic hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during summer conditions (16,833 m^3 Barossa condensate)

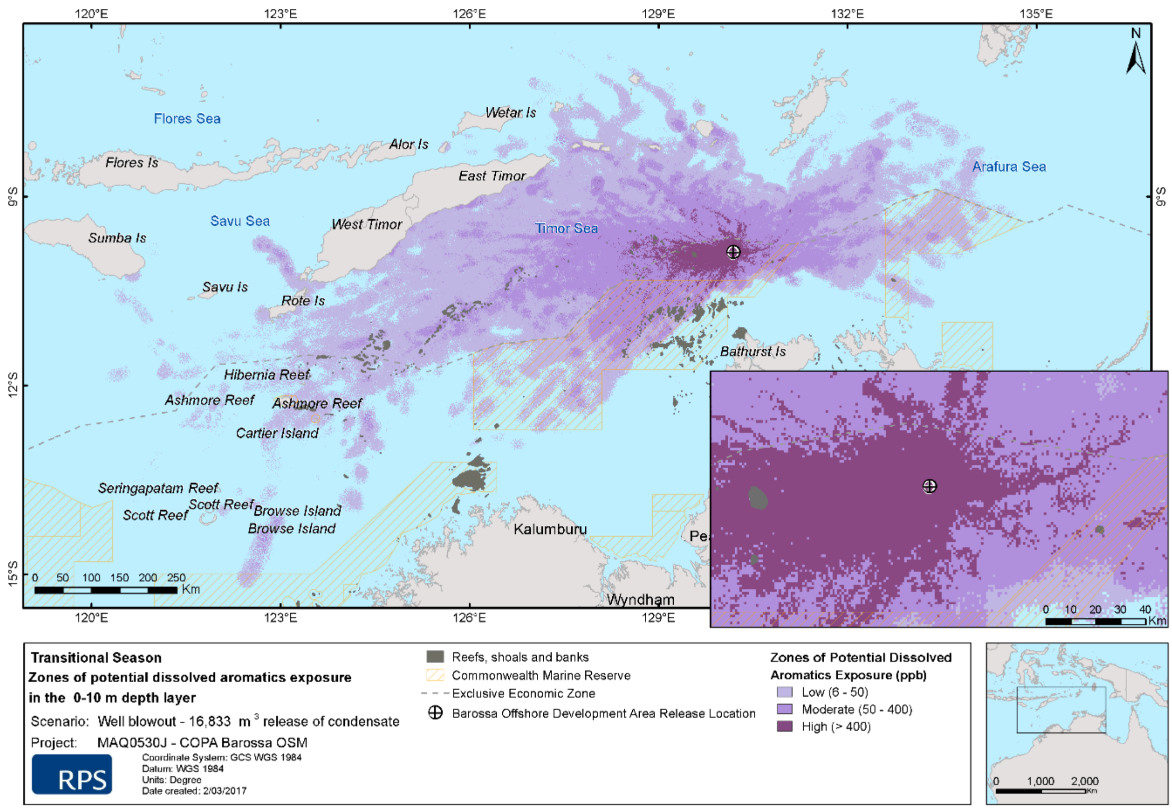


Figure 88 Stochastic modelling outputs showing the potential dissolved aromatic hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during transitional conditions (16,833 m^3 Barossa condensate)

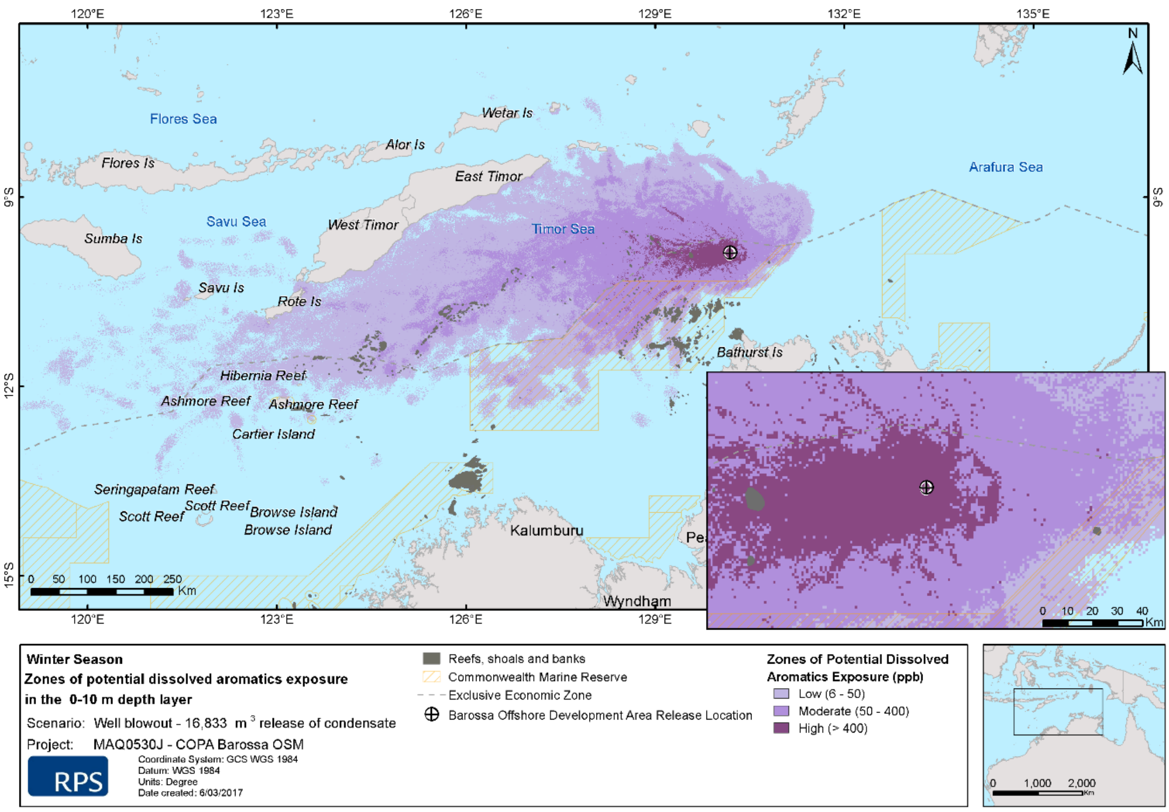


Figure 89 Stochastic modelling outputs showing the potential dissolved aromatic hydrocarbon exposure and adverse exposure zones (0-10 m depth layer) during winter conditions (16,833 m^3 Barossa condensate)

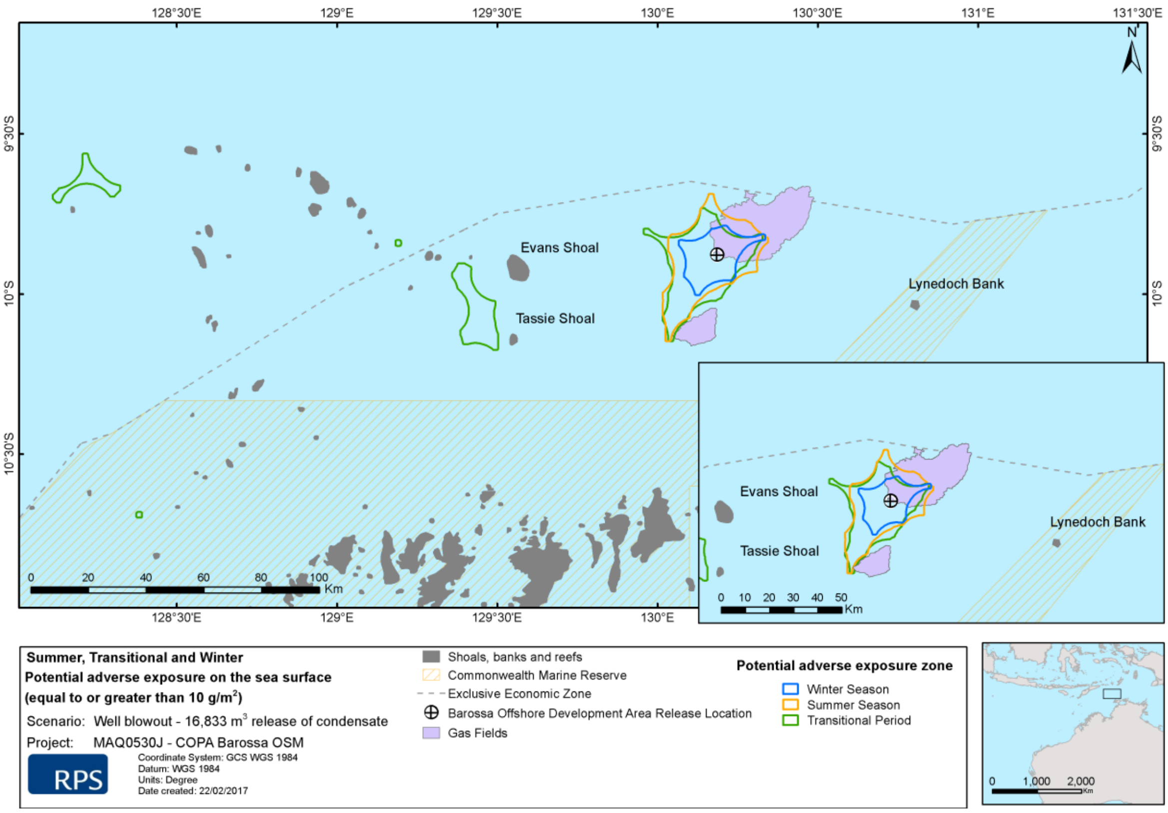


Figure 90 Stochastic modelling outputs showing the potential adverse exposure zone on the sea surface from a long-term well blowout of Barossa condensate (16,833 m^3)

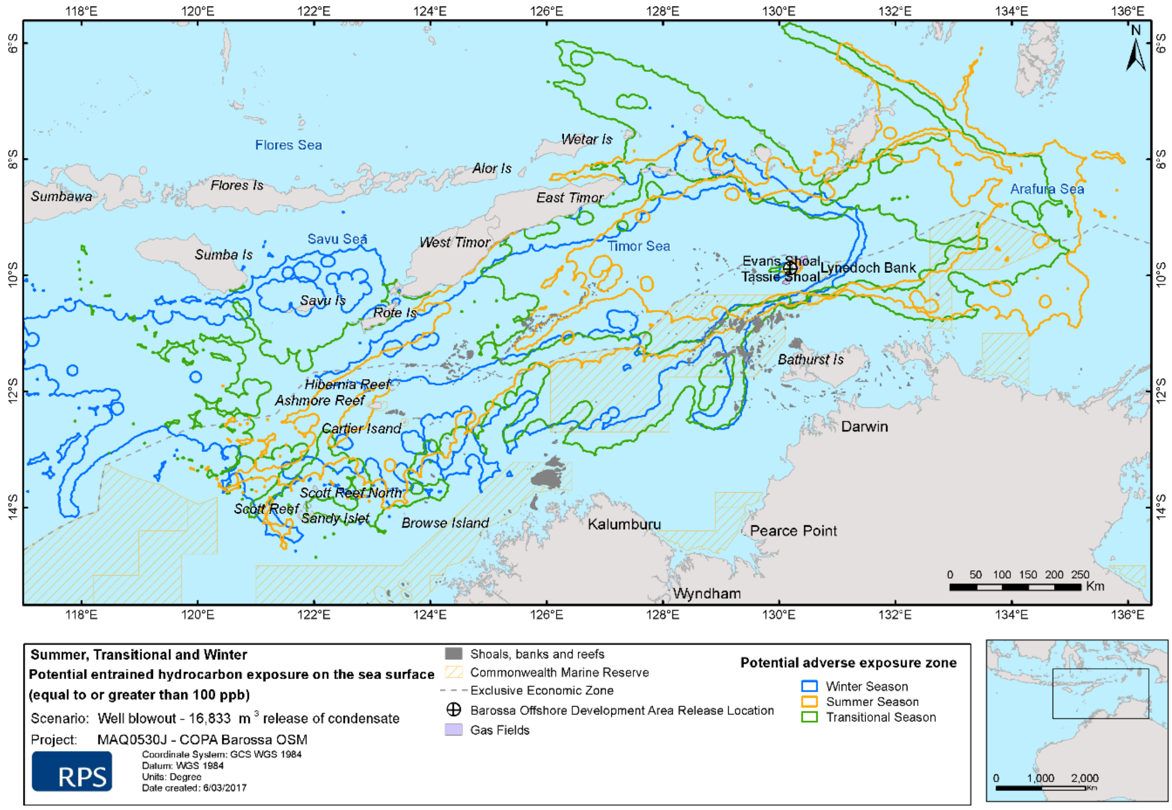


Figure 91 Stochastic modelling outputs showing the potential adverse exposure zone (0-10 m depth layer) for entrained hydrocarbons from a long-term well blowout of Barossa condensate (16,833 m^3)

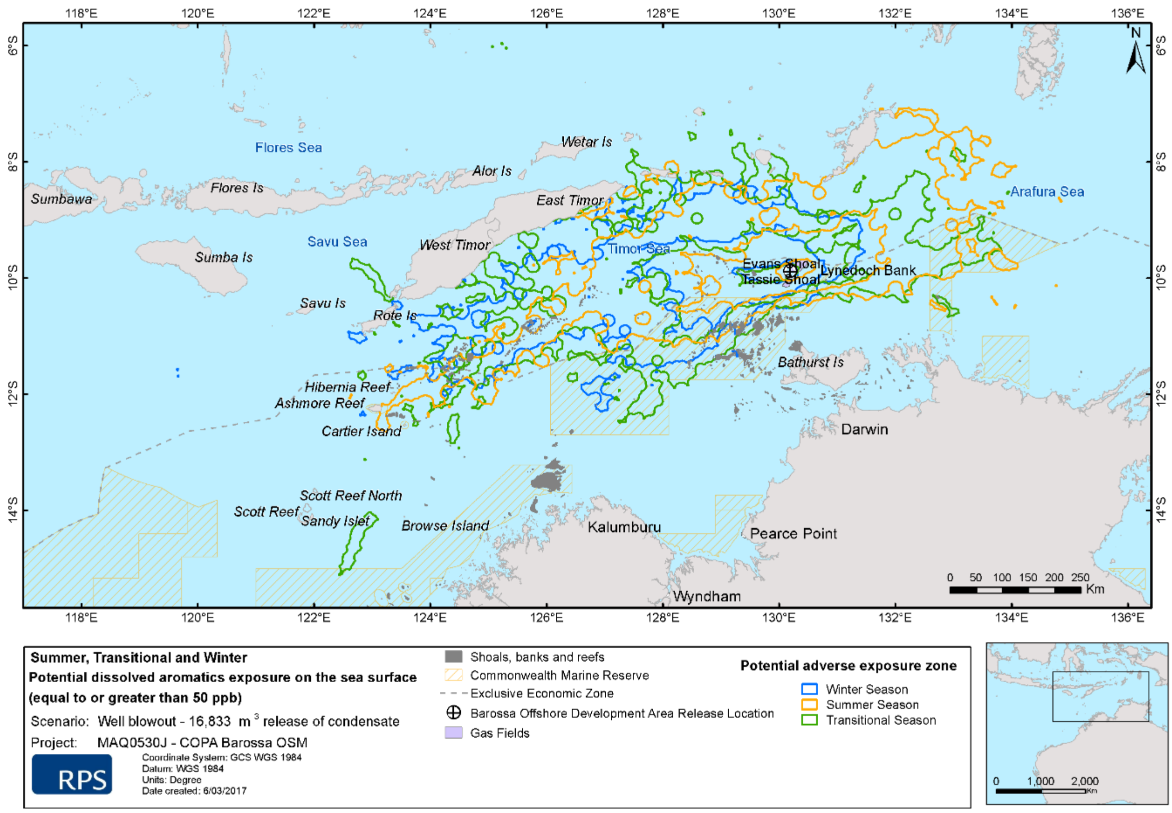


Figure 92 Stochastic modelling outputs showing the potential adverse exposure zone (0-10 m depth layer) for dissolved aromatics hydrocarbons from a long-term well blowout of Barossa condensate (16,833 m^3)

3.5 Scenario 5: Vessel collision leading to loss of a single export tanker fuel tank (650 m^3 HFO)

3.5.1 Single trajectory

Figure 93 shows the potential sea surface hydrocarbon exposure zones over the entire 40 day model simulation. The spill starting at 9 am 21st April 2014 was used an example trajectory to illustrate the potential shoreline exposure to East Timor during the winter season.

The hydrocarbon travelled northwest toward East Timor upon release. The adverse exposure zone (high and moderate exposure) was observed up to 45 km and 115 km, respectively, from the release location. There was no entrained or dissolved aromatic hydrocarbons was predicted within the adverse exposure zone.

Figure 94 illustrates the fates and weathering graph for the corresponding winter spill trajectory. The graph demonstrates that evaporation only occurred over the first 24 hours. The hydrocarbon reached the shoreline 16 days after the release. At the end of the simulation (day 40) approximately 9% (56 m^3) had evaporated and 64% (418 m^3) had decayed.

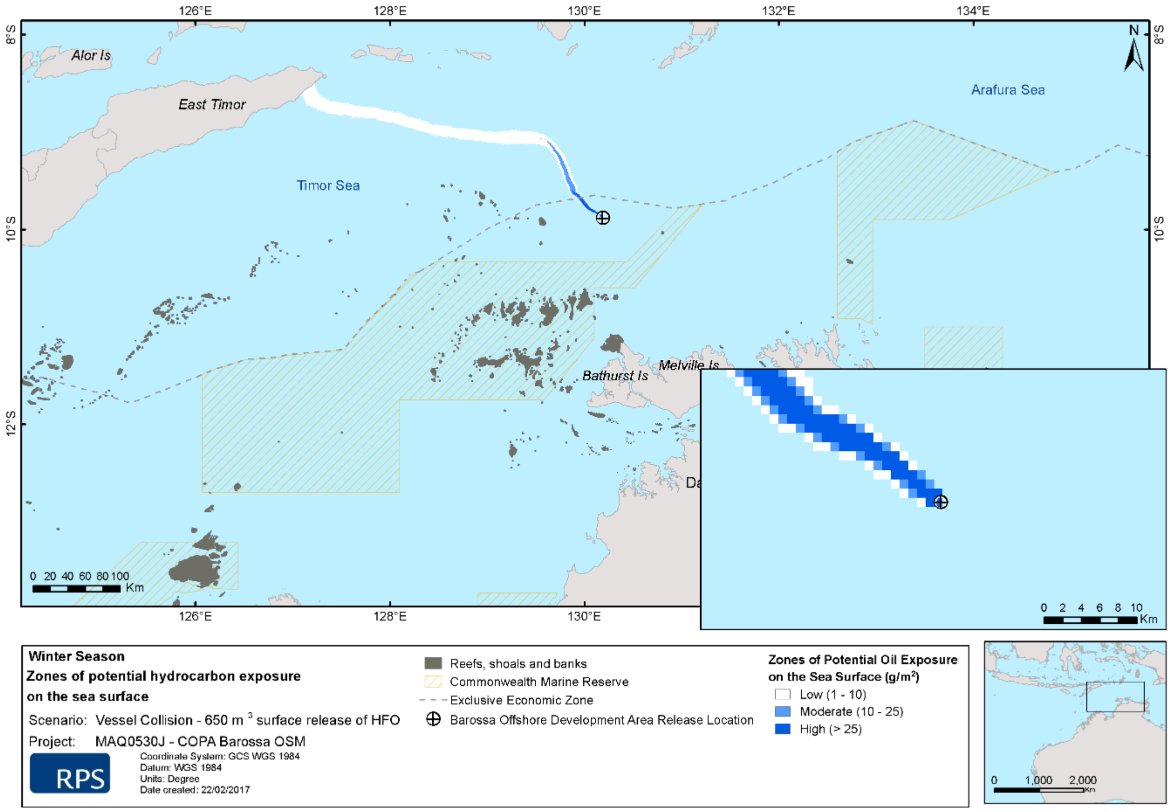


Figure 93 Single spill trajectory outputs showing the potential sea surface exposure zones (650 m^3 HFO)

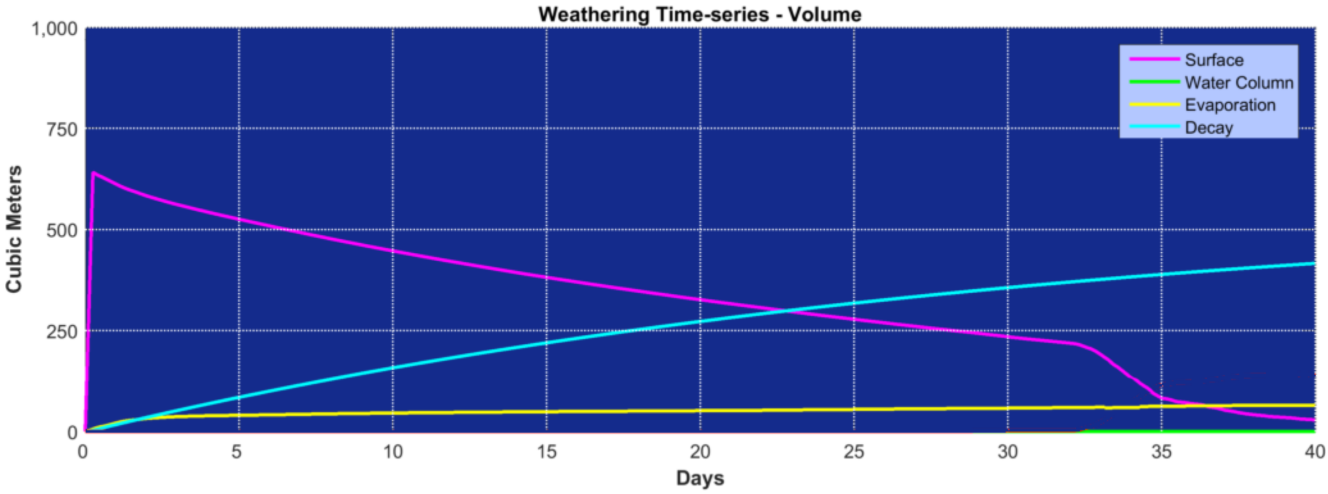


Figure 94 Predicted weathering and fates graph for the example spill trajectory from a 650 m^3 surface release of HFO from a single export tanker fuel tank rupture (tracked for 40 days)

3.5.2 Stochastic modelling

In summary, the stochastic modelling results showed:

- during summer, the released hydrocarbons tended to initially travel east of the release location before travelling in variable directions, whereas during the transitional and winter seasons hydrocarbons were more prone to drift west.
- the maximum distance for the sea surface adverse exposure zone is predicted to vary between seasons with approximately 393 km, 277 km and 805 km during summer, transitional and winter conditions, respectively (Table 31**)**.
- contact was predicted (1–17% probability) by sea surface films within the adverse exposure zone to surface waters above a number of submerged shoals/banks (total of 13), KEFs of the carbonate bank and terrace system of Van Diemen Rise, tributary canyons of the Arafura Depression and the open waters of the Oceanic Shoals and Arafura CMRs, depending on the season (Table 32).
- Figure 95 to Figure 97 shows the potential sea surface exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 98 shows the potential sea surface adverse exposure zone for all seasons.
- during summer conditions, the surface waters above Evans and Tassie Shoal recorded the highest probability of contact with the sea surface adverse exposure zone (1%) while during transitional and winter conditions the waters above Evans Shoal was predicted to have the highest probability of contact with the sea surface adverse exposure zone (17% and 13% respectively).
- contact by the sea surface adverse exposure zone with the waters above the KEF of the shelf break and slope of the Arafura Shelf (a unique seafloor feature) and open waters of the Timor Reef Fishery was predicted in all seasons as the Barossa development area is located within the bounds of these features (Table 32).
- no shoreline contact or contact by entrained or dissolved aromatic hydrocarbons was predicted within the adverse exposure zone during any season.

Table 31 Maximum distances (and direction) from the release location to zones of potential sea surface exposure for each season (650 m^3 HFO)

Season	Distance and direction	Sea surface exposure thresholds		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Summer	Maximum distance travelled (km) by a spill trajectory	839.6	393.4	111.2
	Direction	East	East	East-southeast
Transitional	Maximum distance travelled (km) by a spill trajectory	799.3	277.1	243.5
	Direction	West-southwest	West	West
Winter	Maximum distance travelled (km) by a spill trajectory	1089.6	805.5	789.5
	Direction	West	West-southwest	West-southwest

Table 32 Probability and minimum time before hydrocarbon exposure on the sea surface for receptors assessed (650 m³ HFO)

Summer conditions (December to February)								
Receptor		Maximum probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)	Low (1–10 g/m²)	Moderate (10–25 g/m²)	High (>25 g/m²)
Submerged receptor	Sunset Shoal	-	-	-	0.0	-	-
	Loxton Shoal	1	-	-	17.5	-	-
	Martin Shoal	2	-	-	10.5	-	-
	Sunrise Bank	1	-	-	12.8	-	-
	Troubadour Shoals	1	-	-	8.0	-	-
	Flinders Shoal	2	-	-	10.6	-	-
	Evans Shoal	9	1	-	2.5	2.7	-
	Tassie Shoal	11	1	-	6.4	7.3	-
	Franklin Shoal	2	-	-	10.4	-	-
	Blackwood Shoal	4	-	-	10.3	-	-
	Lynedoch Bank	11	-	-	2.4	-	-
	Margaret Harries Bank	2	-	-	28.3	-	-
	Bellona Bank	1	-	-	34.7	-	-
	Echo Shoals	-	-	-	-	-	-
	Money Shoal	5	-	-	11.1	-	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
	Cootamundra Shoal	7	-	-	13.8	-	-
	Calder Shoal	7	-	-	13.8	-	-
	Sahul Bank	-	-	-	-	-	-
	Dillon Shoal	-	-	-	-	-	-
Emergent receptor	Indonesia	-	-	-	-	-	-
	East Timor	-	-	-	-	-	-
	Ashmore Reef	-	-	-	-	-	-
CMR	Arafura CMR	69	6	-	8.2	9.2	-
	Oceanic Shoals CMR	81	49	6	1.5	1.5	1.8

	Ashmore Reef CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	29	3	-	10.3	11.5	-
	Shelf break and slope of the Arafura Shelf	100	100	100	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	25	15	4	2.4	2.7	5.0
	Pinnacles of the Bonaparte Basin	2	-	-	29.8	-	-
	Continental slope demersal fish communities	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.04	0.04	0.04
Transitional conditions (March and September to November)							
Receptor		**Maximum probability of hydrocarbon exposure on the sea surface (%)**			**Minimum time before receptor exposed to hydrocarbons on the sea surface (days)**		
		Low (1–10 g/m²)	**Moderate (10–25 g/m²)**	**High (>25 g/m²)**	**Low (1–10 g/m²)**	**Moderate (10–25 g/m²)**	**High (>25 g/m²)**
Submerged receptor	Sunset Shoal	13	-	-	6.5	-	-
	Loxton Shoal	10	1	-	5.9	7.5	-
	Martin Shoal	9	-	-	5.6	-	-
	Sunrise Bank	10	-	-	8.1	-	-
	Troubadour Shoals	32	4	-	6.3	6.4	-
	Flinders Shoal	27	9	1	3.5	3.7	3.8
	Evans Shoal	39	17	1	2.3	2.5	2.9
	Tassie Shoal	7	4	-	3.2	3.3	-
	Franklin Shoal	29	6	-	3.5	3.7	-
	Blackwood Shoal	29	2	-	3.0	3.4	-
	Lynedoch Bank	7	1	-	2.8	4.2	-
	Margaret Harries Bank	14	1	-	7.5	9.0	-
	Bellona Bank	8	-	-	16.8	-	-
	Echo Shoals	18	-	-	15.7	-	-
	Money Shoal	-	-	-	-	-	-
	Big Bank Shoals	2	-	-	27.1	-	-
	Karmt Shoal	7	-	-	23.4	-	-
	Cootamundra Shoal	4	-	-	19.8	-	-
	Calder Shoal	-	-	-	-	-	-

	Sahul Bank	8	-	-	24.3	-	-
	Dillon Shoal	2	-	-	25.2	-	-
Emergent receptor	Indonesia	1	-	-	33.2	-	-
	East Timor	3	-	-	33.6	-	-
	Ashmore Reef	-	-	-	-	-	-
CMR	Arafura CMR	1	-	-	11.5	-	-
	Oceanic Shoals CMR	31	9	-	2.4	2.5	-
	Ashmore Reef CMR	-	-	-	-	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	100	100	100	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	32	26	5	2.6	2.7	3.1
	Pinnacles of the Bonaparte Basin	-	-	-	-	-	-
	Continental slope demersal fish communities	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.04	0.04	0.04
Winter conditions (April to August)							
Receptor		**Maximum probability of hydrocarbon exposure on the sea surface (%)**			**Minimum time before receptor exposed to hydrocarbons on the sea surface (days)**		
		Low (1–10 g/m²)	**Moderate (10–25 g/m²)**	**High (>25 g/m²)**	**Low (1–10 g/m²)**	**Moderate (10–25 g/m²)**	**High (>25 g/m²)**
Submerged receptor	Sunset Shoal	16	2	-	5.1	5.2	-
	Loxton Shoal	15	2	-	4.6	4.7	-
	Martin Shoal	18	2	-	3.5	4.2	-
	Sunrise Bank	2	-	-	9.3	-	-
	Troubadour Shoals	14	3	-	4.8	4.9	-
	Flinders Shoal	16	6	-	2.8	3.6	-
	Evans Shoal	27	13	2	1.8	2.1	2.8
	Tassie Shoal	3	1	-	4.0	4.5	-
	Franklin Shoal	14	6	-	2.8	2.8	-
	Blackwood Shoal	17	5	-	2.1	2.2	-
	Lynedoch Bank	1	-	-	5.1	-	-
	Margaret Harries Bank	7	-	-	6.5	-	-

	Bellona Bank	5	-	-	11.1	-	-
	Echo Shoals	14	2	-	10.1	11.9	-
	Money Shoal	-	-	-	-	-	-
	Big Bank Shoals	4	-	-	14.7	-	-
	Karmt Shoal	6	-	-	14.5	-	-
	Cootamundra Shoal	-	-	-	-	-	-
	Calder Shoal	-	-	-	-	-	-
	Sahul Bank	9	1	-	17.0	31.6	-
	Dillon Shoal	2	-	-	19.6	-	-
Emergent receptor	Indonesia	31	-	-	14.4	-	-
	East Timor	22	-	-	15.0	-	-
	Ashmore Reef	-	-	-	-	-	-
CMR	Arafura CMR	-	-	-	-	-	-
	Oceanic Shoals CMR	5	1	-	4.5	9.8	-
	Ashmore Reef CMR	1	-	-	33.7	-	-
KEF	Tributary Canyons of the Arafura Depression	-	-	-	-	-	-
	Shelf break and slope of the Arafura Shelf	100	100	100	0.04	0.04	0.04
	Carbonate bank and terrace system of Van Diemen Rise	26	15	5	1.5	1.6	2.9
	Pinnacles of the Bonaparte Basin	1	-	-	14.3	-	-
	Continental slope demersal fish communities	1	-	-	31.9	-	-
Fishery	Timor Reef Fishery (NT Managed)	100	100	100	0.04	0.04	0.04

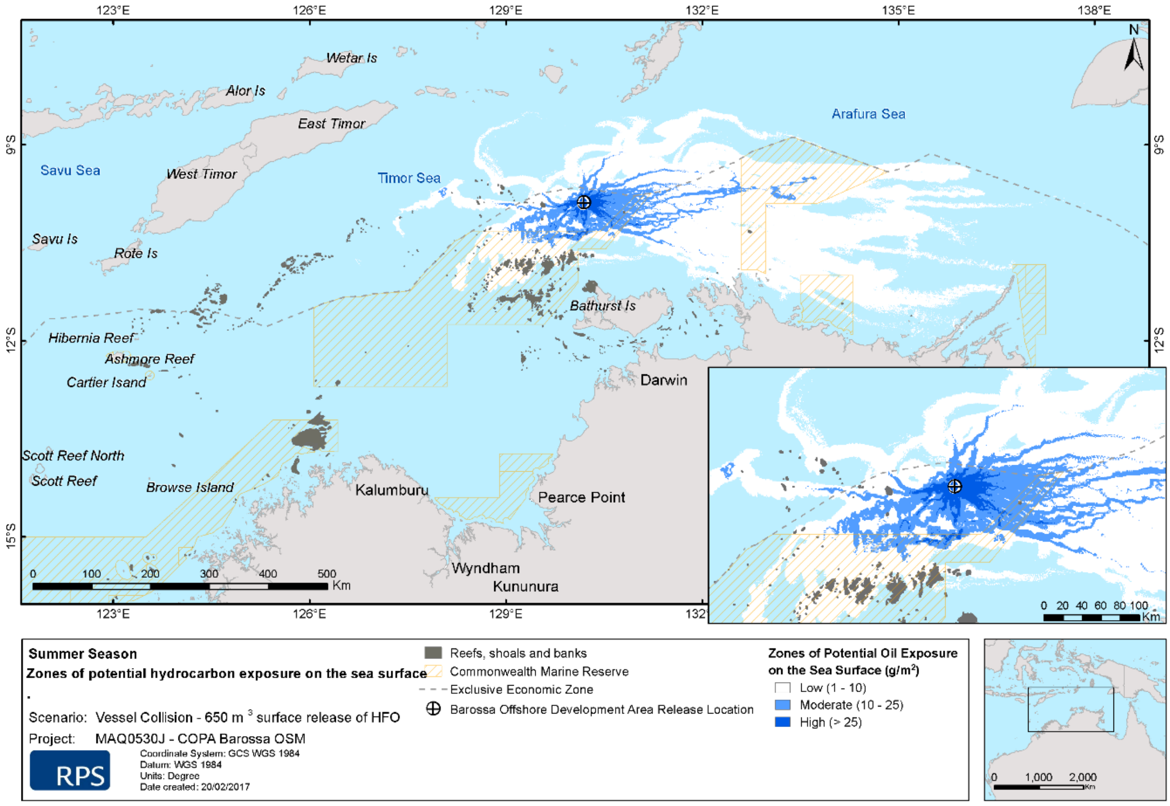


Figure 95 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during summer conditions (650 m³ HFO)

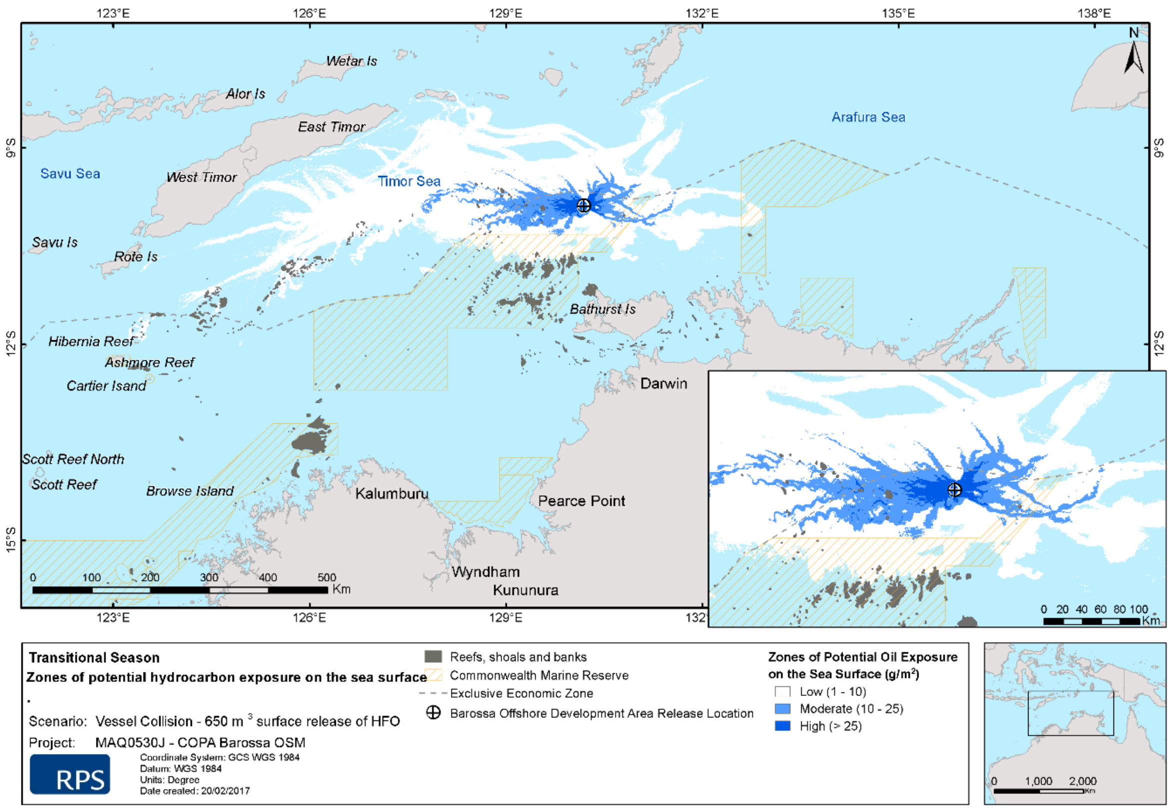


Figure 96 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during transitional conditions (650 m³ HFO)

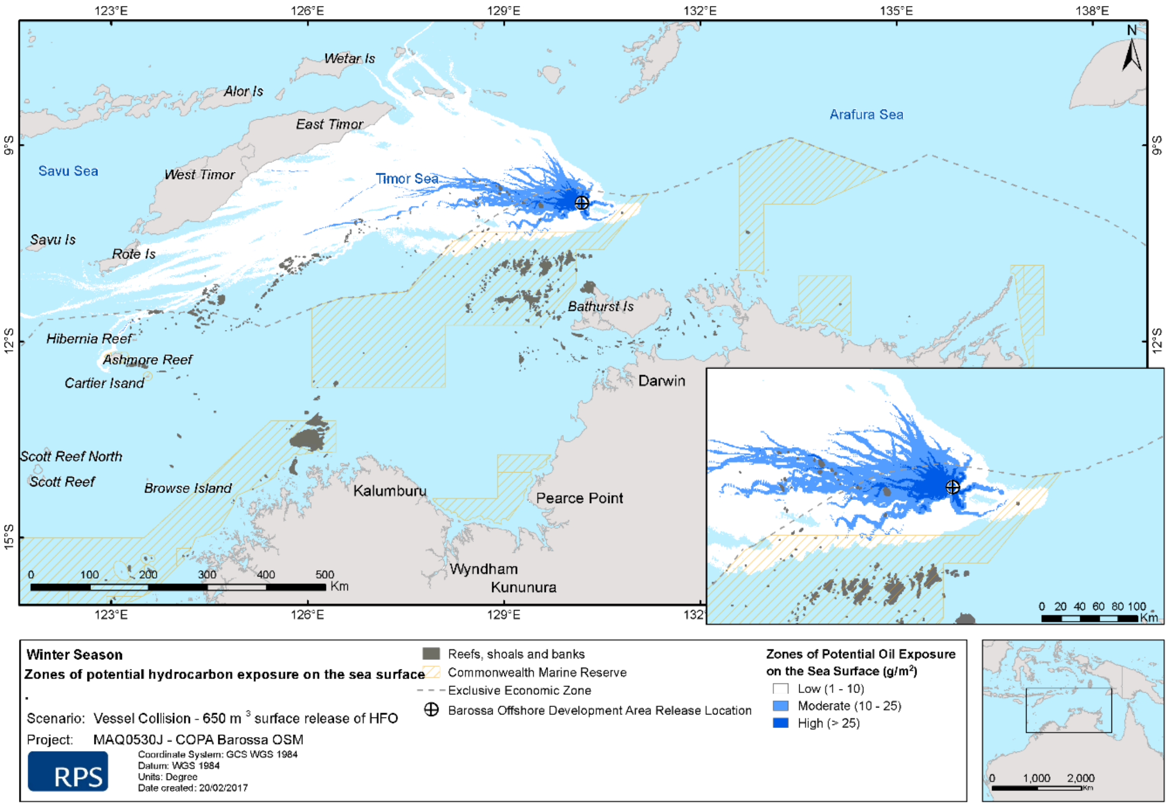


Figure 97 Stochastic modelling outputs showing the potential sea surface hydrocarbon exposure and adverse exposure zones during winter conditions (650 m^3 HFO)

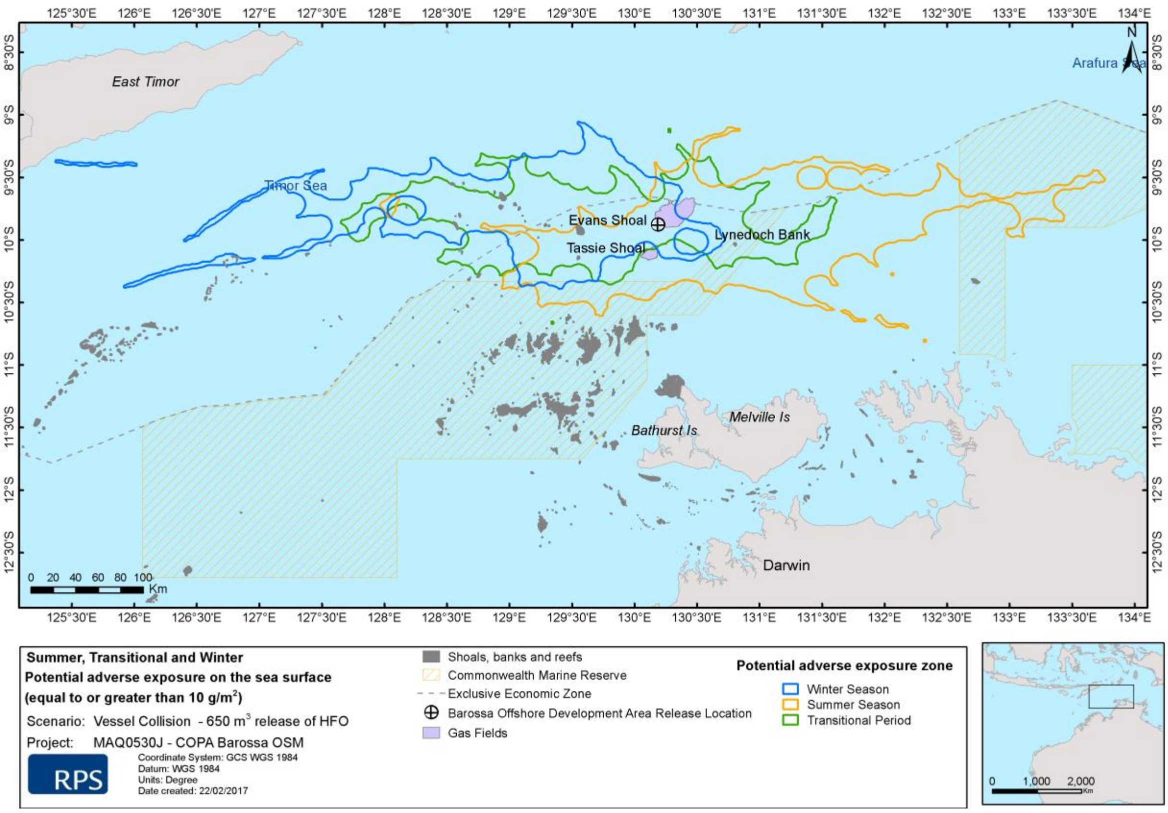


Figure 98 Stochastic modelling outputs showing the potential adverse exposure zone on the sea surface from a vessel collision releasing HFO (650 m^3)

3.6 Scenario 6: Vessel collision leading to loss of a single pipelay vessel fuel tank (500 m^3 IFO-180)

3.6.1 Single trajectory

Figure 99 shows the predicted sea surface hydrocarbon exposure zones over the entire 40 day model simulation. The spill starting at 8 am 24th January 2014 was selected as an example as the hydrocarbon was predicted to travel towards the closest shoreline of Bathurst Island during the summer season.

The hydrocarbon travelled east toward Bathurst Island upon release. The adverse exposure zone (high and moderate exposure) was observed up to 18 km and 79 km, respectively, from the release location.

There was no entrained or dissolved aromatic hydrocarbon exposure is predicted at any threshold; consequently, no subsea images are presented for this scenario.

Figure 100 illustrates the fates and weathering graph for the corresponding summer spill trajectory. The graph demonstrates a higher rate of evaporation over the first 48 hours comparative to the remaining simulation period. The hydrocarbon reached the shoreline 24 hours after the release. At the end of the simulation (day 40) approximately 19% (95 m^3) had evaporated and 57% (287 m^3) had decayed.

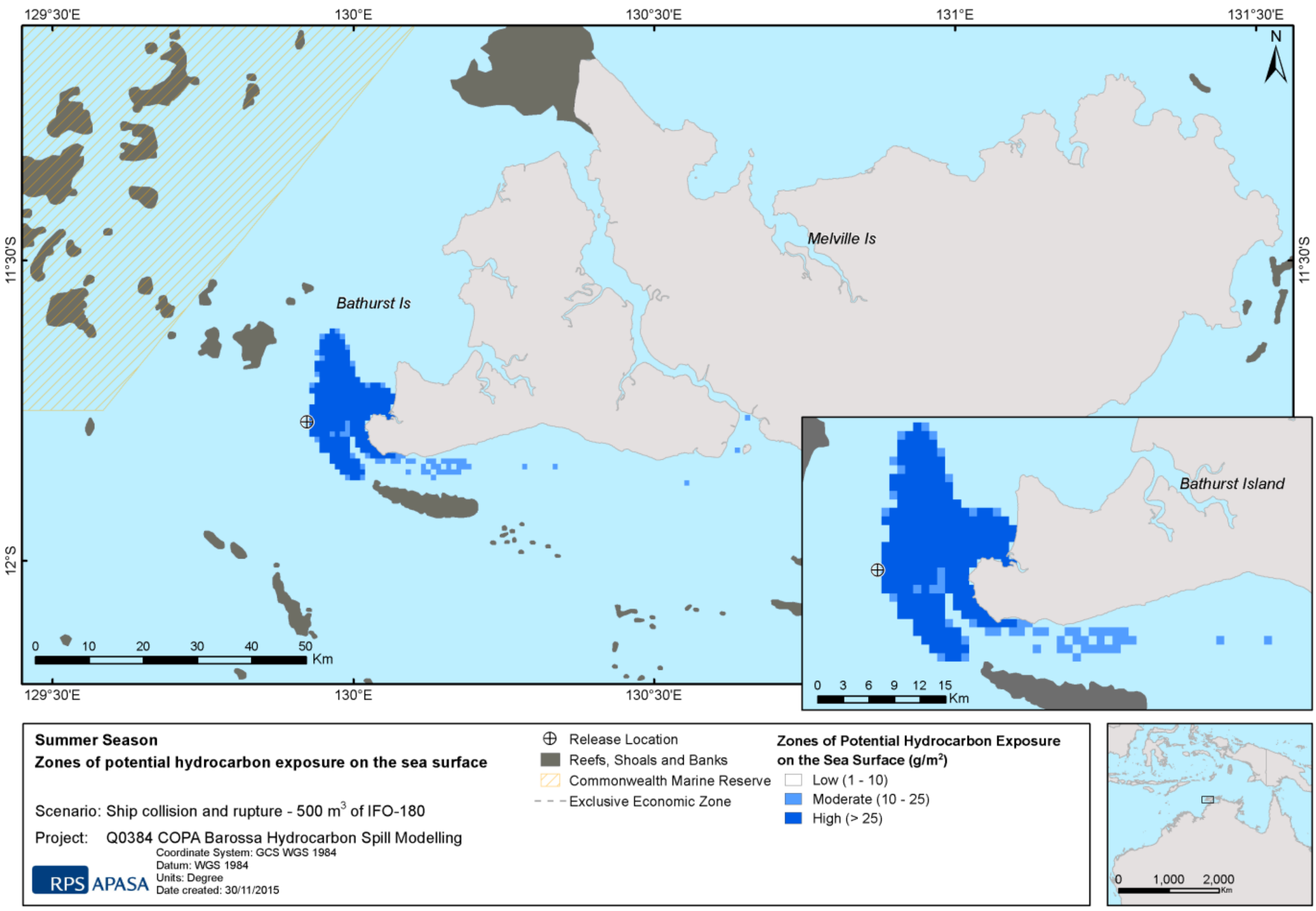


Figure 99 Single spill trajectory outputs showing the potential sea surface exposure zones (500 m^3 IFO-180)

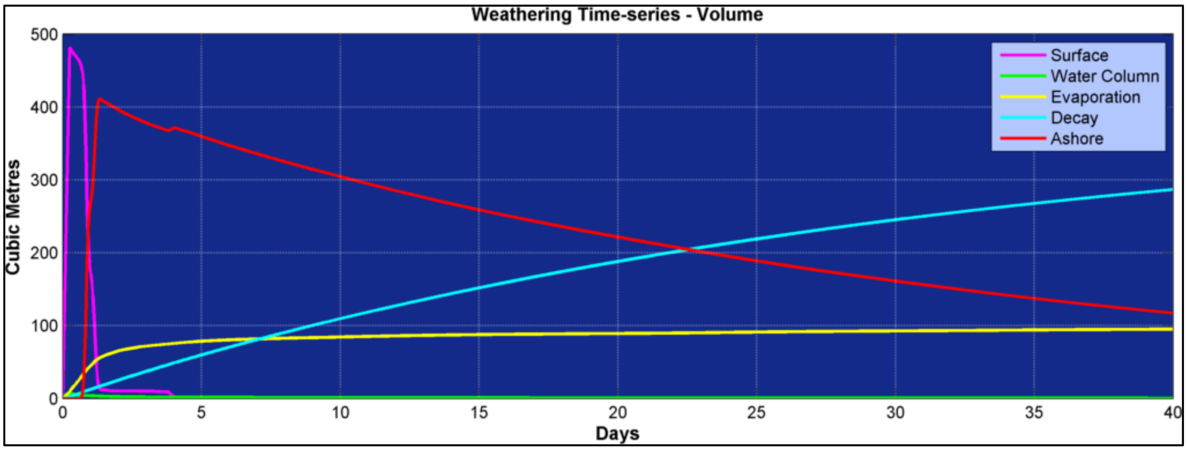


Figure 100 Predicted weathering and fates graph for the example spill trajectory from a 500 m^3 surface release of IFO-180 from a ship collision and rupture (tracked for 40 days)

3.6.2 Stochastic modelling

In summary, the stochastic modelling results showed:

- during the summer and transitional seasons, the hydrocarbon travelled east toward Bathurst Island. In winter, the hydrocarbon was more likely to travel offshore at much greater distances on the sea surface as it was unimpeded by contact with emergent features.
- the maximum distance for the sea surface adverse exposure zone is predicted to vary between seasons with approximately 136 km, 120 km and 395 km during summer, transitional and winter conditions, respectively (Table 33).
- low probability of contact predicted (1–16%) by sea surface films within the adverse exposure zone with the surface waters above three submerged shoals/banks and reefs and KEF of the carbonate bank and terrace system of Van Diemen Rise (40–70% probability), and the open waters of the Oceanic Shoals CMR, depending on the season (Table 34). Figure 101 to Figure 103 shows the potential sea surface exposure zone and adverse exposure zone during summer, transitional and winter conditions respectively. Figure 104 shows the potential sea surface adverse exposure zone for all seasons.
- during summer and transitional conditions, the surface waters above Afghan Shoal recorded the highest probability of contact with the sea surface adverse exposure zone (16% and 14% respectively). During winter conditions, only the waters above Shepparton Shoal were predicted to be contacted by the sea surface adverse exposure zone (4%).
- contact was predicted (1–34% probability) by sea surface films within the adverse exposure zone with Bathurst Island, Melville Island and the Darwin coastline in the summer and transitional seasons only (Table 34).
- no entrained or dissolved aromatic hydrocarbon exposure is predicted at any threshold in any season and therefore no contact with submerged or in-water receptors is expected through this exposure pathway.

Table 33 Maximum distances (and direction) from the release location to zones of potential sea surface exposure for each season (500 m^3 IFO-180)

Season	Distance and direction	Sea surface exposure thresholds		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Summer	Maximum distance travelled (km) by a spill trajectory	305.2	135.7	41.4
	Direction	East	East-southeast	Southeast
Transitional	Maximum distance travelled (km) by a spill trajectory	402.4	120.0	39.9
	Direction	West	Southeast	Southeast
Winter	Maximum distance travelled (km) by a spill trajectory	964.4	395.0	58.6
	Direction	West	West-northwest	Northwest

Table 34 Probability and minimum time before hydrocarbon exposure on the sea surface for receptors assessed (500 m^3 IFO-180)

Summer conditions (December to February)								
Receptors		Maximum probability of hydrocarbon exposure on the sea surface (%)			Minimum time before receptor exposed to hydrocarbons on the sea surface (days)		
		Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)	Low (1–10 g/m^2)	Moderate (10–25 g/m^2)	High (>25 g/m^2)
Submerged receptor	Echo Shoals	-	-	-	-	-	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
	Calder Shoal	-	-	-	-	-	-
	Marie Shoal	-	-	-	-	-	-
	Sahul Bank	-	-	-	-	-	-
	Dillon Shoal	-	-	-	-	-	-
	Mermaid Shoal	4	-	-	7.9	-	-
	Parry Shoal	-	-	-	-	-	-
	Moss Shoal	1	-	-	7.8	-	-
	Barton Shoal	-	-	-	-	-	-
	The Boxers	-	-	-	-	-	-
	Mataram Shoal	-	-	-	-	-	-
	Renard Shoals	1	-	-	16.1	-	-
	Giles Shoal	1	-	-	16.8	-	-
	Christine Shoal	1	-	-	18.4	-	-
	Margaret Shoal	1	-	-	19.5	-	-
	Wells Shoal	2	-	-	9.6	-	-
	Beagle Shoals	1	-	-	15.5	-	-
	Taiyun Shoal	2	-	-	6.5	-	-
	Hunt Patch	2	-	-	8.2	-	-
	Abbott Shoal	1	-	-	16.5	-	-
	Beatrice Reef	1	-	-	20.0	-	-
	Newby Shoal	-	-	-	-	-	-
	Barbara Shoal	1	-	-	17.0	-	-
	Afghan Shoal	48	16	5	0.1	0.1	0.3

	Bill Shoal	-	-	-	-	-	-
	Parsons Bank	2	-	-	2.9	-	-
	Taylor Patches	3	-	-	5.8	-	-
	Shepparton Shoal	15	2	-	1.0	1.0	-
	Tregenna Reef	3	-	-	5.8	-	-
	Harris Reef	7	-	-	3.3	-	-
	Moresby Shoals	13	-	-	3.2	-	-
	Knight Reef	8	-	-	4.3	-	-
	Hancox Shoal	12	-	-	3.5	-	-
	Oliver Reef	12	-	-	3.9	-	-
	Elizabeth Reef	2	-	-	8.3	-	-
	Draytons Reef	2	-	-	6.7	-	-
	Lowry Shoal	6	-	-	3.4	-	-
	Skottowe Shoal	11	-	-	2.3	-	-
	Flat Top Bank	3	-	-	8.5	-	-
	Marsh Shoal	15	-	-	3.9	-	-
	Lyne Reef	12	-	-	3.7	-	-
	Foelsche Bank	9	-	-	3.6	-	-
	Fish Reef	1	-	-	7.8	-	-
	Middle Reef	1	-	-	14.1	-	-
Emergent receptor	Indonesia	-	-	-	-	-	-
	Melville Island	6	1	-	3.0	3.4	-
	Bathurst Island	55	34	11	0.3	0.4	0.5
	West Arnhem Land	1	-	-	17.8	-	-
	North West Vernon Island	17	-	-	2.9	-	-
	Kakadu Coast	7	-	-	3.3	-	-
	East Vernon Island	12	-	-	3.7	-	-
	Kakadu National Park	1	-	-	15.0	-	-
	South West Vernon Island	17	-	-	2.8	-	-
	Darwin Coast	8	2	-	2.8	6.3	-
	Joseph Bonaparte Gulf - Northern Territory	4	-	-	8.3	-	-

	Roche Islands and Reefs	4	-	-	7.7	-	-
	Peron Islands	1	-	-	24.0	-	-
CMR	Oceanic Shoals CMR	5	2	-	2.2	4.5	-
	Joseph Bonaparte Gulf CMR	1	-	-	33.5	-	-
KEF	Carbonate bank and terrace system of Van Diemen Rise	59	40	28	0.04	0.04	0.04
	Pinnacles of the Bonaparte Basin	-	-	-	-	-	-
	Carbonate bank and terrace system of Sahul Shelf	-	-	-	-	-	-
Fishery	Timor Reef Fishery (NT Managed)	-	-	-	-	-	-
Transitional conditions (March and September to November)							
Receptors		**Maximum probability of hydrocarbon exposure on the sea surface (%)**			**Minimum time before receptor exposed to hydrocarbons on the sea surface (days)**		
		Low (1–10 g/m²)	**Moderate (10–25 g/m²)**	**High (>25 g/m²)**	**Low (1–10 g/m²)**	**Moderate (10–25 g/m²)**	**High (>25 g/m²)**
Submerged receptor	Echo Shoals	-	-	-	-	-	-
	Big Bank Shoals	-	-	-	-	-	-
	Karmt Shoal	-	-	-	-	-	-
	Calder Shoal	-	-	-	-	-	-
	Marie Shoal	1	-	-	26.1	-	-
	Sahul Bank	-	-	-	-	-	-
	Dillon Shoal		-	-	-	-	-
	Mermaid Shoal	3	-	-	5.1	-	-
	Parry Shoal	1	-	-	22.7	-	-
	Moss Shoal	-	-	-	-	-	-
	Barton Shoal	-	-	-	-	-	-
	The Boxers	1	-	-	23.6	-	-
	Mataram Shoal	1	-	-	10.3	-	-
	Renard Shoals	1	-	-	7.3	-	-
	Giles Shoal	1	-	-	11.7	-	-
	Christine Shoal	-	-	-	-	-	-
	Margaret Shoal	-	-	-	-	-	-
	Wells Shoal	1	-	-	10.8	-	-
	Beagle Shoals	1	-	-	7.1	-	-

	Taiyun Shoal	1	-	-	7.2	-	-
	Hunt Patch	1	-	-	6.3	-	-
	Abbott Shoal	1	-	-	9.6	-	-
	Beatrice Reef	-	-	-	-	-	-
	Newby Shoal	2	-	-	11.7	-	-
	Barbara Shoal	-	-	-	-	-	-
	Afghan Shoal	31	14	2	0.2	0.3	0.7
	Bill Shoal	1	-	-	8.2	-	-
	Parsons Bank	1	-	-	6.9	-	-
	Taylor Patches	1	-	-	7.8	-	-
	Shepparton Shoal	45	5	-	1.3	1.3	-
	Tregenna Reef	-	-	-	-	-	-
	Harris Reef	3	-	-	5.3	-	-
	Moresby Shoals	7	-	-	4.9	-	-
	Knight Reef	4	-	-	5.6	-	-
	Hancox Shoal	6	-	-	5.0	-	-
	Oliver Reef	4	-	-	5.1	-	-
	Elizabeth Reef	-	-	-	-	-	-
	Draytons Reef	1	-	-	7.9	-	-
	Lowry Shoal	5	-	-	4.5	-	-
	Skottowe Shoal	6	-	-	4.4	-	-
	Flat Top Bank	15	-	-	3.5	-	-
	Marsh Shoal	3	-	-	5.5	-	-
	Lyne Reef	3	-	-	5.8	-	-
	Foelsche Bank	1	-	-	13.3	-	-
	Fish Reef	2	-	-	12.5	-	-
	Middle Reef	2	1	-	12.4	13.1	-
Emergent receptor	Indonesia	-	-	-	-	-	-
	Melville Island	4	1	-	4.5	7.9	-
	Bathurst Island	28	12	1	0.6	0.6	0.8
	West Arnhem Land	-	-	-	-	-	-

	North West Vernon Island	7	-	-	5.1	-	-
	Kakadu Coast	3	-	-	6.6	-	-
	East Vernon Island	7	-	-	5.6	-	-
	Kakadu National Park	-	-	-	-	-	-
	South West Vernon Island	7	-	-	5.5	-	-
	Darwin Coast	3	1	-	4.3	5.8	-
	Joseph Bonaparte Gulf - Northern Territory	3	-	-	4.6	-	-
	Roche Islands and Reefs	4	-	-	12.8	-	-
	Peron Islands	-	-	-	-	-	-
CMR	Oceanic Shoals CMR	10	2	-	0.8	1.8	-
	Joseph Bonaparte Gulf CMR	-	-	-	-	-	-
KEF	Carbonate bank and terrace system of Van Diemen Rise	83	66	43	0.04	0.04	0.04
	Pinnacles of the Bonaparte Basin	6	-	-	18.3	-	-
	Carbonate bank and terrace system of Sahul Shelf	4	-	-	22.5	-	-
Fishery	Timor Reef Fishery (NT Managed)	1	-	-	23.4	-	-
Winter conditions (April to August)							
Receptors		**Maximum probability of hydrocarbon exposure on the sea surface (%)**			**Minimum time before receptor exposed to hydrocarbons on the sea surface (days)**		
		Low (1–10 g/m^2)	**Moderate (10–25 g/m^2)**	**High (>25 g/m^2)**	**Low (1–10 g/m^2)**	**Moderate (10–25 g/m^2)**	**High (>25 g/m^2)**
Submerged receptor	Echo Shoals	8	-	-	17.9	-	-
	Big Bank Shoals	5	-	-	19.8	-	-
	Karmt Shoal	4	-	-	21.3	-	-
	Calder Shoal	2	-	-	7.5	-	-
	Marie Shoal	-	-	-	-	-	-
	Sahul Bank	5	-	-	22.4	-	-
	Dillon Shoal	3	-	-	28.1	-	-
	Mermaid Shoal	-	-	-	-	-	-
	Parry Shoal	-	-	-	-	-	-
	Moss Shoal	-	-	-	-	-	-
	Barton Shoal	1	-	-	34.8	-	-
	The Boxers	22	-	-	7.5	-	-

	Mataram Shoal	-	-	-	-	-	-
	Renard Shoals	-	-	-	-	-	-
	Giles Shoal	-	-	-	-	-	-
	Christine Shoal	-	-	-	-	-	-
	Margaret Shoal	-	-	-	-	-	-
	Wells Shoal	-	-	-	-	-	-
	Beagle Shoals	-	-	-	-	-	-
	Taiyun Shoal	-	-	-	-	-	-
	Hunt Patch	-	-	-	-	-	-
	Abbott Shoal	-	-	-	-	-	-
	Beatrice Reef	-	-	-	-	-	-
	Newby Shoal	21	-	-	3.3	-	-
	Barbara Shoal	-	-	-	-	-	-
	Afghan Shoal	1	-	-	0.8	-	-
	Bill Shoal	-	-	-	-	-	-
	Parsons Bank	-	-	-	-	-	-
	Taylor Patches	-	-	-	-	-	-
	Shepparton Shoal	22	4	-	1.3	1.5	-
	Tregenna Reef	-	-	-	-	-	-
	Harris Reef	-	-	-	-	-	-
	Moresby Shoals	-	-	-	-	-	-
	Knight Reef	-	-	-	-	-	-
	Hancox Shoal	-	-	-	-	-	-
	Oliver Reef	-	-	-	-	-	-
	Elizabeth Reef	-	-	-	-	-	-
	Draytons Reef	-	-	-	-	-	-
	Lowry Shoal	-	-	-	-	-	-
	Skottowe Shoal	-	-	-	-	-	-
	Flat Top Bank	10	-	-	3.4	-	-
	Marsh Shoal	-	-	-	-	-	-
	Lyne Reef	-	-	-	-	-	-

	Foelsche Bank	-	-	-	-	-	-
	Fish Reef	-	-	-	-	-	-
	Middle Reef	-	-	-	-	-	-
Emergent receptor	Indonesia	1	-	-	35.3	-	-
	Melville Island	-	-	-	-	-	-
	Bathurst Island	2	-	-	1.7	-	-
	West Arnhem Land	-	-	-	-	-	-
	North West Vernon Island	-	-	-	-	-	-
	Kakadu Coast	-	-	-	-	-	-
	East Vernon Island	-	-	-	-	-	-
	Kakadu National Park	-	-	-	-	-	-
	South West Vernon Island	-	-	-	-	-	-
	Darwin Coast	-	-	-	-	-	-
	Joseph Bonaparte Gulf - Northern Territory	-	-	-	-	-	-
	Roche Islands and Reefs	-	-	-	-	-	-
	Peron Islands	-	-	-	-	-	-
CMR	Oceanic Shoals CMR	72	11	1	0.7	0.7	0.8
	Joseph Bonaparte Gulf CMR	-	-	-	-	-	-
KEF	Carbonate bank and terrace system of Van Diemen Rise	90	70	52	0.04	0.04	0.04
	Pinnacles of the Bonaparte Basin	16	-	-	10.2	-	-
	Carbonate bank and terrace system of Sahul Shelf	8	-	-	11.4	-	-
Fishery	Timor Reef Fishery (NT Managed)	19	-	-	6.5	-	-

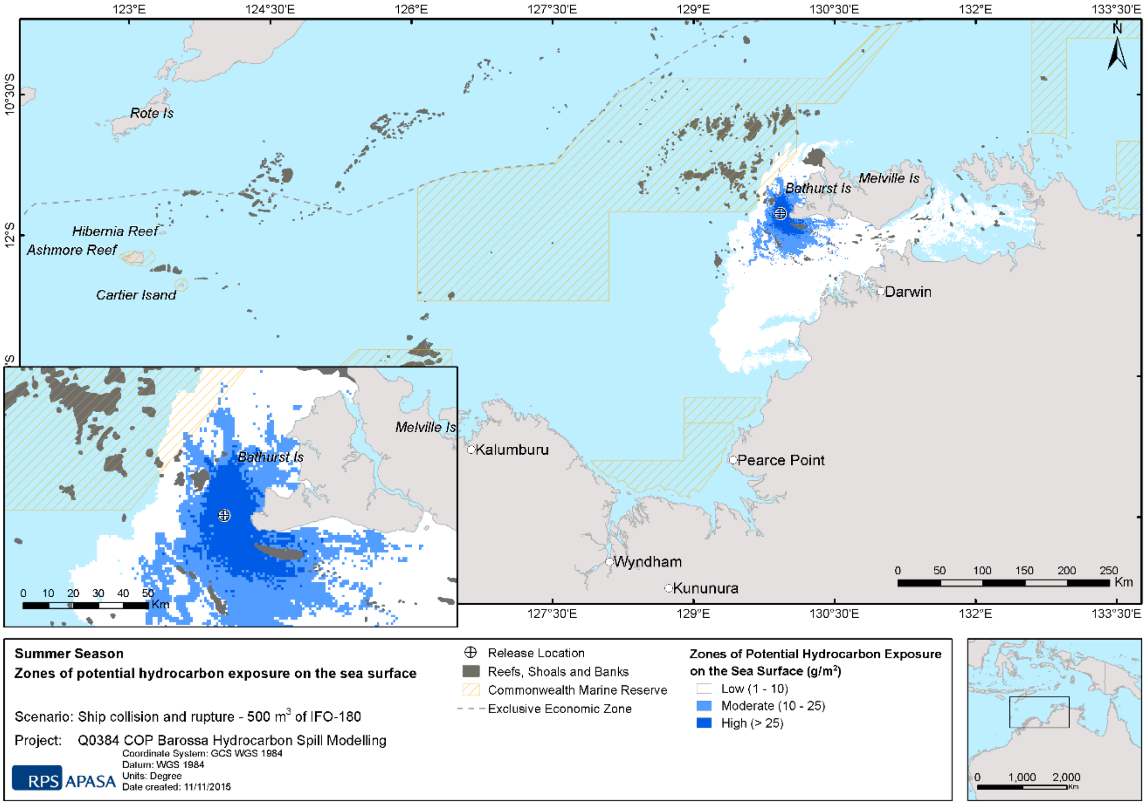


Figure 101 Potential sea surface hydrocarbon exposure and adverse exposure zones during summer conditions (500 m^3 IFO-180)

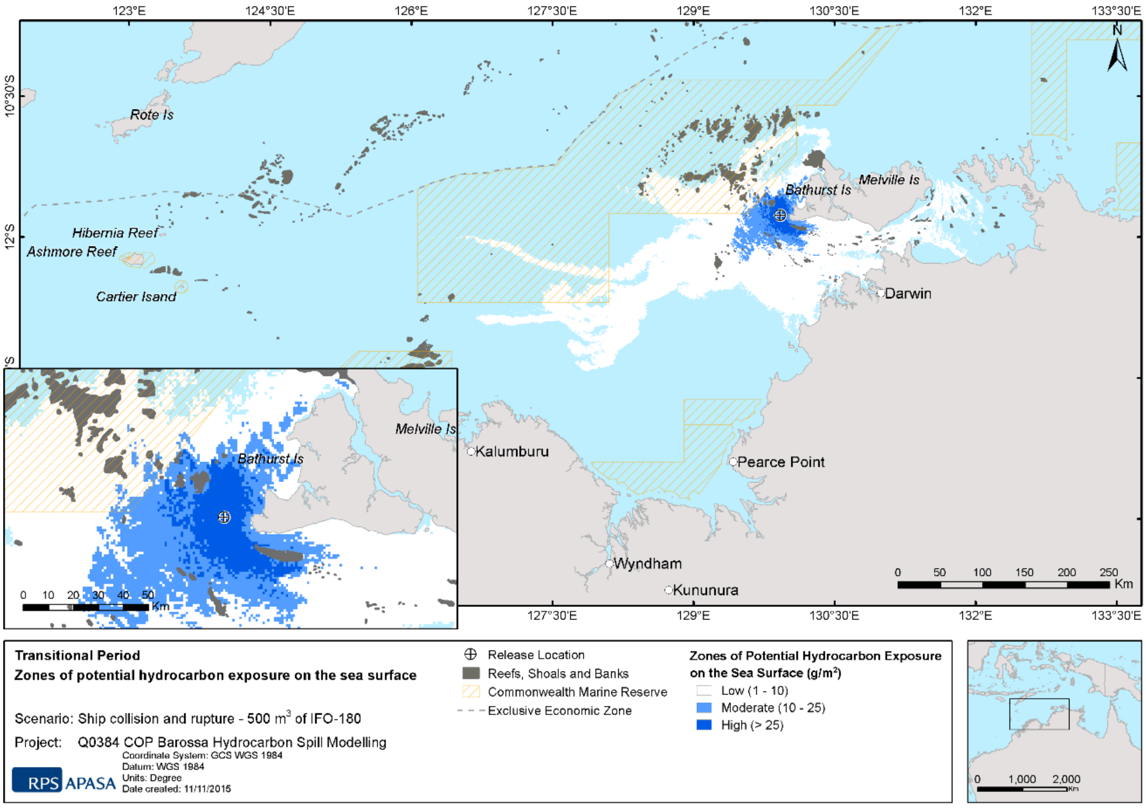


Figure 102 Potential sea surface hydrocarbon exposure and adverse exposure zones during transitional conditions (500 m^3 IFO-180)

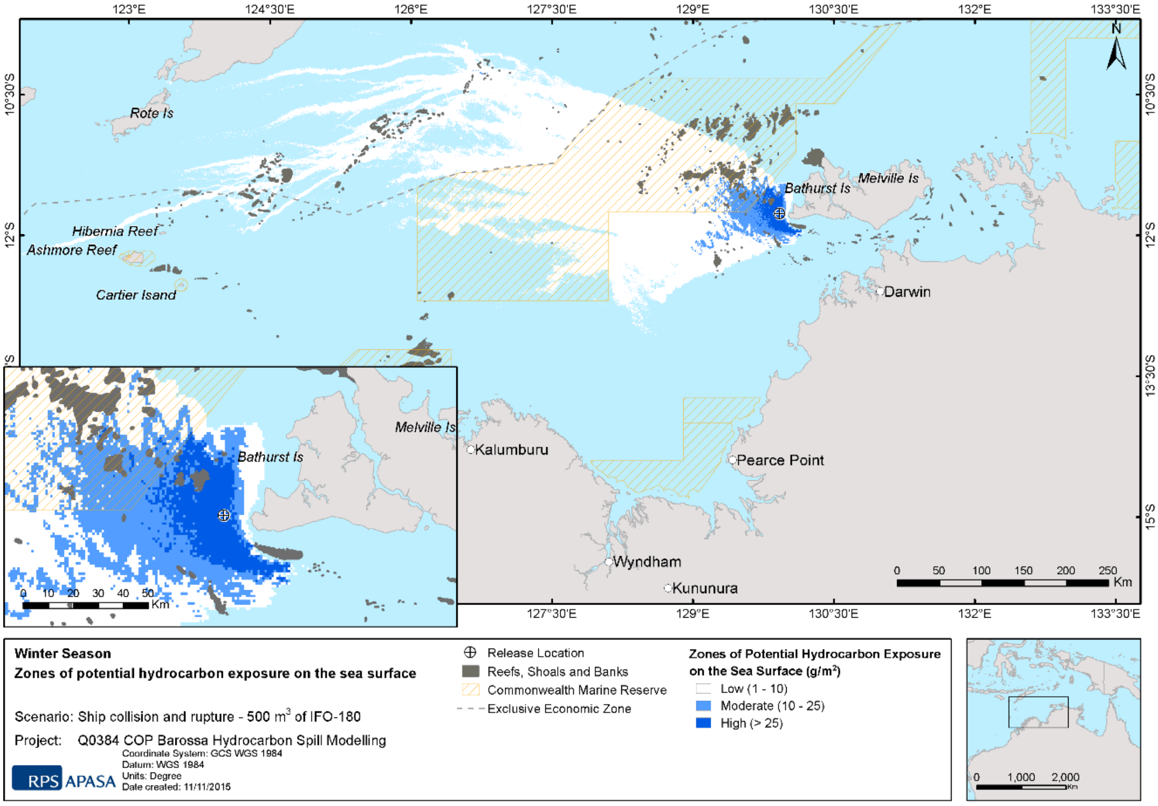


Figure 103 Potential sea surface hydrocarbon exposure and adverse exposure zones during winter conditions (500 m^3 IFO-180)

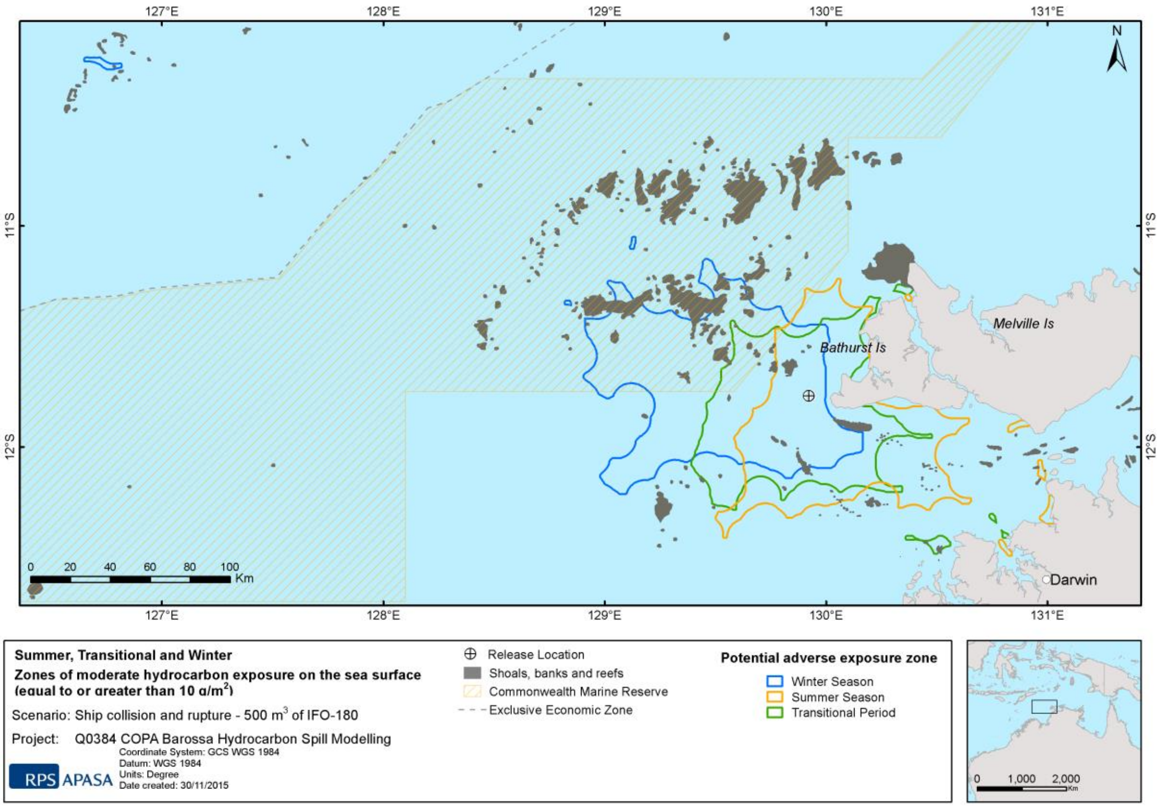


Figure 104 Stochastic modelling outputs showing the potential adverse exposure zone on the sea surface from a pipelay vessel collision releasing IFO-180 (500 m^3)

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Appendix L .

Toxicity Assessment of Barossa Condensate
(Jacobs 2017)

Barossa Environmental Studies

ConocoPhillips

Toxicity Assessment of Barossa-3 Condensate

IW021200-NMS-RP-0028 | Rev 1

30 May 2017

Barossa Environmental Studies

Project no: IW021200
Document title: Toxicity Assessment of Barossa-3 Condensate
Document No.: IW021200-NMS-RP-0028
Revision: Rev 1
Date: 30 May 2017
Client name: ConocoPhillips
Project manager: Chris Teasdale
Author: Celeste Wilson
File name: T:\Transfer\May2017\WVES\TMiley\Barossa Toxicity Report _ Rev 1.docx

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Document history and status

Revision	Date	Description	By	Review	Approved
A	14/12/2015	Technical Review	C Wilson	M Huber	C Teasdale
0	4/01/2016	Final report	C Wilson	C Teasdale	C Teasdale
1	30/05/2017	Update report for inclusion in technical appendices of the Barossa OPP	C Wilson	T Miley	T Miley

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Important note about your report

The sole purpose of this report and the associated services performed by Jacobs is to assess the toxicity of the Barossa-3 condensate in accordance with the scope of services set out in the contract between Jacobs and the Client. That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from toxicity tests undertaken by Ecotox Services Australasia (ESA) and information sourced from the Client (including client provision of condensate samples to ESA for testing) and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

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Abbreviations and Glossary

ACR	acute to chronic ratio
Acute toxicity	A lethal or adverse sub-lethal effect that occurs after a short exposure period relative to the organism's life span.
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agricultural and Resource Management Council of Australia and New Zealand
Chronic toxicity	An adverse effect that occurs after exposure for a substantial proportion of the organism's life span or an adverse sub-lethal effect on a sensitive early life stage.
Contaminant	A substance, inorganic or organic, at or near levels that could be toxic to some organisms.
BTEX	Benzene, toluene, ethylbenzene, and xylenes (meta-, para- and ortho-xylene)
EC_{50}	The concentration of a given contaminant that will cause a sub-lethal effect in 50% of a collection of organisms over a given period of time. Effects can be larval abnormalities, reproductive impairment, and growth inhibition or fertilisation success.
ESA	Ecotox Services Australasia
FSW	Filtered seawater
IC_{10}	The concentration of a given contaminant that will cause the inhibition of growth or reproduction in 10% of a collection of organisms over a given period of time.
IC_{50}	The concentration of a given contaminant that will cause the inhibition of growth or reproduction in 50% of a collection of organisms over a given period of time.
Larva(e)	The early free-living, immature form of any animal that changes structurally when it becomes an adult.
LC_{50}	The concentration of a given contaminant that will cause a lethal effect in 50% of a collection of organisms over a given period of time.
LOEC	(Lowest Observed Effect Concentration). The lowest concentration of a material used in a toxicity test that has a statistically significant adverse effect on the exposed population of test organisms as compared with the controls.
MAH	Monocyclic aromatic hydrocarbons
NATA	National Association of Testing Authorities
NOEC	(No Observed Effect Concentration). The highest concentration of a toxicant at which no statistically significant effect is observable, compared to the controls; the statistical significance is measured at the 95% confidence level.
PAH	Polycyclic aromatic hydrocarbons
PQL	Practical quantitation limit
QA	Quality assurance
SSD	Species sensitivity distribution
Toxicity	The quality or degree of being poisonous or harmful, to humans or biota.

TRH	Total recoverable hydrocarbons
WAF	Water accommodated fraction

Executive Summary

ConocoPhillips Australia Exploration Pty Ltd (ConocoPhillips) are proposing to develop natural gas resources as part of the Barossa area development, located in waters up to 300 m deep in the Bonaparte Basin, in Commonwealth waters offshore of northern Australia. Numerous shoals (submerged calcareous banks or 'seamounts') exist in the broader region around the Barossa area development; the closest being Evans Shoal, 60 km to the west, Tassie Shoal, 70 km south-west and Lynedoch Bank, 40 km to the south-east. In addition, the new Oceanic Shoals Commonwealth marine reserve (multiple use zone) lies to the south and south-east of the permit area.

ConocoPhillips intends to derive threshold concentrations of un-weathered and weathered Barossa-3 condensate to inform the assessment of the potential for toxicity impacts from hydrocarbon from the Barossa field to sensitive marine biota. The aim of this study is to assess the toxicity of the following:

1. Un-weathered Barossa-3 condensate (full suite of toxicants)
2. Weathered Barossa-3 condensate (limited tests involving fish only).

The toxicity tests were undertaken on a broad range of taxa of ecological relevance for which accepted standard test protocols are well established. These ecotoxicology tests are mainly focused on the early life stages of test organisms, when organisms are typically at their most sensitive to hydrocarbons. For the un-weathered condensate, static toxicity tests were conducted on seven mainly tropical species, representing seven taxonomic groups. It was considered that fish would be the more likely receptor to be exposed to the weathered condensate during a hydrocarbons spill, and consequently fish were the focus species for the weathered condensate study.

The moderate guideline value for 95% species protection of un-weathered Barossa-3 condensate was 1146 µg/L and the moderate guideline value for 99% species protection was 456 µg/L. The IC_{10} values for the un-weathered Barossa-3 condensate ranged from 1,051 to 15,875 µg/L. According to the GESAMP (2002) classification, un-weathered Barossa-3 condensate has almost negligible chronic aquatic toxicity.

Neither the un-weathered nor weathered Barossa-3 condensate was particularly toxic to fish larvae. A lower concentration of un-weathered condensate was required to affect the balance of 10% of fish larvae compared with the weathered condensate while a lower concentration of weathered condensate was required to affect the biomass of 10% of fish larvae compared to the un-weathered condensate.

The un-weathered Barossa-3 condensate was more toxic to copepod development and macroalgal growth and less toxic to fish larvae and oyster larval development. Neff (1979) also found that toxicity was most pronounced among crustaceans and least among telesost or ray finned fishes.

From the chemical analysis of the Barossa-3 condensate the most obvious difference between the un-weathered and weathered condensate was in the benzene, toluene, ethylbenzene, and xylenes (BTEX) results. BTEX falls into the class of monocyclic aromatic hydrocarbons (MAHs). The weathered Barossa-3 condensate had much lower concentrations than the un-weathered Barossa-3 condensate, particularly benzene and toluene. BTEX compounds are acutely toxic to aquatic organisms if exposure is sustained. Because of the volatility of BTEX, aquatic organisms typically only experience short exposure times in the order of 12 hours which may circumvent toxic effects.

Of the polycyclic aromatic hydrocarbons (PAH's) analysed for this study, naphthalene was the only chemical that was higher in the weathered condensate compared to the un-weathered condensate. All other PAHs

measured were below the laboratory detection limit or in the case of fluorene and phenanthrene was similar between weathered and un-weathered condensate. However, the myriad of other chemicals present in the condensate were not required to be measured for the purposes of this exercise. Neff et al. (2000) demonstrated that the MAHs are the most important contributors to the acute toxicity of the water accommodated fractions (WAFs) of fresh oils, while the contribution of PAHs to WAF toxicity increases with weathering. However it is generally not well understood which of the many components of oil are responsible for the many toxicity effects induced by oil.

1. Introduction

1.1 Background

ConocoPhillips Australia Exploration Pty Ltd (ConocoPhillips), as proponent on behalf of the current and future joint ventures, are proposing to develop natural gas resources as part of the Barossa area development, located approximately 300 kilometres (km) north of Darwin, Northern Territory (**Figure 1-1**). The Barossa field is situated in petroleum retention lease permit NT/RL5 (referred to as the 'permit area' in this report).

1.2 Overview of existing regional environment

The Barossa area is located in the Northern Marine Region, which comprises the Commonwealth waters of the Gulf of Carpentaria, Arafura Sea and Timor Sea as far west as the Northern Territory and Western Australian border. The Northern Marine Region contains internationally significant breeding and/or feeding grounds for a number of listed threatened and migratory marine species, including nearshore dolphins, turtles, dugongs, seabirds and migratory shorebirds afforded protection under national legislation and international conventions.

The Timor and Arafura Seas support a variety of shark, pelagic finfish and crustacean species of commercial and recreational game-fishing importance, e.g. trawl and various finfish fisheries. The shelf break and slope of the Arafura Shelf is characterised by patch reefs and hard substrate pinnacles that support a diverse array of invertebrate groups, with polychaetes and crustaceans being the most prolific (Heyward et al. 1997, CEE 2002). Surveys indicate that between 50 m and 200 m depth, the seabed consists of predominantly soft, easily resuspended sediments (Heyward et al. 1997, URS 2005, 2007). The diversity and coverage of epibenthos is low and organisms present are predominantly sponges, gorgonians and soft corals (Heyward et al. 1997, URS 2005, 2007).

Numerous shoals (submerged calcareous banks or 'seamounts') exist in the broader region around the permit area; the closest being Evans Shoal, 60 km to the west, Tassie Shoal, 70 km south-west and Lynedoch Bank, 40 km to the south-east. In addition, the new Oceanic Shoals Commonwealth marine reserve (multiple use zone) lies to the south and south-east of the permit area.

1.3 Scope of work

ConocoPhillips intends to derive species sensitivity guideline values (99%, 95% etc.) of un-weathered and weathered Barossa-3 condensate, which have toxic effects on sensitive marine biota, to inform the assessment of the potential for toxicity impacts from hydrocarbons from the Barossa field. The scope consisted of the following components:

Definition of Scope of Ecotoxicity Testing

- Jacobs provided advice on ecotoxicity testing methods including sample collection and numbers of species to test, and liaised with the NATA accredited laboratory that undertook the testing. For this study, Jacobs used the services of Ecotox Services Australasia (ESA).

Interpretation of the Ecotoxicological Data

- Following the ecotoxicity assessment, Jacobs interpreted the ecotoxicity data to inform definition of species protection guideline values as relevant to the Barossa field.

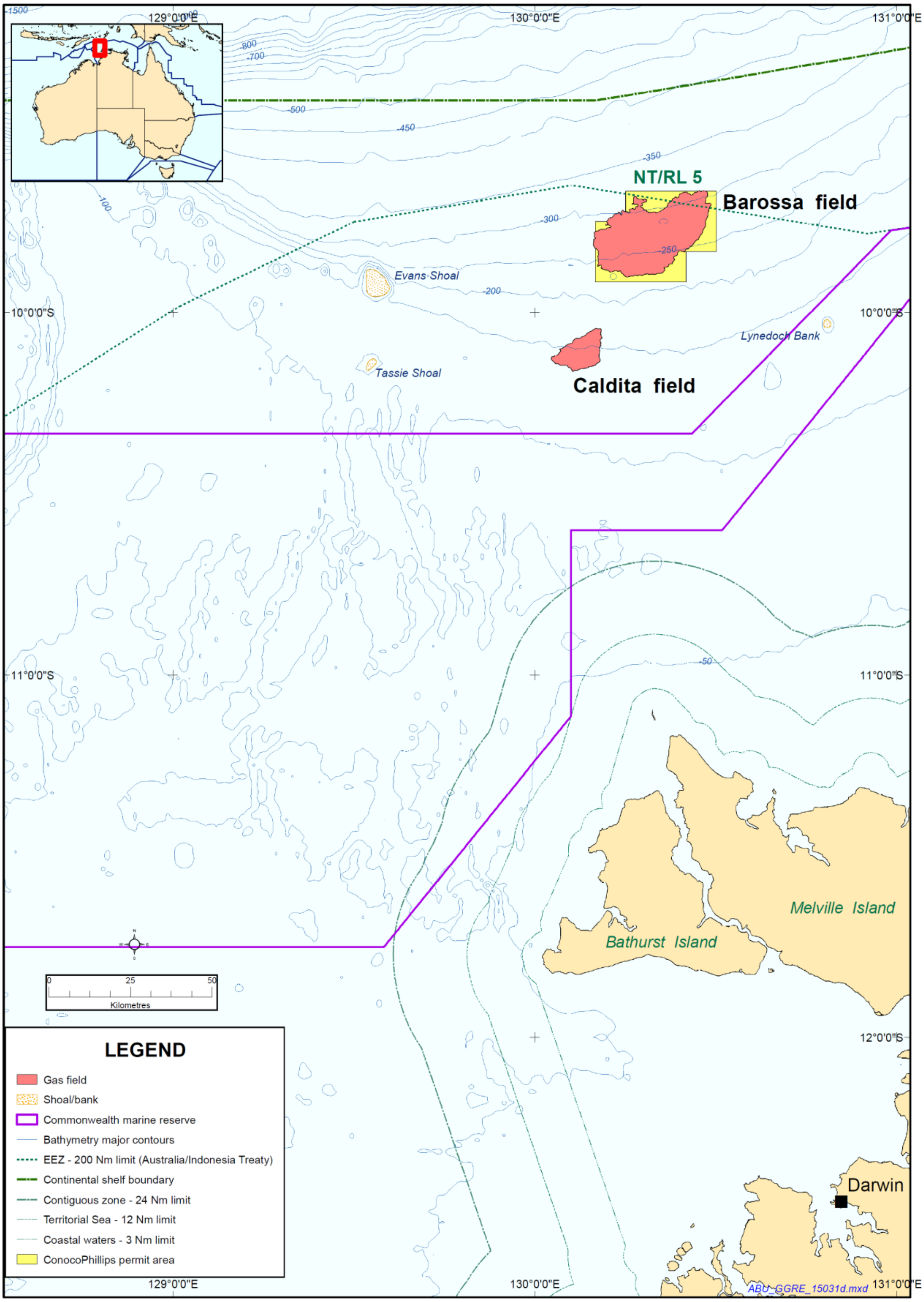

Figure 1-1: Barossa field location

2. Methods

ConocoPhillips sent samples of Barossa-3 condensate to the ESA laboratory in September 2015 for detailed ecotoxicological studies and hydrocarbon chemical analysis. The laboratory-based toxicity tests used a range of Water Accommodated Fraction (WAF) concentrations of weathered and un-weathered condensate to expose the different test organisms.

The toxicity tests were undertaken on a broad range of taxa of ecological relevance for which accepted standard test protocols are well-established. These ecotoxicology tests are mainly focused on the early life stages of test organisms, when organisms are typically at their most sensitive to hydrocarbons. For the un-weathered condensate, static toxicity tests were conducted on seven mainly tropical species, representing seven taxonomic groups demonstrating different levels if the food chain (**Table 2-1**).

Table 2-1: Analytical methods, test species, life stages, durations and test end-points for ecotoxicology

Test Species	Life Stage	Test Duration and End-Point	Type*	Protocol
Microalga (*Isochrysis aff. galbana*)	-	72-hour Growth inhibition (cell yield)	Chronic	ESA SOP 110 (ESA, 2014a). Based on Stauber *et al*. (1994)
Macroalage (*Ecklonia radiata)*	Gametophyte	14-day Growth rate	Chronic	ESA SOP 116 (ESA, 2014f). Based on Bidwell *et al*. (1998) and Burridge et al. (1999)
Sea Urchin (*Heliocidaris tuberculata)*	Gamete	1-hour Fertilisation rate	Chronic	ESA SOP 104 (ESA, 2014b). Based on USEPA (2002a), Simon and Laginestra (1997)
Sea Urchin (*Heliocidaris tuberculata)*	Larvae	72-hour Development rate	Chronic	ESA SOP 105 (ESA, 2014c). Based on APHA (1998), Simon and Laginestra (1997) and Doyle *et. al.* (2003)
Milky Oyster (*Saccostrea echinata)*	Embryo	48-hour Development rate	Chronic	ESA SOP 106 (ESA, 2014d). Based on APHA (1998) and Krassoi (1995)
Copepod (*Parvocalanus crassirostris*)	Juveniles	5-day Development rate	Acute	ESA SOP 124 (ESA, 2014e).
Sea anemone (*Aiptasia pulchella*)	Pedal lacerate	8-day Development rate	Chronic	ESA SOP 128 (ESA, 2014g) based on Howe et al. (2014)
Fish (Barramundi) (*Lates calcarifer*)	Larvae	7-day Biomass	Chronic	ESA SOP 122 (ESA, 2012). Based on USEPA (2002a)
Fish (Barramundi) (*Lates calcarifer*)	Larvae	7-day Imbalance	Chronic	ESA SOP 122 (ESA, 2012). Based on USEPA (2002a)

*Based on test classification according to Warne et al. (2014) guidelines

Based on stochastic modelling results from the RPS APASA (2015) hydrocarbon spill modelling study, the minimum contact time of moderate dissolved aromatic hydrocarbon exposure from a subsea well blowout to the nearest submerged receptors of Evans Shoal, Tassie Shoal and Lynedoch Bank (all less than 100 km from the Barossa Field) was greater than 24 hours in all seasons. Due mainly to the evaporative loss of volatiles, less than 20% of the original volume of condensate would remain after this time. However, the open waters of the Timor Reef Fishery could be affected during a well blowout event during any season, given the Barossa Field is located within this fishery. The times to contact with dissolved aromatic hydrocarbons (90 - 100 m depth layer) were 2.4 hrs for all seasons, with the probability of exposure ranging between 14% and 37%. Considering the predicted exposure to the nearest submerged receptors and the Timor Reef Fishery, it was decided that fish would be the most likely receptor to be exposed to the weathered condensate, and consequently were the focus species for the weathered condensate study.

Aliquots of the Barossa-3 condensate sample were weathered by ESA using the Mackay Chamber Testing techniques for a 12 hour weathering period, with a wind speed of 5.5 m/s (10.7 knots) and water temperature of 28.8°C. The weathering information was based upon the season in which spawning occurs for goldband snapper (*Pristipomoides multidens*), which is the key target species of the Timor Reef Fishery. The most vulnerable life stages for fish are their egg and larval life stages, therefore goldband snapper are most susceptible to hydrocarbons during the spawning period, which is January to April with a peak during March (Newman 2003).

ESA prepared the WAF by combining a prescribed quality of weathered or un-weathered condensate to 0.45 µm filtered seawater in a 1:9 ratio. The combined samples were mixed for 24 hrs using a magnetic stirrer. The WAF and condensate mixture was allowed to settle for 1 hour before the WAF was siphoned off into clean amber glass reagent bottles until required for toxicity testing and total recoverable hydrocarbon (TRH) analysis. The WAFs were serially diluted with filtered seawater (FSW) to prepare the remaining test concentrations.

For each toxicity test, sub-samples of the WAF were sent to Envirolab Services Pty Ltd to be analysed for the determination of TRH, polycyclic aromatic hydrocarbons (PAHs) and benzene, toluene, ethylbenzene and xylenes (BTEX) concentrations of the solution. Total recoverable hydrocarbon concentration is representative of the sum of the hydrocarbons in each test solution for C_6–C_{40}.

ESA performed a full suite of toxicity testing (nine tests with seven test species as detailed in **Table 2-1**) on the un-weathered Barossa-3 condensate and a limited number of tests (7-day fish imbalance and biomass toxicity test) on the weathered Barossa-3 condensate.

Toxicity test results for the WAF are expressed in terms of loading rate of condensate (grams of oil per litre of seawater; **Table 2-2**) and TRH concentrations (µg/L).

Table 2-2: Test dilutions used in toxicity tests

Dilution Factor	1X	2X	4X	8X	16X	32X	64X	128X	Filtered Seawater
% of treatment	100%	50%	25%	12.5%	6.25%	3.125%	1.56%	0.78%	0%
Loading Rate (g/L)-Barossa-3	77.2	38.6	19.3	9.7	4.8	2.4	1.2	0.6	0
Loading Rate (g/L)-Barossa-3 weathered	79.5	39.8	19.9	9.9	5	2.5	1.2	0.6	0

2.1 Quality assurance

Specific quality assurance (QA) procedures for undertaking toxicity testing, procurement and culturing of test organisms, maintenance and calibration of instrument, cleaning, chain of custody and sample handling procedures were in accordance with ESA standard laboratory procedures. ESA is the only National Association of Testing Authorities (NATA) accredited laboratory undertaking toxicity testing in Australia and five of the nine toxicity tests conducted for this study were NATA certified. The 8-day sea anemone pedal lacerate development test using *Aiptasia pulchella*, the 5-day copepod development toxicity test using *Parvocalanus crassirostris*, the

7-day fish imbalance and 7-day fish biomass tests involving barramundi (*Lates calcarifer*) are not NATA certified but only because these are new tests developed by ESA; the quality assurance procedures for these tests are similar to the certified tests.

The pH, salinity and dissolved oxygen concentration of a representative sample from each concentration/treatment was measured. A FSW control and a WAF control were tested concurrently with each test. The WAF control is a way of determining if the process of creating a WAF causes toxicity to test animals. **Appendix A** gives specific quality assurance controls for each of the toxicity tests. The acceptance criteria for each of these measures had to be met in order for the tests to be considered valid. Tests that were invalid were repeated with un-weathered treatment and test organisms, therefore the results presented here represent the final tests in which all acceptance criteria were met.

2.2 Chemical analyses

A total of 39 sub-samples of the WAF were sent by ESA to Envirolab Services for testing in three separate batches. **Table 2-3** lists the practical quantitation limits (PQLs) for the hydrocarbons analysed during this study. The laboratory used for analysis is NATA certified for the parameters measured. As part of their procedures the Envirolab undertakes the required blanks, testing of standards and replicate tests to the satisfaction of NATA requirements.

Table 2-3: Laboratory practical quantitation limits for each of the hydrocarbons analysed

Analyte	PQL (µg/L)
BTEX	
Benzene	1
Toluene	1
Ethylbenzene	1
m+p xylene	2
o-xylene	1
Total Recoverable Hydrocarbons	
C_6-C_{10}	10
>C_{10}-C_{16}	50
>C_{16}-C_{34}	100
>C_{34}-C_{40}	100
Polycyclic Aromatic Hydrocarbons	
Naphthalene	1
Acenaphthylene	1
Acenaphthene	1
Fluorene	1
Phenanthrene	1
Anthracene	1
Fluoranthene	1
Pyrene	1
Benzo(a)anthracene	1
Chrysene	1
Benzo(b,j+k)fluoranthene	2
Benzo(a)pyrene	1
Indeno(1,2,3-c,d)pyrene	1
Dibenzo(a,h)anthracene	1
Benzo(g,h,i)perylene	1

2.3 Data presentation and statistical analysis

The toxicity test data are presented in several ways. Firstly the concentration at which no observed effects are noted (no observed effect concentration, NOEC) is generally used as the most conservative measure of toxicity in that it is the lowest concentration at which no test organisms are affected. The lowest observed effects concentration (LOEC) is the concentration where the first statistically detectable toxicity is observed. The concentration that causes one or more specified effects in 50% of the test organisms in the prescribed test duration (EC_{50}) or which inhibits growth or reproduction of 50% of the test organisms in the prescribed test duration (IC_{50}) are statistically calculated. Similarly IC/EC_{10} values are statistically calculated.

Burrlioz 2.0 is a statistical software package for use in environmental management of species with regard to understanding the effects of levels of toxins in an environment. Depending on the number of observations, Burrlioz 2.0 uses either the log-logistic ($n < 8$) or the Burr Type III ($n \geq 8$) model, to estimate the greatest concentration of a toxin at which no observed effect to a species will be detected. The ANZECC/ARMCANZ (2000) guidelines recommend using the Burrlioz program and stipulate that:

The program determines by statistical means the distribution that best fits the available toxicity data and calculates the 95% protection level (with median confidence) or any other nominated protection level.

For this assessment, the Burrlioz 2.0 program was used to analyse the toxicity results and to plot species sensitivity distributions (SSD) to derive the concentration that protects 80%, 90%, 95% and 99% of species with 50% confidence (PC80(50), PC90(50), PC95(50) and PC99(50) respectively). Analysis by the Burrlioz 2.0

program is designed to utilise EC/IC_{10} values derived from chronic toxicity tests to provide high reliability guideline values. Warne et al (2014) recommend:

EC/IC/LCx where x≤10 are to be used in preference to NOEC and then NOEC estimated values derived from LOEC and LC_{50} values.

In cases where there are insufficient chronic data to derive a guideline value, acute toxicity data can be converted to provide an estimate of chronic toxicity. ANZECC/ARMCANZ (2000) guidelines use LC_{50} or EC_{50} data derived from acute tests in the Burrlioz 2.0 program; however, a chemical-specific acute to chronic ratio (ACR) must be applied to convert the data to a chronic equivalent. A chemical-specific ACR is derived from chronic and acute tests performed on a given species for a test chemical or solution. If this has not been undertaken, the ANZECC/ARMCANZ (2000) guidelines suggest the use of a default value of 10 be applied, meaning that the LC_{50} or EC_{50} data are divided by ten (10) before they are entered into the Burrlioz 2.0 program. The default ACR value of ten was applied to the EC_{50} result for the Acute Copepod Development Test.

It is also worth noting that the Burrlioz 2.0 program is a distribution-fitting application and the more ecotoxicity tests used, the more reliable the guideline values calculated. As a minimum, Warne et al. (2014) state:

The minimum data requirements for using a SSD have not changed from the ANZECC/ARMCANZ (2000) Guidelines i.e. toxicity data for at least five species that belong to at least four taxonomic groups, but using toxicity data from at least 8 species is strongly encouraged and from more than 15 species is considered optimal.

For this investigation, nine tests comprised of seven different taxonomic groups (microalga, macroalga, echinoderm, crustacean, mollusc, cnidarian and fish) were used. As a number of the tests used the same species (e.g. sea urchin *Heliocidaris tuberculata*) a single toxicity value needed to be obtained for each species. At this point in time the laboratory has a limit on the number of tropical test species available, as the new guidelines become more prevalent this will likely change. The lowest value for all combinations of a species and endpoint is adopted as the toxicity value to represent the sensitivity of the species in the SSD calculations (Warne et al. 2014). Therefore, from the nine tests used in the assessment, seven values were used to derive the species protection guideline values. Of the input values, six were derived from chronic tests and one from an acute test.

Burrlioz 2.0 calculates the species protection levels (99%, 95%, etc) based on toxicity data, which are either an EC/IC_{10} or an EC/IC_{50} divided by a factor of ten (10). For a 99% species protection value the Burrlioz 2.0 program assimilates all the test data to derive a value that protects an even higher proportion of the species (i.e. where only one species is affected rather than 10% or 50% of individuals); hence, the values derived will routinely be much lower than the input values from the toxicity testing.

3. Results

The laboratory reports from ESA for each of the toxicity tests are presented in **Appendix B** for un-weathered and weathered treatments of Barossa-3 condensate.

The statistical outputs for the Barossa-3 condensate un-weathered and weathered toxicity tests are summarised in **Table 3-1** and **Table 3-2** respectively. Note that for the chronic tests the IC/EC_{10} values were used as inputs to the Burrlioz 2.0 program, whereas for the Acute Copepod Development Test the EC_{50} value was divided by 10. This factor is applied to ensure that a conservative approach is taken to derive PC95 and PC99 percentages and dilutions in the absence of sufficient chronic toxicity data. The Burrlioz distribution fitting for 95% and 99% species protection of un-weathered Barossa-3 condensate are graphed in **Figure 3-1** to **Figure 3-2**; however, guideline values for all species protection levels (80, 90, 95 and 99%) are highlighted in **Table 3-3**. The Burrlioz output reports are located in **Appendix C.**

Microalga Growth Inhibition Test (72 hour)

For the un-weathered Barossa-3 condensate, algal cell yield was significantly inhibited in the WAF with a loading density corresponding to a TRH concentration of 12,850 µg/L. There was zero cell yield in higher concentrations of the un-weathered condensate (**Appendix B**). The IC_{10} value for the un-weathered condensate was 4,355 µg/L (**Table 3-1**).

Macroalgal Growth Test (14 day)

The WAF of un-weathered Barossa-3 condensate caused significantly lower gametophyte length of the macroalgae *Ecklonia radiata* at a TRH concentration of 3180 µg/L (**Appendix B**). The IC_{10} value for the un-weathered condensate was 1,873 µg/L (**Table 3-1**).

Sea Urchin Fertilisation Success Test (1 hour)

The un-weathered Barossa-3 condensate caused a significantly lower percentage of sea urchin eggs to be fertilised at a TRH concentration of 720 µg/L and no eggs were fertilised at concentrations of 30,860 µg/L or higher (**Appendix B**). The EC_{10} value for the un-weathered condensate was 9,206 µg/L (**Table 3-1**).

Sea Urchin Larval Development Test (72 hour)

The WAF of un-weathered Barossa-3 condensate caused a significant decrease in the number of normally developed sea urchin larvae. No normally developed larvae were observed in the WAF with the highest loading density (corresponding to a TRH concentration of 69,620 µg/L) and a TRH of concentration of 30,860 µg/L caused significantly fewer normally developed larvae (**Appendix B**). The EC_{10} value for the un-weathered condensate was 15,481 µg/L (**Table 3-1**).

Oyster Larval Development Test (48 hour)

Significantly fewer normally developed milky oyster larvae were observed in the WAF's containing a TRH of 14,060 µg/L of un-weathered Barossa-3 condensate and no larvae developed normally with higher concentrations of un-weathered condensate (**Appendix B**). The IC_{10} value for the un-weathered condensate was 11,478 µg/L (**Table 3-1**).

Copepod Acute Development Toxicity Test (5 day)

There was a significant change to the number of healthy copepods affected by un-weathered Barossa-3 at a TPH concentration of 15,830 µg/L compared with the WAF control and at this and higher concentrations of un-weathered condensate all copepods were affected (**Appendix B**). The IC_{10} value for the un-weathered condensate was 27.2 µg/L (**Table 3-1**).

Sea Anemone Pedal Lacerate Development Test (8 day)

The WAF of un-weathered Barossa-3 condensate caused a significant decrease in the number of normally developed sea anemone pedal lacerates. No normally developed larvae were observed in the WAF with the highest loading density (corresponding to a TRH concentration of 63,990 µg/L; **Appendix B**). The IC_{10} value for the un-weathered condensate was 8,862 µg/L (**Table 3-1**).

Fish Imbalance Test (7 day)

The number of healthy fish larvae (unhealthy larvae measured as a loss of balance or equilibrium when swimming and inability to catch prey) in the WAF of un-weathered Barossa-3 condensate was significantly less at a TRH concentration of 29,770 µg/L and there were no healthy fish larvae at higher concentrations (**Appendix B**). The number of healthy fish larvae exposed to weathered Barossa-3 condensate at the highest loading density was not significantly different compared to the FSW control (i.e. 0%; **Appendix B**). The IC_{10} values for the un-weathered and weathered condensate were 15,875 and 19,596 µg/L respectively (**Table 3-1** and **Table 3-2**).

Fish Biomass Toxicity Test (7 day)

The biomass of fish larvae in the WAF of un-weathered Barossa-3 condensate was significantly lower at a TRH concentration of 29,770 µg/L and there were no unaffected fish larvae at higher concentrations (**Appendix B**). The biomass of the fish larvae exposed to weathered Barossa-3 condensate at the highest loading density was not significantly different compared to the FSW control (i.e. 0%; **Appendix B**). The IC_{10} values for the un-weathered and weathered condensate were 17,016 and 13,908 µg/L respectively (**Table 3-1** and **Table 3-2**).

99 and 95% Species Protection

The 95% species protection guideline value of un-weathered Barossa-3 condensate was 456 µg/L (**Figure 3-1** and **Table 3-3**), while the 99% species protection guideline values of un-weathered Barossa-3 condensate was 1146 µg/L (**Figure 3-2** and **Table 3-3**). The IC_{10} values for the un-weathered Barossa-3 condensate ranged from 1,051 to 15,875 µg/L. The reliability of the guideline value was moderate based on the classification scheme outlined in Warne et al. (2014) based on the number of species in which toxicity data are available (n=7), type of toxicity data (mixture of chronic and estimated chronic) and visual assessment of the goodness of fit of the SSD to the toxicity data (good).

Neither the un-weathered nor weathered Barossa-3 condensate was particularly toxic to fish larvae. A lower concentration of un-weathered condensate was required to affect the balance of 10% of fish larvae compared with the weathered condensate (**Table 3-1** and **Table 3-2**) while a lower concentration of weathered condensate was required to affect the biomass of 10% of fish larvae compared to the un-weathered condensate (**Table 3-1** and **Table 3-2**).

Hydrocarbon Concentrations of Weathered and Un-weathered Condensate

The major difference between the hydrocarbon components of the Barosssa-3 weathered and un-weathered condensate was the large reduction in benzene and toluene after 12 hours of weathering (**Table 3-4**). Ethylbenzene and xylenes also decreased but to a much smaller degree. The aliphatic fraction C_{16}-C_{34} and naphthalene increased in weathered condensate but the other PAHs remained unchanged, with most being below the detection limit of the laboratory in both weathered and un-weathered condensates.

Table 3-1: Summary of toxicity tests for un-weathered Barossa-3 condensate (concentrations in µg/L)

Test	NOEC	EC_{10} or IC_{10}	EC_{50} or IC_{50}	Burrlioz Input Values
Microalgal Growth	6670	4355.2	8529.3	4355.2
Macroalgal Germination Success	1673	1873.9	57196.9	1873.9
Sea Urchin Fertilisation	350	9206.2	13202.7	9206.2
Sea Urchin Larval Development	14060	15481.6	20104.4	-
Milky Oyster Larval Development	7160	11478.4	18747.2	11478.4
Copepod Development	8560	27.2	10506.9	1050.7*
Sea Anemone Pedal Lacerate Development	28040	8862.4	30720.0	8862.4
Fish Imbalance	15830	15875.5	23182.2	15875.5
Fish Growth (Biomass)	15830	17016.3	24006.3	-

- indicates that the lowest value for the species was used
* indicates a default acute to chronic ratio was applied to the EC_{50} value

Table 3-2: Summary of toxicity tests for weathered Barossa-3 condensate (concentrations in µg/L)

Test	NOEC	EC_{10} or IC_{10}	EC_{50} or IC_{50}
Fish Imbalance	22480	19596.3	>22480
Fish Growth (Biomass)	22480	13908.1	>22480

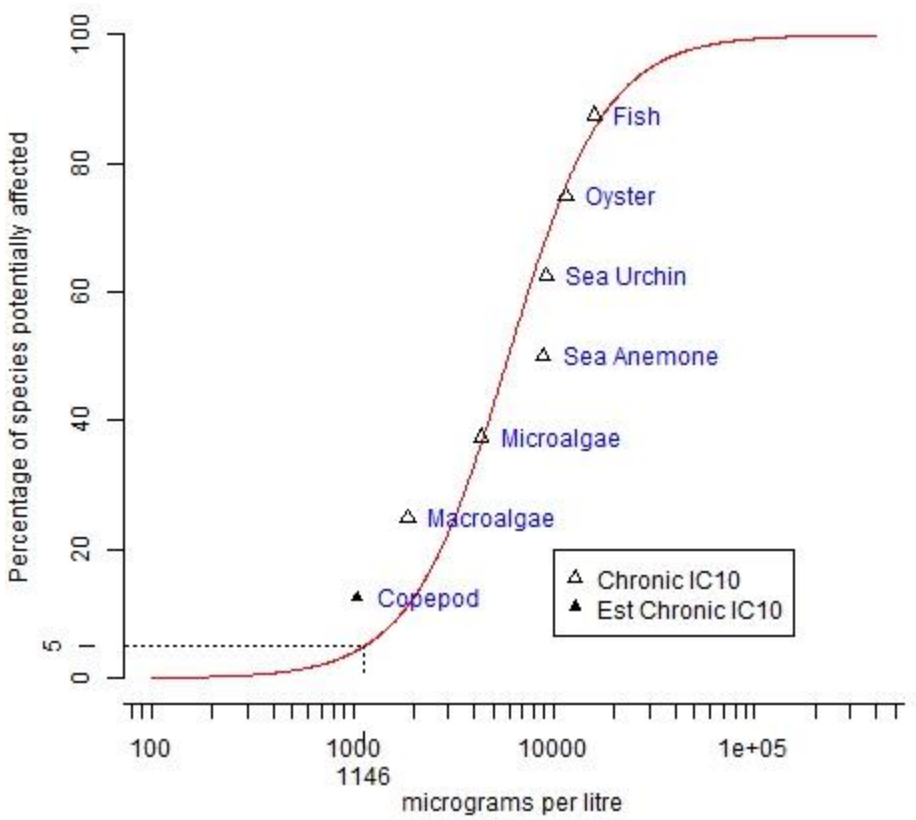

Figure 3-1: Burrlioz distribution fitting for 95% species protection of un-weathered Barossa-3 condensate

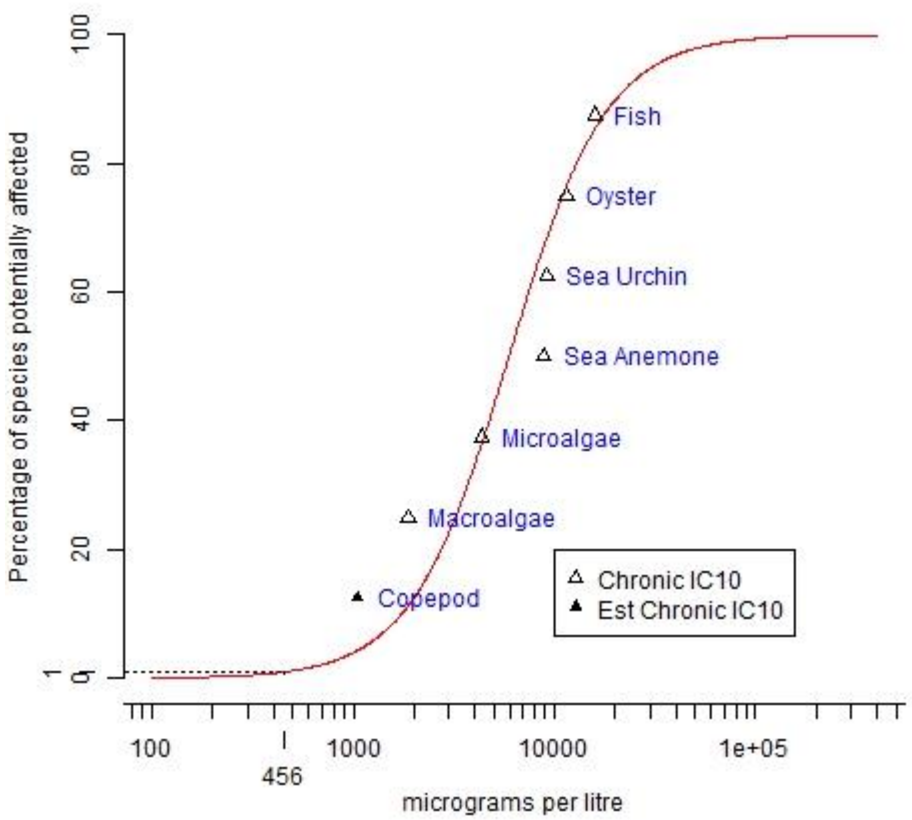

Figure 3-2: Burrlioz distribution fitting for 99% species protection of un-weathered Barossa-3 condensate

Table 3-3: Moderate reliability guideline values derived from Burrlioz species sensitivity distribution curve for un-weathered Barossa-3 condensate

Treatment	Level of Species Protection	Derived Guideline Value for TRH concentration (µg/L)
Un-weathered Barossa-3 condensate	99%	456
	95%	1146
	90%	1739
	80%	2735

Table 3-4: Hydrocarbon concentrations of weathered and un-weathered Barossa-3 condensate

Analyte	100% Un-weathered Condensate (µg/L)	100% Weathered Condensate (µg/L)
BTEX		
Benzene	27000	630
Toluene	21000	7400
Ethylbenzene	490	400
m+*p* xylene	5000	4000
o-xylene	1500	1400
Total Recoverable Hydrocarbons		
C_6-C_{10} (less BTEX)	7000	5200
>C_{10}-C_{16} (less naphthalene)	1200	800
>C_{16}-C_{34}	1900	2600
>C_{34}-C_{40}	140	<100
Polycyclic Aromatic Hydrocarbons		
Naphthalene	250	400
Acenaphthylene	<1	<1
Acenaphthene	<1	<1
Fluorene	3	4
Phenanthrene	2	2
Anthracene	<1	<1
Fluoranthene	<1	<1
Pyrene	<1	<1
Benzo(a)anthracene	<1	<1
Chrysene	<1	<1
Benzo(b,j+k)fluoranthene	<2	<1
Benzo(a)pyrene	<1	<1
Indeno(1,2,3-c,d)pyrene	<1	<1
Dibenzo(a,h)anthracene	<1	<1
Benzo(g,h,i)perylene	<1	<1

4. Conclusions

A large number of studies have been published describing the toxicity of total petroleum hydrocarbon and hydrocarbon components (including French-McCay, 2002; Lewis and Pryor, 2013; Neff et al. 2000). The common theme in the findings is that the observed toxicity of crude and refined hydrocarbons is primarily attributable to volatile and water-soluble aromatic hydrocarbons (MAHs) including BTEX, low molecular weight PAHs such as naphthalene and phenanthrene and higher molecular weight PAHs).

The moderate reliability guideline value for 95% species protection of un-weathered Barossa-3 condensate was 1,146 µg/L and the moderate guideline value for 99% species protection was 456 µg/L. The IC_{10} values for the un-weathered Barossa-3 condensate ranged from 1,051 to 15,875 µg/L. According to the GESAMP (2002) classification, un-weathered Barossa-3 condensate has almost negligible chronic aquatic toxicity.

Neither the un-weathered nor weathered Barossa-3 condensate was particularly toxic to fish larvae. A lower concentration of un-weathered condensate was required to affect the balance of 10% of fish larvae compared with the weathered condensate while a lower concentration of weathered condensate was required to affect the biomass of 10% of fish larvae compared to the un-weathered condensate.

The un-weathered Barossa-3 condensate was more toxic to copepod development and macroalgal growth and less toxic to fish larvae and oyster larvae development. Neff (1979) also found that toxicity was most pronounced among crustaceans and least among teleost or ray-finned fishes.

From the chemical analysis of the Barossa-3 condensate undertaken by Envirolab Services (**Appendix B**), the most obvious difference between the un-weathered and weathered condensate was in the BTEX results. BTEX is the collective name for benzene, toluene, ethylbenzene, and xylenes and falls into the class of MAH. The weathered Barossa-3 condensate had much lower concentrations than the un-weathered Barossa-3 condensate, particularly of benzene and toluene. BTEX compounds are acutely toxic to aquatic organisms if exposure is sustained. Because of the volatility of BTEX, aquatic organisms typically only experience short exposure times in the order of 12 hours which may circumvent toxic effects.

Of the PAHs analysed for this study, naphthalene was the only one measured by Envirolab Services that was higher in the weathered condensate compared to the un-weathered condensate. All other PAHs measured were below the laboratory detection limit or in the case of fluorene and phenanthrene were similar between weathered and un-weathered condensate. However, the myriad of other chemicals present in the condensate were not required to be measured for the purposes of this exercise. Neff et al. (2000) demonstrated that the MAHs are the most important contributors to the acute toxicity of the WAFs of fresh oils, while the contribution of PAHs to WAF toxicity increases with weathering. However it is generally not well understood which of the many components of oil are responsible for the many toxicity effects induced by oil.

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Appendix A. Summary of Quality Assurance for Ecotox Tests

Table A.1: Specific quality assurance (QA) criteria for the Microalga Growth Test

QA Measure	Acceptance Criteria	This Test	Criterion Met?
FSW control mean cell density	≥ 160,000 cells/mL	202,000 ± 32,000 cells/mL	Yes
Control coefficient of variation	< 20%	16.0%	Yes
Reference toxicant test within Cusum chart limits	15.1-46.7 µg/L Cu/L	19.0 µg/L Cu/L	Yes

Table A.2: Specific quality assurance (QA) criteria for the Macroalgal Growth Test

QA Measure	Acceptance Criteria	This Test	Criterion Met?
FSW control mean % germination @ 72 hrs	≥ 70%	90.3 ± 1.12	Yes
Reference toxicant test	86.0-1262.1 µg/L Cu/L	408.5 µg/L Cu/L	Yes

Table A.3: Specific quality assurance (QA) criteria for the Sea Urchin Fertilisation Success Test

QA Measure	Acceptance Criteria	This Test	Criterion Met?
FSW control mean % fertilised eggs	≥ 70%	78.8 ± 3.2%	Yes
Reference toxicant test within Cusum chart limits	23.7-105.6 µg/L Cu/L	26.7 µg/L Cu/L	Yes

Table A.4: Specific quality assurance (QA) criteria for the Sea Urchin Larval Development Test

QA Measure	Acceptance Criteria	This Test	Criterion Met?
FSW control mean % normal larvae	≥ 70%	80.8 ± 5.0%	Yes
Reference toxicant test within Cusum chart limits	10.5-23.1 µg/L Cu/L	12.2 µg/L Cu/L	Yes

Table A.5: Specific quality assurance (QA) criteria for the Milky Oyster Larval Development Test

QA Measure	Acceptance Criteria	This Test	Criterion Met?
FSW control mean % normal larvae	≥ 70%	74.5 ± 4.8%	Yes
Reference toxicant test within Cusum chart limits	10.2-20.0 µg/L Cu/L	14.5 µg/L Cu/L	Yes

Table A.6: Specific quality assurance (QA) criteria for the Acute Copepod Development Toxicity Test

QA Measure	Acceptance Criteria	This Test	Criterion Met?
FSW control mean % unaffected larvae	≥ 70%	70 0 ± 10.7%	Yes
Reference toxicant test within Cusum chart limits*	n/a	2.8 µg/L Cu/L	n/a

* Cusum chart data unavailable due to insufficient tests conducted to build database

Table A.7: Specific quality assurance (QA) criteria for the Sea Anemone Pedal Lacerate Development Test

FSW control mean % normal pedal lacerates	≥ 90%	100 ± 0.0%	Yes
Reference toxicant test within Cusum chart limits*	n/a	11.5 µg/L Cu/L	n/a

* Cusum chart data unavailable due to insufficient tests conducted to build database

Table A.8: Specific quality assurance (QA) criteria for the Larval Fish Imbalance and Growth (Biomass) Test

FSW control mean % unaffected larvae	≥ 80%	100.0 ± 0.0%	Yes
Control Mean Growth	≥ 20% of initial weight	52.6%	Yes
Reference toxicant test within Cusum chart limits	n/a	17.3 mg NH_4^+/L	n/a

* Cusum chart data unavailable due to insufficient tests conducted to build database

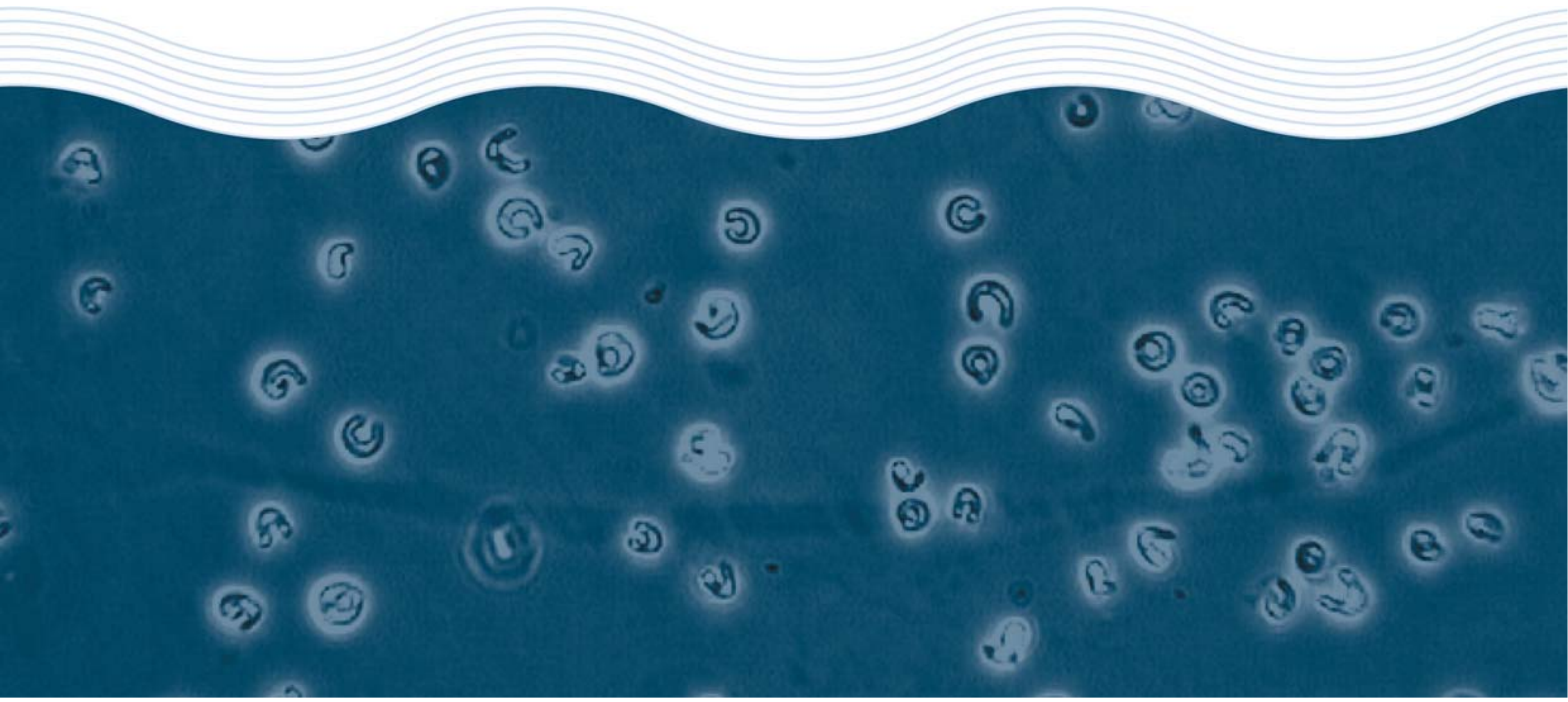
Appendix B. Laboratory Reports

Toxicity Assessment of Fresh and Weathered Barossa Field Condensate

Jacobs SKM

Comprehensive Test Report

November 2015



Toxicity Assessment of Fresh and Weathered Barossa Field Condensate

Jacobs SKM

Comprehensive Test Report

November 2015

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1. Executive Summary

1.1 Executive Summary

Ecotox Services Australasia Pty Ltd (ESA) was commissioned by Jacobs Group (Australia) Pty Ltd to undertake marine toxicity tests with a condensate sample from the Barossa field development site.

The following toxicity tests were undertaken on Water Accommodated Fractions (WAFs) of Barossa Field Condensate:

- 1-hr fertilisation test using the sea urchin *Heliocidaris tuberculata* (based on USEPA Method 1008 and Environment Canada (1992), modified for use with *H. tuberculata* by Simon and Laginestra 1997, and Doyle *et al*. 2003).
- 72-hr larval development test using the sea urchin *Heliocidaris tuberculata* (based on APHA Method 8810D, modified for use with *H. tuberculata* by Simon and Laginestra 1997)
- 48-hr larval abnormality test using the milky oyster *Saccostrea echinata* (based on APHA Method 8610 and USEPA OPPTS 850.1055, Krassoi 1995)
- 72-hr growth (cell-yield) test using the marine micro-alga *Isochrysis aff. galbana* (based on Stauber *et al*., 1994 for *N. closterium.*)
- 14-day macroalgal growth test using *Ecklonia radiata* (based on Bidwell *et al.* 1998 and Burridge *et al.* 1999).
- 8-day sea anemone pedal lacerate development toxicity test using *Aiptasia pulchella* (based on Howe *et al.* 2014)
- 5-day copepodid development toxicity test using the juvenile calanoid copepod *Parvocalanus crassiostris* (based on Rose *et al* 2006).
- 7-d fish imbalance and growth test with barramundi *Lates calcarifer* (based on USEPA 2002b).

All eight toxicity tests were performed on WAFs generated from either the fresh or weathered Barossa Field Condensate (ESA identification number 7323). Sub-samples of the WAFs and individual dilution treatments were shipped to Envirolab Services Pty Ltd for Total Recoverable Hydrocarbons (TRH, C6-C36), Total Petroleum Hydrocarbons (TPHs) and BTEX. The TRH data, in addition to loading rate of condensate in the WAF generation systems, were used to determine toxicity test end-points.

Test data for the Barossa Field Condensate, based on loading rates, are summarised in **Table 1.1**. The bioassays were performed at the ESA laboratory in Lane Cove. This report describes the results of each of the toxicity tests performed. Test reports for each of the tests are given in **Appendices C to J.** Statistical printouts for each test are given in **Appendices K** to **R**. The analytical reports for TRH analysis of the WAF samples are provided in **Appendix B** of this report.

Test results indicated the following:

- ***1-hr Sea Urchin Fertilisation Test*:**
  Based on the loading rate, the WAF of the Barossa Field Condensate had an EL10, EL50, NOEL and LOEL of 14.6, 18.6 (8.97-19.12), 0.6 and 1.2g/L, respectively. Expressed as TRH concentration, the corresponding EC10, EC50, NOEC and LOEC were 9206.2 (7702.42-10203.00), 13202.7 (12495.20-13763.40)µg/L, 350 and 720µg/L, respectively.

- ***72-hr Sea Urchin Larval Development Test*:**
  Based on the loading rate, the WAF of the Barossa Field Condensate had an EL10, EL50, NOEL and LOEL of 21.0 (18.90-2276), 26.5 (24.67-28.01), 19.3 and 38.6g/L, respectively. Expressed as TRH concentration, the corresponding EC10, EC50, NOEC and LOEC were 15481.6 (13727.10-16947.80), 20104.4 (18575.70-21450.10), 14060 and 30860µg/L, respectively.

- ***48-hr Milky Oyster Larval Development Test*:**
  Based on the loading rate, the WAF of the Barossa Field Condensate sample had an EL10, EL50, NOEL and LOEL 15.7 (11.78-18.35), 24.7 (24.11-25.32), 9.7 and 19.3g/L, respectively. Expressed as TRH concentration, the corresponding EC10, EC50, NOEC and LOEC were 11478.4 (9026.54-13230.50), 18747.2 (18266.80-19240.30), 7160 and 14060µg/L, respectively.

- ***72-hr Micro-algal Growth Inhibition Test*:**
  Based on the loading rate, the WAF of the Barossa Field Condensate had an IL10, IL50, NOEL and LOEL of 6.4 (2.18-10.68), 12.6 (7.45-15.09), 9.7 and 19.3g/L, respectively. Expressed as TRH concentration, the corresponding IC10, IC50, NOEC and LOEC were 4355.2 (1641.13-7401.38), 8529.3 (5094.77-10126.00), 6670 and 12850µg/L, respectively.

- ***14-d Macroalgal Growth Test:***
  Based on the loading rate, the WAF of the Barossa Field Condensate had an IL10, IL50, NOEL and LOEL of 2.7, 64.8, 2.4 and 4.8g/L, respectively. Expressed as TRH concentration, the corresponding IC10, IC50, NOEC and LOEC were 1873.9, 57196.9, 1673 and 3180µg/L, respectively.

- ***8-dSea Anemone Development Test:***
  Based on the loading rate, the WAF of the Barossa Field Condensate had an EL10, EL50, NOEL and LOEL of 11.2, 40.1 (31.78-50.60), 38.6 and 77.2g/L, respectively. Expressed as TRH concentration, the corresponding EC10, EC50, NOEC and LOEC were 8862.4, 30720.0 (23961.00-39385.50), 28040, 63990µg/L, respectively.

- ***5-d Copepodid development Test***
  Based on the loading rate, the WAF of the Barossa Field Condensate had an EL10, EL50, NOEL and LOEL of 1.0, 12.2 (10.84-13.73), 9.7 and 19.3g/L, respectively. Expressed as TRH concentration, the corresponding EC10, EC50, NOEC and LOEC were 27.2, 10506.9 (9451.82-11679.80), 8560 and 15830µg/L, respectively.

- ***7-d Fish Imbalance and Growth Test*:**
  Based on the loading rate, the WAF of the fresh Barossa Field Condensate had an EL10, EL50, NOEL and LOEL of 19.4 (13.58-23.28), 29.3 (24.71-34.66),

19.3 and 38.6g/L, respectively, for the imbalance endpoint. Expressed as TRH concentration, the corresponding EC10, EC50, NOEC and LOEC were 15875.5 (11275.40-18756.60). 23182.2 (19851.60-27226.80), 15830 and 29770µg/L, respectively. The EL10, EL50, NOEL and LOEL for the biomass endpoint were 20.9 (8.44-22.09), 30.6 (27.79-31.44), 19.3 and 38.6g/L, respectively expressed as loading rate, and 17016.3 (7373.18-18757.60), 24006.3 (21800.80-24621.00), 15830 and 29770µg/L, respectively, expressed as TRH concentration.

Based on the loading rate, the WAF of the Weathered Barossa Field Condensate had an EL10, EL50, NOEL and LOEL of 69.1, >79.5, 79.5 and >79.5g/L, respectively, for the imbalance endpoint. Expressed as TRH concentration, the corresponding EC10, EC50, NOEC and LOEC were 19596.3, >22480, 22480 and >22480µg/L, respectively. The EL10, EL50, NOEL and LOEL for the biomass endpoint were 48.6, >79.5, 79.5 and >79.5g/L, respectively expressed as loading rate, and 13908.1, >22480.0, 22480 and >22480µg/L, respectively, expressed as TRH concentration.

Table 1.1. Summary of toxicity test data for the Barossa Field Condensate

		Barossa Field Condensate		Weathered Barossa Field Condensate	
Toxicity Test	**Endpoint**	**Loading Rate (g/L)**	**TRH Concentration (µg/L)**	**Loading Rate (g/L)**	**TRH Concentration (µg/L)**
1-hr sea urchin fertilisation	1-hr EL10	14.6*	9206.2 (7702.42-10203.00)	-	-
	1-hr EL50	18.6 (8.97-19.12)	13202.7 (12495.20-13763.40)	-	-
	NOEL	0.6	350	-	-
	LOEL	1.2	720	-	-
72-hr sea urchin larval development	72-hr EL10	21.0 (18.90-22.76)	15481.6 (13727.10-16947.80)	-	-
	72-hr EL50	26.5 (24.67-28.01)	20104.4 (18575.70-21450.10)	-	-
	NOEL	19.3	14060	-	-
	LOEL	38.6	30860	-	-
48-hr milky oyster larval development	48-hr EL10	15.7 (11.78-18.35)	11478.4 (9026.54-13230.50)	-	-
	48-hr EL50	24.7 (24.11-25.32)	18747.2 (18266.80-19240.30)	-	-
	NOEL	9.7	7160	-	-
	LOEL	19.3	14060	-	-
72-hr micro-algal growth	72-hr IL10	6.4 (2.18-10.68)	4355.2 (1641.13-7401.38)	-	-
	72-hr IL50	12.6 (7.45-15.09)	8529.3 (5094.77-10126.00)	-	-
	NOEL	9.7	6670	-	-
	LOEL	19.3	12850	-	-
14-d macroalgal growth	14-d IL10	2.7*	1873.9*	-	-
	14-d IL50	64.8*	57196.9*	-	-
	NOEL	2.4	1673	-	-
	LOEL	4.8	3180	-	-

		Barossa Field Condensate		Weathered Barossa Field Condensate	
Toxicity Test	**Endpoint**	**Loading Rate (g/L)**	**TRH Concentration (µg/L)**	**Loading Rate (g/L)**	**TRH Concentration (µg/L)**
8-d sea anemone development	8-d EL10	11.2*	8862.4*	-	-
	8-d EL50	40.1 (31.78-50.60)	30720.0 (23961.00-39385.50)	-	-
	NOEL	38.6	28040	-	-
	LOEL	77.2	63990	-	-
5-d copepodid development	5-d EL10	1.0**	27.2*	-	-
	5-d EL50	12.2 (10.84-13.73)	10506.9 (9451.82-11679.80)	-	-
	NOEL	9.7	8560	-	-
	LOEL	19.3	15830	-	-
7-d fish imbalance	7-d EL10	19.4 (13.58-23.28)	15875.5 (11275.40-18756.60)	69.1*	19596.3*
	7-d EL50	29.3 (24.71-34.66)	23182.2 (19851.60-27226.80)	>79.5	>22480.0
	NOEL	19.3	15830	79.5	22480
	LOEL	38.6	29770	>79.5	>22480
7-d fish biomass	7-d EL10	20.9 (8.44-22.09)	17016.3 (7373.18-18757.6)	48.6*	13908.1
	7-d EL50	30.6 (27.79-31.44)	24006.3 (21800.80-24621.00)	>79.5	>22480.0
	NOEL	19.3	15830	79.5	22480
	LOEL	38.6	29770	>79.5	>22480

*95% confidence limits are not available/reliable
** Based on extrapolated data

1.2 Glossary of Terms

The following glossary is based on that provided by Environment Canada (1997)

Acute toxicity is an adverse effect (lethal or sub-lethal) induced in the test organisms within a short period of exposure to a test material, usually a few days.

Bioassay is a test (=assay) in which the strength or potency of a substance is measured by the response of living organisms or living system. ***Toxicity test*** is a more specific and preferred term for environmental work.

Chronic toxicity implies long-term effects that are related to changes in metabolism, growth, reproduction, or ability to survive

Control is a treatment in an investigation that duplicates all the factors that might affect results, except the specific condition being studied. In toxicity tests, the control must duplicate all the conditions in the exposure treatment(s) but must contain no test material. The control is used as a check for toxicity due to basic conditions such as quality of dilution water or health and handling of the test organisms. Control is synonymous with ***negative control***. See also ***positive control***.

ECx is the median effective concentration. That is the concentration of material in water that is estimated to cause a specified percent effect (eg. EC10, EC50) of the test organisms. In most instances the EC50 and its 95% confidence limits are statistically derived by analysing the percentages of organisms affected at various test concentrations, after a fixed period of exposure. The duration of exposure must be specified (eg. 48h).

ELx is the median effective loading rate. That is the loading rate of material in water (eg. mg/L) that is estimated to cause cause a specified percent effect (eg. EC10, EC50) of the test organisms. In most instances the EL50 and its 95% confidence limits are statistically derived by analysing the percentages of organisms affected at various test loading densities, after a fixed period of exposure. The duration of exposure must be specified (eg. 48h).

Endpoint means the measurement(s) or value(s) that characterise the results of a test (LL50, EL50, IL50). It also means the reaction of the organism to show the effect which is intended to mark completion of the test (eg. death, number of shell abnormalities).

ILx is the inhibiting loading rate for a specified percent effect (eg. IL50). It represents a point estimate of a loading rate of test material that causes a designated percent inhibition (*p*) compared to the control, in a quantitative biological measurement such as microalgal cell yield attained at the end of a test.

ICx is the inhibiting concentrations for a specified percent effect (eg. IC50). It represents a point estimate of a concentration of test material that causes a designated percent inhibition (*p*) compared to the control, in a quantitative biological measurement such as microalgal cell yield attained at the end of a test.

LOEC is the lowest-observed-effect concentration. This represents the lowest concentration of a test material for which a statistically significant effect on the test organisms was observed, relative to the control.

LOEL is the lowest-observed-effect loading rate. This represents the lowest loading densities of a test material for which a statistically significant effect on the test organisms was observed, relative to the control.

NOEC is the no-observed-effect concentration. This represents the highest test concentration of a test material for which no statistically significant effect on the test organisms was observed, relative to the control.

NOEL is the no-observed-effect loading rate. This represents the highest test loading rate of a test material for which no statistically significant effect on the test organisms was observed, relative to the control.

Positive Control is a toxicity test with a reference toxicant, used to assess the sensitivity of the organisms at the time of the test material is evaluated and the precision of the results obtained by the laboratory for that chemical.

Reference toxicant is a standard chemical used to measure the sensitivity of the test organisms to establish confidence in the toxicity data obtained for a test material. In most instances, a toxicity test with a reference toxicant is performed to assess the sensitivity of the organisms at the time the test material is evaluated and the precision of the results obtained by the laboratory for that chemical.

Replicate is a single test chamber containing a prescribed number of test organisms in either one loading rate of test solution or in dilution water as a control. In a toxicity test comprising five test concentrations and a control, and using four replicates, 24 test chambers would be used. For each loading rate or control, there would be 4 test chambers or replicates. A replicate must be an independent unit, and therefore, any transfer of test material or organisms from one replicate to another would invalidate a statistical analysis based on replication.

Static describes toxicity tests in which test solutions are not renewed during the test.

Sub-lethal means detrimental to the organism, but below the level that directly causes death within the test period.

Toxic means poisonous. A toxic material can cause adverse effects on living organisms, if present in sufficient amount at the right location.

Toxicant is a toxic material.

2. Introduction

Ecotox Services Australasia Pty Ltd (ESA) was commissioned by Jacobs Group (Australia) Pty Ltd to undertake marine toxicity tests with a condensate sample from the Barossa field development site.

The following toxicity tests were undertaken on Water Accommodated Fractions (WAFs) of Barossa Field condensate:

- 1-hr fertilisation test using the sea urchin *Heliocidaris tuberculata* (based on USEPA Method 1008 and Environment Canada (1992), modified for use with *H. tuberculata* by Simon and Laginestra 1997, and Doyle *et al*. 2003).
- 72-hr larval development test using the sea urchin *Heliocidaris tuberculata* (based on APHA Method 8810D, modified for use with *H. tuberculata* by Simon and Laginestra 1997)
- 48-hr larval abnormality test using the milky oyster *Saccostrea echinata* (based on APHA Method 8610C and USEPA OPPTS 850.1055, Krassoi 1995)
- 72-hr growth (cell-yield) test using the marine micro-alga *Isochrysis aff. galbana* (based on Stauber *et al*., 1994 for *N. closterium.*)
- 14-day macroalgal growth test using *Ecklonia radiata* (based on Bidwell *et al.* 1998 and Burridge *et al.* 1999).
- 8-day sea anemone pedal lacerate development toxicity test using *Aiptasia pulchella* (based on Howe *et al.* 2014)
- 5-day copepodid development toxicity test using the juvenile calanoid copepod *Parvocalanus crassiostris* (based on Rose *et al* 2006).
- 7-d fish imbalance and growth test with barramundi *Lates calcarifer* (based on USEPA 2002b).

The condensate sample was shipped to ESA in 20L steel cans and was received in good condition (**Appendices A**). The Barossa Field Condensate was assigned ESA identification number 7323. The condensate sample was stored at room temperature until used for preparing Water Accommodated Fractions (WAFs).

WAFs of the condensate sample were prepared by adding a prescribed quantity of condensate to 0.45µm filtered seawater (FSW) in 2 litre glass bottles in general accordance with CONSERF procedures (Singer *et al*., 2000). The mixing ratio was 1 part condensate: 9 parts filtered seawater. The preparations were stirred for 24 hours using a magnetic stirrer in such a manner as to avoid the formation of a vortex that may form dispersed droplets. The WAF and the overlying condensate layer were allowed to settle for 1 hour before the underlying WAF was siphoned off into clean glass bottles and tested on the day of preparation.

The WAFs were prepared in general accordance with CONSERF procedures (Singer *et al*., 2000), the principal departure being the individual WAFs were not prepared for each test treatment. After consideration, it was determined that a dilution of a single or combined WAF was to be undertaken to prepare test solutions for each toxicity test. The results reported herein are for toxicity tests where dilutions were prepared from a WAF at a mixing ratio of 1 part condensate: 9 parts filtered seawater.

The bioassays were performed at the ESA laboratory in Lane Cove, NSW. This report describes the results of each of the toxicity tests performed. Test reports for each test performed are given in **Appendices C to J**. The statistical printouts from the Toxcalc analytical software for each test are given in **Appendices K** to **R**. Toxicity tests reported herein were undertaken in September to October 2015.

The toxicity test endpoints reported herein are expressed as loading rate of condensate (expressed in terms of grams of condensate/L), and as Total Recoverable Hydrocarbon (TRH, total of C6-C36) determined by subcontracted chemical analyses of each test treatment. Sub-samples of the test treatments (ie dilutions of each WAF) were sent by same-day express courier to Envirolab Services Pty Ltd, Chatswood NSW. The analytical report for the TRH analyses is provided in **Appendix B** of this report.

3. 1-hr Sea Urchin Fertilisation Test

3.1 Summary of Test Methodology

The 1-hr sea urchin fertilisation test using the gametes of *Heliocidaris tuberculata* was undertaken in accordance with ESA Standard Operating Procedure 104, which is based on methods described by USEPA method 1008 (2002) and Environment Canada (1992), ASRM (1995) and APGHA (1998), modified for use by Simon and Langistera (1996) and adapted for use with *H. tuberculata* by Simon and Laginestra (1997). Tests were performed in a constant temperature chamber of 20±1°C with a 16:8h light: dark photoperiod for the entire exposure. Clean seawater was collected from the Sydney region and filtered to 0.45µm on return to the laboratory. Sea urchins used for the tests were obtained by field collection from South Maroubra, NSW and spawned within 6-hr of collection.

The definitive test reported here was initiated on 10 September 2015. The tests were undertaken in 9mL borosilicate glass tissue culture tubes, with four replicate tubes per treatment. A filtered seawater (FSW) control and a Water Accommodated Fraction (WAF) control were tested concurrently with the prepared WAF.

The pH, salinity and dissolved oxygen concentration of a representative sample from each concentration/treatment was measured. Salinity was measured using a WTW Cond330 salinity/conductivity meter with a WTW Tetracon 325 probe. The pH was measured using a WTW pH330 meter with a WTW SenTix 41 electrode. Dissolved oxygen was measured using a WTW Oxi 330 Oximeter, with a WTW CellOx 325 probe. Sub-samples for TRH (Total Recoverable Hydrocarbons, C6-C36), PAHs (Polycyclic aromatic hydrocarbons) and BTEX (benzene, toluene, ethylbenzene, and xylenes) were collected for each WAF dilution and controls and stored at 4°C in the dark until it was determined that the corresponding toxicity tests met QA criteria, upon which samples were forwarded to Envirolab Services Pty Ltd by same-day express courier.

Sperm were exposed to each of the test treatments for 1 hour, after which eggs were added to the test solutions and incubated with the sperm for 20 minutes. The test was then terminated by the addition of buffered formalin. One milliliter of test solution was drawn directly from the bottom of each test vessel and placed in a Sedgwick-Rafter counting chamber. The first 100 eggs were examined and the number of fertilised eggs was recorded. Toxicity test end-points were determined using loading rates and TRH concentrations. The loading rate and TRH concentration of WAF resulting in reductions in fertilisation to 10% and 50% of the test population (1-hr EL and EC values) was determined by either Maximum Liklihood Probit or Trimmed Spearman Karber or Probit Method using Toxcalc v5.0 software. The loading rate and TRH concentration causing no significant toxicity (No Observed Effect Loading Rate/Concentration – NOEL/NOEC), and the lowest loading rate causing significant toxicity (Lowest Observed Effect Loading Rate/Concentration – LOEL/LOEC) were determined by performing a Dunnett's or non-parametric test, depending on the data being normally distributed and homoscedastic.

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Table 3.1. Summary of test conditions for the sea urchin fertilisation test

Test species	Sea urchin *Heliocidaris tuberculata*
Test type	Static, non-renewal
Test duration	1-hour
Test end-point	Fertilisation
Test temperature	20±1°C
Test salinity	35±1‰
Test chamber size / volume	5mL in 9 mL tissue culture tube
Source of test organisms	Field collection, Sydney coastal region
Test concentrations	WAF dilutions of 100, 50, 25, 12.5 and 6.3% or lower
Test acceptability criteria	≥70% fertilisation in controls, reference toxicant results within prescribed range

To test the relative sensitivity of the test organisms and the proficiency of the Laboratory Technician, a separate positive control test was conducted using copper. The test was performed in the same manner as the test with the WAF. The results of the reference toxicant test were compared with the results from previous testing using a control chart.

3.2 Results

The results for the WAF of the Barossa Field Condensate using the sea urchin fertilisation test are summarised in **Table 3.2** below. The mean and standard deviation of the responses of test organisms to each test treatment are given in the summary reports given in **Appendix C**. The statistical output from the Toxcalc statistical analyses are given in **Appendix K**.

Table 3.2. The 1-hr EL/EC10 and EL/EC50 (with 95% confidence limits), NOEL/NOEC and LOEL/NOEC (based on loading rates and TRH concentrations) for Water Accommodated Fractions (WAFs) of the Barossa Field Condensate sample using the sea urchin fertilisation success test.

Sample	1-hr EL/EC10	1-hr EL/EC50	NOEL/ NOEC	LOEL/ LOEC
Barossa Field Condensate – Loading rate (g/L)	14.6*	18.6 (8.97-19.12)	0.6	1.2
Barossa Field Condensate – TRH concentration (µg/L)	9206.2 (7702.42-10203.00)	13202.7 (12495.20-13763.40)	350	720

*95% confidence limits are not reliable

Based on the loading rate, the WAF of the Barossa Field Condensate had an EL10, EL50, NOEL and LOEL of 14.6, 18.6 (8.97-19.12), 0.6 and 1.2g/L, respectively. Expressed as TRH concentration, the corresponding EC10, EC50, NOEC and LOEC were 9206.2 (7702.42-10203.00), 13202.7 (12495.20-13763.40), 350 and 720µg/L, respectively.

The WAF control was not toxic to sea urchin fertilisation.

3.3 Quality Assurance

The sea urchin fertilisation test undertaken with the pepared WAF met all quality assurance criteria. The mean percentage of fertilised eggs in the laboratory control in the test was 78.8%, exceeding the minimum control criteria of 70%. Water quality parameters were also within test acceptability ranges.

The 1-hr EC50 estimate for the copper reference toxicant tests run concurrently with the WAF sample fell within the reference toxicant cusum chart control limits (**Table 3.3**). This indicated that the toxicity test was within the expected range with respect to performance and sensitivity.

Table 3.3 The Quality Assurance limits for the sea urchin fertilisation test.

QA Measure	Criterion	This Test
Control % normally developed	$\geq$ 70%	78.8%
Reference toxicant EC50	23.7-105.6µg Cu/L	26.7µg Cu/L

4. 72-hr Sea Urchin Larval Development Test

4.1 Summary of Test Methodology

The 72-hr sea urchin larval development test using the fertilised eggs of *Heliocidaris tuberculata* was undertaken in accordance with ESA Standard Operating Procedure 105, which is based on methods described by ASTM (1995) and APHA (1998), and adapted for use with *H. tuberculata* by Simon and Laginestra (1997) and Doyle *et al*. (2002). Tests were performed in a constant temperature chamber of 20±1^{o}C with a 16:8h light: dark photoperiod for the entire 72-hr exposure. Clean seawater was collected from the Sydney region and filtered to 0.45µm on return to the laboratory. Sea urchins used for the tests were obtained by field collection from South Maroubra, NSW and spawned within 6-hr of collection.

The definitive test reported here was initiated on 10 September 2015. The tests were undertaken in 9mL borosilicate glass tissue culture tubes, with four replicate tubes per treatment. A filtered seawater (FSW) control and a Water Accommodated Fraction (WAF) control were tested concurrently with the prepared WAF.

The pH, salinity and dissolved oxygen concentration of a representative sample from each concentration/treatment was measured. Salinity was measured using a WTW Cond330 salinity/conductivity meter with a WTW Tetracon 325 probe. The pH was measured using a WTW pH330 meter with a WTW SenTix 41 electrode. Dissolved oxygen was measured using a WTW Oxi 330 Oximeter, with a WTW CellOx 325 probe. Sub-samples for TRH (Total Recoverable Hydrocarbons, C6-C36), PAHs (Polycyclic aromatic hydrocarbons) and BTEX (benzene, toluene, ethylbenzene, and xylenes) were collected for each WAF dilution and controls and stored at 4^{o}C in the dark until it was determined that the corresponding toxicity tests met QA criteria, upon which samples were forwarded to Envirolab Services Pty Ltd by same-day express courier.

Fertilised eggs were exposed to each of the test treatments for 72 hours, after which the test was terminated by the addition of buffered formalin. One milliliter of test solution was drawn directly from the bottom of each test vessel and placed in a Sedgwick-Rafter counting chamber. The first 100 larvae were examined and the number of normally developed larvae was recorded. Toxicity test end-points were determined using loading rates and TRH concentrations. The loading rate and TRH concentration of WAF resulting in reductions in normal development to 10% and 50% of the test population (72-hr EL and EC values) was determined by either Maximum Liklihood Probit or Trimmed Spearman Karber or Probit Method using Toxcalc v5.0 software. The loading rate and TRH concentration causing no significant toxicity (No Observed Effect Loading Rate/Concentration – NOEL/NOEC), and the lowest loading rate causing significant toxicity (Lowest Observed Effect Loading Rate/Concentration – LOEL/LOEC) were determined by performing a Dunnett's or non-parametric test, depending on the data being normally distributed and homoscedastic.

Table 4.1. Summary of test conditions for the sea urchin larval development test

Test species	Sea urchin *Heliocidaris tuberculata*
Test type	Static, non-renewal
Test duration	72-hour
Test end-point	Normal pluteus larvae
Test temperature	20±1°C
Test salinity	35±1‰
Test chamber size / volume	5mL in 9 mL tissue culture tube
Source of test organisms	Field collection, Sydney coastal region
Test concentrations	WAF dilutions of 100, 50, 25, 12.5 and 6.3% or lower
Test acceptability criteria	≥70% normal larvae in controls, reference toxicant results within prescribed range

To test the relative sensitivity of the test organisms and the proficiency of the Laboratory Technician, a separate positive control test was conducted using copper. The test was performed in the same manner as the test with the WAF. The results of the reference toxicant test were compared with the results from previous testing using a control chart.

4.2 Results

The results for the WAF of the Barossa Field Condensate using the sea urchin larval development test are summarised in **Table 4.2** below. The mean and standard deviation of the responses of test organisms to each test treatment are given in the summary reports given in **Appendix D**. The statistical output from the Toxcalc statistical analyses are given in **Appendix L**.

Table 4.2. The 72-hr EL/EC10 and EL/EC50 (with 95% confidence limits), NOEL/NOEC and LOEL/NOEC (based on loading rates and TRH concentrations) for Water Accommodated Fractions (WAFs) of the Barossa Field Condensate sample using the sea urchin larval development test.

Sample	72-hr EL/EC10	72-hr EL/EC50	NOEL/ NOEC	LOEL/ LOEC
Barossa field condensate – Loading rate (g/L)	21.0 (18.90-22.76)	26.5 (24.67-28.01)	19.3	38.6
Barossa field condensate – TRH concentration (µg/L)	15481.6 (13727.10-16947.80)	20104.4 (18575.70-21450.10)	14060	30860

Based on the loading rate, the WAF of the Barossa Field Condensate had an EL10, EL50, NOEL and LOEL of 21.0 (18.90-2276), 26.5 (24.67-28.01), 19.3 and 38.6g/L, respectively. Expressed as TRH concentration, the corresponding EC10, EC50, NOEC and LOEC were 15481.6 (13727.10-16947.80), 20104.4 (18575.70-21450.10), 14060 and 30860µg/L, respectively.

The WAF control was not toxic to sea urchin larvae.

4.3 Quality Assurance

The sea urchin larval development test undertaken with the prepared WAF met all quality assurance criteria. The mean percentage of normal pluteus larvae in the laboratory control in the test was 80.8%, exceeding the minimum control criteria of 70%. Water quality parameters were also within test acceptability ranges.

The 72-hr EC50 estimate for the copper reference toxicant tests run concurrently with the WAF sample fell within the reference toxicant cusum chart control limits (**Table 4.3**). This indicated that the toxicity test was within the expected range with respect to performance and sensitivity.

Table 4.3 The Quality Assurance limits for the sea urchin larval development test.

QA Measure	Criterion	This Test
Control % normally developed	$\geq$ 70%	80.8%
Reference toxicant EC50	10.5-23.1µg Cu/L	12.2µg Cu/L

5. 48-hr Oyster Larval Development Test

5.1 Summary of Test Methodology

The 48-hr larval development toxicity test using the larvae of the milky oyster *Saccostrea echinata* was undertaken in accordance with ESA Standard Operating Procedure 106, which is based on methods described by USEPA (1996) and APHA (1998), with *S. glomerata* by Krassoi (1995). Tests were performed in a constant temperature chamber of 29±1^{o}C with a 16:8h light: dark photoperiod for the entire 48-hr exposure. Clean seawater was collected from the Sydney region and filtered to 0.45μm on return to the laboratory. Oysters used for the tests were obtained from a rocky shore oyster lease in Mackay, QLD.

The definitive test reported here was initiated on 10 September 2015. The tests were undertaken in 9mL borosilicate glass tissue culture vials, with four replicate vials per treatment. A filtered seawater (FSW) control and a Water Accommodated Fraction (WAF) control were tested concurrently with the prepared WAF.

Oysters were spawned by gonad stripping. Viable gametes were selected on the basis of fertilisation success trials and visual examination of gamete maturity. The eggs were fertilised by adding spermatozoa to the egg suspension.

The pH, salinity and dissolved oxygen concentration of a representative sample from each concentration/treatment was measured. Salinity was measured using a WTW Cond330 salinity/conductivity meter with a WTW Tetracon 325 probe. The pH was measured using a WTW pH330 meter with a WTW SenTix 41 electrode. Dissolved oxygen was measured using a WTW Oxi 330 Oximeter, with a WTW CellOx 325 probe. Sub-samples for TRH (Total Recoverable Hydrocarbons, C6-C36), PAHs (Polycyclic aromatic hydrocarbons) and BTEX (benzene, toluene, ethylbenzene, and xylenes) were collected for each WAF dilution and controls and stored at 4^{o}C in the dark until it was determined that the corresponding toxicity tests met QA criteria, upon which samples were forwarded to Envirolab Services Pty Ltd by same-day express courier.

Fertilised eggs were exposed to each test treatment for 48 hours after which a formalin solution was added to each vessel. One mL of test solution was drawn directly from the bottom of each test vessel and placed in a Sedgwick-Rafter counting chamber. The first 100 oyster larvae were examined and the number of normal and abnormal D-veliger larvae was recorded. Toxicity test end-points were determined using loading rates and TRH concentrations. The loading rate and TRH concentration of WAF resulting in reductions in normal development to 10% and 50% of the test population (48-hr EL and EC values) was determined by either Maximum Liklihood Probit or Trimmed Spearman Karber or Probit Method using Toxcalc v5.0 software. The loading rate and TRH concentration causing no significant toxicity (No Observed Effect Loading Rate/Concentration – NOEL/NOEC), and the lowest loading rate causing significant toxicity (Lowest Observed Effect Loading Rate/Concentration – LOEL/LOEC) were determined by performing a Dunnett's or non-parametric test, depending on the data being normally distributed and homoscedastic.

Table 5.1. Summary of test conditions for the milky oyster larval development test

Test species	Milky oyster *Saccostrea echinata*
Test type	Static, non-renewal
Test duration	48 hours
Test end-point	Larval development to D-veliger stage
Test temperature	29±1°C
Test salinity	35±1‰
Test chamber size / volume	5mL in 9 mL tissue culture tube
Source of test organisms	Oyster farms, Mackay QLD
Test concentrations	WAF dilutions of 100, 50, 25, 12.5 and 6.3% or lower
Test acceptability criteria	>70% normally developed larvae in controls, reference toxicant results within prescribed range

To test the relative sensitivity of the test organisms and the proficiency of the Laboratory Technician, a separate positive control test was conducted, using copper. The test was performed in the same manner as for the test with the WAF. The results of this test were compared with the results from previous testing using a control chart.

5.2 Results

The results for the WAF of the Barossa Field Condensate using the milky oyster larval development test are summarised in **Table 5.2** below. The mean and standard deviation of the responses of test organisms to each test treatment are given in the summary reports given in **Appendix E**. The statistical output from the Toxcalc statistical analyses are given in **Appendix M**.

Table 5.2. The 48-hr EL/EC10 and EL/EC50 (with 95% confidence limits), NOEL/NOEC and LOEL/NOEC (based on loading rates and TRH concentrations) for Water Accommodated Fractions (WAFs) of the Barossa Field Condensate sample using the sea urchin larval development test.

Sample	48-hr EL/EC10	48-hr EL/EC50	NOEL/ NOEC	LOEL/ LOEC
Barossa Field Condensate – Loading rate (g/L)	15.7 (11.78-18.35)	24.7 (24.11-25.32)	9.7	19.3
Barossa Field Condensate – TRH concentration (µg/L)	11478.4 (9026.54-13230.50)	18747.2 (18266.80-19240.30)	7160	14060

Based on the loading rate, the WAF of the Barossa Field Condensate sample had an EL10, EL50, NOEL and LOEL 15.7 (11.78-18.35), 24.7 (24.11-25.32), 9.7 and 19.3g/L, respectively. Expressed as TRH concentration, the corresponding EC10, EC50, NOEC and LOEC were 11478.4 (9026.54-13230.50), 18747.2 (18266.80-19240.30), 7160 and 14060µg/L, respectively.

The WAF control was not toxic to the oyster larvae.

5.3 Quality Assurance

The milky oyster larval development toxicity test met all quality assurance criteria. The mean percentage of normally developed D-veliger larvae in the filtered seawater controls in the test was 74.5%, which exceeded the minimum control criteria of 70%. Water quality parameters for control samples were also within test acceptability ranges.

The 48-hr EC50 estimates for the copper reference toxicant tests run concurrently with the prepared WAF fell within the reference toxicant cusum chart control limits (**Table 5.3**). This indicated that the toxicity tests were within the expected range with respect to performance and sensitivity.

Table 5.3. Quality Assurance limits for the 48-hr milky oyster larval development test.

QA Measure	Criterion	This Test
Control % normally developed	≥ 70%	74.5%
Reference toxicant EC50	10.2-20.0µg Cu/L	14.5µg Cu/L

6. 72-hr Micro-Algal Growth Inhibition Test

6.1 Summary of Test Methodology

The 72-hr micro-algal growth inhibition (cell yield) test using Isochrysis *aff. galbana* was undertaken in accordance with ESA Standard Operating Procedure 110 which is based on methods described by Stauber *et al*. (1994). Tests were performed in a constant temperature of 29±1°C. Clean seawater was collected from the Sydney region and filtered to 0.45µm on return to the laboratory. *Isochrysis* used for the tests were obtained from the CSIRO Marine Algal Supply Service, Hobart and cultured in the ESA laboratory using Guillards F/2 culture media.

The definitive test reported here was initiated on 11 September 2015. Guillards F/2 nutrient stock solutions were added to each of the WAF treatments and control treatment at a quarter of the usual concentration added to algal culture media so as to provide the minimum nutrients required for micro-algal growth. The tests were undertaken in 20mL borosilicate glass scintillation vials containing 10mL of test solution, with four replicate vials per treatment. A filtered seawater (FSW) control and a Water Accommodated Fraction (WAF) control were tested concurrently with the prepared WAF.

Micro-algae used to inoculate the test vessels were first concentrated from cultures in log-growth phase by centrifugation, and then re-suspended using dilution water. This process was repeated a second time to remove all traces of original culture medium. The density of the micro-algae was determined using a haemocytometer, and test vessels were inoculated with the micro-algae such that the final concentration at t=0 was 10,000 cells/ml. The test vessels were incubated for 72-hr in a constant temperature cabinet equipped with cool-white fluorescent tubes to provide 4440-8880 Lux lighting on a 12:12 light:dark cycle.

The pH and salinity of a representative sample from each concentration/treatment was measured. Salinity was measured using a WTW Cond330 salinity/conductivity meter with a WTW Tetracon 325 probe. The pH was measured using a WTW pH330 meter with a WTW SenTix 41 electrode. Sub-samples for TRH (Total Recoverable Hydrocarbons, C6-C36), PAHs (Polycyclic aromatic hydrocarbons) and BTEX (benzene, toluene, ethylbenzene, and xylenes) were collected for each WAF dilution and controls and stored at 4°C in the dark until it was determined that the corresponding toxicity tests met QA criteria, upon which samples were forwarded to Envirolab Services Pty Ltd by same-day express courier

At the end of the incubation period, algal density for each replicate vial was determined by measuring absorbance at 750nm using a spectrophotometer. The algal counts were recorded as the number of cells per mL based on a standard curve of cell density against absorbance at 750nm. Toxicity test end-points were determined using loading rates and TRH concentrations. The loading rate and TRH concentration of WAF resulting in inhibition of growth to 10% and 50% of the test population (72-hr IL and IC values) was determined by the Non-Linear Interpolation Method using Toxcalc v5.0 software. The loading rate and TRH concentration causing no significant toxicity (No Observed Effect Loading Rate/Concentration – NOEL/NOEC), and the lowest loading rate causing significant toxicity (Lowest Observed Effect Loading Rate/Concentration – LOEL/LOEC) were determined by performing a Dunnett's or non-parametric test, depending on the data being normally distributed and homoscedastic.

Table 6.1 Summary of test conditions for the micro-algal growth inhibition test

Test species	*Isochrysis aff. galbana* (Tahitian isolate)
Test type	Static, non-renewal
Test duration	72-hour
Test end-point	Cell yield (density)
Test temperature	29 ± 1ºC
Test salinity	35 ± 1‰
Test chamber size / volume	10mL in 20mL scintillation vials
Source of test organisms	Laboratory culture
Test concentrations	WAF dilutions of 100, 50, 25, 12.5 and 6.3% or lower
Test acceptability criteria	>160,000 cells/mL in controls, reference toxicant results within prescribed range, CV <20% for control replicates

To test the relative sensitivity of the test organisms and the proficiency of the Laboratory Technician, a positive (toxic) control test was conducted using copper. The test was performed in the same manner as the WAF test. The results of this test were compared with the results from previous testing using a control chart.

6.2 Results

The results for the WAF of the Barossa Field condensate using the micro-algal growth inhibition assay are summarised in **Table 6.2** below. The mean and standard deviation of the responses of test organisms to each test treatment are given in the summary reports given in **Appendix F**. The statistical output from the Toxcalc statistical analyses are given in **Appendix N.**

Table 6.2. The 72-hr IL/IC10 and IL/IC50 (with 95% confidence limits), NOEL/NOEC and LOEL/NOEC (based on loading rates and TRH concentrations) for Water Accommodated Fractions (WAFs) of the Barossa Field Condensate sample using the micro-algal growth inhibition test.

Sample	72-hr IL/IC10	72-hr IL/IC50	NOEL/ NOEC	LOEL/ LOEC
Barossa Field Condensate – Loading rate (g/L)	6.4 (2.18-10.68)	12.6 (7.45-15.09)	9.7	19.3
Barossa Field Condensate – TRH concentration (µg/L)	4355.2 (1641.13-7401.38)	8529.3 (5094.77-10126.00)	6670	12850

Based on the loading rate, the WAF of the Barossa Field Condensate had an IL10, IL50, NOEL and LOEL of 6.4 (2.18-10.68), 12.6 (7.45-15.09), 9.7 and 19.3g/L, respectively. Expressed as TRH concentration, the corresponding IC10, IC50, NOEC and LOEC were 4355.2 (1641.13-7401.38), 8529.3 (5094.77-10126.00), 6670 and 12850µg/L, respectively.

The WAF control was not toxic to the micro-alga.

6.3 Quality Assurance

The microalgal growth inhibition test undertaken with the prepared WAF met all quality assurance criteria for the test. The mean cell density per 1mL in the filtered seawater control treatment in the test was 212 000, exceeding the minimum control criteria of 160,000 cells/mL. The coefficient of variation was 16.0% and below the criteria of ≤20%. Water quality parameters for control samples were also within test acceptability ranges.

The 72-hr IC50 estimate for the copper reference toxicant test run concurrently with the WAF test fell within the reference toxicant cusum chart control limits (**Table 6.3**). This indicated that the toxicity test was within the expected range with respect to performance and sensitivity.

Table 6.3 The Quality Assurance limits for the marine microalga *I.galbana* growth inhibition test.

QA Measure	Criterion	This Test
Control density x 10^4 cells/mL	16.0	21.2
Control coefficient of variation	<20%	16.0%
Reference toxicant Cusum limits	15.1-46.7µg Cu/L	19.0µg Cu/L

7. 14-d Macro-Alagl Growth Toxicity Test

7.1 Summary of Test Methodology

The 14-day growth toxicity test using the zoospores of the brown kelp *Ecklonia radiata* was undertaken in accordance with ESA Standard Operating Procedure 116, which is based on methods described by Bidwell *et al*. (1998) and Burridge *et al*. (1999). The test was extended to 14 days to encompass the growth endpoint. Tests were performed in a constant temperature chamber of 18±1°C with ambient laboratory lumination for the entire 14-d exposure. Clean seawater was collected from the Sydney region and filtered to 0.45µm on return to the laboratory.

The definitive test reported here was initiated on 10 September 2015. The test was undertaken in 9mL borosilicate glass tissue culture petri dishes, with four replicate vials per treatment. A filtered seawater (FSW) control and a Water Accommodated Fraction (WAF) control were tested concurrently with the prepared WAF.

Kelp used for the test was obtained from Mercury Passage, Tasmania and shipped via overnight freight to the ESA laboratory. The kelp was induced to spawn using temperature shock. A concentrated suspension of motile zoospores a density of 20,000 – 75,000 zoospores/mL was prepared in FSW, using a haemocytometer. The zoospore suspension was added to the test vessels and allowed to settle on to cover slips placed on the bottom of the test vessels for 1 hour, before the excess FSW was pipetted from the dishes, and the WAF sample and controls pipetted in. After the sample had been added to the test vessels, the petri dishes were arranged randomly in a temperature controlled chamber for the duration of the test.

The pH, salinity and dissolved oxygen concentration of a representative sample from each concentration/treatment was measured. Salinity was measured using a WTW Cond330 salinity/conductivity meter with a WTW Tetracon 325 probe. The pH was measured using a WTW pH330 meter with a WTW SenTix 41 electrode. Dissolved oxygen was measured using a WTW Oxi 330 Oximeter, with a WTW CellOx 325 probe. Sub-samples for TRH (Total Recoverable Hydrocarbons, C6-C36), PAHs (Polycyclic aromatic hydrocarbons) and BTEX (benzene, toluene, ethylbenzene, and xylenes) were collected for each WAF dilution and controls and stored at 4°C in the dark until it was determined that the corresponding toxicity tests met QA criteria, upon which samples were forwarded to Envirolab Services Pty Ltd by same-day express courier.

After 14 days exposure, each cover slip containing the settled zoospores was drawn directly from the bottom of each petri dish and placed on a clean microscope slide. The first 10 individuals were examined under 400x magnification and photographed. The length of the gametophyte was recorded. The average length of the 10 gaemetophyte were calculated for each replicate. Toxicity test end-points were determined using loading rates and TRH concentrations. The loading rate and TRH concentration of WAF resulting in reductions in growth to 10% and 50% of the test population (14-d IL and IC values) was determined by the Non-Linear Interpolation Method using Toxcalc v5.0 software. The loading rate and TRH concentration causing no significant toxicity (No Observed Effect Loading Rate/Concentration – NOEL/NOEC), and the lowest loading rate causing significant toxicity (Lowest Observed Effect Loading Rate/Concentration – LOEL/LOEC) were determined by performing a Dunnett's or non-parametric test, depending on the data being normally distributed and homoscedastic.

Table 7.1. Summary of test conditions for the macro-algal growth germination test

Test species	Brown kelp *Ecklonia Radiata*
Test type	Static, non-renewal
Test duration	14 days
Test end-point	Growth of gametophyte
Test temperature	18 ± 1ºC
Test salinity	35±1‰.
Test chamber size / volume	5mL in 9 mL petri dish
Source of test organisms	Mercury Passage, Tasmania
Test concentrations	WAF dilutions of 100, 50, 25, 12.5 and 6.3% or lower
Test acceptability criteria	>70% of zoospores germinated in controls after 72 hours, reference toxicant results within prescribed range

To test the relative sensitivity of the test organisms and the proficiency of the Laboratory Technician, a separate positive (toxic) control test was conducted, using copper. The test was performed in the same manner as for the test with the WAF. The results of this test were compared with the results from previous testing using a control chart.

7.2 Results

The results for the WAF of the Barossa Field Condensate using the macro-algal growth test are summarised in **Table 7.2** below. The mean and standard deviation of the responses of test organisms to each test treatment are given in the summary reports given in **Appendix G**. The statistical output from the Toxcalc statistical analyses are given in **Appendix O**.

Table 7.2. The 14-d IL/IC10 and IL/IC50 (with 95% confidence limits), NOEL/NOEC and LOEL/NOEC (based on loading rates and TRH concentrations) for Water Accommodated Fractions (WAFs) of the Barossa Field Condensate sample using the macro-algal growth test.

Sample	14-d IL/IC10	14-d IL/IC50	NOEL/ NOEC	LOEL/ LOEC
Barossa Field Condensate – Loading rate (g/L)	2.7*	64.8*	2.4	4.8
Barossa Field Condensate – TRH concentration (µg/L)	1873.9*	57196.9*	1673	3180

*95% confidence limits are not reliable

Based on the loading rate, the WAF of the Barossa Field Condensate had an IL10, IL50, NOEL and LOEL of 2.7, 64.8, 2.4 and 4.8g/L, respectively. Expressed as TRH concentration, the corresponding IC10, IC50, NOEC and LOEC were 1873.9, 57196.9, 1673 and 3180µg/L, respectively.

The WAF control was not toxic to the zoospores.

7.3 Quality Assurance

The macro-algal growth toxicity test met all quality assurance criteria. The mean percentage of germinated zoospores after 72 hours in the filtered seawater controls was 90.3%, which exceeded the minimum control criteria of 70.0%. Water quality parameters for the control sample were also within test acceptability ranges.

The 72-hr EC50 estimate for the copper reference toxicant test run concurrently with the WAF sample fell within the reference toxicant cusum chart control limits (**Table 7.3**). This indicated that the toxicity test was within the expected range with respect to performance and sensitivity.

Table 7.3. Quality Assurance limits for the 72-hr macro-algal germination test.

QA Measure	Criterion	This Test
Control % spore germination	$\geq$ 70%	90.3%
Reference toxicant EC50	86.0-1262.1µg Cu/L	408.5µg Cu/L

8. 8-day Sea Anemone Toxicity Test

8.1 Summary of Test Methodology

The 8-day toxicity test using the sea anemone *Aiptasia pulchella* was undertaken in accordance with ESA Standard Operating Procedure 128, which is based on general methods described by the Howe *et al.* (2014). Tests were performed in a constant temperature chamber at m25±1°C with a 16:8h light: dark photoperiod for the entire 96-hr exposure. Clean seawater was collected from the Sydney region and filtered to 0.45µm on return to the laboratory. Pedal lacerates were sourced from in-house laboratory cultures.

The definitive tests reported here were initiated on 27 October 2015. The tests were undertaken in 100 mL borosilicate glass beakers containing 80mL of test solution. WAFs were prepared for the condensate sample and tested using 3 replicate beakers. A filtered seawater (FSW) control and a Water Accommodated Fraction (WAF) control were tested concurrently with the prepared WAF.

The pH, salinity and dissolved oxygen concentration of a representative sample from each concentration/treatment was measured. Salinity was measured using a WTW Cond330 salinity/conductivity meter with a WTW Tetracon 325 probe. The pH was measured using a WTW pH330 meter with a WTW SenTix 41 electrode. Dissolved oxygen was measured using a WTW Oxi 330 Oximeter, with a WTW CellOx 325 probe. Sub-samples for TRH (Total Recoverable Hydrocarbons, C6-C36), PAHs (Polycyclic aromatic hydrocarbons) and BTEX (benzene, toluene, ethylbenzene, and xylenes) were collected for each WAF dilution and controls and stored at 4°C in the dark until it was determined that the corresponding toxicity tests met QA criteria, upon which samples were forwarded to Envirolab Services Pty Ltd by same-day express courier.

A. pulchella pedal lacerates were isolated from in-house laboratory cultures at random and 5 lacerates were placed into each test vessel containing FSW using a Pasteur pipette. Lacerates were allowed to acclimate and re-attach to the test vessel before test solutions were placed in each beaker. The beakers were covered with cling-wrap film to minimise evaporation of test solutions. The sea anemones were observed at on three occasions during the test period and the number of surviving sea anemones were recorded.

After 8 days, the number of surviving and normally developed juvenile sea anemones and physico-chemical parameters recorded. Toxicity test end-points were determined using loading rates and TRH concentrations. The loading rate and TRH concentration of WAF resulting in reductions in normal development to 10% and 50% of the test population (48-hr EL and EC values) was determined by either Maximum Liklihood Probit or Trimmed Spearman Karber or Probit Method using Toxcalc v5.0 software. The loading rate and TRH concentration causing no significant toxicity (No Observed Effect Loading Rate/Concentration – NOEL/NOEC), and the lowest loading rate causing significant toxicity (Lowest Observed Effect Loading Rate/Concentration – LOEL/LOEC) were determined by performing a Dunnett's or non-parametric test, depending on the data being normally distributed and homoscedastic.

Table 8.1. Summary of test conditions for the 8-d sea anemone toxicity test

Test species	Sea anemone *Aptasia pulchella*
Test type	Static, non-renewal
Test duration	8 days
Test end-point	Normally developed juveniles
Test temperature	25±1°C
Test salinity	35±1‰
Test chamber size / volume	80mL in 100mL borosilicate glass beakers
Source of test organisms	In-house laboratory culture
Test concentrations	WAF dilutions of 100, 50, 25, 12.5 and 6.3% or lower
Test acceptability criteria	>90% developed in controls, reference toxicant results within prescribed range

To test the relative sensitivity of the test organisms and the proficiency of the Laboratory Technician, a separate positive control test was conducted using copper. The test was performed in the same manner as for the test conducted with the WAF sample. The results of this test were compared with the results from previous testing using a control chart.

8.2 Results

The results for the WAF of the Barossa Field Condensate using the sea anemone development toxicity tests are summarised in **Table 8.2** below. The mean and standard deviation of the responses of test organisms to the test treatment are given in the summary reports given in **Appendix H**. The statistical output from the Toxcalc statistical analyses are given in **Appendix P**.

Table 8.2. The 8-d EL/EC10 and EL/EC50 (with 95% confidence limits), NOEL/NOEC and LOEL/NOEC (based on loading rates and TRH concentrations) for Water Accommodated Fractions (WAFs) of the Barossa Field Condensate sample using the sea anemone *A. pulchella* toxicity test.

Sample	8-d EL/EC10	8-d EL/EC50	NOEL/ NOEC	LOEL/ LOEC
Barossa Field Condensate – Loading rate (g/L)	11.2*	40.1 (31.78-50.60)	38.6	77.2
Barossa Field Condensate – TRH concentration (µg/L)	8862.4*	30720.0 (23961.00-39385.50)	28040	63990

*95% confidence limits are not reliable

Based on the loading rate, the WAF of the Barossa Field Condensate had an EL10, EL50, NOEL and LOEL of 11.2, 40.1 (31.78-50.60), 38.6 and 77.2g/L, respectively. Expressed as TRH concentration, the corresponding EC10, EC50, NOEC and LOEC were 8862.4, 30720.0 (23961.00-39385.50), 28040, 63990µg/L, respectively.

The WAF control was not toxic to the sea anemone.

8.3 Quality Assurance

The 8-d sea anemone development test undertaken with the WAF sample met all quality assurance criteria. The mean percentage normally developed in the laboratory controls in the test was 100%, meeting the minimum control normally developed criteria of ≥90%. Water quality parameters for control samples were also within test acceptability ranges (**Table 8.3**).

Table 8.3. Quality Assurance limits for the 8-d sea anemone *A. pulchella* test.

QA Measure	Criterion	This Test
Control % normally developed	≥ 90%	100%
Reference toxicant Cusum limits	n/a*	11.5µg Cu/L

* Reference toxicant cusum chart limits are not available due to limited testing

9. 5-d Juvenile Copepodid Development Test

9.1 Summary of Test Methodology

The 5-day chronic toxicity test using the juvenile tropical copepod *Parvocalanus crassiostris* was undertaken in accordance with ESA Standard Operating Procedure 124, which is based on general methods described by the USEPA (2002) for marine crustaceans, and also following the methods described for the Australian copepod *Acartia sinjiensis* (Rose *et al.*, 2006) . Tests were performed in a constant temperature chamber of 28±1°C with a 16:8h light: dark photoperiod for the entire 5-d exposure. Clean seawater was collected from the Sydney region and filtered to 0.45µm on return to the laboratory. Freshly fertilised eggs used for testing were obtained from in-house laboratory cultures, originally sourced from the Queensland Department of Primary Industries Northern Fisheries Centre, Cairns QLD.

The definitive test reported here was initiated on 22 September 2015. The test was undertaken in 24-well polycarbonate tissue culture plates, where each well contained 4mL of test solution. WAFs were prepared for the condensate sample and tested using 4 replicate wells per concentration. A filtered seawater (FSW) control and a Water Accommodated Fraction (WAF) control were tested concurrently with the prepared WAF.

The pH, salinity and dissolved oxygen concentration of a representative sample from each concentration/treatment was measured. Salinity was measured using a WTW Cond330 salinity/conductivity meter with a WTW Tetracon 325 probe. The pH was measured using a WTW pH330 meter with a WTW SenTix 41 electrode. Dissolved oxygen was measured using a WTW Oxi 330 Oximeter, with a WTW CellOx 325 probe. Sub-samples for TRH (Total Recoverable Hydrocarbons, C6-C36), PAHs (Polycyclic aromatic hydrocarbons) and BTEX (benzene, toluene, ethylbenzene, and xylenes) were collected for each WAF dilution and controls and stored at 4°C in the dark until it was determined that the corresponding toxicity tests met QA criteria, upon which samples were forwarded to Envirolab Services Pty Ltd by same-day express courier.

Freshly fertilised copepod eggs were isolated from 30L laboratory mass cultures. Eggs were triple rinsed in FSW to remove debris and ciliates from the water and eggs. Five eggs were transferred to each tissue culture well using a Pasteur pipette and a dissecting microscope. Once seeded, the tissue culture plates were transferred to the constant temperature chamber.

After five days exposure, the number of non-immobilised normally developed copepodids in each test well was counted under a dissecting microscope. Toxicity test end-points were determined using loading rates and TRH concentrations. The loading rate and TRH concentration of WAF resulting in reductions in normal development to 10% and 50% of the test population (48-hr EL and EC values) was determined by either Maximum Liklihood Probit or Trimmed Spearman Karber or Probit Method using Toxcalc v5.0 software. The loading rate and TRH concentration causing no significant toxicity (No Observed Effect Loading Rate/Concentration – NOEL/NOEC), and the lowest loading rate causing significant toxicity (Lowest Observed Effect Loading Rate/Concentration – LOEL/LOEC) were determined by performing a Dunnett's or non-parametric test, depending on the data being normally distributed and homoscedastic.

Table 9.1. Summary of test conditions for the 5-d copepodid development toxicity test

Test species	Calanoid copepod *Parvocalanus crassiostris*
Test type	Static, non-renewal
Test duration	5 day
Test end-point	Normally developed coepodids
Test temperature	28±1°C
Test salinity	35±1‰
Test chamber size / volume	4mL well in 24-well tissue culture plates
Feeding	Isochrysis @ 16,000 cells/ copepod daily
Source of test organisms	In-house laboratory culture
Test concentrations	WAF dilutions of 100, 50, 25, 12.5 and 6.3% or lower
Test acceptability criteria	>70% non-immobilised copepodids in controls, reference toxicant results within prescribed range where range determined

To test the relative sensitivity of the test organisms and the proficiency of the Laboratory Technician, a separate positive control test was conducted using copper. The test was performed in the same manner as for the test conducted with the WAF sample. The results of this test were compared with the results from previous testing using a control chart.

9.2 Results

The results for the WAF of the Barossa Field Condensate using the sea anemone development toxicity tests are summarised in **Table 9.2** below. The mean and standard deviation of the responses of test organisms to the test treatment are given in the summary reports given in **Appendix I**. The statistical output from the Toxcalc statistical analyses are given in **Appendix Q**.

Table 9.2. The 5-d EL/EC10 and EL/EC50 (with 95% confidence limits), NOEL/NOEC and LOEL/NOEC (based on loading rates and TRH concentrations) for Water Accommodated Fractions (WAFs) of the Barossa Field Condensate sample using the copepod *P. crassirostris* toxicity test.

Sample	5-d EL/EC10	5-d EL/EC50	NOEL/ NOEC	LOEL/ LOEC
Barossa Field Condensate – Loading rate (g/L)	1.0*^	12.2 (10.84-13.73)	9.7	19.3
Barossa Field Condensate – TRH concentration (μg/L)	27.2*^	10506.8 (9451.82-11679.80)	8560	15830

*95% confidence limits are not reliable
^calculated from extrapolated data

Based on the loading rate, the WAF of the Barossa Field condensate had an EL10, EL50, NOEL and LOEL of 1.0, 12.2 (10.84-13.73), 9.7 and 19.3g/L, respectively. Expressed as TRH concentration, the corresponding EC10, EC50, NOEC and LOEC were 27.2, 10506.9 (9451.82-11679.80), 8560 and 15830µg/L, respectively.

The WAF control was not toxic to the copepod.

9.3 Quality Assurance

The 5-d copepodid development test undertaken with the WAF samples met all quality assurance criteria. The mean percentage non-immobilised normally developed copepodids in the laboratory controls was 70%, meeting the minimum control criteria of ≥70%. Water quality parameters for the control were also within test acceptability ranges (**Table 9.3**).

Table 10.4. Quality Assurance limits for the 5-d tropical copepod test.

QA Measure	Criterion	This Test
Control % normal	≥ 70%	70.0%
Reference toxicant Cusum limits	n/a*	2.8µg Cu/L

* Reference toxicant cusum chart limits are not available due to limited testing

10. 7-day Fish Imbalance and Growth Test

10.1 Summary of Test Methodology

The 7-day toxicity test using juveniles of the barramundi *Lates calcarifer* was undertaken in accordance with ESA Standard Operating Procedure 122, which is based on methods described by USEPA (2002b). Research with invertebrates in the state of New South Wales is subject to the Animal Research Act, and the toxicity test with juvenile fish was performed by ESA under the Animal Research Authority issued to ESA by the Director-General of NSW Department of Primary Industries (valid from 28 July 2014 to 28 July 2017) and Certificate of Approval from the Animal Care and Ethics Committee of the Director-General of the NSW Department of Primary Industries (valid from 16 May 2014 and 16 May 2017).

The definitive test reported here was initiated on 22 September 2015. Juvenile fish of approximately 10-30 mm in length used for the tests were obtained from a commercial hatchery in South Australia. The juvenile fish were shipped same-day express in a foam box and fish were contained within an air inflated bag containing approximately 4 litres of seawater. Upon arrival at ESA, the fish were transferred to test room of 25°C and provided gentle aeration using a Schego air pump. Clean seawater for holding the fish was collected from the Sydney region and filtered to 0.45μm on return to the laboratory. The seawater was acclimated to 25°C prior to use.

Toxicity tests were undertaken in 600mL glass beakers containing 500mL of test solution, with 4 replicates per treatment. A filtered seawater (FSW) control and a Water Accommodated Fraction (WAF) control were tested concurrently with the prepared WAF of the fresh and weathered condensate.

The pH, salinity and dissolved oxygen concentration of a representative sample from each concentration/treatment was measured. Salinity was measured using a WTW Cond330 salinity/conductivity meter with a WTW Tetracon 325 probe. The pH was measured using a WTW pH330 meter with a WTW SenTix 41 electrode. Dissolved oxygen was measured using a WTW Oxi 330 Oximeter, with a WTW CellOx 325 probe. Sub-samples for TRH (Total Recoverable Hydrocarbons, C6-C36), PAHs (Polycyclic aromatic hydrocarbons) and BTEX (benzene, toluene, ethylbenzene, and xylenes) were collected for each WAF dilution and controls and stored at 4°C in the dark until it was determined that the corresponding toxicity tests met QA criteria, upon which samples were forwarded to Envirolab Services Pty Ltd by same-day express courier.

Five juvenile fish were randomly selected and introduced into each of the test beakers. The beakers were covered with cling-wrap film to minimise evaporation and placed in a constant temperature room of 25±1°C. The test vessels were monitored daily to examine fish for signs of distress or imbalance. Juvenile fish demonstrating such signs were to be removed and euthanased in accordance with ESA SOP 122. Test vessels were also routinely checked to ensure aeration was being provided.

The beakers were examined every 24 hours and the number of surviving and apparently healthy juvenile fish recorded. The test was terminated after 7 days, and the temperature, pH, salinity and dissolved oxygen concentration of a representative sample from each concentration/treatment was measured, as detailed above. At the termination of the test, the juvenile fish were euthanased by the addition of AQUI-S solution. The euthanized fish were then dried at 60°C for 24 hours and then weighed.

Toxicity test end-points were determined using loading rates and TRH concentrations. The loading rate and TRH concentration of WAF resulting in reductions in unaffected fish and biomass to 10% and 50% of the test population (7-d EL and EC values) was determined by either Maximum Liklihood Probit, Trimmed Spearman Karber or Non-Linear Interpolation method using Toxcalc v5.0 software. The loading rate and TRH concentration causing no significant toxicity (No Observed Effect Loading Rate/Concentration – NOEL/NOEC), and the lowest loading rate causing significant toxicity (Lowest Observed Effect Loading Rate/Concentration – LOEL/LOEC) were determined by performing a Dunnett's or non-parametric test, depending on the data being normally distributed and homoscedastic.

Table 10.1 Summary of test conditions for the 7-day fish imbalance and growth test using *Lates calcarifer*

Test species	Barramundi *Lates calcarifer*
Test type	Static, non-renewal
Test duration	7 day
Test end-point	Imbalance, including survival, and biomass.
Test temperature	25 ± 1ºC
Test salinity	35 ± 2‰
Test chamber size / volume	500 mL in 600mL borosilicate glass beakers
Test Feeding	800 brine shrimp per fish, daily
Test concentrations	WAF dilutions of 100, 50, 25, 12.5 and 6.3% or lower
Source of test organisms	Hatchery reared, SA
Test acceptability criteria	≥80% survival in controls

To test the relative sensitivity of the test organisms and the proficiency of the Laboratory Technician, a separate positive control test was conducted using ammonium. The test was performed in the same manner as for the test conducted with the WAF sample. The results of this test were compared with the results from previous testing using a control chart.

10.2 Results

The results for the WAF of the fresh and weathered Barossa Field Condensate using the fish imbalance test are summarised in **Tables 10.2 and 10.3** below. The mean and standard deviation of the responses of test organisms to each test treatment are given in the summary reports given in **Appendix J**. The statistical output from the Toxcalc statistical analyses are given in **Appendix R**.

Table 10.2. The 7-d EL/EC10 and EL/EC50 (with 95% confidence limits), NOEL/NOEC and LOEL/NOEC (based on loading rates and TRH concentrations) for Water Accommodated Fractions (WAFs) of the Barossa Field Condensate sample using the Barramundi fish imbalance and growth test - Imbalance.

Sample	7-d EL/EC10	7-d EL/EC50	NOEL/ NOEC	LOEL/ LOEC
Barossa Field Condensate – Loading rate (g/L)	19.4 (13.58-23.28)	29.3 (24.71-34.66)	19.3	38.6
Barossa Field Condensate – TRH concentration (µg/L)	15875.5 (11275.40-18756.60)	23182.2 (19851.60-27226.80)	15830	29770
Weathered Barossa Field Condensate – Loading rate (g/L)	69.1*	>79.5	79.5	>79.5
Weathered Barossa Field Condensate – TRH concentration (µg/L)	19596.3*	>22480.0	22480	>22480

*95% confidence limits are not reliable/available

Table 10.3. The 7-d IL/IC10 and EL/EC50 (with 95% confidence limits), NOEL/NOEC and LOEL/NOEC (based on loading rates and TRH concentrations) for Water Accommodated Fractions (WAFs) of the Barossa Field Condensate sample using the Barramundi fish imbalance and growth test - Biomass.

Sample	7-d IL/IC10	7-d IL/IC50	NOEL/ NOEC	LOEL/ LOEC
Barossa Field Condensate – Loading rate (g/L)	20.9 (8.44-22.09)	30.6 (27.79-31.44)	19.3	38.6
Barossa Field Condensate – TRH concentration (µg/L)	17016.3 (7373.18-18757.60)	24006.3 (21800.80-24621.00)	15830	29770
Weathered Barossa Field Condensate – Loading rate (g/L)	48.6*	>79.5	79.5	>79.5
Weathered Barossa Field Condensate – TRH concentration (µg/L)	13908.1*	>22480	22480	>22480

*95% confidence limits are not reliable/available

Based on the loading rate, the WAF of the fresh Barossa Field Condensate had an EL10, EL50, NOEL and LOEL of 19.4 (13.58-23.28), 29.3 (24.71-34.66), 19.3 and 38.6g/L, respectively, for the imbalance endpoint. Expressed as TRH concentration, the corresponding EC10, EC50, NOEC and LOEC were 15875.5 (11275.40-18756.60). 23182.2 (19851.60-27226.80), 15830 and 29770µg/L, respectively. The EL10, EL50, NOEL and LOEL for the biomass endpoint were 20.9 (8.44-22.09), 30.6 (27.79-31.44), 19.3 and 38.6g/L, respectively expressed as loading rate, and 17016.3 (737.18-18757.60), 24006.3 (21800.80-24621.00), 15830 and 29770µg/L, respectively, expressed as TRH concentration.

Based on the loading rate, the WAF of the Weathered Barossa Field Condensate had an EL10, EL50, NOEL and LOEL of 69.1, >79.5, 79.5 and >79.5g/L, respectively, for the imbalance endpoint. Expressed as TRH concentration, the corresponding EC10, EC50, NOEC and LOEC were 19596.3, >22480.0, 22480 and >22480µg/L, respectively. The EL10, EL50, NOEL and LOEL for the biomass endpoint were 48.6, >79.5, 79.5 and >79.5g/L, respectively expressed as loading rate, and 13908.1, >22480.0, 22480 and >22480µg/L, respectively, expressed as TRH concentration.

The WAF control was not toxic to the juvenile fish.

10.3 Quality Assurance

The 7-d juvenile fish imbalance and growth test undertaken with the prepared WAFs met all quality assurance criteria. The percentage survival in the controls was 100%, which met the minimum control survival criteria of ≥80%. Water quality parameters for control samples were also within test acceptability ranges (**Table 8.4**).

Table 8.4. Quality Assurance limits for the 7-d barramundi fish imbalance and growth test (1 August 2014).

QA Measure	Criterion	This Test
Control % unaffected	≥ 80%	100%
Control mean growth	≥20% of initial weight	52.6%
Reference toxicant within cusum chart limits	n/a	17.3 mg NH_4^+/L

11. References

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Rose A, Carruthers A-M, Stauber J, Lim R and Blockwell S. (2006). Development of an acute toxicity test with the marine copepod *Acartia sinjiensis*. *Australasian Journal of Ecotoxicology*, 12: 73-81.

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USEPA (2002b) Sheepshead minnow, *Cyprinodon variegatus*, larval survival and growth test. Method 1004.0. In: Short-term methods for estimating the chronic toxicity of effluents and receiving waters to marine and estuarine organisms. Third edition EPA-821-R-02-014. United States Environmental Protection Agency, Office of Research and Development, Washington FC, USA.

Appendix A: Chain of Custody

Datasheet ID: 601.2
Last Revised: 30 April 2009

Sample Receipt Notification

Attention : Celeste Wilson

Client : Jacobs Group (Australia) Pty Ltd
11th Floor, Durack Centre
263 Adelaide Terrace

Email : CXXWilson@skm.com.au
Telephone : 08 9469 4438
Facsimile : 08 9469 4488

Date : 27/08/2015

Re : Receipt of Samples **Pages : 2**

ESA Project : PR1244 ☑ For Review ☐ Additional Documentation Required - Please Respond

Sample Delivery Details

Completed Chain of Custody accompanied samples:	**YES**
Samples received in apparent good condition and correctly bottled:	**YES**
Security seals on sample bottles and esky intact:	**YES**

Date samples received : 27/08/2015
Time samples received : 13:00
No. of samples received : 1
Sample matrix : Other
Sample temperature : room temperature

Comments : Includes 2x20L Barossa Field Condensate (ESA ID# 7323)

Contact Details

Customer Services Officer : Tina Micevska
Telephone : 61 2 9420 9481
Facsimile : 61 2 9420 9484
Email : tmicevska@ecotox.com.au

Please contact customer services officer for all queries or issues regarding samples

Note that the chain-of-custody provides definitive information on the tests to be performed

Core Laboratories Australia Pty Ltd
Reservoir Fluids Laboratory
24 Hour Service

447-449 Belmont Avenue
Kewdale, W.A. 6105
Phone: (61 8) 9353 3944
Fax: (61 8) 9353 1369

Subout and Chain of Custody Record

SCCR Number: 701

Client Information: Conoco Phillips
Highway 60 & 123 (661 S Highway 123),
Bartlesville, OK, United States - 74004.

Subout Authorized By: Brenton Chatfield
Phone Number: 08 6363 2666
Client Accounting Code:

Consignee Information: Ecotox Service Australia Pty Ltd
27/2 Chaplin Drive,
Lane Cove, NSW, Australia - 2066.

Contact: Tina Micevska
Phone Number: 02 9420 9481

Job No.	Sub	Sample Date	Sample Type	Sample Container Size	Cyl No	Pressure (psig)	Temp (°F)	Sample Volume (cc)	Sample Depth (Ft.)	Sand Name	Notes
2015003-29		27/12/2014	Condensate	Can 20L				18000			Surge Tank
2015003-30		27/12/2014	Condensate	Can 20L		0	0	18000			Surge Tank

Notes:
2x 20L cans of Dead Condensate

Client: Conoco Phillips
Well: Barossa-3
Job No: 2015003

Prepared By: Kate Hughes
Billing Code:
Third Party Shipper: Enlog-RGM #AU20124283
Packaging/Handling: GO-15-429

Relinquished By: Kate Hughes
Date: 20-Aug-2015 11:20 AM
Received By: Tina @ESA
Received Date: 27/8/15 @ 1300

#7323

Appendix B: Test Report for TRH Analyses

Summary of Analytical Results for Total Recoverable Hydrocarbons (TRH's)

Barossa- Fresh

Tests	Sea urchin fert Sea urchin larval Milky oyster Ecklonia	Isochrysis	7-d Barramundi Copepod	Sea Anemone
Test Date	10/09/2015	11/09/2015	22/09/2015	27/10/2015
Envirolab Report #	134814	134814	135588	137174
Loading rate (g/L)	TRH's (C6-C36), µg/L			
0	0	0	0	0
0.6	350	-	-	-
1.2	720	650	-	-
2.4	1673	1400	-	-
4.8	3180	3248	3860	2492
9.7	7160	6670	8560	7660
19.3	14060	12850	15830	15840
38.6	30860	27960	29770	28040
77.2	69620	65830	68390	63990

Barossa- Weathered

Tests	7-d Barramundi
Test Date	22/09/2015
Envirolab Report #	135588
Loading rate (g/L)	TRH's (C6-C36), µg/L
0	0
5	1410
9.9	2770
19.9	4850
39.8	11450
79.5	22480

12 Ashley Street, Chatswood, NSW 2067
tel: +61 2 9910 6200

email: sydney@envirolab.com.au
envirolab.com.au

Envirolab Services Pty Ltd - Sydney | ABN 37 112 535 645

CERTIFICATE OF ANALYSIS 137174

Client:
Ecotox Services Australasia Pty Ltd
Unit 27, 2 Chaplin Dr
Lane Cove
NSW 2066

Attention: Tina

Sample log in details:

Your Reference:	**PR1244**		
No. of samples:	8 Waters		
Date samples received / completed instructions received	10/11/15	/	10/11/15

Analysis Details:
Please refer to the following pages for results, methodology summary and quality control data.
Samples were analysed as received from the client. Results relate specifically to the samples as received.
Results are reported on a dry weight basis for solids and on an as received basis for other matrices.
Please refer to the last page of this report for any comments relating to the results.

Report Details:

Date results requested by: / Issue Date:	17/11/15	/	17/11/15
Date of Preliminary Report:	Not Issued		

NATA accreditation number 2901. This document shall not be reproduced except in full.
Accredited for compliance with ISO/IEC 17025. **Tests not covered by NATA are denoted with *.**

Results Approved By:

Jacinta Hurst
Laboratory Manager

ACCREDITED FOR TECHNICAL COMPETENCE

vTRH(C6-C10)/BTEXN in Water						
Our Reference:	UNITS	137174-1	137174-2	137174-3	137174-4	137174-5
Your Reference	-------------	FSW Control 27/10/15	WAF Control 27/10/15	Condensate 6.3% 27/10/15	Condensate 12.5% 27/10/15	Condensate 25% 27/10/15
Date Sampled	------------	27/10/2015	27/10/2015	27/10/2015	27/10/2015	27/10/2015
Type of sample		Water	Water	Water	Water	Water
Date extracted	-	11/11/2015	11/11/2015	11/11/2015	11/11/2015	11/11/2015
Date analysed	-	13/11/2015	13/11/2015	13/11/2015	13/11/2015	13/11/2015
TRH C_6 - C_9	µg/L	<10	<10	2,400	7,300	15,000
TRH C_6 - C_{10}	µg/L	<10	<10	2,800	7,600	16,000
TRH C_6 - C_{10} less BTEX (F1)	µg/L	<10	<10	190	2,300	6,000
Benzene	µg/L	<1	<1	1,300	2,600	4,800
Toluene	µg/L	<1	<1	980	2,000	4,000
Ethylbenzene	µg/L	<1	<1	23	50	93
m+p-xylene	µg/L	<2	<2	230	480	860
o-xylene	µg/L	<1	<1	76	160	290
Naphthalene	µg/L	<1	<1	12	27	79
Surrogate Dibromofluoromethane	%	120	118	113	113	101
Surrogate toluene-d8	%	94	94	98	96	99
Surrogate 4-BFB	%	89	87	88	88	102

vTRH(C6-C10)/BTEXN in Water			
Our Reference:	UNITS	137174-6	137174-7
Your Reference	-------------	Condensate 50% 27/10/15	Condensate 100% 27/10/15
Date Sampled	------------	27/10/2015	27/10/2015
Type of sample		Water	Water
Date extracted	-	11/11/2015	11/11/2015
Date analysed	-	13/11/2015	13/11/2015
TRH C_6 - C_9	µg/L	26,000	60,000
TRH C_6 - C_{10}	µg/L	27,000	62,000
TRH C_6 - C_{10} less BTEX (F1)	µg/L	4,300	7,000
Benzene	µg/L	11,000	27,000
Toluene	µg/L	8,700	21,000
Ethylbenzene	µg/L	210	490
m+p-xylene	µg/L	2,100	5,000
o-xylene	µg/L	650	1,500
Naphthalene	µg/L	110	210
Surrogate Dibromofluoromethane	%	113	111
Surrogate toluene-d8	%	98	97
Surrogate 4-BFB	%	88	90

svTRH (C10-C40) in Water Our Reference: Your Reference Date Sampled Type of sample	UNITS ------------ ------------	137174-1 FSW Control 27/10/15 27/10/2015 Water	137174-2 WAF Control 27/10/15 27/10/2015 Water	137174-3 Condensate 6.3% 27/10/15 27/10/2015 Water	137174-4 Condensate 12.5% 27/10/15 27/10/2015 Water	137174-5 Condensate 25% 27/10/15 27/10/2015 Water
Date extracted	-	13/11/2015	13/11/2015	13/11/2015	13/11/2015	13/11/2015
Date analysed	-	15/11/2015	15/11/2015	15/11/2015	15/11/2015	15/11/2015
TRH C_{10} - C_{14}	µg/L	<50	<50	92	190	410
TRH C_{15} - C_{28}	µg/L	<100	<100	<100	170	320
TRH C_{29} - C_{36}	µg/L	<100	<100	<100	<100	110
TRH >C_{10} - C_{16}	µg/L	<50	<50	74	160	330
TRH >C_{10} - C_{16} less Naphthalene (F2)	µg/L	<50	<50	62	130	250
TRH >C_{16} - C_{34}	µg/L	<100	<100	100	160	360
TRH >C_{34} - C_{40}	µg/L	<100	<100	<100	<100	<100
Surrogate o-Terphenyl	%	87	95	89	93	98

svTRH (C10-C40) in Water Our Reference: Your Reference Date Sampled Type of sample	UNITS ------------ ------------	137174-6 Condensate 50% 27/10/15 27/10/2015 Water	137174-7 Condensate 100% 27/10/15 27/10/2015 Water
Date extracted	-	13/11/2015	13/11/2015
Date analysed	-	15/11/2015	15/11/2015
TRH C_{10} - C_{14}	µg/L	860	1,800
TRH C_{15} - C_{28}	µg/L	900	1,700
TRH C_{29} - C_{36}	µg/L	280	490
TRH >C_{10} - C_{16}	µg/L	720	1,400
TRH >C_{10} - C_{16} less Naphthalene (F2)	µg/L	610	1,200
TRH >C_{16} - C_{34}	µg/L	1,000	1,900
TRH >C_{34} - C_{40}	µg/L	<100	140
Surrogate o-Terphenyl	%	106	96

PAHs in Water Our Reference: Your Reference Date Sampled Type of sample	UNITS ------------- ------------	137174-1 FSW Control 27/10/15 27/10/2015 Water	137174-2 WAF Control 27/10/15 27/10/2015 Water	137174-3 Condensate 6.3% 27/10/15 27/10/2015 Water	137174-4 Condensate 12.5% 27/10/15 27/10/2015 Water	137174-5 Condensate 25% 27/10/15 27/10/2015 Water
Date extracted	-	13/11/2015	13/11/2015	13/11/2015	13/11/2015	13/11/2015
Date analysed	-	13/11/2015	13/11/2015	13/11/2015	13/11/2015	13/11/2015
Naphthalene	µg/L	<1	<1	11	23	50
Acenaphthylene	µg/L	<1	<1	<1	<1	<1
Acenaphthene	µg/L	<1	<1	<1	<1	<1
Fluorene	µg/L	<1	<1	<1	<1	<1
Phenanthrene	µg/L	<1	<1	<1	<1	<1
Anthracene	µg/L	<1	<1	<1	<1	<1
Fluoranthene	µg/L	<1	<1	<1	<1	<1
Pyrene	µg/L	<1	<1	<1	<1	<1
Benzo(a)anthracene	µg/L	<1	<1	<1	<1	<1
Chrysene	µg/L	<1	<1	<1	<1	<1
Benzo(b,j+k)fluoranthene	µg/L	<2	<2	<2	<2	<2
Benzo(a)pyrene	µg/L	<1	<1	<1	<1	<1
Indeno(1,2,3-c,d)pyrene	µg/L	<1	<1	<1	<1	<1
Dibenzo(a,h)anthracene	µg/L	<1	<1	<1	<1	<1
Benzo(g,h,i)perylene	µg/L	<1	<1	<1	<1	<1
Benzo(a)pyrene TEQ	µg/L	<5	<5	<5	<5	<5
Total +ve PAH's	µg/L	NIL (+)VE	NIL (+)VE	11	23	50
Surrogate p-Terphenyl-d14	%	84	88	87	94	89

PAHs in Water			
Our Reference:	UNITS	137174-6	137174-7
Your Reference	-------------	Condensate 50% 27/10/15	Condensate 100% 27/10/15
Date Sampled	------------	27/10/2015	27/10/2015
Type of sample		Water	Water
Date extracted	-	13/11/2015	13/11/2015
Date analysed	-	13/11/2015	13/11/2015
Naphthalene	µg/L	91	250
Acenaphthylene	µg/L	<1	<1
Acenaphthene	µg/L	<1	<1
Fluorene	µg/L	2	3
Phenanthrene	µg/L	2	2
Anthracene	µg/L	<1	<1
Fluoranthene	µg/L	<1	<1
Pyrene	µg/L	<1	<1
Benzo(a)anthracene	µg/L	<1	<1
Chrysene	µg/L	<1	<1
Benzo(b,j+k)fluoranthene	µg/L	<2	<2
Benzo(a)pyrene	µg/L	<1	<1
Indeno(1,2,3-c,d)pyrene	µg/L	<1	<1
Dibenzo(a,h)anthracene	µg/L	<1	<1
Benzo(g,h,i)perylene	µg/L	<1	<1
Benzo(a)pyrene TEQ	µg/L	<5	<5
Total +ve PAH's	µg/L	95	260
Surrogate p-Terphenyl-d14	%	94	80

Method ID	Methodology Summary
Org-016	Soil samples are extracted with methanol and spiked into water prior to analysing by purge and trap GC-MS. Water samples are analysed directly by purge and trap GC-MS. F1 = (C6-C10)-BTEX as per NEPM B1 Guideline on Investigation Levels for Soil and Groundwater.
Org-013	Water samples are analysed directly by purge and trap GC-MS.
Org-003	Soil samples are extracted with Dichloromethane/Acetone and waters with Dichloromethane and analysed by GC-FID. F2 = (>C10-C16)-Naphthalene as per NEPM B1 Guideline on Investigation Levels for Soil and Groundwater (HSLs Tables 1A (3, 4)). Note Naphthalene is determined from the VOC analysis.
Org-012	Soil samples are extracted with Dichloromethane/Acetone and waters with Dichloromethane and analysed by GC-MS. Benzo(a)pyrene TEQ as per NEPM B1 Guideline on Investigation Levels for Soil and Groundwater - 2013.

QUALITY CONTROL vTRH(C6-C10)/BTEXN in Water	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base ll Duplicate ll %RPD	Spike Sm#	Spike % Recovery
Date extracted	-			11/11/2015	137174-1	11/11/2015 || 11/11/2015	LCS-W3	11/11/2015
Date analysed	-			13/11/2015	137174-1	13/11/2015 || 13/11/2015	LCS-W3	13/11/2015
TRH C_6 - C_9	µg/L	10	Org-016	<10	137174-1	<10 || <10	LCS-W3	94%
TRH C_6 - C_{10}	µg/L	10	Org-016	<10	137174-1	<10 || <10	LCS-W3	94%
Benzene	µg/L	1	Org-016	<1	137174-1	<1 || <1	LCS-W3	98%
Toluene	µg/L	1	Org-016	<1	137174-1	<1 || <1	LCS-W3	99%
Ethylbenzene	µg/L	1	Org-016	<1	137174-1	<1 || <1	LCS-W3	101%
m+p-xylene	µg/L	2	Org-016	<2	137174-1	<2 || <2	LCS-W3	86%
o-xylene	µg/L	1	Org-016	<1	137174-1	<1 || <1	LCS-W3	106%
Naphthalene	µg/L	1	Org-013	<1	137174-1	<1 || <1	[NR]	[NR]
Surrogate Dibromofluoromethane	%		Org-016	110	137174-1	120 || 127 || RPD: 6	LCS-W3	97%
Surrogate toluene-d8	%		Org-016	95	137174-1	94 || 90 || RPD: 4	LCS-W3	101%
Surrogate 4-BFB	%		Org-016	88	137174-1	89 || 80 || RPD: 11	LCS-W3	106%

QUALITY CONTROL svTRH (C10-C40) in Water	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base ll Duplicate ll %RPD	Spike Sm#	Spike % Recovery
Date extracted	-			13/11/2015	[NT]	[NT]	LCS-W1	13/11/2015
Date analysed	-			13/11/2015	[NT]	[NT]	LCS-W1	13/11/2015
TRH C_{10} - C_{14}	µg/L	50	Org-003	<50	[NT]	[NT]	LCS-W1	107%
TRH C_{15} - C_{28}	µg/L	100	Org-003	<100	[NT]	[NT]	LCS-W1	104%
TRH C_{29} - C_{36}	µg/L	100	Org-003	<100	[NT]	[NT]	LCS-W1	93%
TRH >C_{10} - C_{16}	µg/L	50	Org-003	<50	[NT]	[NT]	LCS-W1	107%
TRH >C_{16} - C_{34}	µg/L	100	Org-003	<100	[NT]	[NT]	LCS-W1	104%
TRH >C_{34} - C_{40}	µg/L	100	Org-003	<100	[NT]	[NT]	LCS-W1	93%
Surrogate o-Terphenyl	%		Org-003	72	[NT]	[NT]	LCS-W1	125%

QUALITY CONTROL PAHs in Water	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base ll Duplicate ll %RPD	Spike Sm#	Spike % Recovery
Date extracted	-			13/11/2015	[NT]	[NT]	LCS-W1	13/11/2015
Date analysed	-			13/11/2015	[NT]	[NT]	LCS-W1	13/11/2015
Naphthalene	µg/L	1	Org-012	<1	[NT]	[NT]	LCS-W1	91%
Acenaphthylene	µg/L	1	Org-012	<1	[NT]	[NT]	[NR]	[NR]
Acenaphthene	µg/L	1	Org-012	<1	[NT]	[NT]	[NR]	[NR]
Fluorene	µg/L	1	Org-012	<1	[NT]	[NT]	LCS-W1	111%
Phenanthrene	µg/L	1	Org-012	<1	[NT]	[NT]	LCS-W1	98%
Anthracene	µg/L	1	Org-012	<1	[NT]	[NT]	[NR]	[NR]
Fluoranthene	µg/L	1	Org-012	<1	[NT]	[NT]	LCS-W1	101%
Pyrene	µg/L	1	Org-012	<1	[NT]	[NT]	LCS-W1	106%
Benzo(a)anthracene	µg/L	1	Org-012	<1	[NT]	[NT]	[NR]	[NR]

QUALITY CONTROL PAHs in Water	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base ll Duplicate ll %RPD	Spike Sm#	Spike % Recovery
Chrysene	µg/L	1	Org-012	<1	[NT]	[NT]	LCS-W1	111%
Benzo(b,j+k) fluoranthene	µg/L	2	Org-012	<2	[NT]	[NT]	[NR]	[NR]
Benzo(a)pyrene	µg/L	1	Org-012	<1	[NT]	[NT]	LCS-W1	97%
Indeno(1,2,3-c,d)pyrene	µg/L	1	Org-012	<1	[NT]	[NT]	[NR]	[NR]
Dibenzo(a,h)anthracene	µg/L	1	Org-012	<1	[NT]	[NT]	[NR]	[NR]
Benzo(g,h,i)perylene	µg/L	1	Org-012	<1	[NT]	[NT]	[NR]	[NR]
Surrogate p-Terphenyl-d14	%		Org-012	83	[NT]	[NT]	LCS-W1	92%

Report Comments:

Asbestos ID was analysed by Approved Identifier: Not applicable for this job
Asbestos ID was authorised by Approved Signatory: Not applicable for this job

INS: Insufficient sample for this test	PQL: Practical Quantitation Limit	NT: Not tested
NR: Test not required	RPD: Relative Percent Difference	NA: Test not required
<: Less than	>: Greater than	LCS: Laboratory Control Sample

Quality Control Definitions

Blank: This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.

Duplicate: This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.

Matrix Spike : A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.

LCS (Laboratory Control Sample) : This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.

Surrogate Spike: Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.
Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.
Spikes for Physical and Aggregate Tests are not applicable.
For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: <5xPQL - any RPD is acceptable; >5xPQL - 0-50% RPD is acceptable.
Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals; 60-140% for organics (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached.

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Envirolab Services Pty Ltd - Sydney | ABN 37 112 535 645

CERTIFICATE OF ANALYSIS 135588

Client:
Ecotox Services Australasia Pty Ltd
Unit 27, 2 Chaplin Dr
Lane Cove
NSW 2066

Attention: Tina

Sample log in details:

Your Reference:	**PR1244**		
No. of samples:	12 Waters		
Date samples received / completed instructions received	08/10/15	/	08/10/15

Analysis Details:
Please refer to the following pages for results, methodology summary and quality control data.
Samples were analysed as received from the client. Results relate specifically to the samples as received.
Results are reported on a dry weight basis for solids and on an as received basis for other matrices.
Please refer to the last page of this report for any comments relating to the results.

Report Details:

Date results requested by: / Issue Date:	15/10/15	/	14/10/15
Date of Preliminary Report:	Not Issued		

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Results Approved By:

Jacinta Hurst
Laboratory Manager

vTRH(C6-C10)/BTEXN in Water						
Our Reference:	UNITS	135588-1	135588-2	135588-3	135588-4	135588-5
Your Reference	-------------	FSW Control 22/09/15	WAF Control 22/09/15	Condensate 6.3% 22/09/15	Condensate 12.5% 22/09/15	Condensate 25% 22/09/15
Date Sampled	------------	22/09/2015	22/09/2015	22/09/2015	22/09/2015	22/09/2015
Type of sample		Water	Water	Water	Water	Water
Date extracted	-	12/10/2015	12/10/2015	12/10/2015	12/10/2015	12/10/2015
Date analysed	-	12/10/2015	12/10/2015	12/10/2015	12/10/2015	12/10/2015
TRH C_6 - C_9	µg/L	<10	<10	3,400	7,500	14,000
TRH C_6 - C_{10}	µg/L	<10	<10	3,400	7,700	14,000
TRH C_6 - C_{10} less BTEX (F1)	µg/L	<10	<10	480	1,800	2,700
Benzene	µg/L	<1	<1	1,400	2,800	5,500
Toluene	µg/L	<1	<1	1,100	2,300	4,400
Ethylbenzene	µg/L	<1	<1	23	51	90
m+p-xylene	µg/L	<2	<2	300	560	990
o-xylene	µg/L	<1	<1	93	180	330
Naphthalene	µg/L	<1	<1	28	63	110
Surrogate Dibromofluoromethane	%	103	103	101	99	99
Surrogate toluene-d8	%	87	87	94	97	98
Surrogate 4-BFB	%	88	87	102	102	102

vTRH(C6-C10)/BTEXN in Water						
Our Reference:	UNITS	135588-6	135588-7	135588-8	135588-9	135588-10
Your Reference	-------------	Condensate 50% 22/09/15	Condensate 100% 22/09/15	Condensate weathered 6.3% 22/09/15	Condensate weathered 12.5% 22/09/15	Condensate weathered 25% 22/09/15
Date Sampled	------------	22/09/2015	22/09/2015	22/09/2015	22/09/2015	22/09/2015
Type of sample		Water	Water	Water	Water	Water
Date extracted	-	12/10/2015	12/10/2015	12/10/2015	12/10/2015	12/10/2015
Date analysed	-	12/10/2015	12/10/2015	12/10/2015	12/10/2015	13/10/2015
TRH C_6 - C_9	µg/L	26,000	60,000	1,100	2,200	3,600
TRH C_6 - C_{10}	µg/L	26,000	60,000	1,300	2,500	4,000
TRH C_6 - C_{10} less BTEX (F1)	µg/L	4,000	11,000	450	850	1,000
Benzene	µg/L	11,000	26,000	35	64	140
Toluene	µg/L	8,200	19,000	450	870	1,500
Ethylbenzene	µg/L	200	290	26	47	87
m+p-xylene	µg/L	1,900	2,900	250	490	900
o-xylene	µg/L	660	960	89	180	330
Naphthalene	µg/L	220	210	48	82	140
Surrogate Dibromofluoromethane	%	98	98	99	97	96
Surrogate toluene-d8	%	100	100	101	103	107
Surrogate 4-BFB	%	102	101	109	108	108

vTRH(C6-C10)/BTEXN in Water			
Our Reference:	UNITS	135588-11	135588-12
Your Reference	-------------	Condensate weathered 50% 22/09/15	Condensate weathered 100% 22/09/15
Date Sampled	------------	22/09/2015	22/09/2015
Type of sample		Water	Water
Date extracted	-	12/10/2015	12/10/2015
Date analysed	-	13/10/2015	13/10/2015
TRH C_6 - C_9	µg/L	7,900	18,000
TRH C_6 - C_{10}	µg/L	8,700	19,000
TRH C_6 - C_{10} less BTEX (F1)	µg/L	2,600	5,200
Benzene	µg/L	270	630
Toluene	µg/L	3,200	7,400
Ethylbenzene	µg/L	190	400
m+p-xylene	µg/L	1,800	4,000
o-xylene	µg/L	650	1,400
Naphthalene	µg/L	240	400
Surrogate Dibromofluoromethane	%	100	89
Surrogate toluene-d8	%	135	101
Surrogate 4-BFB	%	106	107

svTRH (C10-C40) in Water	UNITS					
Our Reference:	UNITS	135588-1	135588-2	135588-3	135588-4	135588-5
Your Reference	-------------	FSW Control 22/09/15	WAF Control 22/09/15	Condensate 6.3% 22/09/15	Condensate 12.5% 22/09/15	Condensate 25% 22/09/15
Date Sampled	------------	22/09/2015	22/09/2015	22/09/2015	22/09/2015	22/09/2015
Type of sample		Water	Water	Water	Water	Water
Date extracted	-	12/10/2015	12/10/2015	12/10/2015	12/10/2015	12/10/2015
Date analysed	-	12/10/2015	12/10/2015	13/10/2015	13/10/2015	13/10/2015
TRHC_{10} - C_{14}	µg/L	<50	<50	240	460	780
TRHC_{15} - C_{28}	µg/L	<100	<100	220	600	910
TRHC_{29} - C_{36}	µg/L	<100	<100	<100	<100	140
TRH>C_{10} - C_{16}	µg/L	<50	<50	230	480	780
TRH>C_{10} - C_{16} less Naphthalene (F2)	µg/L	<50	<50	200	420	670
TRH>C_{16} - C_{34}	µg/L	<100	<100	170	540	830
TRH>C_{34} - C_{40}	µg/L	<100	<100	<100	<100	<100
Surrogate o-Terphenyl	%	73	87	106	120	118

svTRH (C10-C40) in Water						
Our Reference:	UNITS	135588-6	135588-7	135588-8	135588-9	135588-10
Your Reference	-------------	Condensate 50% 22/09/15	Condensate 100% 22/09/15	Condensate weathered 6.3% 22/09/15	Condensate weathered 12.5% 22/09/15	Condensate weathered 25% 22/09/15
Date Sampled	------------	22/09/2015	22/09/2015	22/09/2015	22/09/2015	22/09/2015
Type of sample		Water	Water	Water	Water	Water
Date extracted	-	12/10/2015	12/10/2015	12/10/2015	12/10/2015	12/10/2015
Date analysed	-	13/10/2015	13/10/2015	13/10/2015	13/10/2015	13/10/2015
TRHC_{10} - C_{14}	µg/L	1,400	3,000	160	270	490
TRHC_{15} - C_{28}	µg/L	2,100	4,900	150	300	760
TRHC_{29} - C_{36}	µg/L	270	490	<100	<100	<100
TRH>C_{10} - C_{16}	µg/L	1,500	3,000	120	220	400
TRH>C_{10} - C_{16} less Naphthalene (F2)	µg/L	1,300	2,800	76	140	260
TRH>C_{16} - C_{34}	µg/L	1,900	4,400	150	280	750
TRH>C_{34} - C_{40}	µg/L	<100	170	<100	<100	<100
Surrogate o-Terphenyl	%	133	#	98	88	92

svTRH (C10-C40) in Water			
Our Reference:	UNITS	135588-11	135588-12
Your Reference	-------------	Condensate weathered 50% 22/09/15	Condensate weathered 100% 22/09/15
Date Sampled	------------	22/09/2015	22/09/2015
Type of sample		Water	Water
Date extracted	-	12/10/2015	12/10/2015
Date analysed	-	13/10/2015	13/10/2015
TRHC $_{10}$ - C $_{14}$	µg/L	1,200	1,600
TRHC $_{15}$ - C $_{28}$	µg/L	2,200	2,700
TRHC $_{29}$ - C $_{36}$	µg/L	150	180
TRH>C $_{10}$ - C $_{16}$	µg/L	990	1,200
TRH>C $_{10}$ - C $_{16}$ less Naphthalene (F2)	µg/L	750	800
TRH>C $_{16}$ - C $_{34}$	µg/L	2,100	2,600
TRH>C $_{34}$ - C $_{40}$	µg/L	<100	<100
Surrogate o-Terphenyl	%	#	#

PAHs in Water						
Our Reference:	UNITS	135588-1	135588-2	135588-3	135588-4	135588-5
Your Reference	-------------	FSW Control 22/09/15	WAF Control 22/09/15	Condensate 6.3% 22/09/15	Condensate 12.5% 22/09/15	Condensate 25% 22/09/15
Date Sampled	------------	22/09/2015	22/09/2015	22/09/2015	22/09/2015	22/09/2015
Type of sample		Water	Water	Water	Water	Water
Date extracted	-	12/10/2015	12/10/2015	12/10/2015	12/10/2015	12/10/2015
Date analysed	-	12/10/2015	12/10/2015	12/10/2015	12/10/2015	12/10/2015
Naphthalene	µg/L	<1	<1	18	34	65
Acenaphthylene	µg/L	<1	<1	<1	<1	<1
Acenaphthene	µg/L	<1	<1	<1	<1	<1
Fluorene	µg/L	<1	<1	<1	1	3
Phenanthrene	µg/L	<1	<1	1	2	3
Anthracene	µg/L	<1	<1	<1	<1	<1
Fluoranthene	µg/L	<1	<1	<1	<1	<1
Pyrene	µg/L	<1	<1	<1	<1	<1
Benzo(a)anthracene	µg/L	<1	<1	<1	<1	<1
Chrysene	µg/L	<1	<1	<1	<1	<1
Benzo(b,j+k)fluoranthene	µg/L	<2	<2	<2	<2	<2
Benzo(a)pyrene	µg/L	<1	<1	<1	<1	<1
Indeno(1,2,3-c,d)pyrene	µg/L	<1	<1	<1	<1	<1
Dibenzo(a,h)anthracene	µg/L	<1	<1	<1	<1	<1
Benzo(g,h,i)perylene	µg/L	<1	<1	<1	<1	<1
Benzo(a)pyrene TEQ	µg/L	<5	<5	<5	<5	<5
Total +ve PAH's	µg/L	NIL (+)VE	NIL (+)VE	19	37	70
Surrogate p-Terphenyl-d14	%	82	103	96	92	90

PAHs in Water						
Our Reference:	UNITS	135588-6	135588-7	135588-8	135588-9	135588-10
Your Reference	-------------	Condensate 50% 22/09/15	Condensate 100% 22/09/15	Condensate weathered 6.3% 22/09/15	Condensate weathered 12.5% 22/09/15	Condensate weathered 25% 22/09/15
Date Sampled	------------	22/09/2015	22/09/2015	22/09/2015	22/09/2015	22/09/2015
Type of sample		Water	Water	Water	Water	Water
Date extracted	-	12/10/2015	12/10/2015	12/10/2015	12/10/2015	12/10/2015
Date analysed	-	12/10/2015	12/10/2015	12/10/2015	12/10/2015	12/10/2015
Naphthalene	µg/L	110	220	22	45	69
Acenaphthylene	µg/L	<1	<1	<1	<1	<1
Acenaphthene	µg/L	<1	<1	<1	<1	<1
Fluorene	µg/L	4	5	<1	<1	2
Phenanthrene	µg/L	4	5	<1	<1	1
Anthracene	µg/L	<1	<1	<1	<1	<1
Fluoranthene	µg/L	<1	<1	<1	<1	<1
Pyrene	µg/L	<1	<1	<1	<1	<1
Benzo(a)anthracene	µg/L	<1	<1	<1	<1	<1
Chrysene	µg/L	<1	<1	<1	<1	<1
Benzo(b,j+k)fluoranthene	µg/L	<2	<2	<2	<2	<2
Benzo(a)pyrene	µg/L	<1	<1	<1	<1	<1
Indeno(1,2,3-c,d)pyrene	µg/L	<1	<1	<1	<1	<1
Dibenzo(a,h)anthracene	µg/L	<1	<1	<1	<1	<1
Benzo(g,h,i)perylene	µg/L	<1	<1	<1	<1	<1
Benzo(a)pyrene TEQ	µg/L	<5	<5	<5	<5	<5
Total +ve PAH's	µg/L	120	230	22	45	72
Surrogate p-Terphenyl-d14	%	92	74	93	91	83

PAHs in Water			
Our Reference:	UNITS	135588-11	135588-12
Your Reference	-------------	Condensate weathered 50% 22/09/15	Condensate weathered 100% 22/09/15
Date Sampled	------------	22/09/2015	22/09/2015
Type of sample		Water	Water
Date extracted	-	12/10/2015	12/10/2015
Date analysed	-	12/10/2015	12/10/2015
Naphthalene	µg/L	130	220
Acenaphthylene	µg/L	<1	<1
Acenaphthene	µg/L	<1	<1
Fluorene	µg/L	3	4
Phenanthrene	µg/L	2	2
Anthracene	µg/L	<1	<1
Fluoranthene	µg/L	<1	<1
Pyrene	µg/L	<1	<1
Benzo(a)anthracene	µg/L	<1	<1
Chrysene	µg/L	<1	<1
Benzo(b,j+k)fluoranthene	µg/L	<2	<2
Benzo(a)pyrene	µg/L	<1	<1
Indeno(1,2,3-c,d)pyrene	µg/L	<1	<1
Dibenzo(a,h)anthracene	µg/L	<1	<1
Benzo(g,h,i)perylene	µg/L	<1	<1
Benzo(a)pyrene TEQ	µg/L	<5	<5
Total +ve PAH's	µg/L	140	230
Surrogate p-Terphenyl-d14	%	77	62

Method ID	Methodology Summary
Org-016	Soil samples are extracted with methanol and spiked into water prior to analysing by purge and trap GC-MS. Water samples are analysed directly by purge and trap GC-MS. F1 = (C6-C10)-BTEX as per NEPM B1 Guideline on Investigation Levels for Soil and Groundwater.
Org-013	Water samples are analysed directly by purge and trap GC-MS.
Org-003	Soil samples are extracted with Dichloromethane/Acetone and waters with Dichloromethane and analysed by GC-FID. F2 = (>C10-C16)-Naphthalene as per NEPM B1 Guideline on Investigation Levels for Soil and Groundwater (HSLs Tables 1A (3, 4)). Note Naphthalene is determined from the VOC analysis.
Org-012 subset	Soil samples are extracted with Dichloromethane/Acetone and waters with Dichloromethane and analysed by GC-MS. Benzo(a)pyrene TEQ as per NEPM B1 Guideline on Investigation Levels for Soil and Groundwater - 2013.

QUALITY CONTROL vTRH(C6-C10)/BTEXN in Water	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Date extracted	-			12/10/2015	135588-1	12/10/2015 || 13/10/2015	LCS-W1	12/10/2015
Date analysed	-			12/10/2015	135588-1	12/10/2015 || 14/10/2015	LCS-W1	12/10/2015
TRHC_6 - C_9	µg/L	10	Org-016	<10	135588-1	<10 || <10	LCS-W1	108%
TRHC_6 - C_{10}	µg/L	10	Org-016	<10	135588-1	<10 || <10	LCS-W1	108%
Benzene	µg/L	1	Org-016	<1	135588-1	<1 || <1	LCS-W1	107%
Toluene	µg/L	1	Org-016	<1	135588-1	<1 || <1	LCS-W1	98%
Ethylbenzene	µg/L	1	Org-016	<1	135588-1	<1 || <1	LCS-W1	107%
m+p-xylene	µg/L	2	Org-016	<2	135588-1	<2 || <2	LCS-W1	113%
o-xylene	µg/L	1	Org-016	<1	135588-1	<1 || <1	LCS-W1	114%
Naphthalene	µg/L	1	Org-013	<1	135588-1	<1 || <1	[NR]	[NR]
Surrogate Dibromofluoromethane	%		Org-016	101	135588-1	103 || 102 || RPD: 1	LCS-W1	102%
Surrogate toluene-d8	%		Org-016	88	135588-1	87 || 92 || RPD: 6	LCS-W1	90%
Surrogate 4-BFB	%		Org-016	90	135588-1	88 || 88 || RPD: 0	LCS-W1	104%

QUALITY CONTROL svTRH (C10-C40) in Water	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Date extracted	-			12/10/2015	[NT]	[NT]	LCS-W3	12/10/2015
Date analysed	-			12/10/2015	[NT]	[NT]	LCS-W3	12/10/2015
TRHC_{10} - C_{14}	µg/L	50	Org-003	<50	[NT]	[NT]	LCS-W3	100%
TRHC_{15} - C_{28}	µg/L	100	Org-003	<100	[NT]	[NT]	LCS-W3	83%
TRHC_{29} - C_{36}	µg/L	100	Org-003	<100	[NT]	[NT]	LCS-W3	83%
TRH>C_{10} - C_{16}	µg/L	50	Org-003	<50	[NT]	[NT]	LCS-W3	100%
TRH>C_{16} - C_{34}	µg/L	100	Org-003	<100	[NT]	[NT]	LCS-W3	83%
TRH>C_{34} - C_{40}	µg/L	100	Org-003	<100	[NT]	[NT]	LCS-W3	83%
Surrogate o-Terphenyl	%		Org-003	84	[NT]	[NT]	LCS-W3	95%

QUALITY CONTROL PAHs in Water	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Date extracted	-			12/10/2015	[NT]	[NT]	LCS-W3	12/10/2015
Date analysed	-			12/10/2015	[NT]	[NT]	LCS-W3	12/10/2015
Naphthalene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	LCS-W3	77%
Acenaphthylene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	[NR]	[NR]
Acenaphthene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	[NR]	[NR]
Fluorene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	LCS-W3	70%
Phenanthrene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	LCS-W3	78%

QUALITY CONTROL PAHs in Water	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Anthracene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	[NR]	[NR]
Fluoranthene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	LCS-W3	77%
Pyrene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	LCS-W3	79%
Benzo(a)anthracene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	[NR]	[NR]
Chrysene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	LCS-W3	100%
Benzo(b,j+k) fluoranthene	µg/L	2	Org-012 subset	<2	[NT]	[NT]	[NR]	[NR]
Benzo(a)pyrene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	LCS-W3	94%
Indeno(1,2,3-c,d)pyrene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	[NR]	[NR]
Dibenzo(a,h)anthracene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	[NR]	[NR]
Benzo(g,h,i)perylene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	[NR]	[NR]
Surrogate p-Terphenyl-d14	%		Org-012 subset	95	[NT]	[NT]	LCS-W3	80%

Report Comments:

TRH_W(semi vol):# Percent recovery is not possible to report as the high concentration of analytes in the sample/s have caused interference.

Asbestos ID was analysed by Approved Identifier:	Not applicable for this job
Asbestos ID was authorised by Approved Signatory:	Not applicable for this job

INS: Insufficient sample for this test	PQL: Practical Quantitation Limit	NT: Not tested
NA: Test not required	RPD: Relative Percent Difference	NA: Test not required
<: Less than	>: Greater than	LCS: Laboratory Control Sample

Quality Control Definitions

Blank: This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.

Duplicate: This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.

Matrix Spike : A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.

LCS (Laboratory Control Sample) : This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.

Surrogate Spike: Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.

Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.

Spikes for Physical and Aggregate Tests are not applicable.

For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: <5xPQL - any RPD is acceptable; >5xPQL - 0-50% RPD is acceptable.

Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals; 60-140% for organics (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

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CERTIFICATE OF ANALYSIS 134814

Client:
Ecotox Services Australasia Pty Ltd
Unit 27, 2 Chaplin Dr
Lane Cove
NSW 2066

Attention: Tina

Sample log in details:

Your Reference:	**PR1244**		
No. of samples:	19 Waters		
Date samples received / completed instructions received	23/09/2015	/	23/09/2015

Analysis Details:
Please refer to the following pages for results, methodology summary and quality control data.
Samples were analysed as received from the client. Results relate specifically to the samples as received.
Results are reported on a dry weight basis for solids and on an as received basis for other matrices.
Please refer to the last page of this report for any comments relating to the results.

Report Details:

Date results requested by: / Issue Date:	30/09/15	/	30/09/15
Date of Preliminary Report:	Not Issued		

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Accredited for compliance with ISO/IEC 17025. **Tests not covered by NATA are denoted with *.**

Results Approved By:

Jacinta Hurst
Laboratory Manager

vTRH(C6-C10)/BTEXN in Water						
Our Reference:	UNITS	134814-1	134814-2	134814-3	134814-4	134814-5
Your Reference	-------------	FSW Control 10/9/2015	WAF Control 10/9/2015	Condensate 0.8% 10/9/2015	Condensate 1.6% 10/9/2015	Condensate 3.1% 10/9/2015
Date Sampled	------------	10/09/2015	10/09/2015	10/09/2015	10/09/2015	10/09/2015
Type of sample		Water	Water	Water	Water	Water
Date extracted	-	28/09/2015	28/09/2015	28/09/2015	28/09/2015	28/09/2015
Date analysed	-	29/09/2015	29/09/2015	29/09/2015	29/09/2015	29/09/2015
TRH C_6 - C_9	µg/L	<10	<10	350	720	1,500
TRH C_6 - C_{10}	µg/L	<10	<10	370	770	1,600
TRH C_6 - C_{10} less BTEX (F1)	µg/L	<10	<10	56	110	250
Benzene	µg/L	<1	<1	160	330	650
Toluene	µg/L	<1	<1	120	260	550
Ethylbenzene	µg/L	<1	<1	2	5	11
m+p-xylene	µg/L	<2	<2	23	49	100
o-xylene	µg/L	<1	<1	8	17	35
Naphthalene	µg/L	<1	<1	2	4	9
Surrogate Dibromofluoromethane	%	98	98	98	96	96
Surrogate toluene-d8	%	102	100	100	101	100
Surrogate 4-BFB	%	97	96	98	99	100

vTRH(C6-C10)/BTEXN in Water						
Our Reference:	UNITS	134814-6	134814-7	134814-8	134814-9	134814-10
Your Reference	-------------	Condensate 6.3% 10/9/2015	Condensate 12.5% 10/9/2015	Condensate 25% 10/9/2015	Condensate 50% 10/9/2015	Condensate 100% 10/9/2015
Date Sampled	------------	10/09/2015	10/09/2015	10/09/2015	10/09/2015	10/09/2015
Type of sample		Water	Water	Water	Water	Water
Date extracted	-	28/09/2015	28/09/2015	28/09/2015	28/09/2015	28/09/2015
Date analysed	-	29/09/2015	29/09/2015	29/09/2015	29/09/2015	29/09/2015
TRH C_6 - C_9	µg/L	2,900	6,600	13,000	29,000	66,000
TRH C_6 - C_{10}	µg/L	3,000	6,800	13,000	29,000	66,000
TRH C_6 - C_{10} less BTEX (F1)	µg/L	340	1,200	2,000	4,800	9,800
Benzene	µg/L	1,300	2,700	5,400	12,000	28,000
Toluene	µg/L	1,100	2,200	4,400	9,600	22,000
Ethylbenzene	µg/L	23	47	81	180	430
m+p-xylene	µg/L	170	460	850	1,800	4,400
o-xylene	µg/L	71	150	280	600	1,400
Naphthalene	µg/L	19	21	30	50	110
Surrogate Dibromofluoromethane	%	97	97	99	98	98
Surrogate toluene-d8	%	99	100	99	98	97
Surrogate 4-BFB	%	101	99	95	98	96

vTRH(C6-C10)/BTEXN in Water						
Our Reference:	UNITS	134814-11	134814-12	134814-13	134814-14	134814-15
Your Reference	-------------	FSW Control 11/9/2015	WAF Control 11/9/2015	Condensate 1.6% 11/9/2015	Condensate 3.1% 11/9/2015	Condensate 6.3% 11/9/2015
Date Sampled	------------	11/09/2015	11/09/2015	11/09/2015	11/09/2015	11/09/2015
Type of sample		Water	Water	Water	Water	Water
Date extracted	-	28/09/2015	28/09/2015	28/09/2015	28/09/2015	28/09/2015
Date analysed	-	29/09/2015	29/09/2015	29/09/2015	29/09/2015	29/09/2015
TRHC_6 - C_9	µg/L	<10	<10	650	1,400	3,000
TRHC_6 - C_{10}	µg/L	<10	<10	690	1,400	3,100
TRHC_6 - C_{10} less BTEX (F1)	µg/L	<10	<10	110	170	670
Benzene	µg/L	<1	<1	290	600	1,200
Toluene	µg/L	<1	<1	230	500	980
Ethylbenzene	µg/L	<1	<1	4	9	21
m+p-xylene	µg/L	<2	<2	43	89	160
o-xylene	µg/L	<1	<1	15	31	65
Naphthalene	µg/L	<1	<1	4	7	17
Surrogate Dibromofluoromethane	%	100	100	97	97	96
Surrogate toluene-d8	%	99	99	102	100	99
Surrogate 4-BFB	%	96	95	100	101	102

vTRH(C6-C10)/BTEXN in Water					
Our Reference:	UNITS	134814-16	134814-17	134814-18	134814-19
Your Reference	-------------	Condensate 12.5% 11/9/2015	Condensate 25% 11/9/2015	Condensate 50% 11/9/2015	Condensate 100% 11/9/2015
Date Sampled	------------	11/09/2015	11/09/2015	11/09/2015	11/09/2015
Type of sample		Water	Water	Water	Water
Date extracted	-	28/09/2015	28/09/2015	28/09/2015	28/09/2015
Date analysed	-	29/09/2015	29/09/2015	29/09/2015	29/09/2015
TRHC_6 - C_9	µg/L	6,200	12,000	26,000	62,000
TRHC_6 - C_{10}	µg/L	6,400	12,000	26,000	62,000
TRHC_6 - C_{10} less BTEX (F1)	µg/L	1,200	1,600	3,900	8,500
Benzene	µg/L	2,500	5,100	11,000	27,000
Toluene	µg/L	2,100	4,100	8,700	21,000
Ethylbenzene	µg/L	42	78	160	380
m+p-xylene	µg/L	410	820	1,700	3,900
o-xylene	µg/L	140	270	530	1,200
Naphthalene	µg/L	19	33	43	110
Surrogate Dibromofluoromethane	%	97	100	100	98
Surrogate toluene-d8	%	99	99	98	97
Surrogate 4-BFB	%	99	97	94	97

svTRH (C10-C40) in Water						
Our Reference:	UNITS	134814-1	134814-2	134814-3	134814-4	134814-5
Your Reference	-------------	FSW Control 10/9/2015	WAF Control 10/9/2015	Condensate 0.8% 10/9/2015	Condensate 1.6% 10/9/2015	Condensate 3.1% 10/9/2015
Date Sampled	------------	10/09/2015	10/09/2015	10/09/2015	10/09/2015	10/09/2015
Type of sample		Water	Water	Water	Water	Water
Date extracted	-	24/09/2015	24/09/2015	24/09/2015	24/09/2015	24/09/2015
Date analysed	-	25/09/2015	25/09/2015	25/09/2015	25/09/2015	25/09/2015
TRHC $_{10}$ - C $_{14}$	µg/L	<50	<50	<50	<50	53
TRHC $_{15}$ - C $_{28}$	µg/L	<100	<100	<100	<100	120
TRHC $_{29}$ - C $_{36}$	µg/L	<100	<100	<100	<100	<100
TRH>C $_{10}$ - C $_{16}$	µg/L	<50	<50	<50	<50	<50
TRH>C $_{10}$ - C $_{16}$ less Naphthalene (F2)	µg/L	<50	<50	<50	<50	<50
TRH>C $_{16}$ - C $_{34}$	µg/L	<100	<100	<100	<100	120
TRH>C $_{34}$ - C $_{40}$	µg/L	<100	<100	<100	<100	<100
Surrogate o-Terphenyl	%	87	79	83	88	97

svTRH (C10-C40) in Water						
Our Reference:	UNITS	134814-6	134814-7	134814-8	134814-9	134814-10
Your Reference	-------------	Condensate 6.3% 10/9/2015	Condensate 12.5% 10/9/2015	Condensate 25% 10/9/2015	Condensate 50% 10/9/2015	Condensate 100% 10/9/2015
Date Sampled	------------	10/09/2015	10/09/2015	10/09/2015	10/09/2015	10/09/2015
Type of sample		Water	Water	Water	Water	Water
Date extracted	-	24/09/2015	24/09/2015	24/09/2015	24/09/2015	24/09/2015
Date analysed	-	25/09/2015	25/09/2015	25/09/2015	25/09/2015	25/09/2015
TRHC $_{10}$ - C $_{14}$	µg/L	120	240	490	880	1,900
TRHC $_{15}$ - C $_{28}$	µg/L	160	320	570	980	1,600
TRHC $_{29}$ - C $_{36}$	µg/L	<100	<100	<100	<100	120
TRH>C $_{10}$ - C $_{16}$	µg/L	98	200	380	660	1,300
TRH>C $_{10}$ - C $_{16}$ less Naphthalene (F2)	µg/L	79	180	350	610	1,200
TRH>C $_{16}$ - C $_{34}$	µg/L	150	300	540	930	1,600
TRH>C $_{34}$ - C $_{40}$	µg/L	<100	<100	<100	<100	<100
Surrogate o-Terphenyl	%	95	93	94	84	84

svTRH (C10-C40) in Water	UNITS					
Our Reference:		134814-11	134814-12	134814-13	134814-14	134814-15
Your Reference	-------------	FSW Control 11/9/2015	WAF Control 11/9/2015	Condensate 1.6% 11/9/2015	Condensate 3.1% 11/9/2015	Condensate 6.3% 11/9/2015
Date Sampled	------------	11/09/2015	11/09/2015	11/09/2015	11/09/2015	11/09/2015
Type of sample		Water	Water	Water	Water	Water
Date extracted	-	24/09/2015	24/09/2015	24/09/2015	24/09/2015	24/09/2015
Date analysed	-	29/09/2015	29/09/2015	29/09/2015	29/09/2015	29/09/2015
TRHC$_{10}$ - C$_{14}$	µg/L	<50	<50	<50	<50	78
TRHC$_{15}$ - C$_{28}$	µg/L	<100	<100	<100	<100	170
TRHC$_{29}$ - C$_{36}$	µg/L	<100	<100	<100	<100	<100
TRH>C$_{10}$ - C$_{16}$	µg/L	<50	<50	<50	<50	63
TRH>C$_{10}$ - C$_{16}$ less Naphthalene (F2)	µg/L	<50	<50	<50	<50	<50
TRH>C$_{16}$ - C$_{34}$	µg/L	<100	<100	<100	<100	170
TRH>C$_{34}$ - C$_{40}$	µg/L	<100	<100	<100	<100	<100
Surrogate o-Terphenyl	%	102	98	91	100	83

svTRH (C10-C40) in Water	UNITS				
Our Reference:		134814-16	134814-17	134814-18	134814-19
Your Reference	-------------	Condensate 12.5% 11/9/2015	Condensate 25% 11/9/2015	Condensate 50% 11/9/2015	Condensate 100% 11/9/2015
Date Sampled	------------	11/09/2015	11/09/2015	11/09/2015	11/09/2015
Type of sample		Water	Water	Water	Water
Date extracted	-	24/09/2015	24/09/2015	24/09/2015	24/09/2015
Date analysed	-	29/09/2015	29/09/2015	29/09/2015	29/09/2015
TRHC$_{10}$ - C$_{14}$	µg/L	190	410	960	1,900
TRHC$_{15}$ - C$_{28}$	µg/L	280	440	1,000	1,800
TRHC$_{29}$ - C$_{36}$	µg/L	<100	<100	<100	130
TRH>C$_{10}$ - C$_{16}$	µg/L	160	320	750	1,400
TRH>C$_{10}$ - C$_{16}$ less Naphthalene (F2)	µg/L	140	290	710	1,300
TRH>C$_{16}$ - C$_{34}$	µg/L	260	410	950	1,700
TRH>C$_{34}$ - C$_{40}$	µg/L	<100	<100	<100	<100
Surrogate o-Terphenyl	%	99	99	128	101

PAHs in Water Our Reference: Your Reference Date Sampled Type of sample	UNITS ------------- ------------	134814-1 FSW Control 10/9/2015 10/09/2015 Water	134814-2 WAF Control 10/9/2015 10/09/2015 Water	134814-3 Condensate 0.8% 10/9/2015 10/09/2015 Water	134814-4 Condensate 1.6% 10/9/2015 10/09/2015 Water	134814-5 Condensate 3.1% 10/9/2015 10/09/2015 Water
Date extracted	-	24/09/2015	24/09/2015	24/09/2015	24/09/2015	24/09/2015
Date analysed	-	25/09/2015	25/09/2015	25/09/2015	25/09/2015	25/09/2015
Naphthalene	µg/L	<1	<1	2	4	8
Acenaphthylene	µg/L	<1	<1	<1	<1	<1
Acenaphthene	µg/L	<1	<1	<1	<1	<1
Fluorene	µg/L	<1	<1	<1	<1	<1
Phenanthrene	µg/L	<1	<1	<1	<1	<1
Anthracene	µg/L	<1	<1	<1	<1	<1
Fluoranthene	µg/L	<1	<1	<1	<1	<1
Pyrene	µg/L	<1	<1	<1	<1	<1
Benzo(a)anthracene	µg/L	<1	<1	<1	<1	<1
Chrysene	µg/L	<1	<1	<1	<1	<1
Benzo(b,j+k)fluoranthene	µg/L	<2	<2	<2	<2	<2
Benzo(a)pyrene	µg/L	<1	<1	<1	<1	<1
Indeno(1,2,3-c,d)pyrene	µg/L	<1	<1	<1	<1	<1
Dibenzo(a,h)anthracene	µg/L	<1	<1	<1	<1	<1
Benzo(g,h,i)perylene	µg/L	<1	<1	<1	<1	<1
Benzo(a)pyrene TEQ	µg/L	<5	<5	<5	<5	<5
Total +ve PAH's	µg/L	NIL (+)VE	NIL (+)VE	2.1	4.3	8.2
Surrogate p-Terphenyl-d14	%	93	89	87	93	91

PAHs in Water						
Our Reference:	UNITS	134814-6	134814-7	134814-8	134814-9	134814-10
Your Reference	-------------	Condensate 6.3% 10/9/2015	Condensate 12.5% 10/9/2015	Condensate 25% 10/9/2015	Condensate 50% 10/9/2015	Condensate 100% 10/9/2015
Date Sampled	------------	10/09/2015	10/09/2015	10/09/2015	10/09/2015	10/09/2015
Type of sample		Water	Water	Water	Water	Water
Date extracted	-	24/09/2015	24/09/2015	24/09/2015	24/09/2015	24/09/2015
Date analysed	-	25/09/2015	25/09/2015	25/09/2015	25/09/2015	25/09/2015
Naphthalene	µg/L	16	29	58	110	220
Acenaphthylene	µg/L	<1	<1	<1	<1	<1
Acenaphthene	µg/L	<1	<1	<1	<1	<1
Fluorene	µg/L	<1	<1	1	2	4
Phenanthrene	µg/L	<1	<1	1	2	3
Anthracene	µg/L	<1	<1	<1	<1	<1
Fluoranthene	µg/L	<1	<1	<1	<1	<1
Pyrene	µg/L	<1	<1	<1	<1	<1
Benzo(a)anthracene	µg/L	<1	<1	<1	<1	<1
Chrysene	µg/L	<1	<1	<1	<1	<1
Benzo(b,j+k)fluoranthene	µg/L	<2	<2	<2	<2	<2
Benzo(a)pyrene	µg/L	<1	<1	<1	<1	<1
Indeno(1,2,3-c,d)pyrene	µg/L	<1	<1	<1	<1	<1
Dibenzo(a,h)anthracene	µg/L	<1	<1	<1	<1	<1
Benzo(g,h,i)perylene	µg/L	<1	<1	<1	<1	<1
Benzo(a)pyrene TEQ	µg/L	<5	<5	<5	<5	<5
Total +ve PAH's	µg/L	16	29	61	110	230
Surrogate p-Terphenyl-d14	%	98	89	90	87	94

PAHs in Water Our Reference: Your Reference Date Sampled Type of sample	UNITS ------------- ------------	134814-11 FSW Control 11/9/2015 11/09/2015 Water	134814-12 WAF Control 11/9/2015 11/09/2015 Water	134814-13 Condensate 1.6% 11/9/2015 11/09/2015 Water	134814-14 Condensate 3.1% 11/9/2015 11/09/2015 Water	134814-15 Condensate 6.3% 11/9/2015 11/09/2015 Water
Date extracted	-	25/09/2015	25/09/2015	25/09/2015	25/09/2015	25/09/2015
Date analysed	-	25/09/2015	25/09/2015	25/09/2015	25/09/2015	25/09/2015
Naphthalene	µg/L	<1	<1	4	7	14
Acenaphthylene	µg/L	<1	<1	<1	<1	<1
Acenaphthene	µg/L	<1	<1	<1	<1	<1
Fluorene	µg/L	<1	<1	<1	<1	<1
Phenanthrene	µg/L	<1	<1	<1	<1	<1
Anthracene	µg/L	<1	<1	<1	<1	<1
Fluoranthene	µg/L	<1	<1	<1	<1	<1
Pyrene	µg/L	<1	<1	<1	<1	<1
Benzo(a)anthracene	µg/L	<1	<1	<1	<1	<1
Chrysene	µg/L	<1	<1	<1	<1	<1
Benzo(b,j+k)fluoranthene	µg/L	<2	<2	<2	<2	<2
Benzo(a)pyrene	µg/L	<1	<1	<1	<1	<1
Indeno(1,2,3-c,d)pyrene	µg/L	<1	<1	<1	<1	<1
Dibenzo(a,h)anthracene	µg/L	<1	<1	<1	<1	<1
Benzo(g,h,i)perylene	µg/L	<1	<1	<1	<1	<1
Benzo(a)pyrene TEQ	µg/L	<5	<5	<5	<5	<5
Total +ve PAH's	µg/L	NIL (+)VE	NIL (+)VE	3.6	7.1	14
Surrogate p-Terphenyl-d14	%	104	107	103	107	94

PAHs in Water Our Reference: Your Reference Date Sampled Type of sample	UNITS ------------ ------------	134814-16 Condensate 12.5% 11/9/2015 11/09/2015 Water	134814-17 Condensate 25% 11/9/2015 11/09/2015 Water	134814-18 Condensate 50% 11/9/2015 11/09/2015 Water	134814-19 Condensate 100% 11/9/2015 11/09/2015 Water
Date extracted	-	25/09/2015	25/09/2015	25/09/2015	25/09/2015
Date analysed	-	25/09/2015	25/09/2015	25/09/2015	25/09/2015
Naphthalene	µg/L	29	55	100	200
Acenaphthylene	µg/L	<1	<1	<1	<1
Acenaphthene	µg/L	<1	<1	<1	<1
Fluorene	µg/L	<1	1	3	3
Phenanthrene	µg/L	<1	<1	2	2
Anthracene	µg/L	<1	<1	<1	<1
Fluoranthene	µg/L	<1	<1	<1	<1
Pyrene	µg/L	<1	<1	<1	<1
Benzo(a)anthracene	µg/L	<1	<1	<1	<1
Chrysene	µg/L	<1	<1	<1	<1
Benzo(b,j+k)fluoranthene	µg/L	<2	<2	<2	<2
Benzo(a)pyrene	µg/L	<1	<1	<1	<1
Indeno(1,2,3-c,d)pyrene	µg/L	<1	<1	<1	<1
Dibenzo(a,h)anthracene	µg/L	<1	<1	<1	<1
Benzo(g,h,i)perylene	µg/L	<1	<1	<1	<1
Benzo(a)pyrene TEQ	µg/L	<5	<5	<5	<5
Total +ve PAH's	µg/L	29	57	110	210
Surrogate p-Terphenyl-d14	%	104	106	115	100

Method ID	Methodology Summary
Org-016	Soil samples are extracted with methanol and spiked into water prior to analysing by purge and trap GC-MS. Water samples are analysed directly by purge and trap GC-MS. F1 = (C6-C10)-BTEX as per NEPM B1 Guideline on Investigation Levels for Soil and Groundwater.
Org-013	Water samples are analysed directly by purge and trap GC-MS.
Org-003	Soil samples are extracted with Dichloromethane/Acetone and waters with Dichloromethane and analysed by GC-FID. F2 = (>C10-C16)-Naphthalene as per NEPM B1 Guideline on Investigation Levels for Soil and Groundwater (HSLs Tables 1A (3, 4)). Note Naphthalene is determined from the VOC analysis.
Org-012 subset	Soil samples are extracted with Dichloromethane/Acetone and waters with Dichloromethane and analysed by GC-MS. Benzo(a)pyrene TEQ as per NEPM B1 Guideline on Investigation Levels for Soil and Groundwater - 2013.

QUALITY CONTROL vTRH(C6-C10)/BTEXN in Water	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Date extracted	-			28/09/2015	134814-1	28/09/2015 || 29/09/2015	LCS-W2	28/09/2015
Date analysed	-			29/09/2015	134814-1	29/09/2015 || 29/09/2015	LCS-W2	29/09/2015
TRH C_6 - C_9	µg/L	10	Org-016	<10	134814-1	<10 || <10	LCS-W2	101%
TRH C_6 - C_{10}	µg/L	10	Org-016	<10	134814-1	<10 || <10	LCS-W2	101%
Benzene	µg/L	1	Org-016	<1	134814-1	<1 || <1	LCS-W2	101%
Toluene	µg/L	1	Org-016	<1	134814-1	<1 || <1	LCS-W2	103%
Ethylbenzene	µg/L	1	Org-016	<1	134814-1	<1 || <1	LCS-W2	99%
m+p-xylene	µg/L	2	Org-016	<2	134814-1	<2 || <2	LCS-W2	100%
o-xylene	µg/L	1	Org-016	<1	134814-1	<1 || <1	LCS-W2	97%
Naphthalene	µg/L	1	Org-013	<1	134814-1	<1 || <1	[NR]	[NR]
Surrogate Dibromofluoromethane	%		Org-016	97	134814-1	98 || 103 || RPD: 5	LCS-W2	96%
Surrogate toluene-d8	%		Org-016	102	134814-1	102 || 95 || RPD: 7	LCS-W2	105%
Surrogate 4-BFB	%		Org-016	97	134814-1	97 || 89 || RPD: 9	LCS-W2	101%

QUALITY CONTROL svTRH (C10-C40) in Water	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Date extracted	-			25/09/2015	[NT]	[NT]	LCS-W2	24/09/2015
Date analysed	-			29/09/2015	[NT]	[NT]	LCS-W2	25/09/2015
TRH C_{10} - C_{14}	µg/L	50	Org-003	<50	[NT]	[NT]	LCS-W2	90%
TRH C_{15} - C_{28}	µg/L	100	Org-003	<100	[NT]	[NT]	LCS-W2	81%
TRH C_{29} - C_{36}	µg/L	100	Org-003	<100	[NT]	[NT]	LCS-W2	83%
TRH $>C_{10}$ - C_{16}	µg/L	50	Org-003	<50	[NT]	[NT]	LCS-W2	90%
TRH $>C_{16}$ - C_{34}	µg/L	100	Org-003	<100	[NT]	[NT]	LCS-W2	81%
TRH $>C_{34}$ - C_{40}	µg/L	100	Org-003	<100	[NT]	[NT]	LCS-W2	83%
Surrogate o-Terphenyl	%		Org-003	90	[NT]	[NT]	LCS-W2	79%

QUALITY CONTROL PAHs in Water	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Date extracted	-			25/09/2015	[NT]	[NT]	LCS-W1	24/09/2015
Date analysed	-			25/09/2015	[NT]	[NT]	LCS-W1	25/09/2015
Naphthalene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	LCS-W1	76%
Acenaphthylene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	[NR]	[NR]
Acenaphthene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	[NR]	[NR]
Fluorene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	LCS-W1	77%
Phenanthrene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	LCS-W1	80%

QUALITY CONTROL PAHs in Water	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base ll Duplicate ll %RPD	Spike Sm#	Spike % Recovery
Anthracene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	[NR]	[NR]
Fluoranthene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	LCS-W1	80%
Pyrene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	LCS-W1	85%
Benzo(a)anthracene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	[NR]	[NR]
Chrysene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	LCS-W1	80%
Benzo(b,j+k) fluoranthene	µg/L	2	Org-012 subset	<2	[NT]	[NT]	[NR]	[NR]
Benzo(a)pyrene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	LCS-W1	85%
Indeno(1,2,3-c,d)pyrene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	[NR]	[NR]
Dibenzo(a,h)anthracene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	[NR]	[NR]
Benzo(g,h,i)perylene	µg/L	1	Org-012 subset	<1	[NT]	[NT]	[NR]	[NR]
Surrogate p-Terphenyl-d14	%		Org-012 subset	84	[NT]	[NT]	LCS-W1	69%

QUALITY CONTROL vTRH(C6-C10)/BTEXN in Water	UNITS	Dup. Sm#	Duplicate Base + Duplicate + %RPD
Date extracted	-	134814-11	28/09/2015 || 29/09/2015
Date analysed	-	134814-11	29/09/2015 || 29/09/2015
TRH C_6 - C_9	µg/L	134814-11	<10 || <10
TRH C_6 - C_{10}	µg/L	134814-11	<10 || <10
Benzene	µg/L	134814-11	<1 || <1
Toluene	µg/L	134814-11	<1 || <1
Ethylbenzene	µg/L	134814-11	<1 || <1
m+p-xylene	µg/L	134814-11	<2 || <2
o-xylene	µg/L	134814-11	<1 || <1
Naphthalene	µg/L	134814-11	<1 || <1
Surrogate Dibromofluoromethane	%	134814-11	100 || 103 || RPD: 3
Surrogate toluene-d8	%	134814-11	99 || 95 || RPD: 4
Surrogate 4-BFB	%	134814-11	96 || 88 || RPD: 9

Report Comments:

Asbestos ID was analysed by Approved Identifier:	Not applicable for this job
Asbestos ID was authorised by Approved Signatory:	Not applicable for this job

INS: Insufficient sample for this test	PQL: Practical Quantitation Limit	NT: Not tested
NA: Test not required	RPD: Relative Percent Difference	NA: Test not required
<: Less than	>: Greater than	LCS: Laboratory Control Sample

Quality Control Definitions

Blank: This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.

Duplicate: This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.

Matrix Spike : A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.

LCS (Laboratory Control Sample) : This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.

Surrogate Spike: Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.
Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.
Spikes for Physical and Aggregate Tests are not applicable.
For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: <5xPQL - any RPD is acceptable; >5xPQL - 0-50% RPD is acceptable.
Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals; 60-140% for organics (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Appendix C: Test Report for the Sea Urchin Fertilisation Test

Toxicity Test Report: TR1244/1

Accredited for compliance with ISO/IEC 17025

Client:	Jacobs Group (Australia) Pty Ltd 263 Adelaide Terrace Perth WA 6001	**ESA Job #:** **Date Sampled:** **Date Received:**	PR1244 27 December 2014 27 August 2015
Attention:	Celeste Wilson	**Sampled By:**	Client
Client Ref:	Not Supplied	**ESA Quote #:**	PL1244_q03

Lab ID No.:	**Sample Name:**	**Sample Description:**
7323	Barossa Field Condensate	Condensate sample received at room temperature in apparent good condition.

Test Performed:	1-hr sea urchin fertilisation success test using *Heliocidaris tuberculata*
Test Protocol:	ESA SOP 104 (ESA 2014), based on USEPA (2002) and Simon and Laginestra (1996)
Test Temperature:	The test was performed at 20±1°C.
Deviations from Protocol:	Nil
Comments on Solution Preparation:	Pre-weighed aliquot of condensate were added to filtered seawater (FSW) at a single loading rate of 1 part oil to 9 parts FSW. The samples were mixed for 24 hours using a magnetic stirrer so that the peak of a vortex is achieved. Following mixing, the solutions were left to settle for 1 hour, after which time the water-accommodated fractions (WAF) were siphoned off. The WAF was serially diluted with FSW to prepare the remaining test concentrations. A FSW control and a WAF control were tested concurrently with the sample. The test concentrations are expressed as loading rates and total recoverable hydrocarbon (TRH) concentrations.
Source of Test Organisms:	Field collected from South Maroubra, NSW.
Test Initiated:	10 September 2015 at 1130h

Sample 7323*: Barossa Field Condensate*

Loading Rate (g/L)	**% Fertilised Eggs (Mean ± SD)**
FSW Control	78.8 ± 3.2
WAF Control	90.0 ± 2.6
0.6	84.3 ± 6.5
1.2	82.3 ± 3.4 *
2.4	80.5 ± 5.2 *
4.8	80.5 ± 4.1 *
9.7	80.0 ± 2.2 *
19.3	34.8 ± 8.8 *
38.6	0.0 ± 0.0
77.2	0.0 ± 0.0

EC10 = 14.6g/L**
EC50 = 18.6 (8.97-19.12)g/L
NOEC = 0.6g/L
LOEC = 1.2g/L

Sample 7323*: Barossa Field Condensate*

Concentration (µg/L)	**% Fertilised Eggs (Mean ± SD)**
FSW Control	78.8 ± 3.2
WAF Control	90.0 ± 2.6
350	84.3 ± 6.5
720	82.3 ± 3.4 *
1673	80.5 ± 5.2 *
3180	80.5 ± 4.1 *
7160	80.0 ± 2.2 *
14060	34.8 ± 8.8 *
30860	0.0 ± 0.0
69620	0.0 ± 0.0

EC10 = 9206.2 (7702.42-10203.00)µg/L
EC50 = 13202.7 (12495.20-13763.40)µg/L
NOEC = 350µg/L
LOEC = 720µg/L

*Significantly lower percentage fertilised eggs compared with the WAF Control (Dunnett's Test, 1-tailed, P=0.05)
**95% Confidence Limits not reliable

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Toxicity Test Report: TR1244/1

QA/QC Parameter	Criterion	This Test	Criterion met?
Control mean % fertilised eggs	≥70.0%	78.8%	Yes
Reference Toxicant within cusum chart limits	23.7-105.6µg Cu/L	26.7µg Cu/L	Yes

Test Report Authorised by: Dr Rick Krassoi, Director on 9 November 2015

Results are based on the samples in the condition as received by ESA.

NATA Accredited Laboratory Number: 14709

Citations:

ESA (2014) ESA SOP 104 - *Sea Urchin Fertilisation Success Test*. Issue No. 13. Ecotox Services Australasia, Sydney NSW.

Simon, J. and Laginestra, E.(1997) Bioassay for testing sublethal toxicity in effluents, using gametes of sea urchin *Heliocidaris tuberculata*. National Pulp Mills Research Program Technical Report No. 20. CSIRO, Canberra ACT

USEPA (2002) Short-term methods for measuring the chronic toxicity of effluents and receiving waters to marine and estuarine organisms. Third Edition. United States Environmental Protection Agency, Office of Water, Washington DC, EPA-821-R-02-014.

Appendix D: Test Report for the Sea Urchin Larval Development Test

Toxicity Test Report: TR1244/2

Accredited for compliance with ISO/IEC 17025

Client:	Jacobs Group (Australia) Pty Ltd 263 Adelaide Terrace Perth WA 6001	**ESA Job #:** **Date Sampled:** **Date Received:**	PR1244 27 December 2014 27 August 2015
Attention:	Celeste Wilson	**Sampled By:**	Client
Client Ref:	Not Supplied	**ESA Quote #:**	PL1244_q03

Lab ID No.:	**Sample Name:**	**Sample Description:**
7323	Barossa Field Condensate	Condensate sample received at room temperature in apparent good condition.

Test Performed:	72-hr sea urchin larval development test using *Heliocidaris tuberculata*
Test Protocol:	ESA SOP 105 (ESA 2014), based on APHA (1998), Simon and Laginestra (1996) and Doyle *et al*. (2003)
Test Temperature:	The test was performed at 20±1°C.
Deviations from Protocol:	Nil
Comments on Solution Preparation:	Pre-weighed aliquot of condensate were added to filtered seawater (FSW) at a single loading rate of 1 part oil to 9 parts FSW. The samples were mixed for 24 hours using a magnetic stirrer so that the peak of a vortex is achieved. Following mixing, the solutions were left to settle for 1 hour, after which time the water-accommodated fractions (WAF) were siphoned off. The WAF was serially diluted with FSW to prepare the remaining test concentrations. A FSW control and a WAF control were tested concurrently with the sample. The test concentrations are expressed as loading rates and total recoverable hydrocarbon (TRH) concentrations.
Source of Test Organisms:	Field collected from South Maroubra, NSW.
Test Initiated:	10 September 2015 at 1245h

Sample 7323: *Barossa Field Condensate*

Loading Rate (g/L)	**% Normal larvae (Mean ± SD)**
FSW Control	80.8 ± 5.0
WAF Control	87.8 ± 2.2
1.2	83.0 ± 3.2
2.4	83.0 ± 5.4
4.8	84.3 ± 6.7
9.7	83.8 ± 4.8
19.3	81.0 ± 4.2
38.6	1.5 ± 1.3 *
77.2	0.0 ± 0.0

EC10 = 21.0 (18.90-22.76)g/L
EC50 = 26.5 (24.67-28.01)g/L
NOEC = 19.3g/L
LOEC = 38.6g/L

Sample 7323: *Barossa Field Condensate*

Concentration (µg/L)	**% Normal larvae (Mean ± SD)**
FSW Control	80.8 ± 5.0
WAF Control	87.8 ± 2.2
720	83.0 ± 3.2
1673	83.0 ± 5.4
3180	84.3 ± 6.7
7160	83.8 ± 4.8
14060	81.0 ± 4.2
30860	1.5 ± 1.3 *
69620	0.0 ± 0.0

EC10 = 15481.6 (13727.10-16947.80)µg/L
EC50 = 20104.40 (18575.70-21450.10)µg/L
NOEC = 14060µg/L
LOEC = 30860µg/L

*Significantly lower percentage of normally developed larvae compared with the WAF Control (Dunnett's Test, 1-tailed, P=0.05)

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Toxicity Test Report: TR1244/2

QA/QC Parameter	Criterion	This Test	Criterion met?
Control mean % normal larvae	≥70.0%	80.8%	Yes
Reference Toxicant within cusum chart limits	10.5-23.1µg Cu/L	12.2µg Cu/L	Yes

Test Report Authorised by: Dr Rick Krassoi, Director on 9 November 2015

Results are based on the samples in the condition as received by ESA.

NATA Accredited Laboratory Number: 14709

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Citations:

APHA (1998) Method 8810 D. Echinoderm Embryo Development Test. In Standard Methods for the Examination of Water and Wastewater, 20th Ed. American Public Health Association, American Water Works Association and the Water Environment Federation, USA.

Doyle, C.J., Pablo, F., Lim, R.P. and Hyne, R.V. (2003) Assessment of metal toxicity in sediment pore water from Lake Macquarie, Australia. *Arch. Environ. Contam. Toxicology*, 44(3): 343-350.

ESA (2014) *ESA SOP 105 - Sea Urchin Larval Development Test*. Issue No. 10. Ecotox Services Australasia, Sydney NSW.

Simon, J. and Laginestra, E.(1997) Bioassay for testing sublethal toxicity in effluents, using gametes of sea urchin *Heliocidaris tuberculata*. National Pulp Mills Research Program Technical Report No. 20. CSIRO, Canberra, ACT.

Appendix E: Test Report for the Milky Oyster Larval Development Test

Toxicity Test Report: TR1244/3

Accredited for compliance with ISO/IEC 17025

Client:	Jacobs Group (Australia) Pty Ltd 263 Adelaide Terrace Perth WA 6001	**ESA Job #:** **Date Sampled:** **Date Received:**	PR1244 27 December 2014 27 August 2015
Attention:	Celeste Wilson	**Sampled By:**	Client
Client Ref:	Not Supplied	**ESA Quote #:**	PL1244_q03

Lab ID No.:	Sample Name:	Sample Description:
7323	Barossa Field Condensate	Condensate sample received at room temperature in apparent good condition.

Test Performed:	48-hr larval development test using the milky oyster *Saccostrea echinata*
Test Protocol:	ESA SOP 106 (ESA 2014), based on APHA (1998) and Krassoi (1995)
Test Temperature:	The test was performed at 29±1°C.
Deviations from Protocol:	Nil
Comments on Solution Preparation:	Pre-weighed aliquot of condensate were added to filtered seawater (FSW) at a single loading rate of 1 part oil to 9 parts FSW. The samples were mixed for 24 hours using a magnetic stirrer so that the peak of a vortex is achieved. Following mixing, the solutions were left to settle for 1 hour, after which time the water-accommodated fractions (WAF) were siphoned off. The WAF was serially diluted with FSW to prepare the remaining test concentrations. A FSW control and a WAF control were tested concurrently with the sample. The test concentrations are expressed as loading rates and total recoverable hydrocarbon (TRH) concentrations
Source of Test Organisms:	Field collected from Mackay, QLD.
Test Initiated:	10 September 2015 at 1800h

Sample 7323: *Barossa Field Condensate*

Loading Rate (g/L)	% Normal larvae (Mean ± SD)
FSW Control	74.5 ± 4.8
WAF Control	72.5 ± 3.1
1.2	70.8 ± 3.6
2.4	72.5 ± 3.1
4.8	72.3 ± 4.2
9.7	73.5 ± 2.1
19.3	62.0 ± 2.2 *
38.6	0.0 ± 0.0
77.2	0.0 ± 0.0

IC10 = 15.7(11.78-18.35)g/L
EC50 = 24.7 (24.11-25.32)g/L
NOEC = 9.7g/L
LOEC = 19.3g/L

Sample 7323: *Barossa Field Condensate*

Concentration (µg/L)	% Normal larvae (Mean ± SD)
FSW Control	74.5 ± 4.8
WAF Control	72.5 ± 3.1
720	70.8 ± 3.6
1673	72.5 ± 3.1
3180	72.3 ± 4.2
7160	73.5 ± 2.1
14060	62.0 ± 2.2 *
30860	0.0 ± 0.0
69620	0.0 ± 0.0

IC10 = 11478.4 (9026.54-13230.50)µg/L
EC50 = 18747.2 (18266.80-19240.30)µg/L
NOEC = 7160µg/L
LOEC = 14060µg/L

*Significantly lower percentage of normal larvae compared with the WAF Control (Dunnett's Test, 1-tailed, P=0.05)

Toxicity Test Report: TR1244/3

QA/QC Parameter	Criterion	This Test	Criterion met?
FSW Control mean % normal	≥70%	74.5%	Yes
Reference Toxicant within cusum chart limits	10.2-20.0µg Cu/L	14.5µg Cu/L	Yes

Test Report Authorised by: Dr Rick Krassoi, Director on 9 November 2015

Results are based on the samples in the condition as received by ESA.

NATA Accredited Laboratory Number: 14709

Citations:

APHA (1998) Standard Methods for the Examination of Water and Wastewater. 20th Ed. American Public Health Association, American Water Works Association and the Water Environment Federation, Washington, DC.

ESA (2014) SOP 106 – *Bivalve Larval Development Test*. Issue No. 14. Ecotox Services Australasia, Sydney, NSW.

Krassoi, R (1995) Salinity adjustment of effluents for use with marine bioassays: effects on the larvae of the doughboy scallop Chlamys asperrimus and the Sydney rock oyster *Saccostrea commercialis*. *Australasian Journal of Ecotoxicology*, 1: 143-148.

Appendix F: Test Report for the Micro-Algal Growth Inhibition Test

Toxicity Test Report: TR1244/4

Accredited for compliance with ISO/IEC 17025

Client:	Jacobs Group (Australia) Pty Ltd 263 Adelaide Terrace Perth WA 6001	**ESA Job #:**	PR1244
		Date Sampled:	27 December 2014
		Date Received:	27 August 2015
Attention:	Celeste Wilson	**Sampled By:**	Client
Client Ref:	Not Supplied	**ESA Quote #:**	PL1244_q03

Lab ID No.:	**Sample Name:**	**Sample Description:**
7323	Barossa Field Condensate	Condensate sample received at room temperature in apparent good condition.

*NATA accreditation does not cover the performance of this service

Test Performed:	72-hr marine algal growth test using *Isochrysis aff. galbana*
Test Protocol:	ESA SOP 110 (ESA 2014), based on Stauber *et al*. (1994)
Test Temperature:	The test was performed at 29±1°C.
Deviations from Protocol:	Nil
Comments on Solution Preparation:	Pre-weighed aliquot of condensate were added to filtered seawater (FSW) at a single loading rate of 1 part oil to 9 parts FSW. The samples were mixed for 24 hours using a magnetic stirrer so that the peak of a vortex is achieved. Following mixing, the solutions were left to settle for 1 hour, after which time the water-accommodated fractions (WAF) were siphoned off. The WAF was serially diluted with FSW to prepare the remaining test concentrations. A FSW control and a WAF control were tested concurrently with the sample. The test concentrations are expressed as loading rates and total recoverable hydrocarbon (TRH) concentrations.
Source of Test Organisms:	In-house culture, originally sourced from CSIRO Microalgae Supply Service, TAS
Test Initiated:	11 September 2015 at 1110h

Sample 7323: *Barossa Field Condensate*

Loading Rate (g/L)	**Cell Yield (Mean number of cells/mL x10⁴ ± SD)**
FSW Control	20.2 ± 3.2
WAF Control	17.8 ± 1.0
1.2	18.9 ± 4.3
2.4	21.4 ± 7.3
4.8	20.8 ± 6.2
9.7	13.6 ± 5.1
19.3	1.1 ± 0.5 *
38.6	0.0 ± 0.0
77.2	0.0 ± 0.0

IC10 = 6.39 (2.18-10.68)g/L
IC50 = 12.6 (7.45-15.09)g/L
NOEC = 9.7g/L
LOEC = 19.3g/L

Sample 7323: *Barossa Field Condensate*

Concentration (µg/L)	**Cell Yield (Mean number of cells/mL x10⁴ ± SD)**
FSW Control	20.2 ± 3.2
WAF Control	17.8 ± 1.0
650	18.9 ± 4.3
1400	21.4 ± 7.3
3248	20.8 ± 6.2
6670	13.6 ± 5.1
12850	1.1 ± 0.5 *
27960	0.0 ± 0.0
65830	0.0 ± 0.0

IC10 = 4355.2 (1641.13-7401.38)µg/L
IC50 = 8529.3 (5094.77-10126.00)µg/L
NOEC = 6670µg/L
LOEC = 12850µg/L

*Significantly lower cell yield compared with the WAF Control (Steel's Many-One Rank Test, 1-tailed, P=0.05)

Toxicity Test Report: TR1244/4

QA/QC Parameter	Criterion	This Test	Criterion met?
Control mean cell density	≥16.0x10^4 cells/mL	21.2x10^4 cells/mL	Yes
Control coefficient of variation	<20%	16.0%	Yes
Reference Toxicant within cusum chart limits	15.1-46.7µg Cu/L	19.0µg Cu/L	Yes

Test Report Authorised by: Dr Rick Krassoi, Director on 9 November 2015

Results are based on the samples in the condition as received by ESA.

NATA Accredited Laboratory Number: 14709

Citations:

ESA (2014) SOP 110 – *Marine Algal Growth Test*. Issue No. 11. Ecotox Services Australasia, Sydney NSW

Stauber, J.L., Tsai, J., Vaughan, G.T., Peterson, S.M. and Brockbank, C.I. (1994) Algae as indicators of toxicity of the effluent from bleached eucalypt kraft pulp mills. National Pulp Mills Research Program, Technical Report No. 3. CSIRO, Canberra, ACT

Appendix G: Test Report for the Macro-Algal Growth Test

Toxicity Test Report: TR1244/5

Client:	Jacobs Group (Australia) Pty Ltd 263 Adelaide Terrace Perth WA 6001	**ESA Job #:**	PR1244
		Date Sampled:	27 December 2014
		Date Received:	27 August 2015
Attention:	Celeste Wilson	**Sampled By:**	Client
Client Ref:	Not Supplied	**ESA Quote #:**	PL1244_q03

Lab ID No.:	**Sample Name:**	**Sample Description:**
7323	Barossa Field Condensate	Condensate sample received at room temperature in apparent good condition.

Test Performed:	14-day macroalgal growth test using *Ecklonia radiata*
Test Protocol:	ESA SOP 116 (ESA 2010), based on Bidwell *et al*. (1998) and Burridge *et al.* (1999)
Test Temperature:	The test was performed at 18±1°C.
Deviations from Protocol:	Test extended from 72 hours to 14 days to encompass growth endpoint.
Comments on Solution Preparation:	Pre-weighed aliquot of condensate were added to filtered seawater (FSW) at a single loading rate of 1 part oil to 9 parts FSW. The samples were mixed for 24 hours using a magnetic stirrer so that the peak of a vortex is achieved. Following mixing, the solutions were left to settle for 1 hour, after which time the water-accommodated fractions (WAF) were siphoned off. The WAF was serially diluted with FSW to prepare the remaining test concentrations. A FSW control and a WAF control were tested concurrently with the sample. The test concentrations are expressed as loading rates and total recoverable hydrocarbon (TRH) concentrations.
Source of Test Organisms:	Field collected from Mercury Passage, TAS
Test Initiated:	10 September 2015 at 1400h

Sample 7323*: Barossa Field Condensate*

Loading Rate (g/L)	**Gametophyte Length, µm (Mean ± SD)**	
FSW Control	23.65 ± 1.12	
WAF Control	24.90 ± 2.80	
1.2	22.93 ± 1.35	
2.4	22.60 ± 3.28	
4.8	21.18 ± 1.14	*
9.7	18.63 ± 1.04	*
19.3	15.00 ± 0.85	*
38.6	13.78 ± 1.51	*
77.2	11.83 ± 1.11	*

14-day IC10 = 2.7g/L**
14-day IC50 = 64.8g/L**
NOEC = 2.4g/L
LOEC = 4.8g/L

Sample 7323: Barossa Field Condensate

Concentration (µg/L)	**Gametophyte Length, µm (Mean ± SD)**	
FSW Control	23.65 ± 1.12	
WAF Control	24.90 ± 2.80	
720	22.93 ± 1.35	
1673	22.60 ± 3.28	
3180	21.18 ± 1.14	*
7160	18.63 ± 1.04	*
14060	15.00 ± 0.85	*
30860	13.78 ± 1.51	*
69620	11.83 ± 1.11	*

14-day IC10 = 1873.9µg/L**
14-day IC50 = 57196.9µg/L**
NOEC = 1673µg/L
LOEC = 3180µg/L

*Significantly lower gametophyte length compared with the WAF Control (Dunnett's Test, 1-tailed, P=0.05)
**95% confidence limits are not reliable

Toxicity Test Report: TR1244/5

QA/QC Parameter	Criterion	This Test	Criterion met?
FSW Control mean % germination @ 72hrs	≥70%	90.3%	Yes
72-hr germination reference Toxicant within cusum chart limits	86.0-1262.1µg Cu/L	408.5µg Cu/L	Yes

Test Report Authorised by: Dr Rick Krassoi, Director on 9 November 2015

Results are based on the samples in the condition as received by ESA. This document shall not be reproduced except in full.

Citations:

Bidwell, J. R., Wheeler, K. W., & Burridge, T. R. (1998). Toxicant effects on the zoospore stage of the marine maroalga Ecklonia radiata (Phaeophyta:Laminariales). *Marine Ecology Progress Series.Vol 163* , 259-265.

Burridge, T. R., Karistanios, M., & Bidwell, J. (1999). The use of aquatic macrophyte ecotoxicological assays inmonitoring coastal effluent discharges in southern Australia. *Marine Pollution Bulletin. Vol 39* , 1-12.

ESA (2010) *SOP 116 – Macroalgal Germination Success Test.* Issue No. 11. Ecotox Services Australasia, Sydney NSW

Appendix H: Test Report for the Sea Anemone Development Test

Toxicity Test Report: TR1244/6

Client:	Jacobs Group (Australia) Pty Ltd 263 Adelaide Terrace Perth WA 6001	**ESA Job #:** **Date Sampled:** **Date Received:**	PR1244 27 December 2014 27 August 2015
Attention:	Celeste Wilson	**Sampled By:**	Client
Client Ref:	Not Supplied	**ESA Quote #:**	PL1244_q03

Lab ID No.:	Sample Name:	Sample Description:
7323	Barossa Field Condensate	Condensate sample received at room temperature in apparent good condition.

Test Performed:	8-day Sea anemone pedal lacerate development test using *Aiptasia pulchella*
Test Protocol:	ESA SOP 128 (ESA 2014), based on Howe *et al.* (2014)
Test Temperature:	The test was performed at 20±1°C.
Deviations from Protocol:	Three replicate were used for the sample concentrations.
Comments on Solution Preparation:	Pre-weighed aliquot of condensate were added to filtered seawater (FSW) at a single loading rate of 1 part oil to 9 parts FSW. The samples were mixed for 24 hours using a magnetic stirrer so that the peak of a vortex is achieved. Following mixing, the solutions were left to settle for 1 hour, after which time the water-accommodated fractions (WAF) were siphoned off. The WAF was serially diluted with FSW to prepare the remaining test concentrations. A FSW control and a WAF control were tested concurrently with the sample. The test concentrations are expressed as loading rates and total recoverable hydrocarbon (TRH) concentrations.
Source of Test Organisms:	In house cultures
Test Initiated:	27 October 2015 at 1130h

Sample 7323*: Barossa Field Condensate*

Loading Rate (g/L)	**% Normal (Mean ± SD)**
FSW Control	100 ± 0.0
WAF Control	95.0 ± 10.0
4.8	93.3 ± 11.6
9.7	86.7 ± 11.6
19.3	80.0 ± 20.0
38.6	73.3 ± 11.6
77.2	0.0 ± 0.0

8-day IC10 = 11.2g/L*
8-day EC50 = 40.1 (31.78-50.60)g/L
NOEC = 38.6g/L
LOEC = 77.2g/L

Sample 7323*: Barossa Field Condensate*

Concentration (µg/L)	**% Normal (Mean ± SD)**
FSW Control	100 ± 0.0
WAF Control	95.0 ± 10.0
2492	93.3 ± 11.6
7660	86.7 ± 11.6
15840	80.0 ± 20.0
28040	73.3 ± 11.6
63990	0.0 ± 0.0

8-day IC10 = 8862.4µg/L*
8-day EC50 = 30720.0 (23961.00-39385.50)µg/L
NOEC = 28040µg/L
LOEC = 63990µg/L

*95% confidence limits are not reliable

QA/QC Parameter	**Criterion**	**This Test**	**Criterion met?**
Control mean % normal pedal lacerates	≥90.0%	100%	Yes
Reference Toxicant within cusum chart limits	n/a	11.5µg Cu/L	n/a

ECOTOX Services Australasia Pty Ltd ABN>45 094 714 904
unit 27/2 chaplin drive lane cove nsw 2066 T>61 2 9420 9481 F>61 2 9420 9484 W>www.ecotox.com.au

Toxicity Test Report: TR1244/6

Test Report Authorised by: Dr Rick Krassoi, Director on 7 December 2015

Results are based on the samples in the condition as received by ESA. This document shall not be reproduced except in full.

Citations:

Cary, L.R. (1911) A study of pedal laceration in actinians. The Biological Bulletin 20, 81-107.

ESA (2014) ESA SOP 128 – *Sea Anemone Pedal Lacerate Development Test*. Issue No. 1. Ecotox Services Australasia, Sydney NSW.

Howe, Pelli L., Reichelt-Brushett, Amanda J. and Clark, Malcolm W (2014) Development of a chronic, early life-stage sub-lethal toxicity test and recovery assessment for the tropical zooxanthellate sea anemone Aiptasia pulchella. Ecotoxicology and Environmental Safety 100: 138-147.

Stauber, Jennifer L, Julie Tsai, Gary T Vaughan, Sharon M Peterson, and Christopher I Brockbank. Algae as indicators of toxicity of the effluent from bleached eucalypt kraft pulp mills. Technical Report Series No. 3. Fyshwick: National Pulp Mills Research Program, 1994.

Appendix I: Test Report for the Copepodid Development Test

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Toxicity Test Report: TR1244/7

Client:	Jacobs Group (Australia) Pty Ltd	**ESA Job #:**	PR1244
	263 Adelaide Terrace	**Date Sampled:**	27 December 2014
Perth	WA 6001	**Date Received:**	27 August 2015
Attention:	Celeste Wilson	**Sampled By:**	Client
Client Ref:	Not Supplied	**ESA Quote #:**	PL1244_q03

Lab ID No.:	Sample Name:	Sample Description:
7323 B	arossa Field Condensate	Condensate s ample re ceived at r oom t emperature in apparent g ood condition.

Test Performed:	5-day copepodid development toxicity test using the copepod *Parvocalanus crassirostris*
Test Protocol:	Based on ESA SOP 124 (2014)
Test Temperature:	The test was performed at 27±1°C.
Deviations from Protocol:	Test extended to 5 days. Copepod eggs added to test solutions at test initiation, and copepodid development counted at test termination. Test run at 28±1°C. Fed Isochrysis at a rate of 16,000 cells/copepod daily.
Comments on Solution Preparation:	Pre-weighed aliquot of c ondensate were added to filtere d s eawater (FSW) at a single loa ding rate of 1 part oil t o 9 p arts F SW. The samples were mixed for 24 hours using a magnetic stirre r so that the peak of a vortex is achieved. Following mixing, the solutions were left to settle for 1 hour, after which time the water-accommodated fractions (WAF) were siphoned off. The WAF was serially diluted with FSW to prepare the remaining test concentrations. A FSW control and a WAF c ontrol were tested concurrently with th e sample. T he test con centrations ar e expressed as loading rates and total recoverable hydrocarbon (TRH) concentrations.
Source of Test Organisms:	In house culture
Test Initiated:	22 September 2015 at 1400h

Sample 7323*: Barossa Field Condensate*

Loading Rate (g/L)	% Normal (Mean ± SD)	
FSW Control	70.0	± 10.7
WAF Control	60.0	± 16.3
4. 8	40.0	± 28.3
9. 7	50.0	± 11.6
19.3	0.0	± 0.0
38.6	0.0	± 0.0
77.2	0.0	± 0.0

IC10 = 1.0g/L*^
EC50 = 12.2 (10.84-13.73)g/L
NOEC = 9.7g/L
LOEC = 19.3g/L

Sample 7323*: Barossa Field Condensate*

Concentration (µg/L)	% Normal (Mean ± SD)	
FSW Control	70 .0	± 10.7
WAF Control	60 .0	± 16.3
38 60	40 .0	± 28.3
85 60	50 .0	± 11.6
15 830	0. 0	± 0.0
29 770	0. 0	± 0.0
68 390	0. 0	± 0.0

IC10 = 27.2µg/L*^
EC50 = 10506.9 (9451.82-11679.80)µg/L
NOEC = 8560µg/L
LOEC = 15830µg/L

%95% confidence limits are not reliable
^ Based on extrapolated data

QA/QC Parameter	Criterion	This Test	Criterion met?
Control mean % Normal	≥70.0%	70.0% Ye	s
Reference Toxicant within cusum chart limits	n/a*	2.8µg Cu/L	n/a

*Reference toxicant cusum chart limits are not available due to limited testing

Toxicity Test Report: TR1244/7

Test Report Authorised by: Dr Rick Krassoi, Director on 12 November 2015

Results are based on the samples in the condition as received by ESA.

NATA Accredited Laboratory Number: 14709

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Citations:

ESA (2014) *SOP 124 – Acute toxicity test using the copepod Gladioferens imparipes*. Issue No. 3. Ecotox Services Australasia, Sydney, New South Wales.

Appendix J: Test Report for the Fish Imbalance and Growth Test

Toxicity Test Report: TR1244/8

Client:	Jacobs Group (Australia) Pty Ltd 263 Adelaide Terrace Perth WA 6001	**ESA Job #:**	PR1244
		Date Sampled:	27 December 2014
		Date Received:	27 August 2015
Attention:	Celeste Wilson	**Sampled By:**	Client
Client Ref:	Not Supplied	**ESA Quote #:**	PL1244_q03

Lab ID No.:	**Sample Name:**	**Sample Description:**
7323 B	arossa Field Condensate	Condensate sample receive d at room tempera ture in apparent goo d condition.

Test Performed:	7-day fish imbalance and biomass toxicity test using barramundi *Lates calcarifer*
Test Protocol:	ESA SOP 122 (ESA 2012), based on USEPA (2002)
Test Temperature:	The test was performed at 25±2°C.
Deviations from Protocol:	Nil
Comments on Solution Preparation:	Pre-weighed aliquot of c ondensate were added to filtere d s eawater (FSW) at a single loa ding rate of 1 part oil t o 9 p arts F SW. The samples were mixed for 24 hours using a magnetic stirrer so that the peak of a vortex is achieved. Following mixing, the solutions were left to settle for 1 hour, after which time the water-accommodated fractions (WAF) were siphoned off. The WAF was serially diluted with FSW to prepare the remaining test concentrations. A FSW control and a WAF c ontrol were tested concurrently with th e sample. T he test con centrations ar e expressed as loading rates and total recoverable hydrocarbon (TRH) concentrations.
Source of Test Organisms:	Hatchery reared, SA
Test Initiated:	22 September 2015 at 1230h

Sample 7323*: Barossa Field Condensate*

Loading Rate (g/L)	**% Unaffected (Mean ± SD)**
FSW Control	100 ± 0.0
WAF Control	100 ± 0.0
4.8	100 ± 0.0
9.7	100 ± 0.0
19.3	90.0 ± 11.6
38.6	20.0 ± 0.0 *
77.2	0.0 ± 0.0

7 day EC10 (unaffected) = 19.4 (13.58-23.28)g/L
7 day EC50 (unaffected) = 29.3 (24.71-34.66)g/L
NOEC = 19.3g/L
LOEC = 38.6g/L

Sample 7323*: Barossa Field Condensate*

Loading Rate (g/L)	**Biomass, mg (Mean ± SD)**
FSW Control	8.3 ± 1.3
WAF Control	8.0 ± 0.8
4.8	7.7 ± 0.4
9.7	8.3 ± 0.3
19.3	7.7 ± 1.2
38.6	1.4 ± 0.2 **
77.2	0.0 ± 0.0

7 day IC10 (biomass) = 20.9 (8.44-22.09)g/L
7 day IC50 (biomass) = 30.6 (27.79-31.44)g/L
NOEC = 19.3g/L
LOEC = 38.6g/L

*Significantly lower percentage of unaffected larval fish compared with the WAF Control (Steel's Many-One Rank Test, 1-tailed, P=0.05)
**Significantly lower fish biomass compared with the WAF Control (Dunnett's Test, 1-tailed, P=0.05)

Toxicity Test Report: TR1244/8

Sample 7323*: Barossa Field Condensate*

Concentration (µg/L)	% Unaffected (Mean ± SD)			
FSW Control	100		± 0.0	
WAF Control	100		± 0.0	
3860	100		± 0.0	
8560	100		± 0.0	
1 5830	90	.0	± 11.6	
2 9770	20	.0	± 0.0	*
6 8390	0.0		± 0.0	

7 day EC10 (unaffected) = 15875.5 (11275.40-18756.60)µg/L
7 day EC50 (unaffected) = 23182.2 (19851.60-27226.80)µg/L
NOEC = 15830µg/L
LOEC = 29770µg/L

Sample 7323*: Barossa Field Condensate*

Concentration (µg/L)	Biomass, mg (Mean ± SD)		
FSW Control	8.3	± 1.3	
WAF Control	8.0	± 0.8	
3 860	7.7	± 0.4	
8 560	8.3	± 0.3	
15830	7.7	± 1.2	
29770	1.4	± 0. 2	**
68390	0.0	± 0.0	

7 day IC10 (biomass) = 17016.3 (7373.18-18757.60)µg/L
7 day IC50 (biomass) = 24006.3 (21800.80-24621.00)µg/L
NOEC = 15830µg/L
LOEC = 29770µg/L

*Significantly lower percentage of unaffected larval fish compared with the WAF Control (Steel's Many-One Rank Test, 1-tailed, P=0.05)
**Significantly lower fish biomass compared with the WAF Control (Dunnett's Test, 1-tailed, P=0.05)

Sample 7323*: Weathered Barossa Field Condensate*

Loading Rate (g/L)	% Unaffected (Mean ± SD)		
FSW Control	100		± 0.0
WAF Control	100		± 0.0
5. 0	100		± 0.0
9. 9	100		± 0.0
19.9	100		± 0.0
39.8	100		± 0.0
79.5	60	.0	± 49.0

7 day EC10 (unaffected) = 69.1g/L*
7 day EC50 (unaffected) = >79.5g/L
NOEC = 79.5g/L
LOEC = >79.5g/L

Sample 7323*: Weathered Barossa Field Condensate*

Loading Rate (g/L)	Biomass, mg (Mean ± SD)	
FSW Control	8.3	± 1.3
WAF Control	8.0	± 0.8
5.0	8.7	± 0.6
9.9	8.0	± 1.0
19 .9	8.1	± 0.3
39 .8	8.6	± 0.7
79 .5	5.0	± 3.8

7 day IC10 (biomass) = 48.6g/L*
7 day IC50 (biomass) = >79.5g/L
NOEC = 79.5g/L
LOEC = >79.5g/L

*95% confidence limits are not available

Sample 7323*: Weathered Barossa Field Condensate*

Concentration (µg/L)	% Unaffected (Mean ± SD)		
FSW Control	100		± 0.0
WAF Control	100		± 0.0
1410	100		± 0.0
2770	100		± 0.0
4850	100		± 0.0
1 1450	100		± 0.0
2 2480	60	.0	± 49.0

7 day EC10 (unaffected) = 19596.3µg/L*
7 day EC50 (unaffected) = >22480.0µg/L
NOEC = 22480µg/L
LOEC = >22480µg/L

Sample 7323*: Weathered Barossa Field Condensate*

Concentration (µg/L)	Biomass, mg (Mean ± SD)	
FSW Control	8.3	± 1.3
WAF Control	8.0	± 0.8
1 410	8.7	± 0.6
2 770	8.0	± 1.0
4 850	8.1	± 0.3
11450	8.6	± 0.7
22480	5.0	± 3.8

7 day IC10 (biomass) = 13908.1µg/L*
7 day IC50 (biomass) = >22480.0µg/L
NOEC = 22480µg/L
LOEC = >22480µg/L

*95% confidence limits are not available

Toxicity Test Report: TR1244/8

QA/QC Parameter	Criterion	This Test	Criterion met?
Control mean % unaffected	$\geq$80.0%	100% Y	es
Control mean growth	$\geq$20% of initial weight	52.6% Ye	s
Reference Toxicant within cusum chart limits	n/a	17.3mg NH_4^+/L n/a	

Test Report Authorised by: Dr Rick Krassoi, Director on 9 November 2015

Results are based on the samples in the condition as received by ESA. This document shall not be reproduced except in full.

Citations:

ESA (2012) SOP 122 – *7-day Fish Imbalance and Growth Test*. Issue No 2. Ecotox Services Australasia, Sydney, NSW

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USEPA (2002) Short-term methods for estimating the chronic toxicity of effluents and receiving waters to marine and estuarine organisms. Third edition EPA-821-R-02-014. United States Environmental Protection Agency, Office of Research and Development, Washington FC, USA

Appendix K: Statistical Analyses of the Sea Urchin Fertilisation Test

Sea Urchin Fertilisation Test-Proportion Fertilised

Start Date:	10/09/2015 11:30	Test ID:	PR1244/01	Sample ID:	Borossa Field Condensate
End Date:	10/09/2015 12:50	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 104	Test Species:	HT-Heliocidaris tuberculata
Comments:	Loading Rate				

Conc-gm/L	1	2	3	4
FSW Control	0.7600	0.7600	0.8200	0.8100
WAF Control	0.9300	0.8900	0.8700	0.9100
0.6	0.7500	0.9000	0.8500	0.8700
1.2	0.8700	0.8100	0.7900	0.8200
2.4	0.7800	0.8700	0.7500	0.8200
4.8	0.8100	0.8500	0.8100	0.7500
9.7	0.8000	0.7800	0.7900	0.8300
19.3	0.4100	0.2300	0.4200	0.3300
38.6	0.0000	0.0000	0.0000	0.0000
77.2	0.0000	0.0000	0.0000	0.0000

			Transform: Arcsin Square Root						1-Tailed		Number	Total
Conc-gm/L	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Resp	Number
FSW Control	0.7875	0.8750	1.0925	1.0588	1.1326	3.593	4					
WAF Control	0.9000	1.0000	1.2510	1.2019	1.3030	3.477	4	*			40	400
0.6	0.8425	0.9361	1.1678	1.0472	1.2490	7.389	4	1.847	2.451	0.1104	63	400
*1.2	0.8225	0.9139	1.1373	1.0948	1.2019	4.034	4	2.525	2.451	0.1104	71	400
*2.4	0.8050	0.8944	1.1161	1.0472	1.2019	6.013	4	2.996	2.451	0.1104	78	400
*4.8	0.8050	0.8944	1.1150	1.0472	1.1731	4.637	4	3.021	2.451	0.1104	78	400
*9.7	0.8000	0.8889	1.1076	1.0826	1.1458	2.473	4	3.185	2.451	0.1104	80	400
*19.3	0.3475	0.3861	0.6280	0.5002	0.7051	15.109	4	13.837	2.451	0.1104	261	400
38.6	0.0000	0.0000	0.0500	0.0500	0.0500	0.000	4				400	400
77.2	0.0000	0.0000	0.0500	0.0500	0.0500	0.000	4				400	400

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)	0.956873	0.924	-0.47569	0.016491
Bartlett's Test indicates equal variances (p = 0.50)	5.347583	16.81189		
The control means are significantly different (p = 1.65E-03)	5.407685	2.446912		

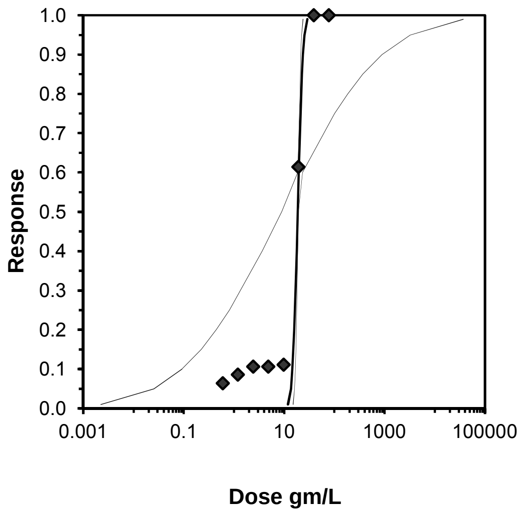
Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSDp	MSB	MSE	F-Prob	df
Dunnett's Test	0.6	1.2	0.848528		0.075077	0.083314	0.16506	0.004053	1.7E-10	6, 21
Treatments vs WAF Control										

Maximum Likelihood-Probit

Parameter	Value	SE	95% Fiducial Limits	
Slope	12.13036	5.86011	0.644542	23.61617
Intercept	-10.3891	7.536889	-25.1614	4.383164
TSCR	0.170772	0.00769	0.155699	0.185845

Control	Chi-Sq	Critical	P-value	Mu	Sigma	Iter
0.1	6.328178	12.59159	0.39	1.268647	0.082438	47

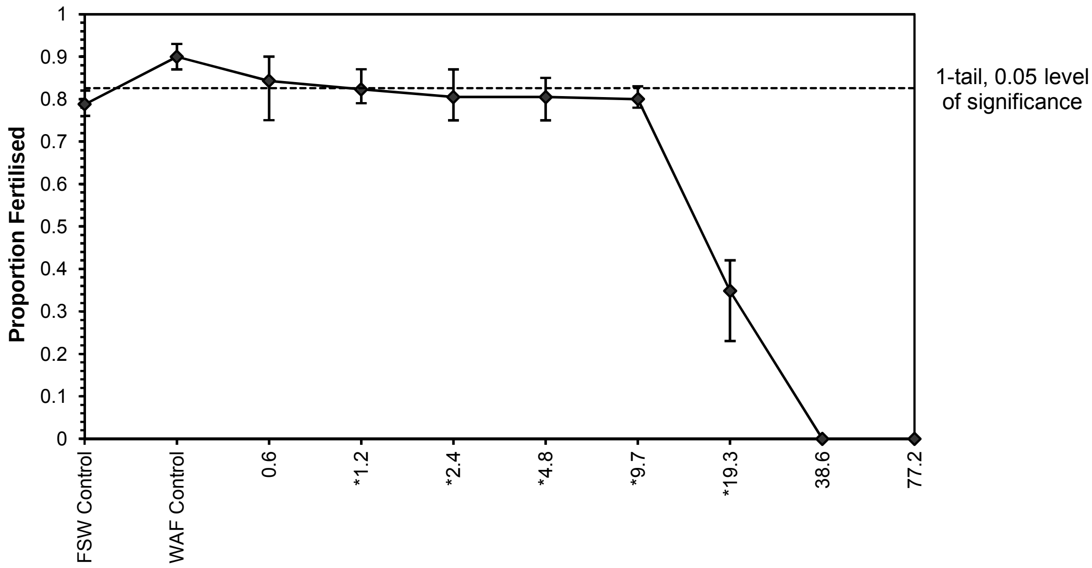
Point	Probits	gm/L	95% Fiducial Limits	
EC01	2.674	11.93624	0.002224	15.10118
EC05	3.355	13.58465	0.025375	16.14361
EC10	3.718	14.55454	0.092886	16.73032
EC15	3.964	15.24774	0.222909	17.13974
EC20	4.158	15.82214	0.446931	17.47387
EC25	4.326	16.33214	0.811669	17.76765
EC40	4.747	17.69136	3.64624	18.55218
EC50	5.000	18.56294	8.966176	19.11728
EC60	5.253	19.47745	18.64012	23.30117
EC75	5.674	21.09843	20.12496	101.2331
EC80	5.842	21.77851	20.48029	183.6966
EC85	6.036	22.59893	20.88954	368.1345
EC90	6.282	23.67527	21.40736	883.1808
EC95	6.645	25.36558	22.19035	3232.15
EC99	7.326	28.8686	23.72618	36865.22



Sea Urchin Fertilisation Test-Proportion Fertilised

Start Date:	10/09/2015 11:30	Test ID:	PR1244/01	Sample ID:	Borossa Field Condensate
End Date:	10/09/2015 12:50	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 104	Test Species:	HT-Heliocidaris tuberculata
Comments:	Loading Rate				

Dose-Response Plot



 ToxCalc v5.0.23 Reviewed by:_____

Sea Urchin Fertilisation Test-Proportion Fertilised					
Start Date:	10/09/2015 11:30	Test ID:	PR1244/01	Sample ID:	Borossa Field Condensate
End Date:	10/09/2015 12:50	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 104	Test Species:	HT-Heliocidaris tuberculata
Comments:	Loading Rate				

		Auxiliary Data Summary					
Conc-gm/L	**Parameter**	**Mean**	**Min**	**Max**	**SD**	**CV%**	**N**
FSW Control	% Fertilised	78.75	76.00	82.00	3.20	2.27	4
WAF Control		90.00	87.00	93.00	2.58	1.79	4
0.6		84.25	75.00	90.00	6.50	3.03	4
1.2		82.25	79.00	87.00	3.40	2.24	4
2.4		80.50	75.00	87.00	5.20	2.83	4
4.8		80.50	75.00	85.00	4.12	2.52	4
9.7		80.00	78.00	83.00	2.16	1.84	4
19.3		34.75	23.00	42.00	8.81	8.54	4
38.6		0.00	0.00	0.00	0.00		4
77.2		0.00	0.00	0.00	0.00		4
FSW Control	pH	8.10	8.10	8.10	0.00	0.00	1
WAF Control		8.10	8.10	8.10	0.00	0.00	1
0.6		8.10	8.10	8.10	0.00	0.00	1
1.2		8.10	8.10	8.10	0.00	0.00	1
2.4		8.10	8.10	8.10	0.00	0.00	1
4.8		8.10	8.10	8.10	0.00	0.00	1
9.7		8.00	8.00	8.00	0.00	0.00	1
19.3		7.90	7.90	7.90	0.00	0.00	1
38.6		7.70	7.70	7.70	0.00	0.00	1
77.2		7.40	7.40	7.40	0.00	0.00	1
FSW Control	Salinity ppt	35.40	35.40	35.40	0.00	0.00	1
WAF Control		35.60	35.60	35.60	0.00	0.00	1
0.6		35.40	35.40	35.40	0.00	0.00	1
1.2		35.40	35.40	35.40	0.00	0.00	1
2.4		35.40	35.40	35.40	0.00	0.00	1
4.8		35.40	35.40	35.40	0.00	0.00	1
9.7		35.50	35.50	35.50	0.00	0.00	1
19.3		35.50	35.50	35.50	0.00	0.00	1
38.6		35.60	35.60	35.60	0.00	0.00	1
77.2		35.80	35.80	35.80	0.00	0.00	1
FSW Control	DO %	100.20	100.20	100.20	0.00	0.00	1
WAF Control		100.90	100.90	100.90	0.00	0.00	1
0.6		100.00	100.00	100.00	0.00	0.00	1
1.2		99.60	99.60	99.60	0.00	0.00	1
2.4		91.80	91.80	91.80	0.00	0.00	1
4.8		96.10	96.10	96.10	0.00	0.00	1
9.7		98.70	98.70	98.70	0.00	0.00	1
19.3		90.10	90.10	90.10	0.00	0.00	1
38.6		90.20	90.20	90.20	0.00	0.00	1
77.2		87.20	87.20	87.20	0.00	0.00	1

Sea Urchin Fertilisation Test-Proportion Fertilised

Start Date:	10/09/2015 11:30	Test ID:	PR1244/01b	Sample ID:	Borossa Field Condensate
End Date:	10/09/2015 12:50	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 104	Test Species:	HT-Heliocidaris tuberculata
Comments:	TRH				

Conc-ug/L	1	2	3	4
FSW Control	0.7600	0.7600	0.8200	0.8100
WAF Control	0.9300	0.8900	0.8700	0.9100
350	0.7500	0.9000	0.8500	0.8700
720	0.8700	0.8100	0.7900	0.8200
1673	0.7800	0.8700	0.7500	0.8200
3180	0.8100	0.8500	0.8100	0.7500
7160	0.8000	0.7800	0.7900	0.8300
14060	0.4100	0.2300	0.4200	0.3300
30860	0.0000	0.0000	0.0000	0.0000
69620	0.0000	0.0000	0.0000	0.0000

			Transform: Arcsin Square Root						1-Tailed		Number	Total
Conc-ug/L	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Resp	Number
FSW Control	0.7875	0.8750	1.0925	1.0588	1.1326	3.593	4					
WAF Control	0.9000	1.0000	1.2510	1.2019	1.3030	3.477	4	*			40	400
350	0.8425	0.9361	1.1678	1.0472	1.2490	7.389	4	1.847	2.451	0.1104	63	400
*720	0.8225	0.9139	1.1373	1.0948	1.2019	4.034	4	2.525	2.451	0.1104	71	400
*1673	0.8050	0.8944	1.1161	1.0472	1.2019	6.013	4	2.996	2.451	0.1104	78	400
*3180	0.8050	0.8944	1.1150	1.0472	1.1731	4.637	4	3.021	2.451	0.1104	78	400
*7160	0.8000	0.8889	1.1076	1.0826	1.1458	2.473	4	3.185	2.451	0.1104	80	400
*14060	0.3475	0.3861	0.6280	0.5002	0.7051	15.109	4	13.837	2.451	0.1104	261	400
30860	0.0000	0.0000	0.0500	0.0500	0.0500	0.000	4				400	400
69620	0.0000	0.0000	0.0500	0.0500	0.0500	0.000	4				400	400

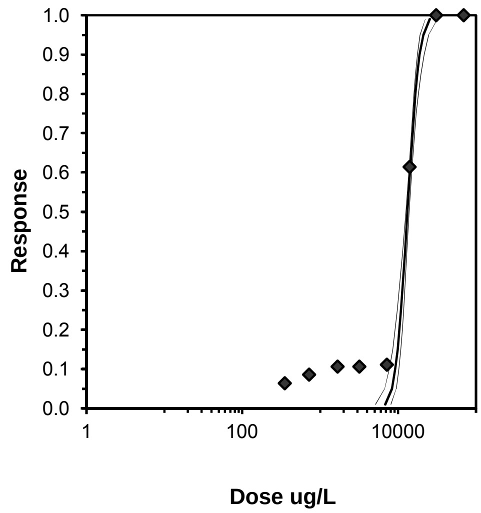
Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)	0.956873	0.924	-0.47569	0.016491
Bartlett's Test indicates equal variances (p = 0.50)	5.347583	16.81189		
The control means are significantly different (p = 1.65E-03)	5.407685	2.446912		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSDp	MSB	MSE	F-Prob	df
Dunnett's Test	350	720	501.996		0.075077	0.083314	0.16506	0.004053	1.7E-10	6, 21
Treatments vs WAF Control										

Maximum Likelihood-Probit

Parameter	Value	SE	95% Fiducial Limits		Control	Chi-Sq	Critical	P-value	Mu	Sigma	Iter
Slope	8.184476	1.175402	5.880688	10.48826	0.1	6.111686	12.59159	0.41	4.120661	0.122183	15
Intercept	-28.7255	4.881007	-38.2922	-19.1587							
TSCR	0.168365	0.007944	0.152795	0.183936							

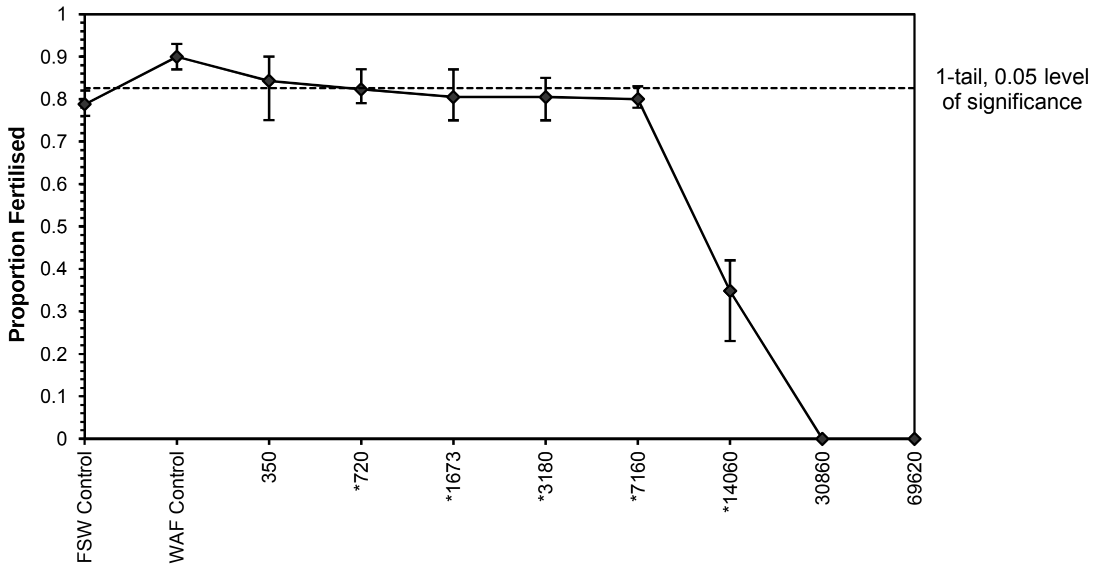
Point	Probits	ug/L	95% Fiducial Limits	
EC01	2.674	6861.551	5129.257	8091.332
EC05	3.355	8311.683	6688.936	9409.815
EC10	3.718	9206.152	7702.422	10203.02
EC15	3.964	9863.415	8468.76	10779.25
EC20	4.158	10419.09	9128.97	11263.89
EC25	4.326	10920.7	9732.943	11700.96
EC40	4.747	12294.38	11406.6	12914.51
EC50	5.000	13202.66	12495.25	13763.39
EC60	5.253	14178.03	13586.08	14777.9
EC75	5.674	15961.44	15266.99	17010.68
EC80	5.842	16729.88	15906.41	18082.49
EC85	6.036	17672.39	16656.57	19451.22
EC90	6.282	18934.09	17624.56	21353.38
EC95	6.645	20971.7	19133.71	24558.6
EC99	7.326	25403.9	22273.69	31994.42



Sea Urchin Fertilisation Test-Proportion Fertilised

Start Date:	10/09/2015 11:30	Test ID:	PR1244/01b	Sample ID:	Borossa Field Condensate
End Date:	10/09/2015 12:50	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 104	Test Species:	HT-Heliocidaris tuberculata
Comments:	TRH				

Dose-Response Plot



 ToxCalc v5.0.23 Reviewed by:_____

Sea Urchin Fertilisation Test-Proportion Fertilised

Start Date:	10/09/2015 11:30	Test ID:	PR1244/01b	Sample ID:	Borossa Field Condensate
End Date:	10/09/2015 12:50	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 104	Test Species:	HT-Heliocidaris tuberculata
Comments:	TRH				

Conc-ug/L	Parameter	Mean	Min	Max	SD	CV%	N
		Auxiliary Data Summary					
FSW Control	% Fertilised	78.75	76.00	82.00	3.20	2.27	4
WAF Control		90.00	87.00	93.00	2.58	1.79	4
350		84.25	75.00	90.00	6.50	3.03	4
720		82.25	79.00	87.00	3.40	2.24	4
1673		80.50	75.00	87.00	5.20	2.83	4
3180		80.50	75.00	85.00	4.12	2.52	4
7160		80.00	78.00	83.00	2.16	1.84	4
14060		34.75	23.00	42.00	8.81	8.54	4
30860		0.00	0.00	0.00	0.00		4
69620		0.00	0.00	0.00	0.00		4
FSW Control	pH	8.10	8.10	8.10	0.00	0.00	1
WAF Control		8.10	8.10	8.10	0.00	0.00	1
350		8.10	8.10	8.10	0.00	0.00	1
720		8.10	8.10	8.10	0.00	0.00	1
1673		8.10	8.10	8.10	0.00	0.00	1
3180		8.10	8.10	8.10	0.00	0.00	1
7160		8.00	8.00	8.00	0.00	0.00	1
14060		7.90	7.90	7.90	0.00	0.00	1
30860		7.70	7.70	7.70	0.00	0.00	1
69620		7.40	7.40	7.40	0.00	0.00	1
FSW Control	Salinity ppt	35.40	35.40	35.40	0.00	0.00	1
WAF Control		35.60	35.60	35.60	0.00	0.00	1
350		35.40	35.40	35.40	0.00	0.00	1
720		35.40	35.40	35.40	0.00	0.00	1
1673		35.40	35.40	35.40	0.00	0.00	1
3180		35.40	35.40	35.40	0.00	0.00	1
7160		35.50	35.50	35.50	0.00	0.00	1
14060		35.50	35.50	35.50	0.00	0.00	1
30860		35.60	35.60	35.60	0.00	0.00	1
69620		35.80	35.80	35.80	0.00	0.00	1
FSW Control	DO %	100.20	100.20	100.20	0.00	0.00	1
WAF Control		100.90	100.90	100.90	0.00	0.00	1
350		100.00	100.00	100.00	0.00	0.00	1
720		99.60	99.60	99.60	0.00	0.00	1
1673		91.80	91.80	91.80	0.00	0.00	1
3180		96.10	96.10	96.10	0.00	0.00	1
7160		98.70	98.70	98.70	0.00	0.00	1
14060		90.10	90.10	90.10	0.00	0.00	1
30860		90.20	90.20	90.20	0.00	0.00	1
69620		87.20	87.20	87.20	0.00	0.00	1

Appendix L: Statistical Analyses of the Sea Urchin Larval Development Test

Sea Urchin Larval Development Test-Proportion Normal

Start Date:	10/09/2015 12:45	Test ID:	PR1244/02	Sample ID:	Borossa Field Condensate
End Date:	13/09/2015 12:45	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 105	Test Species:	HT-Heliocidaris tuberculata
Comments:	Loading Rate				

Conc-gm/L	1	2	3	4
FSW Control	0.8600	0.8400	0.7600	0.7700
WAF Control	0.9000	0.8700	0.8500	0.8900
1.2	0.8500	0.8600	0.8200	0.7900
2.4	0.7800	0.7900	0.8600	0.8900
4.8	0.9100	0.7500	0.8500	0.8600
9.7	0.8900	0.8600	0.7800	0.8200
19.3	0.8400	0.8400	0.8100	0.7500
38.6	0.0200	0.0300	0.0000	0.0100
77.2	0.0000	0.0000	0.0000	0.0000

			Transform: Arcsin Square Root						1-Tailed		Number	Total
Conc-gm/L	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Resp	Number
FSW Control	0.8075	0.9202	1.1190	1.0588	1.1873	5.710	4					
WAF Control	0.8775	1.0000	1.2142	1.1731	1.2490	2.772	4	*			49	400
1.2	0.8300	0.9459	1.1470	1.0948	1.1873	3.644	4	1.552	2.451	0.1062	68	400
2.4	0.8300	0.9459	1.1493	1.0826	1.2327	6.320	4	1.497	2.451	0.1062	68	400
4.8	0.8425	0.9601	1.1684	1.0472	1.2661	7.752	4	1.056	2.451	0.1062	63	400
9.7	0.8375	0.9544	1.1588	1.0826	1.2327	5.630	4	1.278	2.451	0.1062	65	400
19.3	0.8100	0.9231	1.1214	1.0472	1.1593	4.713	4	2.142	2.451	0.1062	76	400
*38.6	0.0150	0.0171	0.1165	0.0500	0.1741	46.067	4	25.329	2.451	0.1062	394	400
77.2	0.0000	0.0000	0.0500	0.0500	0.0500	0.000	4				400	400

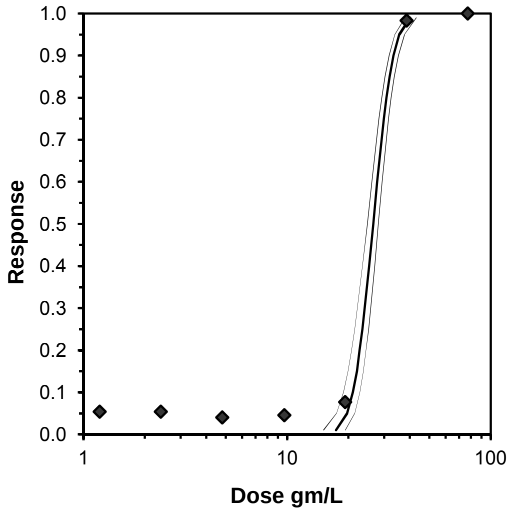
Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)	0.9702	0.924	-0.29751	-0.48312
Bartlett's Test indicates equal variances (p = 0.76)	3.405559	16.81189		
The control means are significantly different (p = 0.04)	2.636326	2.446912		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSDp	MSB	MSE	F-Prob	df
Dunnett's Test	19.3	38.6	27.29432		0.077486	0.088239	0.62519	0.003756	1.4E-16	6, 21
Treatments vs WAF Control										

Maximum Likelihood-Probit

Parameter	Value	SE	95% Fiducial Limits		Control	Chi-Sq	Critical	P-value	Mu	Sigma	Iter
Slope	12.80885	1.109446	10.63434	14.98337	0.1225	1.216596	11.0705	0.94	1.422494	0.078071	8
Intercept	-13.2205	1.676767	-16.507	-9.93405							
TSCR	0.1565	0.008124	0.140576	0.172424							

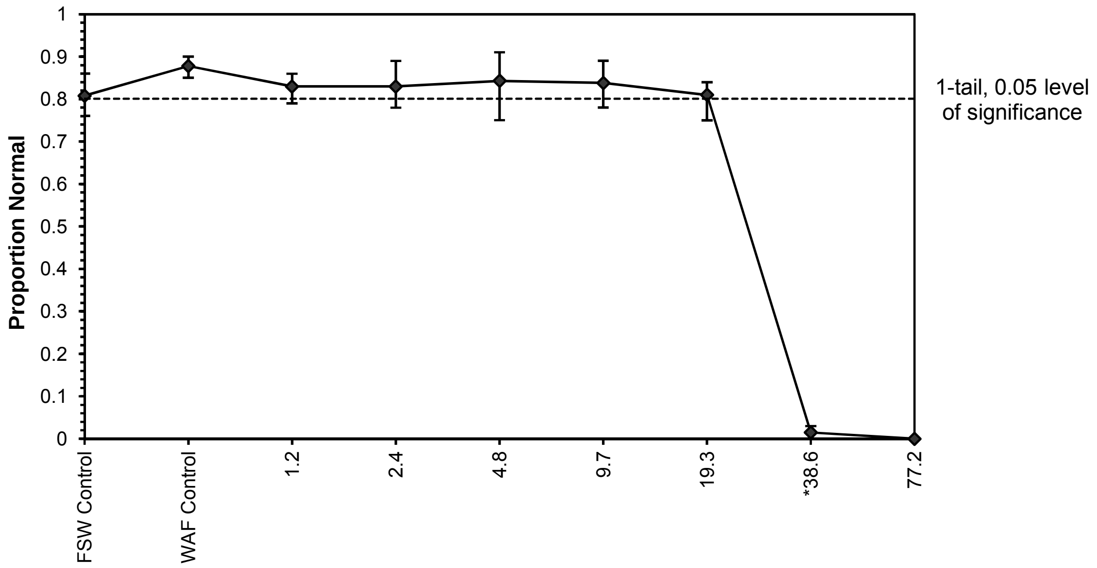
Point	Probits	gm/L	95% Fiducial Limits	
EC01	2.674	17.41299	15.13301	19.30053
EC05	3.355	19.68241	17.49698	21.48321
EC10	3.718	21.01075	18.89652	22.75572
EC15	3.964	21.95726	19.89879	23.66218
EC20	4.158	22.73984	20.7296	24.41245
EC25	4.326	23.43341	21.46688	25.07866
EC40	4.747	25.27636	23.42552	26.85922
EC50	5.000	26.45414	24.67237	28.00939
EC60	5.253	27.68679	25.96848	29.22808
EC75	5.674	29.86425	28.22241	31.43128
EC80	5.842	30.77512	29.14738	32.37631
EC85	6.036	31.87198	30.24463	33.53511
EC90	6.282	33.30777	31.65174	35.08805
EC95	6.645	35.55568	33.78822	37.6012
EC99	7.326	40.18962	37.97549	43.05577



Sea Urchin Larval Development Test-Proportion Normal

Start Date:	10/09/2015 12:45	Test ID:	PR1244/02	Sample ID:	Borossa Field Condensate
End Date:	13/09/2015 12:45	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 105	Test Species:	HT-Heliocidaris tuberculata
Comments:	Loading Rate				

Dose-Response Plot



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Sea Urchin Larval Development Test-Proportion Normal

Start Date:	10/09/2015 12:45	Test ID:	PR1244/02	Sample ID:	Borossa Field Condensate
End Date:	13/09/2015 12:45	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 105	Test Species:	HT-Heliocidaris tuberculata
Comments:	Loading Rate				

		Auxiliary Data Summary					
Conc-gm/L	**Parameter**	**Mean**	**Min**	**Max**	**SD**	**CV%**	**N**
FSW Control	% Normal	80.75	76.00	86.00	4.99	2.77	4
WAF Control		87.75	85.00	90.00	2.22	1.70	4
1.2		83.00	79.00	86.00	3.16	2.14	4
2.4		83.00	78.00	89.00	5.35	2.79	4
4.8		84.25	75.00	91.00	6.70	3.07	4
9.7		83.75	78.00	89.00	4.79	2.61	4
19.3		81.00	75.00	84.00	4.24	2.54	4
38.6		1.50	0.00	3.00	1.29	75.75	4
77.2		0.00	0.00	0.00	0.00		4
FSW Control	pH	8.10	8.10	8.10	0.00	0.00	1
WAF Control		8.10	8.10	8.10	0.00	0.00	1
1.2		8.10	8.10	8.10	0.00	0.00	1
2.4		8.10	8.10	8.10	0.00	0.00	1
4.8		8.10	8.10	8.10	0.00	0.00	1
9.7		8.00	8.00	8.00	0.00	0.00	1
19.3		7.90	7.90	7.90	0.00	0.00	1
38.6		7.70	7.70	7.70	0.00	0.00	1
77.2		7.40	7.40	7.40	0.00	0.00	1
FSW Control	Salinity ppt	35.40	35.40	35.40	0.00	0.00	1
WAF Control		35.60	35.60	35.60	0.00	0.00	1
1.2		35.40	35.40	35.40	0.00	0.00	1
2.4		35.40	35.40	35.40	0.00	0.00	1
4.8		35.40	35.40	35.40	0.00	0.00	1
9.7		35.50	35.50	35.50	0.00	0.00	1
19.3		35.50	35.50	35.50	0.00	0.00	1
38.6		35.60	35.60	35.60	0.00	0.00	1
77.2		35.80	35.80	35.80	0.00	0.00	1
FSW Control	DO %	100.20	100.20	100.20	0.00	0.00	1
WAF Control		100.90	100.90	100.90	0.00	0.00	1
1.2		99.60	99.60	99.60	0.00	0.00	1
2.4		91.80	91.80	91.80	0.00	0.00	1
4.8		96.10	96.10	96.10	0.00	0.00	1
9.7		98.70	98.70	98.70	0.00	0.00	1
19.3		90.10	90.10	90.10	0.00	0.00	1
38.6		90.20	90.20	90.20	0.00	0.00	1
77.2		87.20	87.20	87.20	0.00	0.00	1

Sea Urchin Larval Development Test-Proportion Normal

Start Date:	10/09/2015 12:45	Test ID:	PR1244/02b	Sample ID:	Borossa Field Condensate
End Date:	13/09/2015 12:45	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 105	Test Species:	HT-Heliocidaris tuberculata
Comments:	TRH				

Conc-ug/L	1	2	3	4
FSW Control	0.8600	0.8400	0.7600	0.7700
WAF Control	0.9000	0.8700	0.8500	0.8900
720	0.8500	0.8600	0.8200	0.7900
1673	0.7800	0.7900	0.8600	0.8900
3180	0.9100	0.7500	0.8500	0.8600
7160	0.8900	0.8600	0.7800	0.8200
14060	0.8400	0.8400	0.8100	0.7500
30860	0.0200	0.0300	0.0000	0.0100
69620	0.0000	0.0000	0.0000	0.0000

			Transform: Arcsin Square Root						1-Tailed		Number	Total
Conc-ug/L	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Resp	Number
FSW Control	0.8075	0.9202	1.1190	1.0588	1.1873	5.710	4					
WAF Control	0.8775	1.0000	1.2142	1.1731	1.2490	2.772	4	*			49	400
720	0.8300	0.9459	1.1470	1.0948	1.1873	3.644	4	1.552	2.451	0.1062	68	400
1673	0.8300	0.9459	1.1493	1.0826	1.2327	6.320	4	1.497	2.451	0.1062	68	400
3180	0.8425	0.9601	1.1684	1.0472	1.2661	7.752	4	1.056	2.451	0.1062	63	400
7160	0.8375	0.9544	1.1588	1.0826	1.2327	5.630	4	1.278	2.451	0.1062	65	400
14060	0.8100	0.9231	1.1214	1.0472	1.1593	4.713	4	2.142	2.451	0.1062	76	400
*30860	0.0150	0.0171	0.1165	0.0500	0.1741	46.067	4	25.329	2.451	0.1062	394	400
69620	0.0000	0.0000	0.0500	0.0500	0.0500	0.000	4				400	400

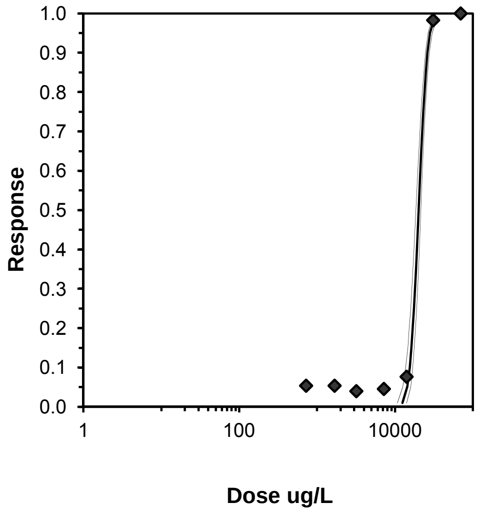
Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)	0.9702	0.924	-0.29751	-0.48312
Bartlett's Test indicates equal variances (p = 0.76)	3.405559	16.81189		
The control means are significantly different (p = 0.04)	2.636326	2.446912		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSDp	MSB	MSE	F-Prob	df
Dunnett's Test	14060	30860	20830.06		0.077486	0.088239	0.62519	0.003756	1.4E-16	6, 21
Treatments vs WAF Control										

Maximum Likelihood-Probit

Parameter	Value	SE	95% Fiducial Limits		Control	Chi-Sq	Critical	P-value	Mu	Sigma	Iter
Slope	11.29387	0.978228	9.376539	13.21119	0.1225	1.216603	11.0705	0.94	4.30329	0.088544	8
Intercept	-43.6008	4.30439	-52.0374	-35.1642							
TSCR	0.1565	0.008124	0.140576	0.172424							

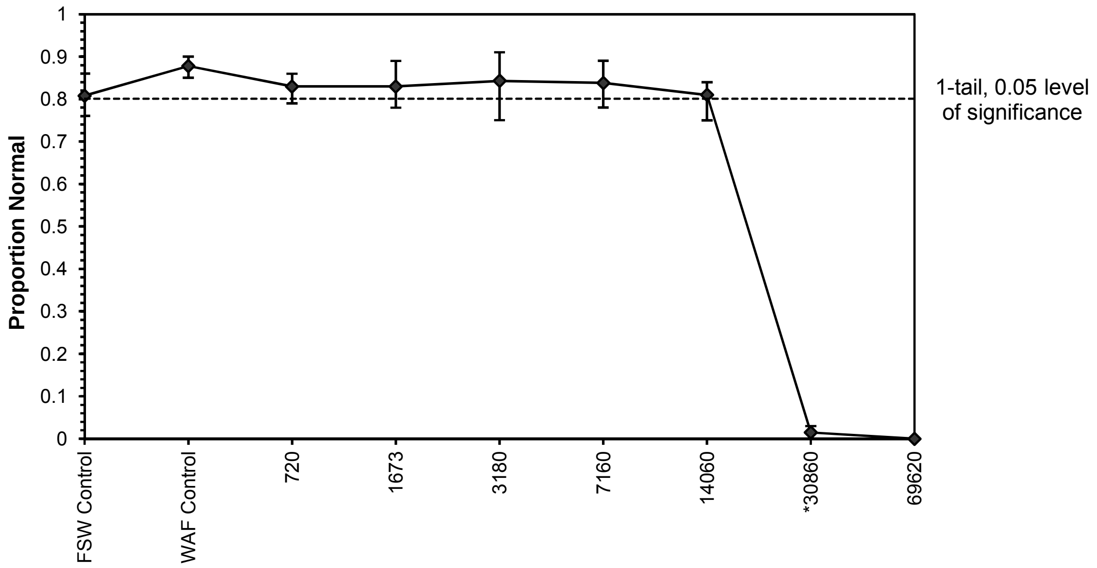
Point	Probits	ug/L	95% Fiducial Limits	
EC01	2.674	12511.43	10670.46	14060.43
EC05	3.355	14376.36	12579.9	15877.06
EC10	3.718	15481.64	13727.1	16947.82
EC15	3.964	16274.99	14555.74	17715.52
EC20	4.158	16934.41	15246.91	18353.93
EC25	4.326	17521.39	15863.37	18923.02
EC40	4.747	19092.29	17514.7	20453.87
EC50	5.000	20104.36	18575.71	21450.06
EC60	5.253	21170.08	19686.28	22511.6
EC75	5.674	23068.11	21635.17	24445.67
EC80	5.842	23867.7	22441.11	25280.93
EC85	6.036	24834.76	23401.61	26309.6
EC90	6.282	26107.39	24640.21	27695.61
EC95	6.645	28114.58	26534.89	29955.98
EC99	7.326	32305.29	30294.34	34930.5



Sea Urchin Larval Development Test-Proportion Normal

Start Date:	10/09/2015 12:45	Test ID:	PR1244/02b	Sample ID:	Borossa Field Condensate
End Date:	13/09/2015 12:45	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 105	Test Species:	HT-Heliocidaris tuberculata
Comments:	TRH				

Dose-Response Plot



 ToxCalc v5.0.23 Reviewed by:_____

Sea Urchin Larval Development Test-Proportion Normal

Start Date:	10/09/2015 12:45	Test ID:	PR1244/02b	Sample ID:	Borossa Field Condensate
End Date:	13/09/2015 12:45	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 105	Test Species:	HT-Heliocidaris tuberculata
Comments:	TRH				

		Auxiliary Data Summary					
Conc-ug/L	**Parameter**	**Mean**	**Min**	**Max**	**SD**	**CV%**	**N**
FSW Control	% Normal	80.75	76.00	86.00	4.99	2.77	4
WAF Control		87.75	85.00	90.00	2.22	1.70	4
720		83.00	79.00	86.00	3.16	2.14	4
1673		83.00	78.00	89.00	5.35	2.79	4
3180		84.25	75.00	91.00	6.70	3.07	4
7160		83.75	78.00	89.00	4.79	2.61	4
14060		81.00	75.00	84.00	4.24	2.54	4
30860		1.50	0.00	3.00	1.29	75.75	4
69620		0.00	0.00	0.00	0.00		4
FSW Control	pH	8.10	8.10	8.10	0.00	0.00	1
WAF Control		8.10	8.10	8.10	0.00	0.00	1
720		8.10	8.10	8.10	0.00	0.00	1
1673		8.10	8.10	8.10	0.00	0.00	1
3180		8.10	8.10	8.10	0.00	0.00	1
7160		8.00	8.00	8.00	0.00	0.00	1
14060		7.90	7.90	7.90	0.00	0.00	1
30860		7.70	7.70	7.70	0.00	0.00	1
69620		7.40	7.40	7.40	0.00	0.00	1
FSW Control	Salinity ppt	35.40	35.40	35.40	0.00	0.00	1
WAF Control		35.60	35.60	35.60	0.00	0.00	1
720		35.40	35.40	35.40	0.00	0.00	1
1673		35.40	35.40	35.40	0.00	0.00	1
3180		35.40	35.40	35.40	0.00	0.00	1
7160		35.50	35.50	35.50	0.00	0.00	1
14060		35.50	35.50	35.50	0.00	0.00	1
30860		35.60	35.60	35.60	0.00	0.00	1
69620		35.80	35.80	35.80	0.00	0.00	1
FSW Control	DO %	100.20	100.20	100.20	0.00	0.00	1
WAF Control		100.90	100.90	100.90	0.00	0.00	1
720		99.60	99.60	99.60	0.00	0.00	1
1673		91.80	91.80	91.80	0.00	0.00	1
3180		96.10	96.10	96.10	0.00	0.00	1
7160		98.70	98.70	98.70	0.00	0.00	1
14060		90.10	90.10	90.10	0.00	0.00	1
30860		90.20	90.20	90.20	0.00	0.00	1
69620		87.20	87.20	87.20	0.00	0.00	1

Appendix M: Statistical Analyses of the Milky Oyster Larval Development Test

Bivalve Larval Development Test-Proportion Normal

Start Date:	10/09/2015 18:00	Test ID:	PR1244/04	Sample ID:	Borossa Field Condensate
End Date:	12/09/2015 16:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 106	Test Species:	SE-Saccostrea echinata
Comments:	Loading Rate				

Conc-gm/L	1	2	3	4
FSW Control	0.7200	0.7900	0.7800	0.6900
WAF Control	0.6800	0.7300	0.7400	0.7500
1.2	0.7600	0.7000	0.6800	0.6900
2.4	0.6900	0.7400	0.7100	0.7600
4.8	0.7800	0.7200	0.6800	0.7100
9.7	0.7100	0.7600	0.7400	0.7300
19.3	0.6300	0.5900	0.6400	0.6200
38.6	0.0000	0.0000	0.0000	0.0000
77.2	0.0000	0.0000	0.0000	0.0000

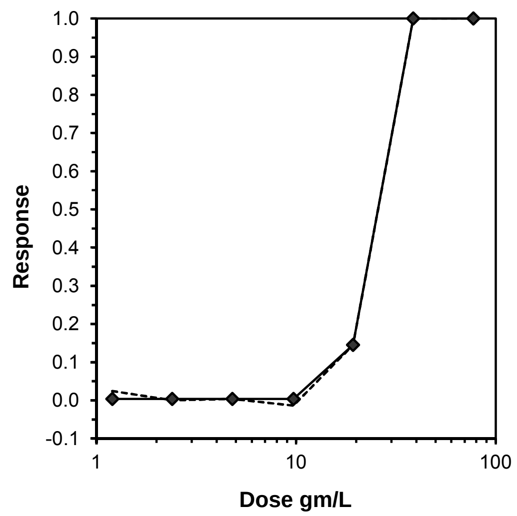
			Transform: Arcsin Square Root						1-Tailed		Number	Total
Conc-gm/L	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Resp	Number
FSW Control	0.7450	1.0276	1.0427	0.9803	1.0948	5.272	4					
WAF Control	0.7250	1.0000	1.0192	0.9695	1.0472	3.376	4	*			110	400
1.2	0.7075	0.9759	1.0000	0.9695	1.0588	4.023	4	0.779	2.410	0.0596	117	400
2.4	0.7250	1.0000	1.0192	0.9803	1.0588	3.421	4	-0.001	2.410	0.0596	110	400
4.8	0.7225	0.9966	1.0169	0.9695	1.0826	4.679	4	0.095	2.410	0.0596	111	400
9.7	0.7350	1.0138	1.0303	1.0021	1.0588	2.291	4	-0.447	2.410	0.0596	106	400
*19.3	0.6200	0.8552	0.9067	0.8759	0.9273	2.448	4	4.553	2.410	0.0596	152	400
38.6	0.0000	0.0000	0.0500	0.0500	0.0500	0.000	4				400	400
77.2	0.0000	0.0000	0.0500	0.0500	0.0500	0.000	4				400	400

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)	0.974316	0.916	0.369425	-0.29632
Bartlett's Test indicates equal variances (p = 0.82)	2.211731	15.08627		
The control means are not significantly different (p = 0.50)	0.724702	2.446912		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSDp	MSB	MSE	F-Prob	df
Dunnett's Test	9.7	19.3	13.68247		0.054646	0.075334	0.008512	0.001222	8.8E-04	5, 18
Treatments vs WAF Control										

Trimmed Spearman-Karber

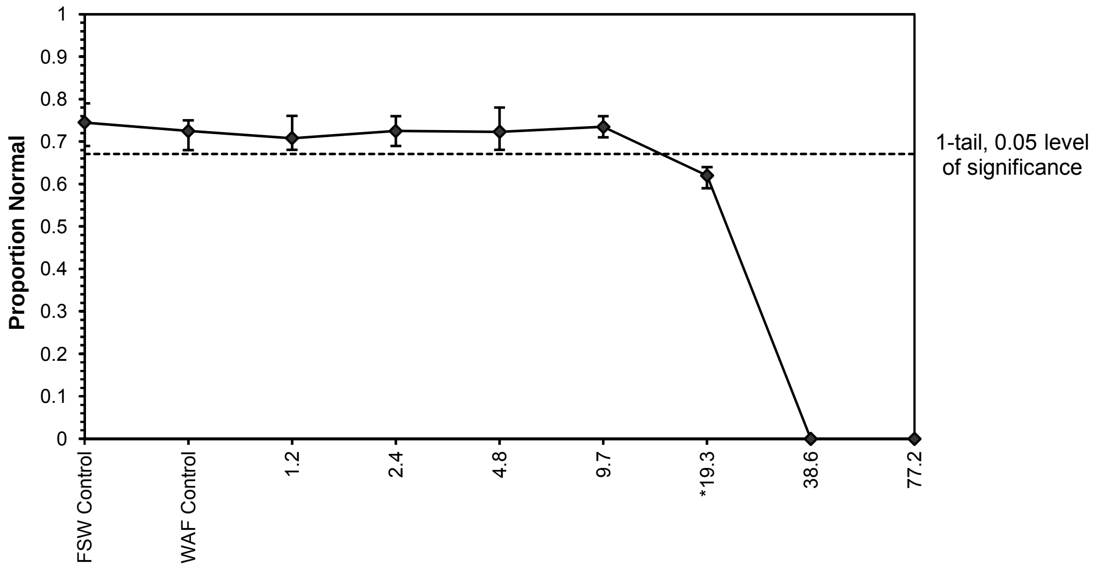
Trim Level	EC50	95% CL	
0.0%			
5.0%	25.222	24.515	25.950
10.0%	25.608	24.672	26.579
20.0%	25.738	25.313	26.171
Auto-0.3%	24.709	24.110	25.323



Bivalve Larval Development Test-Proportion Normal

Start Date:	10/09/2015 18:00	Test ID:	PR1244/04	Sample ID:	Borossa Field Condensate
End Date:	12/09/2015 16:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 106	Test Species:	SE-Saccostrea echinata
Comments:	Loading Rate				

Dose-Response Plot



Bivalve Larval Development Test-Proportion Normal

Start Date:	10/09/2015 18:00	Test ID:	PR1244/04	Sample ID:	Borossa Field Condensate
End Date:	12/09/2015 16:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 106	Test Species:	SE-Saccostrea echinata
Comments:	Loading Rate				

		Auxiliary Data Summary					
Conc-gm/L	**Parameter**	**Mean**	**Min**	**Max**	**SD**	**CV%**	**N**
FSW Control	% Normal	74.50	69.00	79.00	4.80	2.94	4
WAF Control		72.50	68.00	75.00	3.11	2.43	4
1.2		70.75	68.00	76.00	3.59	2.68	4
2.4		72.50	69.00	76.00	3.11	2.43	4
4.8		72.25	68.00	78.00	4.19	2.83	4
9.7		73.50	71.00	76.00	2.08	1.96	4
19.3		62.00	59.00	64.00	2.16	2.37	4
38.6		0.00	0.00	0.00	0.00		4
77.2		0.00	0.00	0.00	0.00		4
FSW Control	pH	8.10	8.10	8.10	0.00	0.00	1
WAF Control		8.10	8.10	8.10	0.00	0.00	1
1.2		8.10	8.10	8.10	0.00	0.00	1
2.4		8.10	8.10	8.10	0.00	0.00	1
4.8		8.10	8.10	8.10	0.00	0.00	1
9.7		8.00	8.00	8.00	0.00	0.00	1
19.3		7.90	7.90	7.90	0.00	0.00	1
38.6		7.70	7.70	7.70	0.00	0.00	1
77.2		7.40	7.40	7.40	0.00	0.00	1
FSW Control	Salinity ppt	35.40	35.40	35.40	0.00	0.00	1
WAF Control		35.60	35.60	35.60	0.00	0.00	1
1.2		35.40	35.40	35.40	0.00	0.00	1
2.4		35.40	35.40	35.40	0.00	0.00	1
4.8		35.40	35.40	35.40	0.00	0.00	1
9.7		35.50	35.50	35.50	0.00	0.00	1
19.3		35.50	35.50	35.50	0.00	0.00	1
38.6		35.60	35.60	35.60	0.00	0.00	1
77.2		35.80	35.80	35.80	0.00	0.00	1
FSW Control	DO %	100.20	100.20	100.20	0.00	0.00	1
WAF Control		100.90	100.90	100.90	0.00	0.00	1
1.2		99.60	99.60	99.60	0.00	0.00	1
2.4		91.80	91.80	91.80	0.00	0.00	1
4.8		96.10	96.10	96.10	0.00	0.00	1
9.7		98.70	98.70	98.70	0.00	0.00	1
19.3		90.10	90.10	90.10	0.00	0.00	1
38.6		90.20	90.20	90.20	0.00	0.00	1
77.2		87.20	87.20	87.20	0.00	0.00	1

Bivalve Larval Development Test-Proportion Normal

Start Date:	10/09/2015 18:00	Test ID:	PR1244/04	Sample ID:	Borossa Field Condensate
End Date:	12/09/2015 16:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 106	Test Species:	SE-Saccostrea echinata
Comments:	Loading Rate				

Conc-gm/L	1	2	3	4
FSW Control	0.7200	0.7900	0.7800	0.6900
WAF Control	0.6800	0.7300	0.7400	0.7500
1.2	0.7600	0.7000	0.6800	0.6900
2.4	0.6900	0.7400	0.7100	0.7600
4.8	0.7800	0.7200	0.6800	0.7100
9.7	0.7100	0.7600	0.7400	0.7300
19.3	0.6300	0.5900	0.6400	0.6200
38.6	0.0000	0.0000	0.0000	0.0000
77.2	0.0000	0.0000	0.0000	0.0000

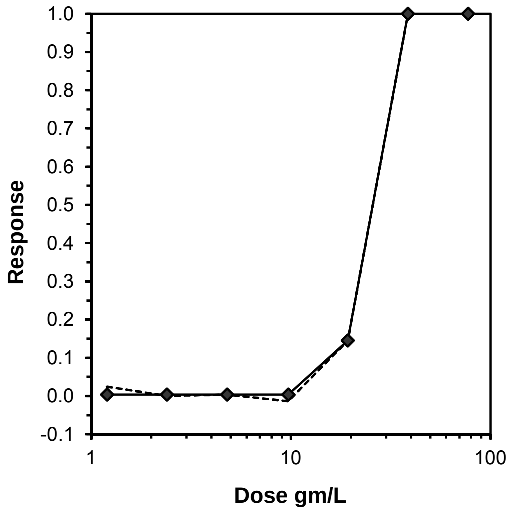
			Transform: Arcsin Square Root						1-Tailed		Isotonic	
Conc-gm/L	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Mean	N-Mean
FSW Control	0.7450	1.0276	1.0427	0.9803	1.0948	5.272	4					
WAF Control	0.7250	1.0000	1.0192	0.9695	1.0472	3.376	4	*			0.7250	1.0000
1.2	0.7075	0.9759	1.0000	0.9695	1.0588	4.023	4	0.779	2.410	0.0596	0.7225	0.9966
2.4	0.7250	1.0000	1.0192	0.9803	1.0588	3.421	4	-0.001	2.410	0.0596	0.7225	0.9966
4.8	0.7225	0.9966	1.0169	0.9695	1.0826	4.679	4	0.095	2.410	0.0596	0.7225	0.9966
9.7	0.7350	1.0138	1.0303	1.0021	1.0588	2.291	4	-0.447	2.410	0.0596	0.7225	0.9966
*19.3	0.6200	0.8552	0.9067	0.8759	0.9273	2.448	4	4.553	2.410	0.0596	0.6200	0.8552
38.6	0.0000	0.0000	0.0500	0.0500	0.0500	0.000	4				0.0000	0.0000
77.2	0.0000	0.0000	0.0500	0.0500	0.0500	0.000	4				0.0000	0.0000

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)	0.974316	0.916	0.369425	-0.29632
Bartlett's Test indicates equal variances (p = 0.82)	2.211731	15.08627		
The control means are not significantly different (p = 0.50)	0.724702	2.446912		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSDp	MSB	MSE	F-Prob	df
Dunnett's Test	9.7	19.3	13.68247		0.054646	0.075334	0.008512	0.001222	8.8E-04	5, 18
Treatments vs WAF Control										

Log-Logit Interpolation (200 Resamples)

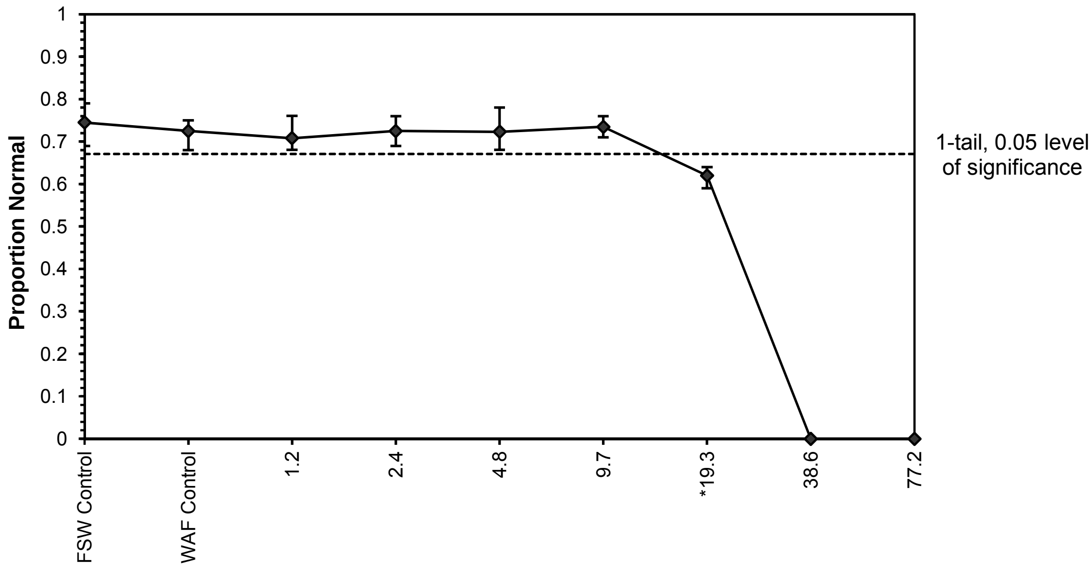
Point	gm/L	SD	95% CL(Exp)		Skew
IC05	12.371	1.054	9.095	13.474	-5.6672
IC10	15.745	1.017	11.783	18.345	-0.1579
IC15	19.322	0.819	14.886	19.494	-1.6728
IC20	19.535	0.082	19.253	19.698	-1.9600
IC25	19.744	0.071	19.470	19.901	-0.5760
IC40	20.378	0.066	20.122	20.523	-0.5922
IC50	20.829	0.064	20.582	20.970	-0.5981



Bivalve Larval Development Test-Proportion Normal

Start Date:	10/09/2015 18:00	Test ID:	PR1244/04	Sample ID:	Borossa Field Condensate
End Date:	12/09/2015 16:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 106	Test Species:	SE-Saccostrea echinata
Comments:	Loading Rate				

Dose-Response Plot



Bivalve Larval Development Test-Proportion Normal

Start Date:	10/09/2015 18:00	Test ID:	PR1244/04	Sample ID:	Borossa Field Condensate
End Date:	12/09/2015 16:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 106	Test Species:	SE-Saccostrea echinata
Comments:	Loading Rate				

		Auxiliary Data Summary					
Conc-gm/L	**Parameter**	**Mean**	**Min**	**Max**	**SD**	**CV%**	**N**
FSW Control	% Normal	74.50	69.00	79.00	4.80	2.94	4
WAF Control		72.50	68.00	75.00	3.11	2.43	4
1.2		70.75	68.00	76.00	3.59	2.68	4
2.4		72.50	69.00	76.00	3.11	2.43	4
4.8		72.25	68.00	78.00	4.19	2.83	4
9.7		73.50	71.00	76.00	2.08	1.96	4
19.3		62.00	59.00	64.00	2.16	2.37	4
38.6		0.00	0.00	0.00	0.00		4
77.2		0.00	0.00	0.00	0.00		4
FSW Control	pH	8.10	8.10	8.10	0.00	0.00	1
WAF Control		8.10	8.10	8.10	0.00	0.00	1
1.2		8.10	8.10	8.10	0.00	0.00	1
2.4		8.10	8.10	8.10	0.00	0.00	1
4.8		8.10	8.10	8.10	0.00	0.00	1
9.7		8.00	8.00	8.00	0.00	0.00	1
19.3		7.90	7.90	7.90	0.00	0.00	1
38.6		7.70	7.70	7.70	0.00	0.00	1
77.2		7.40	7.40	7.40	0.00	0.00	1
FSW Control	Salinity ppt	35.40	35.40	35.40	0.00	0.00	1
WAF Control		35.60	35.60	35.60	0.00	0.00	1
1.2		35.40	35.40	35.40	0.00	0.00	1
2.4		35.40	35.40	35.40	0.00	0.00	1
4.8		35.40	35.40	35.40	0.00	0.00	1
9.7		35.50	35.50	35.50	0.00	0.00	1
19.3		35.50	35.50	35.50	0.00	0.00	1
38.6		35.60	35.60	35.60	0.00	0.00	1
77.2		35.80	35.80	35.80	0.00	0.00	1
FSW Control	DO %	100.20	100.20	100.20	0.00	0.00	1
WAF Control		100.90	100.90	100.90	0.00	0.00	1
1.2		99.60	99.60	99.60	0.00	0.00	1
2.4		91.80	91.80	91.80	0.00	0.00	1
4.8		96.10	96.10	96.10	0.00	0.00	1
9.7		98.70	98.70	98.70	0.00	0.00	1
19.3		90.10	90.10	90.10	0.00	0.00	1
38.6		90.20	90.20	90.20	0.00	0.00	1
77.2		87.20	87.20	87.20	0.00	0.00	1

Bivalve Larval Development Test-Proportion Normal

Start Date:	10/09/2015 18:00	Test ID:	PR1244/04b	Sample ID:	Borossa Field Condensate
End Date:	12/09/2015 16:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 106	Test Species:	SE-Saccostrea echinata
Comments:	TRH				

Conc-ug/L	1	2	3	4
FSW Control	0.7200	0.7900	0.7800	0.6900
WAF Control	0.6800	0.7300	0.7400	0.7500
720	0.7600	0.7000	0.6800	0.6900
1673	0.6900	0.7400	0.7100	0.7600
3180	0.7800	0.7200	0.6800	0.7100
7160	0.7100	0.7600	0.7400	0.7300
14060	0.6300	0.5900	0.6400	0.6200
30860	0.0000	0.0000	0.0000	0.0000
69620	0.0000	0.0000	0.0000	0.0000

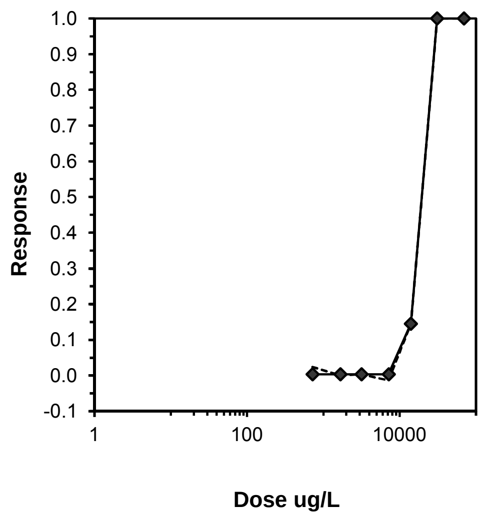
			Transform: Arcsin Square Root						1-Tailed		Number	Total
Conc-ug/L	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Resp	Number
FSW Control	0.7450	1.0276	1.0427	0.9803	1.0948	5.272	4					
WAF Control	0.7250	1.0000	1.0192	0.9695	1.0472	3.376	4	*			110	400
720	0.7075	0.9759	1.0000	0.9695	1.0588	4.023	4	0.779	2.410	0.0596	117	400
1673	0.7250	1.0000	1.0192	0.9803	1.0588	3.421	4	-0.001	2.410	0.0596	110	400
3180	0.7225	0.9966	1.0169	0.9695	1.0826	4.679	4	0.095	2.410	0.0596	111	400
7160	0.7350	1.0138	1.0303	1.0021	1.0588	2.291	4	-0.447	2.410	0.0596	106	400
*14060	0.6200	0.8552	0.9067	0.8759	0.9273	2.448	4	4.553	2.410	0.0596	152	400
30860	0.0000	0.0000	0.0500	0.0500	0.0500	0.000	4				400	400
69620	0.0000	0.0000	0.0500	0.0500	0.0500	0.000	4				400	400

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)	0.974316	0.916	0.369425	-0.29632
Bartlett's Test indicates equal variances (p = 0.82)	2.211731	15.08627		
The control means are not significantly different (p = 0.50)	0.724702	2.446912		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSDp	MSB	MSE	F-Prob	df
Dunnett's Test	7160	14060	10033.42		0.054646	0.075334	0.008512	0.001222	8.8E-04	5, 18
Treatments vs WAF Control										

Trimmed Spearman-Karber

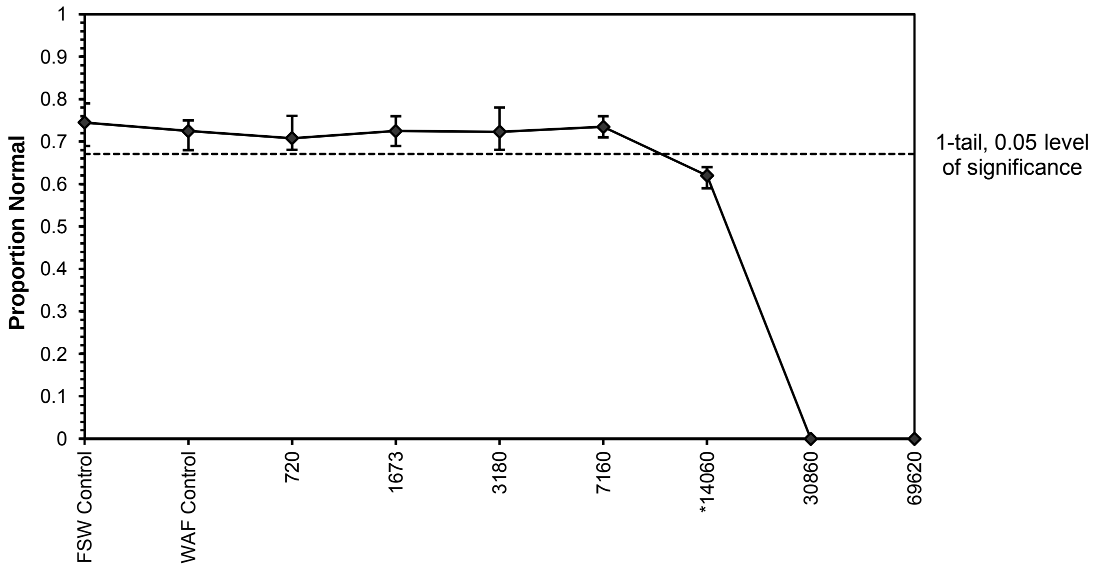
Trim Level	EC50	95% CL	
0.0%			
5.0%	19116.99	18552.77	19698.36
10.0%	19394.51	18656.02	20162.23
20.0%	19488.61	19123.45	19860.75
Auto-0.3%	18747.24	18266.79	19240.34



Bivalve Larval Development Test-Proportion Normal

Start Date:	10/09/2015 18:00	Test ID:	PR1244/04b	Sample ID:	Borossa Field Condensate
End Date:	12/09/2015 16:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 106	Test Species:	SE-Saccostrea echinata
Comments:	TRH				

Dose-Response Plot



Bivalve Larval Development Test-Proportion Normal

Start Date:	10/09/2015 18:00	Test ID:	PR1244/04b	Sample ID:	Borossa Field Condensate
End Date:	12/09/2015 16:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 106	Test Species:	SE-Saccostrea echinata
Comments:	TRH				

Auxiliary Data Summary

Conc-ug/L	Parameter	Mean	Min	Max	SD	CV%	N
FSW Control	% Normal	74.50	69.00	79.00	4.80	2.94	4
WAF Control		72.50	68.00	75.00	3.11	2.43	4
720		70.75	68.00	76.00	3.59	2.68	4
1673		72.50	69.00	76.00	3.11	2.43	4
3180		72.25	68.00	78.00	4.19	2.83	4
7160		73.50	71.00	76.00	2.08	1.96	4
14060		62.00	59.00	64.00	2.16	2.37	4
30860		0.00	0.00	0.00	0.00		4
69620		0.00	0.00	0.00	0.00		4
FSW Control	pH	8.10	8.10	8.10	0.00	0.00	1
WAF Control		8.10	8.10	8.10	0.00	0.00	1
720		8.10	8.10	8.10	0.00	0.00	1
1673		8.10	8.10	8.10	0.00	0.00	1
3180		8.10	8.10	8.10	0.00	0.00	1
7160		8.00	8.00	8.00	0.00	0.00	1
14060		7.90	7.90	7.90	0.00	0.00	1
30860		7.70	7.70	7.70	0.00	0.00	1
69620		7.40	7.40	7.40	0.00	0.00	1
FSW Control	Salinity ppt	35.40	35.40	35.40	0.00	0.00	1
WAF Control		35.60	35.60	35.60	0.00	0.00	1
720		35.40	35.40	35.40	0.00	0.00	1
1673		35.40	35.40	35.40	0.00	0.00	1
3180		35.40	35.40	35.40	0.00	0.00	1
7160		35.50	35.50	35.50	0.00	0.00	1
14060		35.50	35.50	35.50	0.00	0.00	1
30860		35.60	35.60	35.60	0.00	0.00	1
69620		35.80	35.80	35.80	0.00	0.00	1
FSW Control	DO %	100.20	100.20	100.20	0.00	0.00	1
WAF Control		100.90	100.90	100.90	0.00	0.00	1
720		99.60	99.60	99.60	0.00	0.00	1
1673		91.80	91.80	91.80	0.00	0.00	1
3180		96.10	96.10	96.10	0.00	0.00	1
7160		98.70	98.70	98.70	0.00	0.00	1
14060		90.10	90.10	90.10	0.00	0.00	1
30860		90.20	90.20	90.20	0.00	0.00	1
69620		87.20	87.20	87.20	0.00	0.00	1

Bivalve Larval Development Test-Proportion Normal

Start Date:	10/09/2015 18:00	Test ID:	PR1244/04b	Sample ID:	Borossa Field Condensate
End Date:	12/09/2015 16:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 106	Test Species:	SE-Saccostrea echinata
Comments:	TRH				

Conc-ug/L	1	2	3	4
FSW Control	0.7200	0.7900	0.7800	0.6900
WAF Control	0.6800	0.7300	0.7400	0.7500
720	0.7600	0.7000	0.6800	0.6900
1673	0.6900	0.7400	0.7100	0.7600
3180	0.7800	0.7200	0.6800	0.7100
7160	0.7100	0.7600	0.7400	0.7300
14060	0.6300	0.5900	0.6400	0.6200
30860	0.0000	0.0000	0.0000	0.0000
69620	0.0000	0.0000	0.0000	0.0000

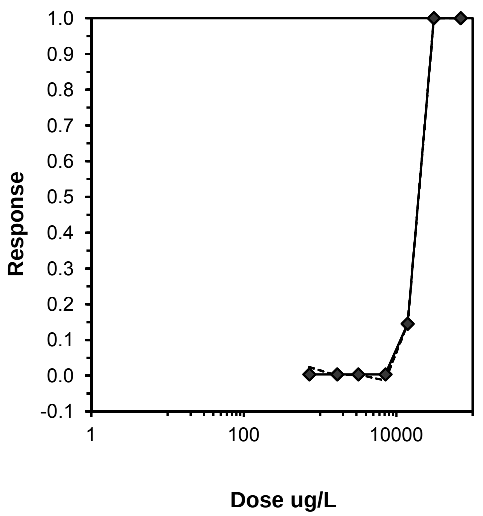
			Transform: Arcsin Square Root						1-Tailed		Isotonic	
Conc-ug/L	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Mean	N-Mean
FSW Control	0.7450	1.0276	1.0427	0.9803	1.0948	5.272	4					
WAF Control	0.7250	1.0000	1.0192	0.9695	1.0472	3.376	4	*			0.7250	1.0000
720	0.7075	0.9759	1.0000	0.9695	1.0588	4.023	4	0.779	2.410	0.0596	0.7225	0.9966
1673	0.7250	1.0000	1.0192	0.9803	1.0588	3.421	4	-0.001	2.410	0.0596	0.7225	0.9966
3180	0.7225	0.9966	1.0169	0.9695	1.0826	4.679	4	0.095	2.410	0.0596	0.7225	0.9966
7160	0.7350	1.0138	1.0303	1.0021	1.0588	2.291	4	-0.447	2.410	0.0596	0.7225	0.9966
*14060	0.6200	0.8552	0.9067	0.8759	0.9273	2.448	4	4.553	2.410	0.0596	0.6200	0.8552
30860	0.0000	0.0000	0.0500	0.0500	0.0500	0.000	4				0.0000	0.0000
69620	0.0000	0.0000	0.0500	0.0500	0.0500	0.000	4				0.0000	0.0000

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)	0.974316	0.916	0.369425	-0.29632
Bartlett's Test indicates equal variances (p = 0.82)	2.211731	15.08627		
The control means are not significantly different (p = 0.50)	0.724702	2.446912		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSDp	MSB	MSE	F-Prob	df
Dunnett's Test	7160	14060	10033.42		0.054646	0.075334	0.008512	0.001222	8.8E-04	5, 18
Treatments vs WAF Control										

Log-Logit Interpolation (200 Resamples)

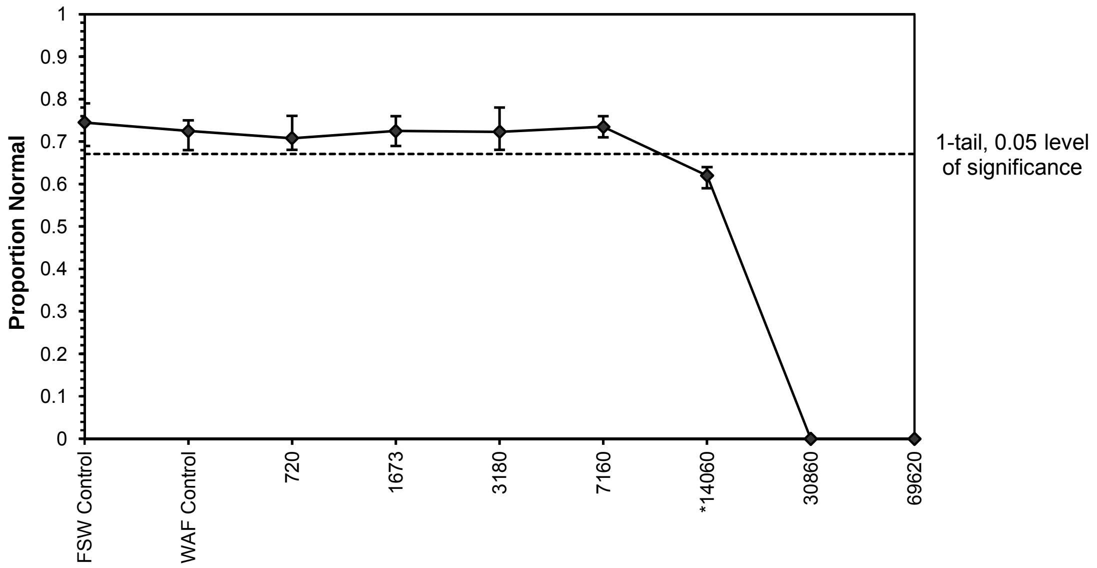
Point	ug/L	SD	95% CL(Exp)		Skew
IC05	9055.039	550.0583	6722.156	9886.09	-0.4671
IC10	11478.4	746.7707	9026.542	13230.49	0.0761
IC15	14078.12	576.9736	11380.46	14211.57	-1.1160
IC20	14251.33	59.23795	14048.25	14383.92	-0.1525
IC25	14422.52	57.71578	14222.15	14551.48	-0.1687
IC40	14942.4	54.40733	14753.36	15064.09	-0.2065
IC50	15313.95	52.80835	15128.32	15435.3	-0.2244



Bivalve Larval Development Test-Proportion Normal

Start Date:	10/09/2015 18:00	Test ID:	PR1244/04b	Sample ID:	Borossa Field Condensate
End Date:	12/09/2015 16:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 106	Test Species:	SE-Saccostrea echinata
Comments:	TRH				

Dose-Response Plot



 ToxCalc v5.0.23 Reviewed by:_____

Bivalve Larval Development Test-Proportion Normal

Start Date:	10/09/2015 18:00	Test ID:	PR1244/04b	Sample ID:	Borossa Field Condensate
End Date:	12/09/2015 16:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 106	Test Species:	SE-Saccostrea echinata
Comments:	TRH				

		Auxiliary Data Summary					
Conc-ug/L	**Parameter**	**Mean**	**Min**	**Max**	**SD**	**CV%**	**N**
FSW Control	% Normal	74.50	69.00	79.00	4.80	2.94	4
WAF Control		72.50	68.00	75.00	3.11	2.43	4
720		70.75	68.00	76.00	3.59	2.68	4
1673		72.50	69.00	76.00	3.11	2.43	4
3180		72.25	68.00	78.00	4.19	2.83	4
7160		73.50	71.00	76.00	2.08	1.96	4
14060		62.00	59.00	64.00	2.16	2.37	4
30860		0.00	0.00	0.00	0.00		4
69620		0.00	0.00	0.00	0.00		4
FSW Control	pH	8.10	8.10	8.10	0.00	0.00	1
WAF Control		8.10	8.10	8.10	0.00	0.00	1
720		8.10	8.10	8.10	0.00	0.00	1
1673		8.10	8.10	8.10	0.00	0.00	1
3180		8.10	8.10	8.10	0.00	0.00	1
7160		8.00	8.00	8.00	0.00	0.00	1
14060		7.90	7.90	7.90	0.00	0.00	1
30860		7.70	7.70	7.70	0.00	0.00	1
69620		7.40	7.40	7.40	0.00	0.00	1
FSW Control	Salinity ppt	35.40	35.40	35.40	0.00	0.00	1
WAF Control		35.60	35.60	35.60	0.00	0.00	1
720		35.40	35.40	35.40	0.00	0.00	1
1673		35.40	35.40	35.40	0.00	0.00	1
3180		35.40	35.40	35.40	0.00	0.00	1
7160		35.50	35.50	35.50	0.00	0.00	1
14060		35.50	35.50	35.50	0.00	0.00	1
30860		35.60	35.60	35.60	0.00	0.00	1
69620		35.80	35.80	35.80	0.00	0.00	1
FSW Control	DO %	100.20	100.20	100.20	0.00	0.00	1
WAF Control		100.90	100.90	100.90	0.00	0.00	1
720		99.60	99.60	99.60	0.00	0.00	1
1673		91.80	91.80	91.80	0.00	0.00	1
3180		96.10	96.10	96.10	0.00	0.00	1
7160		98.70	98.70	98.70	0.00	0.00	1
14060		90.10	90.10	90.10	0.00	0.00	1
30860		90.20	90.20	90.20	0.00	0.00	1
69620		87.20	87.20	87.20	0.00	0.00	1

Appendix N: Statistical Analyses of Micro-Algal Growth Inhibition Test

Marine Algal Growth Test-Cell Yield

Start Date:	11/09/2015 11:10	Test ID:	PR1244/05	Sample ID:	Borossa Field Condensate
End Date:	14/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 110	Test Species:	IG-isochrysis aff galbana
Comments:	Loading Rate				

Conc-gm/L	1	2	3	4	5	6	7	8
FSW Control	24.809	22.609	15.409	21.609	17.009	22.609	18.409	18.809
WAF Control	18.209	17.609	16.409	18.809				
1.2	19.009	22.609	12.809	21.009				
2.4	32.209	16.409	18.209	18.809				
4.8	16.409	16.209	29.409	21.009				
9.7	14.009	6.409	18.009	16.009				
19.3	0.409	1.409	1.609	1.009				
38.6	0.000	0.000	0.000	0.000				
77.2	0.000	0.000	0.000	0.000				

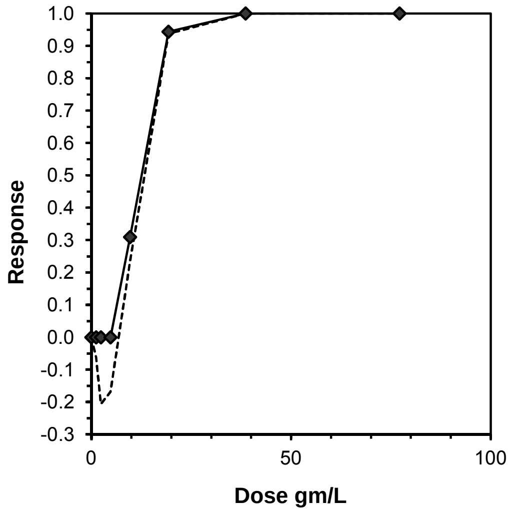
			Transform: Untransformed					Rank	1-Tailed	Isotonic	
Conc-gm/L	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical	Mean	N-Mean
FSW Control	20.159	1.1351	20.159	15.409	24.809	16.030	8				
WAF Control	17.759	1.0000	17.759	16.409	18.809	5.770	4	*		19.697	1.0000
1.2	18.859	1.0619	18.859	12.809	22.609	22.768	4	22.00	10.00	19.697	1.0000
2.4	21.409	1.2055	21.409	16.409	32.209	33.966	4	20.50	10.00	19.697	1.0000
4.8	20.759	1.1689	20.759	16.209	29.409	29.761	4	18.50	10.00	19.697	1.0000
9.7	13.609	0.7663	13.609	6.409	18.009	37.256	4	12.00	10.00	13.609	0.6909
*19.3	1.109	0.0624	1.109	0.409	1.609	47.713	4	10.00	10.00	1.109	0.0563
38.6	0.000	0.0000	0.000	0.000	0.000	0.000	4			0.000	0.0000
77.2	0.000	0.0000	0.000	0.000	0.000	0.000	4			0.000	0.0000

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)	0.940018	0.916	0.707398	1.092201
Bartlett's Test indicates unequal variances (p = 5.62E-03)	16.46936	15.08627		
The control means are not significantly different (p = 0.19)	1.419305	2.228139		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
Steel's Many-One Rank Test	9.7	19.3	13.68247	
Treatments vs WAF Control				

Linear Interpolation (200 Resamples)

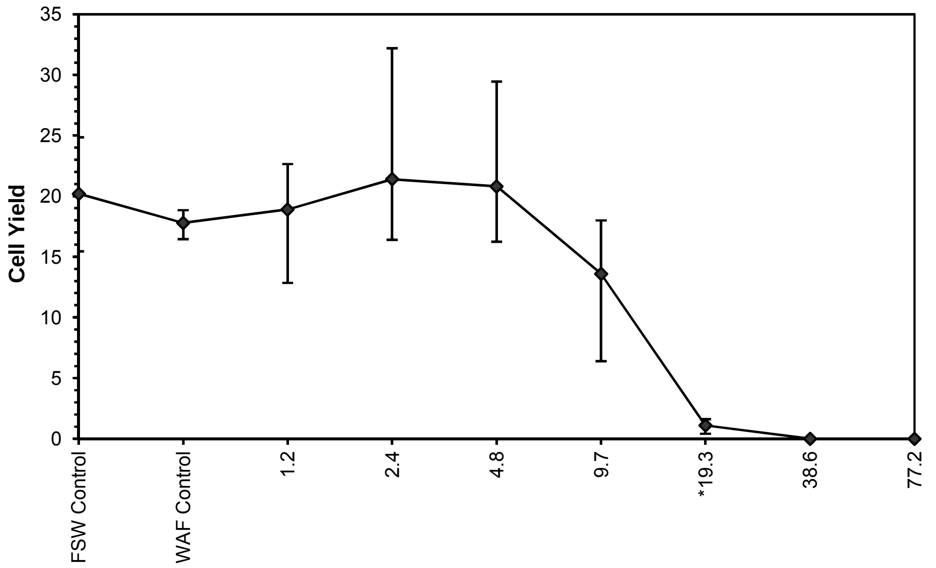
Point	gm/L	SD	95% CL(Exp)		Skew
IC05	5.593	1.260	0.093	7.552	-0.6336
IC10	6.385	1.313	2.183	10.675	0.1652
IC15	7.178	1.381	3.325	11.694	0.4336
IC20	7.971	1.427	4.320	12.176	0.2373
IC25	8.764	1.374	5.558	12.659	0.1009
IC40	11.076	1.350	6.896	14.139	-0.3797
IC50	12.588	1.286	7.448	15.094	-0.8271



Marine Algal Growth Test-Cell Yield

Start Date:	11/09/2015 11:10	Test ID:	PR1244/05	Sample ID:	Borossa Field Condensate
End Date:	14/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 110	Test Species:	IG-isochrysis aff galbana
Comments:	Loading Rate				

Dose-Response Plot



Marine Algal Growth Test-Cell Yield

Start Date:	11/09/2015 11:10	Test ID:	PR1244/05	Sample ID:	Borossa Field Condensate
End Date:	14/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 110	Test Species:	IG-isochrysis aff galbana
Comments:	Loading Rate				

		Auxiliary Data Summary					
Conc-gm/L	**Parameter**	**Mean**	**Min**	**Max**	**SD**	**CV%**	**N**
FSW Control	Cell Yield	20.16	15.41	24.81	3.23	8.92	8
WAF Control		17.76	16.41	18.81	1.02	5.70	4
1.2		18.86	12.81	22.61	4.29	10.99	4
2.4		21.41	16.41	32.21	7.27	12.60	4
4.8		20.76	16.21	29.41	6.18	11.97	4
9.7		13.61	6.41	18.01	5.07	16.55	4
19.3		1.11	0.41	1.61	0.53	65.59	4
38.6		0.00	0.00	0.00	0.00		4
77.2		0.00	0.00	0.00	0.00		4
FSW Control	pH	8.10	8.10	8.10	0.00	0.00	1
WAF Control		8.10	8.10	8.10	0.00	0.00	1
1.2		8.10	8.10	8.10	0.00	0.00	1
2.4		8.10	8.10	8.10	0.00	0.00	1
4.8		8.10	8.10	8.10	0.00	0.00	1
9.7		8.10	8.10	8.10	0.00	0.00	1
19.3		8.00	8.00	8.00	0.00	0.00	1
38.6		7.80	7.80	7.80	0.00	0.00	1
77.2		7.60	7.60	7.60	0.00	0.00	1
FSW Control	Salinity ppt	34.90	34.90	34.90	0.00	0.00	1
WAF Control		35.90	35.90	35.90	0.00	0.00	1
1.2		35.60	35.60	35.60	0.00	0.00	1
2.4		35.40	35.40	35.40	0.00	0.00	1
4.8		35.30	35.30	35.30	0.00	0.00	1
9.7		35.30	35.30	35.30	0.00	0.00	1
19.3		35.60	35.60	35.60	0.00	0.00	1
38.6		35.40	35.40	35.40	0.00	0.00	1
77.2		35.40	35.40	35.40	0.00	0.00	1

Marine Algal Growth Test-Cell Yield

Start Date:	11/09/2015 11:10	Test ID:	PR1244/05b	Sample ID:	Borossa Field Condensate
End Date:	14/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 110	Test Species:	IG-isochrysis aff galbana
Comments:	TRH				

Conc-ug/L	1	2	3	4	5	6	7	8
FSW Control	24.809	22.609	15.409	21.609	17.009	22.609	18.409	18.809
WAF Control	18.209	17.609	16.409	18.809				
650	19.009	22.609	12.809	21.009				
1400	32.209	16.409	18.209	18.809				
3248	16.409	16.209	29.409	21.009				
6670	14.009	6.409	18.009	16.009				
12850	0.409	1.409	1.609	1.009				
27960	0.000	0.000	0.000	0.000				
65830	0.000	0.000	0.000	0.000				

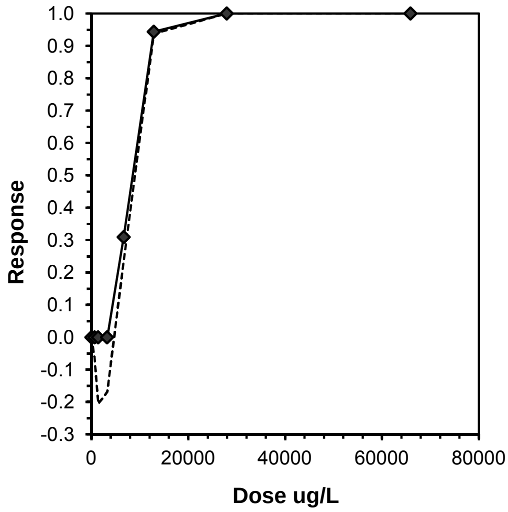
			Transform: Untransformed					Rank	1-Tailed	Isotonic	
Conc-ug/L	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical	Mean	N-Mean
FSW Control	20.159	1.1351	20.159	15.409	24.809	16.030	8				
WAF Control	17.759	1.0000	17.759	16.409	18.809	5.770	4	*		19.697	1.0000
650	18.859	1.0619	18.859	12.809	22.609	22.768	4	22.00	10.00	19.697	1.0000
1400	21.409	1.2055	21.409	16.409	32.209	33.966	4	20.50	10.00	19.697	1.0000
3248	20.759	1.1689	20.759	16.209	29.409	29.761	4	18.50	10.00	19.697	1.0000
6670	13.609	0.7663	13.609	6.409	18.009	37.256	4	12.00	10.00	13.609	0.6909
*12850	1.109	0.0624	1.109	0.409	1.609	47.713	4	10.00	10.00	1.109	0.0563
27960	0.000	0.0000	0.000	0.000	0.000	0.000	4			0.000	0.0000
65830	0.000	0.0000	0.000	0.000	0.000	0.000	4			0.000	0.0000

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)	0.940018	0.916	0.707398	1.092201
Bartlett's Test indicates unequal variances (p = 5.62E-03)	16.46936	15.08627		
The control means are not significantly different (p = 0.19)	1.419305	2.228139		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
Steel's Many-One Rank Test	6670	12850	9257.943	
Treatments vs WAF Control				

Linear Interpolation (200 Resamples)

Point	ug/L	SD	95% CL(Exp)		Skew
IC05	3801.606	785.5934	207.0058	5212.784	-0.7487
IC10	4355.211	856.1277	1641.129	7401.379	0.2877
IC15	4908.817	918.0294	2434.842	8021.064	0.5678
IC20	5462.423	938.173	3189.309	8299.437	0.4571
IC25	6016.028	930.5002	3814.942	8577.81	0.2738
IC40	7555.524	913.1011	4589.661	9476.525	-0.1698
IC50	8529.32	856.3443	5094.774	10125.96	-0.5333

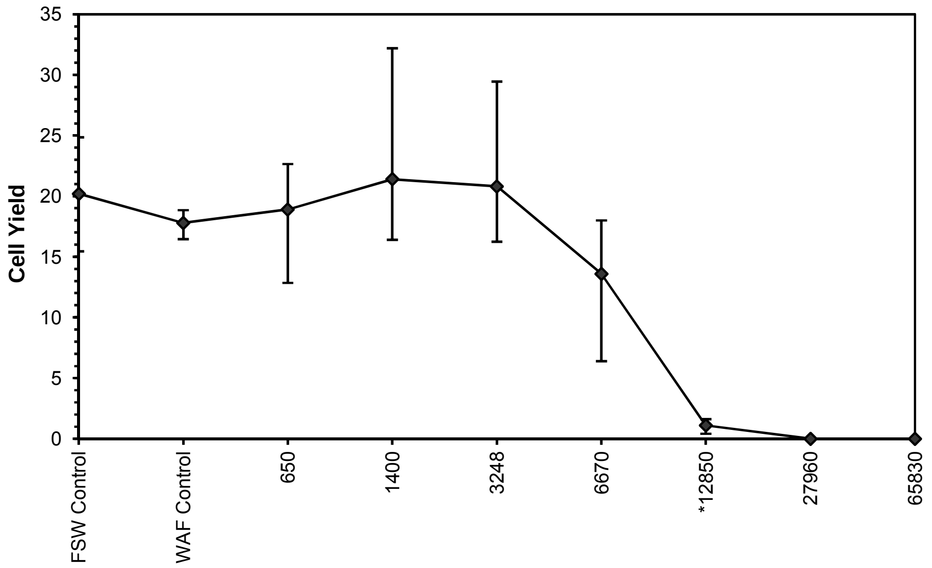


 ToxCalc v5.0.23 Reviewed by:_____

Marine Algal Growth Test-Cell Yield

Start Date:	11/09/2015 11:10	Test ID:	PR1244/05b	Sample ID:	Borossa Field Condensate
End Date:	14/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 110	Test Species:	IG-isochrysis aff galbana
Comments:	TRH				

Dose-Response Plot



Marine Algal Growth Test-Cell Yield

Start Date:	11/09/2015 11:10	Test ID:	PR1244/05b	Sample ID:	Borossa Field Condensate
End Date:	14/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 110	Test Species:	IG-isochrysis aff galbana
Comments:	TRH				

		Auxiliary Data Summary					
Conc-ug/L	**Parameter**	**Mean**	**Min**	**Max**	**SD**	**CV%**	**N**
FSW Control	Cell Yield	20.16	15.41	24.81	3.23	8.92	8
WAF Control		17.76	16.41	18.81	1.02	5.70	4
650		18.86	12.81	22.61	4.29	10.99	4
1400		21.41	16.41	32.21	7.27	12.60	4
3248		20.76	16.21	29.41	6.18	11.97	4
6670		13.61	6.41	18.01	5.07	16.55	4
12850		1.11	0.41	1.61	0.53	65.59	4
27960		0.00	0.00	0.00	0.00		4
65830		0.00	0.00	0.00	0.00		4
FSW Control	pH	8.10	8.10	8.10	0.00	0.00	1
WAF Control		8.10	8.10	8.10	0.00	0.00	1
650		8.10	8.10	8.10	0.00	0.00	1
1400		8.10	8.10	8.10	0.00	0.00	1
3248		8.10	8.10	8.10	0.00	0.00	1
6670		8.10	8.10	8.10	0.00	0.00	1
12850		8.00	8.00	8.00	0.00	0.00	1
27960		7.80	7.80	7.80	0.00	0.00	1
65830		7.60	7.60	7.60	0.00	0.00	1
FSW Control	Salinity ppt	34.90	34.90	34.90	0.00	0.00	1
WAF Control		35.90	35.90	35.90	0.00	0.00	1
650		35.60	35.60	35.60	0.00	0.00	1
1400		35.40	35.40	35.40	0.00	0.00	1
3248		35.30	35.30	35.30	0.00	0.00	1
6670		35.30	35.30	35.30	0.00	0.00	1
12850		35.60	35.60	35.60	0.00	0.00	1
27960		35.40	35.40	35.40	0.00	0.00	1
65830		35.40	35.40	35.40	0.00	0.00	1

Appendix O: Statistical Analyses of Macro-Algal Growth Test

Macroalgal Growth Test-Gametophyte Length

Start Date:	10/09/2015 14:00	Test ID:	PR1244/15	Sample ID:	Borossa Field Condensate
End Date:	24/09/2015 14:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 116	Test Species:	ER-Ecklonia radiata
Comments:	Loading Rate				

Conc-gm/L	1	2	3	4
FSW Control	23.400	22.900	23.000	25.300
WAF Control	28.200	21.900	23.400	26.100
1.2	23.600	22.600	21.200	24.300
2.4	26.200	22.400	23.500	18.300
4.8	20.400	22.100	22.200	20.000
9.7	17.200	18.500	19.500	19.300
19.3	15.800	15.300	15.100	13.800
38.6	12.400	12.900	14.000	15.800
77.2	13.100	10.800	12.400	11.000

			Transform: Untransformed						1-Tailed		Isotonic	
Conc-gm/L	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Mean	N-Mean
FSW Control	23.650	0.9498	23.650	22.900	25.300	4.740	4					
WAF Control	24.900	1.0000	24.900	21.900	28.200	11.259	4	*			24.900	1.0000
1.2	22.925	0.9207	22.925	21.200	24.300	5.867	4	1.519	2.480	3.224	22.925	0.9207
2.4	22.600	0.9076	22.600	18.300	26.200	14.519	4	1.769	2.480	3.224	22.600	0.9076
*4.8	21.175	0.8504	21.175	20.000	22.200	5.376	4	2.865	2.480	3.224	21.175	0.8504
*9.7	18.625	0.7480	18.625	17.200	19.500	5.603	4	4.826	2.480	3.224	18.625	0.7480
*19.3	15.000	0.6024	15.000	13.800	15.800	5.683	4	7.615	2.480	3.224	15.000	0.6024
*38.6	13.775	0.5532	13.775	12.400	15.800	10.936	4	8.557	2.480	3.224	13.775	0.5532
*77.2	11.825	0.4749	11.825	10.800	13.100	9.376	4	10.057	2.480	3.224	11.825	0.4749

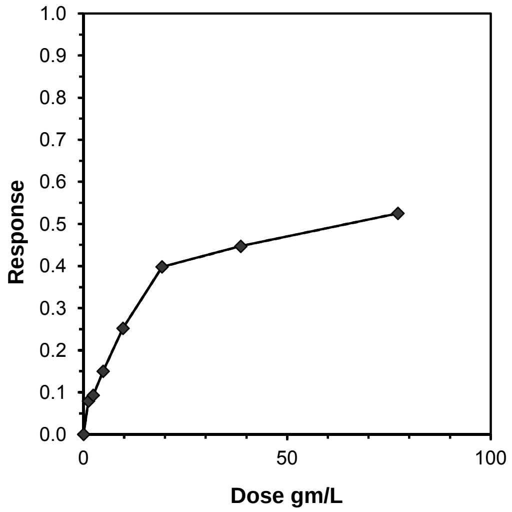
Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)	0.969423	0.93	-0.20116	1.06828
Bartlett's Test indicates equal variances (p = 0.20)	9.76692	18.47531		
The control means are not significantly different (p = 0.44)	0.827984	2.446912		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSDp	MSB	MSE	F-Prob	df
Dunnett's Test Treatments vs WAF Control	2.4	4.8	3.394113		3.224348	0.129492	92.94603	3.380729	5.5E-10	7, 24

Linear Interpolation (200 Resamples)

Point	gm/L	SD	95% CL(Exp)		Skew
IC05*	0.756	1.099	0.175	5.754	1.4236
IC10	2.720	1.551	0.000	7.717	0.6850
IC15	4.819	1.913	0.000	10.477	0.1349
IC20	7.212	2.030	0.601	13.586	0.0468
IC25	9.604	2.128	3.717	16.457	0.1881
IC40	20.245	7.848	11.624	55.512	1.4840
IC50	64.828				

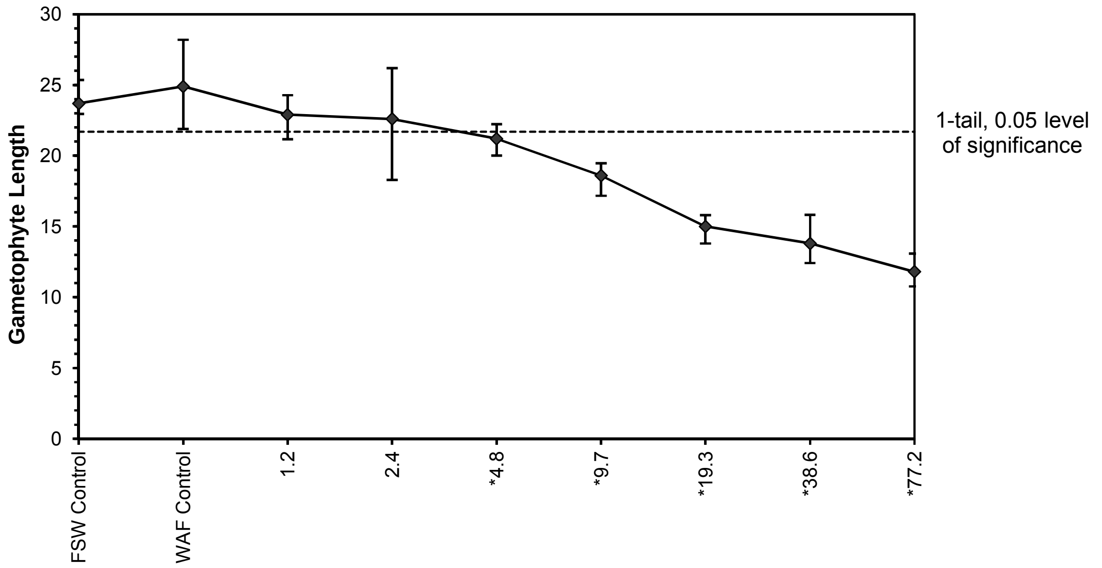
* indicates IC estimate less than the lowest concentration



Macroalgal Growth Test-Gametophyte Length

Start Date:	10/09/2015 14:00	Test ID:	PR1244/15	Sample ID:	Borossa Field Condensate
End Date:	24/09/2015 14:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 116	Test Species:	ER-Ecklonia radiata
Comments:	Loading Rate				

Dose-Response Plot



Macroalgal Growth Test-Gametophyte Length

Start Date:	10/09/2015 14:00	Test ID:	PR1244/15	Sample ID:	Borossa Field Condensate
End Date:	24/09/2015 14:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 116	Test Species:	ER-Ecklonia radiata
Comments:	Loading Rate				

Auxiliary Data Summary

Conc-gm/L	Parameter	Mean	Min	Max	SD	CV%	N
FSW Control	Length um	23.65	22.90	25.30	1.12	4.48	4
WAF Control		24.90	21.90	28.20	2.80	6.72	4
1.2		22.93	21.20	24.30	1.35	5.06	4
2.4		22.60	18.30	26.20	3.28	8.02	4
4.8		21.18	20.00	22.20	1.14	5.04	4
9.7		18.63	17.20	19.50	1.04	5.49	4
19.3		15.00	13.80	15.80	0.85	6.16	4
38.6		13.78	12.40	15.80	1.51	8.91	4
77.2		11.83	10.80	13.10	1.11	8.90	4
FSW Control	pH	8.10	8.10	8.10	0.00	0.00	1
WAF Control		8.10	8.10	8.10	0.00	0.00	1
1.2		8.10	8.10	8.10	0.00	0.00	1
2.4		8.10	8.10	8.10	0.00	0.00	1
4.8		8.10	8.10	8.10	0.00	0.00	1
9.7		8.00	8.00	8.00	0.00	0.00	1
19.3		7.90	7.90	7.90	0.00	0.00	1
38.6		7.70	7.70	7.70	0.00	0.00	1
77.2		7.40	7.40	7.40	0.00	0.00	1
FSW Control	Salinity ppt	35.40	35.40	35.40	0.00	0.00	1
WAF Control		35.60	35.60	35.60	0.00	0.00	1
1.2		35.40	35.40	35.40	0.00	0.00	1
2.4		35.40	35.40	35.40	0.00	0.00	1
4.8		35.40	35.40	35.40	0.00	0.00	1
9.7		35.50	35.50	35.50	0.00	0.00	1
19.3		35.50	35.50	35.50	0.00	0.00	1
38.6		35.60	35.60	35.60	0.00	0.00	1
77.2		35.80	35.80	35.80	0.00	0.00	1
FSW Control	DO % sat	100.20	100.20	100.20	0.00	0.00	1
WAF Control		100.90	100.90	100.90	0.00	0.00	1
1.2		99.60	99.60	99.60	0.00	0.00	1
2.4		91.80	91.80	91.80	0.00	0.00	1
4.8		96.10	96.10	96.10	0.00	0.00	1
9.7		98.70	98.70	98.70	0.00	0.00	1
19.3		90.10	90.10	90.10	0.00	0.00	1
38.6		90.20	90.20	90.20	0.00	0.00	1
77.2		87.20	87.20	87.20	0.00	0.00	1

Macroalgal Growth Test-Gametophyte Length

Start Date:	10/09/2015 14:00	Test ID:	PR1244/15b	Sample ID:	Borossa Field Condensate
End Date:	24/09/2015 14:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 116	Test Species:	ER-Ecklonia radiata
Comments:	TRH				

Conc-ug/L	1	2	3	4
FSW Control	23.400	22.900	23.000	25.300
WAF Control	28.200	21.900	23.400	26.100
720	23.600	22.600	21.200	24.300
1673	26.200	22.400	23.500	18.300
3180	20.400	22.100	22.200	20.000
7160	17.200	18.500	19.500	19.300
14060	15.800	15.300	15.100	13.800
30860	12.400	12.900	14.000	15.800
69620	13.100	10.800	12.400	11.000

			Transform: Untransformed						1-Tailed		Isotonic	
Conc-ug/L	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Mean	N-Mean
FSW Control	23.650	0.9498	23.650	22.900	25.300	4.740	4					
WAF Control	24.900	1.0000	24.900	21.900	28.200	11.259	4	*			24.900	1.0000
720	22.925	0.9207	22.925	21.200	24.300	5.867	4	1.519	2.480	3.224	22.925	0.9207
1673	22.600	0.9076	22.600	18.300	26.200	14.519	4	1.769	2.480	3.224	22.600	0.9076
*3180	21.175	0.8504	21.175	20.000	22.200	5.376	4	2.865	2.480	3.224	21.175	0.8504
*7160	18.625	0.7480	18.625	17.200	19.500	5.603	4	4.826	2.480	3.224	18.625	0.7480
*14060	15.000	0.6024	15.000	13.800	15.800	5.683	4	7.615	2.480	3.224	15.000	0.6024
*30860	13.775	0.5532	13.775	12.400	15.800	10.936	4	8.557	2.480	3.224	13.775	0.5532
*69620	11.825	0.4749	11.825	10.800	13.100	9.376	4	10.057	2.480	3.224	11.825	0.4749

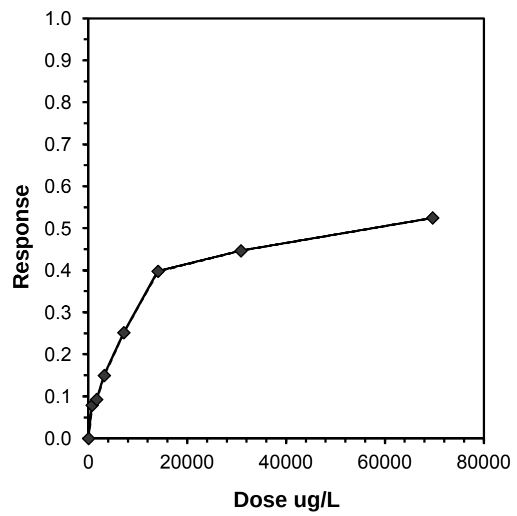
Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)	0.969423	0.93	-0.20116	1.06828
Bartlett's Test indicates equal variances (p = 0.20)	9.76692	18.47531		
The control means are not significantly different (p = 0.44)	0.827984	2.446912		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSDp	MSB	MSE	F-Prob	df
Dunnett's Test	1673	3180	2306.543		3.224348	0.129492	92.94603	3.380729	5.5E-10	7, 24
Treatments vs WAF Control										

Linear Interpolation (200 Resamples)

Point	ug/L	SD	95% CL(Exp)		Skew
IC05*	453.8734	743.0149	88.53384	3725.254	1.1789
IC10	1873.933	1097.594	0	5705.609	0.4406
IC15	3195.608	1427.685	0	7450.03	0.1707
IC20	5138.784	1630.032	0	9230.277	-0.0001
IC25	7081.961	1574.98	2817.731	11498.48	0.1329
IC40	14882.86	7355.097	9376.753	48927.62	1.1696
IC50	57196.92				

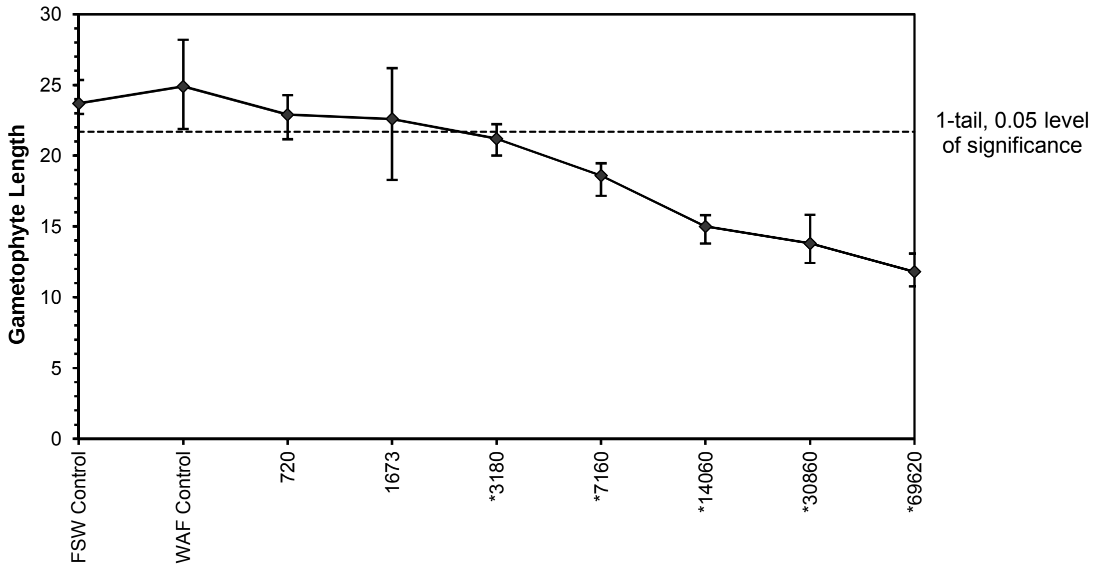
* indicates IC estimate less than the lowest concentration



Macroalgal Growth Test-Gametophyte Length

Start Date:	10/09/2015 14:00	Test ID:	PR1244/15b	Sample ID:	Borossa Field Condensate
End Date:	24/09/2015 14:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 116	Test Species:	ER-Ecklonia radiata
Comments:	TRH				

Dose-Response Plot



Macroalgal Growth Test-Gametophyte Length

Start Date:	10/09/2015 14:00	Test ID:	PR1244/15b	Sample ID:	Borossa Field Condensate
End Date:	24/09/2015 14:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 116	Test Species:	ER-Ecklonia radiata
Comments:	TRH				

		Auxiliary Data Summary					
Conc-ug/L	**Parameter**	**Mean**	**Min**	**Max**	**SD**	**CV%**	**N**
FSW Control	Length um	23.65	22.90	25.30	1.12	4.48	4
WAF Control		24.90	21.90	28.20	2.80	6.72	4
720		22.93	21.20	24.30	1.35	5.06	4
1673		22.60	18.30	26.20	3.28	8.02	4
3180		21.18	20.00	22.20	1.14	5.04	4
7160		18.63	17.20	19.50	1.04	5.49	4
14060		15.00	13.80	15.80	0.85	6.16	4
30860		13.78	12.40	15.80	1.51	8.91	4
69620		11.83	10.80	13.10	1.11	8.90	4
FSW Control	pH	8.10	8.10	8.10	0.00	0.00	1
WAF Control		8.10	8.10	8.10	0.00	0.00	1
720		8.10	8.10	8.10	0.00	0.00	1
1673		8.10	8.10	8.10	0.00	0.00	1
3180		8.10	8.10	8.10	0.00	0.00	1
7160		8.00	8.00	8.00	0.00	0.00	1
14060		7.90	7.90	7.90	0.00	0.00	1
30860		7.70	7.70	7.70	0.00	0.00	1
69620		7.40	7.40	7.40	0.00	0.00	1
FSW Control	Salinity ppt	35.40	35.40	35.40	0.00	0.00	1
WAF Control		35.60	35.60	35.60	0.00	0.00	1
720		35.40	35.40	35.40	0.00	0.00	1
1673		35.40	35.40	35.40	0.00	0.00	1
3180		35.40	35.40	35.40	0.00	0.00	1
7160		35.50	35.50	35.50	0.00	0.00	1
14060		35.50	35.50	35.50	0.00	0.00	1
30860		35.60	35.60	35.60	0.00	0.00	1
69620		35.80	35.80	35.80	0.00	0.00	1
FSW Control	DO % sat	100.20	100.20	100.20	0.00	0.00	1
WAF Control		100.90	100.90	100.90	0.00	0.00	1
720		99.60	99.60	99.60	0.00	0.00	1
1673		91.80	91.80	91.80	0.00	0.00	1
3180		96.10	96.10	96.10	0.00	0.00	1
7160		98.70	98.70	98.70	0.00	0.00	1
14060		90.10	90.10	90.10	0.00	0.00	1
30860		90.20	90.20	90.20	0.00	0.00	1
69620		87.20	87.20	87.20	0.00	0.00	1

Appendix P: Statistical Analyses of Sea Anemone Development Test

Anemone Larval Toxicity Test-% Normal

Start Date:	27/10/2015 11:30	Test ID:	PR1244/31	Sample ID:	Barossa Field Condensate
End Date:	4/11/2015 10:30	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 128	Test Species:	AI-Aiptasia pulchella
Comments:					

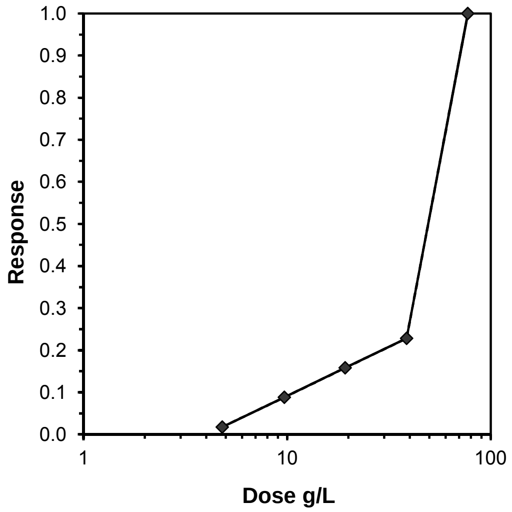
Conc-g/L	1	2	3	4
FSW Control	1.0000	1.0000	1.0000	1.0000
WAF Control	1.0000	1.0000	0.8000	1.0000
4.8	0.8000	1.0000	1.0000	
9.7	0.8000	0.8000	1.0000	
19.3	0.6000	0.8000	1.0000	
38.6	0.8000	0.6000	0.8000	
77.2	0.0000	0.0000	0.0000	

			Transform: Arcsin Square Root						1-Tailed		Number	Total
Conc-g/L	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Resp	Number
FSW Control	1.0000	1.0526	1.3453	1.3453	1.3453	0.000	4					
WAF Control	0.9500	1.0000	1.2857	1.1071	1.3453	9.261	4	*			1	20
4.8	0.9333	0.9825	1.2659	1.1071	1.3453	10.861	3	0.170	2.593	0.3023	1	15
9.7	0.8667	0.9123	1.1865	1.1071	1.3453	11.587	3	0.851	2.593	0.3023	2	15
19.3	0.8000	0.8421	1.1128	0.8861	1.3453	20.637	3	1.483	2.593	0.3023	3	15
38.6	0.7333	0.7719	1.0335	0.8861	1.1071	12.350	3	2.164	2.593	0.3023	4	15
77.2	0.0000	0.0000	0.2255	0.2255	0.2255	0.000	3				15	15

Auxiliary Tests						Statistic		Critical		Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)						0.931661		0.887		-0.22409	-0.77909
Bartlett's Test indicates equal variances (p = 0.88)						1.183699		13.2767			
The control means are not significantly different (p = 0.36)						1		2.446912			
Hypothesis Test (1-tail, 0.05)	**NOEC**	**LOEC**	**ChV**	**TU**		**MSDu**	**MSDp**	**MSB**	**MSE**	**F-Prob**	**df**
Bonferroni t Test	38.6	77.2	54.58864			0.227972	0.247547	0.036184	0.023292	0.254275	4, 11
Treatments vs WAF Control											

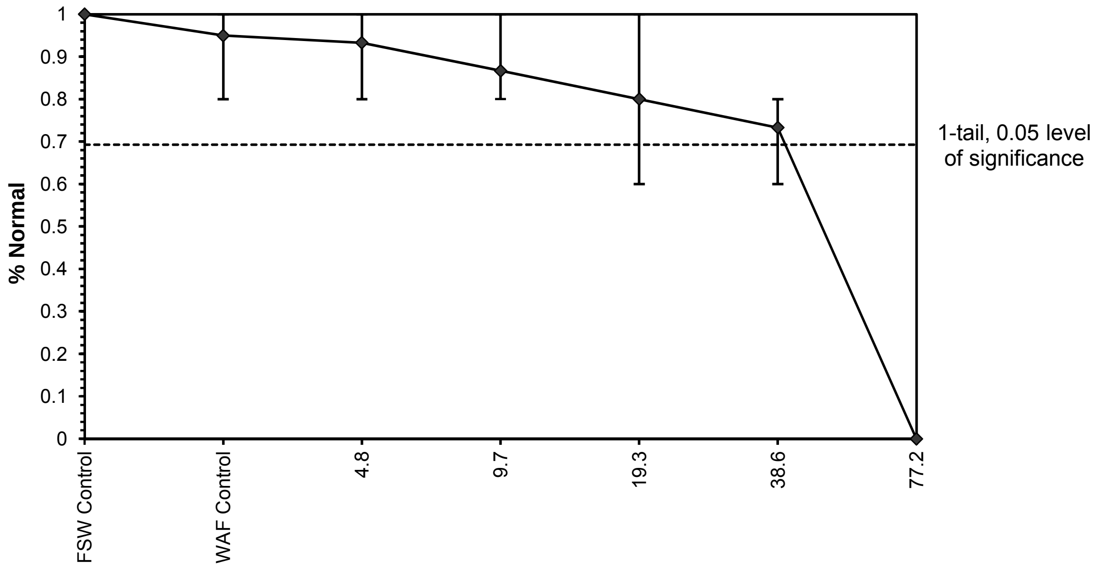
Trimmed Spearman-Karber

Trim Level	EC50	95% CL	
0.0%			
5.0%	42.079	33.018	53.627
10.0%	44.949	35.034	57.670
20.0%	48.986	36.746	65.302
Auto-1.8%	40.101	31.780	50.600



Anemone Larval Toxicity Test-% Normal					
Start Date:	27/10/2015 11:30	Test ID:	PR1244/31	Sample ID:	Barossa Field Condensate
End Date:	4/11/2015 10:30	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 128	Test Species:	AI-Aiptasia pulchella
Comments:					

Dose-Response Plot



Anemone Larval Toxicity Test-% Normal

Start Date:	27/10/2015 11:30	Test ID:	PR1244/31	Sample ID:	Barossa Field Condensate
End Date:	4/11/2015 10:30	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 128	Test Species:	AI-Aiptasia pulchella
Comments:					

Auxiliary Data Summary

Conc-g/L	Parameter	Mean	Min	Max	SD	CV%	N
FSW Control	% Normal	100.00	100.00	100.00	0.00	0.00	4
WAF Control		95.00	80.00	100.00	10.00	3.33	4
4.8		93.33	80.00	100.00	11.55	3.64	3
9.7		86.67	80.00	100.00	11.55	3.92	3
19.3		80.00	60.00	100.00	20.00	5.59	3
38.6		73.33	60.00	80.00	11.55	4.63	3
77.2		0.00	0.00	0.00	0.00		3
FSW Control	pH	8.10	8.10	8.10	0.00	0.00	1
WAF Control		8.10	8.10	8.10	0.00	0.00	1
4.8		8.10	8.10	8.10	0.00	0.00	1
9.7		8.10	8.10	8.10	0.00	0.00	1
19.3		8.00	8.00	8.00	0.00	0.00	1
38.6		7.90	7.90	7.90	0.00	0.00	1
77.2		7.60	7.60	7.60	0.00	0.00	1
FSW Control	Salinity ppt	35.10	35.10	35.10	0.00	0.00	1
WAF Control		35.10	35.10	35.10	0.00	0.00	1
4.8		34.90	34.90	34.90	0.00	0.00	1
9.7		34.90	34.90	34.90	0.00	0.00	1
19.3		35.00	35.00	35.00	0.00	0.00	1
38.6		35.00	35.00	35.00	0.00	0.00	1
77.2		35.10	35.10	35.10	0.00	0.00	1
FSW Control	DO %	102.10	102.10	102.10	0.00	0.00	1
WAF Control		101.60	101.60	101.60	0.00	0.00	1
4.8		103.90	103.90	103.90	0.00	0.00	1
9.7		105.10	105.10	105.10	0.00	0.00	1
19.3		105.20	105.20	105.20	0.00	0.00	1
38.6		104.50	104.50	104.50	0.00	0.00	1
77.2		110.40	110.40	110.40	0.00	0.00	1

Anemone Larval Toxicity Test-% Unaffected

Start Date:	27/10/2015 11:30	Test ID:	PR1244/31b	Sample ID:	BAROSSA FIELD CONDENSATE
End Date:	4/11/2015 10:30	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 128	Test Species:	AI-Aiptasia pulchella
Comments:	TRH Concentration				

Conc-ug/L	1	2	3	4
FSW Control	1.0000	1.0000	1.0000	1.0000
WAF Control	1.0000	1.0000	0.8000	1.0000
2492	0.8000	1.0000	1.0000	
7660	0.8000	0.8000	1.0000	
15840	0.6000	0.8000	1.0000	
28040	0.8000	0.6000	0.8000	
63990	0.0000	0.0000	0.0000	

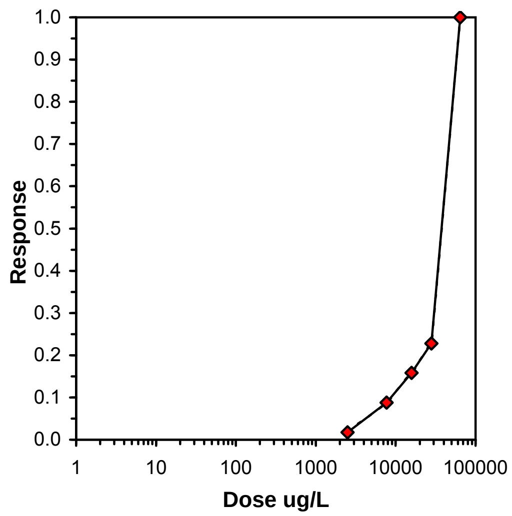
			Transform: Arcsin Square Root						1-Tailed		Number	Total
Conc-ug/L	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Resp	Number
FSW Control	1.0000	1.0526	1.3453	1.3453	1.3453	0.000	4					
WAF Control	0.9500	1.0000	1.2857	1.1071	1.3453	9.261	4	*			1	20
2492	0.9333	0.9825	1.2659	1.1071	1.3453	10.861	3	0.170	2.593	0.3023	1	15
7660	0.8667	0.9123	1.1865	1.1071	1.3453	11.587	3	0.851	2.593	0.3023	2	15
15840	0.8000	0.8421	1.1128	0.8861	1.3453	20.637	3	1.483	2.593	0.3023	3	15
28040	0.7333	0.7719	1.0335	0.8861	1.1071	12.350	3	2.164	2.593	0.3023	4	15
63990	0.0000	0.0000	0.2255	0.2255	0.2255	0.000	3				15	15

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)	0.931661	0.887	-0.22409	-0.77909
Bartlett's Test indicates equal variances (p = 0.88)	1.183699	13.2767		
The control means are not significantly different (p = 0.36)	1	2.446912		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSDp	MSB	MSE	F-Prob	df
Bonferroni t Test	28040	63990	42358.94		0.227972	0.247547	0.036184	0.023292	0.254275	4, 11
Treatments vs WAF Control										

Trimmed Spearman-Karber

Trim Level	EC50	95% CL	
0.0%			
5.0%	32491.19	25241.84	41822.52
10.0%	34715.36	27194.92	44315.51
20.0%	37324.45	28220.84	49364.76
Auto-1.8%	30719.95	23960.98	39385.52

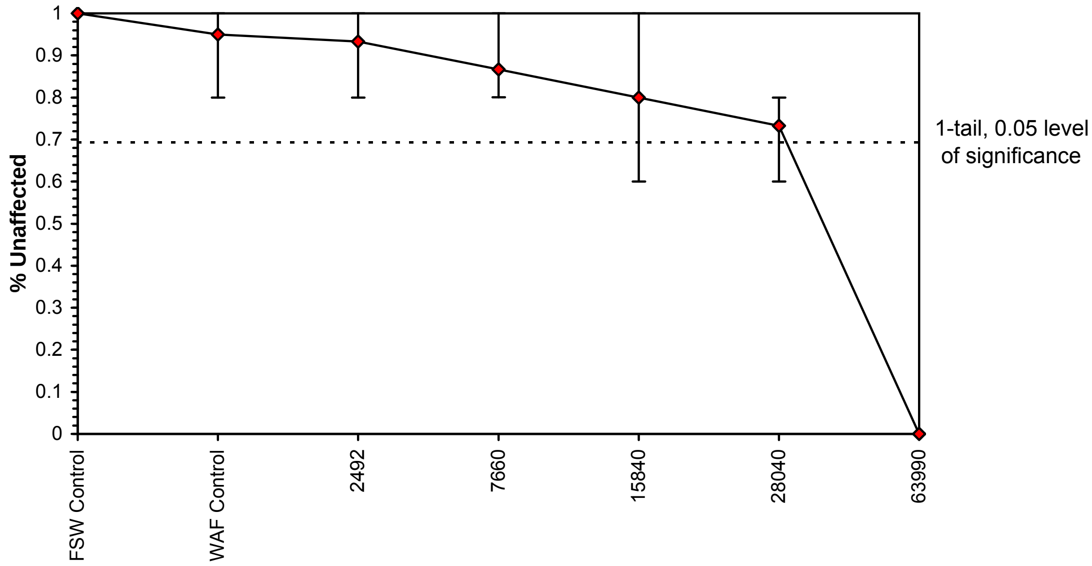


 ToxCalc v5.0.23 Reviewed by:_____

Anemone Larval Toxicity Test-% Unaffected

Start Date:	27/10/2015 11:30	Test ID:	PR1244/31b	Sample ID:	BAROSSA FIELD CONDENSATE
End Date:	4/11/2015 10:30	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 128	Test Species:	AI-Aiptasia pulchella
Comments:	TRH Concentration				

Dose-Response Plot



 ToxCalc v5.0.23 Reviewed by:_____

Anemone Larval Toxicity Test-% Unaffected

Start Date:	27/10/2015 11:30	Test ID:	PR1244/31b	Sample ID:	BAROSSA FIELD CONDENSATE
End Date:	4/11/2015 10:30	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 128	Test Species:	AI-Aiptasia pulchella
Comments:	TRH Concentration				

		Auxiliary Data Summary					
Conc-ug/L	**Parameter**	**Mean**	**Min**	**Max**	**SD**	**CV%**	**N**
FSW Control	% Normal	100.00	100.00	100.00	0.00	0.00	4
WAF Control		95.00	80.00	100.00	10.00	3.33	4
2492		93.33	80.00	100.00	11.55	3.64	3
7660		86.67	80.00	100.00	11.55	3.92	3
15840		80.00	60.00	100.00	20.00	5.59	3
28040		73.33	60.00	80.00	11.55	4.63	3
63990		0.00	0.00	0.00	0.00		3
FSW Control	pH	8.10	8.10	8.10	0.00	0.00	1
WAF Control		8.10	8.10	8.10	0.00	0.00	1
2492		8.10	8.10	8.10	0.00	0.00	1
7660		8.10	8.10	8.10	0.00	0.00	1
15840		8.00	8.00	8.00	0.00	0.00	1
28040		7.90	7.90	7.90	0.00	0.00	1
63990		7.60	7.60	7.60	0.00	0.00	1
FSW Control	Salinity ppt	35.10	35.10	35.10	0.00	0.00	1
WAF Control		35.10	35.10	35.10	0.00	0.00	1
2492		34.90	34.90	34.90	0.00	0.00	1
7660		34.90	34.90	34.90	0.00	0.00	1
15840		35.00	35.00	35.00	0.00	0.00	1
28040		35.00	35.00	35.00	0.00	0.00	1
63990		35.10	35.10	35.10	0.00	0.00	1
FSW Control	DO %	102.10	102.10	102.10	0.00	0.00	1
WAF Control		101.60	101.60	101.60	0.00	0.00	1
2492		103.90	103.90	103.90	0.00	0.00	1
7660		105.10	105.10	105.10	0.00	0.00	1
15840		105.20	105.20	105.20	0.00	0.00	1
28040		104.50	104.50	104.50	0.00	0.00	1
63990		110.40	110.40	110.40	0.00	0.00	1

Anemone Larval Toxicity Test-% Normal

Start Date:	27/10/2015 11:30	Test ID:	PR1244/31	Sample ID:	Barossa Field Condensate
End Date:	4/11/2015 10:30	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 128	Test Species:	AI-Aiptasia pulchella
Comments:					

Conc-g/L	1	2	3	4
FSW Control	1.0000	1.0000	1.0000	1.0000
WAF Control	1.0000	1.0000	0.8000	1.0000
4.8	0.8000	1.0000	1.0000	
9.7	0.8000	0.8000	1.0000	
19.3	0.6000	0.8000	1.0000	
38.6	0.8000	0.6000	0.8000	
77.2	0.0000	0.0000	0.0000	

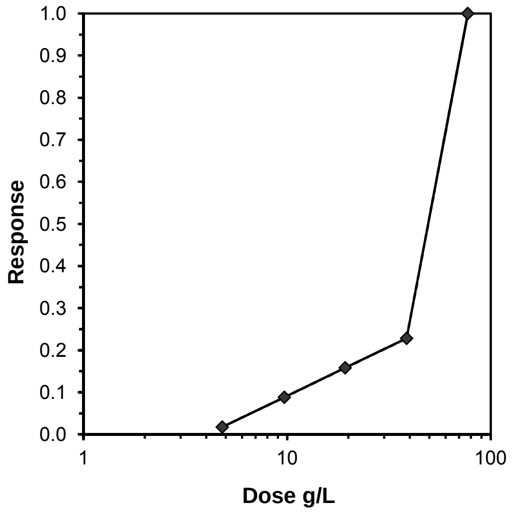
			Transform: Arcsin Square Root						1-Tailed		Isotonic	
Conc-g/L	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Mean	N-Mean
FSW Control	1.0000	1.0526	1.3453	1.3453	1.3453	0.000	4					
WAF Control	0.9500	1.0000	1.2857	1.1071	1.3453	9.261	4	*			0.9500	1.0000
4.8	0.9333	0.9825	1.2659	1.1071	1.3453	10.861	3	0.170	2.593	0.3023	0.9333	0.9825
9.7	0.8667	0.9123	1.1865	1.1071	1.3453	11.587	3	0.851	2.593	0.3023	0.8667	0.9123
19.3	0.8000	0.8421	1.1128	0.8861	1.3453	20.637	3	1.483	2.593	0.3023	0.8000	0.8421
38.6	0.7333	0.7719	1.0335	0.8861	1.1071	12.350	3	2.164	2.593	0.3023	0.7333	0.7719
77.2	0.0000	0.0000	0.2255	0.2255	0.2255	0.000	3				0.0000	0.0000

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)	0.931661	0.887	-0.22409	-0.77909
Bartlett's Test indicates equal variances (p = 0.88)	1.183699	13.2767		
The control means are not significantly different (p = 0.36)	1	2.446912		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSDp	MSB	MSE	F-Prob	df
Bonferroni t Test	38.6	77.2	54.58864		0.227972	0.247547	0.036184	0.023292	0.254275	4, 11
Treatments vs WAF Control										

Log-Logit Interpolation (200 Resamples)

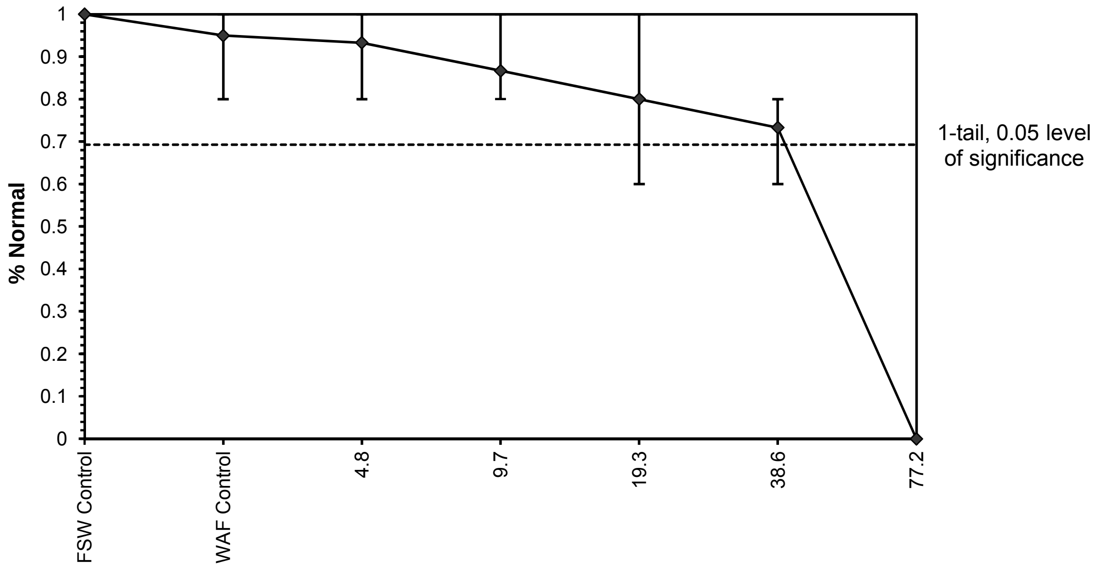
Point	g/L	SD	95% CL(Exp)		Skew
IC05	7.069	4.665	0.000	29.205	1.5128
IC10	11.167	7.033	0.284	38.143	1.0232
IC15	18.066	8.803	1.959	48.486	0.5551
IC20	29.791	10.145	1.565	44.843	-0.1692
IC25	38.875	8.426	3.066	40.413	-1.1606
IC40	40.571	0.665	38.281	42.074	-0.1870
IC50	41.642	0.649	39.342	43.120	-0.1869



Anemone Larval Toxicity Test-% Normal

Start Date:	27/10/2015 11:30	Test ID:	PR1244/31	Sample ID:	Barossa Field Condensate
End Date:	4/11/2015 10:30	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 128	Test Species:	AI-Aiptasia pulchella
Comments:					

Dose-Response Plot



ToxCalc v5.0.23

Reviewed by:_____

Anemone Larval Toxicity Test-% Normal

Start Date:	27/10/2015 11:30	Test ID:	PR1244/31	Sample ID:	Barossa Field Condensate
End Date:	4/11/2015 10:30	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 128	Test Species:	AI-Aiptasia pulchella
Comments:					

		Auxiliary Data Summary					
Conc-g/L	**Parameter**	**Mean**	**Min**	**Max**	**SD**	**CV%**	**N**
FSW Control	% Normal	100.00	100.00	100.00	0.00	0.00	4
WAF Control		95.00	80.00	100.00	10.00	3.33	4
4.8		93.33	80.00	100.00	11.55	3.64	3
9.7		86.67	80.00	100.00	11.55	3.92	3
19.3		80.00	60.00	100.00	20.00	5.59	3
38.6		73.33	60.00	80.00	11.55	4.63	3
77.2		0.00	0.00	0.00	0.00		3
FSW Control	pH	8.10	8.10	8.10	0.00	0.00	1
WAF Control		8.10	8.10	8.10	0.00	0.00	1
4.8		8.10	8.10	8.10	0.00	0.00	1
9.7		8.10	8.10	8.10	0.00	0.00	1
19.3		8.00	8.00	8.00	0.00	0.00	1
38.6		7.90	7.90	7.90	0.00	0.00	1
77.2		7.60	7.60	7.60	0.00	0.00	1
FSW Control	Salinity ppt	35.10	35.10	35.10	0.00	0.00	1
WAF Control		35.10	35.10	35.10	0.00	0.00	1
4.8		34.90	34.90	34.90	0.00	0.00	1
9.7		34.90	34.90	34.90	0.00	0.00	1
19.3		35.00	35.00	35.00	0.00	0.00	1
38.6		35.00	35.00	35.00	0.00	0.00	1
77.2		35.10	35.10	35.10	0.00	0.00	1
FSW Control	DO %	102.10	102.10	102.10	0.00	0.00	1
WAF Control		101.60	101.60	101.60	0.00	0.00	1
4.8		103.90	103.90	103.90	0.00	0.00	1
9.7		105.10	105.10	105.10	0.00	0.00	1
19.3		105.20	105.20	105.20	0.00	0.00	1
38.6		104.50	104.50	104.50	0.00	0.00	1
77.2		110.40	110.40	110.40	0.00	0.00	1

Appendix Q: Statistical Analyses of Copepodid Development Test

Marine Copepod Development Test-% Normal

Start Date:	22/09/2015 14:00	Test ID:	PR1244/02	Sample ID:	Borossa Field Condensate
End Date:	27/09/2015 14:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:		Test Species:	PC-Parvocalanus crassirostris
Comments:					

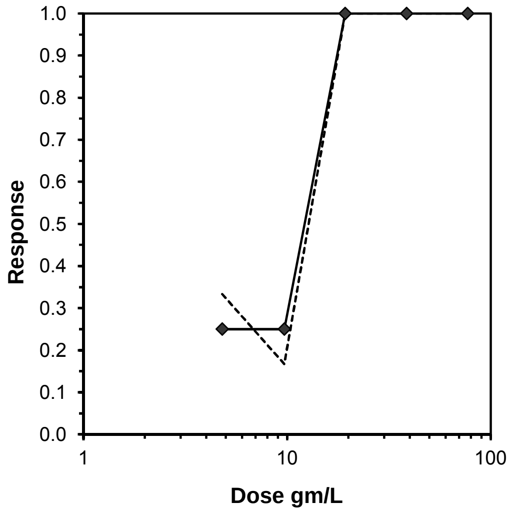
Conc-gm/L	1	2	3	4	5	6	7	8
FSW Control	0.6000	0.8000	0.6000	0.8000	0.6000	0.8000	0.6000	0.8000
WAF Control	0.8000	0.4000	0.6000	0.6000				
4.8	0.4000	0.6000	0.6000	0.0000				
9.7	0.6000	0.6000	0.4000	0.4000				
19.3	0.0000	0.0000	0.0000	0.0000				
38.6	0.0000	0.0000	0.0000	0.0000				
77.2	0.0000	0.0000	0.0000	0.0000				

			Transform: Arcsin Square Root						1-Tailed		Number	Total
Conc-gm/L	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Resp	Number
FSW Control	0.7000	1.1667	0.9966	0.8861	1.1071	11.857	8					
WAF Control	0.6000	1.0000	0.8910	0.6847	1.1071	19.366	4	*			8	20
4.8	0.4000	0.6667	0.6706	0.2255	0.8861	46.456	4	1.441	2.180	0.3334	12	20
9.7	0.5000	0.8333	0.7854	0.6847	0.8861	14.802	4	0.691	2.180	0.3334	10	20
19.3	0.0000	0.0000	0.2255	0.2255	0.2255	0.000	4				20	20
38.6	0.0000	0.0000	0.2255	0.2255	0.2255	0.000	4				20	20
77.2	0.0000	0.0000	0.2255	0.2255	0.2255	0.000	4				20	20

Auxiliary Tests					Statistic		Critical		Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)					0.909212		0.859		-0.97373	1.125224
Bartlett's Test indicates equal variances (p = 0.28)					2.518146		9.21034			
The control means are not significantly different (p = 0.24)					1.260902		2.228139			
Hypothesis Test (1-tail, 0.05)	**NOEC**	**LOEC**	**ChV**	**TU**	**MSDu**	**MSDp**	**MSB**	**MSE**	**F-Prob**	**df**
Dunnett's Test	9.7	19.3	13.68247		0.324825	0.537057	0.048608	0.046781	0.392639	2, 9
Treatments vs WAF Control										

Trimmed Spearman-Karber

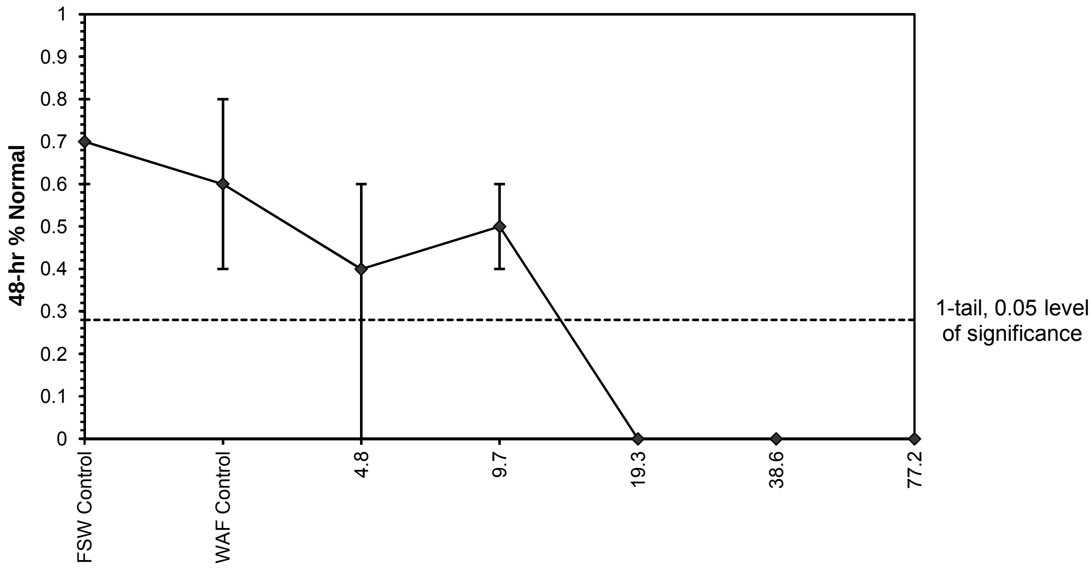
Trim Level	EC50	95% CL	
0.0%			
5.0%			
10.0%			
20.0%			
Auto-25.0%	12.200	10.838	13.734



Marine Copepod Development Test-% Normal

Start Date:	22/09/2015 14:00	Test ID:	PR1244/02	Sample ID:	Borossa Field Condensate
End Date:	27/09/2015 14:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:		Test Species:	PC-Parvocalanus crassirostris
Comments:					

Dose-Response Plot



Marine Copepod Development Test-% Normal

Start Date:	22/09/2015 14:00	Test ID:	PR1244/02	Sample ID:	Borossa Field Condensate
End Date:	27/09/2015 14:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:		Test Species:	PC-Parvocalanus crassirostris
Comments:					

		Auxiliary Data Summary					
Conc-gm/L	**Parameter**	**Mean**	**Min**	**Max**	**SD**	**CV%**	**N**
FSW Control	% normal	70.00	60.00	80.00	10.69	4.67	8
WAF Control		60.00	40.00	80.00	16.33	6.74	4
4.8		40.00	0.00	60.00	28.28	13.30	4
9.7		50.00	40.00	60.00	11.55	6.80	4
19.3		0.00	0.00	0.00	0.00		4
38.6		0.00	0.00	0.00	0.00		4
77.2		0.00	0.00	0.00	0.00		4
FSW Control	pH	8.20	8.20	8.20	0.00	0.00	1
WAF Control		8.20	8.20	8.20	0.00	0.00	1
4.8		8.10	8.10	8.10	0.00	0.00	1
9.7		8.10	8.10	8.10	0.00	0.00	1
19.3		8.00	8.00	8.00	0.00	0.00	1
38.6		7.80	7.80	7.80	0.00	0.00	1
77.2		7.30	7.30	7.30	0.00	0.00	1
FSW Control	DO %	99.80	99.80	99.80	0.00	0.00	1
WAF Control		92.80	92.80	92.80	0.00	0.00	1
4.8		96.30	96.30	96.30	0.00	0.00	1
9.7		95.70	95.70	95.70	0.00	0.00	1
19.3		96.70	96.70	96.70	0.00	0.00	1
38.6		95.60	95.60	95.60	0.00	0.00	1
77.2		85.10	85.10	85.10	0.00	0.00	1
FSW Control	Salinity ppt	34.90	34.90	34.90	0.00	0.00	1
WAF Control		35.10	35.10	35.10	0.00	0.00	1
4.8		35.10	35.10	35.10	0.00	0.00	1
9.7		35.10	35.10	35.10	0.00	0.00	1
19.3		35.20	35.20	35.20	0.00	0.00	1
38.6		35.30	35.30	35.30	0.00	0.00	1
77.2		35.30	35.30	35.30	0.00	0.00	1

Marine Copepod Development Test-% Normal

Start Date:	22/09/2015 14:00	Test ID:	PR1244/02	Sample ID:	Borossa Field Condensate
End Date:	27/09/2015 14:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:		Test Species:	PC-Parvocalanus crassirostris
Comments:					

Conc-gm/L	1	2	3	4	5	6	7	8
FSW Control	0.6000	0.8000	0.6000	0.8000	0.6000	0.8000	0.6000	0.8000
WAF Control	0.8000	0.4000	0.6000	0.6000				
4.8	0.4000	0.6000	0.6000	0.0000				
9.7	0.6000	0.6000	0.4000	0.4000				
19.3	0.0000	0.0000	0.0000	0.0000				
38.6	0.0000	0.0000	0.0000	0.0000				
77.2	0.0000	0.0000	0.0000	0.0000				

			Transform: Arcsin Square Root						1-Tailed		Isotonic	
Conc-gm/L	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Mean	N-Mean
FSW Control	0.7000	1.1667	0.9966	0.8861	1.1071	11.857	8					
WAF Control	0.6000	1.0000	0.8910	0.6847	1.1071	19.366	4	*			0.6000	1.0000
4.8	0.4000	0.6667	0.6706	0.2255	0.8861	46.456	4	1.441	2.180	0.3334	0.4500	0.7500
9.7	0.5000	0.8333	0.7854	0.6847	0.8861	14.802	4	0.691	2.180	0.3334	0.4500	0.7500
19.3	0.0000	0.0000	0.2255	0.2255	0.2255	0.000	4				0.0000	0.0000
38.6	0.0000	0.0000	0.2255	0.2255	0.2255	0.000	4				0.0000	0.0000
77.2	0.0000	0.0000	0.2255	0.2255	0.2255	0.000	4				0.0000	0.0000

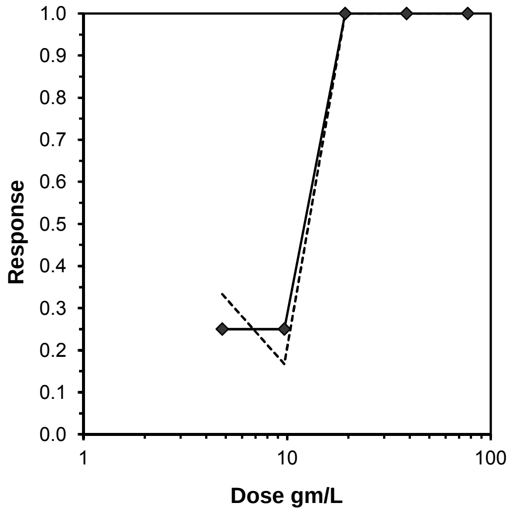
Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)	0.909212	0.859	-0.97373	1.125224
Bartlett's Test indicates equal variances (p = 0.28)	2.518146	9.21034		
The control means are not significantly different (p = 0.24)	1.260902	2.228139		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSDp	MSB	MSE	F-Prob	df
Dunnett's Test Treatments vs WAF Control	9.7	19.3	13.68247		0.324825	0.537057	0.048608	0.046781	0.392639	2, 9

Log-Logit Interpolation (200 Resamples)

Point	gm/L	SD	95% CL(Exp)		Skew
IC05*	0.431	3.000	0.067	14.446	1.9198
IC10*	1.036	3.573	0.073	14.258	1.1432
IC15*	1.886	3.723	0.004	13.948	0.6563
IC20*	3.088	3.708	0.000	13.465	0.2468
IC25	9.700	3.615	0.000	10.280	-0.2825
IC40	9.989	2.233	0.000	10.530	-2.2276
IC50	10.203	1.300	0.965	10.723	-4.2905

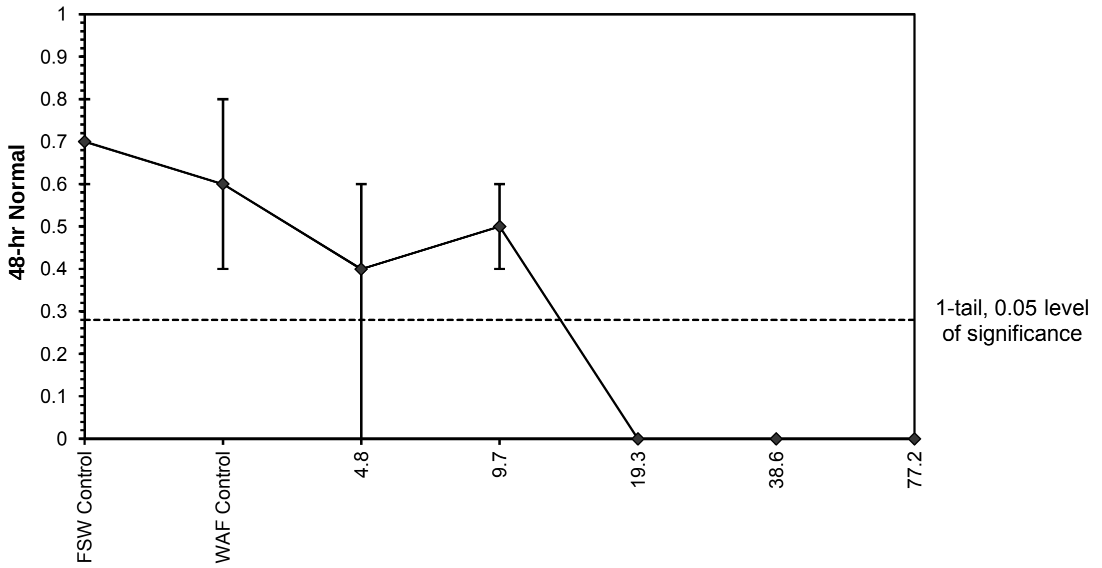
* indicates IC estimate less than the lowest concentration



Marine Copepod Development Test-% Normal

Start Date:	22/09/2015 14:00	Test ID:	PR1244/02	Sample ID:	Borossa Field Condensate
End Date:	27/09/2015 14:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:		Test Species:	PC-Parvocalanus crassirostris
Comments:					

Dose-Response Plot



Marine Copepod Development Test-% Normal

Start Date:	22/09/2015 14:00	Test ID:	PR1244/02	Sample ID:	Borossa Field Condensate
End Date:	27/09/2015 14:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:		Test Species:	PC-Parvocalanus crassirostris
Comments:					

		Auxiliary Data Summary					
Conc-gm/L	**Parameter**	**Mean**	**Min**	**Max**	**SD**	**CV%**	**N**
FSW Control	% normal	70.00	60.00	80.00	10.69	4.67	8
WAF Control		60.00	40.00	80.00	16.33	6.74	4
4.8		40.00	0.00	60.00	28.28	13.30	4
9.7		50.00	40.00	60.00	11.55	6.80	4
19.3		0.00	0.00	0.00	0.00		4
38.6		0.00	0.00	0.00	0.00		4
77.2		0.00	0.00	0.00	0.00		4
FSW Control	pH	8.20	8.20	8.20	0.00	0.00	1
WAF Control		8.20	8.20	8.20	0.00	0.00	1
4.8		8.10	8.10	8.10	0.00	0.00	1
9.7		8.10	8.10	8.10	0.00	0.00	1
19.3		8.00	8.00	8.00	0.00	0.00	1
38.6		7.80	7.80	7.80	0.00	0.00	1
77.2		7.30	7.30	7.30	0.00	0.00	1
FSW Control	DO %	99.80	99.80	99.80	0.00	0.00	1
WAF Control		92.80	92.80	92.80	0.00	0.00	1
4.8		96.30	96.30	96.30	0.00	0.00	1
9.7		95.70	95.70	95.70	0.00	0.00	1
19.3		96.70	96.70	96.70	0.00	0.00	1
38.6		95.60	95.60	95.60	0.00	0.00	1
77.2		85.10	85.10	85.10	0.00	0.00	1
FSW Control	Salinity ppt	34.90	34.90	34.90	0.00	0.00	1
WAF Control		35.10	35.10	35.10	0.00	0.00	1
4.8		35.10	35.10	35.10	0.00	0.00	1
9.7		35.10	35.10	35.10	0.00	0.00	1
19.3		35.20	35.20	35.20	0.00	0.00	1
38.6		35.30	35.30	35.30	0.00	0.00	1
77.2		35.30	35.30	35.30	0.00	0.00	1

Marine Copepod Development Test-% Normal

Start Date:	22/09/2015 14:00	Test ID:	PR1244/02	Sample ID:	Borossa Field Condensate
End Date:	27/09/2015 14:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:		Test Species:	PC-Parvocalanus crassirostris
Comments:					

Conc-gm/L	1	2	3	4	5	6	7	8
FSW Control	0.6000	0.8000	0.6000	0.8000	0.6000	0.8000	0.6000	0.8000
WAF Control	0.8000	0.4000	0.6000	0.6000				
3860	0.4000	0.6000	0.6000	0.0000				
8560	0.6000	0.6000	0.4000	0.4000				
15830	0.0000	0.0000	0.0000	0.0000				
29770	0.0000	0.0000	0.0000	0.0000				
68390	0.0000	0.0000	0.0000	0.0000				

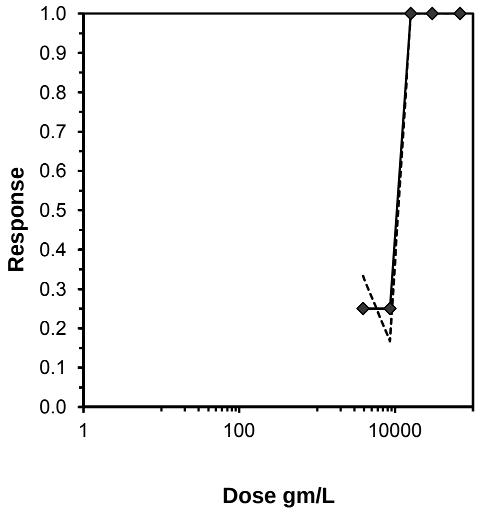
			Transform: Arcsin Square Root						1-Tailed		Number	Total
Conc-gm/L	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Resp	Number
FSW Control	0.7000	1.1667	0.9966	0.8861	1.1071	11.857	8					
WAF Control	0.6000	1.0000	0.8910	0.6847	1.1071	19.366	4		*		8	20
3860	0.4000	0.6667	0.6706	0.2255	0.8861	46.456	4	1.441	2.180	0.3334	12	20
8560	0.5000	0.8333	0.7854	0.6847	0.8861	14.802	4	0.691	2.180	0.3334	10	20
15830	0.0000	0.0000	0.2255	0.2255	0.2255	0.000	4				20	20
29770	0.0000	0.0000	0.2255	0.2255	0.2255	0.000	4				20	20
68390	0.0000	0.0000	0.2255	0.2255	0.2255	0.000	4				20	20

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)	0.909212	0.859	-0.97373	1.125224
Bartlett's Test indicates equal variances (p = 0.28)	2.518146	9.21034		
The control means are not significantly different (p = 0.24)	1.260902	2.228139		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSDp	MSB	MSE	F-Prob	df
Dunnett's Test	8560	15830	11640.65		0.324825	0.537057	0.048608	0.046781	0.392639	2, 9
Treatments vs WAF Control										

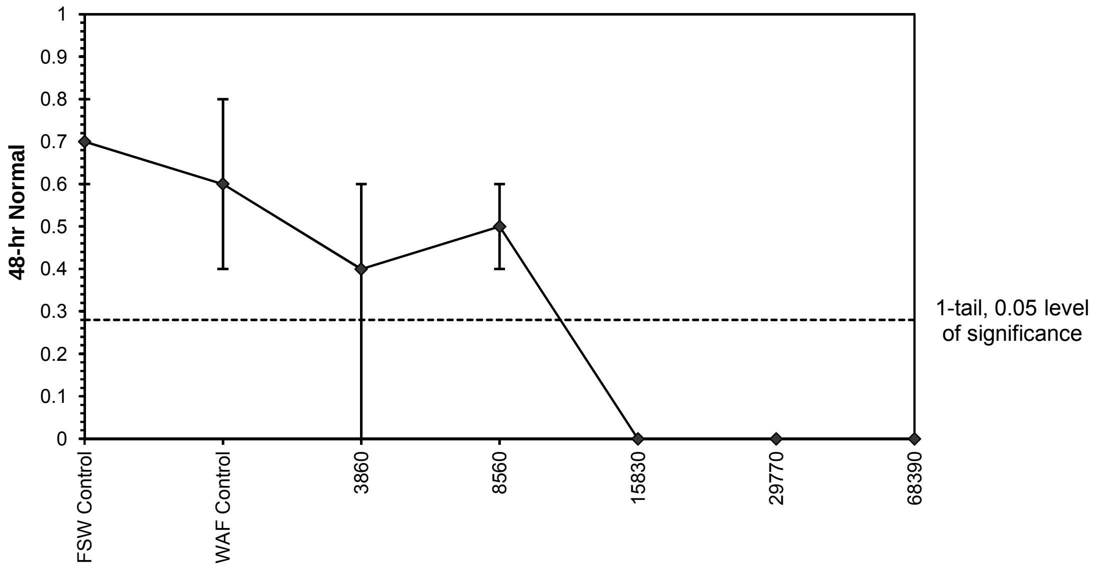
Trimmed Spearman-Karber

Trim Level	EC50	95% CL	
0.0%			
5.0%			
10.0%			
20.0%			
Auto-25.0%	10506.94	9451.822	11679.84



Marine Copepod Development Test-% Normal					
Start Date:	22/09/2015 14:00	Test ID: PR1244/02		Sample ID:	Borossa Field Condensate
End Date:	27/09/2015 14:00	Lab ID: 7323		Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:		Test Species:	PC-Parvocalanus crassirostris
Comments:					

Dose-Response Plot



Marine Copepod Development Test-% Normal

Start Date:	22/09/2015 14:00	Test ID:	PR1244/02	Sample ID:	Borossa Field Condensate
End Date:	27/09/2015 14:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:		Test Species:	PC-Parvocalanus crassirostris
Comments:					

		Auxiliary Data Summary					
Conc-gm/L	**Parameter**	**Mean**	**Min**	**Max**	**SD**	**CV%**	**N**
FSW Control	% normal	70.00	60.00	80.00	10.69	4.67	8
WAF Control		60.00	40.00	80.00	16.33	6.74	4
3860		40.00	0.00	60.00	28.28	13.30	4
8560		50.00	40.00	60.00	11.55	6.80	4
15830		0.00	0.00	0.00	0.00		4
29770		0.00	0.00	0.00	0.00		4
68390		0.00	0.00	0.00	0.00		4
FSW Control	pH	8.20	8.20	8.20	0.00	0.00	1
WAF Control		8.20	8.20	8.20	0.00	0.00	1
3860		8.10	8.10	8.10	0.00	0.00	1
8560		8.10	8.10	8.10	0.00	0.00	1
15830		8.00	8.00	8.00	0.00	0.00	1
29770		7.80	7.80	7.80	0.00	0.00	1
68390		7.30	7.30	7.30	0.00	0.00	1
FSW Control	DO %	99.80	99.80	99.80	0.00	0.00	1
WAF Control		92.80	92.80	92.80	0.00	0.00	1
3860		96.30	96.30	96.30	0.00	0.00	1
8560		95.70	95.70	95.70	0.00	0.00	1
15830		96.70	96.70	96.70	0.00	0.00	1
29770		95.60	95.60	95.60	0.00	0.00	1
68390		85.10	85.10	85.10	0.00	0.00	1
FSW Control	Salinity ppt	34.90	34.90	34.90	0.00	0.00	1
WAF Control		35.10	35.10	35.10	0.00	0.00	1
3860		35.10	35.10	35.10	0.00	0.00	1
8560		35.10	35.10	35.10	0.00	0.00	1
15830		35.20	35.20	35.20	0.00	0.00	1
29770		35.30	35.30	35.30	0.00	0.00	1
68390		35.30	35.30	35.30	0.00	0.00	1

Marine Copepod Development Test-% Normal

Start Date:	22/09/2015 14:00	Test ID:	PR1244/02	Sample ID:	Borossa Field Condensate
End Date:	27/09/2015 14:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:		Test Species:	PC-Parvocalanus crassirostris
Comments:					

Conc-gm/L	1	2	3	4	5	6	7	8
FSW Control	0.6000	0.8000	0.6000	0.8000	0.6000	0.8000	0.6000	0.8000
WAF Control	0.8000	0.4000	0.6000	0.6000				
3860	0.4000	0.6000	0.6000	0.0000				
8560	0.6000	0.6000	0.4000	0.4000				
15830	0.0000	0.0000	0.0000	0.0000				
29770	0.0000	0.0000	0.0000	0.0000				
68390	0.0000	0.0000	0.0000	0.0000				

			Transform: Arcsin Square Root						1-Tailed		Isotonic	
Conc-gm/L	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Mean	N-Mean
FSW Control	0.7000	1.1667	0.9966	0.8861	1.1071	11.857	8					
WAF Control	0.6000	1.0000	0.8910	0.6847	1.1071	19.366	4	*			0.6000	1.0000
3860	0.4000	0.6667	0.6706	0.2255	0.8861	46.456	4	1.441	2.180	0.3334	0.4500	0.7500
8560	0.5000	0.8333	0.7854	0.6847	0.8861	14.802	4	0.691	2.180	0.3334	0.4500	0.7500
15830	0.0000	0.0000	0.2255	0.2255	0.2255	0.000	4				0.0000	0.0000
29770	0.0000	0.0000	0.2255	0.2255	0.2255	0.000	4				0.0000	0.0000
68390	0.0000	0.0000	0.2255	0.2255	0.2255	0.000	4				0.0000	0.0000

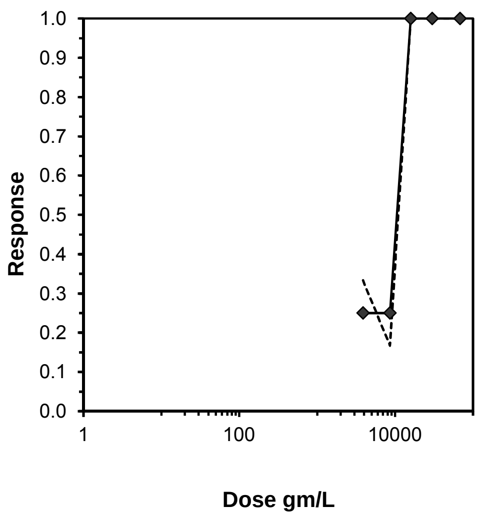
Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)	0.909212	0.859	-0.97373	1.125224
Bartlett's Test indicates equal variances (p = 0.28)	2.518146	9.21034		
The control means are not significantly different (p = 0.24)	1.260902	2.228139		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSDp	MSB	MSE	F-Prob	df
Dunnett's Test	8560	15830	11640.65		0.324825	0.537057	0.048608	0.046781	0.392639	2, 9
Treatments vs WAF Control										

Log-Logit Interpolation (200 Resamples)

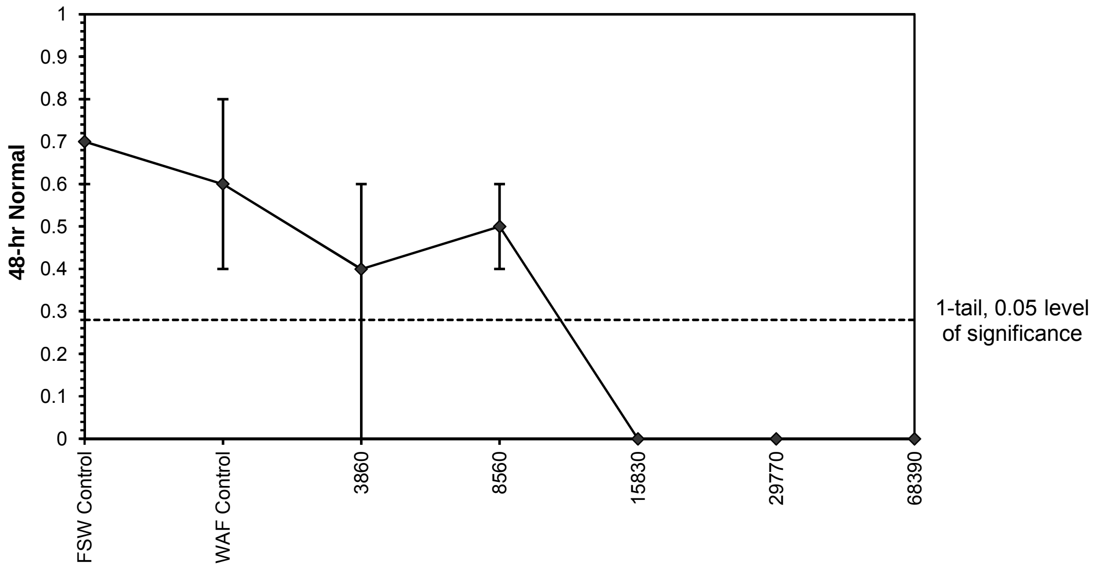
Point	gm/L	SD	95% CL(Exp)		Skew
IC05*	4.388444	2798.854	0	12928.47	2.0197
IC10*	27.21423	3271.518	0	13008.23	1.3764
IC15*	144.3927	3767.918	0	13041.84	0.7201
IC20*	745.2861	4038.67	0	12835.18	0.2071
IC25	8560	3983.675	0	9023.806	-0.2610
IC40	8781.697	2442.853	0	9221.466	-2.2951
IC50	8946.181	1148.001	8126.509	9372.164	-5.9722

* indicates IC estimate less than the lowest concentration



Marine Copepod Development Test-% Normal					
Start Date:	22/09/2015 14:00	Test ID:	PR1244/02	Sample ID:	Borossa Field Condensate
End Date:	27/09/2015 14:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:		Test Species:	PC-Parvocalanus crassirostris
Comments:					

Dose-Response Plot



Marine Copepod Development Test-% Normal

Start Date:	22/09/2015 14:00	Test ID:	PR1244/02	Sample ID:	Borossa Field Condensate
End Date:	27/09/2015 14:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:		Test Species:	PC-Parvocalanus crassirostris
Comments:					

Auxiliary Data Summary

Conc-gm/L	Parameter	Mean	Min	Max	SD	CV%	N
FSW Control	% normal	70.00	60.00	80.00	10.69	4.67	8
WAF Control		60.00	40.00	80.00	16.33	6.74	4
3860		40.00	0.00	60.00	28.28	13.30	4
8560		50.00	40.00	60.00	11.55	6.80	4
15830		0.00	0.00	0.00	0.00		4
29770		0.00	0.00	0.00	0.00		4
68390		0.00	0.00	0.00	0.00		4
FSW Control	pH	8.20	8.20	8.20	0.00	0.00	1
WAF Control		8.20	8.20	8.20	0.00	0.00	1
3860		8.10	8.10	8.10	0.00	0.00	1
8560		8.10	8.10	8.10	0.00	0.00	1
15830		8.00	8.00	8.00	0.00	0.00	1
29770		7.80	7.80	7.80	0.00	0.00	1
68390		7.30	7.30	7.30	0.00	0.00	1
FSW Control	DO %	99.80	99.80	99.80	0.00	0.00	1
WAF Control		92.80	92.80	92.80	0.00	0.00	1
3860		96.30	96.30	96.30	0.00	0.00	1
8560		95.70	95.70	95.70	0.00	0.00	1
15830		96.70	96.70	96.70	0.00	0.00	1
29770		95.60	95.60	95.60	0.00	0.00	1
68390		85.10	85.10	85.10	0.00	0.00	1
FSW Control	Salinity ppt	34.90	34.90	34.90	0.00	0.00	1
WAF Control		35.10	35.10	35.10	0.00	0.00	1
3860		35.10	35.10	35.10	0.00	0.00	1
8560		35.10	35.10	35.10	0.00	0.00	1
15830		35.20	35.20	35.20	0.00	0.00	1
29770		35.30	35.30	35.30	0.00	0.00	1
68390		35.30	35.30	35.30	0.00	0.00	1

Appendix R: Statistical Analyses of the Fish Imbalance and Growth Test

Fish Growth Test-7 Day Unaffected

Start Date:	22/09/2015 12:30	Test ID:	PR1244/06	Sample ID:	Barossa Field Condensate
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	Loading Rate				

Conc-gm/L	1	2	3	4
FSW Control	1.0000	1.0000	1.0000	1.0000
WAF Control	1.0000	1.0000	1.0000	1.0000
4.8	1.0000	1.0000	1.0000	1.0000
9.7	1.0000	1.0000	1.0000	1.0000
19.3	0.8000	0.8000	1.0000	1.0000
38.6	0.2000	0.2000	0.2000	0.2000
77.2	0.0000	0.0000	0.0000	0.0000

			Transform: Arcsin Square Root					Rank	1-Tailed	Number	Total
Conc-gm/L	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical	Resp	Number
FSW Control	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4				
WAF Control	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	*		0	20
4.8	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	18.00	10.00	0	20
9.7	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	18.00	10.00	0	20
19.3	0.9000	0.9000	1.2262	1.1071	1.3453	11.212	4	14.00	10.00	2	20
*38.6	0.2000	0.2000	0.4636	0.4636	0.4636	0.000	4	10.00	10.00	16	20
77.2	0.0000	0.0000	0.2255	0.2255	0.2255	0.000	4			20	20

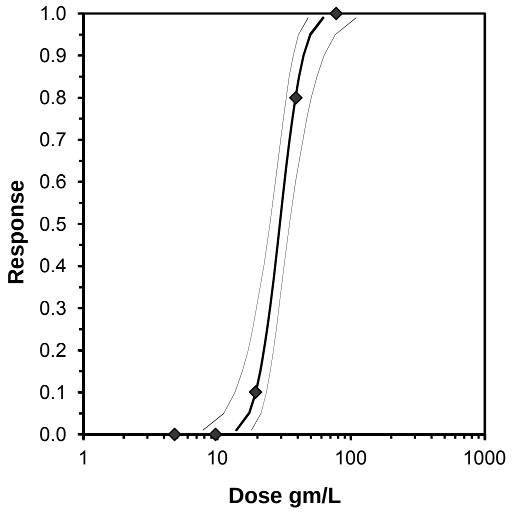
Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates non-normal distribution (p <= 0.05)	0.63123	0.905	5.4E-15	2.980392
Equality of variance cannot be confirmed				
The control means are not significantly different (p = 1.00)	0	2.446912		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
Steel's Many-One Rank Test	19.3	38.6	27.29432	
Treatments vs WAF Control				

Maximum Likelihood-Probit

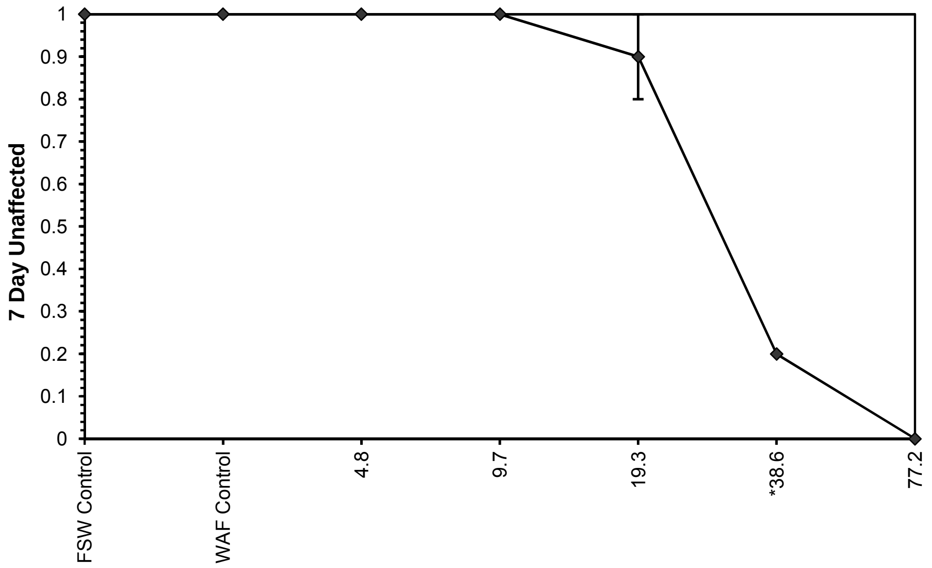
Parameter	Value	SE	95% Fiducial Limits		Control	Chi-Sq	Critical	P-value	Mu	Sigma	Iter
Slope	7.178029	1.531775	4.175749	10.18031	0	0.036857	7.814728	1	1.466663	0.139314	3
Intercept	-5.52775	2.261845	-9.96097	-1.09453							
TSCR											

Point	Probits	gm/L	95% Fiducial Limits	
EC01	2.674	13.88578	7.816206	17.95356
EC05	3.355	17.27874	11.23676	21.21538
EC10	3.718	19.41445	13.58027	23.28484
EC15	3.964	21.00263	15.38899	24.86277
EC20	4.158	22.35701	16.95756	26.25341
EC25	4.326	23.58834	18.39006	27.56814
EC40	4.747	27.00029	22.27634	31.5769
EC50	5.000	29.28622	24.7131	34.66116
EC60	5.253	31.76568	27.14661	38.42481
EC75	5.674	36.36044	31.12336	46.50115
EC80	5.842	38.36303	32.69047	50.41624
EC85	6.036	40.83692	34.52706	55.54199
EC90	6.282	44.17752	36.87479	62.9259
EC95	6.645	49.63802	40.48028	76.03354
EC99	7.326	61.76696	47.84469	109.285



Fish Growth Test-7 Day Unaffected					
Start Date:	22/09/2015 12:30	Test ID:	PR1244/06	Sample ID:	Barossa Field Condensate
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	Loading Rate				

Dose-Response Plot



ToxCalc v5.0.23
Reviewed by:_____

Fish Growth Test-7 Day Unaffected

Start Date:	22/09/2015 12:30	Test ID:	PR1244/06	Sample ID:	Barossa Field Condensate
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	Loading Rate				

Auxiliary Data Summary

Conc-gm/L	Parameter	Mean	Min	Max	SD	CV%	N
FSW Control	% Un-affected	100.00	100.00	100.00	0.00	0.00	4
WAF Control		100.00	100.00	100.00	0.00	0.00	4
4.8		100.00	100.00	100.00	0.00	0.00	4
9.7		100.00	100.00	100.00	0.00	0.00	4
19.3		90.00	80.00	100.00	11.55	3.78	4
38.6		20.00	20.00	20.00	0.00	0.00	4
77.2		0.00	0.00	0.00	0.00		4
FSW Control	Biomass	8.33	7.12	10.12	1.31	13.72	4
WAF Control		7.98	7.16	9.02	0.79	11.13	4
4.8		7.74	7.34	8.30	0.43	8.50	4
9.7		8.26	7.94	8.58	0.30	6.63	4
19.3		7.74	6.22	9.04	1.16	13.93	4
38.6		1.36	1.20	1.60	0.17	30.57	4
77.2		0.00	0.00	0.00	0.00		4
FSW Control	pH	8.20	8.20	8.20	0.00	0.00	1
WAF Control		8.20	8.20	8.20	0.00	0.00	1
4.8		8.10	8.10	8.10	0.00	0.00	1
9.7		8.10	8.10	8.10	0.00	0.00	1
19.3		8.00	8.00	8.00	0.00	0.00	1
38.6		7.80	7.80	7.80	0.00	0.00	1
77.2		7.30	7.30	7.30	0.00	0.00	1
FSW Control	Salinity	34.90	34.90	34.90	0.00	0.00	1
WAF Control		35.10	35.10	35.10	0.00	0.00	1
4.8		35.10	35.10	35.10	0.00	0.00	1
9.7		35.10	35.10	35.10	0.00	0.00	1
19.3		35.20	35.20	35.20	0.00	0.00	1
38.6		35.30	35.30	35.30	0.00	0.00	1
77.2		35.30	35.30	35.30	0.00	0.00	1
FSW Control	% DO	99.80	99.80	99.80	0.00	0.00	1
WAF Control		92.80	92.80	92.80	0.00	0.00	1
4.8		96.30	96.30	96.30	0.00	0.00	1
9.7		95.70	95.70	95.70	0.00	0.00	1
19.3		96.70	96.70	96.70	0.00	0.00	1
38.6		95.60	95.60	95.60	0.00	0.00	1
77.2		85.10	85.10	85.10	0.00	0.00	1

Fish Growth Test-7 Day Unaffected

Start Date:	22/09/2015 12:30	Test ID:	PR1244/06b	Sample ID:	Barossa Field Condensate
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	TRH				

Conc-ug/L	1	2	3	4
FSW Control	1.0000	1.0000	1.0000	1.0000
WAF Control	1.0000	1.0000	1.0000	1.0000
3860	1.0000	1.0000	1.0000	1.0000
8560	1.0000	1.0000	1.0000	1.0000
15830	0.8000	0.8000	1.0000	1.0000
29770	0.2000	0.2000	0.2000	0.2000
68390	0.0000	0.0000	0.0000	0.0000

			Transform: Arcsin Square Root					Rank	1-Tailed	Number	Total
Conc-ug/L	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical	Resp	Number
FSW Control	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4				
WAF Control	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	*		0	20
3860	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	18.00	10.00	0	20
8560	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	18.00	10.00	0	20
15830	0.9000	0.9000	1.2262	1.1071	1.3453	11.212	4	14.00	10.00	2	20
*29770	0.2000	0.2000	0.4636	0.4636	0.4636	0.000	4	10.00	10.00	16	20
68390	0.0000	0.0000	0.2255	0.2255	0.2255	0.000	4			20	20

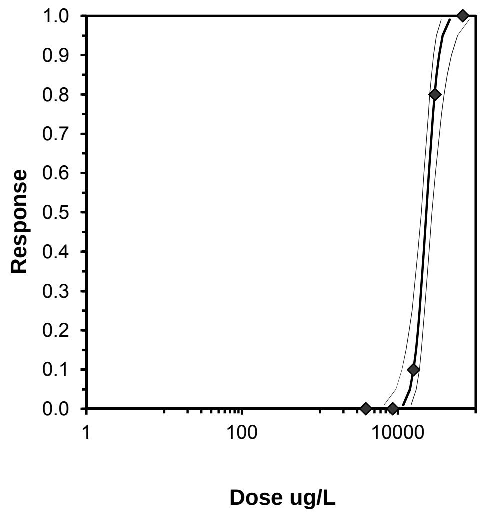
Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates non-normal distribution (p <= 0.05)	0.63123	0.905	5.4E-15	2.980392
Equality of variance cannot be confirmed				
The control means are not significantly different (p = 1.00)	0	2.446912		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
Steel's Many-One Rank Test	15830	29770	21708.5	
Treatments vs WAF Control				

Maximum Likelihood-Probit

Parameter	Value	SE	95% Fiducial Limits		Control	Chi-Sq	Critical	P-value	Mu	Sigma	Iter
Slope	7.794081	1.747035	4.369893	11.21827	0	0.010855	7.814728	1	4.365154	0.128302	3
Intercept	-29.0224	7.620937	-43.9594	-14.0853							
TSCR											

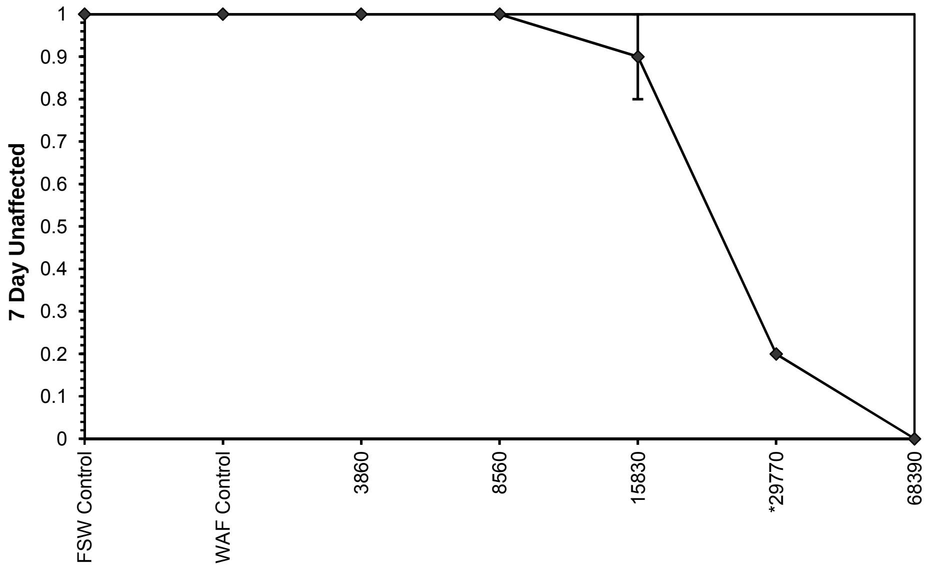
Point	Probits	ug/L	95% Fiducial Limits	
EC01	2.674	11659.45	6649.302	14800.89
EC05	3.355	14259.87	9408.471	17228.43
EC10	3.718	15875.53	11275.41	18756.63
EC15	3.964	17067.8	12704.42	19919.32
EC20	4.158	18078.91	13934.91	20944.57
EC25	4.326	18993.97	15050.69	21916.11
EC40	4.747	21510.44	18029.4	24903.08
EC50	5.000	23182.19	19851.65	27226.81
EC60	5.253	24983.86	21633.54	30076.32
EC75	5.674	28293.92	24480.92	36177.54
EC80	5.842	29726	25588.28	39117.39
EC85	6.036	31487.01	26878.99	42948.14
EC90	6.282	33851.71	28519.97	48434.02
EC95	6.645	37687.14	31023.54	58093.9
EC99	7.326	46092.54	36082.36	82267.42



Fish Growth Test-7 Day Unaffected

Start Date:	22/09/2015 12:30	Test ID:	PR1244/06b	Sample ID:	Barossa Field Condensate
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	TRH				

Dose-Response Plot



ToxCalc v5.0.23
Reviewed by:_____

Fish Growth Test-7 Day Unaffected

Start Date:	22/09/2015 12:30	Test ID:	PR1244/06b	Sample ID:	Barossa Field Condensate
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	TRH				

Auxiliary Data Summary

Conc-ug/L	Parameter	Mean	Min	Max	SD	CV%	N
FSW Control	% Un-affected	100.00	100.00	100.00	0.00	0.00	4
WAF Control		100.00	100.00	100.00	0.00	0.00	4
3860		100.00	100.00	100.00	0.00	0.00	4
8560		100.00	100.00	100.00	0.00	0.00	4
15830		90.00	80.00	100.00	11.55	3.78	4
29770		20.00	20.00	20.00	0.00	0.00	4
68390		0.00	0.00	0.00	0.00		4
FSW Control	Biomass	8.33	7.12	10.12	1.31	13.72	4
WAF Control		7.98	7.16	9.02	0.79	11.13	4
3860		7.74	7.34	8.30	0.43	8.50	4
8560		8.26	7.94	8.58	0.30	6.63	4
15830		7.74	6.22	9.04	1.16	13.93	4
29770		1.36	1.20	1.60	0.17	30.57	4
68390		0.00	0.00	0.00	0.00		4
FSW Control	pH	8.20	8.20	8.20	0.00	0.00	1
WAF Control		8.20	8.20	8.20	0.00	0.00	1
3860		8.10	8.10	8.10	0.00	0.00	1
8560		8.10	8.10	8.10	0.00	0.00	1
15830		8.00	8.00	8.00	0.00	0.00	1
29770		7.80	7.80	7.80	0.00	0.00	1
68390		7.30	7.30	7.30	0.00	0.00	1
FSW Control	Salinity	34.90	34.90	34.90	0.00	0.00	1
WAF Control		35.10	35.10	35.10	0.00	0.00	1
3860		35.10	35.10	35.10	0.00	0.00	1
8560		35.10	35.10	35.10	0.00	0.00	1
15830		35.20	35.20	35.20	0.00	0.00	1
29770		35.30	35.30	35.30	0.00	0.00	1
68390		35.30	35.30	35.30	0.00	0.00	1
FSW Control	% DO	99.80	99.80	99.80	0.00	0.00	1
WAF Control		92.80	92.80	92.80	0.00	0.00	1
3860		96.30	96.30	96.30	0.00	0.00	1
8560		95.70	95.70	95.70	0.00	0.00	1
15830		96.70	96.70	96.70	0.00	0.00	1
29770		95.60	95.60	95.60	0.00	0.00	1
68390		85.10	85.10	85.10	0.00	0.00	1

Fish Growth Test-7 day Biomass

Start Date:	22/09/2015 12:30	Test ID:	PR1244/06	Sample ID:	Barossa Field Condensate
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	Loading Rate				

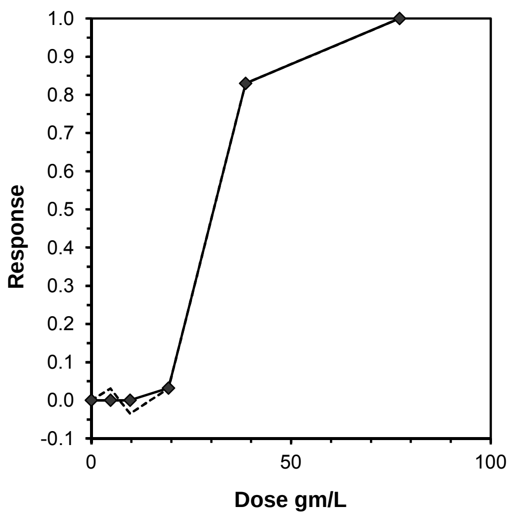
Conc-gm/L	1	2	3	4
FSW Control	8.4200	10.1200	7.1200	7.6600
WAF Control	8.0800	9.0200	7.1600	7.6600
4.8	7.3400	8.3000	7.8400	7.4600
9.7	7.9400	8.4400	8.5800	8.0800
19.3	7.7200	6.2200	7.9600	9.0400
38.6	1.2800	1.2000	1.6000	1.3600
77.2	0.0000	0.0000	0.0000	0.0000

			Transform: Untransformed						1-Tailed		Isotonic	
Conc-gm/L	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Mean	N-Mean
FSW Control	8.3300	1.0439	8.3300	7.1200	10.1200	15.691	4					
WAF Control	7.9800	1.0000	7.9800	7.1600	9.0200	9.884	4	*			7.9917	1.0000
4.8	7.7350	0.9693	7.7350	7.3400	8.3000	5.595	4	0.513	2.360	1.1266	7.9917	1.0000
9.7	8.2600	1.0351	8.2600	7.9400	8.5800	3.629	4	-0.587	2.360	1.1266	7.9917	1.0000
19.3	7.7350	0.9693	7.7350	6.2200	9.0400	15.020	4	0.513	2.360	1.1266	7.7350	0.9679
*38.6	1.3600	0.1704	1.3600	1.2000	1.6000	12.707	4	13.868	2.360	1.1266	1.3600	0.1702
77.2	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	4				0.0000	0.0000

Auxiliary Tests					Statistic		Critical			Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)					0.940823		0.905			-0.16077	2.019523
Bartlett's Test indicates equal variances (p = 0.04)					10.16842		13.2767				
The control means are not significantly different (p = 0.66)					0.458533		2.446912				
Hypothesis Test (1-tail, 0.05)	**NOEC**	**LOEC**	**ChV**	**TU**	**MSDu**	**MSDp**	**MSB**	**MSE**	**F-Prob**	**df**	
Dunnett's Test	19.3	38.6	27.29432		1.126604	0.141178	34.69307	0.455773	8.9E-10	4, 15	
Treatments vs WAF Control											

Linear Interpolation (200 Resamples)

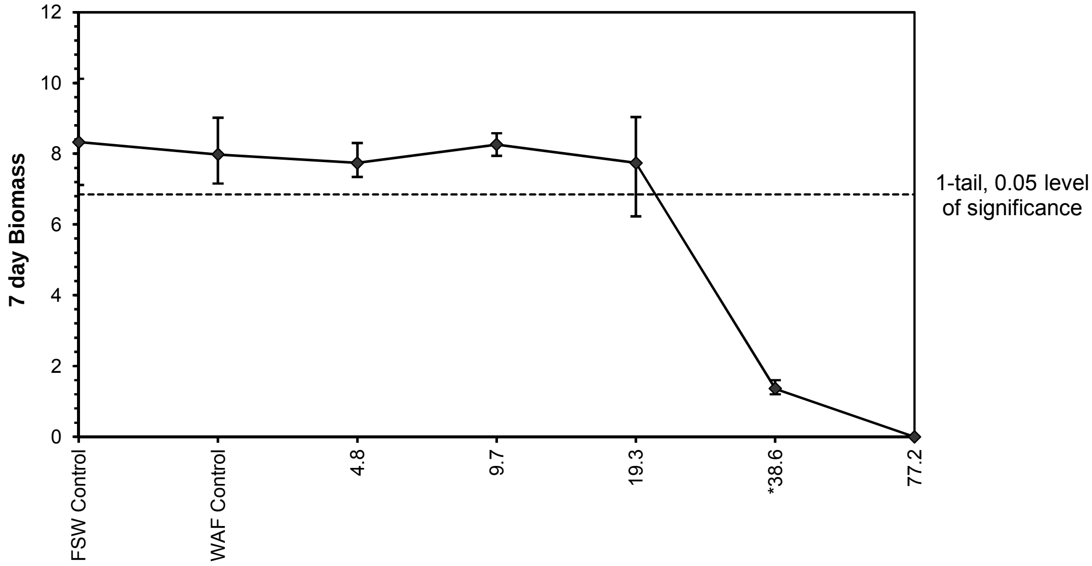
Point	gm/L	SD	95% CL(Exp)		Skew
IC05	19.733	5.770	0.000	20.929	-1.2041
IC10	20.942	2.422	8.439	22.092	-2.6612
IC15	22.152	1.438	15.155	23.255	-2.0412
IC20	23.362	1.168	17.945	24.430	-1.4775
IC25	24.572	1.055	19.614	25.602	-1.2318
IC40	28.201	0.804	24.611	29.105	-1.1814
IC50	30.620	0.643	27.794	31.439	-1.0997



Fish Growth Test-7 day Biomass

Start Date:	22/09/2015 12:30	Test ID:	PR1244/06	Sample ID:	Barossa Field Condensate
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	Loading Rate				

Dose-Response Plot



Fish Growth Test-7 day Biomass

Start Date:	22/09/2015 12:30	Test ID:	PR1244/06	Sample ID:	Barossa Field Condensate
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	Loading Rate				

		Auxiliary Data Summary					
Conc-gm/L	**Parameter**	**Mean**	**Min**	**Max**	**SD**	**CV%**	**N**
FSW Control	% Un-affected	100.00	100.00	100.00	0.00	0.00	4
WAF Control		100.00	100.00	100.00	0.00	0.00	4
4.8		100.00	100.00	100.00	0.00	0.00	4
9.7		100.00	100.00	100.00	0.00	0.00	4
19.3		90.00	80.00	100.00	11.55	3.78	4
38.6		20.00	20.00	20.00	0.00	0.00	4
77.2		0.00	0.00	0.00	0.00		4
FSW Control	Biomass	8.33	7.12	10.12	1.31	13.72	4
WAF Control		7.98	7.16	9.02	0.79	11.13	4
4.8		7.74	7.34	8.30	0.43	8.50	4
9.7		8.26	7.94	8.58	0.30	6.63	4
19.3		7.74	6.22	9.04	1.16	13.93	4
38.6		1.36	1.20	1.60	0.17	30.57	4
77.2		0.00	0.00	0.00	0.00		4
FSW Control	pH	8.20	8.20	8.20	0.00	0.00	1
WAF Control		8.20	8.20	8.20	0.00	0.00	1
4.8		8.10	8.10	8.10	0.00	0.00	1
9.7		8.10	8.10	8.10	0.00	0.00	1
19.3		8.00	8.00	8.00	0.00	0.00	1
38.6		7.80	7.80	7.80	0.00	0.00	1
77.2		7.30	7.30	7.30	0.00	0.00	1
FSW Control	Salinity	34.90	34.90	34.90	0.00	0.00	1
WAF Control		35.10	35.10	35.10	0.00	0.00	1
4.8		35.10	35.10	35.10	0.00	0.00	1
9.7		35.10	35.10	35.10	0.00	0.00	1
19.3		35.20	35.20	35.20	0.00	0.00	1
38.6		35.30	35.30	35.30	0.00	0.00	1
77.2		35.30	35.30	35.30	0.00	0.00	1
FSW Control	% DO	99.80	99.80	99.80	0.00	0.00	1
WAF Control		92.80	92.80	92.80	0.00	0.00	1
4.8		96.30	96.30	96.30	0.00	0.00	1
9.7		95.70	95.70	95.70	0.00	0.00	1
19.3		96.70	96.70	96.70	0.00	0.00	1
38.6		95.60	95.60	95.60	0.00	0.00	1
77.2		85.10	85.10	85.10	0.00	0.00	1

Fish Growth Test-7 day Biomass

Start Date:	22/09/2015 12:30	Test ID:	PR1244/06b	Sample ID:	Barossa Field Condensate
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	TRH				

Conc-ug/L	1	2	3	4
FSW Control	8.4200	10.1200	7.1200	7.6600
WAF Control	8.0800	9.0200	7.1600	7.6600
3860	7.3400	8.3000	7.8400	7.4600
8560	7.9400	8.4400	8.5800	8.0800
15830	7.7200	6.2200	7.9600	9.0400
29770	1.2800	1.2000	1.6000	1.3600
68390	0.0000	0.0000	0.0000	0.0000

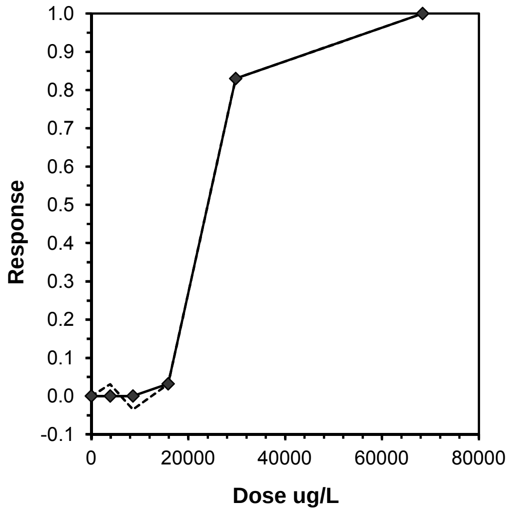
			Transform: Untransformed						1-Tailed		Isotonic	
Conc-ug/L	Mean	N-Mean	Mean	Min	Max	CV%	N	t-Stat	Critical	MSD	Mean	N-Mean
FSW Control	8.3300	1.0439	8.3300	7.1200	10.1200	15.691	4					
WAF Control	7.9800	1.0000	7.9800	7.1600	9.0200	9.884	4	*			7.9917	1.0000
3860	7.7350	0.9693	7.7350	7.3400	8.3000	5.595	4	0.513	2.360	1.1266	7.9917	1.0000
8560	8.2600	1.0351	8.2600	7.9400	8.5800	3.629	4	-0.587	2.360	1.1266	7.9917	1.0000
15830	7.7350	0.9693	7.7350	6.2200	9.0400	15.020	4	0.513	2.360	1.1266	7.7350	0.9679
*29770	1.3600	0.1704	1.3600	1.2000	1.6000	12.707	4	13.868	2.360	1.1266	1.3600	0.1702
68390	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	4				0.0000	0.0000

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates normal distribution (p > 0.05)	0.940823	0.905	-0.16077	2.019523
Bartlett's Test indicates equal variances (p = 0.04)	10.16842	13.2767		
The control means are not significantly different (p = 0.66)	0.458533	2.446912		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU	MSDu	MSDp	MSB	MSE	F-Prob	df
Dunnett's Test	15830	29770	21708.5		1.126604	0.141178	34.69307	0.455773	8.9E-10	4, 15
Treatments vs WAF Control										

Linear Interpolation (200 Resamples)

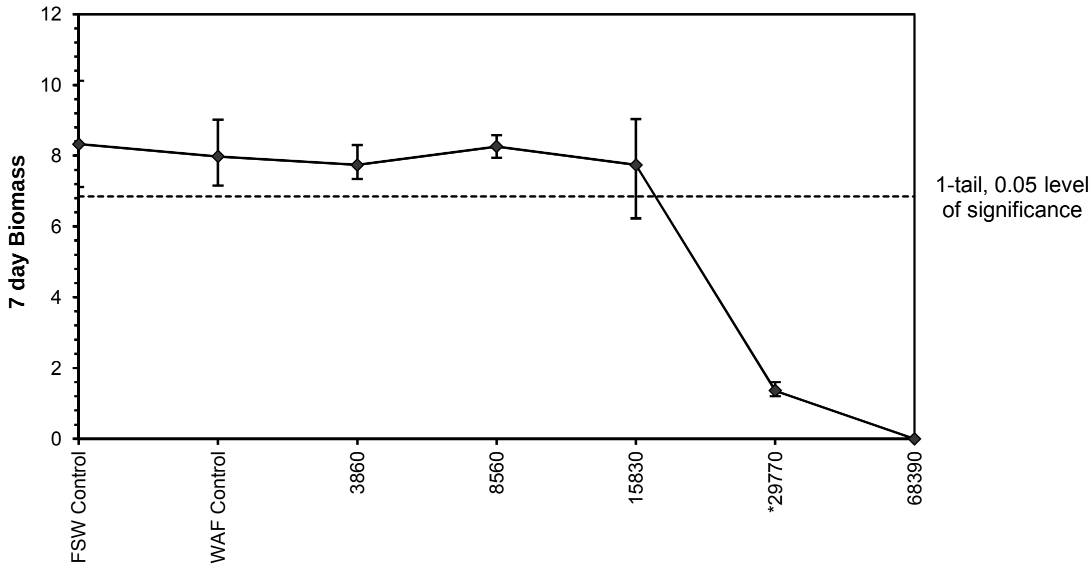
Point	ug/L	SD	95% CL(Exp)		Skew
IC05	16142.51	4671.806	0	17012.18	-1.2421
IC10	17016.27	1954.101	7373.185	17857.61	-2.6555
IC15	17890.02	1097.801	11899.05	18703.04	-2.2030
IC20	18763.78	880.4609	14909.07	19548.47	-1.5117
IC25	19637.53	784.3117	16057.69	20393.89	-1.1569
IC40	22258.8	599.5128	19503.55	22930.18	-1.1881
IC50	24006.31	479.4807	21800.79	24621.04	-1.2016



Fish Growth Test-7 day Biomass

Start Date:	22/09/2015 12:30	Test ID:	PR1244/06b	Sample ID:	Barossa Field Condensate
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	TRH				

Dose-Response Plot



Fish Growth Test-7 day Biomass

Start Date:	22/09/2015 12:30	Test ID:	PR1244/06b	Sample ID:	Barossa Field Condensate
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	TRH				

Auxiliary Data Summary

Conc-ug/L	Parameter	Mean	Min	Max	SD	CV%	N
FSW Control	% Un-affected	100.00	100.00	100.00	0.00	0.00	4
WAF Control		100.00	100.00	100.00	0.00	0.00	4
3860		100.00	100.00	100.00	0.00	0.00	4
8560		100.00	100.00	100.00	0.00	0.00	4
15830		90.00	80.00	100.00	11.55	3.78	4
29770		20.00	20.00	20.00	0.00	0.00	4
68390		0.00	0.00	0.00	0.00		4
FSW Control	Biomass	8.33	7.12	10.12	1.31	13.72	4
WAF Control		7.98	7.16	9.02	0.79	11.13	4
3860		7.74	7.34	8.30	0.43	8.50	4
8560		8.26	7.94	8.58	0.30	6.63	4
15830		7.74	6.22	9.04	1.16	13.93	4
29770		1.36	1.20	1.60	0.17	30.57	4
68390		0.00	0.00	0.00	0.00		4
FSW Control	pH	8.20	8.20	8.20	0.00	0.00	1
WAF Control		8.20	8.20	8.20	0.00	0.00	1
3860		8.10	8.10	8.10	0.00	0.00	1
8560		8.10	8.10	8.10	0.00	0.00	1
15830		8.00	8.00	8.00	0.00	0.00	1
29770		7.80	7.80	7.80	0.00	0.00	1
68390		7.30	7.30	7.30	0.00	0.00	1
FSW Control	Salinity	34.90	34.90	34.90	0.00	0.00	1
WAF Control		35.10	35.10	35.10	0.00	0.00	1
3860		35.10	35.10	35.10	0.00	0.00	1
8560		35.10	35.10	35.10	0.00	0.00	1
15830		35.20	35.20	35.20	0.00	0.00	1
29770		35.30	35.30	35.30	0.00	0.00	1
68390		35.30	35.30	35.30	0.00	0.00	1
FSW Control	% DO	99.80	99.80	99.80	0.00	0.00	1
WAF Control		92.80	92.80	92.80	0.00	0.00	1
3860		96.30	96.30	96.30	0.00	0.00	1
8560		95.70	95.70	95.70	0.00	0.00	1
15830		96.70	96.70	96.70	0.00	0.00	1
29770		95.60	95.60	95.60	0.00	0.00	1
68390		85.10	85.10	85.10	0.00	0.00	1

Fish Growth Test-7 Day Unaffected

Start Date:	22/09/2015 12:30	Test ID:	PR1244/08	Sample ID:	Barossa Field Condensate Weathered
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	LR				

Conc-gm/L	1	2	3	4
FSW Control	1.0000	1.0000	1.0000	1.0000
WAF Control	1.0000	1.0000	1.0000	1.0000
5	1.0000	1.0000	1.0000	1.0000
9.9	1.0000	1.0000	1.0000	1.0000
19.9	1.0000	1.0000	1.0000	1.0000
39.8	1.0000	1.0000	1.0000	1.0000
79.5	1.0000	1.0000	0.4000	0.0000

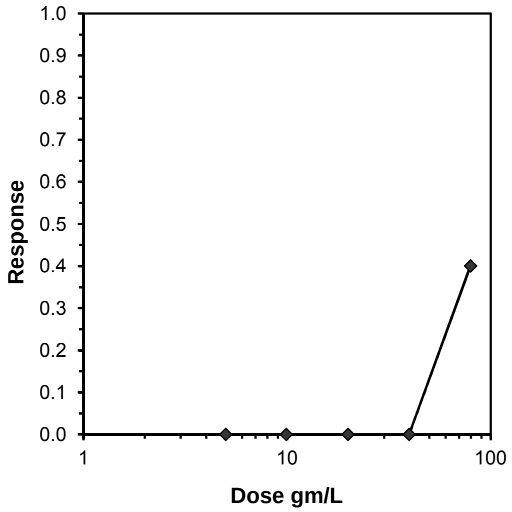
			Transform: Arcsin Square Root					Rank	1-Tailed	Isotonic	
Conc-gm/L	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical	Mean	N-Mean
FSW Control	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4				
WAF Control	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	*		1.0000	1.0000
5	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	18.00	10.00	1.0000	1.0000
9.9	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	18.00	10.00	1.0000	1.0000
19.9	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	18.00	10.00	1.0000	1.0000
39.8	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	18.00	10.00	1.0000	1.0000
79.5	0.6000	0.6000	0.9002	0.2255	1.3453	60.771	4	14.00	10.00	0.6000	0.6000

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates non-normal distribution (p <= 0.05)	0.557919	0.916	-0.86578	7.231261
Equality of variance cannot be confirmed				
The control means are not significantly different (p = 1.00)	0	2.446912		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
Steel's Many-One Rank Test	79.5	>79.5		
Treatments vs WAF Control				

Log-Logit Interpolation (200 Resamples)

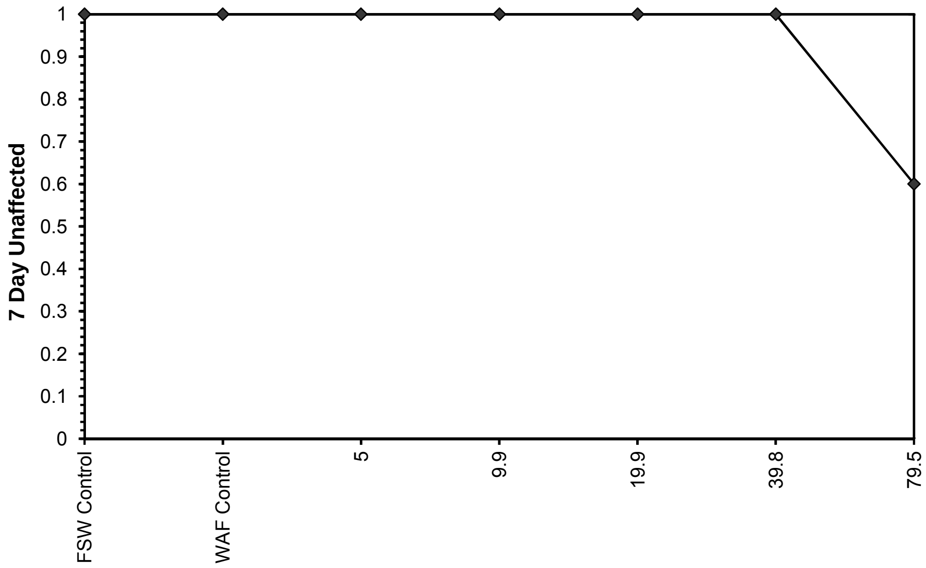
Point	gm/L	SD	95% CL(Exp)	Skew
IC05	65.174			
IC10	69.103			
IC15	71.651			
IC20	73.631			
IC25	75.307			
IC40	>79.5			
IC50	>79.5			



Fish Growth Test-7 Day Unaffected

Start Date:	22/09/2015 12:30	Test ID:	PR1244/08	Sample ID:	Barossa Field Condensate Weathered
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	LR				

Dose-Response Plot



Fish Growth Test-7 Day Unaffected

Start Date:	22/09/2015 12:30	Test ID:	PR1244/08	Sample ID:	Barossa Field Condensate Weathered
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	LR				

Auxiliary Data Summary

Conc-gm/L	Parameter	Mean	Min	Max	SD	CV%	N
FSW Control	% Un-affected	100.00	100.00	100.00	0.00	0.00	4
WAF Control		100.00	100.00	100.00	0.00	0.00	4
5		100.00	100.00	100.00	0.00	0.00	4
9.9		100.00	100.00	100.00	0.00	0.00	4
19.9		100.00	100.00	100.00	0.00	0.00	4
39.8		100.00	100.00	100.00	0.00	0.00	4
79.5		60.00	0.00	100.00	48.99	11.67	4
FSW Control	Biomass	8.33	7.12	10.12	1.31	13.72	4
WAF Control		7.98	7.16	9.02	0.79	11.13	4
5		8.65	7.82	9.24	0.60	8.93	4
9.9		7.95	7.18	9.34	0.95	12.29	4
19.9		8.11	7.64	8.32	0.32	6.97	4
39.8		8.57	7.90	9.46	0.66	9.50	4
79.5		4.95	0.00	8.58	3.78	39.25	4
FSW Control	pH	8.20	8.20	8.20	0.00	0.00	1
WAF Control		8.20	8.20	8.20	0.00	0.00	1
5		8.10	8.10	8.10	0.00	0.00	1
9.9		8.20	8.20	8.20	0.00	0.00	1
19.9		8.20	8.20	8.20	0.00	0.00	1
39.8		8.20	8.20	8.20	0.00	0.00	1
79.5		8.20	8.20	8.20	0.00	0.00	1
FSW Control	Salinity	34.90	34.90	34.90	0.00	0.00	1
WAF Control		35.10	35.10	35.10	0.00	0.00	1
5		35.40	35.40	35.40	0.00	0.00	1
9.9		35.20	35.20	35.20	0.00	0.00	1
19.9		35.20	35.20	35.20	0.00	0.00	1
39.8		35.20	35.20	35.20	0.00	0.00	1
79.5		35.20	35.20	35.20	0.00	0.00	1
FSW Control	% DO	99.80	99.80	99.80	0.00	0.00	1
WAF Control		92.80	92.80	92.80	0.00	0.00	1
5		96.40	96.40	96.40	0.00	0.00	1
9.9		96.90	96.90	96.90	0.00	0.00	1
19.9		96.60	96.60	96.60	0.00	0.00	1
39.8		96.70	96.70	96.70	0.00	0.00	1
79.5		94.70	94.70	94.70	0.00	0.00	1

Fish Growth Test-7 Day Unaffected

Start Date:	22/09/2015 12:30	Test ID:	PR1244/07b	Sample ID:	Barossa Field Condensate Weathered
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	TRH				

Conc-ug/L	1	2	3	4
FSW Control	1.0000	1.0000	1.0000	1.0000
WAF Control	1.0000	1.0000	1.0000	1.0000
1410	1.0000	1.0000	1.0000	1.0000
2770	1.0000	1.0000	1.0000	1.0000
4850	1.0000	1.0000	1.0000	1.0000
11450	1.0000	1.0000	1.0000	1.0000
22480	1.0000	1.0000	0.4000	0.0000

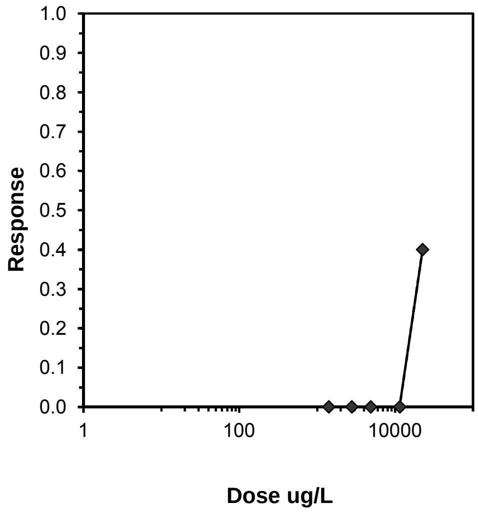
			Transform: Arcsin Square Root					Rank	1-Tailed	Isotonic	
Conc-ug/L	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical	Mean	N-Mean
FSW Control	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4				
WAF Control	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	*		1.0000	1.0000
1410	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	18.00	10.00	1.0000	1.0000
2770	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	18.00	10.00	1.0000	1.0000
4850	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	18.00	10.00	1.0000	1.0000
11450	1.0000	1.0000	1.3453	1.3453	1.3453	0.000	4	18.00	10.00	1.0000	1.0000
22480	0.6000	0.6000	0.9002	0.2255	1.3453	60.771	4	14.00	10.00	0.6000	0.6000

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates non-normal distribution (p <= 0.05)	0.557919	0.916	-0.86578	7.231261
Equality of variance cannot be confirmed				
The control means are not significantly different (p = 1.00)	0	2.446912		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
Steel's Many-One Rank Test	22480	>22480		
Treatments vs WAF Control				

Log-Logit Interpolation (200 Resamples)

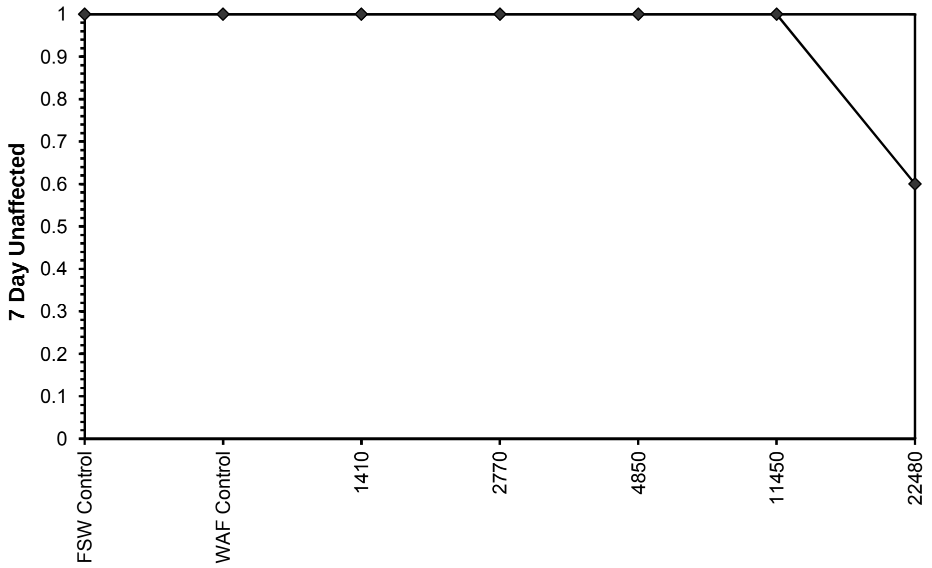
Point	ug/L	SD	95% CL(Exp)	Skew
IC05	18505.88			
IC10	19596.3			
IC15	20303.38			
IC20	20852.52			
IC25	21317.26			
IC40	>22480			
IC50	>22480			



Fish Growth Test-7 Day Unaffected

Start Date:	22/09/2015 12:30	Test ID:	PR1244/07b	Sample ID:	Barossa Field Condensate Weathered
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	TRH				

Dose-Response Plot



Fish Growth Test-7 Day Unaffected

Start Date:	22/09/2015 12:30	Test ID:	PR1244/07b	Sample ID:	Barossa Field Condensate Weathered
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	TRH				

Auxiliary Data Summary

Conc-ug/L	Parameter	Mean	Min	Max	SD	CV%	N
FSW Control	% Un-affected	100.00	100.00	100.00	0.00	0.00	4
WAF Control		100.00	100.00	100.00	0.00	0.00	4
1410		100.00	100.00	100.00	0.00	0.00	4
2770		100.00	100.00	100.00	0.00	0.00	4
4850		100.00	100.00	100.00	0.00	0.00	4
11450		100.00	100.00	100.00	0.00	0.00	4
22480		60.00	0.00	100.00	48.99	11.67	4
FSW Control	Biomass	8.33	7.12	10.12	1.31	13.72	4
WAF Control		7.98	7.16	9.02	0.79	11.13	4
1410		8.65	7.82	9.24	0.60	8.93	4
2770		7.95	7.18	9.34	0.95	12.29	4
4850		8.11	7.64	8.32	0.32	6.97	4
11450		8.57	7.90	9.46	0.66	9.50	4
22480		4.95	0.00	8.58	3.78	39.25	4
FSW Control	pH	8.20	8.20	8.20	0.00	0.00	1
WAF Control		8.20	8.20	8.20	0.00	0.00	1
1410		8.10	8.10	8.10	0.00	0.00	1
2770		8.10	8.10	8.10	0.00	0.00	1
4850		8.00	8.00	8.00	0.00	0.00	1
11450		7.80	7.80	7.80	0.00	0.00	1
22480		7.30	7.30	7.30	0.00	0.00	1
FSW Control	Salinity	34.90	34.90	34.90	0.00	0.00	1
WAF Control		35.10	35.10	35.10	0.00	0.00	1
1410		35.10	35.10	35.10	0.00	0.00	1
2770		35.10	35.10	35.10	0.00	0.00	1
4850		35.20	35.20	35.20	0.00	0.00	1
11450		35.30	35.30	35.30	0.00	0.00	1
22480		35.30	35.30	35.30	0.00	0.00	1
FSW Control	% DO	99.80	99.80	99.80	0.00	0.00	1
WAF Control		92.80	92.80	92.80	0.00	0.00	1
1410		96.30	96.30	96.30	0.00	0.00	1
2770		95.70	95.70	95.70	0.00	0.00	1
4850		96.70	96.70	96.70	0.00	0.00	1
11450		95.60	95.60	95.60	0.00	0.00	1
22480		85.10	85.10	85.10	0.00	0.00	1

Fish Growth Test-7 day Biomass

Start Date:	22/09/2015 12:30	Test ID:	PR1244/08	Sample ID:	Barossa Field Condensate Weathered
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	LR				

Conc-gm/L	1	2	3	4
FSW Control	8.4200	10.1200	7.1200	7.6600
WAF Control	8.0800	9.0200	7.1600	7.6600
5	8.8000	9.2400	7.8200	8.7400
9.9	9.3400	7.7200	7.5600	7.1800
19.9	8.1800	8.3200	8.3000	7.6400
39.8	8.3000	7.9000	9.4600	8.6200
79.5	7.0600	8.5800	4.1600	0.0000

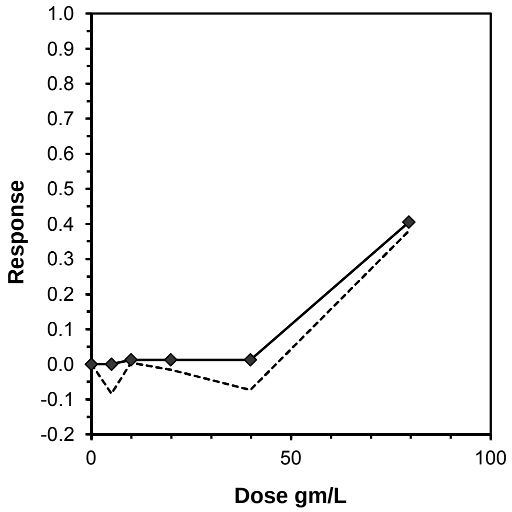
			Transform: Untransformed					Rank	1-Tailed	Isotonic	
Conc-gm/L	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical	Mean	N-Mean
FSW Control	8.3300	1.0439	8.3300	7.1200	10.1200	15.691	4				
WAF Control	7.9800	1.0000	7.9800	7.1600	9.0200	9.884	4	*		8.3150	1.0000
5	8.6500	1.0840	8.6500	7.8200	9.2400	6.896	4	22.00	10.00	8.3150	1.0000
9.9	7.9500	0.9962	7.9500	7.1800	9.3400	11.999	4	18.00	10.00	8.2100	0.9874
19.9	8.1100	1.0163	8.1100	7.6400	8.3200	3.938	4	20.00	10.00	8.2100	0.9874
39.8	8.5700	1.0739	8.5700	7.9000	9.4600	7.730	4	22.00	10.00	8.2100	0.9874
79.5	4.9500	0.6203	4.9500	0.0000	8.5800	76.266	4	13.00	10.00	4.9500	0.5953

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates non-normal distribution (p <= 0.05)	0.824168	0.916	-0.91513	6.12451
Bartlett's Test indicates unequal variances (p = 5.86E-04)	21.74163	15.08627		
The control means are not significantly different (p = 0.66)	0.458533	2.446912		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
Steel's Many-One Rank Test	79.5	>79.5		
Treatments vs WAF Control				

Linear Interpolation (200 Resamples)

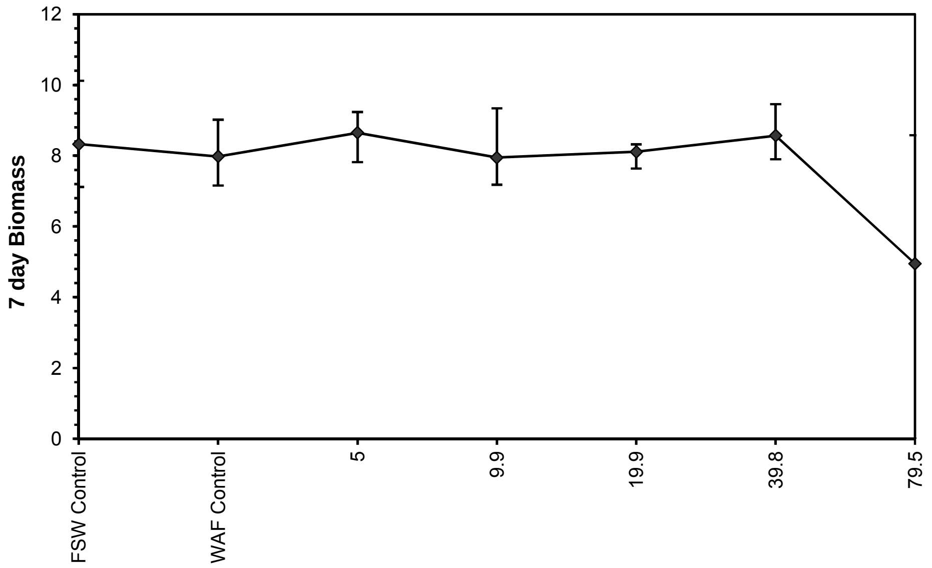
Point	gm/L	SD	95% CL(Exp)	Skew
IC05	43.584			
IC10	48.647			
IC15	53.710			
IC20	58.773			
IC25	63.836			
IC40	79.025			
IC50	>79.5			



Fish Growth Test-7 day Biomass

Start Date:	22/09/2015 12:30	Test ID:	PR1244/08	Sample ID:	Barossa Field Condensate Weathered
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	LR				

Dose-Response Plot



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Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	LR				

Auxiliary Data Summary

Conc-gm/L	Parameter	Mean	Min	Max	SD	CV%	N
FSW Control	% Un-affected	100.00	100.00	100.00	0.00	0.00	4
WAF Control		100.00	100.00	100.00	0.00	0.00	4
5		100.00	100.00	100.00	0.00	0.00	4
9.9		100.00	100.00	100.00	0.00	0.00	4
19.9		100.00	100.00	100.00	0.00	0.00	4
39.8		100.00	100.00	100.00	0.00	0.00	4
79.5		60.00	0.00	100.00	48.99	11.67	4
FSW Control	Biomass	8.33	7.12	10.12	1.31	13.72	4
WAF Control		7.98	7.16	9.02	0.79	11.13	4
5		8.65	7.82	9.24	0.60	8.93	4
9.9		7.95	7.18	9.34	0.95	12.29	4
19.9		8.11	7.64	8.32	0.32	6.97	4
39.8		8.57	7.90	9.46	0.66	9.50	4
79.5		4.95	0.00	8.58	3.78	39.25	4
FSW Control	pH	8.20	8.20	8.20	0.00	0.00	1
WAF Control		8.20	8.20	8.20	0.00	0.00	1
5		8.10	8.10	8.10	0.00	0.00	1
9.9		8.20	8.20	8.20	0.00	0.00	1
19.9		8.20	8.20	8.20	0.00	0.00	1
39.8		8.20	8.20	8.20	0.00	0.00	1
79.5		8.20	8.20	8.20	0.00	0.00	1
FSW Control	Salinity	34.90	34.90	34.90	0.00	0.00	1
WAF Control		35.10	35.10	35.10	0.00	0.00	1
5		35.40	35.40	35.40	0.00	0.00	1
9.9		35.20	35.20	35.20	0.00	0.00	1
19.9		35.20	35.20	35.20	0.00	0.00	1
39.8		35.20	35.20	35.20	0.00	0.00	1
79.5		35.20	35.20	35.20	0.00	0.00	1
FSW Control	% DO	99.80	99.80	99.80	0.00	0.00	1
WAF Control		92.80	92.80	92.80	0.00	0.00	1
5		96.40	96.40	96.40	0.00	0.00	1
9.9		96.90	96.90	96.90	0.00	0.00	1
19.9		96.60	96.60	96.60	0.00	0.00	1
39.8		96.70	96.70	96.70	0.00	0.00	1
79.5		94.70	94.70	94.70	0.00	0.00	1

Fish Growth Test-7 day Biomass

Start Date:	22/09/2015 12:30	Test ID:	PR1244/07b	Sample ID:	Barossa Field Condensate Weathered
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	TRH				

Conc-ug/L	1	2	3	4
FSW Control	8.4200	10.1200	7.1200	7.6600
WAF Control	8.0800	9.0200	7.1600	7.6600
1410	8.8000	9.2400	7.8200	8.7400
2770	9.3400	7.7200	7.5600	7.1800
4850	8.1800	8.3200	8.3000	7.6400
11450	8.3000	7.9000	9.4600	8.6200
22480	7.0600	8.5800	4.1600	0.0000

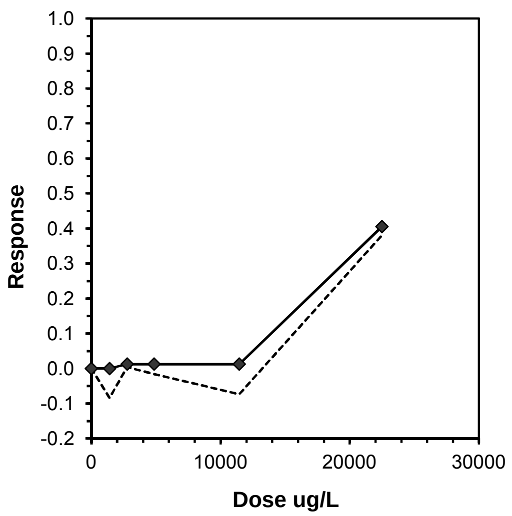
			Transform: Untransformed					Rank	1-Tailed	Isotonic	
Conc-ug/L	Mean	N-Mean	Mean	Min	Max	CV%	N	Sum	Critical	Mean	N-Mean
FSW Control	8.3300	1.0439	8.3300	7.1200	10.1200	15.691	4				
WAF Control	7.9800	1.0000	7.9800	7.1600	9.0200	9.884	4	*		8.3150	1.0000
1410	8.6500	1.0840	8.6500	7.8200	9.2400	6.896	4	22.00	10.00	8.3150	1.0000
2770	7.9500	0.9962	7.9500	7.1800	9.3400	11.999	4	18.00	10.00	8.2100	0.9874
4850	8.1100	1.0163	8.1100	7.6400	8.3200	3.938	4	20.00	10.00	8.2100	0.9874
11450	8.5700	1.0739	8.5700	7.9000	9.4600	7.730	4	22.00	10.00	8.2100	0.9874
22480	4.9500	0.6203	4.9500	0.0000	8.5800	76.266	4	13.00	10.00	4.9500	0.5953

Auxiliary Tests	Statistic	Critical	Skew	Kurt
Shapiro-Wilk's Test indicates non-normal distribution (p <= 0.05)	0.824168	0.916	-0.91513	6.12451
Bartlett's Test indicates unequal variances (p = 5.86E-04)	21.74163	15.08627		
The control means are not significantly different (p = 0.66)	0.458533	2.446912		

Hypothesis Test (1-tail, 0.05)	NOEC	LOEC	ChV	TU
Steel's Many-One Rank Test	22480	>22480		
Treatments vs WAF Control				

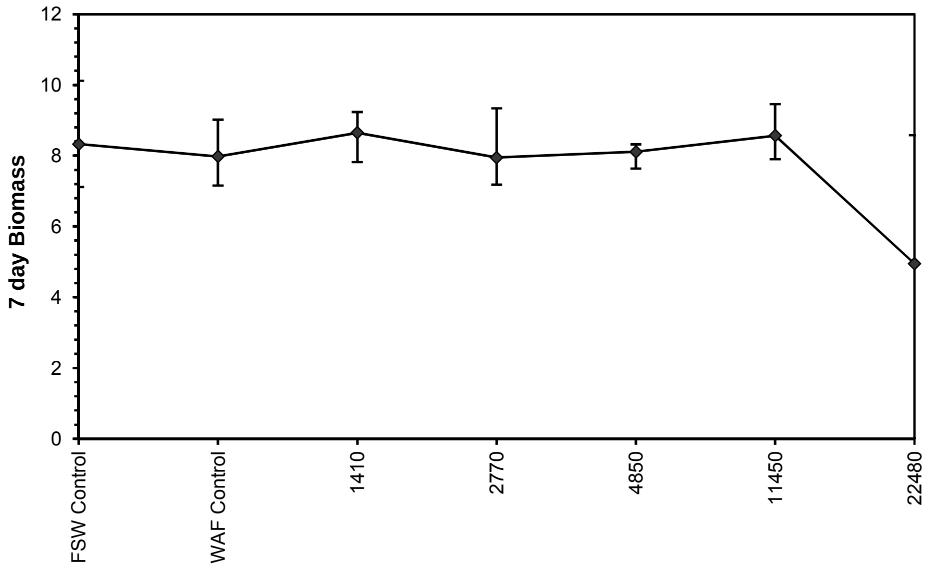
Linear Interpolation (200 Resamples)

Point	ug/L	SD	95% CL(Exp)	Skew
IC05	12501.4			
IC10	13908.07			
IC15	15314.73			
IC20	16721.39			
IC25	18128.06			
IC40	22348.05			
IC50	>22480			



Fish Growth Test-7 day Biomass					
Start Date:	22/09/2015 12:30	Test ID:	PR1244/07b	Sample ID:	Barossa Field Condensate Weathered
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	TRH				

Dose-Response Plot



Fish Growth Test-7 day Biomass

Start Date:	22/09/2015 12:30	Test ID:	PR1244/07b	Sample ID:	Barossa Field Condensate Weathered
End Date:	29/09/2015 11:00	Lab ID:	7323	Sample Type:	WAF-Water Accommodated Fraction
Sample Date:		Protocol:	ESA 122	Test Species:	LT-Lates calcarifer
Comments:	TRH				

Auxiliary Data Summary

Conc-ug/L	Parameter	Mean	Min	Max	SD	CV%	N
FSW Control	% Un-affected	100.00	100.00	100.00	0.00	0.00	4
WAF Control		100.00	100.00	100.00	0.00	0.00	4
1410		100.00	100.00	100.00	0.00	0.00	4
2770		100.00	100.00	100.00	0.00	0.00	4
4850		100.00	100.00	100.00	0.00	0.00	4
11450		100.00	100.00	100.00	0.00	0.00	4
22480		60.00	0.00	100.00	48.99	11.67	4
FSW Control	Biomass	8.33	7.12	10.12	1.31	13.72	4
WAF Control		7.98	7.16	9.02	0.79	11.13	4
1410		8.65	7.82	9.24	0.60	8.93	4
2770		7.95	7.18	9.34	0.95	12.29	4
4850		8.11	7.64	8.32	0.32	6.97	4
11450		8.57	7.90	9.46	0.66	9.50	4
22480		4.95	0.00	8.58	3.78	39.25	4
FSW Control	pH	8.20	8.20	8.20	0.00	0.00	1
WAF Control		8.20	8.20	8.20	0.00	0.00	1
1410		8.10	8.10	8.10	0.00	0.00	1
2770		8.10	8.10	8.10	0.00	0.00	1
4850		8.00	8.00	8.00	0.00	0.00	1
11450		7.80	7.80	7.80	0.00	0.00	1
22480		7.30	7.30	7.30	0.00	0.00	1
FSW Control	Salinity	34.90	34.90	34.90	0.00	0.00	1
WAF Control		35.10	35.10	35.10	0.00	0.00	1
1410		35.10	35.10	35.10	0.00	0.00	1
2770		35.10	35.10	35.10	0.00	0.00	1
4850		35.20	35.20	35.20	0.00	0.00	1
11450		35.30	35.30	35.30	0.00	0.00	1
22480		35.30	35.30	35.30	0.00	0.00	1
FSW Control	% DO	99.80	99.80	99.80	0.00	0.00	1
WAF Control		92.80	92.80	92.80	0.00	0.00	1
1410		96.30	96.30	96.30	0.00	0.00	1
2770		95.70	95.70	95.70	0.00	0.00	1
4850		96.70	96.70	96.70	0.00	0.00	1
11450		95.60	95.60	95.60	0.00	0.00	1
22480		85.10	85.10	85.10	0.00	0.00	1

Appendix C. Burrlioz Output Report

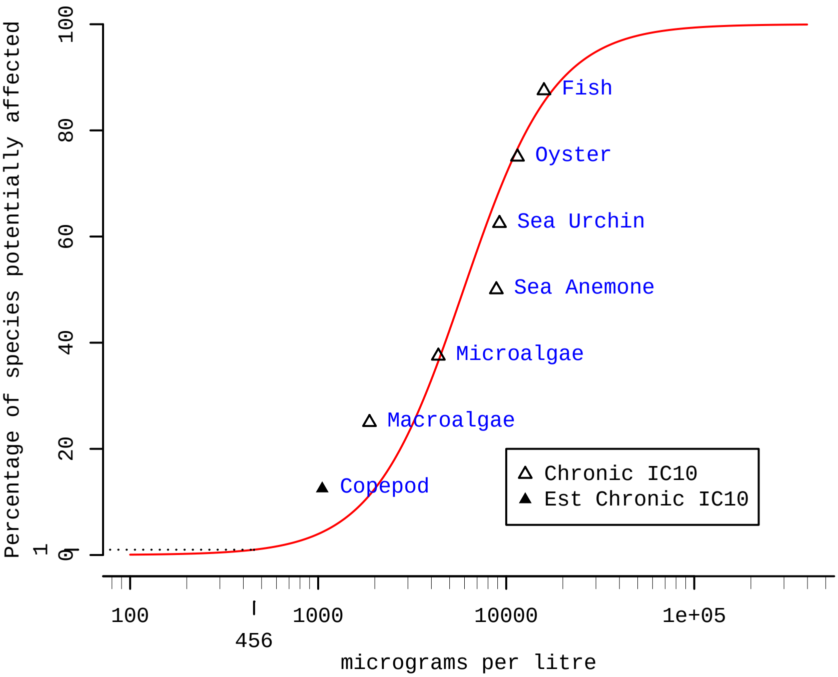
Burrlioz 2.0 report

Toxicant: Barossa-3 condensate
Input file: C:\Users\cxxwilson\Documents\Celeste Desktop\Conoco Phillips\Barossa\Ecotox\
Time read: Thu Dec 10 10:10:24 2015
Units: micrograms per litre
Model: log logistic

Protection level information

Protect. level	Guideline Value	lower 95% CI	upper 95% CI
99%	456	121	4285
95%	1146	367	5928
90%	1739	605	6680
80%	2735	1051	7859

notes: 6 chronic IC10 values and 1 estimated chronic value



Data:

Data	Species	Type	Test
4355.2	Isochrysis aff. Galbana	Microalgae	Chronic IC10
1873.9	Ecklonia radiata	Macroalgae	Chronic IC10
9206.2	Heliocidaris tuberculata	Sea Urchin	Chronic IC10
11478.4	Saccostrea echinata	Oyster	Chronic IC10
1050.7	Parvocalanus crassirostris	Copepod	Est Chronic IC10
8862.4	Aiptasia pulchella	Sea Anemone	Chronic IC10
15875.5	Lates calcarifer	Fish	Chronic IC10

Appendix M.

Underwater noise modelling study - FPSO facility anchor piling (JASCO 2017)

FPSO Facility Anchor Piling Acoustic Modelling

Barossa Field

Submitted to:
Brenton Chatfield
ConocoPhillips Australia

Authors:
Craig McPherson
Jorge Quijano

28 March 2017

P001241-003
JASCO Document 01346
Version 1.0
ConocoPhillips Document BAA-00-HS-RPT-00009

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Suggested citation:

McPherson, C.R, J. Quijano. 2017. *FPSO Facility Anchor Piling Acoustic Modelling, Barossa Field*. JASCO Document 01346, Version 1.0. ConocoPhillips Document BAA-00-HS-RPT-00009. Technical report by JASCO Applied Sciences for ConocoPhillips Australia.

Revision History Table

Person who prepared content	Person who approved content	Date of preparation/approval
J. Quijano	C. McPherson	7 March 2017
C. McPherson	D. Hannay	9 March 2017
C. McPherson	C. McPherson	28 March 2017

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1. Introduction

This report presents the results of an acoustic modelling study designed to estimate potential effects on marine fauna associated with pile driving activities in the Barossa field.

The modelling study specifically assesses distances from pile driving operations at which underwater sound levels decay to thresholds corresponding to various levels of impact near submerged pile driving. The animal types considered here include marine mammals, fishes (including fish eggs and larvae) and turtles. Due to the variety of species considered, there are several different thresholds for evaluating effects, including: mortality, injury, temporary hearing acuity reduction and behavioural disturbance.

This study considers multiple alternative scenarios for the installation of subsea anchor cylindrical piles, and how noise levels generated by these activities are influenced by pile dimensions, bathymetry, and choice of pile driving equipment.

2. Acoustic Impact Criteria

The perceived loudness of sound, especially impulsive noise such as that generated by pile driving, is not generally proportional to the instantaneous acoustic pressure. Rather, perceived loudness depends on pulse rise-time and duration, and frequency content. Thus, several sound level metrics are commonly used to evaluate noise and its effects on marine life. The metrics applied in this report, including peak pressure level (PK), sound pressure level (SPL), and sound exposure level (SEL), are defined in Appendix A.1. The period of accumulation associated with SEL is defined, with this report referencing either a 'per strike' assessment or accumulation over 24 hours, SEL_{24h}. Any applied frequency weighting is indicated by appropriate subscripts, with unweighted SEL defined as required. Recent updates to the ANSI and ISO standards for acoustic terminology, ANSI-ASA S1.1 (ANSI S1.1-2013 R2013) and ISO/DIS 18405.2:2016 (2016, draft) have also been incorporated into the acoustic metrics applied in this report.

The assessment criteria applied in this study arose from several recognised scientific sources that have defined acoustic exposure levels applicable to marine fauna. Since 2007, several expert groups have investigated an SEL-based assessment approach for injury, with a handful of key papers published on the topic. Likewise, the number of studies investigating the level of disturbance to marine fauna by underwater noise has increased substantially. This section discusses the proposed methods and thresholds applied in the current study, which are consistent with those applied for other recent projects in the Barossa field (McPherson et al. 2016).

Results of the modelling study are presented in terms of the following noise criteria, which have been chosen to include thresholds commonly applied in Australia and outlined in Sections 2.1 and 2.2:

1. Single shot threshold for cetaceans (unweighted per-pulse SEL of 160 dB re 1 $\mu Pa^2 \cdot s$) (from marine seismic surveys).This process is outlined in the Australian Environment Protection and Biodiversity Conservation (EPBC) Act Policy Statement 2.1, Department of the Environment, Water, Heritage and the Arts (DEWHA 2008).This has been provided for reference for single strikes from piling operations.
2. Marine mammal behavioural disturbance threshold based on the current interim United States National Marine Fisheries Service (NMFS) criterion (NMFS 2013) for marine mammals of 160 dB re 1 µPa SPL for impulsive sound sources.
3. M-weighted sound exposure level (SEL_{24h}) thresholds for marine mammal injury based on Wood et al. (2012).
4. Sound exposure guidelines for fish, including temporary threshold shift (TTS), and injury to fish, fish eggs and fish larvae, and turtles proposed by Popper et al. (2014).
5. Threshold for turtle behavioural response (NSF 2011), 166 dB re 1 µPa (SPL), applied by the US National Marine Fisheries Service.

2.1. Marine Mammals

The criteria applied in this study to assess possible effects of noise generated by pile driving activities on cetaceans are summarised in Table 1 and detailed in Sections 2.1.1 and 2.1.2, with frequency weighting explained in Appendix A.2.

Table 1. The unweighted per-strike SPL, SEL and SEL_{24h} thresholds for acoustic effects on cetaceans.

Hearing group	DEWHA (2008)	NMFS (2013)	Wood et al. (2012)
	Unweighted per-pulse SEL (dB re 1 µPa2·s)	SPL (dB re 1 µPa)	M-weighted SEL_{24h} (dB re 1 µPa2·s)
		Behaviour	Injury (PTS)
Low-frequency cetaceans	160	160	192
Mid-frequency cetaceans			198
High-frequency cetaceans			179

2.1.1. Behavioural Response

Southall et al. (2007) extensively reviewed marine mammal behavioural responses to sounds as documented in the literature. Their review found that most marine mammals exhibit varying responses between an SPL of 140 and 180 dB re 1 µPa, but a lack of convergence in the data from multiple studies prevented them from suggesting explicit step functions. Why studies varied included the lack of control groups, imprecise measurements, inconsistent metrics, and context dependency of responses including the animal's activity state. To create meaningful qualitative data from the collected information, Southall et al. (2007) proposed a severity scale that increased with increasing sound levels.

Wood et al. (2012) published an updated set of criteria for injury that built upon the work undertaken by Southall et al. (2007) in a study in which Southall was a co-author, thus criteria were developed with some consistency. The new criteria suggested by Wood et al. (2012) include M-weighting similarly to Southall et al. (2007).

NMFS has historically used a relatively simple sound level criterion to measure potential disturbance to marine mammals. For impulsive sounds, this criterion is an SPL of 160 dB re 1 µPa for pinnipeds and cetaceans (NMFS 2013), which this report refers to as the NMFS marine mammal behavioural response criterion.

2.1.2. Injury and Hearing Sensitivity Changes

For seismic surveys in Australian waters, the EPBC Act Policy Statement 2.1 determines suitable exclusion zones with an unweighted per-pulse SEL threshold of 160 dB re 1 $\mu Pa^2 \cdot s$ (DEWHA 2008). This threshold minimises the likelihood of TTS in mysticetes and large odontocetes. The Policy Statement does not apply to smaller dolphins and porpoises because DEWHA assessed these cetaceans as having peak hearing sensitivities that occur at higher frequency ranges than those that seismic arrays typically produce. Recent regulation updates in the US (NMFS 2016) and publications on higher frequency components of airgun signals (Hermannsen et al. 2015) suggest that the policy might need to be updated. The Policy Statement can also be applied to other impulsive sources such as pile driving.

There are two categories of auditory threshold shifts or hearing loss: permanent threshold shift (PTS), a physical injury to an animal's hearing organs, and TTS, a temporary reduction in an animal's hearing sensitivity as the result of receptor hair cells in the cochlea becoming fatigued.

To assess the potential for marine mammals to be injured from pile driving, this report applies the EPBC Act Policy Statement 2.1 and the criteria recommended by Wood et al. (2012) for PTS, as outlined in Appendix A.2.1. The report excludes ranges to the PK components of this criteria because the ranges to the 24 h SEL criteria are significantly greater.

2.2. Fish and Turtles

In 2006, the Working Group on the Effects of Sound on Fish and Turtles was formed to continue developing noise exposure criteria for fish and turtles, work begun by a NOAA panel two years earlier. The resulting guidelines included specific thresholds for different levels of effects and for different groups of species (Popper et al. 2014). These guidelines defined quantitative thresholds for three types of immediate effects:

- Mortality, including injury leading to death.
- Recoverable injury, including injuries unlikely to result in mortality, such as hair cell damage and minor haematoma.
- Temporary Threshold Shift.

Masking and behavioural effects are assessed qualitatively, by assessing relative risk rather than by specific sound level thresholds. As the presence or absence of a swim bladder has a role in hearing, susceptibility to injury from noise exposure varies depending on the fish species and the presence and possible role of a swim bladder in hearing. Thus, different thresholds were proposed for fish without a swim bladder (also appropriate for sharks and applied to whale sharks in the absence of other information), fish with a swim bladder not used for hearing, and fish that use their swim bladders for hearing. Turtles, fish eggs, and fish larvae are considered separately.

This report applies the Popper et al. (2014) threshold criteria for the TTS-based impairment of fish exposed to pile driving. Table 2 summarises the effects thresholds from Popper et al. (2014). In general, any adverse effects of impulsive sound on fish behaviour depends on the species, the state of the individuals exposed, and other factors. While it is evident that animals might adjust their behaviour when they are exposed to pile driving sounds, there are few data appropriate to develop guidelines (Popper et al. 2014). Estimates of the behavioural responses can be conducted using the relative-risk criteria. The SEL metric integrates noise intensity over an exposure period. As the period of integration for regulatory assessments is not well defined for sounds that do not begin or end at a specific time, or for exposures that last a long time, Popper et al. (2014) recommended an integration time of 24 hours, similar to the Southall et al. (2007) criteria for marine mammals. Integration times in this study have been applied over the time a single pile was driven since only one pile will be driven per day.

Table 2. Criteria for pile driving noise exposure for fish and turtles, adapted from Popper et al. (2014).

Type of animal	Mortality and potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Fish I: No swim bladder (particle motion detection)	> 219 dB 24 h SEL or > 213 dB PK	> 216 dB 24 h SEL or > 213 dB PK	>> 186 dB 24 h SEL	(N) Moderate (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish II: Swim bladder not involved in hearing (particle motion detection)	210 dB 24 h SEL or > 207 dB PK	203 dB 24 h SEL or > 207 dB PK	>> 186 dB 24 h SEL	(N) Moderate (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish III: Swim bladder involved in hearing (primarily pressure detection)	207 dB 24 h SEL or > 207 dB PK	203 dB 24 h SEL or > 207 dB PK	186 dB 24 h SEL	(N) High (I) High (F) Moderate	(N) High (I) High (F) Moderate
Turtles	210 dB 24 h SEL or > 207 dB PK	(N) High (I) Low (F) Low	(N) High (I) Low (F) Low	(N) High (I) Moderate (F) Low	(N) High (I) Moderate (F) Low
Fish eggs and fish larvae	> 210 dB 24 h SEL or > 207 dB PK	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low

Peak sound pressure level dB re 1 µPa; 24 h SEL dB re 1µPa^2·s. All criteria are presented as sound pressure even for fish without swim bladders since no data for particle motion exist. Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

2.2.1. Turtle Behavioural Response

To inform this report, a review of available literature on how turtles respond to acoustic exposure was undertaken. Most information is available from behavioural response to seismic sources, in lieu of specific information about pile driving.

McCauley et al. (2000) observed the behavioural response of caged turtles—green (*Chelonia mydas*) and loggerhead (*Caretta caretta*)—to an approaching seismic airgun. For received levels above 166 dB re 1 µPa (SPL), the turtles increased their swimming activity and above 175 dB re 1 µPa they began to behave erratically, which was interpreted as an agitated state. The 166 dB re 1 µPa level has been used as the threshold level for a behavioural disturbance response by NMFS and applied in the Arctic Programmatic Environment Impact Statement (PEIS) (NSF 2011). At that time, and in the absence of any data from which to determine the sound levels that could injure an animal, TTS or PTS onset were considered possible at an SPL of 180 dB re 1 µPa (NSF 2011). Some additional data suggest that behavioural responses occur closer to an SPL of 175 dB re 1 µPa, and TTS or PTS at even higher levels (Moein et al. 1994), but the received levels were unknown and the NSF (2011) PEIS maintained the earlier NMFS criteria levels of 166 and 180 dB re 1 µPa (SPL) for behavioural response and injury, respectively.

Popper et al. (2014) suggested injury to turtles could occur for sound exposures above 207 dB re 1 µPa (PK) or above 210 dB re 1 µPa^2·s (SEL_{24h}) (Table 2). Sound levels defined by Popper et al. (2014) show that animals are very likely to exhibit a behavioural response when they are near a pile driving (tens of metres), a moderate response if they encounter the source at intermediate ranges (hundreds of metres), and a low response if they are far (thousands of metres) from the pile driving. Both the NMFS criteria for behavioural disturbance (SPL of 166 dB re 1 µPa) and the Popper et al. (2014) injury criteria were included in this analysis.

3. Methods

This section details the methodology for predicting the source levels, modelling the sound propagation, and assessing distances to the selected impact criteria.

3.1. Modelling Overview

The alternative scenarios have been selected to account for water depth, hammer strength and pile diameter, and geological resistance. These considerations are explained in detail in Sections 3.1.1 to 3.1.3.

3.1.1. Water Depth

While the Barossa project is at an early stage of project definition, it is possible that subsea impact pile driving might need to be used to install anchor piles for the Floating Production, Storage and Offloading (FPSO) facility. To inform an early assessment of potential pile driving activities, two representative locations within the Barossa field were selected. Available information indicates that the geology and sound speed profiles are consistent across the region (Sections 3.6.2 and 3.6.3). Due to this similarity, the factor that has the greatest influence on the sound propagation across the Barossa field is bathymetry, including the depth at individual locations and the seabed profile of the surrounding area. To understand how the sound propagates depends upon bathymetry, in addition to the operational parameters. The selection of the two representative locations was based on bathymetry(Table 3 and Figure 1) and represent the range of shallow and deeper waters that the FPSO may be located within the Barossa field.

Table 3. Representative locations of piling activities.

Site	Water depth (m)	Latitude	Longitude	UTM (Zone 52S)	
				X (m)	Y (m)
1	235	9° 52' 35.7683" S	130° 11' 8.3587" E	630000	8908000
2	288	9° 44' 58.8305" S	130° 16' 34.8945" E	640000	8922000

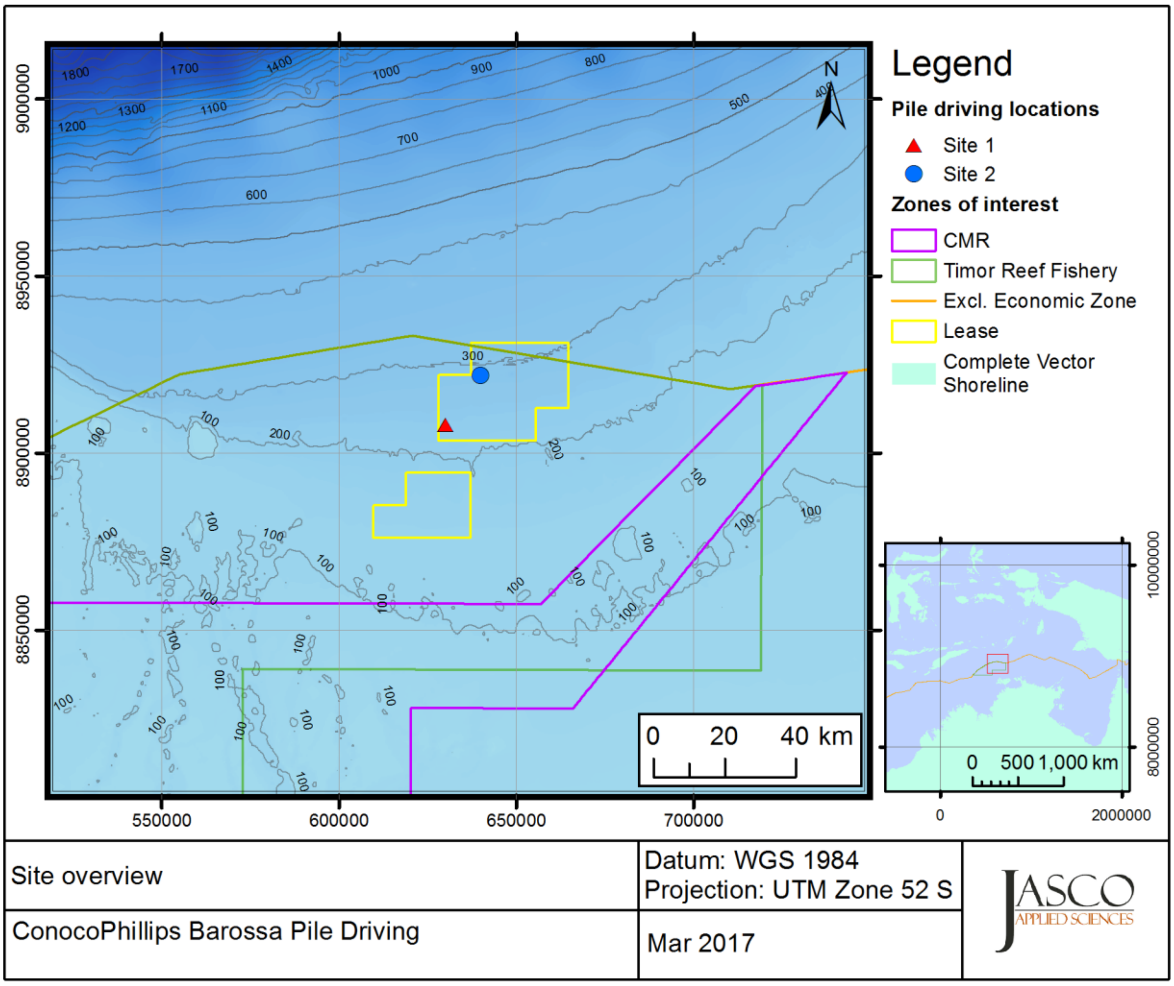

Figure 1. Survey region and modelling locations (note, CMR refers to the Oceanic Shoals Commonwealth Marine Reserve).

3.1.2. Hammer Strength and Pile Diameters

As the engineering design for the project is yet to be finalised, the modelling study considers a combination of a range of possible hammers, pile diameters and lengths. The range of considered inputs, in addition to modelling sites at two different water depths (Table 3), provides a comprehensive overview of possible noise footprints, and the factors related to sound propagation across the Barossa field. The study includes two different hammers with energies of 600 kJ and 1730 kJ, and two different pile diameters of 4 and 5 m. Two different pile lengths of 43 or 39 m were also considered, with 15 m always remaining above the sea floor.

Due to the depth of water these will be driven in to the sediment using subsea hammers. Table 4 defines the modelling scenarios. Only one pile will be driven each day so pile driving equipment can be relocated and setup. It is assumed that the pile will only experience negligible settling before driving commences. We have assumed maximum rated hammer energy over the duration of the drive, derived from GRLWEAP (Section 3.2), which is a very conservative assumption.

3.1.3. Geological Resistance

To determine cumulative effects of pile driving activities, the expected number of strikes needed to drive each pile into the sediment is required. Given it is not yet known whether pile driving will be required, a conservative estimate of the number of strikes needed for each hammer and pile combination has been applied based on practical experience from similar pile driving activities, an assessment of the piling model applied by JASCO and the geological profile that defined the geoacoustics (Section 3.6.2). In practice the number of strikes required will be affected by factors such as soil resistance (i.e. high soil resistance requires more strikes) and hammer settings (i.e. shorter strike distance require more strikes). To understand how the sound propagation/noise footprint would vary if fewer hammer strikes were required, which could occur given a lower soil resistance, two scenarios (9 and 10 in Table 4) with a lower average strike count for the larger hammer were also modelled.

3.1.4. Modelling Scenarios

The modelling scenarios were numbered initially per modelling site, with the order of pile size and hammer applied the same for both sites. Scenarios 9 and 10, although being at different locations, were grouped together based upon soil resistance characteristics, as they consider a different soil resistance to the other eight scenarios.

In summary, to understand how different parameters would influence the sound propagation across the Barossa field, the alternative scenarios have been selected to consider:

- a premise case of an indicative FPSO location within the Barossa field (i.e. Scenarios 1-4)
- a change in the FPSO facility location to a deeper water depth (i.e. Scenarios 5-8)
- a change in geological resistance (i.e. Scenario 9-10).

The model assumed no acoustic mitigation around the pile driving operation. Therefore, the modelling scenarios represent the maximum noise footprint from pile driving activities as a conservative estimate.

Table 4. Modelling scenario details.

<table>
<tr><th rowspan="2">Scenario</th><th rowspan="2">Location</th><th colspan="3">Pile dimensions* (m)</th><th rowspan="2">Hammer†</th><th rowspan="2">Strikes to full penetration</th><th rowspan="2">Penetration rate (mm/strike)</th><th rowspan="2">Total driving time (min)</th></tr>
<tr><th>Length</th><th>Diameter</th><th>Penetration</th></tr>
<tr><td>1</td><td rowspan="4">Site 1</td><td>43</td><td>4</td><td>28</td><td>MHU 600T</td><td>1843</td><td>15.2</td><td>61</td></tr>
<tr><td>2</td><td>43</td><td>4</td><td>28</td><td>MHU 1700S</td><td>433</td><td>64.7</td><td>14</td></tr>
<tr><td>3</td><td>39</td><td>5</td><td>24</td><td>MHU 600T</td><td>1579</td><td>15.2</td><td>53</td></tr>
<tr><td>4</td><td>39</td><td>5</td><td>24</td><td>MHU 1700S</td><td>371</td><td>64.7</td><td>12</td></tr>
<tr><td>5</td><td rowspan="4">Site 2</td><td>43</td><td>4</td><td>28</td><td>MHU 600T</td><td>1843</td><td>15.2</td><td>61</td></tr>
<tr><td>6</td><td>43</td><td>4</td><td>28</td><td>MHU 1700S</td><td>433</td><td>64.7</td><td>14</td></tr>
<tr><td>7</td><td>39</td><td>5</td><td>24</td><td>MHU 600T</td><td>1579</td><td>15.2</td><td>53</td></tr>
<tr><td>8</td><td>39</td><td>5</td><td>24</td><td rowspan="3">MHU 1700S</td><td>371</td><td>64.7</td><td>12</td></tr>
<tr><td>9</td><td>Site 1</td><td>39</td><td>5</td><td>24</td><td>301</td><td>79.7</td><td>10</td></tr>
<tr><td>10</td><td>Site 2</td><td>39</td><td>5</td><td>24</td><td>301</td><td>79.7</td><td>10</td></tr>
</table>

* All piles modelled as having 50 mm pile wall thickness.
† MHU 600T (660 kJ energy) and MHU 1700S (1730 kJ energy) operating at a 30 strikes/minute.

3.2. Acoustic Source and Propagation Models

The following three steps comprise the general approach this study applies to modelling pile driving activities:

1. Piles driven into the sediment by impact driving are characterised as sound-radiating sources. This characterisation strongly depends on local properties such as pile dimensions, pile driving equipment, and rate and extent of pile penetration.
2. The theory of underwater sound propagation is applied to predict how sound propagates from the pile into the water column as a function of range, depth, and azimuthal direction. Propagation

depends on several conditions including the frequency content of the sound, the bathymetry, the sound speed in the water column, and sediment geoacoustics.

3. The propagated sound field is used to compute received levels over a grid of simulated receivers, from which distances to criteria thresholds and maps of ensonified areas can be generated.

This section describes the characterisation of the sound at the pile wall resulting from a single hammer strike. Details on sound propagation and computation of specific metrics are provided in the in the subsections of these Methods and in Appendix B.2.

To model sounds resulting from impact pile driving of cylindrical pipes, JASCO's Pile Driving Source Model (PDSM), a physical model of pile vibration and near-field sound radiation (MacGillivray 2014), was used in conjunction with the GRLWEAP 2010 wave equation model (GRLWEAP, Pile Dynamics 2010). Once the impact pile driver model and the pile dimensions were input into GRLWEAP, it was possible to compute the force at the top of the pile generated by the driver (Figure 2) and then input that into the PDSM.

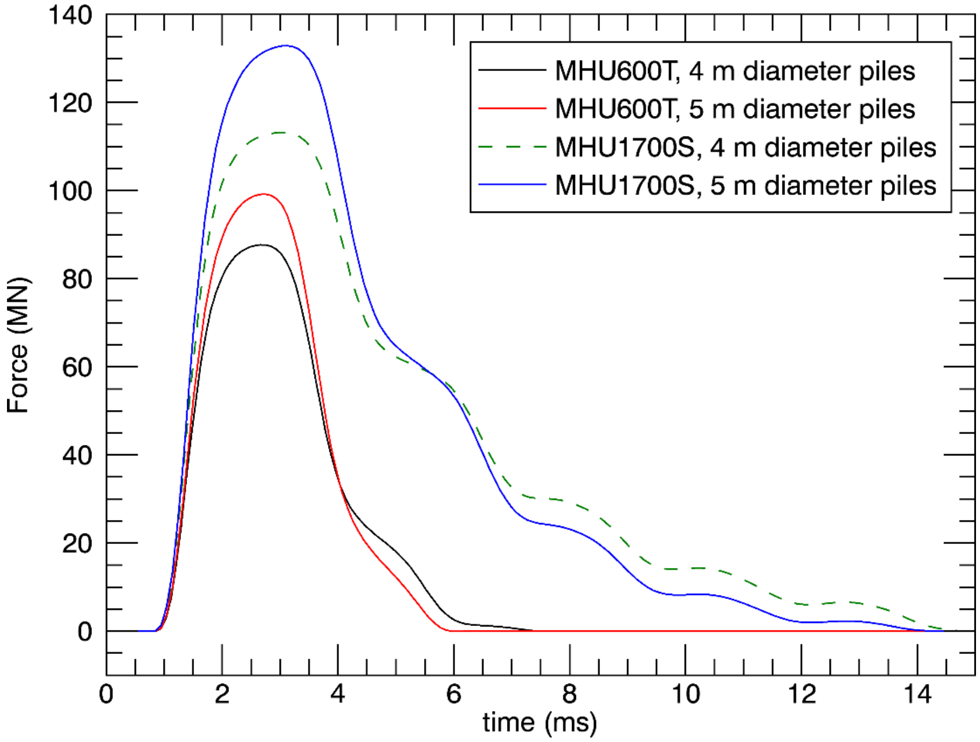

Figure 2. Force at the top of the pile corresponding to impact pile driving of 4 m and 5 m diameter piles, computed using the GRLWEAP 2010 wave equation model for the MHU 600T and the MHU 1700S hammers.

Forcing functions (Figure 2) were input to the PDSM to obtain equivalent pile driving signatures consisting of a vertical array of discrete point sources (Appendix B.1); these represent the pile as an acoustic source and accounted for several parameters that determined the operation: pile type, material, size, and length; the pile driving equipment; and approximate pile penetration rate. The amplitude and phase of the point sources along the array were computed so that they collectively mimicked the time-frequency characteristics of the acoustic wave at the pile wall that results from a hammer strike at the top of the pile. This approach accurately estimates spectral levels within the band 10–800 Hz where most of the energy from impact pile driving is concentrated.

JASCO's Marine Operations Noise Model (MONM; Appendix B.2.2) computes received per-pulse (in this case, per-strike) SEL for directional impulsive sources at a specified source depth. It is a far-field transmission loss model, which assumes that the separation between the source and receiver is sufficiently large that the physical dimensions of the source can be neglected. JASCO's time-domain Full Waveform Range-dependent model (FWRAM; Appendix B.2.3) on the other hand calculates sound propagation from physically distributed sources such as those obtained from PDSM. FWRAM, while valid at all distances, becomes computationally inefficient at long ranges. For this reason, received sound levels were calculated using FWRAM only along a few radials, and transmission loss was calculated using MONM on a long-range three-dimensional grid. A far-field point source representation of the acoustic PDSM signature from the pile was then determined by back-propagating the received sound levels generated with FWRAM using the transmission loss calculated with MONM. This point source representation accurately characterises the vertical directivity of the pile-driving signature, with the advantage that it can be applied to MONM for computationally efficient long-range modelling.

In the present study, FWRAM was applied along three 20 km long radials with azimuths 0^0, 90^0, and 180^0 centred at both pile locations. This allowed us to examine the effect of predominantly downward, flat, and upward bathymetries on source levels. Back propagation using MONM transmission loss resulted in three equivalent monopole sources per scenario. The final 1/3-octave-band levels for each scenario (Figure 3) were obtained by taking the maximum SEL at each band, which resulted in the most conservative choice. Source levels above 800 Hz were obtained by extrapolation, following the decay trend observed in the modelled 1/3-ocatave-bands from 200 Hz to 800 Hz. Source levels were similar for scenarios that differed only on the site (i.e., Scenarios 1, 2, 3, 4, and 9 compared to 5, 6, 7, 8, and 10, respectively).

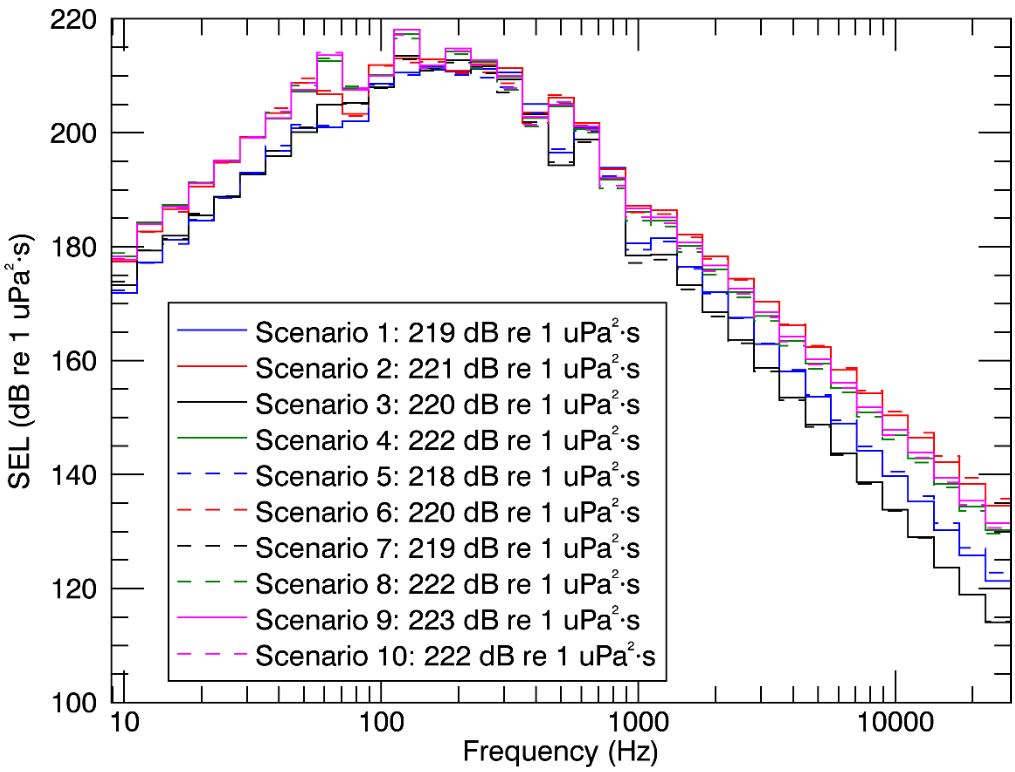

Figure 3. 1/3-octave-band and broadband sound exposure source level for impact pile driving that correspond to the modelling scenarios in Table 4.

3.3. Accumulated SEL

The modelling approach outlined in Section 3.1 provides per-strike SEL. At this early stage of project definition, information on soil resistance as a function of pile depth was not available at the time of this report. The source level of the pile driving was calculated based on the assumption that the pile was at its final penetration into the sediment, with maximum soil resistance and hammer energy. The sound speed profile (Section 3.6.3) will cause transmission loss to vary only slightly with increasing depth, and therefore changes in source depth will not influence the result.

The total number of strikes required to install a pile for each scenario (Table 4) was used in this report to obtain SEL over the period of installation, referred to in this report as SEL_{24h} as only one pile was predicted to be driven per day, by applying Equation 1:

$$SEL = \text{per-strike SEL} + 10\log_{10}N_{24h} \quad (1)$$

where N_{24h} represents the total number of hammer blows for impact pile driving.

3.4. Estimating SPL from Modelled SEL Results

The per-strike SEL of sound pulses is an energy-like metric related to the dose of sound received over the pulse's entire duration. The pulse SPL on the other hand is related to its intensity over a specified time interval. The time interval often applied to assess seismic pulses is the 90% time window (T_{90}) (Appendix A). Pile driving pulses typically lengthen in duration as they propagate away from their source, due to seafloor and sea surface reflections, as well as other waveguide dispersion effects. The changes in pulse length, and therefore T_{90}, affect the numeric relationship between SPL and SEL. Full-waveform modelling is often used to estimate T_{90}, but this type of modelling is computationally intensive, and can be prohibitively time consuming when run at high spatial resolution over large areas.

For the current study, the Full Waveform Range-dependent Acoustic Model (FWRAM; Appendix B.2.3) was used to model pile driving pulses over the frequency range 10–1024 Hz. This was performed for each scenario at three radials along predominantly downward, flat, and upward bathymetry. FWRAM uses Fourier synthesis to recreate the signal in the time domain so that both the SEL and SPL resulting from the source can be calculated. The difference between the SEL and SPL was extracted for all radials, ranges and depths. A 125 millisecond fixed time window positioned to maximise the SPL over the pulse duration was applied. The resulting SEL-to-SPL offsets were averaged in 2.0 km range bins along each modelled radial and depth, and the 90th percentile was selected at each range in order to generate a range-dependent conversion function for each scenario. Due to the similarity of the conversion factor among all scenarios (Figure 4), a single generalised conversion factor was obtained as the mean value per range among all scenarios, and was applied to predicted per-strike SEL results from MONM to model SPL values.

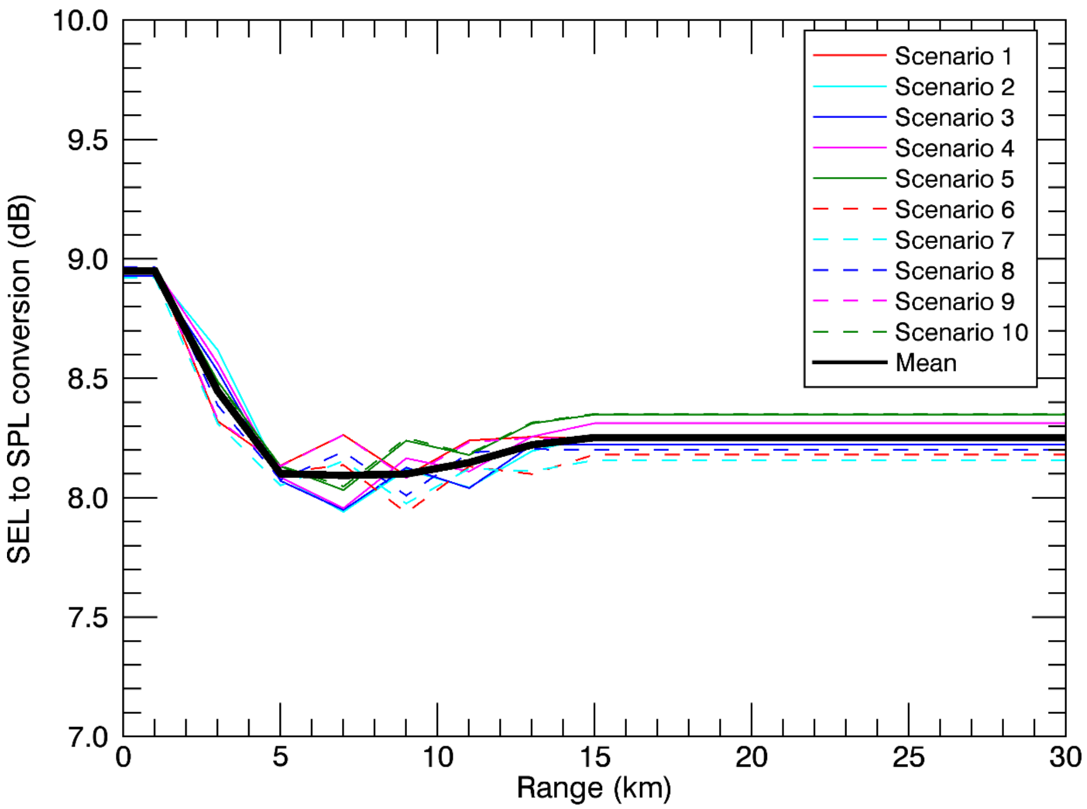

Figure 4. Range-dependent conversion function for converting SEL to SPL for pile driving pulses. Due to the similarity between the conversion factor for each scenario, modelling was conducted using a mean conversion function.

3.5. Estimating Ranges to Threshold Levels

Sound level contours were calculated based on the underwater sound fields predicted by the propagation models, sampled by taking the maximum value over all modelled depths above the sea floor for each location in the modelled region. The predicted distances to specific levels were computed from these contours. Two distances relative to the source are reported for each sound level: 1) R_{max}, the maximum range to the given sound level over all azimuths, and 2) $R_{95\%}$, the range to the given sound level after the 5% farthest points were excluded (see examples in Figure 5).

The $R_{95\%}$ is used because sound field footprints are often irregularly shaped. In some cases, a sound level contour might have small protrusions or anomalous isolated fringes (Figure 5a). In such cases, where relatively few points are excluded in any given direction, R_{max} can misrepresent the area of the region exposed to such effects, and $R_{95\%}$ is considered more representative. On the other hand, in strongly asymmetric cases (Figure 5b), $R_{95\%}$ does not account for significant protrusions in the footprint. In such cases R_{max} might better represent the region of effect in specific directions. These situations are usually associated with bathymetric features that affect propagation. The difference between R_{max} and $R_{95\%}$ depends on the source directivity and how uniform the acoustic environment is.

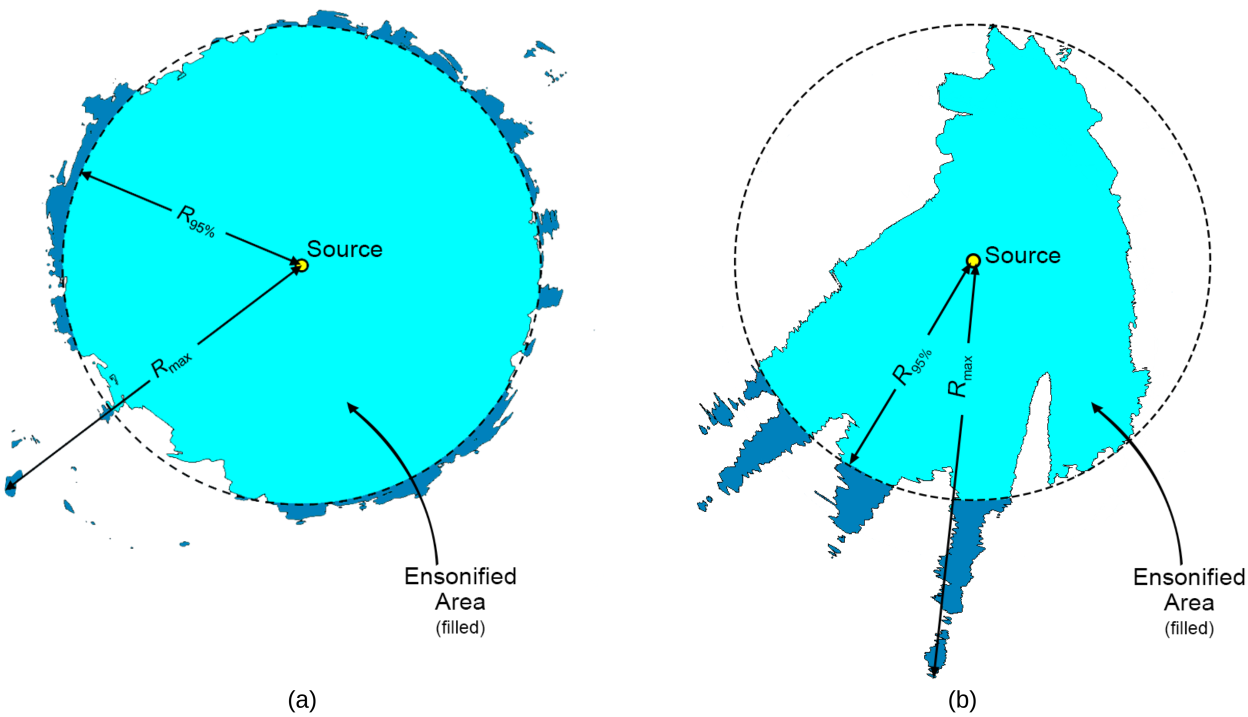

Figure 5. Sample areas ensonified to an arbitrary sound level with R_{max} and $R_{95\%}$ ranges shown for two different scenarios. (a) Largely symmetric sound level contour with small protrusions. (b) Strongly asymmetric sound level contour with long protrusions. Light blue indicates the ensonified areas bounded by $R_{95\%}$; darker blue indicates the areas outside this boundary which determine R_{max}.

3.6. Environmental Parameters

3.6.1. Bathymetry

ConocoPhillips provided accurate bathymetry data for the Barossa field and the surrounding area with a regular grid spacing of 500 × 500 m. This dataset has been supplemented by bathymetry data extracted from a 250 × 250 m resolution grid of Australian waters (Whiteway 2009). For the modelling, bathymetry data for a region of 280 × 280 km, encompassing a 100 km buffer zone around the potential piling locations, were extracted and re-gridded with a regular spacing of 250 × 250 m. The resulting bathymetry contour map and the extent of the modelling regions at Site 1 and Site 2 are shown in Figure 6.

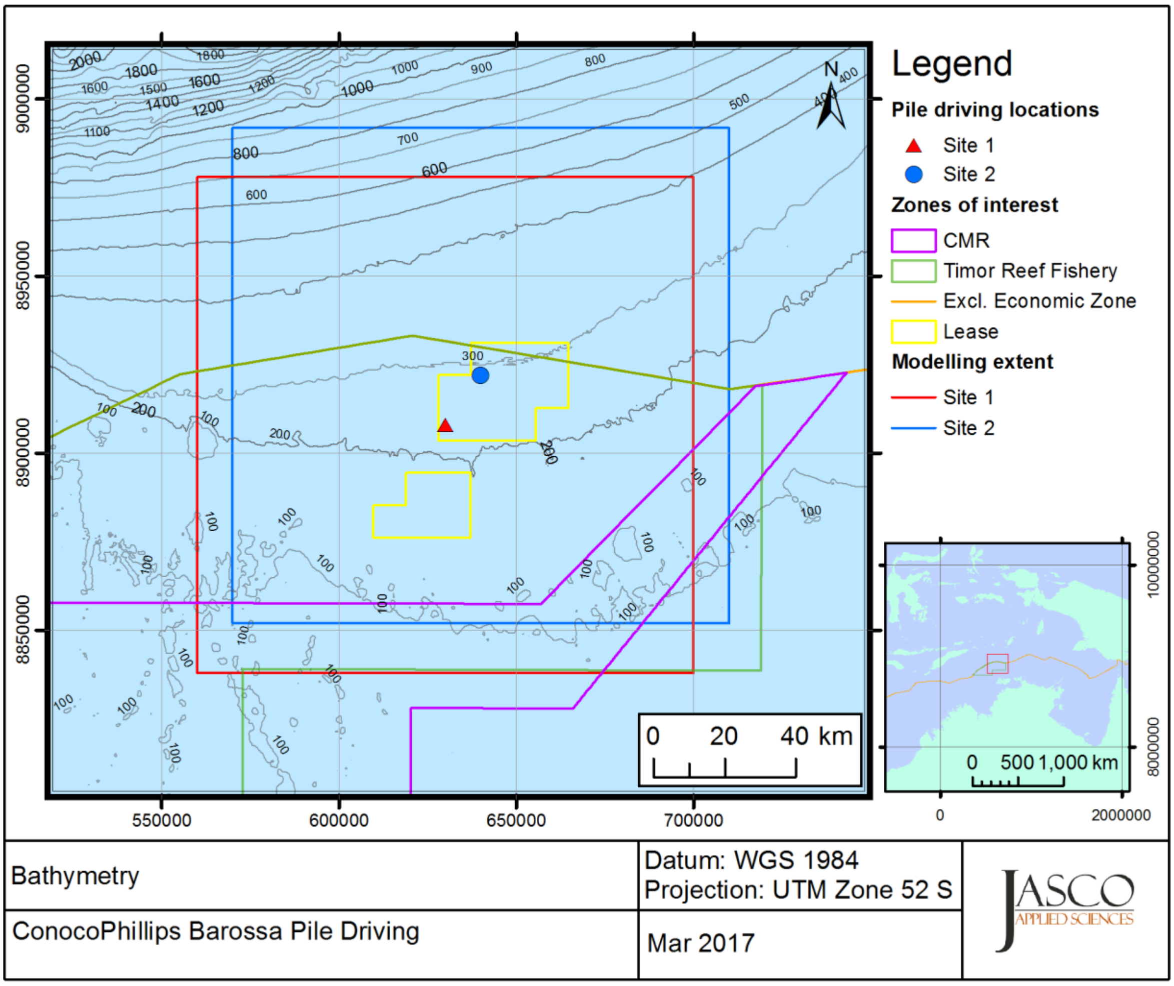

Figure 6. The bathymetry used for the modelling. The edge of the contour area indicates the extent of the modelling grids sampled at a 250 × 250 m resolution.

3.6.2. Geoacoustics

Geotechnical data were obtained from the ARUP report (Lane 2015), supplied by ConocoPhillips to JASCO, and a single geoacoustic profile representing the top sediment layer was created from that analysis. The sediment thickness in the region is over 1,200 m according to the World Ocean Atlas (Whittaker et al. 2013) and therefore this report assumes that the sediment is composed of similar grain types beyond 35 m depths. The parameters derived were based on empirical relationships from Buckingham (2005). The geoacoustic profile used in the modelling is shown in Table 5.

Table 5. Estimated geoacoustic profile used in the modelling. Within each depth range, each parameter varies linearly within the stated range.

Depth below seafloor (m)	Material	Density (g/cm³)	P-wave speed (m/s)	P-wave attenuation (dB/λ)	S-wave speed (m/s)	S-wave attenuation (dB/λ)
0–9	Coarse Sand	2.09	1655.3–2133.8	0.76–1.46	322.7	0.246
9–35	Clay	1.46	1539.8–1582.9	0.33–0.51		
35–500	Medium Sand	2.08	2275.2–3453.2	1.73–2.82		

3.6.3. Sound speed profile

The sound speed profiles (SSPs) for the modelled sites were provided to JASCO by ConocoPhillips. The profiles were principally derived from monthly measurements of temperature and salinity profiles over an entire year. The data were from two sites and included sample depths from 33 m to the seafloor. Data from the US Naval Oceanographic Office's *Generalized Digital Environmental Model V 3.0* (GDEM; Teague et al. 1990, Carnes 2009) supplemented those profiles. GDEM provides an ocean climatology of temperature and salinity for the world's oceans on a latitude-longitude grid with 0.25° resolution, with a temporal resolution of one month, based on global historical observations from the US Navy's Master Oceanographic Observational Data Set (MOODS). The temperature-salinity profiles were converted to sound speed profiles according to Coppens (1981).

For each monthly profile, the supplied data were extrapolated to provide results to the water surface based on the gradients of the profile from the GDEM data. The average of the SSPs taken across all months provides a representative SSP for the area across the year (Figure 7).

The resulting SSP represents a mixed isothermal surface layer with a slight upward-refracting profile. Below 80 m depth the profile is driven by lower temperatures, which produce a steep downward-refracting profile. For depths within the modelling extent, no sound channel is realised in deeper waters.

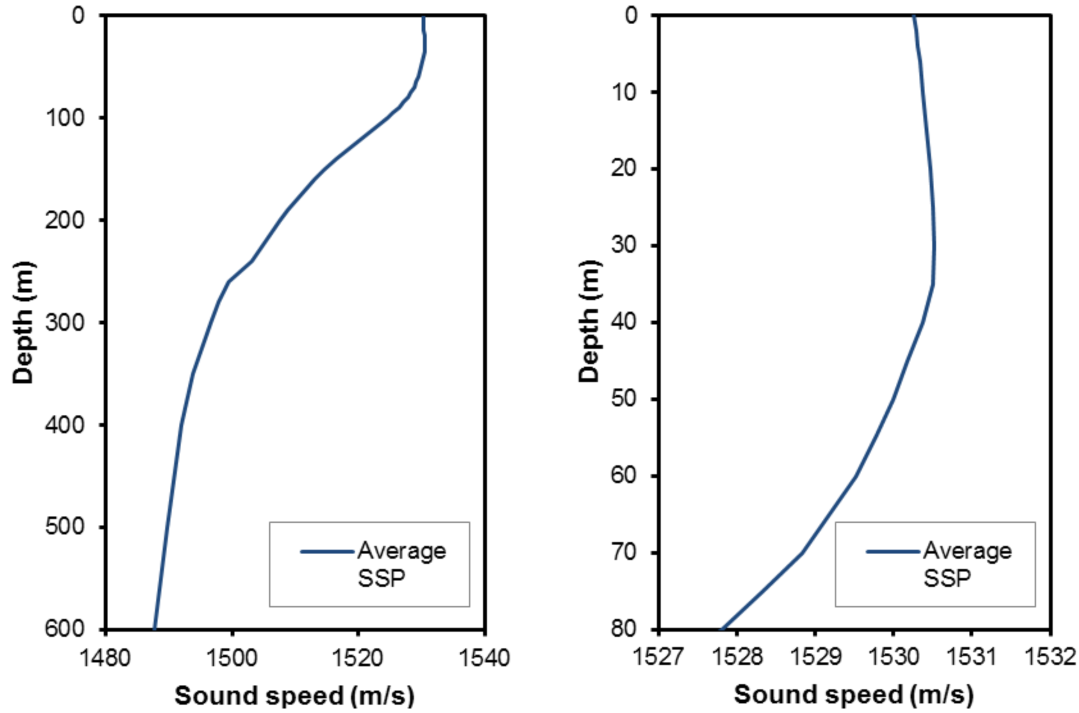

Figure 7. Sound speed profile used for the modelling (a) the average of all monthly profiles, (b) detail of the top 80 m of the SSP.

3.7. Geometry and Modelled Regions

The sound field from pile driving pulses at the two sites shown in Figure 1 were modelled using MONM in the frequency range 10 Hz–25 kHz (Appendix B.2.2) up to distances of 70 km from the source, with a horizontal separation of 20 m between receiver points along the modelled radials. Sound fields were modelled with a horizontal angular resolution of $\Delta\theta = 2.5°$ for a total of $N = 144$ radial planes. To provide greater fidelity close to the source positions, additional model runs were carried out over an area of 1 × 1 km with a horizontal separation of 5 m between receiver points, with the same horizontal angular resolution. In both cases, receiver depths were chosen to span the entire water column over the modelled areas, from 1 m to a maximum of 2500 m, with step sizes that increased with depth. At depths closer to the pile, receivers were 2 m apart over the entire length of the pile.

FWRAM (Appendix B.2.3) was run in the frequency range 10–1024 Hz, a bandwidth wide enough to include most of the energy typically generated by impact pile driving (Figure 3). 20 km radials with 5 m step size (only 3 per site for computational efficiency) were simulated to obtain equivalent 1/3-octave-band levels for input to MONM, the SEL-to-SPL offsets (Section 3.2), and to estimate radii to peak criteria thresholds.

4. Modelling Results

The modelling scenarios are grouped per modelling site, with the order of pile size and hammer applied the same for both sites (Table 4). Scenarios 9 and 10, although considering a different soil resistance to all other scenarios are grouped in association with their location in the tabulated results presented in Section 4.1. The results presented for each scenario can be compared to examine the effect on noise footprints of hammer size and pile dimensions at either possible location (site), the influence of bathymetry and depth between the two sites for similar scenarios, and the effect of different soil resistance for the same pile and hammer inputs at both modelling sites.

To assist with the comparison of the results for different hammer sizes, pile dimensions and soil resistance across the same bathymetric environment, maps and graphical representations of the sound fields at Site 1, Scenarios 1–4 and 9, are included in Section 4.2. Site 1 is the premise case for the indicative FPSO facility location and is also the site closest to the Oceanic Shoals CMR, and most central to the Timor Reef Fishery area. Representations for Site 2, Scenarios 5–8 and 10, are included in Appendix C.

4.1. Tables

Table 6 shows the estimated ranges to unweighted per-strike SEL isopleths. Tables 7–11 show the estimated ranges for the various applicable effects criteria (Section 2).

Table 6. Horizontal distances (in km) modelled maximum-over-depth unweighted per-strike SEL isopleths.

Isopleth SEL (dB re 1 µPa²·s)	Distance (km)																			
	Site 1										Site 2									
	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 9		Scenario 5		Scenario 6		Scenario 7		Scenario 8		Scenario 10	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
185	0.07	0.07	0.07	0.07	0.07	0.07	0.11	0.11	0.07	0.07	0.07	0.07	0.07	0.07	0.11	0.11	0.07	0.07	0.07	0.07
180	0.14	0.14	0.14	0.14	0.14	0.14	0.22	0.22	0.11	0.11	0.14	0.14	0.14	0.14	0.22	0.22	0.14	0.14	0.14	0.14
170	0.61	0.59	0.81	0.78	0.71	0.70	1.08	1.03	0.54	0.51	0.71	0.66	0.61	0.60	0.89	0.85	0.61	0.59	0.81	0.78
160	5.92	5.48	6.42	6.00	6.07	5.66	8.99	8.16	4.39	3.92	7.24	6.72	4.92	4.40	7.81	7.34	5.92	5.48	6.42	6.00
150	20.27	17.12	23.80	20.83	23.45	18.99	30.86	24.28	21.09	17.72	27.39	21.74	23.56	19.45	31.94	25.76	20.27	17.12	23.80	20.83

Table 7. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) to modelled maximum-over-depth M-weighted 24 h SEL permanent hearing threshold shift (PTS) thresholds for marine mammals (Wood et al. 2012).

Threshold (SEL_{24h})	Distance (km)																			
	Site 1										Site 2									
	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 9		Scenario 5		Scenario 6		Scenario 7		Scenario 8		Scenario 10	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
Low-frequency cetaceans (192 dB re 1 µPa²·s)	5.98	5.60	3.09	2.94	6.07	5.66	3.26	3.10	3.20	3.05	4.88	4.31	2.04	1.85	4.92	4.37	3.34	3.20	2.57	2.03
Mid-frequency cetaceans (198 dB re 1 µPa²·s)	0.79	0.69	0.32	0.31	0.76	0.63	0.32	0.31	0.30	0.28	0.52	0.50	0.27	0.26	0.54	0.51	0.27	0.27	0.26	0.25
High-frequency cetaceans (179 dB re 1 µPa²·s)	16.59	14.05	8.86	7.60	15.39	13.17	8.27	7.48	7.95	6.37	18.75	13.39	7.47	6.95	16.66	12.66	7.42	6.89	7.24	6.81

Table 8. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) to modelled maximum-over-depth DEWHA (2008) criterion and applied marine mammal and turtle behavioural response thresholds.

Threshold	Distance (km)																			
	Site 1										Site 2									
	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 9		Scenario 5		Scenario 6		Scenario 7		Scenario 8		Scenario 10	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
DEWHA (2008), Unweighted SEL (160 dB re 1 µPa²·s)	5.92	5.48	6.42	6.00	6.07	5.66	8.99	8.16	9.68	8.59	4.39	3.92	7.24	6.72	4.92	4.40	7.81	7.34	9.80	7.52
NMFS (2013) Marine mammal behaviour, Unweighted SPL (160 dB re 1 µPa)	17.16	14.26	20.23	16.96	18.14	15.65	23.83	20.34	26.93	21.92	17.88	14.23	22.12	17.83	19.46	15.43	28.30	21.40	28.76	22.39
Turtle behaviour (NSF 2011), unweighted SPL (166 dB re 1 µPa)	7.53	6.18	9.90	8.62	8.84	7.90	12.04	10.19	13.82	11.09	7.29	6.87	9.58	7.49	7.54	6.99	14.25	10.47	14.41	10.99

Table 9. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) to modelled maximum-over-depth 24 h SEL mortality and potential mortal injury thresholds for fish, turtles, fish eggs, and fish larvae.

Threshold (SEL_{24h})	Distance (km)																			
	Site 1										Site 2									
	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 9		Scenario 5		Scenario 6		Scenario 7		Scenario 8		Scenario 10	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
Fish I: no swim bladder (219 dB re 1 μPa²·s)	0.08	0.08	0.05	0.05	0.08	0.08	0.05	0.05	0.05	0.05	0.07	0.07	0.04	0.04	0.07	0.07	0.05	0.05	0.05	0.04
Fish II: swim bladder involved in hearing (207 dB re 1 μPa²·s)	0.34	0.31	0.18	0.17	0.34	0.33	0.20	0.19	0.19	0.18	0.28	0.27	0.16	0.16	0.29	0.28	0.19	0.18	0.18	0.17
Fish III: swim bladder not involved in hearing (210 dB re 1 μPa²·s) Turtles, fish eggs, and fish larvae (210 dB re 1 μPa²·s)	0.22	0.21	0.13	0.12	0.23	0.22	0.14	0.14	0.14	0.13	0.20	0.19	0.12	0.11	0.20	0.20	0.13	0.13	0.12	0.12

Table 10. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) to modelled maximum-over-depth 24 h SEL recoverable injury and temporary (hearing) threshold shift (TTS) thresholds for fish.

Threshold (SEL_{24h})	Distance (km)																			
	Site 1										Site 2									
	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 9		Scenario 5		Scenario 6		Scenario 7		Scenario 8		Scenario 10	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
Fish I: no swim bladder (216 dB re 1 µPa²·s)	0.11	0.10	0.07	0.06	0.11	0.11	0.07	0.07	0.07	0.07	0.10	0.09	0.06	0.06	0.10	0.10	0.07	0.07	0.06	0.06
Fish II: swim bladder involved in hearing (203 dB re 1 µPa²·s)	0.67	0.59	0.30	0.29	0.67	0.59	0.35	0.34	0.34	0.31	0.50	0.48	0.27	0.26	0.53	0.50	0.29	0.28	0.28	0.27
Fish III: swim bladder not involved in hearing (203 dB re 1 µPa²·s)																				
Fish I, II, III TTS (186 dB re 1 µPa²·s)	14.04	11.79	7.38	6.18	14.81	11.85	8.89	7.97	8.36	6.49	13.93	11.07	7.32	6.90	14.65	11.64	7.79	7.13	7.53	6.86

Table 11. Maximum (R_{max}) horizontal distances (in km) to modelled maximum-over-depth peak mortality and potential mortal recoverable injury thresholds for fish, turtles, fish eggs, and fish larvae.

Threshold (PK)	Distance (km)									
	Site 1					Site 2				
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 9	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 10
	R_{max}	R_{max}	R_{max}	R_{max}	R_{max}	R_{max}	R_{max}	R_{max}	R_{max}	R_{max}
Fish I: no swim bladder (> 213 dB re 1 µPa)	0.08	0.10	0.09	0.10	0.10	0.08	0.09	0.09	0.10	0.10
Fish II: swim bladder not involved in hearing (> 207 dB re 1 µPa)	0.16	0.20	0.15	0.19	0.19	0.16	0.20	0.15	0.19	0.19
Fish III: swim bladder involved in hearing (> 207 dB re 1 µPa)										
Turtles (> 207 dB re 1 µPa)										
Fish eggs and fish larvae (> 207 dB re 1 µPa)										

4.2. Maps and Graphs

Plots of the estimated sound field and threshold contours in the horizontal plane (maps) are shown for Site 1, Scenarios 1–4 and 9. Representations for Site 2, Scenarios 5–8 and 10, are included in Appendix C.

Maps were created to display the unweighted 24 h SEL footprints with the M-weighted 24 h PTS thresholds for marine mammals (Figures 8–12), the unweighted 24 h SEL footprints with the thresholds for fish, turtles, fish eggs, and fish larvae (Figures 13–17), and SPL footprints with thresholds for marine mammals and turtles (Figures 18–22). Graphs of unweighted SEL in the vertical plane for each of the scenarios are shown in Figures 23–27.

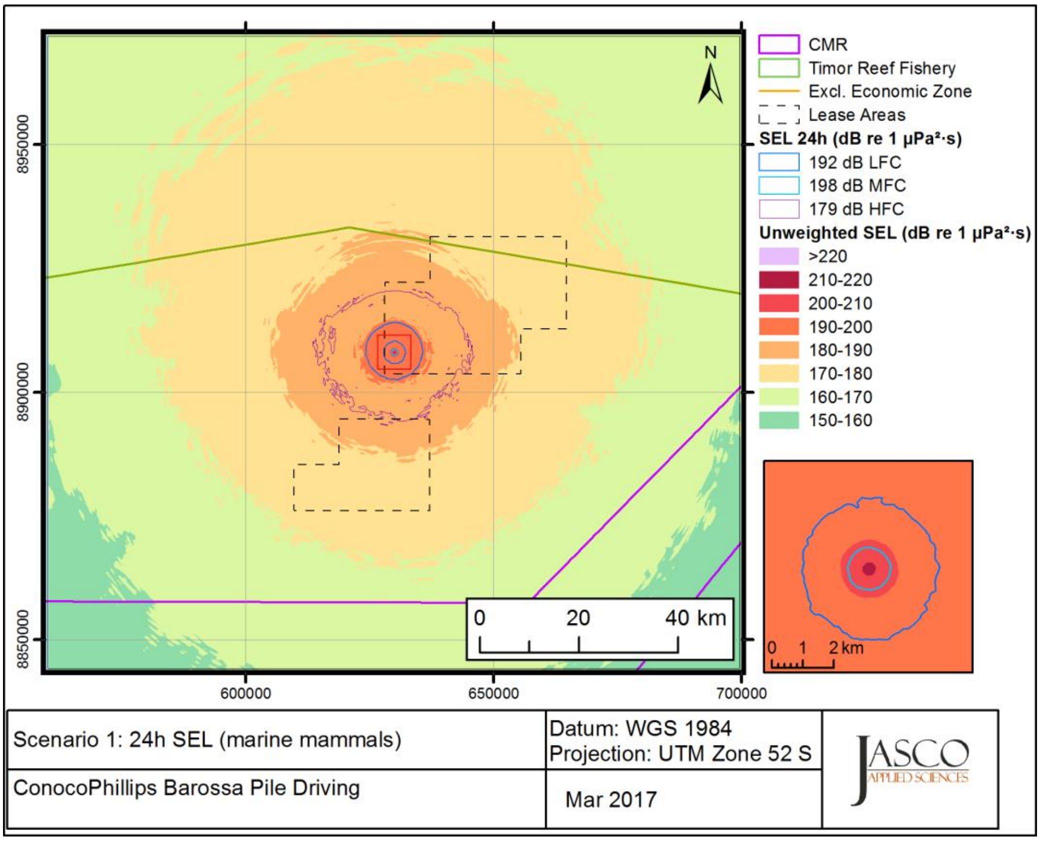

Figure 8. Scenario 1: Sound level contour map showing maximum-over-depth SEL_{24h} results with marine mammal PTS thresholds.

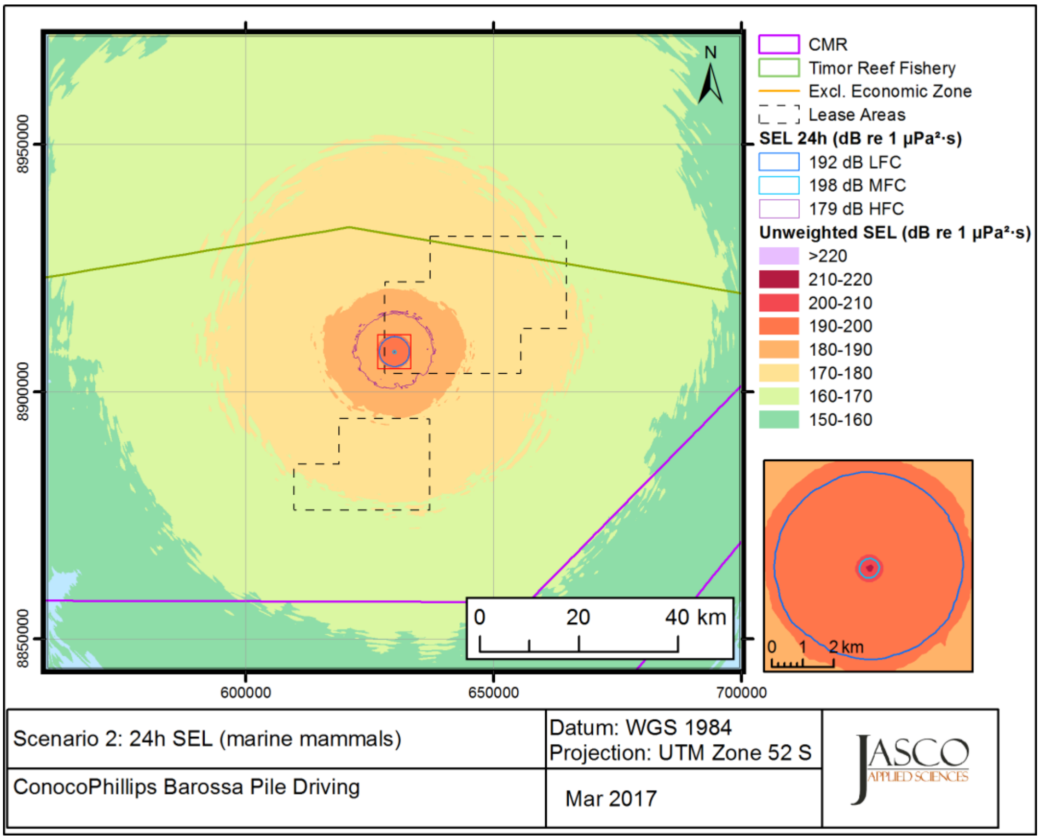

Figure 9. Scenario 2: Sound level contour map showing maximum-over-depth SEL_{24h} results with marine mammal PTS thresholds.

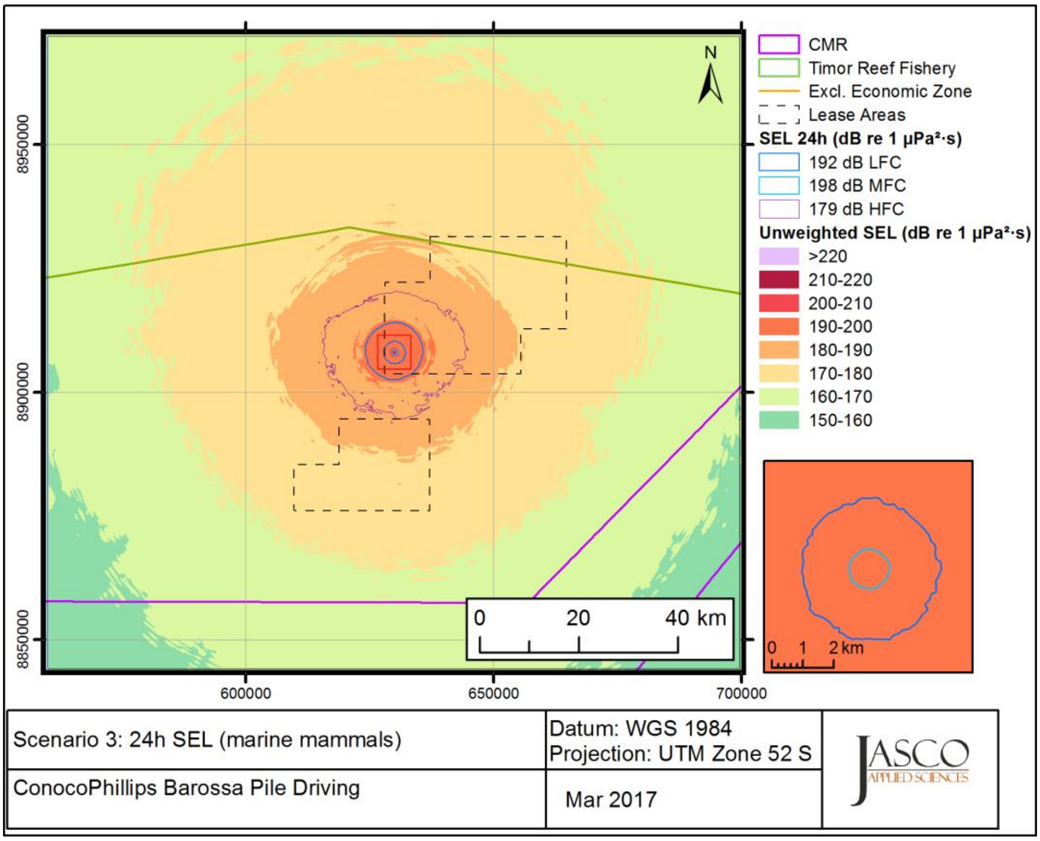

Figure 10. Scenario 3: Sound level contour map showing maximum-over-depth SEL_{24h} results with marine mammal PTS thresholds.

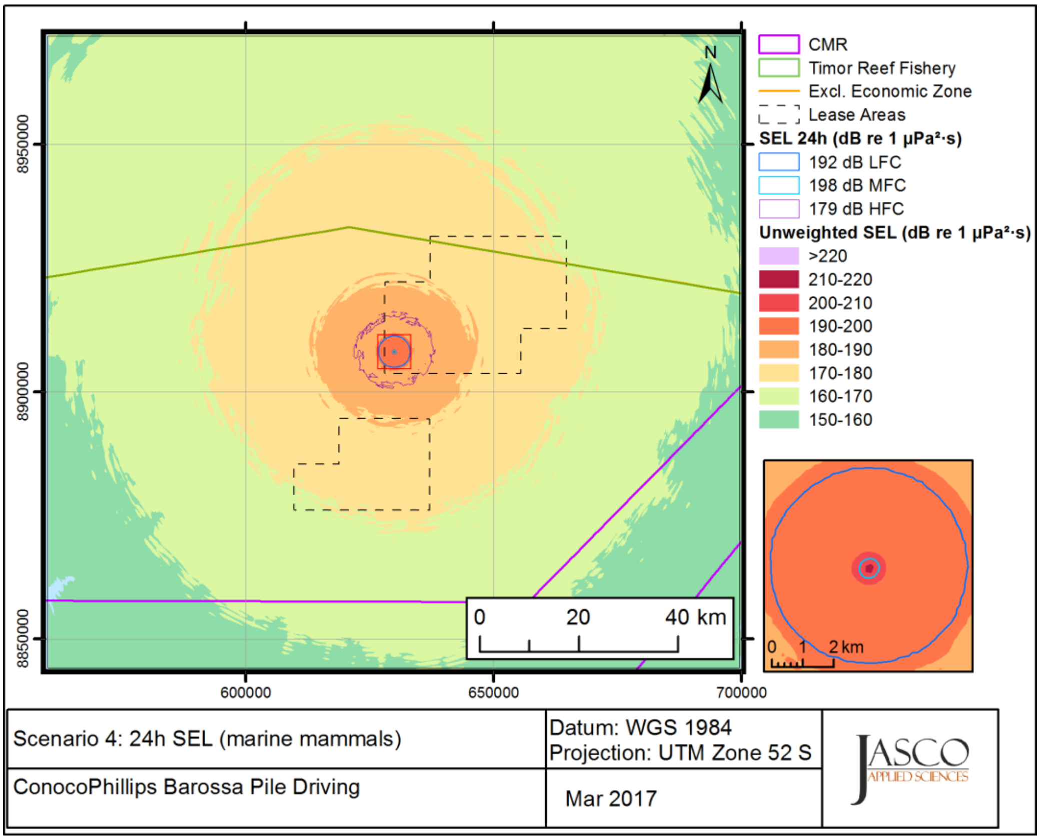

Figure 11. Scenario 4: Sound level contour map showing maximum-over-depth SEL_{24h} results with marine mammal PTS thresholds.

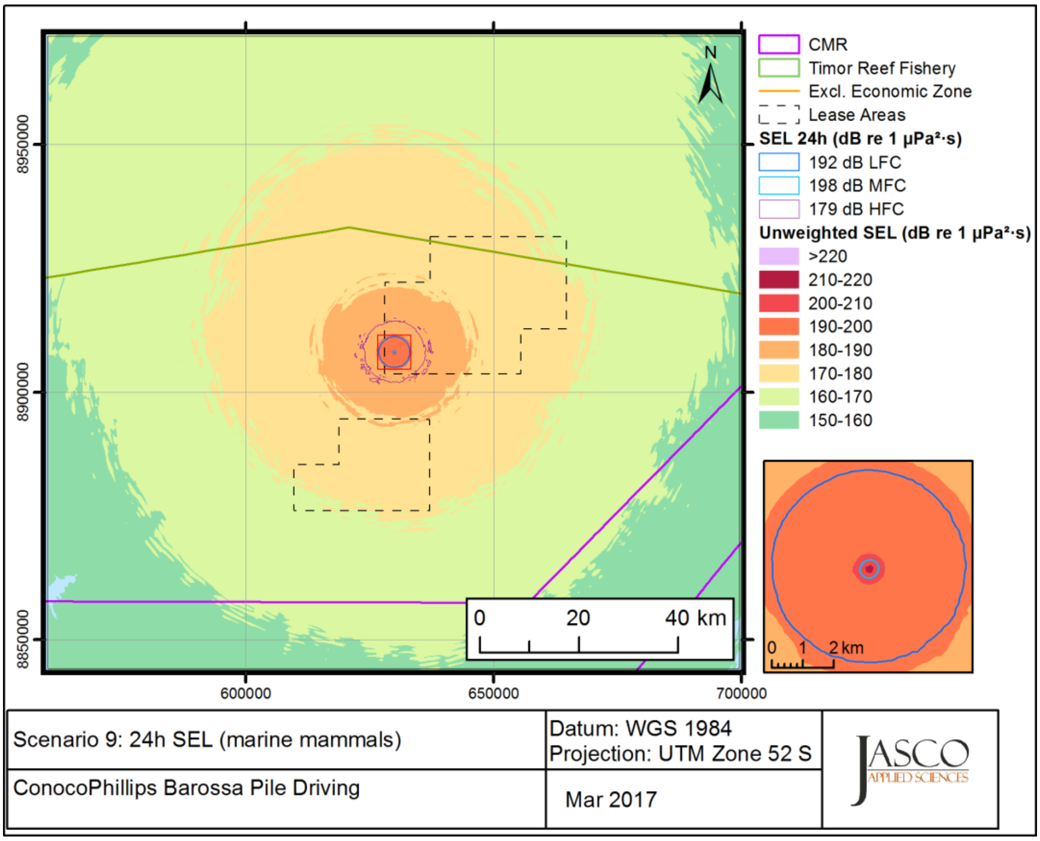

Figure 12. Scenario 9: Sound level contour map showing maximum-over-depth SEL_{24h} results with marine mammal PTS thresholds.

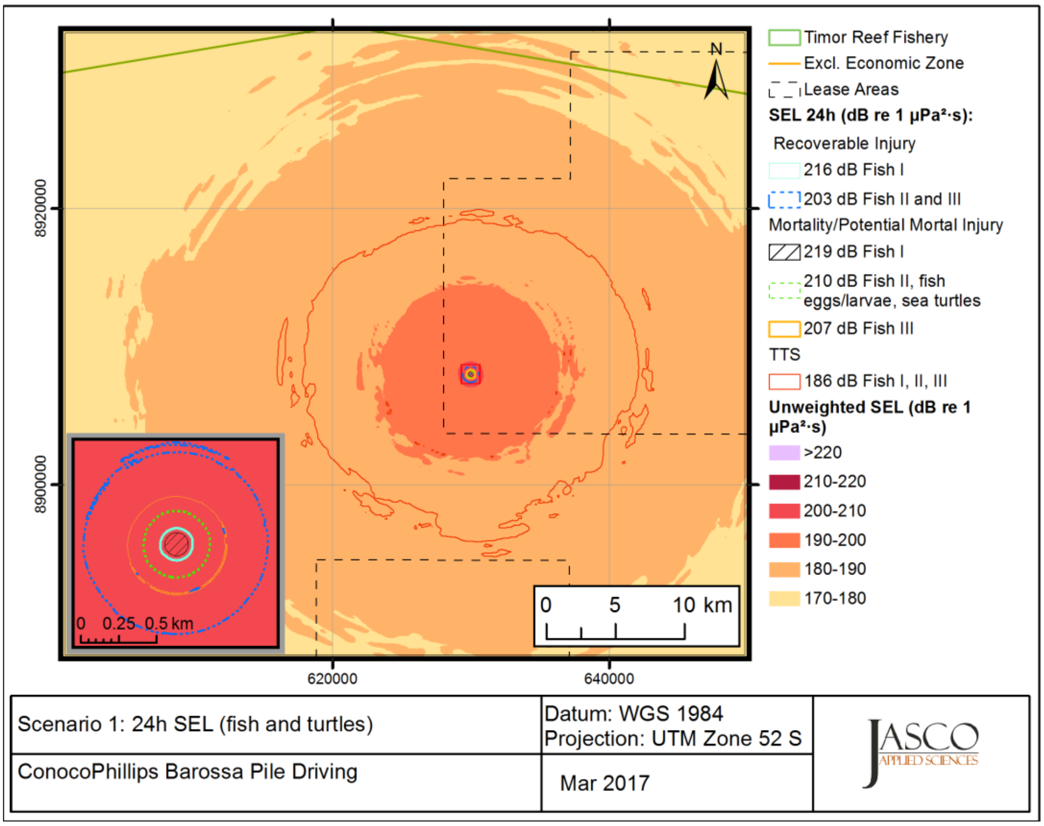

Figure 13. Scenario 1: Sound level contour map showing maximum-over-depth SEL_{24h} results with fish and turtle thresholds.

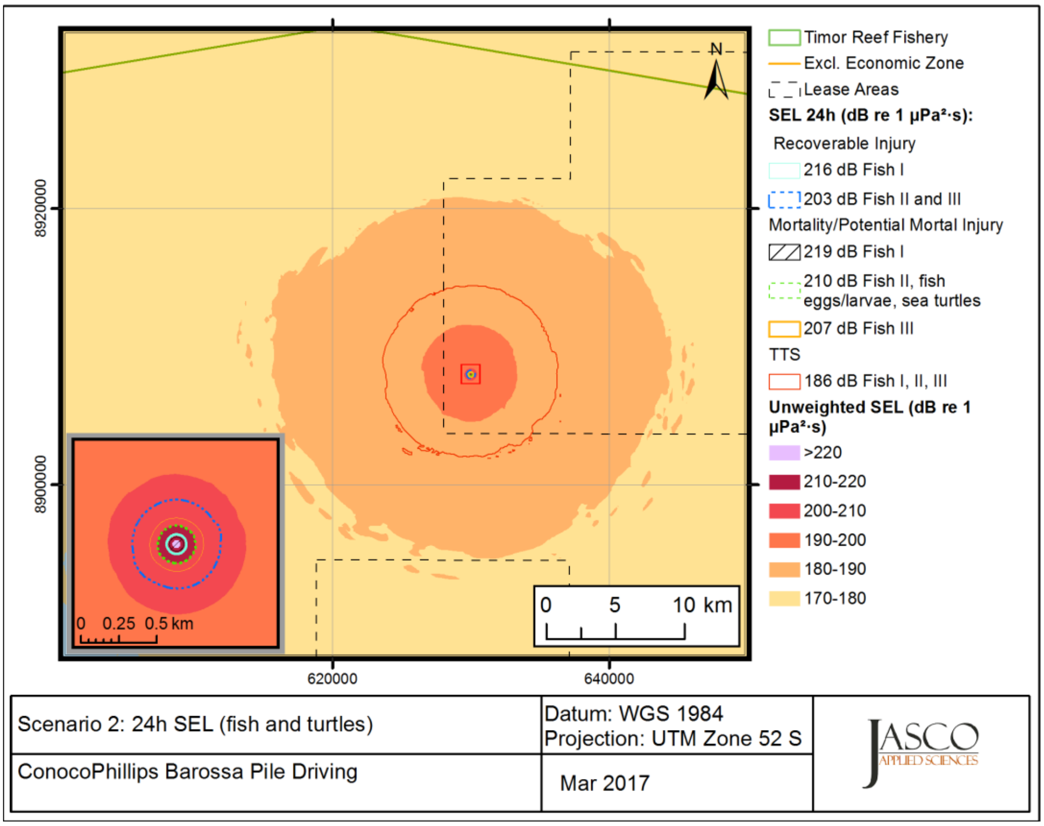

Figure 14. Scenario 2: Sound level contour map showing maximum-over-depth SEL_{24h} results with fish and turtle thresholds.

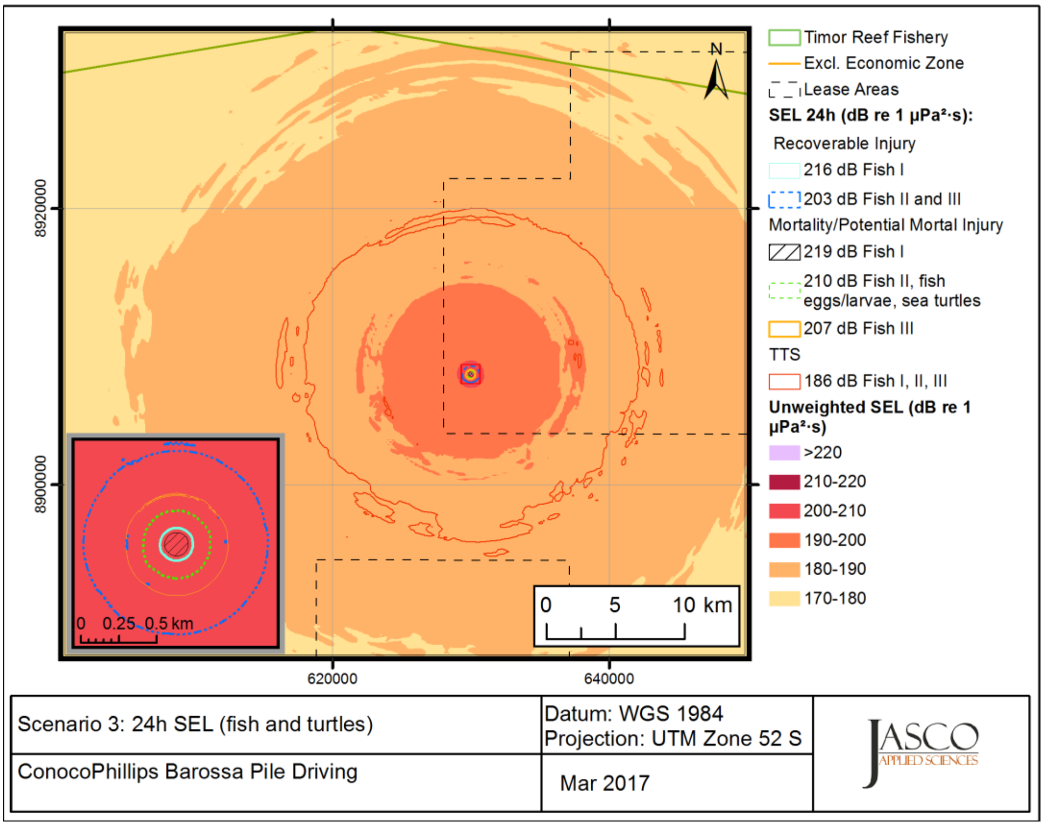

Figure 15. Scenario 3: Sound level contour map showing maximum-over-depth SEL_{24h} results with fish and turtle thresholds.

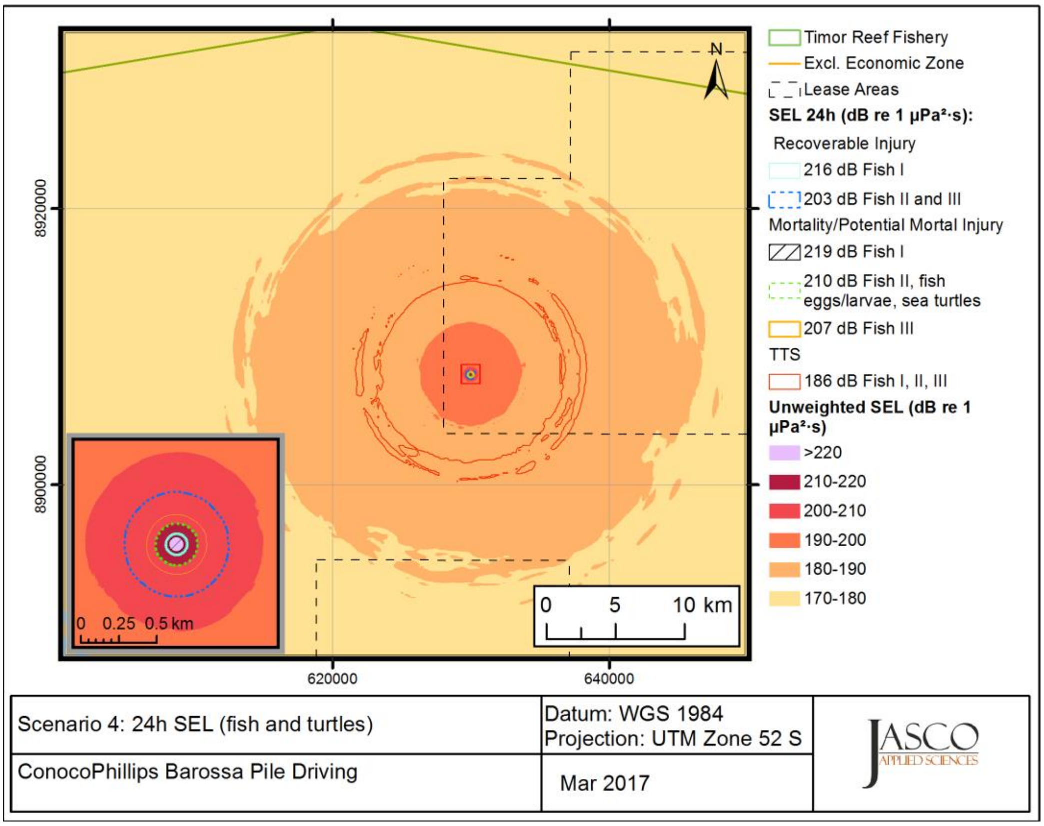

Figure 16. Scenario 4: Sound level contour map showing maximum-over-depth SEL_{24h} results with fish and turtle thresholds.

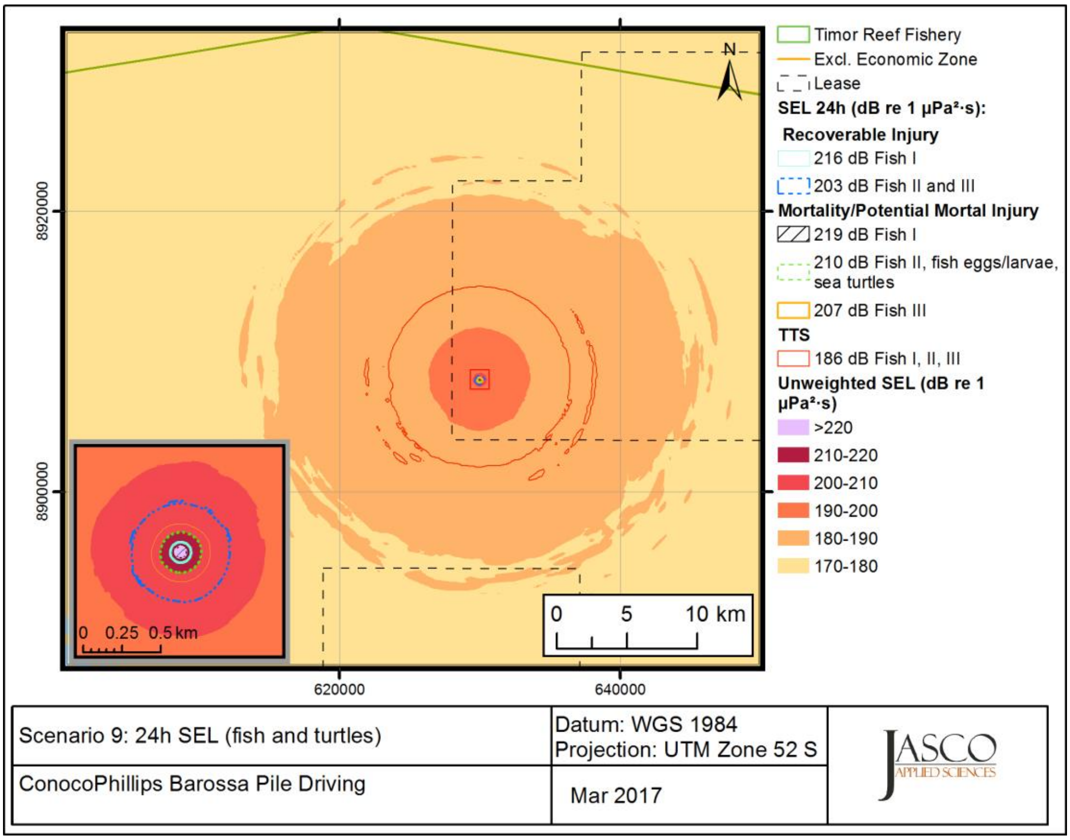

Figure 17. Scenario 9: Sound level contour map showing maximum-over-depth SEL_{24h} results with fish and turtle thresholds.

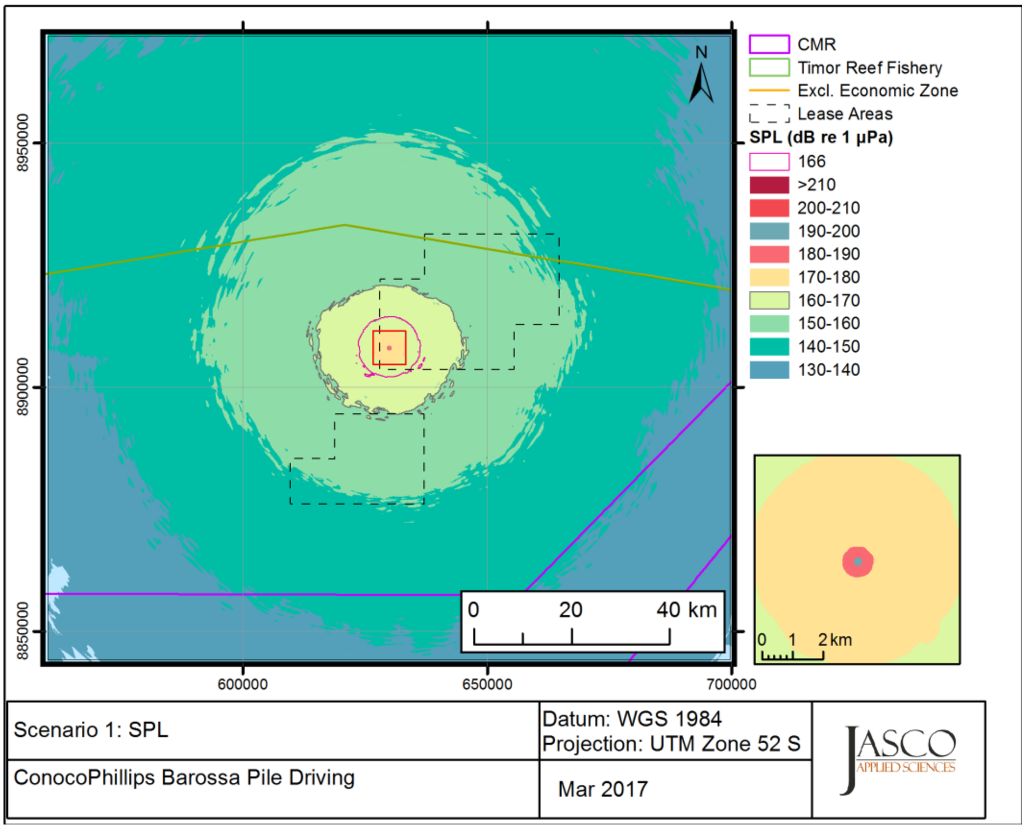

Figure 18. Scenario 1: Sound level contour map showing unweighted maximum-over-depth SPL results, showing isopleths for marine mammal and turtle behaviour thresholds.

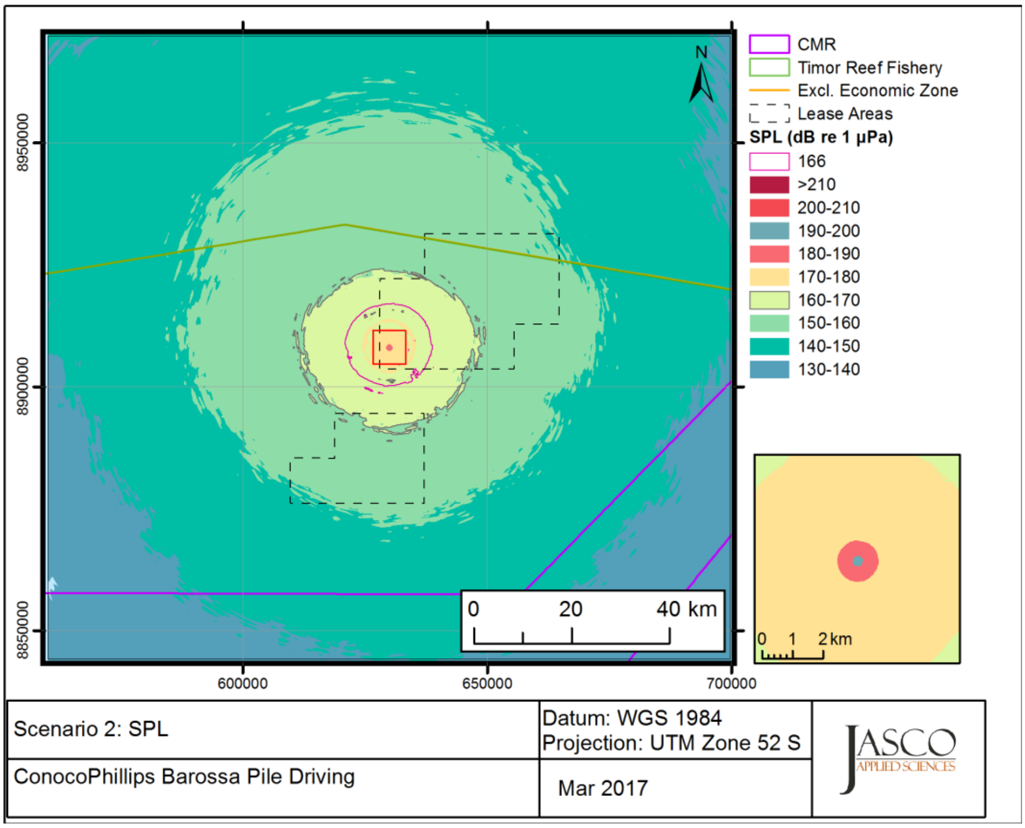

Figure 19. Scenario 2: Sound level contour map showing unweighted maximum-over-depth SPL results, showing isopleths for marine mammal and turtle behaviour thresholds.

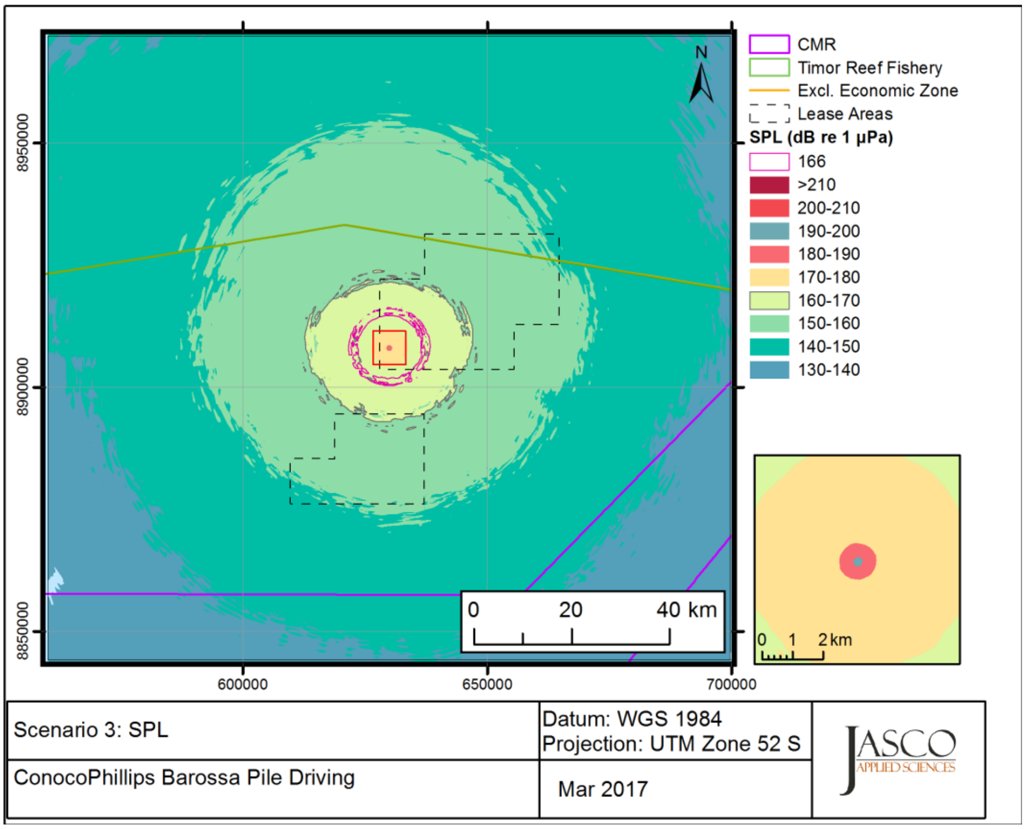

Figure 20. Scenario 3: Sound level contour map showing unweighted maximum-over-depth SPL results, showing isopleths for marine mammal and turtle behaviour thresholds.

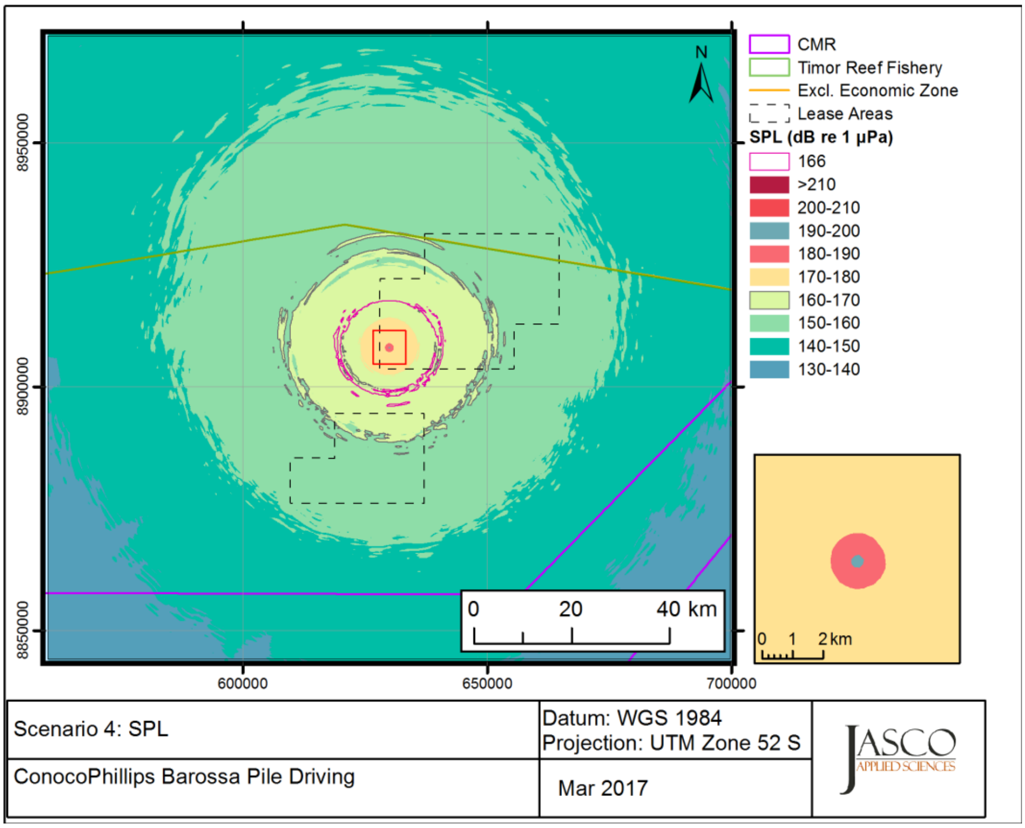

Figure 21. Scenario 4: Sound level contour map showing unweighted maximum-over-depth SPL results, showing isopleths for marine mammal and turtle behaviour thresholds.

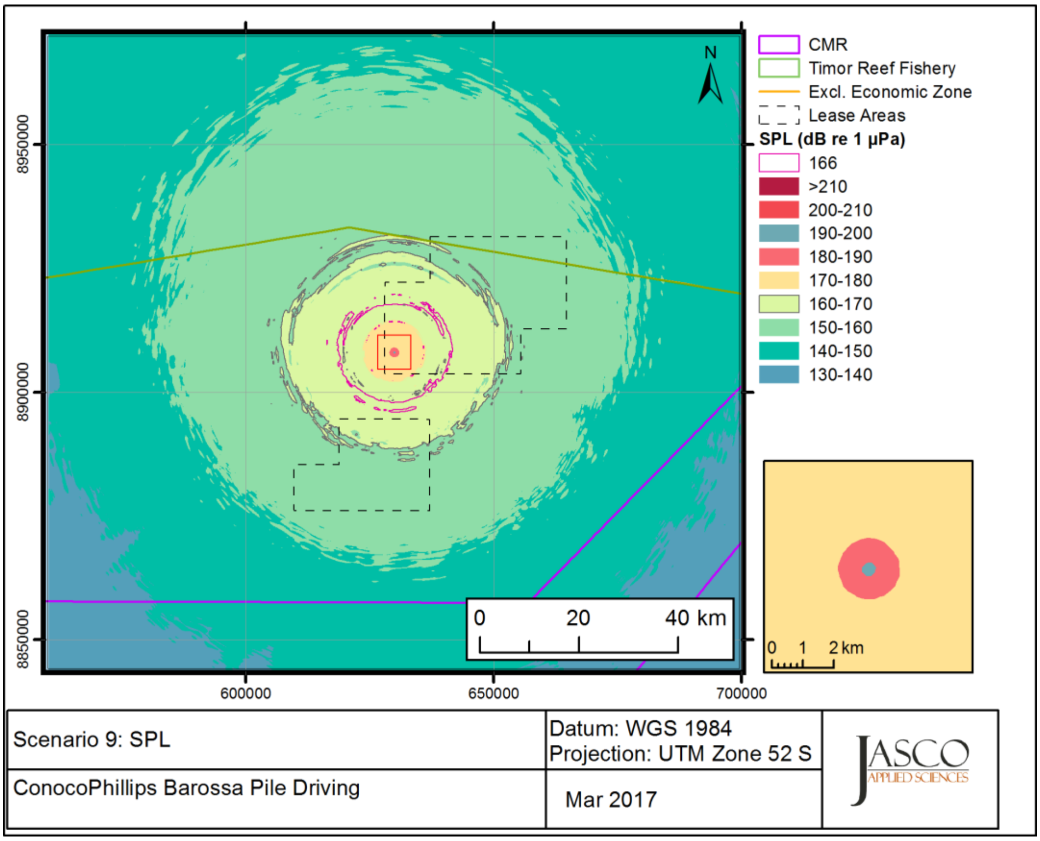

Figure 22. Scenario 9: Sound level contour map showing unweighted maximum-over-depth SPL results, showing isopleths for marine mammal and turtle behaviour thresholds.

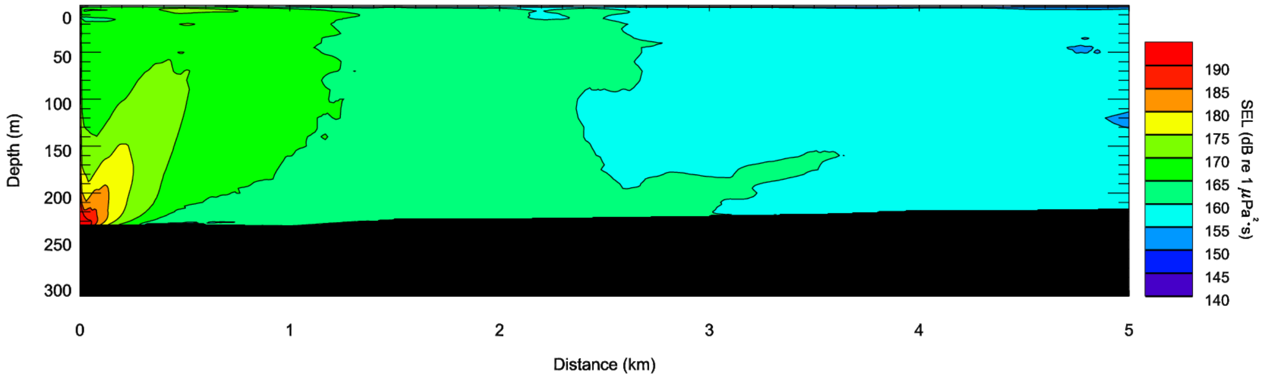

Figure 23. Scenario 1: Predicted unweighted per-strike SEL as a vertical slice. Levels are shown along a single transect of azimuth 180°.

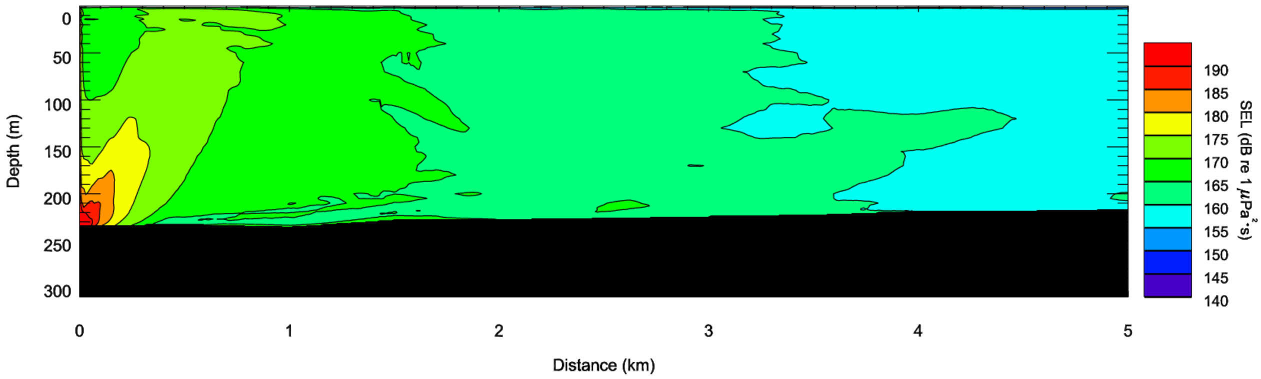

Figure 24. Scenario 2: Predicted unweighted per-strike SEL as a vertical slice. Levels are shown along a single transect of azimuth 180°.

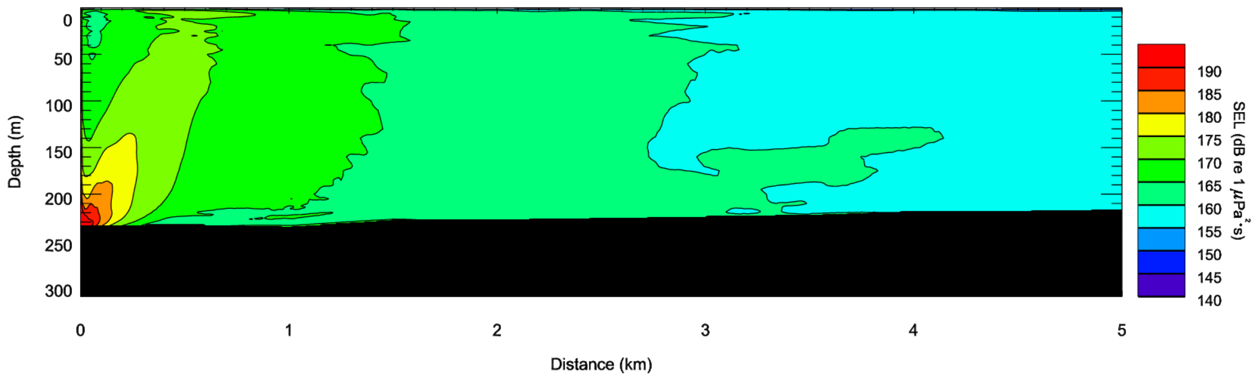

Figure 25. Scenario 3: Predicted unweighted per-strike SEL as a vertical slice. Levels are shown along a single transect of azimuth 180°.

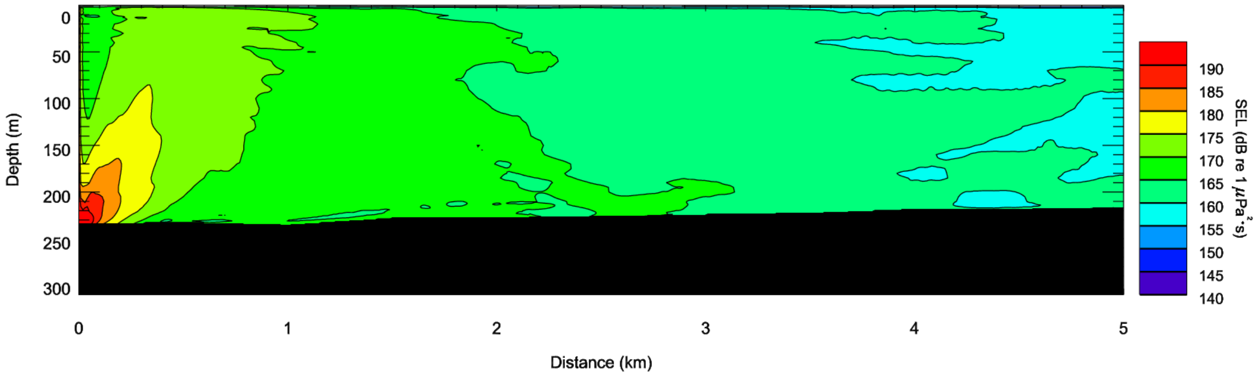

Figure 26. Scenario 4: Predicted unweighted per-strike SEL as a vertical slice. Levels are shown along a single transect of azimuth 180°.

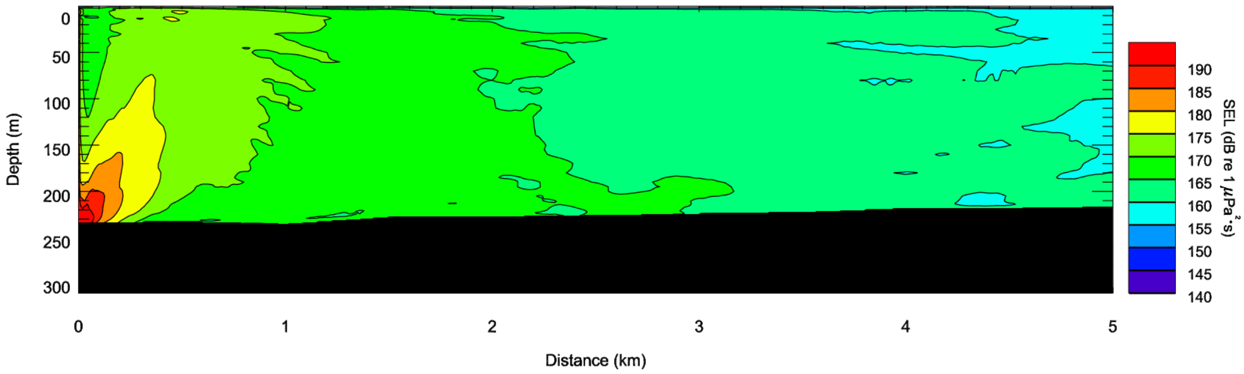

Figure 27. Scenario 9: Predicted unweighted per-strike SEL as a vertical slice. Levels are shown along a single transect of azimuth 180°.

5. Discussion and Conclusion

5.1. Overview

By modelling a combination of possible hammer sizes, pile diameters and lengths at two different water depths, a comprehensive understanding of possible noise footprints, and an understanding of the factors related to sound propagation across the Barossa field development area has been developed. Considering all modelling scenarios, the far-field source level of the pile was predominantly influenced by the hammer size, with the highest far-field per-strike source levels being attributed to the larger hammer (1730 kJ; Figure 3). Water depth marginally influenced the far-field source levels. The peak sound energy from the pile driving is concentrated in the frequency range 40 to 500 Hz (Figure 3). For the modelling scenarios, noise emissions from pile driving are considered to be cylindrically isotropic (i.e. omnidirectional in the horizontal plane). As such, variations in noise that propagates across azimuths are attributed to the bathymetry alone, with this accounted for in the modelling methodology.

Larger effect zones are predicted for per-strike species thresholds of all three metrics (SEL, SPL, and PK) for the 1730 kJ hammer relative to the 660 kJ hammer, regardless of the pile characteristics. The 39 m long, 5 m diameter pile had larger per-strike ranges than the 43 m long, 4 m diameter pile for SEL and SPL metrics, but not always for peak pressure (PK). However, the range differences were small (less than 10 m). The smaller 660 kJ hammer always had larger ranges to 24 h SEL injury isopleths than the larger hammer because it took more blows for this hammer to drive a pile (Table 4).

To compare all scenarios with similar soil resistance (Scenarios 1–8), one metric that can be used is to compare the distances is the per-strike 160 dB re 1 µPa²·s isopleth, associated with seismic EPBC Act Policy Statement 2.1 (DEWHA 2008). From this, the median difference between R_{max} and $R_{95\%}$ distances across is 470 m, or 8% of R_{max}, with the smallest difference associated with Scenario 3 (407 m), and the largest with Scenario 4 (832 m). These isopleths have $R_{95\%}$ distances of 3.9 to 7.3 km. The SEL_{24h} isopleths associated with PTS follow a similar trend to the per-strike SEL isopleths higher than 160 dB, and differ minimally. At lower isopleths, such as the single-strike 150 dB re 1 µPa²·s or 160 dB re 1 µPa levels, the difference between R_{max} and $R_{95\%}$ increases, with the median difference being 14.14 km for the 140 dB re 1 µPa²·s isopleth. This occurs when distances are larger and bathymetry predominantly controls the noise footprint, increasing propagation towards deeper waters (to the north) because it loses less energy when it interacts with the seabed. The R_{max} radius is more representative of the effective extent of the footprint because the source is stationary and is more conservative, given detailed geological profiles of the area are yet to be defined.

The piling scenarios that considered the lower soil resistance and therefore the lower number of average strikes (Scenarios 9 and 10; Table 4) can be compared to Scenarios 4 and 8. The distances to the single strike SEL is smaller for Scenario 9 compared to Scenario 4 (Site 1), but greater for Scenario 10 compared to Scenario 8 (Site 2). However, the ranges to the marine mammal behavioural criteria of 160 dB re 1 µPa for cetaceans (NMFS 2013) are larger for Scenarios 9 and 10, although only slightly larger for Scenario 10 compared to Scenario 8. The distances to PK and SEL_{24h} metrics were slightly smaller for Scenarios 9 and 10.

The subsections that follow focus on the results from the modelling of the eight scenarios with the expected soil resistance based on the assumed average strike count (i.e. Scenarios 1-8). The model assumed no acoustic mitigation around the pile driving operation. Therefore, the modelling scenarios represent the maximum noise footprint from pile driving activities as a conservative estimate given likely soil resistance.

5.2. Marine Mammals

Considering Scenarios 1–8, the maximum distances to the to the DEWHA (2008) per-strike threshold (160 dB re 1 µPa²s) for Sites 1 and 2 are 8.99 and 7.81 km respectively, with Scenarios 4 and 8 based on the wider pile and the larger hammer (Table 8).

Considering Scenarios 1-8, the maximum distances to the NMFS SPL threshold for possible behavioural effects on marine mammals (SPL 160 dB re 1 µPa) (NMFS 2013) at Sites 1 and 2 are 23.83 and 28.30 km respectively (Scenarios 4 and 8; Table 8).

Marine mammals could experience PTS near the piling operations based on the 24 h SEL criteria from Wood et al. (2012). Considering Scenarios 1-8 and Sites 1 and 2 respectively, the maximum distance an animal could be experience PTS is 6.07 or 4.92 km for low-frequency cetaceans, 0.79 or 0.54 km for mid-frequency cetaceans, and 16.59 or 18.75 km for high-frequency cetaceans (Table 7). The 24 h SEL is a cumulative metric that reflects the dosimetric impact of noise levels within 24 hours based on the assumption that an animal is consistently exposed to such noise levels at a fixed position. The corresponding radii are significantly larger than those for peak pressure criteria, but they represent an unlikely worst case scenario since, more realistically, marine mammals would not stay in the same location or at the same range for 24 hours. Therefore, a reported radius of 24 h SEL criteria does not mean that any animal travelling within this radius of the source will be injured, but rather that it could be injured if it remained in that range for 24 hours.

5.3. Turtles

Considering the locations of Site 1 and 2 separately from Scenarios 1–8, the maximum distance to the NMFS SPL threshold for possible behavioural effects on turtles (SPL 160 dB re 1 µPa) (NSF 2011) at modelling Sites 1 and 2 is 12.04 and 14.25 km, respectively, also for Scenarios 4 and 8 (Table 8).

Turtles could suffer a mortal injury based on both 24 h SEL criteria (210 dB re 1 $\mu Pa^2 \cdot s$) and PK criteria. Considering Sites 1 and 2 respectively, for 24 h SEL this could occur at 230 m (Scenario 3) or 200 m (Scenarios 5 and 7; Table 9). For the PK criteria, this could occur at 200 m (Scenario 2 or 6; Table 11). While the larger distance from either criterion should be applied, the distance from the PK is more relevant to operational considerations.

5.4. Fish

Fish could suffer a potential mortal injury based on both 24 h SEL and PK criteria. Of the two metrics mentioned, the larger distance is the measure that should be applied. The results in this section focus on Scenarios 1–8 and modelling Sites 1 and 2 respectively, with results in Tables 9–11. Mortal and potential mortal acoustic injury to fish without a swim bladder (Fish I) could occur within 80 or 70 m (24 h SEL criteria) or 100 m (PK criteria). Fish with a swim bladder (Fish II and III), fish eggs, and fish larvae could sustain the same types of injuries if they are within 340 or 290 m (24 h SEL criteria) or 200 m (PK criteria).

Recoverable injury to fish without a swim bladder (Fish I) could occur within 110 or 100 m (24 h SEL criteria) or 100 m (PK criteria). Similar injury to fish with a swim bladder (Fish II and III) could occur within 670 or 530 m (24 h SEL criteria) or 200 m (PK criteria). The maximum distance at which fish could experience TTS at either modelling site is 14.81 or 14.65 km.

Glossary

1/3-octave-band
Non-overlapping passbands that are one-third of an octave wide (where an octave is a doubling of frequency). Three adjacent 1/3-octave-bands comprise one octave. One-third-octave-bands become wider with increasing frequency. Also see octave.

A-weighting
Frequency-selective weighting for human hearing in air that is derived from the inverse of the idealized 40-phon equal loudness hearing function across frequencies.

absorption
The conversion of acoustic energy into heat, which is captured by insulation.

attenuation
The gradual loss of acoustic energy from absorption and scattering as sound propagates through a medium.

auditory weighting function (frequency-weighting function)
Auditory weighting functions account for marine mammal hearing sensitivity. They are applied to sound measurements to emphasize frequencies that an animal hears well and de-emphasize frequencies they hear less well or not at all (Southall et al. 2007, Finneran and Jenkins 2012, NOAA 2013).

azimuth
A horizontal angle relative to a reference direction, which is often magnetic north or the direction of travel. In navigation it is also called bearing.

bandwidth
The range of frequencies over which a sound occurs. Broadband refers to a source that produces sound over a broad range of frequencies (e.g., seismic airguns, vessels) whereas narrowband sources produce sounds over a narrow frequency range (e.g., sonar) (ANSI/ASA S1.13-2005 R2010).

cetacean
Any animal in the order Cetacea. These are aquatic, mostly marine mammals and include whales, dolphins, and porpoises.

compressional wave
A mechanical vibration wave in which the direction of particle motion is parallel to the direction of propagation. Also called primary wave or P-wave.

continuous sound
A sound whose sound pressure level remains above ambient sound during the observation period (ANSI/ASA S1.13-2005 R2010). A sound that gradually varies in intensity with time, for example, sound from a marine vessel.

decibel (dB)
One-tenth of a bel. Unit of level when the base of the logarithm is the tenth root of ten, and the quantities concerned are proportional to power (ANSI S1.1-1994 R2004).

ensonified
Exposed to sound.

far-field
The zone where, to an observer, sound originating from an array of sources (or a spatially-distributed source) appears to radiate from a single point. The distance to the acoustic far-field increases with frequency.

frequency
The rate of oscillation of a periodic function measured in cycles-per-unit-time. The reciprocal of the period. Unit: hertz (Hz). Symbol: *f*. 1 Hz is equal to 1 cycle per second.

hearing group
Groups of marine mammal species with similar hearing ranges. Commonly defined functional hearing groups include low-, mid-, and high-frequency cetaceans, pinnipeds in water, and pinnipeds in air.

geoacoustic
Relating to the acoustic properties of the seabed.

hearing threshold
The sound pressure level that is barely audible for a given individual in the absence of significant background noise during a specific percentage of experimental trials.

hertz (Hz)
A unit of frequency defined as one cycle per second.

high-frequency cetacean (HFC)
The functional hearing group that represents odontocetes specialized for using high frequencies.

impulsive sound
Sound that is typically brief and intermittent with rapid (within a few seconds) rise time and decay back to ambient levels (NOAA 2013, ANSI S12.7-1986 R2006). For example, seismic airguns and impact pile driving.

low-frequency cetacean (LFC)
The functional hearing group that represents mysticetes (baleen whales).

median
The 50th percentile of a statistical distribution.

mid-frequency cetacean (MFC)
The functional hearing group that represents some odontocetes (dolphins, toothed whales, beaked whales, and bottlenose whales).

M-weighting
The process of band-pass filtering loud sounds to reduce the importance of inaudible or less-audible frequencies for broad classes of marine mammals. “Generalized frequency weightings for various functional hearing groups of marine mammals, allowing for their functional bandwidths and appropriate in characterizing auditory effects of strong sounds” (Southall et al. 2007).

mysticete
Mysticeti, a suborder of cetaceans, use their baleen plates, rather than teeth, to filter food from water. They are not known to echolocate, but use sound for communication. Members of this group include rorquals (Balaenopteridae), right whales (Balaenidae), and gray whales (*Eschrichtius robustus*).

non-impulsive sound
Sound that is broadband, narrowband or tonal, brief or prolonged, continuous or intermittent, and typically does not have a high peak pressure with rapid rise time (typically only small fluctuations in decibel level) that impulsive signals have (ANSI/ASA S3.20-1995 R2008). For example, marine vessels, aircraft, machinery, construction, and vibratory pile driving (NIOSH 1998, NOAA 2015).

octave
The interval between a sound and another sound with double or half the frequency. For example, one octave above 200 Hz is 400 Hz, and one octave below 200 Hz is 100 Hz.

odontocete
The presence of teeth, rather than baleen, characterizes these whales. Members of the Odontoceti are a suborder of cetaceans, a group comprised of whales, dolphins, and porpoises. The toothed whales' skulls are mostly asymmetric, an adaptation for their echolocation. This group includes sperm whales, killer whales, belugas, narwhals, dolphins, and porpoises.

parabolic equation method
A computationally-efficient solution to the acoustic wave equation that is used to model transmission loss. The parabolic equation approximation omits effects of back-scattered sound, simplifying the computation of transmission loss. The effect of back-scattered sound is negligible for most ocean-acoustic propagation problems.

particle velocity
The physical speed of a particle in a material moving back and forth in the direction of the pressure wave. Unit: meters per second (m/s). Symbol: v.

peak pressure level (PK)
The maximum instantaneous sound pressure level, in a stated frequency band, within a stated period. Also called zero-to-peak pressure level. Unit: decibel (dB).

permanent threshold shift (PTS)
A permanent loss of hearing sensitivity caused by excessive noise exposure. PTS is considered auditory injury.

pinniped
A common term used to describe all three groups that form the superfamily Pinnipedia: phocids (true seals or earless seals), otariids (eared seals or fur seals and sea lions), and walrus.

point source
A source that radiates sound as if from a single point (ANSI S1.1-1994 R2004).

pressure, acoustic
The deviation from the ambient hydrostatic pressure caused by a sound wave. Also called overpressure. Unit: pascal (Pa). Symbol: p.

pressure, hydrostatic
The pressure at any given depth in a static liquid that is the result of the weight of the liquid acting on a unit area at that depth, plus any pressure acting on the surface of the liquid. Unit: pascal (Pa).

received level
The sound level measured at a receiver.

rms
root-mean-square.

shear wave
A mechanical vibration wave in which the direction of particle motion is perpendicular to the direction of propagation. Also called secondary wave or S-wave. Shear waves propagate only in solid media, such as sediments or rock. Shear waves in the seabed can be converted to compressional waves in water at the water-seabed interface.

signature
Pressure signal generated by a source.

sound
A time-varying pressure disturbance generated by mechanical vibration waves travelling through a fluid medium such as air or water.

sound exposure
Time integral of squared, instantaneous frequency-weighted sound pressure over a stated time interval or event. Unit: pascal-squared second ($Pa^2 \cdot s$) (ANSI S1.1-1994 R2004).

sound exposure level (SEL)
A cumulative measure related to the sound energy in one or more pulses. Unit: dB re 1 $\mu Pa^2 \cdot s$. SEL is expressed over the summation period (e.g., per-pulse SEL [for airguns], single-strike SEL [for pile drivers], 24-hour SEL).

sound field
Region containing sound waves (ANSI S1.1-1994 R2004).

sound pressure level (SPL)
The decibel ratio of the time-mean-square sound pressure, in a stated frequency band, to the square of the reference sound pressure (ANSI S1.1-1994 R2004).

For sound in water, the reference sound pressure is one micropascal (p_0 = 1 µPa) and the unit for SPL is dB re 1 µPa:

$$\mathrm{SPL} = 10\log_{10}\left(p^2 / p_0^2\right) = 20\log_{10}\left(p / p_0\right)$$

Unless otherwise stated, SPL refers to the root-mean-square sound pressure level. See also 90% sound pressure level and fast-average sound pressure level. Non-rectangular time window functions could be applied to calculate the rms value, in which case the SPL unit should identify the window type.

sound speed profile
The speed of sound in the water column as a function of depth below the water surface.

source level (SL)
The sound level measured in the far-field and scaled back to a standard reference distance of 1 metre from the acoustic centre of the source. Unit: dB re 1 µPa @ 1 m (sound pressure level) or dB re 1 $\mu Pa^2 \cdot s$ (sound exposure level).

temporary threshold shift (TTS)
Temporary loss of hearing sensitivity caused by excessive noise exposure.

transmission loss (TL)
The decibel reduction in sound level between two stated points that results from sound spreading away from an acoustic source subject to the influence of the surrounding environment. Also called propagation loss.

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Appendix A. Acoustic Metrics

A.1. Acoustic Metrics

Underwater sound pressure amplitude is measured in decibels (dB) relative to a fixed reference pressure of p_0 = 1 µPa. Because the perceived loudness of sound, especially impulsive noise such as from seismic airguns, pile driving, and sonar, is not generally proportional to the instantaneous acoustic pressure, several sound level metrics are commonly used to evaluate noise and its effects on marine life. We provide specific definitions of relevant metrics used in the accompanying report. Where possible we follow the ANSI and ISO standard definitions and symbols for sound metrics, but these standards are not always consistent.

The zero-to-peak sound pressure level, or peak sound pressure level (PK; dB re 1 µPa), is the maximum instantaneous sound pressure level in a stated frequency band attained by an acoustic pressure signal, $p(t)$:

$$L_{p,pk} = 20\log_{10}\left[\frac{\max(|p(t)|)}{p_0}\right] \tag{A-1}$$

$L_{p,pk}$ is often included as a criterion for assessing whether a sound is potentially injurious; however, because it does not account for the duration of a noise event, it is generally a poor indicator of perceived loudness.

The peak-to-peak sound pressure level (dB re 1 µPa) is the difference between the maximum and minimum instantaneous sound pressure levels in a stated frequency band attained by an impulsive sound, $p(t)$:

$$L_{p,pk-pk} = 10\log_{10}\left\{\frac{\left[\max(p(t)) - \min(p(t))\right]^2}{p_0^2}\right\} \tag{A-2}$$

The root-mean-square (rms) sound pressure level (SPL; dB re 1 µPa) is the rms pressure level in a stated frequency band over a specified time window (T, s) containing the acoustic event of interest. It is important to note that SPL always refers to an rms pressure level and, therefore, not instantaneous pressure:

$$L_p = 10\log_{10}\left(\frac{1}{T}\int_T p^2(t)dt \Big/ p_0^2\right) . \tag{A-3}$$

The SPL represents a nominal effective continuous sound over the duration of an acoustic event, such as the emission of one acoustic pulse, a marine mammal vocalisation, the passage of a vessel, or over a fixed duration. Because the window length, T, is the divisor, events with similar sound exposure level (SEL) but more spread out in time have a lower SPL.

In studies of impulsive noise, the time window T is often defined as the “90% time window” (T_{90}): the period over which cumulative square pressure function passes between 5% and 95% of its full per-pulse value. The SPL computed over this T_{90} interval is commonly called the 90% SPL (SPL(T_{90}); dB re 1 µPa):

$$L_{p90} = 10\log_{10}\left(\frac{1}{T_{90}}\int_{T_{90}} p^2(t)dt \Big/ p_0^2\right) . \tag{A-4}$$

The sound exposure level (SEL, dB re 1 µPa²·s) is a measure related to the acoustic energy contained in one or more acoustic events (*N*). The SEL for a single event is computed from the time-integral of the squared pressure over the full event duration (*T*):

$$L_E = 10\log_{10}\left(\int_T p^2(t)dt \Big/ T_0 p_0^2\right) \quad \text{(A-5)}$$

where T_0 is a reference time interval of 1 s. The SEL continues to increase with time when non-zero pressure signals are present. it therefore can be construed as a dose-type measurement so the integration time used must be carefully considered in terms of relevance for impact to the exposed recipients.

SEL can be calculated over periods with multiple acoustic events or over a fixed duration. For a fixed duration, the square pressure is integrated over the duration of interest. For multiple events, the SEL can be computed by summing (in linear units) the SEL of the *N* individual events:

$$L_{E,N} = 10\log_{10}\left(\sum_{i=1}^{N} 10^{\frac{L_{E,i}}{10}}\right) . \quad \text{(A-6)}$$

To compute the SPL(T_{90}) and SEL of acoustic events in the presence of high levels of background noise, Equations A-4 and A-5 are modified to subtract the background noise energy from the event energy:

$$L_{p90} = 10\log_{10}\left(\frac{1}{T_{90}}\int_{T_{90}} (p^2(t) - \overline{n^2})dt \Big/ p_0^2\right) \quad \text{(A-7)}$$

$$L_E = 10\log_{10}\left(\int_T (p^2(t) - \overline{n^2})dt \Big/ T_0 p_0^2\right) \quad \text{(A-8)}$$

where $\overline{n^2}$ is the mean square pressure of the background noise, generally computed by averaging the squared pressure of a temporally-proximal segment of the acoustic recording during which acoustic events are absent (e.g., between pulses).

Because the SPL(T_{90}) and SEL are both computed from the integral of square pressure, these metrics are related by the following expression, which depends only on the duration of the energy time window *T*:

$$L_p = L_E - 10\log_{10}(T) \quad \text{(A-9)}$$

$$L_{p90} = L_E - 10\log_{10}(T_{90}) - 0.458 \quad \text{(A-10)}$$

where the 0.458 dB factor accounts for the 10% of SEL missing from the SPL(T_{90}) integration time window.

Energy equivalent SPL (dB re 1 µPa) denotes the SPL of a stationary (constant amplitude) sound that generates the same SEL as the signal being examined, *p*(*t*), over the same period of time, *T*:

$$L_{eq} = 10\log_{10}\left(\frac{1}{T}\int_T p^2(t)dt \Big/ p_0^2\right) . \quad \text{(A-11)}$$

The equations for SPL and the energy-equivalent SPL are numerically identical; conceptually, the difference between the two metrics is that the former is typically computed over short periods (typically of one second or less) and tracks the fluctuations of a non-steady acoustic signal, whereas the latter reflects the average SPL of an acoustic signal over times typically of one minute to several hours.

If applied, the frequency weighting of an acoustic event should be specified, as in the case of M-weighted SEL (e.g., $SEL_{LFC,24h}$; Appendix A.2). The use of fast, slow, or impulse exponential-time-averaging, or other time-related characteristics should else be specified.

A.2. Impact Criteria

A.2.1. Marine Mammals

In recognition of shortcomings of the SPL-only based injury criteria, in 2005 NMFS sponsored the Noise Criteria Group to review literature on marine mammal hearing to propose new noise exposure criteria. Some members of this expert group published a landmark paper (Southall et al. 2007) that suggested assessment methods similar to those applied for humans. The resulting recommendations introduced dual acoustic injury criteria for impulsive sounds that included peak pressure level thresholds and SEL_{24h} thresholds, where the subscripted 24h refers to the accumulation period for calculating SEL. The peak pressure level criterion is not frequency weighted whereas the SEL_{24h} is frequency weighted according to one of four marine mammal species hearing groups: Low-, Mid- and High-Frequency Cetaceans (LFC, MFC, and HFC respectively) and Pinnipeds in Water (PINN). These weighting functions are referred to as M-weighting filters (analogous to the A-weighting filter for human; Appendix A.2). The SEL_{24h} thresholds were obtained by extrapolating measurements of onset levels of Temporary Threshold Shift (TTS) in belugas by the amount of TTS required to produce Permanent Threshold Shift (PTS) in chinchillas. The Southall et al. (2007) recommendations do not specify an exchange rate, which suggests that the thresholds are the same regardless of the duration of exposure (i.e., it infers a 3 dB exchange rate).

Wood et al. (2012) refined Southall et al.'s (2007) thresholds, suggesting lower injury values for LFC and HFC while retaining the filter shapes (Appendix A.2). Their revised thresholds were based on TTS-onset levels in harbour porpoises from Lucke et al. (2009), which led to a revised impulsive sound PTS threshold for HFC of 179 dB re 1 $\mu Pa^2 \cdot s$. Because there were no data available for baleen whales, Wood et al. (2012) based their recommendations for LFC on results obtained from MFC studies. In particular they referenced Finneran and Schlundt (2010) research, which found mid-frequency cetaceans are more sensitive to non-impulsive sound exposure than Southall et al. (2007) assumed. Wood et al. (2012) thus recommended a more conservative TTS-onset level for LFC of 192 dB re 1 $\mu Pa^2 \cdot s$.

In August 2016, after substantial public and expert input into three draft versions and based largely on the above-mentioned literature (NOAA 2013, 2015, 2016), NMFS finalised technical guidance for assessing the effect of anthropogenic sound on marine mammal hearing (NMFS 2016). The guidance describes injury criteria with new thresholds and frequency weighting functions for the five hearing groups described by Finneran and Jenkins (2012).

As of 2016, an optimal approach to determining the potential for injury is not apparent. There is consensus in the research community that an SEL-based method is preferable either separately or in addition to an SPL-based approach to assess the potential for injuries. While the scientific community is trending towards the NMFS (2016) criteria, for consistency with other recent assessments in the Barossa field, this report applies the criteria recommended by Wood et al. (2012).

A.3. Marine Mammal Frequency Weighting

The potential for noise to affect animals depends on how well the animals can hear it. Noises are less likely to disturb or injure an animal if they are at frequencies that the animal cannot hear well. An exception occurs when the sound pressure is so high that it can physically injure an animal by non-auditory means (i.e., barotrauma). For sound levels below such extremes, the importance of sound components at particular frequencies can be scaled by frequency weighting relevant to an animal's sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007).

A.3.1. Marine Mammal Frequency Weighting Functions

Auditory weighting functions for marine mammals—called *M-weighting* functions—were proposed by Southall et al. (2007). Functions were defined for five functional hearing groups of marine mammals:

- Low-frequency cetaceans (LFCs)—mysticetes (baleen whales)
- Mid-frequency cetaceans (MFCs)—some odontocetes (toothed whales)
- High-frequency cetaceans (HFCs)—odontocetes specialized for using high-frequencies
- Pinnipeds in water—seals, sea lions, and walrus
- Pinnipeds in air (not addressed here)

The M-weighting functions have unity gain (0 dB) through the passband and their high and low frequency roll-offs are approximately –12 dB per octave. The amplitude response in the frequency domain of each M-weighting function is defined by:

$$G(f) = -20\log_{10}\left[\left(1+\frac{a^2}{f^2}\right)\left(1+\frac{f^2}{b^2}\right)\right] \qquad \text{(A-12)}$$

where *G*(f) is the weighting function amplitude (in dB) at the frequency *f* (in Hz), and *a* and *b* are the estimated lower and upper hearing limits, respectively, which control the roll-off and passband of the weighting function. The parameters *a* and *b* are defined uniquely for each functional hearing group (Table A-1). The auditory weighting functions recommended by Southall et al. (2007) are shown in Figure A-1.

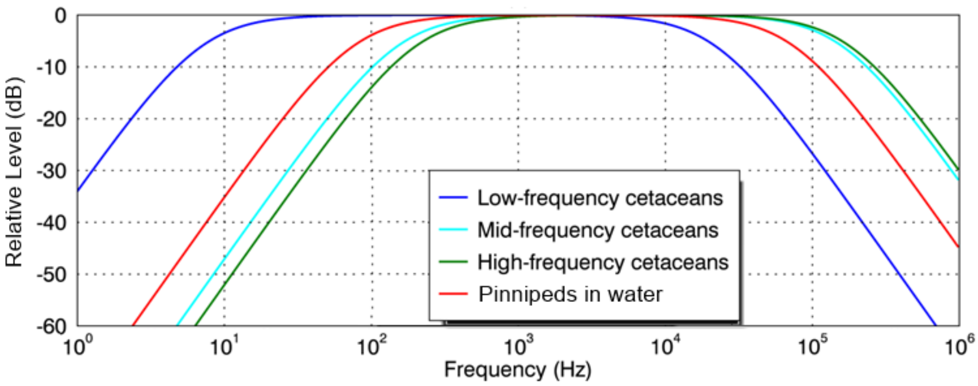

Figure A-1. Auditory weighting functions for functional marine mammal hearing groups as recommended by Southall et al. (2007).

Table A-1. Parameters for the auditory weighting functions recommended by Southall et al. (2007).

Functional hearing group	Southall et al.	
	a (Hz)	*b* (Hz)
Low-frequency cetaceans (LFC)	7	22,000
Mid-frequency cetaceans (MFC)	150	160,000
High-frequency cetaceans (HFC)	200	180,000
Pinnipeds in water (Pw)	75	75,000

Appendix B. Source and Propagation Models

B.1. Pile Driving Source Model

A physical model of pile vibration and near-field sound radiation is used to calculate source levels of piles. The physical model employed in this study computes the underwater vibration and sound radiation of a pile by solving the theoretical equations of motion for axial and radial vibrations of a cylindrical shell. These equations of motion are solved subject to boundary conditions, which describe the forcing function of the hammer at the top of the pile and the soil resistance at the base of the pile (Figure B-1). Damping of the pile vibration due to radiation loading is computed for Mach waves emanating from the pile wall. The equations of motion are discretised using the finite difference (FD) method and are solved on a discrete time and depth mesh.

To model the sound emissions from the piles, the force of the pile driving hammers also had to be modelled. The force at the top of each pile was computed using the GRLWEAP 2010 wave equation model (GRLWEAP, Pile Dynamics 2010), which includes a large database of simulated hammers—both impact and vibratory—based on the manufacturer's specifications. The forcing functions from GRLWEAP were used as inputs to the FD model to compute the resulting pile vibrations.

The sound radiating from the pile itself is simulated using a vertical array of discrete point sources. The point sources are centred on the pile axis. Their amplitudes are derived using an inverse technique, such that their collective particle velocity—calculated using a near-field wave-number integration model—matches the particle velocity in the water at the pile wall. The sound field propagating away from the vertical source array is then calculated using a time-domain acoustic propagation model (Section B.2.3). MacGillivray (2014) describes the theory behind the physical model in more detail.

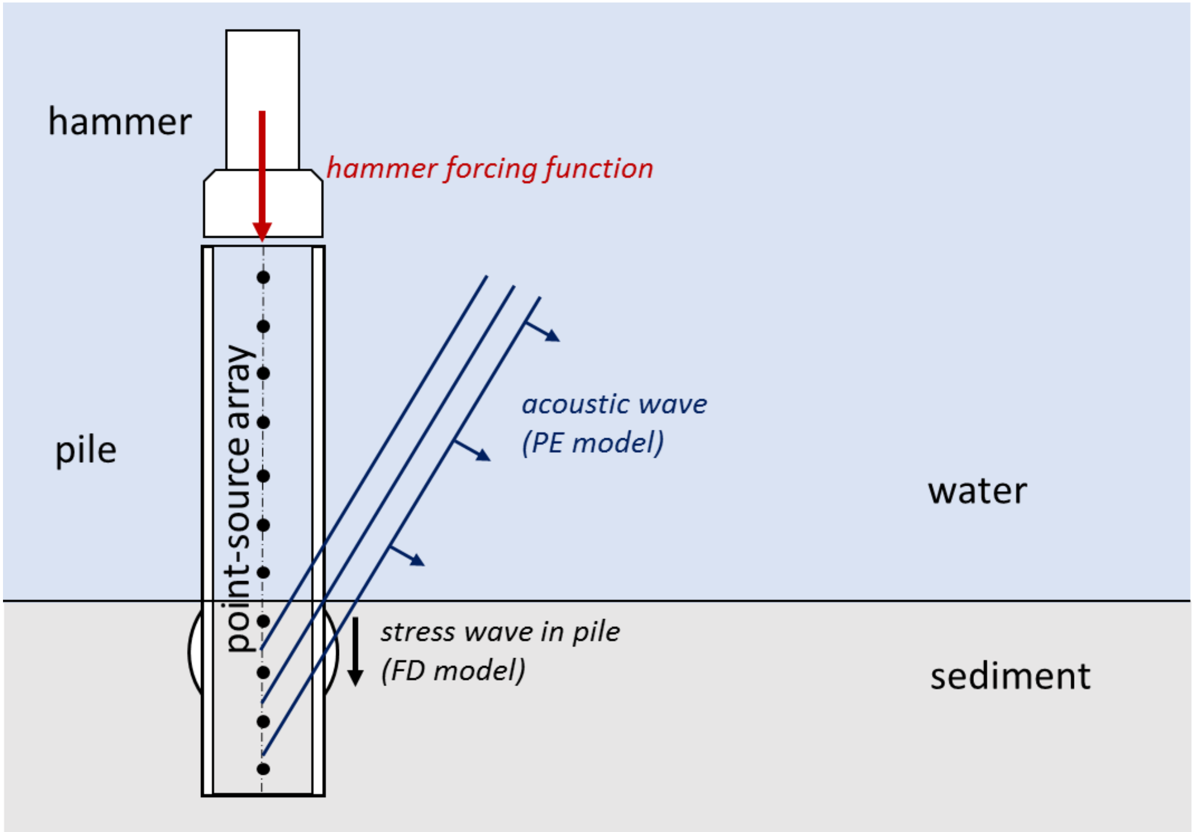

Figure B-1. Physical model geometry for impact driving of a cylindrical pile (vertical cross-section). The hammer forcing function is used with the finite difference (FD) model to compute the stress wave vibration in the pile. A vertical array of point sources is used with the parabolic equation (PE) model to compute the acoustic waves that the pile wall radiates.

B.2. Sound Propagation Models

B.2.1. Transmission Loss

The propagation of sound through the environment was modelled by predicting the acoustic transmission loss—a measure, in decibels, of the decrease in sound level between a source and a receiver some distance away. Geometric spreading of acoustic waves is the predominant way by which transmission loss occurs. Transmission loss also happens when the sound is absorbed and scattered by the seawater, and absorbed scattered, and reflected at the water surface and within the seabed. Transmission loss depends on the acoustic properties of the ocean and seabed; its value changes with frequency.

If the acoustic source level (SL), expressed in dB re 1 µPa @ 1 m, and transmission loss (TL), in units of dB, at a given frequency are known, then the received level (RL) at a receiver location can be calculated in dB re 1 µPa @ 1 m by:

$$RL = SL - TL \tag{B-1}$$

B.2.2. Noise Propagation with MONM

Underwater sound propagation (i.e., transmission loss) at frequencies of 10 Hz to 5 kHz was predicted with JASCO's Marine Operations Noise Model (MONM). MONM computes received per-pulse SEL (per-strike for pile driving) for directional impulsive sources at a specified source depth.

MONM computes acoustic propagation via a wide-angle parabolic equation solution to the acoustic wave equation (Collins 1993) based on a version of the U.S. Naval Research Laboratory's Range-dependent Acoustic Model (RAM), which has been modified to account for a solid seabed (Zhang and Tindle 1995). The parabolic equation method has been extensively benchmarked and is widely employed in the underwater acoustics community (Collins et al. 1996). MONM accounts for the additional reflection loss at the seabed, which results from partial conversion of incident compressional waves to shear waves at the seabed and sub-bottom interfaces, and it includes wave attenuations in all layers. MONM incorporates the following site-specific environmental properties: a bathymetric grid of the modelled area, underwater sound speed as a function of depth, and a geoacoustic profile based on the overall stratified composition of the seafloor.

MONM computes acoustic fields in three dimensions by modelling transmission loss within two-dimensional (2-D) vertical planes aligned along radials covering a 360° swath from the source, an approach commonly referred to as N×2-D. These vertical radial planes are separated by an angular step size of $\Delta\theta$, yielding $N = 360°/\Delta\theta$ number of planes (Figure B-2).

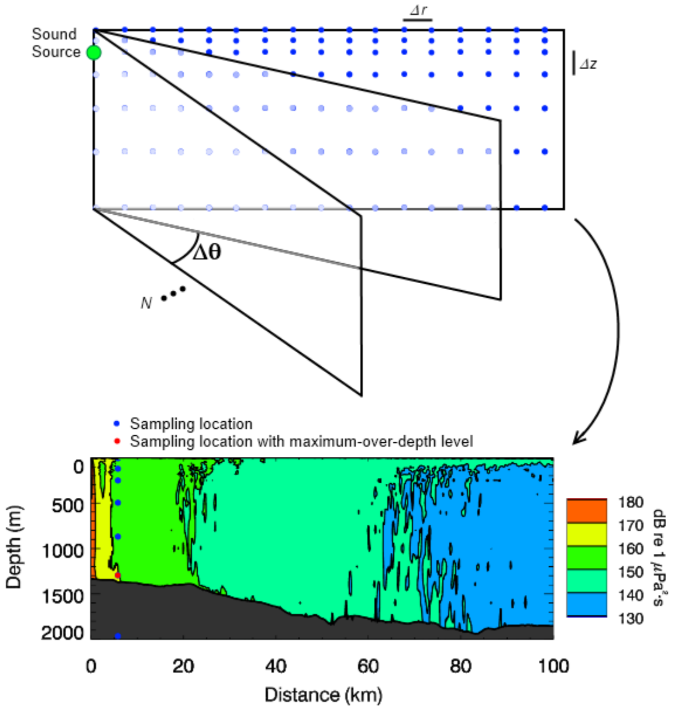

Figure B-2. The N×2-D and maximum-over-depth modelling approach used by MONM.

MONM treats frequency dependence by computing acoustic transmission loss at the centre frequencies of 1/3-octave-bands. Sufficiently many 1/3-octave-bands, starting at 10 Hz, are modelled to include the majority of acoustic energy emitted by the source. At each centre frequency, the transmission loss is modelled within each of the N vertical planes as a function of depth and range from the source. The 1/3-octave-band received per-pulse SELs are computed by subtracting the band transmission loss values from the directional source level in that frequency band. Composite broadband received SELs are then computed by summing the received 1/3-octave-band levels.

The frequency-dependent transmission loss computed by MONM can be corrected to account for the acoustic energy attenuating by molecular absorption in seawater. The volumetric sound absorption is quantified by an attenuation coefficient, expressed in units of decibels per kilometre (dB/km). The absorption coefficient depends on the temperature, salinity, and pressure of the water as well as the sound frequency. In general, the absorption coefficient increases with the square of the frequency. The absorption of acoustic wave energy has a noticeable effect (> 0.05 dB/km) at frequencies above 1 kHz. For example, at 10 kHz the absorption loss over 10 km distance can exceed 10 dB. The coefficient for seawater can be computed according to the formulae of François and Garrison (1982b, b), which consider the contributions of pure seawater, magnesium sulfate, and boric acid. The formula applies to all oceanic conditions and frequencies from 200 Hz to 1 MHz. For this project, absorption coefficients were computed and applied for all modelled frequencies greater than 2 kHz. Because of the computational expense associated with parabolic equation modelling at frequencies at or above several kHz and the relative importance of absorption at such frequencies, the transmission loss in each frequency band between 6.3 and 25 kHz was approximated from the transmission loss computed at 5 kHz by applying the correct frequency-dependent absorption coefficient in each band.

The received per-pulse SEL sound field within each vertical radial plane is sampled at various ranges from the source, generally with a fixed radial step size. At each sampling range along the surface, the sound field is sampled at various depths, with the step size between samples increasing with depth below the surface. The step sizes are chosen to provide increased coverage near the depth of the source and at depths of interest in terms of the sound speed profile. For areas with deep water, sampling is not performed at depths beyond those reachable by marine mammals. The received per-pulse SEL at a surface sampling location is taken as the maximum value that occurs over all samples within the water column, i.e., the maximum-over-depth received per-pulse SEL. These maximum-over-depth per-pulse SELs are presented as colour contours around the source.

MONM's predictions have been validated against experimental data from several underwater acoustic measurement programs conducted by JASCO (Hannay and Racca 2005, Aerts et al. 2008, Funk et al.

2008, Ireland et al. 2009, O'Neill et al. 2010, Warner et al. 2010, Racca et al. 2012a, Racca et al. 2012b, Martin et al. 2015).

B.2.3. Noise Propagation with FWRAM

For impulsive sounds from impact pile driving, time-domain representations of the pressure waves generated in the water are required to calculate SPL and peak pressure level. Furthermore, the pile must be represented as a distributed source to accurately characterise vertical directivity effects in the near-field zone. For this study, synthetic pressure waveforms were computed using FWRAM, which is a time-domain acoustic model based on the same wide-angle parabolic equation (PE) algorithm as MONM. FWRAM computes synthetic pressure waveforms versus range and depth for range-varying marine acoustic environments, and it takes the same environmental inputs as MONM (bathymetry, water sound speed profile, and seabed geoacoustic profile). Unlike MONM, FWRAM computes pressure waveforms via Fourier synthesis of the modelled acoustic transfer function in closely spaced frequency bands. FWRAM employs the array starter method to accurately model sound propagation from a spatially distributed source (MacGillivray and Chapman 2012).

Besides providing direct calculations of the peak pressure level and SPL, the synthetic waveforms from FWRAM can also be used to convert the SEL values from MONM to SPL.

Appendix C. Results

Maps and graphical representations of the sound fields for Site 2, Scenarios 5–8 and 10 are shown in the following section. Representations for Site 1, Scenarios 1–4 and 9, are included in Section 4.2.

Maps were created to display the unweighted 24 h SEL footprints with the M-weighted 24 h PTS thresholds for marine mammals (Figures C-1 to C-5), the unweighted 24 h SEL footprints with the thresholds for fish, turtles, fish eggs, and fish larvae (Figures C-6 to C-10), and SPL footprints with thresholds for marine mammals and turtles (Figures C-11 to C-15). Graphs of unweighted SEL in the vertical plane for each of the scenarios are shown in Figures C-16 to C-20.

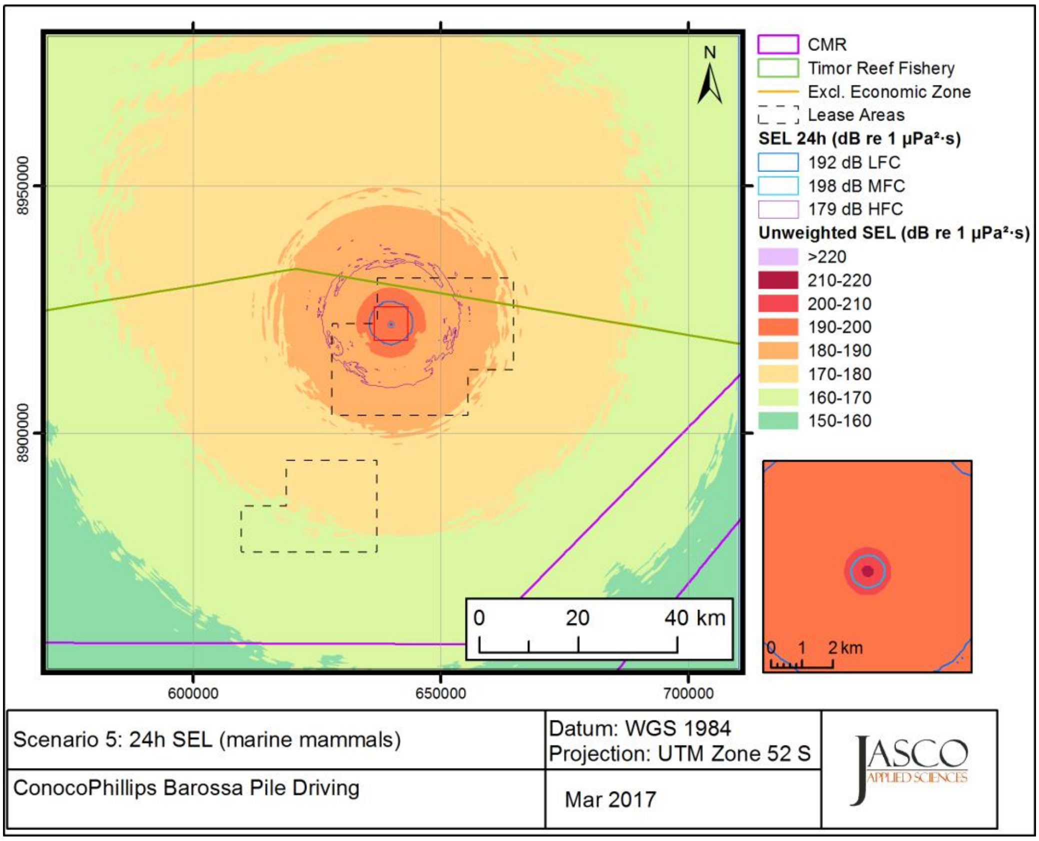

Figure C-1. Scenario 5: Sound level contour map showing maximum-over-depth SEL_{24h} results with marine mammal PTS thresholds.

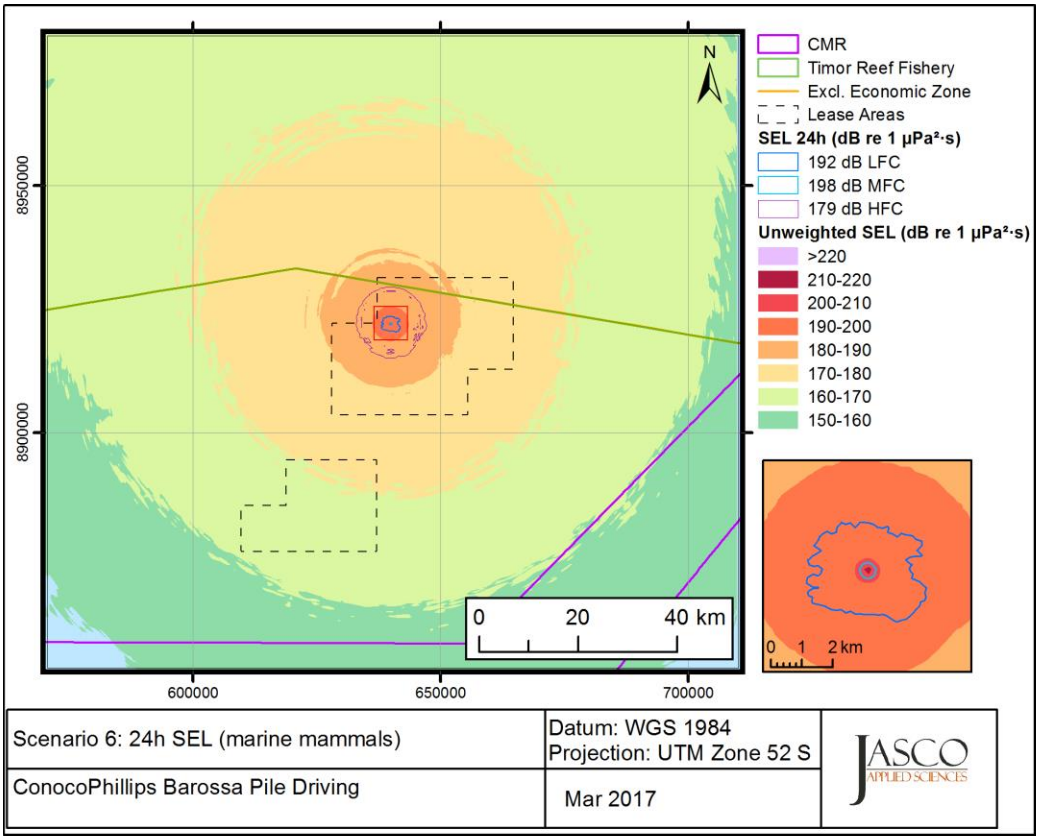

Figure C-2. Scenario 6: Sound level contour map showing maximum-over-depth SEL_{24h} results with marine mammal PTS thresholds.

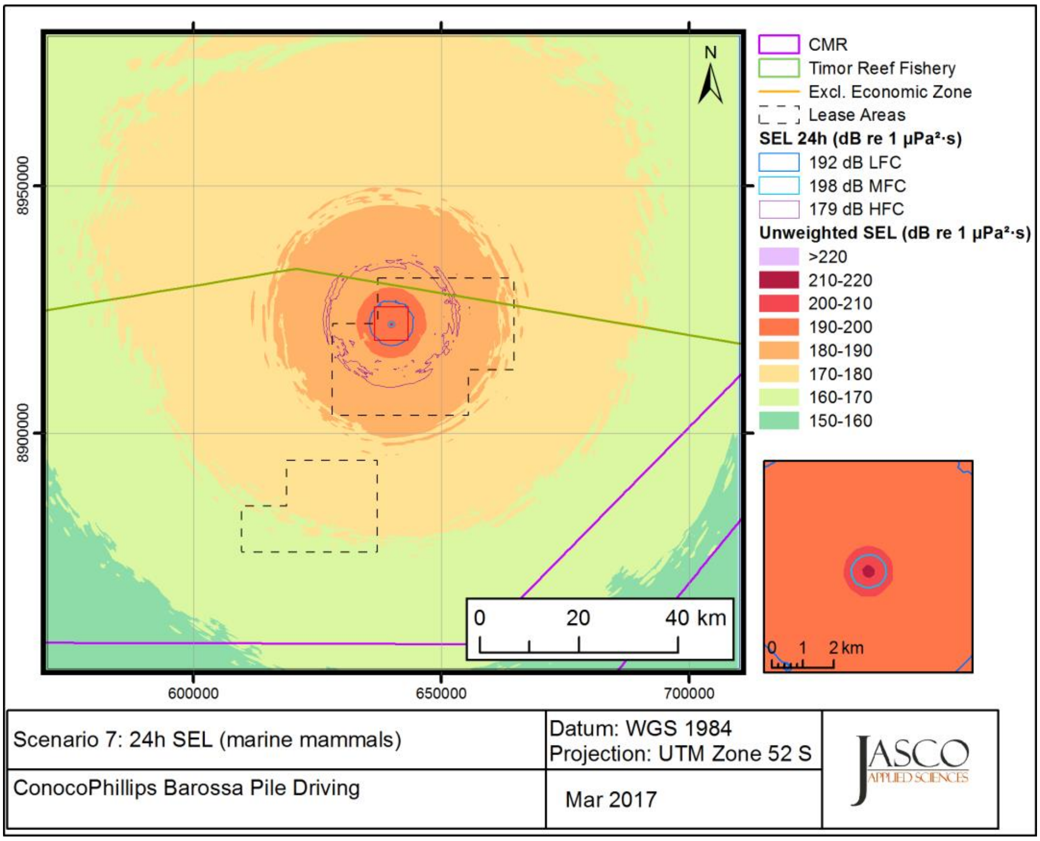

Figure C-3. Scenario 7: Sound level contour map showing maximum-over-depth SEL_{24h} results with marine mammal PTS thresholds.

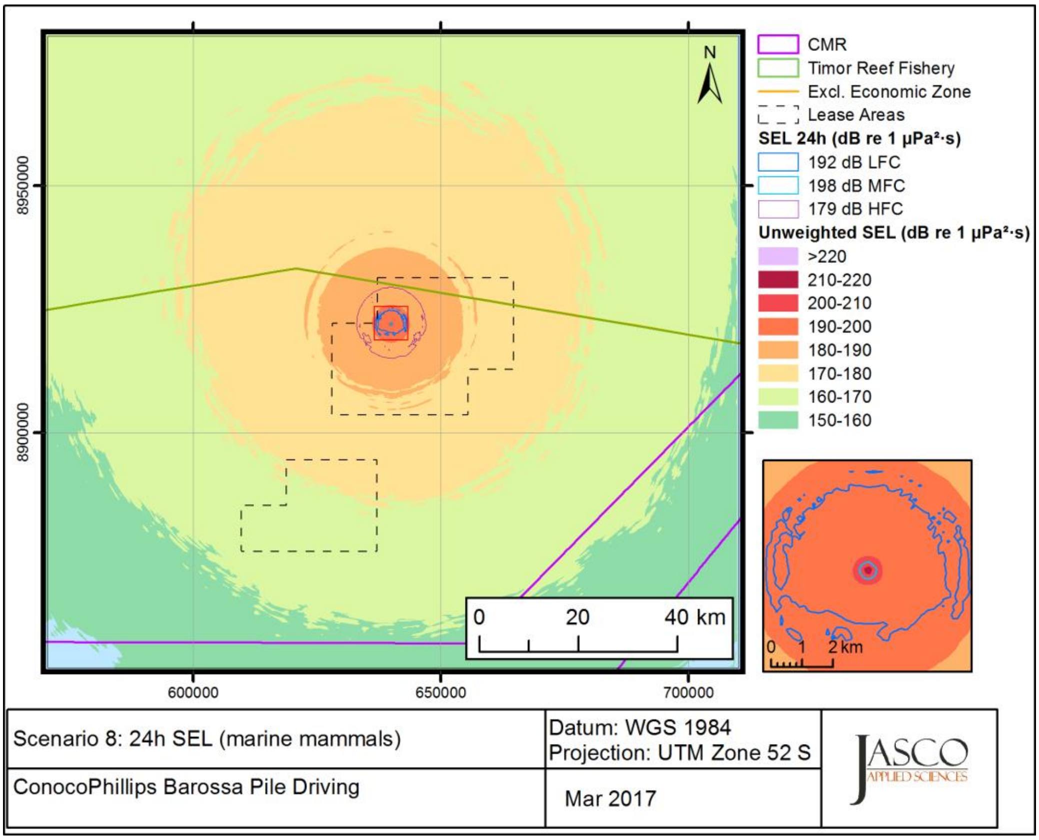

Figure C-4. Scenario 8: Sound level contour map showing maximum-over-depth SEL_{24h} results with marine mammal PTS thresholds.

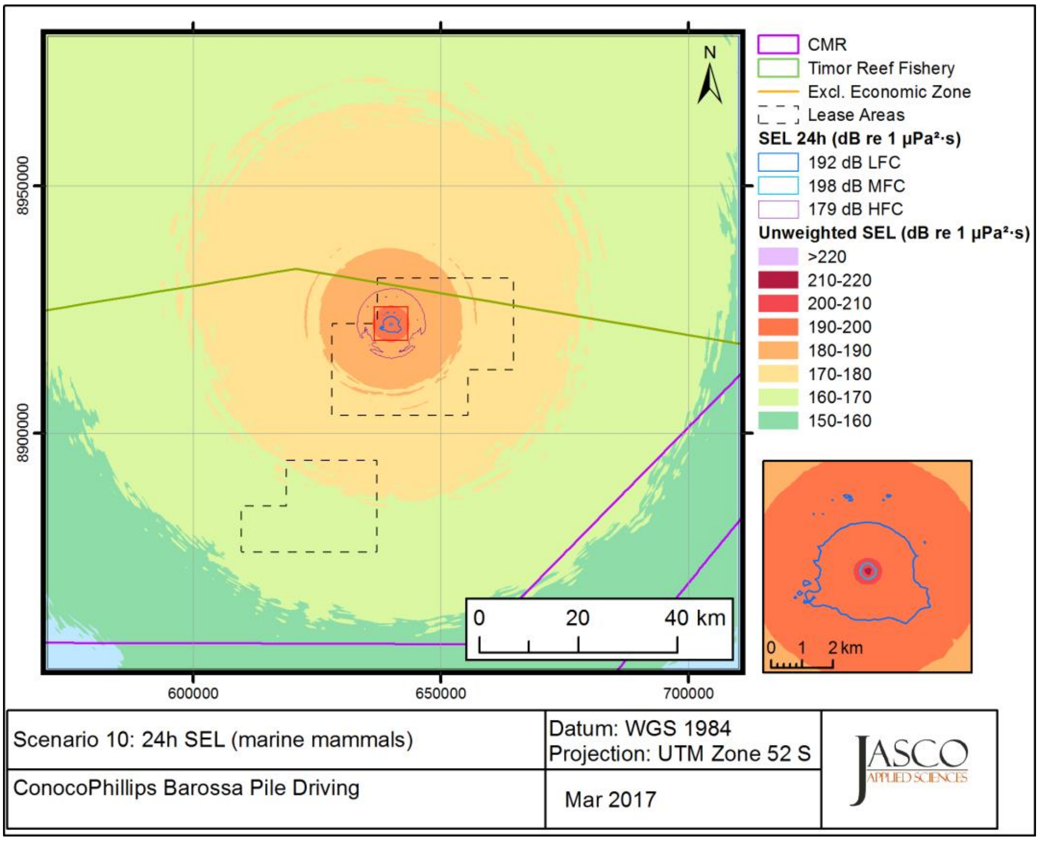

Figure C-5. Scenario 10: Sound level contour map showing maximum-over-depth SEL_{24h} results with marine mammal PTS thresholds.

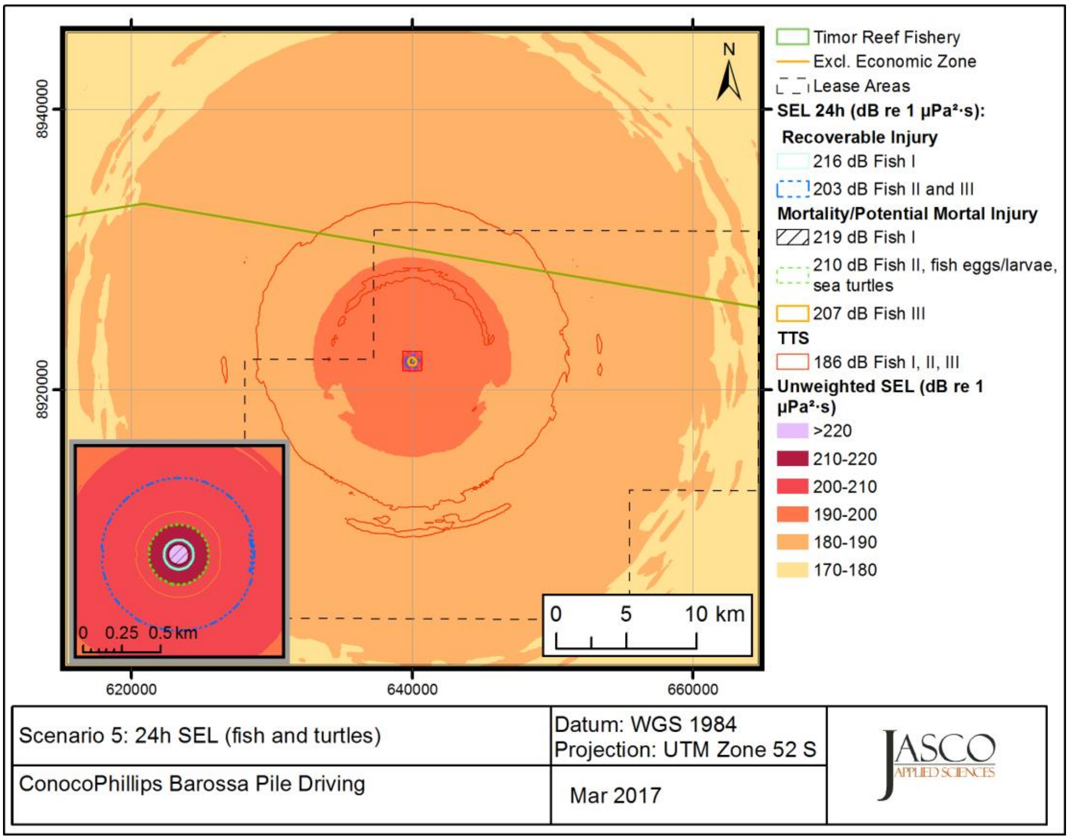

Figure C-6. Scenario 5: Sound level contour map showing maximum-over-depth SEL_{24h} results with fish and turtle thresholds.

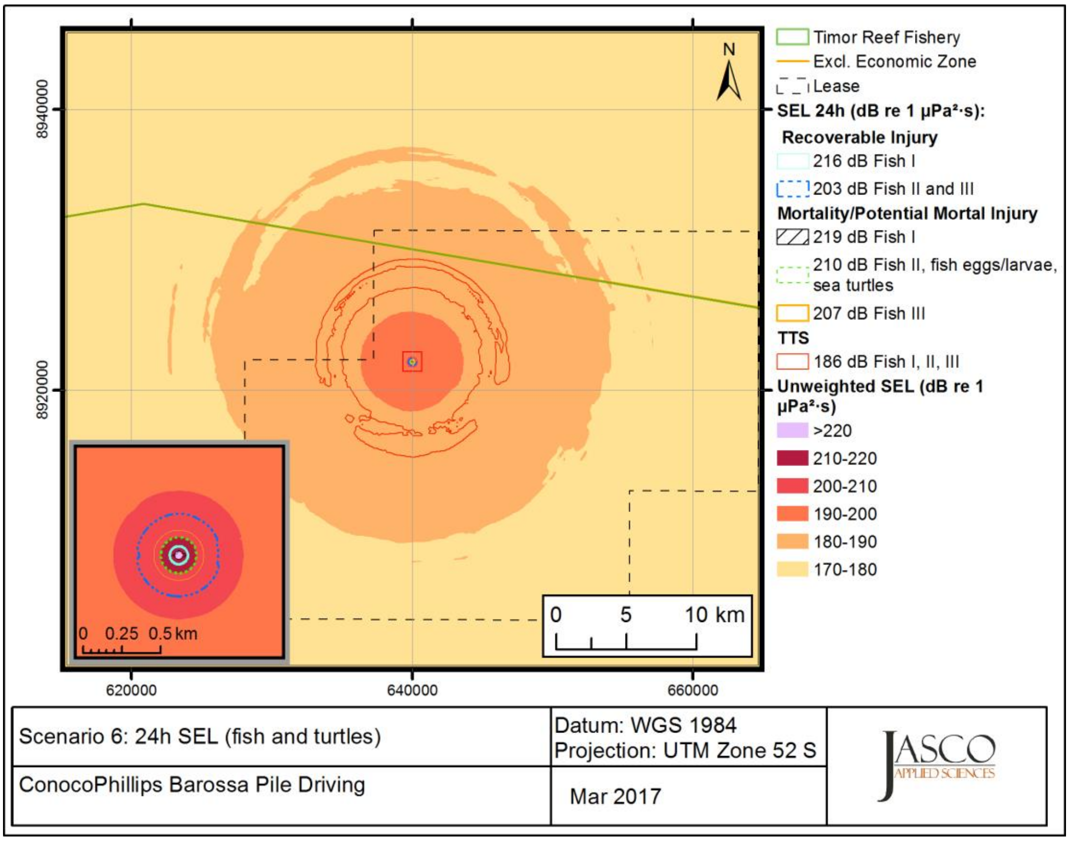

Figure C-7. Scenario 6: Sound level contour map showing maximum-over-depth SEL_{24h} results with fish and turtle thresholds.

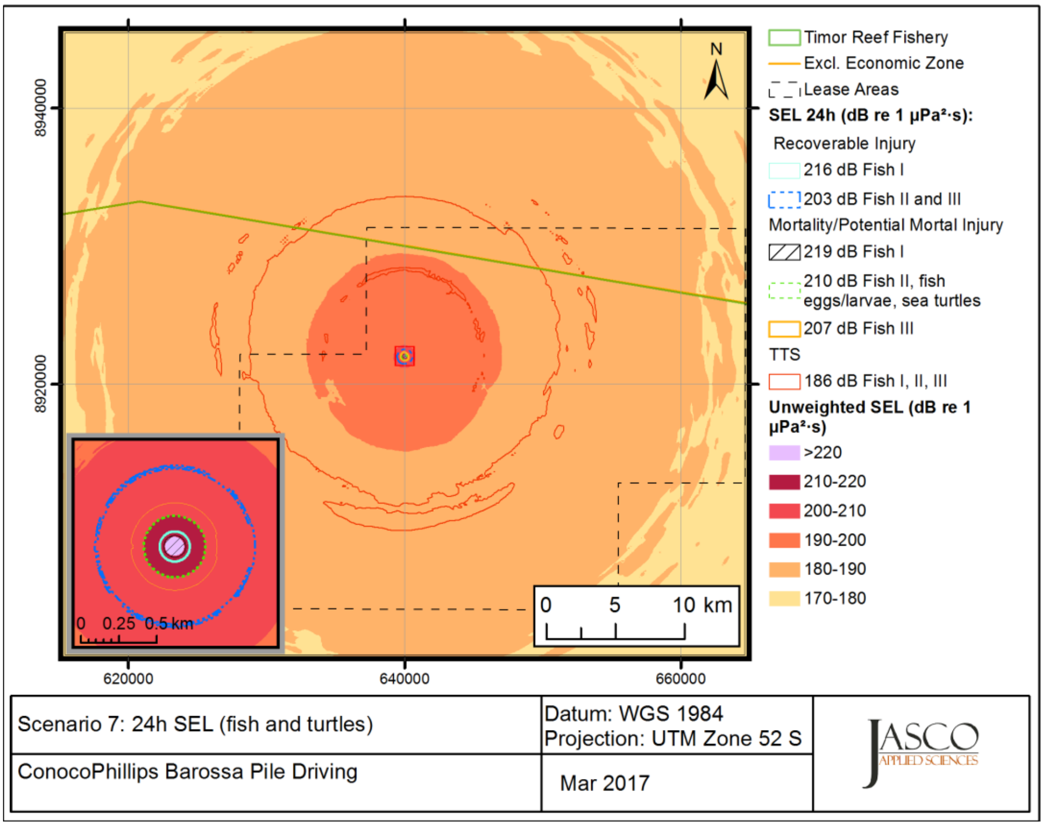

Figure C-8. Scenario 7: Sound level contour map showing maximum-over-depth SEL_{24h} results with fish and turtle thresholds.

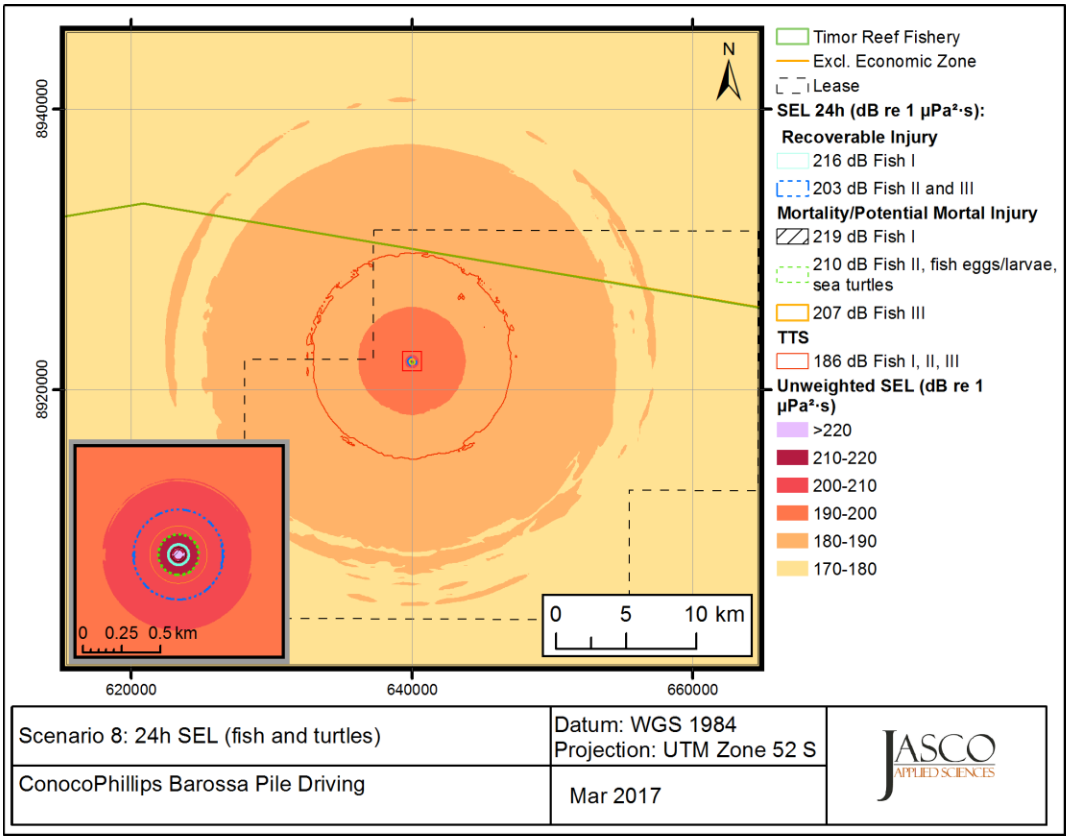

Figure C-9. Scenario 8: Sound level contour map showing maximum-over-depth SEL_{24h} results with fish and turtle thresholds.

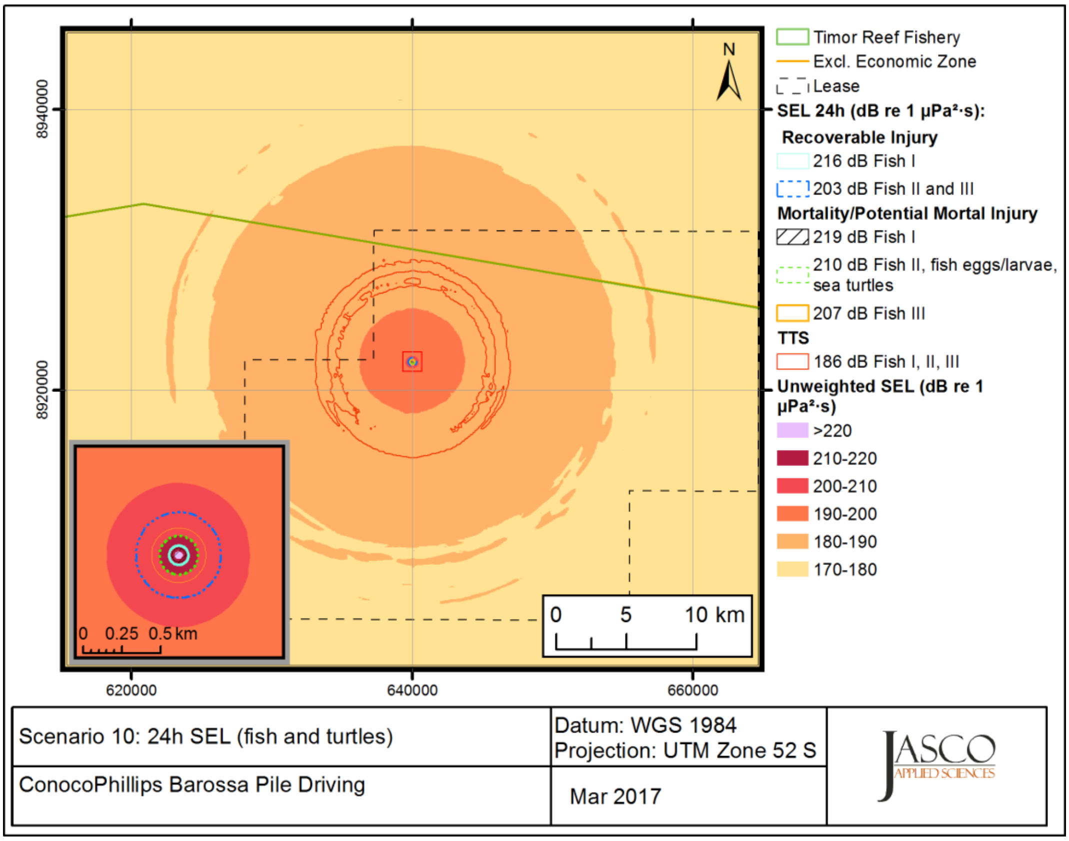

Figure C-10. Scenario 10: Sound level contour map showing maximum-over-depth SEL_{24h} results with fish and turtle thresholds.

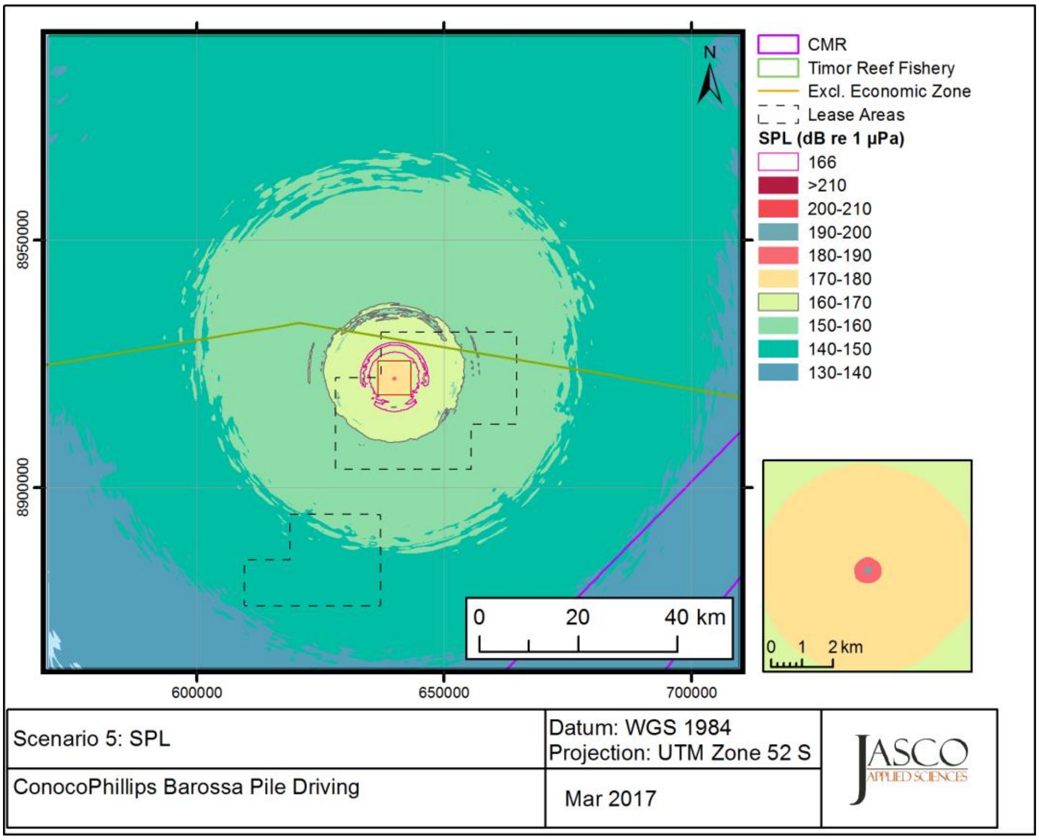

Figure C-11. Scenario 5: Sound level contour map showing unweighted maximum-over-depth SPL results, showing isopleths for marine mammal and turtle behaviour thresholds.

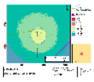

Figure C-12. Scenario 6: Sound level contour map showing unweighted maximum-over-depth SPL results, showing isopleths for marine mammal and turtle behaviour thresholds.

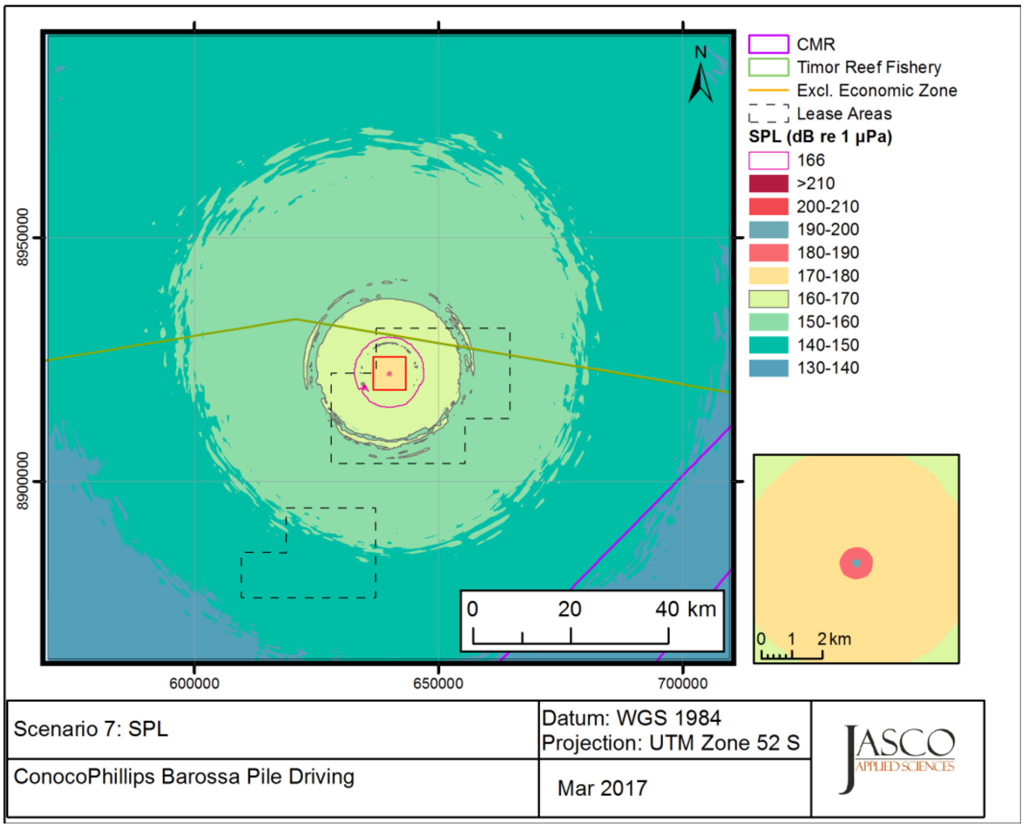

Figure C-13. Scenario 7: Sound level contour map showing unweighted maximum-over-depth SPL results, showing isopleths for marine mammal and turtle behaviour thresholds.

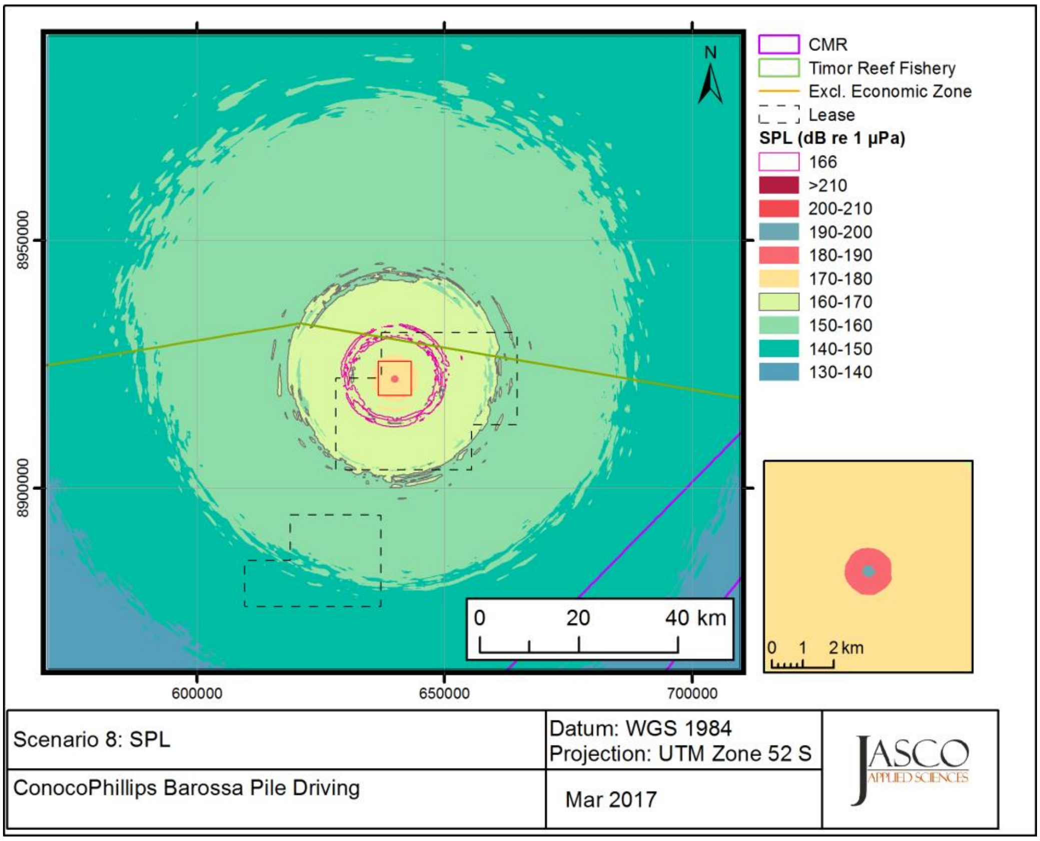

Figure C-14. Scenario 8: Sound level contour map showing unweighted maximum-over-depth SPL results, showing isopleths for marine mammal and turtle behaviour thresholds.

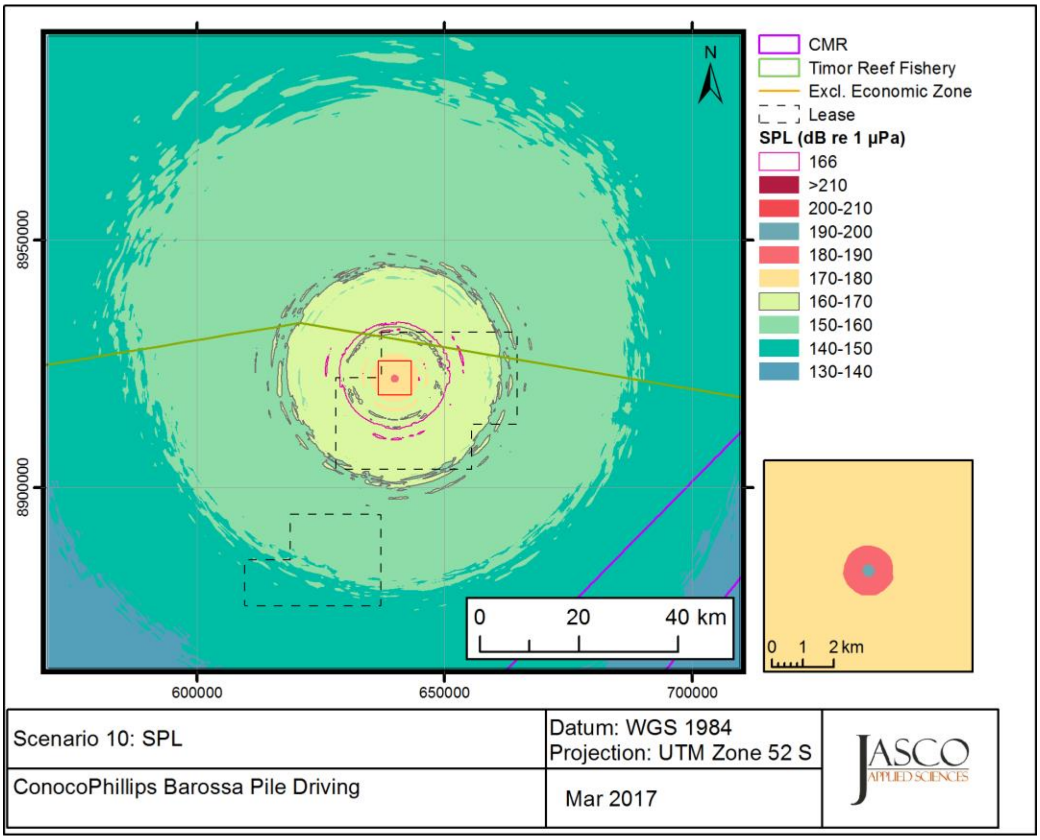

Figure C-15. Scenario 10: Sound level contour map showing unweighted maximum-over-depth SPL results, showing isopleths for marine mammal and turtle behaviour thresholds.

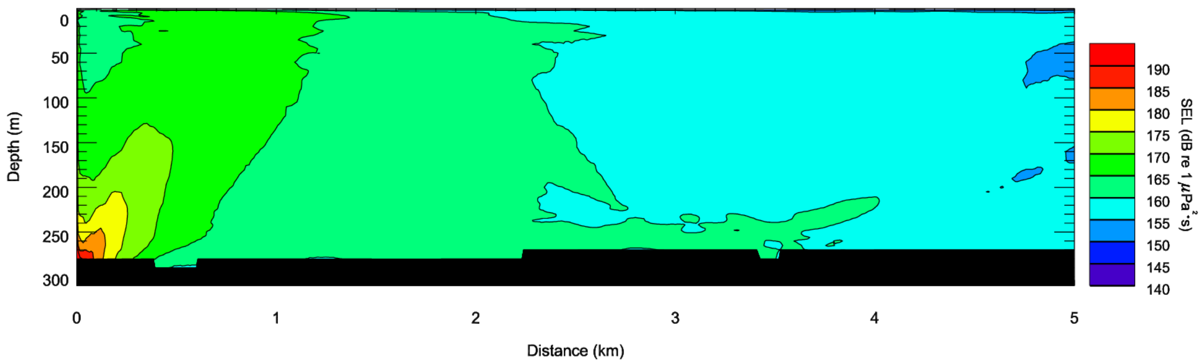

Figure C-16. Scenario 5: Predicted unweighted per-strike SEL as a vertical slice. Levels are shown along a single transect of azimuth 180°.

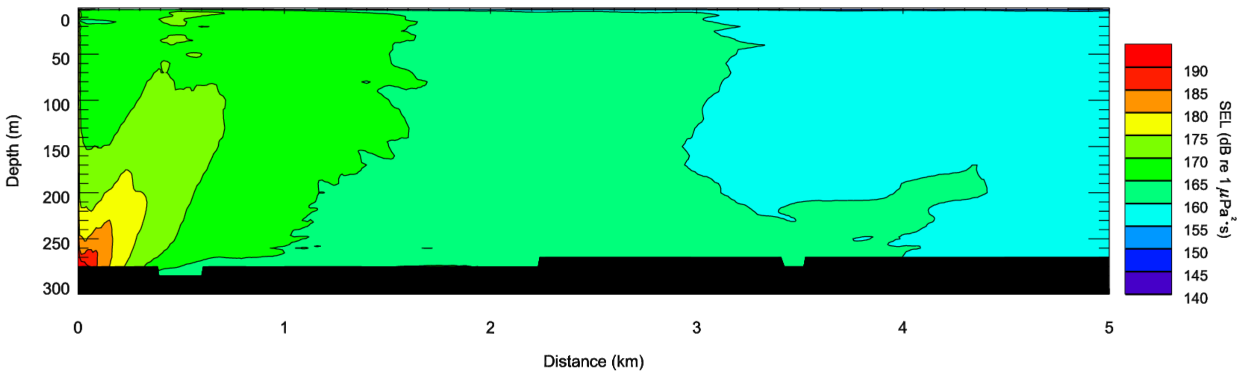

Figure C-17. Scenario 6: Predicted unweighted per-strike SEL as a vertical slice. Levels are shown along a single transect of azimuth 180°.

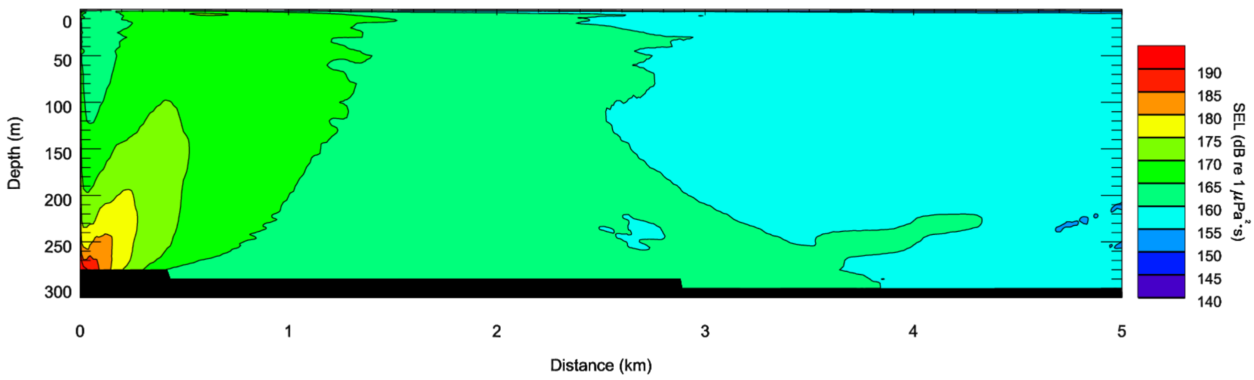

Figure C-18. Scenario 7: Predicted unweighted per-strike SEL as a vertical slice. Levels are shown along a single transect of azimuth 180°.

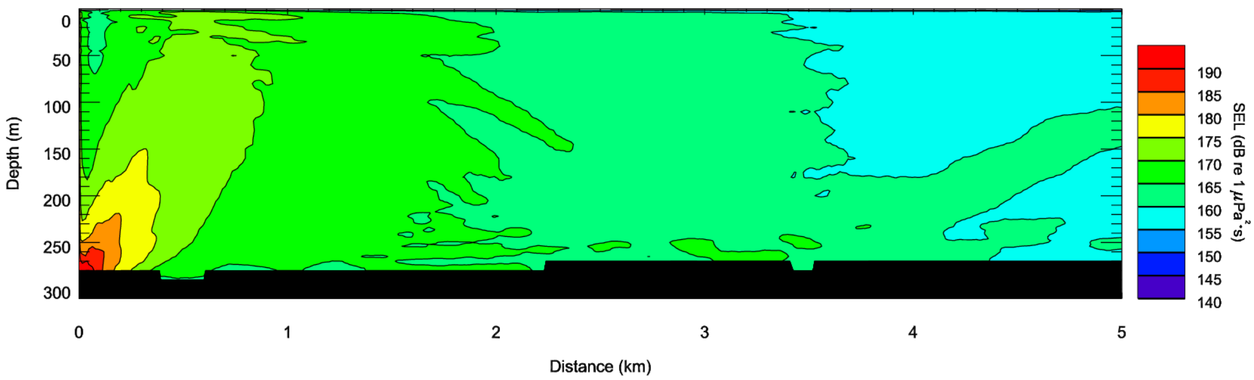

Figure C-19. Scenario 8: Predicted unweighted per-strike SEL as a vertical slice. Levels are shown along a single transect of azimuth 180°.

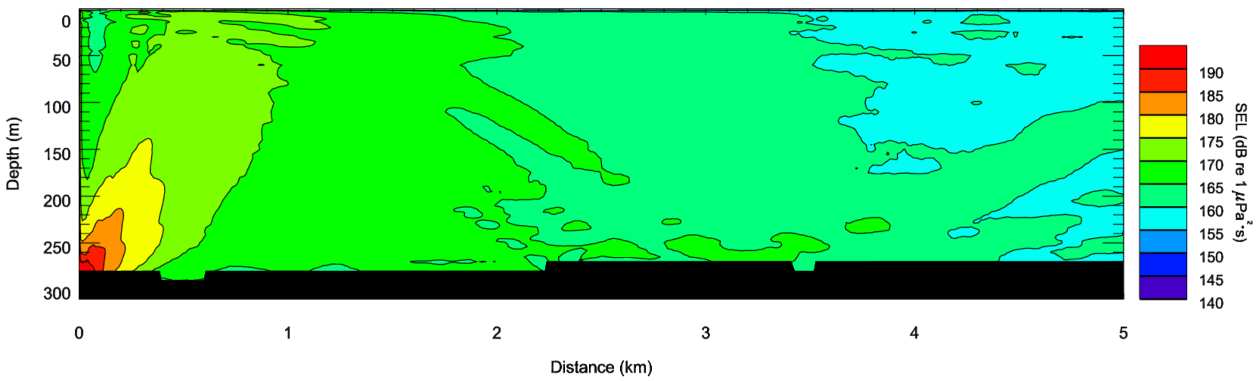

Figure C-20. Scenario 10: Predicted unweighted per-strike SEL as a vertical slice. Levels are shown along a single transect of azimuth 180°.

Appendix N.

Underwater noise modelling study - FPSO facility operations (JASCO 2016b)

Potential Impacts of Underwater Noise from Operation of the Barossa FPSO Facility on Marine Fauna

ConocoPhillips Barossa Project

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19 August 2016

P001241-002
Document 01117
Version 1.0

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Suggested citation:

McPherson, C.R, M. Wood and R. Racca 2016. *Potential Impacts of Underwater Noise from Operation of the Barossa FPSO Facility on Marine Fauna, ConocoPhillips Barossa Project*. Document 01117, Version 1.0. Technical report by JASCO Applied Sciences for Jacobs.

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1. Introduction

JASCO Applied Sciences (Australia) (JASCO) predicted underwater sound levels associated with the ConocoPhillips Barossa floating production, storage and offloading (FPSO) facility and the potential impacts on marine fauna.

This assessment focuses primarily on the continuous sounds produced by the FPSO facility and other vessels in association with the FPSO facility operation. The animal types considered here include: marine mammals, fishes (including whale sharks and fish eggs and larvae), plankton, turtles, sea snakes and invertebrates. To provide context, other anthropogenic sounds in the marine environment, such as those due to shipping, and natural ambient sounds are discussed where relevant.

2. General Effects of Continuous Sound on Marine Species

When marine animals are exposed to underwater anthropogenic sounds, the types and scale of their responses—physiological, behavioural, and acoustic—vary depending on the level of exposure, the physical environment in which the subjects are at the time of exposure, and other factors unique to each animal. Important factors can include the location of the animal in relation to the sound source, how long the animal is exposed to the sound, how often the sound repeats (repetition frequency), and the ambient sound level. Factors specific to each animal that determine how it responds include its activity level, its reproductive and metabolic states at time of exposure, and how well it hears and how it perceives the sound. For example, an animal that hears a sound while it is in an area it uses for mating or rearing offspring might respond much differently than the same animal in another area or time period unrelated to its reproductive state. An individual that has historically been exposed to sound could also have a different response than an animal lacking such exposure. If its prior exposure to a sound type or intensity did not result in physical harm, the animal could have learned to distinguish between dangerous and benign sounds.

This assessment focuses primarily on the continuous sounds produced by an FPSO facility and other vessels in association with the FPSO facility operation. The animal types considered here include: marine mammals, fishes (including whale sharks and fish eggs and larvae), plankton, turtles, sea snakes and invertebrates. To provide context, other anthropogenic sounds in the marine environment, such as those due to shipping, and natural ambient sounds are discussed where relevant. Throughout Section 2, the FPSO facility is included with noise from commercial shipping, due to the similarity of the sound sources.

Sounds from large commercial vessels rarely exceed the acoustic injury levels required to induce Permanent Threshold Shift (PTS) unless the animal is in very close proximity to the vessel (usually within meters). The typical source levels of large vessels only approach threshold levels in very low frequencies (<100 Hz, Figure 1) and when travelling at high velocities or when vessel propulsion systems are not well maintained, which is due to cavitation sounds that contribute to the measured sound levels in higher frequencies. The accumulation of shipping noise in an area, however, can reduce the suitability of a habitat if non-injurious sound levels that exceed behavioural thresholds consistently.

The main concerns are for potential negative effects of shipping sounds on marine fauna. Therefore, this assessment primarily focusses on behavioural disruption, including masking and non-auditory health effects.

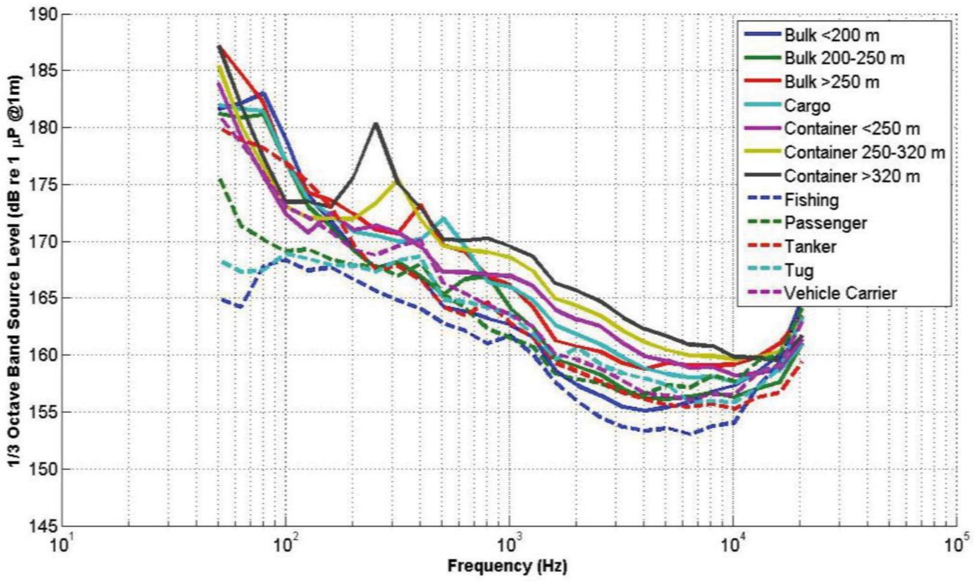


Figure 1. TWMBR recorded mean third octave band source levels for different vessel types (Hemmera et al. 2014).

2.1. Marine Mammals

Because the sounds that marine mammals hear and generate carry information relevant for their survival and reproduction, variation in the acoustic characteristics of these sounds—fundamental frequency, frequency bandwidth, spectral energy, temporal patterning, and directivity—is also relevant. The effects of anthropogenic and ambient sounds on these characteristics can be cumulative and can have significant implications for individuals and populations. Behavioural disruption, including masking and non-auditory health effects are reviewed below, followed by a summary of the circumstances under which marine mammals could be exposed to sounds from this operation.

2.1.1. Acoustic Masking

Acoustic masking occurs when sounds interfere with an animal's ability to perceive biologically relevant sounds. It can be defined as a reduction in communication and listening space (active acoustic space) that an individual experiences due to an increase in background noise (ambient and anthropogenic) in the frequency bands relevant for communicating and listening. For example, acoustic masking can decrease the range over which an animal might communicate with conspecific individuals, or detect predators or prey, by decreasing their listening space or total active acoustic space (Clark et al. 2009). Masking can occur naturally from wind, precipitation, wave action, seismic activity, and other natural phenomena. For example, the ranges over which fish-eating killer whales use echolocation clicks to detect chinook salmon can be reduced by more than 50% in moderate rain (Au et al. 2004). Biological sounds can also naturally mask signals. Some fish, for example, create low-frequency sounds (50–2000 Hz, but most often 100–500 Hz) that can form a significant component of local ambient sound levels (Zelick et al. 1999). Snapping shrimp in many locations produce high-amplitude sounds over a broad range of frequencies that often dominate the underwater sound field.

Marine mammals almost certainly have adapted to naturally occurring signal masking, yet the reduced active acoustic space under noisy natural conditions is a physical constraint that cannot be overcome completely and must be taken into consideration in acoustic assessments. Anthropogenic sounds contribute to the ambient soundscape, and can mask biologically important sounds, potentially reducing the active (perception) space to levels that cannot support active foraging and socialising. The amount of masking an animal experiences is determined by the amplitude, timing, and frequency content of the interfering sounds, as well as how sounds are spatially distributed.

Studies on acoustic masking in the ocean have traditionally focused on mysticetes (a suborder of cetaceans that use baleen plates to filter their food; includes humpback, rorquals, blue, fin, minke and right whales) and shipping sounds (Clark et al. 2009). Mysticetes communicate using calls with energy primarily in low-frequency bands that overlap completely with the bands carrying the main energy of shipping sounds (Arveson and Vendittis 2000, Allen et al. 2012, Bassett et al. 2012). Over the past 50 years, commercial shipping, the largest contributor of masking noise (McDonald et al. 2008), has increased the ambient sound levels in the deep ocean at low frequencies by 10–15 dB (Hatch and Wright 2007). Hatch et al. (2012) estimated that shipping noise could be responsible for North Atlantic right whales (*Eubalaena glacialis*) losing, on average, 63–67% of their communication space. Dunlop (2016) suggested that humpback whales may not be able to cope with an increase in anthropogenic noise in the same way they cope with an increase in natural noise when comparing communication source levels and repertoire. This may be due to the specific overlap of noise in important frequency bands.

Sound output from ships can also extend to relatively high frequencies (e.g., up to 30 kHz, Arveson and Vendittis 2000, and up to 44.8 kHz, Aguilar Soto et al. 2006) and therefore can affect odontocetes (toothed whales) especially at shorter ranges. Aguilar Soto et al. (2006) used a Digital Acoustic Recording Tag (DTAG) attached to a Cuvier's beaked whale (*Ziphius cavirostris*) to record a passing vessel, which demonstrated that vessel sounds masked the whale's ultrasonic vocalisations and reduced the whale's maximum communication range by 82% when it was exposed to a 15 dB increase in ambient sound levels at the vocalisation frequencies. The study also determined that the effective detection distance of Cuvier's beaked whales' echolocation clicks by conspecifics would be reduced by 58%. Noise profiles from ships are highly variable, and high-frequency components attenuate more rapidly than do low frequencies (Hatch and Wright 2007), which limits the area over which Cuvier's beaked whales would be affected.

Some cetaceans might compensate for masking, to a limited degree, either by increasing the amplitude of their calls (Lombard effect) or by changing their spectral (frequency content) or temporal vocalisation properties (Hotchkin and Parks 2013). North Atlantic right whales produced calls with a higher average fundamental frequency and lowered their call rate in high noise conditions (Parks et al. 2007), whereas blue whales increased their discrete, audible calls when ship sounds were nearby (Melcon et al. 2012).

2.1.2. Behavioural disturbance

Behavioural responses to underwater sound are difficult to determine because animals vary widely in their response type and strength, and conspecifics who are exposed to the same sound react differently (Nowacek et al. 2004). An individual's response to a stimulus is influenced by the context in which the animal receives the stimulus and how relevant the individual perceives the stimulus to be. A number of biological and environmental factors can affect an animal's response—behavioural state (e.g., foraging, travelling or socializing), reproductive state (e.g., female with or without calf, or single male), age (juvenile, sub-adult, adult), and motivational state (e.g., hunger, fear of predation, courtship) at the time of exposure as well as perceived proximity, motion, and biological meaning of the sound and nature of the sound source.

Animals might temporarily avoid anthropogenic sounds, but could display other behaviours, such as approaching novel sound sources, increasing vigilance[1], hiding and/or retreating, that might decrease their foraging time (Purser and Radford 2011). Marine mammals have also reduced their vocalisations in response to anthropogenic sounds, sometimes ceasing to call for weeks or months (IWC 2007). Some cetaceans might also compensate for masking, to a limited degree, either by increasing the amplitude of their calls (Lombard effect) or by changing their spectral (frequency content) or temporal vocalisation properties (Hotchkin and Parks 2013). North Atlantic right whales produced calls with a higher average fundamental frequency and lowered their call rate in high noise conditions (Parks et al. 2007), whereas blue whales increased their discrete, audible calls when ship sounds were nearby (Melcon et al. 2012). Whales seemed most reactive when the sound level was increasing, which they could perceive as an approaching sound. An animal could exhibit a startle effect at the onset of a sound. Although limited data are available, cetaceans respond less to stationary anthropogenic activities that produce continuous sounds (such as dredging, drilling, and oil-production-related activities) than they do to moving and/or transient sound sources, including seismic surveys and ships (Richardson et al. 1995). Some cetaceans may partially habituate to continuous sounds (Richardson et al. 1995).

The BRAHSS (Behavioural Response of Australian Humpback whales to Seismic Surveys) project conducts studies at Peregian Beach, Qld, and Dongara, WA, to better understand the behavioural responses of humpback whales to noise from the operation of seismic air gun arrays (Cato et al. 2013). It has also considered behavioural responses to ships. Results from the first sets of experiments have recently been published (Dunlop et al. 2015, Dunlop et al. 2016, Godwin et al. 2016), together with concurrent studies of the effects of vessel noise on humpback whale communications (Dunlop 2016). Dunlop et al. (2016) used land based observations of behavioural responses in migrating humpback whales to playbacks of the first stages of air-gun ramp-up operations and playbacks of 'constant' source sounds, and compared the results with the observed behaviours during 'controls' in which shipping sounds where present and the array was towed but not operated. The behavioural baseline used for the identification of responses was established using observations of groups in the absence of the source vessel. In most exposure scenarios a distance increase from the sound source was observed and interpreted as potential avoidance. The study, however, found no difference in the 'avoidance' response to either 'ramp-up' or the constant source (vessel) producing sounds at a higher level than early ramp-up stages. In fact, a small number of groups showed inspection behaviour of the source during both treatment scenarios. 'Control' groups also responded, which suggested that the presence of the source vessel alone had some effect on

[1] Scanning for the source of the stimulus.

the behaviour of the whales. Despite this, the majority of groups appeared to avoid the source vessel at distances greater than the radius of most seismic injury based mitigation zones.

A review by Southall et al. (2007) found no responses or limited responses by low-frequency cetaceans to continuous (non-pulsed) received levels up to 120 dB re 1 µPa, but an increasing probability of avoidance and other behavioural responses beginning at 120 to 160 dB re 1 µPa. In relation to high-frequency cetaceans, in the Bay of Fundy, Nova Scotia, Polacheck and Thorpe (1990) noted that harbour porpoises, which are high-frequency cetaceans, tended to swim away from approaching vessels. Off the western coast of North America, Barlow (1988) observed that harbour porpoises within 1 km of a survey vessel moved rapidly out of its path. Cuvier's beaked whales responded to ship sounds by decreasing their vocalisations when they attempted to catch prey (Aguilar Soto et al. 2006). Foraging changes were observed in Blainville's beaked whales (*Mesoplodon densirostris*) when they were exposed to vessel noise (Pirotta et al. 2012). Groups of Pacific humpback dolphins (*Sousa chinensis*) that contained mother-calf pairs increased their rate of whistling after a boat had transited the area (Van Parijs and Corkeron 2001). The authors postulated that vessel sounds disrupted group cohesion, especially between mother-calf pairs, requiring it to be re-established by vocal contact after boat noise masked communication. In response to high levels of boat traffic, killer whales increased the duration (Foote et al. 2004) or the amplitude (Holt et al. 2009) of their calls. Bottlenose dolphins (*Tursiops truncatus*) have been observed to produce more whistles when boats approached (Buckstaff 2004).

2.1.3. Non-auditory effects

Non-auditory physiological responses to noise exposure have been studied mainly in humans (Stansfeld and Matheson 2003), but some studies exist on the physiological stress response to noise in captive marine mammals.

Thomas et al. (1990) played drilling noise to four captive beluga whales and found no changes in their blood adrenaline or noradrenaline levels, measured immediately after. Miksis et al. (2001) found that the heart rate in a captive bottlenose dolphin increased in response to threat sounds produced by other dolphins. Rolland et al. (2012) concluded that right whales might feel chronic stress when they are exposed to low-frequency ship noise.

2.2. Fishes

A working group of experts reviewed available data and determined broadly applicable sound exposure guidelines for fishes and sea turtles. The working group's recommendations are available in a technical report, Popper et al. (2014), which was developed and approved by the Accredited Standards Committee S3/SC 1 Animal Bioacoustics and registered with the American National Standards Institute (ANSI). The technical report contains the most recent and thorough synthesis of available information, recommending sound exposure guidelines which were used as the criteria to assess the potential for noise impacts on fish, fish larvae, and fish eggs.

2.2.1. Behavioural disturbance

The National Research Council (NRC) (2005) discussed the possible effects of sound on marine mammal behaviour, including on communication between conspecifics and on detection of predators and prey. This is applicable to fish, and as such Popper et al. (2014) summarised, "In its report, the NRC states that an action or activity becomes biologically significant to an individual animal when it interferes with normal behaviour and activity, or affects the animal's ability to grow, survive, and reproduce. Such effects might have consequences at the population-level and might affect the viability of the species" (NRC 2005).

Studying the responses of fish to anthropogenic sound is complex as many factors could influence the results, and a careful approach based on well-designed experiments must be adopted. Experiments done with caged animals need to be considered in conjunction with studies on free-living animals, as results might differ due to the different ecological factors that influence an animal's behaviour in the wild.

A range of responses have been observed when the behaviour of wild fishes has been studied in the presence of anthropogenic sounds. Studies suggest that fish will generally move away from a loud acoustic source in order to minimise their exposure, but this response might depend on the animal's motivational state. Anthropogenic sounds have been shown to cause changes in schooling patterns and distribution, including in relation to ships (including commercial shipping, trawlers, ferries and research vessels) (Engås et al. 1996, Engås and Løkkeborg 2002, Sara et al. 2007, De Robertis and Handegard 2013). As there is currently a lack of quantification of sound exposure levels that elicit responses to ships makes it impossible to provide numerical guidelines for behavioural responses of fish to sounds from ships (Popper et al. 2014).

2.2.2. Acoustic Masking

Masking impairs an animal's hearing with respect to the relevant sounds normally detected within the environment and can have long-lasting effects on survival, reproduction and population dynamics of fishes (Popper et al. 2014). The consequences of masking for fishes, however, have not yet been fully examined. Popper et al. (2014) surmised, "It is likely that increments in background sound within the hearing bandwidth of fishes and sea turtles may render the weakest sounds undetectable, render some sounds less detectable, and reduce the distance at which sound sources can be detected. Energetic and informational masking may increase as sound levels increase, so that the higher the sound level of the masker, the greater the masking."

While limited scientific information is available, it has been demonstrated that oyster toadfish respond to vessel disturbances by calling less when vessels are present. The authors of the study suggested that toadfish cannot call over loud vessel noise, reducing the overall calling rate, and may have to call more often when vessels are not present (Luczkovich et al. 2016).

2.3. Elasmobranchs

The effect of anthropogenic noise on elasmobranchs (i.e. cartilaginous fish) is not well understood as relatively few studies have been undertaken. Elasmobranchs are not known to utilise acoustic communication, and therefore anthropogenic noise would most likely be an issue for masking of the sounds of prey species. Bullock and Corwin (1993) noted a degree of acoustic masking in Carcharhinidae and Triakidae tropical sharks with sounds of flowing water, white noise and with swimming, artificial white noise and of relevance to anthropogenic noise from shipping masking around 100 Hz by a 100 Hz tone. There are no stress studies examining the effect of noise on elasmobranchs.

Casper and Mann (2009) demonstrated that the Atlantic sharpnose (Carcharhinidae) had a peak sensitivity at 20 Hz in terms of particle acceleration which when converted to pressure units was comparable to an ambient signal level of 83 dB re 1 µPa, a level readily exceeded by many vessels at a broad range of distances. Casper et al. (2012) considered that little information was available to consider noise masking of elasmobranchs.

2.4. Turtles

The Popper et al. (2014) report examined sea turtles and fish, ultimately recommending criteria to assess the potential for noise impacts on turtles. Data on sea turtles are less conclusive than for other species, from the perspective of both the level of harm inflicted and the animal's reaction to sound. Recommendations on studies that could be done to increase the understanding of the impact of anthropogenic noise on turtles are provided in Willis (2016).

The majority of studies have focused on airguns, which can be applied to other impulsive sources such as pile driving, however are difficult to apply to continuous sound sources such as shipping. Sea turtles have been shown to avoid low-frequency sounds (Lenhardt 1994), and in a 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).

2.5. Sea Snakes

There is currently no scientific information on how sea snakes use sound or how susceptible they might be to underwater noise, although this is an area of current research. For this assessment, because snakes and turtles are both marine reptiles, it has been assumed that sea snakes are similarly or less sensitive to low level sounds than are turtles. Therefore, the thresholds established for turtles are a reasonable proxy for sea snakes. However, as quantifiable distances for assessing impacts from continuous sounds only exist for fish, fish have been used as a surrogate for this assessment (Section 3.3).

2.6. Invertebrates

The existing body of scientific information on the direct effects of exposure to anthropogenic sound on marine invertebrates is very limited, with few peer-reviewed papers published (Morley et al. 2014). However, there is evidence of the potential for adverse effects on invertebrates. Based on the physical structure of their sensory organs, marine invertebrates appear to be specialised to respond to particle displacement components of an impinging sound field and not to the pressure component (Popper et al. 2001).

de Soto (2016) provides the most recent review of anthropogenic noise on marine invertebrates considering a broad range of taxa and their ontogenetic stages, with the summarised studies showing that the noise effects on marine invertebrates range from apparently null through to behavioural/physiological responses and possible mortalities. However, caution was urged in regards to the conclusion of a number of the reports, particularly in relation to ensuring peer-review, and that 'the conclusions must be scientifically correct and fit the power of the experimental protocol. Studies target discrete questions and their conclusions should not be over interpreted.' and 'survival in the laboratory is not comparable to survival in the wild'. Therefore, the conclusions of the summarised studies must be considered carefully.

There is limited information on the direct effects on marine invertebrates to exposure to shipping-related sounds, however a summary of the information is provided below. It should be noted that the majority of these studies relate to actual shipping in shallow water, and a close proximity between the source and the fauna. This is a different scenario to that which will occur in relation to the FPSO facility.

Squid

Squid were found to respond to sound between 30 and 500 Hz, being most sensitive between 100 and 200 Hz. This suggests that squid detect sound similarly to most fish, with the statocyst acting as an accelerometer through which squid detect the particle motion component of a sound field (Mooney et al. 2010).

Nudibranch

In a field experiment Nedelec et al. (2014) used playbacks to investigate the effect of boat noise on the early life and survival of a coral reef marine invertebrate, the sea hare *Stylocheilus striatus.* Nedelec et al. (2014) found that exposure of the nudibranch to small boat-noise playback compared to ambient-noise playback, stopped development of nudibranch embryos by 21%. For the nudibranch embryos remaining, a further mortality of 22% occurred for hatched larvae.

Lobster

Filiciotto et al. (2014) and Celi et al. (2014) conducting exposure studies with European panilurid lobster to short duration shipping sounds observed significant biochemic and immune response effects. Furthermore, simulated exposure of the Norway lobster (*Nethrops norvegicus*) to continuous ship noise (equivalent to 100 m distance) or pile driving sound (equivalent to 60 m distance) for seven days repressed burying and bio-irrigation behaviour with both treatments, and reduced locomotor activity compared to controls (Solan et al. 2016).

Prawns

Lagardère (1982) reproduced shipping noise at 30 dB above ambient sound levels for three months across the known hearing range of the northern hemisphere prawn *Crangon crangon* and noted a significant reduction in growth and reproduction rates of the prawn and to a lesser extent increased cannibalism.

The common decapod European prawn *Paleomon serratus*, is an animal that usually burrows or takes shelter in rocky crevices. When exposed to as little as 30 minutes of a range of vessel noises it was noted that the prawn remained out of available shelters possibly due to acoustic resonance (increased sound pressure level) within the structures, and showed a wide range of significant biochemical changes (Filiciotto et al. 2016). This prawn is related to Australia’s freshwater and brackish Macrobranchium.

Crabs

Wale et al. (2013b) demonstrated a potential association between shipping noise and a predation risk increase in small shore crabs due to a behaviour change. While shipping noise did not alter the speed and success of crabs targeting their prey, the noise was associated with a reduced rate of crabs righting themselves (such as may occur in a predatory attack) and a slower rate of seeking shelter after an attack.

Underwater playback of ship noise to shore crabs demonstrated an increase in oxygen uptake potentially indicating increased stress (Wale et al. 2013a), and hermit crabs (*Pagurus bernhardus*) have been shown to be sensitive to substrate-borne vibration and anthropogenic noise (Roberts et al. 2016).

Bivalves

Exposure of the bivalve clam *Ruditapes philippinarum* to simulated continuous ship noise (equivalent to 100 m distance) or simulated pile driving sounds typical during offshore wind turbine construction (equivalent to 60 m distance) for seven days appeared to effect the clam’s behaviour by repressing the burying and bio-irrigation behaviour, and potentially reducing locomotor activity compared to controls (Solan et al. 2016). The observed behaviour change increased predation risk, demonstrated a potential concern for shell degradation through acidosis and potentially modified the soil environment.

3. Acoustic Thresholds

3.1. Marine Mammals

Acoustic modelling results can be compared against various sound level threshold effects assessment criteria for underwater noise. This assessment considered the following criteria for marine mammals:

- Current interim U.S. National Marine Fisheries Service (NMFS) (NMFS 2014) threshold for behavioural response criteria for to non-pulsed noise.
- Cetacean criteria recommended by Southall et al. (2007).

There are two categories of auditory threshold shifts or hearing loss:

- Permanent threshold shift (PTS), a physical injury to an animal's hearing organs.
- Temporary threshold shift (TTS), a temporary reduction in an animal's hearing sensitivity, the result of receptor hair cells in the cochlea becoming fatigued.

3.1.1. Behavioural responses

Southall et al. (2007) extensively reviewed marine mammal behavioural responses to sounds. Their review found that most marine mammals exhibited varying responses between SPLs of 140 and 180 dB re 1 µPa, but lack of convergence in the data from multiple studies prevented them from suggesting explicit step functions. Variations between studies included lack of control groups, imprecise measurements, appropriate metrics, and context dependency of responses including the animal's activity state. To create meaningful qualitative data from the collected information, Southall et al. (2007) proposed a severity scale that increases with increased sound levels.

The NMFS non-pulse noise criteria were selected for this assessment because it represents the most commonly applied behavioural response criterion by regulators. The distances at which behavioural responses could occur were determined to therefore occur in areas ensonified above an unweighted SPL of 120 dB re 1 µPa (NMFS 1995, NMFS 2000, NMFS 2014).

3.1.2. Injury and hearing sensitivity changes

The Noise Criteria Group, sponsored by NMFS, an office of the U.S. National Oceanic and Atmospheric Administration (NOAA) within the Department of Commerce, was established in 2005 to address shortcomings of the SPL based criteria mentioned above, which was initially implemented in 2005 (NMFS and NOAA 2005). The Group's goal was to review the literature on marine mammal hearing and their behavioural and physiological responses to anthropogenic noise and to propose new noise exposure criteria. In 2007, the findings were published by an assembly of experts (Southall et al. 2007). They introduced dual criteria consisting of both zero-to-peak (peak) SPL thresholds, expressed in dB re 1 µPa, and cumulative sound exposure level (SEL) thresholds, expressed in dB re 1 µPa^2·s. A received sound exposure was assumed to cause PTS if it exceeds the peak SPL criterion, the SEL criterion, or both. The peak SPL is not frequency-weighted whereas the SEL is frequency-weighted for different marine mammal functional hearing groups (Section 3.1.1). These criteria included categories for pulsed and non-pulsed sound. While recommendations for updates to the criteria from Southall et al. (2007) for pulsed sound have been made (Wood et al. 2012), the non-pulsed criteria remain the same. The Southall et al. (2007) SEL threshold for injury (PTS) is defined as being 215 dB re 1 µPa^2·s for all cetacean hearing groups. When multiple events, or continuous sound occur over 24 hours, SELs are integrated over 24 h or the duration of the activity (Southall et al. 2007). However, the criteria were not applied in this assessment as the modelled sound levels did not reach the threshold.

3.1.1. Marine mammal frequency weighting

The potential for sound to affect marine fauna depends on whether and how well the animals can hear the frequency of the received sound. Loud sounds (noises) are less likely to disturb or injure an animal if they are at frequencies that the animal cannot hear well. An exception occurs when the sound pressure is so high that it can cause physical injury through non-auditory mechanisms (i.e., barotrauma). For sound levels below such extremes, frequency weighting can be applied to scale the importance of sound components at particular frequencies in a manner reflective of an animal's sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007).

Based on a literature review of marine mammal hearing and on physiological and behavioural responses to anthropogenic sound, Southall et al. (2007) proposed standard frequency weighting functions—called M-weighting functions (similar to C-weighting of noise in disturbance assessments on human hearing) —for five functional hearing groups of marine mammals:

- Low-frequency cetaceans—mysticetes (baleen whales).
- Mid-frequency cetaceans—some odontocetes (toothed whales).
- High-frequency cetaceans—odontocetes specialised for using high-frequencies.
- Pinnipeds in water—seals, sea lions, and walrus (not addressed here).
- Pinnipeds in air (not addressed here).

The discount applied by the M-weighting functions for less-audible frequencies is less than that indicated by the corresponding audiograms (where available) for member species of these hearing groups. The rationale for applying a smaller discount than suggested by audiograms is due in part to an observed characteristic of mammalian hearing that perceived equal loudness curves increasingly have less rapid roll-off outside the most sensitive hearing frequency range as sound levels increase. This is why, for example, C-weighting curves for humans, used for assessing loud sounds such as blasts, are flatter than A-weighting curves, used for quiet to mid-level sounds. Additionally, out of band frequencies, though less audible, can still cause physical injury if pressure levels are sufficiently high. The M-weighting functions therefore are primarily intended to be applied at high sound levels where effects such as temporary (TTS) or permanent (PTS) hearing threshold shifts might occur. Figure 2 shows the decibel frequency weighting of the four underwater M-weighting functions.

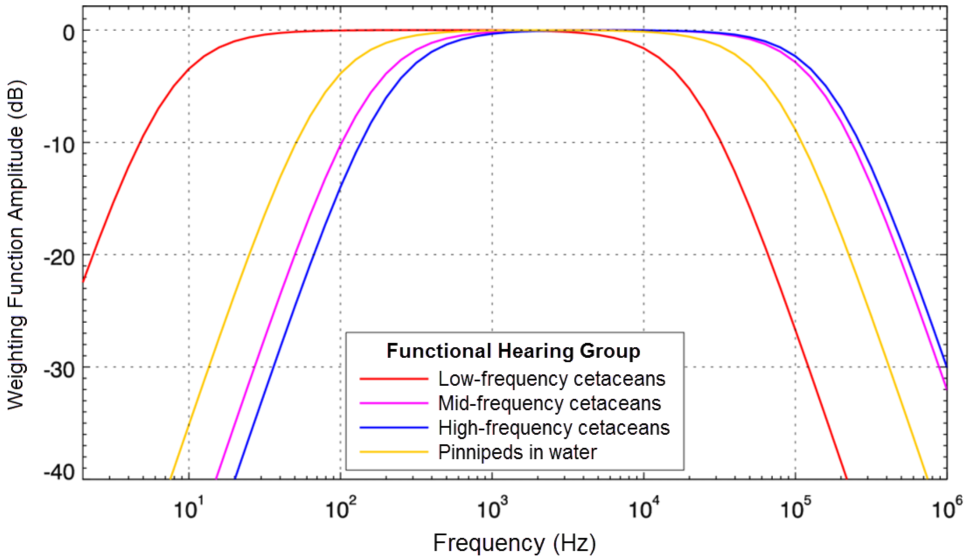


Figure 2. The standard M-weighting functions for the four underwater marine mammal functional hearing groups (Southall et al. 2007).

The M-weighting functions have unity gain (0 dB) through the passband and their high and low frequency roll-offs are approximately –12 dB per octave. The amplitude response in the frequency domain of the M-weighting functions is defined by:

$$G(f) = -20\log_{10}\left[\left(1+\frac{a^2}{f^2}\right)\left(1+\frac{f^2}{b^2}\right)\right] \tag{1}$$

The roll-off and passband of this function are controlled by the parameters *a* and *b*, the estimated lower and upper hearing limits, respectively, of the given functional hearing group (Table 1).

Table 1. The low (a) and high (b) frequency cut-off parameters of the standard M-weighting functions for the four underwater marine mammal functional hearing groups (Southall et al. 2007).

Functional hearing group	*a* (Hz)	*b* (Hz)
Low-frequency cetaceans	7	22 000
Mid-frequency cetaceans	150	160 000
High-frequency cetaceans	200	180 000
Pinnipeds in water	75	75 000

3.2. Fish, Sea Turtles, Plankton, Fish Eggs and Fish Larvae

In 2006, the Working Group on the Effects of Sound on Fish and Turtles was formed to continue developing noise exposure criteria for fish and sea turtles, on which work was begun by a NOAA panel two years earlier. The resulting guidelines (Popper et al. 2014) included specific thresholds for different levels of effects and for different groups of species. These guidelines defined quantitative thresholds for three different types of immediate effects:

- Mortality: includes injury leading to death.
- Recoverable injury: Injuries unlikely to result in mortality, such as hair cell damage and minor haematoma.
- Temporary Threshold Shift.

Masking and behavioural effects were assessed qualitatively, by assessing relative risk rather than by a specific threshold. Because the presence or absence of a swim bladder has a role in hearing, sounds differentially affect animals' susceptibility to injury from noise exposure. Thus, different thresholds were proposed for fish without a swim bladder (including sharks), fish with a swim bladder that is not used for hearing, and fish that use their swim bladders for hearing; sea turtles, fish eggs, and fish larvae are considered separately. Whale sharks are treated as fish without swim bladders for this assessment, although they have a different hearing apparatus. The effects thresholds are summarised in Table 2

This report applied the Popper et al. (2014) threshold criteria and likelihood of impacts for fish, sea turtles, fish eggs, and fish larvae (including plankton) exposed to continuous sound.

The likelihood of impairment due to masking or a behavioural change considers the distance of a fish from a source. The ranges, relative to the source, were quantified as near—within tens of metres—intermediate—within hundreds of metres—and far—in thousands of metres.

The relative risk of an effect was then rated as being "high," "moderate," and "low" with respect to source distance and animal type. Popper et al. (2014) make no assumptions about source or received levels because there are insufficient data to quantify what these distances might be. However, in general, the nearer the animal is to the source, the higher the likelihood is that it will be exposed to high energy and exhibit a response. In determining these distances and the potential effects, actual source and received levels, along with the sensitivity to the sources by the animals of concern, were considered. Popper et al. (2014) admit that the ratings for effects exhibited by animals discussed are highly subjective; however, because the authorship group represents some of the most respected experts in the field, and the ratings represent the general consensus of the group, they are used in this assessment.

As with fish, Popper et al. (2014) suggest relative risks for turtles as a function of distance. For exposure to shipping noise, the relative risks for turtles are the same as fish, except that potential behavioural disruption near the source is expected to be high.

Table 2. Relevant criteria / risk for assessment of FPSO facility, tanker and support vessel, derived from criteria for shipping and continuous sounds, adapted from Popper et al. (2014). For the most part, data in this table are based on knowing that fish will respond to sounds and their hearing sensitivity, but, as discussed in the text, there are no data on exposure or received levels that enable guideline numbers to be provided.

Type of Animal	Impairment			Behaviour
	Recoverable injury	TTS	Masking	
Fish: no swim bladder (particle motion detection)	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: swim bladder is not involved in hearing (particle motion detection)	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: swim bladder is involved in hearing (primarily pressure detection)	170 dB SPL for 48 h	158 dB SPL for 12 h	(N) High (I) High (F) High	(N) High (I) Moderate (F) Low
Sea turtles	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) High (I) Moderate (F) Low
Eggs and larvae	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low	(N) Moderate (I) Moderate (F) Low

Notes: SPL dB re 1 µPa; All criteria are presented as sound pressure even for fish without swim bladders since no data for particle motion exist. Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

3.3. Sea Snakes

No criteria exist for assessing the impact of sound on sea snakes. Previous assessments have suggested using cetaceans as a surrogate for sea snakes, however a sea snake, being a reptile, has an anatomy more similar to a turtle. It was initially proposed to use turtles as a surrogate for sea snakes for this assessment. However, as quantifiable distances for assessing impacts from continuous sounds only exist for fish, fish have been used as a surrogate for this assessment.

4. Methodology for Predicting Sound Propagation from the FPSO Facility

4.1. Modelling Overview

The main source of underwater noise introduced by the Barossa project will be the FPSO facility and associated support vessels. The modelling scenarios include the modelling of an operational FPSO facility (Scenario 1, Section 4.1.1), and an FPSO facility with offloading tanker and a support vessel in attendance (Scenario 2, Section 4.1.2), located at the proposed FPSO facility site in the Barossa field, as shown in Figure 3.

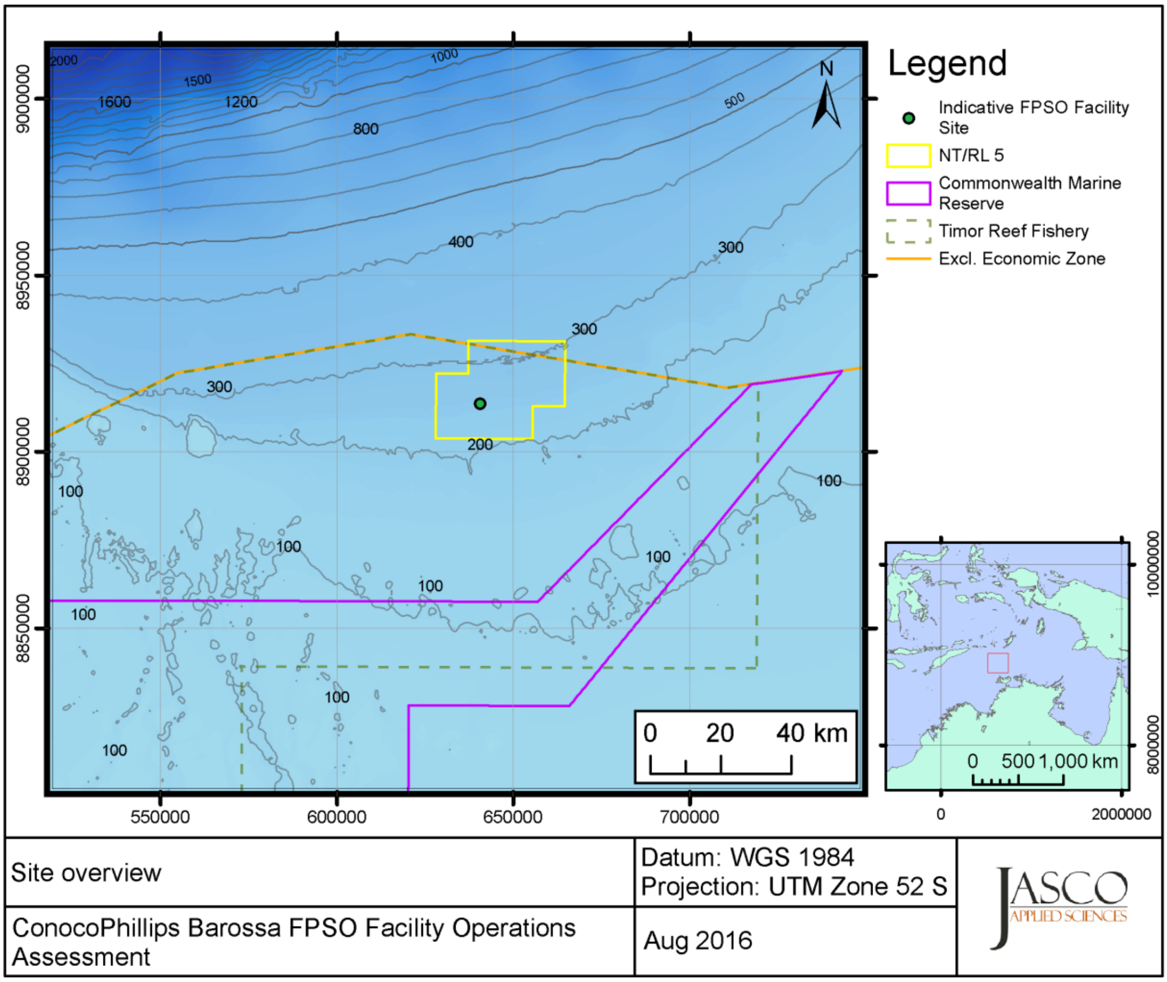


Figure 3. Survey region for the ConocoPhillips Barossa FPSO facility acoustic modelling.

4.1.1. Scenario 1

Scenario 1 assumes an FPSO facility maintaining position in the Barossa field at 9° 49' 33.17" S, 130° 16' 56.31" E without the use of thrusters. The geometric centre of the vessel was used as its acoustic source location.

4.1.2. Scenario 2

Scenario 2 assumes an FPSO facility maintaining position in the Barossa field at 9° 49' 33.17" S, 130° 16' 56.31" E using dynamic positioning (DP) with thrusters. The assessment as assumed that offloading will occur in conjunction with a fuel tanker 250 m east of the FPSO facility and a support vessel 250 m south of the FPSO facility (Figure 4). The tanker distance is an edge-to-edge distance, while the support vessel distance is a centre-to-centre distance. All vessels were modelled on DP; the tanker and FPSO facility were assumed to use no more than 50% of their maximum power while operating. The geometric centre of each vessel was used as its acoustic source location.

Table 3. Location details for acoustic source centres.

Vessel	Water depth (m)	Latitude	Longitude	UTM (Zone 52S)	
				X (m)	Y (m)
FPSO facility	255.9	9° 49' 33.17" S	130° 16' 56.31" E	640620.5	8913570
Tanker	254.2	9° 49' 33.11" S	130° 17' 12.41" E	641111.0	8913570
Support vessel	255.1	9° 49' 41.31" S	130° 16' 55.85" E	640605.5	8913320

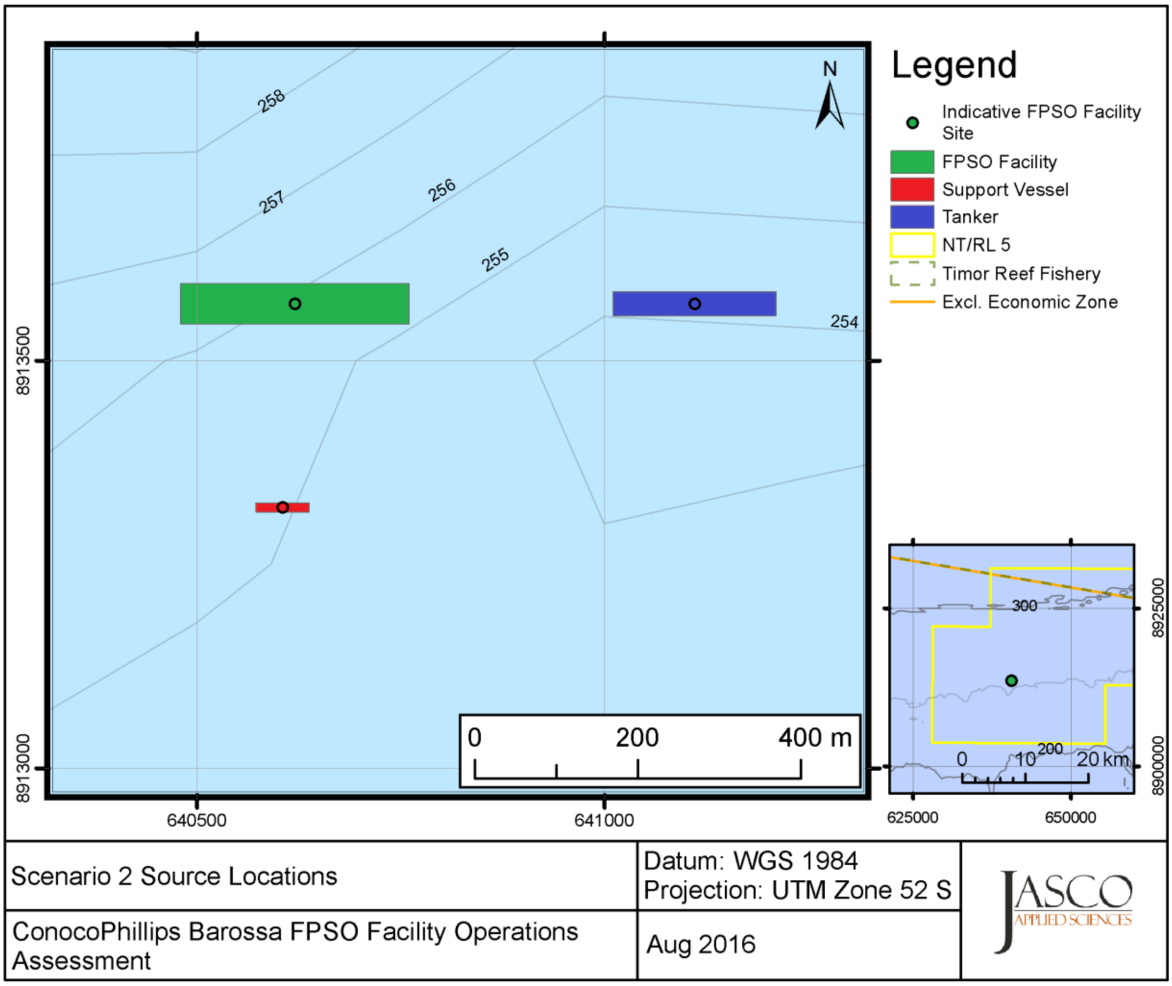


Figure 4. Proposed vessel placement for FPSO facility model, negligible orientation.

4.2. Sound Propagation Models

4.2.1. Marine Operations Noise Model

Underwater sound propagation was predicted with JASCO's Marine Operations Noise Model (MONM). This model computes transmission loss from acoustic sources via the Parabolic Equation model (Collins 1993) for low to mid frequencies (10 Hz–2 kHz), and the BELLHOP Gaussian beam acoustic ray-trace model (Porter and Liu 1994) for higher frequencies (2 kHz–20 kHz). MONM accounts for sound attenuation due to energy absorption through ion relaxation and water viscosity in addition to acoustic attenuation due to reflection at the medium boundaries and internal layers (Fisher and Simmons 1977). Sound attenuation from energy absorption is significant for frequencies higher than 5 kHz and cannot be neglected without noticeably affecting the model results.

MONM computes acoustic fields in three dimensions by modelling transmission loss within two-dimensional (2-D) vertical planes aligned along radials covering a 360° swath from the source, an approach commonly referred to as *N*×2-D. These vertical radial planes are separated by an angular step size of $\Delta\theta$, yielding $N = 360°/\Delta\theta$ number of planes. The angular step size of the radials is chosen to sufficiently sample the source beam pattern and the environmental variability. The transmission loss values from MONM are added to frequency-resolved sound source levels, and summed over frequency to provide broadband received sound level estimates. Frequency-weighting is optionally applied in the summation.

The modelled SEL field within each vertical radial plane is sampled at various ranges from the source with a fixed radial step size. At each range, the sound field is sampled at various depths. The received SEL at a planar sampling location is taken as the maximum value that occurs over all samples within the water column at that position, i.e., the maximum-over-depth received SEL. This conservatively predicts the received sound level around the source, independent of depth. These maximum-over-depth SELs are presented as colour contours around the source. In principle, the modelled sound field can be sampled at a vertical step size as fine as the acoustic field modelling grid, which varies from 2 m for low frequencies to 6 cm for high frequencies. However, the depth spacing between samples is chosen based on the vertical variability of the acoustic field and the depths of importance for the considered marine species.

For this assessment, the transmission loss was modelled along 144 radial profiles (angular step 2.5°) to a rectangular boundary 50 km to the north, south, east, and west of the source location. The modelling step along the radials was 30 m. A secondary model was run in a 10 km square boundary with radial steps of 10 m for finer resolution of the close range levels. At each planar location, the sound field was sampled at the following depths: 1 m, 2 m, 5 m, 10 m, 15 m, 20 m, 25 m, 30 m, 40 m, 50 m, 100 m, 200 m, 250 m, 300 m, 400 m, and 500 m.

4.3. Acoustic Source Parameters

4.3.1. Floating production, storage, and offloading facility

The proposed FPSO facility is a dynamically positioned production vessel approximately 281 m long and 51.6 m wide with a draft of 18.8 m. During DP, it operates on two stern thrusters, each rated at 4000 horsepower (HP). The vessel type and specifications are similar to production vessels *Ngujima* and *Nganhurra*, from which JASCO gathered measurements in 2010 (Erbe et al. 2013). The measured spectra for these two vessels were averaged and used as a surrogate for the FPSO facility. Because the *Nugujima* and *Nganhurra* were moored, they were not offloading, and the weather was calm, they were not under DP when they were measured; therefore, sound levels of thruster noise were added to the source spectrum to determine the source levels for Scenario 2. Sound levels for DP thruster noise were based on measurements of the dive support vessel *DSV Fu Lai* (MacGillivray 2006). The surrogate vessels' specifications are given in Table 4.

The final composite source spectrum for Scenario 2 was adjusted for the difference in total operational power level between the DSV *Fu Lai* and the FPSO facility using the following equation:

$$SL = SL_{FuLai} + 10\log(HP / HP_{ref}) \quad (2)$$

where HP_{ref} is the level of reference power. The source spectrum was additionally modified to consider the operational level of the *Fu Lai* thrusters relative to the desired operational level for the FPSO facility. Given that DP does not require full thrust, the *Fu Lai*'s thrusters only operated at between 20% and 30% of capacity when measured. To achieve a conservative estimate, FPSO facility thrusters were modelled at 50% power capacity.

The acoustic modelling source depth was determined by assuming the bottoms of the thrusters were at the draft of the vessel, but the noise from cavitation is known (Wright and Cybulski 1983) to be centralised at approximately three quarters of the propeller's height. Assuming a propeller of 1.7 m diameter and a draft of 18.8 m, the source depth was approximated at 17.5 m. For modelling, it was assumed that both thrusters operated at the middle (50%) of their constant power range, at a constant speed. The thrusters are located at the stern section of the vessel; for modelling purposes, however, the source location was placed in the planar centre of the vessel to approximate a point source. Because this assessment is focused on the far-field noise from all sources on the vessel (including not just thruster noise, but also noise from ancillary equipment for power generation, etc.) the point source approximation is suitable. Figure 5 shows 1/3-octave-band source levels for the FPSO facility and its proxy vessels.

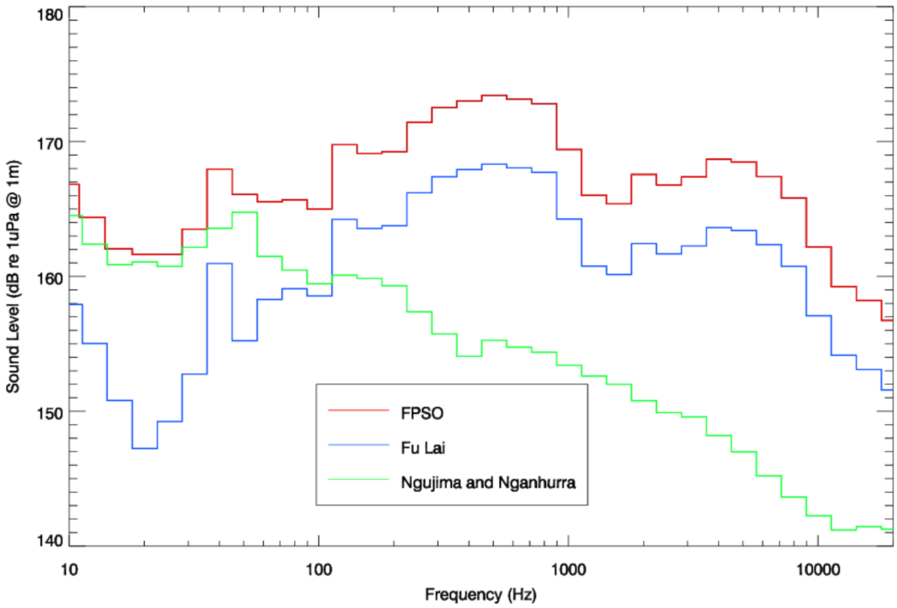


Figure 5. 1/3-octave bands of modelled FPSO facility without DP (Scenario 1, the *Ngujima/Nganhurra* average), the modelled FPSO facility for Scenario 2, and the *Fu Lai* is included for reference.

4.3.2. Tanker vessel

The proposed FPSO facility tanker vessel is approximately 200 m long with a 12 m draft. The main propulsion consists of a single bow thruster; the DP propulsion system consists of two transverse thrusters aft and two transverse thrusters forward, summing to a power of 12,605 HP. The sound spectrum of the DSV *Fu Lai* was used to model the tanker through power conversions using Equation 2. One-third octave-band source levels for both *Fu Lai* and the tanker are shown in Figure 6.

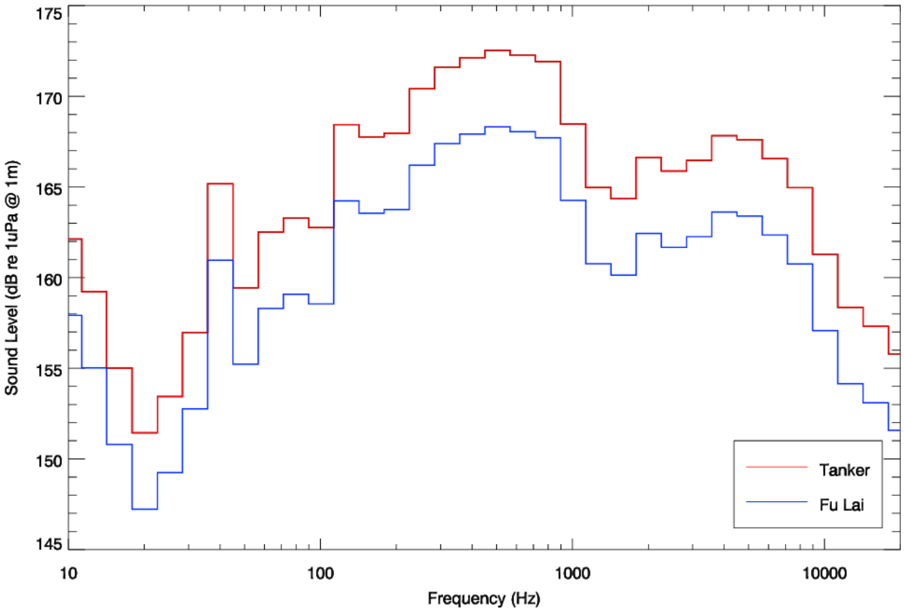


Figure 6. 1/3-octave bands of the tanker after power adjustment. 1/3-octave bands of *Fu Lai* are included as a reference.

4.3.3. Support vessel

Support vessel 1/3-octave-band source levels used in this report were derived from measured levels of the *Setouchi Surveyor* (Hannay et al. 2004). The *Setouchi Surveyor* is 64.8 m long with an 11.3 m beam. It operates on 4600 HP while producing a broadband source level of 186.1 dB at a depth of 3.4 m. Its acoustic levels are believed to be representative of the support vessel's noise production for the specific activities near the FPSO facility site. The 1/3-octave-band spectra for the *Setouchi Surveyor* are shown in Figure 7.

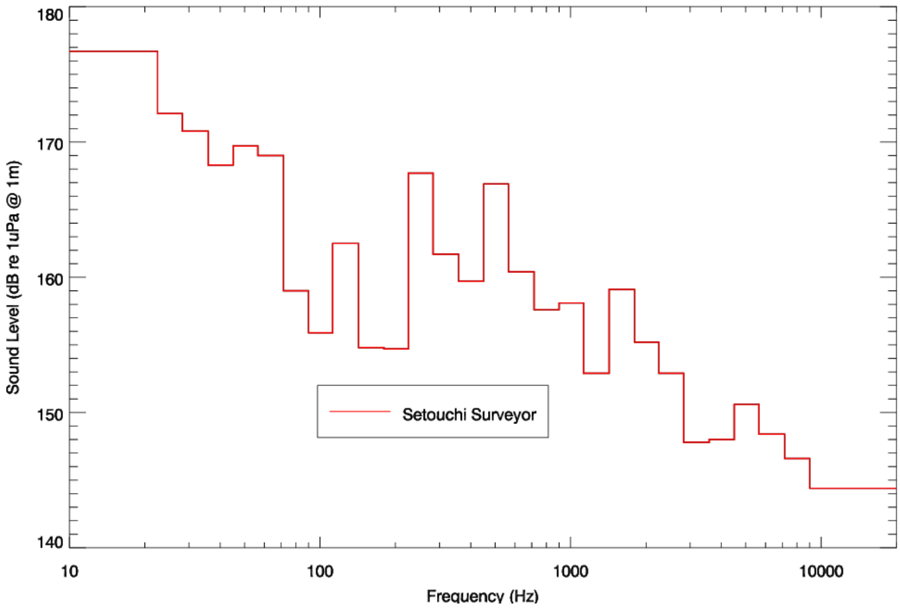


Figure 7. 1/3-octave-band source levels of side thruster on the *Setouchi Surveyor*.

Table 4. Vessels that will be engaged in the Barossa project during either scenario. The proxy vessel that was used to establish the broadband source level (indicated) is also provided for each proposed vessel.

Vessel type	Representative vessel			Proxy vessel	
	Power (kW)	Broadband SL (dB re 1 µPa at 1 m)	Source depth (m)	Vessel name	Total power (kW)
FSPO	N/A	173.9	17.4	*Ngujima* *Nganhurra*	27000 15800
FSPO (under DP)	6300	183.6	17.4	*Fu Lai*	9600
				Ngujima *Nganhurra*	27000 15800
Fuel Tanker	9400	182.4	7.2	*Fu Lai*	9600
Support Vessel	3400	184.1	3.4	*Setouchi Surveyor*	3400

Sound spectra for all vessels modelled in Scenario 2 are shown together in Figure 8.

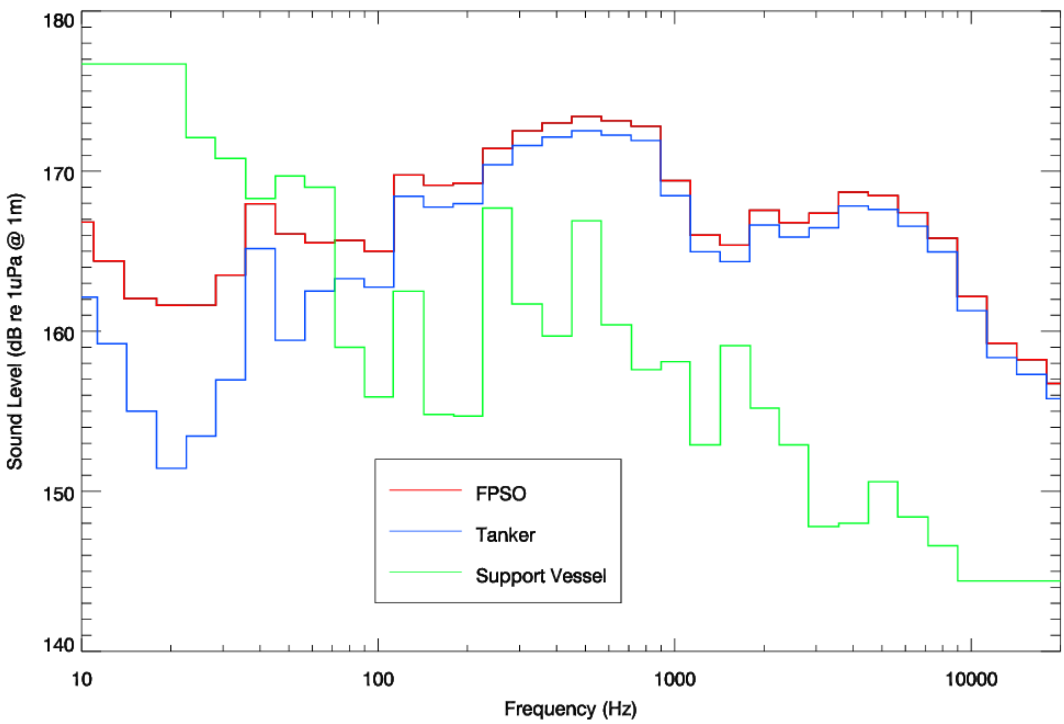


Figure 8. 1/3-octave-band source levels used to model Scenario 2.

4.4. Environmental Parameters

4.4.1. Bathymetry

High-accuracy bathymetry data for the Barossa field and the surrounding area with a regular grid spacing of 500 × 500 m was provided by ConocoPhillips. This dataset has been supplemented by bathymetry data extracted from a 250 × 250 m resolution grid of Australian waters (Whiteway 2009). For the modelling, bathymetry data for a 105 × 105 km area centred on the indicative FPSO facility site were extracted and re-gridded onto a grid with a regular spacing of 250 × 250 m. The resulting bathymetry and bathymetry extents is shown in Figure 9.

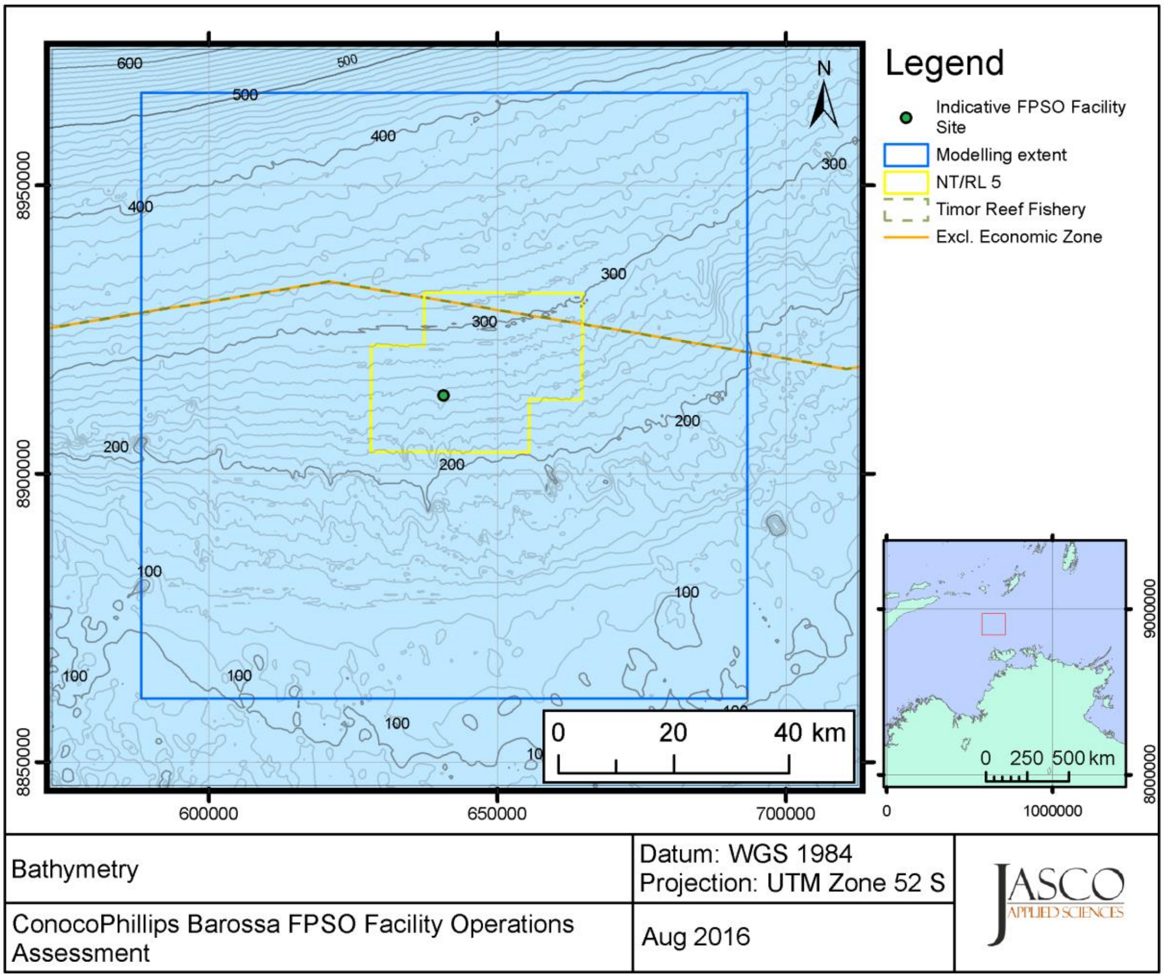


Figure 9. The bathymetry used for the modelling. The blue line indicates the extents of the modelling grid sampled at a 250 × 250 m resolution.

4.4.2. Geoacoustics

Geotechnical data were obtained from the ARUP report (Lane 2015) supplied to JASCO by ConocoPhillips, and a single geoacoustic profile representative of the top layer of sediment was derived from that analysis. The sediment thickness in the region is over 1200 m according to World Ocean Atlas (Whittaker et al. 2013). Consequently, it is assumed that at depths beyond 35 m, the sediment is composed of similar grain types. Parameters have been derived based on empirical relationships by Buckingham (2005). The geoacoustic profile used in the modelling is shown in Table 5.

Table 5. Estimated geoacoustic profile used in the modelling. Within each depth range, each parameter varies linearly within the stated range.

Depth below seafloor (m)	Material	Density (g/cm3)	P-wave speed (m/s)	P-wave attenuation (dB/λ)	S-wave speed (m/s)	S-wave attenuation (dB/λ)
0–9	Coarse Sand	2.09	1655.3 – 2133.8	0.76 – 1.46	322.7	0.246
9–35	Clay	1.46	1539.8 – 1582.9	0.33 – 0.51		
35–500	Medium Sand	2.08	2275.2 – 3453.2	1.73 – 2.82		

4.4.3. Sound speed profile

The sound speed profiles (SSPs) for the modelled sites were principally derived from temperature and salinity profiles provided to JASCO by ConocoPhillips comprising monthly data over the year. The data are provided for two sites although only sample depths from 33 m to the seafloor. The data is supplemented with results from the U.S. Naval Oceanographic Office's *Generalized Digital Environmental Model V 3.0* (GDEM; Teague et al. 1990, Carnes 2009). GDEM provides an ocean climatology of temperature and salinity for the world's oceans on a latitude-longitude grid with 0.25° resolution, with a temporal resolution of one month, based on global historical observations from the U.S. Navy's Master Oceanographic Observational Data Set (MOODS). The temperature-salinity profiles were converted to sound speed profiles according to the equations of Coppens (1981):

$$\begin{aligned} c(z,T,S,\phi) &= 1449.05 + 45.7t - 5.21t^2 - 0.23t^3 \\ &\quad + \left(1.333 - 0.126t + 0.009t^2\right)(S-35) + \Delta \\ \Delta &= 16.3Z + 0.18Z^2, \quad Z = \frac{z}{1000}\left[1 - 0.0026\cos(2\phi)\right], \quad t = \frac{T}{10} \end{aligned} \tag{3}$$

where z is water depth (m), T is temperature (°C), S is salinity (psu), and ϕ is latitude (radians).

For each monthly profile, the supplied data were extrapolated to provide results to the water surface based on the gradients of the profile from the GDEM data. The average of the SSPs taken across all months provides a representative SSP for the area across the year; this is shown in Figure 10.

The resulting SSP represents a mixed isothermal surface layer with a slight upward-refracting profile. Below 80 m depth the profile is driven by the reduction in temperature producing a steep downward-refracting profile. For depths within the modelling extent, no sound channel is realised in deeper waters.

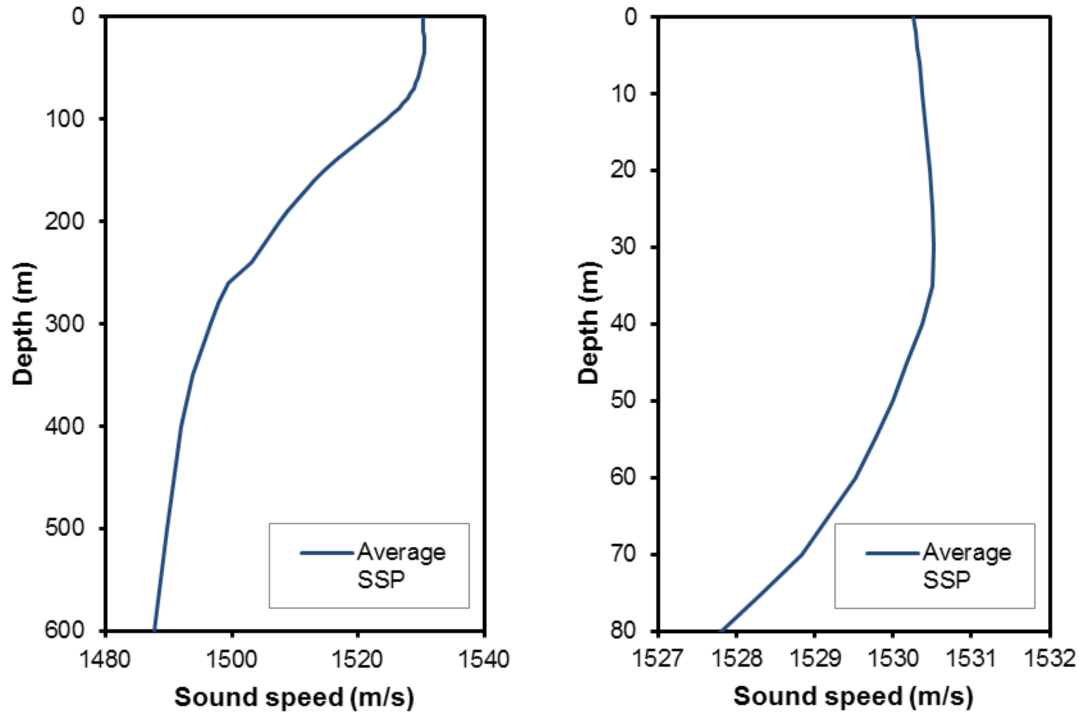


Figure 10. Sound speed profile used for the modelling taken as the average of all monthly profiles (a), and detail of the top 80 m of the SSP (b).

5. Modelling Results

Modelled sound levels were summed over all sources to obtain the total, maximum-over-depth anthropogenic sound footprints associated with operation of the FPSO facility in the Barossa field. The maximum-over-depth levels are presented as coloured isopleths for the sound level thresholds of interest. Sound isopleths are shown in separate maps for SPL and for SEL accumulated over the appropriate activity duration—for Scenario 1, 24 hrs for the FPSO facility option, and for Scenario 2, 24 hrs for the FPSO facility with tanker offload. The appropriate M-weighting was applied to assess the areas of potential impact for different marine species. Because the sources are distributed, the zones of potential impact are non-circular and therefore expressed as maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) for the pertinent thresholds for each species. $R_{95\%}$ is defined the radius of a circle that encompasses 95% of the area ensonified above a given threshold, and is often a more relevant distance to associate with a criterion because it ignores small, localised protrusions in the sound level contour that could force the maximum range to over-represent the effective extent of the sound exposure.

The maximum distances from either the FPSO facility or the centroid, to each of the thresholds are also provided. Where a noise level contour forms a single contiguous line around all three vessels, the R_{max} result is taken as the distance from the average of vessel location to the furthest distance at which the associated noise level is reached. Where the noise contours form separate zones of higher noise levels, the R_{max} result is taken as the maximum distance from any one vessel to its own noise contour at that level. This is illustrated graphically in Figure 11.

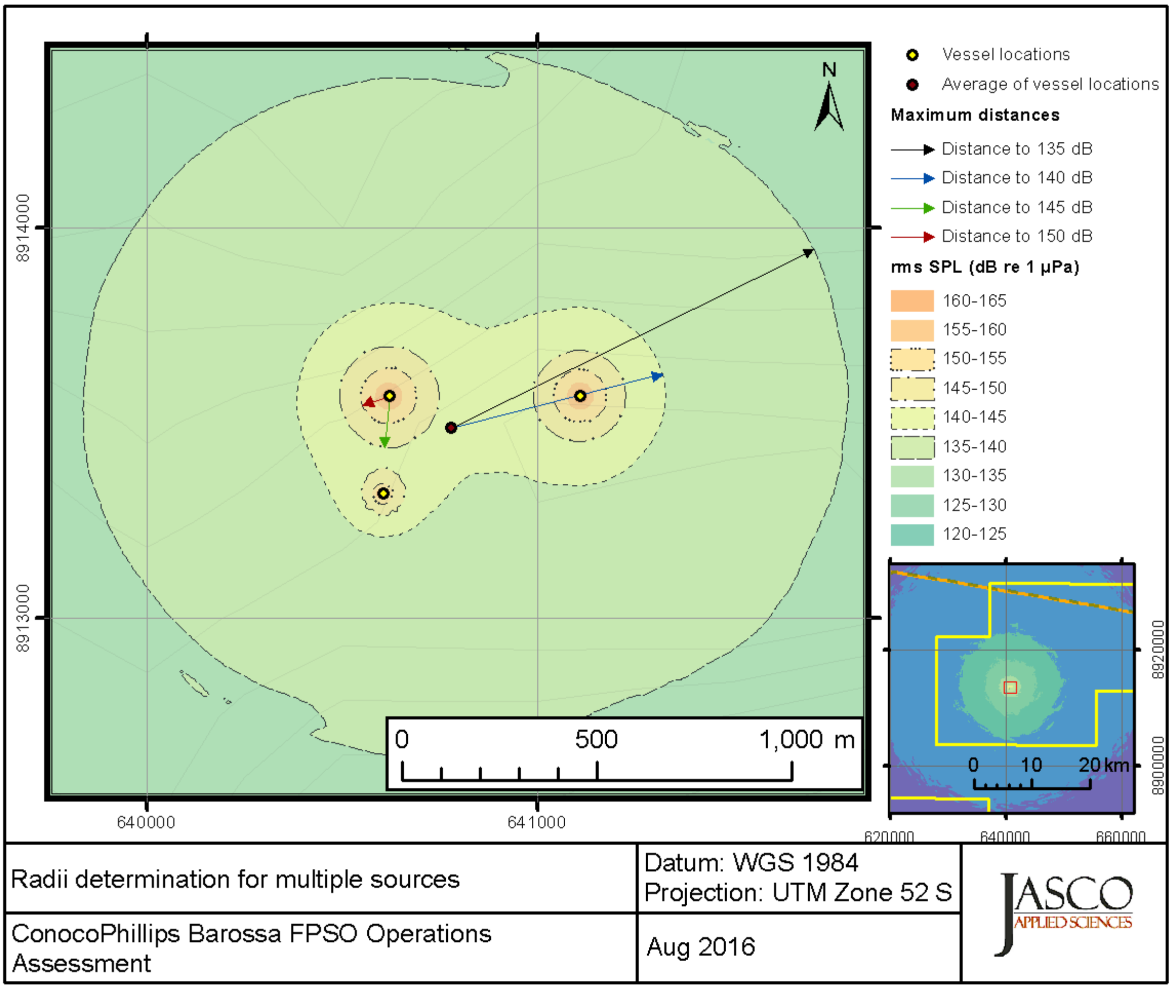


Figure 11. Determining the radii for multiple sources. Where the noise contour is a contiguous line around all sources, the average location (centroid) is assumed to be the source location for determining distances. Where the contours are separate areas around each vessel, the distances are determined from the original vessel locations.

5.1. Scenario 1

The modelling results associated with the 24 h operation of the proposed FPSO facility are presented in Tables 6–9, and shown graphically in Figures 12 and 13.

Table 6. Horizontal distances (in m) from the proposed FPSO facility to modelled maximum-over-depth unweighted SEL and SPL

Unweighted 24-hour SEL			SPL		
Threshold (dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Threshold (dB re 1 µPa)	R_{max} (m)	$R_{95\%}$ (m)
210	<10	<10	160	<10	<10
200	20	20	150	20	20
190	60	60	140	70	70
180	200	200	130	220	210
170	1400	1290	120	1420	1330
160	5890	5100	110	6460	5430
150	18600	15000	100	20900	16000

Table 7. Horizontal distances (in m) from the proposed FPSO facility to modelled maximum-over-depth weighted 24 h SEL

Low-frequency cetaceans			Mid-frequency cetaceans			High-frequency cetaceans		
Threshold (dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Threshold (dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Threshold (dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)
205	<10	<10	205	<10	<10	205	<10	<10
200	20	20	200	<10	<10	200	<10	<10
195	30	30	195	<10	<10	195	<10	<10
190	60	60	190	20	20	190	20	20
185	110	100	185	50	50	185	40	40
180	190	190	180	90	90	180	80	80
175	560	540	175	160	150	175	140	130
170	1380	1110	170	280	270	170	240	240
165	3210	2620	165	780	750	165	640	620
160	5880	4980	160	1840	1590	160	1400	1300
155	10100	9150	155	5150	4180	155	4330	3580
150	18500	14800	150	11300	8320	150	9520	7130

Table 8. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the proposed FPSO facility under normal operations to modelled maximum-over-depth SPL thresholds for marine mammals.

Threshold	Distance (km)	
	R_{max}	$R_{95\%}$
NMFS (2014) Behaviour, Unweighted SPL: 120 dB re 1 µPa	1.42	1.33

Table 9. Maximum horizontal distances (in m) from the proposed FPSO facility under normal operations to quantifiable thresholds for fish (Table 2). (Popper et al. (2014).

	Recoverable injury (170 dB SPL for 48 h)	TTS (158 dB SPL for 12 h)
	SPL (dB re 1 µPa)	SPL (dB re 1 µPa)
Fish: swim bladder involved in hearing	<10 m	<10 m

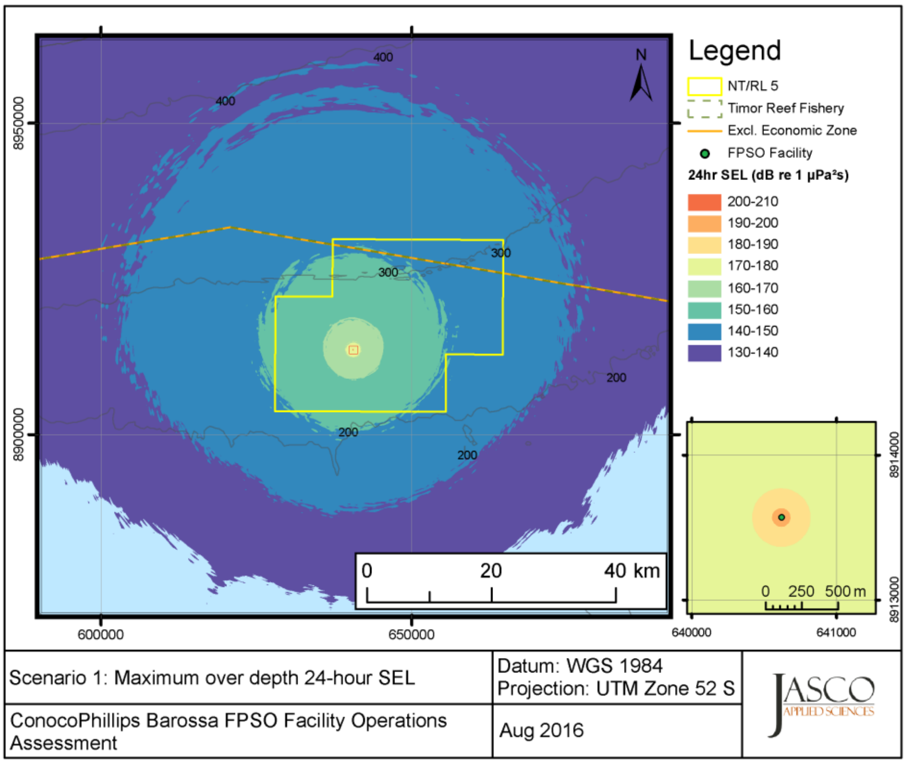
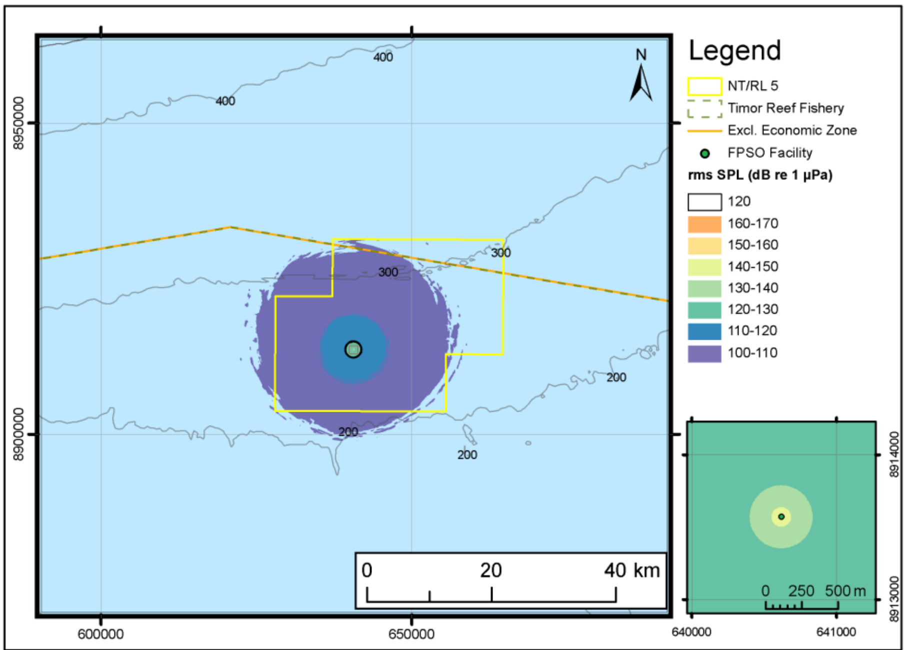


Figure 12. Scenario 1: Sound level contour map showing unweighted 24 h SEL results.



Scenario 1: Maximum over depth rms SPL	Datum: WGS 1984 Projection: UTM Zone 52 S	JASCO APPLIED SCIENCES
ConocoPhillips Barossa FPSO Facility Operations Assessment	Aug 2016	

Figure 13. Scenario 1: Sound level contour map showing unweighted SPL results and the SPL 120 dB behavioural disturbance threshold for cetaceans.

5.2. Scenario 2

The modelling results associated with the 24 h operation of the proposed FPSO facility with tanker offload are presented in Tables 10–13 and shown graphically in Figures 14 and 15.

Table 10. Horizontal distances (in m) from the proposed FPSO facility during offload to modelled maximum-over-depth unweighted SEL and SPL. Levels indicated by an asterisk (*) show distances from individual sources instead of the average of source locations.

Unweighted 24-hour SEL			SPL		
Threshold (dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Threshold (dB re 1 µPa)	R_{max} (m)	$R_{95\%}$ (m)
210*	<20	<20	160*	<20	<20
200*	70	60	150*	70	70
190	540	470	140	560	490
180	1860	1660	130	2120	1840
170	10800	8330	120	11400	8880
160	28900	23400	110	29200	24800
150	>50000	>50000	100	>50000	>50000

Table 11. Horizontal distances (in m) from the proposed FPSO facility during offload to modelled maximum-over-depth weighted 24 h SEL. Levels indicated by an asterisk (*) show distances from individual sources instead of the average of source locations.

Low-frequency cetaceans			Mid-frequency cetaceans			High-frequency cetaceans		
Threshold (dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Threshold (dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Threshold (dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)
210*	<20	<20	210*	<20	<20	210*	<20	<20
205*	30	30	205*	30	30	205*	30	30
200*	70	60	200*	60	60	200*	60	50
195*	120	110	195*	110	100	195*	100	100
190	540	470	190	520	460	190*	200	180
185	970	880	185	740	640	185	680	600
180	1830	1640	180	1390	1250	180	1310	1160
175	5610	4140	175	4340	3440	175	4110	2790
170	10800	8280	170	9160	6980	170	9040	6480
165	17100	14100	165	15000	12300	165	15000	11800
160	28900	23300	160	25200	20800	160	24200	19600
155	46100	36600	155	41900	32500	155	37700	30800
150	>50000	>50000	150	>50000	>50000	150	>50000	>50000

Table 12. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the proposed FPSO facility offloading to modelled maximum-over-depth SPL thresholds for marine mammals.

Threshold	Distance (km)	
	R_{max}	$R_{95\%}$
NMFS (2014) Behaviour, Unweighted SPL: 120 dB re 1 µPa	11.4	8.9

Table 13. Maximum horizontal distances (in m) from the proposed FPSO facility offloading to quantifiable thresholds for fish (Table 2). (Popper et al. (2014).

	Recoverable injury (170 dB SPL for 48 h)	TTS (158 dB SPL for 12 h)
	SPL (dB re 1 µPa)	SPL (dB re 1 µPa)
Fish: swim bladder involved in hearing	<10 m	<10 m

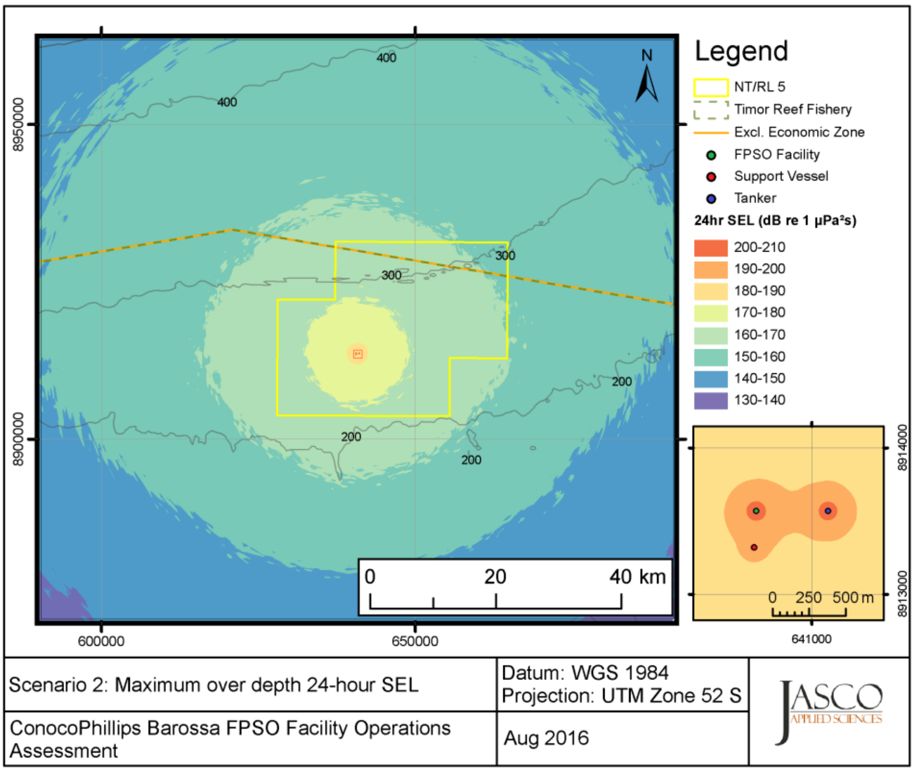


Figure 14. Scenario 2: Sound level contour map showing unweighted 24 h SEL results.

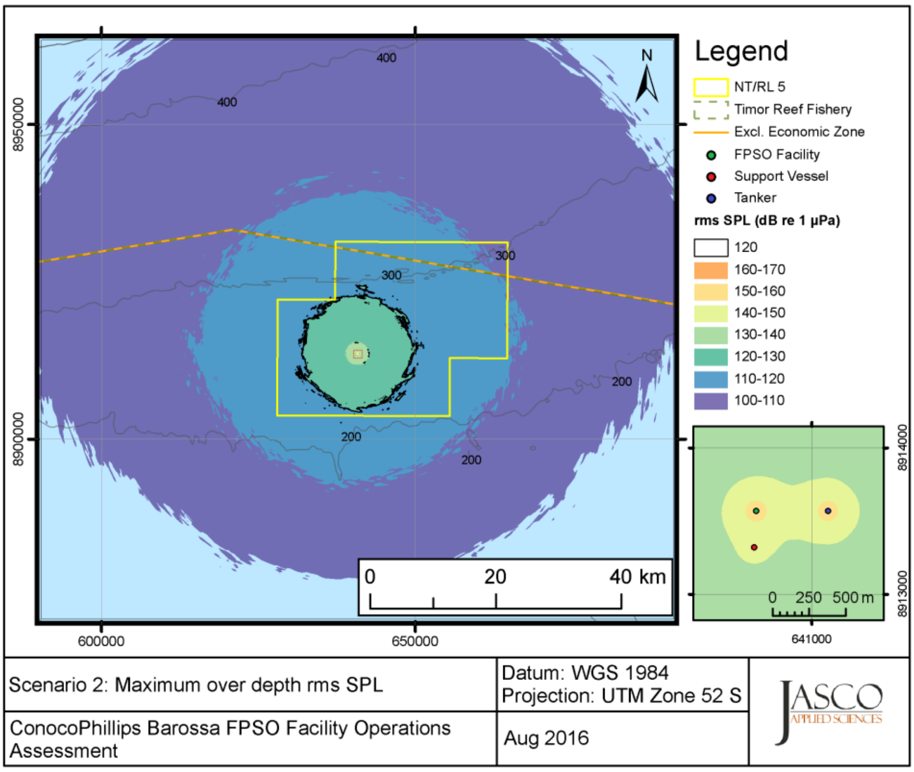


Figure 15. Scenario 2: Sound level contour map showing unweighted SPL results and the SPL 120 dB behavioural disturbance threshold for cetaceans.

6. Discussion

6.1. Relation to Ambient Soundscape

To characterise the soundscape, and determine typical ambient sound levels in the region, JASCO conducted a 12-month acoustic monitoring program at locations within and surrounding the Barossa field location (McPherson et al. 2016). For the purposed of the assessment the data periods influenced by the drilling program are excluded. This excludes the data recorded at one station (Station J2) from four months of Deployment 1.

The levels reported in the tables below are broadband, 10 Hz–24 kHz, and considered representative of typical ambient conditions. The minimum levels of ambient sound were consistent across all stations, with a mean minimum 1-min SPL of 81.4 dB re 1 µPa (s=1.4 dB). The mean median (L_{50}) and mean fifth percentile (L_{5}) 1-min SPL's were 96.7 dB re 1 µPa (s=3.1 dB) and 107.9 dB re 1 µPa (s=3.3 dB). The mean maximum at all stations was 145.5 dB re 1 µPa (s=2 dB). The median daily SELs from the ambient monitoring program (Table 14) were computed for periods from Deployment 1 not influenced by the Mobile Offshore Drilling Unit (MODU), and for all of Deployment 2, which overall was less influenced by the MODU. The mean median from all stations is 151.4 dB re 1 µPa²·s, accounting for the deployment duration. The mean maximum daily SEL from the two stations furthest from the MODU is 170.8 dB re 1 µPa²·s (s = 3.4 dB).

Table 14. Median daily SELs throughout the full deployment period but excluding periods influenced by drilling operations. SEL units: dB re 1 µPa²·s.

Station	Deployment 1 (without MODU periods)	Deployment 2
J1	149.4	151.9
J2	150.6	153.8
J3	146.3	152.8

The modelling outputs from Section 5 can be compared to the typical ambient noise conditions in the Barossa region in order understand the estimated sound levels in the acoustic context of the region in which the activity is proposed. This comparison can assist in assessing the impacts of the survey in terms of masking, non-auditory effects and behavioural impacts

Estimating the ranges at which the modelled SPLs and daily SELs from the proposed FPSO facility are equivalent to measurements from the acoustic monitoring program (as discussed above) provides an understanding of the spatial extent over which the sound from the activities exceeds the normal conditions (Tables 15 and 16).

Table 15. $R_{95\%}$ and R_{max} distances to SPL thresholds

Monitoring program representative equivalent sound level	Modelling study isopleth	Scenario 1		Scenario 2	
	SPL (dB re 1 µPa)	$R_{95\%}$ Distance (km)	R_{max} Distance (km)	$R_{95\%}$ Distance (km)	R_{max} Distance (km)
Mean maximum (145.5 dB, s=2)	140	0.07	0.07	0.49	0.56
Mean 5th percentile (107.9 dB, s=3.3)	110	5.4	6.5	24.8	29
Mean median (96.7 dB, s=3.1)	100	16	20.9	54	66

Table 16. $R_{95\%}$ and R_{max} distances to unweighted daily SEL levels

Scenario	Mean median daily SEL (~150 dB re 1 µPa²·s)		Mean maximum daily SEL (~170 dB re 1 µPa²·s)	
	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)
1	15	18.5	1.29	1.4
2	52.5	62	8.33	10.8

6.2. Potential Impacts to Marine Fauna

As the FPSO facility be present in the Barossa field year-round, the potential impacts of the operations should be considered over the entire year. To understand the usage of and movements through the region by marine mammals and fish JASCO conducted a baseline acoustic monitoring program over a period of 12 months in the Barossa field and surrounds (McPherson et al. 2016). The key findings of the monitoring program are outlined below, with further detail provided in McPherson et al. (2016):

- Pygmy blue whales were detected during their northward migration once in August 2014, primarily over the period 29 May-5 June 2015, and also on the 16 and 30 June, and 1 July 2015. The detections are over 400 km further east than the north-bound migration corridor of pygmy blue whales described in Double et al. (2014). No detections were logged from the south-bound migration, suggesting a different migration path. The highest calling rates of the three monitoring station occurred at the Barossa field, which may reflect its greater depth and proximity to the trench.
- Omura's whales, identified through descriptions of their acoustic repertoire by Cerchio et al. (2015), were present consistently from April to September inclusive (with detections increasing from February, and fading out in early November), with a peak in June and July. Based on the year of recordings, the whales seemed to enter the region in a south-west to north-east direction, then maintain a higher presence within the Barossa field area (than compared to the Evans Shoal or Caldita areas) for the autumn and winter months. They appeared to leave the region in a north-east to south-west direction, reversing their entry path, leaving the area by the end of October.
- Bryde's whales, assumed to be the source of downsweeping calls detected, and distinguished from the Omura's whales through variations in the spatial and temporal occurrence of vocalisations, were present in the region from summer (January) to the following spring (October). They appear to move into the area in a south to north direction during summer and autumn, then utilise the region with a preference for the shallower sections (Evans Shoal and Caldita field areas) over the Barossa field region. They then left the area in a north – south direction, with the last detections in early October.
- Odontocetes were extremely common. Many species were detected on a daily basis, with a primarily nocturnal diel cycle. Although systematic species differentiation was not performed, pilot whales were opportunistically identified.
- Beaked whales of an unknown species were detected on four days over the entire program at the stations at the Barossa and Caldita fields.
- Fish chorused at dawn and dusk over the entire deployment period at all three stations. Their chorusing varied in intensity over the deployment period, but was reasonably consistent in diel patterns.

6.2.1. Marine Mammals

If any marine mammals are exposed to sound levels above the PTS thresholds, auditory injury might result, which in extreme cases could lead to death as marine mammals rely on hearing to communicate with conspecifics, find food and/or avoid predators. However, as the 24 h PTS threshold ranges for all marine mammal hearing groups are less than 20 m (the minimum modelling resolution), the likelihood that any marine mammal will find itself at such close proximity to the source for hours on end is negligible. It is therefore expected that marine mammals will not experience PTS from any of the operations associated with the proposed FPSO facility. It is possible that behavioural responses could occur within 1.33 or 1.42 km during normal FPSO facility operations and 8.9 or 11.4 km during offload operations ($R_{95\%}$ and R_{max} distances respectively) using the 120 dB re 1 µPa NMFS criterion.

From the summary presented in Section 3.1, it is expected that there will be a reduced behavioural response to the proposed FPSO facility as it is stationary, in comparison to a moving and/or transient sound source, and that for resident animals there might be partial habituation. Should any resident animals spend long periods of time in the area (i.e. months) there might be partial habituation. However, the area of possible behavioural response in comparison to the available habitat is small, and therefore potential impacts are unlikely. The probability of the FPSO facility operations having a negative impacting on mysticetes marine mammals due to alteration of their migratory path to avert the immediate region of activities is considered low, given the presence nearby of similar oceanic environments and the natural width of the migratory corridors.

Due to the extremely limited use of the region by beaked whales, as determined by the acoustic monitoring program, it appears unlikely that they will interact with the FPSO facility activities to a significant extent at any time.

Aside from potentially inducing some avoidance or other behavioural reactions, the FPSO facility operations could result in longer-range acoustic masking effects. Masking due to anthropogenic sounds cannot be determined based on the broadband accumulated sound exposure level, because the effect depends on the spectral noise level within the frequency band of the sounds in question and therefore varies dynamically with receiver distance from the sound (noise) source. Masking is typically reported as a percent reduction of active acoustic space (Clark et al. 2009). In order to estimate the reduction quantitatively it is necessary to take into account parameters such as call source levels (and the adaptive compensation of the same in the presence of competing noise, known as Lombard response), detection thresholds based on the receiver perception capabilities, signal directivity, band-specific (spectral) noise levels, and noise and signal duration. The relationship between communication space and the health of the pygmy blue, Omura's and Bryde's whales is presently unknown, but it is reasonable to assume that communication serves an important purpose, as it does in other marine mammals, (e.g. attracting, mates, identifying and tracking offspring, and maintaining group structure) and that disruption in communication could affect an individual's and possibly a population's health. Adding anthropogenic noise decreases the communication space, so the possible effects of anthropogenic noise on Bryde's whales can be inferred by examining the reduction in the amount of communication space. A quantitative assessment is beyond the scope of the present work and therefore a qualitative assessment of masking is done here.

The $R_{95\%}$ exceedance distance (Table 15) for the 140 dB isopleth, used as a conservative surrogate for the mean maximum 1-minute measured ambient SPL of 146 dB re 1 µPa, was 0.07 and 8.9 km in for normal and offloading operations respectively. The calls from mysticetes known to use the area are typically at least several seconds in duration (15–25 seconds for blue whales, 2–10 seconds for Omura's and 0.5–2 seconds for Bryde's) (McPherson et al. 2016). The continuous nature of the sound from FPSO facility operations and its progressive increase in level with decreasing range from the facility will result in complete masking of calls within a certain boundary. The area over which this occurs will vary depending upon the vocalising marine mammal (pygmy blue, Omura's, Bryde's or odontocetes); a quantitative estimation is beyond the scope of this assessment. However, odontocetes will likely only experience masking for the low frequency components of their calls; this effect will be limited to the local area surrounding the facility and is not expected to influence the whales' ability to echolocate when feeding due to the frequency range of their echolocation clicks. Pygmy blue whales, Omura's and Bryde's whales will experience masking when in the vicinity of the FPSO facility, and given the lower vocalisation source levels for the latter two species, the area over which masking will occur will be larger than for pygmy blue whales. Masking from the FPSO facility activities is expected to be more relevant for Omura's and Bryde's whales because of their more regular presence within the region encompassing the Barossa field from summer through to early spring, whereas the migratory pygmy blue whales will only be affected for a short period of time.

Generally, the spatial and temporal scale of behavioural response effects on marine mammals would be limited to the localised area surrounding the proposed FPSO facility and the periods of intensified activities. These ranges will be greater during offload operations. Because the facility will be located at a static site, and therefore only influence a small region within the Timor Sea not known to be a critical habitat, significant effects at the population level are not expected.

6.2.2. Fishes

Sound produced by the FPSO and associated operations, such as offload activities, could cause physiological effects, and recoverable injury, to some fish species, but only if the animals are in very close proximity to the sound sources–within a planar distance of 10 m. No population-level effects would be expected given the restricted zone of pathological effects. Temporary impairment due to TTS could occur at similar short ranges if fish remain at the same point within the sound field for long periods of time (12 h). However, there is a tendency for fish to aggregate around oil and gas structures, particularly in featureless environments such as where the FPSO facility will be located (Rabaoui et al. 2015). Masking could occur within thousands of metres under a worst-case scenario (moderate risk, Table 2), however typically any effect will be limited to within hundreds of metres.

The same arguments about temporal and spatial scale of behaviour effects that were made for marine mammals (Section 6.2.1) can be applied to fish. Therefore, adverse behavioural effects on various life stages of fish caused by the operation of the FPSO facility are expected to be negligible.

6.2.3. Turtles

Despite the limited amount of literature available (Section 2.4), it is expected that the sound produced by the FPSO facility and associated operations, such as offload activities, has a low probability of inducing injury to turtles. No population-level effects would be expected given the restricted zone of pathological effects. Temporary impairment due to TTS could occur at close ranges (within tens of metres).

The same arguments about temporal and spatial scale of behaviour effects that were made for marine mammals (Section 6.2.1) and applied to fish can also be applied to turtles. Therefore, adverse behavioural effects on turtles caused by the operation of the FPSO facility are expected to be negligible. Although turtles are known to vocalise (Ferrara et al. 2014a, Ferrara et al. 2014b, Guinea et al. 2014), any masking effects will likely be restricted to ranges within hundreds of metres.

Generally, the temporal and spatial scale of behavioural response on turtles would likely be short-term and limited to the localised area surrounding the FPSO facility operations. Because of the small spatial scale of the area of effect, adverse effects on sea turtles caused by exposure to the FPSO facility are expected to be negligible.

6.2.4. Plankton, Fish Eggs, and Fish Larvae

The impacts on these species are expected to be extremely low, with mortality rates caused by exposure to operational sounds being low compared to natural mortality. Any impacts that do occur are likely to only occur in very close proximity (< 5 m) to the FPSO facility, the range at which they are likely to suffer mortality and tissue damage, and the proportion of population that can reasonably be expected to be effected will be miniscule. These impacts are considered to be very small.

6.2.5. Sea Snakes

Sea snakes are unlikely in the operational area, as most sea snakes have shallow benthic feeding patterns and are rarely found in water depths exceeding 30 m (Cogger 1975). However, very little is known about the distribution of the individual species of sea snakes in the region. Given the water depths and distance offshore it is unlikely that sea snakes will be present around the FPSO facility. However, if sea snakes were to be encountered, sound produced by the FPSO facility could cause physiological effects, or recoverable injury, if they are within a planar distance of 10 m, using fish as a surrogate.

6.2.6. Marine Invertebrates

There is no marine invertebrate fishery in the region. A study undertaken by Jacobs (2016) on benthic communities in the Barossa field and surrounds observed that benthic macrofauna groups appeared in relatively low numbers while infaunal communities were characterised by burrowing taxa and were present in low abundance and species diversity. The impact on marine invertebrates is expected to be confined to close to the FPSO facility, and using fish as a surrogate, confined to within a planar distance of 10 m of the facility. The probability of impacts occurring is expected to be small, and overall impacts limited.

6.3. Summary

Direct impacts associated with the proposed FPSO facility due to elevated noise levels are expected to primarily relate to masking the communication of marine mammals. There are not expected to be any ecologically significant impacts on marine mammals, fish, turtles, sea snakes or marine invertebrates.

Glossary

1/3-octave-band
Non-overlapping passbands that are one-third of an octave wide (where an octave is a doubling of frequency). Three adjacent 1/3-octave-bands make up one octave. One-third-octave-bands become wider with increasing frequency. Also see octave.

90%-energy time window
The time interval over which the cumulative energy rises from 5% to 95% of the total pulse energy. This interval contains 90% of the total pulse energy. Symbol: T_{90}.

90% root-mean-square sound pressure level (90% rms SPL)
The root-mean-square sound pressure levels calculated over the 90%-energy time window of a pulse. Used only for pulsed sounds.

attenuation
The gradual loss of acoustic energy from absorption and scattering as sound propagates through a medium.

audiogram
A graph of hearing threshold level (sound pressure levels) as a function of frequency, which describes the hearing sensitivity of an animal over its hearing range.

auditory weighting function (frequency-weighting function)
Auditory weighting functions account for marine mammal hearing sensitivity. They are applied to sound measurements to emphasise frequencies that an animal hears well and de-emphasise frequencies they hear less well or not at all (Southall et al. 2007, Finneran and Jenkins 2012, NOAA 2013).

azimuth
A horizontal angle relative to a reference direction, which is often magnetic north or the direction of travel. In navigation it is also called bearing.

bandwidth
The range of frequencies over which a sound occurs. Broadband refers to a source that produces sound over a broad range of frequencies (e.g., seismic airguns, vessels) whereas narrowband sources produce sounds over a narrow frequency range (e.g., sonar) (ANSI/ASA S1.13-2005 R2010).

bar
Unit of pressure equal to 100 kPa, which is approximately equal to the atmospheric pressure on Earth at sea level. 1 bar is equal to $10^{6\ \mathrm{Pa}}$ or $10^{11\ \mu\mathrm{Pa}}$.

cetacean
Any animal in the order Cetacea. These are aquatic, mostly marine mammals and include whales, dolphins, and porpoises.

compressional wave
A mechanical vibration wave in which the direction of particle motion is parallel to the direction of propagation. Also called primary wave or P-wave.

communication space
A communication space assessment considers the region of ocean within which marine fauna can detect calls from conspecifics.

decibel (dB)
One-tenth of a bel. Unit of level when the base of the logarithm is the tenth root of ten, and the quantities concerned are proportional to power (ANSI S1.1-1994 R2004).

frequency
The rate of oscillation of a periodic function measured in cycles-per-unit-time. The reciprocal of the period. Unit: hertz (Hz). Symbol: *f*. 1 Hz is equal to 1 cycle per second.

functional hearing group
Grouping of marine mammal species with similar estimated hearing ranges. Southall et al. (2007) proposed the following functional hearing groups: low-, mid-, and high-frequency cetaceans, pinnipeds in water, and pinnipeds in air.

geoacoustic
Relating to the acoustic properties of the seabed.

hearing threshold
The sound pressure level that is barely audible for a given individual in the absence of significant background noise during a specific percentage of experimental trials.

hertz (Hz)
A unit of frequency defined as one cycle per second.

high-frequency cetacean
The functional hearing group that represents odontocetes specialised for using high frequencies.

impulsive sound
Sound that is typically brief and intermittent with rapid (within a few seconds) rise time and decay back to ambient levels (NOAA 2013, ANSI S12.7-1986 R2006). For example, seismic airguns and impact pile driving.

listening space
The term listening area, refers to the distance (three dimensionally) over which sources of sound can be detected by an animal at the centre of the space.

low-frequency cetacean
The functional hearing group that represents mysticetes (baleen whales).

mid-frequency cetacean
The functional hearing group that represents some odontocetes (dolphins, toothed whales, beaked whales, and bottlenose whales).

M-weighting
The process of band-pass filtering loud sounds to reduce the importance of inaudible or less-audible frequencies for broad classes of marine mammals. “Generalized frequency weightings for various functional hearing groups of marine mammals, allowing for their functional bandwidths and appropriate in characterizing auditory effects of strong sounds” (Southall et al. 2007).

mysticete
Mysticeti, a suborder of cetaceans, use their baleen plates, rather than teeth, to filter food from water. They are not known to echolocate, but use sound for communication. Members of this group include rorquals (Balaenopteridae), right whales (Balaenidae), and the grey whale (*Eschrichtius robustus*).

non-impulsive sound
Sound that is broadband, narrowband or tonal, brief or prolonged, continuous or intermittent, and typically does not have a high peak pressure with rapid rise time (typically only small fluctuations in decibel level) that impulsive signals have (ANSI/ASA S3.20-1995 R2008). Marine vessels, aircraft, machinery, construction, and vibratory pile driving are examples.

octave
The interval between a sound and another sound with double or half the frequency. For example, one octave above 200 Hz is 400 Hz, and one octave below 200 Hz is 100 Hz.

odontocete
The presence of teeth, rather than baleen, characterises these whales. Members of the Odontoceti are a suborder of cetaceans, a group comprised of whales, dolphins, and porpoises. The toothed whales' skulls are mostly asymmetric, an adaptation for their echolocation. This group includes sperm whales, killer whales, belugas, narwhals, dolphins, and porpoises.

parabolic equation method
A computationally-efficient solution to the acoustic wave equation that is used to model transmission loss. The parabolic equation approximation omits effects of back-scattered sound, simplifying the computation of transmission loss. The effect of back-scattered sound is negligible for most ocean-acoustic propagation problems.

peak sound pressure level (peak SPL)
The maximum instantaneous sound pressure level, in a stated frequency band, within a stated period. Also called zero-to-peak sound pressure level. Unit: decibel (dB).

permanent threshold shift (PTS)
A permanent loss of hearing sensitivity caused by excessive noise exposure. PTS is considered auditory injury.

pinniped
A common term used to describe all three groups that form the superfamily Pinnipedia: phocids (true seals or earless seals), otariids (eared seals or fur seals and sea lions), and walrus.

point source
A source that radiates sound as if from a single point (ANSI S1.1-1994 R2004).

power spectrum density
The acoustic signal power per unit frequency as measured at a single frequency. Unit: $\mu Pa^2/Hz$, or $\mu Pa^2 \cdot s$.

power spectrum density level
The decibel level ($10\log_{10}$) of the power spectrum density, usually presented in 1 Hz bins. Unit: dB re 1 $\mu Pa^2/Hz$.

pressure, acoustic
The deviation from the ambient hydrostatic pressure caused by a sound wave. Also called overpressure. Unit: pascal (Pa). Symbol: *p*.

pulsed sound
Discrete sounds with durations less than a few seconds. Sounds with longer durations are called continuous sounds.

received level
The sound level measured at a receiver.

rms
root-mean-square.

rms sound pressure level (SPL)
The root-mean-square average of the instantaneous sound pressure as measured over some specified time interval. For continuous sound, the time interval is one second. Also see sound pressure level (SPL) and 90% rms SPL.

shear wave
A mechanical vibration wave in which the direction of particle motion is perpendicular to the direction of propagation. Also called secondary wave or S-wave. Shear waves propagate only in solid media,

such as sediments or rock. Shear waves in the seabed can be converted to compressional waves in water at the water-seabed interface.

signature
Pressure signal generated by a source.

sound
A time-varying pressure disturbance generated by mechanical vibration waves travelling through a fluid medium such as air or water.

sound exposure
Time integral of squared, instantaneous frequency-weighted sound pressure over a stated time interval or event. Unit: pascal-squared second ($Pa^2 \cdot s$) (ANSI S1.1-1994 R2004).

sound exposure level (SEL)
A measure related to the sound energy in one or more pulses. Unit: dB re 1 $\mu Pa^2 \cdot s$.

sound field
Region containing sound waves (ANSI S1.1-1994 R2004).

sound pressure level (SPL)
The decibel ratio of the time-mean-square sound pressure, in a stated frequency band, to the square of the reference sound pressure (ANSI S1.1-1994 R2004).

For sound in water, the reference sound pressure is one micropascal (p_0 = 1 µPa) and the unit for SPL is dB re 1 µPa:

$$\text{SPL} = 10\log_{10}\left(p^2/p_0^2\right) = 20\log_{10}\left(p/p_0\right)$$

Unless otherwise stated, SPL refers to the root-mean-square sound pressure level (rms SPL).

sound speed profile (SSP)
The speed of sound in the water column as a function of depth below the water surface.

source level (SL)
The sound pressure level measured 1 meter from a theoretical point source that radiates the same total sound power as the actual source. Unit: dB re 1 µPa @ 1 m.

spectrum
An acoustic signal represented in terms of its power (or energy) distribution versus frequency.

temporary threshold shift (TTS)
Temporary loss of hearing sensitivity caused by excessive noise exposure.

transmission loss (TL)
Also called propagation loss, this refers to the decibel reduction in sound level between two stated points that results from sound spreading away from an acoustic source subject to the influence of the surrounding environment.

wavelength
Distance over which a wave completes one oscillation cycle. Unit: meter (m). Symbol: λ.

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Appendix O.

EPBC Act Protected Matters database searches

Australian Government
Department of the Environment and Energy

EPBC Act Protected Matters Report

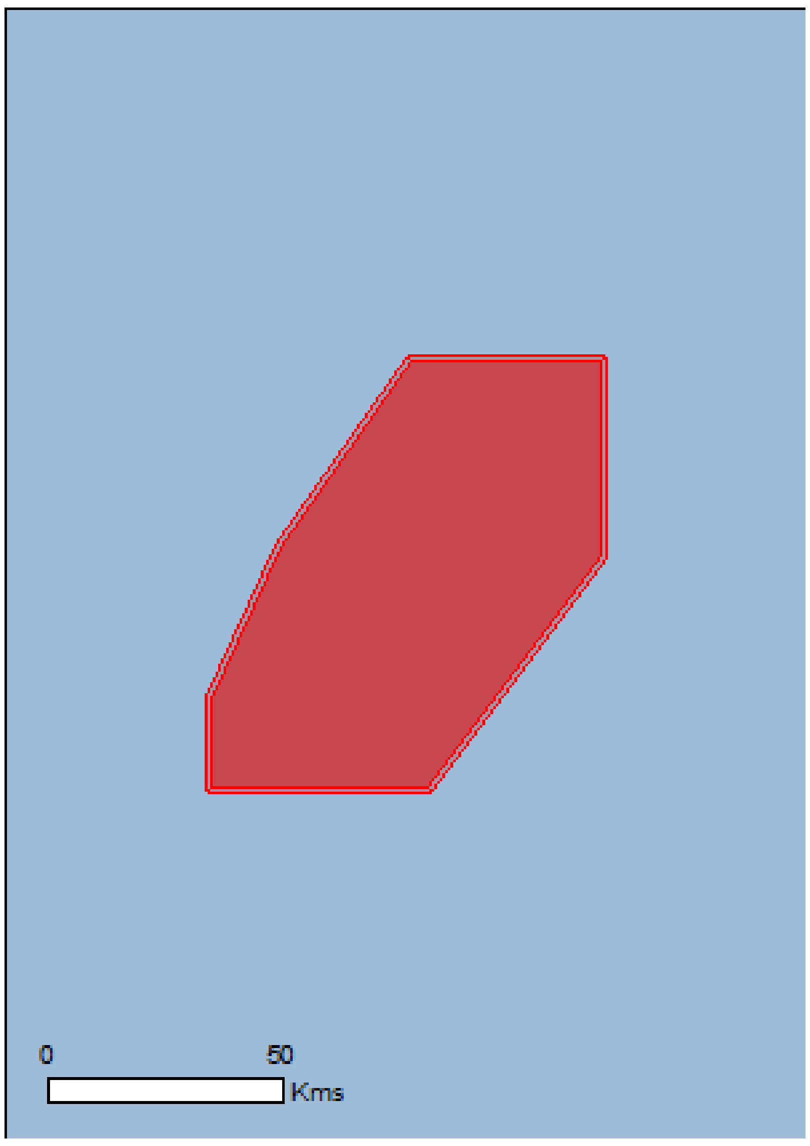
This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

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: 04/03/17 12:36:08

- Summary
- Details
  - Matters of NES
  - Other Matters Protected by the EPBC Act
  - Extra Information
- Caveat
- Acknowledgements



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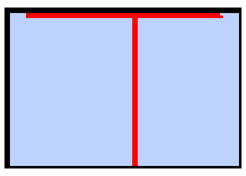

Summary

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:	2
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	18
Listed Migratory Species:	29

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:	61
Whales and Other Cetaceans:	24
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Commonwealth Reserves Marine:	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
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

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
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 known 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
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat known to occur within area
Sharks		
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Glyphis garricki Northern River Shark, New Guinea River Shark [82454]	Endangered	Species or species habitat may occur within area
Glyphis glyphis Speartooth Shark [82453]	Critically Endangered	Species or species habitat may occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	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
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat may occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat may occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
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 may 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 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 likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Species or species habitat likely to occur within area
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat may occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat 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 pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area

Name	Threatened	Type of Presence
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
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat may occur within area
Migratory Wetlands Species		
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area

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		
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat may occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat may occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		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
Fish		
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Corythoichthys intestinalis Australian Messmate Pipefish, Banded Pipefish [66202]		Species or species habitat may occur within area
Corythoichthys schultzi Schultz's Pipefish [66205]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus dunckeri Red-hair Pipefish, Duncker's Pipefish [66220]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
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

Name	Threatened	Type of Presence
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Solenostomus paegnius Rough-snout Ghost Pipefish [68425]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat likely 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

Name	Threatened	Type of Presence
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Enhydrina schistosa Beaked Seasnake [1126]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Hydrophis atriceps Black-headed Seasnake [1101]		Species or species habitat may occur within area
Hydrophis coggeri Slender-necked Seasnake [25925]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis inornatus Plain Seasnake [1107]		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
Hydrophis pacificus Large-headed Seasnake, Pacific Seasnake [1112]		Species or species habitat may occur within area
Lapemis hardwickii Spine-bellied Seasnake [1113]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat known to occur within area
Parahydrophis mertoni Northern Mangrove Seasnake [1090]		Species or species habitat may 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 bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat may occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area

Name	Status	Type of Presence
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
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
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	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 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

Name	Status	Type of Presence
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat may occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

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
Shelf break and slope of the Arafura Shelf	North

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

-9.44851 130.2694,-9.44851 130.63227,-9.81332 130.63227,-10.25088 130.30138,-10.25086 129.88964,-10.08383 129.88822,-9.79931 130.02065,-9.44851 130.2694

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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Department of the Environment and Energy

EPBC Act Protected Matters Report

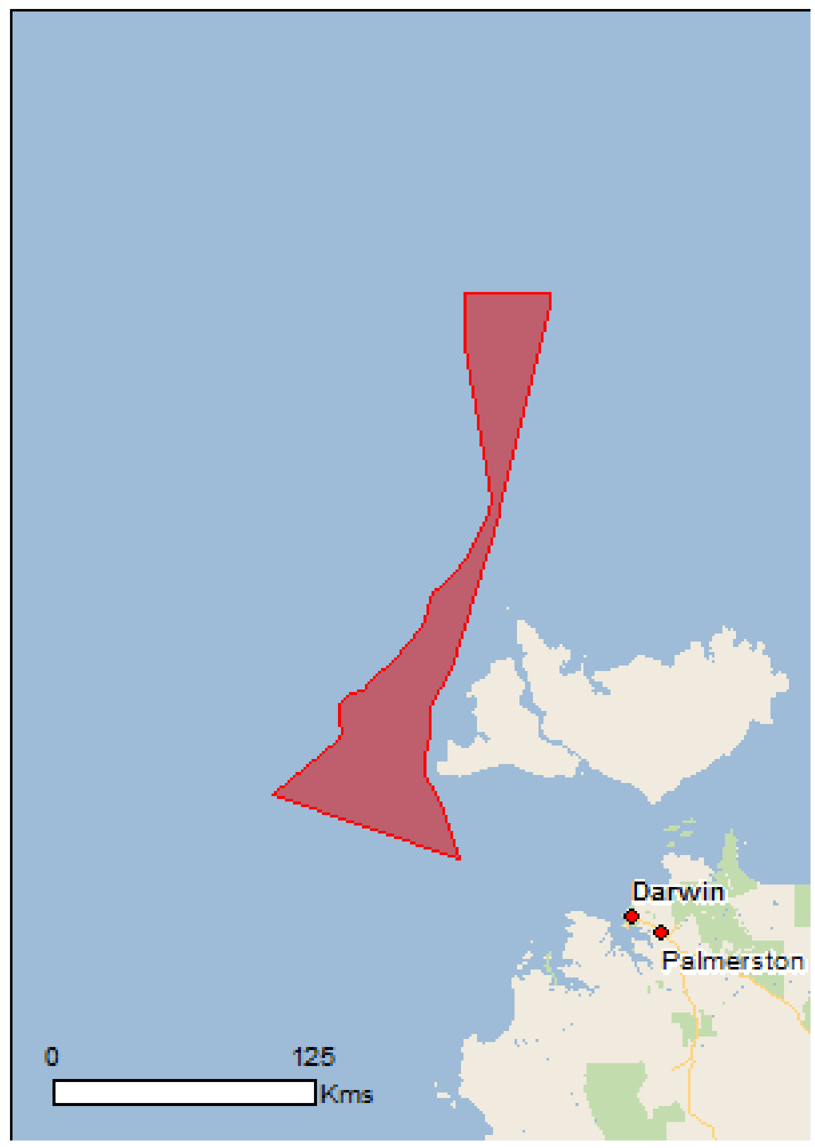
This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

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.

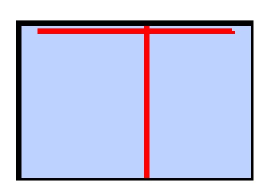
Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 04/03/17 12:32:08

- Summary
- Details
  - Matters of NES
  - Other Matters Protected by the EPBC Act
  - Extra Information
- Caveat
- Acknowledgements



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:	19
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:	72
Whales and Other Cetaceans:	26
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Commonwealth Reserves Marine:	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)	2

Details

Matters of National Environmental Significance

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside the Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Name
EEZ and Territorial Sea

Marine Regions [Resource Information]

If you are planning to undertake action in an area in or close to the Commonwealth Marine Area, and a marine bioregional plan has been prepared for the Commonwealth Marine Area in that area, the marine bioregional plan may inform your decision as to whether to refer your proposed action under the EPBC Act.

Name
North

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
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 likely to occur within area
Reptiles		
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Name	Status	Type of Presence
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Eretmochelys imbricata		
Hawksbill Turtle [1766]	Vulnerable	Congregation or aggregation known to occur within area
Lepidochelys olivacea		
Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Congregation or aggregation known to occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sharks		
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Glyphis garricki		
Northern River Shark, New Guinea River Shark [82454]	Endangered	Species or species habitat may occur within area
Glyphis glyphis		
Speartooth Shark [82453]	Critically Endangered	Species or species habitat may occur within area
Pristis clavata		
Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	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 may occur within area
Fregata ariel		
Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Fregata minor		
Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat likely to occur within area
Migratory Marine Species		

Name	Threatened	Type of Presence
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat may 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 may 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 known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour 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
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Congregation or aggregation 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 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 likely to occur within area

Name	Threatened	Type of Presence
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Orcaella brevirostris Irrawaddy Dolphin [45]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
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 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		
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat may occur within area
Thalasseus bergii Crested Tern [83000]		Breeding likely to 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		
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat likely to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat may occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat likely to 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 bergii Crested Tern [816]		Breeding likely to occur within area
Fish		
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Corythoichthys haematopterus Reef-top Pipefish [66201]		Species or species habitat may occur within area
Corythoichthys intestinalis Australian Messmate Pipefish, Banded Pipefish [66202]		Species or species habitat may occur within area
Corythoichthys schultzi Schultz's Pipefish [66205]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Festucalex cinctus Girdled Pipefish [66214]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus dunckeri Red-hair Pipefish, Duncker's Pipefish [66220]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys cyanospilos Blue-speckled Pipefish, Blue-spotted Pipefish [66228]		Species or species habitat may occur within area
Hippichthys parvicarinatus Short-keel Pipefish, Short-keeled Pipefish [66230]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Solenostomus paegnius Rough-snout Ghost Pipefish [68425]		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 duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur

Name	Threatened	Type of Presence
		within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Enhydrina schistosa Beaked Seasnake [1126]		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 atriceps Black-headed Seasnake [1101]		Species or species habitat may occur within area
Hydrophis coggeri Slender-necked Seasnake [25925]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis inornatus Plain Seasnake [1107]		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
Hydrophis pacificus Large-headed Seasnake, Pacific Seasnake [1112]		Species or species habitat may occur within area
Lapemis hardwickii Spine-bellied Seasnake [1113]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Congregation or aggregation known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Name	Threatened	Type of Presence
Parahydrophis mertoni Northern Mangrove Seasnake [1090]		Species or species habitat may 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 bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat may 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 may 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
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
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat likely to occur within area
Orcaella brevirostris Irrawaddy Dolphin [45]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area

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 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
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

Commonwealth Reserves Marine [Resource Information]

Name	Label
Oceanic Shoals	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
Carbonate bank and terrace system of the Van	North
Shelf break and slope of the Arafura Shelf	North

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

-11.74427 129.97067,-11.7778 129.96148,-11.80994 129.96379,-11.83678 129.97452,-11.85143 129.98488,-11.93115 130.03075,-12.16758 130.11149,-11.8982 129.31533,-11.65935 129.60258,-11.643 129.60878,-11.61601 129.60814,-11.59285 129.59596,-11.55453 129.59305,-11.52714 129.60018,-11.50128 129.61397,-11.47933 129.63352,-11.46736 129.65495,-11.45756 129.69583,-11.44737 129.70997,-11.42055 129.72885,-11.32672 129.83647,-11.19037 129.95982,-11.11535 129.97469,-11.11534 129.97469,-11.07394 129.98779,-11.07393 129.9878,-11.04411 130.00458,-11.0441 130.00459,-11.01478 130.02951,-11.01477 130.02951,-10.94705 130.09999,-10.90675 130.14041,-10.71397 130.24675,-10.65016 130.2522,-9.99839 130.13863,-9.77788 130.13788,-9.77612 130.50095,-9.8311 130.50042,-10.67787 130.29322,-10.71756 130.28656,-11.36558 130.08105,-11.5309 129.99,-11.64372 129.99,-11.74427 129.97067

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

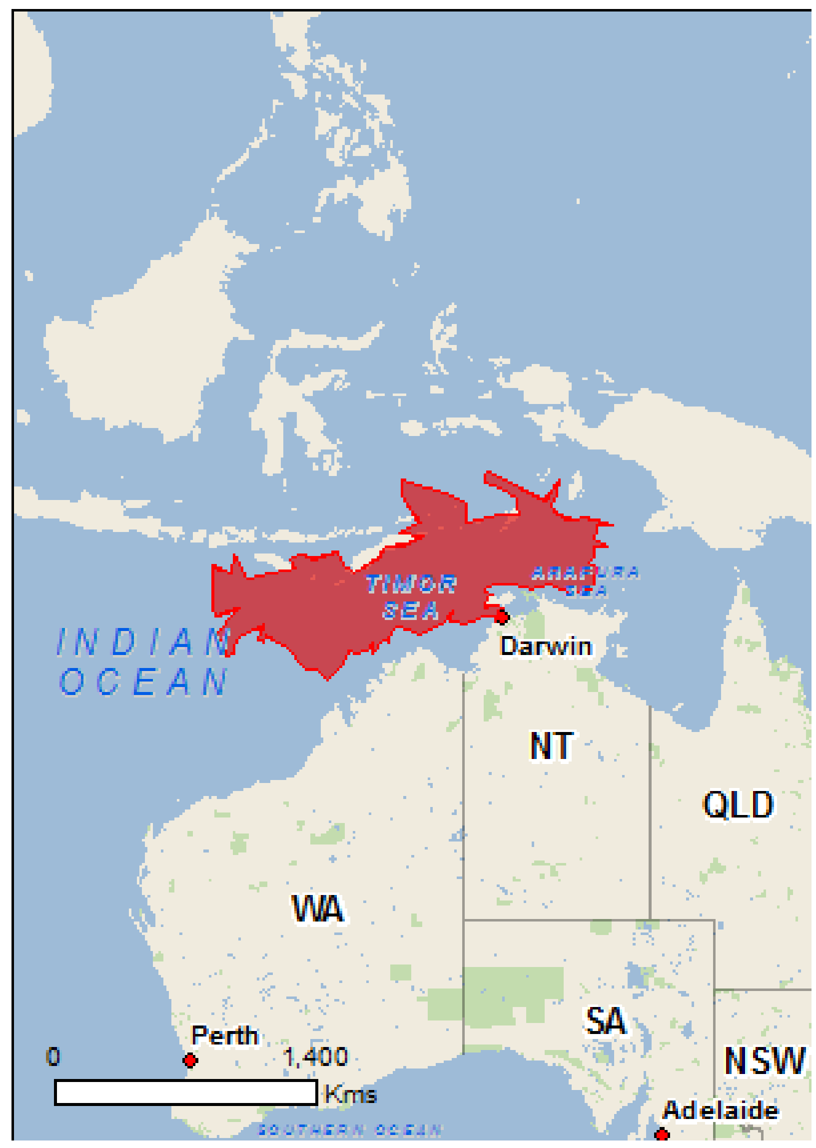
This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

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.

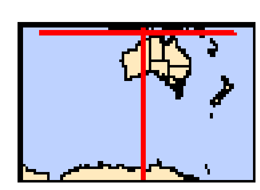
Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 31/05/17 22:11:17

- Summary
- Details
  - Matters of NES
  - Other Matters Protected by the EPBC Act
  - Extra Information
- Caveat
- Acknowledgements



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:	1
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	2
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	53
Listed Migratory Species:	71

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:	3
Commonwealth Heritage Places:	4
Listed Marine Species:	121
Whales and Other Cetaceans:	30
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Commonwealth Reserves Marine:	7

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	1
Regional Forest Agreements:	None
Invasive Species:	30
Nationally Important Wetlands:	1
Key Ecological Features (Marine)	10

Details

Matters of National Environmental Significance

Wetlands of International Importance (Ramsar)	[Resource Information]
Name	Proximity
Ashmore reef national nature reserve	Within Ramsar site

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside the Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Name
EEZ and Territorial Sea
Extended Continental Shelf

Marine Regions [Resource Information]

If you are planning to undertake action in an area in or close to the Commonwealth Marine Area, and a marine bioregional plan has been prepared for the Commonwealth Marine Area in that area, the marine bioregional plan may inform your decision as to whether to refer your proposed action under the EPBC Act.

Name
North
North-west

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Species or species habitat likely to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat likely to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Species or species habitat likely to occur within area
Erythrotriorchis radiatus Red Goshawk [942]	Vulnerable	Species or species habitat known to occur within area
Erythrura gouldiae Gouldian Finch [413]	Endangered	Species or species habitat known to occur within area

Name	Status	Type of Presence
Geophaps smithii smithii Partridge Pigeon (eastern) [64441]	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 may occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Bar-tailed Godwit (menzbieri) [86432]	Critically Endangered	Species or species habitat may occur within area
Melanodryas cucullata melvillensis Tiwi Islands Hooded Robin, Hooded Robin (Tiwi Islands) [67092]	Endangered	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
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area
Tyto novaehollandiae kimberli Masked Owl (northern) [26048]	Vulnerable	Species or species habitat likely to occur within area
Tyto novaehollandiae melvillensis Tiwi Islands Masked Owl [26049]	Endangered	Species or species habitat known to occur within area
Mammals		
Antechinus bellus Fawn Antechinus [344]	Vulnerable	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 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
Conilurus penicillatus Brush-tailed Rabbit-rat, Brush-tailed Tree-rat, Pakooma [132]	Vulnerable	Species or species habitat known to occur within area
Dasyurus hallucatus Northern Quoll, Digul [331]	Endangered	Species or species habitat known to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Mesembriomys gouldii gouldii Black-footed Tree-rat (Kimberley and mainland Northern Territory), Djintamoonga, Manbul [87618]	Endangered	Species or species habitat likely to occur within area

Name	Status	Type of Presence
Mesembriomys gouldii melvillensis Black-footed Tree-rat (Melville Island) [87619]	Vulnerable	Species or species habitat likely to occur within area
Mesembriomys macrurus Golden-backed Tree-rat, Koorrawal [119]	Vulnerable	Species or species habitat may occur within area
Petrogale concinna canescens Nabarlek (Top End) [87606]	Endangered	Species or species habitat may occur within area
Phascogale pirata Northern Brush-tailed Phascogale [82954]	Vulnerable	Species or species habitat likely to occur within area
Saccolaimus saccolaimus nudicluniatus Bare-rumped Sheath-tailed Bat, Bare-rumped Sheathtail Bat [66889]	Vulnerable	Species or species habitat likely to occur within area
Sminthopsis butleri Butler's Dunnart [302]	Vulnerable	Species or species habitat likely to occur within area
Xeromys myoides Water Mouse, False Water Rat, Yirrkoo [66]	Vulnerable	Species or species habitat known to occur within area
Plants		
Burmannia sp. Bathurst Island (R.Fensham 1021) [82017]	Endangered	Species or species habitat likely to occur within area
Typhonium jonesii a herb [62412]	Endangered	Species or species habitat likely to occur within area
Typhonium mirabile a herb [79227]	Endangered	Species or species habitat may occur within area
Xylopia monosperma a shrub [82030]	Endangered	Species or species habitat likely to occur within area
Reptiles		
Acanthophis hawkei Plains Death Adder [83821]	Vulnerable	Species or species habitat known to occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour 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	Congregation or aggregation known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area

Name	Status	Type of Presence
Lepidochelys olivacea		
Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Breeding known to occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Sharks		
Carcharodon carcharias		
White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Glyphis garricki		
Northern River Shark, New Guinea River Shark [82454]	Endangered	Species or species habitat may occur within area
Glyphis glyphis		
Speartooth Shark [82453]	Critically Endangered	Species or species habitat may occur within area
Pristis clavata		
Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus		
Common Noddy [825]		Breeding known to occur within area
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardenna pacifica		
Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Calonectris leucomelas		
Streaked Shearwater [1077]		Species or species habitat may occur within area
Fregata ariel		
Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor		
Great Frigatebird, Greater Frigatebird [1013]		Breeding known to occur within area
Hydroprogne caspia		
Caspian Tern [808]		Breeding known to occur within area
Onychoprion anaethetus		
Bridled Tern [82845]		Breeding known to occur within area
Phaethon lepturus		
White-tailed Tropicbird [1014]		Breeding known to occur within area
Phaethon rubricauda		
Red-tailed Tropicbird [994]		Breeding known to occur within area

Name	Threatened	Type of Presence
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons Little Tern [82849]		Congregation or aggregation known to occur within area
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Sula sula Red-footed Booby [1023]		Breeding known to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat may 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 may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Congregation or aggregation 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

Name	Threatened	Type of Presence
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Breeding 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	Breeding known to occur within area
Orcaella brevirostris Irrawaddy Dolphin [45]		Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
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 known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Breeding known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		
Cecropis daurica Red-rumped Swallow [80610]		Species or species habitat may occur within area
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur

Name	Threatened	Type of Presence
		within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat likely to occur within area
Migratory Wetlands Species		
Acrocephalus orientalis Oriental Reed-Warbler [59570]		Species or species habitat known to occur within area
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Species or species habitat likely to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris alba Sanderling [875]		Species or species habitat likely 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 tenuirostris Great Knot [862]	Critically Endangered	Species or species habitat likely to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat likely to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Species or species habitat likely to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		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
Numenius phaeopus Whimbrel [849]		Species or species habitat likely to occur

Name	Threatened	Type of Presence
		within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Pluvialis squatarola Grey Plover [865]		Species or species habitat likely to occur within area
Thalasseus bergii Crested Tern [83000]		Breeding known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Land [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Name
Commonwealth Land -
Defence - LARRAKEYAH BARRACKS
Defence - Patrol Boat Base (DARWIN NAVAL BASE)

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Natural		
Ashmore Reef National Nature Reserve	EXT	Listed place
Scott Reef and Surrounds - Commonwealth Area	EXT	Listed place
Historic		
Larrakeyah Barracks Headquarters Building	NT	Listed place
Larrakeyah Barracks Precinct	NT	Listed place

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Acrocephalus orientalis Oriental Reed-Warbler [59570]		Species or species habitat known to occur within area
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous minutus Black Noddy [824]		Breeding known to occur within area
Anous stolidus Common Noddy [825]		Breeding known to occur within area
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Anseranas semipalmata Magpie Goose [978]		Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area

Name	Threatened	Type of Presence
Ardea alba Great Egret, White Egret [59541]		Species or species habitat known to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Arenaria interpres Ruddy Turnstone [872]		Species or species habitat likely to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris alba Sanderling [875]		Species or species habitat likely 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 tenuirostris Great Knot [862]	Critically Endangered	Species or species habitat likely to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat may occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat likely to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Species or species habitat likely to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
Cuculus saturatus Oriental Cuckoo, Himalayan Cuckoo [710]		Species or species habitat known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Breeding known to occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Hirundo daurica Red-rumped Swallow [59480]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Species or species habitat likely to occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to 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 phaeopus Whimbrel [849]		Species or species habitat likely to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Breeding known to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Pluvialis squatarola Grey Plover [865]		Species or species habitat likely to occur within area
Puffinus pacificus Wedge-tailed Shearwater [1027]		Breeding known to occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat likely to occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat may occur within area
Sterna albifrons Little Tern [813]		Congregation or aggregation known to occur within area
Sterna anaethetus Bridled Tern [814]		Breeding known to occur within area
Sterna bengalensis Lesser Crested Tern [815]		Breeding known to occur within area
Sterna bergii Crested Tern [816]		Breeding known to occur

Name	Threatened	Type of Presence
		within area
Sterna caspia Caspian Tern [59467]		Breeding known to occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Sula sula Red-footed Booby [1023]		Breeding known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area
Fish		
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Corythoichthys haematopterus Reef-top Pipefish [66201]		Species or species habitat may occur within area
Corythoichthys intestinalis Australian Messmate Pipefish, Banded Pipefish [66202]		Species or species habitat may occur within area
Corythoichthys schultzi Schultz's Pipefish [66205]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Festucalex cinctus Girdled Pipefish [66214]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus dunckeri Red-hair Pipefish, Duncker's Pipefish [66220]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys cyanospilos Blue-speckled Pipefish, Blue-spotted Pipefish [66228]		Species or species habitat may occur within area
Hippichthys parvicarinatus Short-keel Pipefish, Short-keeled Pipefish [66230]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Solenostomus paegnius Rough-snout Ghost Pipefish [68425]		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 foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus fuscus Dusky Seasnake [1119]		Species or species habitat known to occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Crocodylus johnstoni Freshwater Crocodile, Johnston's Crocodile, Johnston's River Crocodile [1773]		Species or species habitat may occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area

Name	Threatened	Type of Presence
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Congregation or aggregation 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
Enhydrina schistosa Beaked Seasnake [1126]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis atriceps Black-headed Seasnake [1101]		Species or species habitat may occur within area
Hydrophis coggeri Slender-necked Seasnake [25925]		Species or species habitat may occur within area
Hydrophis czeblukovi Fine-spined Seasnake [59233]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis inornatus Plain Seasnake [1107]		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
Hydrophis pacificus Large-headed Seasnake, Pacific Seasnake [1112]		Species or species habitat may occur within area
Lapemis hardwickii Spine-bellied Seasnake [1113]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Breeding known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Parahydrophis mertoni Northern Mangrove Seasnake [1090]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans		[Resource Information]
Name	Status	Type of Presence
Mammals		
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat may 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 may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
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	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
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area
Orcaella brevirostris Irrawaddy Dolphin [45]		Species or species

Name	Status	Type of Presence
		habitat known to 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 may occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Breeding known to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
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

Commonwealth Reserves Marine [Resource Information]

Name	Label
Arafura	Multiple Use Zone (IUCN VI)
Arnhem	Special Purpose Zone (IUCN VI)
Ashmore Reef	Recreational Use Zone (IUCN II)
Ashmore Reef	Sanctuary Zone (IUCN Ia)
Cartier Island	Sanctuary Zone (IUCN Ia)
Kimberley	Multiple Use Zone (IUCN VI)
Oceanic Shoals	Multiple Use Zone (IUCN VI)

Extra Information

State and Territory Reserves	[Resource Information]
Name	State
Scott Reef	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		
Acridotheres tristis Common Myna, Indian Myna [387]		Species or species habitat likely to occur within area
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Passer domesticus House Sparrow [405]		Species or species habitat likely to occur within area
Passer montanus Eurasian Tree Sparrow [406]		Species or species habitat likely to occur within area
Sturnus vulgaris Common Starling [389]		Species or species habitat likely to occur within area
Frogs		
Rhinella marina Cane Toad [83218]		Species or species habitat likely to occur within area
Mammals		
Bos taurus Domestic Cattle [16]		Species or species habitat likely to occur within area
Bubalus bubalis Water Buffalo, Swamp Buffalo [1]		Species or species habitat likely to occur within area
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area
Equus caballus Horse [5]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Sus scrofa Pig [6]		Species or species

Name	Status	Type of Presence
		habitat likely to occur within area
Plants		
Andropogon gayanus Gamba Grass [66895]		Species or species habitat likely to occur within area
Annona glabra Pond Apple, Pond-apple Tree, Alligator Apple, Bullock's Heart, Cherimoya, Monkey Apple, Bobwood, Corkwood [6311]		Species or species habitat may occur within area
Brachiaria mutica Para Grass [5879]		Species or species habitat likely to occur within area
Cabomba caroliniana Cabomba, Fanwort, Carolina Watershield, Fish Grass, Washington Grass, Watershield, Carolina Fanwort, Common Cabomba [5171]		Species or species habitat likely to occur within area
Cenchrus ciliaris Buffel-grass, Black Buffel-grass [20213]		Species or species habitat may occur within area
Dolichandra unguis-cati Cat's Claw Vine, Yellow Trumpet Vine, Cat's Claw Creeper, Funnel Creeper [85119]		Species or species habitat likely to occur within area
Hymenachne amplexicaulis Hymenachne, Olive Hymenachne, Water Stargrass, West Indian Grass, West Indian Marsh Grass [31754]		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
Lantana camara Lantana, Common Lantana, Kamara Lantana, Large-leaf Lantana, Pink Flowered Lantana, Red Flowered Lantana, Red-Flowered Sage, White Sage, Wild Sage [10892]		Species or species habitat likely to occur within area
Mimosa pigra Mimosa, Giant Mimosa, Giant Sensitive Plant, ThornySensitive Plant, Black Mimosa, Catclaw Mimosa, Bashful Plant [11223]		Species or species habitat likely to occur within area
Parkinsonia aculeata Parkinsonia, Jerusalem Thorn, Jelly Bean Tree, Horse Bean [12301]		Species or species habitat likely to occur within area
Pennisetum polystachyon Mission Grass, Perennial Mission Grass, Missiongrass, Feathery Pennisetum, Feather Pennisetum, Thin Napier Grass, West Indian Pennisetum, Blue Buffel Grass [21194]		Species or species habitat likely to occur within area
Salvinia molesta Salvinia, Giant Salvinia, Aquarium Watermoss, Kariba Weed [13665]		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
Lepidodactylus lugubris Mourning Gecko [1712]		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

Name	State
Ashmore Reef	EXT

Key Ecological Features (Marine) [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Carbonate bank and terrace system of the Van	North
Pinnacles of the Bonaparte Basin	North
Shelf break and slope of the Arafura Shelf	North
Tributary Canyons of the Arafura Depression	North
Ancient coastline at 125 m depth contour	North-west
Ashmore Reef and Cartier Island and surrounding	North-west
Carbonate bank and terrace system of the Sahul	North-west
Continental Slope Demersal Fish Communities	North-west
Pinnacles of the Bonaparte Basin	North-west
Seringapatam Reef and Commonwealth waters in	North-west

Caveat
The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates
-9.07350858968 135.267801657,-9.56854392301 135.241042991,-9.72909592301 135.053732324,-10.0769585897 135.401594991,-10.6790285897 135.281180991,-11.0652073318 135.110177035,-11.1550786216 134.185355976,-10.9921854669 133.551634662,-10.8114410075 133.268245201,-10.7846640506 133.127666177,-10.9051603568 132.717086171,-10.9029289438 132.585432799,-11.0220461668 132.261540147,-10.7593045897 131.254001657,-10.7994425897 130.518138324,-10.8807126417 130.166854987,-11.2119405833 130.037219263,-11.2905836612 130.216040122,-11.2850751582 130.395984553,-11.3034368349 130.407001559,-11.347504859 130.245418804,-11.4732864315 130.124517467,-11.7567433333 129.967721111,-11.8594459838 130.054918943,-11.8437301881 130.566804861,-11.8689764771 130.895422159,-11.9167168365 130.930309345,-11.9938358786 130.627341679,-12.4924755648 130.829571314,-12.2820981237 130.62040404,-12.489557334 130.537117496,-12.3312705534 130.478167433,-12.3312681707 129.973998404,-12.5039128305 129.398516205,-12.7053316004 129.082000995,-12.5614610505 128.362648245,-12.029140016 128.43458352,-12.6477833804 127.945423651,-13.13694325 126.780072197,-12.9499115351 126.247751162,-12.7628798203 125.801752458,-13.0506209201 125.514011358,-13.5541678446 125.427689028,-13.4102972947 125.154334983,-13.9857794942 124.679562169,-13.5110066797 124.636401004,-13.8994571643 124.319885794,-14.0048282472 123.796253007,-13.944953023 123.45696007,-14.4893264188 123.226469615,-15.2374532781 122.420794536,-14.8202286835 121.931634666,-14.8058416285 121.413700687,-13.7099449113 120.436233131,-13.5110066797 119.989382243,-13.2232655799 119.514609428,-13.5259647633 119.411194465,-13.4663811224 119.175568249,-12.7341057103 119.413900043,-12.9495780441 119.015483926,-13.1522128342 118.373897444,-13.6836513395 117.96080749,-14.0513841419 117.986603779,-14.1759681183 117.610143502,-13.5685548996 117.399712345,-13.2664267449 116.95371364,-11.8819982732 118.246474997,-12.1076128294 117.770521002,-12.2881070057 117.111971245,-11.8325485075 116.951509257,-9.97179115275 116.996874805,-10.2595322525 117.84571105,-9.38192189827 117.9895816,-10.4897251323 118.608224964,-10.2883063625 119.744802308,-10.1875969776 120.478542112,-10.0421782923 120.871712137,-9.64246052301 120.700850796,-9.3531477883 121.183507807,-9.59399999027 121.794880393,-9.32437367832 122.909954405,-9.87018215614 123.258187851,-10.3026934175 123.73001654,-9.56895361311 124.952916213,-9.06540668855 125.298205533,-8.96469730364 126.175815887,-8.47143858968 127.066270324,-8.34605393918 125.873687733,-7.92882934455 126.880781582,-6.66276850566 126.003171228,-5.79491110644 126.09123906,-6.64838145067 128.52090585,-7.02244488034 129.168323325,-7.89355910834 129.168323325,-7.55324035029 130.83457951,-7.53889668997 131.662620951,-7.02244488034 131.585348563,-6.69154261563 131.527800343,-6.25993096601 130.808447593,-5.97218986626 130.045933679,-5.64128760155 129.959611349,-5.51180410666 130.232965394,-6.90734844044 132.894570566,-5.84270637137 133.599536261,-6.64838145067 133.412504546,-6.93612255042 133.254246941,-7.36773420004 133.383730436,-7.69863646475 133.858503251,-7.81373290465 134.333276065,-7.57502325634 134.812904324,-8.05667925634 136.150837657,-8.05743406397 135.329054892,-8.4323762691 135.412305189,-8.63379503893 135.210886419,-9.06540668855 135.944626224,-9.07350858968 135.267801657

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 P.

Potential Impacts of Pipeline Installation Activities on Marine Turtles (Pendoley 2017)

CDM Smith

ConocoPhillips Barossa Project – Potential Impacts of Pipeline Installation Activities on Marine Turtles

REV 1

Prepared by

Pendoley Environmental Pty Ltd

For

CDM Smith

6th June 2017

PENDOLEY ENVIRONMENTAL
MARINE CONSERVATION ENVIRONMENTAL SERVICES

DOCUMENT CONTROL INFORMATION

TITLE: ConocoPhillips Barossa Project – Potential Impacts of Pipeline Installation Activities on Marine Turtles

Disclaimer and Limitation

This report has been prepared on behalf of and for the use of CDM Smith. Pendoley Environmental Pty Ltd. takes no responsibility for the completeness or form of any subsequent copies of this Document. Copying of this Document without the permission of CDM Smith is not permitted.

Document History

Revision	Description	Date issued	Date received	Personnel
Draft	Report Draft	26/05/2017		Dr K Pendoley
Rev A	Internal Review	25/05/2017	29/09/2017	Dr C Bell/Dr P Whittock
Rev D	Client review	29/05/2017		K McCann
Rev 0	Final report issued	31/05/2017		Dr K Pendoley
Rev 1	Minor updates	6/06/2017		Dr K Pendoley

Printed:	6 June 2017
Last saved:	6 June 2017 07:05 PM
File name:	P:\06 Projects\J54 CDM Smith\05 Projects\J54001\Report\J54001 Technical Note REV 1.docx
Author:	Dr K Pendoley
Project manager:	Dr K Pendoley
Name of organisation:	Pendoley Environmental Pty Ltd
Name of project:	ConocoPhillips Barossa Project
Client	CDM Smith
Client representative:	K McCann
Report number:	J54001
Cover photo:	NA

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1 INTRODUCTION

ConocoPhillips, as proponent of the Barossa Area Development, is progressing early-stage environmental assessment of a potential field development concept in the Timor Sea, 300 km north of Darwin, Northern Territory (NT). As part of this development concept, a potential gas export pipeline connection is being evaluated to connect the offshore gas field to the existing Bayu-Undan to Darwin gas export pipeline.

On behalf of ConocoPhillips, CDM Smith has requested Pendoley Environmental, as Subject Matter Experts, to provide an independent review and professional opinion on the potential impacts of the Barossa gas export pipeline installation, on local marine turtles, as it passes through waters west of the Tiwi Islands (**Figure 1**).

At this early stage, a broad corridor for the gas export pipeline has been identified, and therefore this assessment conservatively assumes a pipeline alignment at its eastern-most extent that is closest to shore, which may not be the case if future route selection determines a deeper water alignment further to the west. This therefore represents a conservative assessment of the potential interactions with marine turtles in the vicinity.

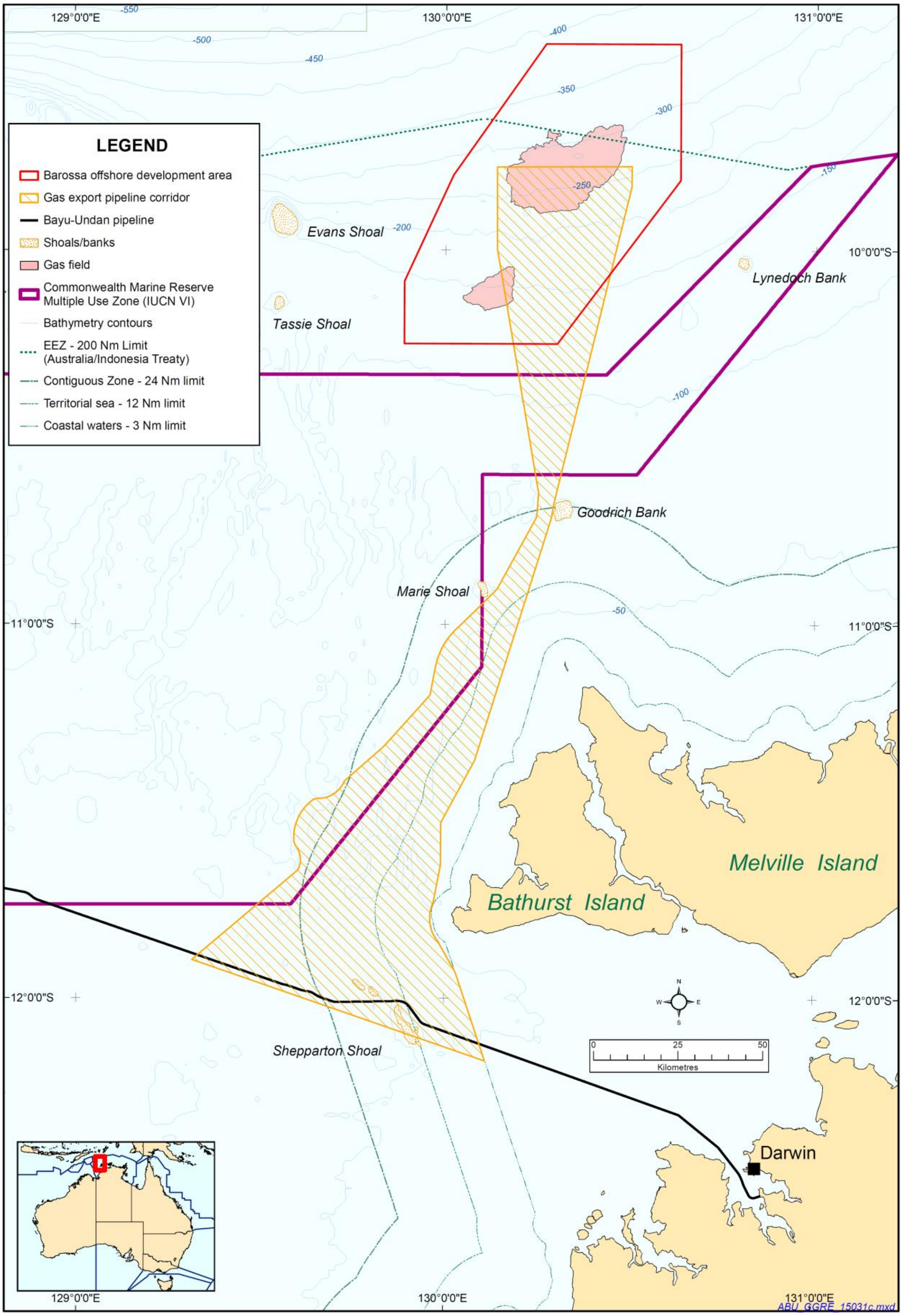

Figure 1: Barossa Project pipeline corridor location relative to Tiwi Islands.

2 OBJECTIVES

The objective of this study is to review published and grey literature with a focus on the impacts of artificial light on marine turtles as a priority, and to include a review of the impact of the physical presence of vessels and noise on marine turtles.

The project scope is as follows:

1. Review of the current Biologically Important Areas (BIA) boundaries using recent publications on flatback turtle internesting behaviour by Whittock et al. (2014, 2016), to more precisely define the likely internesting zone to the north and west of Tiwi Islands (primarily Bathurst and Melville Island).

2. Development of a project specific impact assessment, within the context of the site specific factors (e.g. local turtle species and their habitat usage, seabed bathymetry, benthic habitats, distance of the project footprint offshore, temporary nature of the light source, currents, tidal influences, existing anthropogenic light sources). The assessment will:

    a. Target the highest conservation value receptors (i.e. internesting flatback and olive ridley females turtles and dispersing hatchlings);

    b. Integrate the site specific factors to define a notional area extent at which potential impacts may be anticipated; and

    c. Form a conclusion on whether the proposed activities represent a significant risk to flatback and olive ridley turtles at a population level, as per Department of the Environment and Energy's 'Significant Impact Guidelines 1.1 – Matters of National Environmental Significance'.

3 ASSESSMENT SCOPE

3.1 Local Species Status and Nesting Seasonality

The species that are the focus of this assessment, flatback and olive ridley turtles, are listed as vulnerable and endangered, respectively, under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Marine turtles are long lived, migratory animals who are slow to reach sexual maturity; they nest every 1 – 9 years, producing 1-3 clutches and show no paternal care following egg nesting (Bjorndal *et al,* 2013; Miller, 1997; Hirth, 1980).

Population estimates for Tiwi Island regional nesting populations of marine turtles have been reported using a mix of aerial track census and ground based surveys by Chatto & Baker (2008). The west coast beaches of Bathurst Island and the north coast beaches of Melville Island are dominated by flatback turtle nesting followed by dispersed olive ridley nesting Whiting et al 2007a). Flatback turtles are endemic to Australia, their nesting range extending from the Pilbara region of Western Australia (WA), across the NT into Queensland (Limpus et al. 1988, Chatto & Baker 2008, Pendoley et al. 2014, Pendoley et al. 2016). Extrapolation of tagging data from the Pilbara, together with track census results from Cape Domett and the Tiwi Islands suggests that flatback turtles nest in the tens of thousands throughout this range (Pendoley et al. 2014, Whiting et al. 2008). Studies undertaken by Chatto & Baker (2008) along sections of coastline in the NT, including the Tiwi Islands, observed that estimates suggest high numbers of flatback turtles nest in five segments (Segments 3.5 to 3.9; **Figure 2**) of the Tiwi Islands coastline, producing in the order of thousands of nests annually.

In comparison, olive ridley turtle nesting is geographically constrained, restricted to nesting sites in the NT and western Cape York in Queensland (Chatto & Baker, 2008). The Species Nesting Map for olive ridley turtles provided in the Commonwealth Recovery Plan for Marine Turtles in Australia (Department of the Environment and Energy (DoEE) 2017), together with Chatto & Baker (2008), identify the Tiwi Island rookeries as matters of national environmental significance supporting high levels of annual nesting (thousands of nests/year), compared to the wider geographical region which reports approximately 1000 nests/year (Indonesia), 100's nests/year (Myamar and Brunei) and <50 nests/year (Papua New Guinea, Malaysia, Thailand and Vietnam) (see Jensen et al*.* 2013 and references therein). The greatest concentration of olive ridley turtles has been recorded around Cape Van Diemen and on Seagull Island (Segment 3.8 and 3.9, respectively; **Figure 2**) (Whiting et al., 2007a).

Both flatback and olive ridley turtles nest at low numbers year round in the NT, however there are recognised windows of peak breeding activities during the Austral winter, as shown in **Table 1** (M Guinea pers comm.; DoEE 2017).

Table 1: Annual activity calendar for olive ridley and flatback turtles in the Tiwi Islands. Light grey: year round low level, dispersed activity; dark grey: peak months for each activity.

Species/Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flatback (Arafura stock, Tiwi Islands)												
Nesting												
Internesting												
Hatchlings												
Olive Ridley (NT stock, Tiwi Islands)												
Nesting												
Internesting												
Hatchlings												

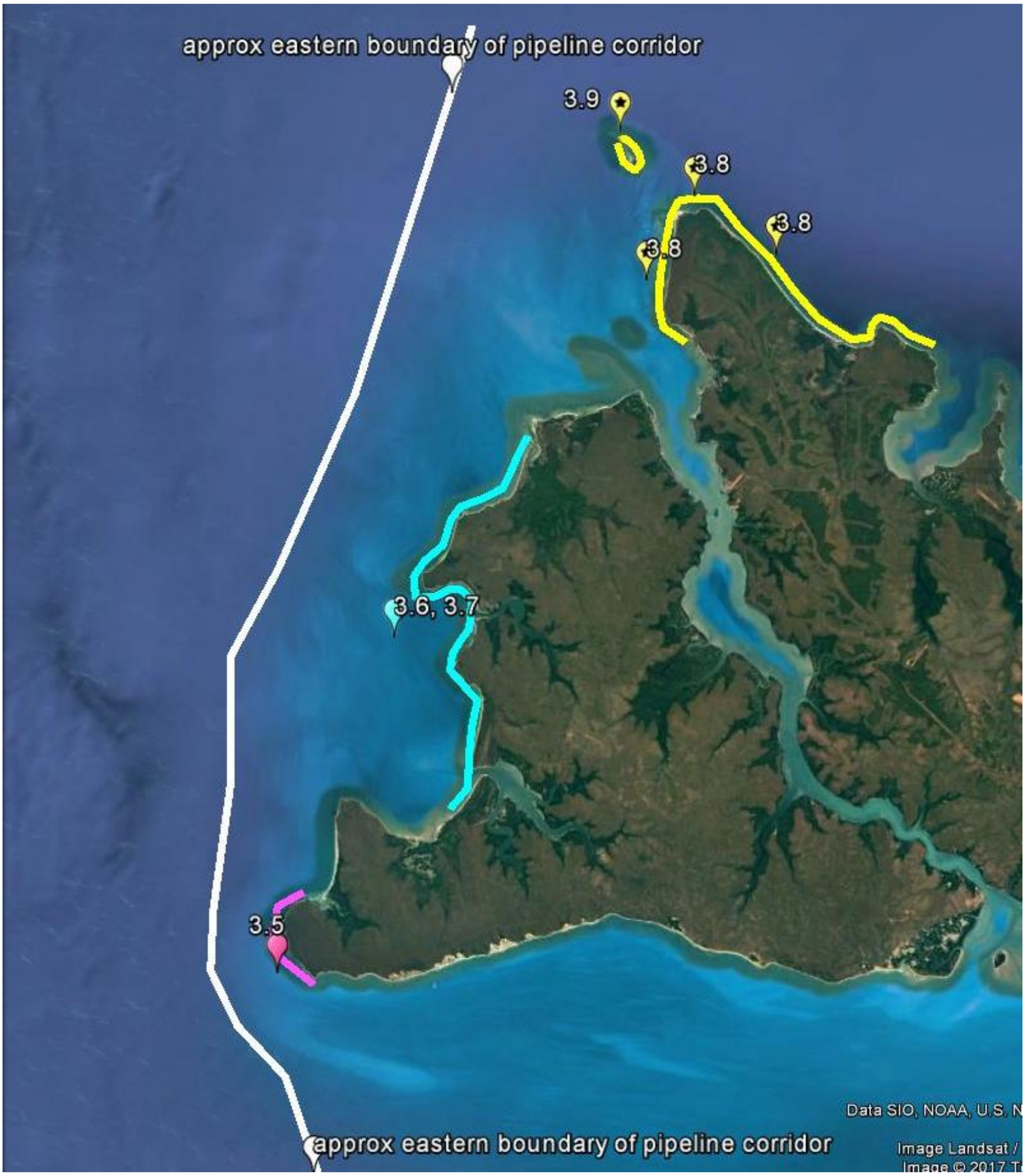

Figure 2: Location of nearshore pipe lay corridor boundary relative to Tiwi Islands marine turtle nesting beaches. Survey segment codes 3.5 – 3.9 from Chatto & Baker (2008).

4 IMPACT ASSESSMENT OF BAROSSA PIPELINE INSTALLATION

4.1 Project Description

The vessels required for the installation of a pipeline typically comprises a slow moving pipe lay vessel and an attendant supply vessel that may or may not be permanently stationed in the vicinity of the pipe lay vessel. The entire gas export pipeline will be installed over an approximately 6 – 12 month period, potentially across the peak of the flatback and olive ridley turtle internesting/nesting seasons. The pipeline corridor traverses the floor of the Timor Sea, including a portion to the west of the Tiwi Islands, approaching to within approximately 6-7 km at its closest point near Cape Fourcroy in the southwest, approximately 12 km off Rocky Point on the mid-west coast and approximately 18 km off Seagull Island to the northwest (**Figure 3**). Water depths along the eastern edge of the pipeline corridor range from approximately 20 m deep northwest of Rocky Point to 50 m deep as the corridor rounds Cape Fourcroy, to the west of Bathurst Island.

The existing predominant source of light, boat strike and underwater noise in the pipeline corridor has been identified as commercial shipping. However, the most heavily used shipping routes are located to the south of the Tiwi Islands

4.2 Internesting Females

4.2.1 Literature review

An exhaustive analysis of a large dataset of 47 internesting flatback turtles satellite-tracked from five different mainland and island rookeries and providing 5402 internesting positions over 1289 tracking days showed flatback females remained in water depths of <44 m, favouring a mean depth of <10 m (Whittock et al. 2016). These results were consistent with those of Sperling et al. (2010) who observed flatback turtles off Bare Sand Island in the NT in a maximum depth of 44 m.

Whittock et al. (2016) defined suitable internesting habitat as water 0 – 16 m deep and within 5 – 10 km of the coastline while unsuitable internesting habitat was defined as water >25 m deep and >27 km from the coastline (Whittock et al. 2016). Flatback turtles generally demonstrate internesting displacement distances of 3.4 – 62 km from the nesting beach, typically confined to longshore movements in nearshore coastal waters or traveling coastal waters between island rookeries and the adjacent mainland (Whittock et al. 2014). There is no evidence to date to indicate flatback turtles swim out into deep offshore waters during the internesting period.

The literature on internesting olive ridley turtles is less complete than flatback turtles. Eight internesting olive ridley turtles, satellite tracked post-nesting from Cape Van Diemen on the Tiwi Islands, were initially recorded travelling 'slowly' through waters 45 – 55 m deep at distances 17 – 37 km from the nesting beach before moving into shallower water, waiting offshore from the nesting beach in the days prior to renesting (Whiting et al. 2007, Whiting et al. 2005). The internesting habitat was located to the north and west of Cape Van Diemen. The selection of this internesting habitat appears to be deliberate given that two olive ridleys tracked from Groote Eylandt (approximately 700 km east of Cape Van Diemen) travelled long distances of 125 and 200 km during extended internesting periods, and it is understood that this behaviour may be linked to a relatively low metabolic rate in this species (Hamel et al. 2008, McMahan et al. 2007).

Similar internesting behaviour was observed in olive ridleys tracked in the Atlantic Ocean. The internesting habitat described for four of five olive ridleys nesting in the mouth of the Congo River in Angola travelled over 50 km from the nesting beach along the coast, remaining within waters 6 – 20 m deep. A fifth animal selected internesting habitat <6 m deep and within 4 km of the nesting beach (Pikesley et al. 2013, K Pendoley *pers obs* 2009).

Vessel collision with adult turtles is recognised as a cause of sea turtle mortality when they bask on the surface, rise to the surface to breathe or surface as a ‘startle’ response to a sudden sound (dredging noise, explosions) or visual cues (MMS 2007). The collision risk between vessels and sea turtles is linked to vessel speed; specifically, turtles are struck by boats travelling at 11 km h^{-1} more often than by boats travelling at 4 km h^{-1} (Hazel et al. 2007). In the US, 9 % – 18 % of stranded turtles displayed boat strike injuries (Lutcavage et al. 1996) while in Queensland, 56 % of 139 stranded turtle records showed injuries consistent with boat strike (Haines & Limpus 2000). Species impacted included green, loggerhead, hawksbill and olive ridley turtles.

While sound induced stress in marine turtles has been documented (Samuel et al. 2005) turtles have also been observed rapidly acclimating to regular, continuous noise (O'Hara & Wilcox 1990, Dickerson et al. 2004, Geraci & Aubin 1980, Whittock et al. 2017), with the response dependent on the distance from the sound source (Bartol et al. 1999).

The bulk of the large and apparently stable nesting population of flatback turtles using the west and north coast beaches of the Tiwi Islands for nesting are expected to use the shallow nearshore waters adjacent to the Bathurst Island and Melville Island coast for internesting; in <16 m deep and within 10 km of the coastline (Whittock et al. 2016) with individuals occasionally moving into waters up to 44 m deep (within 5 – 15 km of the coastline). While most of the nesting females in the area are not expected to inter-nest within the pipeline corridor it is possible some individuals will use waters extending into the corridor up to 50 m deep (**Figure 3**). The seabed characteristics off Cape Fourcroy (i.e. narrow continental shelf, steep seabed slope and relatively high current speeds) are not typical of the internesting habitat used by flatback turtles and consequently they are unlikely to inter-nest in the pipeline corridor waters in this area. Further to the north where the continental shelf is wider and slopes more gently offshore, the 10 m deep internesting grounds are located approximately 10 – 20 km inshore of the pipeline corridor.

While the literature is less complete regarding Australian olive ridley internesting behaviour, the females nesting on Cape Van Diemen and Seagull Island beaches are expected to move through the waters <55 m deep and < 37 km from the coast during the average 1.5 internesting periods (Marquez 1990). In the days prior to nesting, the olive ridley turtles, like flatback turtles, are likely to rest on the seabed in the shallow waters off their nesting beaches (Whiting et al. 2005), approximately 10 – 20 km away from the pipeline corridor. While the majority of the nesting olive ridley females are not expected to inter-nest within the pipeline corridor it is possible some individuals will use waters extending into the corridor up to 55 m deep.

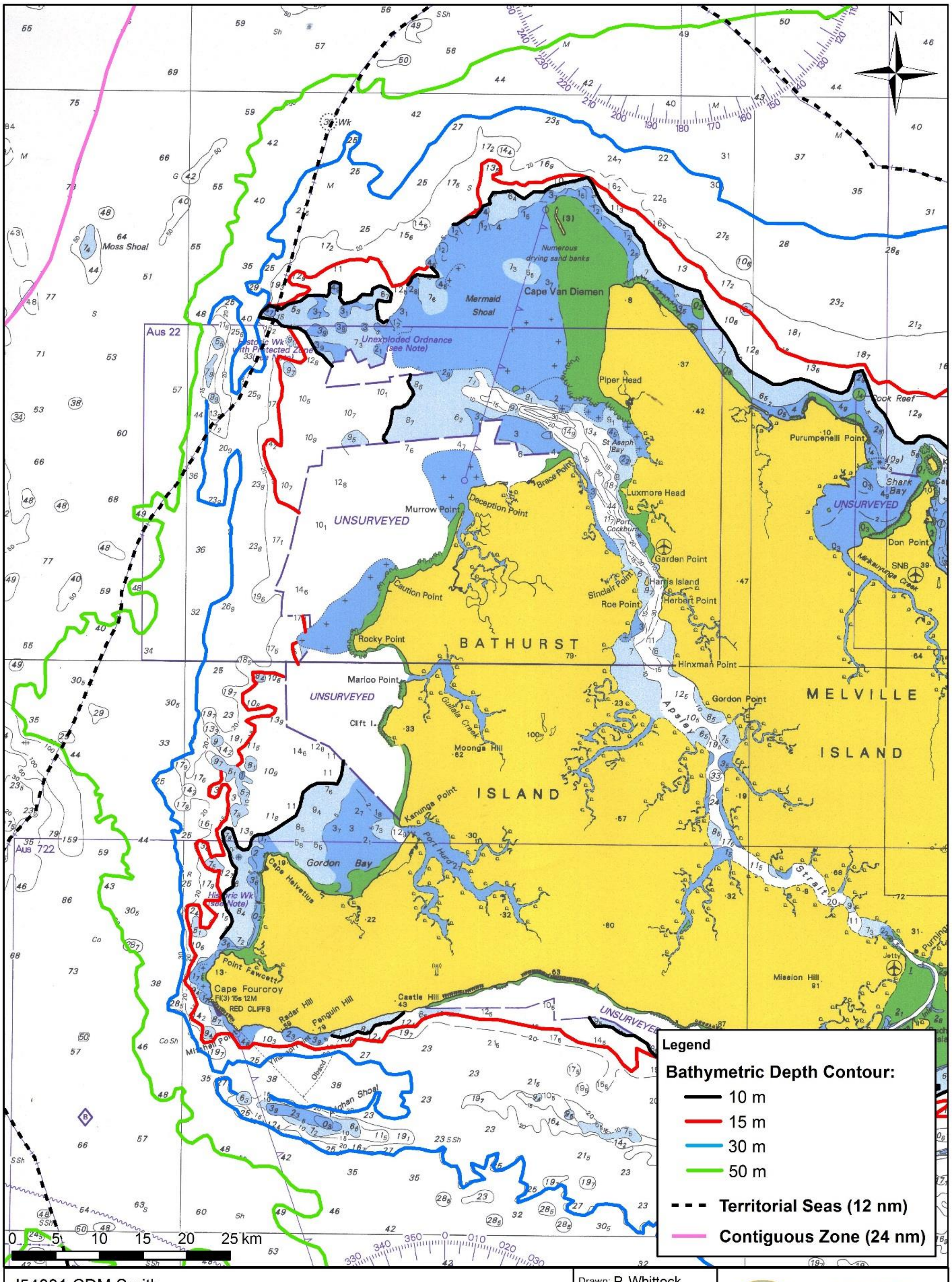

Figure 3: Bathymetry and territorial sea boundaries.
NOT TO SCALE

4.2.2 Impact Assessment

The number of internesting females potentially exposed to the pipelay operations over the approximate 6 – 12 month period the pipeline installation will take to complete will be generally low due to the presence of low level nesting effort throughout the year, and will increase during the April to September peak in nesting of both species.

The threats to the few individual internesting females that may occur in the pipeline corridor include; light, boat strike and underwater noise, in addition to the current levels of risk posed by the existing shipping in the area.

There is no evidence, published or anecdotal to suggest internesting turtles are impacted by light from offshore vessels, and nothing in their biology would indicate this is a plausible threat. The physical presence and risk of boat strike the pipelay vessel anchored or moving slowly through the ocean is also not expected to impact internesting females. Fast moving supply vessels are a greater risk of boat strike (Hazel et al. 2007), however Whittock et al. (2017) found no evidence of vessels associated with a full dredge spread causing an increase in boat strike in shallow waters <5 km offshore from a major flatback rookery on Barrow Island. This lack of impact is likely due to the internesting turtles resting on the seabed, physically removing them from the surface activity of the vessels.

Noise from the project will be confined to engines on the pipe lay vessel and supply vessels. This low level constant noise will be audible over a long distance and will not cause a startle response in turtles. It is likely animals in the vicinity will become rapidly habituated to the sound.

4.3 Dispersing Hatchlings

4.3.1 Literature Review

Following an incubation period of between 37 – 85 days (flatback) and 42 – 63 days (olive ridley) (Hirth 1980, Miller 1985, Whiting et al. 2008, Pendoley et al. 2014) hatchlings emerge from the sand, crawl to the ocean and swim offshore, under the influence of tides and currents, into deeper, less predator rich, waters. Hatchlings rely on their internal egg yolk reserves to sustain the offshore migration for the first 3 – 6 days at sea until they intercept food, typically associated with seaweed rich convergent zones (Trullas et al. 2006). This offshore migration occurs in the top 30 cm of the ocean in both species and this swimming behaviour is regularly interrupted by rest periods when hatchlings float on or near seaweed at the sea surface (Duran & Dunbar 2015, K Pendoley pers obs).

Coastal tides and surface currents in excess of approximately 0.5 knots will carry hatchlings offshore. While larger than all other hatchlings, flatback turtles typically swim at <0.4 ms (0.8 knots) which is consistent with other marine turtle species (Wyneken 1997, K Pendoley pers obs). Unlike the olive ridley, flatback turtles do not have an oceanic (pelagic) phase instead residing exclusively in neritic (i.e. shallow) waters on the Australian continental shelf (Walker & Parmenter 1990). The coastal dispersal of flatback hatchlings is facilitated by the inshore location of nesting beaches, local water circulation and directional swimming as the hatchling grows (Wildermann et al. 2017).

Hatchlings emerging from the sand locate the ocean using a combination of topographic and brightness cues, orienting towards the lower, brighter oceanic horizon and away from elevated silhouettes of dunes and/or vegetation bordering the beach on the landward side (Limpus 1971, Salmon et al. 1992, Limpus & Kamrowski 2013, Pendoley & Kamrowski 2017). Hatchling behaviour is impacted by both direct, point source lighting (e.g. unshielded lights) and indirect 'sky glow' an accumulation of light from multiple sources (Salmon et al. 1995, Salmon 2006, Kamrowski et al. 2014). Hatchling orientation has been shown to be disrupted by light produced at distances of up to 18 km from the nesting beach (Hodge et al. 2007, Kamrowski et al. 2014). The relative brightness, and therefore potentially disorienting impact of artificial lighting, fluctuates as a function of moon phase (Salmon & Witherington 1995, Pendoley 2005), and the amplification effects of cloud cover (Kyba et al. 2011).

A substantial body of research exists which demonstrates most species of turtle hatchlings, including olive ridley and flatbacks, show a preference for (and are therefore more influenced by) shorter wavelength, high intensity light (Witherington & Bjorndal 1991a, Witherington & Bjorndal 1991b, Witherington 1992, Pendoley 2005, Pendoley & Kamrowksi 2016, Karnard et al. 2009). Light rich in short wavelength emissions are the most disruptive to hatchling sea-finding behaviour in all species of marine turtles (Pendoley & Kamrowski 2016).

Once hatchlings enter the ocean, an internal compass set while crawling down the beach, together with wave cues, are used to reliably guide them offshore (Lohmann & Lohmann 1992, Stapput & Wiltschko 2005). In the absence of wave cues however, swimming hatchlings have been shown to orient towards light cues (Lorne & Salmon 2007, Harewood & Horrocks 2008). Research quantifying swimming hatchling response to artificial lights is lacking but hatchlings have been documented 'pooling' in areas of artificial light offshore (Limpus 1991).

The paucity of data describing the impact of offshore light on hatchling behaviour during their initial offshore migration is due to the highly variable environmental conditions and logistical complications implicit in these studies. Acoustic tracking methods have, however, shown that over short distances of up to 150 m, flatback hatchlings are more influenced by light than wave cues (i.e. the light cue overrode the wave cue). Hatchlings were not trapped indefinitely in light pools and eventually continued the migration offshore (Thums et al. 2013; 2016). Hatchlings may be exposed to an increased risk of predation when trapped in light spill from vessels.

There is no published or anecdotal information on the impacts of underwater noise on hatchlings. It is possible they will be sensitive to sound in the same way as adults, though this will depend on the development on the internal ear structure.

4.3.2 Impact Assessment

Both species of hatchlings leaving the Tiwi Islands nesting beaches will swim offshore under the influence of tides and currents dispersing over large geographical areas of the ocean. Limited observations on hatchling behaviour as they leave the beach suggests that they will search out and use floating weed to rest on after several hours of swimming (Trullas et al. 2006, K Pendoley pers obs). This, together with the overriding influence of tides and currents (stronger than 0.5 knot) on swimming speeds, will carry the hatchlings to some common convergent zones where they will use floating rafts of seaweed for shelter and foraging (Musick & Limpus 1997). The primary threat hatchlings face from the pipe lay operations is the attraction to vessel lights and predation within the light spill zone.

Overnight observations of flatback turtle hatchlings trapped by the light spill from a pipelay barge moored approximately 10 km off the east coast of Barrow Island found hatchlings remained within the light spill in the lee of the barge all night until dawn when they swam away from the barge and were carried away by currents (K Pendoley pers obs 2003). None of the monitored hatchlings were predated. These observations, together with experimental results that demonstrated the attraction of hatchlings to light at sea over 150 m (Thums et al. 2016), suggests that hatchlings carried by currents into the vicinity (estimated 500 – 1000 m) of a pipe lay barge can become trapped by light. The 2010 study by Thums et al. found this light trapping was very temporary (minutes) possibly due to the small size of the vessel which did not provide the same shelter from tides as a pipe lay vessel (K Pendoley pers obs). The risk of trapping and possible predation is greatest in the southern end of the pipeline corridor where it passes at its closest point to Bathurst Island off Cape Fourcroy.

The risk of this occurring is considered relatively low when taking into account: the limited time the pipe lay vessel and associated support vessel will be present on any one location off the west coast of the Tiwi Islands, the temporally restricted four month peak hatchling season (June – September), the low risk of hatchlings intersecting a small zone (approximately 500 m – 1000 m) around the pipe lay vessel over which they might be influenced to orient towards the vessel lights, the low likelihood the hatchlings will be in slow moving water (< 0.5 knots) that will allow them to swim against a current towards, and the short (overnight) time frame the hatchlings could be trapped. Any hatchlings that do become trapped in the light spill from a vessel may be at risk from an increased risk of predation however the risk of this is likely reduced due to the distance offshore from predator rich inshore waters. The risk to the olive ridley and flatback turtle populations from the proposed project is therefore considered to be low and undetectable against normal population fluctuations.

4.4 BIA Assessment

Currently the Biological Important Area (BIA) as defined by the Recovery Plan and the Commonwealth EPBC site (National Conservation Values Atlas) ranges from 60 – 80 km for flatback turtles. These boundaries are intended to provide additional protection for internesting turtles nesting on the Tiwi Islands. Recently published literature describing the range of flatback turtle internesting habitat can now be used to better refine these boundaries for more effective protection this species during this life-stage.

The following boundary limit is presented here for consideration. The existing 24 nm (44.5 km) Contiguous Zone boundary, as shown in **Figure 3**, would comfortably encompass the olive ridley and flatback internesting habitat (including Seagull Island) and is beyond the 50 m depth contour to the north and west of the Tiwi Islands.

5 CONCLUSIONS

The installation of the Barossa gas export pipeline is not expected to form a significant risk to flatback and olive ridley turtles at a population level, as per DoEE's Significant Impact Guidelines 1.1 – Matters of National Environmental Significance. This conclusion is based on the following points:

1. There is a spatial separation (approximately 10 – 20 km) between the favoured coastal internesting habitat for flatback and olive ridley turtles, and the offshore pipeline corridor.

2. The relatively short 6 – 12 month time frame of the pipeline installation is insignificant within the context of the long breeding period of marine turtles and so the time frame the breeding females are potentially exposed to the project is low.
3. Pipelay vessels are mobile and will not be on any one location for extended periods of time. Any exposure of internesting females or dispersing hatchlings to project related risk will be temporary.
4. The seasonally dispersed nesting behaviour reduces the risk of exposure to the entire breeding population.
5. While migrating offshore, hatchlings will be dispersed by currents across large areas of ocean, under the influence of tides and currents which will reduce the opportunity for individuals to intercept or pool around a vessel.
6. Hatchlings are unable to swim against fast moving tides and currents and a few individuals might be trapped by light spill from a vessel if they are carried directly to the vessel location by tides or currents.
7. Hatchlings will only be able to engage in directional swimming (i.e. to actively swim directly towards a vessel light) during the few hours a day when water speeds are very slow or at slack water and will be swept away as the tide gains strength. The number of individuals potentially impacted are expected to be low.
8. The current large (60 – 80 km) BIA boundary to the north and west of Tiwi Islands can be re-assessed based on recent publications that indicate internesting habitat for flatback and olive ridley turtles is in shallow water closer to shore and can be comfortably encompassed by the Contiguous Zone Boundary (24 nm, 44.5 km).

An assessment against the significance impact criteria in the Significant Impact Guidelines 1.1 – Matters of National Environmental Significance is provided in Table 2. Note, the assessment has been undertaken against the endangered species criteria, as this represents a more conservative approach.

Table 2: Assessment against the significant impact criteria

Significant Impact Criteria	Assessment of Significance
Lead to a long-term decrease in the size of a population	No significant impact at a population level Due to the short time frame of the activity, the spatially restricted area of impact, the lack of identified risk and the limited number of individuals that might be exposed to the activities.
Reduce the area of occupancy of the species	No significant impact on area of occupancy of the species. Due to the limited degree of overlap between the pipeline corridor and the defined internesting habitat and the limited impact of vessel lighting on hatchling dispersal.
Fragment an existing population into two or more populations	No significant impact. The project will not fragment the population.
Adversely affect habitat critical to the survival of a species	No significant impact. Due to the spatially and temporally limited duration of the activities, footprint of the pipe lay spread, overlap between the project area and the internesting habitat, the speed of tides and currents sweeping hatchlings along and the small number of

Significant Impact Criteria	**Assessment of Significance**
	individuals animals that might be present, both in the internesting habitat and in the surface waters used by dispersing hatchlings
Disrupt the breeding cycle of a population	No significant impact at a population level Due to the short time frame of the activity, the spatially restricted area of impact, the lack of identified risk and the limited number of individuals that might be exposed to the activities.
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	No significant impact to population. The small amount of habitat potentially removed by the installation of a pipeline will be balanced by the creation of artificial reef habitat once the pipeline is installed.
Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat	No significant impact at population level. No invasive species risks have been identified by this assessment.
Introduce disease that may cause the species to decline	No significant impact at population level. Assuming all AQIS guidelines for vessels are followed there are no identified risks of introduced disease.
Interfere with the recovery of the species	No significant impact at population level. No threats to the recovery of the species were identified during this assessment.

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